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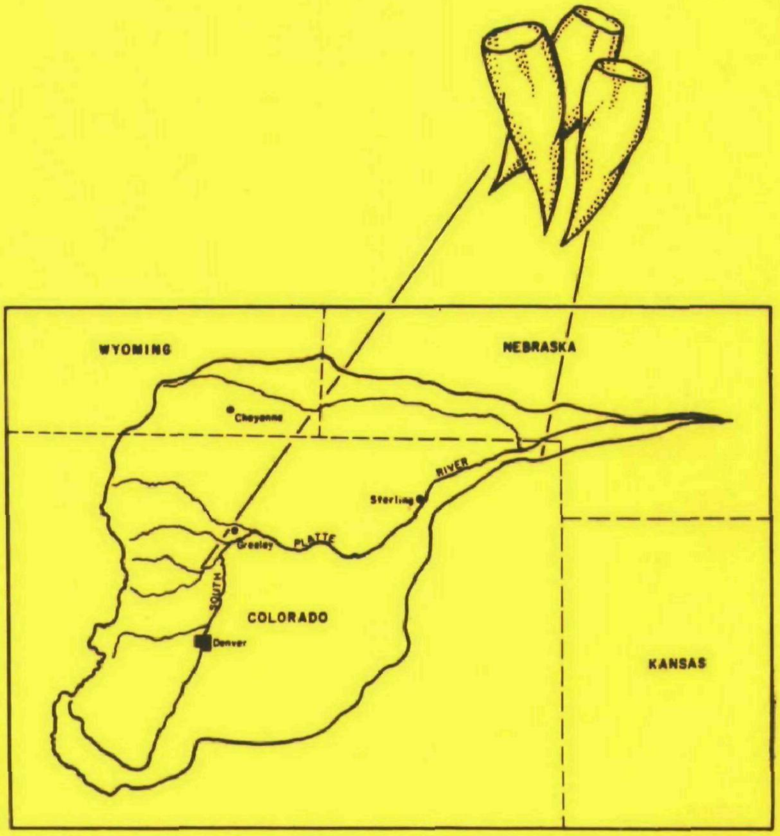
THE BEET SUGAR INDUSTRY--

THE WATER POLLUTION PROBLEM AND STATUS OF WASTE ABATEMENT AND TREATMENT



U.S. DEPARTMENT OF THE INTERIOR
Federal Water Pollution Control Administration
South Platte River Basin Project
Denver, Colorado

June 1967

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ACKNOWLEDGMENT

The excellent cooperation by the beet sugar industry, various State Health Departments, private and public groups, Federal agencies, and individual investigators, was a major factor in making this report possible. Recognition is given to the following who contributed in significant measure to the study. Their assistance is gratefully acknowledged.

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The Colorado State Department of Public Health for their overall interest in the study.

The State Health Departments of California, Iowa, Minnesota, Montana, Nebraska, Wyoming, and Utah, who provided information on sugar process operations within their areas.

The Beet Sugar Development Foundation and indirectly the British Columbia Research Council, who by virtue of previous studies, were a source of much valuable information used in the report.

Various investigators who provided specific information and their reports of findings in the area of sugar factory operations and methods of waste abatement and treatment.

SUMMARY

Primary attention is focused upon the beet sugar industry in the South Platte River Basin. Beet sugar wastes are the largest source of pollution within the area. Ten sugar factories are dispersed throughout the region and affect water quality over 300 miles of Basin streams. This report comprises five major parts. Section I consists of introduction and background to the problem, and description of process operations. Section II gives the results of industrial surveys and status evaluation on each of the ten factories in the Basin. Section III discusses total factory waste loads before and after treatment. Section IV describes the bacteriological aspects of sugar beet waste pollution across the country. Section V offers a comprehensive review and evaluation of waste abatement and treatment throughout the industry both in the U.S. and abroad.

In 1955, sugar beets were grown on almost one million acres of land mostly situated in the Western U.S., by some 60,000 farmers in 22 States. Eighteen sugar companies managed 73 sugar beet factories located in 16 different States. The basic processes within the mill consist of diffusion, juice purification, evaporation, crystallization, and recovery of sugar from molasses. The typical factory operates round-the-clock for a continuous period of 80 to 160 days during the year.

Detailed study was made of the nine sugar beet mills and of the Johnstown, Colorado (sugar recovery - Monosodium Glutamate) factory, located in the South Platte River Basin. Information was secured on process and operation, water supply, the beet flume system and waste flume water, beet pulp, lime mud wastes, the main plant sewer, and available waste abatement and treatment facilities. Special emphasis is given in these studies to the source, nature and magnitude of in-plant waste loads together with various factors governing these loads. The report includes process description of the Johnstown, Colorado plant which is the only one of its type in the Western Hemisphere, and a discussion of the closed flume water recovery system recently installed at the Brighton, Colorado factory.

Total factory waste loads and flows are defined in terms of unit process rate, and these loads were investigated with regard to reasons for change and the increments from particular operations. Total factory BOD loads varied from a low of 10 pounds per ton beets processed to a high of 33 pounds, with the average of 15 pounds for all Basin plants. The addition of lime mud could be expected to increase normal BOD and COD loads from a sugar factory by 10-40 percent whereas, if pulp silo drainage is also added, the basic waste loads could be increased by 50-200 percent. Total suspended solids loads varied from 22 to 121 pounds per ton beets processed. Complete lime mud wasting could be expected to increase basic plant TSS loads from 100-300 percent, whereas pulp silo drainage contributed a minor portion of the TSS loads. Bacterial loads varied from 0-68

BQU total coliform bacteria and fecal coliform bacteria from 0-8.4 BQU per 100 tons beets processed. The studies indicated that pH levels exceeding 9.0 were particularly destructive to organisms of the coliform group.

The survey results showed that lime mud wasting from a Steffen house factory would add about 5 pounds BOD, 7 pounds COD, 90 pounds TSS and 45 pounds alkalinity per ton beets processed, to the basic plant loads. A straight-house factory would approximate one-half to three-fourths of these respective levels. Pulp silo drainage would add another 16 pounds BOD and 22 pounds COD to the total plant wastes. The nine sugar processing establishments (excluding Brighton), contributed total factory waste loads of 175 tons BOD and 780 tons TSS on a daily basis together with 6900 BQU total coliform bacteria. Overall waste reduction by means of available treatment at the mill sites was only 8 percent for BOD and 58 percent for TSS, whereas total coliform bacteria loads demonstrated a 23 percent overall increase. The big picture of sugar beet waste disposal in the South Platte River Basin strongly implies that much remains to be done.

Results were collected on the bacteriological aspects of sugar beet waste pollution from many studies conducted across the country. Interpretation and findings are condensed in this report as to the probable sources of bacteriological pollution within the sugar beet factory, changes due to waste storage, survival tendencies of bacterial organisms, differentiation between human and animal-caused pollution, pathogens in sugar beet wastes, and criteria for reducing bacterial pollution. The studies show that incoming dirt and trash together with the sugar beets represent the significant sources of bacterial entry to the sugar mill. These bacteria are strongly associated with the fertilization of agricultural lands by means of animal manure, a practice common to the industry. Disregarding recent changes in the South Platte River Basin, the treated factory effluents contained total coliform densities in the range of 1.6 to 49 million/100 ml and fecal coliform densities between 18,000 and 4.1 million /100 ml. The serious nature of bacteriological pollution in the Basin cannot be disputed. Pathogenic Salmonella organisms were found at the East Grand Forks and Moorhead, Minnesota factories and the river waters below the mills. Similar isolations were also made at the Fremont, Ohio and Longmont, Colorado plants. These waste effluents are considered significantly polluted and definite hazard is involved for human contact.

The waste abatement and treatment section of the report is divided into description of major wastes, in-plant measures, minimum treatment (primary treatment or less), intermediate treatment methods, high-levels of treatment, and other considerations. Description and information from the literature are given on the major wastes including spent flume waters, process waters, pulp silo drainage, lime mud slurry, Steffen house filtrates, and condenser waters. In-plant measures are considered of great importance and include the proper handling of sugar beets before reaching the factory, redesign of the beet flume system particularly dry-handling techniques, the value of reusing process waters, handling of lime muds, Steffen filtrate conversion to usable end-products, disposition of excess condenser waters, and the reuse and recovery of various flows in the typical factory.

Methods and procedures of waste abatement and treatment are grouped for ease and clarity in presentation rather than giving a rigorous definition of the system. In this report, high-level treatment is meant to provide factory waste loads not exceeding 2 pounds BOD and TSS per ton beets processed.

Primary treatment measures include fine-mesh screening, grit and solids removal by mechanical means, treatment lagoons and ponds, and aeration fields. Adequate screening of the waste flows from a typical factory can remove 10 to 40 tons of coarse wet solids daily which are reused in the process or sold as animal feed. Mechanical clarifiers should be preceded by grit removal and screening, and are generally employed in closed wastewater recycle systems. The large quantities of accumulated dirt and debris are usually deposited into sludge storage ponds. Treatment lagoons and ponds have widespread use throughout the industry but too often their performance is quite poor. Both earthen lagoons and mechanical clarifiers may cause serious problems without proper operation and maintenance care. Aeration fields provide reasonably good suspended solids removal but little change in organic waste loads.

Intermediate waste treatment methods include long-term waste storage, mechanically-aerated ponds and lagoons, chemical treatment and the irrigation of agricultural lands with waste effluents. Extended waste storage over the winter months at one factory produced almost complete removal of suspended solids together with 50 percent reduction in organic material. Laboratory studies on the feasibility of treating sugar beet wastes in aerated lagoons showed encouraging results and the desirability of full-scale systems application. Chemical precipitation of waste flume waters provided 57 percent reduction of the BOD load at a Michigan factory. The use of sugar factory effluents for irrigating agricultural lands directly or indirectly, is widely practiced throughout the Western United States. Examples are cited in the States of California and Texas, and the South Platte River Basin within the State of Colorado.

High-level waste treatment is sub-divided into recirculation-reuse systems, biological systems, and biological-recirculation systems. The complete recycle system has generally proven superior to biological methods in terms of overall results. A closed flume water recirculation circuit is described as one with continuous recycling of waste flume waters together with essential treatment units on the line enabling complete reuse of such waters. This system is explained for four different factories including Fremont, Ohio; Ottawa, Ohio; Fort Garry in Manitoba, Canada; and Brighton, Colorado. The total discharge load at Fremont was only 0.8-0.9 pounds BOD per ton beets processed, and the levels at Fort Garry were 0.3

pounds BOD and 0.6 pounds TSS per ton of beets processed. The Brighton factory with its waste treatment system has achieved better than 90 percent reduction in BOD waste loads compared to previous conditions. Condenser waters may be added into the recycle circuit because of economics, regulation, or the need for heat content. Examples are given of the integrated flume and condenser water systems at the Findlay, Ohio and Betteravia, California factories. The total plant waste load ultimately discharged from the Findlay factory has averaged only 0.1 pounds BOD per ton beets processed.

Many studies have been performed on the treatment of sugar beet wastes by biological systems including activated sludge, trickling filters, and other means. Pilot-plant evaluation of activated sludge treatment at Hereford, Texas has provided reasonably good results. Nitrogen and phosphorous deficiency in biological waste treatment must be taken into account. Trickling filter studies undertaken at Hereford, Texas and many full-scale installations in Great Britain and Western Europe have shown biological filters to have real merit in sugar beet waste treatment. On the other hand, two such installations in the U.S. at Rupert, Idaho and Lewiston, Utah, have failed in large degree. This is believed due to gross under-estimation of the processing rate and difficulty in design and selection of treatment units. Neither system was given the opportunity to develop the full potential of the waste treatment processes.

Anaerobic-aerobic lagoons have been utilized on a pilot-study basis at Tracy, California for treating sugar beet wastes. The results are generally encouraging and future improvements will be made in this system. The Hereford, Texas waste treatment system is typified by two discrete treatment phases consisting of waste recycling followed by stabilization ponds and disposal of wastes onto agricultural lands. The Hereford system demonstrated a few problems which presumably will be corrected, but good overall performance has been reported.

The proper design, operation and maintenance of all waste treatment procedures and facilities are considered essential to an effective waste management program. Awareness of the problem, correct blending of attitudes, and status recognition are thought to be ingredients necessary in the program. Many details are mentioned including staffing patterns requisite to adequate management. Lastly, six areas of research are specified as valuable to the interests of the beet sugar industry and the broad needs of waste abatement.

SECTION I

INTRODUCTION, BACKGROUND, AND DESCRIPTION

I. INTRODUCTION, BACKGROUND, AND DESCRIPTION

A. INTRODUCTION AND BACKGROUND

This report is of first importance directed to the problems of sugar beet waste disposal and associated stream pollution found in the South Platte River Basin. However, broad application to the industry is found in the particular sections of the report devoted to bacteriological aspects and waste abatement procedures and treatment methods. The South Platte River Basin Project, of the Federal Water Pollution Control Administration, Department of the Interior, has conducted studies on sugar beet waste pollution since December 1963. Part of the Project's findings in this area has been presented in prior publications (1, 2, 3). The remainder of data collected over the past three years is contained herein, and together with previous findings, serves as a rather complete documentation on the definition of the waste problem, its nature and magnitude, and potential and probable solutions.

On July 18, 1963 Governor Love of Colorado requested the Secretary of Health, Education, and Welfare to assist the State in determining the quality of waters and sources of pollution in the South Platte River Basin within the State of Colorado. The Secretary convened the First Session of the Conference in the matter of Pollution of the South Platte River Basin which was held in Denver, Colorado on October 29, 1963 under enforcement provisions of the Federal Water Pollution Control Act as amended (33 U.S.C. 466g). At this Conference it was established that a study would be undertaken by facilities of the U.S. Public Health Service, which is now the Federal Water Pollution Control Administration in the Department of the Interior. The First Session of the Conference provided a general review of water quality conditions in the Basin and referred to the urgent need for information towards clarifying and solving the existing problems (1).

The South Platte River Basin Project was given the primary responsibility for assisting the State of Colorado in developing necessary plans for the control and abatement of pollution in the Basin. This program is directed to: 1) determine sources of pollution and adverse effects on water uses; 2) conduct field studies on the condition of Basin streams; 3) compute necessary waste load reductions for desired water quality and to recommend commensurate water quality control measures; and 4) recommend remedial time schedules for pollution abatement action.

Immediate attention was focused on the sugar beet industry since it was the largest single source of pollution in the Basin. A cooperative program was formulated with the State and the industry to define the problem, develop additional knowledge where necessary, and evaluate ways and means to combat the problems.

Informal meetings were called at various times for progress evaluation and the exchange of information with the State and the industry. The first major delineation of findings and conclusions was made at the Second Session of the Conference in the matter of Pollution of the South Platte River Basin held in Denver, Colorado on April 27-28, 1966. Detailed information was presented at the second conference session on the quality of stream waters in the area of sugar beet processing, the biological life in the streams, the bacterial pollution, and a recommended pollution abatement schedule for the industry towards achieving desirable water quality in the Basin (2).

The recommendations of the Federal report at the second conference session were submitted to the newly-formed Colorado Water Pollution Control Commission for implementation. The State authorities were given sufficient time to study and evaluate the Federal report, and to develop a program for implementation of remedial measures and time schedules. The Second Session of the Conference was reconvened on November 10, 1966 (3). This conference session developed certain conclusions and recommendations and those having specific reference to the beet sugar industry are given as follows:

1) "Pollution of the South Platte River Basin which endangers health and welfare, caused by municipal and industrial discharges, is occurring."

2) "All discharges into the South Platte River Basin shall have adequate remedial or control facilities in full operation by June 30, 1971, so as to comply with water quality standards established by the Colorado Water Pollution Control Commission as approved by the Secretary of the Interior."

3) "State and Federal authorities will have progress evaluation meetings at six-month intervals to determine compliance with the above requirements."

The water quality standards referred to above are those required to be set by each of the 50 States before June 30, 1967, under provisions of the Federal Water Quality Act of 1965, Public Law 89-234. Particular note must be taken of item 11 contained in the Guidelines for establishing these Water Quality Standards developed by the FWPCA in May 1966 (4). This item states "the use or uses of the waters concerned, the water quality criteria to provide for such use or uses, and the plan for implementing the water quality criteria . . . should encompass any remedial program recommended by the Secretary as a result of an enforcement action taken under Section 10 of the Act; and should be revised to reflect any recommendations resulting as such programs and actions develop."

Specific recommendations concerning sugar beet waste abatement were given at the Second Session of the Conference on April 27-28, 1966 (2) These recommendations specify that:

"1) The industry provide treatment of wastes so that the total 5-day BOD load discharged in any one day in the total effluents entering Basin streams shall not exceed the values given below for respective plants. Residual wastes may be discharged over an extended period of the year if necessary.

Brighton	-	1100	pounds 5-day BOD per day
Longmont	-	1450	"
Loveland	-	1750	"
Johnstown	-	800	"
Windsor	-	1100	"
Eaton	-	1000	"
Greeley	-	1100	"
Fort Morgan	-	3000	"
Sterling	-	2200	"
Ovid	-	2800	"

"2) There shall be no settleable solids contained in the total effluents, and that suspended solids loads in these effluents not exceed the numerical levels prescribed above for 5-day BOD.

"3) Disinfection be provided for each and every waste discharge so that the receiving stream or waterway directly below each mill shall not shown an increase of more than 5,000 total coliform bacteria per 100 ml, and 1,000 fecal coliform per 100 ml, over corresponding densities upstream of the mill discharge.

"4) Dissolved oxygen in the treated waste effluents not be less than 2 mg/l at any time to insure minimum dissolved concentrations of 4.0 mg/l in the receiving streams or waterways.

"5) There be absence of grease, oil, floating solids, slime or sludge banks in the receiving streams, or waterways, as a result of waste discharges from the sugar beet mill.

"6) Waste treatment and control measures and other procedures shall not cause pollution of the underlying valley-fill aquifiers.

"7) There be no disagreeable odors or other nuisance in the areas outside of, and immediately adjacent to, the plant sites.

"8) Each sugar beet mill shall conduct continuous monitoring of the quality of final waste effluents and of each receiving stream above and below the points of waste discharge to these streams. Adequate records shall be maintained by each plant on water quality and shall be reported regularly to the State Water Pollution Control Agency.

"9) Final approval of design plans on all waste treatment and control measures, inspection during and following construction of facilities, and final joint evaluation (together with the industry) of waste treatment and control performance shall be provided by the State Water Pollution Control Agency."

The above recommendations more or less set the limits of this report. The stream survey and biological sampling results associated with sugar beet processing are not included herein since such information was reported upon at the Second Session of the Conference.

Section I of this report consists of introduction and background to the problem, description of the study area, explanation of analytical methods and important technical terms, and description of the various operations within the sugar beet processing plant. Section II gives the full results of industrial plant surveys and status evaluation for each of the ten sugar factories in the South Platte River Basin. Section III discusses the total waste load leaving the factory and the discharge load entering the receiving stream from the South Platte River Basin mills. Unit operations are related to magnitude of waste load. Section IV describes the bacteriological aspects of sugar beet processing wastes derived from various studies conducted across the country. Section V offers a comprehensive review and evaluation of current methods for waste abatement and treatment within the modern sugar factory. Both published and unpublished information from the United States, Canada, and foreign countries have been used. Innovations and broad implications for the future are also examined.

B. DESCRIPTION OF AREA

1. Geographic Features

The study area comprises the South Platte River from the city of Brighton, some 20 miles below Denver, downstream to the Colorado-Nebraska Stateline a total distance of 210 miles; St. Vrain Creek from Longmont to the stream mouth some 23 miles; the Big Thompson River from Loveland to the stream mouth, 27 miles; and the Cache la Poudre River from Windsor to below Greeley, about 26 miles. Total stream distance approximates 300 miles. The Brighton, Longmont, Johnstown, Loveland, Windsor, Eaton, and Greeley sugar factories are located in the Middle portion of the Basin. The Fort Morgan, Sterling, and Ovid factories are in the Lower Basin. The ten mill sites are shown in Figure 1. St. Vrain Creek, the Big Thompson River, and the Cache la Poudre River are the three largest tributary streams to the South Platte River in the study area.

The lands of the Middle and Lower sectors of the Basin are primarily devoted to farming, with the growing of field and vegetable crops and cattle raising as the agricultural mainstays. This enterprise is highly dependent upon extensive irrigation systems which divert large amounts of surface water from the main-stem South Platte River and vari-

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ous tributary streams. Supplemental agricultural water is received from numerous wells sunk into the shallow ground-water aquifers along the river valleys.

In addition to many small farming communities, there are a number of population centers having great importance in the social-economic well-being of the Rocky Mountain region. These include Fort Collins - 26,695 persons; Greeley - 26,314; Boulder - 37,718; Sterling - 10,751; Fort Morgan - 7,379; Brighton - 7,055; Brush - 3,621; and Julesburg - 1,840 (5).

Commercial trade and some light industry are present mainly in the larger cities and towns. The Great Western Sugar Company contributes significantly to the economy of the area.

The region is well-traversed by good roads, rail and airline routes. Facilities for transporting people, goods, and services are considered excellent.

2. Water Resources and Uses

The water resources of the area are in extremely heavy demand. In fact, water rights greatly exceed the available supplies. Resources comprise surface waters, ground water, and transmountain diversions. Agricultural irrigation is the major water use, comprising 90 percent or more of the total demands from both surface and ground water sources (1). Large-scale withdrawals continue unabated throughout the year, in the summer for direct-use irrigation and in the winter for irrigation water storage. Streamflows are augmented in large degree by return ground-water inflow from previous agricultural irrigation. Streamflows are generally lowest in the period from June to September. The secondary period of low flow occurs from October through February. Minimum conditions occur frequently and at many locations especially below large diversion systems. Flows less than 20 cubic feet per second (cfs.) are not uncommon.

At present time, all surface withdrawals for municipal water supply are situated above sugar beet mill locations. These cities and towns receive their supplies from the upper watersheds of St. Vrain Creek, the Big Thompson River, and the Cache la Poudre River. Two major factors preclude any such use of the lower stream waters. The waters are grossly polluted with sugar beet wastes, and also are high in salinity content from irrigation return flows and natural sources. Treatment of these waters under the present conditions would involve undue expense or otherwise could not guarantee a product of sufficient purity.

Many towns in the study area utilize ground water with salinity content equal or exceeding that in nearby surface waters. The question is posed whether these surface waters, reasonably free of organic wastes, could serve as supplementary or alternate sources of municipal water supply. If salinity loads are decreased in the future, special study of these resources would be more than appropriate. Overall benefit-cost relationships are not properly defined at this time. However, future populations exerting continuously increasing demand, will alter the distribution and upgrade the classes of uses to which these waters will be directed.

Effects of organic wastes on irrigation water use are mitigated since the seasons do not generally coincide. However, the Johnstown picture is different where waste discharges occur throughout the year. Farmers below the Johnstown sugar recovery - MSG plant have reported serious odor and a high degree of coloration in the irrigation waters. The situation indicates that the service life of irrigation structures and appurtenances may be shortened because of undesirable effects of waste discharges. Major problems are the disagreeable odors and the undesirable physical appearance of stream and irrigation waters (6).

The fisheries resource below each sugar factory and the city of Denver has been reduced almost to the point of complete extinction (6). Only tolerant species are found which include carp, suckers, and minnows. The potential demand for creating a game fishery in the presently affected streams of the Basin is very real, and development of this resource would have important merit. The Colorado Game, Fish and Parks Department has stated that a desirable fishery could be maintained in the streams, regardless of the low flows, if only an effective waste abatement program was established (7). Accordingly, large-scale benefits could be made available to the residents of the Denver Metropolitan area, the many thousands of tourists in the region, and the general population.

Recreation on a broad spectrum is a very active pursuit within the State of Colorado and when linked with tourism is ranked as the State's third largest industry. As such it contributes in great measure to the region's economy. In the past, the valley and plains areas have received much less attention than the mountain region but this pattern is undergoing rapid change. Also the lower areas must be traversed by tourists and other people in their travel to and from the mountains. The following points are pertinent to recreational use of the waters in the Middle and Lower Basin:

1) Large use is made today of the limited recreational facilities, particularly the facilities located on irrigation water storage reservoirs.

2) Residual wastes from industry and various municipalities may have serious adverse effects upon the recreational uses envisioned for the future Narrows reservoir.

3) The poor physical appearance of affected watercourses with solids, floating materials, sugar beet chunks, scum, odors, and other conditions of gross degradation are aesthetically objectionable.

Brief reference must be made to the insect vector problems of the Basin. A previous Project document (8) has shown that the Basin area possesses all the natural features for the large-scale buildup of insect populations and the associated vectors of disease to man, livestock, and wildlife. When large amounts of organic material are added to the system, in this case from inadequately treated sugar beet wastes and municipal sewage, all the necessary environmental factors are present both in time and space. The organic wastes trapped in pools, off-channel areas, and available as stream bottom sludge deposits greatly enhance insect production. Many of the various species of mosquitoes and flies transmit disease or otherwise create serious nuisance. Also, mosquito-borne encephalitis is present in relatively high degree in the South Platte River Basin. On this account, maximum effort should be made to reduce the organic level caused by sewage and industrial wastes. Sugar beet wastes comprise the majority of this waste load.

The above discussion on present water uses and adverse effects is not by any means all-inclusive. The prime objective is to provide greater understanding and recognition of the serious water quality problem existing within the South Platte River Basin. Even more important, this situation visualized for the future could be far more serious and with widening consequences. The Middle Basin together with Metropolitan Denver are projected as a region with great future growth in people, material goods, and services (9). This area and the needs of the large population will demand far more from its natural resources, including adequate water quality and quantity to be made available on a large scale.

C. ANALYTICAL METHODS

Except in a few cases where special techniques were found necessary, all laboratory procedures and analyses were undertaken in accordance with "Standard Methods" (10). Special procedures are described in the following.

Bacteriological testing was based upon 5 replicate tubes at each of 3 significant dilutions to obtain the MPN (Most Probable Number) value. The total coliform bacteria determination corresponded to the confirmed coliform test as given in Standard Methods. The fecal coliform bacteria determination consisted of a confirmation of the positive presumptive tubes from the standard coliform analysis using EC broth at 44.5 ± 0.5°C. with an incubation period of 24 hours (11, 12). Soil samples for bacteriological testing were mixed with buffered distilled water in a weight ratio of 1 soil: 9 water, in a Waring blender under sterile conditions. The soil-water mixture was then subjected to the same testing procedure as for a water sample.

Fecal streptococci were evaluated by direct plate count on KF agar from an appropriate sample dilution. The incubation period was 48 hours at a temperature of 35°C (13). Samples for Salmonella determination were filtered through a membrane filter and pre-filter, and the filters were inoculated into various enrichment media, as was the straight sample.

The enrichment media included GN Broth, Hajna, SBG Sulfa Enrichment, and Tetrathionate Broth Base. The growth on these media was subsequently streaked onto selective plating media which consisted of Bismuth Sulfite, MacConkey, and SS Agar. Colonies with characteristics typical of Salmonella-Shigella were picked, purified, and run through appropriate biochemical tests, followed by serological identification (14, 15).

A small percentage of the 1963-1964 bacteriological results were reported as exceeding or being less than a certain number. For ease in computation, such results were converted into absolute values. Coliform densities are given in this report as MPN or Most Probable Number per 100 ml, and the daily bacterial loads as BQU, or Bacterial Quantity Units (see Section ID). All data in the report except those for bacteria and pH are average values. The latter are reported in terms of the median or geometric mean values. Lastly, the river mileages for various locations within the study area are derived from the "River Mileage Index for the South Platte River Basin" previously published by the Project (16).

D. DEFINITION OF TERMS

The definition of certain technical terms appearing most frequently or otherwise important in better understanding this report are given as follows:

Biochemical Oxygen Demand (5-day BOD, BOD) is a measure of the oxygen demand of sewage and industrial wastes determined by biochemical techniques. BOD in the stream is a measure of oxygen used by living organisms in decomposing these wastes.

Bacterial Quantity Unit (BQU) is one measure of the total load of bacteria passing a given stream location and is particularly useful in comparing relative loads between stations. The number of BQU's is derived as the product of flow in cfs and coliform density in MPN/100 ml, divided by 100,000.

Chemical Oxygen Demand (COD) is a measure of the oxygen demand in sewage and industrial wastes or in the stream, determined by chemical techniques. A definite relationship between COD and BOD for a specific waste flow may generally be established from proper laboratory evaluation.

Conductivity is a measure of the ability of water in conducting an electrical current. In practical terms, it is used for approximating the salinity or total dissolved solids content of water.

Fecal Coliform Bacteria represent a specific group of microorganisms from the gut of warm-blooded animals. Enumeration yields an index for that portion of the coliform group which is of fecal origin with a 95-percent level of confidence. Similarly, coliform organisms from other sources are excluded from the test with about the same level of confidence. As the numbers of fecal coliform increase, the relative probability of hazard from enteric disease also increases.

MPN is an abbreviation of the phrase "Most Probable Number." The term MPN derives from bacteriological testing procedures and represents the number of bacteria most likely to occur in statistical theory under particular conditions of the test.

pH is a measure of the relative acidity or alkalinity of water. a pH value of 7.0 indicates a neutral condition, less than 7 a predominance of acids, and greater than 7 a predominance of alkalis. There is a 10-fold increase (or decrease) from one pH unit level to the next, e.g., 10-fold increase in alkalinity from pH 8 to pH 9.

Population Equivalents (P.E.) describe the pollutional effect of various waste discharges in terms of a corresponding effect of discharging raw sewage from an equivalent number of human population. Each P.E. represents the waste contributed by one person in a single day.

Total Coliform Bacteria represent a diverse group of microorganisms whose presence have been classically used as indication of sewage pollution in water supplies. They are always present in the intestinal tract of man and other warm-blooded animals and are excreted in large numbers by fecal wastes. Where such fecal pollution exists, there is always the possibility of the presence of enteric pathogenic bacteria and other pathogenic entities. Increasing density of the coliform bacteria group is assumed to represent an increase in the quantity of pollution and, therefore, greater hazard. It must be noted under some circumstances total coliform may be present which are derived from sources other than fecal excreta.

Total Suspended Solids (TSS) are solids found in wastewater or in the stream which can be easily removed by filtration. The origin of suspended matter may be man-made wastes or natural sources such as silt from erosion.

E. DESCRIPTION OF SUGAR BEET PROCESSING

1. History

The culture of sugar beets is recorded in the earliest periods of man's history. The beet root is known to have been part of the diet of the Egyptians during the building of the Great Pyramids. It was later found as a common food substance throughout the Middle Ages. Extraction of sugar from the beet was first started on a commercial scale both in Germany and France in the early nineteenth century. Improvement in the manufacturing process evolved in slow degree until some success was achieved around the 1850's. The earliest sugar beet enterprises in the United States were established in the 1830's in Pennsylvania, Massachusetts and Michigan, but these plants and many others that followed failed in a few years. After many disappointing ventures, the Alvarado, California sugar beet mill achieved an economic break-through in 1879 and was subsequently described as the first successful operation in the United States.

The first sugar beet factory in the State of Colorado was established in Grand Junction and operated from 1899 to 1943. This was followed by Rocky Ford and Sugar City in 1900, and then the factories located in the South Platte River Basin acquired by and built for the Great Western Sugar Company. The Basin plants were established as follows: Loveland - 1901, Greeley - 1902, Eaton - 1902, Windsor - 1903, Longmont - 1903, Sterling - 1905, Fort Morgan - 1906, Brighton - 1917, Johnstown - 1926, and Ovid - 1926. Factories were also constructed at Fort Collins, Brush, and Fort Lupton, in 1903, 1906 and 1920 respectively, but these have been discontinued in recent years (17).

Up to the late 1940's the economic stability of both the sugar beet and cane sugar industry fluctuated widely. Tariff reductions on import of foreign sugar very seriously depressed the domestic sugar economy throughout its early growth. The sugar industry is now protected and operates on a quota system established by the Sugar Act of 1948 which was extended and amended in July 1962. Quotas are exercised on both domestic and foreign sugar and in most cases the administration of this Act has been favorable to the industry in this country. The domestic sugar industry at present time provides an annual payroll in excess of 160 million dollars (18).

In 1955, it was reported that sugar beets were grown on almost one million acres of land, the large majority in the Western United States, by some 60,000 farmers in 22 States. Sugar from this acreage accounted for almost one-fourth of the total consumption of sugar in the country. At that time, there were 18 processing companies operating 73 sugar beet factories in 16 States (19).

2. Process Operations

The various commercial operations required for converting sugar beets into refined sugar are many, and in some cases relatively complex. The sugar company in large degree is responsible for the sugar beets long before these reach the processing plant. The company obtains acreage allotments, conducts research on developing beet seed most adaptable for growing in the local areas, undertakes contracts with the individual farmers for the proper growing, harvesting, and delivery of sugar beets to the processing plant, and offers advice and assistance to the farmers in solving their particular agricultural problems. The company generally stores the granulated sugar and the various sugar products at the factory site. Management at this point becomes engaged in arranging and delivering its products, advertising, product and plant improvement, and other functions necessary to skillful and competitive merchandising.

The sugar beet plant utilizes a series of physical and chemical unit operations and processes which over many years of experience has proven most successful. The prime objectives of the sugar factory are maximum sugar recovery together with consistently high purity in the finished products. The incoming beets contain 15-16 percent sugar content which means about 300 pounds of refined sugar are extracted from each ton of raw beets processed. The mill produces a variety of sugar products including granulated, brown, confectioners, powdered, fondant, cube, and molded sugars together with various syrups and molasses (17).

Sugar mills operate over a 24-hour day and employ from 40 to more than 400 workers at a single plant. In the northern climes, beet processing is generally conducted from late September or early October until January, for a continuous period of 90-120 days. In other respect, beet processing in California occurs over the summer and fall months and sometimes for short durations in late spring, approximating 110-160 days each year.

The Great Western Sugar Company provides a good illustration on the process flow within the sugar factory together with a detailed explanation of the various operations, both contained in Figure 2. Supplementary information on the major unit operations is given in the following discussion. Further details on the individual Basin factories are included in the next section of this report. Many exceptions are possible on the process line depending upon the particular factory and sugar company.

The sugar beets are delivered to the individual factories by truck or railroad car. The beets are stored in large piles on the factory grounds or enter directly into processing. Large beet piles are not common in California or other warm climates since the rate of decay is too great in storage. Sugar beets are removed from the storage piles or directly from the incoming trucks or railroad cars and placed into the wet hopper of the beet flumes. The flumes consist of long concrete channels through which beets are conveyed via a continuous stream of water to the inside of the factory. Beet chips and tailings, stones and miscellaneous debris are removed by various devices on the flume line. The beet flume system may be very extensive or in some mills extremely limited. A few factories employ belt conveyors for moving the beets part of the way into the mill. The water supply for the flumes is received from the main water supply tank, excess condenser water, recirculated flume water, or other sources.

Inside the plant, the beets are separated from the flume water, enter a beet wheel and are elevated to a beet washing tank, pass over a roller-spray table, and are then ready for slicing. Water supply for washing and spraying in most cases is obtained from the main water supply tank. The progress of the beets so far has been followed up to the point of entering the main processing. The basic processes consist of diffusion, juice purification, evaporation, crystallization, and recovery of sugar from molasses. The auxiliary stages include pulp drying and concentration of Steffen filtrate. A Steffen house employs a number of additional operations over and above the straight-house factory and is designed to extract additional sugar from molasses. The molasses is an end product from the straight-house factory (17).

The washed beets are sliced into thin strips or cossettes and passed to the continuous diffuser. A few mills may still employ the old type diffusion battery consisting of 12 to 14 cells in series arrangement. The diffuser extracts sugar from the cossettes under counter-current flow of water. In this process, the sugar passes through the porous membrane of the beet cossettes into the water. The liquor impregnated with sugar is termed "raw juice" which is sent to the purification operations.

The exhausted cossettes or wet pulp are transferred to the pulp presses and the dryer. Otherwise the wet pulp is flumed into a pulp silo for storage and later use as livestock feed. The pulp is generally transported to the presses by conveyor belt; if instead water is used, this is known as pulp transport water and may constitute plant waste. Liquor extruded from the pulp in pressing is known as pulp press water and is generally returned to the diffuser; if discarded, this liquor becomes part of the plant wastes. It is also common terminology to describe all wastes associated with the handling of pulp as "process wastes."

Raw juice is limed and carbonated and sent to the Dorr clarification system. Non-sugars and undesirable sugars are in large part absorbed into the precipitated calcium carbonate which settles out in the thickener-clarifier tanks. A second carbonation removes the last traces of dissolved lime. The purified liquor from the second carbonation is termed "thin juice." Sludges from the thickener-clarifier tanks and second carbonation are filtered. The end filter cake is slurred with water and sent to waste. This waste is known as lime mud or lime mud slurry.

The thin juice passes through the multi-effect evaporators under high-pressure steam, the end result which is to raise the sugar solids in the juice from 10-15 percent up to 55-70 percent. The concentrated liquor from the evaporators is termed "thick juice." The thick juice is mixed with remelt sugar and forwarded to the vacuum pans. The solutions are boiled under high vacuum, a supersaturation condition is created, the solution is then "shocked" by introducing small quantities of powdered sugar, and crystals begin to form.

The crystals and the mother liquor, or "massecuite," are passed from the pans to a mixer, followed by retention in the centrifugals for spinning off the liquid, the granulator for drying, and then the finished product is received for packaging and for storage. The remaining crystallization and separation operations shown in Figure 2 involve the treatment and recovery of additional sugar from the middle and low-grade syrups and massecuite.

PAGE NOT

AVAILABLE

DIGITALLY

Process for Beet Sugar

It is all-important in beet sugar operations for the technician to understand the basic flow of the process, step-by-step, through the factory. The process itself remains virtually the same from the early days of Great Western at the turn of the century, but its actual operation differs now with the addition of newer equipment and controls and with the higher standards for the finished product. The explantation here traces the basic flow through the main stages, designated by different colors, on the diagram on the opposite side. This flow sheet may be preserved in a three-ring notebook for study and reference by loosening the staple in the fold at far left.

BEET HANDLING

• Sugar beets are delivered to the sugar factory in trucks or railroad cars. They are piled on the ground, over flumes, or dumped directly from rail cars into wet hoppers, where jets of warm water help unload the beets. The beets float into the factory itself by water in a flume. On the way, they pass through a rock-catcher or rock-drag for the removal of any rocks, mud or sand, and then through another

Trash Removal

section for the removal of any trash, weeds, or leaves. They then flow into a beet wheel to be elevated into the beet washer. From the washer, they move across a roller-spray table for additional washing and removal of trash. The beet elevator then carries the beets to the top floor of the factory to the picking table. While moving across the table, the beets undergo a hand search for any more trash or foreign material. From there, they drop into a hopper above the beet slicers.

DIFFUSION BY EXTRACTION

• The beets are fed from the hopper into the slicers, where they are cut into long noodle-like pieces resembling shoestring potatoes. These are called cossettes or chips. Emerging from the slicers, the cossettes fall on to a conveyor belt to be carried across a continuous weighing device and then discharged into a chute leading to the diffuser. Here the sugar is removed from the cossettes by being dissolved in

The Diffuser

hot water. The diffuser itself stands on a slope. Water enters the higher end and flows down the slope, while the cossettes enter the lower end and move upward through the water by means of scrolls. (Note: The Loveland and Fort Morgan factories employ diffusers with different mechanical equipment, but operate on the same principle of diffusion.) The diffuser works continuously to extract sugar from the cossettes. The process of diffusion uses osmosis, or the passage of sugar

The Pulp

through the porous membrane of the beet cossettes to the water. The sugar solution leaves the diffuser at the lower end in the form of "raw juice." When the cossettes reach the upper end—free of most of their sugar—they become beet pulp and move on to the pulp dryer or the wet pulp silo to be used as livestock feed.

PURIFICATION & FILTRATION

• Upon leaving the diffuser, the raw juice moves through the various stages of purification and filtration to remove impurities and other non-sugars. It is first heated in the raw juice heaters. It is then pumped to the first of the two tanks of the first carbonation station. Here the raw juice is mixed with milk of lime or saccharate milk. It then moves on to the second tank for treatment by carbon

First Carb dioxide gas (CO_2) from the lime kiln. The CO_2 enters the gassing tank under control to give the juice the proper pH or alkalinity upon leaving the first carb station.

The Dorr Thickener • Now the carbonated juice flows on to the Dorr thickener at most factories. The thickener tank acts to settle out the precipitate formed in the juice by milk of lime, or saccharate milk, and carbon dioxide. This leaves a clear juice to be sent to the heaters and then on to the second carbonation station. The mud or sludge remaining on the bottom of the thickener goes to the drum filters for washing in order to recover any other sugar. After this, the mud goes to the sewer. **Sweetwater** The filtrate and the wash water from the drum filters now become "sweetwater." It goes either to the lime house to be mixed with burned lime, or to the Steffen house at factories with that process; any excess goes back to the first carb tank.

The Pre-Limer System • There is one exception to this flow of the juice at three factories—Greeley, Windsor and Sterling. These three houses send the raw juice to a pre-liming tank ahead of first carbonation. There, the juice is mixed directly with milk of lime and then moves on to first carbonation, where more lime is added and carbonated. Upon leaving there, it goes to a direct filtration station, with either Grand Pont or Kelly filters, instead of to the Dorr thickener. The juice then resumes the normal course through the drum filters to second carbonation.

Second Carb • In the second carb tank, the clear juice again mixes with CO_2 gas at a controlled rate to obtain the proper pH or alkalinity. It then moves on to the second carb filters for the removal of precipitates formed by the CO_2 gas and the lime left in the juice from first carbonation. This precipitate goes to the sludge tank and then back to the drum filters for further washing, while the clear juice from the second filters moves on to the third saturation station.

Third Saturation • In third saturation, the juice mixes with sulphur dioxide (SO_2) gas from the sulphur stove. This gas removes some color-forming materials in the juice that would eventually appear in the finished sugar, but its main function is the final adjustment of pH for sugarend liquors. The juice then moves on to the evaporator supply tank and becomes known now as "thin juice."

EVAPORATION • From the supply tank, the thin juice moves through heaters and then to the evaporation station. This consists of five bodies, or effects, usually horizontal, but in some factories also vertical. Inside the bodies, steam heat removes excess water from the thin juice in five successive stages. **Thick Juice** It concentrates the dry substance in the juice from a range of 13% to 15% upon entering the first body to 65% to 70% upon leaving the fifth body. In other words, while going through the evaporation station, the thin juice becomes thick juice.

CRYSTALLIZATION & SEPARATION • The thick juice now moves on to the "blow-ups," a tank for mixing the juice with melted sugar from the sugarend. After heating and filtration, this concentration becomes known as "standard liquor"—or the purified material for making crystallized sugar. It goes to the standard liquor storage tank. (In some factories, the evaporator thick juice goes to the high melter station instead of the blow-ups. In this flow, the thick juice is used instead of thin juice to dilute and melt the high raw sugar. It is then sent through the heaters and filters to the standard liquor storage tank.) **White Pan** In either case, the standard liquor moves on to the white pan to be boiled and crystallized to a high concentration of sugar called "white massecuite." This heavy mass then drops into the white mixer.

White Centrifugals • From the mixer, the white massecuite drops into the white centrifugal machines. Here, the spinning action of the centrifugals separates the sugar crystals from the liquor containing sugar syrups and impurities. The crystals remaining in the centrifugal basket undergo further spinning for washing and some drying. **The Granulator** The spun sugar then drops to a conveyor to be moved up to the granulator for further drying and cooling. The finished sugar then passes over screen sifters and moves on to the bulk sugar bins for storage or to the warehouse for packaging. This completes the "straight-line" flow of the process from sugar beets to beet sugar—but other "side-line" processes still remain to recover more of the sugar from the beet.

The White Side • The "white side" of the sugarend comprises only the first stage in the complete crystallization and separation process—that is, the white pan and white centrifugals handle the material with the highest purity and the greatest yield. Other sugar—along with important by-products—still remain in the syrups and wash-water spun off by the white centrifugals. These must be re-crystallized in the sugarend.

Lower Purity Syrups • There is the "hi-green" syrup. It is spun off by the white centrifugals before the application of hi-wash water on the massecuite. There is also the "hi-wash" spun off by the white machines during the actual washing period. The hi-wash usually flows to the hi-melter and then on to the blow-up tank to enrich the mixture. Meantime, the hi-green goes to its storage tank and then to the hi-raw pan.

Hi-Raw Sugar Cycle There, much like on the white side, the syrup is boiled down to a high concentration, until the sugar crystallizes. It then drops into the hi-raw mixer. From there, it goes to the hi-raw centrifugals, where the spinning action again separates the crystals from other sugar and impurities in the liquor. It is also washed to increase its purity. From the centrifugals, the hi-raw crystals go back to the process, instead of to final product storage. Hi-raw sugar moves to the hi-melter to be mixed with the high wash and also thin juice at a controlled brix or concentration. This hi-melter mixture flows back to the blow-up tank to be mixed with thick juice, where it re-enters the process as standard liquor on the white side.

Lo-Raw Sugar Cycle • There is also the "machine syrup" spun off by the hi-raw centrifugals. It goes to the machine syrup storage tank on the pan floor and then to the lo-raw pan. Here again, boiling crystallizes the sugar in the mass. But instead of going directly from the pan to the centrifugal machines, the lo-raw massecuite drops to the crystallizers for cooling and further crystallization over a period ranging from 20 to 40 hours.

The Crystallizers With this completed, the lo-raw mass goes to the lo-raw mixer and then to the lo-raw centrifugal. Once again, the spinning action separates the crystals from the liquor. The lo-raw sugar goes to the lo-melter, with thin juice added there, and then on to the lo-melter storage tank for use in the hi-raw pan or in some cases the lo-raw pan again.

The Melters The lo-melter can also be sent to the blow-ups to be mixed with the hi-melter and re-enter the process with the standard liquor, or it can also be sent back to the first carb station to be mixed in with the raw juice. (Some factories operate with only one melter. In this case, the melted sugar from the lo-raw centrifugals goes with the melted sugar from the hi-melter to mix with the thick juice to form the standard liquor.) The crystallization and separation cycles end with the "lo-green" or molasses spun off by the lo-raw centrifugals.

Molasses • At a non-Steffen house, this molasses will be shipped by rail tank car to a nearby factory with the Steffen process. At a factory with a Steffen house, however, this same sugarend molasses is shipped to the Johnstown sugar factory for further processing. All our Steffen factories, with the exception of Billings, work 100% non-Steffen molasses in the Steffen process. The Billings factory works half of its own molasses in the Steffen house with the other half coming from the Lovell factory.

STEFFEN PROCESS • The Steffen process employs a different method to extract more sugar from the molasses left over at the end of the regular sugar factory process. At present, six Great Western factories operate Steffen houses—Loveland, Longmont, Fort Morgan, Scottsbluff, Gering and Billings. The process begins with burned lime from the factory lime kiln. The lime goes through a crusher and then to a Raymond mill, where it is pulverized. The powdered lime then moves to the Steffen cooler tanks

Cooler Solution to be mixed in measured amounts with a "cooler solution." This solution is made up in the for-cooler tank with non-Steffen molasses mixed with water and recycled cold filtrate from the Steffen process itself. In the cooler tanks, the powdered lime combines with the sugar in the molasses solution to form tri-calcium saccharate. The precipitate of this mixture in the coolers moves to the cold drum filters for washing. The cold saccharate cake from the filters goes on to the saccharate mixing tank to be diluted with sweetwater from the regular factory process. Meanwhile,

Filtration · **Saccharate Milk**

the cold filtrate from the cold drum filters goes through a heater and then to the hot Steffen Dorr thickener tank, where the precipitate or the hot saccharate cake settles out. It is then sent to the hot Steffen filters. From there, the hot cake goes to the saccharate tank to be mixed with sweetwater and the cold saccharate cake from the Steffen process. The saccharate milk in the tank then flows back to the first carb station to enter the regular factory process flow. There remains the filtrate from the Dorr thickener and the hot drum filters. It goes to the process for making CSF—concentrated Steffen filtrate. About 40 percent of the cold saccharate filtrate returns to the for-cooler tank of the Steffen cycle. In three of the Steffen houses, the cake from the hot Dorr thickener goes back to the for-cooler tank, instead of the hot drum filter, to make up part of the Steffen cooler solution.

