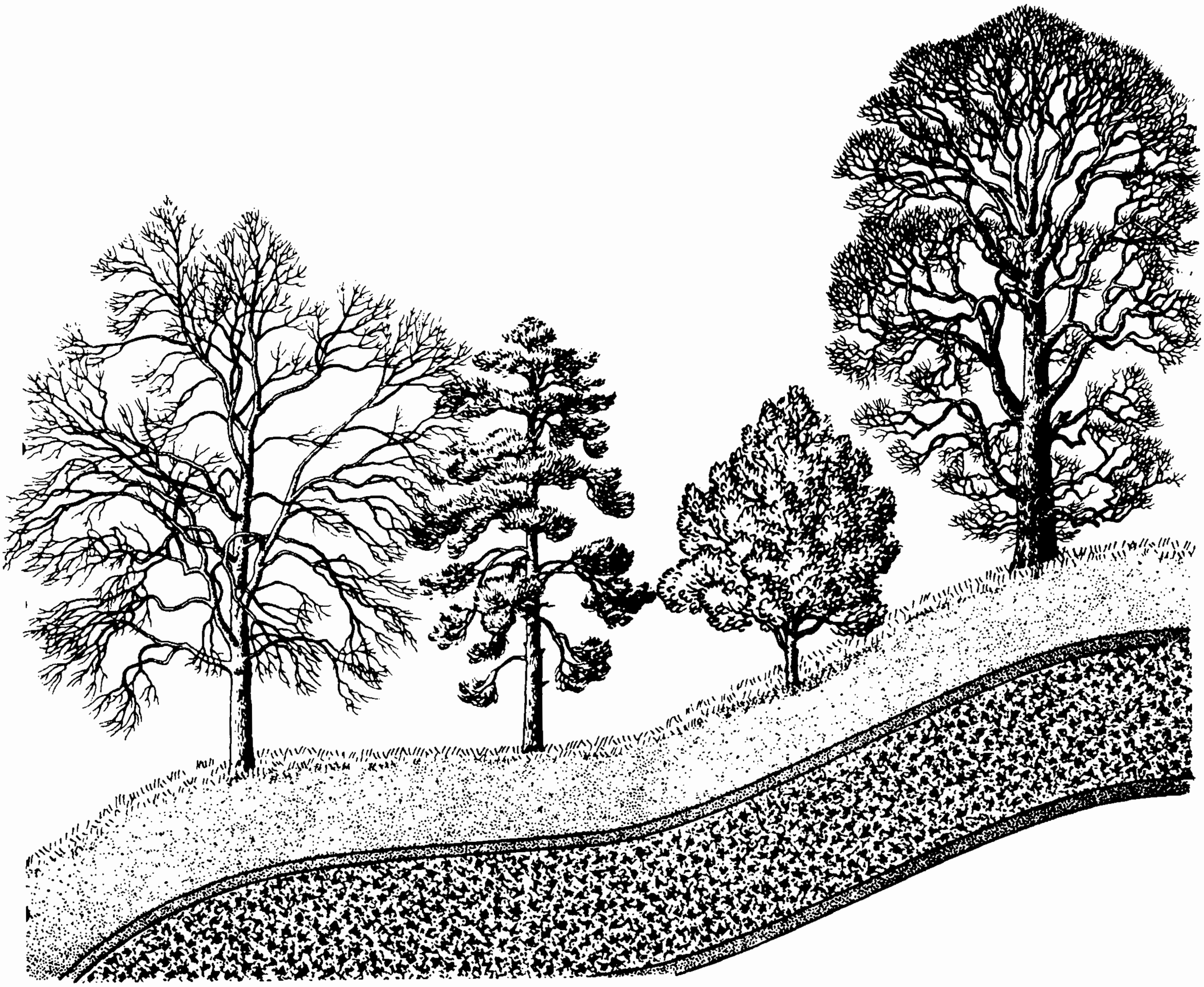
DISPOSAL OF SEWAGE SLUDGE



INTO A SANITARY LANDFILL

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This final report (SW-71d) on work performed under Federal solid waste disposal demonstration grant No. S801582 to the City of Oceanside, California, was prepared under the direction of RALPH STONE

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FOREWORD

This report describes the results of a three-year demonstration study of the disposal of liquid sewage sludge and septic tank pumpings into solid waste at a sanitary landfill. Bench-scale laboratory studies were conducted to determine the moisture-absorbing capacity of typical solid waste constituents and to establish characteristics of admixture with various sludges. The composition and quantity of solid waste produced in the City of Oceanside were determined by quarterly waste samplings and waste collection vehicle weighings.

Pilot plant lysimeters were employed to investigate the effects of sewage and septic tank sludges on solid waste temperature, decomposition, leachate, settlement, insects, odor and gas characteristics. Three large field lysimeters were built at the City of Oceanside, California municipal landfill, each holding one week's production of all municipal solid waste and sewage sludge. The field test cells were lined with a 10-mil polyethylene membrane to collect the leachate for measuring and sampling. Full-scale demonstration landfill operations studies were conducted at the City landfills -- initially with limited sludge disposal one day per week, and with 100 percent sludge disposal later in the study.

The large field lysimeters were monitored for leachate, temperature, gas, compaction, settlement and waste decomposition (as determined by core sampling). The full-scale landfill disposal of sludge was monitored for runoff, leachate, equipment operating efficiency (time and motion studies), odor, vector problems, blowing litter, and weather conditions (rainfall, temperature, wind and evaporation).

Results of the study indicated that Oceanside solid waste has sufficient ability to absorb moisture without producing runoff. Full-scale sludge disposal at the Oceanside landfill produced no leachate and was economically feasible. Benefits of full-scale disposal included increased landfill compaction, greater density, and reduced blowing of litter and dust; problems included odors following raw sludge or septic tank pumpings disposal (not recommended unless special protection measures are provided), and bird foraging.

The report describes the sanitary landfill operating and design factors for disposing digested sludge and its effects on the sanitary landfill and environment. The demonstration study was supported in part by the U.S. Environmental Protection Agency under Grant Number S801582.

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SUMMARY

A. Study Background

1. Objectives and Scope. This report describes the results of a three-year investigation of the environmental and economic effects of disposing liquid sewage sludge and septic tank pumpings into a sanitary landfill. The objectives of the study were to determine: 1) the capacity of solid waste to assimilate the moisture in liquid sewage sludge and septic tank pumpings; 2) the significant parameters affecting that capacity; 3) the optimum means for nuisance-free admixture of liquid sludge with solid waste in a landfill; 4) the effects of combined liquid sludge-solid waste disposal on the environment, landfill equipment, operating efficiencies, and personnel performance; 5) the effects of liquid sludge on landfill compaction and solid waste decomposition; and 6) the most economically feasible methods for dewatering, transporting, and disposing liquid sludge.

The three-year study included laboratory evaluations of water absorption by solid waste, pilot-scale simulation of landfill conditions, full-scale field test cells for controlled landfill simulation, full-scale demonstration of liquid sewage sludge disposal into a sanitary landfill, and characterization of the sewage sludges and solid wastes generated by the City of Oceanside. A special nationwide survey of the disposal of sewage sludge and septic tank pumpings into sanitary landfills was made by contacting responsible State public health authorities and municipal landfill managers.

2. Description of the Study Area. Oceanside is located along the Pacific Ocean coastline in northern San Diego County. In 1970, the City population was 40,494; it is projected to increase to 75,000 in 1980 and 109,000 in 2000. The climate is moderate with average temperatures (F) generally ranging from a winter low in the 50's to a summer high in the 80's, and a mean annual precipitation of about 12 inches.

All the liquid sewage sludge used in the demonstration was derived from the City of Oceanside's three sewage treatment plants, two of which are activated sludge plants, and the third a primary plant. Field tests were conducted at the City of Oceanside municipal sanitary landfill. Laboratory and pilot-scale studies were conducted at Los Angeles-based laboratories, using Oceanside liquid sludge samples and solid waste composition. Prior to September 1972 the Oceanside landfill working face was not covered daily with soil. Operation as a sanitary landfill, with daily soil cover, commenced in September 1972.

B. Sludge Disposal Practices.

1. Current Disposal Problems. Federal regulations (1971) have established strict limitations on disposal of sewage sludge into water bodies. This is forcing many municipalities to seek alternative methods for the processing, transport, and ultimate disposal of sludges. Sludge processing represents from 25 to 50 percent of the total

capital and operating costs of municipal sewage treatment plants. In many cases, ultimate sludge disposal requires dewatering, which accounts for a significant fraction of the total sludge disposal costs. In urban areas, the need for environmentally acceptable and economically feasible methods of sludge management is acute. The lack of suitable nearby disposal sites results in additional costs for transport.

The combined disposal of digested liquid sludge with solid wastes into sanitary landfills appears to have considerable promise. This alternatitive can reduce the number of waste disposal locations and eliminate costly sludge dewatering.

2. Nationwide Surveys of Sludge Disposal Into Landfills. Nationwide questionnaire surveys of State Public Health Departments and local landfill managers were completed in 1971. The objective was to assess the state-of-the-art for sewage sludge and septic tank sludge disposal into sanitary landfills, as well as to determine existing problems and authoritative opinions.

Of the 50 State Public Health Departments surveyed, 26 responded and 24 provided answers to most or all of the questions. Landfill disposal of sewage or septic tank sludge was permitted by State regulations in 80 percent of the responding States. The Health Departments identified the following problems associated with landfill sludge disposal: increased leachate production from liquid sludge; odor; adverse public opinion; equipment damage and compaction difficulties; nuisance and potential spread of pathogens by vectors; and difficulty in burying sludge. Four of the responding States indicated no known problems. Respondents' ratings of potential environmental hazards indicated they anticipated little to moderate hazard from landfill disposal of either type of sludge; more hazards, however, were expected from septic tank pumpings than from sewage sludge.

Of 122 responding landfill managers from 475 cities contacted, 30 percent indicated that sludge disposal was permitted at their landfills. Septic tank sludge represented less than one-half of one percent of the total sludge quantity of 537.4 million gal per year reported admixed into 24 landfills. Landfill managers also anticipated more problems and hazards with septic tank sludge than with sewage sludge landfill disposal.

A separate nationwide survey completed by Ralph Stone for the American Society of Civil Engineers, Sanitary Engineering Division, Solid Waste Research Committee in 1962 indicated that 19 percent of reporting landfill managers permitted disposal of sewage and septic tank sludges.

C. Oceanside Solid Waste and Liquid Sewage Sludge Characteristics

1. Solid Waste Characteristics. A sample of the solid waste produced in the City of Oceanside was obtained by using random numbers to select one percent each of the single-family residential, multiple-unit residential, and commercial stops for special

collection. Samples were taken during each of the four quarters of 1971 and hand-sorted into the nine standard categories with subcategories for absorptive materials. The average moisture content for the four quarterly samples was 25.1 percent, dry weight, and the average organic content was 61.2 percent, dry weight. Of the total waste sampled, 60.7 percent was classified as moisture-absorbing material and the remaining 39.3 percent as nonabsorbent.

Once each quarter for six consecutive collection days during 1971, all the Oceanside Waste Disposal Department collection vehicle loads were weighed. The average daily solid waste quantity collected was about 85 tons Monday through Friday, and 25 tons on Saturday. Total solid waste collected during 1971 was estimated to be 24,000 tons. In 1972, a platform scale was installed at the landfill.

Throughout a one-week, six-day test period each month, all vehicles disposing solid waste into the Oceanside manicipal landfill were counted. Of the total of 3,175 loads counted, 1,153 or 36.2 percent were from private vehicles; 1,229 or 38.7 percent were from the Oceanside Waste Disposal Department; and the remaining vehicles were from other City Departments. Demolition waste loads totalled 431 or 13.6 percent of the latter category.

2. Sewage Sludge Characteristics. The wet-weight solids contents of liquid digested sludge produced at each of the three City of Oceanside municipal treatment plants was: La Salina Plant, two-stage digester mixed primary and secondary sludge of 3.9 to 5.4 percent; Buena Vista Plant, one-stage digester mixed primary and secondary sludge of 2.3 to 11.2 percent; and San Luis Rey Plant, one-stage digester primary sludge of 3.3 to 8 percent. During 1971 the total quantities of liquid sludge hauled for disposal from each plant were: La Salina, 1,000,650 gal; Buena Vista, 738,700 gal; San Luis Rey, 542,000 gal. Total production was thus 2,281,350 gal.

D. Solid Waste Water Absorption Studies

1. Water Absorption Capacity of Solid Waste. Laboratory tests were made to determine the moisture-absorbing capability of particular components normally found in solid waste. Triplicate samples of solid waste were weighed, immersed in water for varying periods, then removed and weighed again. Duplicate samples were weighed, oven-dried, and reweighed to determine their dry weight. Newsprint, miscellaneous types of paper, cardboard, grass, leaves, plant trimmings, and food scraps all reached maximum absorption (saturation) within 80 minutes after water immersion. Wood blocks did not reach saturation after 200 hrs, but textiles reached saturation within 10 minutes. The water absorption to saturation capacities in percent of dry weight for each waste category tested were: newsprint, 290; cardboard, 170; miscellaneous paper, 100 to 400; leaves and grass, 60 to 200; tree and shrub prunings, 10 to 100; food waste, 0 to 100; textiles, 100 to 300; and plastics and inorganics, 0. Based on these results, the expected in-situ moisture absorption capacity of all Oceanside solid waste as-received at the municipal landfill would range from 60 to 180 percent (0.6 to 1.8 lb of water per 1.0 lb of dry weight solid waste) on a dry weight solid waste basis. This would be

equivalent to 48 to 145 percent (0.48 to 1.45 lb of water per 1.0 lb of solid waste) on an as-received wet weight solid waste basis.*

2. Sludge Retention Capacity of Oceanside Solid Waste. Initial tests were conducted in 13 pilot test drums to simulate the capability of solid waste of Oceanside composition to retain liquid sewage sludge. The sludge moisture saturation capacities of the test drums ranged from 0.43 to 2.1 lb of sludge per 1.0 lb of solid waste wet weight, with 10 drums falling within the 1.0 to 1.7 lb range. This range is equivalent to 0.57 to 2.72 lb per lb on a dry weight basis. The results indicate that the actual sludge retention capacity of Oceanside solid waste fell in the upper half of the expected range of absorption.

The ratio of liquid sludge to solid waste production in the City of Oceanside was found to be in the range of 0.50 to 0.61 lb of liquid sludge to 1.0 lb of solid waste (dry weight); this would be in the low range of predicted absorption capacity of the solid waste. Field tests conducted at the Oceanside landfill during 1971 and 1972 with a liquid sludge to solid waste ratio of 0.5 to 0.61 lb to 1.0 wet weight produced no observed leachate over the course of the study, thus indicating complete absorption.

3. Water-Holding Capacity of Soils. Water saturation results primarily from the mechanism of entrainment between solid particles rather than from absorption within particles. Water absorption tests run on typical fine sandy loam soil used as cover material at the Oceanside landfill indicated an average saturation value of 42 percent, dry weight.

E. Septic Tank Pumpings Evaluation

A literature survey, pilot tests, and a technical evaluation were completed of the feasibility of disposing septic tank pumpings into a solid waste sanitary landfill. It was found that enteric "raw sewage type" pathogens were common in septic tank pumpings. Biological organisms that have been identified include the following: bacteria--*E. coli*, shigella, salmonella, fecal streptococci, typhoid and cholera; viruses--poliomyelitis, coxsackie, infectious hepatitis, influenza, reo, and adeno; protozoa--*Entamoeba histolytica*; and helminthiasis and various species of tapeworm.

The common vectors for transmission of the pathogens at landfill sites include: direct human contact during disposal or working the solid waste; and vermin and insects that may transmit pathogens (houseflies, cockroaches and mosquitoes are responsible for transmitting diseases such as amoebic dysentery, cholera, coxsackie, infectious hepatitis, polio, shigellosis, typhoid and paratyphoid fever, and worm infestations). Transmission also may occur by drinking polluted surface water and groundwater, and by direct or indirect contamination of other animal life (sea gulls, rats, etc.).

* Absorption capacities given are for absorption of additional moisture above the initial as-received wet weight moisture content.

Although the common sewage sludge digestion process can remove or debilitate 90 to 98 percent of the pathogens, the septic tank process is relatively ineffective. Results of Oceanside core sample analyses indicate that gas and high temperatures in sanitary landfills result in an environment sufficiently antagonistic to destroy most enteric indicator bacteria such as fecal coliform, Pseudomonas aeruginosa and fecal steptococci. In leachate from Oceanside Cell 1, fecal coliform were 3,000 MPN nine days after filling, 300 MPN 21 days after filling and negligible 28 days after filling. The viability and survival rates for virus in landfills are unknown. Several studies including the aforementioned core sample bacterial analyses indicate that coliform bacteria may seldom be found in sanitary landfill soils or in landfilled solid waste below four-foot depths, and rarely below seven feet. Reports indicate that coliform entering groundwater granular stratums do not survive filtration beyond a 50-yard distance from point of entry. E. coli can be removed through filtration through as little as three feet of loam or other less permeable soils.

Septic tank pumpings can present severe odor problems and fly vector attraction problems. The 1971 national survey of landfill practices previously-cited indicated that odors and pathogenic organisms were the major operation concerns. Personnel health risks can be minimized when disposing septic pumpings into landfills by the following procedures: providing protective clothing and minimizing exposure of personnel to landfill environments; constructing storm drainage, runoff and leachate underdrain control facilities to isolate the landfill from most water entry, and collect leachate for return to sewers or other treatment; admixing septic tank pumpings with solid waste in a ratio (0.5 lb pumpings per 1.0 lb solid waste dry weight) low enough to insure complete absorption; and covering at least daily with a minimum of six inches of moist, well-compacted soil to bury the wastes and control vectors.

F. Pilot-Scale Simulation of Landfill Conditions

1. Study Design. Pilot-scale tests were conducted at Los Angeles-based laboratories using replicated solid waste compositions found in Oceanside and the representative liquid sewage sludges obtained from the three Oceanside sewage treatment plants. Domestic septic tank pumpings were obtained from Los Angeles sources. The pilot tests were conducted in eighteen 55-gal drums to study, under controlled conditions, the behavior of various combinations of liquid sewage sludge, septic tank pumpings and solid waste compositions with respect to: absorptive capacities of solid waste for liquid sludge, septic tank pumpings and water; characteristics of leachate generated by the various admixtures; decomposition; and environmental impact in terms of leachate, odor, fly and insect propagation, and gas generation. The quantity of wet weight solid waste placed was 100 lbs in Drum 1 and 80 lbs in Drums 2 through 18. The initial compaction was applied via layers in 14 drums and once en masse in four drums to simulate two methods of landfilling. Initial wet weight waste density in Drum 1 was 22 lb per cu ft; in Drums 2 through 18 density varied from 12.4 to 22.1 lb per cu ft. Two of the drums received only water, two were dry controls, and two were subjected to forced aeration (for five minutes every hour, air was provided at 5 Standard Cubic Feet per Minute (SCFM).

With the exception of the aerated drums, each drum was sealed with an airtight cover, and all were exposed to the ambient environment in Los Angeles (temperatures of 45 F to 95 F).

2. Absorption Test. Liquid sewage, septic tank sludges, and water were added to each drum over a 10-day period until saturation was indicated by the onset of leaching. Before saturation, the quantity of liquid added to each of 13 drums used in this test ranged from 0.5 to 2.72 lb liquid per lb of dry weight solid waste with an average of 1.74 lb per lb. Viscous digested sludge appeared to be absorbed by the solid waste more easily than water or septic tank sludge.

3. Leachate Generation. After the absorption test, water was added to 16 drums (excluding two dry control drums) at a rate of one gal per working day--daily for two weeks and then revised to 3 gal every three days, thus maintaining the gallon per day rate. This rate of water addition simulated 36 in. of cumulative rainfall over 59 days on the surface area of the test drums. The water application rate was then reduced to 3 gal per week from the 59th day to the sixth month, which represented a rate of 94 in. per year. After 6 months the water application rate was further reduced to 3 gal per month, representing a rate of 22 in. per year. The total water applied to each drum (excluding two dry controls) was 90 inches. The resulting leachates were collected and the volume determined after each water application. Every two weeks leachate samples were collected for laboratory analyses (including pH, conductivity, turbidity, and BOD_5) from which 50 ml was accumulated to form a composite for other detailed analyses (of pH, conductivity, nitrate, chloride, total phosphate, sulfate, fluoride, organic nitrogen, iron, copper, lead, mercury, chromium and barium).

The total quantity of water added per lb dry weight of solid waste (and dry sludge solids where applicable) varied from 14 to 20 lb per lb. Two moisture content determinations were made on each of the test drums one and two months after the saturation tests; three out of 15 drums showed increased moisture contents, and the remainder decreased or were unchanged. A final moisture content determination two years after the saturation tests indicated increased moisture content in all but two drums.

4. Leachate Characteristics. Analyses for BOD_5 indicated a rapid increase to peak values within 100 days of sludge/water application and a steady decrease thereafter up to 260 days. The maximum BOD_5 levels were in the range of 350 to 4,400 mg/l. The initial increase in BOD_5 may be attributed to rapid breakdown and entering into solution of complex organics in the solid waste and sludge. The subsequent decrease in BOD_5 may indicate a gradual depletion of readily soluble organics from bacterial oxidation.

The BOD_5 values for the two forced-aeration drums followed the same increasing value trend as the anaerobic drums, but decreased much more rapidly after peaking. This was attributed to the more rapid oxidation of organics in the presence of excess oxygen. The BOD_5 values in all drums stabilized below 60 mg/l between 100 and 300 days after filling. No correlation was observed between the quantity of water added and BOD_5 stabilization; however, it was evident that intermittent wetting and drying with more than 11 lbs of water per lb dry wt of solid wastes over a 300-plus day period greatly reduced the leachate pollution constituents (< 60 mg/l BOD_5).

The color of the leachates initially was black or grey in 12 drums, and yellow or tea color in three drums. Most leachates were opaque. No distinction in leachate color was detected between drums receiving only water and those with sludge. The color changed over time and after 190 to 250 days it was a clear yellow or straw color. Two grab samples of leachate from the old Oceanside landfill were grey and semi-opaque in appearance.

Leachate turbidities followed much the same increasing-then-decreasing trend of the BOD_5 values. No correlation was evident between turbidity and BOD_5.

Leachate conductivity measurements also exhibited the same increasing-decreasing historical trend as BOD_5 and turbidity. Correlation between conductivity and turbidity was found to be insignificant.

A comparison of leachates from three sources - the pilot test drums, a full-scale field test cell (Cell 1) constructed at the new Oceanside landfill and filled with mixed digested sewage sludges and solid waste, and two grab samples of leachate from the old landfill indicated the following: the maximum BOD_5 value in Cell 1 (19,600 mg/l) during the first 211 days after filling was four times greater than the maximum test drum leachate BOD_5 (4,300 mg/l); the pH of the drums ranged higher (5.0 to 8.6) than both the landfill leachates (5.1 to 5.2) and the Cell 1 leachate (4.6 to 5.9); turbidities were in the same general range; conductivities in the test drums were in the same range during the first 100 days after the drums were filled, but thereafter drum conductivities were less than one-half the conductivities in the landfill and the Cell 1 leachates; odors were similarly sour and septic up to 100 days after the drums were filled, after which the drum leachate odors became earthy and weak.

A comparison of "residual" test drum leachate occurring several weeks after water additions and "fresh" leachate occurring immediately after water addition showed that "residual" leachates had greater BOD_5, turbidity and conductivity, and lower pH values.

Analyses were made of leachate composites accumulated during 1971, 1972, and 1973 for CO_2,chlorides, phosphates, calcium, total nitrogen, nitrates, iron, copper, lead, zinc, magnesium, chromium, manganese, fluorides, barium, sulfates, conductivity, pH, and turbidity. The results showed no trends that were attributable to the type of sludge applied to each drum. Concentrations of lead, chromium, copper and manganese were negligible.

5. Gas Generation. Gas samples taken from each drum every two to four weeks were analyzed for CO_2, O_2, N_2, and CH_4. Due to introduction of excess air into the space in each drum above the level occupied by the sludge-waste admixture, the early results were inconclusive. The two forced-aeration drums contained only air,

except on two occasions when the blower was inoperable and methane was detected. Some aerobic decomposition occurred in all the drums which was indicated by the presence of O_2 and generally low concentrations of CH_4 in all drums. This resulted from air entrapment in a void space between the drum covers in 1971, which was only partially corrected by adding polyethylene seal covers in 1972.

6. Compaction and Settlement. Test drum solid waste was compacted every two weeks by dropping a 200-lb weight twice from a height of 1 ft above the waste surface in each drum. All of the drums indicated an initial rapid settlement during the first 20 to 50 days after filling, with the exception of the high-density Drum 1. After 200 days, settlements ranged from 40 to 65 percent of initial volume in all drums except Drum 1 (30 percent in 200 days and 40 percent at 300 days) and Drum 12 (75 percent). Negligible settlement occurred after 250 days. Drum 1 was initially 32.5 percent greater in density than the other drums, which probably accounted for its slower settlement. No significant differences in settlement rate were observed for the two aeration drums, while the two dry control drums tended to settle faster than several wet drums. Apparently, settlement was random, excepting Drum 1, indicating that dense sludge-waste mixtures compact more slowly and to a lesser degree than less dense mixtures such as the dry controls.

7. Percolation. Percolation tests were performed to determine the time-rate of leachate volume flow in the test drums. For Drum 1, initial flow rate (0.18 gal per hr) and total leachate were significantly less than for all other drums. Comparison with Drum 9 (0.5 gal per hr) and all other drums (1.38 to 1.5 gal per hr or less) indicates the effect of high sludge-waste densities on inhibiting leachate flow. No cause was determined for the behavior of Drum 9.

8. Temperature. Temperatures measured 6 in. below the surface of the sludge-waste mixture in Drums 6 through 18 indicated a rise during the first 90 days after filling, from a range of 76 F to 84 F, to a peak range of 85 F to 92 F. The temperature in these drums then decreased steadily thereafter to a range of 45 F to 68 F after 200 days. Temperatures in Drums 1 through 5 (filled 50 to 55 days earlier than the others) reached the same temperature ranges on the same dates, peaking 155 days after filling and reaching the lower range 250 days after filling. This indicated that temperatures in all drums followed ambient air temperature cycles; significant thermophiloc bacterial effects were not encountered. This was due to a lack of insulation and the small mass to large surface area ratio of the drums; whereas in a full-scale landfill, there is a relatively large solid waste mass to small surface area ratio and relatively good insulation.

9. Odors. Drums filled with solid waste or with water and solid waste rapidly developed odors characteristic of landfills (decaying garbage). In other drums, a septic or sulfide odor occurred in intensities related to garbage smells varying from complete masking in two drums receiving raw primary sludge to partial masking in drums receiving mixed digested sludges. The drums with raw primary sludge emitted the strongest septic odors.

Odors from all drums were strongest during the first 90 to 110 days after initial liquid applications and became increasingly similar in type. After 130 to 170 days, scents in all but one drum changed to a moderate barnyard or compost odor, and after 150 to 205 days, smell: were a negligible compost and earthy-type.

Odors in the drum leachates followed essentially the same trend but were more rapidly stabilized than the odors in the drum solids.

10. Molds and Plant Growths. Mold and plant growths were observed in all but three drums from the first month through the twelfth month. No significance could be attributed to growth in any drum other than an extremely large colony in Drum 1 that covered up to 30 percent of the sludge-waste surface area, compared to a maximum coverage of less than 5 percent of the surface area at one time in the other drums.

11. Insects. Flies, spiders, ants, and sow bugs were observed; of these, flies were by far the most numerous, occurring in groups of up to 200 in one drum at a time. Only small flies commonly found in sewers, septic materials, or decaying organic matter were observed. Minute black scavengers (Scatopsidae), fungus gnats (Mycetophilidae), moth or filter flies (Psychodidae) and Diptera larvae were identified. The fly population was negligible in 1972 due to the addition of the polyethylene drum seals which restricted fly travel into and from the wastes in the drums.

12. Leachate Constituents. The quantities of constituents leached from the drums were determined in terms of lb of constituent per lb of dry weight solid waste and sludge solids in each drum. Quantities of major constituents leached from the drums varied as follows in lb per lb: BOD_5 - 1.01 to 11.1 $(10)^{-3}$; magnesium - 1.2 to 3.3 $(10)^{-4}$; iron - 3.3 to 19.1 $(10)^{-6}$; zinc - 3.8 to 11.8 $(10)^{-6}$; sulfate - 0 to 17.3 $(10)^{-4}$; phosphate - 1.1 to 17.5 $(10)^{-6}$; and nitrate - 3.9 to 292 $(10)^{-6}$. No correlation was found between type of material in each drum and quantities of leached constituents.

13. Comparison of Control Drums with Drums Receiving Sludge. The major differences between the wet control Drum 17 and other drums receiving sludges were: the control drum leachate pH range (6.3 to 7.2) was generally higher and narrower than for drums receiving sludges (sewage sludge and septic tank pumpings); and gas analyses showed CO_2 and CH_4 concentrations in control drums to be in the low range of drums with sludges. No differences were observed in temperature or settlement between drums with sludges and the controls. The major detectable effect of adding sludges to solid waste in the drums was the production of a more acidic leachate.

G. Controlled Field Test Cell Simulation of a Sanitary Landfill

1. Test Cell Design. During January-February 1972, three test cells were constructed at the Oceanside landfill and filled to about a 13-ft depth with solid waste and admixed liquid sewage sludges. A 10-mil polyethylene membrane liner was placed on the bottom of each cell and covered with 8 in. of loose sandy soil. A sump with a 1-in.

polyvinyl chloride (PVC) leachate drain pipe and valve was installed to collect leachate. Differential settlement markers, gas probes at mid-depth and bottom (2-in. PVC pipe), and temperature probes at the surface, mid-depth, and bottom (1-in. PVC pipe) were placed in each cell.

Each cell was filled with about one-week's production of liquid sludge and wet weight solid waste as follows: Cell 1, 45,500 gal of raw primary sludge and 473 tons of solid waste; Cell 2, 38,500 gal of mixed primary and secondary digested sludge and 394 tons of solid waste; and Cell 3, 56,000 gal of mixed primary and secondary digested sludge and 486 tons of solid waste. The total in-place combined densities of sludge solids and solid waste were 876, 902, and 923 lb per cu yd wet weight for Cells 1, 2, and 3, respectively.

2. Test Cell Study Results

a. Leachates. Prior to November 1972, only Cell 1 had produced leachate. Most of the Cell 1 leachate (44.8 gallons) was encountered during the first week after cell filling. Between November 1972 and June 1973, Cell 1 yielded 60 gallons, Cell 3 produced 2,316 gallons, and Cell 2 remained dry. In July 1973, Cells 1 and 3 were saturated manually with 13,000 and 15,000 gallons of water, respectively. Subsequently, leachate quantity equaled the amount of water applied to the cells.

The Cell 1 leachate analyes indicated a steadily increasing BOD_5 level (5,000 to 30,000 mg/l); a steadily growing pH (4.6 to 5.9 units); rising organic nitrogen values (150 to 700 mg/l); and increasing conductivity (3,000 to 14,000 μmhos). Chlorides and total dissolved solids reached peak levels near the 400th day (2,300 mg/l and 34,000 mg/l, respectively), and then tapered off. Test Cell 3 leachate followed patterns similar to those of Cell 1 leachate. Quaterly composite leachate analyses indicated little or no manganese, arsenic, or chromium. Lead never exceeded 20 mg/l and copper remained below 1 mg/l. The pesticide aldrin reached a level of 0.015 mg/l in the initial quarterly composite sample, but was negligible thereafter.

b. Temperatures. Temperatures recorded during the study varied from 64 to 92 F at the bottom (71 F average), 60 to 82 at mid-depth (76 F average), and 62 to 90 F near the surface (78 F average) in each cell.

c. Gas Analyses. Gas analyses taken at mid-depth and near the bottom of each cell indicated steadily increasing concentrations of methane during the study in each cell. Reported methane concentrations varied between 17 and 40 percent at the bottom of the cells and between 10 and 30 percent at mid-depth in the cells. Readings were taken periodically for H_2S; quantities detected in Cells 1 and 3 (1 to 750 mg/l) were significantly greater than in Cell 2 (0 to 25 mg/l).

d. Settlement. Final settlement in the three test cells was 3.0, 2.4, and 3.1 percent per year (based on initial depth) for Cells 1, 2, and 3, respectively.

e. Core Sampling. Seven core sampling studies were completed during the overall study. Temperatures, moisture content, and organic content were determined at two-foot depth intervals in each cell to a 12-foot depth below the surface.

Temperatures of cores from all three cells generally decreased from 98 to 70 F.

Organic and moisture contents of core samples showed no differences between the three cells. Organic content varied from 13.9 to 62.8 percent dry weight; moisture content varied from 14.6 to 100.1 percent dry weight.

Moisture saturation tests were run on core samples with the highest and lowest moisture contents in each cell. The samples varied widely with respect to saturation values (initial plus added moisture).

The saturated samples noted above were used to generate leachate for BOD_5 analysis. The BOD_5 values decreased dramatically during the 58 days between the second and third core sampling (from a range of 170 to 3,070 mg/l, to a range of 28 to 561 mg/l). BOD_5 values in subsequently generated leachates remained low.

Core samples taken at 4- and 12-foot depths in sterile bottles on the first core sampling in July 1972 were analyzed for fecal coliform, fecal streptococci and Pseudomonas aeruginosa. The results showed some of each bacteria at the 4-foot depth and none at 12 feet. This is similar to data on coliform bacteria in soil, which reportedly do not survive below a soil depth of seven feet.

Odors were determined at each two-foot core sample depth interval. Scents during the first sampling were strongest in Cell 1, which was relatively sweet; in Cells 2 and 3 odors were more putrid and septic. Odors on subsequent samplings were generally scur and putrid in all cells, becoming slightly sour or earthy by study completion.

No differences were noted in core sample appearance, color, readability of print on paper and container labels, or biodegradability between each of the three test cells or at different depths.

f. Comparison of Sludge Admixed Solid Waste with Normal Solid Waste. A comparison of data from the Oceanside test cells with landfills in some other Southern California locations and other field test cells was completed. The Oceanside test cell leachate pH (4.6 to 5.9 units) was lower than the range of values for landfills (5.6 to 7.8 units). Oceanside Cell 1 leachate BOD_5 (19,600 mg/l) was higher than for most landfills (10,900 mg/l). Temperature and gas composition followed trends at values similar to those of normal landfills. Settlement rates in the Oceanside test cells averaged two times greater than normal landfill settlement rates; this was attributed primarily to the lower original in-place density of the Oceanside test cells (623-640 lb per cu yd versus 800-1,000 lb per cu yd for wet weight solid waste only).

H. Field Demonstration of Landfill Disposal of Liquid Sludge

1. Preliminary Field Tests. Initial field demonstration tests were conducted in special test areas one day per week at the old Oceanside municipal landfill site from April to November 1971, and at the new landfill site from November 1971 to February 1972. During the first two testing weeks in 1971, one 1,250-gal tank-truck-load of liquid sewage sludge was spread onto two truckloads (16,000 lb) of solid waste; during the second two weeks, 1,750 gal of sludge was applied to three truckloads of waste; after the first month, 3,500 gal of liquid sludge was spread on six truckloads of solid waste. During the first phase test period, temperatures ranged from 46 to 92 F, wind intensity was calm to moderate, and rain occurred on one day when sludge was disposed.

It was found in the initial demonstration tests that driving a rubber-tired tank-truck on compacted solid waste was impractical; sea gulls and other birds which normally foraged on the open landfill face avoided the solid waste where liquid sludge was admixed; the earthy odor of well-digested sludge was discernible for up to 30 min after application within 30 ft of the test area; and solid waste absorbed the sludge with negligible runoff and leachate.

Extended field tests indicated that the CAT 977 and 977 K landfill dozers could work the sludge-waste admixture more easily than normal waste, due to the sludge moisture improving consolidation of the sludge-wet solid waste on the landfill dozer blade. Also, less dust was generated during compaction. Greater track slippage, however, occurred when working on steep fill slopes (greater than 30 percent slope) or in areas where wet sludge was pooled.