CSF Process · **CSF Carbonation**

• The CSF process, for making concentrated Steffen filtrate, takes the filtrate from the hot Dorr thickener and the hot drum filters. It first passes through the flash cooler and then on to the hydrolysis tank to be retained for about 40 hours. From there, the filtrate flows to a carbonation tank to be mixed with CO_2 gas from the lime kiln. It is carbonated to about 7pH. The filtrate then goes to the CSF Dorr thickener tank for the removal of the sludge formed by carbonation. This sludge goes to the drum filters, where the filtrate is retained in the process and the mud discarded. Meanwhile, the clear liquor from the CSF Dorr thickener goes on through heaters and then to the CSF evaporators. With the removal of water, the Steffen filtrate becomes concentrated and goes to storage tanks. It is then shipped by rail tank cars to the Johnstown MSG Plant, in Colorado, for the extraction of monosodium glutamate, a flavor-enhancer for many foods.

THE LIME KILN

Milk of Lime · **CO_2 Gas**

• The lime kiln supplies burned lime and CO_2 gas for both the regular factory process and the Steffen process. Both products result from the burning of limestone with coke in controlled amounts in the kiln. There is one exception, at the Fort Morgan factory, where the kiln operates automatically on natural gas fuel without the use of coke. For the regular factory process, the burned lime goes to the slacker to be mixed with sweetwater. This produces milk of lime for use in first carbonation. For the Steffen process, the burned lime goes through a crusher and then a Raymond mill. The powdered lime then moves on to the Steffen cooler to be mixed with water, molasses and recycled filtrate to form the Steffen cooler solution. The CO_2 gas from the lime kiln enters the regular factory process at both first and second carbonation and also goes to the carbonation tank in the CSF process.

THE PULP DRYER

Pulp Presses · **Dryer Drums** · **Pellet Mills**

• There are pulp drying operations at most Great Western sugar factories. A direct by-product of the sugar process, dried or pelleted beet pulp provides highly nutritious feed for livestock. The operation begins with the exhausted cossettes or chips emerging from the upper end of the diffuser in the sugar factory. This pulp, still wet, moves to the dryer house on belts or through pipelines to the pulp presses. The mechanical squeezing action of the presses reduces the moisture of the pulp to about 80%. At this time, the protein content of the pressed pulp may be increased from about 8% to 13% by adding a liquid protein concentrate (LPC) from the Johnstown MSG Plant. The pressed pulp then enters the dryer drums, fired by either coal or natural gas, where the furnaces reduce the moisture content from 80% to about 5% or 10%. Now in dried form, the pulp moves on conveyors to bulk storage in the pulp warehouse or to the pellet mills. Under the compaction of the pellet mills, the pulp emerges in a hardened form for easier handling. It then goes to bulk storage in the pulp warehouse. Both dried and pelleted pulp may also be sacked, depending on the facilities at the factory. If there is no pulp dryer at the factory, the wet pulp goes to an open silo to be stored until trucked away in wet form for stock feed.

STEAM & POWER

Coal & Gas

• Almost all of the processing operations in the sugar factory depend upon the steam boilerhouse and electric generators for power. A critical factor in economical processing, the steam boilers may be fired either by coal or by natural gas, depending on the equipment at each factory. Steam furnishes the supply of heat required for many process operations, and also passes through turbo-generators to provide electrical power to move machinery. Some electrical power may also be purchased locally.

Three main types of waste are produced from the concentration steps of the process. The first consists of spillage, leakage, etc. which escapes to the floor drains. This type waste may actually occur anywhere in the plant. The second waste is the result of cleaning and reconditioning the evaporators, pans, and other equipment. The third waste consists of the excess condenser water and condensates from the multiple-effect evaporators and vacuum pans not reused within the plant. Condenser waters receive organic load by virtue of material becoming entrained in the vapors and being carried over into the condenser system.

The Steffen process found only in a Steffen house factory receives molasses, and employs a two-stage lime precipitation of sugar (from the molasses) giving cold and hot saccharate cakes off the filters. A mixture of the cold and hot saccharate sludges is slurried and returned as the liming agent in the first carbonation stage of raw juice purification.

The CSF (concentrated Steffen filtrate) process also associated with Steffen house operations is a procedure for concentrating the filtrate essentially from the hot saccharate filter cake described above, for eventual reuse. The CSF product in the South Platte River Basin is shipped to the Johnstown, Colorado sugar recovery-MSG factory, described in the next section of this report. The final sludges resulting from the CSF process are believed to be mixed in with lime mud for disposal. The CSF evaporator condensates are wasted to the plant sewer. Results collected by the Project show that this condensate compares in strength to that received from straight-house operations but comprises only 5-8 percent of the straight-house volume.

Pulp pressing and drying operations produce a nutritional feed for livestock. The dried pulp contains 5-10 percent moisture and may be additionally fortified with liquid protein concentrate. The product may be pelletalized for easier handling and appeal, and is sold in bulk or packaged form.

SECTION II

INDUSTRIAL PLANT SURVEYS

II. INDUSTRIAL PLANT SURVEYS

This section of the report provides evaluation of the industrial waste picture at each of the nine sugar beet mills and the Johnstown, Colorado (sugar recovery - MSG) chemical operations, all located in the South Platte River Basin. Detailed information is given on the source, nature and magnitude of in-plant waste loads and associated factors. Studies were conducted at the Loveland, Windsor, and Greeley sugar processing factories in January 1964; the Fort Morgan, Sterling, and Ovid factories in December 1963; the Brighton factory in January 1965; and the Longmont, Eaton, and Johnstown plants in November 1965. The evaluations are dependent upon conditions that were present at the time of particular surveys. However, additional comments are included at the end of each plant report describing recent changes incorporated by the company together with future plans.

1. Loveland, Colorado

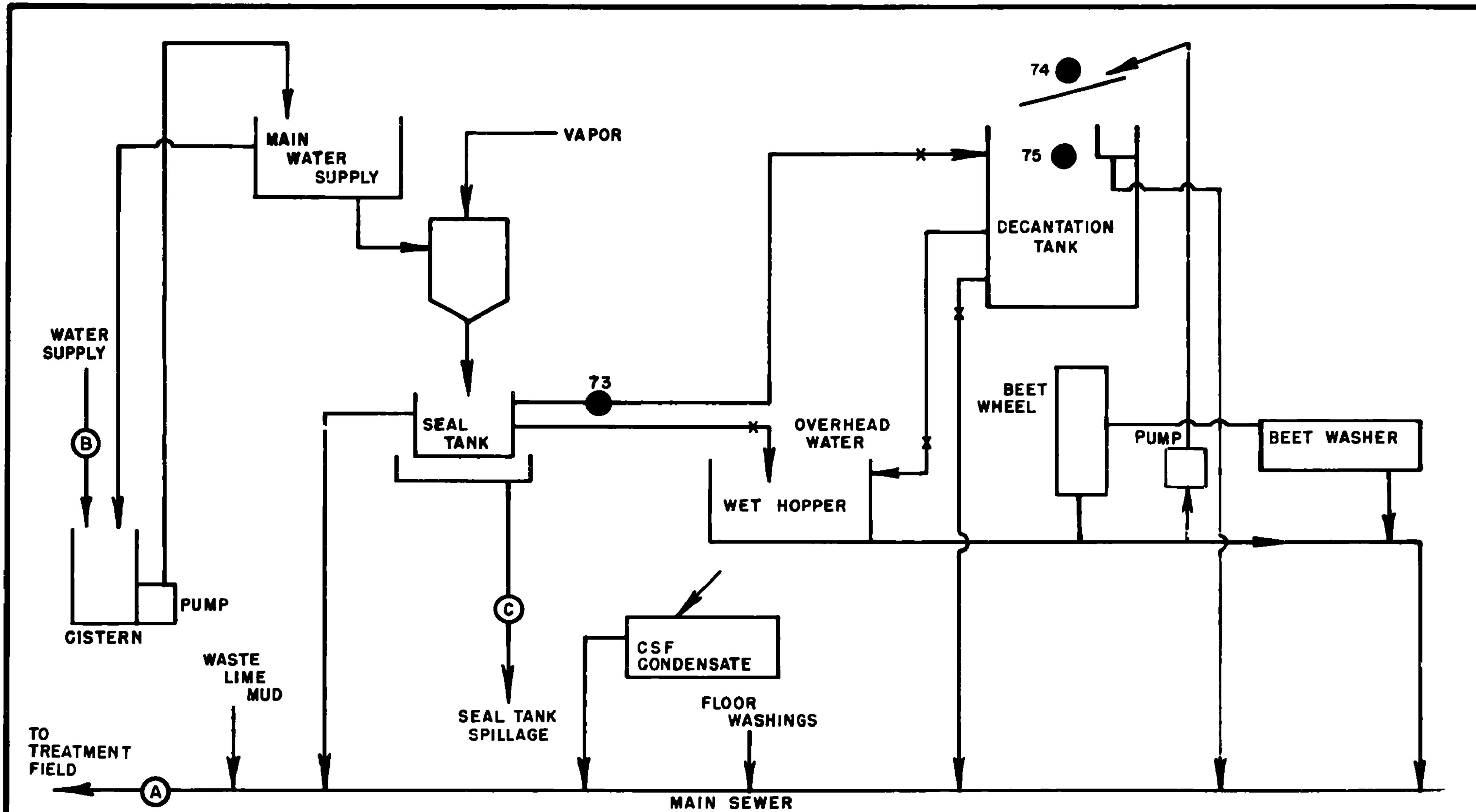
Process and Operation

The Loveland sugar factory, the oldest plant in the South Platte River Basin, was established in 1902. A modernization program was initiated in 1947 which included installation of the chain-type diffuser. During the 1963-1964 campaign, Loveland processed an average of 3,500 tons of beets per day. The plant included a Steffen house operation receiving molasses from the Eaton and Windsor mills; the average rate of molasses over the period of survey was 180 tons per day.

All incoming sugar beets were received in railroad cars, and overhead water used for thawing frozen beets directly in the cars. The plant had full pulp-pressing and drying facilities with full recirculation of press waters to the diffuser. The exhausted pulp was conveyed to the pulp presses by means of a scroll and there was no transport water. The relative locations of sampling points for the Loveland factory survey are shown in Figures 3 and 4.

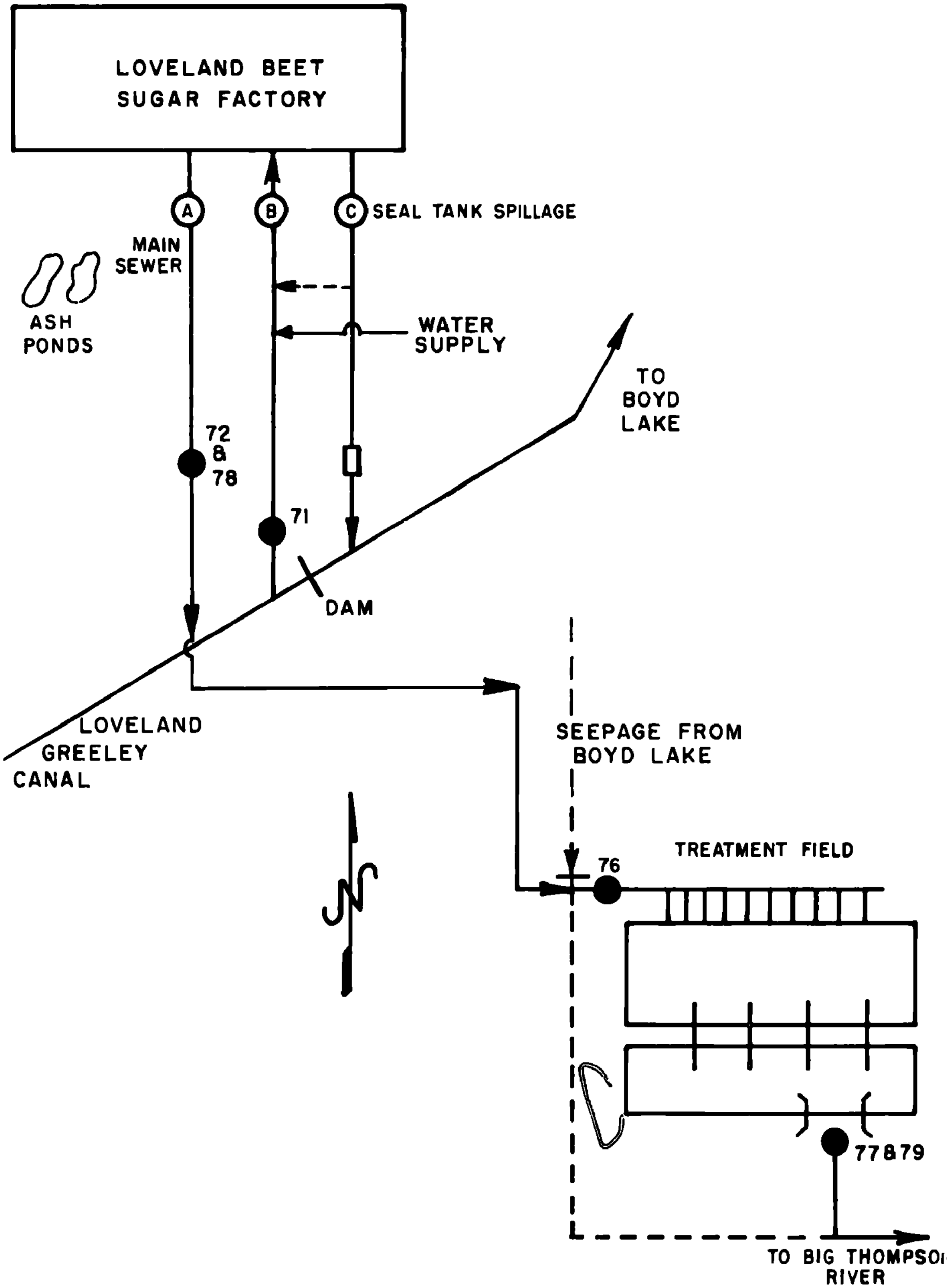
Plant Water Supply

The large majority of plant water supply was obtained from Lake Loveland via the Loveland-Greeley Canal, and this water was sampled at Station 71. A steel pipe carried the water to a cistern where it was then pumped to an elevated main water supply tank within the factory. Overflow from the main supply tank returned to the cistern. City water at the rate of 1.5 cfs was used for diffuser makeup and cooling in the barometric condenser on the cold Oliver filters. Total factory water consumption approximated 18 cfs.



LOVELAND SUGAR FACTORY
IN-PLANT FLOWS
JANUARY 1964

FIGURE 3



LOVELAND SUGAR FACTORY
PLANT AREA
JANUARY 1964

FIGURE 4

Condenser Water

Main supply tank water furnished needs of the barometric condensers which in turn discharged to a seal tank. Seal tank overflow was separately discharged into the Loveland-Greeley Canal downstream of the point of canal water intake as shown by Figures 4 and 5. The Loveland-Greeley Canal terminated at Boyd Lake near Loveland.

Figure 5.
Loveland sugar factory; 1-18-67. Loveland-Greeley Canal in foreground with diversion dam at extreme left, plant water intake canal at center of picture, and seal tank spillage discharging to Loveland-Greeley Canal at lower right corner.

Beet Flume System and Waste Flume Water

The wet hopper at the beginning of the flume system received water from two sources. The seal tank supplied the total needs of overhead spray water, and the decantation tank provided continuous underflow to the wet hopper. The latter source consisted of recirculated flume water pumped at the rate of 1500 to 3000 gpm over a vibrating screen into the decantation tank mixed together with seal tank water. Details are shown in Figure 3. The primary purpose of the decantation tank was to separate sand and tailings from the water. Sand from the bottom of the tank was flushed to the main sewer and screened tailings were sent to the pulp presses. Overflow from the decantation tank discharged to the main sewer. In-plant sampling of the Loveland beet flume system included: a) seal tank water at Station 73 added to the decantation tank; b) the recirculated flume water over the vibrating screen at Station 74, and; c) the mixed contents of the decantation tank at Station 75. The quality of water obtained at Station 74 represented the characteristics of waste flume water ahead of the beet washer.

Main Plant Sewer

The main plant sewer received waste flume water, beet washer effluent, roller spray table washings, decantation tank overflow and underflow, floor washings, CSF condensates, seal tank overflow, waste lime mud, and miscellaneous. Flows to the main sewer are illustrated in Figure 3. Grab samples were taken at a manhole on the main sewer and designated as Station 72; composite samples collected at this same point during the day shift (6-8 hours) were designated as Station 78. These stations are shown in Figure 4.

The ashes resulting from coal burning were removed from the boiler room by flushing with condenser water into one of two ash ponds. Frequent overflow from the ash ponds also entered the main plant sewer. Sanitary wastes from the plant discharged separately to the municipal sewers of the city of Loveland. Waste from the boilout and cleaning of evaporators and vacuum pans, consisting of scale residue and small quantities of hydrochloric acid and caustic soda, likewise were released to the main plant sewer.

The 24-inch main sewer crossed under the Loveland-Greeley Canal and discharged into an open drain which carried the wastes to a treatment area located approximately 1.5 miles east of the mill site.

Waste Treatment

The treatment (aeration) field utilized during the 1963-1964 campaign is shown by Figure 4. The first or primary cell covered 92 acres in area, and the secondary cell 41 acres. The waste flowed through the first unit in numerous shallow channels, one to five inches in depth, was collected by three culverts at the lower end of the field and passed to the second unit. Liquid depth in the second unit was somewhat greater, ranging from a few inches to about two-feet. The waste discharged from the treatment field through a rectangular weir into a collection ditch leading to the Big Thompson River. Grab samples obtained at the treatment field outlet were designated as Station 77; composite samples collected at the same point over the daytime period (6-8 hours) were designated as Station 79.

Subsequent to 1964, the company slightly modified the treatment field. An earthen dike was constructed across the width of the first cell dividing this unit into two sections. The present treatment scheme consists of three areas receiving the waste flow in series arrangement.

At the end of processing campaign, the residual waste volume trapped within the lower pond is entirely drained to the river by removal of the outfall weir device. This practice may also be followed at the other sugar factories to facilitate cleaning of treatment units before the next campaign.

TABLE I

LOVELAND SUGAR FACTORY
SUMMARY OF IN-PLANT DATA
January 15-23, 1964

Sta. No.	Flow (cfs) Meas-ured	Flow (cfs) Esti-mated	No. of Samples	BOD mg/l	BOD %	COD mg/l	COD %	Total Suspended Solids mg/l	Total Suspended Solids %	Volatile Suspended Solids mg/l	Volatile Suspended Solids %	Total Alka-linity mg/l	Total Alka-linity %	Conduc-tivity umhos	pH	Temp. °C	Confirmed Coli. Bact. MPN/100 ml	Confirmed Coli. Bact. %	Fecal Coli Bact. MPN/100 ml	Fecal Coli Bact. %	Station Description
71			7	2		11		12		3		75		290	7.9	2.5	1,650		430		Canal Water Intake
							450		50		170		120					0		5	
73			21			49		6		5		87		305	8.7	50.9	32		20		Seal Tank Water
74			21			1080		2000		310		150		440	7.4	28.0	7,850,000		403,000		Waste Flume Water
							90		90		80		130					90		100	
75			21			1010		1740		250		200		435	7.6	28.4	6,760,000		398,000		Flume Inlet Water
							110		120		120		80					120		100	
74			21			1080		2000		310		150		440	7.4	28.0	7,850,000		403,000		Waste Flume Water
							100		90		130		400					90		360	
72		18	21			1080		1830		390		600		650	8.6	35 1	7,150,000		1,440,000		MH Grabs
78		18	7	680		(1100)		(730)		(130)		(330)		480	8.7						MH Composites
							100		230		120		440					0		0	
76			14			1050		4150		470		2660		720	10.1	20.6	44,000		100		Treatment Field Inlet
							80		20		20		20					5		-	
77	19.1		14			800		860		110		540		555	10.4	10.5	2,700		590		Tréatment Field Effluent Grabs
79			6	(510)		(1250)		(530)		(80)		(480)		550	10.5						Treatment Field Effluent Composites

NOTE:
% - Remaining between stages
Values in parenthesis not used in calculating percent remaining between stages.

Presentation and Discussion of Sampling Data

The average values of data collected from the Loveland survey are given in Table I. A key feature of the table is the percent remaining of selected waste variables between consecutive stages of process and treatment. These values are shown underscored in the table.

Between the point of canal water intake at Station 71 and the seal tank water at Station 73, there was reasonable increase in COD and Volatile Suspended Solids (VSS) concentrations likely caused by condenser carryover. Bacterial organisms were almost completely eliminated in the seal tank water due to high water temperatures.

Waste concentrations increased many fold from the canal water intake at Station 71 to near the beet flume outlet as reflected by Station 74. Discarded flume water was the major waste load from the plant. Main sewer waste at Stations 72-78 compared to the waste flume water showed no increase in COD concentration, a four-fold increase in alkalinity presumably due to entry of lime mud, and an increase in the fecal coliform bacteria numbers.

The wastes entering the treatment field (Station 76) compared to that leaving the factory (Stations 72-78) showed a two-fold increase in TSS, a four-fold increase in total alkalinity, and a significant rise in pH value. The full explanation for these changes cannot be given although lime mud was suspected. Relatively low levels of coliform bacteria apparent in the total wastes entering and leaving the treatment field definitely were attributed to high alkalinity and pH levels.

The treatment field was estimated in January 1964 as providing an average waste detention time of only 37 hours over the entire 133 acres of treatment surface. Treatment results show that COD and BOD concentrations were reduced in the order of 20 to 25 percent, and TSS, VSS, and alkalinity levels were decreased approximately 80 percent.

Recent Operational Changes

Modifications made in the treatment field during 1965 and 1966 are described above. The factory has also experienced some increase in processing rate; an average of 3680 tons beets per day was reported during the 1966-1967 campaign.

2. Windsor, Colorado

Process and Operation

The 1966-1967 campaign was the last season of operation at the Windsor sugar factory. Construction of a new plant at Goodland, Kansas, and other management considerations lead to the closing of this factory in January 1967. Survey results for Windsor must necessarily relate to conditions existing prior to shutdown.

The Windsor sugar factory over the 1963-1964 campaign received an average of 2,200 tons beets per day. Straight-house operations included a continuous diffuser, and molasses was generally shipped to the Loveland Steffen house.

Part of the incoming sugar beets were received by truck and piled in the yard; the remainder entered in railroad cars via a highline system. The railroad tracks were elevated to provide for beet storage below the tracks and the beets were brought into the plant by lateral flumes. Beets in the factory yard were transferred to the lateral flumes by an end-loader.

The Windsor factory produced wet pulp exclusively which was stored within a pulp silo. Lime mud was placed in a large pond however, producing continuous overflow. The relative locations of sampling points for the Windsor plant are shown by Figures 6 and 7.

Plant Water Supply

The large majority of plant water supply was obtained via canal from Lake Windsor, and this rate of supply approximated 12 cfs. Around 1.5 cfs of city water was employed directly for diffuser makeup. Canal water supply was impounded on the mill property and sampled at Station 81. "Excess" water from the impoundment bypassed and flowed into the main waste drain as illustrated by Figure 7.

Beet Flume System and Waste Flume Water

Overflow from the main water tank together with seal tank water supplied the lateral flumes in the beet receiving area. If the seal tanks overflowed, this volume entered the beginning of the main plant sewer following the beet washer and roller spray table. No recirculation was provided in the Windsor flume system.

Beet Pulp and Pulp Silo

The exhausted wet pulp was transported from the diffuser to the pulp silo by means of diffuser water. The pulp passed through a fanger screen elevated above the silo. Screen water discharged to the main waste drain, and the pulp deposited and stored in the silo as shown by Figures 6 and 8. Pulp silo underdrainage was collected, screened, and subsequently pumped to the lime mud pond. It was intended that part of the acidity in the pulp silo drainage would be neutralized in the lime mud pond.

Lime Mud Waste

Lime mud slurry was pumped to a large pond as illustrated by Figures 9 and 10. Pulp silo underdrainage also entered the pond as mentioned above. Only a small portion of the basin was used for effective waste settling. The continuous outflow from the far end of the pond containing large quantities of suspended and dissolved waste material discharged to the main waste drain as shown in Figure 11.

Ashes

The burning of coal for heat and power in the Windsor factory produced ashes requiring disposal. The ashes were flumed into a pond with the heavier solids settling to the bottom. Continuous overflow from the ash pond was released into the excess water bypass canal prior to joining the main plant drain. This separate discharge is shown in Figure 12. Ashes accumulated in the pond at the end of campaign were reported to be used by the State Department of Highways for winter road maintenance.

Main Plant Sewer

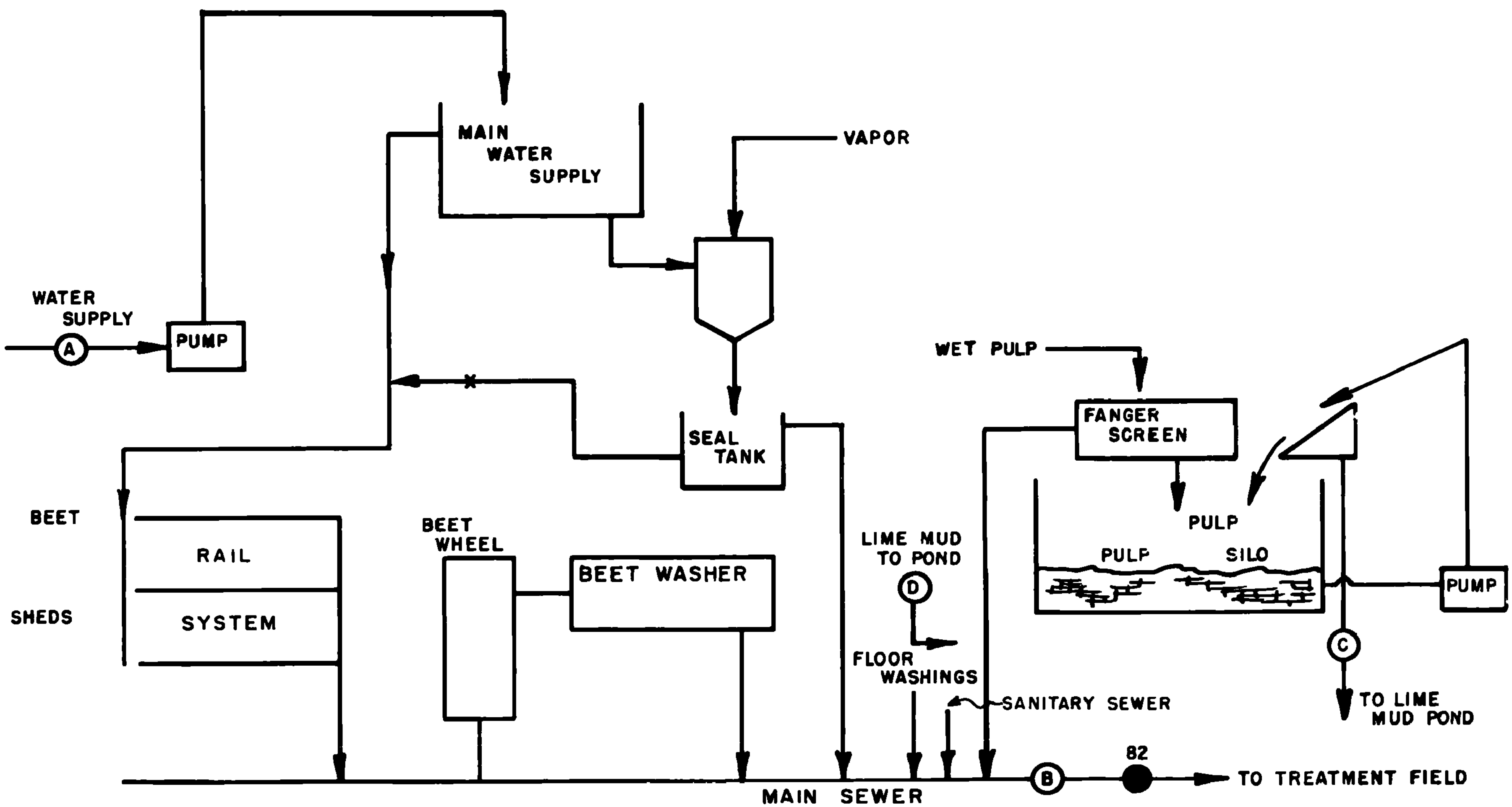
The main sewer immediately after leaving the factory converted into an open drain. Station 82 established at the beginning of the open drain represented the characteristics of the main plant sewer wastes plus the fanger screen water from the pulp silo. The main sewer received waste flume water, seal tank overflow, floor washings, sanitary sewage and miscellaneous. Sanitary sewage was diverted from the main plant sewer to the municipal facilities in 1965.

Main Plant Drain

The main plant drain collected and transported the total plant wastes to a treatment area located about one mile south of the factory site. The main drain was sampled both at Stations 83 and 84, shown in Figure 7. Station 83 included the main plant sewer wastes plus the fanger screen water originating from the pulp silo, ash pond overflow, excess water bypass, and the outflow from the lime mud pond which in turn contained some part of the pulp silo drainage previously introduced to the lime pond. Station 84 represented the total plant wastes immediately before treatment.

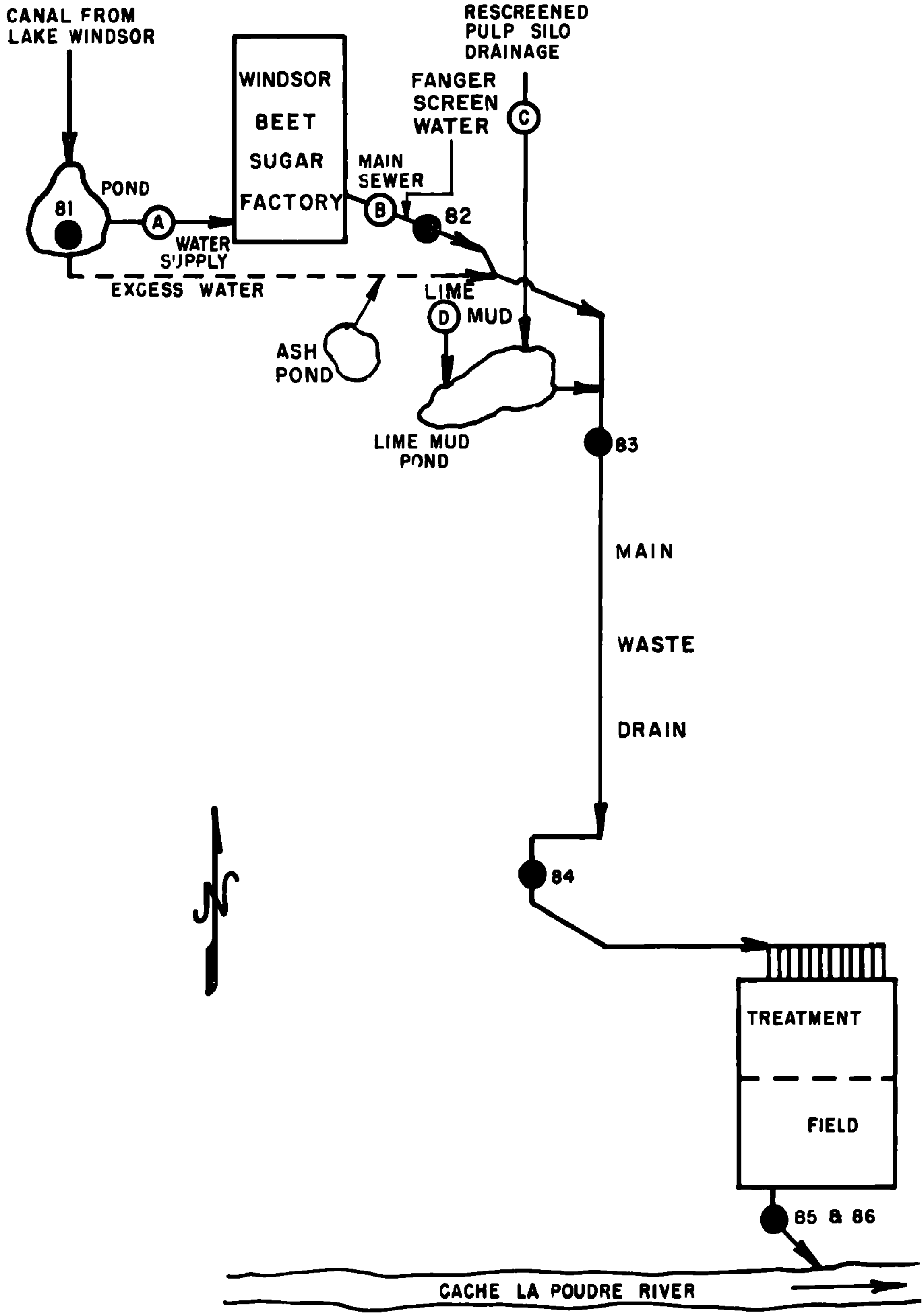
Waste Treatment

The treatment (aeration) field in place during the 1963-1964 processing campaign is illustrated by Figure 7. The waste flowed down the field in numerous shallow furrows or channels. A corrugated steel weir was placed across the mid-point of the field to reduce short-circuiting. The influent waste canal and upper section of the treatment field are shown in Figure 13. The effluent from the treatment field was sampled in the discharge ditch leading to the Cache la Poudre River; grab samples were designated as Station 85 and composite samples as Station 86.



WINDSOR SUGAR FACTORY
IN-PLANT FLOWS
JANUARY 1964

FIGURE 6



WINDSOR SUGAR FACTORY
PLANT AREA
JANUARY 1964

FIGURE 7

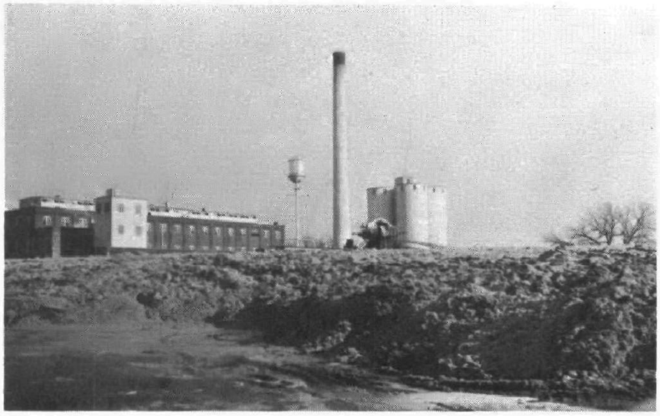


Figure 8.
Windsor sugar factory;
1-5-67
Wet pulp accumulated in pulp silo, near end of campaign. Note fanger screen at top center of picture.

Figure 9.
Windsor sugar factory;
1-5-67
Lime mud slurry entering upper end of impoundment pond.

Figure 10.
Windsor sugar factory;
1-5-67
Interior of lime mud pond. Lower end of pond and discharge are in the far background.

Figure 11.
Windsor sugar factory;
1-5-67
Continuous outflow from lime mud pond into main plant drain. Drain was flowing from right to left.

Figure 12.
Windsor sugar factory;
1-5-67
Liquid overflow from ash pond to the excess water bypass canal.

Figure 13.
Windsor sugar factory;
1-5-67
Total plant wastes delivered in concrete channel to upper end of treatment field. Part of the wastes were bypassed around the upper field as shown on right side of picture. Note pattern of waste flow down the field towards the river located at tree-line.

Presentation and Discussion of Sampling Data

The average values of data collected from the Windsor survey are given in Table II. The percents remaining of selected waste variables between consecutive stages of process and treatment are also described in the table.

The canal water supply to the plant at Station 81 was shown to be of relatively good quality. Waste concentrations increased in very large measure between the point of canal water intake at Station 81 and the main sewer leaving the plant at Station 82. Main sewer wastes exhibited COD and TSS levels of 1360 and 3270 mg/l respectively. Total and fecal coliform bacteria densities were 2,630,000 and 48,800 per 100 ml respectively. Waste flume water and fanger screen water constituted the major waste loads.

Between Station 82 and Station 83 the excess water inflow served to reduce waste concentrations, followed by lime pond discharge which conversely increased the waste levels. The net effects caused substantially no change in COD, TSS, VSS, and alkalinity concentrations between the two stations. On the other hand, coliform bacteria levels increased four to five-fold over the numbers found in the main sewer.

Waste concentrations remained at essentially the same high levels from Station 83 to the point of entry into the treatment field except for a further increase in total coliform bacteria. On the basis of waste strength, the treatment field reduced the waste level as follows: 10 to 15 percent in COD, approximately one-half of the total and volatile suspended solids, one-third of the alkalinity, and two-thirds of the coliform numbers. The dissolved oxygen level in the effluent was only 0.6 mg/l. The aeration field provided only minimum treatment of processing wastes before final disposal into the river.

Recent Operational Changes

The transfer of domestic sewage from the main plant sewer to the city facilities was completed in 1965. The significant change was the final and complete shutdown of Windsor in January 1967.

3. Greeley, Colorado

Process and Operation

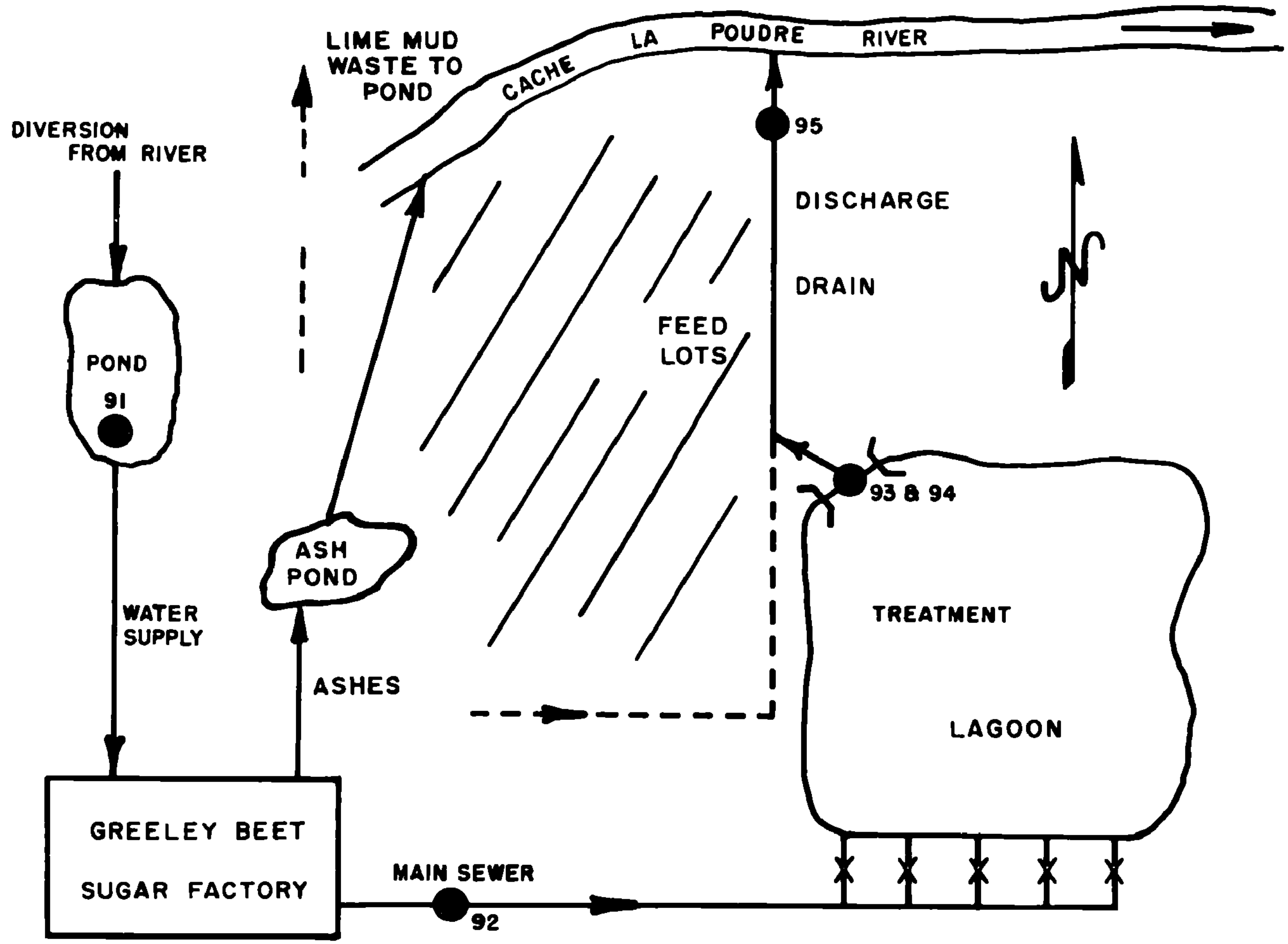
The Greeley sugar factory was a straight-house operation having a continuous diffuser and complete pulp drying facilities. During the 1963-1964 campaign the Greeley establishment processed an average of 2,200 tons beets per day. Molasses from the process was shipped to the Longmont and Loveland mills.

TABLE II

WINDSOR SUGAR FACTORY
SUMMARY OF IN-PLANT DATA
January 24-February 1, 1964

Sta. No.	Flow (cfs) Meas-ured	Flow (cfs) Esti-mated	No. of Samples	BOD mg/l	BOD %	COD mg/l	COD %	Total Suspended Solids mg/l	Total Suspended Solids %	Volatile Suspended Solids mg/l	Volatile Suspended Solids %	Total Alka-linity mg/l	Total Alka-linity %	Conduc-tivity umhos	pH	Temp. °C	Confirmed Coli. Bact. MPN/100 ml	Confirmed Coli. Bact. %	Fecal Coli. Bact. MPN/100 ml	Fecal Coli. Bact. %	DO mg/l	Station Description
81			7	6		31		15		7		270		1710	8.2	2.2	94		32			Canal Water Intake
82			21			1360	120	3270	80	630	80	1750	100	1530	9.2	20.7	2,630,000	390	48,800	480		Main Sewer
83			21			1660	100	2770	90	480	100	1720	100	1790	8.4	17.5	10,200,000	170	234,000	70		Drain below Lime Pond
84	12 4		14			1740	90	2610	40	470	50	1650	60	1790	8.3	17.1	17,800,000	40	165,000	30		Inlet to Aeration Field
85			14			1480		1060		220		1080		1920	7.9	9.1	6,620,000		52,100		0.6	Effluent from Aeration Field Grabs
86			7	1,110		(1670)		(1120)		(230)		(1190)		1760	7.8							Effluent from Aeration Field Composites

NOTE:
% - Remaining between stages.
Values in parenthesis not used in calculating percent remaining between stages.



GREELEY SUGAR FACTORY
PLANT AREA
JANUARY 1964

FIGURE 14

In 1963-1964, all incoming beets to the plant were received by railroad cars and a highline system. The large majority of beets is now delivered by truck. Trucked beets are dumped into a wet hopper and the beets are flumed a short distance into the factory. Remaining beets are conveyed to the plant through a considerably longer flume. Lime mud was stored in a large pond with no reported overflow. The relative locations of sampling points for the Greeley plant are shown in Figure 14.

Plant Water Supply

The principal source of plant water supply was the Cache la Poudre River. River waters were diverted into a small pond on the mill property. The pond also received inflow from a city storm sewer. In January 1964 the diversion, although located upstream of the city sewage treatment plant, probably received some raw municipal sewage bypassed around the treatment facility and into the factory canal. The point of river water intake is now believed located above all sewage discharges of major consequence in Greeley. River water was used predominantly in beet fluming. Supplemental water supply was obtained from the city of Greeley and a single company well and directed to diffuser makeup and the washing of sugar.

River water usage approximated 10 to 12 cfs, and total factory consumption around 13 to 16 cfs. The river water in January 1964 was of extremely poor quality, reflecting gross pollution. The intake from the water supply pond to the factory was designated as sampling Station 91 as shown in Figure 14. A picture of the water supply pond is illustrated by Figure 15.

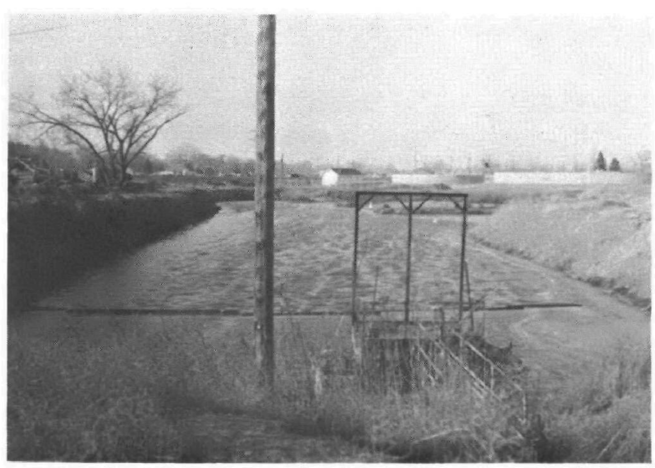


Figure 15.
Greeley sugar factory; 1-6-67.
Water supply pond principally receiving inflow from the Cache la Poudre River. Grease and scum on pond water surface. Note municipal sewage treatment plant in right background.

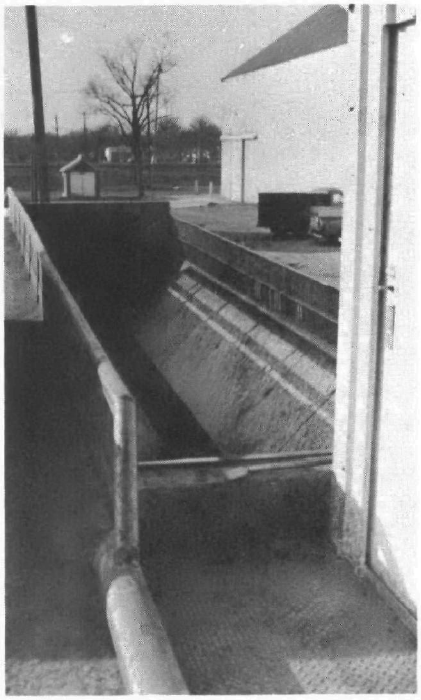


Figure 16.
Greeley sugar factory; 1-6-67
Wet hopper for receiving trucked beets. The flume at bottom of hopper conveyed beets into the plant.

Figure 17.
Greeley sugar factory; 1-6-67
Overflow from lagoon into discharge drain. Drain was flowing from right to left. Backup wastes in drain above point of overflow.

Beet Flume System and Waste Flume Water

Water received from the main supply tank and seal tanks furnished the needs of the beet flume system. No recirculation was provided in the circuit. The wet truck hopper recently installed at the Greeley plant is shown in Figure 16.

Beet Pulp

The exhausted pulp leaving the diffuser is now transported to the pulp presses via scroll and there is no transport water. All pulp is sent to the dryer, and press waters are returned and reused in the diffuser. The pulp dryer was first placed in operation during the 1963-1964 campaign. The break-in period for the dryer coincided with the field survey and at that time some wet pulp was discharged to the pulp silo. Tailings from the beet washer and roller spray table were also discarded to the silo, but are now combined with the pressed pulp and subsequently converted into dry pulp pellets.

Pulp silo drainage which separately discharged to the Cache la Poudre River during the January 1964 survey was considered to be temporary and therefore not sampled.

Lime Mud Waste

Lime mud slurry was pumped to a storage pond directly across the river from the sugar factory. No overflow was reported to the river although some indirect seepage may have occurred.

Ashes

The burning of coal for power and heat within the plant produced ashes which were slurried to the ash pond. Overflow from the pond discharged directly into the river. Manpower limitation did not permit the sampling of this waste during the January 1964 survey. This waste flow still exists at the Greeley factory.

Main Plant Sewer

The main sewer after leaving the factory was enclosed for some distance and then converted to an open flume before reaching the treatment lagoon. Station 92 was established at the beginning of the open section. The main sewer carried the total plant wastes exclusive of lime mud and ash pond overflow. Sanitary sewage from the plant separately discharged to the municipal sewers.

Waste Treatment

Main plant sewer wastes flowed into a treatment lagoon located directly east of the factory. In January 1964 the facility operated as a lagoon with liquid depths in the pond from one to three feet. Dye tracer studies showed an average waste detention time in the pond of 200 minutes; short-circuiting started at 115 minutes and delayed flow persisted up to 240 minutes. Because of odors created by the lagoon, the company over the last two campaigns has instead operated the facility as a treatment field similar to the Loveland and Windsor installations. A rectangular weir regulated the outflow from the lagoon. This effluent was designated as Station 93 for grab samples, and Station 94 for composite samples.

Discharge Drain to River

The wastes from the treatment lagoon were released into a discharge drain as shown by Figures 14 and 17, which in turn emptied to the Cache la Poudre River. Dye studies indicated an average waste detention in the drain of approximately 10 minutes. The drain was sampled near its mouth at Station 95. Results indicated a poor degree of waste treatment in the lagoon. Additional waste load was believed added to the drainway from adjacent feed-lots, particularly during times of surface runoff.