Even application of liquid sewage sludge was critical in preventing runoff and avoiding pooling at the toe of the fill slope. Initially, liquid sludge was applied by gravity feed through a 4-in. pipe extending from the bottom of the tank-truck; this method proved inadequate, however, due to the force of the concentrated discharge stream undermining the waste and running off along the bottom of the fill surface. Solid waste dikes were built on and at the bottom of the fill working face to minimize sludge drainage. If the liquid sludge was allowed to soak into the waste for at least one hour, the dozer traction improved and the drier sludge-waste admixture was then more easily worked with minimum unusual slippage of the dozer.

During the initial 9-month preliminary test period, observations were made of odor, blowing litter, animals, and flies. Normal landfill odors prevailed. Blowing litter was reported on only one day, indicating that the applied liquid sludge reduced litter. Sea gulls, the most abundant wildlife observed at the landfill, avoided the sludge-covered wastes. Flies from normal solid wastes were observed foraging on damp sludge-covered wastes. Some sludge runoff occurred on six days, and poor sludge-waste admixing was noted on two days.

2. Full-Scale Landfill Disposal of Liquid Sewage Sludge.

a. Landfill Operations. A full-scale demonstration wherein all liquid sewage sludge produced in the City of Oceanside was disposed into the solid waste at the landfill was initiated in February 1972.

Minor runoff at the toe of the working face due to partially ineffective sludge admixing techniques was observed. The then-existing liquid sludge disposal schedule of two days per six-day landfill work week overloaded the solid waste, creating excessive runoff. Revising the sludge admixture schedule to five days per week reduced but did not fully eliminate minor runoff. Utilization of solid waste dikes to contain the sludge at the toe of the working face proved unsatisfactory due to dozer problems in working the pooled sludge-waste admixture. The slope of the working face was reduced from 45 to 30 percent, but the sludge tended to flow in rivulets through channels down the fill slope. Use of a flat test spreading area made it difficult to admix the sludge evenly by gravity drainage unless the tank-trucks were driven over the flat waste area. As an alternative, the cover soil was scarified on the flat, filled landfill lift area, and sludge was discharged into the area. When the old waste fill was excavated and exposed to allow sludge admixture, severe landfill odors escaped. The surface was, therefore, quickly recovered with soil.

Alternative improved methods were investigated for spreading liquid sludge from the tank-truck; these included an eight-foot movable boom suspending a four-inch diameter eight-foot long flexible hose, and a double-splash plate spreader. The boom and hose assembly was satisfactory; however, it required the truck driver to manually manipulate the boom to spread evenly. The moving boom was found to cause a driving problem. This was changed to the presently employed splash plates which mechanically cover a 12-foot wide by 6-foot half-circle twice during the spreading procedures.

The sludge truck landfill unloading time was changed to a later hour so that there would be far more compacted solid waste present. The landfill working face was also reduced to a 30-ft width, 70- to 80-ft length, and 20-ft depth. The sludge runoff was then negligible or minimal. Other more costly methods of admixing sludge evenly to the working face by pumping or mechanical mixing with solid waste were not tested.

Observations of sludge disposal during rainfall periods indicated that if solid waste is saturated with rainwater,sludge will become diluted by the water and some additional runoff will result. The absorbed rain also reduces the equivalent amount of liquid sludge that can be admixed or retained by the solid waste; however, during rainy periods, liquid sludge was satisfactorily disposed into the wet solid waste at reduced rates in the Oceanside site.

b. General Observations. During a two-month period, one landfill dozer operator reported strong noxious odors from the solid waste-sewage sludge admixed fill. Field investigations and gas sampling, however, did not confirm the report. It was concluded that the dozer operator was exposed to a psychologically unpleasant environment while eating his lunch at the fill site. The fill operator now leaves the area for lunch and has continued to work without further complaint.

During warm September weather a complaint about landfill odors was received from the adjacent elementary school cafeteria. Landfill operations were discontinued in the canyon area within immediate proximity to the cafeteria. They will not be initiated in that area while school is in session. Septic, partially digested or raw sewage sludges may cause odor through disposal unless immediately covered with soil.

Blowing litter in the landfill was greatly reduced when liquid sludge was admixed.

Observations of sea gulls showed that they initially avoided solid waste admixed with digested liquid sludge. After seven months of full-scale sludge disposal, the sea gulls abandoned their aversion and started foraging in areas with sludge.

Fly emergence studies were performed with sludge admixed solid waste and non-sludge solid waste test areas beginning in August 1972. No difference in the two areas' emergence was discernible during the tests. It was observed that flies foraged and larvae moved to dry areas in the sludge-admixed solid waste.

Accident and injury records for the landfill operations showed no injuries that were attributable to liquid sludge disposal.

A review of studies on pathogenic organisms in solid waste indicated fecal coliform and fecal streptococci bacteria may be present in large quantities. No illness has been reported by concerned school authorities, residents, or landfill personnel that could be attributed to pathogens or vectors from the solid waste or sewage sludge.

3. Landfill Auger Sampling. Auger sampling was done by drilling bore holes in three types of landfill areas: 1) freshly placed sludge-waste up to 2 weeks old; 2) sludge-waste placed about the same time as the test cells; and 3) solid waste without sludge placed approximately the same time as the test cells.

Temperatures in fresh sludge-waste core samples averaged 108 and 110 F on the first two sampling periods; this was much greater than in the older sludge-waste and solid waste fill areas (79 to 90 F). Steam was observed escaping from the fresh sludge-waste bore holes. Organic contents did not differ in the three types of fill. As expected, moisture contents in the pure solid waste fill bore hole were lower than in the two sludge-solid waste bore holes.

Soil samples taken from the soil bottom below the fill in two holes, and the bottom of a lift in one hole, indicated low moisture contents well below field capacity.

No leaching was observed in the area of the bore holes and the quality of the groundwater samples from the test well at the mouth of the landfill indicated little or no leachate contamination. Laboratory moisture saturation tests conducted on core samples with the highest and lowest in-situ moisture contents indicated that amount of additional moisture absorbed to field capacity (saturation) was related to neither in-situ moisture or organic content, nor depth.

Analyses of BOD_5 from leachates of the laboratory-saturated core samples showed no differences in trends or values attributable to the different fill solid waste or liquid sludge-solid waste admixtures. The appearance of the core samples from the fill area that receivedno sludge was dry and powdery, in comparison with wetter "pasty" agglomerated material in the sludge-admixed solid waste fill auger samples. The color of the sludge-admixed waste normal bore samples was usually greyish from the sludge, while the solid waste fill samples were more brownish. Readability of printed items was affected by neither fill condition. The state of biodegradation of cored materials obtained for the various sludge/non-sludge fill conditions did not noticeably differ.

Analyses of gas samples obtained from the bore holes in 1972 indicated possible trends of concentrations of CO_2 and CH_4 in the sludge-solid waste fill over the non-sludge solid waste fill. Gas samples obtained in 1973 did not bear out any relationships.

4. Compaction Studies. A two-week comparison of solid waste-sludge density with normal solid waste density was conducted in June 1973. Solid waste admixed with sludge resulted in 4 percent greater density under controlled conditions. A study of solid waste-sludge admixture density under normal landfill conditions was performed in August 1973. Solid waste-sludge as received at the landfill had an in-place density of 1,119 lbs per cu yd. This extends far into the upper range of landfill compaction densities.

5. Time and Motion Studies. Comparisons between working solid waste with and without sludge admixture indicated no differences in time requirement at the normal sludge to solid waste ratio (0.56 to 0.60 lb sludge per lb dry weight solid waste). Doubling the sludge to solid waste ratio significantly impaired operations, however, due to dozer slippage. Working fills in excess of 20 to 30 percent slope resulted in dozer slippage when sludge was present.

6. Landfill Disposal and Sludge Transport Costs. Sludge disposal at the landfill should affect only dozer operations. In 1971 at the old Oceanside landfill, operational and maintenance costs for the dozers without sludge disposal were $0.72 per ton of wet weight solid waste. During 1972 at the new landfill, operational costs including sludge disposal were $0.64 per ton, and in 1973 $0.92 per ton. The costs for 1973 were affected by addition of a second dozer operator to provide soil cover (soil covering commenced September 1972). The vehicular transport of sludge in 1972 was $25.23 per ton of sludge solids disposed, and in 1973, $31.74 per ton.

I. Economics of Sludge Transportation

The economic analysis is based on hauling liquid sludge from the existing La Salina Plant and a new San Luis Rey Plant which is scheduled to be on-line in 1974.

The new San Luis Rey Plant will be 5 miles from the existing landfill, and the La Salina Plant is 2 miles away. Assuming a sludge solids content of 3.0 to 5.5 percent wet weight for each plant, a total sludge quantity of 2,217 tons of dry sludge per year was projected for 1985.

1. Truck Haul. Three types of trucks were studied for possible truck haul of liquid sewage sludge: a modified "standard" 3,300 gallon water truck spreader; a 10,000 gallon fuel truck; and a 7,000 gallon vacuum pumper. The average costs for each truck per ton-mile haul on a dry solids basis and a 10-year useful truck life were estimated to be $3.95 for the spreader, $1.64 for the refueler, and $2.17 for the vacuum pumper. These costs apply to a weighted average load haul distance from the sewage treatment plants to the landfill of 4.38 miles with one hour per trip total for loading, travel, and unloading.

2. Pipeline Transport. Pipe head-loss and flow requirements indicated an 8-in. diameter pipe with an estimated useful life of 30 years was needed. The cost per ton-mile of dry solids was calculated to be $21.61 for the La Salina pipeline and $4.07 for the new San Luis Rey pipeline.

3. Economic Summary. Results suggest that: pipeline transportation of sludge is decidedly not economical; rail transport is not feasible; and truck sludge transportation is both the most economical and most practicable transportation alternative.

CONCLUSIONS

A. General

Three years of field investigation at the Oceanside, California landfill and three years of laboratory simulation tests have demonstrated the technical, economic, and environmental feasibility of combined disposal of digested liquid sewage sludge in a solid waste sanitary landfill. Through use of proper sludge-spreading techniques, the Oceanside landfill demonstration has shown that solid waste has sufficient absorptive capability to hold moisture. The total quantity of Oceanside's sewage sludge production has been satisfactorily disposed to the landfill at reasonable costs since December 1972, and the landfill solid waste in-situ retained over half its original available moisture-absorbing capacity. Landfill disposal of sludges from Oceanside's three local treatment plants was shown to be economically competitive with other sludge disposal alternatives, while providing the ancillary environmental benefits of increased landfill compaction, greater density and reduced blowing of litter and dust. The major environmental problems encountered in full-scale disposal of sludge to the landfill were noxious odors following disposal of raw sludge or septic tank pumpings, extensive sea gull foraging and waste scattering, and stormwater runoff problems associated with grading, all of which can be reduced by proper soil covering, grading, and other techniques as outlined in this report.

The findings of this demonstration project can be extrapolated to feasibility evaluations of disposing liquid sewage sludge to landfill sites other than at Oceanside, California. The exact absorption capacity of a particular solid waste fill can be established by determining the moisture capacity of local solid waste samples, local sludge characteristics, and the extent of local rainfall and drainage. New landfills designed for combined sludge disposal should preferably be sited with protective buffer zones that will minimize adverse landfill impacts such as noise, odor, dust, vectors, and potential public health problems; if located in a wet climate, it may be desirable to provide a leachate collection, recirculation, or disposal system.

Sanitary landfills should not be used for disposal of septic tank pumpings, raw sludge, or other hazardous wastes unless special operator, equipment, and environmental protection measures are instituted. Runoff and leachate control facilities to prevent possible groundwater and surface water contamination should be incorporated at all landfills receiving liquid sewage sludge to prevent by-passing. At Oceanside, the following techniques met with success: keeping liquid additions well below the solid waste absorption capacity; spreading sludge on a working face of less than thirty degrees slope; providing solid waste/earthen dikes at working face toes, constructing engineered storm drain facilities, providing an absorptive solid waste layer prior to sludge admixture into the landfill; and furrowing the landfill cover soil in front of and perpendicular to the advancing fill face to confine sludge runoff and enhance infiltration capability.

B. Specific

1. Laboratory moisture absorption tests indicated that solid waste similar in composition to Oceanside's can absorb 0.6 to 1.8 lb liquid per lb dry weight solid waste.

2. Oceanside's entire sewage sludge production, consisting of activated and primary digested liquid sludge, has been successfully disposed to the Oceanside landfill since December 1972 without approaching the fill solid waste absorption capacity. The City produces an average of 0.6 lb liquid sludge per lb dry weight solid waste, with a range of 48 to 75 percent lb per lb. Moisture added to the landfill as a result of rainfall (13 inches for 1972 through 1973) was mostly concentrated within the local December to March rainy seasons and amounted to less than 0.1 lb rain per lb wet weight solid waste. Heavy rainfalls (as much as 2 inches in one storm) failed to affect absorption of the liquid sewage sludge by landfill solid waste. Augered landfill samples taken in 1973 indicated that the solid waste fill material was 60 percent below saturation capacity, even for locations where sludge admixture had been practiced for as long as two years. This 60 percent liquid absorption capacity remained available for future liquid sludge, rainfall, or other moisture addition.

3. Field observations indicated that all sludge produced by Oceanside was satisfactorily applied and absorbed in the landfill while apparently producing little or no leachate. Analysis of landfill bottom and intermediate lift cover soil samples obtained from bore holes indicated that less moisture had entered the bottom soils than the intermediate soils. The moisture content of both the bottom and intermediate soils (average 14.0 percent dry weight) was higher than the moisture content of the air-dried surface cover soil.

4. The application of liquid digested sewage sludge by spreading onto the compacted landfill working face proved to be a better methodology than admixing solid waste into a pool of liquid sludge. The landfill dozers experienced no slippage in working the liquid sludge when it was spread and allowed to dry and infiltrate for a few minutes over and into the surface of a working face of less than 30 percent slope. At greater working face slopes and in pooled or fresh liquid sludge, the dozers experienced some slippage. On an experimental basis, finished, nearly level fill areas were used as drying beds for liquid sludge. Applying sludge to these areas resulted in very quick sludge drying, and appears to be a feasible application procedure.

5. Adding sewage sludge to the solid waste landfill resulted in better solid waste fill compaction and increased fill material density. In a controlled field test, compaction was approximately 4 percent better following sludge application. Density of the fill averaged 1,120 lb per cu yd, which is well into the upper range of solid waste-only landfills. (Sewage sludge solids were excluded from the density calculations.)

6. Properly-engineered landfill facilities and use of appropriate working techniques can control liquid sludge runoff in landfills. For Oceanside, these factors included: admixing liquid sludge into the solid waste within an absorption ratio range

of 0.46 to 1.39 lb of liquid sludge per lb of as-received, wet weight solid waste (0.6 to 1.8 lb per lb, dry weight basis); spreading (and drying for a few minutes) liquid sludge uniformly over a landfill working face slope of less than 30 percent to avoid short-circuiting rivulets; constructing earthern solid waste dikes at the toe of the working face to contain minor sludge and rainfall runoff; furrowing the landfill cover soil in front of and perpendicular to the advancing fill face to confine sludge runoff and enhance infiltration capabilities; maintaining storm drain facilities to divert external rainfall runoff away from the sanitary landfill; constructing a conventional dry solid waste lift as an absorptive layer beneath the landfill prior to admixing liquid sludge; providing routine daily covering of the solid waste and sewage sludge with the generally accepted minimum 6 inches of soil; and supplying proper engineering, planning and maintenance of the considered solid waste management system and the sewage sludge treatment and disposal system.

7. A comparison of leachates from pilot test drums, field test cells, and the non-sludge admixed landfill indicated that the sludge-solid waste admixture produced a more acidic leachate with a higher BOD_5 content than leachate produced from solid waste alone, but that chemical composition did not otherwise significantly differ. No major differences in temperature, carbon dioxide and methane gas concentrations, settlement or leachate mineral constituents were noted between sludge-admixed solid waste and normal solid waste. Intermittent addition of 6.7 to 12.2 lb water per lb dry weight solid waste to the simulators stabilized the leachate BOD_5 and mineral concentrations after about 205 days. BOD_5 stabilized at 50 mg/l.

8. Qualitatively, addition of liquid sewage sludge to solid waste in the Oceanside landfill was observed to reduce dust and blowing litter as a result of the increased moisture content of the disposed materials.

9. Qualitative observations of odors resulting from admixed normal "well-digested" liquid sludge and solid waste indicated a similarity in strength to typical solid waste landfill odors. The pilot test drums, field test cells, and the demonstration landfill tests indicated that admixture with well-digested primary and secondary sludges produced a mild, earthy, non-noxious odor until the absorbed sludge dried, after which normal landfill odor types prevailed. Undigested raw sewage sludges and septic tanks pumpings in the pilot test drums, however, produced moderate to strong noxious septic odors. Such noxious odors can be expected whenever raw sludge is disposed to landfills in cases of digester upsets, treatment plant strikes, natural catastrophes, etc. The septic odors can be controlled by immediate cover with six inches of soil or normal landfill dry solid waste. Even though the Oceanside landfill was located in immediate proximity to an urbanized area including apartments and two schools, very few complaints concerning odors were received.

10. No apparent difference was observed between fly foraging in the admixed sludge-solid waste and in the dry solid waste fill. Most flies trapped at the fill were fruit flies, which pose little danger as vectors to public health as compared to houseflies. Domestic houseflies and fly larvae in solid waste were observed entrapped in and escaping from the digested liquid sludge runoff. The migrating larvae and mature flies came into direct contact with wet sludge. Since wet sludge may contain pathogenic organisms, the flies pose a potential sanitation problem unless the sludge and admixed solid waste fill is covered daily with six inches of well-compacted suitable soil.

11. Large numbers of sea gulls were observed at the landfill after the first two years of sludge application, posing a potential nuisance to the surrounding environment. During the first two years, the gulls avoided the sludge-admixed solid waste, preferring the non-admixed solid waste. Daily covering with six inches of well-compacted suitable soils can reduce gull foraging.

12. The extent of sanitary landfill leachate generation is dependent on the amount of external water introduced by surface or groundwater drainage, rainfall, irrigation or other water sources. Collection and treatment of leachate from landfills, both with and without admixed liquid sludge, can control groundwater and surface water contamination.

13. Both Oceanside field test data and responses to a 1971 Ralph Stone and Company, Inc. nationwide survey of State Public Health Officials and local landfill operating management indicated no reported accidents, health hazards, or illnesses attributable to landfill sludge disposal; also, no such reports were found in published literature. The above-mentioned 1971 survey also revealed that no increased disease outbreaks occurred due to landfill disposal of septic tank pumpings. This should be expected, since septic tank pumpings are basically the same as raw sewage, containing common types of pathogenic organisms (bacteria, virus, and parasites).

14. Disposal of septic tank pumpings into a sanitary landfill may be feasible only under the following special controlled conditions: 1) a six-inch minimum earth cover is applied immediately after spreading the liquid; 2) proper liquid spreading techniques are used to control runoff and leachate; 3) protective clothing and face masks are worn by operating personnel; 4) the disposal site is isolated by sufficient buffer zones or enclosures from populated areas to positively protect public health from vectors and to eliminate odors; 5) adequate leachate control facilities are provided.

15. Liquid sewage sludge in Oceanside could be most economically transported by truck, particularly by "refueler" truck.

16. The cost of full-scale truck transport, unloading, and disposal of liquid sewage sludge into the Oceanside landfill during 1972 was $25.23 per ton of dry sludge

solids, and in 1973 was $31.74; this was economically competitive with alternative liquid digested sludge processing and disposal methods.

17. The cost of solid waste landfill disposal dozer operations during 1972 of $0.64 per ton solid waste (wet weight) with full-scale disposal of liquid sewage sludge was not significantly different from the cost in 1971 of $0.72 per ton of solid waste (wet weight) without sludge. Costs increased to $0.92 per ton in 1973, due to conversion of the Oceanside landfill to a sanitary landfill, entailing increased additional earth-moving and cover soil placement to provide daily soil cover. However, additional engineering, personnel training, operation supervision and earth cover requirements are needed when disposing sewage sludges into a solid waste sanitary landfill and, hence, an increase in long-term operating costs should be anticipated. The cost effectiveness of combined (multi-purpose) disposal of both solid waste and sewage sludges appears to be improved over the duplication of disposal in separate sanitary landfill and sludge disposal works.

18. Several administrative and institutional difficulties were encountered in converting the solid waste-only fill to a sludge-solid waste fill. These mainly involved lack of proper coordination between public and private agencies, psychological misgivings expressed by landfill personnel with respect to sludge disposal, and sludge disposal personnel preferring not to have to work in landfills.

RECOMMENDATIONS

1. Special studies are needed to determine the populations and the potential for survival of pathogenic organisms in solid waste, liquid digested sewage sludge, and septic tank pumpings in a sanitary landfill environment.

2. An assessment of pathogenic organisms such as virus and bacteria in leachate from landfilled liquid sewage sludge admixed with solid waste should be conducted to evaluate public health hazards and possible surface and groundwater contamination.

3. The potential vector public health hazards associated with disposal of digested liquid sewage sludge into a sanitary landfill needs further evaluation to determine the incidence of vector contamination by pathogenic organisms (virus, bacteria, and parasites).

4. Comprehensive analyses for toxic heavy metals and other hazardous constituents in leachate from sludge admixed solid waste should be performed to assess the potential for surface and groundwater contamination.

5. Further wet climate and irrigation-type demonstration tests are needed to determine the effectiveness of liquid sludge disposal into a sanitary landfill under varying local conditions. Long-term monitoring (as much as 20 years) is needed to fully determine the long-term behavior of liquid sludge admixed with solid waste in a landfill environment. This monitoring can establish, for instance, the feasibility of reclaiming the landfill site for recreational or other uses. Additional long-term leachate monitoring studies are needed to fully establish pathogen and toxic material residence times, mobility, and long-term pollutional potentials.

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Ralph Stone and Company, Inc. were the project consultants responsible for the detailed studies described in the report. Supervisory personnel included: Ralph Stone, Technical Supervisor; Richard Kahle, Project Coordinator; and James Rowlands, Field Engineer. Other Ralph Stone and Company, Inc. staff assisting in the study were Edward Daley, J. Rodney Marsh, Paul Mak, Timothy Zimmerlin, Albert Herson, Howard Smith, and John East.

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I. INTRODUCTION

A. Objectives and Scope of the Investigation

An investigation of the economic and environmental effects of disposing of liquid sewage sludge and septic tank pumpings into a sanitary landfill has been conducted over three years. This report presents and discusses the results of the three-year investigation. The objectives which have been achieved during the study consist of the following:

1. Determination of the capacity of solid waste to assimilate the water in digested liquid sludge and septic tank pumpings.
2. Identification of the parameters affecting the capacity of solid waste to absorb water from liquid sludge and septic tank pumpings.
3. Determination of the optimum means for nuisance-free admixture of liquid sewage sludge with solid waste in a sanitary landfill.
4. Investigation and monitoring of sanitary landfill environmental effects following combined liquid sludge-solid waste disposal, i.e., temperature, odor, gas composition, settlement, flies, birds, other vectors, landfill leachate, groundwater contamination, and runoff.
5. Definition of the landfill effects of liquid sludge on solid waste compaction, decomposition rates, blowing dust and paper.
6. Determination of the effects of liquid sludge application on operating efficiencies of landfill equipment and personnel.
7. Investigation of alternative means for dewatering, handling, and disposal of liquid sludge and establish cost comparisons.

The three-year demonstration program has consisted of the following areas of effort: a) establishing the water absorption characteristics of Oceanside sewage sludge and solid waste; b) pilot-scale landfill simulation experiments; c) large-scale field experiments under controlled conditions (field test cells); d) full-scale field demonstration; and e) special laboratory and/or field studies to eliminate or define sanitary landfill requirements. Three special studies which were undertaken are: a) laboratory evaluation of water absorption by solid waste; b) two nationwide postal surveys of landfill disposal of municipal sewage and septic tank sludges; and c) a literature search concerning digested sewage sludge and septic tank pathogens and vectors.

All the solid waste and sewage sludge used in the field demonstration study were obtained from the City of Oceanside. The full-scale Oceanside field demonstration disposed of the City's entire generation of liquid digested sludge into the solid waste at the City landfill.

B. Study Area Description

1. The City of Oceanside. The City of Oceanside, California is located within northern San Diego County, as illustrated in Figure 1-1. The City of Oceanside had a population of 40,494 in 1970. The City Planning Department has projected a 1980 population of 75,000, and a year 2000 population of 109,000. The year 2000 population is the maximum level for Oceanside in accordance with the proposed land uses. Residential density averaged 2.98 persons per household in the 1970 census. Of the total of 14,594 housing units, 9,139 were single dwelling residences, 4,307 were multi-unit residences, and 1,111 were mobile homes or trailers. Camp Pendleton, a major United States Marine Corps Base supporting about 35,000 Marine and Navy personnel, is located along the northern boundary of the City. Many of the Camp Pendleton personnel shop and visit in Oceanside.

The major land use categories for November 1967 in the City limits are given in Table 1-1. The average residential zoning density was about 19 persons per acre in 1970.

Selected Oceanside climatological data for 1971, 1972, and 1973 are given in Table 1-2. The U. S. Weather station at the nearby Palomar Airport reports a mean 112-year historical precipitation average of about 12 inches annually.

2. Sewage Treatment Plants. The City of Oceanside has three existing sewage treatment plants; two are activated sludge plants named La Salina and Buena Vista. A third is a primary-type plant named San Luis Rey. Detailed description of these sewage plants and a discussion of the quantity and characteristics of the sludge produced in each plant are presented in Chapter IV. The plant sites are shown in Figure 1-2.

3. Sanitary Landfills. During the first year of the study, all preliminary demonstration field tests were made at the old City sanitary landfill (see Figure 1-2) located southerly of Mission Avenue and easterly of the San Diego Freeway (Interstate 5). The old site was completely filled and a new City sanitary fill site was prepared including 3 test cells for the second and third year demonstration work. The new site, shown in Figure 1-2,is in a canyon located northerly of Mission Avenue and easterly of Cape Glouchester Street. A Marine Corps housing project and primary and elementary schools are the neighbors on the canyon rim abutting the new site. The Oceanside landfill receives primarily commercial and residential waste from within the City. As will be discussed in detail in Chapter IV, relatively little industrial waste is received at the new landfill. The local soils are coarse to fine sand over well-consolidated sandstone. Geology, soil and groundwater conditions are described in Appendix F . Prior to September 9, 1972, the Oceanside landfill did not receive daily cover soil on the working face. In order to comply with EPA sanitary landfill requirements, a six-inch minimum compacted cover soil was applied daily to the landfill working face after September 9, 1972.

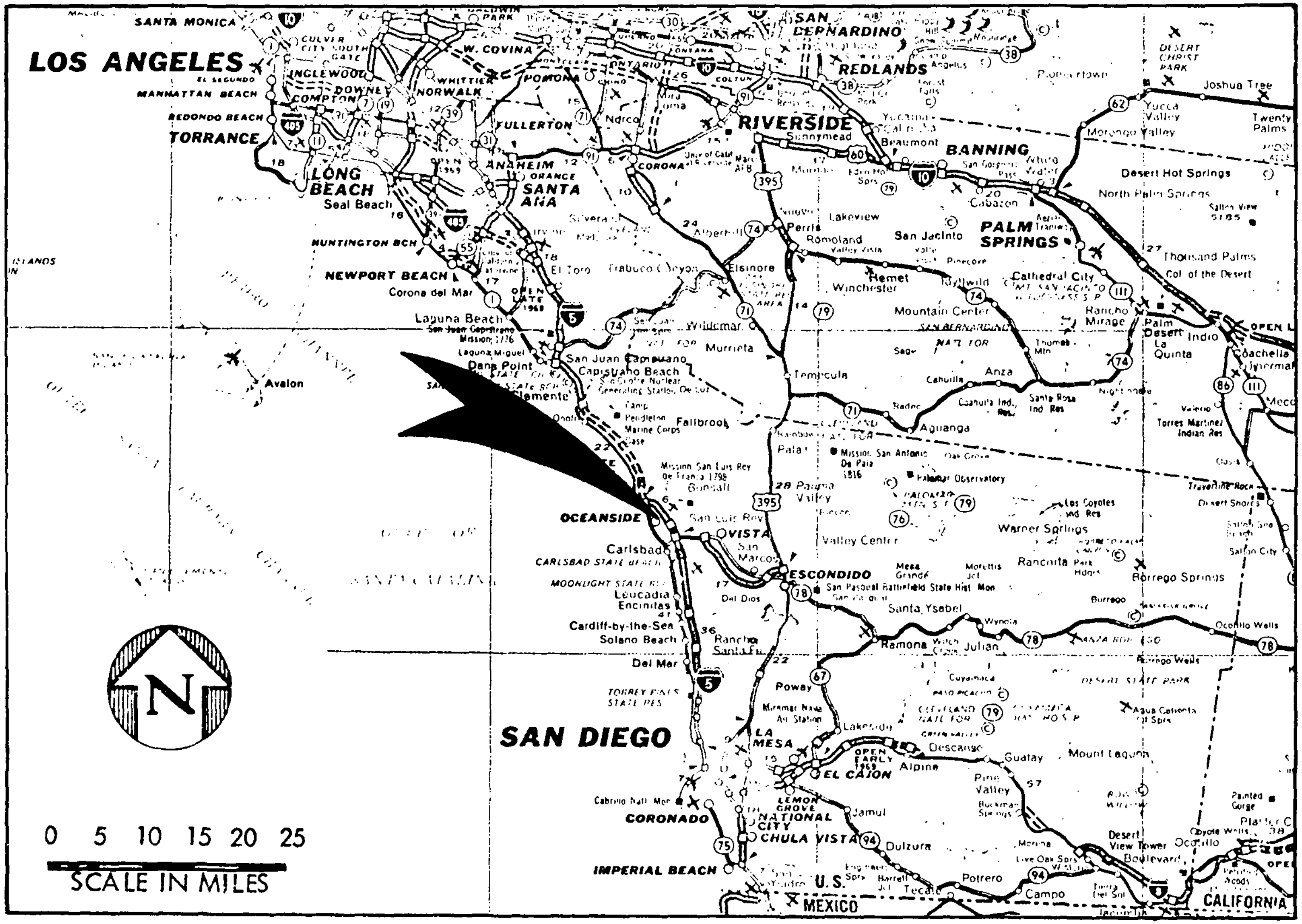


FIGURE 1-1

STUDY AREA LOCATION

TABLE I-1

MAJOR CLASSES OF LAND USE IN OCEANSIDE (NOVEMBER 1967)

Land use	Acres	Percentage of Total city	Percentage of Developed area
Residential	2,131.70	10	38
Industrial	465.54	3	8
Commercial	461.23	3	8
Highways--streets	1,607.84	7	28
Public & semi-public	1,050.10	5	18
Developed area (subtotal)	5,716.41	28	100
Agriculture	3,447.13	15	
Vacant	12,660.58	57	
Total area	21,824.12	100	

From: Oceanside Planning Department.

TABLE I-2

OCEANSIDE CLIMATOLOGICAL DATA

Month	Temperature (F) Avg max	Avg min	Avg	High/low	Precipitation (in.) Total	24 hr max
1971						
Jan	64	43	57	78/30	0.39	0.36
Feb	64	44	58	81/35	1.34	0.68
Mar	64	47	59	74/34	0.10	0.10
Apr	69	49	62	84/42	0.89	0.66
May	66	51	63	78/48	0.69	0.32
June	71	58	68	78/49	0	0
Jul	76	61	71	80/46	0	0
Aug	82	66	77	86/60	0	0
Sept	78	61	73	85/80	0	0
Oct	74	52	69	98/36	0.67	0.47
Nov	66	46	59	75/41	0.13	0.08
Dec	61	41	54	69/34	3.37	0.81
		1971 Total precipitation - -			7.58	
1972						
Jan	62	41	55	80/35	0	0
Feb	64	41	57	71/37	0.11	0.11
Mar	65	50	59	73/41	0	0
Apr	68	49	63	72/40	0.05	0.03
May	70	54	66	76/47	0.16	0.10
June	73	60	69	77/54	0.20	0.11
July	78	62	73	83/51	0	0
Aug	79	63	75	87/49	0.03	0.03
Sept	77	60	70	82/53	0.17	0.10
Oct	75	55	69	89/47	0.92	0.48

TABLE I-2 (CONT.)

OCEANSIDE CLIMATOLOGICAL DATA

	Temperature (F)				Precipitation (in.)	
Month	Avg max	Avg min	Avg	High/low	Total	24 hr max
1972 (Cont.)						
Nov	69	46	62	81/36	2.63	0.80
Dec	66	43	58	84/33	1.19	0.36
		1972 Total precipitation - -			5.46	
1973						
Jan	65	42	57	74/36	2.19	0.78
Feb	66	45	60	76/35	2.66	0.81
Mar	65	46	59	68/38	2.62	0.68
Apr	69	49	62	79/40	0	0
May	68	54	64	73/46	0.03	0.02
June	74	60	71	89/55	0	0
July	74	62	71	78/48	0	0
Aug	76	62	72	89/56	0	0
Sept	75	58	74	94/43	0	0
Oct	74	54	68	78/49	0	0
Nov	67	47	61	75/36	1.71	0.46
Dec	66	47	69	80/37	0.09	0.08
		1973 Total precipitation - -			9.30	

From: Oceanside fire station.

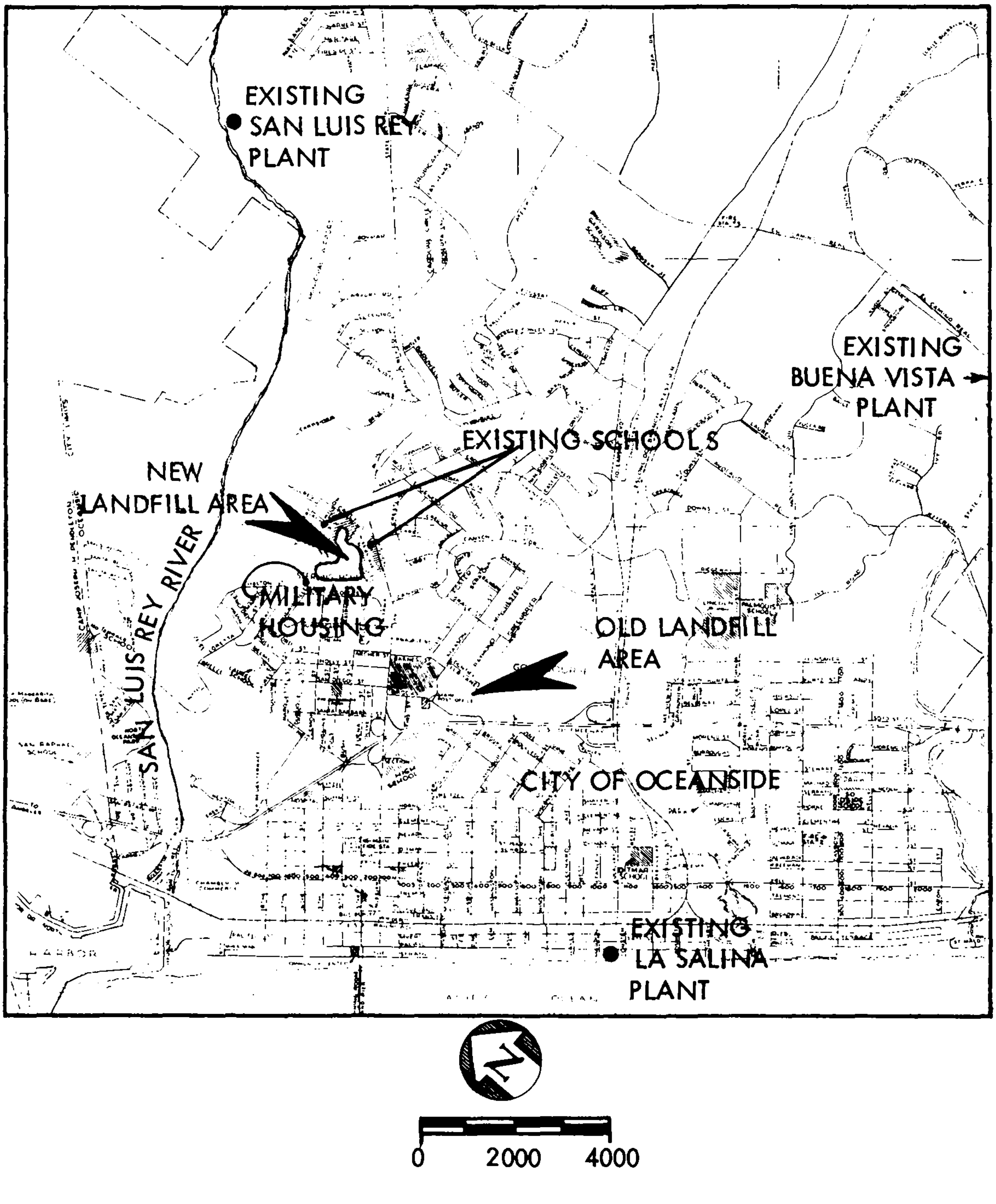


FIGURE I - 2
OCEANSIDE MUNICIPAL
LANDFILL SITE

II. SLUDGE DISPOSAL PRACTICES

A. General Aspects of Sludge Disposal in the United States

Currently, sludge processing, handling and disposal represent about 25 to 50 percent of the total capital and operating cost of municipal sewage treatment plants. Sludge disposal involves the ultimate complex phase of wastewater treatment and plant management. While sewage sludge has some limited fuel, soil conditioning and fertilizing value, it is generally a liability at treatment plants due to a lack of markets for these latter uses. Commercial chemical fertilizers are less expensive to handle; they do not present potential environmental problems from odors or public health hazards from pathogenic organisms and vectors associated with poorly digested sewage sludges.