Presentation and Discussion of Sampling Data

The average values of data collected from the Greeley survey are given in Table III.

As mentioned previously, the water received from the river for factory supply was of poor quality. The plant intake at Station 91 contained 270 mg/l BOD, 500 mg/l COD, only 2.1 mg/l dissolved oxygen, and very high levels of total and fecal coliform bacteria. The waters obtained by the other sugar factories were of far better quality.

There was a many fold increase in waste concentrations from the point of factory water intake to the main sewer at Station 92. The BOD and TSS levels in the total wastes entering the treatment field were 1,010 and 1,300 mg/l, respectively. Total and fecal coliform densities approximated 11.0 million and 0.53 million MPN per 100 ml respectively. The waste flume water contributed a major part of the increase in waste load.

A single pass through the treatment lagoon in January 1964 provided marginal reduction of waste levels, reflected by sampling results obtained at Stations 93 and 94. Waste reductions were in the order of 10-15 percent for BOD and COD, 75 to 90 percent for TSS and VSS, 25 percent in alkalinity, and 70 to 80 percent in coliform densities. Effluent waste concentrations remained high. The decrease in pH value from 8.2 to 6.9 indicated anaerobic conditions in the pond, substantiated by an abundance of free hydrogen sulfide in the vicinity of the pond. The aeration field in present use by the company is believed even less effective in waste treatment compared to the previous lagoon.

TABLE III

GREELEY SUGAR FACTORY
SUMMARY OF IN-PLANT DATA
January 24-February 1, 1964

Sta. No.	Flow (cfs) Meas-ured	Flow (cfs) Esti-mated	No. of Samples	BOD mg/l	BOD %	COD mg/l	COD %	Total Suspended Solids mg/l	Total Suspended Solids %	Volatile Suspended Solids mg/l	Volatile Suspended Solids %	Total Alka-linity mg/l	Total Alka-linity %	Conduc-tivity umhos	pH	Temp. °C	Confirmed Coli. Bact. MPN/100 ml	%	Fecal Coli. Bact. MPN/100 ml	%	DO mg/l	Station Description
91			7	270	370	500	280	142	920	100	260	400	200	1690	7.5	2.6	4,700,000	230	80,700	650	2.1	Plant Water Intake from Pond
92	7.9		14	1010	85	1400	85	1300	10	260	25	810	70	1610	8.2	21.9	11,000,000	30	529,000	20		Main Sewer
93	6.0		14			1210		120		64		590		1770	6.9	12.5	3,060,000		103,000			Treatment Lagoon Effluent Grabs
94			7	860	100	(1230)	90	(130)	80	(71)	100	(580)	100	1690	7.0			190		160		Treatment Lagoon Effluent Composites
95	9.0		7	850		1100		93		63		590		1760	7.0	12.5	5,690,000		162,000			Drainage Drain at Mouth

NOTE:
% - Remaining between stages.
Values in parenthesis not used in calculating percent remaining between stages.

There was no significant change in concentration of waste within the discharge drain before final disposal to the river.

Recent Operational Changes

Changes which have been previously mentioned include the majority of incoming beets now being received by truck rather than railroad car, full pulp drying capacity with elimination of pulp silo drainage, and the conversion of the treatment lagoon into an aeration field.

4. Fort Morgan, Colorado

Process and Operation

The Fort Morgan factory was one of the largest sugar beet processing plants in the South Platte River Basin. Operations included a Steffen house receiving molasses from the Ovid and Sterling mills. The Fort Morgan plant had a continuous chain diffuser and full pulp-drying capacity. During the 1963-1964 campaign, the average rate of processing was about 3,000 tons beets per day, but has since increased to around 3,250 tons beets per day. Approximately 25,000 acres of farmland, almost entirely within Colorado, were devoted to the growing of sugar beets required by the Fort Morgan factory in the 1966-1967 campaign.

The Fort Morgan mill received about 70 percent of incoming beets by railroad car and the remainder by truck. Beets from the railroad cars were deposited directly into the wet hopper. Trucked beets and those piled in the yard were elevated over and into the wet hopper via belt conveyor. One purpose of the conveyor was to reduce dirt and debris on the beets entering the flume system.

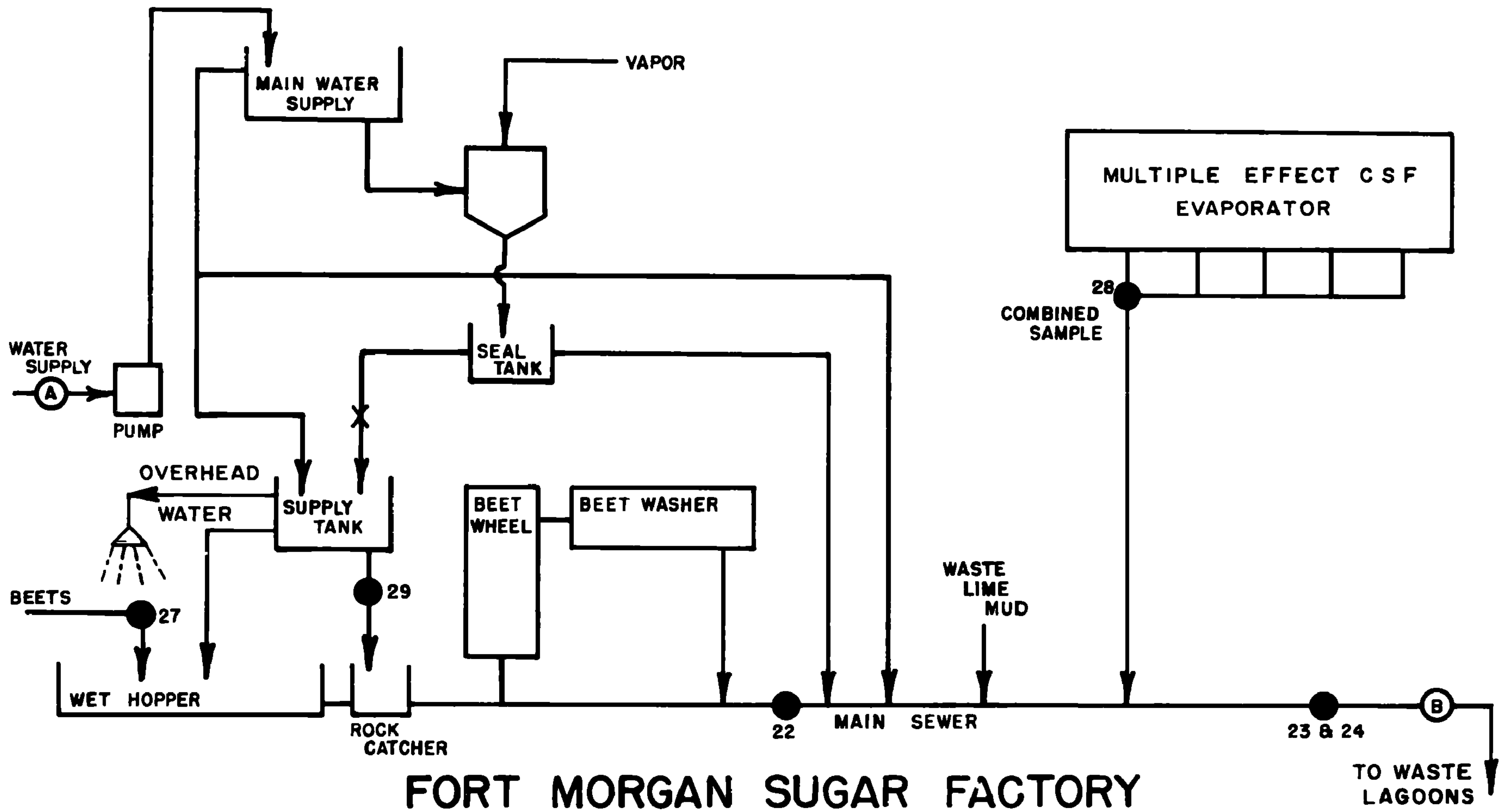
The plant pressed and dried all pulp for the production of dry pulp pellets. Exhausted pulp from the diffuser was transferred to the presses via scroll and there was no transport water. The pulp press waters returned to the diffuser.

The average amount of molasses worked during the 1963-1964 campaign approximated 145 tons per day and this increased to 161 tons per day over the 1966-1967 season. The residual filtrates in the Steffen house were hydrolyzed and evaporated to produce concentrated Steffen filtrate, otherwise known as CSF. The CSF represented raw material necessary in the Johnstown, Colorado sugar recovery operations.

The relative locations of sampling points for the Fort Morgan factory are shown in Figures 18 and 19.

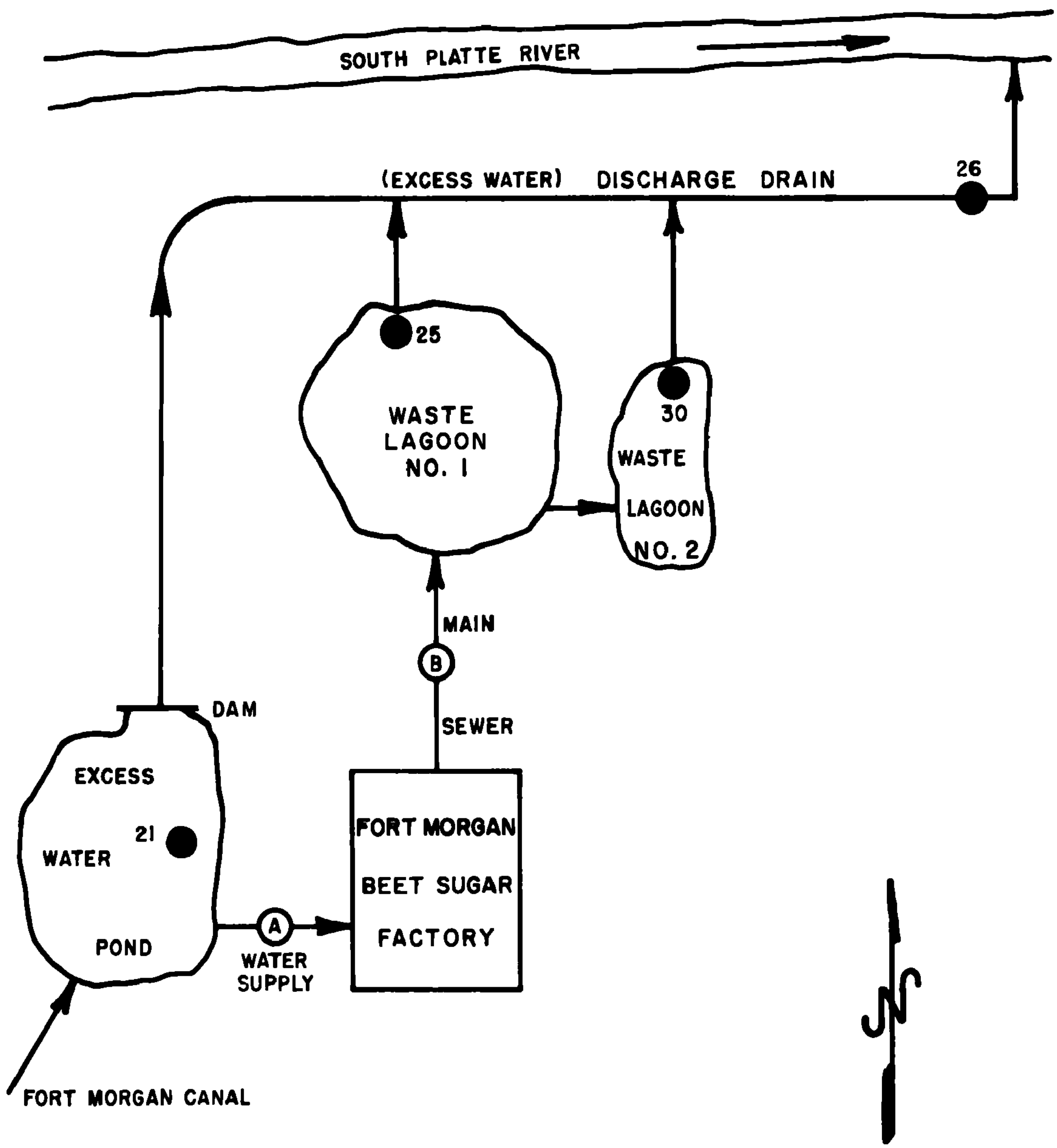
Plant Water Supply

Water supply for the factory was obtained from the South Platte River via the Fort Morgan Canal at the rate of 35 to 40 cfs, and delivered to a small pond on the mill property. Samples collected from



FORT MORGAN SUGAR FACTORY
IN-PLANT FLOWS
DECEMBER 1963

FIGURE 18



FORT MORGAN SUGAR FACTORY
PLANT AREA
DECEMBER 1963

FIGURE 19

the lake were designated as Station 21. Pond water was pumped to the main water supply tank located inside the Fort Morgan factory. Overflow or excess water from the lake flowed into a discharge drain which circuited around the company waste treatment lagoons and subsequently returned to the River. Small amounts of city water were also essential in plant operations. Total water use within the factory approximated 13 to 15 cfs.

Beet Flume System and Waste Flume Water

Both overhead spray water and underflow water to the wet hopper on the beet flume system were derived from the seal tanks and main water supply tank, as shown in Figure 18. This source of water was sampled at Station 29. The amounts of water in the beet flume system were limited by this factory, and the seal tank water not required in fluming overflowed to the main plant sewer following the beet washer. During colder weather the frozen beets in the railroad cars were soaked and thawed with hot overhead water as shown in Figure 20.

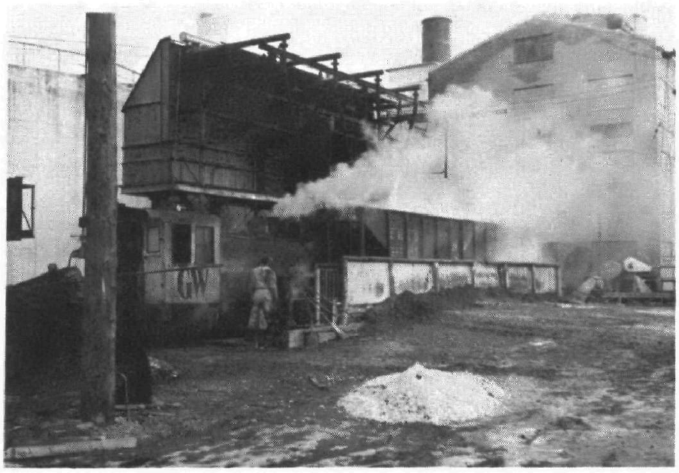


Figure 20.
Fort Morgan sugar factory; 1-20-67.
Hot overhead water applied to frozen sugar beets received in railroad cars. Thawed beets were deposited into the wet hopper located directly below the overhead water station.

Additional sampling was conducted at both ends of the beet flume. Representative soil portions taken from the belt conveyor moving the beets into the wet hopper were designated as Station 27. Wastewater at the tail end of the flume was described as Station 22.

CSF Condensates

The combined flow of the condensate lines from the quintuple effect CSF evaporators was designated as Station 28. This type waste was sampled only at the Fort Morgan factory. The condensates were disposed of to the main plant sewer.

Main Plant Sewer

The main plant sewer received waste flume water (which included beet washer and roller spray table wastes), the main water supply and seal tank overflows, waste lime mud, CSF condensates, floor washings, and miscellaneous. Sanitary sewage separately discharged to the municipal sewers. Miscellaneous wastes in part comprised the boilout of evaporators and vacuum pans. Evaporators were cleaned with acid followed by caustic, then flushed and rinsed. Evaporator bodies Nos. 1 and 2 were cleaned only at the end of campaign. However, bodies Nos. 3, 4, and 5 as an aggregate received boilout on the average of once every two weeks. Vacuum pans were cleaned with a chemical compound known as SR-10 mixed with water. The boilout schedule was described as every 32-hours for the white pans and once-a-month for the raw pans. The Fort Morgan plant relied entirely on natural gas to provide power and heat, and consequently no ashes were produced.

Total factory wastes were sampled on the main sewer line outside and adjacent to the plant. Grab samples were described as Station 23 and composite samples during the day shift (6-8 hours) as Station 24, shown in Figure 18. Total wastes then flowed in a closed line to the waste treatment lagoons maintained by the company adjacent to the South Platte River.

Waste Treatment

Waste treatment facilities at the Fort Morgan sugar factory consisted of two shallow waste lagoons. Overflows from the lagoons were released on a continuous basis to the (excess water) drain previously described and shown in Figure 19. The total contents of the discharge drain emptied to the South Platte River a short distance below the ponds.

Cell No. 1 received the total wastes directly from the factory, covered about 20 acres and overflowed both to the discharge drain and to cell No. 2. The secondary pond received only part of the total wastes previously entering cell No. 1, covered about 15 acres and had a separate overflow to the discharge ditch. The ponds were cleaned only when absolutely necessary after three or more consecutive campaigns. As a result, liquid operating depths were minimal in the ponds, ranging from 1-2 inches up to a maximum of about 2 feet. There was considerable weed growth and short-circuiting of waste flow through the ponds. An observation taken of the east side of pond No. 2 is given by Figure 21.

The December 1963 survey provided separate sampling of the final overflows from the two waste treatment ponds. The effluent from cell No. 1 was described as Station 25, and that from cell No. 2 as Station 30. Recent pictures of these two outflows are shown respectively in

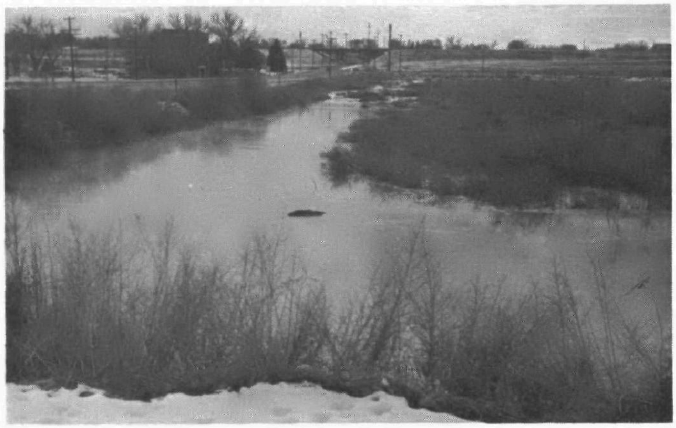


Figure 21.
Fort Morgan sugar factory;
1-20-67
View of the east portion of waste treatment pond No. 2. Waste flow was towards the observer and then to the right. Note dense weed growth, and solids deposition extending to pond surface at center of picture.

Figure 22.
Fort Morgan sugar factory;
1-20-67
Final overflow from waste treatment pond No. 1 entering discharge drain. Flow in drain was from left to right. Note significant change in color between excess water above and mixed waste flow below.

Figure 23.
Fort Morgan sugar factory;
1-20-67
Final overflow from waste treatment pond No. 2 entering discharge drain.

Figures 22 and 23. Some of the lagooned wastes probably reached the drain by indirect seepage. Additional sampling was taken at the end of the discharge drain after it received the waste effluents from the two waste treatment ponds and this point was designated as Station 26.

Presentation and Discussion of Sampling Data

The average values of data collected from the Fort Morgan survey are given in Table IV.

The pond water intake at Station 21, and the mixture of seal tank and main water supply tank waters at Station 29 serving as flume inlet water, were both of relatively good quality. High water temperatures at Station 29 reflected the seal tank water derived from the evaporators and vacuum pans.

The waste flume water at Station 22 compared to the flume inlet water at Station 29 showed substantial increase in waste load due to beet fluming and washing operations. This waste was particularly high in suspended solids content and coliform bacteria densities. The addition of waste lime mud, CSF condensates, and other inflows between Station 22 and Stations 23-24 caused appreciable and further increase in COD, TSS, VSS, and alkalinity concentrations in the total wastes. The pH value also increased from 8.4 to 9.1. The entry of waste lime mud into the main plant sewer was reflected in TSS and alkalinity levels of 5,020 and 1,900 mg/l respectively at Station 24.

The primary lagoon even with serious short-circuiting and minimum operating depths effected moderate reduction in waste concentrations shown by the results collected at Station 25. BOD and COD levels were lowered about 20 percent, and total and volatile suspended solids concentrations about 60 percent. It is believed that waste treatment within the ponds could be far more effective if greater care were taken in cleaning and overall management of the treatment facility. Results on the effluent from the secondary pond were considered relatively unimportant during the survey because of the small discharge flow present at that time.

Chemical waste concentrations of the total flow at the end of the discharge drain corresponding to Station 26 were lower than in the primary lagoon effluent because of considerable dilution offered by the excess water arriving from above the mill site. Coliform bacteria densities at the end of the drain reflected better sampling conditions and likely were more representative of plant waste effects than results obtained directly from the lagoon effluents.

Recent Operational Changes

There have been no significant changes in the Fort Morgan waste picture since the December 1963 survey.

TABLE IV

FORT MORGAN SUGAR FACTORY
SUMMARY OF IN-PLANT DATA
December 7-16, 1963

Sta. No.	Flow (cfs) Measured	Flow (cfs) Estimated	No. of Samples	BOD mg/l	BOD %	COD mg/l	COD %	Total Suspended Solids mg/l	Total Suspended Solids %	Volatile Suspended Solids mg/l	Volatile Suspended Solids %	Total Alkalinity mg/l	Total Alkalinity %	Conductivity umhos	pH	Temp. °C	Confirmed Coli. Bact. MPN/100 ml	Confirmed Coli. Bact. %	Fecal Coli. Bact. MPN/100 ml	Fecal Coli. Bact. %	Station Description
21			5	3		25		9		3		275		1480	8.1	0.3	870		80		Main Water Supply
29			20			47		9		3		293		1380	8.5	31.2	2,300		70		Flume Inlet Water
22			29			440		1690		230		400		1400	8.4	25.6	4,500,000		43,000		Waste Flume Water
							150		300		260		470					70		70	
23		13.4	9	480		(810)		(3940)		(490)		(2240)		1285	9.1						MH Composites
24		13.4	20			640		5020		600		1900		1270	9.1	26.1	3,200,000		30,000		MH Grabs
					80		80		40		40		50					30		60	
25	12.0		6	380		510		2010		240		890		1380	8.5	18.5	1,000,000		18,000		Primary Lagoon Effluent Grabs
30			3	(140)		(230)		(31)		(20)		(460)		1340	8.0	6.3	(270,000)		(3,200)		Secondary Lagoon Effluent Grabs
					30		30		20		25		50					160		70	
26	36.2		6	115		165		440		61		445		1380	8.2	5.0	1,600,000		13,000		Discharge Drain near Mouth
28			30	57		132		42		4		246		210	9.7	60.5					CSF Condensate

NOTE:
% - Remaining between stages,
Values in parenthesis not used in calculating percent remaining between stages.

5. Sterling, Colorado

Process and Operation

The Sterling sugar factory was a straight-house operation with a continuous diffuser and produced wet pulp exclusively. Molasses was shipped to the Fort Morgan mill. The processing rate during the 1963-1964 campaign was 2,200 tons beets per day, but has since increased to 2,390 tons beets per day.

In previous campaigns, all incoming sugar beets were received by railroad car and deposited directly into the flume. Approximately one-third of the total beets are now delivered by truck. Beets are side-dumped from the truck into a dry hopper. The dry hopper subsequently connects to the original flume system for transport of beets into the plant.

The Sterling factory stored wet pulp in a large silo. Lime mud previously discharged in 1963-1964 to the main sewer is now separately impounded. The mill utilized nautral gas for power and heat production thereby eliminating the handling of ashes. The relative locations of sampling points for the Sterling survey are shown in Figures 24 and 25.

Plant Water Supply

The large majority of plant water supply was obtained from the South Platte River via the Sterling No. 1 Canal and a factory supply canal. The factory canal received an excess of water to prevent ice formation during freezing weather. Some well water was also added to the canal. Canal water was diverted into a supply pond on the mill property and the excess water remained in the canal bypassing around the main factory as represented in Figure 25. Pond waters were pumped to the main water supply tank within the plant. This supply was sampled at Station 31. Other water was received from the city of Sterling at the rate of 1 cfs for diffuser makeup. Total water use by the factory approximated 10 to 12 cfs.

Beet Flume System and Waste Flume Water

Railroad cars with incoming beets were hauled to a prescribed location on the tracks, dosed with overhead water if necessary, and the beets dumped directly into the wet hopper and flume system for transport into the plant. The flume was completely washed out several times a day between periods of unloading the cars. The total flume system at Sterling was far less extensive than one associated with a system of beet sheds.

Various sources of water for the beet flume included fanger screen water returned from the pulp silo and reused as overhead water for the wet hopper; overflow from the main water supply and seal tanks serving as underflow to the flume inlet and the influent to the rock catcher; and the main water supply tank serving the beet washer.

The Sterling mill also recirculated the drainage from the tailings discarded at the roller spray table. Tailings were screened on an A-frame and the drainage returned to the wet hopper at the front end of the flume system as shown in Figure 24.

Waste flume water was sampled at Station 34 and included all wastes to the flume except beet washer waters.

Beet Pulp and Pulp Silo

The exhausted wet pulp from the diffuser was transported to the open pulp silo by means of spent diffuser water. The pulp was placed onto a fanger screen elevated above the silo and the solids deposited into the silo. The fanger screen water returned for use as overhead water to the wet hopper. Excess fanger screen water not used in the flume discharged via a supply tank to the main plant sewer.

Underdrainage from the pulp silo was separately collected and pumped to a second or stationary screen over the silo. Solids collected on the screen were redeposited in the silo and the screen waters in this case were released to the discharge drain.

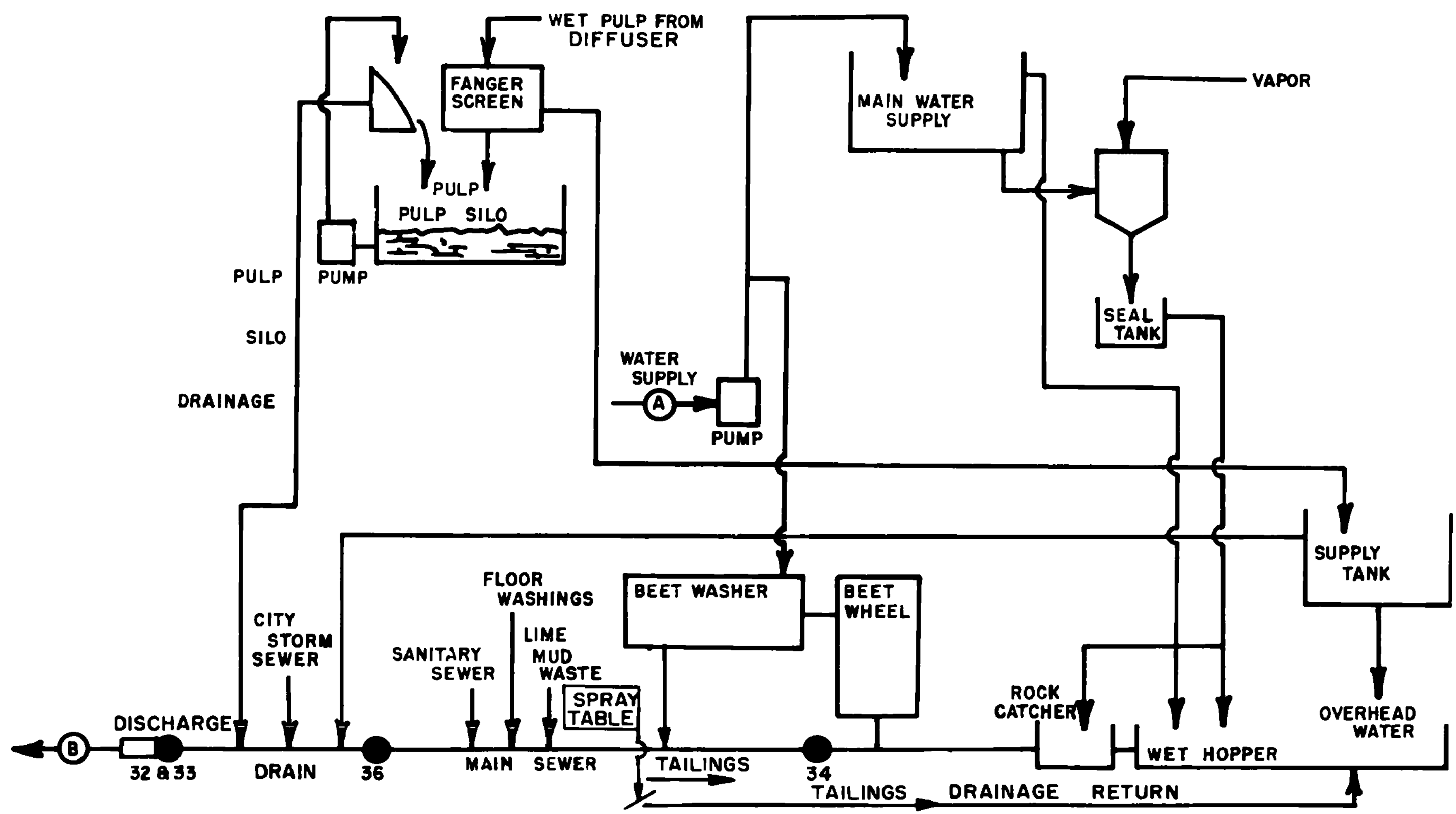
The Sterling mill is expected to complete the construction of full pulp pressing and drying facilities to be ready for the 1967-1968 campaign. These facilities will provide for the complete elimination of wet pulp and the pulp silo operation. Pulp press waters will be entirely reused in the diffuser.

Lime Mud Waste

Commencing with the 1964-1965 campaign, the lime mud was removed from the main plant sewer and transported to a newly-constructed lime mud storage pond located north of the main discharge drain near Station 35. No overflow has been reported or observed from the storage pond.

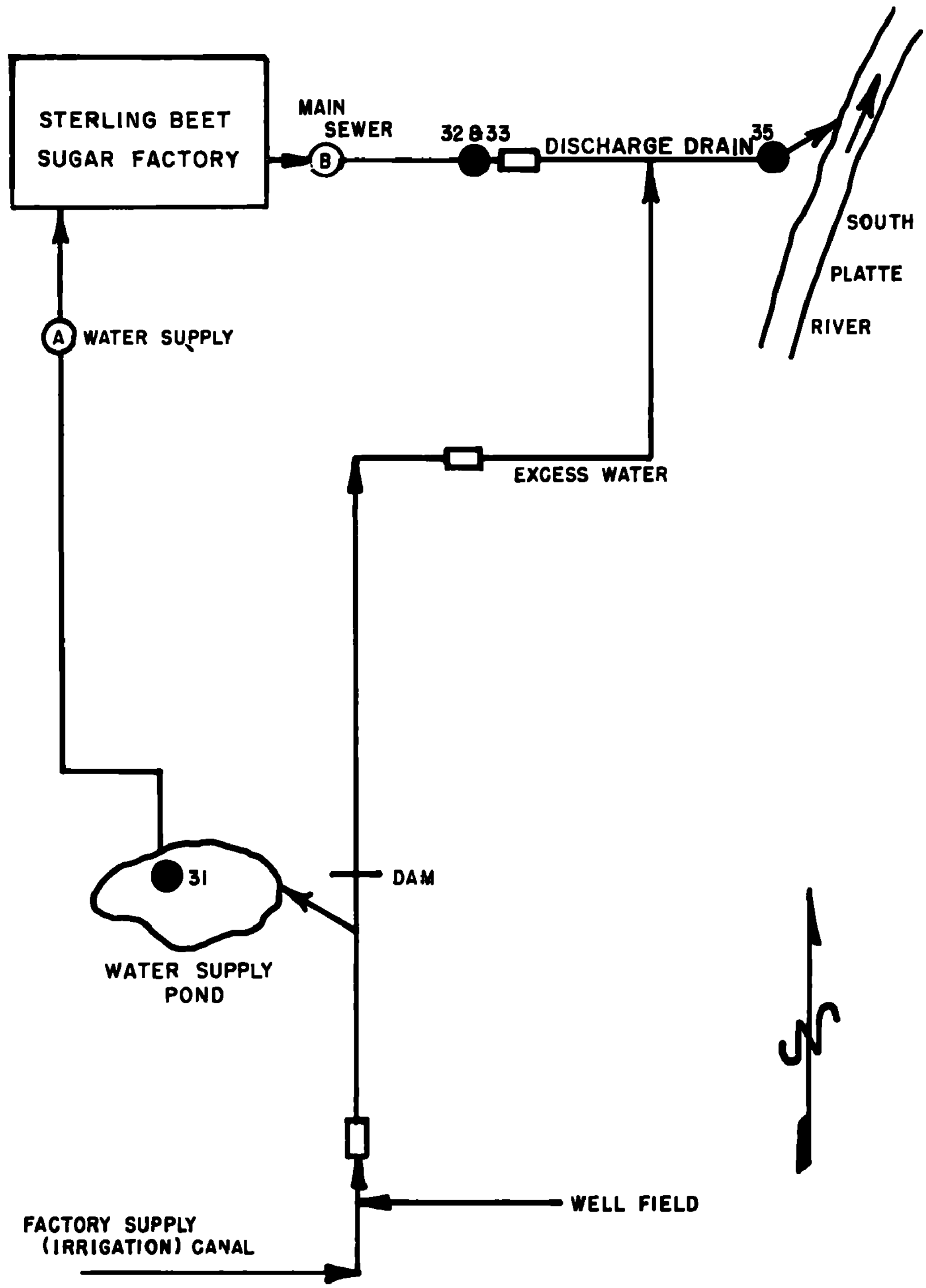
Main Plant Sewer

The main plant sewer immediately after leaving the factory converted into a short run of open steel flume and then to the discharge drain. This line was sampled in the open flume section at Station 36, and the various wastes included were waste flume water, lime mud waste, sanitary sewage, floor washings, and miscellaneous. Boilout of the evaporators and vacuum pans contributed part of the miscellaneous wastes. On the average, one evaporator and one vacuum pan were cleaned every two weeks.



STERLING SUGAR FACTORY
IN-PLANT FLOWS
DECEMBER 1963

FIGURE 24



STERLING SUGAR FACTORY
PLANT AREA
DECEMBER 1963

FIGURE 25

Discharge Drain

The discharge drain carried the total factory wastes. Waste flows additive to Station 36 consisted of fanger screen water originating from the pulp silo and not used as overhead water, together with screened underdrainage also from the pulp silo. A city storm sewer entered this section of the drain but did not flow, at least during the period of the survey. Grab samples taken on the discharge drain were described as Station 32; composite samples collected at the same point over the 6-8 hour daytime shift were designated as Station 33.

The discharge drain downstream of Stations 32-33 was joined by the excess canal water bypass from the site of the water supply pond as shown in Figure 25. Total plant wastes combined with the excess water and were carried in a continuation of the discharge drain about 0.7 miles before final disposal to the South Platte River. The discharge drain was further sampled near its end at Station 35. Dye studies showed that time of waste flow from Station 36 on the main plant sewer to Station 35 near the River was only about 35 minutes.

Waste Treatment

The Sterling factory during the December 1963 survey had no treatment facilities for any part of its plant wastes.

Presentation and Discussion of Sampling Data

Average values of the data received from the Sterling survey are presented in Table V. The results indicated the plant water intake at Station 31 was of relatively good quality, low in organics, suspended solids, and bacterial content. The waters near the end of the beet flume at Station 34 reflected heavy waste loads with significantly high levels of COD, suspended solids, and total and fecal coliform bacteria. Increases from Station 31 to Station 34 were as follows: COD from 20 to 710 mg/l, TSS from 37 to 2,780 mg/l, total coliform bacteria from 382 to 1,090,000 organisms per 100 ml, and fecal coliform bacteria from 50 to 103,000 organisms per 100 ml.

Inflows of beet washer water, lime mud, floor washings and sanitary sewage to the main sewer between Station 34 and Station 36, caused further rise in the waste concentrations. Total suspended solids and alkalinity levels increased another 40 and 60 percent respectively.

The third increment of waste flows to the plant drain included the pulp screen water and underdrainage from the pulp silo entering between Station 36 and Stations 32-33. Waste concentration increases were 100 percent in COD, 60 percent in alkalinity, and many fold in coliform bacteria between the two sampling locations. Total coliform bacteria density expanded from 1,090,000 to 20,400,000 per 100 ml, and fecal coliform bacteria from 87,800 to 313,000 per 100 ml.

TABLE V

STERLING SUGAR FACTORY
SUMMARY OF IN-PLANT DATA
December 7-16, 1963

Sta. No.	Flow (cfs) Meas-ured	Flow (cfs) Esti-mated	No. of Samples	BOD mg/l	BOD %	COD mg/l	COD %	Total Suspended Solids mg/l	Total Suspended Solids %	Volatile Suspended Solids mg/l	Volatile Suspended Solids %	Total Alka-linity mg/l	Total Alka-linity %	Conduc-tivity umhos	pH	Temp. °C	Confirmed Coli. Bact. MPN/100 ml	Confirmed Coli. Bact. %	Fecal Coli. Bact. MPN/100 ml	Fecal Coli. Bact. %	Station Description
31			7	2		20		37		5		280		1700	7.9	4.5	382		50		Water Supply Pond
34			28			710		2780		480		460		1680	7.9	22.2	1,090,000		103,500		Waste Flume Water
							100		140		130		160					100		80	
36		6.5	18			670		3980		620		710		1640	8.6	22.1	1,090,000		87,800		Main Plant Sewer
							200		90		90		160					1900		360	
32	9.3		8	870		(1310)		(4220)		(660)		(1400)		1620	8.1						Discharge Drain Composites
33	9.0		10			1350		3470		570		1100		1840	8.2	18.7	20,400,000		313,000		Discharge Drain Grabs
					50		50		50		50		100					80		80	
35			10	410		690		1950		280		1100		1790	8.0	12.5	17,100,000		251,000		Discharge Drain near River

NOTE:
% - Remaining between stages.
Values in parenthesis not used in calculating percent remaining between stages.

Total plant wastes after mixing with excess water flow showed about 50 percent reduction in chemical waste concentrations at Station 35, compared to the previous station. This indicated a volume ratio of total plant wastes: excess water of approximately 1:1 within the discharge drain. However, coliform densities were reduced only 20 percent after the addition of excess water. Aftergrowth of bacterial organisms was probable within the open discharge ditch leading to the River.

Recent Operational Changes

Significant improvements since December 1963 and those planned for the near future, are changing the waste picture at the Sterling mill. Receiving of beets by truck and the installation of a truck hopper may have caused some reduction over the unit waste load and volume experienced in December 1963. However, a greater volume of beets noted in the 1966-1967 campaign has probably offset this reduction.

The lime storage pond completed in the summer of 1964 has removed the lime mud from the main waste discharge and should be effective if underdrainage is precluded from entering the River. The completion of pulp pressing and drying facilities at the Sterling mill ahead of the 1967-1968 campaign will eliminate the large pollutional loads associated with the pulp silo and this action represents one important step towards successful pollution abatement by the company.

6. Ovid, Colorado

Process and Operation

The Ovid sugar factory was a straight-house operation with a continuous diffuser and partial facilities for pulp drying. In 1963-1964 dry pulp was produced from 1800 tons beets per day and the remainder was pressed and disposed of. The Ovid establishment, during the 1963-1964 campaign, processed an average of 2,800 tons beets per day; this has remained fairly constant in subsequent campaigns. Molasses from the process was generally shipped to the Fort Morgan mill.

During the plant survey all beets were delivered by railroad car; beets were either stored in beet sheds, or deposited directly into the wet hopper. Daytime operations consisted of dumping beets directly into the flume. At night, beets were moved from the beet sheds into the factory by means of lateral flumes. The Ovid factory now receives a substantial part of its incoming beets by truck and has eliminated the beet sheds and the lateral flumes. Storage of beets in the yard, rather than in sheds, has reduced the deterioration of sugar beets upon standing.

Lime mud was handled separately and stored in a large pond as shown in Figure 26. No overflow was reported or apparent from the lime pond. The mill utilized natural gas for power and heat thereby eliminating ashes. The relative locations of sampling points for the Ovid factory survey are shown in Figures 27 and 28.

Figure 26.
Ovid sugar factory; 1-10-67.
Lime mud storage pond approximately three-quarters full.

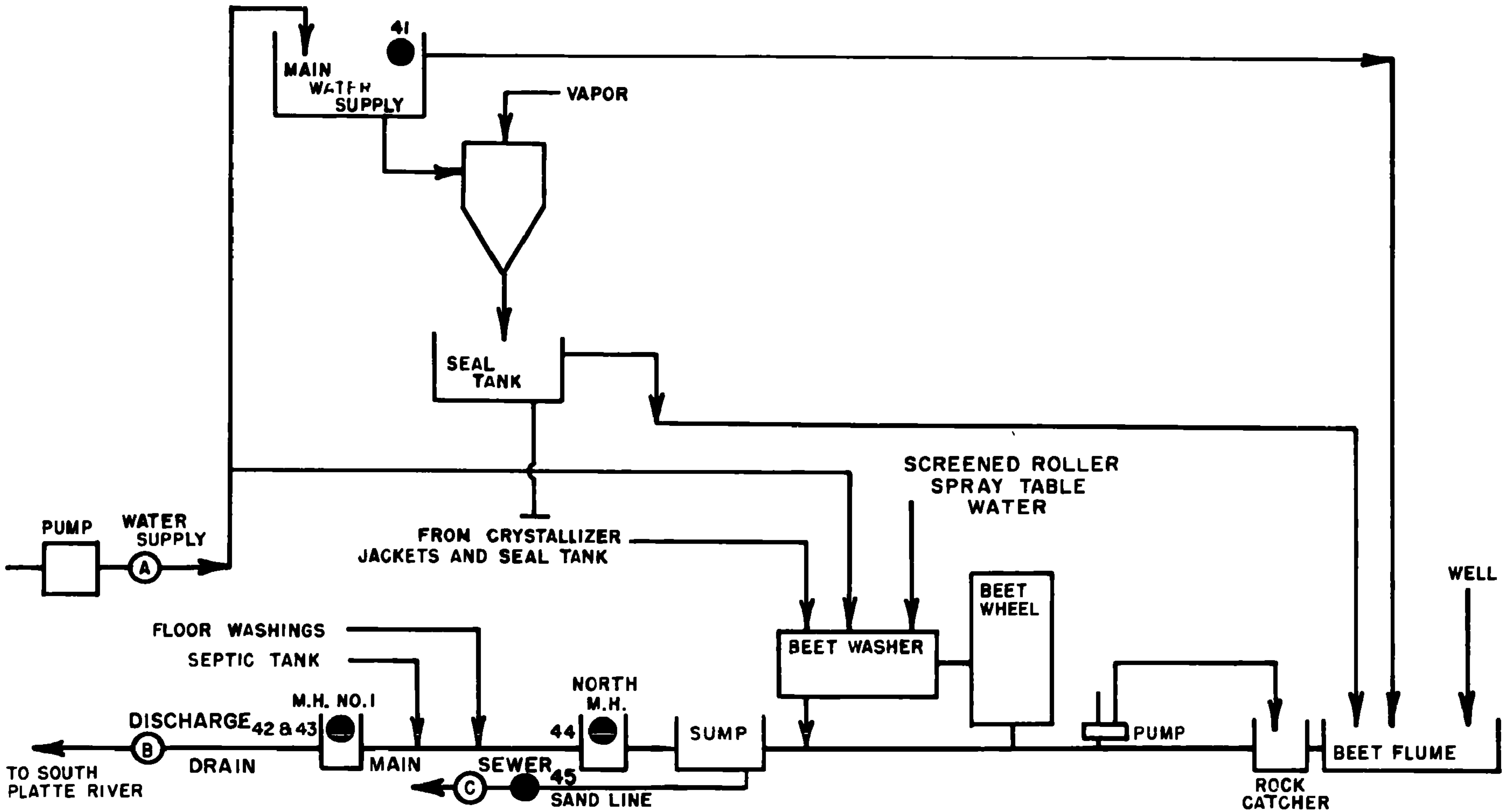
Plant Water Supply

The large majority of plant water was obtained from the South Platte River via the Peterson Canal, transported down Lodgepole Creek and withdrawn at the factory site. Five company wells supplemented this supply. Raw water was received into the main water supply tank within the factory and sampled at Station 41. A sixth well, on occasion, provided water directly to the beet flume. Total water use by the Ovid mill approximated 12 to 15 cfs.

Beet Flume System and Waste Flume Water

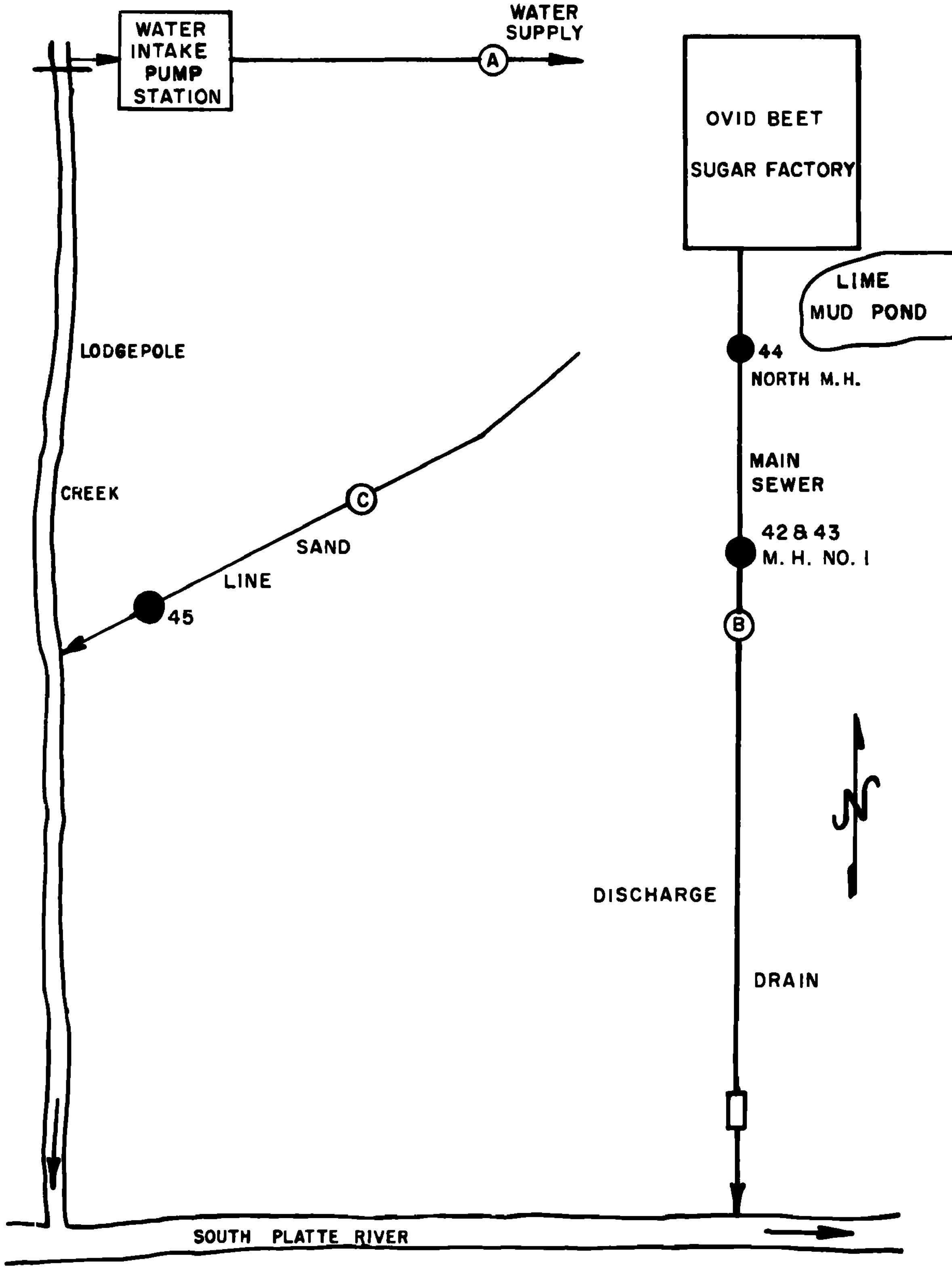
Discounting the lateral flumes which have been abandoned along with the beet sheds, the present flume system may be described as relatively short, transporting beets into the plant from both the railroad car and truck receiving areas. Beets are dumped from the railroad cars directly into the original flume. Trucked beets are stored in the yard or side-dumped into a truck hopper located immediately adjacent to the railroad car receiving station. A new flume section underlying the truck hopper connects to the original flume. Truck unloading at Ovid is illustrated by Figure 29.