A number of sludge treatment and disposal methods are utilized which include: anaerobic and aerobic digestion, composting, drying, wet burning, chlorination, incineration, landfilling or burial, reclamation as a soil conditioner, lagooning, deep well injection and discharge to water bodies. A study completed in 1968 by Burd[1] summarized the costs for alternative handling and disposal methods for municipal sewage sludge. These costs are given in Tables II-1 and II-2. Lagooning and landfilling were indicated as among the least costly handling and processing methods (see Table II-1). As a means for ultimate disposal, landfilling with dewatered sludge is more costly than lagooning, barging to sea, and pipeline to sea (see Table II-2). In many cases, ultimate sludge disposal requires pretreatment for dewatering. The cost of dewatering often accounts for a significant fraction of the total disposal cost.

The Marine Protection and Sanctuaries Act of 1972 (PL 92-532) sets strict requirements on the ocean disposal of sewage sludge; the Federal Water Quality Act (PL 92-500) as amended in 1972, sets strict requirements on pipeline discharges into the ocean. These regulations may eventually force many municipalities to seek alternative methods for sludge processing and disposal. The need for environmentally desirable and economic methods of sludge processing and disposal is particularly acute in some urban areas where current methods are unacceptable (e.g., elimination of sludge burning due to air pollution, or removal of sludge discharges from receiving waters and prohibitively high costs of sludge handling due to the unavailability of suitable nearby disposal sites). One method of sludge disposal which has received some attention in recent years and which appears to be of considerable promise is the admixture of liquid digested sludges to solid waste in a landfill. As will be discussed later, certain advantages are inherent in this combination approach to the solution of sludge and refuse disposal problems, which may make the method very appealing to some communities.

B. Nationwide Surveys of Sludge Disposal to Landfills

In 1971, Ralph Stone and Company, Inc. independently undertook a nationwide survey of State Public Health Departments and local landfill managers to assess the prevalence of sludge disposal to landfills and explore any problem(s) which may be associated with this method of sludge disposal. Copies of the questionnaires are included in Appendix B.

TABLE II-1

SLUDGE HANDLING AND PROCESSING COSTS (1968)

System	Capital and operating costs ($/dry ton) Average	Range
A. Thickening		
(1) gravity	-	1.50 - 5
(2) air flotation+	-	6 -15
(3) centrifugation+	-	3 -20
B. Dewatering		
(1) vacuum filtration	15	8 -50
(2) centrifugation	12	5 -35
(3) sand bed drying	-	3 -20
C. Anaerobic digestion	-	4 -18
D. Elutriation	-	2 - 5
E. Lagooning	2	1 - 5
F. Landfilling	-	1 - 5#
G. Pipeline transportation	5	*
H. Liquid sludge disposal on land as a soil conditioner	10	4 -30
I. Heat drying	35	25 -40
J. Incineration	20	8 -40
K. Barging to sea	10	4 -25

From: Burd, R. S. A study of sludge handling and disposal. FWPCA Publication No. AP-20-4, 1968, p. 320.

+ Varies widely depending on the need for chemicals.

Long hauls would be higher.

* Moderate distances; cost varies with length.

TABLE II-2

ULTIMATE DISPOSAL COSTS FOR SEWAGE SLUDGE (1968)

System	Capital and operating costs+ ($/dry ton) Average	Range
A. Composting	Not accurately known	
B. Heat drying#	50	40-55
C. Incineration		
(1) wet combustion	42	-
(2) multiple hearth and fluidized bed	30	10-50
D. Landfilling dewatered sludge	25	10-50
E. Disposal as a soil conditioner w/o heat drying (dewatered)	25	10-50
F. Disposal on land as a liquid soil conditioner	15	8-50
G. Lagooning	12	6-25
H. Barging to sea	12	5-25
I. Underground disposal	Unknown, potentially inexpensive	
J. Pipeline to sea	11	-

From: Burd, R. S. A study of sludge handling and disposal. FWPCA Publication No. WP-20-4, 1968, p. 320.

+ Includes cost of preparation, such as dewatering, digestion, etc. given in Table II -1.

Gross cost, does not account for money received from sale of sludge.

1. Health Departments Survey. The questionnaire (see Appendix B) was designed to survey prevailing nationwide practices and opinions concerning sewage sludge and septic tank sludge landfill disposal. The sanitary engineers/environmental health officers in the 50 State Departments of Public Health were sent questionnaires. A total of 26 states responded; 24 provided answers to all or most questions. The following is a summary of the survey results.

a. Sludge Disposal Regulations. Landfill disposal of sewage and/or septic tank sludge was permitted by 80 percent of reporting states. The responses for municipal sewage sludge were: permitted, 16; prohibited, 4; and for septic tank sludge: permitted, 17; prohibited, 4. Most of the states had the same disposal policy for both types of sludge. One state, however, restricted landfill sludge disposal to municipal sludge only, and two states limited such disposal to septic tank sludge.

Regulation of landfill disposal of municipal sewage sludge was reported by 10 states; of septic tank sludge, by 11 states. State inspection was reported by six states; two of these prohibited all sludge disposal, three permitted both municipal and septic tank sludge disposal, and one of the inspecting states permitted only septic tank sludge disposal. Several states indicated that municipal sewage sludge accepted for landfill disposal had to be dried and/or dewatered.

b. Problems Associated with Landfill Disposal. Most of the states which permitted municipal-sewage and/or septic tank sludge disposal to landfill also permitted landfill disposal of industrial, other liquid, and/or hazardous wastes. It was, therefore, not always possible to determine which type of sludge was responsible for associated environmental difficulties. The following list of comments on adverse sludge-related problems was compiled:

- High water content of sludge makes landfilling almost impossible.
- Adverse public opinion; damage to equipment.
- Increased potential leachate problem.
- Excessive leachate production; inefficient and sloppy operation; flash fires; probable groundwater pollution (being investigated on one site).
- Increased probability of spread of disease by vectors.
- Creation of a nuisance because of disposal in an unsafe manner and in unregulated places.
- Odor problems when regulations not complied with.
- Difficulty in compacting liquid wastes prior to daily cover.
- Difficulty in burying sewage (vacuum filtered) sludge. (Improved mixing with solid waste not a problem.)

Four states reported no known problems to date; two states indicated a lack of information; and the remainder either failed to respond to the question, or specified the problems were caused by other types of liquid/hazardous wastes.

c. Recommended or Existing Alternatives to Landfill Disposal. Incineration, treatment, and recycling (especially as fertilizer by direct land application) were the most commonly listed alternatives to landfill disposal of municipal sewage/septic tank sludge. The following are respondents' comments concerning recommended or existing alternatives:

- Incinerate sludge; provide tertiary treatment of the liquid from sludge dewatering.
- Incineration and pretreatment prior to discharge.
- Incineration, recycling, or recovery.
- Incineration, higher degree of neutralization or chemical treatment.
- Combustion where applicable.
- Recycling, incineration conversion to solids.
- Better treatment plants; recycling or finding new uses for the wastes.
- Treatment when available, sludge drying and land disposal, special burial areas.
- Anaerobic or aerobic digestion or treatment.
- Dispose liquid or dry digested sludge on flat farm land, and plow under.
- Dispose of municipal sewage sludge on farm land.
- Drying bed, then use as fertilizer (sewage sludge from municipal plants).
- Ground sludge used for municipal parks, septic tank wastes discharged to central sewage treatment plants.
- Land spreading, lagooning, incineration, or "purifying".
- Deposit in silt trench and allow moisture to leach away into soil. Cover periodically.
- Sand drying beds or lagoons.
- Lagoons.
- Written permission now required; cease and desist orders on existing sites with problems; no approval for sites with leachate or potential groundwater problems.
- Methods should be according to conditions.

d. Environmental Impact. Respondents were asked to evaluate on a scale of 0 (none) to 10 (very great) the severity of hazards and problems anticipated from landfill disposal of sewage sludge. Table II-3 summarizes the obtained information.

The median and the mode are values indicating central tendency. The median is the middle value, or that rating value which divides the ranked data into two equal parts. The mode is the value of greatest frequency, or that rating value which received the largest number of responses. The medians were: municipal sewage sludge, 3; septic tank sludge, 4--indicating respective clusters of consensus at the very little and very moderate levels of anticipated environmental hazard. The modes were 1 (6 out of 24 responses) for sewage sludge and 4 (7 out of 24 responses) for septic tank pumpings.

In the no-to-little hazard categories (0 through 3), the number of responses were: municipal sewage sludge, 13; septic tank sludge, 7. Responses in the moderate

TABLE II-3

ANTICIPATED LEVEL OF ENVIRONMENTAL HAZARDS AND PROBLEMS ASSOCIATED WITH LANDFILL DISPOSAL OF MUNICIPAL SEWAGE/SEPTIC TANK SLUDGE

(scale of 0 to 10; 0 = none, 10 = great hazard)

	Rating level of hazards/problems by number of responses														
	None	Little				Moderate					Great				
Type of sewage	0	1	2	3	Sub-total	4	5	6	7	Sub-total	8	9	10	Sub-total	Total
Municipal sewage	1	6	2	4	13	1	5	0	4-1/2*	10-1/2	1/2*	0	0	1/2	24
Septic tank	0	2	3	2	7	7	4	2	2-1/2*	15-1/2	1-1/2*	0	0	1-1/2	24

*Two respondents gave range of 7-8.

rating range (4 through 7) reversed these proportions: municipal sewage sludge, 10 1/2 responses; septic tank sludge, 15 1/2. The only responses in the category of great anticipated hazard (8 through 10) were municipal sewage sludge, 1/2, and septic tank sludge, 1 1/2. (Fractions result from two 7-8 rating responses.)

In general, therefore, the responding state department of health officials anticipated only little or moderate environmental hazard as the result of landfill disposal of either type of sludge; more serious difficulties, however, were expected for septic tank than for municipal sewage sludge.

2. Detailed Description of Survey of Landfill Managers. The postal questionnaire (see Appendix B) was designed to survey prevailing practices and opinions concerning the disposal to sanitary landfills of sewage and septic tank sludge. The questionnaire was distributed nationwide to the City Engineers or Directors of Public Works of 475 cities with minimum populations of 10,000 (19.2 percent coverage). A total of 174 cities and two counties responded; of these, 44 had no operating landfills under their direct jurisdiction. The questionnaires were therefore answered, in whole or in part, by officials of 132 jurisdictions. Incomplete responses are responsible for the wide variations in totals which, for any one question, were usually below the possible maximum.

a. Landfill Sludge Disposal. The majority of 122 landfills reporting on whether sludge disposal was permitted did not permit disposal of any sludge (sewage/septic tank/industrial, liquid, or hazardous wastes). The responses were: disposal permitted, 36 (30 percent); prohibited, 86 (70 percent). Twenty-nine of the landfills which permitted sludge disposal identified the waste as sewage and/or septic tank sludge: sewage sludge only, 19; septic tank sludge only, 3; sewage and septic tank sludge, 7.

b. Service Population. The service population distribution for the 29 cities permitting sewage/septic tank landfill sludge disposal was:

Population			Number of Cities
10,000	-	50,000	11
50,001	-	100,000	7
100,001	-	500,000	8
		> 500,000	3
Total		4,622,000	29

c. Distance from Nearest Residential Area. Of 27 reporting sewage/septic tank disposal landfills, 25 were 1/4 mile or more from the nearest residential area. The most commonly identified distance was 1/2 mile (nine landfills). The two landfills in close proximity to residential areas were about 200 ft from the nearest housing.

d. Public Versus Private Operation. Of a total of 118 responding landfills, 99 (85 percent) were public, and the remaining 19 (15 percent) were private operations. Of the 29 landfills permitting sewage/septic tank sludge disposal, 23 (79 percent) were public, 5 (17 percent) were private, and 1 (4 percent) was unidentified.

e. Future Landfill Use. The 28 responses received concerning the future land use of the landfills accepting sewage/septic tank sludge were: park/recreation/golf course/landscaping, 15; agriculture, 5 (farm/crops, 3, and grazing, 2); agriculture or recreation, 1; storage area for digested sludge to be used as soil conditioner, 1; return to landowner, 1; not known, 4; and no future use planned, 1.

f. Type of Landfill Operation. The distribution of responses received from the 29 landfills permitting sewage/septic tank sludge disposal was: cut and cover, 13; canyon or ravine, 5; pit or quarry, 3; unidentified, 2; and the remaining 6 were variously described as sludge harvest, diked flood plain area, spread and dry, diked in marshland, trench, and area fill. One of the cut and cover operations was identified as an old strip mine.

g. Size of Landfill. Most of the 18 sites reporting sewage/septic tank sludge disposal into landfills were 100 acres or less in area. The area size distribution was:

Acres	No. of Landfills
< 50	8
51 - 100	4
101 - 150	0
151 - 200	5
> 2,500	1
Total	18

For 21 landfills reporting sewage/septic tank sludge disposal, the distribution of final depth of fill was:

Final Depth (ft)	No. of Landfills
< 10	5
11 - 20	7
21 - 30	5
50 - 100	4
Total	21

h. Quantities of Sewage/Septic Tank Sludge Disposed. Septic tank pumpings represented less than one-half of one percent of the total sewage sludge disposed at reporting landfills. Table II-4 summarizes the data.

i. Sludge Disposal Methods. The following are the responses to the inquiry concerning the methods of applying sewage/septic tank sludge at landfills:

-Dumped in sand and gravel within open pits previously dug by bulldozer; pits then filled to control odor and other problems.

TABLE II-4

ESTIMATED QUANTITIES OF SEWAGE AND SEPTIC TANK SLUDGE DISPOSED AT REPORTING LANDFILLS

Type of sludge	Quantity disposed: No. of reporting landfills*	Quantity disposed: Total annual quantity (1000 gal/yr)	Quantity disposed: Total annual quantity (Percent)	Quantity disposed: Avg. annual quantity per landfill (1000 gal/yr)	Sludge solids content: No. of reporting landfills*	Sludge solids content: Range (Percent dry weight)	Sludge solids content: Median (Percent dry weight)
Municipal sewage	16	534,945	99.6	33,434	24	0.5-97+	8
Septic tank	8	2,461	0.4	308	7	2-85+	10
Total		537,406	100.0				

* Some landfills allow both municipal and septic tank sludges.

\+ Probably contains appreciable amounts of sand and other inert solids.

Note: Liquid sludge solids are generally in the range of 1.5 to 6 percent dry weight. Dried sludge, of course, has far less water.

-Dumped at site and leveled.
-Dumped on top of fill and mixed with refuse during compaction.
-Dumped into pit.
-Dewatered by vacuum filtration; moved to landfill, dumped, and immediately buried.
-Only air-dried digested sludge accepted.
-City landfill disposal of sludge unregulated.
-All sludges incinerated (ashes presumably disposed to landfill).
-Six-percent solids sludge pumped to area, liquid discharged daily to sloped drying beds; separated clear supernatant decanted to sewer system; remaining solids drained, dired, and harvested for park fertilizer use.
-Spread and tilled into the soil.
-Spread on field where no other waste allowed; tilled and mixed with field dirt.
-Allowed to air-dry, then shredded and used for lawn fertilizer.

j. Environmental Protection. Table II-5 summarizes the responses to key questions related to the existing environmental protection procedures (use of daily refuse cover, compaction, etc.) at landfills which accept municipal sewage sludge and septic tank pumpings.

k. Anticipated Hazards and Problems. All respondents, irrespective of local sewage sludge disposal practice, were asked to evaluate on a scale of 0 (none) to 10 (very great) the potential severity of hazards and problems which might result from landfill disposal of sewage and septic tank sludge. The data is summarized in Table II-6.

The median ratings for municipal sewage sludge and septic tank sludge were 2 and 5, respectively. This indicates that the respondents believed that the municipal sewage sludge (presumably well digested) is considerably less hazardous than septic tank sludge. The modal values were zero (22 out of 99 responses) and 8 (13 out of 92 responses) for the municipal sewage sludge and septic tank sludge, respectively. There was a considerable divergence of opinion on hazards of septic tank sludge; rating values ranging from zero to 10 were reported by 12 of the respondents. The results thus indicated that septic tank pumpings were considered potentially more hazardous than municipal sewage sludge.

l. Special Comments. Practical experience with septic tank pumpings has demonstrated that they are both odoriferous and contain pathogenic type micro-organisms.[4] Nevertheless, the septic tank pumpings may be satisfactorily disposed of within sanitary landfills if special precautions are taken to assure proper spreading, absorption into solid waste, soil cover, leachate control and sanitation. Good sanitation practices would include isolation of operating personnel and vectors from contact with the pumpings. Isolation of personnel may require restricting their access to areas where septic tank pumpings are disposed (except for equipment operators),

TABLE II-5

ENVIRONMENTAL PROTECTION PROCEDURES AT LANDFILLS ACCEPTING SEWAGE/SEPTIC TANK SLUDGE

Question Do procedures exist for:	No. of responses Yes	No	Response Description/comment
Catching drainage from sludge overflow?	13	12	Reservoirs; no overflow; mix sludge with refuse; dikes and decant beds.
Isolating landfill from contact with groundwater?	14	12	Compact base prior to filling; trenches lined with clay: clay liner is used: contained inside diked area; pumped; lagooned: seepage to bay.
Isolating landfill from surface drainage?	15	10*	Storm sewer system around the site; bury before contact: berms; dikes and levees; diked; lagooned; landfill not located in natural drainage channel; little surface drainage; only rainfall enters.
Daily cover of refuse?	22	5	
Compaction?	12	10	

*One reporting landfill plans to establish procedure in the future.

TABLE II-6
OPINION RATINGS OF ANTICIPATED PROBLEMS/HAZARDS ASSOCIATED WITH LANDFILL DISPOSAL OF SEWAGE AND SEPTIC TANK SLUDGE
(scale of 0 to 10; 0 = none, 10 = very great hazard)

Type of waste	Problem/hazard rating value responses in percent: None 0	Little 1-3	Moderate 4-7	Great 8-10	Mean	Mode
Municipal digested sewage sludge	22	39	26	12	2	0*
Septic tank pumpings	12	21	38	28	5	8+

* Of 99 responses, 22 were at zero.
\+ Of 92 responses, 13 were at eight.

wearing face masks and protective clothing. Effective operating supervision is needed to assure prompt soil cover of the fill, thereby eliminating odor nuisance, protecting against pathogens and restricting vectors.

The Great Britain Royal Commission on Environmental Pollution presented two reports to Parliament in February 1971 and March 1972 which identified wastes disposed into landfills in England that were considered "toxic". No mention of sewage sludge as being toxic or otherwise hazardous was made in either report.

3. 1962 Survey Comparison. A separate survey completed in 1962 by Ralph Stone for the ASCE[2] indicated that 19 percent of reporting landfill operators permitted the disposal of sewage and septic tank sludges. The lower rate of permitted disposal was given by respondents as resulting from disposal sites being located too near usable waters. The risk of contamination from leachate was considered too high for septic tank sludge disposal into many reporting landfills.

Comparing the results of the 1962 and 1971 Ralph Stone and Company, Inc. surveys, the percentage of respondents in 1971 that indicated landfill disposal of digested liquid sewage and septic tank sludges was permitted was 50 percent greater than the number of respondents indicating such permission in the 1962 survey. This comparison assumes that the respondents in both surveys were equally representative of all landfill operations. The cause of any trend could result from increasingly more stringent water quality standards preventing disposal to water bodies and high costs of alternative sludge disposal methods. Also many, if not most, of the landfills now probably receive some partially dried sludges. In regard to the high risk of water contamination, only about 50 percent of landfills permitting sewage sludge disposal in the 1971 survey had established procedures to catch drainage from sludge overflow and to isolate the leachate from ground water contact; 60 percent had procedures for isolating their landfill from surface drainage. Thus, while protection of receiving waters is of major problematic concern from a public health and water quality standpoint, operating practices do not appear to fully reflect this concern.

III. OCEANSIDE SOLID WASTE AND SEWAGE SLUDGE CHARACTERISTICS

A. Solid Waste Characteristics

In order to determine the feasibility of disposing all of the liquid digested sewage sludge generated in the City of Oceanside into the Oceanside landfill, a study was undertaken to establish the quantity, general make-up, organic content, and moisture percentage of the Oceanside solid waste. The description and results of this study are presented below.

1. Sampling Methodology. The City's Waste Disposal Department collects once a week from single family and small apartment residential units, and two to three times per week from large apartment buildings, commercial and industrial sites. No private collectors operated in the City as of 1972. The collectors completed a special census to determine the number and type of collection stops during a one-week period in February 1971. The resulting information concerning the distribution of collection stops serviced each day of the week and the type of stops (residential, apartment, commercial/industrial) are given in Table III-1.

A one percent solid waste sample size based on the total number of stops collected per week was selected; based on a total of 12,430 stops, the one percent sample size (133 stops) should provide a statistical confidence level of 95 percent at about 9 percent precision (error). The stops used for sampling solid waste were selected using random number tables and then counting down the City Sewer Department billing list and recording the address each time a specified random number was reached. The number of stops for sampling were stratified by type of stop and day of the week as shown in Table III-1.

One waste collection truck operated by a two-man crew was accompanied by a member of the Consultant's staff to test-sample the solid waste. The vehicle preceded the regular collection trucks each day, Monday through Friday, once each seasonal quarter of the first year demonstration, to obtain four separate representative solid waste samplings from the same randomly selected collection stops. All waste sample vehicles were weighed and then the samples were taken to the City's landfill for hand sorting into the standard nine major categories defined by the Environmental Protection Agency (EPA), Office of Solid Waste Management Programs (OSWMP). Several of the nine major categories were further broken down by sorting into sub-categories to separate wastes that absorb moisture from those that are non-absorbent as follows: paper--newsprint, cardboard, and miscellaneous paper; garden wastes--tree and shrub prunings, leaves, and grass; plastic, rubber, and leather--foam materials and solid materials; dirt, ash and sand, which were differentiated from concrete and rock.

TABLE III-1

SOLID WASTE SAMPLING*

Feb 1971 week Day	Collection stops (no.)				Sample stops (no.)			
	Res.	Apt.	Com. & indus.	Total	Res.	Apt.	Com. & indus.	Total
Mon	1,332	428	540	2,300	14	5	7	26
Tue	1,823	116	367	2,306	19	2	4	25
Wed	1,329	140	586	2,055	15	3	7	25
Thu	1,729	269	364	2,362	18	3	4	25
Fri	2,282	213	442	2,937	23	3	6	32
Sat	64	151	255	470	0	0	0	0
Total	8,559	1,317	2,554	12,430	89	16	28	133

*Sample size is 1 percent of the total number of stops in the City of Oceanside, California.

In addition to sampling wastes quarterly, all of the wastecollection vehicle loads collected during a one-week period each quarter of the first year demonstration were weighed prior to unloading at the landfill. One week each month the vehicles disposing to the City landfill were tabulated daily by type of vehicle and type of solid waste. A designated landfill equipment operator was trained to perform this latter categorization. The landfill vehicle tabulation data sheet is shown in Appendix B.

A platform scale was installed near the landfill entrance in February 1973. From March 12, 1973 until the end of the study period, each Oceanside Waste Disposal Department collection vehicle was weighed prior to disposing its solid waste load at the landfill. The weight of the vehicle was subtracted from the gross weight to determine the net weight of solid waste. A daily record was kept of the weighed solid waste received at the landfill by the Oceanside Waste Disposal Department.

2. Waste Characteristics. The solid waste sampling procedure described in the preceding section yielded the results shown in Table III-2 for the four sampling periods of 1971. The percentages in the total column are based on the combined weights of each component for all four sampling periods.

Moisture analyses of the samples selected as representative of each component are given in Table III-3. It should be kept in mind that these analyses represent the moisture content of solid waste as received at the landfill site. During the April sampling period, one day of rainfall occurred as the truck traversed the route collecting the sample for one day's test sorting. This rainfall is probably reflected in the notably higher moisture content of papers, textiles, and foam plastics during the latter period than was found in the other three sampling periods.

The organic content of the various components is presented in Table III-4, and shows relatively little seasonal variation. Of possible significance may be the greater organic content of the dirt, ash and sand category in July (summer) which may be attributed to the greater grass cutting during the warm growing season. Methods used to determine moisture and organic content are described in Appendix A.

During 1971 the Boys' Club conducted a newspaper drive and the Girl Scouts sponsored an aluminum can salvage program. A comparison of the City of Oceanside solid waste composition with that of the City of Los Angeles in Table III-5 shows less newsprint, but more metals, for Oceanside. Apparently, the aluminum can salvage had little effect on metals content in the solid waste. But the newspaper drive, which was highly publicized and had special collection bins in shopping center parking lots, did significantly reduce the newsprint content in the solid waste. Other reported solid waste contents are also described in Table III-5 for comparison purposes.

During the first year, a portion of the old Oceanside municipal landfill was excavated as part of a construction project. Several samples of solid waste materials were obtained and analyzed from the excavation to a depth of 15 to 20 feet. The

TABLE III-2
COMPOSITION OF OCEANSIDE MUNICIPAL SOLID WASTE
(1971)

Category of waste	Composition (percent dry weight) April	July	Oct	Dec	Weighted average*
Newspaper	6.1	4.9	8.6	10.3	7.2
Cardboard (corrugated & solid)	6.3	8.5	9.3	9.8	8.3
Miscellaneous paper	24.4	28.2	17.4	23.8	23.6
Total paper	36.8	41.6	35.2	43.9	39.1
Food waste	9.5	9.5	7.5	9.7	9.2
Glass & ceramics	15.5	9.9	12.1	15.5	13.3
Metals	8.3	8.4	9.6	9.4	8.8
Trees & shrub prunings, Leaves	9.7	6.3	4.8	3.1	6.3
Grass	2.0	7.9	1.8	1.7	3.8
Total garden waste	11.7	14.2	6.6	4.8	10.1
Textiles	1.9	2.7	2.6	2.1	2.3
Total rubber, plastics, and leather	7.9	2.7	5.7	4.4	5.3
Wood	1.9	1.8	2.9	1.8	2.1
Dirt, ash, & sand	0.5	0.3	0.8	0.4	0.5
Concrete & rock	0.1	1.3	0.4	Neg	0.4
Other (unclassifiable)	5.9	5.6+	16.5+	8.0+	8.9
Grease	0	0.4	0	0	
Total	100.0	100.0	100.0	100.0	100.0

*Obtained by summing the weight of quarterly samples for each category of waste, and then calculating the weighted average based on the total 14.5 tons dry weight of all samples.

+ All material passing through 2-inch sieve.

TABLE III-3

MOISTURE CONTENT OF OCEANSIDE SOLID WASTE

(1971)

Category of waste	One week's average (percent dry weight) April	July	Oct	Dec	Weighted average*
Garbage	58.1	79.7	73.2	72.8	70.9
Textiles	24.9	11.2	19.8	9.9	16.4
Grass	57.1	51.3	65.6	56.3	57.6
Wood	17.6	11.1	14.0	15.5	14.6
Newsprint	43.4	27.6	27.3	15.7	28.5
Cardboard	34.4	14.9	26.1	21.3	24.2
Misc. paper	35.6	17.9	21.6	17.4	23.1
Prunings, leaves	--	58.7	29.5	42.4	43.5
Foam plastic, rubber	51.9	4.6	17.8	--	24.8
Hard plastic, rubber and leather	9.4	4.9	--	10.4	8.2
Dirt, ash, & sand	23.8	30.8	8.4	2.0	16.2
Misc. (2" sieve)	28.3	26.9	35.0	37.0	31.8
Total	29.8	26.3	23.4	21.0	25.1

*Obtained by summing the weight of moisture in each week's samples by category of waste, and calculating percentages of the total weight of samples by waste category.

TABLE III-4
SEASONAL EFFECT ON
ORGANIC CONTENT OF OCEANSIDE SOLID WASTE
(1971)

Category of waste	One week's average (percent dry weight)				
	April	July	Oct	Dec	Weighted average*
Garbage	87.8	85.7	83.6	74.4	82.9
Textiles	97.2	89.5	86.0	86.2	89.7
Grass	74.8	89.3	81.0	84.6	82.4
Wood	98.4	90.4	87.5	82.7	89.8
Newsprint	99.2	80.5	92.8	85.7	89.6
Cardboard	94.8	91.3	91.8	86.8	91.2
Misc. paper	93.3	88.7	88.4	86.1	89.1
Prunings, leaves	92.6	89.7	88.0	84.5	88.7
Foam plastic, rubber	--	96.8	73.3	98.3	89.5
Hard plastic, rubber and leather	--	89.5	--	96.0	92.8
Dirt, ash, & sand	4.1	30.5	13.4	8.6	14.2
Misc. (2" sieve)	--	61.7	31.3	66.8	53.3
Total	57.3	69.6	55.8	61.9	61.2

*Obtained by summing the weight of organics in each week's samples by category of waste, and calculating percentages of the total weight of samples by waste category.

TABLE III-5
COMPOSITION OF MUNICIPAL SOLID WASTES

Category of waste	Percent, wet weight: Oceanside*	Los Angeles+	Santa Clara #	Long Island **	National average ++
Newsprint	7.4	10.7	-	14.0	-
Cardboard	8.2	3.6	-	25.0	-
Miscellaneous paper	23.3	27.0	-	7.0	-
Total paper	38.9	41.3	55.0	46.0	48.0
Food	12.3	5.3	0.0	12.0	19.0
Glass & ceramics	10.6	7.3	0.0	10.0	8.0
Metals	7.1	6.0	8.0	8.0	9.0
Total vegetation (tree and shrub-prunings, grass & leaves)	12.4	33.1	34.0	10.0	4.0
Textiles	2.2	2.0	0.0	5.0	3.0
Hard rubber, leather, plastics	4.3	-	-	-	-
Foam rubber & plastic	0.2	-	-	-	-
Total rubber, leather, plastic	4.5	2.6	3.0	4.0	4.0
Wood	1.7	1.6	0.0	5.0	2.0
Dirt, sand, ash	0.5			0	3.0
Concrete, rock	0.4	0.8		0	0
Total soil, concrete, rock, ash	0.9	0.8	0.0	0	3.0
Other (2" sieve)	9.4	-		-	-

* *Composited from four quarterly samples taken during 1971.*

+Los Angeles, California (wet wt) as received 1/14/71 (88 loads).

#Santa Clara, California. From: Underground incineration of solid wastes. Ralph Stone and Company, Inc., U. S. Public Health Service Grant No. 1 GO6-EC-00190-01, July 1970.

** Long Island, New York (suburban, similar to Oceanside). Kaiser, Elmer. Thermal processes for refuse reduction, presented at APWA, Institute for Solid Wastes, Annual Meeting, Boston, Mass., Oct. 1-5, 1967.

++ Hickman, Lanier, Jr. Characteristics of municipal solid wastes. Scrap Age, Feb. 1969.

samples were analyzed for total solids and organic content. The results are shown in Table III-6. A comparison of the materials obtained from the excavation which were placed in January 1963 with those samples in 1971 shows very little difference in organic content, thus indicating that the decomposition was negligible. The excavated magazines and newspapers were easily read, and tree, shrub, and grass leaves were still green. The sampled wastes exhibited negligible degradation after almost nine years of sanitary landfill burial. The opened landfill was extremely odoriferous and the old waste was quickly reburied and covered with earth.

3. Waste Generation. The quantity of solid waste produced in the City of Oceanside during four seasons of 1971 is given in Table III-7. The quantity generated during June exceeds the average of the quantities for January, March, and October, possibly due to increased summer tourist population and greater garden and other plant growth. The reason for variations in daily quantities between each season is not known. The solid waste daily average production was about 85 tons Monday through Friday, and about 25 tons on Saturdays.

The daily and monthly quantities of solid waste received at the new City landfill beginning March 12, 1973 as weighed on the platform scale are given in Table III-8. As in 1971, more solid waste was produced during the summer months. The solid waste daily average production in 1973 was 115 tons Monday through Friday and 36 tons on Saturday, and in 1971, 87 and 26 tons, respectively. This is a 35 percent increase since 1971, probably reflecting the growth of the Oceanside area during the study period.

A summary of the landfill vehicle counts for 1971 is given in Table III-9. Loads of demolition wastes are tabulated separately as these materials were largely from highway construction and other special sources. The data for December were taken at the new City landfill which initiated operation on November 15, 1971. Private householders are generally not allowed to dispose at the new landfill site; commercial gardeners and those that deliver cover materials may, however, unload at the fill. Of the total of 3,175 loads counted during 1971, 1,153 or 36.4 percent were delivered by private vehicles, and the Oceanside Waste Disposal Department accounted for 38.7 percent of the loads. The remainder of the vehicles were operated by the other City Departments. The types of solid wastes varied from normal household, commercial and industrial wastes to black top, dirt, gravel, street sweepings, brush, demolition, stoves, refrigerators, etc. Of course, the major solid waste volume and weight were delivered by the large Waste Disposal Department collection vehicles, rather than in the smaller vehicles of the other disposers.

B. Characteristics of Sewage Sludge and Septic Tank Pumpings

1. Types of Sewage Sludges. The Oceanside sewage treatment system employs three separate wastewater treatment works: the La Salina, Buena Vista, and San Luis Rey Plants.

TABLE III-6
MOISTURE AND VOLATILE SOLIDS CONTENT
OF OCEANSIDE SOLID WASTE FROM OLD LANDFILL SITE
(PLACED IN LANDFILL JANUARY 1963; SAMPLED SEPTEMBER 1971)

Category of waste	Content, percent dry weight	
	Moisture*	Volatile solids*
Newsprint	47.3	95.2
Cardboard	35.5	84.5
Grass	62.1	83.9
Leaves	61.7	83.9
Textiles	18.0	82.4

*From: Standard Methods, 13th Edition.[3]

TABLE III-7
TOTAL WET WEIGHT OF SOLID WASTE
PRODUCED IN OCEANSIDE
(1971)

Day	Weight, tons*				
	January	March	June	October	Average
Monday	104.71	84.54	93.45	104.45	96.79
Tuesday	76.37	87.52	100.45	55.47	79.95
Wednesday	56.81	60.07	82.82	76.88	69.15
Thursday	78.03	84.65	88.83	65.71	79.31
Friday	103.29	99.24	130.62	109.27	110.61
Saturday	25.60	28.31	26.54	21.95	25.60
Total weight for the week	444.81	444.33	522.71	433.73	461.41+

* Wet weight as-received.
+ Estimated quantity of waste for 52 weeks is 23,992.8 tons per year.

TABLE III-8

OCEANSIDE SOLID WASTE WET WEIGHT
(1973)

	Weight, tons*						
Month	Mon	Tue	Wed	Thur	Fri	Sat	Monthly total
Mar	154.98	113.43	112.83	92.56	149.34	28.64	1,800.26
Apr	144.00	99.25	107.00	87.50	144.00	29.00	2,587.00
May	135.39	100.06	105.50	87.59	147.10	27.90	2,707.23
June	148.74	115.51	114.97	93.07	151.56	30.85	2,801.23
July	146.01	113.36	119.13	105.13	135.55	63.02	2,869.04
Aug	145.39	118.29	119.61	97.26	146.29	31.53	2,996.68
Sep	136.18	109.14	114.81	88.49	134.42	25.83	2,461.31
Oct	128.08	96.77	105.59	82.16	132.65	22.28	2,600.51
Nov	125.48	98.19	101.12	78.40	116.34	55.46	2,416.43
Dec	117.76	87.99	91.82	81.61	108.50	47.04	2,215.69
Average	136.99	104.87	106.39	89.45	136.37	36.22	2,545.54

* Wet weight as-received.