Recent observations were made at both the Ovid and Brighton mills regarding the manner in which beets were dumped from the truck into the hopper. The Brighton mill was served by trucks with greater capacity, a longer load platform, and provisions for end-unloading. It was concluded that side-unloading produces a much higher degree of cutting, splitting and abrading of beets in the hopper. The vertical drop from the truck into the hopper and design of the hopper appear quite impor-



OVID SUGAR FACTORY
IN-PLANT FLOWS
DECEMBER 1963

FIGURE 27



OVID SUGAR FACTORY
PLANT AREA
DECEMBER 1963

FIGURE 28

Figure 29.
Ovid sugar factory;
1-10-67
Side-dump of sugar beets into the truck hopper at the truck receiving station.

Figure 30.
Ovid sugar factory;
1-10-67
Drop section in the open discharge drain leading to the South Platte River.

tant in reducing wear and tear on the beets and the amount of sugar and other materials eventually lost to the flume water. Waste load would be proportionately affected.

At the Ovid factory, flume inlet water was supplied from the main water supply and seal tanks, and an intermittent well supply. The rock catcher installed in the flume system received return flume water from the pump ahead of the beet washer. Water supply for the beet washer was provided from three sources--drainage from the tailings screen on the spray table, the main water supply line, and return from the crystallizers and seal tanks.

The waste flume water before entering the closed main sewer passed through a small sump for removal of gross settleable solids. The sump was intended to provide protection of the solids recovery pump on the roller spray table. A sand line drained the sump and discharged to Lodgepole Creek. This was sampled at Station 45 as shown in Figures 27 and 28. Outside the main plant Station 44 was taken to represent waste flume water, although additional wastes were undoubtedly present at this point.

Beet Pulp

In December 1963, drying facilities were available only for about two-thirds of the pulp produced. The remaining pulp was pressed and deposited into a pit for eventual use as cattle feed. Drainage from the pulp pit discharged to an absorption ditch from which there was no surface overflow.

Today, all pulp is reported to be pressed and dried at the Ovid plant. However, Ovid is the last mill in the Basin using wet transport of pulp to the presses. Although transport water is recirculated in the pulp carrier system, some portion is probably wasted to the main sewer.

Main Plant Sewer

The main sewer was sampled at Stations 42-43 as shown in Figure 27, and included waste flume water, floor washings, effluent from the septic tank receiving domestic sewage, and miscellaneous wastes. Grab samples taken on the main sewer were described as Station 43; composite samples collected at the same point over the daytime shift (6-8 hours) were designated as Station 42. Miscellaneous wastes included boilout material from evaporators and vacuum pans. On the average, one pan was cleaned every 12 hours, and one evaporator each week. The main plant sewer eventually converted into an open discharge drain leading to the South Platte River as shown in Figure 30.

Waste Treatment

The impoundment of lime mud and disposal of pressed pulp drainage onto the ground represented the only forms of waste treatment employed by the Ovid sugar mill in December 1963.

Presentation and Discussion of Sampling Data

The average values of data collected from the Ovid mill survey are given in Table VI.

The quality of raw water intake at Station 41 was shown quite satisfactory for factory needs. As expected, concentrations of measured waste variables at the Ovid mill increased many times between the point of water intake and the end of the beet flume system (Station 44). From Station 41 to Station 44, increases were as follows: COD from 25 to 640 mg/l; TSS from 78 to 1,300 mg/l; VSS from 9 to 270 mg/l; total coliform bacteria from 7,700 to 9,800,000 organisms per 100 ml; and fecal coliform bacteria from 227 to 159,000 organisms per 100 ml. The spent flume water represented a major waste load from the Ovid factory.

The sand lime discharge at Station 45 and the spent flume water at Station 44 were found to be essentially one and the same waste. The sump in the flume system did not appear to provide any real degree of protection for the solids recovery pump on the roller spray table, and furthermore had no benefit whatsoever in pollution control.

Floor washings, sanitary sewage and miscellaneous plant inflows did not cause appreciable change in waste concentration between Station 44 at the end of the waste flume and Stations 42-43 on the main sewer. However, concentrations remained quite high and these were associated with a greater waste flow and loading at the downstream location.

Recent Operational Changes

The truck receiving station installed at the Ovid factory may have caused slight reduction over the unit waste volume and load experienced in December 1963. The new system should require less water compared to the old lateral flumes and the elimination of some overhead water. Additional pulp drying capacity completed in summer 1964 has precluded handling of pressed pulp and the waste drainage associated with this pulp.

The sugar company at present time is negotiating with the town of Ovid for construction of municipal waste treatment facilities on a cost-share basis. Under this arrangement, all domestic sewage from the mill would be diverted from the factory drain to the sewage treatment plant.

TABLE VI

OVID SUGAR FACTORY
SUMMARY OF IN-PLANT DATA
December 7-16, 1963

Sta. No.	Flow (cfs) Meas-ured	Flow (cfs) Esti-mated	No. of Samples	BOD mg/l	BOD %	COD mg/l	COD %	Total Suspended Solids mg/l	Total Suspended Solids %	Volatile Suspended Solids mg/l	Volatile Suspended Solids %	Total Alka-linity mg/l	Total Alka-linity %	Conduc-tivity umhos	pH	Temp. °C	Confirmed Coli. Bact. MPN/100 ml	Confirmed Coli. Bact. %	Fecal Coli. Bact. MPN/100 ml	Fecal Coli. Bact. %	Station Description
41			7	5		25		78		9		290		1630	7.8	7.1	7,700		227		Main Water Supply
44			28			640		1300		270		420		1550	8.2	23.4	9,800,000		159,000		North MH
							100		110		90		170					100		110	
42	12.6		8	500		(990)		(2290)		(340)		(1050)		1540	8.5						MH No. 1 Composites
43	13.1		28			610		1440		250		710		1910	8.6	23.5	9,480,000		177,000		MH No. 1 Grabs
45			26			746		1216		226		323		1592	7.8	22.8	18,700,000		362,000		Sand Line

NOTE:
% - Remaining between stages.
Values in parenthesis not used in calculating percent remaining between stages.

7. Brighton, Colorado

Process and Operation

The Brighton sugar factory was a straight-house operation with a continuous diffuser and complete facilities for drying pulp. Wet pulp was carried to the presses by conveyor belt and the press waters entirely reused in the diffuser. Molasses was shipped to the Longmont sugar mill for further sugar recovery. The Brighton establishment employed 70 to 75 persons on a permanent basis and 375 additional persons during the campaign. The rate of processing averaged 2400 tons beets per day over the 1964-1965 campaign.

Incoming sugar beets to the mill were received both by railroad car and truck. Approximately 80 percent of total beets were brought in from Kansas by railroad car. The remaining beets originated from Colorado; three-fourths of these beets being received by truck and one-fourth by railroad car. The beets in the railroad cars were deposited directly into the wet hopper of the flume system. The trucks unloaded to the beet piles or to the truck hopper. The truck hopper in turn was tied into the original beet flume system. The railroad car and truck hopper flumes subsequently combined into one header flume which transported the beets inside the factory.

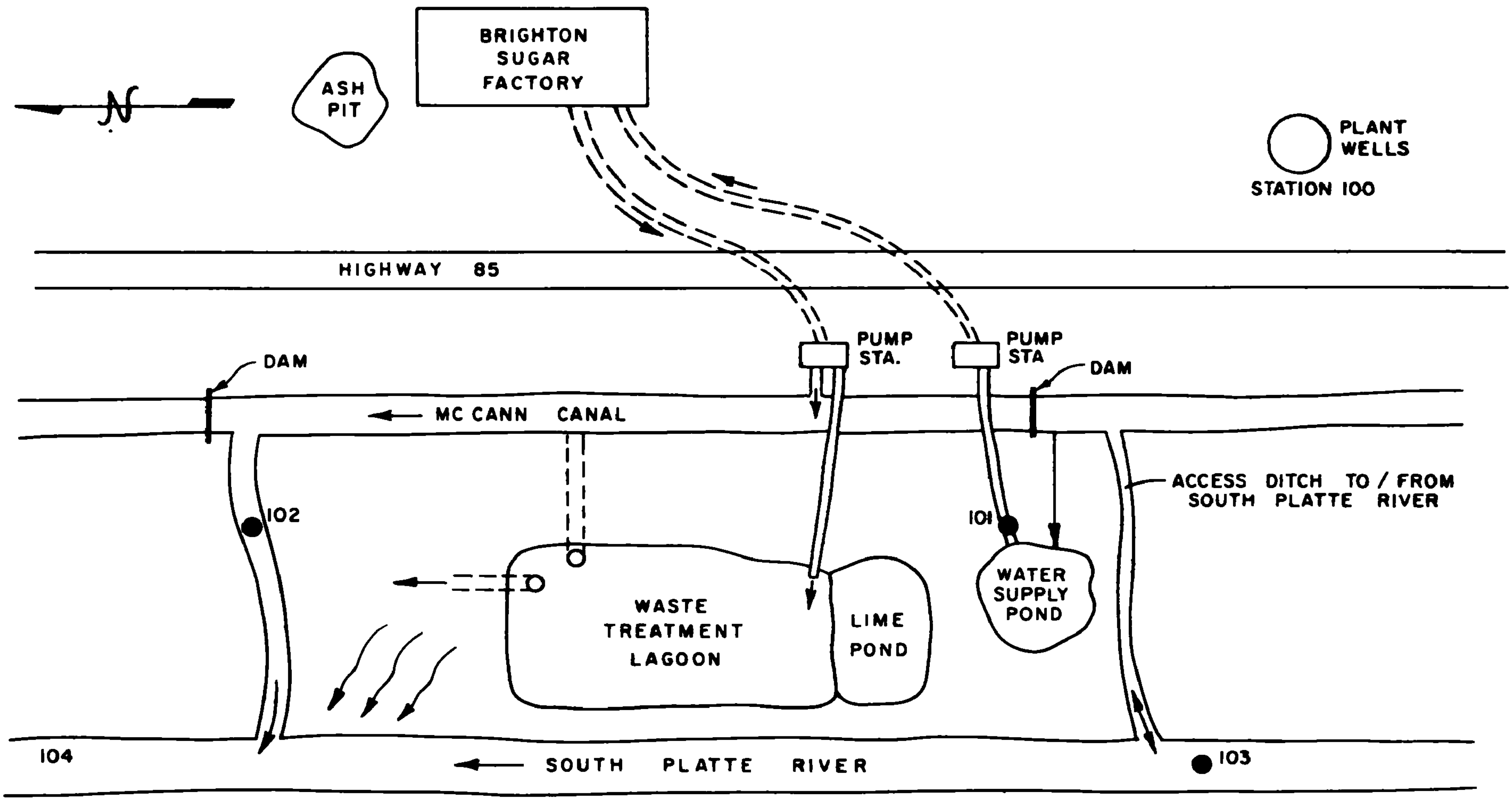
Lime mud was separately handled and stored in a holding pond with no reported overflow. Ashes were flumed to an ash pit area and the liquid percolated into the ground. The relative locations of sampling points employed for Brighton plant survey of January 1965 are illustrated in Figure 31.

Significant changes were incorporated in the waste abatement and treatment system at the Brighton sugar factory in the summer of 1966. These improvements are described later.

Plant Water Supply

In January 1965, the factory received water supply from the McCann Canal, the South Platte River, the city of Brighton, and three company wells. Water was diverted from the South Platte River and McCann Canal into a supply pond and then pumped to the factory. Pond supply was utilized in the beet flume system and occasionally in the diffuser. The three wells operating on a 24-hour basis provided for needs of the diffuser. Municipal water was employed only for domestic purposes. Pond and well supplies at that time were rated at about 10-12 cfs, and 2 cfs respectively. The pond and well supplies to the mill were sampled during the January 1965 survey and designated as Stations 101 and 100, as shown in Figure 31.

The waste handling and abatement system starting in October 1966 caused decrease in plant water use. Withdrawal from the water supply pond is now believed in the range of 7-8 cfs, and the wells provide about 2.0-2.5 cfs.



BRIGHTON SUGAR FACTORY
PLANT AREA
JANUARY, 1965

FIGURE 31

Beet Flume System and Waste Flume Water

In January 1965, all incoming beets were delivered by railroad car, dosed with overhead spray water, and deposited directly into the wet hopper of the flume system. The truck hopper was not used during the January 1965 survey. The truck hopper, when in operation, was served by a secondary flume as shown in Figure 32. The apparent advantages of end-unloading trucks over side-unloading have been mentioned previously.

About 40 percent of the waste flume water was recirculated in the beet flume system in January 1965. The new waste handling scheme in effect as of October 1966 provides now for 100 percent return of waste flume water.

Lime Mud Waste

Lime mud slurry was pumped to a separate 5-acre holding pond located next to the South Platte River. An overflow line available from the pond to the River could be used infrequently. It is known that an accidental discharge of lime mud to the River occurred in December 1966 following a break in the pond walls. The duration and extent of this spill were not documented.

Ashes

The residual ashes from coal-burning at the Brighton plant were flumed by condenser water into an ash pit. A high rate of percolation precluded any surface water overflow from this site. Some questions have been raised about the possibility of ground-water contamination in the vicinity of the ash pit, but evidence for this condition has not been found.

Main Plant Sewer and Old Waste Treatment System

In January 1965, all wastes from the Brighton sugar factory excluding lime mud, ashes, and domestic sewage were collected into the main plant sewer and then carried either to a waste treatment lagoon, or directly into the McCann Canal for disposal as depicted in Figure 31. Domestic sewage from the mill discharged to the municipal sewers. The industrial wastes in the McCann Canal were directed to the South Platte River via a discharge drain a short distance below the mill. The wastewater in the discharge drain was sampled at Station 102. The treatment lagoon covered approximately 10 acres in area and varied in depth from a few inches up to 3 feet. The lagoon was greatly limited in volume and, as a result, provisions were available for frequent waste releases to both the McCann Canal and the South Platte River. Overflow structures were located on the north and east sides of the pond. The remaining pond contents were disposed of by evaporation, percolation and underdrainage to the River, or direct spillage to the River following the not infrequent breaks in the pond walls. Waste treatment prior to

October 1966 was considered far from adequate. The January 1965 waste survey of course did not reflect the later changes made at the Brighton mill, but did offer a basis of comparison upon which these changes could be evaluated.

Presentation and Discussion of Sampling Data

The average values of data collected from the Brighton survey of January 1965 are given in Table VII. The results at Stations 100 and 101 indicated the well and pond water supplies were both of reasonably good quality. Bacterial densities, particularly fecal streptococci, in the pond supply were, however, somewhat higher than expected. The discharge drain at Station 102 was comprised entirely of factory wastes being released to McCann Canal. This wastewater was extremely high in organic material, suspended solids and bacterial content, and very low in available oxygen. During the January 1965 study at least some part of the main sewer wastes from the factory were believed retained in the waste treatment lagoon. Therefore, the discharge drain did not represent all, but rather some portion of the total factory wastes. These results may or may not have reflected the minimum waste loads discharged by the Brighton mill to the South Platte River over the 1964-1965 campaign.

The South Platte River reaching Brighton, Colorado, in 1965 and previous years was in essence an open sewer receiving heavy waste loads from Denver and other communities. This condition was verified by results from Station 103 immediately above Brighton. The sugar mill operations in January 1965 caused further severe degradation of the River reflected by sampling results below the mill at Station 104. Over this three and one-half miles of River, BOD increased from 77 to 112 mg/l, TSS from 122 to 391 mg/l, total coliform bacteria from 3.3 to 4.6 million per 100 ml, and fecal coliform from 0.79 to 1.7 million per 100 ml. Also, dissolved oxygen decreased from 3.1 to 1.6 mg/l. Most, if not all the change, was attributed to the Brighton sugar factory waste effluents. The new waste handling system at the Brighton sugar factory and recent completion of the Metropolitan Denver Sewage Disposal District No. 1 treatment facilities, are two major factors leading to the present recovery of the South Platte River in and below Metropolitan Denver.

New Waste Treatment System

The waste handling system recently installed at the Brighton mill essentially provides for the recirculation, treatment, and complete reuse of waste flume waters within the factory. The basic units consist of a pump station for directing flume water to and from the treatment basins, two vibrating screens for removing waste solids and debris, and three ponds in series for treating and maintaining a proper flow balance within the circuit. Some condenser water is bled into the circuit but the majority is discharged to a spray pond with subsequent overflow to the South Platte River. Excess water built up in the flume water circuit and spillage are transferred to a 10-acre storage pond. The

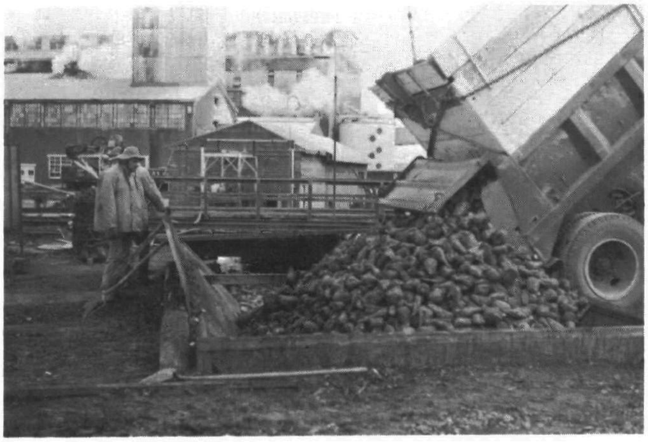
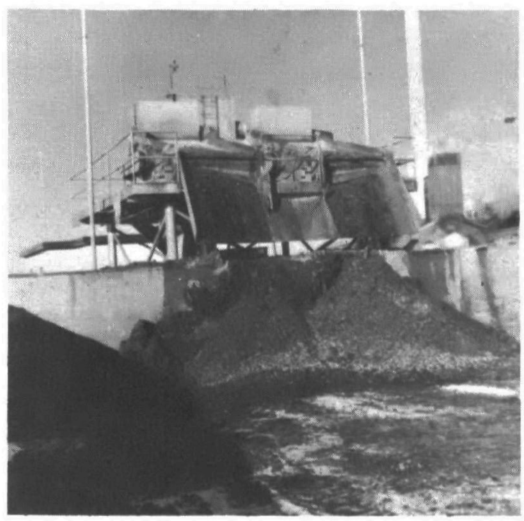
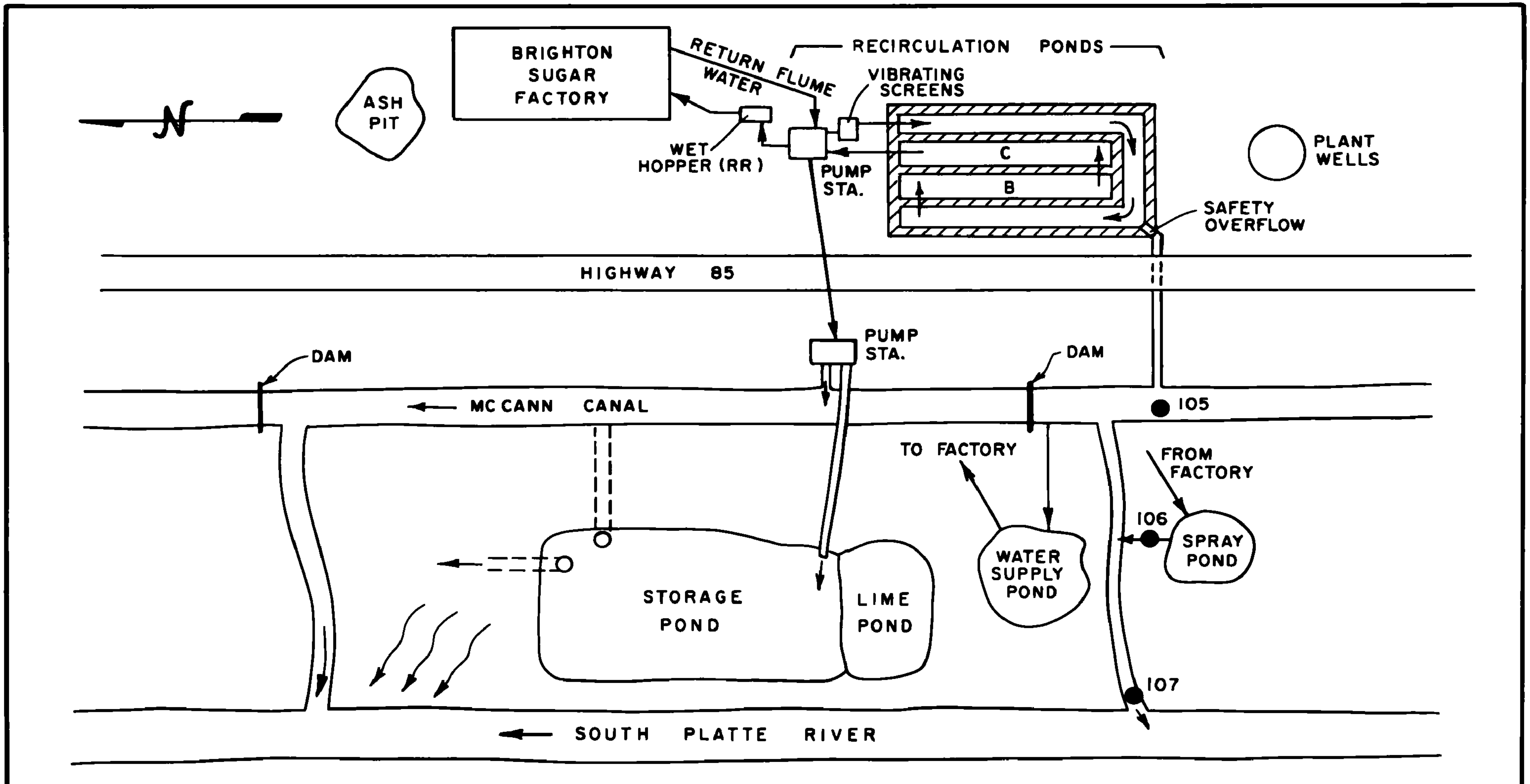


Figure 32.
Brighton sugar factory; 1-12-67
End-dumping of sugar beets into the truck hopper at the truck receiving station.

Figure 34.
Brighton sugar factory; 12-28-66
Dual vibrating screens removing tailings from waste flume water before entering the recirculation basins.





BRIGHTON SUGAR FACTORY
PLANT AREA
1966 - 1967

FIGURE 33

Brighton system initiated in October 1966 is illustrated by Figure 33. This system is described in detail since it is believed a forerunner of treatment facilities to be made available at many sugar mills in the not too distant future.

Waste flume water at the Brighton plant includes the beet washer and spray table effluents, floor drainage and miscellaneous wastes. Lime mud, ashes, and sanitary sewage are separately disposed of as before. The main plant sewer wastes drain to the pump station and are lifted over the vibrating screens having 1/8 by 5/8-inch openings and the screened waters enter the recirculation treatment basins. The screens together with the solids removed are shown in Figure 34. These solids, amounting to about 30 tons per day (wet), are sold to local farmers at $2 per ton and used as livestock feed.

The three recirculation basins cover a total area of 6 acres including dikes, and the maximum capacity before filling with solids was approximately 6 million gallons. Compartment A is the largest of the three ponds, and the wastes are circulated in a horseshoe-shaped circuit. The east, south, and west loops of compartment A are shown respectively in Figures 35, 36, and 37. The wastewater then flows consecutively through the inner compartments B and C, shown by Figure 33, is collected and returned to the pump station. The stabilized wastewater is entirely reused as water supply to the wet hopper below the railroad car receiving station, and also for the beet washer.

The recirculation chambers are designed for solids settling and therein lies a problem. The Brighton system was not equipped for automatic removal of solids and the solids level builds up rapidly, causing considerable reduction in the effective settling volume. Prior to mid-January 1967, the accumulated solids have been removed only one time (by dragline) and deposited on the dikes surrounding the outer recirculation pond. Scum and floatable solids on the pond surface may create other difficulties such as reduction of surface aeration, odor, etc. Compartment A is provided with a safety or overflow which can discharge directly into the McCann Canal. There was no indication of overflow during the 1966-1967 campaign.

Substantial quantities of various chemicals are added to the recirculation treatment ponds to counteract low pH levels and odorous conditions. Chemical requirements for the duration of the 1966-1967 campaign were estimated in the order of 19 tons caustic soda, 1000 tons of lime as $CaCO_3$, and HTH (chlorine) added intermittently at the rate of 25 pounds per day. Also, 73 tons of coke were necessary in converting limestone into usable lime in the form of CaO. Odors appear more critical within the pump station rather than the ponds but have presented no large problems to date.

Excess condenser waters from the plant are cooled and reconditioned within a spray pond which overflows to a discharge drain to the South Platte River. Although appearance of this drain was not good,

Figure 35.
Brighton sugar factory;
12-28-66
East leg of Compartment A in the recirculation pond system. Main factory shown at upper right of picture.

Figure 36.
Brighton sugar factory;
12-28-66
South leg of Compartment A in the recirculation pond system in foreground. Inner Compartments B and C shown in upper left and right sides of picture, respectively.

Figure 37.
Brighton sugar factory;
1-12-67
West leg of Compartment A in the recirculation pond system. Note heavy scum layer on pond surface and safety or overflow structure at lower left hand corner of picture.

the waters were found reasonably low in waste content, indicated by later results. The rate of condenser water discharge to the River is believed around 6-10 cfs.

The 10-acre pond used as a treatment lagoon prior to October 1966 has now been converted into a storage pond for holding excess volume from the flume water recirculation circuit, together with spills and accidental discharges. Liquid depths probably range from a few inches up to 4 or so feet in the pond. Two undesirable features underlie this part of the system. First, the pump used for transfer of waste material to the storage pond is undersized and improperly maintained, causing waste drainage into McCann Canal. Second, the rate of percolation from the storage pond into the South Platte River is believed significant, probably resulting in appreciable waste load introduced to the River via this means. Furthermore, the overflow device from the north side of the pond continues to exist and may cause additional discharge to the River. The storage pond and the adjacent lime pond are illustrated by Figure 38.

Figure 38.
Brighton sugar factory; 1-12-67.
Storage pond at center, and lime mud pond at left. Inlet to storage pond shown entering from right side of picture. Note bridge crossing South Platte River in center background.

Both on October 21 and November 12, 1966, the single pump for transferring waste flume water from the sugar factory to the recirculation treatment ponds became inoperative. Consequently this waste volume was diverted to the pump station serving the storage pond. This second pump was unable to handle the large volume and one-half or more of the waste was thereby released to McCann Canal and eventually to the South Platte River. The waste flume pump was down 48 hours on the first occasion and 12 hours on the second. Since that time, the company has installed a second flume water transfer pump.

TABLE VII

SUMMARY OF DATA FOR
BRIGHTON SUGAR FACTORY
AND SOUTH PLATTE RIVER
January 4-8, 1965

Sta. No.	Flow (cfs) Meas-ured	Flow (cfs) Esti-mated	No. of Samples	BOD mg/l	COD mg/l	Total Suspended Solids mg/l	Volatile Suspended Solids mg/l	Total Alka-linity mg/l	Conduc-tivity umhos	Temp. °C	pH	Dis-solved Oxygen mg/l	Confirmed Coli. Bact. MPN/100 ml	Fecal Coli. Bact. MPN/100 ml	Fecal Strep. No./100 ml	Station Description
								Sugar Mill								
100		2	2 (Grabs)	1	6	6	5	279	1520	26.8	7.6	---	<3	<3	---	Well water
101		11	4 (Grabs)	4	17	17	11	310	1350	4.3	7.9	11.3	12,000	2,300	11,000	Water supply pond
102	4.9		10 (Grabs)	935	---	2,040	390	---	1510	25.4	7.0	1.0	19,500,000	4,100,000	11,000,000	Discharge drain to So. Platte River after receiving McCann Canal wastes.
								South Platte River								
103		105	7 (Grabs)	77	97	122	75	290	1260	5.4	7.7	3.1	3,300,000	790,000	260,000	At State Hwy. 7 bridge, Brighton
104		115	7 (Grabs)	112	151	391	134	310	1370	5.5	7.6	1.6	4,600,000	1,700,000	1,600,000	At Wattenburg Road bridge, N. of Brighton

The sugar company is preparing an evaluation report of the Brighton waste handling system. The company has collected analytical data on various waste characteristics within the system, the spray pond, McCann Canal and the South Platte River above and below the Brighton factory. Unfortunately these results were not available to the Project at the time of this writing. However, the Project in January 1967 did collect a few samples in the area of the spray pond and drainage ditch; sampling stations are shown in Figure 33.

The January 1967 data are presented in Table VIII, but must be considered as preliminary to the sugar company report:

TABLE VIII

BRIGHTON SUGAR FACTORY SAMPLING
January 12-13, 1967

Sta. No.	Number of Samples	BOD mg/l	Total Suspended Solids mg/l	Temp °C	Confirmed Coli.Bact. MPN/100 ml	Fecal Coli.Bact. MPN/100 ml	Station Description
105	6	9	41	2.8	3,950	170	McCann Canal above spray pond.
106	6	10	22	22.0	12,000	7	Spray pond overflow to discharge drain.
107	6	6	32	23.0	9,450	4	Discharge drain flow into South Platte River.

The Brighton system, patterned after the Fremont and Findlay, Ohio sugar plants, operates on the basic principle of minimizing excess wastewater in the recirculation circuit as much as possible. The company estimated the capital cost of the Brighton system (excluding cost of land which was already available) around $160,000. At this stage of evaluation, the system would appear to have performed quite well and with a high degree of success in removing the serious pollution acknowledged in January 1965. The present picture would seem to indicate better than 90 percent reduction in waste loads compared to the previous period.

The company has indicated future improvements to be made in the Brighton system as follows: a) enlargement of compartment A; b) enlargement of the spray pond together with additional sprays provided; and c) levelling of the storage pond with provision for greater capacity.

8. Longmont, Colorado

Process and Operation

The Longmont factory compared in size and complexity to the Loveland and Fort Morgan mills. The Longmont installation included a Steffen house with a continuous diffuser and complete pulp-drying facilities. Wet pulp was carried to the presses by conveyor belt with press waters entirely reused in the diffuser. Molasses was received from the Brighton and Greeley mills; the average input was 186 tons per day over the 1965-1966 campaign. Residual material in the Steffen house was hydrolyzed and evaporated to produce CSF, eventually shipped to the Johnstown, Colorado recovery operations. The Longmont factory processed an average of 3570 tons sugar beets per day during the 1965-1966 campaign.

The plant received about 90 percent of raw sugar beets by railroad car and the remaining 10 percent by truck. Approximately 72 percent of the incoming beets originated from Colorado, 20 percent from Kansas, and 8 percent from Texas. Beets received by railroad car were dosed with overhead water when necessary, and deposited directly into the wet hopper and beet flume system. Trucked beets were stored in the factory yard for later retrieval.

An extensive waste survey was conducted at the Longmont plant in November 1965. At that time lime mud wastes were separately impounded, but there was no other treatment of factory wastes. A follow-up study conducted in November 1966 reflected changes following the construction of a treatment lagoon for total plant wastes. The results of both studies are given in this report. The relative locations of sampling points are given in Figure 39.

Plant Water Supply

Factory water supply was obtained from St. Vrain Creek together with relatively small amounts from the city of Longmont. Intake from the stream approximated 18 to 20 cfs, and the city supply directed to diffuser makeup and other special needs was in the order of 1 cfs. During the campaign, the complete flow of St. Vrain Creek was diverted into a factory water supply canal. Essential water for the factory was stored in a supply pond and the excess water returned to St. Vrain Creek as shown in Figure 39. Effluents from the city of Longmont sewage treatment plant were disposed of either into the factory water supply canal, as illustrated in Figure 40, or otherwise to St. Vrain Creek. The water intake line from the supply pond into the factory was sampled in 1965 at Station 110.

Beet Flume System and Waste Flume Water

Two separate flumes, one serving the railroad car receiving station and the other for the beet piles in the yard, combined into a single system for transporting the beets into the factory. Beets were trans-

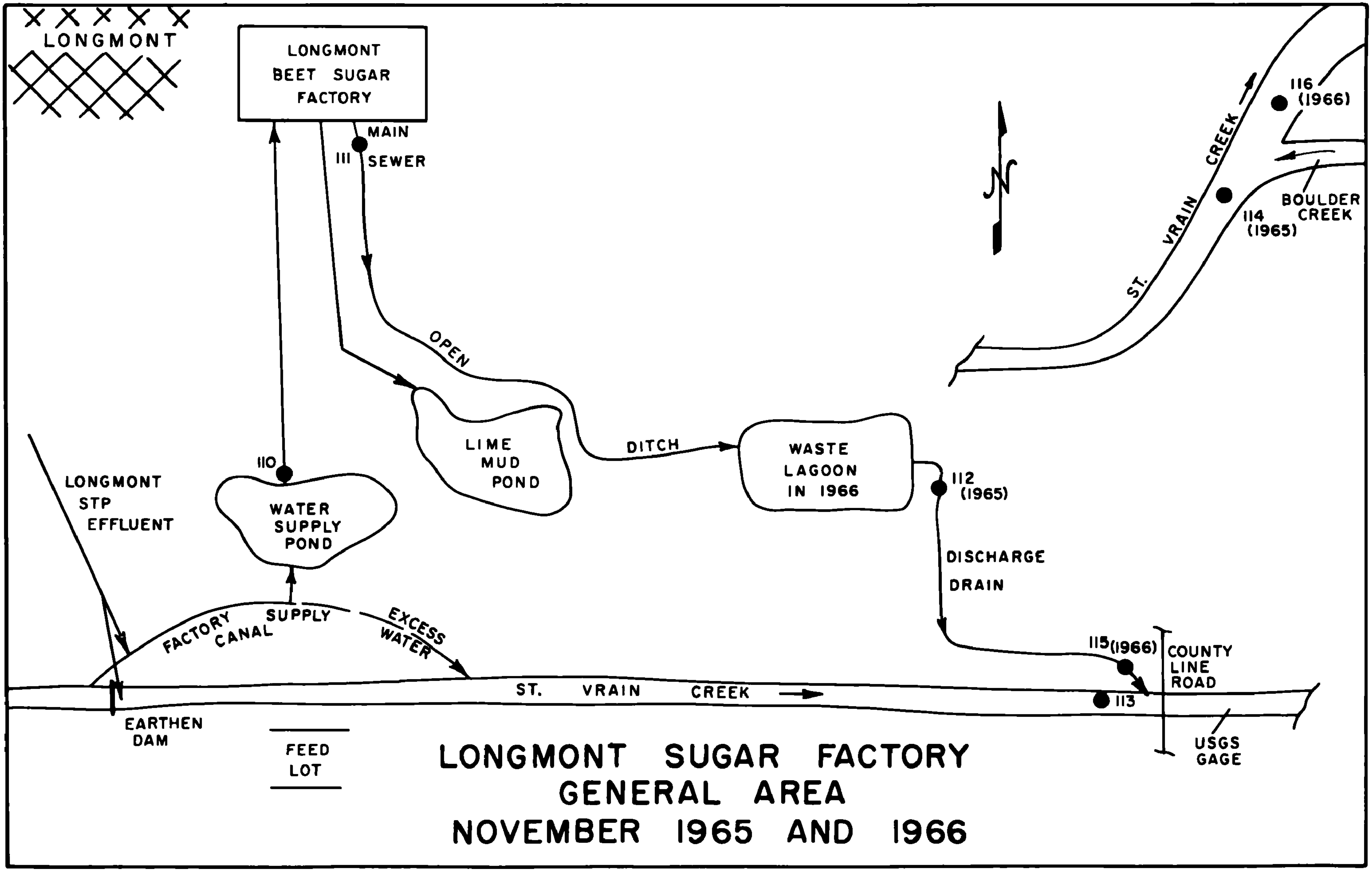

LONGMONT
LONGMONT BEET SUGAR FACTORY
MAIN SEWER
111
110
OPEN DITCH
LIME MUD POND
WASTE LAGOON IN 1966
112 (1965)
DISCHARGE DRAIN
LONGMONT STP EFFLUENT
WATER SUPPLY POND
FACTORY CANAL SUPPLY
EXCESS WATER
ST. VRAIN CREEK
EARTHEN DAM
FEED LOT
115(1966)
113
COUNTY LINE ROAD
USGS GAGE
116 (1966)
114 (1965)
BOULDER CREEK
ST. VRAIN CREEK
LONGMONT SUGAR FACTORY
GENERAL AREA
NOVEMBER 1965 AND 1966

FIGURE 39

ferred from the piles into the flume by an end-loader. Flume inlet water was derived from the main water supply and seal tanks. No recirculation was provided in the Longmont flume system.

Figure 40.
Longmont sugar factory; 1-18-67.
Factory water supply canal receiving St. Vrain Creek waters. Note Longmont sewage treatment plant effluents entering canal from left side.

Lime Mud Waste

Lime mud slurry was pumped to a separate holding pond with no reported overflow. However, in November 1966, Project personnel found a line from the lime mud pond leading to the open ditch above the waste lagoon. The company declared this was a case of accidental discharge; nevertheless this line has neither been removed nor permanently sealed.

Ashes

Ashes resulting from coal-burning at the Longmont sugar factory were flumed with main supply tank water to an ash pit with no reported overflow. The high rate of percolation evidently precluded any surface runoff.

Main Plant Sewer and Open Ditch

The main plant sewer was sampled adjacent to the factory and designated as Station 111. With the exception of lime mud, the main sewer received all plant wastes plus domestic sewage. The main sewer converted into an open ditch some distance from the factory, and total plant wastes carried to the treatment lagoon constructed in 1966.

Waste Treatment

Total plant wastes were passed through a waste treatment lagoon covering approximately 14 acres in area. Continuous overflow from the lagoon was released to the discharge drain and then to St. Vrain Creek. The influent and effluent ends of the lagoon were recently observed as shown in Figures 41 and 42. The waste flowed in rapid fashion through the upper half of the basin, whereas the lower end was clogged with solids thereby resulting in short-circuiting and incomplete treatment. This means of treatment at best must be considered only a stopgap measure.

Discharge Drain to Receiving Stream

The discharge drain leading to St. Vrain Creek was sampled at Station 112 in 1965, and at Station 115 during 1966. Since the early survey was prior to the treatment lagoon, results at Station 112 reflected conditions of no waste treatment. Data at Station 115 reflected changes with the treatment lagoon in place.

St. Vrain Creek

Both the 1965 and 1966 surveys included sampling of St. Vrain Creek at Station 113 immediately above the Longmont discharge drain as shown by Figure 39. St. Vrain Creek was also sampled below the sugar mill at Station 114 in 1965, and at Station 116 in 1966. These two stations were approximately 4 miles below the factory discharge drain.

St. Vrain Creek through the Longmont area was affected by other factors upstream of the sugar mill. The Longmont sewage plant provided reasonable secondary waste treatment except for high bacterial densities in their effluents. Important waste loads into St. Vrain Creek were also contributed by the Kuner Empson cannery, a municipal storm sewer south of the cannery, and the Ludlow Cattle Company feedlot.

Presentation and Discussion of Sampling Data

The average values of data collected during both the 1965 and 1966 surveys for Longmont are given in Table IX. Two important observations must be made prior to a data interpretation. First, in November 1965, the samples collected on the main plant sewer at Station 111 were judged to be not truly representative, and therefore the results were discounted. Secondly, in November 1966, sampling at Station 115 was believed to reflect, in part, lime mud being released from the lime pond eventually passing through the waste treatment lagoon.

With reference to Table IX, the factory water intake (Station 110) was found to be of fair quality. Dissolved oxygen, suspended solids and mineral content were satisfactory, but BOD and bacterial content definitely indicated the presence of upstream wastes.

Figure 41.
Longmont sugar factory;
11-15-66
Inlet area of waste treatment lagoon. Note heavy weed growth, and channeling of waste flow.

Figure 42.
Longmont sugar factory;
11-15-66
Lower end of waste treatment lagoon and overflow structure. Poor solids separation, septic and odorous conditions were experienced at this site.

The total wastes from the Longmont sugar factory represented a very large waste load imposed on St. Vrain Creek. The waste strength was lower in comparison to the other mills because of the large volume of water used. The 1965 data at Station 112 prior in time to the waste lagoon showed the total plant wastes with 320 mg/l BOD, 1750 mg/l TSS, a temperature of 39.2°C, pH of 8.3, 2.3 mg/l dissolved oxygen, and total and fecal coliform bacteria respectively of 490,000 and 17,500 organisms per 100 ml.

The completion of the waste treatment lagoon in 1966 appears to have produced mixed results on the total wastes subsequently released to the stream (Station 115). Suspended solids and temperature were significantly lowered, but dissolved organic and bacterial content remained the same or even increased. The drop in pH level from 8.3 to 7.5 was attributed to anaerobic decomposition in the treatment lagoon. Although dissolved oxygen was not taken in 1966, all indications pointed to septicity in the treated wastes; and there was good reason to expect odors in the general area of the lagoon. The increase in coliform bacteria or aftergrowth was believed due to favorable environmental conditions within the treatment lagoon. Retention was too short to produce bacterial reductions. Total wastes discharged to St. Vrain Creek in 1966 showed 340 mg/l BOD, 470 mg/l TSS, and total and fecal coliform bacteria respectively of 4,600,000 and 515,000 organisms per 100 ml.

St. Vrain Creek above the Longmont factory (Station 113) was of fair to poor quality. The average flow was 25 cfs in 1965 and approximately 6 cfs in 1966. In 1965, the stream contained 9 mg/l BOD, 8.3 mg/l dissolved oxygen, and total and fecal coliform bacteria respectively of 790,000 and 71,500 organisms per 100 ml. In 1966, values were as follows: 20 mg/l BOD, 2.5 mg/l dissolved oxygen, and total and fecal coliform bacteria respectively of 3,300,000 and 330,000 organisms per 100 ml. Clearly, the water quality situation above the Longmont factory was not a good one and was severely restricted by the lack of dilution water in the stream system. The ability of the sugar company to completely dry up the natural watercourse below the factory intake canal was rather surprising.

Below the sugar factory (Stations 114 and 116), St. Vrain Creek waters were of exceptionally poor quality. The stream contained high organic, suspended solids and bacterial loads, and lack of sufficient dissolved oxygen. In 1966, Station 116 on St. Vrain Creek showed waste levels of 107 mg/l BOD, 95 mg/l TSS, 2.2 million total coliform per 100 ml, and a complete absence of dissolved oxygen in the stream.

Acceptable stream water quality through the Longmont area can only be achieved in the future by greatly reducing waste loads not only from the sugar factory but other sources as well. Also, a water resources management plan for protection of all present and future needs must be provided. This management plan for achieving desirable water quality will probably require additional stream flows to be made available throughout the system.

TABLE IX

SUMMARY OF DATA FOR
LONGMONT SUGAR FACTORY
AND ST. VRAIN CREEK
November 1-5, 1965 and
October 31 - November 15, 1966

Sta No.	Period	Flow (cfs) Meas-ured	Flow (cfs) Esti-mated	No. of Samples	BOD mg/l	COD mg/l	Total Suspended Solids mg/l	Volatile Suspended Solids mg/l	Total Alka-linity mg/l	Conduc-tivity umhos	Temp. °C	pH	Dis-solved Oxygen mg/l	Confirmed Coli. Bact. MPN/100 ml	Fecal Coli. Bact. MPN/100 ml	Fecal Strep. No./100 ml	Station Description
								Sugar Mill									
110	1965	---	19	6 (Grabs)	12	20	18	12	240	1350	8.7	8.1	9.0	41,000	2,300	7,200	Intake from water supply pond
111	"	20.5	---	4 (24-hr. Composites)	290	390	990	181	250	1280	---	8.8	---	---	---	---	Main plant sewer
112	"	21.0	---	14 (Grabs)	320	420	1750	250	228	1370	39.2	8.3	2.3	490,000	17,500	6,350,000	Discharge drain
115	1966	---	---	4 (Grabs)	340	525	470	119	310	1520	28.5	7.5	---	4,600,000	515,000	---	Discharge drain
								St. Vrain Creek									
113	1965	25.2	---	10 (Grabs)	9	19	18	11	229	1360	10.4	8.1	8 3	790,000	71,500	22,000	Imm. above sugar factory discharge drain
114	"	46.2	---	10 (Grabs)	42	74	450	102	270	1600	15.0	7.8	0.7	490,000	94,500	1,100,000	Below factory and above Boulder Cr.
113	1966	---	6	3 (Grabs)	20	81	25	20	243	1510	13.0	7.8	2.5	3,300,000	330,000	---	Imm. above sugar factory discharge drain
116	"	---	---	3 (Grabs)	107	240	95	42	247	1750	16.8	7.7	0.0	2,200,000	130,000	---	Below factory and below Boulder Cr.

Recent Operational Changes

A major change in waste abatement is planned for the Longmont sugar factory. The company, in 1968, will construct a waste recirculation system followed by anaerobic and/or aerobic polishing ponds. The project will be supported in part by Demonstration Grant funds of the Federal Water Pollution Control Administration. There is overall optimism that this system will solve most if not all the waste problems presently experienced at the Longmont mill.

9. Eaton, Colorado

Process and Operation

The Eaton sugar factory was a straight-house operation with a continuous diffuser, and complete pulp drying facilities. It must be noted that the pulp dryer was installed in the summer of 1966 following the waste survey of November 1965. Therefore, the survey reflected prior conditions of wet pulp handling and storage. The Eaton mill processed an average of 2135 tons beets per day during the 1965-1966 campaign. Molasses was shipped to the Loveland factory.

Over the 1965-1966 campaign, the mill received sugar beets both by railroad car and truck. Beets were unloaded from the railroad cars directly into the flume. Trucked beets were stored in the factory yard; beets were retrieved from the piles by means of lateral flumes. Sugar beets are now totally received by truck. Lime mud was separately stored in a large pond with no reported or apparent overflow. The relative locations of sampling points for the Eaton survey both at the plant and on the receiving stream are shown in Figure 43.

Plant Water Supply

The large majority of plant water supply was obtained from company wells. Well water was delivered to a spray pond. The pond also received condenser water from the plant and some flow from Eaton Draw. The spray pond served to cool and recondition the condenser waters before their reuse in the factory. Mixed waters were then transferred to the main water supply tank within the factory. Water for domestic needs was received from the city and amounted to about 400,000 gallons per month. Total plant water use at the time of survey approximated 5 cfs.

Beet Flume System and Waste Flume Water

Most of the incoming sugar beets are now unloaded from trucks directly into a truck hopper. Beets are moved from the storage piles by front loaders into the lateral flumes as shown by Figure 44. The truck hopper joins the original flume system immediately adjacent to the main factory.

The beet flume received water from the main water supply and seal tanks. The plant employed 20-25 percent recirculation of waste flume water following the beet washer and roller spray table, back to the flume inlet.

Beet Pulp and Pulp Silo

Drainage from the wet pulp silo existing at the time of survey entered the plant discharge drain. Fanger screen water from the silo returned to the beet flume. The pulp silo drainage was independently sampled at Station 121 as shown in Figure 43.

Under present operation, wet pulp and the pulp silo have been eliminated. The exhausted pulp from the diffuser is conveyed to the press via scroll without transport water, and the press waters are entirely reused in the diffuser.

Ashes

The burning of coal for power and heat within the Eaton mill produced ashes which were carried by condenser water to a ponded area located adjacent to the plant discharge drain. No overflow was reported but the possiblity of underdrainage could not be excluded.

Main Plant Sewer and Discharge Drain

The main plant sewer converted into an open discharge drain after leaving the factory. The main sewer received all plant wastes excluding the lime mud, pulp silo drainage, and sanitary sewage. Domestic wastes discharged to the municipal sewer.