Note: Scale operation commenced March 12, 1973.

TABLE III-9

OCEANSIDE LANDFILL VEHICLE LOAD COUNT
(1971)

Week total (1971)	No. of loads by vehicle type					
	Auto/trailer/ st. wagon	Truck, 1/4-1 ton pick-up/ van	Truck, over 1 ton	Oceanside waste disp.	Municipal/ other	Total
February	21	69	40 (49) *	117	14	261 (310)+
March	3	38	25 (4)	136	47	249 (253)
April	14	83	77 (129)	134	28	336 (465)
May	12	81	86 (21)	135	14	328 (349)
June	4	48	74 (127)	91	0	217 (344)
July	7	106	52 (13)	125	1	291 (304)
August	9	83	8 (55)	121	7	228 (283)
October	18	110	74 (6)	126	3	331 (337)
November	8	71	36 (27)	123	12	250 (277)
December	0	91	29 (0)	121	12	253 (253)
Total veh. loads	96	780	501 (431)	1,229	138	2,744 (3,175)

* Loads of demolition waste.

+ Total including demolition waste.

The La Salina Plant has a flow capacity of 5 mgd and provides primary settlement followed by secondary activated sludge treatment. The plant process units consist of primary clarifiers, aeration tanks, secondary clarifiers, and heated two-stage sludge digesters. The digesters produce a final sludge with a total solids content varying between 3.9 to 5.4 percent, wet weight.

The San Luis Rey Plant has a design flow of 1.85 mgd (in 1971 it operated at around 50 percent of its design capacity). It provides treatment in a grit removal chamber, primary settling tanks, and a single-stage heated sludge digester. This plant also serves the limited but significant industrial wastes from plants in the City. The total solids content of the primary digested sludge varies from 3.3 to 8 percent, wet weight. The large variations are probably partially due to the variable flows from the industrial plants. The digested sludge from this plant tends to be more odoriferous than the digested activated sludges from the other two plants.

The Buena Vista Plant is the smallest of the three plants with a design flow of 0.5 mgd, and it provides activated sludge treatment and sludge digestion similar to the La Salina Plant. The treatment process units consist of a combination primary clarifier-aeration tank (Clarator), a secondary clarifier, and a heated sludge digester. The total solids content of the single stage digested sludge varies widely from 2.3 to 11.2 percent, wet weight.

Both the old San Luis Rey and Buena Vista Plants are scheduled to be closed down by 1975 when construction of a new San Luis Rey Plant should be completed to provide integrated tertiary treatment.

2. Sewage Sludge Characteristics and Quantities. Routine analyses were performed on sludge samples from all three treatment plants by both the City of Oceanside and Ralph Stone and Company, Inc. All of these tests have been plotted to show trends since the inception of the project. The results of these analyses are discussed below. All analytical methods used for sludge analyses were in accordance with Standard Methods,[3] 13th Edition, where applicable (see Appendix A).

The data on total solids and volatile solids for each of the treatment plants are shown in Figures III-1 through III-6. The data in these figures indicate a range of about 2 to 10 percent for over one year operation, with about 30 to 70 percent volatile solids based on dry weight; there was lesser variation in total solids or volatile solids content in the La Salina and San Luis Rey Plants' sludges.

The quantities of sewage sludge hauled for disposal from the three municipal sewage treatment plants are summarized in Table III-10. The sludge production was projected based on estimated raw sewage volumes and characteristics for the existing and planned sewage treatment plants providing activated sludge treatment of the total wastewater flow with normal sludge digestion efficiency. The projections are given in Table III-11.

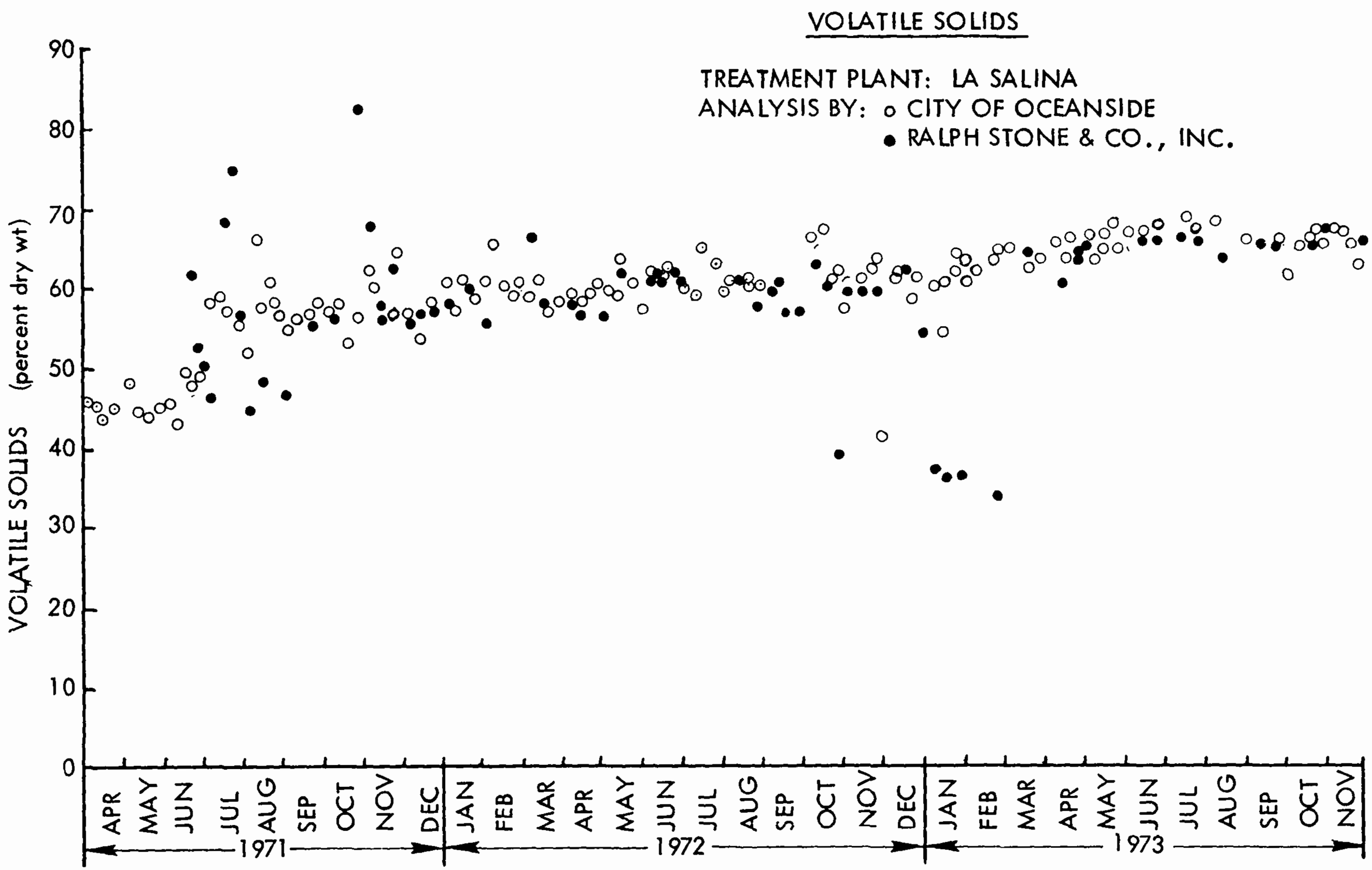


FIGURE III-1
PROPERTIES OF SLUDGES
FROM OCEANSIDE, CALIFORNIA

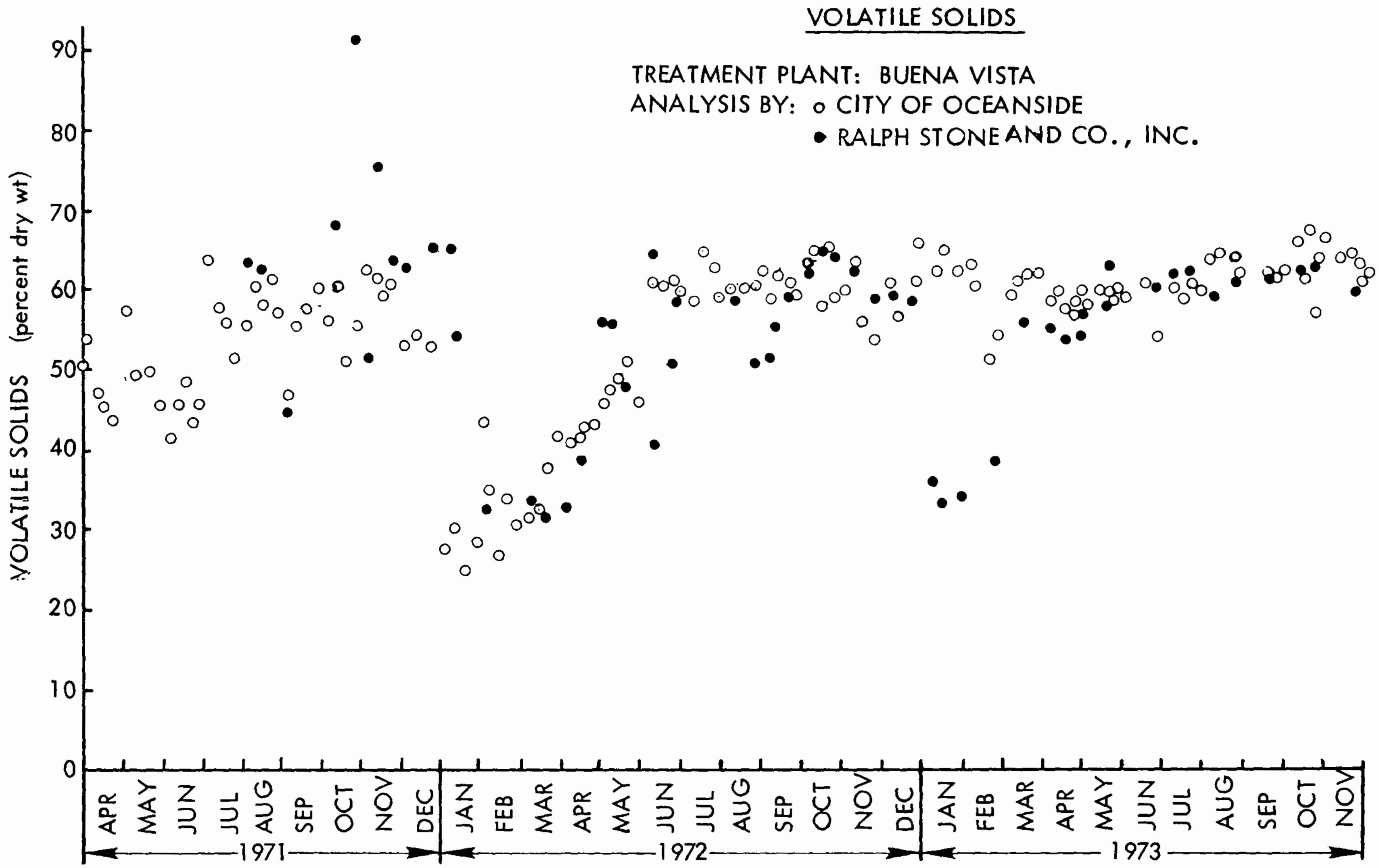


FIGURE III-2
PROPERTIES OF SLUDGES
FROM OCEANSIDE, CALIFORNIA

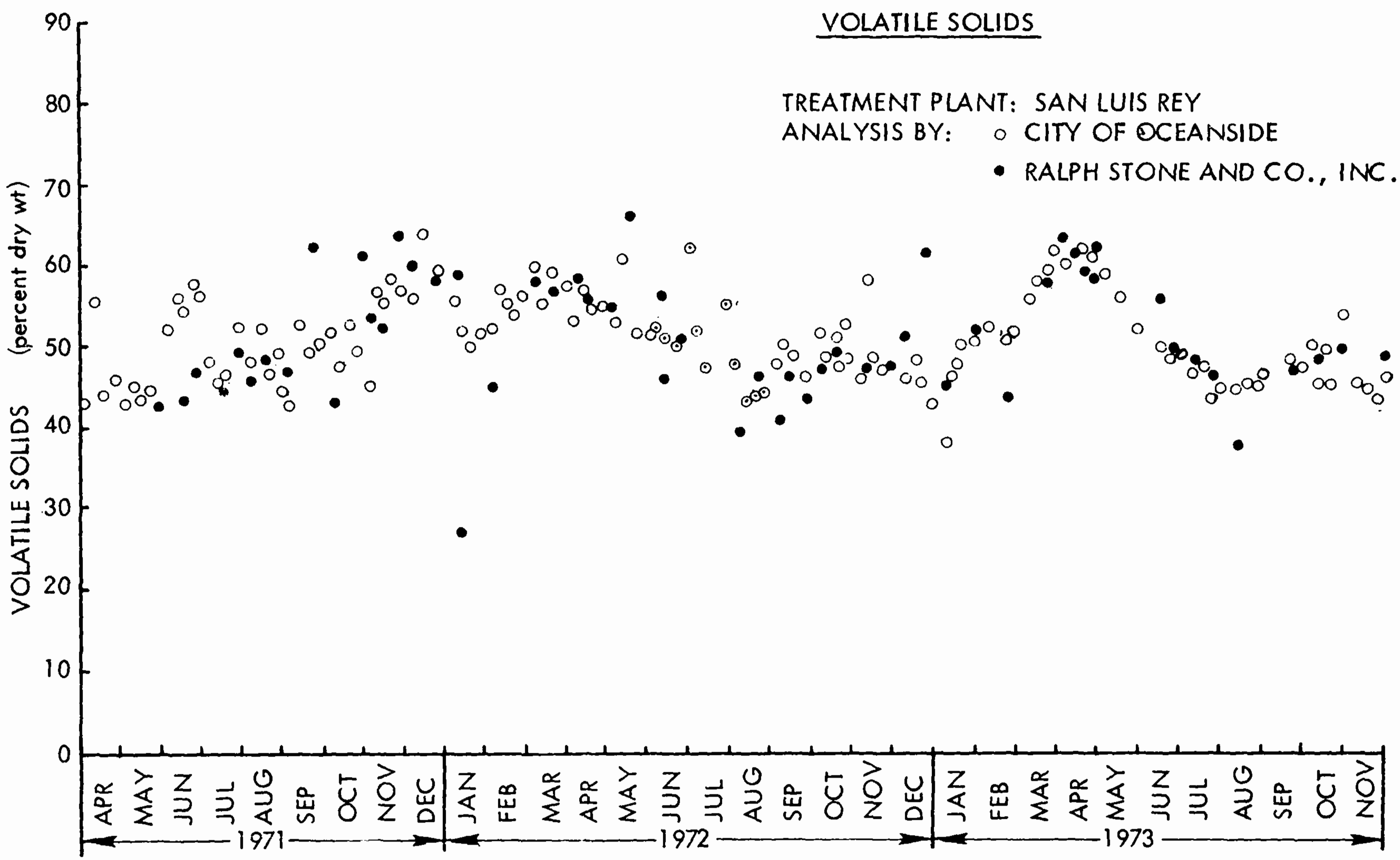


FIGURE III-3
PROPERTIES OF SLUDGES
FROM OCEANSIDE, CALIFORNIA

TOTAL SOLIDS

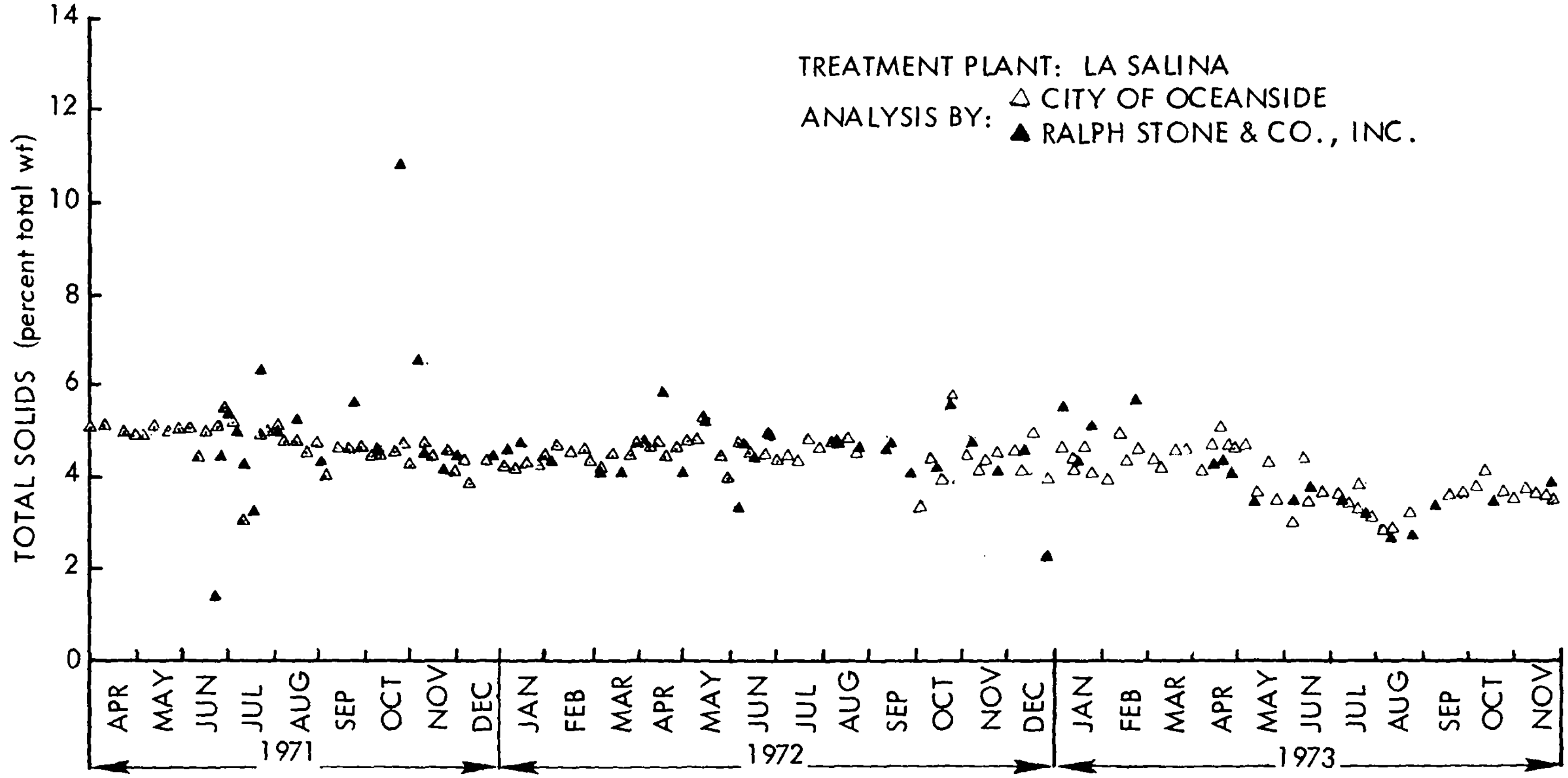


FIGURE III-4
PROPERTIES OF SLUDGES
FROM OCEANSIDE, CALIFORNIA

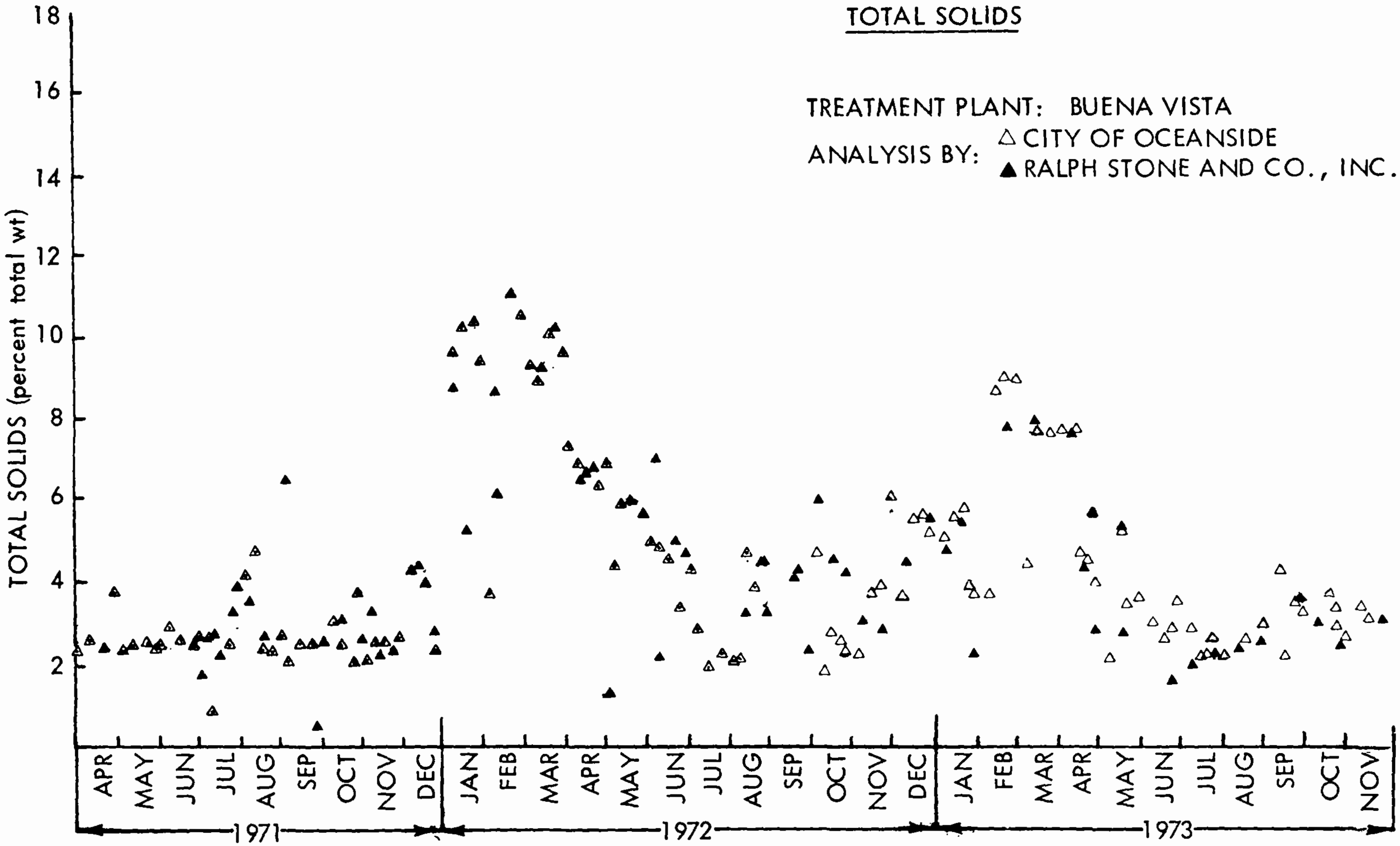


FIGURE III-5
PROPERTIES OF SLUDGES
FROM OCEANSIDE, CALIFORNIA

TOTAL SOLIDS

TREATMENT PLANT: SAN LUIS REY
ANALYSIS BY: △ CITY OF OCEANSIDE
▲ RALPH STONE & CO., INC.

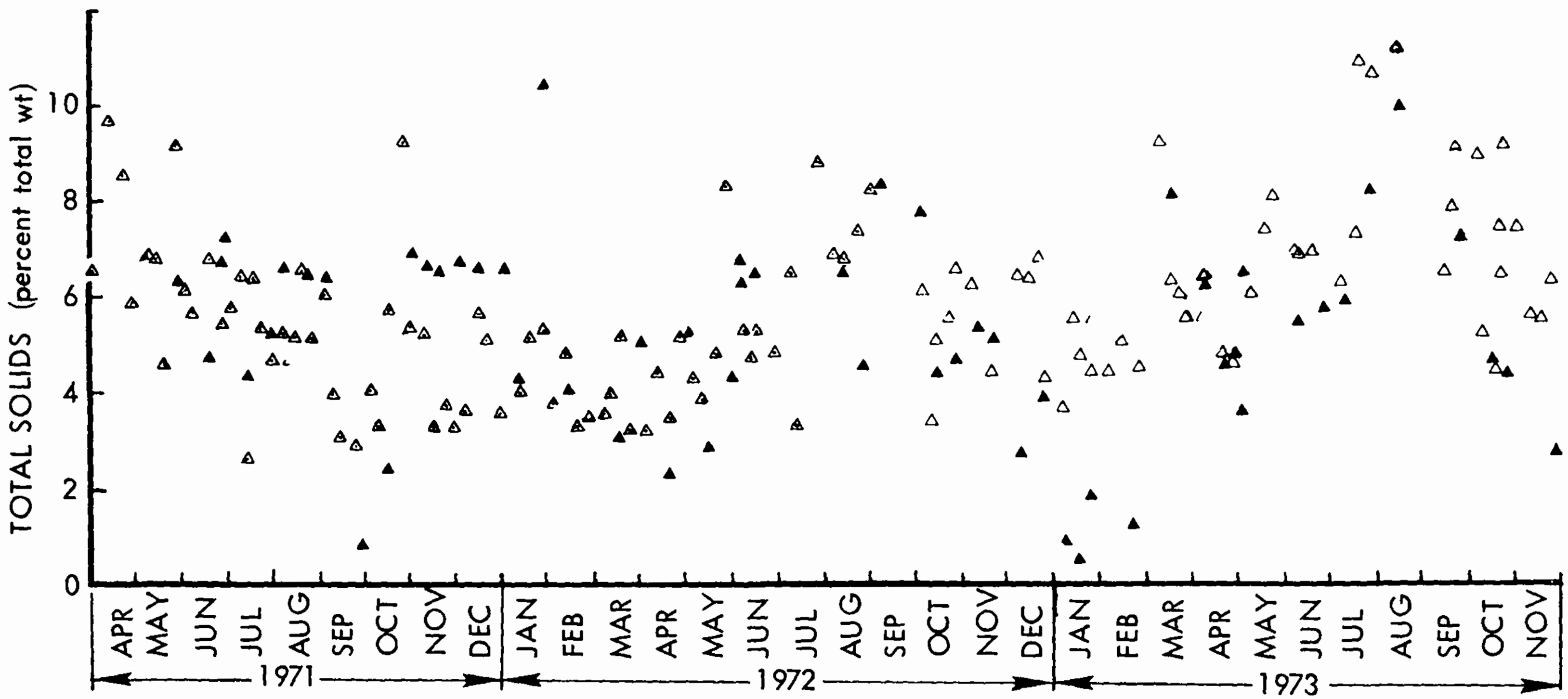


FIGURE III-6
PROPERTIES OF SLUDGES
FROM OCEANSIDE, CALIFORNIA

TABLE III-10
SLUDGE HAULED FOR DISPOSAL

Month	Gallons per plant			
	La Salina	Buena Vista	San Luis Rey	Total
1971				
Jan	133,000	49,000	21,000	203,000
Feb	162,000	52,000	24,000	238,000
Mar	108,000	68,000	35,000	211,000
Apr	63,000	78,200	45,500	186,700
May	56,000	84,000	52,500	192,500
June	59,500	66,500	50,750	176,750
July	63,000	63,000	59,500	185,500
Aug	68,250	70,000	64,750	203,000
Sep	56,000	56,000	63,000	175,000
Oct	81,000	71,500	45,500	198,000
Nov	91,000	59,500	45,500	196,000
Dec	59,500	21,000	35,000	115,500
Total	1,000,250	738,700.	542,000	2,280,950
1972				
Jan	91,000	56,000	38,500	185,500
Feb	66,500	101,500	35,000	203,000
Mar	101,500	31,500	38,500	171,500
Apr	178,500	17,500	42,000	238,000
May	210,000	38,500	85,500	334,000
June	188,000	83,500	36,500	308,000
July	234,500	80,500	31,500	346,500
Aug	234,500	77,000	38,500	350,000
Sep	220,500	91,000	56,000	367,500
Oct	102,000	75,500	50,000	227,500
Nov	56,000	77,000	59,500	192,500
Dec	94,500	63,000	38,500	196,000
Total	1,777,500	792,500	550,000	3,120,000

TABLE III-10 (CONT.)
SLUDGE HAULED FOR DISPOSAL

Month	Gallons per plant			
	La Salina	Buena Vista	San Luis Rey	Total
1973				
Jan	89,000	82,000	38,500	209,500
Feb	87,500	45,500	42,000	175,000
Mar	73,500	73,500	17,500	164,500
Apr	66,500	17,500	21,000	105,000
May	143,500	80,500	45,500	269,500
June	142,000	79,000	22,500	243,500
July	175,000	66,500	45,500	287,000
Aug	101,500	63,000	59,500	224,000
Sep	45,000	50,600	29,600	125,200
Oct	64,000	61,500	67,000	192,500
Nov	59,500	59,500	52,500	171,500
Dec	91,000	70,000	63,000	224,000
Total	1,138,000	749,100	504,100	2,391,200

TABLE III-11
PROJECTED TOTAL SLUDGE QUANTITIES

Sludge wet weight	Year 1985		Year 2000	
	(1,000 gal/day)	(million gal/yr)	(1,000 gal/day)	(million gal/yr)
Fresh sludge 3.5-4.5 percent solids	60	22.0	80	29.2
Digested sludge 5.0-6.0 percent solids	29	10.6	38	13.9

3. Characteristics of Septic Tank Pumpings. The differences and similarities between septic tank pumpings and digested liquid sewage sludges are of importance from the standpoint of landfill disposal. Septic tank pumpings may be expected to show a far wider variability in their composition than digested and municipal sludges. Septic tank pumpings were used in the present study in connection with the pilot-plant landfill simulation experiments (see Chapter VI). The pouring and penetrating properties of these pumpings were noted to be significantly different from those of digested municipal sewage sludges. One of the spetic tank samples analyzed was thin, having a BOD_5 reading of only 130 mg/l and flow viscosity characteristics essentially the same as water.[5] A thicker sample showed a BOD_5 reading of 1,630 mg/l, which would be fairly low for a municipal sludge, and about 2 percent total solids. Most significant was the nature of the solids; they were more granular and faster-settling than the solids of municipal sludge, having negligible effect on the flow characteristics of the liquid. Conductivities of the particular septic tank pumpings from outlying areas were 1,900 and 1,200 μmhos for the thick and thin pumpings, respectively, whereas the Oceanside sewage sludge was considerably more saline with 3,190 to 4,200 μmhos.

4. Analysis of a Composite Sewage Sludge Sample for Heavy Metals. A knowledge of the concentrations of various trace metals present in sewage sludge is essential for proper evaluation of the potential for groundwater pollution through leaching or pollution of surface waters through runoff. Since these analyses were too costly for numerous individual samples, a composite sample was made by taking 50 ml portions from all bi-weekly sludge samples received from the three Oceanside treatment plants. The La Salina Plant produces a larger quantity of sludge than the other two plants. For this reason, the bi-weekly composites were composed of a 100 ml portion from La Salina and 50 ml portions from Buena Vista and San Luis Rey. The results of these analyses for 1971, 1972, and 1973 are presented in Table III-12.

The concentrations for lead, chromium, and mercury (toxic heavy metals) were less than 0.1, 0.01, and 0.1 μg/l, respectively. It should be noted that these concentration levels represent the detection limits of the analytical techniques used and not the actual concentrations of the heavy metals. It is entirely possible that the actual concentrations were significantly lower than the indicated detection limits. Heavy metals in sewage sludges usually originate in industrial wastes discharged into the municipal sewerage systems. Since industrial wastes do not account for a significant portion of the total wastewater flow in Oceanside, the sludges from Oceanside plants would not be expected to contain significant quantities of heavy metals. (Although sludge from non-industrial urban areas can contain significant amounts of heavy metals, sludges from municipal plants serving highly industrialized urban centers usually contain appreciably higher amounts of heavy metals.) Even if a sludge does contain high concentrations of heavy metals, not all the heavy metals may be leached out from the landfill. Considerable heavy metal content may also be present in normal or industrial solid waste disposed into a landfill.

TABLE III-12

CHEMICAL ANALYSIS OF SLUDGE COMPOSITE SAMPLES
FROM OCEANSIDE TREATMENTS PLANTS*

Element present	Concentration (mg/l) 1971	1972	1973
Copper	3.0+	0.23+	1.14+
Iron	0.16+	1.08+	0.15+
Fluorides	1.1#	2.4#	0.49#
Lead	<0.1+	<0.1+	<0.1+
Mercury	<0.1+	<0.1+	<0.1+
Chromium	<0.01+	<0.01+	<0.01+
Chlorides	400#	289#	298#
Hardness as $CaCO_3$	344#	260#	321#
Calcium	138+	48+	58+

* Composite was compiled from 100-ml portions taken from bi-weekly samples of sewage sludge from each of the three Oceanside treatment plants.

\+ Analyses by atomic absorption per Standard Methods, 13th Edition.[3]

\# Analyses as follows per Standard Methods, 13th Edition:[3] fluorides - SPADNS Method, Sec. 121C, p. 174; chlorides - Argentometric Method, Sec. 112A, p. 96; calcium carbonate-calculation method, Sec. 122A, p. 179.

IV. SOLID WASTE WATER ABSORPTION STUDIES

A. Purpose and Scope

The water retention or field capacity of municipal solid waste in a landfill is of considerable importance in that it influences the amount of leachate that may result from a given amount of rainfall or other source of water. Sanitary landfills may offer convenient and environmentally preferable disposal sites for liquid digested sewage sludge, particularly in dry climates. Some of the major factors to be considered in the design and operation of a combined sludge-solid waste landfill disposal system include: the quantity and characteristics of solid waste and sewage sludge generated by a community, the annual rainfall, and the maximum storm intensity. The composition range of municipal solid waste may be ascertained by standard sampling techniques; the results of such analyses are available for several communities. Similarly, the tonnage of solid waste and sewage sludge produced and the pertinent rainfall data can be determined or estimated for each community. To predict the quantity of sludge that could be applied to a landfill without exceeding its water retention capacity, data are needed on the absorptive capacities of the various component waste substances. Since such data have been heretofore lacking, laboratory tests were conducted to obtain data on absorption for substances commonly found in municipal solid waste. The physical properties evaluated were the saturation capacity, expressed as grams of water per gram of dry weight sample material, and the rate of absorption, expressed as the time required for an immersed sample to approach saturation. As discussed in subsequent chapters of this report, the laboratory test results were later evaluated in pilot-scale and field demonstration landfill tests.

B. Factors Affecting Absorption

The absorption of water from liquid sludge by the solid waste is affected by the physical and chemical (material) properties of both the sludge and the solid waste components. The important physical properties of a solid waste component are surface characteristics, shape, and size (dimensions). In general, the saturation capacity is a property of each solid waste component type, independent of size or shape, whereas the rate of absorption is affected by the material properties, the internal structure of the sample particle, and its minimum dimension. In the case of cloth, paper, and grass, the minimum dimension (i.e., thickness) may be minor for water passage; therefore, the rate of absorption may be effectively treated as a material property. For wood or soil, however, the rate at which a sample approaches saturation varies over a wide range, depending upon the minimum dimensions of the wooden object or depth and voids in the soil type. In other words, the time required for the center of a piece of wood or soil sample to approach saturation is roughly proportional to the minimum distance to be traveled by the water soaking through it, while a sample of cloth or paper, being of negligible thickness, may become saturated in a reasonably characteristic time interval with secondary effects due to the sample area. Wetted materials that are hydroscopic, permeable, and with a large surface area to volume ratio will reach field capacity more quickly than materials with contrary characteristics. This distinction should be kept in mind when comparing the water absorption properties of different constituents.

The nature and arrangement of the solid waste components also affect the rates of travel and absorption of water and the quality of the leachate. A small but unpredictable amount of water may be retained through interstitial entrainment of liquid in voids between particles. The extent of liquid entrainment is a function of the size, shape, and arrangement of solid waste component particles, and the viscosity of the liquid.