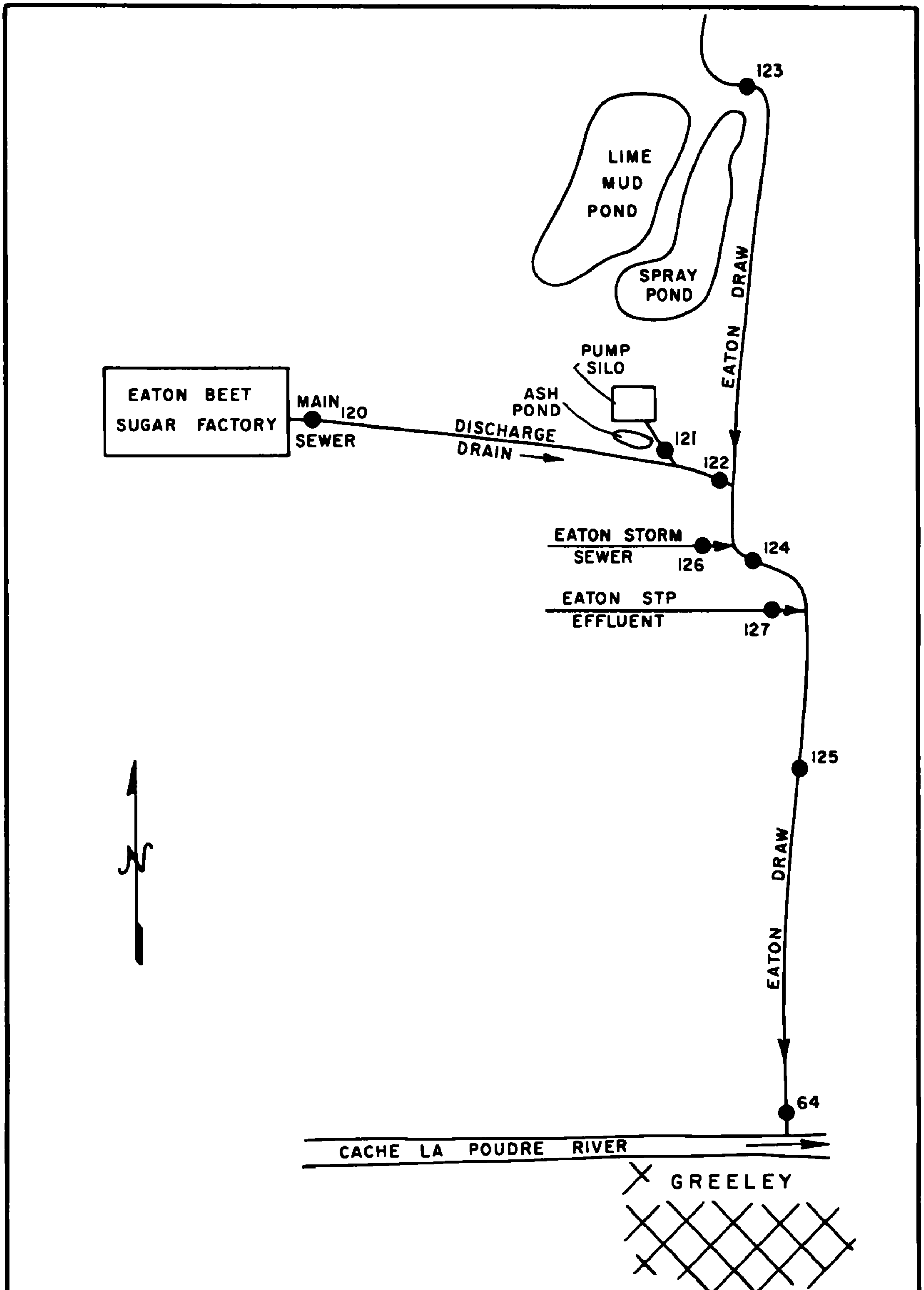
The discharge drain was sampled in November 1965 at two locations. Station 120 was located close to the factory. Station 122 was situated at the end of the drain below the pulp silo drainage line, and immediately before the total plant wastes entered Eaton Draw. The discharge drain is shown in Figure 45.

Waste Treatment

The only waste treatment provided by the Eaton mill in November 1965 was the separate handling and storage of lime mud. The water conservation practices within the plant of condenser water reuse, recirculation of waste flume water, and close regulation of the well water supply undoubtedly served in some degree towards reducing waste volumes and possibly waste loads. However, these procedures were not, per se, waste treatment measures.

Eaton Draw

Eaton Draw, originating north of Eaton and extending south five miles to the Cache la Poudre River, served as the waste receiving stream



EATON SUGAR FACTORY
GENERAL AREA
NOVEMBER, 1965

FIGURE 43

Figure 44.
Eaton sugar factory; 1-6-67
Sugar beets being transferred by front-loader from storage pile into the lateral flumes. Note abandoned high-line system.

Figure 45.
Eaton sugar factory; 1-6-67
Discharge drain from Eaton mill before entering Eaton Draw. Ash pond shown in right background.

in the area. Eaton Draw was also used during the summertime to convey irrigation water within certain sections. In addition to the sugar factory effluents, Eaton Draw received various wastes from the municipal sewage treatment plant in Eaton, a storm sewer in the town, two feedlots south of Eaton, and other agricultural enterprises. The November 1965 survey included sampling of the Eaton storm sewer at Station 126, the municipal sewage treatment plant effluents at Station 127, and four points on Eaton Draw as follows: Station 123 immediately above the sugar factory spray pond, Station 124 below the sugar factory discharge, Station 125 adjacent to the Cache la Poudre No. 1 irrigation canal, and Station 64 at the mouth of Eaton Draw. These stations are shown in Figure 43.

Presentation and Discussion of Sampling Data

Average values of data received from the Eaton survey are given in Table X.

The on-site survey data for the Eaton sugar mill were represented by Stations 120, 121, and 122. The main sewer flows at Station 120 were relatively high in waste concentration commensurate with a low water use within the plant. Suspended solids levels averaged 3020 mg/l. Pulp silo drainage at Station 121, although of limited volume, was very high in waste strength and acidic in nature. The BOD level was greater than 7200 mg/l, and COD approximated 11,600 mg/l. Bacterial densities were surprisingly high considering the low pH levels. Pulp silo drainage contributed about 40 percent of the BOD and COD loads found in the plant discharge drain. Total plant wastes at Station 122 showed 860 mg/l BOD, 1430 mg/l COD, 3320 mg/l TSS, a temperature of 35.3°C (96°F), only 0.3 mg/l dissolved oxygen, total coliform bacteria of 33,000,000 per 100 ml, and fecal coliform bacteria of 640,000 per 100 ml.

Eaton Draw was sampled at Stations 123, 124, 125, and 64. The flow data indicated that Eaton Draw in large part consisted of sugar factory effluents and the remainder originated from the Eaton storm sewer and municipal sewage treatment plant. Eaton Draw may be described as a conveyance means for disposing large amounts of organic and solid waste material into the Cache la Poudre River at Greeley.

The small flow of water in the upper end of Eaton Draw at Station 123 was somewhat high in mineral content but otherwise of fair quality. The stream at Station 124 below the Eaton sugar factory strongly reflected the waste discharge from the mill. Waste concentrations in the Draw were only slightly lower than found in the total wastewater leaving the factory and the dissolved oxygen level of 0.3 mg/l indicated near septic conditions.

Inadequately treated wastes from the community of Eaton served to augment severe conditions in the Draw. Agricultural enterprises in the area besides the sugar beet mill may have intensified the waste picture. Station 125, located four miles from the mouth of Eaton Draw, and Sta-

TABLE X

SUMMARY OF DATA FOR
EATON SUGAR FACTORY
AND EATON DRAW
November 15-19, 1965

Sta. No	Flow (cfs) Meas- ured	Flow (cfs) Esti- mated	No of Samples	BOD mg/l	COD mg/l	Total Suspended Solids mg/l	Volatile Suspended Solids mg/l	Total Alka- linity mg/l	Conduc- tivity umhos	Temp. °C	pH	Dis- solved Oxygen mg/l	Confirmed a/ Coli. Bact. MPN/100 ml	Fecal Coli. Bact MPN/100 ml	Station Description
								Sugar Mill							
120	4.37		4 (Composites)	560	980	3020	610	388	2170	---	7.9	---	---	---	Main plant sewer
121	0.11		15 (Grabs)	> 7200	11,600	340	250	---	2500	35.5	4.2	---	3,300,000	250,000 a/	Pulp silo drainage
122	4.48		15	860	1,430	3320	630	350	1800	35.3	6 8	0.3	33,000,000	640,000 b/	Total plant wastes, discharge drain at mouth
								Eaton Draw							
123	0 50		10 (Grabs)	< 15	56	104	32	350	1560	22.1	8.2	6.4	7,450	410 c/	Imm. above spray pond
124	5.14		10 (Grabs)	> 580	860	3150	820	360	2040	31.6	7 0	0.3	29,000,000	380,000 d/	Below sugar mill at Galeton Road
125	5 39		15 (Grabs)	700	930	2480	520	340	2000	23.7	6.9	0.0	94,500,000	3,650,000 e/	Near Cache la Poudre No. 1 Canal
64	5 68		10 (Grabs)	> 580	760	2400	540	430	1980	17.7	7.5	0.0	330,000,000	4,900,000 f/	At mouth
								Eaton Storm Sewer							
126	0.23		5 (Grabs)	49	85	322	85	---	1570	11.8	7.8	---	23,000,000	30,000	Near Galeton Road
								Eaton STP Effluent							
127	0 44		15 (Grabs)	100	118	99	53	470	2580	14.6	7 7	---	15,000,000	5,950,000 g/	---

a/ Median Fecal Strep density was 57,000,000 per 100 ml.
b/ Median Fecal Strep density was 62,000,000 per 100 ml.
c/ Median Fecal Strep density was 15,000 per 100 ml.
d/ Median Fecal Strep density was 63,000,000 per 100 ml.
e/ Median Fecal Strep density was 137,500,000 per 100 ml.
f/ Median Fecal Strep density was 150,500,000 per 100 ml.
g/ Median Fecal Strep density was 1,100,000 per 100 ml.

tion 64 at the mouth, more or less showed the same waste pattern as directly below Eaton. The BOD and solids levels remained very high and dissolved oxygen was completely absent at these two stations. Total and fecal coliform bacteria continued to increase throughout the entire distance from Eaton to Greeley. Eaton Draw at Greeley contained 330 million total coliform and 4.9 million fecal coliform bacteria per 100 ml. Bacterial regrowth undoubtedly occurred, aided by a favorable environment and the presence of large amounts of inadequately treated wastes.

Recent Operational Changes

There has been considerable change at the Eaton factory since the time of the November 1965 survey. Complete pulp-drying facilities and elimination of the pulp silo with associated drainage represents an important first step in waste abatement at the Eaton mill. In-plant water conservation practices have served in some degree to reduce the waste problems. More important, these practices should minimize the costs of extensive waste treatment required in the future. Management indicates that the Eaton sugar factory will install a waste treatment system similar to the Brighton mill.

10. Johnstown, Colorado

Process and Operation

The Johnstown, Colorado operations comprised two separate plants --the sugar recovery house and the MSG (monosodium glutamate) establishment. The two plants, although distinct, were more or less dependent on each other. The following information on process description for the Johnstown factory has been derived from McGinnis on "Beet Sugar Technology" (17) and from correspondence with the sugar company.

The Sugar Recovery House originally built in 1926, employs the barium saccharate process for final extraction of sugar from discard molasses. The molasses is received from five Steffen houses. The Johnstown plant is the only one of its type in the Western Hemisphere. The procedures within the barium plant are similar in many respects to those in a conventional Steffen house. Major differences however are the use of barium hydrate in place of calcium oxide and the economic necessity of recovering and reusing the barium salt in maximum degree. The barium saccharate process is much more specific than the Steffen process towards eliminating raffinose, and undesirable sugar, together with other impurities. The barium plant was ideally suited for the South Platte River Basin because the discard molasses produced over the Rocky Mountain region contains relatively large amounts of raffinose.

The barium saccharate process at Johnstown is divided into two main operations: the regeneration of barium carbonate, and the precipitation of sugar from discard molasses by barium hydrate. A schematic showing the major operations at the barium plant is given by the upper half of Figure 46.

The barium regeneration cycle is started with witherite (naturally occurring barium hydrate) and sand (silica) in the ratio of 3:1, the mixture being fed to a rotary kiln. Carbon dioxide is driven off and a clinker remains. The clinker is fed with water to a ball mill and in this operation approximately two-thirds of the BaO is leached from the clinker into the water; the solids residue consists of $BaO \cdot SiO_2$. The effluent from the ball mill is then sent to a series of thickener tanks. The liquid overflow from the tanks is collected and cooled to produce barium hydrate slurry. The slurry is filtered; the crystals are saved and the filtrate and wash which also contain BaO are returned to the ball mill.

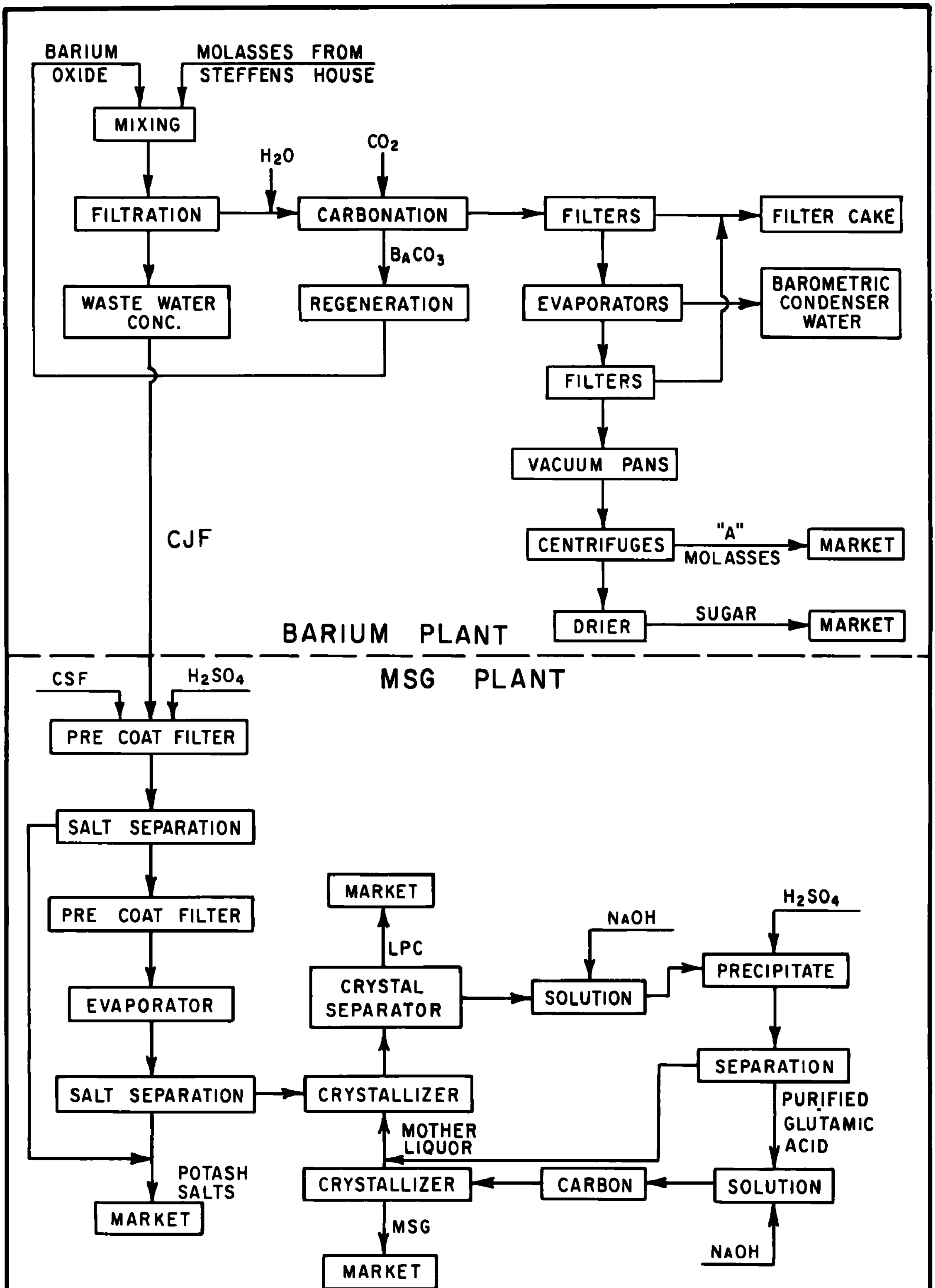
The used barium carbonate from the sugar house is mixed with the sludge ($BaO \cdot SiO_2$) recovered from the thickener tanks (to which barium sulfate is added to make up losses) and this slurry is filtered. The filter cake constitutes the basic feed to the rotary kiln and the regeneration cycle is renewed. Barium hydroxide may also be added to the kiln to make up barium losses in the circuit.

In the sugar recovery operations, discard molasses is mixed with barium hydrate liquid and heated to about 80°C before entering a series of precipitation tanks. Approximately 200 tons of molasses are handled over the 24-hour day. Barium saccharate sludge is produced, filtered, and washed; the filter cake is saved, and the filtrate and wash mixture are collected, carbonated, and filtered. From the second filter the barium carbonate cake is returned to the kiln house, and the filtrate in this case is specially treated for the recovery of stock-feed additives and fertilizer salts.

The washed barium saccharate cake from the first filter is mixed with sweetwater, carbonated, and then re-filtered. The thin juice resulting from these operations is subsequently processed for sucrose recovery more or less using the same procedures as a straight-house sugar factory. Final or "A" molasses may be sold as stock-feed additive, or treated in subsequent steps for the separate recovery of raffinose.

The MSG Manufacturing Plant was originally built in 1954 to provide further recovery of valuable materials remaining in the final waste effluents from the Steffen houses and the barium saccharate plant. The severe stream pollution problems caused by the Steffen house residues necessitated the extensive waste abatement and recovery operations undertaken by the sugar companies in the 1950's. This action still continues in certain parts of the country.

The Johnstown MSG plant, one of very few in the United States, is ideally suited to the conditions and supply of raw materials found in the South Platte River Basin. Although the market price for MSG is reported to have fallen in recent years, the Johnstown MSG operation is essential to the functioning of the sugar company and to its overall economics. This plant probably represents the largest single source of



MATERIAL FLOW DIAGRAM FOR THE JOHNSTOWN, COLORADO SUGAR RECOVERY AND MSG PLANTS

FIGURE 46

MSG in the United States, producing in the order of 5 million pounds annually.

The MSG establishment utilizes CJF (concentrated Johnstown filtrate) and CSF (concentrated Steffen filtrate) as the two primary raw materials in the feed ratio of 3:2 CJF to CSF. The CJF represents the exhausted material from the Johnstown barium plant. Five Steffen houses supply CSF to Johnstown, including Loveland, Longmont and Fort Morgan located in the South Platte River Basin, and Gering and Scottsbluff, Nebraska. These five factories also provide the discard molasses for the Johnstown barium plant. Storage of raw material at the five Steffen houses and at Johnstown enable year-round operation of the barium and MSG plants.

The manufacture of MSG is essentially the recovery of glutamic acid from glutamine, both amino acids. Production is complex and exacting. A schematic of major units operations at the Johnstown MSG plant is given by the lower half of Figure 46. The CSF and CJF mixture is filtered and concentrated, and within these operations potash salts are separated from the mixture. The potash salts are sold as fertilizer ingredients. The desalted mixture is allowed to set and crystallize. A liquid protein concentrate known as LPC is withdrawn at this stage to be later used as an additive to dried beet pulp as cattle feed. The process stream is next hydrolyzed with caustic soda for conversion into L-glutamic acid. Sulfuric acid is added until the isoelectric point of glutamic acid is reached at approximately pH 3.2. The mixture is then cooled and the separation of glutamic acid crystals occurs. The mother liquor is reboiled and returned to the process for additional crystal recovery. The crystals are purified in a solution of caustic soda, decolorized, concentrated, and re-crystallized. The final crystals are further separated, dried, and packed.

The waste studies at the Johnstown, Colorado operations anticipated the presence of a complex process effluent which indeed was found. The relative locations of sampling points for two surveys, one conducted in August 1965 and a second in November 1965, are illustrated in Figure 47.

Plant Water Supply

Sources of plant water supply included the Little Thompson River, the Hillsboro Canal, municipal water from Johnstown, and a series of company wells. Average water demand according to company records is given as follows:

Source	Summer (May - Sept)	Winter
Little Thompson River (direct)	7.6 cfs	---
Hillsboro Canal	---	6.3 cfs
Municipal Supply	0.7 cfs	0.7 cfs
Company Wells	1.2 cfs	0.6 cfs
Total	9.5 cfs	7.6 cfs

Waste Collection System and Treatment for All Johnstown Operations

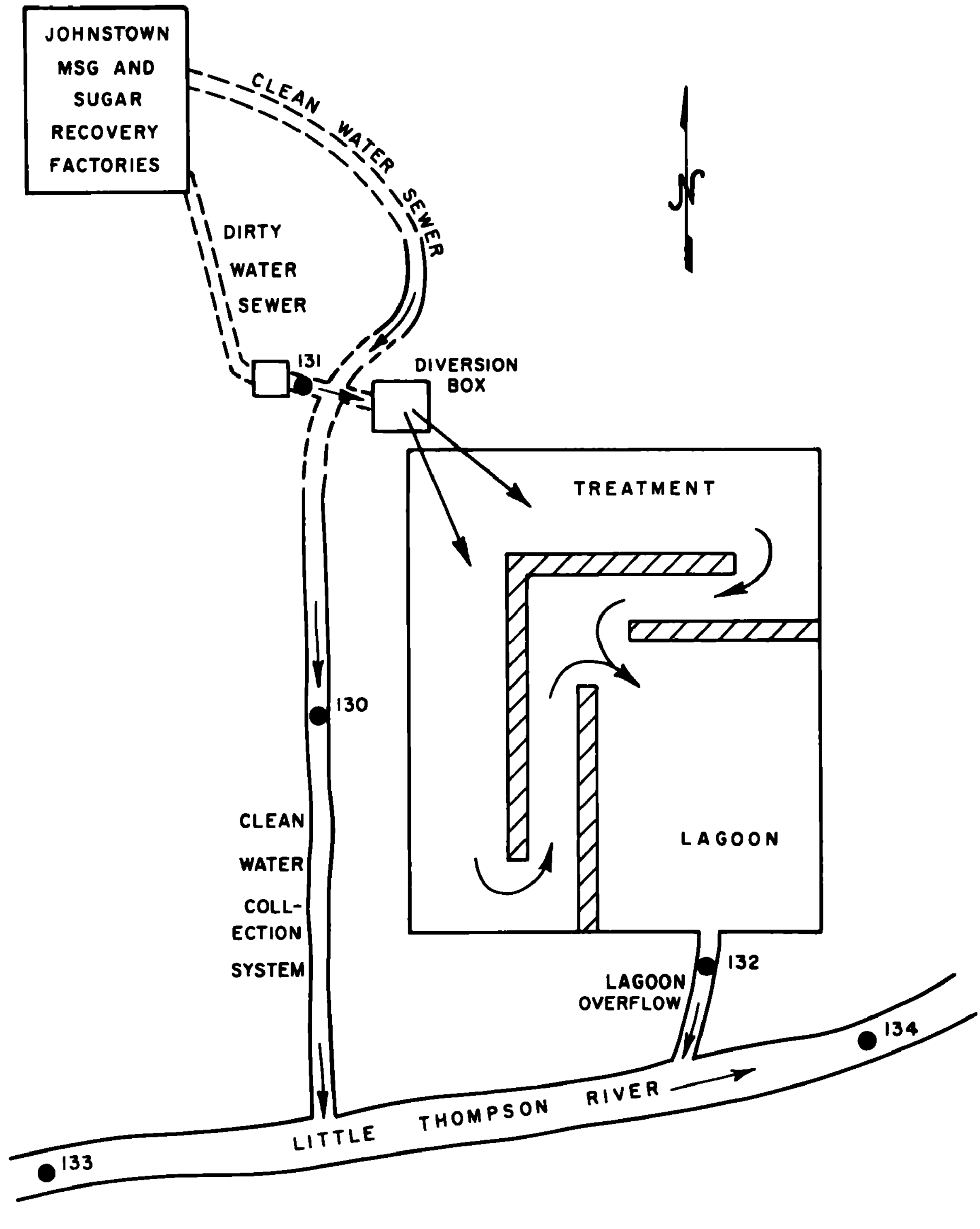
As implied in previous discussion, the Johnstown, Colorado operations did not receive or process sugar beets as such; consequently there were no flume waters or lime mud wastes. The wastes from both the barium and MSG plants were collected into two systems, designated by the company as the "clean water" sewer and the "dirty water" sewer. The clean water system, which was a misnomer, received various waste flows reported as relatively unpolluted, and these were discharged directly to the Little Thompson River without treatment. The remaining plant wastes within the dirty water system flowed into a waste treatment lagoon with continuous overflow also to the Little Thompson River. Both systems are shown in Figure 47.

Many improvements were reported to have been made in the Johnstown waste collection system during the summer of 1965. These changes supposedly consisted of segregating weak and strong wastes respectively to the clean water system and the dirty water system. The pre-coat filter material originating in the MSG plant was also removed from the dirty water system, and thereafter disposed of by incineration. The August and November 1965 surveys were intended to show the before and after conditions, reflecting such changes.

The clean water sewer contained the following waste streams according to the company records:

Effluent Stream	Average Daily Flow (cfs)
MSG pan cooler	0.09
Juice evaporator	0.73
CGA, PGA - Carbon cooler	0.02
A, B, C, D pan condensers	0.73
Nash pumps	0.09
Sulfuric acid cooling water	0.02
MSG cooling water	0.09
CJF cooling water	0.02
LPC cooling water	0.03
Total	1.82 cfs

The clean water collection system was sampled during November 1965 in the open drainway south of the main plants and below the diversion box to the treatment lagoon. This location was designated as Station 130.



JOHNSTOWN MSG AND
SUGAR RECOVERY OPERATIONS
PLANT AREA
AUGUST AND NOVEMBER, 1965

FIGURE 47

The dirty water sewer conveyed the remainder of the plant wastes to the treatment lagoon and according to company records consisted of the following flows:

Effluent Stream	Average Daily Flow (cfs)
MSG crude evaporator	1.05
MSG pan heater	0.02
Sweetwater evaporator	0.87
BaO crystallizer wastewater	0.13
Gas scrubber	0.28
BaO crystallizer cooler	0.13
Moore filters	0.16
Floor drains	---
Sanitary sewage	---
Total	2.64 cfs

In November 1965, both incoming and outgoing wastes from the treatment lagoon were sampled respectively at Stations 131 and 132.

The waste treatment lagoon at Johnstown covered 15-20 acres, varied in depth from a few inches to 18-20 inches, and was divided into three compartments as shown by Figure 47. The dirty water collection system was split at a diversion box into two flows which entered the first compartment on two sides. The flow continued through the second and third chambers to the overflow structure and then to the Little Thompson River. Waste detention time in the lagoon approximated 1-2 days. According to the company, the lagoon had not been cleaned over recent years, undoubtedly causing serious reduction in treatment efficiency.

Little Thompson River

The August 1965 study comprised sampling of the Little Thompson River at two locations shown in Figure 47. Station 133 approximately one mile above the sugar company provided background conditions on the Johnstown operations. Station 134 about 0.2 miles below the treatment lagoon effluent and 0.5 miles below the clean sewer discharge indicated the stream water quality changes resulting from the Johnstown industrial operations. These two river stations were re-sampled concurrent with the in-plant survey conducted in November 1965.

Presentation and Discussion of Sampling Data

The average values of data collected from both the August and November 1965 studies in the Johnstown area are given in Table XI.

The sugar plant results were rather surprising in many aspects. First of all, the aggregate wastes in the clean water sewer (Station 130) were found in November 1965 to be considerably stronger in strength compared to the dirty water sewer. The clean water line showed average waste values of 510 mg/l BOD, 438 mg/l TSS, 0.9 mg/l dissolved oxygen, temperature of near 40°C, and relatively low coliform bacteria. The company had previously sampled this line early in 1965, and at that time reported a BOD waste load of 6100 pounds per day. Following the plant changes made during the summer 1965, the November 1965 results were expected to show improvements in the clean water sewer. However, this was not the case with the BOD load increasing to 7700 pounds per day. The company said that the clean water sewer in November contained used condenser water with slight waste loads. It was clear that the company picture did not coincide with the results of the November 1965 survey. Some part of the clean water flows may have been transferred to the lagoon after November; nevertheless the total waste loads to the receiving stream would have remained at their former high level due to the poor waste removals experienced in the treatment lagoon.

The dirty water line entering the lagoon at Station 131 represented a waste stream with 282 mg/l BOD, 53 mg/l TSS, dissolved oxygen of 0.5 mg/l, temperature of 35°C, a pH of 4.6, and moderate levels of coliform bacteria. The company reported for early 1965 the dirty water sewer was rated at 7800 pounds BOD per day, whereas the November 1965 study showed a decrease to 4100 pounds per day. The low pH level of this waste would appear to have reduced biological activity within the initial stages of lagoon treatment.

The results on the waste overflow from the lagoon at Station 132 indicated a surprising recovery of pH to near neutral levels, but on the other hand there was a remarkable proliferation of coliform bacteria. Total and fecal coliform increased 220 and 160-fold respectively from pond inlet to outlet. Inhibitory effects, if present in the incoming wastes, would seem to have been removed by mixing and dilution with the existing pond contents. Undoubtedly, the environmental conditions were extremely favorable for bacterial growth. The presence of sanitary sewage in the lagoon may have contributed to the observed bacterial response.

The treatment lagoon was found almost completely ineffective for waste reduction. The effluents contained 264 mg/l BOD indicating only 10 percent BOD removal together with a complete absence of dissolved oxygen and very high coliform bacteria densities.

The effects of the Johnstown factory effluents on the Little Thompson River were pronounced and severe. The very large increases of organic BOD and bacteria content in the stream together with the lowering of dissolved oxygen were particularly significant. BOD values above to below Johnstown were increased from 9 to 60 mg/l in August 1965; and from 3 to 36 mg/l in November 1965. The bacteriological data specially showed that in-plant changes of summer 1965, rather than improving the waste picture, in fact created more serious conditions. During the earlier survey, total and fecal coliform bacteria were raised 17 and 10-fold respectively in the stream. The later survey showed increases of 300 and 18-fold respectively. Representative values of total coliform within the Little Thompson River below the factory were in the range of 1.0 to 4.0 million organisms per 100 ml.

Dissolved oxygen in the stream was lowered from 9.1 to 7.2 mg/l in November 1965, and from 7.1 to 3.2 mg/l during August 1965, from above to directly below the Johnstown operations. Other August 1965 data not shown in Table XI but included in Project files showed that dissolved oxygen three miles below the factory ranged from 0.0 to 2.0 mg/l with an average content of only 0.9 mg/l.

The composite effluents from the Johnstown factory were high in complex organic materials and bacterial content. Disposal of this wastewater into the Little Thompson River was shown to produce severe stream degradation and limitation of the various water uses. Extensive waste abatement and treatment should be initiated at the Johnstown factory without further delay.

<u>Recent Operational Changes</u>

Over the past year, the sugar company through the Beet Sugar Development Foundation has employed the consulting services of the British Columbia Research Council. Study has been directed to the Johnstown waste problems and development of adequate treatment procedures. From these studies a pilot plant will be started in late spring 1967 for treating part of the Johnstown factory wastes. The installation will probably comprise an aerated lagoon with recirculation of activated sludge. It is hoped this program will provide a new course of action in regard to waste pollution problems at Johnstown.

TABLE XI

SUMMARY OF DATA FOR
JOHNSTOWN SUGAR RECOVERY-MSG PLANTS
AND LITTLE THOMPSON RIVER
August 25-28, 1965 and
November 1-5, 1965

Sta. No.	Period	Flow (cfs) Meas-ured	Flow (cfs) Esti-mated	No. of Samples	BOD mg/l	COD mg/l	Total Suspended Solids mg/l	Volatile Suspended Solids mg/l	Total Alka-linity mg/l	Conduc-tivity umhos	Temp. °C	pH	Dis-solved Oxygen mg/l	Confirmed Coli. Bact. MPN/100 ml	Fecal Coli. Bact. MPN/100 ml	Fecal Strep. No./100 ml	Station Description
								Sugar Plants									
130	Nov., 1965	2.8		15 (Grabs)	510	560	438	63	250	1580	39.7	8.6	0.9	13,000	4,900	160,000	"Clean Water" sewer below the diversion box on the dirty water line
131	"		2.9	15 (Grabs)	282	---	53	24	(low)	1690	34.9	4.6	0.5	225,000	59,500	7,800	"Dirty Water" sewer inlet to lagoon
132	"	2.9		15 (Grabs)	264	---	30	28	280	1380	12.5	7.8	0.0	49,000,000	950,000	3,600	Lagoon effluent to river
								Little Thompson River									
133	Aug., 1965	42		8 (Grabs)	<9	23	345	36	300	2660	18.4	8.0	7.1	59,500	5,950	10,300	County road bridge 1 mi. directly S. Johnstown
134	"	41		8 (Grabs)	60	---	379	34	300	2570	20.8	8.0	3.2	1,045,000	56,000	---	County road bridge 0.2 mi. below sugar factory lagoon effluent
133	Nov., 1965	44		10 (Grabs)	3	12	82	19	270	2550	8.9	8.2	9.1	13,000	3,600	1,650	County road bridge 1 mi. directly S. Johnstown
134	"	62		10 (Grabs)	36	38	79	19	275	2400	10.6	8.2	7.2	3,950,000	63,500	26,200	County road bridge 0.2 mi. below sugar factory lagoon effluent

SECTION III

TOTAL POLLUTION LOADS FROM SUGAR BEET MILLS

III. TOTAL POLLUTION LOADS FROM SUGAR BEET MILLS

This section of the report focuses on the total waste loads originating from the ten sugar factories in the South Platte River Basin. Evaluation is provided on the waste loads leaving the factory and secondly, on the loads actually discharged to the receiving stream after available treatment, if any.

The total waste load directly from the factory as found in the main sewer or discharge drain is significant in two respects:

1) The waste material represents that portion which has not been eliminated by factory operations.

2) The total plant waste load before general treatment establishes a level of comparison between various factories with their particular operations. The information contained in this section of the report is intended to supplement the 1952 Industrial Waste Guide for the Beet Sugar Industry (20) describing typical wastes expected from sugar beet mills.

Knowledge of the waste load entering the receiving stream is important in at least three respects:

1) To determine the physical, chemical and biological responses of the river in relation to these loads.

2) To determine the adverse effect and impairment of stream waters for legitimate and beneficial uses.

3) To assess waste load reductions and control measures necessary to achieve the desired stream water quality objectives.

A. TOTAL FACTORY WASTE LOADS

The picture of total plant waste loads from factories in the South Platte River Basin has been developed in large part from data previously included in Tables I - XI of this report. The factory discharges are described in terms of unit waste loads predicated on the basis of a single ton of raw sugar beets received for processing. Major emphasis is centered on the following: a) summary table giving the unit waste flow and load characteristics for each of nine sugar beet processing establishements; b) important factors and the reasons for change in unit waste loads, and; c) waste load from particular unit operations. It must be recognized that conditions in the South Platte River Basin may be somewhat different compared to other areas of the country.

Some adverse comments have been expressed on the timing of the in-plant surveys, particularly for the months of December and January during which certain studies were conducted. Severe cold-weather was reported to be associated with a higher percentage of frozen beets. These conditions were reported responsible for greater operational difficulty and higher waste loads. Although low temperatures such as experienced in the January 1964 studies undoubtedly did reflect higher waste loads, nevertheless, these conditions and others were believed representative and typical for the study area. Plant studies were also conducted in November and December. Weather was an important, but not an overriding factor.

Plant waste loads from the nine sugar beet mills in the South Platte River Basin are summarized in Table XII. The data array at first glance gives the impression of wide variation in values, but suitable explanation is given in the subsequent discussion.

1. Classification

Waste loads are arrayed in Table XII with respect to particular unit operations at the sugar mills. The Greeley, Ovid and Brighton factories excluded lime mud waste from the main sewer and, additionally, did not have pulp silo drainage. The Loveland and Fort Morgan factory had no pulp silo drainage; however they discharged the total lime mud to the main sewer. The Sterling and Windsor mills added both pulp silo drainage and lime mud to the waste drainage system. Eaton and Longmont did not conveniently fit any of above three categories. The Eaton factory was atypical of the general group because of its high degree of in-plant water conservation; however pulp silo drainage was discharged. The Longmont installation, although possessing lime mud holding facilities, was releasing part of the lime mud to the drain; no pulp silo drainage was present. The Longmont plant was grouped with Loveland and Fort Morgan on the basis of lime mud wasting.

One important point must be made clear regarding lime mud. The Steffen houses which included Loveland, Fort Morgan and Longmont may be expected to use nearly twice the amount of lime within the process compared to the straight-house factories. Lime mud slurry from a Steffen house factory is also about 50 percent higher in waste strength (19).

2. Waste Flows

Wastewater volumes from the factories were believed to represent 90 percent or more of total plant water use. The various mills in Table XII may be categorized as low, medium, and high water-using establishments using the study area as baseline. Minimum wastewater volumes were reflected at the Greeley plant and particularly the Eaton plant by restrictions, imposed or otherwise, in securing available water supply. The Loveland, Windsor, and Longmont mills had relatively free access to surface waters in the Middle Basin resulting in above average water consumption. Steffen house operations included at the Loveland and Longmont mills may have accounted in part for the higher water use. The three sugar factories of the Lower Basin including Fort Morgan, Sterling and

TABLE XII

UNIT WASTE LOADS FOR TOTAL FACTORY EFFLUENTS [a]
REPRESENTING NINE SUGAR BEET MILLS IN THE
SOUTH PLATTE RIVER BASIN

1963 - 1966

	Greeley	Ovid	Brighton	Longmont	Loveland	Fort Morgan	Sterling	Windsor	Eaton	Average Values [b]
Station No.	92	42-43	102	112	76	23-24	32-33	83	122	---
Waste Flow (gals/ton)	2300	3000	---	3700	3300	2900	2700	3600	1400	2950
BOD (lbs/ton)	14 [c]	12	10 [d]	10	19	12	20	33	10	15
COD (lbs/ton)	17 [c]	15	---	13	29	15	30	50	16	22
TSS (lbs/ton)	25	36	22 [d]	55	115	121	78	84	38	67
Total Alkalinity (lbs/ton)	16	18	---	7	74	46	25	52	4	32
Total Coli. Bacteria (BQU/100 tons)	23 [c]	44	40 [d]	3	0	14	85	58	69	33
Fecal Coli. Bacteria (BQU/100 tons)	1.6 [c]	0.8	8.4 [d]	0	0	0	1.3	1.3	1.3	1.4

a/ Excludes wastes disposed of by separate means and not appearing in the main plant sewer. These values reflected waste loads before general treatment.
b/ Weighted in respect to production rate.
c/ Adjusted for waste load in the plant water intake.
d/ Probable minimum values.

Ovid were classed in the intermediate range. The Lower Basin plants probably experienced a small degree of difficulty in obtaining water since the available supply in this region is largely dependent upon return irrigation flows from upstream areas. Results from other parts of the country certainly do indicate that the South Platte River Basin factories could greatly reduce water consumption, if desired. In turn, minimum wastewater volumes would promise less problems in waste handling and lower costs in future treatment.

3. BOD and COD Loads

Table XII shows that BOD waste load varied from a low of 10 pounds per ton of beets observed at three mills--Brighton, Longmont, and Eaton, to a high of 33 pounds at the Windsor mill. The average for the nine plants was 15 pounds BOD per ton beets processed. The COD loads were more or less proportional to BOD, and varied from 13 to 50 pounds per ton beets.

Pulp silo drainage, in particular, and lime mud waste were determined to be major factors contributing to the magnitude of organic (BOD and COD) waste load from a sugar factory. Field observations further indicated that the quantity of pulp silo drainage would increase throughout the season related to the total accumulation and the age of wet solids in the silo.

The BOD and COD waste loads showed progressive increase across Table XII which were correlated with increasing amounts of pulp silo drainage and lime mud wastes from the various mills. The Eaton mill was an exception, and the waste load associated with pulp silo drainage in this case was believed on the low side. This waste load was low only because the survey data was collected early in the campaign when there was a minimum accumulation of wet solids and drainage in the pulp silo. The data in Table XII show that the addition of lime mud may be expected to increase the normal BOD and COD loads from a sugar factory by 10 to 40 percent. If pulp silo drainage is also added, basic waste loads could be increased from 50 percent up to 200 percent.

4. TSS Loads

Total suspended solids loads varied from a minimum of 22 pounds per ton of beets at the Brighton mill to a maximum of 121 pounds observed at the Fort Morgan mill. Lime mud wasting was the predominating factor contributing to high suspended solids loads in the factory effluents. The four plants which provided for separate handling and disposal of lime mud slurry--Greeley, Ovid, Brighton, and Eaton, experienced the least TSS loads. TSS levels for these plants ranged from 22 to 38 pounds per ton beets with an average of 30 pounds TSS. The remaining five factories demonstrated TSS waste loads in the range of 55 to 121 pounds solids, with an average of 91 pounds solids. Pulp silo drainage was believed to contribute a minor portion of the TSS load.

The Loveland and Fort Morgan mills with entire wasting of lime mud together with relatively large amounts of lime generally expected from Steffen houses, typified extremely high levels of TSS. These loads were respectively 115 and 121 pounds TSS per ton beets processed. The survey data indicated that complete lime mud wasting may be expected to increase basic plant TSS loads from 100 up to 300 percent. This increase would undoubtedly be greater for a Steffen house compared to a straight-house factory.

5. Total Alkalinity Loads

The total alkalinity within sugar factory wastes varied from the low of 4 pounds per ton beets observed at the Eaton mill to a maximum of 74 pounds at the Loveland mill. Lime mud wastes greatly increased the alkalinity loads, which would be more significant for a Steffen house factory. The Greeley, Ovid and Eaton plants without lime mud wasting demonstrated a level of 4-18 pounds total alkalinity per ton beets processed. The other five plants (excluding Brighton) averaged 41 pounds alkalinity. These alkalinity values were not adjusted for loads in the plant water supply.

Pulp silo drainage when mixed with total plant wastes served in partially neutralizing excess alkalinity, particularly that portion contributed by lime mud. Alkalinity levels were very high at Loveland and Fort Morgan where the lime was completely discharged and the absence of pulp silo drainage precluded any neutralization. The combining of the two wastes at both Windsor and Sterling caused some reduction in alkalinity loads at these mills. Greeley, Ovid, and Brighton discharged neither waste. The Eaton mill represented the case where lime mud was absent and the pulp silo drainage served to almost completely neutralize all the available alkalinity. The Longmont situation with low alkalinity levels unfortunately could not be explained on the basis of known information.

6. Bacterial Loads

The bacterial loads shown in Table XII varied from 0 to 68 BQU of total coliform bacteria discharged per 100 tons beets, and fecal coliform bacteria from 0 to 8.4 BQU. Six of the nine factories contained very high levels of coliform bacteria in the effluent wastes. For comparative purposes, the raw sewage discharged by a human population of 1,000 persons would be expected to contain around 15-30 BQU of total coliform bacteria and 5-20 BQU of fecal coliforms.

The various sugar mills may be categorized as low, medium, and high bacterial load-producing plants. The three factories at Longmont, Loveland and Fort Morgan demonstrated relatively low bacterial loads because of lime mud wasting contributing to very high pH levels in the total plant wastes. The field surveys showed that pH levels exceeding 9.0 were particularly destructive to organisms of the coliform group. The alkaline environment may include other factors associated with, but incidental to lime mud, causing the destruction of bacterial organisms. Loveland factory wastes were in the pH range of 10.1 to 10.5, and the Fort Morgan effluents approximated a pH value of 9.1. The flows from both factories were highly alkaline. The Longmont plant discharges were in the pH range of 8.3 to 9.1 during the survey, although higher pH levels were believed present at other times.

Windsor, Sterling, and Eaton discharged pulp silo drainage which appeared to offer the most favorable conditions for bacterial growth. The silo drainage from the Eaton mill with a pH level of only 4.2 was found to contain 3.3 million total coliform and 0.25 million fecal coliform/100 ml. No inhibitory effects could be demonstrated after the pulp drainage was mixed with total plant wastes. The drainage would also contain a wide variety of substrate material suitable for bacterial propagation. The Windsor, Sterling and Eaton factories all with pulp silo drainage, experienced the maximum bacterial loads.

Greeley, Ovid and Brighton, with neither lime mud nor pulp drainage, demonstrated intermediate, but nevertheless fairly high bacterial loads. The proportion of fecal to total coliform was notably high at the Brighton mill but a full explanation for this occurence cannot be given.

The reader is informed that Section IV of this report contains detailed information on the overall nature and consequences of bacterial pollution caused by sugar beet processing wastes. Special emphasis is given to the in-plant sources, changes due to waste storage, pathogenic association, survival trends, and effective measures towards bacterial reduction. Such information is considered essential to a full understanding of the bacterial problems inherent to sugar beet processing.

7. Summary of Overall Factory Loads

The Industrial Waste Guide for Beet Sugar (20) published in 1952 gave extensive review of the waste problems which existed in the industry through the 1940's and early 1950's. However, since that time, many modifications have been made in equipment, practices and procedures. The Industrial Waste Guide contributed valuable information on the characteristics, volumes and unit loads associated with various waste streams in the sugar factory. Major waste effluents at that time included flume water, pulp screenwater, pulp press water, pulp silo drainage, lime cake slurry, barometric condenser water, and Steffen filtrate.

The present studies must necessarily update some of the information given in the Industrial Waste Guide. One of the more important changes within the industry has been the increase in water reuse and recovery. Future conditions may dictate almost complete reuse of wastewater resulting in little or no effluent to the receiving stream. The large majority of present-day sugar factories have virtually eliminated the pulp press and pulp screen waters. It is also important to note that all Steffen filtrate in the South Platte River Basin is shipped to the Johnstown chemical operations; this waste, per se, is not a problem over the area.

Basic waste loads are defined in this report as those originating from waste flume water, excess condenser water and minor sources; lime mud wastes and pulp silo drainage are excluded. In Table XII basic waste loads are found to approximate 10 pounds BOD, 14 pounds COD, 28 pounds suspended solids, and 17 pounds alkalinity, per ton beets processed. This BOD load is about double that given by the Industrial Waste Guide and presumably reflects miscellaneous wastes not accounted for in the original studies and/or different operating conditions encountered in the South Platte surveys.

Lime mud waste and pulp silo drainage cause significant increase in factory waste load far beyond the basic levels. Therefore, unit waste loads are developed from the information in Table XII specifically for lime mud and pulp drainage. Predicated upon this data collection, it is determined that lime mud from a Steffen house factory would contribute about 5 pounds BOD, 7 pounds COD, 90 pounds TSS, and 45 pounds alkalinity per ton of beets processed. A straight-house operation would approximate from one-half to three-fourths of these respective loads. Pulp silo drainage would be expected to add another 16 pounds BOD, 22 pounds COD, and minor amounts of TSS to the total plant load. Unit BOD loads are in fair agreement with those previously given in the Industrial Waste Guide, whereas COD, TSS and alkalinity loads represent new values not found in the original Guide.

B. WASTE LOADS TO THE RECEIVING STREAM

The pollutant waste material entering the receiving stream represents the total plant waste load less the portion removed by available on-site treatment. Excluding the new Brighton system, the various sugar mills in the South Platte River Basin provided only minimum treatment, with the large majority of total plant waste loads then reaching the stream.

Waste treatment consisted of aeration fields at the Loveland and Windsor factories, and shallow lagoons at the Greeley, Fort Morgan, Brighton, Longmont, and Johnstown factories. The Sterling, Ovid and Eaton mills provided essentially no waste treatment. Waste removal varied from zero efficiency to the equivalent of primary treatment. The status of waste treatment is summarized for each factory in Table XIII, giving the treatment method, waste loads before and after treatment, and nature of the final discharge to the receiving stream. Discussion of the results received from individual mills over the 1963-1966 seasons is given by the following:

The Loveland aeration field covered an extensive area of 133 acres. Suspended solids and alkalinity removals were reasonably good, but soluble organic wastes were reduced only in minimum degree. The facility provided less than equivalent primary treatment, and waste concentrations within the final effluents remained at high levels. The merits of maintaining an extensive treatment area may be seriously questioned in view of results obtained. Recent modifications made at Loveland have not changed the overall picture. Twenty percent reduction in BOD, and discharge loads of 26 tons BOD and 44 tons TSS daily are definitely not compatible with the water quality needs of the area.

The Windsor plant was rated highest of all mills in terms of organic BOD load discharged to the receiving stream. The aeration field at Windsor was found less effective than Loveland, producing only 0-10 percent removal of BOD and 60 percent reduction of TSS. The wastewater entering the Cache la Poudre River contained in the order of 1100 mg/l BOD, 1060 mg/l TSS, and 6.6 million total coliform bacteria/100 ml.

The Greeley factory in January 1964 maintained a small, shallow lagoon for waste treatment. This facility afforded reasonably good removal of TSS, but virtually no change in the organic waste loads released to the receiving stream. Severe odor problems were associated with the lagoon operation and the installation was converted to an aeration field in 1965. Present waste removals are likely to be even less promising than before.