The rate of travel of the liquid through solid waste depends on three factors: the hydraulic pressure, the size of the voids and length of channels between particles, and the capillary action. The liquid flows via gravity fairly rapidly through large voids and thus can by-pass absorption onto surfaces; it also moves by capillary action through the materials at a slower rate dependent on the intercellular structure of the materials.

When a liquid wets a solid, there generally exists a greater attraction between the liquid and the solid than between particles of the liquid; e.g., adhesion is stronger than cohesion. The adhesive attraction of water and liquid sludge for the majority of of solid waste components provides the capillary mechanism by which these liquids travel and disperse through a landfill.

C. Laboratory Test Procedures

To determine the field capacity of the municipal solid waste materials for absorption of water, representative samples of typical solid waste components were immersed separately in water for varying lengths of time. The following substances were used: pulp and paper products (toilet tissue, paper towel, newsprint, corrugated cardboard, solid cardboard, and glossy magazine paper); wood (plywood, sticks and blocks); textile and related products (cotton, wool, synthetics, hemp, nylon, and leather); vegetation (garden trimmings such as live leaves, dead leaves, twigs from branches); and kitchen garbage (orange, banana and grapefruit peels).

Except for some plant samples which were immersed enclosed in a wire mesh basket, all test samples were immersed by suspending them from wire hangers into one-liter beakers filled with water. All tests were performed at ambient temperature (20± 2 C). For each material and immersion interval, three separate identical samples were used. The three samples were immersed in water as received; e.g., the samples were in the wet weight condition as normally received in a landfill. A fourth sample was dried overnight at 100 C and weighed to determine initial moisture content and dry weight. The amount of water absorbed by each test specimen was determined by subtracting the as-received (wet) weight from the weight after immersion. The moisture absorbed on a dry weight basis was calculated by dividing the water absorbed by the dry weight of each sample material. The "after-immersion" weights for the paper samples were determined after the samples were drip-dried for a sufficient length of time so that no water drop would occur after one minute. In the case of cloth samples, the specimens were weighed after they were lightly wrung between rolls to the extent that they slightly wetted the fingers when touched, but did not drip. Following immersion, the garden trimmings' samples were shaken and slightly blotted to dry their surfaces before weighing.

In the laboratory tests, less-absorbent waste constituents such as rock, concrete, metal, glass, hard plastic, ceramics, and rubber were not tested for moisture absorption. Soil (dirt, sand, ashes, etc.),which may be considered an inert material (and which is used to cover the consecutive strata of solid waste in a landfill), was tested for its capacity to entrain water in its pore, and for water percolation rates.

The following types of soil and soil-related materials were used in the laboratory tests: loam, clay (of marine sedimentary origin), Ottawa sand, humus (domestic garden compost), and charcoal ash (from barbecue charcoal briquettes). The maximum water-holding capacity of each sample was determined as follows. A small plastic cup containing the sample saturated with water was allowed to stand until the rate of dripping from an orifice in the bottom became negligible. The moist sample was then weighed, dried for 24 hrs at 200 F and weighed again. The saturated sample weight loss was reported as a percent of the final (oven-dry) weight.

The soil percolation experiments were conducted on loam and clay only. Prior tests have been completed with sandy soils which obviously have higher permeability. (Loam and clay account for typical common soils available at municipal landfill sites.) The loam samples were pulverized to varying fineness in order to obtain samples having a wide range of bulk specific gravities. The percolation experiments involved measuring the time required for downward movement of water through a 7 1/2-inch column of soil, 1-inch in diameter, under a constant head of 2-inches above the top of the column. The escape of the first drop of water from a screen at the bottom of the column was recorded to establish the percolation rate.

D. Results and Discussion

1. Water Absorption by Solid Waste Components. Figures IV-1 through IV-5, and Table IV-1 show the laboratory test data for the absorption of water by a variety of waste components. In these figures, the quantity of water absorbed expressed as percent of oven-dry weight above the initial as-received wet weight of the samples is plotted as a function of the immersion time. In cases where the spread in data for several samples was great, the envelope curves were drawn through the lowest absorption value, thus providing conservative absorption ranges. As indicated in Figure IV-1, the rate of absorption of water and the maximum absorption capacity varied widely with different types of paper products. For the samples tested, the water absorbed varied from 120 percent for the glossy magazine paper to more than 700 percent for the toilet tissue. The rate of water absorption was also higher for the toilet tissue than for any other type of paper tested. In all cases, however, maximum or equilibrium absorption capacity was attained in less than 40 minutes. Except for paper towel samples, which showed some variation in their absorption capacity, the results were consistently reproducible for similar paper products tested.

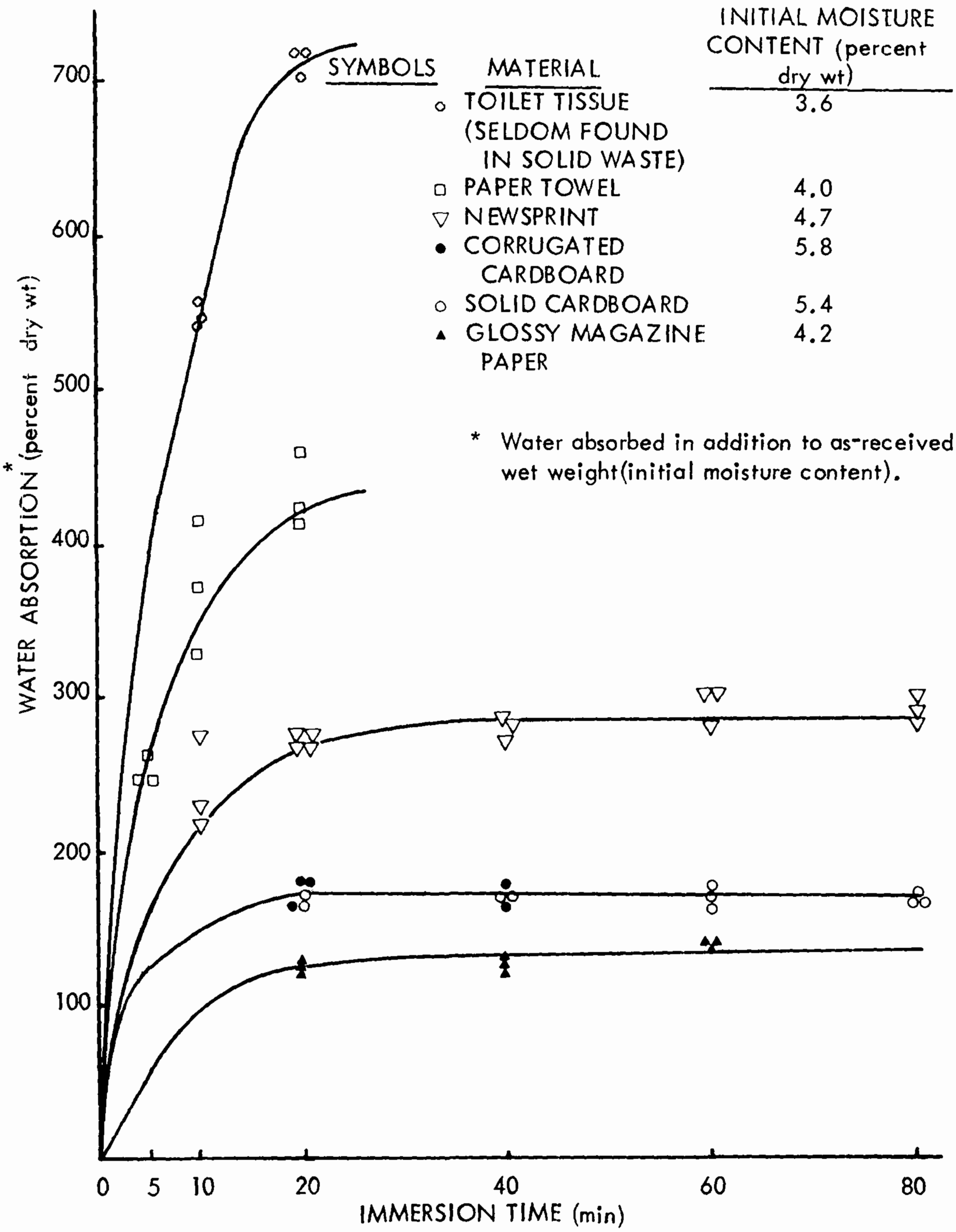


FIGURE IV-1

WATER ABSORPTION OF PAPERS

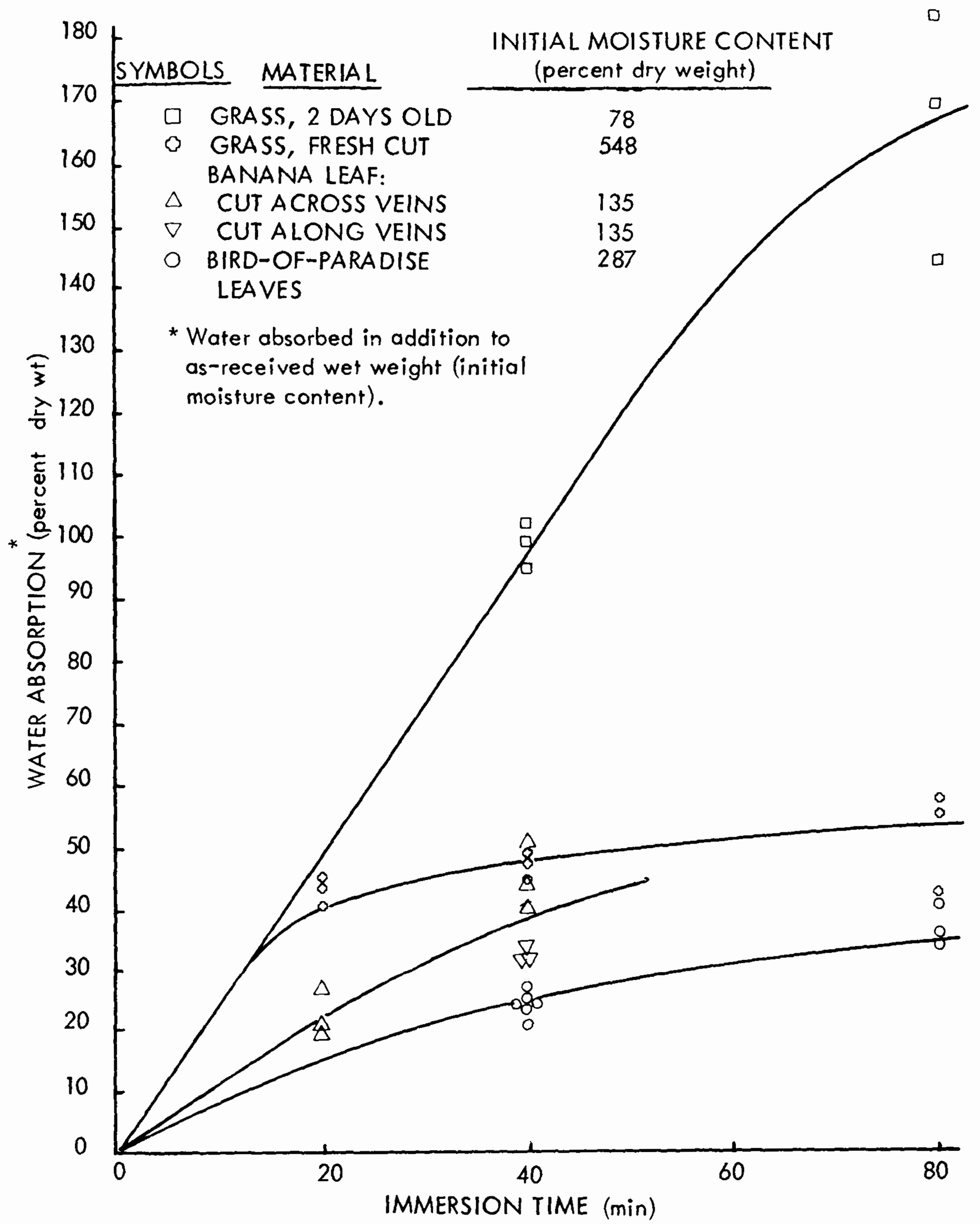


FIGURE IV-2
WATER ABSORPTION OF
PLANT TRIMMINGS (GRASS AND
OTHER MONOCOTYLEDONS)

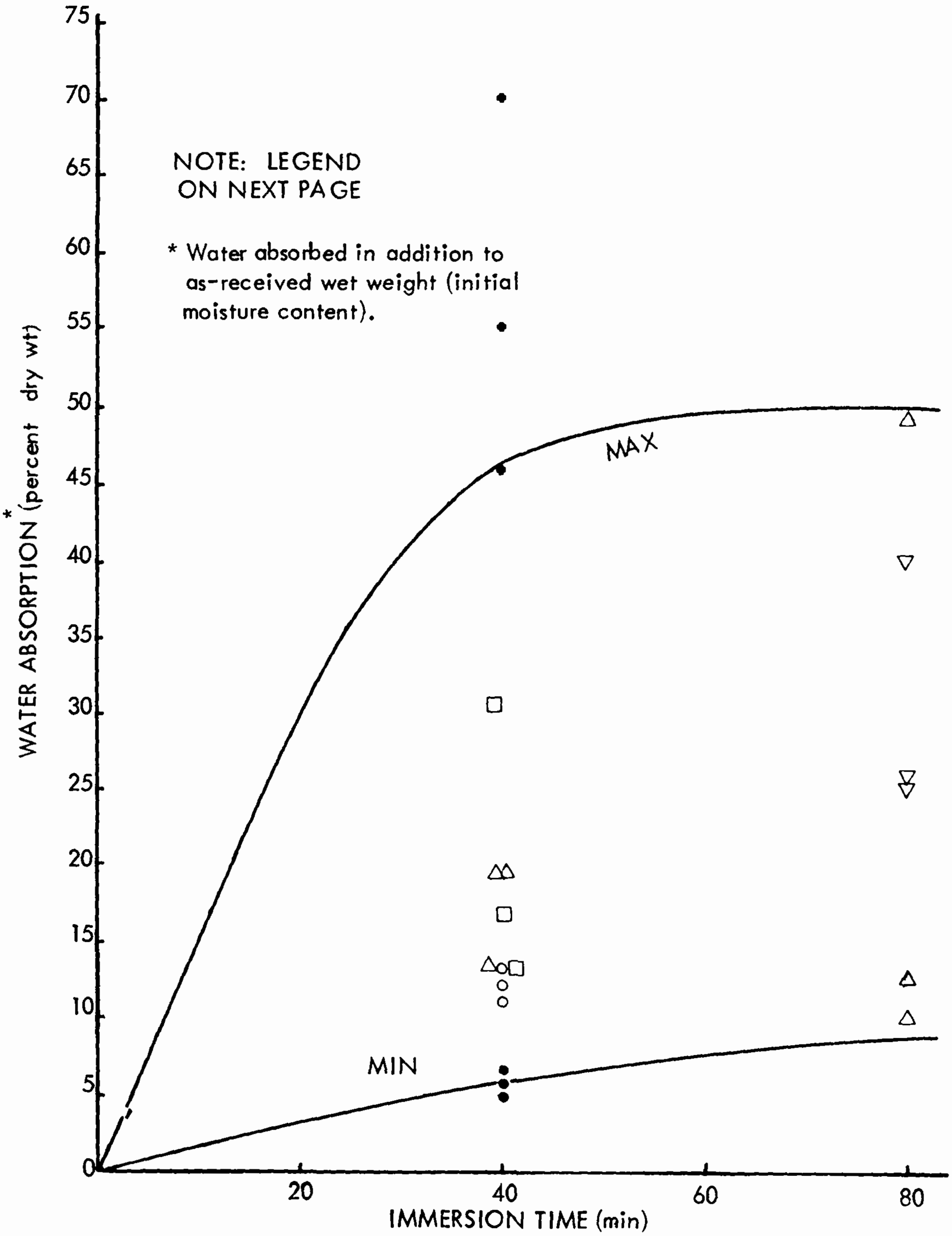


FIGURE IV-3
WATER ABSORPTION
OF PLANT TRIMMINGS
(WOODY SHRUBS)

SYMBOLS	MATERIAL	INITIAL MOISTURE CONTENT (percent dry weight)
•	PRIVET EVERGREEN: NEW GROWTH ONLY	190
MAX / MIN	RANGE OF:	
	BAY TREE:	4
•	DEAD LEAVES ONLY	
○	TWIGS ONLY	35
□	IVY	296
▽	JUNIPER	96
△	PODOCARPUS	179

* Water absorbed in addition to as-received wet weight (initial moisture content).

FIGURE IV-3
(CONT.)

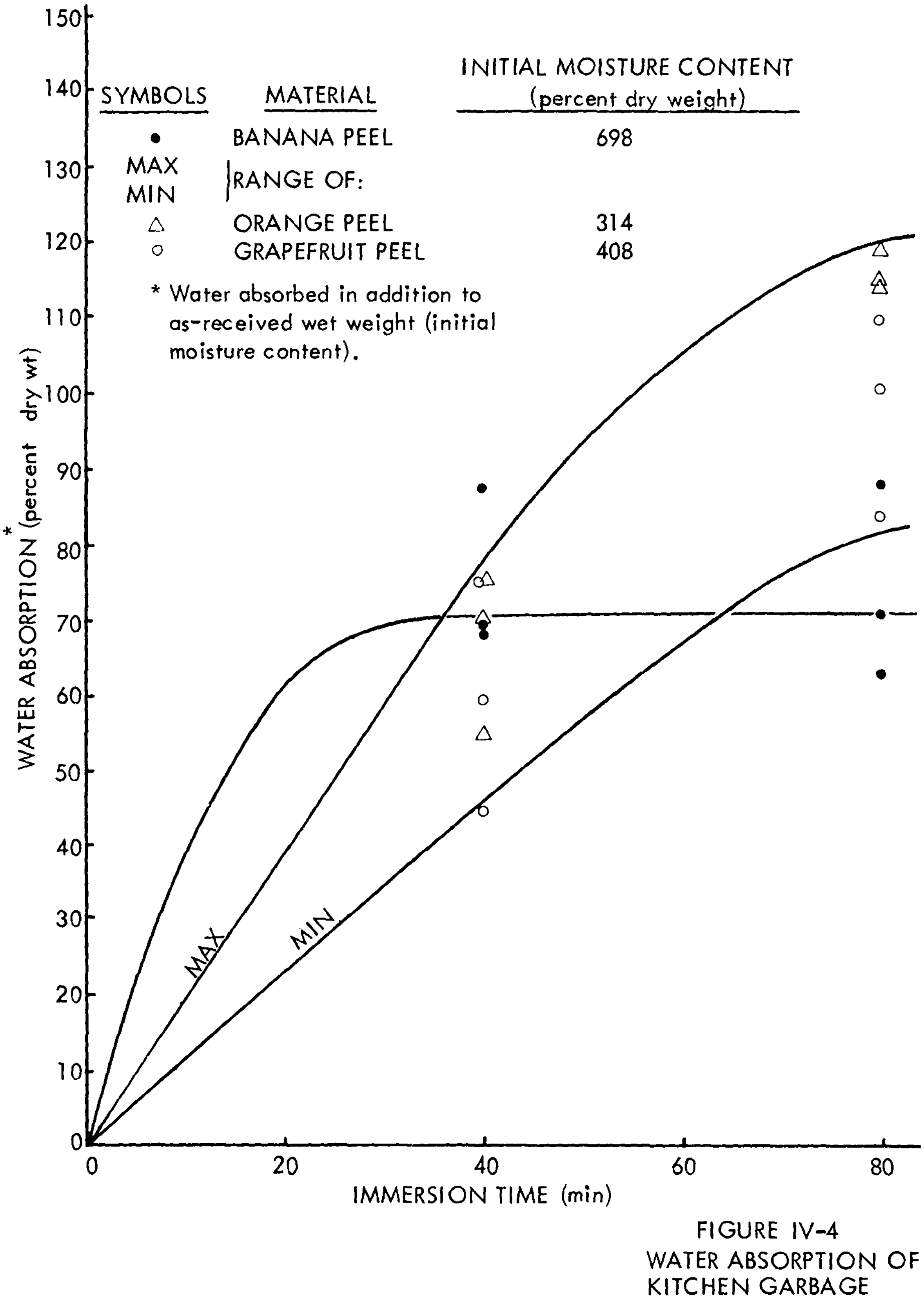


FIGURE IV-4
WATER ABSORPTION OF
KITCHEN GARBAGE
(VEGETABLE)

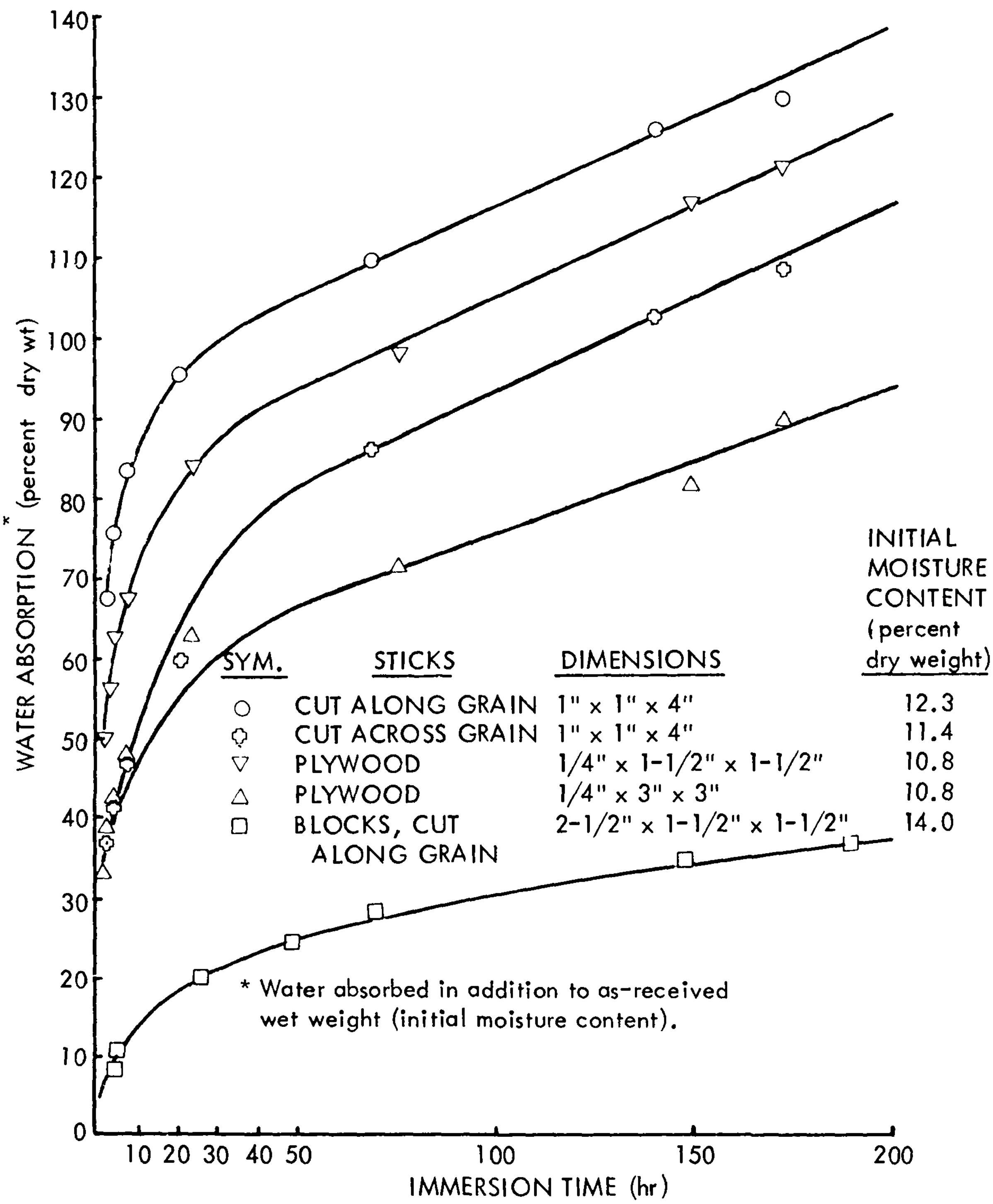


FIGURE IV-5
WATER ABSORPTION
OF WOOD

TABLE IV-1
MOISTURE ABSORPTION BY TEXTILES AND LEATHER

Item	Water absorbed: Average* (percent dry weight)	Water absorbed: Maximum variation from average percent
Cotton (T-shirt)	313	+23
Cotton (towel)	409	+18
Wool	185	+ 3
Acetate or similar synthetic		
Wool-like, double-knit	194	+13
Silk-like, light weight	165	+ 8
Hemp rope	129	+40
Nylon rope	41	+14
Leather	42	+15

* Average of three or more replicate measurements. Saturation was reached in 10 minutes or less; thus no characteristic curve was generated. Water absorbed in addition to as-received wet weight (initial moisture content). Initial moisture content of these materials (less than 3 percent dry weight) was less than the data variation and, therefore, the average water absorbed is the total absorption capacity.

Figures IV-2 and IV-3 present the absorption test results for plant trimmings (monocotyledons and woody shrubs, respectively). As with the paper products, different plant materials appear to have a range of capacities for water absorption. For example, with an immersion time of 40 minutes the quantities of water absorbed were 5, 50 and 100 percent for juniper trimmings, freshly cut grass, and 2-day-old cut grass, respectively. Cutting along banana leaf veins on one sample produced little difference in absorption from cutting across the veins; thus the samples cut across veins were used as representative of banana leaf. Considering that the lawn clippings are among the most common plant components in municipal solid waste, and that plant cuttings may account for as much as 35 percent of the residential solid waste, the significance of storage time (drying) in relation to overall water holding capacity of solid waste becomes apparent. The data in Figures IV-2 and IV-3 indicate a lack of good reproducibility for experiments with woody shrub trimmings and 2-day-old cut grass. This lack of reproducibility may be due (in part) to some degree of non-homogeneity in the drying of the vegetation.

Figure IV-4 indicates a range of water absorption capacities for the common fruit components of kitchen garbage (banana, orange and grapefruit peels). The water absorption data for five different wood specimens are presented in Figure IV-5. The data in this figure indicate that in contrast to plant trimmings and fruit waste (see Figures IV-1 through IV-4), which become saturated with water fairly quickly, an immersion time of greater than 200 hr was required for the saturation of the wood specimens tested. The data in Figure IV-5 indicate that on a percent dry-weight basis and for a contact time less than that required for complete saturation, the quantity of water absorbed by a piece of wood is affected both by the type and the dimensions of the specimen. For example, for an immersion time of 50 hr, a 1-1/2 x 1-1/2 x 1/4-in. piece of plywood holds approximately 46 percent more water per unit dry weight than a 3 x 3 x 1/4-in plywood specimen. Because of the slow rate of water absorption, the ultimate absorption capacity of wood will require a considerable number of days' exposure in a combined liquid sludge-solid waste landfill operation. The water in the liquid sludge added to fresh lumber waste would tend to percolate down or be absorbed by other more absorbent components of the solid waste at a faster rate than it could be absorbed by bulky wood waste components.

Absorption experiments with cotton and wool samples indicated no significant change in the quantity of water absorbed when the immersion time was increased from 10 to 20 minutes. This indicates that textile materials such as cotton and wool saturate more rapidly than other waste components. Table IV-1 presents absorption data (20-minute immersion) for leather and various textile products tested. Due to the short time (10 minutes) to reach moisture saturaction for items in Table IV-1, a time-absorption characteristic curve was not generated. On a dry-weight basis, the quantity of water absorbed ranged from 41 percent for nylon rope to 409 percent for cotton toweling.

The rate of absorption of water by an isotropic water-absorbing substance may be approximated heuristically by a first-order reaction equation $y = y_m (1-e^{-kt})$, where y_m = saturation (maximum) moisture content, y = moisture content at time t, and k is a constant the magnitude of which is dependent on the type of material, the liquid properties, the surface area of the material and the grain or fiber direction relative to surface area. The experimental data presented above for paper products follow a curve characteristically described by the exponential absorption equation. For other wastes tested, however, the conformity is not very good and this may be attributed to the non-isotropic nature of the test specimen (e.g., in the case of wood) and to non-homogeneity of the sample (e.g., in the case of plant trimmings).

2. Water-Holding Capacities of Soil and Related Materials. Table IV-2 presents data on the water-holding capacities of loam, humus, sand, charcoal ash, and clay. The samples show minor variation in the three replication runs for each material.

The data in Table IV-2 indicate some of the differences in the water-holding capacity of various soils. Based on the average values, the water-holding capacity ranged from 15.7 percent for sand to 94.5 percent for humus; this range may be due to varying absorption, pore and permeability characteristics. Water-holding or field capacity is affected by the soil particle size, gradation, chemical composition, and compaction density.

The results of percolation tests (ASTM 2434-68) for fine loam, fine clay, and coarse clay are presented in Table IV-3. The data in Table IV-3 indicate a significantly larger percolation rate for the fine loam samples than for either of the clay specimens. The percolation rates ranged from 0.94 to 1.58 inches/minute for loams and from 0.19 to 0.554 inches/minute for clay. For each test specimen a rate factor was calculated by dividing the observed percolation rate by its bulk specific gravity. The rate factor was used to determine if a correlation existed between bulk specific gravity and percolation rates for a given soil. Capacity and soil permeability cannot, however, be predicted accurately based only on specific gravity. Permeability is affected by pore sizes, particle gradation, temperature and other physical parameters. Table IV-3 presents the range of permeability which might be expected for various soils. A study[38] of the permeability of solid waste resulted in a permeability of 6×10^{-4} cm/sec for solid waste with a dry weight density of 710 lbs per cubic yard. In Table IV-3, this permeability is about in the middle of the scale.

From the data in Table IV-3, it is apparent that the difference between clay and loam is significant, but the permeability of either cannot be controlled appreciably by the degree of compaction, beyond assuring that all large void channels are eliminated. In-house studies, not presented here, have shown that downward percolation through lightly compacted solid waste, sand or gravel may easily be more than an order of magnitude greater than the above figures for loam.

The soil cover strata in a landfill would be expected to provide three important hydrological functions: 1) generous layers of loam or clay would significantly increase the liquid retention capacity per volume of completed landfill; 2) these layers with even poor compaction may retard the downward percolation, thereby increasing the time available to each layer of refuse to absorb the maximum possible amount of liquid; 3) the solids in sludge, that may flow through the interstices of municipal refuse, would be effectively stopped by filtration through layers of soil, and reduce the soil permeability still further by filling the intergranular pores. These phenomena could turn into a liability under some conditions. For example, if a heavy rain and sludge application occurred on a sloping landfill face, especially if the cover soil is clay, the relatively impermeable strata could force lateral or diagonal percolation of thin sludge and rain water to the bottom of the working face, instead of downward through lower strata of the fill.

TABLE IV-2

WATER-HOLDING CAPACITY OF TYPICAL SOILS

Material	Fine, sandy loam	Natural humus	Ottawa sand	Charcoal ashes	Clay
Organic content (% dry weight)	4.87	17.65	-	-	5.77
Saturation moisture content (% dry weight)	44.3	104.0	15.3	71.8	31.5
	40.4	87.6	15.6	71.2	32.5
	42.5	92.0	16.1	69.5	31.0
Average	42.3	94.5	15.7	70.8	31.7

TABLE IV-3

SOIL PERMEABILITY AND DRAINAGE CHARACTERISTICS

(cm per sec - log scale)

10^{2} 10^{1} 1.0 10^{-1} 10^{-2} 10^{-3} 10^{-4} 10^{-5} 10^{-6} 10^{-7} 10^{-8} 10^{-9}

Drainage	Good		Poor	Practically impervious
Soil type	Clean gravel	Clean sands, clean sand and gravel mixtures	Very fine sands, organic and inorganic silts, mixtures of sand silt and clay, glacial till, stratified clay deposits, etc.	"Impervious" soils, e.g., homogeneous clays below zone of weathering
			"Impervious" soils modified by effects of vegetation and weathering	

3. Prediction of Sludge Retention Capacity for Oceanside Solid Waste. Based on the aforementioned laboratory results for the absorption of water by various solid waste components, rough estimates may be made of the liquid sludge capacity of municipal solid wastes of known compositions.

A review of the data in Figures IV-1 through IV-5, and Table IV-1 indicates that for newsprint, cardboard, miscellaneous paper and textiles the as-received (initial dry weight) moisture content of the samples was less than the variation in absorption between samples of the same material. Thus, for the above named solid waste constituents, the available absorptive capacity is given as equal to the moisture absorption capacity determined in the laboratory tests. The absorption capacities are summarized in Table IV-4. The moisture absorbed by grass, plant, leaves, shrubbery, tree prunings and food waste in the laboratory tests was less than the as-received (initial) moisture contents of these materials. This occurred because vegetation and food contain mostly water (up to 90 percent wet weight). In order to arrive at a meaningful estimate of the absorption capacity of waste vegetation and food in solid waste, it was assumed that the laboratory-determined moisture absorption plus an average as-received moisture content would equal the total moisture holding capacity of vegetation and food waste components. The total moisture absorption capacity of vegetation and food waste is given in Table IV-4. A minimum value of zero is given for food waste because it often enters the landfill in a saturated moisture condition.

The data may be applied to any landfill as illustrated in the following examples. If the composition of solid waste entering a landfill is known but the moisture content is unknown, the water absorption capability given in Table IV-4 can be used to estimate the available moisture absorption capacity. Applying this method to the composition of solid waste determined for Oceanside in April 1971 (see Table IV-5), the maximum (180 percent dry weight) and minimum (60 percent dry weight) available absorption capacities were determined as shown in Figures IV-6 and IV-7. The data in Figures IV-6 and IV-7 assume that no moisture was added to the solid waste; e.g.,that the solid waste components were in their "natural" as-received condition. Rainfall and soaking with discarded household liquids would, of course, increase the as-received moisture content and decrease the available absorptive capacity.

If the moisture content of solid waste as-received at a landfill was known in addition to the dry weight solid waste composition, the data in Table IV-4 for total moisture holding capacity would be used to determine the available field moisture absorption capacity. Thus, in wetter climates (>30 inches precipitation per year), the available field capacity may be less than the water absorption and evaporation capability of a landfill.

4. Application of the Laboratory Test Data to Joint Sludge-Solid Waste Disposal at Oceanside. The available field moisture absorption capacity of solid waste as-received at the Oceanside landfill was calculated for the averaged annual solid waste composition and moisture content (see Tables III-2 and III-3). The results are presented in Table IV-6. The range of field absorptive capacities in Oceanside were estimated as from 60 to 178

TABLE IV-4
WATER ABSORPTION RANGES FOR SOLID WASTE COMPONENTS

Component	Moisture content, percent dry weight					
	Water absorption capability			Total moisture-holding capacity *		
	Maximum	Average	Minimum	Maximum	Average	Minimum
Newsprint +		290			290#	
Cardboard (solid and corrugated) +		170			170#	
Other miscellaneous paper	400		100	400#		100#
Lawn clippings (grass and leaves)	200		60	370		140
Shrubbery, tree prunings	100		10	250		0
Food waste (kitchen garbage)	100		0	300		0
Textiles (cloth of all types, rope)	300		100	300#		100#
Wood, plastic, glass, metal (all inorganics)		0			0	

* Calculated from water absorption plus initial moisture content in as-received samples. Initial moisture content from Figures IV-1 through IV-5.

+ Sample variation was negligible.

Initial moisture contents as-received were less than 6 percent in the laboratory tests; therefore, they were considered negligible compared to the variation in moisture absorbed.

TABLE IV-5
CITY OF OCEANSIDE SOLID WASTE COMPOSITION
(PERCENT DRY WT BASIS)

Category of waste (April 1971)	One week average (percent dry wt)	Maximum daily variation (percent of one-week avg)
Newsprint	6.73	+106
Cardboard	6.50	- 34
Miscellaneous paper	25.45	+ 84
Total paper	(38.68) *	+ 42
Food waste	11.62	+ 89
Glass & ceramics	11.97	- 52
Metals	6.40	- 19
Tree and shrub prunings	1.85	-100
Leaves	10.47	-100
Grass	2.40	+480
Total garden waste	(14.72) *	+100
Textiles	1.79	+ 45
Tires	3.76	-100
Foam plastic & rubber	0.24	+138
Other rubber & plastic	2.74	+ 38
Total rubber & plastic	(6.74) *	+300
Wood	1.69	+131
Dirt, sand, ash	0.44	+ 43
Concrete and rock	0.10	+480
Other (unclassifiable)	5.82	+ 75
Total	100.0	-

* Sub-totals; not included in total.

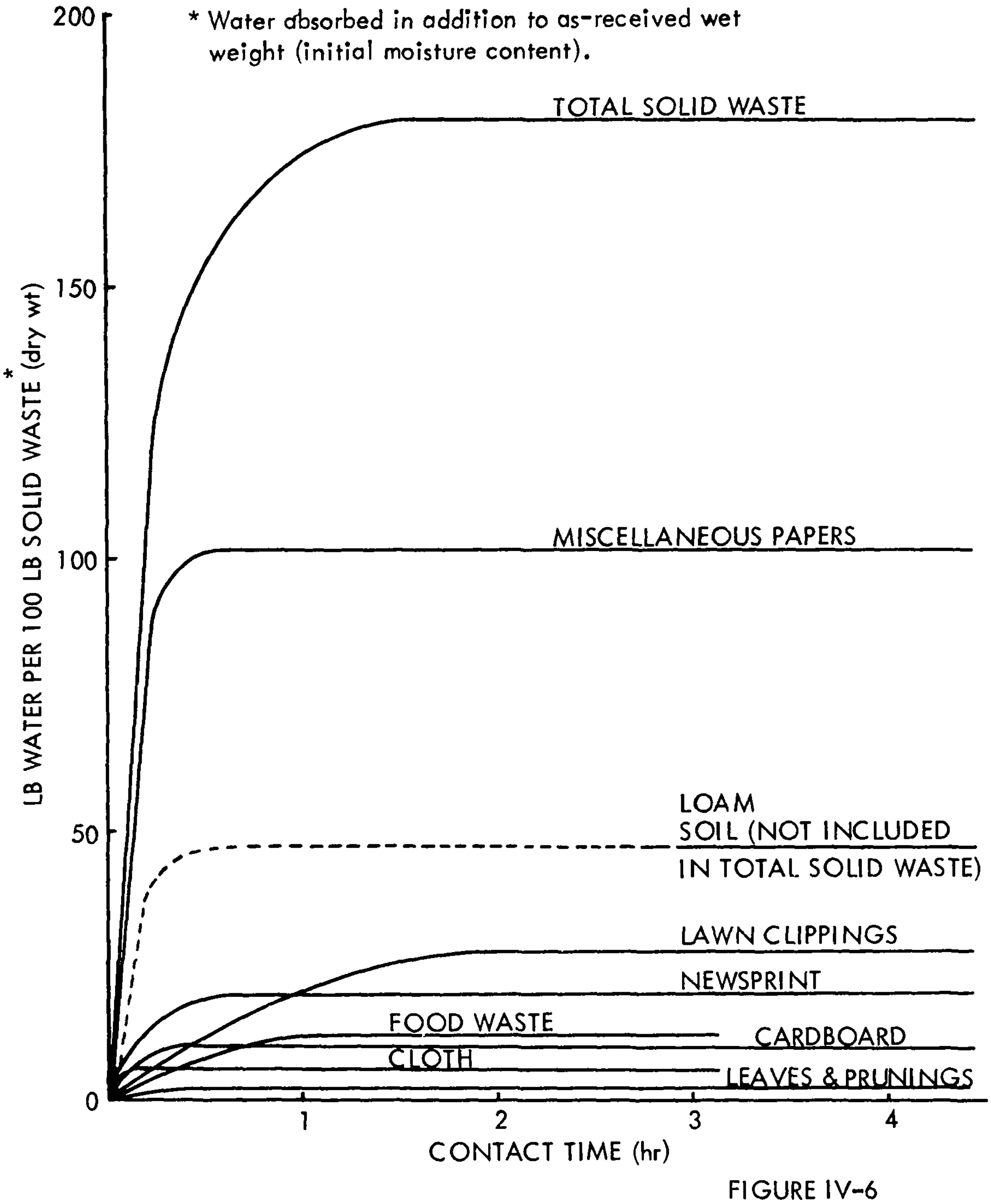


FIGURE IV-6
MAXIMUM ABSORPTION OF WATER IN MUNICIPAL REFUSE (EQUIVALENT DATA ON SOIL (LOAM) PRESENTED FOR COMPARISON)

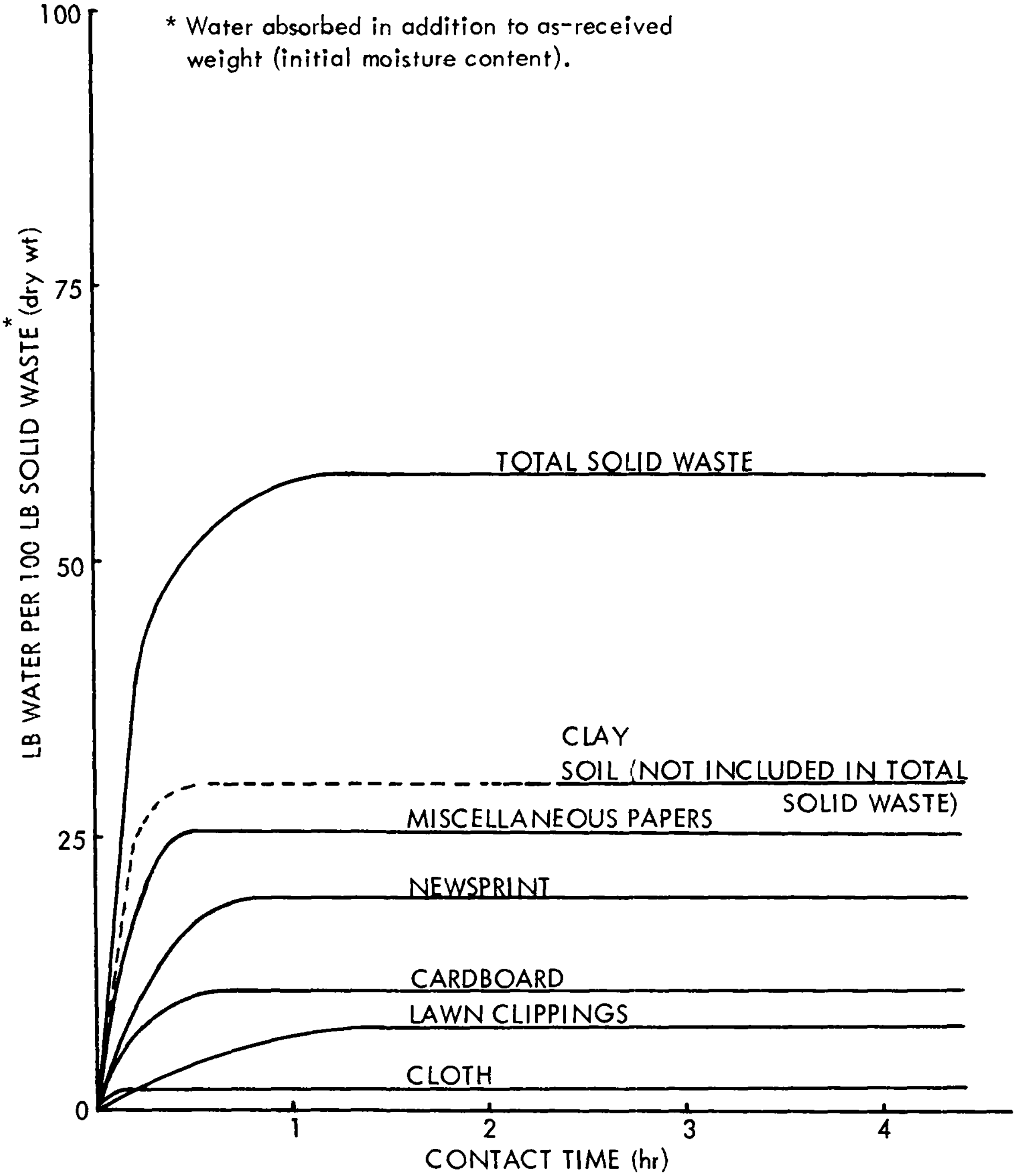


FIGURE IV-7
MINIMUM ABSORPTION OF WATER IN MUNICIPAL REFUSE (EQUIVALENT DATA FOR SOIL (CLAY) PRESENTED FOR COMPARISON)

TABLE IV-6

PREDICTED RANGE OF ABSORPTIVE CAPACITY OF MUNICIPAL REFUSE AS RECEIVED AT OCEANSIDE LANDFILL

Component	Total moisture-holding capacity as determined in laboratory tests*		Available field absorption capacity of waste components +		Average composition # (percent)	Field absorptive capacity**	
	Maximum	Minimum	Maximum	Minimum		Maximum	Minimum
Newsprint	290		262		7.2	19	
Cardboard	170		146		8.3	12	
Miscellaneous paper	400	100	397	97	23.6	94	23
Leaves and grass	370	140	312	92	3.8	12	4
Prunings	250	10	207	0	6.3	13	0
Garbage (food waste)	300	0	229	0	9.2	21	0
Textiles	300	100	284	84	2.3	7	2
Non-absorbents++	0	0	0	0	39.3	0	0
Total					100.0	178	60

* Oven-dried samples, from Table IV-4, percent dry wt basis.

\+ The absorptive capacities determined in laboratory tests reduced by the measured moisture contents from Oceanside waste samples, percent dry wt basis.

\# Average of year's (four quarters) composition of collected refuse arriving at Oceanside municipal landfill site.

** Pounds water per 100 pounds of average mixed refuse as received at the landfill; derived from product of available absorptive capacity and average composition for each component.

++ Includes wood (absorption very slow), foam plastic (insignificant quantity), and dirt, sand, and ashes (which entrain but do not absorb).

percent dry weight basis. The close agreement between the absorptive capacity data in Table IV-6 (60 to 178 percent) and Figures IV-6 and IV-7 (60 to 180 percent) is attributed to the Oceanside as-received solid waste moisture content consisting of primarily natural moisture in the solid waste components. There was little rainfall during the periods when the Oceanside solid waste samples were taken; thus the only source of moisture would be from discarded household waste liquids and normal content, as-received.

5. Summary of Moisture Absorption Capacity. The composite curves in Figures IV-6 and IV-7 (e.g., Total Solid Waste) indicate the ultimate saturation values that may be reached if the solid waste layers and associated cover soil layers are sufficiently compacted so that applied fluids remain in contact with the waste mass for approximately one hour before excess water drains through to lower strata. If the weight ratio of cover and admixed soil to waste were known, the ultimate absorption capacity of the soil would be included with those of waste components in estimating the total capacity for an operating landfill.

The data in Figures IV-6 and IV-7 and Table IV-6 indicate that 0.6 to 1.8 lb of liquid could be added for every 1.0 lb of dry weight solid waste before complete saturation is reached. As will be discussed in Chapter VI, subsequent larger-scale water absorption studies ("drum" tests), conducted in April 1971, Oceanside-type refuse composition indicated an average saturation value of 1.74 lb of liquid per 1.0 lb of dry weight solid waste. For the 13 drums tested , the spread in lb per 1.0 lb dry weight was from 0.57 to 2.72, with only three points outside the 1.0-2.2 range and eight points in the 1.0-1.9 range.

The City of Oceanside produces approximately 0.6 lb of sludge for every 1.00 lb dry weight of municipal refuse. Theoretically, therefore, the solid wastes generated by the City should have adequate capacity to absorb all the water in the liquid sludge. This was verified in a number of field tests at the Oceanside landfill in which sewage sludge was applied to solid waste at a rate of 0.35-0.6 lb of sludge per 1.0 lb of solid waste wet weight. A total of 35 applications were made (one day per week for 35 weeks over a ten-month period). No leachate was observed during this period. In cases where minor sludge runoff occurred, it was the result of an inappropriate spreading technique and the runoff was absorbed into the fill cover.

The above data indicate that the water retention capacity of Oceanside municipal solid waste falls above the upper half of the range predicted by the sum of the specified absorptivities of its major identifiable components. The increase in retention capacity may be attributed to entrainment of some fluid between particles (in addition to the amount absorbed). The drum having the lowest absorptivity (0.57 lb liquid per 1.0 lb solid waste) received very thin (watery) septic tank pumpings. In this particular test, there were also indications that the applied fluid percolated rapidly through the solid waste and, hence, there was little absorption time which reduced the amount absorbed. The high drum absorptivity reading (2.72 lb per 1.0 lb drum solid waste) occurred with the thickest sewage sludge. Due to its relatively high viscosity, a thick sludge cannot percolate through the solid waste particles very rapidly,and hence a higher absorptivity was obtained. The aforementioned water-absorption to solid waste weight ratios indicate that the retention capacity of a municipal solid waste can be predicted fairly accurately when the composition of the solid waste and the water-absorption capacities of its components are known. The required data can be generated by field sampling and laboratory tests such as those used in this study.

V. SEPTIC TANK PUMPINGS EVALUATION

A. Purpose and Scope

A literature survey and pilot test drum evaluation of septic tank pumpings admixed with solid wastes was undertaken. Since septic tank pumpings consist of raw or partially stored sewage, they are known to contain pathogenic organisms. The study scope was proposed by the E. P. A. Project Officer in lieu of demonstration landfill tests to evaluate the potential hazards that might be created if septic tank pumpings were avoided because of the limited available septic tank pumpings and also concern about the possible health hazards and noxious odors.

B. Pathogenic Organisms in Septic Tank Pumpings

1. Types of Organisms. The types of pathogenic organisms associated with municipal sewage, sewage sludge and septic tank pumpings are identical. Septic tank pumpings are basically raw or partially digested fecal waste and are similar to raw sewage in pathogenic organism types and populations. However, well digested treatment plant sludges contain far fewer pathogenic organisms than the "raw" sewage and septic tank pumpings.

The pathogens in human fecal waste and raw sewage have been well-documented. In a review of the literature, Hanks[4] has identified the disease agents associated with fecal waste, including septic tank pumpings, as follows:

a. Bacterial Infections. Typhoid fever, paratyphoid fevers A and B, cholera, and shigellosis are enteric bacterial diseases in man. E. coli organisms have sometimes exhibited pathogenicity, though the nature of the controlling conditions is unclear.

The viability of these bacteria in the environment is summarized as follows: Shigella can remain viable in tap water for as long as 6 months and in sea water for 2 to 5 months. Shigella can be destroyed by pasteurization and chlorination. The viability of Salmonella typhi is from 2 to 3 weeks in groundwater, 1 to 2 months for fecal matter in privies, and at least 3 months in ice or snow. E. coli, salmonella and shigella can be killed by pasteurization at 66 C for 30 minutes or by chlorination with 0.5 to 1.0 mg/l concentrations.[5]

b. Viruses. The major viruses commonly found in human excrement are adeno, reo, poliomyelitis, coxsackie and infectious hepatitis. Poliomyelitis and coxsackie are viable in sewage and septic tank pumpings.

Most viruses may be destroyed by extreme temperatures greater than 100 C. Recently, Shell and Boyd[36] determined in composting dewatered sewage sludge that poliovirus type 1 was destroyed by temperatures as low as 50 C (122 F), although admittedly this is just one type of virus. Chlorination can prevent the spread of infectious hepatitis, and most adinoviruses and enteroviruses are destroyed after remaining a period of 10 minues in contact with residual chlorine levels of 0.3 to 0.5 mg/l.

c. Protozoal Infections. The most significant protozoa disease agent is Entamoeba histolytica which is the only specie found in the United States. Cysts of Entamoeba histolytica are destroyed by dessication, sunlight and heat (forty-five minues at 45 C). Thus, it would appear that protozoa would not likely survive in the landfill environment.

d. Helminthiasis. This type of pathogen consists of worm infestations of human fecal origin. The most common are the tapeworms including Diphyllobothrium latum (fish tapeworm), Taenia saginata (beef tapeworm), Taenia solium (pork tapeworm) and Enterolines vermiculoris (pinworm). Also included are the human roundworm (Ascaris lumbriocoides), the whipworm (Trichuris trichiura), and the human hookworms (Necator americanus and Ancylostoma duodinale).

2. Vectors. Either direct or indirect contact with infected fecal matter must occur before an infection or disease can result. The four major disease routes are vector-borne, soil-borne, direct contact, and waterborne; air-borne is a secondary pathway.

A major mode of disease transmission is by direct contact with biological vectors (houseflies, cockroaches and domestic mosquitoes). The diseases transmitted by these vectors are amoebic dysentery, cholera, coxsackie (disease), infectious hepatitis, poliomyelitis, shigellosis, typhoid and paratyphoid fevers, and worm (helminth) infections.

Disease transmission routes related to septic tank pumpings disposal into a landfill would include: direct contact during disposal or while working solid waste; transmission by water (surface and groundwater contamination from runoff and leachate); contact by vectors such as houseflies foraging in infected wastes; and by contamination of other foraging wildlife (birds, dogs, rats, etc.) that could come into contact with humans. The methods of transmitting coxsackie and polio viruses are not well-defined; viruses have been found in water and in flies having access to infected feces.[4] Also there is data suggesting polio virus can survive in contaminated water, i.e., the disease may be waterborne. Infectious hepatitis is transferred chiefly through direct contact or fecal contamination of water supplies. There is evidence that municipal sewage treatment plants do not effectively remove the hepatitis virus. This is substantiated by higher hepatitis morbidity in communities where treated sewage is discharged into streams or estuaries. Hazards may be expected to hold for septic tank pumpings.

The primary route of typhoid propogation is the human typhoid carrier. Typhoid infected fecal waste has been associated with the direct contamination of well water by septic tanks and privies as well as other water supplies, and milk or food not properly protected.

Worm infestations of human feces are common. Sewage sludges have been found to contain eggs of pathogenic helminths. The use of untreated (raw) sewage as soil conditioners for food crops is not recommended in order to protect against worm infestations through direct contact.[6]

3. Pathogenic Characteristics of Septic Tank Pumpings and Sewage Sludge. Concentrations of pathogenic organisms in septic tank pumpings would be about as great as in raw sewage due to both the continual daily addition and admixture of fresh raw sewage, and the low degree of biological treatment in comparison to sewage plant sludge treatment and digestion. Laboratory analyses have shown that between 90 and 98 percent of coxsackie and polio virus are removed by the activated sludge process. The primary sedimentation sewage treatment process which is similar to the septic tank process is relatively ineffective in virus removal.[7] The same rate of removal noted above for virus can also be achieved for pathogenic bacteria by the activated sludge process.

Chlorination may be used for disinfection to produce a virus - and bacteria-free sewage sludge and septic tank pumpings. Long-contact periods with high chlorine residual concentrations are necessary to insure destruction of pathogens.[8] Heat-dried sludge has been considered to be free from disease agents.[9,10]

C. Potential Pathogenic Effects of Disposing Septic Tank Pumpings into Sanitary Landfills.

1. Viability and Survival of Pathogens in Landfills. As previously discussed, the pathogenic bacteria can be eliminated by pasteurization at 66 C for 30 minutes; virus destruction requires exposure to temperatures of 50 C or greater. Gotaas,[11] and Golueke and Gotaas[12] have demonstrated that a temperature of 60 C for one hour should kill all non-spore-bearing pathogens. Gaby[13] has shown that a minimum temperature of 49 C for a period of 4 to 7 days is necessary to kill all pathogenic bacteria. The upper range of temperatures generally found in sanitary landfills with and without sewage sludge admixture is 45 C to 65 C. The higher end of the landfill temperature range in combination with the greatly increased time of exposure to the high landfill temperatures appears to be sufficient to destroy bacteria. Temperatures recorded in the controlled field test-cell simulation of a sanitary landfill segment of this project never exceeded 38 C (see Figures VII-18 to VII-20), yet when samples taken after six months from four- and twelve-foot depths in the three Oceanside field test cells (one of which received raw primary sludge) were analyzed for fecal coliform, fecal streptococci and Pseudomonas aeruginosa, at depths of 12 feet (see Table VII-22) none of these fecal bacteria were detected.

The viability and survival period of viruses in the landfill environment is generally unknown. It appears, however, that landfill temperatures will eliminate some viruses. Gaby[14] demonstrated that type 2 poliovirus inserted into composting solid waste were inactivated after 3 to 7 days' exposure to 120 F. Engelbrecht[15] mentions a report where type 1 poliovirus were inactived in less than 10 days after insertion into a simulated landfill.

An average of 5 - 10 million bacteria and fungi, and 740,000 coliform bacteria, have each been measured in one gram of solid waste.[16] Leachate analyses from other studies have shown concentrations as high as 9,500 coliforms per ml[17]; coliform counts (MPN) up to 100,000 per mg have been measured experimentally.[18]

E. coli in oven-dry fresh solid waste has been found in densities over 5,000 organisms per gram. This value was reduced to 0-100 organisms per gram after a three-year storage period. Corresponding values for Streptococcus faecalis were 2,500 and 0-60 organisms per gram of dry solid waste, respectively.[19] Thus, solid waste and septic tank pumpings are both sources of pathogenic organisms, particularly during material handling and landfilling processes.

2. Pathogen Transmission. Ralph Stone and Company, Inc. found in pilot test drums receiving septic tank pumpings that the pumpings settled out to form distinct separable liquid and solid phases. Also the spread septic tank liquid behaved like water and rapidly penetrated into the solid waste interstices leaving a layer of solids on the solid waste surface. The rapid liquid percolation produced instant drainage. The raw primary sewage sludge applied to field test Cell 1 also produced immediate leachate drainage; Cell 1 was the only one of three test cells to have minor leachate drainage (until heavy rainfall when some short-circuiting occurred). It was noted that the odor, appearance, consistency, viscosity, and low total solids content (2.5 percent) of the raw primary sludge disposed into Cell 1 were similar to septic tank pumpings applied to the pilot test Drums 3 and 16 (compare Tables VI-4 and VII-4). Thus, if septic tank pumpings were disposed into a sanitary landfill, leachate would more readily occur unless carefully controlled disposal techniques were used.

Analyses made of Cell 1 leachate indicated an E. coli count of over 3,000 MPN in a sample taken eight days after Cell 1 filling was completed. On leachate samples taken after 15 days E. coli was 300 MPN, and after 28 days E. Coli counts were less than 3 MPN. During the summer of 1973, water was applied to Cells 1 and 3. Coliform counts at 510 days after cell filling increased to 2,400 MPN in the first leachate sample obtained from Cell 1, and then decreased to ≤ 3 MPN within six weeks after water saturation (see Figure VII-17). It is not known whether the water applied to the cell surface acquired coliform from the top of the cell or whether coliform existed throughout the cell. The former explanation appears more reasonable since it is in agreement with the core sample analysis previously cited (see Table VII-22) which showed coliform at the 4-foot depth, but none at 11 to 12 feet.

It is apparent from the pilot test drum and field test Cell 1 data that a potential hazard could exist from septic tank pumpings disposal into a sanitary landfill unless adequate runoff and leachate control facilities are constructed.

3. Leachate Contamination of Ground and Surface Waters. Most pathogens can live from 10 to 80 days in soil, depending on the soil type and its physical conditions. Viruses are usually inactivated in less than 30 days.[20] Many viruses and bacteria can live up to several months in groundwater or polluted water. Bacteria can migrate

horizontally through soil for distances up to 250 feet; however, they are virtually never found below ten feet.[20] Viruses are removed by soil much quicker than bacteria and generally only migrate a few feet at most.[20] Clay is the most efficient bacteria- and virus-removing soil component.[20]

One study demonstrated that shallow landfills may leach the bulk of pathogens in a relatively short period of time, thereby exceeding the dilution capacity of the receiving groundwaters.[21] Residence times of 1 - 3 weeks are necessary for pathogen deactivation and elimination.

4. Odors and Fly Problems. A major nuisance accompanying septic tank pumpings (and also anaerobically digested sludge) is odors. Foul septic odors can annoy residents near landfills. Odors attract flies which contact wastes resulting in an increased risk of disease spread by fly transmission. Daily covering of the landfill working face can control fly and odor problems.[22]

Fly problems are usually only associated with open dumps or inadequately covered landfills. Flies may migrate up to five miles from an open dump imposing a disease threat on residents within the five-mile radius. Disease transmission via rodents and other biological vectors make open dumps unacceptable from a public health standpoint. A properly maintained sanitary landfill eliminates rodents and flies by removing their food and shelter with a compacted soil cover. Six inches or more of compacted earth will prevent the emergence of flies covered by the soil; in contrast, flies can emerge through five feet of uncompacted soil.

D. Existing Practices for Disposal of Septic Tank Pumpings into Sanitary Landfills

At present some communities have reservations about discharging septic sludge directly into landfills and have passed legislation prohibiting the processing of untreated sludges at landfills.[23] A 1968 survey of California disposal sites showed that 37 percent of the open dumps and 44 percent of the sanitary landfills were operating under ordinances banning sewage treatment residues.[24]

The 1971 national survey completed by Ralph Stone and Company, Inc. (see Chapter II) indicated disposal of septic tank and liquid sewage sludges was prohibited by 70 percent of responding landfills. Respondents cited odors and pathogenic organisms as major hazards.

E. Management of Landfill Hazards from Septic Tank Pumpings Disposal

The public health hazard from septic tank sludge disposal can be minimized if a properly located, designed, and operated landfill is employed. Landfills should be designed to direct runoff away from surface waters, and to provide protection from groundwater infiltration. Since pathogens migrate in the direction of water flow, landfill site planning should emphasize avoidance of local water supply contamination. Mixing liquid sludge with dried sludge can also inhibit the leaching process.[23] Similarly, admixture of liquid sludge and solid waste can deter leaching. Of course, a fill area may eventually be saturated with sufficient rain or irrigation water to cause leaching. Thus, to safeguard public health, an impermeable seal or landfill underdrain system, and facilities for runoff and storm drain are both recommended for controlling and collecting leachate. The collected leachate may then be treated in-situ (by oxidation) or returned to available nearby sewers.

The ratio of septic tank pumpings to solid waste may be reduced below the minimum expected moisture absorption ratio of the local solid waste (0.6 dry weight basis for the City of Oceanside) to increase the probability of complete absorption without runoff or leaching. Other techniques include reducing the slope of the landfill working face, constructing soil dikes at the toe of the working face and uniform spreading of septic tank pumpings onto the surface of solid waste fill. Continuous fresh earth cover of the liquid pumpings, admixed to the solid waste must be carefully applied with a minimum daily final cover of six inches of clean compacted earth to control odor, pathogen and vector problems.

F. Summary

Given the results of the previous discussions, it appears that the major identifiable health hazard associated with disposal of septic tank pumpings into a sanitary landfill will occur during the disposal operation. This will result due to the following: existing pathogenic organisms will be at their peak, virulent populations; the fresh septic tank pumpings will be exposed and, therefore, readily accessible to flies, other insects, birds and vermin such as rats; the landfill operating personnel will be in closest contact with the septic tank pumpings; and the potential for runoff due to short-circuiting through landfilled solid waste interstitial passages will exist. The potential health hazards will decrease and eventually become negligible with increasing time after disposal. If the landfill operating techniques, protective clothing, runoff and leachate control facilities described in the preceding section are utilized, landfill disposal of septic tank pumpings could be feasible.

VI. PILOT-SCALE SIMULATION OF LANDFILL CONDITIONS

A. Purpose and Scope

The objectives of the pilot tests were to simulate, under controlled conditions, the behavior of a representative mass of municipal solid waste in a landfill to which liquid sewage sludge and water are applied to: a) determine the quantity of sewage sludge, water, and septic tank pumpings that can be absorbed by solid waste; b) assess the environmental effects that might result from such sludge disposal; and c) evaluate the potential for groundwater pollution from leachates.

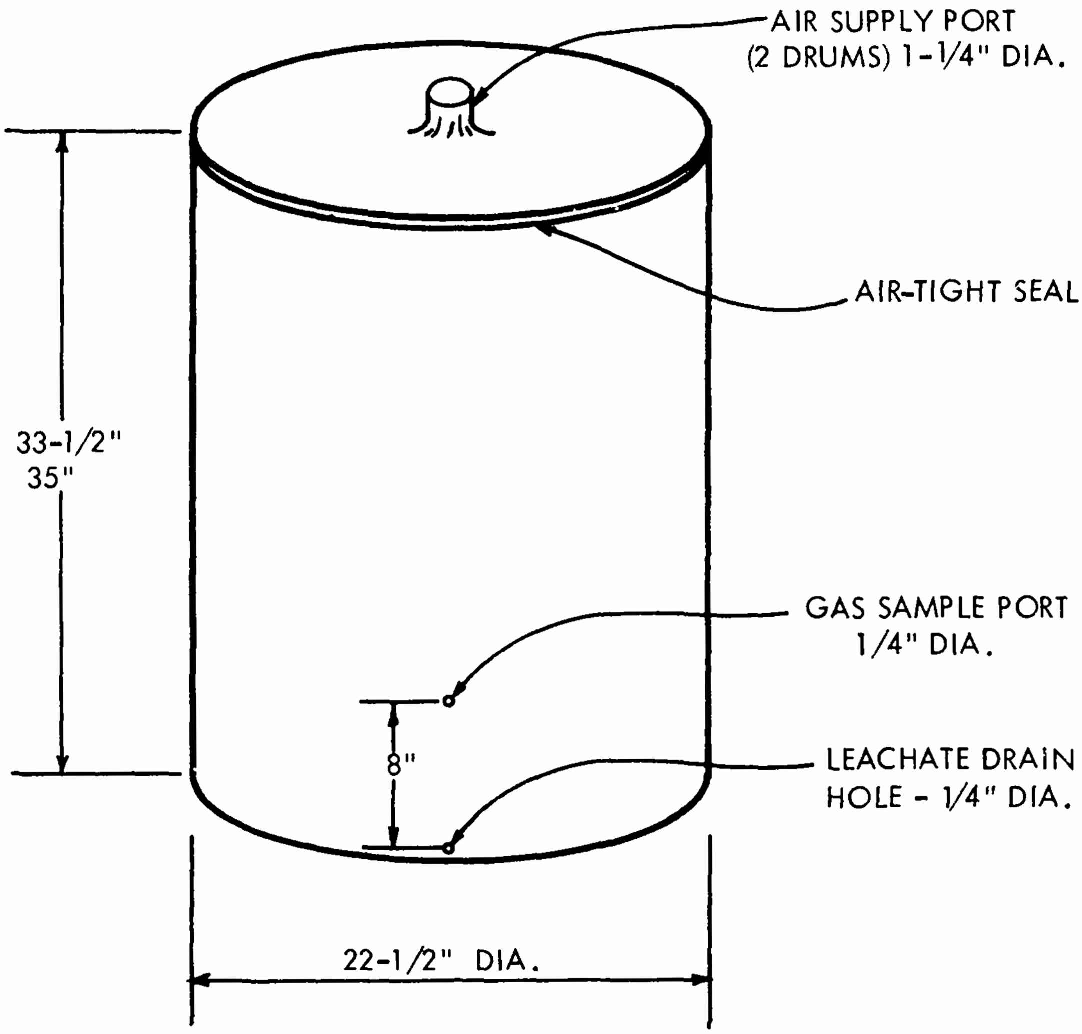
The constant control parameters were the amount and composition of solid waste and the compactive force applied to each solid waste mass. The variable parameters were the kind, amount, and sequence of liquids applied, and the sequence of compaction. The measured variables of primary interest were the time-variation of BOD_5 value of the leachates and the rate of subsidence. Other measured variables were the rate of leachate emission, temperature, gas composition, and chemical properties of the leachates, including conductivity, pH, turbidity, and total nitrogen. Qualitative observations were made for odor, color of leachates, apparent degree of decomposition of solid wastes, population and types of insects, and microorganism growths.

Based on the premise that the tests adequately simulated the operation of a landfill, the resulting data provided an indication of the results to be expected from the joint solid waste-sludge landfill disposal operation.

B. Description of the Study

1. Pilot Test Facilities Configuration. The pilot test facilities were installed at the Los Angeles, California, home office of the Consultant, Ralph Stone and Company, Inc. (In regard to temperature and rainfall, the weather in Los Angeles is very similar to that in Oceanside.) The pilot test facilities consisted of eighteen 55-gallon drums, as illustrated in Figure VI-1. Seven of the drums were 35 in. in height, whereas the remaining eleven drums were $33\frac{1}{2}$ in. in height. Each drum was provided with a leachate drain and a gas sample port. Two drums were aerated intermittently through an air supply port located on the top of the drums (see Figure VI-1). The leachate drain hole in each aerated drum remained open throughout the test period to provide an air exit after passage through the solid waste. Anaerobic conditions were attempted in the remaining 16 drums by providing a polyethylene air barrier and sealing the drum lids. (See Photograph VI-1c and Figure VI-1.)

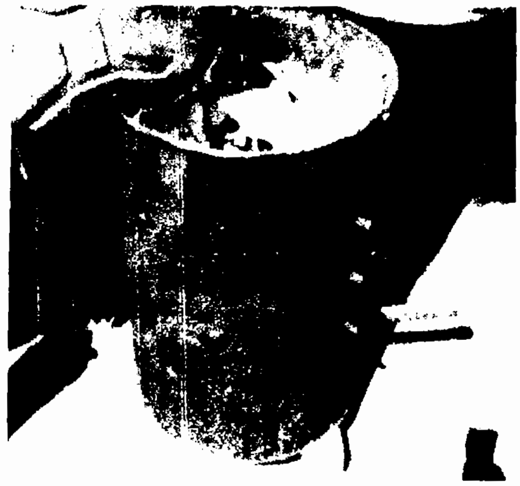
2. Solid Waste Characteristics. The drums were filled with solid waste of a composition approximating that of Oceanside, California (as established by hand sorting of statistically valid samples). The actual composition of the wastes placed



NOTE: DRUMS OF TWO HEIGHTS WERE USED - 7 DRUMS AT 35", 11 AT 33-1/2" (STEEL DRUMS WERE ASPHALT COATED)

FIGURE VI-1
PILOT TEST DRUM
CONFIGURATION

a. PILOT DRUM FILLED WITH SOLID WASTE.



b. ADMIXING SEWAGE SLUDGE INTO PILOT DRUM.

c. POLYETHYLENE MEMBRANE AIR (OXYGEN) BARRIER TO SIMULATE ANAEROBIC LANDFILL CONDITIONS.

PHOTOGRAPH VI-1

PILOT TEST DRUMS

in each drum, plus the Oceanside standard sample composition, is given in Table VI-1. Of course, there was minor variance within each of the categories of Table VI-1 of the drum materials filled on different dates. Efforts were made, however, to insure maximum random conformity within each waste category from the variety of materials available at the time. (See Photograph VI-1a.)

The weighed quantities of each component were placed in each drum by hand, taking reasonable care to avoid excessive concentrations of any one component in a single location. No effort was made to achieve completely random mixing, such as by tumbling in a large container. Instead, it was attempted to duplicate visually the appearance of waste materials lying in a landfill.

3. Filling and Compaction Procedures. The purpose of the first test (Drum No. 1) was to establish the maximum amount of sludge that can be absorbed by a known quantity and composition of solid waste. In the pilot plant the sequence of solid waste and sludge additions, mixing, and compacting was intended to simulate landfill operating conditions. Half of the total charge of 100 lb of solid waste was first placed in the drum, compacted, and then sludge was added. The mass was then stirred several times to promote complete admixture, and compacted a second time. Small amounts (about 10 lbs) of solid waste were applied daily until 100 lbs were in the test drum. Liquid sewage sludge was admixed daily with the solid waste, and added after 10 lbs of solid waste was in the drum until leachate started to drip from the bottom drain, at which time it was assumed that saturation conditions were reached. Due to the high viscosity of applied sludge and careful arrangement of solid waste in an attempt to prevent channeling, it was assumed that the leachate represented the excess liquid sludge that percolated through the saturated mass of refuse. Due to the method of filling (compaction), Drum No. 1 initially contained 100 lb (wet weight) of solid waste at about 22 lb/cu ft wet density (594 lb/cu yd). All other drums contained 80 lb of solid waste, each at initial wet densities ranging from 12.4 to 22.1 lb/cu ft (see Table VI-2). (See Photograph VI-1b.)