The Fort Morgan operations consisted of two shallow lagoons which functioned singularly or in series. As in the case of other factories, the treatment facilities received little or no attention. The waste treatment lagoons were nearly filled with solids negating effective treatment. Considering the lack of supervision and maintenance, the BOD and TSS removals of 35 and 75 percent respectively were rather surprising. Heavy lime mud loads added to the ponds were responsible in part. Bacterial levels were effectively lowered within the ponds by an alkaline environment, but these loads showed rapid increase in the receiving stream and bacterial aftergrowth was suspected. Waste loads imposed on the South Platte River were quite high, approximating 11 tons BOD and 43 tons TSS discharged daily.

At both the Sterling and Ovid factories, total plant wastes were released directly without change into the South Platte River. The organic BOD, TSS and bacterial loads from the two mills contributed heavily to water quality degradation of the lower South Platte River. The Sterling mill was rated highest of all mills in terms of TSS and total coliform bacteria loads discharged to the receiving stream. The serious nature of final effluents from Sterling and Ovid is evident from the waste concentrations shown in Table XIII. Combined waste loads from the two factories were 38 tons BOD, 54 tons COD, and 136 tons TSS contributed daily to the South Platte River, together with 3100 BQU total coliform bacteria and 52 BQU fecal coliform bacteria. Records clearly show that these plants have been responsible for significant pollution of the South Platte River at the Colorado-Nebraska Stateline which has been occurring for many previous years.

The Brighton plant was evaluated in January 1965 based only on the waste loads to the receiving stream; total factory loads were not known. At that time, the shallow waste lagoon would seem to have provided an order of treatment similar to Greeley for that portion of the wastewater being retained in the pond. The majority of factory wastes were discharged to the River without treatment. Daily BOD and TSS loads were 12 tons and 27 tons respectively. The bacterial loads were extremely high particularly in terms of fecal coliform bacteria.

Longmont factory wastes in November 1966 were retained in a shallow lagoon approximating 14 acres in area. Waste retention was severely limited by solids filling, extensive weed growth and unevenness of the pond bottom. Furthermore, anaerobic conditions likely prevailed at the lower end of the lagoon and within the final effluents. The Longmont situation was similar to Fort Morgan in that the majority of suspended solids were settled in the lagoon but appreciable amounts which could otherwise be removed by effective treatment were permitted access to the receiving stream. Longmont experienced virtually no reduction in organic waste material and furthermore the environment was extremely favorable to increasing bacterial densities in the final effluents. Future treatment measures envisioned for Longmont, if successful, would effect tremendous improvement in the water quality of St. Vrain Creek.

The Eaton sugar mill provided no waste treatment and the total plant wastes caused severe pollution not only in Eaton Draw but also in the lower Cache la Poudre River through the Greeley area. Eaton waste loads approximated 10 tons BOD and 40 tons TSS on a daily basis together with 1480 BQU total coliform bacteria and 29 BQU fecal coliforms. Waste concentrations were quite high. About one-third of the BOD load has since been removed due to elimination of the pulp silo with its associated drainage. However, there still remains a great need for extensive waste treatment facilities.

The Johnstown operations made certain in-plant changes during the summer of 1965 designed to decrease waste loads placed upon the Little Thompson River. However, appropriate studies showed only minor differences resulting from such changes. Both the clean and dirty water collection systems carried heavy waste loads. Wastes in the clean water sewer received no treatment before final discharge and contained daily loads of 3.8 tons BOD and 3.3 tons TSS together with a dissolved oxygen level of only 0.9 mg/l. The contents of the dirty water sewer were passed through a shallow lagoon providing limited retention and little or no waste treatment. Organic waste loads were essentially unchanged in the pond and, of equal importance, very large bacterial increases were observed in the final effluents to the receiving stream. Near septic conditions also occurred within the lagoon system associated with poor treatment efficiency. The Johnstown waste treatment facilities appeared to serve no useful purpose in view of the performance record.

The nine sugar establishments (excluding Brighton) possessed total factory waste loads of 175 tons BOD and 780 tons TSS on a daily basis together with 6900 BQU total coliform bacteria. Total waste loads reaching the stream after general treatment from these same nine plants approximated 161 tons BOD and 330 tons TSS daily, with 8450 BQU total coliform bacteria. Adding Brighton, the total loads reaching the stream were about 10 percent greater. Overall waste reductions by means of treatment were only 8 percent for BOD and 58 percent for total suspended solids. On the other hand, total coliform bacteria loads actually increased 23 percent associated with the available treatment measures. This reversal in bacterial loads was largely attributed to the picture obtained at the Johnstown and Longmont establishments. It is realized that the closure of the Windsor mill in 1967 has altered the above analysis.

The overall picture of sugar beet waste disposal in the South Platte River Basin strongly illustrates that much remains to be done. The sugar company has taken the first steps towards a major waste abatement program sorely needed in the Basin. However, such a program to be truly effective will also require imaginative and bold thinking, proper resources, and a keen and discerning attitude on the part of industry to complete the task clearly at hand.

TABLE XIII

STATUS OF WASTE TREATMENT AND WASTE LOADS DISCHARGED TO RECEIVING STREAMS FOR THE BEET SUGAR INDUSTRY IN THE SOUTH PLATTE RIVER BASIN 1963 - 1966

Factory	Total Plant Loads Before General Treatment	Treatment: Type	Treatment: Loads Out	Treatment: % Removal	Receiving Stream	Characteristics of Waste Discharge to Receiving Stream: BOD mg/l	TSS mg/l	Total Coliform Bacteria MPN/100 ml
Loveland	BOD- 33 Tons/Day	Aeration Fields	BOD- 26 Tons/Day	20	Big Thompson River	510	860	2,700
	COD- 51 Tons/Day		COD- 41 Tons/Day	20				
	TSS- 201 Tons/Day		TSS- 44 Tons/Day	80				
	Alk.- 129 Tons/Day		Alk.- 28 Tons/Day	80				
	Tot. Coli.- 0 BQU		Tot. Coli.- 0 BQU	--				
	Fec. Coli.- 0 BQU		Fec. Coli.- 0 BQU	--				
Windsor	BOD- 37 Tons/Day	Aeration Fields	BOD- 37 Tons/Day	0-10	Cache la Poudre River	1,110	1,060	6,620,000
	COD- 55 Tons/Day		COD- 49 Tons/Day	10				
	TSS- 93 Tons/Day		TSS- 35 Tons/Day	60				
	Alk.- 57 Tons/Day		Alk.- 36 Tons/Day	35				
	Tot. Coli.- 1280 BQU		Tot. Coli.- 820 BQU	35				
	Fec. Coli.- 29 BQU		Fec. Coli.- 6 BQU	80				
Greeley	BOD- 16 Tons/Day[a]	Shallow Lagoon	BOD- 15 Tons/Day[a]	5-10	Cache la Poudre River	850	93	5,690,000
	COD- 19 Tons/Day[a]		COD- 16 Tons/Day[a]	15				
	TSS- 28 Tons/Day		TSS- 2 Tons/Day	95				
	Alk.- 17 Tons/Day		Alk.- 14 Tons/Day	20				
	Tot. Coli.- 505 BQU[a]		Tot. Coli.- 140 BQU[a]	50				
	Fec. Coli.- 35 BQU[a]		Fec. Coli.- 8 BQU[a]	75				
Fort Morgan	BOD- 17 Tons/Day	Shallow Lagoons and Dilution	BOD- 11 Tons/Day	35	South Platte River	115	440	1,600,000
	COD- 23 Tons/Day		COD- 16 Tons/Day	30				
	TSS- 181 Tons/Day		TSS- 43 Tons/Day	75				
	Alk.- 69 Tons/Day		Alk.- 27 Tons/Day[b]	60				
	Tot. Coli.- 430 BQU		Tot. Coli.- 580 BQU	0				
	Fec. Coli.- 4 BQU		Fec. Coli.- 5 BQU	0				

a/ Adjusted for loads in the plant water intake.

b/ Adjusted for loads in the discharge drain above the treatment lagoons.

TABLE XIII (Cont.) - STATUS OF WASTE TREATMENT AND WASTE LOADS DISCHARGED TO RECEIVING STREAMS FOR THE BEET SUGAR INDUSTRY IN THE SOUTH PLATTE RIVER BASIN 1963 - 1966

Factory	Total Plant Loads Before General Treatment	Treatment: Type	Treatment: Loads Out	Treatment: % Removal	Receiving Stream	Characteristics of Waste Discharge to Receiving Stream: BOD mg/1	TSS mg/1	Total Coliform Bacteria MPN/100 ml
Sterling	BOD- 21 Tons/Day COD- 33 Tons/Day TSS- 86 Tons/Day Alk.- 27 Tons/Day Tot. Coli.- 1870 BQU Fec. Coli.- 29 BQU	Dilution only	Same as loads before general treatment	None	South Platte River	410	1,950	17,100,000
Ovid	BOD- 17 Tons/Day COD- 21 Tons/Day TSS- 50 Tons/Day Alk.- 25 Tons/Day Tot. Coli.- 1220 BQU Fec. Coli.- 23 BQU	None	Same as loads before general treatment	None	South Platte River	500	1,440	9,480,000
Brighton	———	Shallow Lagoon	BOD- 12 Tons/Day c/ TSS- 27 Tons/Day c/ Tot. Coli.- 955 BQU c/ Fec. Coli.- 200 BQU c/	Undefined	South Platte River	935	2,040	19,500,000
Longmont d/	BOD- 18 Tons/Day COD- 24 Tons/Day TSS- 99 Tons/Day Alk.- 13 Tons/Day Tot. Coli.- 105 BQU Fec. Coli.- 4 BQU	Shallow Lagoon	BOD- 18 Tons/Day COD- 28 Tons/Day TSS- 25 Tons/Day Alk.- 17 Tons/Day Tot. Coli.- 920 BQU Fec. Coli.- 105 BQU	0-10 0-10 75 0 Large Incr. Large Incr.	St. Vrain Creek	340	470	4,600,000
Eaton	BOD- 10 Tons/Day COD- 17 Tons/Day TSS- 40 Tons/Day Alk.- 4 Tons/Day Tot. Coli. - 1480 BQU Fec. Coli. - 29 BQU	In-Plant water conservation, but no treatment	Same as loads before general treatment	None	Eaton Draw	860	3,320	33,000,000

c/ Probable minimum values.
d/ Total plant loads before general treatment determined in 1965 before treatment lagoon was provided. Loads after treatment determined in 1966 after the lagoon was built. Characteristics of waste discharge given for the 1966 campaign.

TABLE XIII (Cont.) - STATUS OF WASTE TREATMENT AND WASTE LOADS DISCHARGED TO RECEIVING STREAMS FOR THE BEET SUGAR INDUSTRY IN THE SOUTH PLATTE RIVER BASIN 1963 - 1966

Factory	Total Plant Loads Before General Treatment	Treament: Type	Treament: Loads Out	Treament: % Removal	Receiving Stream	Characteristics of Waste Discharge to Receiving Stream: BOD mg/l	TSS mg/l	Total Coliform Bacteria MPN/100 ml
Johnstown e/ (2 Plants)	BOD- 6.1 Tons/Day	Shallow Lagoon for Dirty Water Collection System; no trmt. for Clean Water Collection System.	BOD- 5.9 Tons/Day	0	Little Thompson River	Clean Water System		
	TSS- 3.7 Tons/Day		TSS- 3.5 Tons/Day	5		510	438	13,000
	Alk.- 1.9 Tons/Day		Alk.- 4.1 Tons/Day	100% Incr.				
	Tot. Coli.- 7 BQU		Tot. Coli.- 1420 BQU	V.Large Incr.		Dirty Water System after Lagoon		
	Fec. Coli.- 2 BQU		Fec. Coli.- 28 BQU	V.Large Incr.		264	30	49,000,000

e/ Waste loads represent combined values for clean and dirty water collection systems.

SECTION IV

BACTERIOLOGICAL ASPECTS OF SUGAR BEET PROCESSING WASTES

IV. BACTERIOLOGICAL ASPECTS OF SUGAR BEET PROCESSING WASTES

The large numbers of total coliform, fecal coliform, and fecal streptococci bacteria in sugar beet wastes has been a matter of serious concern for some time. Extensive bacterial studies were undertaken by the U.S. Public Health Service in 1961-1963 on the North Platte River in Wyoming and Nebraska below five sugar beet mills from Torrington, Wyoming to Bayard, Nebraska. Laboratory investigations were carried out from late 1963 through 1966 by the FWPCA facilities associated with the Sanitary Engineering Center in Cincinnati, Ohio. The Cincinnati staff also conducted special studies from January-May 1965 on the waste treatment ponds of the Fremont and Findlay, Ohio sugar mills. Laboratory and field studies of the South Platte River Basin Project have been undertaken since late 1963 at each of the ten sugar factories in the Basin. Additional surveys were undertaken in November 1964 and again in October 1965 by the U.S. Public Health Service (now the FWPCA facilities) of four sugar beet mills in Minnesota and North Dakota on the Red River of the North.

The available data focuses on the probable sources of bacteriological pollution within the sugar beet factory, changes due to waste storage, importance of pathogens in sugar beet wastes, survival tendencies of bacterial organisms, differentiation between human and animal-caused pollution, and lastly, criteria for reducing or eliminating bacterial pollution. The following discussion is primarily derived from the studies listed above, with special reference given to the South Platte River Basin.

A. BACKGROUND ON BACTERIAL POLLUTION

Coliform bacteria universally occur in sanitary sewage. With few exceptions, these bacteria are not harmful and have been used by regulatory agencies for many decades as an indicator of the probable presence of pathogenic organisms. Objections have been made to the use of _total coliform_ densities in that their origin is not exclusively from fecal sources. While this is true, the Eschericia species comprising part of the total coliform group is derived exclusively from human or animal excreta and its presence is evidence of fecal contamination. A second indicator group, the _fecal coliform_ bacteria, is almost exclusively derived from the guts of warm-blooded animals and man. In the past 2-3 years, the _fecal streptococci_ group has been accepted and used as a third indicator of warm-blooded animal and man pollution. This group is not known to multiply in surface waters and rarely occurs on uncontaminated surface soil or vegetables.

Salmonella is a genus of bacteria pathogenic to man and to warm-blooded animals. These pathogens are discharged from the intestines of infected man and animals. Because of disease-producing capabilities, their presence in receiving waters constitutes a health hazard through indirect or direct contact with these waters. Recent techniques now make possible the isolation of Salmonella even at extremely low concentrations.

The relationship between fecal coliform and fecal streptococci numbers provides further indication of the origin of fecal pollution. Ratios of fecal coliform to fecal streptococci that are greater than 2:1 generally indicate that pollution was primarily derived from domestic sewage. Ratios less than 1:1 indicate that the majority of pollution originated from the wastes of warm-blooded animals other than man (21). More recent interpretation suggests that source delineation may be more exacting if the ratios are either in excess of 4:1, or less than 0.6:1 (22).

The North Platte River in the area of five sugar beet processing plants was found to contain large numbers of total coliform, fecal coliform, and fecal streptococci bacteria. In 1962 the control station above the first sugar mill showed average concentrations as follows: 60/100 ml total coliform, 30/100 ml fecal coliform, and 90/100 ml fecal streptococci. Within the stretch of river from Torrington, Wyoming to Bayard, Nebraska, the bacterial values increased to maximum levels of 219,000/100 ml total coliform, 81,600/100 ml fecal coliform, and 2,250,000/100 ml fecal streptococci. These large increases were ascribed to inadequately treated municipal wastes, but particularly sugar beet wastes discharged to the river. Suggested water quality control measures for the North Platte River were directed to protection of present interests together with future provisions for municipal and industrial water supply, recreation and fishing (23, 24, 25).

The initial plans of the South Platte River Basin Project, recognizing the North Platte River study and the fact that ten sugar factories were operating in the study area, thereby called for extensive bacteriological analyses. The Project over the period 1963-1966 determined that extremely high levels of bacteriological pollution were indeed present in all Basin waterways downstream of sugar beet factories. These findings were presented at the Second Session of the Conference in the matter of Pollution of the South Platte River Basin (2). Of great importance, the Conference established that bacterial levels over most the area tremendously exceeded the recommended limits for desired water quality.

The report to the Conference stated that St. Vrain Creek below the Longmont sugar mill contained total coliform bacteria in the range of 490,000 to 790,000/100 ml and fecal coliform from 23,000 to 94,500/100 ml. The Little Thompson River above the Johnstown operations experienced 13,000/100 ml total coliform and 3,600/100 ml fecal coliform, whereas the downstream values were increased to 3,950,000/100 ml and 63,500/100 ml respectively. Bacterial densities in the Cache la Poudre River were 1,100/100 ml total coliform and 490/100 ml fecal coliform for the control station above Windsor. On the same river below the Windsor, Eaton, and Greeley sugar mills, values were in the range of 220,000 to 11,000,000 /100 ml total coliform, and 3,300 to 790,000/100 ml fecal coliform. Lastly, on the lower South Platte River from Fort Morgan to the Colorado-Nebraska Stateline, background levels approximated 490 and 80/100 ml for total and fecal coliform respectively, whereas below three sugar mills in this area, maximum values were 2,300,000/100 ml and 45,000 /100 ml respectively. There is no doubt that sugar beet wastes contain very high bacteria numbers and cause serious pollution of the receiving waterways.

B. SOURCES OF BACTERIAL POLLUTION WITHIN THE SUGAR FACTORY

Special studies have been directed to determining the specific sources and causes of bacterial pollution introduced to the sugar processing plant. These investigations were undertaken at four factories including Torrington, Wyoming (North Platte), Fort Morgan, Colorado (South Platte), and Crookston and East Grand Forks, Minnesota (Red River of the North).

The Torrington, Wyoming study indicated that bacterial growth in the beet flume approached optimum conditions when water temperatures approximated 33-35°C and pH levels were 7.0-7.5. Furthermore, the various nutrients present in sugar beet wastes were thought to sustain or even contribute to the bacterial growth. The investigation concluded that total coliform organisms within the flume water and the main sewer system were substantially derived from the soils on the incoming sugar beets. On the other hand, fecal coliform bacteria were believed to originate from the incoming soils, but multiplication was also probable in the flume system itself.

The Fort Morgan, Colorado mill was sampled by the South Platte River Basin Project in December 1963, and the various operations are described in Section II of this report. All incoming sugar beets were retrieved from the piles. The soils associated with the beets before entering the wet hopper were sampled and designated as Station 27. A relatively constant water flow was maintained in the flume system and the detention time was calculated as 5 minutes, although pockets of stagnant water were likely present. The water supply for the wet hopper consisted of overflow from the main water supply tank mixed together with seal tank water, and this supply was designated as Station 29. Finally, the wastewater leaving the flume system (after the beet washer) was designated as Station 22.

It was assumed that each gram of total suspended solids in the flume outlet was equivalent to one gram of dry soil previously introduced to the wet hopper at Station 27. The average temperature and pH of the flume inlet waters were 31.2°C and 8.5 respectively, whereas the flume outlet waters averaged 25.6°C with a pH of 8.4. Accounting of the soil and coliform bacteria entering and leaving the Fort Morgan flume system is given by Table XIV.

TABLE XIV

COLIFORM BACTERIA IN THE FORT MORGAN FLUME SYSTEM
December 1963

TSS in Flume Outlet at Station 22 (mg/l)	1,690
1. Total Coliform Bacteria	
a. In soil at Station 27 (MPN/gram)	3,300,000
b. In flume water, equivalent to the numbers found on incoming soil, assuming no bacterial growth within flume (MPN/100 ml)	575,000
c. In the flume inlet waters at Station 29 (MPN/100 ml)	2,300
d. Total input (MPN/100 ml)	577,300
e. Observed in the flume outlet waters at Station 22 (MPN/100 ml)	4,500,000
f. Observed Ratio Increase of Total Coliforms (Outlet:Inlet)	8:1
2. Fecal Coliform Bacteria	
a. In soil at Station 27 (MPN/gram)	4
b. In flume water, equivalent to the numbers found on incoming soil, assuming no bacterial growth within flume (MPN/100 ml)	1
c. In the flume inlet waters at Station 29 (MPN/100 ml)	69
d. Total input (MPN/100 ml)	70
e. Observed in the flume outlet waters at Station 22 (MPN/100 ml)	43,000
f. Observed Ratio Increase of Fecal Coliforms (Outlet:Inlet)	600:1

Analytical techniques, although the best available for the Fort Morgan study, did not provide full recovery of coliform bacteria from the soils; hence coliform values in MPN/gram soil were likely on the low side. Regardless of this factor, the majority of total coliforms would seem to have originated from the incoming soils rather than the flume water supply. The reverse appeared true for the fecal coliform organisms. Very large increases in coliform organisms were apparent within the flume system. The study concluded that incoming soils attached to the beets represented a significant source of bacterial entry to the sugar mill. Bacteria on the soils were associated with the fertilization of agricultural lands by animal manure, a practice common in the industry. Bacteria growth in the flume system was enhanced by the extremely favorable environment, including an abundance of nutrients, proper temperatures, stagnant pockets and availability of fixed surfaces.

Studies were carried out at the Crookston and East Grand Forks, Minnesota factories during October 1965 using improved analytical procedures to provide better delineation of the bacterial sources. Table XV shown below has been taken from the Red River of the North report indicating the bacterial densities found on the raw sugar beets and associated dirt, trash and fertilizers.

Total coliform results given in Table XV show that the dirt from freshly unloaded beets contained 490,000 organisms/gram. Somewhat surprising were the very high total coliforms on the sliced beets, and even higher densities on the beet trash removed from the flume. These levels were respectively 13,000,000 and 17,200,000 total coliform/gram material. Surface peelings of the beets taken from freshly stored piles indicated a total coliform density of 2,800,000/gram. These bacterial levels on the material entering the flume were said to account for the excessive total coliform bacteria found in the flume and wash waters at both Minnesota plants. A bacterial balance on the system was not attempted.

The sources of fecal coliforms were somewhat more difficult to ascertain in the Red River of the North study. The only materials yielding significant fecal coliform were the sliced beets after washing and the beet trash. It was indicated that growths adhering to the sides of the flume and wash tank may have been responsible in part for fecal coliform bacteria in the circuit. High fecal streptococcus counts observed on the soils, the sliced beets, beet trash, and the beet surface peelings were said to account for the excessive streptococci densities in the flume waters. These investigations considerably improved upon and even changed some of the interpretations made available in the earlier Fort Morgan, Colorado study.

TABLE XV

BACTERIOLOGICAL DENSITIES - PARTICULATE MATERIAL [a]

Description	Bacterial Count Per Gram		
	Total Coliform	Fecal Coliform	Fecal Streptococci
Beet dirt [b]	490,000	10.9	2,200
Sliced beets	13,000,000	172,000	580,000
Beet trash [c]	17,200,000	49,000	3,800,000
Beet surface peelings	2,780,000	<0.2	5,200
Wet beet field soil	94	1.3	150
Dry beet field soil	0.9	<0.2	210
Beet fertilizer (artificial)-A	<0.2	<0.2	1.4
Beet fertilizer (artificial)-B	<0.2	<0.2	0.2
Beet fertilizer (artificial)-C	<0.2	<0.2	<0.2

a/ Taken from the Proceedings of the Conference in the matter of Pollution of the Interstate Waters of the Red River of the North; North Dakota-Minnesota (26).

b/ Composite scraped from 10-15 freshly unloaded beets.

c/ Stalks and weed material recovered from flume.

Exploratory studies at the Taft Sanitary Engineering Center in Cincinnati, Ohio have provided additional information on bacterial sources. The acquired data showed that sugar beets in the field, with respect to both the beet surfaces and the soil adjacent to the root area, may become contaminated with fecal organisms from irrigation water, animal, and /or rodent excreta. Wildlife populations may also be contributing factors. Whereas chemical fertilizers contributed little, animal manure used for fertilization was found to be an important source of fecal coliforms and the associated enteric pathogens which entered the sugar mill on contaminated soils or beets. The persistence of such organisms through field cultivation up to harvesting was influenced by many factors, such as, moisture content, exposure to sunlight, pH level, and available nutrients retained in the fecal pellets (27).

Sugar beets stored in large piles at the plant site or in outlying areas such as railroad sidings may be exposed to rodent activity and additional pollution from new truck or railroad car unloadings. Rainfall may assist the spread of existing contamination. A preponderance of fecal streptococci over fecal coliforms has been found in beet piles. All streptococci examined were identified as Streptococcus fecalis. These findings strongly indicated the presence of rodent or storm water pollution. Within the factory, river water used for fluming and washing purposes may represent another source of fecal coliforms. These bacteria were found generally originating from domestic waste discharges upstream (27).

C. EFFECTS OF WASTE STORAGE UPON BACTERIAL POPULATIONS

Wastewater storage is currently employed by industry as a treatment means to reduce organic and solids waste loads together with bacterial loads. The available data resolves itself into the conditions expected from long-term storage vs. limited or no waste holding.

During the Red River of the North survey extensive bacteriological data was collected on the waste holding pond at the East Grand Forks factory. The holding facility was a flow-through type, consisting of eleven bays in series providing a waste detention time of about 32 days. Samples were collected at various locations in the pond, the respective detention time was determined for the waste corresponding to each sample, and bacterial concentration-time curves were developed.

Total coliform bacteria in transit through the East Grand Forks pond increased from an influent value of 12.3 million/100 ml up to 50.3 million/100 ml after 6.3 days. From this point, there was steady die-away in total coliforms and the final effluents after 32 days waste retention contained 350,000 organisms per 100 ml, or 97 percent reduction in the original coliform numbers. The fecal types did not proliferate but instead decreased throughout the pond. From an influent value of 1.5 million/100 ml, the final effluents contained 1,400 fecal coliforms /100 ml representing a 99 percent reduction in the original numbers. The fecal streptococcus densities declined rapidly throughout the pond compared to the coliform organisms, and influent and effluent values were 840,000 and 400/100 ml respectively, representing a 99.5 percent reduction after 32 days of waste storage (26).

The Red River of the North report described the bacterial die-away rates within the East Grand Forks pond as extraordinarily slow and attributed this to a high level of nutrients. Not only were the fecal coliforms sustained over a relatively long period, but there was also early-stage multiplication in the total numbers of coliform bacteria (26).

Detailed bacteriological studies were conducted on the waste handling-treatment systems of both the Fremont and Findlay, Ohio sugar factories during the first five months of 1965 (28). The Fremont plant employed a waste holding lagoon as an integral unit of a closed flume water recycle system. The Findiay plant had a closed flume and condenser water recycle system with mechanical settling, lime mud pond, sludge pond, spray pond, and excess water pond, all integrated into the circuit. The reader is referred to Section V, E 1 and 2 of this report for full description of the Fremont and Findlay systems. At both factories, the wastes retained in the ponds after the close of campaign (occurring around mid-January) represented accumulated wastewater under conditions of long-term storage.

Three locations in the Fremont wastewater lagoon showed total and fecal coliform densities on January 20 approximating 2,000 organisms/100 ml. During storage, total coliform increased to levels of 0.2 - 0.9

million/100 ml on February 10. After this time, the total numbers of coliform demonstrated a gradual die-away with values in the order of 2,000 - 8,000/100 ml on April 7, which was 2 days before the pond was emptied into high flows within the receiving stream. Fecal coliform bacteria in the pond varied from about 100 to 10,000/100 ml over the period of waste storage. The die-away trend in fecal coliforms was very gradual with values of 50-300/100 ml recorded on April 7. Overall coliform reductions were only partially encouraging, primarily due to relatively low initial counts. Wastewater temperatures during winter storage at Fremont were in the range of 0-10°C (28).

Bacterial data considered most important at the Findlay installation were received from the spray pond and the excess water pond. The observation was made that bacterial densities in the Findlay system were many times higher than Fremont, aided by sludge pond overflow into the Findlay circuit. Wastes were retained until the end of May and the role of temperature was quite important over this period. Wastewater temperatures decreased sharply in mid-January and remained at 0-2°C until April 7. Thereafter, temperatures increased rapidly reaching 24°C on May 26.

The spray pond effluent showed both total and fecal coliform bacteria in the range of 10-40 million/100 ml from mid-January until February 3. Die-away rates were very gradual throughout February and March with total and fecal coliforms around 3 million/100 ml on March 28. Coincident with rising temperatures, the bacterial densities rapidly decreased to minimum levels on April 28. On this date, total coliforms were 500/100 ml and fecal coliforms were 90/100 ml. Surprising enough, this was followed in May by significant increases in both total and fecal coliform. Final values of 150,000 total coliform and 2,000 fecal coliform/100 ml were reached on May 26. Considerable bacterial reduction was obtained up to the end of April but this was partly offset by bacterial regrowth during May.

The excess water pond effluent showed more or less a bacterial pattern similar to the spray pond up to the end of March. At that point, total coliforms stabilized around 40,000-300,000/100 ml, whereas fecal coliforms steadily decreased until a level of about 1,000/100 ml was reached on May 26. Only the fecal coliform reduction was considered satisfactory at Findlay (28).

The Red River of the North survey found that holding facilities of the Crookston, Minnesota plant provided a waste detention of 11 days prior to discharge. The influent to the holding pond contained 5.3 million total coliform/100 ml, and 1.7 million fecal coliform/100 ml, whereas the fecal streptococci were too numerous to count. Total coliform densities in the effluent averaged 37 million/100 ml, and fecal coliform were 12.5 million/100 ml. As illustrated by previous results from the East Grand Forks mill, the Crookston time of storage was about optimum for producing peak levels of coliform bacteria. Since no reduction in bacterial loads was obtained, this situation may be described as a reversal effect.

The merits of waste treatment upon bacterial loads originating from the ten sugar factories in the South Platte River Basin were previously tabulated in Table XIII. Three establishments were without waste treatment facilities and adequate data was not received at a fourth plant. The remaining six factories utilized shallow lagoons or aeration fields for waste treatment with detention times varying from a few hours up to 1.5 days. The Loveland factory wastes contained very low bacterial densities attributed to a highly alkaline environment. Treatment at the Windsor and Greeley factories caused apparent bacterial removals of 35-80 percent. On the other hand, Fort Morgan factory wastes experienced no appreciable reduction in bacterial numbers through treatment, and results from the two remaining factories at Longmont and Johnstown were even more discouraging. Total and fecal coliforms increased many fold in passing through the waste treatment lagoons at both Longmont and Johnstown.

Discounting recent changes in the South Platte River Basin, the treated factory wastes generally contained total coliform densities in the range of 1.6 to 49 million/100 ml. Corresponding fecal coliform densities were between 18,000 and 4.1 million/100 ml. The serious nature of bacteriological pollution in the South Platte River Basin cannot be disputed. In summary, it is foreseen that only long-term storage of sugar beet wastes may possibly reduce the bacterial densities to satisfactory levels. In contrast, limited waste retention may create large increases in coliform, streptococci and pathogenic organisms. Other waste treatment methods should be sought for greater efficiency in bacterial removal.

D. BACTERIAL SURVIVAL

Sugar beets are known to be a complex mixture of various carbohydrates including pectin, pentosans, cellulose, purines, and related compounds such as betaine and urea together with vitamins. The conversion of these organic components to waste causes large problems in sugar beet process treatment and disposal. These nutrients retard the normal die-away of bacterial organisms both within the treatment system and the receiving stream. The longer survival time and possible regrowth of bacteria in the stream negate in part the reduction of bacterial loads by natural assimilative means. The information given below indicates the persistence of bacterial organisms within the treatment system.

Representative wastewater samples were taken in October 1965 at various in-plant locations at the Crookston and East Grand Forks sugar factories, as well as the influent and effluent of the holding ponds from these two factories plus the Moorhead factory. The samples, after collection, were sterilized and reinoculated with known quantities of fecal coliform, fecal streptococci, and Salmonella of the typhimurium series. The reconstituted samples received incubation for periods up to 14 days at or near the temperature of collection (26).

Fecal coliform concentrations in the water supplies showed some initial decrease, then remained relatively constant through the third day, followed by a gradual rate of die-away. Fourteen percent and 6 percent of the original fecal coliform were remaining after 7 days in the two separate water supplies. An initial period of acclimatization, the lag phase, and the gradual die-away were likely caused by a favorable nutrient level. Fecal streptococci in the water supplies exhibited an immediate adaptability and increased numbers in the first day or two, then a gradually accelerating die-away until the densities were virtually nil on the seventh day. Salmonella showed near the same pattern as fecal streptococci but demonstrated a greater resistance to die-away from the fourth day on. The Salmonella densities were approximately 2 percent of the initial concentrations after 7 days.

Fecal coliforms in the flume waters were reduced to insignificant quantities after one day. Fecal streptococci showed a gradually accelerating die-away in flume waters until the densities were approximately 2-3 percent of the initial concentrations after 3 days. For Crookston, Salmonella numbers increased 56 percent over original numbers on the first day followed by rapid die-away. At East Grand Forks, the Salmonella experienced an initial die-away, followed by an increase, then a very slow die-away with 5 percent of the original numbers remaining after 14 days. The results of the beet washer waters indicated that added nutrients greatly encouraged the multiplication and survival of Salmonella in the plant wastes. The holding pond effluents showed that fecal coliform die-away was most rapid of the three bacterial groups with negligible quantities remaining after 14 days. Salmonella had a rapid initial die-away but after 3 days the concentrations declined slowly. At Crookston and East Grand Forks, the 14-day Salmonella concentrations were respectively 5 percent and 0.5 percent of the original numbers. The fecal streptococci exhibited the slowest die-away rate with significant concentrations as high as 34 percent remaining after 7 days (26).

The above study conducted in vitro will not precisely duplicate conditions in the field. Nevertheless, the results provide a sound basis for predicting bacterial survival trends in sugar beet processing wastes. From the available information, there is no reason to believe that enteric pathogens in general are less persistent and have shorter survival times than indicator organisms. This extends the time and distance required both in the treatment system and the receiving stream for recovery to non-hazardous levels. It must therefore be concluded that a health hazard is involved whenever the presence of inadequately treated sugar beet wastes are associated with the use of receiving waters.

E. FECAL COLIFORM - STREPTOCOCCI RELATIONSHIPS

The relationship between numerical levels of fecal coliforms and fecal streptococci within various wastewaters serves to describe the nature of the waste and its major contributing sources. A preponderance of fecal coliforms with a FC/FS ratio greater than 4 indicates the presence of domestic wastes including laundry wastes and food refuse. A dominance of fecal streptococci bacteria with a FC/FS ratio less than 0.6 indicates pollution derived from livestock and dairy animals such as found on farm-feedlots and stockyards or from storm-water runoff. Further separation of sources can be made by studying the distribution of fecal streptococci strains present within the wastewater (21, 22, 27). These differentiation principles were employed with good success in the South Platte River Basin area.

Typical bacterial densities in the wastes from four sugar factories and the receiving stream above and below these locations are given in Table XVI. Although total coliform densities were quite important, particular emphasis is placed upon the fecal coliform and fecal streptococci values. These levels were quite high with the possible exception of the clean water sewer at the Johnstown factory. The bacterial quality of stream waters closely reflected the discharge from the factory. The Johnstown establishment was quite unlike the other sugar mills in that it received discard molasses and concentrated Steffen filtrate rather than raw sugar beets.

The ratios of fecal coliform to fecal streptococci contained in the final waste discharges from the Brighton, Longmont, and Eaton plants were respectively 0.37, 0.003, and 0.01. There was no doubt for these three plants that bacterial pollution was primarily and originally derived from the fecal excreta of animals rather than humans. The bacterial picture at Johnstown, because of the nature of operations, demonstrated a different picture with a high FC/FS ratio obtained on the dirty water sewer and a low ratio on the clean water system. The clean water sewer was reported to be primarily associated with the sugar house operations rather than the MSG process. The relatively low fecal coliform counts may also have been caused by temperature sensitivity to particular unit operations. However, the full explanation for the Johnstown results was not available.

The River waters above Brighton in January 1965 were known to contain large volumes of inadequately treated municipal sewage originating from Metropolitan Denver. The stream was heavily polluted and showed a FC/FS ratio of 3.0 indicative of upstream waste sources. Downstream of the Brighton sugar factory, this ratio decreased to 1.0, governed by the large numbers and preponderance of fecal strep discharged from the Brighton mill at that time. At Longmont, the relative numbers of fecal coliform and fecal strep changed drastically in the river from above to below the Longmont sugar mill. Again a predominance of streptococci caused a shift in the FC/FS ratio of 3.3 upstream to 0.09 downstream. The stream below the Eaton sugar mill experienced a 930-fold

TABLE XVI

BACTERIAL DENSITIES IN
SUGAR BEET PLANT WASTES AND RECEIVING STREAMS
SOUTH PLATTE RIVER BASIN

Factory	Date	Description	Total Coli. (MPN/100 ml)	Fecal Coli. (MPN/100 ml)	Fecal Strep. (No./100 ml)
Brighton	1-65	Factory discharge to river	19,500,000	4,100,000	11,000,000
		River above plant	3,300,000	790,000	260,000
		River below plant	4,600,000	1,700,000	1,600,000
Longmont	11-65	Factory discharge to river	490,000	17,500	6,350,000
		River above plant	790,000	71,500	22,000
		River below plant	490,000	94,500	1,100,000
Eaton	11-65	Factory discharge to stream	33,000,000	640,000	62,000,000
		Stream above plant	7,450	410	15,000
		Stream below plant	29,000,000	380,000	63,000,000
Johnstown	11-65	"Clean water sewer" discharge to river	13,000	4,900	160,000
		Dirty water sewer after lagoon treatment	49,000,000	950,000	3,600
		River above plant	13,000	3,600	1,650
		River below plant	3,950,000	63,500	26,200

increase in fecal coliforms and a 4200-fold increase in fecal strep, producing a FC/FS ratio of 0.006. This was the least ratio found at any location in the South Platte River Basin. The relative effects upon the river of fecal coliform and fecal streptococci from the two waste discharges at Johnstown appeared to be counterbalancing. This factor, however, did not mitigate the severe degradation in bacterial quality below the Johnstown factory.

In November 1965 the South Platte River Basin Project also conducted special tests on the Eaton factory effluent and the town of Eaton sewage treatment plant effluent in order to identify and differentiate special groups of fecal streptococci present in the two wastes. The treated municipal sewage showed 38 percent of the streptococci were of the enterococcus group which were of human origin, 26 percent were of the strep bovis species and 22 percent of the strep equinis group, both associated with animal origin, and 14 percent were undefined. The municipal sewage may have contained some additions of food processing and related industrial wastes. On the other hand, the sugar beet wastes contained entirely strep bovis. The strep bovis group is strongly associated with cattle and other domestic animal feces. Other investigators have shown that the excreta from cows contains 63 percent or more strep bovis together with other streptococci species (21). It was thereby concluded that animal manure commonly used in the South Platte River Basin for fertilization of sugar beets very likely transmitted large numbers of fecal microorganisms to the processing plant, carried in by the raw sugar beets. These organisms subsequently appeared in the waste processing effluents and then in the Basin streams.

F. SALMONELLA ASSOCIATED WITH SUGAR BEET WASTES

The recovery of pathogenic organisms associated with sugar beet wastes, specifically Salmonella, has been verified in the Red River of the North study, the Fremont and Findlay plant surveys, and also in the South Platte River Basin investigations.

At the East Grand Forks factory, Salmonella were not isolated in the influent wastes to the holding pond but were found within the treatment basin. These wastewaters were reported to be significantly contaminated with pathogenic organisms representing a health hazard to anyone coming in contact with such. Attempts to recover Salmonella from the influent and effluent of the Crookston holding pond did not prove successful. However, similar attempts on the Moorhead factory effluent were positive for Salmonella. Successful recoveries were also made in the river below the Fargo, North Dakota and Moorehead, Minnesota municipal and industrial waste discharges whereas, significantly, no Salmonella was isolated upstream. The Red River of the North report emphasized that nutrients added by processing of sugar beets promoted the growth and multiplication of Salmonella within the factory wastes. Furthermore, the study recommended that these nutrients should be reduced or eliminated as soon as possible (26).

During the bacteriological sampling program at Fremont, Ohio positive recovery of Salmonella was made on the treatment lagoon effluent on April 9, 1965, the day on which the pond contents were emptied to the river. The pathogens had evidently survived the long period of winter waste storage (28).

The South Platte River Basin Project on January 20, 1967 collected a single sample of the treatment lagoon effluent at the Longmont, Colorado sugar factory. The lagoon effluent was again sampled on January 25, at which time the wastewaters leaving the main factory at Longmont (ahead of treatment) were also sampled. Eleven Salmonella cultures were recovered from the three samples and identified as four serotypes. The wastewater of January 20 showed the presence of Salmonella san diego; the plant effluent of January 25 contained Salmonella tennessee and Salmonella san diego; and the pond effluent of January 25 showed both Salmonella cubana and Salmonella thompson.

The Longmont results confirmed the presence of potentially pathogenic Salmonella within the wastes direct from the sugar mill and in the treatment pond overflows. These effluents were considered severely polluted with definite hazard involved for human contact. A similar hazard was implied for the receiving stream.

Research in the general area of pathogenesis shows that there has been a gradual rise in the occurrence of non-typhoid Salmonellosis across the United States within recent years. Over 900 serotypes, including the four mentioned above, have been isolated from man, domestic and wild animals, and their environments, and nearly all have been implicated in human disease. The Salmonella serotypes in large majority have been identified as non-host specific and spread from man to man, animal to man, and from animal products to man, either directly or through intermediate contaminated material (29, 30).

G. CRITERIA FOR BACTERIAL REDUCTION

Guidelines for the necessary reduction of bacterial loads within sugar beet processing effluents were recommended at the Conference on interstate pollution of the Red River of the North in September 1965, and at the Second Session of the Conference on the intrastate pollution of the South Platte River in Colorado, April 1966 (2, 26).

For protection of the various water uses on the Red River of the North, including municipal water supply, fish and other aquatic life, in both the States of Minnesota and North Dakota, certain criteria were outlined at the Conference. With respect to bacterial loads from the domestic and industrial sources including the four sugar factories, the Minnesota and Federal conferees recommended that these waste discharges not contain total coliform densities in excess of 5,000/100 ml. The North Dakota conferees recommended that such discharges not cause total coliform densities in the river, after mixing, to exceed the level of 5,000/100 ml. The Moorhead and Crookston factories were to provide controlled waste discharge which would likely require complete storage of wastes over the processing campaign. No industrial plants were permitted to discharge process wastes under ice cover. Furthermore, the Minnesota and Federal conferees recommended that the regulatory agencies allow 5 years to accomplish removal of nutrients from the various municipal and industrial waste discharges, where delays in development of effective removal processes indicated that such time was necessary. The North Dakota conferees recommended that 5 years be allowed to accomplish removal of nutrients from the various waste discharges if by that time a feasible method of nutrient removal was developed (26).

The Conference on the South Platte River recommended certain measures on bacterial waste control in accordance with overall remedial and control facilities to be made available for the entire Basin by June 30, 1971. Specifically for the ten sugar factories, disinfection or equivalent means were to be provided for each waste effluent so that the receiving stream or waterway directly below each mill not show an increase of more than 5,000 total coliform bacteria/100 ml, and no more than 1,000 fecal coliform/100 ml over the corresponding densities upstream of the mill discharge. Each mill was advised to conduct continuous monitoring of the quality of final waste effluents and of each receiving stream below the points of waste discharge, and to maintain adequate records of such. This study assumed that high-level waste treatment would be provided by each mill in the future and would serve to remove the nutrient loads. Only then would disinfection or equivalent means provide for the necessary destruction of the residual bacterial organisms.

Alternative measures and differing philosophies have undoubtedly been used and expressed with regard to bacterial waste control in other parts of the country. In all cases, control procedures and regulations must be linked both to a proper and full recognition of the problem and the explicit needs of the given area.

SECTION V

WASTE ABATEMENT AND TREATMENT IN THE BEET SUGAR INDUSTRY

V. WASTE ABATEMENT AND TREATMENT IN THE BEET SUGAR INDUSTRY

The need for overall review and evaluation of waste abatement and treatment within the beet sugar industry is of considerable importance today. The Industrial Waste Guide for Beet Sugar (20) published some 15 years ago, was the latest report giving a summary status of waste conditions throughout the industry. Although the Waste Guide was excellent in many respects, there has been much change over the intervening years. Modifications have occurred in the basic process, handling of raw materials and products, methodology, conversion of old wastes into useful by-products, changing attitudes on water and air pollution, new and improved treatment schemes, and also the formulation of new problems.

Whereas the preceding sections of this report emphasized the prevailing conditions in the South Platte River Basin, the discussion on waste abatement and treatment is orientated to the nationwide picture. This information is based in very large part upon the available literature and to a lesser extent upon the author's personal experience with sugar beet mills particularly but not exclusively in the South Platte area. Heavy reliance is placed upon materials received from the British Columbia Research Council, Vancouver, Canada. This group has performed various research work for the Beet Sugar Development Foundation. The industry must be commended for its interest in such studies. Of great importance, the data are derived from many areas, and therefore have widespread and representative application to the entire industry.

The sugar industry is considered to be a principal contributor to pollution of the Nation's waterways because of large amounts of organic wastes being discharged. The concentration of sugar factories in certain areas has undoubtedly enlarged this reputation. Also, the urban population has expanded its zone of influence into semi-rural and rural areas. This has lead to a greater awareness of land and water resources by larger numbers of people. Unfortunately, it has also resulted in conflict where the waters were previously used for industrial and agricultural waste disposal. For example, the sugar beet factories in the South Platte River region account for 15 percent of the total establishments in the United States but however, occupy only 0.4 percent of the Nation's land area.

Sugar beet processing plants may be grouped into four geographical areas of the United States: 1) the west and north central U.S.; 2) the Red River region particularly the States of North Dakota and Minnesota; 3) the general Great Lakes area and; 4) the State of California. Sugar beets are processed in modern factories in Canada, Great Britain, Western Europe, Poland, the Soviet Union, and other countries. In all there are some 800 beet sugar factories in Europe and North America. Information gathered from foreign experience has been added to this report.

A wide variety of interests and skills are represented and affected by industry action including the sugar companies, the farmers, seed manufacturers, farm equipment manufacturers, irrigation companies and districts, migratory labor, product wholesalers and retailers, resident groups, and local, regional, State and Federal Government. The industry in the past ten years has made reasonable progress in most areas towards the elimination of processing effluents and serious pollution problems. Nevertheless, the present-day demand for improved water quality will mean acceleration of this program to be required of industry.

This report reviews and explores the techniques of recent application and those under current study for successful handling of waste problems. Abatement and treatment methods were found in most cases to comprise particular systems which were a combination of measures best suited to the individual factory. Not all the examples in the literature could be cited. This part of the report is subdivided into the following sections: description of major wastes, in-plant measures, minimum treatment (primary treatment or less), intermediate treatment, high levels of treatment, and other considerations.

A. DESCRIPTION OF MAJOR WASTES

The most important wastes from sugar beet processing are the spent flume waters; the process waters including pulp transport and pulp press waters, and pulp silo drainage; lime mud cake (slurry); Steffen house filtrate; and the excess condenser waters. These wastes resulting from a sugar beet factory, are discussed below:

1. Spent Flume Water

Flume water is used to convey the beets hydraulically from the railroad car or truck unloading area or from the beet piling areas, into the main factory. The beets are floated in shallow, concrete flumes. The flume waters after passing the beet wheel receive beet washing and spray table overflows. This mixture is generally described as spent flume water.

Information was compiled by the British Columbia Research Council on the flume waters of many factories both in the U.S. and Canada. This study included mills varying from a high degree of flume water recirculation to once-through systems. The BOD levels ranged from 115 to 1525 mg/l with an average of 565 mg/l. The suspended solids content averaged 210 mg/l, with a low of 127 mg/l and high of 4500 mg/l. European experience has indicated BOD values from 150 to 250 mg/l; furthermore, the average BOD level varied from year to year. In the United States these BOD values have most frequently ranged from 200-500 mg/l. A number of investigators have also commented upon the increasing BOD in the flume waters as the season progresses. Increases were attributed to frozen beets or deterioration due to poor or prolonged storage conditions. Consequently the BOD may increase 3-fold when handling frozen beets.

During fluming, large quantities of dirt are removed from the incoming sugar beets, ranging from 7 percent of the beet weight during dry seasons up to 20 percent during wet seasons; average tare was 10-15 percent. Another study indicated that a typical factory may receive around 40,000 tons incoming dirt over the average campaign. Flume water generally accounted for two-thirds to 80 percent of total plant water consumption and resulting wastewater volume.