The initial compaction for Drums 2 through 5 consisted of dropping a 200-lb weight two times, from approximately 1 ft above the solid waste surface. Drums 6 through 18 were subjected to continuous manual tamping of solid waste layers with a shovel during packing. This resulted in a more thorough and uniform compaction throughout the waste charge. The difference in initial compaction procedures simulated two sets of landfill conditions: a) compaction of each fill layer (Drums 6-18); and b) compaction of a complete fill (Drums 2-5). The variation in initial density of waste material in the drums is given in Table VI-2.

4. Liquid Application. Liquids were applied to all but one (Drum No. 18) of the 18 drums as shown in Table VI-3. Raw sludge, digested primary and activated sludges, mixed sludge, septic tank pumpings, and water were used in these tests to achieve saturation during either primary or secondary application as indicated in Table VI-3. The term "Initial Application" in Table VI-3 refers to a first phase of the liquid addition, in which sludge was poured into the newly filled drums of solid waste in the amounts indicated. The ratio of 0.61 lb of liquid sludge per pound of solid waste (wet wt) used in most drums reflects the higher ratio of sewage sludge

TABLE VI-1
COMPOSITION OF SOLID WASTE IN TEST DRUMS

Constituent	Composition (percent wet wt)						Oceanside waste standard*
	Drum number						
	1	2	3	4	5	6 through 18	
Newsprint	13.1	8.8	11.3	12.3	12.9	7.5	6.73
Cardboard	5.4	2.5	0.1	3.9	5.1	7.5	6.50
Misc. paper	22.8	21.3	19.7	23.8	18.4	25.0	25.45
Total paper[+]	41.3	32.6	31.1	40.0	36.4	40.0	38.68
Prunings	21.0	2.5	4.0	4.5	4.2	1.9	1.85
Leaves & grass	13.4	29.8	21.3	22.5	28.2	13.1	12.87
Total yard waste[+]	34.4	32.3	25.3	27.0	32.4	15.0	14.72
Food waste	0	18.8	12.5	8.8	9.1	12.5	11.62
Cans & bottles	0	16.3	16.7	9.6	9.2	18.8	18.37
Wood	1.9	2.5	2.5	4.7	3.5	2.5	1.69
Cloth	0.5	0	3.2	1.8	0	2.5	1.79
Gravel	11.3	0	0	0	Trace	2.5	0.10
Film or foam plastic[#]	Trace	Trace	Trace	Trace	Trace	Trace	6.73
Miscellaneous**	10.6	7.5	8.7	8.1	9.4	6.2	6.30
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0

*Typical municipal solid waste of Oceanside, California, based on April 1971 hand sorting of statistically valid representative samples.

[+]Not included in totals.

[#]Visually conspicuous, but of insignificant weight.

**Mostly dirt in test drums, and unclassifiables in standard.

TABLE VI-2
INITIAL DENSITY OF SOLID
WASTE IN TEST DRUMS*

Drum number	Wet wt of solid waste (lb)	Initial wet density (lb/cu ft)	Initial wet density (lb/cu yd)
1	100	22.0	594
2	80	13.5	365
3	"	14.6	394
4	"	13.0	351
5	"	14.1	381
6	"	15.6	421
7	"	12.4	335
8	"	14.1	381
9	"	20.3	548
10	"	17.4	470
11	"	15.2	410
12	"	12.8	346
13	"	14.9	402
14	"	20.3	548
15	"	16.6	448
16	"	22.1	597
17	"	16.6	448
18	"	15.9	429

*Before admixture of liquid.

TABLE VI-3

APPLICATION OF SLUDGE AND WATER TO TEST DRUMS

Drum no.	Initial application	Second application	
		Sludge	Water
1	Saturated with mixed municipal sludges, digested activated sludge (La Salina) and digested primary sludge (San Luis Rey). Ratio*: 1.64.		X
2	Water only.	La Salina	
3	Domestic septic tank pumpings. Ratio: 0.61.		X
4	Dry control with single water application.	Left dry	
5	Mixed digested sludges (La Salina, San Luis Rey). Ratio: 0.61.	La Salina	
6	Digested activated sludge (La Salina). Ratio: 0.61.	La Salina	
7	Digested activated sludge (La Salina). Ratio: 0.61.		X
8	Saturated with thinner digested activated sludge (La Salina). Ratio: 1.16.	La Salina	
9	Saturated with thicker digested activated sludge (La Salina). Ratio: 2.10.		X
10	Raw primary sludge (San Luis Rey). Ratio: 0.61.	San Luis Rey (raw)	
11	Raw primary sludge (San Luis Rey). Ratio: 0.61.		X
12	Digested primary sludge (San Luis Rey). Ratio: 0.61.	San Luis Rey (digested)	

TABLE VI-3 (CONT.)

Drum no.	Initial application	Second application Sludge	Water
13	Digested primary sludge (San Luis Rey). Ratio: 0.61.		X
14	Digested activated sludge; drum aerated (La Salina). Ratio: 0.61.	La Salina	
15	Digested activated sludge; drum aerated (La Salina). Ratio: 0.61.		X
16	Domestic septic tank pumpings. Ratio: 0.61.	Septic tank pumpings	
17	Water only.		X
18	Dry control.	Left dry	

* Ratio = lb liquid per lb dry wt solid waste in each drum.

to municipal solid waste generated by the community of Oceanside over recent years. These drums thus simulate the absorptive capacity that would be required for sludge disposal for the City of Oceanside.

Drums in which the solid waste was brought to field capacity with liquid sludge simulated appropriate sanitary landfill conditions. Field capacity refers to the maximum amount of liquid (sludge or water) that the contents of the drums could absorb without producing leachate, as evidenced by prolonged slow dripping from the leachate drain hole in the bottom. In several cases, it was observed that rapid "run-through" (runoff) of applied liquid occurred due to short-circuiting through voids and channeling along the drum walls prior to reaching the 0.61 ratio. In these cases, the effluent was caught and poured back in the drum until the leakage ceased. In cases where the leachate flow decreased to a slow drip that lasted for over 16 hours, the contents were assumed to have reached field capacity.

During the "primary water application" program, Drums 1, 8 and 9 were selected for field capacity tests with liquid sewage sludge.

After "primary water applications," initial determinations were made of subsidence under compaction, quality of leachate (where leachates were formed), temperature rise, and attractiveness to flies and other vectors. A program of "secondary water applications" was then started. Secondary liquid sludge and water applications were made to the drums at a rate of 1 gal per day, 5 days per week, until each pilot drum was saturated, after which only water was applied to each drum at approximately the same rate for a total of 59 working days. The total quantity of water added (59 gallons per drum) is equivalent to 36 in. of cumulative rainfall on the surface area of the test drums. An annual rainfall of 36 in. is equal to a maximum rainfall condition for the City of Oceanside. However, since one year of "rainfall" was applied during a period of only 59 days, the experiment may be regarded as a simulation of a very wet period.

Initially, the addition of water at a rate of 1 gal/day consisted of actual addition of 1 gal of water to each drum, except 4 and 18 (dry controls), once every working day. This procedure, however, was found somewhat time-consuming and hence was modified to involve addition of 2 or 3 gallons of water at one time every 2 or 3 days. Thus, an "average" rate of 1 gal/day was maintained throughout the period of "heavy rainfall" simulation.

To simulate an intermediate rainfall, the rate of water addition was later reduced to three gallons once every week for a total quantity of 21.6 inches. The rate of water addition was continued until January 1972, since which time the rate has been further reduced to simulate light rainfall, 3 gal once a month for a total of about 21.6 in. of rainfall per year.

Since the contents of most of the drums were at or near saturation at all times (generally as a result of secondary applications), the liquid would drip continuously when the drain holes were left open. This created some anaerobic odor nuisance in the immediate vicinity, as well as major losses of leachate due to overflowing and evaporation from leachate collection pans. Thus, about 60 days after beginning of the study, the leachate drain holes were kept corked, except when leachates were collected. As a result, most of the drums accumulated a gallon or less of free leachate in their bottoms.

5. Forced Aeration Conditions. Two of the test drums, 14 and 15, were provided with forced aeration from a blower. The hoses entered via connections through the lids of the drums (see Figure VI-1); these lids were provided with gaskets in insure an airtight seal. Unlike the other drums, the gas sampling holes on these two drums were left uncorked, allowing the air from the blower to percolate downward through the solid waste and out the holes. The leachate drains were initially kept corked, as with the other drums, and then opened to allow the air to flow through the bottom of the waste charge. The blower was activated by a timer, which operated it for 5 min each hour, at a divided flow providing approximately 5 SCFM to each drum. This aeration sequence was believed adequate to prevent any significant accumulation of carbon dioxide or methane, thus maintaining aerobic conditions while not causing excessive drying.

6. Monitoring Program. The following is a brief description of sample collection and monitoring procedures employed in connection with the drum tests.

a. Leachate Collection and Analysis. In general, the leachates obtained from each drum were of two types: an occasional residual leachate accumulated in the interim between water additions, and a drainage leachate obtained during the first 24 hr after liquid addition. These leachates were collected and their respective volumes were measured. After adding liquids, the leachates were also analyzed for biological oxygen demand (BOD_5), pH, conductivity, and turbidity. For each drum, a composite leachate sample was collected by accumulating some of the individual leachate samples. The composite samples were analyzed for pH, conductivity, nitrate, chloride, total phosphate, sulfate, fluoride, organic nitrogen (Kjeldahl), iron, copper, lead, mercury, chromium, and barium. With some exceptions (see Appendix A), all analytical procedures were in accordance with Standard Methods.[3] (See Photograph VI-2a for leachate collection method.)

b. Sludge Analysis. The sludge used in each application to a drum was a composite of several samples, collected over a period of up to a month. Each composite sludge was analyzed for BOD_5, pH, organic nitrogen, total volatile acids, total organic content, total phosphate, and conductivity. In addition to these composites of individual sludge types, a mixed composite sample was accumulated of digested sludge samples obtained every two weeks from the three treatment plants at Oceanside. This composite sample consisted of some samples taken in the proportion of 2:1:1 from biweekly collected digested sludge samples from La Salina, Buena Vista, and San Luis Rey treatment plants, respectively. The proportion was approximately the relative quantities of digested sludges generated by each plant. The mixed composite sample was analyzed for copper, lead, mercury, chromium, iron, barium, calcium, total hardness, and chloride.

a. DRUM LEACHATE MEASUREMENT AND SAMPLING.

b. METHANE/EXPLOSIVE GAS TEST EQUIPMENT.

c. HYPODERMIC GAS SAMPLER.

PHOTOGRAPH VI-2

TEST DRUM MONITORING EQUIPMENT

c. Gas Sampling. At various intervals during the period of study, samples of gas were drawn from an intermediate point (see Figure VI-1) within the mass of solid waste in each drum and analyzed by gas chromatography (using a Varian Aerograph Model A90 P3) for carbon dioxide, methane, oxygen, and nitrogen. Both holes were kept plugged with corks except when gas or leachate samples were being drawn. All gas samples were taken at times just prior to removing the drum lids (for liquid addition) or drain hole corks (for leachate collection). The gas sampling technique involved the insertion of a 12-in. long hypodermic needle into the refuse via the gas sample port with provision for an airtight seal. A polyethylene bag was placed inside the barrel over the solid waste in order to further minimize air movement. The gas samples may thus be presumed representative of the gases present in the interstitial cavities in the lower portion of each drum, plus any of the head space gases that may have been pulled down through open channels during the drawing of the sample, but relatively free of air that may have entered during placement of the sample hose. (See Photograph VI-2b and c for gas sampling methods.)

d. Vectors and Microorganisms. Qualitative visual observations were made of the presence of insects and breeding colonies in the various drums. In some, the major species of the insects present were also identified.

e. Temperature Measurements. Temperature was measured prior to water application/leachate sampling. Temperatures measured were those of ambient air, air inside a special empty drum, and the solid waste. Solid waste temperatures were obtained by implanting a Weston Model 2265 (0 to 120 F scale) bimetal element thermometer with an 8-in. stem into the top center of the waste mass.

f. Settlement Analysis. Settlement was determined by dropping a 200-lb weight twice from a height of 1 ft, then measuring the distance of the waste surface below a reference point at the top of the drum with a ruler.

g. Odor Tests. Each time the drums were opened, an observer noted the strength and type of odor detected.

h. Check on Moisture Content. Moisture content in the drums was checked once within the first 20 to 127 days, once within 79 to 155 days after filling with solid waste, and monthly after one year since filling. Three methods were used for the determination of moisture content. The first method consisted of weighing the drums before and after each liquid addition and dividing the difference by the weight of the solid waste initially placed in the drums. The second method was based on the difference in weight between the total amount of liquid added and the total amount of leachate obtained. The third method consisted of determining the dry and wet weights of the representative waste samples from each drum.

i. Sample Handling. Gas samples were analyzed immediately after they were obtained. Drum leachate samples were stored in a refrigerator immediately after they were obtained and were analyzed within a week. Leachate composite samples were stored at ambient temperature (70 F). Because of the long storage period or the composite samples, nitrates and chloride (from chlorine in the water added initially) analyses may tend to be slightly high and other constituents may tend to be slightly low (due to adsorbtion onto the surface of the sample bottle).

C. Results and Discussion

1. Liquid Application and Leachate Flow. The characteristics of sewage sludge and septic tank pumpings applied to the pilot test drums are shown in Table VI-4. Table VI-5 presents the pounds of liquid applied per 100 lb dry weight solid waste to reach saturation in each drum. Except for the high dry weight values of 213, 272, 201 and 204, the drum saturation values are in close agreement with the laboratory test results which predicted a range of 60 to 180 lb liquid per 100 lb dry weight solid waste based on both April 1971 Oceanside solid waste composition and annual data given in Tables IV-5 and IV-6, respectively. The drum field capacity moisture contents were clustered in the high end of the predicted absorption range; this was attributed to superior entrainment due to good distribution of the added water.

The ratio of the lb water per lb dry weight of solid waste and sewage sludge solids added to each of the 16 wet drums is shown in Figure VI-2. The rapid initial rise represents the high rate of water application during the first six months (3-gal per day), after which applications of 3-gal per month were made.

Table VI-6 presents actual water contents of the drums as found by weighing on a 300-lb capacity scale on three different occasions. The data in this table indicate that with the exception of only a few drums, there was a reduction in the water content of the drums during the period between the first two water determinations. The third water determination conversely indicated an increase in the water content of the drums. This was attributed to a decrease in the size of the voids in the solid waste. Less channeling was able to occur and more water was therefore trapped in the voids. Comparison of the data in Table VI-6 with the data in Table VI-5 indicates that, with the exception of Drum 16, the actual water content of the waste in each drum was considerably less than the field capacity value. Also, compaction and biodegration tended to reduce the number and size of voids in the solid waste. Increases in drum temperature and humidity may also have reduced the effective field capacity.

2. Leachate Characteristics.

a. BOD_5 Content. The data on changes in the BOD_5 content of the fresh leachate are presented in Appendix D for each individual drum. Unless otherwise stated, the leachates referred to in this section are the "fresh" leachates from the drums. Fresh leachate is the leachate obtained within the first hour after each addition of water. "Residual" leachate is the leachate removed prior to each water addition that had accumulated between water additions.

Figure VI-3 is a composite plot containing the BOD_5 values for all the drums. The three curves in this figure represent the maximum, the minimum, and the arithmetic average (20-day increments) of all the data points. The data in Figure VI-3 indicate that

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the BOD_5 increased to a peak sometime within the first 100 days of sludge application, and gradually decreased to become asymptotic thereafter. The initial increase in BOD_5 may be attributed to the breakdown and solubilization of complex organics in the solid waste and sludge. The liquid appplications to drums were started between April 16 and July 17, 1971, with the majority of them (Drums 6 through 15, and 17) started in mid-June. The hot summer temperature thus might have contributed to some extent to the observed high initial BOD_5 levels. The subsequent decrease in BOD_5 may represent a gradual depletion of the more readily soluble organics due to bacterial oxidation.

Figure VI-3 indicates the leachate BOD_5 trends of Drums 14 and 15 with the composite BOD_5 trend for all the drums. Drums 14 and 15 were the only two test drums which had been provided with forced aeration. Figure VI-3 indicates that after reaching maximum values, the BOD_5 for Drums 14 and 15 dropped off initially at a faster rate than for most other drums,[5] and then fell near the average for all drums. This would be expected since oxidation of organics generally proceeds at a faster rate under aerobic than anaerobic oxidation.

b. Color. The color observed in the leachates was initially black in seven drums, grey in five drums, and yellow or tea color in three drums. Most of the leachates were opaque in appearance. No relation was observed between the type of liquid applied and color; for example, leachates from drums which received water only were also black. The color changed with time to green, olive and yellow, to a straw color, and after 190 to 250 days, the colors were generally yellow or straw, clear or brownish.

During the final year of the study, the leachate was a grayish yellow when first collected, but after exposure to air, the color slowly changed to a brownish yellow. A similar color change was observed for the Oceanside test cell leachate, though these latter colors were much darker. Following extensive dilution of the test cell leachate and concentration of the drum leachate, the colors were observed to be the same. This lead to the conclusion that the color change is due to the same chemical reaction in the test cell leachate and the test drum leachate. This reaction is most likely an oxidation reaction, possibly a change in oxidation state of one or more of the dissolved metal ions. This reaction would not change the chemical analysis performed on the leachate.

c. Turbidity. The results of turbidity measurements on leachate samples are presented in Appendix D. In general, the changes in turbidity with time followed a pattern much similar to that of the BOD_5. To explore any correlation which may exist between the BOD_5 and turbidity of a leachate, the turbidity and BOD_5 values were plotted on log-log paper. The results presented in Figure VI-4 indicate some correlation between the two variables. Although the mean BOD_5 affected the Johnson turbidity units (JTU), the low coefficient of correlation indicates wide variation of BOD_5 about the mean value. This, as expected, indicates that BOD_5 (including dissolved materials) is a poor measure of the turbidity values. This is not surprising, since turbidity is a light-scattering phenomenon whose value is affected by the size, shape, and concentration of the particulate matter, whereas BOD_5 is only a measure of the biodegradable constituents (dissolved or particulate matter)[5] of the waste sample. Hence, inorganic particulate matter such as silt and iron oxide which contribute to turbidity do not exert BOD_5 demand. Similarly, soluble organic or reduced inorganic compounds which constitute BOD_5 do not register as turbidity.

TABLE VI-4
CHARACTERISTICS OF SEWAGE SLUDGE AND SEPTIC TANK PUMPINGS APPLIED TO PILOT TEST DRUMS

Sample by source	Drum application Primary	Drum application Secondary	Conductivity (µmhos)	BOD_5 (ppm)	Total solids (%)	Total organics (% dry wt)	Total nitrogen (%)	Total phosphate (ppm)	Total vol. acids (ppm)
Mixed sludges	1	2	3800	3050	-	-	-	110	-
	-*	5							
La Salina:									
Digested	6	6							
activated	7	7	3800	3200	1.4	60.7	1.68	370	216
sludge	8	8							
	9	-							
	14	14	4200	-	4.5	53.2	1.77	80	46
	15	-							
San Luis Rey:									
Primary raw	10	10	4000	-	1.2	61.6	-	-	-
	11	-							
Digested primary	12	12	3190	-	3.4	45.3	-	-	-
	13	-							
Septic tank pumpings:									
Thick	3	-	1900	1630	2.0	40.5	-	-	-
Thin	16	16	1200	130	-	-	-	-	-

*Indicates not applicable or analyses not completed.

TABLE VI-5
MOISTURE ABSORPTION TO SATURATE
SOLID WASTE SAMPLES

Drum no.	Moisture as % of sample wt* Dry wt	Wet wt
1	213	164
6	188	145
7	188	145
8	151	116
9	272	210
10	188	145
11	201	155
12	92	71
13	161	124
14	204	158
15	169	130
16	57	43
17	175	135
Avg	174 dry wt	134 wet wt

* Samples from test drums at field capacity.

TABLE VI-6

TEST DRUM WATER CONTENT DETERMINATIONS

Days since filling:	Drum water weight					
	127		155		953	
Drum no.	Wt	% of initial wet wt of solid waste*	Wt	% of initial wet wt of solid waste*	Wt	% of initial wet wt of solid waste*
1	103	103	91	86	101	101
2	65	81	57	72	58	73
3	63	79	63	79	89	111
4	--[+]	--	23	29	60	75
5	102	128	94	117	59	74
6	60	76	54	67	58	73
7	20	29	36	45	57	71
8	33	42	25	33	65	81
9	62	77	45	56	77	96
10	47	59	50	62	81	101
11	--	--	41	51	82	101
12	30	38	24	30	71	89
13	20	26	18	23	60	75
14	46	58	23	29	22	28
15	--	--	20	25	39	49
16	33	41	34	42	73	91
17	32	40	30	37	75	94
18	-0.4	0	3	4	51	64

*Initial wet weight of solid waste placed in drums was: Drum 1 - 100 lb; Drums 2 through 18 - 80 lb.

[+]Not weighed.

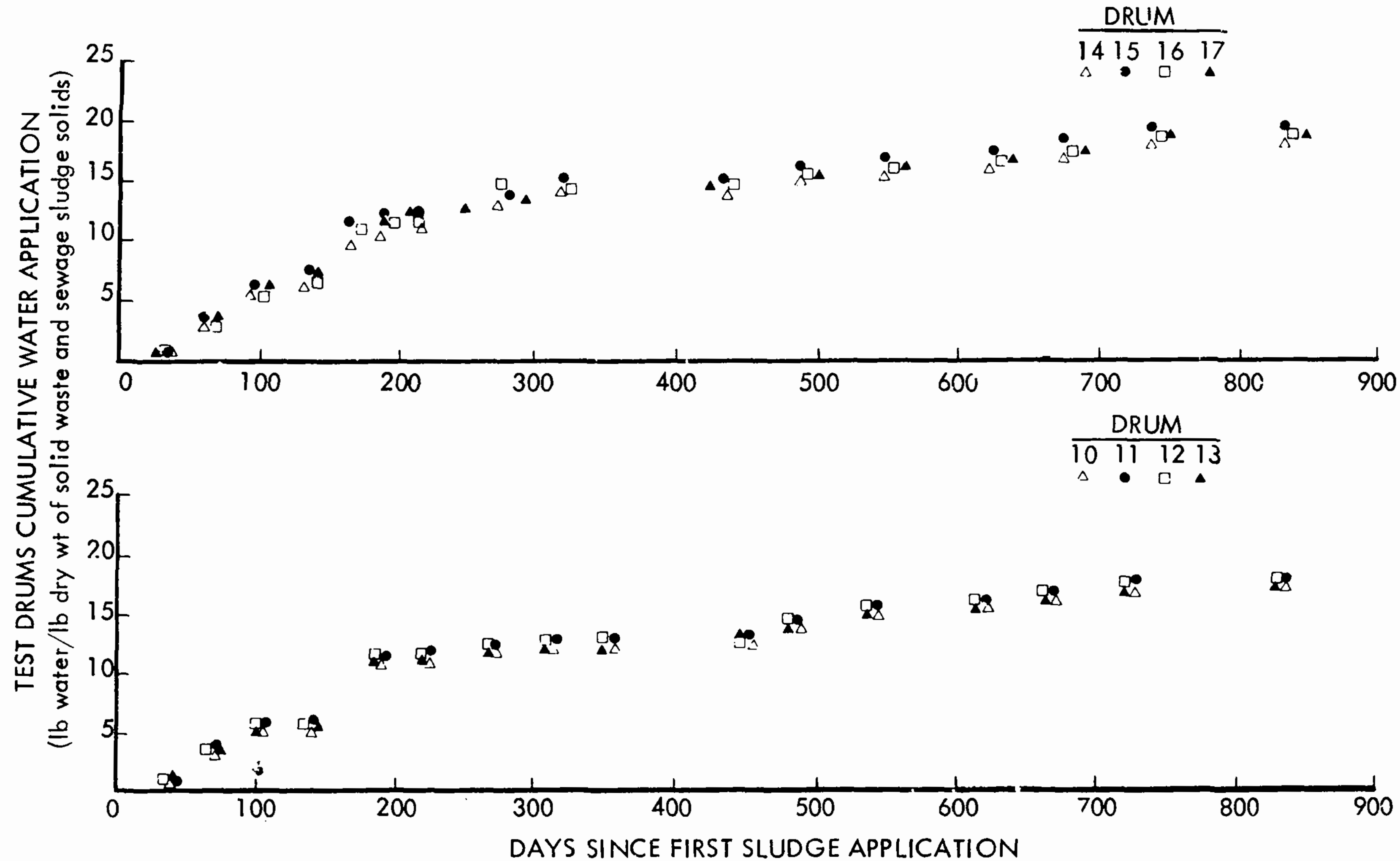

FIGURE VI-2A

TEST DRUM WEIGHT
RATIO OF WATER TO SOLIDS ADDITIONS

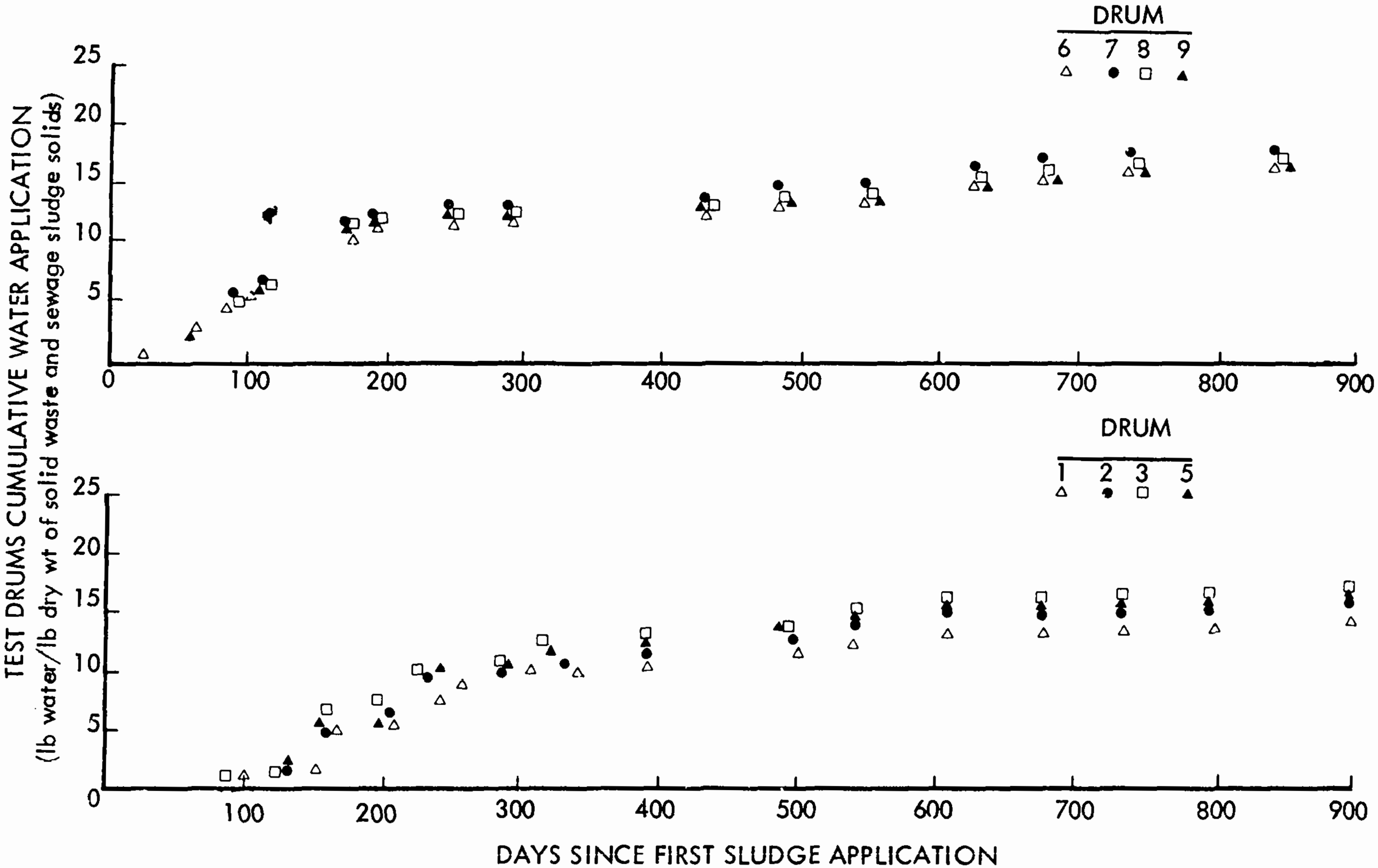

FIGURE VI-2B

TEST DRUM WEIGHT
RATIO OF WATER TO SOLIDS
ADDITIONS

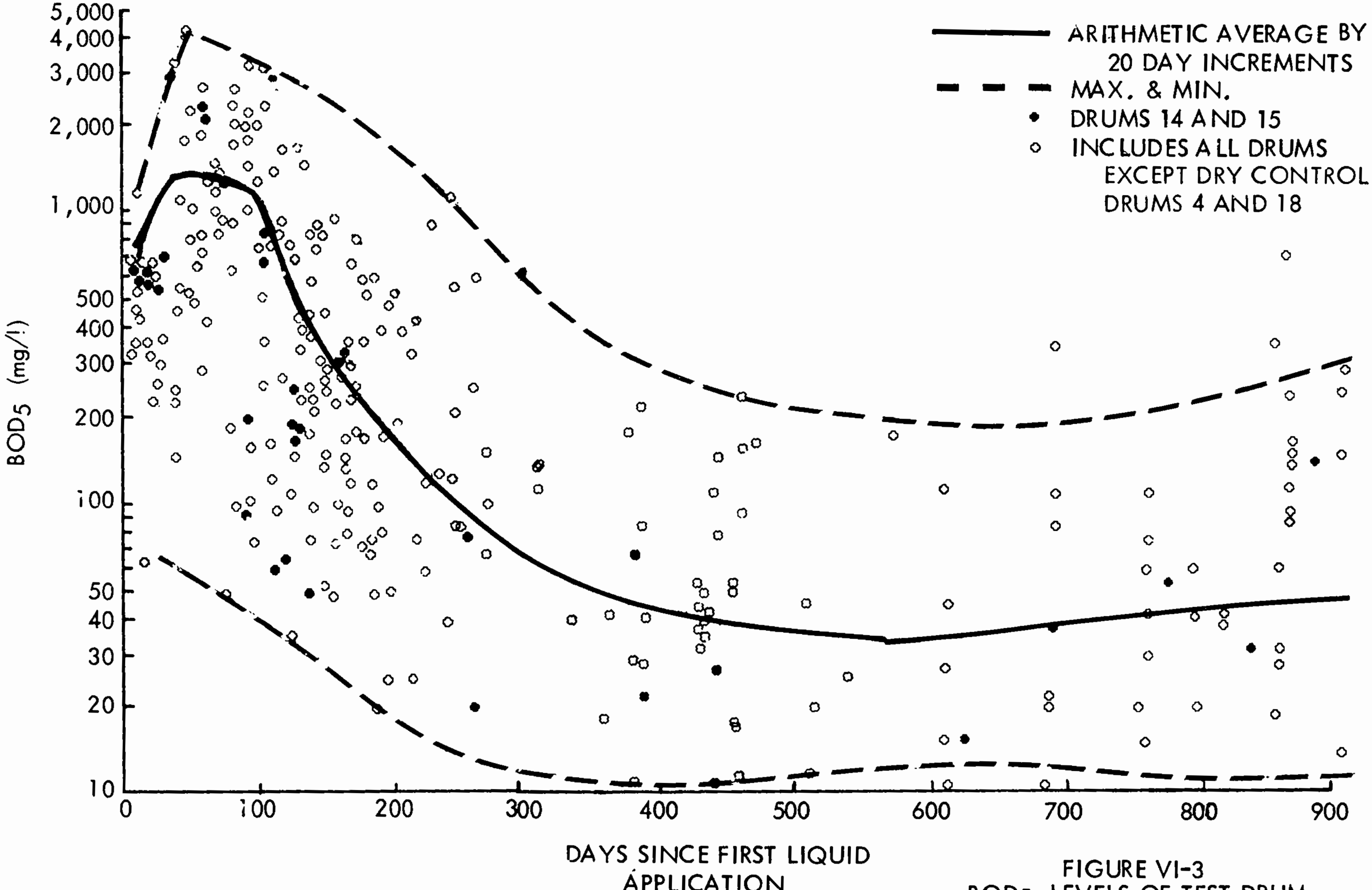

FIGURE VI-3
BOD_5 LEVELS OF TEST DRUM LEACHATES--DRUMS 14 AND 15 VS. COMPOSITE TRENDS

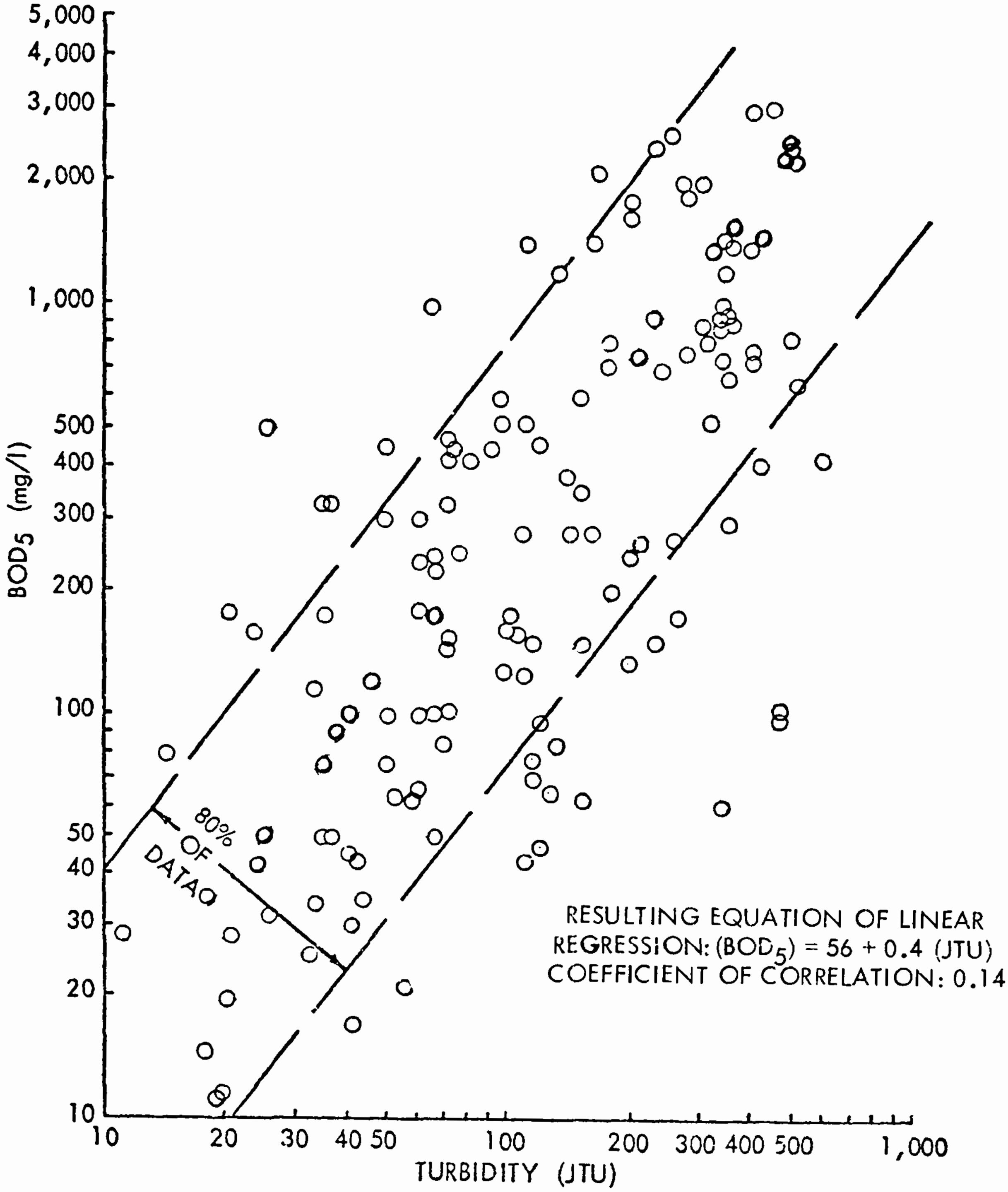

FIGURE VI-4
CORRELATION OF TEST DRUM
LEACHATE BOD_5 WITH TURBIDITY

d. Electrical Conductance (Conductivity). Electrical conductance is a measure of the capacity of a liquid to conduct electrical current. It is affected by the nature and concentration of charged species (mainly dissolved inorganic salts) in solution. A correlation exists between electrical conductivity and total dissolved solids of a liquid sample.