The Industrial Waste Guide described unit waste values for flume water of 2600 gallons and 4.5 pounds BOD per ton beets processed. A value cited from the European literature was 5.0 pounds BOD. Previous studies in Minnesota showed that the average pounds of BOD per ton beets varied from 2.0-4.4 at the beginning of the season up to 9.2-10.3 near the end of campaign. The suspended solids loads averaged about 7.0 pounds over the same season.

Very high bacterial densities are common within waste flume water, the consequences of which were described in Section IV of this report. Depending upon particular in-plant measures, flume water volume and strength may vary greatly. At present time, flume water is the most complex waste disposal problem remaining in the industry (19, 20, 30, 31, 32, 33, 34, 35).

2. Process Waters

Process waters consist of the drainings from exhausted wet pulp after diffusion. Continuous diffusers are in common use today facilitating the use of closed or nearly-closed process water systems. If water means are employed for conveying wet pulp to the presses, the residual water volume is known as pulp transport or pulp screen water. Many factories provide belt conveyors for moving wet pulp to the presses thereby eliminating this potential waste. The liquors extruded in the pressing of pulp are termed pulp press waters which should be returned to the diffuser. Pulp transport and press waters represent relatively low volume but high strength wastes.

The British Columbia Research Council from a study of 59 mills showed that process waters averaged 2960 mg/l in 5-day BOD with a range from 800 to 7000 mg/l. Suspended solids averaged 860 mg/l with a range from 530 to 1800 mg/l. The Industrial Waste Guide described the process waste loads associated with a continuous diffuser as approximating 580 gallons and 5.6 pounds BOD per ton beets. The industry after many years of experimentation has proved that these waters can be completely reused in the process, with profitable sugar recovery and considerable reduction in stream pollution.

One other form of process wastewater is the drainage accruing from wet pulp in the pulp silo. Fortunately, there are less than 12 factories across the country without pulp press and pulp drying facilities. These plants produce wet rather than dry pulp as the end product. Pulp silo drainage is acidic in nature and exceptionally high in dissolved organic content. The Industrial Waste Guide indicated that pulp silo drainage had unit waste values of 210 gallons and 12.3 pounds BOD per ton beets processed. The studies in the South Platte River Basin showed pulp silo drainage contributed 16 pounds BOD and 22 pounds COD to the total plant load per ton beets processed. Considering the excellent market for dry pulp together with additional sugar recovery, all wet pulp silos in the U.S. should be phased-out in the near future (17, 18, 20, 31, 36, 37).

3. Lime Mud Slurry

Hydrated lime is added to the beet juice as a purifying agent and then precipitated by carbon dioxide. The calcium carbonate sludge with impurities removed from the juice is vacuum filtered, slurried with water, and this mixture is known as lime mud waste. Steffen house factories use nearly double the quantity of lime employed in straight-house operations, and the lime cake slurry was reported as about 50 percent higher in strength. Sludges from the CSF process and boilouts from the cleaning of evaporators and vacuum pans may also be mixed together with the lime muds in waste disposal. Lime cake generated from juice purification operations amounts to 1.5-3.0 percent of the weight of beets worked in U.S. practice, and about 5.0 percent in European practice. The large difference between U.S. and European values was not explained. A factory handling 150,000 tons of beets over the season could produce 3000-4000 tons lime cake. The weight of slurry would be considerably greater.

Lime sludge is predominately alkaline with extremely high organic and solids content, and as such represents a serious disposal problem. Besides calcium carbonate, the sludge includes nitrogen pectins, albuminoids and significant sugars. Study of 59 mills in the U.S. and Canada showed lime mud slurries to have an average BOD of 6,370 mg/l with a range of 1,060 to 27,800 mg/l BOD. The suspended solids content of these slurries averaged 229,000 mg/l with a range from 143,000 to 357,000 mg/l TSS. The amounts of water added to the filter cake varied greatly and were mainly responsible for the wide range demonstrated in BOD and TSS values. Nearly all the dry solids were in the suspended form. The British Columbia Research Council reported that lime mud was ponded separately or together with other plant wastes at 55 of the 59 mills. However, it is well known that many of these factories actually discharge lime mud direct to the receiving stream.

The Industrial Waste Guide indicated that lime mud slurry would be expected to have unit waste values of 210 gallons and 6.5 pounds BOD per ton beets processed. From experiences in Europe and Great Britain, both lower and higher BOD values have been reported. The data obtained from three Steffen house factories in the South Platte River Basin showed average unit waste values approximating 5 pounds BOD, 7 pounds COD, 90 pounds TSS, and 45 pounds alkalinity per ton beets processed (17, 19, 20, 31, 34, 35, 38).

4. Steffen Filtrate

Steffen filtrate originates from the filtering of saccharate cake in the precipitation of lime-treated diluted molasses in the Steffen house. The Steffen filtrate through the 1940's represented the most damaging waste product from the sugar factory. The filtrates are highly alkaline with a pH level around 11, and 3-5 percent organic solids. The Industrial Waste Guide described Steffen filtrate as containing around 10,500 mg/l BOD, 25,000 to 40,000 mg/l total solids, and 100 to 700 mg/l TSS. Unit waste values were 2650 gallons (11 tons) and 231 pounds BOD per ton molasses (expressed as 50 percent sucrose). Steffen filtrate produced in the South Platte River Basin was entirely converted to CSF (concentrated Steffen filtrate) and reused. Steffen filtrate conversion is discussed later in the report (20, 31).

5. Excess Condenser Waters

Vacuum is created on the multiple-effect evaporators and across the vacuum pans by a barometric condenser system. Steam and vapors from the fifth-effect of the multiple-effect evaporator and from the vacuum pans are condensed by direct contact with the waters passing through the barometric condensers. The degree of contamination in the barometric condenser waters depends upon the liquid entrainment in the vapors passing over from the fifth-effect. In the evaporator system, condensates from the first effect are relatively pure in quality. Subsequent condensates are affected in higher degree due to entrainment of liquid in the vapors passing from one effect to the next. Condensates are largely if not totally reused in the factory but some may be wasted. The CSF evaporators are likewise included in this picture. In most mills the condenser and cooling water systems are the principal sources of water supply for the beet flumes.

The British Columbia Research Council study on various factories reported an average BOD for excess condenser waters of 43 mg/l with a range of 25 to 130 mg/l BOD. Suspended solids averaged 67 mg/l with a range from 0 to 100 mg/l TSS. Experience indicates that accidents, shock loads, etc., cause heavy entrainment of the vapors and these conditions are reflected in the waste lines. Based upon U.S. and European practices, the best control procedures will lower the condenser BOD to 15-30 mg/l. The Industrial Waste Guide attributed 0.7 pounds BOD per ton beets to the barometric condenser waters. The South Platte River Basin studies showed that the CSF condensates could be expected to create additional waste load, amounting to 0.7 pounds BOD for each ton of molasses worked.

Condenser waters may be reused within the plant, discharged directly, passed through cooling towers before entering the receiving stream, or may be continuously recycled and reused in an integrated flume and condenser water recovery system (17, 20, 31, 34, 38, 39).

B. IN-PLANT MEASURES

1. Handling of Sugar Beets Before Reaching the Factory

Although handling of the beets in the field and enroute to the factory are not part of in-plant operations, these procedures are directly related to factory waste disposal problems and therefore warrant close attention. The two major items of importance are the dirt and bacteria brought in with the beets. The sugar company, however, generally considers the condition, sugar content and purity of the beets to be of highest concern.

The farm soil may theoretically be removed either by the farmer or by the company. Universal practice calls for the company to assume this responsibility. In consequence, the dirt and associated trash become part of the plant waste system and may eventually enter the stream. Some tare is removed by shaking and screening prior to process, and returned to the delivery trucks. However, the large majority of dirt enters directly into the mill. This condition has stemmed from the increasing trend toward mechanization on the farm. Jensen (18) reported that beet roots were originally loosened from the ground by a lifting machine and the field workers removed most of the dirt by shaking and then they cut off the leaves. The discard material thereupon remained in the field. In the U.S., because of high costs and labor scarcity, more mechanical harvesting became necessary. In turn, mechanical harvesting was responsible for much more soil adhering to the beets as well as the unwanted leaves and trash.

Large quantities of bacteria in sugar factory effluents were first suspected, and are now known as originating with the incoming sugar beets. Animal manures applied in raising crops have been established as the major source of bacterial release within the sugar beet factory.

The future of waste abatement would suggest a much needed change in bringing sugar beets to the factory. The removal of soil, leaves, and trash at the farm would provide the mill with the cleanest possible raw product and solve many of the present problems. Late-season irrigation and wet-field harvesting, although advantageous at times to the farmer, contribute to increased waste treatment or stream pollution by the factory. Many if not all sugar companies possess adequate leverage to require that proper measures be taken by the farmers. Dry removal techniques are highly desirable although harvesting costs would undoubtedly rise. However, if extensive factory waste treatment is to be relied upon for removing these materials, the results will not only be more costly but also less efficient.

2. Redesign of the Beet Flume System

The hydraulic fluming method of transporting beets into the factory was developed by German technicians in 1879. The flume system replaced the then conventional means of handling beets by small cars, conveyor belts, and even wheelbarrows. The basic system has been modified many times, but in view of major attention being given to wastewater problems it should be re-examined once again. Hydraulic fluming from the standpoint of the company offers an effective and easy means of transporting and cleaning the beets and thawing frozen material. One disadvantage is the loss of sugar to the flume waters. In pollution abatement, the waste flume waters represent a formidable problem.

Deterioration of the sugar beets within storage can be minimized by maintaining proper conditions in the stockpiles and reducing storage time as much as possible. More care should be given to preventing damage and breakage of the beets and in this regard, the mechanical equipment and handling procedures for loading and unloading could be considerably improved. These measures are highly important for reducing waste loads in the beet flume. The reuse of beet flume waters is the best means available at this time for eliminating this waste and will be discussed later. Major emphasis herein is given to the basic flume system.

In recent years, many factories have reduced beet storage facilities and also have shortened their flume system, integrated with truck delivery and a truck hopper installation on the line. Other factories have provided belt conveyors for transporting beets at least part of the way into the plant. Minimum contact time of the sugar beets with the flume water and dry handling procedures whenever possible, serve to reduce the waste loads imposed upon the beet flume system. The Bay City, Michigan factory stored its beets on a large concrete slab, and the beets were moved by front loader and truck, and deposited into an extremely short flume directly ahead of the beet washer. The elimination of flumes from the piling area, dry handling with mechanical equipment, and very short contact time of beets with the flume water were all responsive to significant waste load reduction in the Bay City flume system.

The next step possibly indicated for the future is the completely dry handling of beets until they reach the washer. The British Columbia Research Council suggested that the beets may receive mechanical shaking or scrubbing for removing most of the dirt and solids followed by high pressure jets at the washing table. The jets would provide maximum washing with minimum water contact. It was cautioned that these techniques could be of serious disadvantage in colder climates where flume waters promote necessary warming and thawing of sugar beets. However, hot exhaust gases and steam generally available at the factory may be adaptable for satisfying even this requirement. Otherwise, recycling and treatment of waste flume waters are the long-range alternatives (17, 31, 34).

3. The Value of Process Water

The reuse of process waters has been one of the exemplary areas of waste elimination by the industry. The favorable economics in producing dry pulp for a ready market and additional sugar recovery have contributed in large degree to this change. Problems still exist where wet pulp remains or the process system has not been closed, but progress is continuing.

Pulp transport water has been eliminated in many factories by the belt conveyor means of moving exhausted pulp to the presses. Transition plants should provide for continuous recycling and/or reuse of transport waters within the diffuser until such time as a belt conveyor system can be installed. A few factories with full pulp pressing and drying facilities continue to discharge press waters to the drain rather than reusing these waters, and this practice should be discontinued as soon as possible. It must be noted that process waters may be reused for a variety of in-plant needs although general practice favors return to the diffuser.

Wet pulp produced exclusively by a few remaining factories is associated with pulp screen waters and pulp silo drainage both of which are strong pollutional wastes. Successful waste control measures call for complete elimination of the wet pulp system or extensive treatment of these liquors. Over the past two years, the last four plants with wet pulp in the South Platte River Basin have abandoned this system. Three mills converted to pulp drying, whereas the other mill discontinued operations (17, 31, 36, 37, 40, 41, 42).

4. Handling of Lime Muds

Calcium carbonate sludges are generated from juice purifying and other operations within the beet sugar factory. Lime cake is recovered from the vacuum filters at approximately 50 percent moisture content. Universal practice in the United States consists of adding various quantities of water to the lime cake thereby producing a slurry, easily removed from the plant. A number of factories in Europe, Great Britain, and the Canada and Dominion mill located in Chatham, Ontario, employ dry means of disposal. It is believed one or two plants in the U.S. over past years have attempted dry removal but data on recent operations were not available.

Disposal of lime mud slurry has represented a continuing problem in the industry. Direct discharge of this waste to the receiving stream still occurs at many factories. The large majority of plants impound the lime mud slurry in large storage ponds, but very often continuous overflow is permitted from the ponds. Lime mud drainage is extremely detrimental to the receiving stream and every effort should be made to prohibit any such discharge. The same principle applies to the groundwater aquifer where any use whatsoever is made of these waters. A disturbing feature in the literature advocates waste disposal by percolation means whenever possible. Construction not only of lime mud ponds but other waste holding facilities purposely located over the permeable aquifer or directly adjacent to surface streams, indicates less than desirable action towards protecting these water resources. Factories in the U.S. commonly use a single storage pond for lime mud whereas European practices employ separate ponding of the settled solids and the supernatant. Problems of fermentation and noxious odors have been associated with the long-term holding of lime mud wastes.

Previous reports emphasize that the concept of slurrying an already semi-dry filter cake for the purpose of pumping must be considered intrinsically wrong. Besides creating pollution, the lime-water mixture represents a large volume of difficult-to-separate material, with considerable problems still remaining in its ultimate disposal. It is seriously questioned if any liquid waste discharge should arise from these operations. The lime cake off the filters should be collected directly and disposed of onto an enclosed land area, to and from which all drainage is excluded. If the mill insists on slurrying and ponding, there should be no overflow or percolation to the nearby surface stream and the ground-water aquifer.

Acidic soils have been upgraded by adding lime mud. European studies have shown that one ton of lime filter cake contains about 7 pounds organic nitrogen, 13 pounds phosphoric acid, 2 pounds potassium, and 440 pounds organic matter. At Tirlemont, Belgium, the lime cake was dried in a kiln, pulverized, and optimum moisture content for land spreading was maintained around 17 percent. Both in the U.S. and other countries, studies have been directed to the reuse of burnt lime residue within the factory and in the manufacture of cement and related products. These methods, whether profitable or not, must be balanced against future waste abatement and treatment costs that can be expected at the factory (17, 18, 19, 31, 34, 43).

5. Steffen Filtrate Conversion

Excluding a few factories, the Steffen filtrate is not considered a major waste today. The filtrates resulting from the double precipitation of hot and cold saccharates in the Steffen factory are generally converted to CSF (concentrated Steffen filtrate) and used in the manufacture of MSG (Monosodium Glutamate). The CSF is otherwise added to animal feeds.

The British Columbia Research Council in 1964-1965 reported that 13 of 19 Steffen houses produced CSF as an end product. The Johnstown, Colorado plant is believed to be the only facility in the industry manufacturing MSG directly from the filtrate. The CSF is high in protein content and a valuable additive to animal feeds when used in moderation. A number of mills introduce CSF into the pressed pulp prior to drying. Some plants also recycle part of the Steffen filtrate for reuse as Steffen dilution water. Remaining wastes from the Steffen house include CSF condensates and sludges, both previously mentioned.

There are no other known uses for Steffen filtrate. Seven or eight of the above Steffen houses released part or all of the filtrate into the lime mud storage ponds or the general waste ponding system.

Only one factory located in Montana was reported to be discharging Steffen filtrate directly into the receiving stream (17, 18, 20, 31, 43).

6. Condenser Waters Desirable in Some Cases

Most sugar factories must reuse their condenser waters and condensates to conserve hot water supply. These waters are directed to the boilers, diffuser makeup, main tank supply, the beet flumes, lime mud and ash slurrying, and miscellaneous needs. Entrainment of organic matter in the vapors before condensation requires careful control of particular unit operations. The excess condenser waters representing water buildup in the factory are handled in a manner reflecting company policy and regulatory provisions. Many persons in industry believe that condenser water should not be classed as waste. Compared to other effluents, condenser waters are relatively low in organic and suspended solids content. Condenser waters are detrimental to the receiving stream by virtue of their high temperature and almost complete absence of dissolved oxygen.

Where water supply is adequate and regulations permit, the condenser waters are discharged directly to the receiving stream after one pass through the condenser system. In other regions, the waters must be first passed through cooling towers or the pH level modified before entry to the stream. With direct discharge, the BOD content should not exceed 20-30 mg/l. BOD levels have been reported in excess of 100 mg/l, which definitely should not be tolerated with continuous operation. It is important to consider whether the factory must operate within the limits of a specified effluent quality or allowable waste load to the stream. The literature has indicated that increasing population pressures around sugar beet processing sites may result in more stringent regulations where the release of any waste in the future over 20 mg/l BOD may be prohibited.

A European writer has suggested that since condenser waters contain only 2 percent of the factory waste load, the installation of expensive cooling towers is not justified for these waters. Cost of the cooling system was described as greater than that required in reusing process effluents or storing lime sludge, and it was therefore implied that the latter wastes should receive prior attention (17, 31, 34, 43).

The highest degree of control is represented by recycling the condenser waters in a separate system or within a joint recirculation system together with flume waters. Both methods are discussed later in the report.

7. Reuse and Recovery of Various Flows

In addition to previously mentioned practices, certain other procedures are important towards water reuse and waste recovery. The continuous diffuser which has largely replaced multiple diffusion cells, has created flexibility in process water reuse and significantly reduced the volume of such waters outside the diffuser. Process water return to the continuous diffuser requires careful control and in some cases, intermediate treatment of these waters. Although some decrease in processing rate may be experienced, this is offset by increased recovery gains in both sugar and pulp.

At least one sugar factory uses process water for molasses dilution in the Steffen house, or washing the lime cake filters. Waste flume water is partly reused at many plants within the wet hopper of the beet flume system. Under strict regulatory control, the various water use patterns evolve into closed systems, the more important of which are the process water closed circuit, the flume water recirculation system, and the condenser and flume water recycling circuit. Treatment is generally required in the closed system ranging from simple chlorination up to extensive biological oxidation. A high degree of factory water reuse is intrinsic with the flume and condenser water recirculation systems. The British Columbia Research Council in its study of 59 mills has classed the various mills into five basic types corresponding to the degree of in-plant water reuse. The Council's report gave flow diagrams for the major types and described the numerous modifications possible in the basic flow patterns.

Trash collectors, traps, screens, and other recovery devices should be placed at all major waste collection points within the factory. Proper design, installation, and maintenance of these appurtenances are essential for adequate performance. Coarse materials in particular should be removed by mechanical means rather than by biological oxidation. Control is necessary not only over routine wastes but also in regard to spills, leakage and inadvertent releases to the floor drains. A modern waste control program implies the best operation of equipment, a high level of job skill and performance, and true awareness of the total picture (17, 18, 31, 32, 34, 40, 41).

C. MINIMUM WASTE ABATEMENT AND TREATMENT

It is difficult to define in many cases what is meant by minimum, intermediate or high-level waste abatement and treatment. Attempts to classify various forms of treatment into a singular category may be questioned. The particular format was chosen for ease and clarity in presentation rather than giving a rigorous definition of the system. Minimum or primary treatment is considered a means of removing most of the settleable and suspended matter. High-level treatment implies extensive measures for removing dissolved organic matter together with other undesirable waste constituents. Biological oxidation units as such may or may not be used in high-level treatment of sugar beet wastes. In this report, high-level treatment is meant to provide factory waste loads not exceeding 2 pounds BOD and TSS per ton of beets processed. Intermediate treatment represents a compromise between the low and high treatment levels.

1. Fine-Mesh Screening

The screening operation is a preliminary step in waste treatment intended to reduce waste loads placed upon subsequent treatment units. Adequate screening of the waste flows from a typical factory may remove from 10 to 40 tons of coarse wet solids daily. The recovered screenings may be shredded and introduced into the pressed pulp going to the dryer, or sold directly to the farmers for use as animal feed. When the material contains a large portion of beet slices or chips, it may be returned to the diffuser. Both vibrating and rotary type screens are used in waste treatment; industry experience gives preference to the vibrating screen. In screening technology, the term "mesh" is synonymous with the number of screen openings per linear inch. Screens are commonly designated by the space between wires and the wire diameter, both expressed in inches, such as 1/4" -0.135. Screens may also be equipped with mechanical and hydraulic devices to give more efficient solids removal from the screen cloth. Industry applications are described as follows.

The Brighton, Colorado factory provided dual vibrating screens having 1/8x5/8-inch slotted openings, as the first unit within its flume water recirculation system. The screens removed about 30 tons wet solids daily which were sold directly to local farmers for use as stock feed. The Fort Garry plant in Manitoba, Canada installed a screening station ahead of its clarifier integrated within a closed flume water system. The station has been equipped with a travelling water screen in series with four 4x8-foot vibrating screens operating in parallel. The Findlay, Ohio sugar mill has three vibrating screens installed in parallel which are preceded by a liquid cyclone for removal of heavy grit and solids. The Findlay screens, each 5x12-foot, are illustrated in Figure 48. The grit-solids separator and screen station were an essential part of the closed flume and condenser water system at Findlay. The main objective of the screens was to remove light solids, beet tops and other organic debris from the circuit. These materials were utilized for animal feed, green fertilizer and other needs.

The Torrington, Wyoming factory discharged its waste flume water through two 6-foot long rotary screens in parallel, before final disposal to the river. The screenings from the rotating drums were pumped to a vibrating screen for further de-watering and the wet solids loaded into farmers' trucks. The modern factory at Hereford, Texas screened and settled the wastewater within its 5000 gpm flume water recycling system. The screening station consisted of four vibrating 20-mesh deck screens into which the total flow was manually divided. The screens were considered vital in maintaining the flume waters as fresh as possible and removing solids which would be otherwise deposited in the lime mud and stabilization ponds. Peak flows caused some overloading of the screens which could be remedied by additional screening capacity. The Hereford study emphasized for best efficiency, the screens should receive uniform flow over the entire width of cloth and furthermore, incoming velocities should be as low as possible (6, 17, 28, 31, 32, 38, 39, 43, 44).

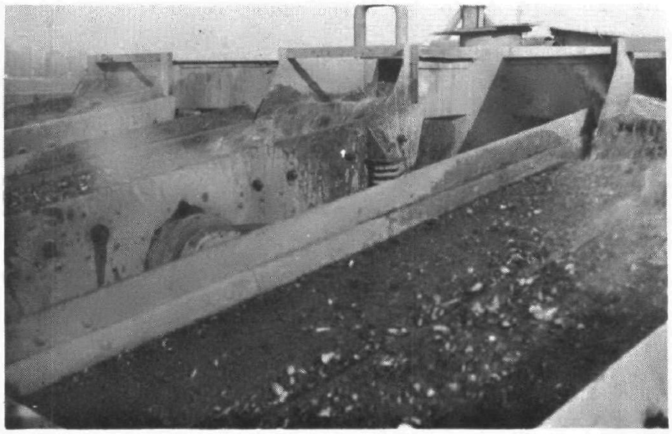


Figure 48.
Findlay, Ohio sugar factory; 12-9-65.
Three vibrating screens in parallel, treating waste flume and condenser waters in the closed circuit.

2. Grit and Solids Removal by Mechanical Means

Mechanical clarifiers preceded by grit removal and/or fine screening, are generally used in closed wastewater recycle systems. In other cases, the wastewater may be screened and settled and even subjected to chemical flocculation, then discharged to the receiving stream. Mechanical settling units usually imply a high degree of water reuse in the factory. Natural ponds are used in lieu of mechanical units where the percentage return is less. The objective is to remove as much dirt, soil and other solids as possible, particularly critical in the closed system.

The Garland, Utah factory was the only mill in the U.S. without some reuse being made of the clarifier effluent. The Bay City, Michigan plant provided for grit separation of spent flume waters, followed by chemical flocculation and partial return of the treated waters. This installation is discussed later under chemical treatment. The Croswell, Caro and Sebewaing factories in Michigan passed their waste flume waters through a grit chamber before release to long-term storage ponds.

Mechanical settling of wastewater is relatively important in both the U.S. and Canada. The Dyer, California factory treated a mixture of flume water, process water and Steffen waste by screening together with a thickener and mechanical clarifier. The settled sludges were sent to a series of mud ponds, and the pond and clarifier supernatants were used primarily for crop irrigation. The Moses Lake, Washington mill passed its flume water through a mechanical clarifier and the supernatants from both the clarifier and sludge ponds were used for irrigation or disposed of into percolation basins. At Carlton, California, screened flume waters were received into a thickener and clarifier followed by three treatment ponds totalling 70 acres, and a final pond of 35 acres. Total waste retention in the system was 8-10 weeks. The literature indicated that considerable anaerobic action occurred within the Carlton ponds. The Dyer, Moses Lake, and Carlton factories all reused flume water within the plant. The Alvarado, California mill discharged a mixture of flume water and Steffen waste through a thickener and clarifier system. Settled sludges were transferred to a series of mud ponds and part of the clarifier supernatant was returned to the beet flumes. Treated effluents were released into a marshy lowlands area but in the future will be retained in shallow evaporation ponds.

The mechanical clarifier merits careful attention particularly when flows are recirculated. It is important that sludge underflows and floatable scum and grease be removed quickly, preferably on a continuous basis. If waste detention times are excessive, organic fermentation may occur in the tank resulting in organic acid and hydrogen sulfide buildup. Chlorination may be used to retard such action. In any case, efficient screening is essential ahead of the settling tank. The literature indicated that clarifiers with detention times from 30 to 120 minutes will produce minimum odor compared to settling ponds. With continuous wastewater recirculation, dissolved organic material may increase to rather high levels, and it is sometimes difficult to maintain fresh conditions. European experience suggested a compromise between the amount of water recirculated and the quantity of clean water continuously added to the circuit.

Previously, in Belgium, many factories provided for flume water settling within Dorr clarifiers or large natural basins in order to comply with an effluent standard of 0.5 ml/l settleable solids. In recent years, the regulations have become more restrictive and today most factories recycle and reuse the waters after settling. The present picture shows that waste flows enter the mechanical clarifier with settleable solids of 30-125 ml/l, and the final waters contain 0.3-1.0 ml/l settleable material. Intensive recirculation requires fermentation control by chlorine and lime additions. Fine clay particles which do not readily settle must be removed by chemical flocculation in the pH range 10.5-11.5. Shock doses of lime not only retard fermentation but serve to raise the pH level necessary in flocculation. Following chemical treatment, the pH level must be modified to below 8.5 to permit final effluent disposal.

Experience in Great Britain has indicated that flume waters with about 20,000 mg/l TSS were reduced to around 200-400 mg/l TSS by means of special settling tanks or large lagoons. Two types of circular tanks both with hopper bottoms were reported in use. One was divided radially into 8-10 compartments receiving flow in series whereas the second type had no inter-partitions. Sludges of 25-30 percent solids were disposed of to large lagoons and the supernatants therefrom were returned to the factory.

Three factories, the Findlay, Ohio and Hereford, Texas plants in the U.S., and the Fort Garry establishment in Winnipeg, Canada, placed heavy reliance upon the mechanical settling unit as an integral part of their flume and condenser water recirculation systems. The Fort Garry factory added milk of lime to the screened flume waters prior to settling. Consequently the pH level was maintained around 11.8-12.0, which provided rapid settling together with fermentation control. The sludges were delivered to a mud pond with supernatant return to the clarifier, and the clarifier effluent was reused in the beet flumes. Recent changes in the Fort Garry system have included: 1) modification of the feed well in the settling tank to achieve better performance; 2) small amounts of defoaming oil added to the clarifier to reduce foam buildup; 3) alternating use of the sludge and water lines to and from the mud ponds to mitigate lime deposits in the circuit; and 4) speed reduction on the mud pumps to prolong pump life. At Findlay, Ohio, combined flume and condenser waters after grit separation and screening were divided between two Dorr clarifiers each 63'-8" in diameter by 12-foot deep. The Dorr units were rated at 2450 gpm with an average waste detention time of 67.5 minutes. One such unit is shown by Figure 49. Sludges were deposited into a sludge pond, and the pond supernatant returned to the circuit.

Figure 49.
Findlay, Ohio sugar factory; 12-9-65. One of the two Dorr clarifiers treating screened flume and condenser waters in the closed circuit. Note excess water pond in background.

The flume and condenser water recycling system at the Hereford, Texas factory was designed for continuous bleedoff and the waste effluents from the circuit received biological treatment. All recycle waters were screened and settled. Screened waters were received into a single clarifier (100-foot in diameter by 8-foot deep) equipped with an industrial thickener mechanism to handle heavy mud loads, particularly from wet harvests. At the average rate of 5000 gpm, the settler provided 1.5 hours waste detention with an overflow of 1000 gallons/sq.ft./day.

The resulting sludges were pumped to a mud storage pond. Some difficulty was experienced with fine colloidal clays and peaking flows in the circuit. Although quicklime, slaked lime and spent lime slurry have all shown the ability to assist clay removal, further improvement was desired.

The British Columbia Research Council, although reporting favorable results with mechanical and pond settling, made clear the point that soil disposal will be an ever-continuing problem. They suggested that soil buildup within the factory could be eliminated only by physical transport in the opposite direction. In the future, it is possible that the beet farmer may be required to retrieve sludge solids from the system equivalent to his incoming tare (6, 17, 31, 32, 34, 38, 39).

3. Treatment Lagoons and Ponds

Waste treatment lagoons and ponds have widespread use in the beet sugar industry particularly in the United States. Their function is similar to that provided by mechanical settling, although less care is generally given in design, operation and maintenance with the consequence that treatment performance is often lower than expected. The lack of operating data on this method of treatment is somewhat surprising considering the current application within the industry. Waste detention times in the earthen ponds generally range from 24 to 48 hours. The upper limit is suggested for minimizing noxious odors associated with organic fermentation. The following discussion primarily relates to the handling and treatment of waste flume and condenser waters, with only brief reference being made to lime mud and other wastes.

Jensen has stated that the lagoon system using single or multiple basins has been the most common means of treating sugar beet wastewaters (18). These systems must be shallow and flowing in order to avoid the nuisances of hydrogen sulfide gas. From his experiences on the Continent, Henry (34) favored settling ponds for reasons of economy and also suggested the following principles in relation to these ponds. First of all, the wastewater should enter the unit with minimum velocity and circulate evenly but quickly without interference to settling. Secondly, large ponds are advised in order to minimize dike construction and thirdly, ponds should be levelled and grass and weeds removed on a frequent schedule. The removal of solids from the ponds was reported by many factories as uneconomical; solids are placed on the dike walls causing buildup of the dikes. Eventually the pond together with valuable land are abandoned. Studies have been conducted in Belgium using ponds in series and square arrangement, and the alternation of basins from one campaign to the next. Other studies in Great Britain have indicated that the ideal shape for a settling pond may be a rectangle 5-6 times long as wide providing a flow-through velocity of about 0.8 fpm. The British investigations also suggested that small ponds were advantageous in the event of dike rupture since less waste material would accidentally enter the receiving stream.

The odor problem becomes very important when waste treatment lagoons or ponds are used for beet sugar processing wastes. Oxygen deficiency in the pond and various forms of anaerobic bacteria originating with the soils and the sugar beets give ready opportunity for organic and inorganic reduction. The conversion of sulfates into hydrogen sulfide is particularly critical. Observations at the Greeley, Colorado mill in January 1964 indicated severe odor problems associated with the then present waste treatment lagoon. The pond provided about 17 hours detention of total factory wastes spread over a few acres, 1-2 feet deep. Survey personnel noted extremely foul odors around the lagoon and study showed that the settled effluents were nearly devoid of oxygen and contained around 27 mg/l dissolved sulfide. Sulfide if present in surface water used for drinking purposes may cause severe odor and taste problems with the minimum detectable level being around 0.05 mg/l hydrogen sulfide. The threshold value of hydrogen sulfide for industrial water use ranges from 0.2 to 1.0 mg/l, whereas sensitive fish species may tolerate no more than 0.5 to 1.0 mg/l sulfide in water. The South Platte River Basin studies of January 1965 illustrated that sulfide was limited at all river stations except for the single location below the Greeley, Colorado sugar mill, where the average level was recorded as 0.63 mg/l.

British studies have shown that sugar beet waste samples if stored in the laboratory for 3-4 weeks may contain up to 7 mg/l sulfide whereas little or none should be present in a properly operated waste treatment system. Other information was offered on odor suppression by dichlorophen, bacterial inhibition by means of chromium compounds or copper sulfate, and supplying available oxygen by sodium nitrate.

Phenolics were measured in the beet sugar wastes from the Greeley, Colorado mill in January 1964 but were determined as causing no problems in respect to water uses. However, the possibility of phenols or similar taste and odor compounds present in beet sugar wastes cannot be discounted. A city located on the Red River of the North has reported recent taste and odor problems in their municipal water supply possibly attributed to release of sugar beet wastes from upstream holding ponds. Field studies will be conducted during early 1968 on the water quality conditions in the affected area (28).

The British Columbia Research Council, reporting on 59 factories in the U.S. and Canada, described 16 mills as having pond systems with 5 days or less detention, two mills with intermediate waste detention of 6-20 days, and 8 mills with long-term waste storage. The ponds with limited retention served essentially as settling basins. Of the 16 factories in the first category, 8 mills handled flume waters only, whereas the remaining 8 mills mixed other wastes together with the flume waters. Of this same group, 13 mills discharged the total pond effluents directly to the receiving stream, whereas 3 mills recirculated some part of the treated water for factory reuse. The Council suggested that waste settling could be readily accomplished in ponds with 1-3 days detention. Mechanical clarifiers were recommended where strict limitations would be placed upon the use of lagoons or ponds. In the U.S., shallow lagoons are preferred to deep ponds and operating depths are generally in the range of 3-5 feet. However, in actual practice, the ponds will rapidly fill with solids and effective settling depths will range between a few inches up to 1-2 feet. Settling ponds frequently are located on porous soil or immediately adjacent to the surface stream. In such cases there should be no contamination of the ground-water aquifer, and indirect seepage to the stream must be accounted for in assessing the total factory waste load placed upon that stream.

Previous information is given in Section II of this report on the waste treatment lagoons at the Greeley, Fort Morgan, Longmont, and Johnstown factories, all located in the South Platte River Basin. Demonstrated waste removals were considered as ranging from fair to very poor. Overall BOD and COD reductions were about 10 and 20 percent respectively. Excluding Johnstown with very poor performance, suspended solids removals varied from 75-95 percent whereas bacterial reductions were between 0-75 percent. Pictures of the waste treatment lagoons operating at the Fort Morgan and Longmont mills are also shown in Section II of the report. In the case of all four factories, large quantities of waste material were subsequently discharged to the receiving stream.

An industrial waste survey was conducted in 1956 at the Belle Fourche factory in South Dakota. Waste flume water was passed through three ponds in series covering a total of 16 acres, with an average liquid depth around 3 feet, and a total waste detention time approximating 3 days. Overall reductions in BOD and TSS waste loads, taking into account both evaporation and seepage, amounted to 20 and 95 percent respectively. Waste concentrations were reduced in less degree. Furthermore, very high coliform bacteria numbers were remaining in the lagoon effluents.

Two sugar mills in Great Britain were compared on the basis of one mill (Factory A) discharging settled pond water directly to the river, and the second mill (Factory B) being required to settle and completely recycle all campaign waters. The settling pond at Factory A showed a high rate of percolation and overall waste reductions as follows: BOD - 30 to 70 percent; TSS - 87 to 96 percent; and settleable solids - 92 to 100 percent. Factory B employed its pond system over consecutive seasons with virtually no opportunity for soil removal, and waste concentrations in the pond were high as expected in a complete recycle system. Although appreciable purification occurred in the recycle system, volatile acids consisting predominately of acetic and propionic acids were present in significant amounts, and up to 140 mg/l total nitrogen was also found in the closed circuit. Factory B is discussed in this section of the report not by virtue of representing minimum treatment, but because it could be directly compared with Factory A.

Lime mud ponds are associated with primary treatment in the sense of removing suspended solids from the waste treatment system. All factories in the U.S. release lime mud in the form of a slurry, which in the majority of cases is stored or at least partially separated by means of lime mud ponds. A typical sugar factory may employ one or more lime mud ponds varying in depth from 2 to 10 feet, and on occasion other wastes may be added together with the lime muds. Deposits from a given campaign are generally scraped from the pond bottom and added onto the dike walls. Active fermentation may start near the end of campaign and is accelerated by the warmer temperatures occurring through spring and summer. This problem is solved from the standpoint of the factory if it is permitted to discharge the pond contents during high river flow, or otherwise. High rates of percolation are favored by the industry in locating the ponds although this may readily lead to other serious problems previously described. The various difficulties in storing lime mud slurry such as the viscous nature of the waste, land and construction costs, odor conditions and many others, would seem to offer strong reasons for converting to a dry system of handling and disposal (6, 17, 18, 31, 32, 34, 43, 45, 46, 47).

4. Aeration Fields

In many ways, the term "aeration field," referred to and used for waste treatment within the industry, is a misnomer. The aeration fields in the South Platte River Basin and presumably at other locations, consist of spreading the waste effluents over large land areas. The fields support little or no vegetation, and the wastes trickle down the field in numerous, shallow channels to be collected and disposed of at the far end. Because of short-circuiting, the wastes cover only a small portion of the field. Although the majority of suspended solids can be removed, there is little or no apparent benefit in aeration. The aeration field covers an expansive area yet provides the equivalent of less than primary treatment.

The history of the aeration field in the U.S. started with studies conducted at the Loveland, Colorado mill in 1951. Full-scale facilities were constructed at the Bayard, Nebraska factory during 1952 and evaluation studies were carried out over the 1952-1953 campaign. It must be mentioned in first place that the Bayard aeration field was inherently different and apparently more effective than the installations which were to follow. The combined Bayard factory wastes were delivered to a 3500 by 1750-foot area of fairly level contour. Although native buffalo grass was present, only part of the field was described as a grassland filter compared to earlier such installations in Europe. Waste channeling was reported quite evident at Bayard and nearly 50 percent of the waste volume disappeared by downward percolation before reaching the end of the field.

The 1952-1953 survey results for Bayard showed that incoming flows with 483 mg/l BOD were reduced to 158 mg/l in the aeration field effluents providing 67 percent BOD removal. Corresponding values of suspended solids were 5215 mg/l and 63 mg/l giving 99 percent apparent TSS reduction. Likewise total coliform bacteria numbers were reduced

89 percent. Although algal and fungal growths were abundant, the dissolved oxygen was quite low in the field. Average waste detention approximated 14 hours and the results indicated that odor production was at a minimum. The evaluation report while describing the merits of the system also made certain recommendations for improved treatment including the necessary correction of operational and maintenance problems and levelling of the aeration field.

There were no other reports apparent in the literature besides Bayard giving information on aeration fields within the industry. In actual practice, aeration fields were used at two factories in the South Platte River Basin during the 1963-1964 campaign and later at a third factory. These facilities included Loveland, Greeley and Windsor, the operations of which are fully described in Section II of this report. Most important, it was observed that the treatment facilities at the three Colorado mills did not embody many of the favorable characteristics of the Bayard installation and, furthermore the aeration fields in Colorado were beset with numerous operational and maintenance problems. Loveland with 133 acres of treatment achieved 20 percent removal of waste BOD and COD, and 80 percent reduction in TSS. The Windsor plant experienced the following waste reductions: BOD - 0 to 10 percent; COD - 10 percent; TSS - 60 percent; and coliform bacteria - 35 to 80 percent. Performance data was not collected at the Greeley location. The South Platte River Basin studies concluded that aeration fields, as they are maintained today, could not by any means satisfy the water quality criteria recommended for the Basin (6, 18, 19, 48).

D. INTERMEDIATE WASTE ABATEMENT AND TREATMENT

Intermediate waste treatment in the beet sugar industry is divided into four areas of interest: long-term waste storage, aerated ponds or lagoons, chemical treatment, and direct reuse in crop irrigation. In some cases, these methods may provide a lesser degree of waste removal than factories previously included under primary treatment. The disposal of processing effluents to irrigation use is classed as intermediate treatment because only certain wastes may be used for this purpose and the practice is generally limited to a few weeks or months of the year.

1. Long-Term Waste Storage

Long-term holding is generally associated with a prescribed degree of waste stabilization after which time the wastes are released, most often under controlled conditions. The literature has stated that this means of treatment has been employed with only limited knowledge of the factors contributing to purification and the degree of purification realized during storage.

The first extensive study of long-term waste storage was carried out at the Moorhead, Minnesota factory over 1949-1951. At this plant, waste flume waters together with pulp press waters were released into two 12-foot deep lagoons identical in capacity, with a total area of 81 acres and total volume of 335 million gallons. A third lagoon, 3-foot deep covering 50 acres and providing 50 million gallons capacity, was maintained in reserve until late in the campaign. It is noted that total campaign wastewater volume was 422 million gallons in 1950. Permissive discharge from the ponds started in early spring following severe winter conditions and considerable ice cover over the ponds. The study showed that waste treatment during the campaign itself was caused largely by settling of suspended matter within the ponds. Over this period, BOD reductions ranged from 48 to 58 percent and suspended solids removal was about 97 percent. After the campaign the stored waters underwent no further decrease in waste loads. This reaction was attributed to complete cessation of biological activity within the ponds under freezing water conditions. The study concluded that long-term waste storage even in cold climates, would provide effective removal of suspended solids, and additionally remove about one-half of the BOD loads.

Later study was undertaken in 1964-1965 in the Red River of the North which included not only the Moorhead, Minnesota factory (above) but also the East Grand Forks and Crookston factories in Minnesota. Both Moorhead and East Grand Forks were reported to have facilities for long-term waste storage. Discharge was controlled according to the amount of flow, dissolved oxygen and BOD in the receiving stream, and was permitted prior to and following ice cover on the river. The study results showed in November 1964 that the Moorhead pond effluents contained 449 mg/l BOD, 163 mg/l TSS, and median values of 1.5 million total coliform bacteria and 1.25 million fecal coliforms per 100 ml. The East Grand Forks factory demonstrated final effluent values of 164 mg/l BOD, 54 mg/l TSS, 22,100 total coliform/100 ml, and 1,720 fecal coliform /100 ml. Waste removal efficiencies could not be determined because of the nature of the survey. The Red River of the North study concluded that the ponding systems performed reasonably well. It recommended however, that strict limits be set on the controlled amounts of waste discharge from the Moorhead and Crookston factories in addition to necessary bacterial reductions on the East Grand Forks effluents. Specific discussion on bacteriological findings from the Red River of the North investigations are given previously in Section IV of this report.

At least seven other mills were reported as providing long-term waste holding. Four factories in California exercising a high degree of recycling and with favorable evaporation and seepage conditions were able to retain all wastes in the ponding systems without resulting discharge. These installations were characterized by the use of many interconnected ponds generally in series, specifically designed for settling, fermentation, evaporation or seepage. The various ponds ranged from 2 to 10-feet in depth, and covered a minimum of 35 acres at one site up to several hundred acres found at another. The shallow ponds were aerobic whereas the deeper basins were designed for controlled fermentation. The settling ponds and the initial anaerobic ponds in some cases were covered by a heavy proteinaceous scum layer and the fermentation ponds at times produced serious odors. The British Columbia Research

Council has remarked that increasing duration of the campaign in California has intensified difficulties in using the present ponds for waste treatment and disposal. Also, in other areas, long-term waste storage extended through the spring months has been associated with intense odors.

The Caro, Croswell and Sebewaing mills in Michigan utilized deep anaerobic ponds for waste storage during the wintertime followed by discharge to high river flows in spring. Condenser waters were released directly and continuously to the receiving stream at all three mills. Special attention is given to the fact that both Caro and Croswell were required to add lime to the ponds in attempts to maintain neutral pH conditions (18, 20, 26, 31, 33).

2. Mechanically-Aerated Ponds and Lagoons

No beet sugar factory is known at present time to be using mechanically-aerated lagoons or ponds for waste treatment. The Fort Garry mill in Manitoba, Canada for a short time during the 1964 campaign recirculated its pond effluent over an aeration deck attempting to increase the oxygen content of the wastewaters. The Fort Garry results however were not conclusive and the factory subsequently converted to a closed flume water recycle system.

Recent information obtained from the current pilot-scale treatment studies at Tracy, California indicated mechanical aeration to be initiated in the future. The Tracy study has been investigating the anaerobic-faculative-aerobic lagooning system for treating sugar beet wastes. This treatment system, to be described later in the report, envisions that four low-head propeller pumps will be installed at a single location in the aerobic pond to provide mixing and to supplement the oxygen input from algal growths. The pumps will be operated intermittently, each with a capacity of 12,000 gpm and generating flow velocities in the pond from 0.25 to 1.0 fps.

Laboratory studies have been conducted by the British Columbia Research Council to determine the feasibility of aerated lagoons in treating waste flume waters from the sugar factory. The investigation was intended to provide data on optimum load conditions, time required in startup relative to the beginning of campaign, and adaptability of the aerated lagoon to intermittent operation and temperature change. The studies were initiated on the basis of activated sludge treatment with moderate lagoon retention and controlled through-put and storage of sludge. The tests comprised 6 runs under 48-hour aeration with and without activated sludge being added from a nearby sewage treatment plant. Two runs (1 and 6) consisted simply of 48-hour aeration. The other runs (2 through 5) were successive using the settled floc from the preceding 48-hour period. The waste flume water was obtained from a factory with a high degree of recycle and initial BOD values ranging from 821 to 1121 mg/l.

The results of the laboratory tests showed that runs 2-5 (after settling) produced residual BOD values from 30-140 mg/l whereas, corresponding values in runs 1 and 6 were significantly higher because time was too short for full development of an active floc. The batch system was found to achieve an effluent BOD less than 50 mg/l only if substrate limiting conditions were maintained.

The report on the laboratory studies reached the following conclusions:

1) Biological oxidation using an active floc could offer effective BOD reductions in the range of 93 to 97 percent.

2) Whereas the batch studies attained maximum BOD removal rates within 96 hours, a full-scale installation would require less time.

3) Within a large and properly compartmented full-scale lagoon, there would be progressive decrease in BOD toward the discharge end. Also, controlled sludge entry and removal would provide the most desirable ratio of substrate to active floc.

4) Chemical flocculation could be used to improve the quality of lagoon effluents when necessary, most probably at the start of campaign or with peak loads on the system.

The above studies were conducted with the Johnstown, Colorado factory wastes in mind and this factory is expected in the near future to construct a pilot-plant along the lines of the above study. Because this method of treatment has achieved reasonably good success in respect to municipal wastes and various industrial wastes, there is strong belief that it will apply equally well in treating sugar processing effluents. The proposed Johnstown system should provide interesting results (31, 40, 41, 43, 49, 50, 51, 52).

3. Chemical Treatment

The various uses of chemical agents in the process cycle and for minimizing odor have already been touched upon in preceding sections of this report. Although chemical additives are in fact used throughout the sugar factory, this discussion is limited to chemical flocculation as a unit operation employed in waste treatment.

The foremost example of waste treatment by chemical precipitation is the Bay City, Michigan factory. At this plant, waste flume waters were received into a grit separator for removal of heavy solids followed by chemical flocculation, with 40 percent of the treated waters being returned to the beet flume and the remainder discharging to the river. Separan-AP-30, a commercial flocculating reagent, was used at a concentration of 0.1 mg/l. The sludges from both the grit separator and the flocculation basin were directed to sludge ponds with return of supernatants to the grit chamber. The Bay City factory utilized dry handling techniques in moving the sugar beets from the piles to the wet hopper resulting in minimum waste loads to the flume system. The average BOD level in the flume waters before treatment was 223 mg/l. Treatment results showed that the chemical flocculation system was quite effective--with 90 percent removal of suspended solids, and final BOD levels from 70 to 130 mg/l. The treated flume waters showed a 57 percent reduction in BOD content with a residual waste load of 0.86 pounds BOD per ton beets processed. Other factory wastes not accounted for in the total waste balance included the continuous discharge of excess condenser waters and some overflow from the lime mud ponds both reaching the river.

The British Columbia Research Council has given preliminary attention to chemical flocculation as a polishing means following activated sludge treatment. The results indicated that straight flume waters were unaffected by separan plus alum. However, the effluents from the aeration units were measurably improved by adding lime or lime together with separan. The European literature has referred to calcium oxide for improving waste settling from 80-85 percent to a level of 97-98 percent. Other flocculating agents also considered in the past have been the aluminum and iron salts (31, 50, 53).

4. Land Irrigation

Sugar beet processing wastes are applied directly to agricultural lands when the processing campaign coincides with the growing season, notably true in the warmer climates particularly the State of California. Over much of the remaining Western U.S., the wastewaters are generally stored in off-stream reservoirs until irrigation commences the following spring. A high degree of water reuse in the water-short areas of the Western U.S. predominately for agricultural irrigation is strongly reinforced by Western water law, and comprises the way of life in this part of the country. Wastewater whether derived from a city, industrial plant or previous irrigation is subsequently reused for downstream irrigation interests.

Irrigation in general does not require as high a water quality as other needs, and in most cases the limits have not been established with a high degree of certainty. This report simply describes the widespread practice of using wastewater for crop irrigation as it exists today, and implies neither justification nor disapproval. However, the implications within the system should be clearly understood, particularly the bacteriological aspects. Considering the overall picture, sugar beet effluents in most agricultural areas should receive a reasonably high degree of treatment.

Information reported for the State of California indicated that five factories were releasing part of their waste effluents for irrigation. The Dyer mill discharged Steffen filtrate together with other plant wastes into a general ponding system, the overflow being used for crop irrigation or otherwise diverted to the plant sewer. The Tracy establishment discharged its combined plant wastes to irrigation whenever feasible or used the San Joaquin River for final disposal. The Santa Ana, Mendota and Alvarado plants were known to provide some part of their wastes for irrigation; however Alvarado has discontinued its practice of irrigating duck feeding grounds. Waste discharge regulations are relatively comprehensive and the California factories generally exercise a high degree of waste control and treatment. One regulation stipulates there shall be no pollution or water quality impairment of the ground-water aquifer resulting from waste handling and treatment measures.

The situation in the South Platte River Basin was described in part by a letter of June 30, 1965 from the sugar company to the State of Colorado. The company made the comment that practically all surface river waters below its ten mills were believed used by the sugar factories or for irrigation purposes. The position was taken that these wastes were more beneficial than harmful when used for irrigation and it was further reported that the factories returned more water to the streams than used. This letter has been taken to illustrate the importance placed upon irrigation in the West. Although the statement was true in context and reflected the company policy in 1965, it did not take into account many particulars or the importance of other water uses both present and future. Since that time, the company has instituted a number of waste improvements and given strong indication of so continuing in the future.

Further reference is made to the Hereford, Texas factory having a waste treatment system designed to provide reclaimed water for irrigating 400 acres of company lands upon which milo and sugar beet crops were grown. Also, certain literature from abroad has described various factories in Poland and Russia as extensively reusing flume and process waters for land irrigation (6, 31, 32, 40, 41, 43, 54, 55).

E. HIGH-LEVEL WASTE ABATEMENT AND TREATMENT

A system of methods and operations which may provide a high degree of waste control and treatment within the sugar factory is ambiguous in three ways. First of all, it is difficult to describe. Secondly, the system will vary greatly from plant to plant, and thirdly, the various procedures cannot be conveniently categorized. For purposes of this report, less emphasis has been placed upon modifications and variations, and waste treatment has been simply divided as to recirculation-reuse systems, biological systems, and biological-recirculation systems.

1. Recirculation-Reuse Systems

The closed or nearly-closed wastewater recirculation system represents the apex of rigorous waste control and treatment. The complete recycle system has generally proved superior to biological methods in terms of overall results.

a. Flume Water Recycle Systems

A closed flume water recirculation circuit is described as one with continuous recycling of waste flume waters together with essential treatment units on the line enabling complete reuse of such waters. This system is definitely known to be in operation at three factories: Fremont, Ohio; Fort Garry in Manitoba, Canada; and Brighton, Colorado. The same system is under construction or recently completed at Moses Lake, Idaho; Toppenish, Washington; Chaska, Minnesota, and possibly others. The Ottawa, Ohio mill previously employed this procedure but has since converted to an integrated flume and condenser water closed circuit.

The Fremont, Ohio factory installed its closed flume water circuit during the 1950's. The Fremont factory was a straight-house operation receiving about 1800 tons beets per day, with pulp drying and return of press waters to the diffuser, and the separate ponding of lime muds. The beets were carried to the flumes via belt conveyor and then flumed a short distance into the mill. The spent flume waters flowed into a 9-acre shallow lagoon, received treatment in the pond, and returned for complete reuse in the beet flumes. Although details were not available, the installation included waste screening. The Fremont waste treatment works were considered relatively simple and a partial view of the system is shown in Figure 50. The picture shows heavy foam buildup along the length of the incoming canal which undoubtedly created certain problems.

Figure 50.
Fremont, Ohio sugar factory; 12-9-65.
Overhead view of the Fremont lagoon with center dike. Inflow at bottom left entering pond from top left. Outflow canal from pond shown at right flowing toward observer for return to the beet flumes.

Operational data on the Fremont system showed that lime additions were necessary in the waste lagoon to minimize fermentation which occurred mostly during the start of campaign and again in late spring. There were many homes located 1000-feet or less downwind of the pond, but most likely major complaints if any, were due to the fly-ash problem observed around the plant. The flume waters remaining after campaign were stored in the lagoon and subsequently discharged to high streamflows during the spring. The stored wastewaters were reported to contain around 0.2 pounds BOD per ton beets processed, at their time of release. The excess condenser waters at Fremont were permitted free and continuous discharge to the river. These waters contained around 45 mg/l BOD, with a waste load estimate of 0.6-0.7 pounds BOD per ton beets processed. The total factory waste load of around 0.8-0.9 pounds BOD per ton beets was remarkably low in view of the simplified waste treatment system.

The Ottawa, Ohio factory utilized a closed flume water recycle system through the 1964-1965 campaign. The procedure at that time consisted of passing flume water through a grit chamber only, with complete return of the waters to the beet flumes. The grit sludge was directed to a 2-acre pond followed by overflow into two 8-acre ponds. The three mud ponds were drained to the adjacent stream at times of high flow. Pulp press waters were completely returned to the diffuser, but excess condenser waters together with overflow from the lime mud basins were released to the stream. Discounting the last feature, the Ottawa installation because of its uniqueness is deserving of attention. Unfortunately, no further information could be obtained on the past system or the new integrated flume and condenser water system believed to have been recently installed at Ottawa.

The sugar plant at Fort Garry in Manitoba, Canada was a straight-house operation receiving 3,000 tons beets per day with pulp drying and process waters being returned to the diffuser. The spent flume waters were recycled in a closed circuit consisting of a screen station, a Dorr clarifier, and a 12-acre pond receiving sludges from the clarifier. Operation of the screen station and Dorr unit is previously described in Sections V C 1 and 2 of this report, and will not be repeated here. Supernatant from the sludge pond was returned to the clarifier, and the treated waters leaving the settling tank were cycled for reuse in the beet flumes. Some condenser water was necessary in the flume water circuit to prevent freezing in the system. Excess condenser water averaging 27 mg/l BOD and 50 mg/l TSS, discharged freely to the river. Septic tank effluents also entered the receiving stream. Lime mud slurry was stored in a large lagoon from which there was no reported overflow.

The Fort Garry plant considered the closed flume water system to have demonstrated satisfactory performance in terms of both normal operation and necessary maintenance care. The BOD content of the recirculated flume waters increased somewhat more than expected to levels of 7,000 mg/l BOD, but routine lime additions were successful in maintaining freshness in the circuit. The system encountered other problems during its first campaign in 1965 as previously described, and these were corrected. Prior to the closed system, the Fort Garry plant was discharging total waste loads to the receiving stream in the order of 7.4 pounds BOD and 1.7 pounds TSS per ton beets processed. The closed flume water system in 1965 reduced total factory waste loads to 0.3 pounds BOD and 0.6 pounds TSS per ton beets processed, excluding residual wastes from the circuit stored at the end of campaign.

The Brighton, Colorado factory was a straight-house operation receiving about 2400 tons beets per day with full pulp drying facilities and return of press waters to the diffuser. Lime mud was stored in a separate holding pond with generally no discharge. The Brighton waste treatment system is fully described in Section II of this report and therefore only a brief summary is given in the following. The Brighton flume water recirculation circuit was more elaborate than both the Fremont and Fort Garry plants.

The Brighton system consisted essentially of a pumping station, fine-mesh screening station, and three ponds in series for solids settling and reconditioning the waters for their return to the beet flumes. The ponds covered a total area of 6 acres comprising an outer horseshoe-shaped basin and two inner basins. Excess condenser water was released to a spray pond and then to the South Platte River. A reserve treatment lagoon of approximately 12 acres was employed for the collection and storage of excess wastewater from the closed circuit together with accidental spills.

During the 1966-1967 Brighton campaign, undue fermentation was present in the closed circuit and strong counter-measures were taken. Total chemicals added to the system over the campaign included 19 tons of caustic soda, 1000 tons of lime as $CaCO_3$, and small, intermittent doses of HTH (chlorine). There was substantial solids settling within the ponds, pointing once again to the desirability of reducing the incoming soil and dirt to the factory. Analytical results are not yet available from the sugar company concerning the Brighton system. However, preliminary information has indicated better than 90 percent reduction in BOD waste loads compared to previous conditions, and the overall system performance has been most encouraging.

British studies on comparing two factories, one with and the other without a closed wastewater system, are previously described in Section V C 3 of this report. In reference to Factory B equipped with a Dorr clarifier and settling pond in the closed circuit, pH conditions were maintained between 5.6-6.9. The levels of BOD and volatile acid (as acetic) increased respectively to 9-12,000 mg/l and 5-6,000 mg/l, but surprisingly enough the waste concentrations did not show much increase after the first few weeks of campaign. In other words, irrespective of new waste additions, a constant waste load was sustained in the system. It must be presumed under these conditions that fermentation was controlled by chemical means.

Henry (34), in his report of European practices, referred to a sugar factory with recycling of flume and condenser waters in a closed system, and compared the new to the previous conditions. Henry commented that (now) the "polluting matter discharged is not reduced proportionately, since recirculation concentrates the polluting agents in a small volume of water. Recycling . . . is aimed more at making good water shortages than at reducing the pollution of the river." Nevertheless, Wintzell has estimated that pollution in 1953 (for this same factory) had been reduced by 81 percent compared with 1939. Further reference was made by Henry to the British situation where he stated "although the water authorities enforce the recirculation of water from barometric condensers, the pollution position grows worse."

The principles stressed by Henry certainly merit close scrutiny, but the impressions given above, particularly when taken in context with the remainder of his report, appear somewhat pessimistic. However, a difference does indeed exist between a system with less than 100 percent recycle described by Henry, compared to the full recycle system. The Fremont, Fort Garry and Brighton factories all employing 100 percent recirculation, provided very encouraging results. It is noted that the addition of condenser water into the circuit probably requires more operational care and diligence. Henry further mentioned that flume water after extensive recirculation may reach up to 2,000-3,000 mg/l BOD and 1,000 mg/l TSS. Besides fermentation, he remarked that recycling could have the secondary effect of accumulating saponins leading to excessive foaming and problems in fluming. This condition was previously observed at the Fremont, Ohio factory.

The British Columbia Research Council described British mills as employing intensive reuse and treatment practices, with screening and settling of flume waters and complete recirculation in some cases. Under these conditions, the BOD level reached up to 2,000 mg/l, coagulation was used to improve solids settling, and fermentation was controlled by 10 mg/l chlorine addition. Condenser waters at certain mills were recycled in a separate circuit with a cooling tower or less desirably a spray pond, and these waters could attain BOD levels up to 1,000 mg/l. With condenser waters, 3 mg/l chlorine was used to retard fermentation.

Additional study by the British Columbia Research Council indicated although flume water recycling would reduce water consumption and size of waste treatment facilities, the total waste load in the circuit would not be appreciably lowered until 100 percent recycle was attained. Equilibrium must be reached where the soluble material level in the waters equals that in the sugar beets and minimum diffusion exchange occurs. This condition may be approached when the recycle waters contain 2-3,000 mg/l BOD, but in other cases the BOD level may be higher. For proper operation of a closed system, effective screening and settling are considered essential, and coagulants, alkalis and chlorine additions may also be found beneficial and even necessary (6, 31, 34, 39, 40, 43, 47).

b. Integrated Flume and Condenser Water Recycle Systems

Much has already been said on condenser water within the flume water recycling system and it is difficult in many cases to consider the two on separate bases. Two examples are given below of the integrated systems at Findlay, Ohio and Betteravia, California, followed by discussion of the system. Many factories in Great Britain and Europe employ the integrated system in whole or part, because of economics, regulation, or the need for heat content in the circuit.

The Findlay, Ohio factory was a straight-house operation receiving about 1700 tons beets per day. The pulp was dried with press waters being returned to the diffuser, and lime mud slurry was stored in a separate lagoon. The Findlay system installed in 1956 had as its basic components a screen station, mechanical settling tanks, sludge pond, spray pond, lime pond, excess water storage pond, and a distribution line leading from the excess water pond back into the factory. The various pond areas were as follows: sludge pond - 6 acres; lime pond - 5.5 acres; spray pond - 1.4 acres; and excess water basin - 1.1 acres. Sludges from the clarifiers were pumped to the mud pond, and supernatant overflows from both the mud pond and the lime pond entered into the spray pond. It may therefore be seen that the system in reality contained more than flume and condenser waters. The total capacity of the system was about 9.5 million gallons. Reclaimed waters were pumped from the excess water pond to the factory main water supply tank which in turn served the beet flumes, beet washer, roller spray table, the condenser system, and for slurrying of lime mud. Previous information in Sections V C 1 and 2 of this report gives detailed description on the screen station and Dorr clarifiers found at the Findlay plant.

An important element of the Findlay system was an arrangement between the company and the city whereby excess wastes from the integrated closed circuit could be disposed of to the municipal sewage treatment plant. A surcharge was levied for this service and company policy therefore was directed towards minimizing the frequency, amounts and particularly the strength of the wastewaters so discharged. Wastes stored after the close of campaign could also be disposed of in similar manner. Plant observations indicated that minimum odor has been associated with the industrial waste treatment facilities. Lime mud in the circuit has created certain problems particularly clogging of the lines in the plant condenser system; effective lime settling is essential. The various basins were reported to be cleaned once each year with the exception of the lime pond which received more frequent attention. The company estimated the capital costs of the waste treatment system at $253,000.

Within the Findlay system itself, BOD and TSS levels showed wide variation. During October and November, the BOD value was around 700 mg/l. Near the end of campaign in January the BOD and TSS levels approximated 2,600 mg/l and 1,800 mg/l respectively. The BOD content of the wastes under storage conditions decreased to around 700 mg/l in mid-March, and decreased further to 70-200 mg/l BOD when the wastes were held until June. The total amounts of waste pumped to the municipal sewage treatment plant during and after campaign have ranged from a high of 5.2 million gallons down to no volume. The city received no revenues in 1963-1964, whereas $746 was received over the 1962-1963 season. The total plant waste load ultimately discharged from the Findlay factory over the 1956-1964 period has averaged only 0.1 pounds BOD for each ton of sugar beets processed. This residual waste level is remarkably low and reflects considerable merit upon the factory and its waste treatment methods.

Lastly, the Findlay system has been examined by Force (38) for possible improvement. Two areas were indicated to be of particular significance:

1) Separate flume and condenser water recycling systems would serve to reduce the high flume water temperatures existing during October. A spray pond would be desirable on the condenser water circuit. In colder weather, the two systems could be combined, taking advantage of the heat content then desired within the flume waters.

2) The lime pond overflow should probably be eliminated from the circuit because of the many problems caused by high solids. Similar exclusion of sludge pond overflow would aid the circuit, although to a lesser extent.

The Betteravia, California factory was a straight-house operation processing about 4500 tons beets per day. A portion of the condenser water was used for lime mud slurrying and for diffuser makeup, and the excess was directed to the beet flumes. The spent flume waters were discharged into a 3-pond system, received treatment, and recycled back to the factory for reuse in the condenser system and the beet flumes. In essence, the Betteravia system was an integrated flume and condenser water closed circuit, however rigid control was lacking on other plant wastes. Even though pulp drying facilities were available, press waters, rather than being used in the diffuser were wasted to the lime mud pond. The lime pond in turn had continuous overflow to the receiving stream. Improvements could be easily undertaken at the Betteravia mill.

The merits of an integrated recycle system compared to separate flume water recirculation will depend upon conditions at the particular factory. With the typical integrated circuit, excess water buildup approximating 60 gallons per ton of beets processed may be expected during the campaign. Percolation and evaporation may reduce this volume. The British Columbia Research Council estimated that a 4000 ton per day factory may accumulate 32 million gallons of concentrated wastewater by the end of campaign. The excess water buildup must not only be continuously removed from the integrated circuit but furthermore, proper storage facilities must be provided during and following campaign and the accumulated volume eventually disposed of. If this wastewater was treated by trickling filtration on a continuous basis as the case at two British mills, the accumulated volume may be reduced to 7-10 million gallons. Alternate solutions are flume water recycling with separate discharge of condenser water, dry methods of conveying beets into the plant, or a combination of various measures, in-plant and treatment, to achieve desired waste load reductions (31, 34, 38, 43, 47).

2. Biological Systems

Many studies have been performed on the treatment of sugar beet wastes by biological means, including activated sludge, trickling filters, and other methods. In many cases, results have been obtained well beyond the pilot-plant stage, and full-scale trickling filters in particular, have proven successful in Great Britain and Europe. The sugar beet industry in the U.S. has conducted waste treatment research with emphasis on basic studies and new methods. However, the results already available in the literature should not be discounted. More information is needed on the adaptability of present biological methods to sugar beet wastes; pilot-plant and full-scale studies in this direction would be more than appropriate.

a. Activated Sludge

Three series of laboratory studies were conducted by the British Columbia Research Council to determine the feasibility of activated sludge in treating sugar beet wastes. One series was intended to provide projection data for aerated lagoons, the results of which are previously given in Section V D 2 of this report. The treatment units were maintained at a temperature of 71 ± 0.5°F. Of major importance was the conclusion that activated sludge could effectively reduce the organic load in waste flume waters by 93 to 97 percent. The maximum time required in fully adapting the floc to the substrate was less than 96 hours.

A second series of tests obtained on laboratory activated sludge units showed that bio-oxidation of sugar beet wastes was successful and initial BOD values of 135-2,000 mg/l could be lowered to 0-50 mg/l within 20-30 hours. Temperature was controlled at 73 ± 2°F. The third study consisted of aerating a single flume water sample received from each of 48 factories using 72-hour activated sludge treatment. Despite the limitations of the experiment, these results were also encouraging and showed residual BOD values below 100 mg/l for all but 10 mills. Of these ten, six mills had initial BOD values in the range of 1028-2709 mg/l BOD. Better control of the system and full adaption of the activated floc would have provided even lower residual BOD. It was concluded that flume waters from all the mills were definitely amenable to bio-oxidation by activated sludge.

The waste treatment system at the Hereford, Texas factory was evaluated with respect to present capacity and possible future needs. In this regard both activated sludge and trickling filtration were studied as potential means of pre-treatment superimposed upon the existing system. The experiments were conducted on the composite plant wastes before entering the existing waste stabilization ponds. The majority of these wastes originated as bleedoff from the flume water recycle system within the factory. It is noted that the Hereford recycle system was not a closed one. Only about 85 percent of the waters were recirculated in the system and the bleedoff was replaced by fresh water. The plant wastes were not precisely defined although BOD values were probably in the range of 650-800 mg/l and COD around 1,000-1,200 mg/l. The existing facilities at Hereford are described in more detail later in this report.

The bench-scale activated sludge experiments at Hereford provided data on COD removal as a function of COD loading, unit rate of COD removal as a function of COD concentration, oxygen transfer rates for the wastewater, and other operational factors. Within the range of 0.5-7.5 pounds COD/pound MLVS/day, the COD removals approximated 85 percent. The MLVS refers to the mixed liquor volatile solids, the level of which is directly related to amounts of active biological life in the system. COD removal as a function of concentration indicated a straight-line relationship within the range of testing. At 100 mg/l COD, the removal was 1.2 pounds COD/pound MLVS/day; and at 500 mg/l, 8.0 pounds COD were removed/pound MLVS/day. The oxygen uptake rate at 23°C. for the wastewater was 3.30/hr. compared to 6.95/hr. for distilled water, giving an uptake ratio of 0.475.

The activated sludge studies were significant in other respects. A strong tendency was noted toward the predominance of few bacterial species in the system. Sphaerotilis was present in relatively large numbers whereas protoza were nearly absent. Species imbalance was associated with high loadings and also occurred when the volatile solids level decreased below 1500 mg/l. Furthermore, the system was conducive to appreciable "washout" of bacteria. The observations gave no guarantee that filamentous forms might take over the system but on the other hand, offered no assurance that they might not. Although the rate of organic removal was high, the system tendency to lose species balance and settleability was not encouraging. The Hereford study in summary, showed the activated sludge system could produce good organic removals, but was rather easily upset. A system loading of 1 pound COD/pound MLVS/day with 3000-4000 mg/l MLVS was suggested. The difficulty at Hereford was that activated sludge would give too high an efficiency, when in fact, only pre-treatment was desired.

Nitrogen and phosphorous deficiency in biological waste treatment has been associated with various industrial effluents, and sugar beet waste appears to be one of these. Proper nutrients are necessary to support the growth and propagation of biological life within the system. Bacteria which are part of the system require about 12 percent nitrogen and 0.5 percent phosphorous in their makeup. Sawyer (56) in reference to biological systems has recommended a BOD:nitrogen ratio of

17:1 with a maximum of 32:1. The recommended BOD:phosphorous ratio was 90:1 with a maximum of 150:1. If nitrogen and phosphorous are lacking, the biological system and its treatment performance may suffer greatly.

The Hereford, Texas factory recognized the need for nutrient supplement by installing a nutrient feed station in its waste treatment system. The Hereford report emphasized that "no phase of Holly's (sugar company) biological treatment program is more important than proper nutrient supply." The nutrient feed station as part of the existing treatment facilities would also serve activated sludge or trickling filter units to be added in the future. Plant management has provided nomographs which describe the proper rate of ammonium nitrate and triple super phosphate that must be added to the wastewater depending upon its flow rate and COD concentration.

The nutrient requirements given above have direct and meaningful application to all biological systems whether activated sludge, trickling filters, stabilization ponds, aerated lagoons, and other. With this in mind, the South Platte River Basin Project collected special data in January 1964 from the Loveland and Greeley, Colorado factories, and these results are given as follows:

Factory Site	5-Day BOD mg/l	Org. N as N mg/l	NO_3 as N mg/l	Tot. P as PO_4 mg/l	BOD: N Ratio	BOD: P Ratio
Loveland, total plant wastes	609	0.1	0.1	7.5	3,050	250
Loveland, aeration field effluent	490	0.1	0.1	4.7	2,450	320
Greeley, main sewer wastes	---	0.0	0.0	11.2	V. High	230 (est.)
Greeley, lagoon effluent	772	0.2	---	6.1	---	390

The data array on Loveland and Greeley showed that the general nitrogen level was considerably lower than phosphorous. However, both nitrogen and phosphorous were relatively low in respect to BOD. Undoubtedly, the Loveland and Greeley effluents would require nutrient supplements for successful biological treatment.

Laboratory activated sludge units were also used in Great Britain, in this case for treating wastewaters received from a factory settling pond. Aeration periods varied from 6-24 hours, and operations were sequential consisting of aeration, settling, disposal of the supernatant, adding wastewater to the previously settled floc, and then repeating the process. The first three runs using aeration times of 6-17 hours provided BOD reductions of 48-83 percent; the active floc may not have been fully adapted in these runs. Five other runs using aeration times of 18-24 hours produced BOD reductions in the range of 89-95 percent. Initial BOD values in the above tests were around 400 mg/l. The report concluded that further studies would be undertaken to evaluate the activated sludge process as an alternative means to the trickling filter system in current use at British factories (6, 31, 32, 47, 49, 50, 56).

b. Trickling Filters

Trickling filters have found wide favor at a number of sugar factories in Great Britain and Western Europe. In the U.S., only two installations of this type are known to have been constructed. Consideration is given to past treatment results derived from laboratory and pilot-plant studies followed by the experience gained from full-scale facilities.

Pilot-plant studies were conducted at the Hereford, Texas factory to determine the feasiblity of trickling filters as a pre-treatment measure for the existing system. The installation consisted of a 30-foot high by 3-foot diameter tower filled with plastic media. No recirculation was provided since the filter was intended only as a roughening unit. The wastewaters were screened and settled prior to treatment, and the dosing rates were between 1 and 2 gpm/sq. ft. filter surface. The various tests gave a performance curve relating COD removal to the applied COD loading.

The results of the Hereford trickling filter experiments showed that 60 percent COD reduction was obtained with an applied load of 210 pounds COD/1000 cu. ft./day, whereas 33 percent COD removal was received at 750 pounds COD/1000 cu. ft./day. Preliminary design stipulated that the filter should remove about one-third of the applied load of 17,000 pounds BOD per day. It was noted that caustic dumps were troublesome during the study and caused some adverse effects upon the filter. The study concluded that the system would eventually stabilize at a higher performance level permitting about 50 percent increase in load with the same removal efficiencies shown above. The first cost of a full-scale filter was estimated at $125,000 with annual operating and maintenance costs approximating $1500. Hereford preferred trickling filters over activated sludge because the unit demonstrated more stable performance and the operating skills were less demanding.

Phipps (35) in Great Britain has suggested that trickling filters offer a logical means of treating the accumulated wastewaters resulting from the integrated flume and condenser water recycling system. The wastewater would be stored over the campaign in a large pond and drawn off for treatment at a relatively slow rate throughout the year. The average factory would probably require storage capacity of 20-30 million gallons. Phipps preferred a shallow rather than deep pond to take advantage of wind mixing and aeration. Research was conducted in this regard using a 20-acre lagoon and a percolating filter of 60-foot diameter by 6-foot deep. Wastes were diluted with river water when necessary giving an initial BOD of about 200 mg/l onto the filter. The monthly volume applied to the filter over 9 consecutive months of operation varied from 0.6 to 6 million gallons. Filter inflow ranged from 17 to 230 mg/l BOD content and the outflow from 7 to 71 mg/l BOD. The results showed when waste concentrations were reasonably high, the filter system produced BOD reductions from 70 to 90 percent.

A pilot-plant installation receiving municipal sewage from the city of Nampa, Idaho, together with processing wastes from the Nampa sugar mill was the subject of extensive study in December 1963. In general, about 20 percent of the total wastes from the factory after settling were admixed with the municipal wastes. The combined wastes approximating 2 MGD were treated on two filters each 130-foot in diameter by 4-foot deep connected in series and employing principles of high-rate recirculation. The filters were preceded and followed by primary and secondary settling. The sugar beet wastes before mixing demonstrated a varying strength of 275 to 625 mg/l BOD, with an average of 400 mg/l BOD. The hydraulic loading onto the filters was about 38 MGAD and filter recirculation ratios were between 1.7 and 5.0. Near the end of study, the treatment plant was receiving straight sugar beet wastes with no adverse effects.

Results of the Nampa investigation showed that sugar beet wastes were highly amenable to treatment over a wide range of loading onto the filters. The first-stage filter was safely loaded up to 4.5-5.0 pounds 5-day BOD/yd.^{3} filter/day including recirculation, and produced 65-70 percent BOD removal. First-stage efficiencies were based on the unsettled filter effluent. The second-stage filter loaded up to 2.0-2.5 pounds BOD/yd.^{3} filter/day including recirculation, produced 65 percent BOD removal. Second-stage efficiencies were based on the effluent after secondary settling. Overall waste removal averaged 95 percent and the final effluents were presumed in the range of 15-30 mg/l BOD.

Over the last 2 weeks of study, the Nampa pilot-plant received straight sugar beet wastes at filter loads of 2.0-2.5 pounds BOD/yd.^{3} filter/day including recirculation. Although BOD reductions remained high, the test period was considered too short in predicting the long-range effects of straight wastes on filter performance, particularly at the higher loadings. Although nutrient needs were not determined, phosphoric acid was continuously added to the process.

The high waste removals at the Nampa pilot-plant were apparently aided by high waste temperatures (95°F. or more), absence of inhibitory substances, the process design, size gradation of the filter providing a relatively high surface area, and the presence of municipal wastes. It must be concluded from the study results that the two-stage filter system in many respects would provide superior performance over a single-stage installation. The major objectives of the Nampa experiments were to demonstrate overall effectiveness and predict design and operating criteria for the new municipal treatment plant proposed at Nampa, Idaho. The current status of these new facilities is not known to the author.

The full-scale waste treatment system at the Bardney factory in Great Britain consisted of a single filter operating either at low or high-rate application and receiving settled factory wastewater. Flume waters were taken from a settling-storage pond and diluted with river water prior to filter dosing. The pond effluents varied in BOD concentration from 1239 mg/l in March decreasing to around 38 mg/l in October. The report on the Bardney factory provided monthly data on filter operation extending from January to December.

The Bardney results indicated that the wastewater temperature varied from 3-21°C. and filter loadings ranged from 0.07 to 0.77 pounds BOD/yd.^{3} filter/day with the average load around 0.4 pounds BOD. During the year 1955 the total waste volume receiving treatment was 38 million gallons. BOD reductions varied from 55-97 percent, with removal levels of 83 percent or higher occurring in 9 of the 12 months. Final effluent BOD values were not reported but apparently were in the area of 20 mg/l.

Other pertinent information was given in the British reports referring both to low and high-rate trickling filters. One reference was made to studies conducted by the Water Pollution Control Laboratory in Great Britain where it was shown that properly operated filters could consistently produce effluents with less than 20 mg/l BOD when the initial levels were between 105 and 180 mg/l. A second reference suggested that in starting up a filter, domestic sewage should be applied together with the industrial wastes, to reduce the time required for full filter adaption. Primary and secondary settling were considered essential, and it was further recommended that for every 100 mg/l BOD, the wastewater should contain a phosphorous equivalent not less than 1 mg/l. A third reference was made to Russian experiences where strong wastes of 4000-5000 mg/l BOD have been directly applied at low rates to a three-stage filter system giving 75-85 percent waste reduction.

In the United States, there have been two full-scale trickling filter plants specifically constructed for the treatment of sugar beet wastes. In both cases, however, treatment performance has been most disappointing. The following discussion relates the experiences at the Rupert, Idaho and Lewiston, Utah sugar factories.

At Rupert, Idaho, a more or less conventional trickling filter plant was completed in the summer of 1965 to provide treatment of wastes expected from the Rupert factory the following campaign. Lime mud slurry was separately impounded and all other factory wastes which comprised essentially the flume and condenser waters were directed to treatment. Design and operating criteria for the Rupert plant were believed derived from the pilot studies previously undertaken in 1963 at Nampa, Idaho. The Rupert facility consisted of a screen station with six vibrating screens in parallel, twin hydro-separators also arranged in parallel, followed by a primary settling tank, a single high-rate trickling filter, secondary settling tank, and a Kessener brush aerator installed on the effluent discharge canal. The hydro-separators with 20 minutes waste detention provided for removal of the heavier solids, and flows in excess of 5500 gpm through the separators were returned to the beet flumes. From the separators, the wastewater entered the primary clarifier approximately 120-foot in diameter, 10-foot in depth, and having a waste detention of about 2.5 hours. Unfortunately the treatment plant was grossly overloaded and only 3000 gpm of settled wastewater was subsequently applied to the trickling filter; the remaining 2500 gpm was discharged to the receiving stream. Sludges from both the separators and primary settler were pumped to a storage pond. The trickling filter approximated 200-foot in diameter, 10-foot in depth, and contained slag material of 2-6 inch size, however not uniformly distributed within the filter. The recirculation ratio was about 3:1 for this single-stage filter. Filter effluent was then received into the secondary clarifier, which appeared similar to the primary tank in size, and the final effluent was released to the stream.

The $450,000 treatment plant at Rupert failed completely in terms of providing a high level of waste removal. It is of paramount importance that the apparent and possible causes of failure should be thoroughly examined. Although in retrospect many reasons may be given, the major causes would seem to have been gross under-estimation of the processing rate and difficulty toward design and selection of treatment units. The design plans called for 3500 tons beets per day to be processed by the Rupert factory however during the very first campaign the average processing rate actually amounted to 6500 tons per day. Even further increase was expected for the next campaign--up to 7000 tons beets per day. Treatment plant overload was inescapable and drastic. Going back to the Nampa pilot studies, it was stated at that time that "provision of a second-stage filter . . . is necessary for two reasons: 1) during the periods of high loading rates and high strength incoming wastes, the first-stage filter operating alone, will not produce an acceptable effluent and 2) the process apparently undergoes a cyclic unloading . . . (and) is therefore necessary to have a second filter in operation to pick up the load from the first-stage filter when this cyclic unloading sequence occurs." Provision of a second filter at Rupert would have helped the situation.

Although firm data were not available concerning Rupert, it was estimated the hydraulic load onto the trickling filter approximated 25 MGAD and the waste load was in the order of 7 to 12 pounds BOD/yd.^{3} filter /day including recirculation. These applied filter loads were extremely high. Besides poor distribution of media, there was little or no visible biological growth on the surface of the filter. Of great importance, the steam and water vapor forming over the filter during cold weather retarded air downdraft tending to suffocate the bed. Provisions for inducing air undercurrents through the side and bottom of the bed possibly would have alleviated this condition. Furthermore, a skimming device preferably automatic, was greatly desired on the primary settler to remove the substantial accumulation of scum and grease present. Information obtained for Rupert indicated that the treatment plant was providing around 30-40 percent BOD removal for that portion of the sugar beet wastes receiving treatment.

The various conditions described above were observed principally during the 1965-1966 season and do not reflect changes since that time.

The second trickling filter was located at Lewiston, Utah, and as in the case of Rupert, innumerable problems and difficulties were experienced. Although the available information is somewhat incomplete, the Lewiston trickling filter was constructed around 1961 and intended for treating and recycling waste flume water from the Lewiston sugar mill. During the off-season the filter received various wastes from the factory holding pond.

The Lewiston facility consisted of a screen station, grit chamber, a mechanically-operated clarifier 90-foot in diameter by 10-foot deep, followed by a single filter 120-foot in diameter by 5-foot deep. Two and one-half hours waste detention was provided in the primary settler and part of the filter effluent could be returned to the clarifier. The treatment system was reported in 1963 to have three major defects. First, the overflow weir on the clarifier was above the side wall and the water surface was completely exposed to wind and weather action. Serious deficiencies in the trickling filter included a poor underdrainage system and improper media conditions. The underdrainage system experienced frequent flooding and required additional pumping capacity. The filter rock varied greatly in size from less than 2-inches to beyond 9-inches but even more important it was reported that trucks had been driven onto the filter in the process of placing the media. Compaction of the media and damage to the underdrains were thereby suspected. The reduction of media interspace would serve to minimize air circulation through the filter and retard biological growths. The Lewiston factory wastes were also indicated as nutrient deficient which may have caused even further difficulty in treatment.

The Lewiston filter was initiated too late in the 1961 season to develop adequate biological growth. The filter was re-activated in March 1962 using holding pond wastes. The results collected over March-May 1962 showed 0-30 percent BOD reduction with hydraulic and organic loads (including recirculation) of 4.7 MGAD and 6 pounds BOD/yd.^{3} filter/day respectively. Wastewater temperatures varied from 8-14°C. during April 1962. Through June 1962, the BOD removal increased to 40-60 percent with the applied filter loads around 3.5 pounds BOD/yd.^{3}/day. When the next campaign began on October 10, the filter was in very poor condition and major attention was devoted to re-establishing suitable biological growth. Through November 1962, the treatment plant provided BOD reduction in the range of 10-50 percent.

The advantages of two-stage filtration over single-stage were not present at both Rupert and Lewiston. The absence of a secondary clarifier at Lewiston in similar fashion was considered detrimental to satisfactory biological treatment. The Lewiston and Rupert plants were comparable in the respect that neither system was given the opportunity to develop the full potential of the waste treatment processes. These results were certainly not representative of good treatment performance expected from trickling filters (6, 28, 31, 32, 34, 35, 47, 57, 58).

c. Anaerobic-Aerobic Lagoons

Pilot-plant studies have been continuing at the Tracy, California factory since June 1965, applying the anaerobic-facultative-aerobic lagoon system in treatment of sugar beet wastes. The installation consisted of three ponds in series receiving part of the factory waste flume water plus some septic tank drainage. These wastes were settled prior to entering the ponds. Detention times varied from about 10-25 days in the anaerobic pond, 10-30 days for the facultative pond, and 10-20 days in the aerobic or algal pond. Over the first two years of study, the anaerobic, facultative and aerobic ponds were used respectively as the first, second and third units in series, but this sequence will be rearranged in future work. The major objectives of the study were to demonstrate the waste removal efficiencies of the system and to minimize odor in connection with this means of treatment. The system was evaluated with respect to varying feed rates and recirculation ratios upon organic waste removal, and the degree of odor control and microbial growth associated with the operations.

The most useful results were those received in September-November, 1966. During this period, influent BOD values generally ranged from 1200-1650 mg/l. In the first experimental run, the recirculation:feed ratio was 1:1, and the applied organic loadings were 1235 pounds BOD /acre/day on the anaerobic pond, 831 pounds BOD on the facultative pond, and 660 pounds BOD on the aerobic pond. Pond depths in this and the following runs were 15, 7, and 3-foot respectively for the anaerobic, facultative and aerobic units. The conditions of the first run represented an overall waste detention period of about 35 days and provided 70 percent BOD removal and 38 percent COD removal. The BOD concentrations from inflow to outflow were reduced from approximately 1200 mg/l to 350 mg/l. In the third run, there was no recirculation of treated waters, and the applied loadings were 1640 pounds BOD/acre/day on the anaerobic pond, 448 pounds BOD on the facultative pond, and 317 pounds BOD on the algal pond. Overall waste detention time was 70 days which provided 93 percent BOD removal and 77 percent COD removal. Correspondingly, the BOD concentrations were reduced from about 1650 mg/l down to 170 mg/l. The studies also included the enumeration of algae, purple sulfur bacteria, coliform and fecal streptococci bacteria present within the system. Efficient removals were achieved in regard to both coliforms and fecal streptococci organisms.

The investigators believed that the Tracy system with suitable modifications would demonstrate future improvements in waste removal efficiency. The previous work showed that the majority of waste reduction had occurred within the anaerobic pond whereas the other two ponds contributed only in minor degree. The low efficiencies in the facultative and aerobic ponds were attributed to a lack of algal growth which in turn was caused by heavy loading, improper mixing, or toxic elements that were present in the waste. Provisions will be made in future studies to overcome these difficulties and achieve full effectiveness in all three phases of the system. Nutrient additions may be made if necessary. The industry has commented that the system performed well with a marked reduction in odor. Lastly, it must be recognized this means of treatment may have definite limitations in cold climates, and additional studies will be necessary to prove its application to other regions of the country (40, 51, 52).

3. Biological-Recirculation Systems

The wastewater treatment system at the Hereford, Texas factory comprised two discrete treatment phases. The Hereford installation employed waste recycling, collection of all wastes, then followed by biological treatment. It must be noted that the Findlay, Ohio waste treatment facilities previously classed in this report under the recirculation-reuse system used similar treatment means, however in the case of Findlay all units were integrated into a single circuit. The Hereford system was inherently different from the various other treatment schemes. The Hereford plant has been referred to on earlier occasions within this report.

The one-million dollar waste treatment system was constructed simultaneously with the 24-million dollar Hereford factory. The expected rate of processing was 6000 tons beets per day. The treatment measures were intended to preclude any wastewater from entering the receiving stream. The Hereford system consisted basically of a flume and condenser water circuit with about 85 percent recycle, stabilization-evaporation ponds covering about 160 acres, and final disposal of wastewater onto company-owned agricultural lands. The flume and condenser water circuit served by a screen station, mechanical clarifier and sludge storage pond, is previously described in Sections V C 2 and V E 2 a of this report. Remaining process wastes from the factory were released to the lime mud pond. Overflows from the lime and sludge ponds were collected together with bleedoff from the flume circuit into a catch basin. This collection basin also received septic tank drainage and was fed nutrient supplements. The total contents of the catch basin were subsequently pumped to the series of stabilization ponds. The waste system was designed on the basis on 1000 gpm total plant wastewater, comprised of 725 gpm flume and condenser water bleedoff, 120 gpm sludge pond overflow, 145 gpm lime pond overflow, and 5 gpm each of boiler blowdown and septic tank drainage. Design plans called for composite plant wastes to contain around 660 mg/l BOD and 1000 mg/l COD.

The Hereford, Texas interests also included feedlot operations adjacent to the factory. Lagoons were provided to withstand a 3-inch runoff and effluent pumps were available for displacing routine feedlot wastes and runoff to the stabilization ponds. The six stabilization-evaporation ponds in series could retain up to 7-foot of wastewater which was twice the volume expected from the beet sugar processing campaign.

Although analytical results for the Hereford system were not found in the literature, general information was made available. Odors have been experienced from the main sewer line leading to the stabilization ponds and from the feedlot lagoons. The flume and condenser water circuit also demonstrated a tendency towards turning sour. The Hereford report commented that the wastewater recycle circuit was surely not intended as a biological treatment unit but nevertheless this reaction did occur. With the lack of aeration facilities, anaerobic conditions could be expected, resulting in the buildup of disagreeable by-products. Three corrective measures were proposed for the recycle circuit: 1) killing of the bacteria by chlorine or other chemical agents; 2) distressing the bacteria by adding lime or some metallic biocide; and 3) aerating the circuit by continuous blowdown or other means.

In regard to the main sewer and lagoons, air injection was suggested directly into the sewer to minimize odors enroute to the stabilization ponds. The feedlot runoff in the lagoons became septic about the second or third day, turning gray or black and then generating considerable odor. Prompt drawdown of these liquors was indicated as essential in overcoming this problem.

The six stabilization-evaporation ponds could be operated a number of different ways, series or parallel. The most feasible schemes were six-stage independent operation, three-stage control using cell pairs, or two-stage control. Operating depths in the above cases apparently ranged from 2 to 7-foot. Possible odors from the sludge and lime mud ponds could be minimized by maximum drawdown of the supernatants or adding copper sulfate or chromium reagents to the waste inflow (32, 40).

F. OTHER CONSIDERATIONS

Waste control and abatement implies certain action to be necessarily undertaken by industry. The British Columbia Research Council in its report to the Beet Sugar Development Foundation stated that "a broad spectrum of water reuse and waste disposal practices (exists) throughout individual mills of the beet sugar processing industry in North America. Utilizing the experience of mills in other geographic areas, those mills employing a lesser degree of pollution control at the present time may base future measures, as they become necessary on the experience of other mills. The time and place at which specific action is required, with regard to a specific mill and specific beet sugar processing wastes, will vary considerably. Answers are evident for many situations whereas some remain to be resolved."

Regarding the approach by industry, it must be noted however, the necessary measures undertaken too often are those which precisely match the minimum requirements expected by the regulatory agency, or in other cases, a lesser degree of control corresponding to the level understood to be tolerated by that agency. The greatest progress would seem to be in the area of those measures intended to return a profit or reach a "break-even" position. Indeed this should be the case, which further emphasizes that in-plant measures are probably more effective than waste treatment in contributing to a successful waste management program. Recognition by industry of the essential nature and overall consequences of water pollution would guarantee protection not only for present water uses but also future uses and our natural water resources.

1. Design, Operation, and Maintenance

A successful waste management program implies that there be a reasonably high level of proficiency in all aspects of design, operation, and maintenance, both within and without the sugar factory. Concerning this issue, awareness of the waste problem and a blending of positive attitudes are essential. A situation should be created whereby the necessary measures are made available and then used in attaining the highest level of waste control on a day-in day-out basis. Also it is important that much greater status recognition be given to the entire area of waste abatement.

Most industry, and sugar beet processing is no exception, partakes in waste abatement. On design of waste control measures much has been done by the beet sugar industry, but also much remains. Too great a reliance is sometimes placed upon standardized treatment units. It is suggested that a qualified industrial waste engineer be attached to the permanent staff of the sugar processing company and be given ample opportunity to support the design in its entirety. The engineer, whether in the consulting or staff position, should be well-versed in the area of assignment, have some degree of vested interest in the project, supervise if necessary, and follow-through on all essential elements leading up to and beyond job completion.

The company must provide realistic estimates on factory operation for proper planning and design of treatment works. The criteria or guidelines should be reasonable in all cases. Items should not be deleted or units undersized unless there is certainty that no decrease in waste treatment performance will thereby result. By-pass structures should be designed to serve only in true emergency and the plans should call for intercepting various spills and unintentional waste discharges and returning these to the waste treatment system. Excess capacity is important and should be incorporated into the treatment units. Proper compaction and construction of treatment lagoons and holding ponds but particularly of the surrounding walls are necessary. If construction criteria are lacking for earthen structures, it is suggested that the criteria for storage ponds in the uranium milling industry may be used. Many more aspects of proper design could be elaborated upon but are not feasible within the scope of this report.

Once the waste control and treatment facilities are in place, the operation and maintenance of these facilities are all important. Each and every device and procedure intended for waste abatement should be given a status of importance near equal to the process operations.

Experience indicates too often the waste treatment system is relegated to the background and made to function almost solely on its own capabilities. Only when major trouble develops, will it then receive attention. A new philosophy is needed not only in the industrial waste field but also in regard to municipal wastes, which would upgrade waste treatment to the level of a precise and professional enterprise. This concept is thought both desirable and possible by many authorities. Also since industrial wastes are created by industry and presumably, the manpower of the regulatory agencies will never be sufficient to assess the efficiency of each and every industrial treatment installation, the latter task in very large part ultimately must become the responsibility of industry.

The sugar beet companies and each mill having extensive control and treatment facilities, should have an adequate staff whose services would be devoted to the design, operation and maintenance of these facilities. Possibly some time would be available for research. A qualified industrial waste engineer could be expected in charge of activities. There may be some flexibility in numbers of supporting personnel and it is presumed that supplementary forces would be provided as needed.

The importance of administrative control and plant records was emphasized in relation to the wastewater control program at Hereford, Texas. Without proper administration it was pointed out that the program must suffer serious shortcomings. Therefore, a logical division of responsibility and organized approach were found necessary. The Hereford report did not offer any detailed thinking in this regard however mentioned general duties of the Superintendent, Chief Mechanic and Chief Chemist that would fall under this program. These thoughts lead to the concept of a successful program requiring that lines of authority and responsibility be fully delineated and that each and every person clearly understand his explicit role. The Hereford report also recognized the importance of plant records and a prescribed format of data gathering and recording was considered essential to the program.

The many improvements that are possible in operation and maintenance of waste control and treatment facilities cannot be satisfactorily covered in the present report, but it is hoped that other groups may expand upon this thinking in future studies. In final analysis, no amount of money devoted to treatment is worthwhile unless proper logic and care have been used throughout the design and construction phases and furthermore, these facilities are operated and maintained in a truly satisfactory manner (31, 32).

2. Research

Concerning research, it is true quite often too much can be said, and at other times not enough. From the known information, it is more than clear that all sugar beet wastes can be adequately treated by the technical means available. The problem remaining is one of economics. The conjecture that certain wastes cannot be treated and must await further research would not appear justified except in the economic sense. However additional research cannot be disputed in view of improvements needed both in process and treatment and also in minimizing overall costs. Other forms of competitive waste treatment may be found in the future, but most likely these forms will represent modifications of existing treatment methods.

Research is necessary to secure the highest economies and to deliver an even better product to the receiving stream. The British Columbia Research Council has been performing continuous research work for the Beet Sugar Development Foundation. Applied research is being carried out at Tracy, California, similar studies will start soon at Longmont, Colorado, and undoubtedly there are other investigations in progress. All this represents an important step in the right direction. Again, much more can be done, and the pertinent suggestions previously given by the British Columbia Research Council would constitute a springboard by evaluating and converting the best suggestions into actual practice.

Worthwhile and challenging research could be performed in the specific areas of: 1) dry-disposal of lime cake; 2) transporting the beets to the factory by dry-handling techniques; 3) eliminating waste loads from flume waters by treatment or, even more important, by not permitting these loads to come initially into contact with the waters; 4) new and improved in-plant waste control measures; 5) the best means of handling excess condenser waters; and 6) modified forms of biological treatment which may be truly adaptable to sugar beet wastes, particularly spent flume waters. Activated sludge, trickling filters, aerated lagoons, and other methods should be studied in detail to fully determine their legitimate role in sugar beet waste treatment.

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