The dissolved inorganic content of solid waste leachates is important from the standpoint of its potential effect on groundwater quality. When leachates containing high salts content gain entrance to the groundwater, they may cause an appreciable increase in the salinity of the groundwater and/or impart other undesirable properties to it.

The data on the conductivity of the leachate samples are presented in Appendix D. Figure VI-5 is a composite plot of conductivity values for Drums 6 through 17. A composite curve for Drums 2, 3 and 5 (see Appendix D) indicate similar peaks and asymptotically decreasing values for conductivity. They occur within roughly similar periods about 120 days after filling versus about 70 days, as shown in Figure VI-5. Drums 2, 3 and 5 were filled about 50 days earlier than the other drums, which accounts for the different periods of sampling since filling to reach peak values. Drum 1 behaved differently in that its peak conductivity value occurred 30 days after filling, which was 90 days prior to peaks on all other drums. The data in this figure and those presented in Appendix D indicate that the variation of conductivity with time is very similar to those of BOD_5 and turbidity, i.e., rising to a maximum within the first 100 days, decreasing and then becoming fairly constant. As with BOD_5 and turbidity, the pattern of change in conductivity may reflect variations in the rate of biodegradation and solubilization of the organic waste material. The conductivity data also indicate that, under the conditions of the experiments, the quality of the leachate was relatively insensitive to the kind and amount of liquid originally applied to the drums.

The second small peak occurring around 140 days on Figure VI-5 corresponded to a two-week period of increasing ambient air temperatures (see Figures VI-13 through VI-16). This indicates the temperature-dependence of the biological activity in the test drums.

In an exploratory effort to investigate any correlation which may exist between the conductivity and turbidity of a leachate sample, the conductivity values for the leachate samples were plotted against the corresponding turbidities on an arithmetic paper. The results presented in Figure VI-6 do not appear to indicate any simple direct correlation between the two variables. This is understandable, since turbidity is a measure of particulate matter in water whereas conductivity merely reflects the concentration of the charged species.

e. pH. The pH of the leachates is plotted individually for each drum in Appendix D. In general, the changes in pH were fairly small and the pH values were all in the 5 to 8 range. In most cases, the pH dropped initially, reaching a minimum value within the first 100 days. The decrease in pH is probably due to the

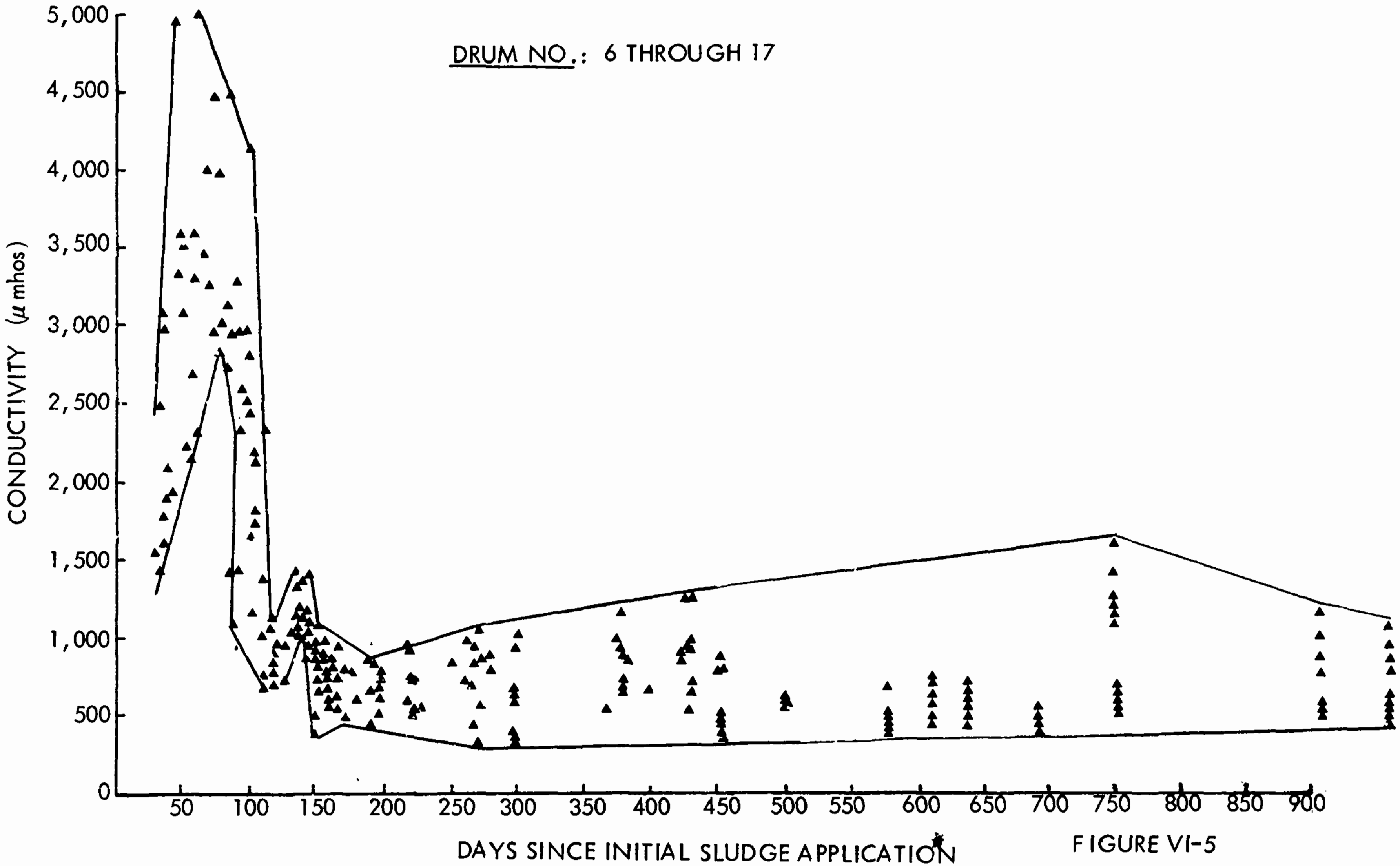

FIGURE VI-5

CONDUCTIVITY OF LEACHATES--
COMPOSITE

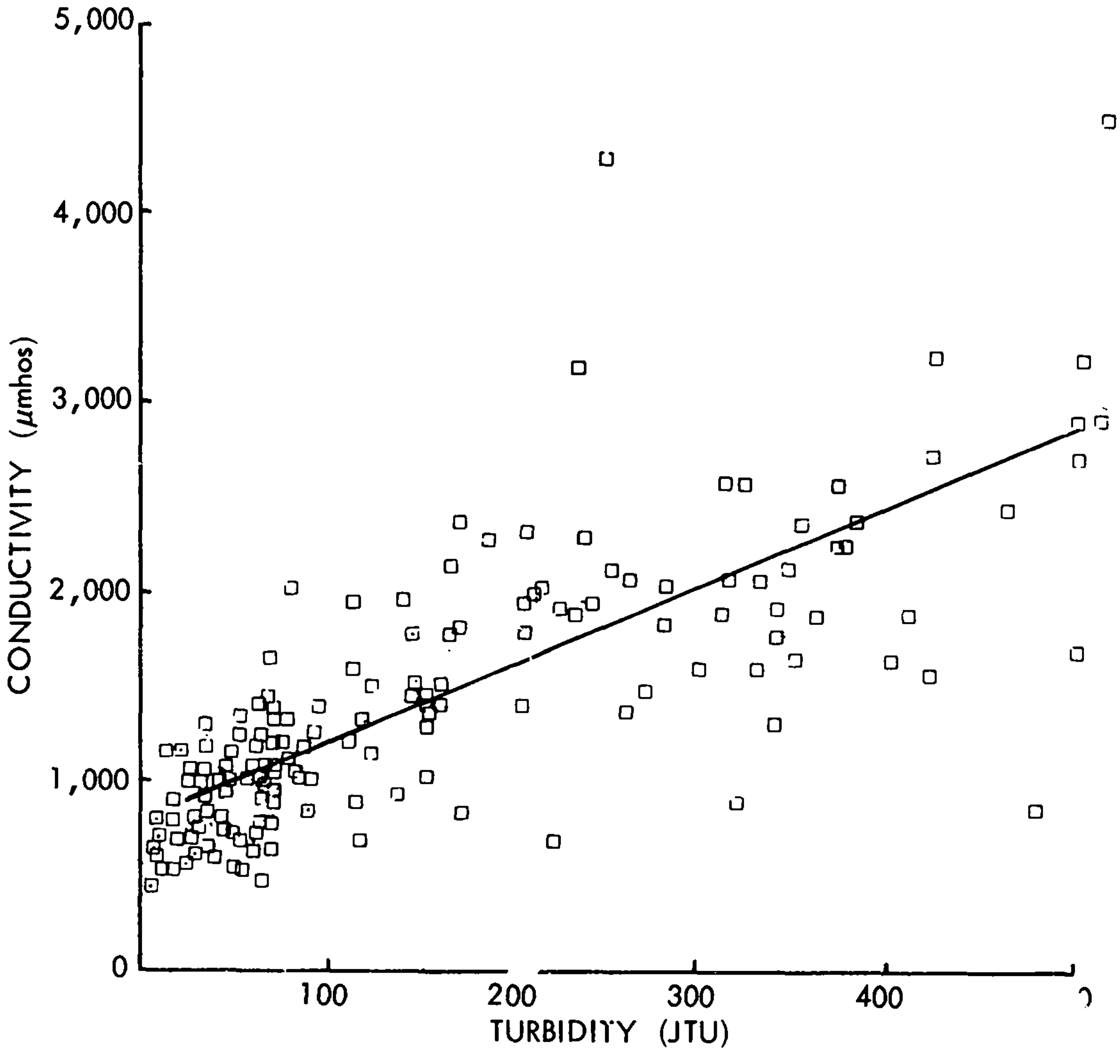

FIGURE VI-6
CORRELATION OF CONDUCTIVITY
WITH TURBIDITY

formation of acidic end-products resulting from the anaerobic biodegradation of organic wastes. Following the initial drop, the pH gradually increased, reaching values in the 6.2 to 7.2 range after 250 days. The increase in pH may reflect a slowdown in the rate of biodegradation of organics or reflect growth of methane producing bacteria which oxidize organic acids.

f. Comparison of Test Drum Leachate Characteristics with Landfill and Test Cell Leachates. Tables VI-7 and VI-8 present comparisons of test drum, test cell and landfill leachate characteristics for different ages of solid waste fill. Where ranges of values are given they represent maximum and minimum values for different samples (test cell and landfill) and different test drums. The data in Tables VI-7 and VI-8 indicate that the test cell leachates were significantly stronger in BOD_5 and conductivity than the test drum and landfill leachates. The high BOD_5, high conductivity, low pH, and foul odor of the test cell leachate are indications that extensive water to organic contact existed during or prior to the time of drainage and sampling. The data indicate that the leached soluble organics in the test cells were significantly greater than in the test drums during comparable time periods after filling. The low test drum BOD_5 range is attributed to the high rate of water application (12 to 15 lb water per lb dry wt solid waste) compared to the test cells which received 0.45 lb liquid per lb dry wt solid waste upon being filled. The test drum water, having less contact time than liquid in the test cells, apparently produced a diluted leachate and thus lower BOD_5.

g. Characteristics of "Fresh" and "Residual" Leachates. As it was described above in Section C.2., two types of leachates were obtained from each test drum: the "residual" (old) leachate collected at the bottom of drums due to the preceding liquid addition, and the "fresh" (new) leachate resulting immediately following each water addition. The first analyses of residual leachate were made in April, 1972. Table VI-9 presents typical data on quantity and quality of the residual and fresh leachates for sampling runs in 1972 and 1973. Additional residual leachate analyses are plotted in Appendix D with the fresh leachates. In the 1972 sampling the old leachates appear to contain more turbidity and show higher conductivity and lower pH levels, but the BOD_5 data do not indicate any consistent pattern. The 1973 samplings of turbidity, conductivity, and pH levels follow the same expected patterns as the 1972 samplings, whereas the 1973 BOD_5 residual leachates appear greater than for corresponding fresh leachates. Based on BOD_5 and turbidity results, the residual leachate appears to have higher content of dissolved organic material than the fresh leachate. This may be due to the significantly longer solid-liquid contact time for the old leachate.

h. Specific Dissolved Salts. On several occasions during the initial period of the study, spot checks were made on free carbon dioxide, chloride, phosphate, calcium and nitrogen content of the leachates. The results are presented in Table VI-10. A running composite was kept of some portions of all leachate samples obtained from each drum. After the December sampling in each of the three study years, the composite samples were similarly analyzed. These results are given in Table VI-11.

The data in Tables VI-10 and VI-11 indicate no significant differences between the leachates from the various drums, thus confirming the general conclusion presented earlier that, in the drum tests, the leachate characteristics did not appear to be materially

TABLE VI-7

COMPARISON OF NATURAL AND SIMULATED LEACHATES

Measured variable	Field test cell 1, days since filling			Pilot test drums, days since filling			Old Oceanside landfill
	1st 57	365	658	1st 50	365	658	>365*
BOD_5 (mg/l)	5,450 - 11,850	24,800	20,500	60 - 4,300	0-200	0-664	250 - 380
Turbidity (JTU)	53 - 210	54	59	40 - 510	0-100	7-255	#
Conductivity (μ mhos)	2,250 - 4,400	3,500	8,370	1,400 - 5,000	0-1,300	384-3,955	4,700 - 4,800
pH (units)	4.6 - 5.5	5.5	4.85	5.0 - 8.6	5.0-7.8	4.9-7.1	5.1 - 5.2
Odor	Very sour	Sour	Very sour	Septic sulfide	Earthy	Earthy	Sour

* Grab samples of leachate taken from small pools in cover soil on the side of the completed landfill about 20 feet below the top of the fill.

\# Not enough sample volume to complete analyses.

TABLE VI-8

COMPARISON OF NATURAL AND SIMULATED LEACHATES

Measured variable	Field test cell 3, days since filling		Pilot test drums, days since filling		Old Oceanside landfill
	280	645	280	645	>365*
BOD_5 (mg/l)	11,100	17,000	2-1330	0-664	250-380
Turbidity (JTU)	#	59	33-215	7-255	#
Conductivity (μ mhos)	#	7,850	510-2,000	384-3,955	4,700-4,800
pH (units)	5.6	4.8	6.00-6.94	4.9-7.1	5.1-5.2
Odor	Sour	Very sour	Earthy	Earthy	Sour

* Grab samples of leachate taken from small pools in the cover soil on the side of the completed landfill about 20 ft below the top of the fill.

\# Not enough sample volume to complete analyses.

TABLE VI-9

COMPARISON OF FRESH AND RESIDUAL TEST DRUM LEACHATES (1973)

	Residual leachate*					Fresh leachate+				
Drum no.	Qty (gal)	Turbidity (JTU)	Conductivity (μ mhos)	pH (units)	BOD_5 (mg/l)	Qty (gal)	Turbidity (JTU)	Conductivity (μmhos)	pH (units)	BOD_5 (mg/l)
1	0	--	--	--	--	0	--	--	--	--
2	0.2	48	552	6.45	100	2.4	17	466	7.05	78
3	0.4	210	1,068	6.52	0	2.5	7	357	6.82	0
5	0.6	200	1,080	6.40	0	2.0	9	483	6.72	0
6	0	--	--	--	--	2.3	10	397	7.05	22
7	0.6	15	732	6.61	10	.8	5	345	7.00	117
8	0.6	210	1,068	6.15	200	1.3	27	391	6.05	22
9	0.1	205	1,212	6.12	0	Negl.**	--	—	7.35	--
10	0.5	150	816	6.20	40	1.9	22	334	6.60	0
11	0.3	185	1,536	6.42	15	2.8	5	368	6.81	0
12	0.5	150	1,452	5.55	130	.5	130	541	5.82	340
13	0.1	240	1,128	6.58	0	.1	73	621	6.80	20
14	0	--	--	--	--	2.4	5	564	6.75	0
15	1.3	140	742	6.42	60	2.4	6	368	7.05	0
16	0.6	170	744	6.45	50	2.1	9	385	6.98	10
17	0.3	155	1,178	6.18	0	2.0	24	500	6.55	10

* Samples of May 1, 1973 leachate remaining from last 3-gallon water application 52 days earlier, on March 10, 1973.

\+ Leachate occurring within about ½ hour of water application, May 1, 1973.

** Quantity of leachate enough for analyses, but insignificant in gallons.

TABLE VI-10
ANALYSES FOR SPECIFIC SOLUBLE COMPONENTS*

Drum no.	Dissolved CO_2 +	Chloride +	Phosphate +	Calcium #	Total nitrogen +	Nitrate #	Organic ¢ nitrogen
1	30	130	5	257	26.3	1.94	1.73
2	75	270	4	329	16.9	1.73	-
3	210	185	3	312	53.0	1.94	0.45
5	105	200	4	178	61.6	0.45	0.91
6	340	267	5	164	-	0.69	-
7	45	293	4	297	30.8	1.25	0.45
8	255	221	5	209	81.2	1.25	1.25
9	60	86	4	304	52.6	0.91	0.69
10	90	205	3	369	54.2	0.69	0.45
11	210	167	4	226	-	1.60	1.25
12	565	258	4	259	-	1.14	-
13	90	245	3	230	14.8	1.60	1.60
14	240	262	3	208	31.4	1.60	1.25
15	330	336	5	329	44.8	0.69	0.45
16	120	145	4	262	22.0	1.25	-
17	225	190	4	176	17.8	1.94	1.94

*All values in mg/l. Samples taken on dates as follows: + 9/10/71; #9/14/71; and ¢9/24/71.

TABLE VI-11

CHEMICAL ANALYSES OF LEACHATE COMPOSITES*
(1971)

Drum no.	F	Fe	SO_4	PO_4	Cl	Ca	NO_3	Conductivity	Total organic nitrogen	pH	Turbidity
1	0.10	0.12	100	1.0	225	74	0.30	1650	34	6.80	5
2	0.75	0.17	170	1.0	205	46	0.60	1150	45	7.35	14
3	0.50	0.21	42	0.80	200	81	0.90	1250	56	7.35	26
5	0.10	0.12	50	0.70	195	107	28.0	1300	62	7.00	18
6	0.35	0.10	96	0.45	140	116	0.70	1050	73	7.80	16
7	0.40	0.21	72	0.50	200	68	0.19	1400	72	7.90	24
8	0.50	0.21	86	0.45	190	78	0.83	1350	79	7.15	6
9	0.75	0.17	55	0.20	190	149	23.2	1350	17	7.15	13
10	0.67	0.21	56	1.00	220	129	2.00	1400	95	6.90	7
11	0.90	0.15	28	1.20	107	111	1.04	100	15	7.50	10
12	0.75	0.20	40	0.80	192	76	2.25	1500	60	7.85	45
13	1.00	0.12	34	0.80	182	111	1.37	1300	26	8.10	22
14	0.70	0.10	48	1.00	180	166	3.00	1150	31	7.40	8
15	0.65	0.23	78	1.00	110	57	1.16	875	46	7.80	9
16	0.50	0.25	72	0.50	190	73	20.0	1450	50	7.55	24
17	0.40	0.21	58	0.70	140	106	16.6	1250	41	7.05	25

*All values in mg/l; except pH (units); conductivity (μ-mhos/cm) , and turbidity (JTU).

TABLE VI-11 (CONT.)

CHEMICAL ANALYSES OF LEACHATE COMPOSITES*
(1972)

Drum no.	SO_4	PO_4	Cl	Ca	NO_3	Conductivity	Total inorganic nitrogen	pH	Turbidity
1	87	1.7	280	50	1.34	1,200	25.3	7.73	4
2	40	1.3	388	7	1.08	950	31.8	7.41	30
3	38	1.5	156	35	2.38	880	11.1	7.42	9
5	46	1.0	196	36	1.32	920	4.5	7.77	6
6	37	0.70	316	18	4.38	910	15.0	7.80	10
7	35	0.60	299	26	1.12	820	6.7	7.80	6
8	39	0.44	266	29	1.88	770	18.3	7.37	6
9	80	1.5	440	23	1.04	1,200	7.8	7.68	7
10	32	0.28	333	24	3.40	800	8.7	7.18	21
11	25	0.48	585	7	2.42	1,000	8.9	7.69	12
12	45	0.36	470	50	0.20	1,200	17.3	6.92	49
13	28	0.46	182	54	1.92	960	8.9	7.20	11
14	98	0.44	270	32	1.04	1,100	24.6	7.00	4
15	55	0.58	241	26	2.74	1,000	5.8	7.12	6
16	25	0.40	410	3	1.84	1,000	6.8	7.79	17
17	15	0.50	416	4	1.38	1,200	5.8	7.78	20

* All values in mg/l; except pH (units), conductivity (μ mhos/cm), and turbidity (JTU).

TABLE VI-11 (CONT.)

CHEMICAL ANALYSES OF LEACHATE COMPOSITES*
(1973)

Drum no.	SO_4	PO_4	Cl	Ca	NO_3	Conductivity	Total inorganic nitrogen	pH	Turbidity
1	30	0.7	330	23.2	3.5	655	18.3	7.40	13.0
2	23	0.8	167	7.4	2.1	482	21.5	7.10	16.0
3	0.0	0.0	310	18.6	3.0	645	10.3	7.25	5.0
5	20	0.0	330	16.8	1.5	690	1.3	6.30	7.0
6	6	0.0	256	7.4	10.2	377	17.2	7.05	4.25
7	0.0	0.3	278	21.8	3.5	475	1.1	6.80	5.0
8	11	0.0	330	21.8	3.2	495	9.7	7.30	10.0
9	0.0	1.0	278	26.7	0.5	655	5.4	7.10	6.0
10	0.0	0.0	330	13.0	7.0	470	4.3	7.90	10.0
11	0.0	0.0	444	9.0	4.6	655	7.8	8.15	6.0
12	0.0	0.0	388	9.0	1.0	530	15.1	7.45	6.5
13	4	0.2	388	13.8	30.5	570	1.0	7.95	6.0
14	94	0.3	555	17.0	1.0	635	15.6	7.25	3.2
15	38	0.0	326	10.6	2.5	492	1.5	7.90	7.2
16	1.5	0.0	287	5.8	3.2	520	4.1	8.20	7.1
17	0.0	0.4	403	21.8	0.8	617	0.9	8.20	16.0

* All values in mg/l; except pH (units), conductivity (μ mhos/cm), and turbidity (JTU).

affected by the kind and amount of the liquid applied to the solid waste. Some differences which have been observed may in fact be related, at least partially, to differences which may have existed in the makeup of the solid waste placed in each drum. The fact that the nitrate (nitrogen oxide) values are significantly lower than the total organic nitrogen values suggests that either the oxidation of nitrogenous compounds which usually follows oxidation of carbonaceous material had not been advanced to any appreciable extent, or anaerobiosis had further reduced any nitrates to nitrogen gas.

Analyses were also completed for heavy metals on each of the three yearly composites. The results are given in Table VI-12. Concentrations of lead, chromium, copper and manganese were all below 1 mg/l, or negligible. Concentrations of zinc and iron were generally slightly higher in the 1972 and 1973 composites, while magnesium was slightly lower in 1972, and higher in 1973. Apparently some zinc coatings on metals in the waste and some corrosion of the steel drums affected the leachate concentrations for zinc and iron.

3. Gas Generation. Table VI-13 presents the results of gas analyses for the 18 test drums. The gas analyses were variable, both from drum to drum and within the same drum as time progressed. The variability in gas sample compositions resulted from the existence of a comparatively large air space above the surface of the solid waste in each drum, as well as the necessity of exposing each drum to the atmosphere during compaction, water addition, and other periodic monitoring work. Each time this was performed, fresh air was introduced and methane and carbon dioxide were diffused. It was also suspected that the gas sampling sidewall ports may not have been airtight, and some air may have been drawn along the sidewall gap and perhaps from the air mixture above the solid waste surface.

Two methods were adopted in June 1972 in an attempt to achieve airtight conditions. Rubber septums were placed over the gas sample ports and samples were drawn using a 12-inch long hypodermic needle that was inserted into the middle of the solid waste mass. Also, polyethylene bag covers were loosely placed over the tops of the solid waste mass and sealed at the drum lid to minimize the drum air pocket. The gas analyses after June 1972 show increases in methane in Drums 1, 8, 9, 10, 11, 12, 13 and 17. Air contamination still remained a problem in the drums due to the need to remove the polyethylene bag seals to apply water. The drums other than those aforementioned had greater aeration occurring probably due to sealing failures; slight leaks can cause significant aeration in small test containers. Special high vacuum seals must be used to avoid air leaks if natural landfill conditions are to be simulated. No simple explanation is available for the wide variation in methane concentrations.

4. Compaction. The solid waste material in the drums was compacted prior to each water application to simulate the preload found at full-scale landfills from cover soil and vehicular travel. The compaction method utilized for all drums was the one described in Section B.3. for drums 2 through 5. The degree of settlement after compaction, expressed as a percent reduction in the depth of solid waste plotted against days since filling, is presented in Figures VI-7 through VI-11. These results indicate no relationship between settlement rates with or without forced aeration,

TABLE VI - 12

HEAVY METAL ANALYSIS OF LEACHATE COMPOSITES
(1971)

Drum no.	Concentration, mg /l					
	Pb	Cr	Mg	Cu	Mn	Zn
1	< 0.1	< 0.03	15.0	0.05	< 0.02	0.6
2	< 0.1	< 0.03	11.7	< 0.01	< 0.02	0.5
3	< 0.1	< 0.03	12.2	< 0.01	< 0.02	0.2
5	< 0.1	< 0.03	14.6	< 0.01	< 0.02	0.3
6	< 0.1	< 0.03	11.9	< 0.01	< 0.02	0.6
7	< 0.1	< 0.03	14.2	< 0.01	< 0.02	0.2
8	< 0.1	< 0.03	14.2	< 0.01	< 0.02	0.2
9	< 0.1	< 0.03	15.0	< 0.01	< 0.02	0.3
10	0.4	< 0.03	14.2	< 0.01	< 0.02	0.4
11	< 0.1	< 0.03	15.4	< 0.01	< 0.02	0.3
12	< 0.1	< 0.03	6.0	< 0.01	< 0.02	0.5
13	< 0.1	< 0.03	13.6	< 0.01	< 0.02	0.2
14	< 0.1	< 0.03	12.2	< 0.01	< 0.02	0.2
15	< 0.1	< 0.03	6.2	< 0.01	< 0.02	0.3
16	0.4	< 0.03	12.1	0.10	< 0.02	0.5
17	< 0.1	< 0.03	11.5	< 0.01	< 0.02	0.3

TABLE VI - 12 (CONT.)

HEAVY METAL ANALYSIS OF LEACHATE COMPOSITES
(1972)

	Concentration, mg/l						
Drum no.	Fe	Pb	Cr	Mg	Cu	Mn	Zn
1	2.2	0.6	< 0.03	12.00	0.10	< 0.02	0.8
2	25.0	< 0.1	< 0.03	5.00	0.05	0.10	0.9
3	2.2	< 0.1	< 0.03	6.00	< 0.01	< 0.02	0.3
5	2.2	0.4	< 0.03	8.50	< 0.01	< 0.02	0.8
6	1.8	0.2	< 0.03	13.40	< 0.01	< 0.02	0.3
7	2.4	0.4	< 0.03	6.80	< 0.01	< 0.02	0.2
8	2.0	0.4	< 0.03	6.20	< 0.01	< 0.02	0.3
9	3.0	< 0.1	< 0.03	14.10	< 0.01	0.10	0.5
10	1.8	< 0.1	< 0.03	3.80	0.05	< 0.02	0.2
11	8.2	< 0.1	< 0.03	15.00	0.05	< 0.02	0.3
12	2.2	< 0.1	< 0.03	12.80	< 0.01	0.20	1.8
13	2.0	0.2	< 0.03	6.80	< 0.01	< 0.02	0.3
14	2.2	< 0.1	< 0.03	9.00	< 0.01	0.20	1.8
15	2.2	< 0.1	< 0.03	1.10	< 0.01	< 0.02	0.3
16	4.4	0.6	< 0.03	10.00	< 0.01	< 0.02	1.6
17	2.2	0.4	< 0.03	11.70	< 0.01	< 0.02	0.5

TABLE VI-12 (CONT.)

HEAVY METAL ANALYSIS OF LEACHATE COMPOSITES (1973)

Drum no.	Concentration, mg/l						
	Fe	Pb	Cr	Mg	Cu	Mn	Zn
1	5.0	<0.1	<0.03	54.0	0.13	<0.02	0.6
2	5.0	<0.1	<0.03	19.0	0.25	<0.02	0.8
3	0.8	<0.1	<0.03	49.0	<0.01	<0.02	1.1
5	1.3	<0.1	<0.03	65.0	<0.01	<0.02	1.7
6	<0.1	<0.1	<0.03	10.0	<0.01	<0.02	0.9
7	0.7	<0.1	<0.03	22.5	0.13	<0.02	0.1
8	1.6	<0.1	<0.03	17.0	0.13	<0.02	1.1
9	1.6	<0.1	<0.03	65.0	0.13	<0.02	<0.1
10	<0.1	<0.1	<0.03	11.5	0.25	<0.02	1.3
11	<0.1	<0.1	<0.03	47.0	0.25	<0.02	1.2
12	1.6	<0.1	<0.03	81.0	0.13	<0.02	0.9
13	0.8	<0.1	<0.03	74.0	<0.01	<0.02	1.2
14	<0.1	<0.1	<0.03	31.0	<0.01	<0.02	2.1
15	<0.1	<0.1	<0.03	15.0	0.25	<0.02	1.8
16	0.8	<0.1	<0.03	21.0	0.13	<0.02	<0.1
17	0.5	<0.1	<0.03	74.0	0.37	<0.02	--

TABLE VI-13

COMPOSITION OF GAS SAMPLES FROM TEST DRUMS

Drum no.	Date	Day *	CO_2	O_2	N_2	CH_4
			Gas composition (percent by volume)			
	1971					
1+,#	8/6	122	0	18.1	82.1	0
	8/1	127	42.5	3.8	25.9	27.8
	8/26	142	32.2	4.6	44.6	18.6
	9/14	161	7.9	0.5	59.2	32.4
	11/17	224	2.3	20.0	77.7	0
	12/29	265	9.0	14.1	60.9	16.0
	1972					
	1/19	286	12.1	14.5	62.7	10.7
	6/28	447	12.0	0.3	87.7	0
	8/14	513	8.8	6.0	85.2	0
	9/18	548	12.0	6.5	81.3	0.2
	10/20	580	3.4	8.6	85.0	3.0
	11/22	613	18.3	1.4	47.5	32.8
	12/20	641	16.6	3.9	56.6	22.9
	1973					
	2/1	684	20.5	0.8	59.3	19.4
	6/28	831	24.8	0.8	43.2	31.2
	8/29	893	1.8	19.1	78.2	0.9
	10/16	941	20.4	1.0	71.3	7.3

Drum no.	Date	Day *	CO_2	O_2	N_2	CH_4
			Gas composition (percent by volume)			
	1971					
2#	8/6	98	0	21.0	79.0	0
	8/11	103	0.4	20.6	79.0	0
	8/26	118	0.1	20.9	79.0	0
	9/14	137	0	19.9	80.1	0
	11/17	200	1.8	20.1	78.1	0
	12/29	224	0	18.1	81.9	0
	1972					
	6/28	Inaccurate - Air leak into drum.				
	9/18	488	30	14.4	82.6	0
	10/20	520	1.8	19.6	78.6	0
	11/22	553	2.1	19.3	78.6	0
	12/20	581	0	21.1	78.9	0
	1973					
	2/1	624	1.2	18.2	80.6	0
	6/28	771	1.7	13.1	85.1	0
	8/29	833	0	25.8	74.2	0
	10/16	881	0	21.9	78.1	0

TABLE VI-13 (CONT.)

COMPOSITION OF GAS SAMPLES FROM TEST DRUMS

Drum no.	Date	Day *	Gas composition (percent by volume)				Drum no.	Date	Day *	Gas composition (percent by volume)			
			CO_2	O_2	N_2	CH_4				CO_2	O_2	N_2	CH_4
	1971							1971					
3	8/6	98	0	21.0	79.0	0	4 **	8/6	95	0	20.0	80.0	0
	8/11	103	0	21.0	79.0	0		8/11	100	0	21.4	78.6	0
	8/26	118	19.0	4.2	76.8	0		8/26	115	8.2	16.2	76.6	0
	9/14	137	25.5	3.3	71.2	0		9/14	137	21.5	10.5	60.2	7.8
	11/17	200	5.6	17.0	77.4	0		11/17	200	5.9	16.5	77.6	0
	12/29	239	2.8	17.6	79.6	0		12/29	241	5.2	18.0	76.8	0
	1972							1972					
	1/19	260	4.6	16.8	78.6	0		1/19	262	5.2	16.3	78.1	0.4
	6/28	421	9.5	7.6	82.9	0		6/28	423	2.2	13.1	84.7	0
	8/14	468	17.3	0.3	82.4	0		8/14	470	2.9	17.1	80.0	0
	9/18	499	14.6	4.2	81.2	0		9/18	501	6.5	12.4	81.1	0
	10/20	531	0	20.9	79.1	0		10/20	533	0	20.9	79.1	0
	11/22	564	5.9	12.4	81.7	0		11/22	566	2.5	17.8	79.7	0
	12/20	592	5.2	13.0	81.4	0.4		12/20	594	5.7	15.1	79.2	0
	1973							1973					
	2/1	635	2.6	17.4	80.0	0		2/1	637	0.8	11.0	88.2	0
	6/28	782	2.0	6.8	91.0	0.2		6/28	784	2.2	17.4	80.4	0
	8/29	844	0.7	15.7	82.8	0.8		8/29	846	4.8	12.9	82.3	0
	10/16	892	2.5	17.3	80.2	0		10/16	894	4.2	18.5	77.3	0

TABLE VI-13 (CONT.)

COMPOSITION OF GAS SAMPLES FROM TEST DRUMS

Drum no.	Date	Day *	Gas composition (percent by volume) CO_2	O_2	N_2	CH_4
	1971					
5#	8/11	103	6.8	15.7	77.5	0
	8/26	118	7.4	17.6	75.0	0
	9/14	137	9.8	8.0	82.2	0
	11/17	200	6.9	14.9	78.2	0
	12/29	239	7.7	17.0	74.9	0.4
	1972					
	1/19	260	7.6	14.0	78.4	0
	6/28	421	4.5	9.2	86.3	0
	8/14	468	11.2	7.3	81.5	0
	9/18	499	9.5	9.1	81.4	0
	10/20	531	3.8	15.2	81.0	0
	11/22	564	3.1	16.7	80.2	0
	12/20	592	2.8	16.2	81.0	0
	1973					
	2/1	635	2.7	18.4	78.9	0
	6/28	782	12.6	6.5	20.6	60.3
	8/29	844	0	24.4	75.6	0
	10/16	892	0	16.9	83.1	0

Drum no.	Date	Day *	Gas composition (percent by volume) CO_2	O_2	N_2	CH_4
	1971					
6#	8/6	52	31.2	2.6	59.5	6.7
	8/11	57	12.0	12.0	76.0	0
	8/26	73	10.2	11.5	78.3	0
	9/14	92	9.3	14.7	76.0	0
	11/17	155	12.2	10.3	77.5	0
	12/29	196	3.0	18.0	79.0	0
	1972					
	1/19	217	12.6	9.2	78.2	0
	6/28	378	Inaccurate - Air leak into drum.			
	8/14	425	11.2	7.3	81.5	0
	9/18	456	8.5	11.3	80.2	0
	10/20	488	3.4	11.6	85.0	0
	11/22	521	2.3	18.2	79.5	0
	12/20	549	2.5	18.0	79.5	0
	1973					
	2/1	592	2.4	19.5	78.1	0
	6/28	739	2.7	12.8	84.5	0
	8/29	801	3.1	13.9	83.0	0
	10/16	849	2.2	16.9	80.9	0

TABLE VI-13 (CONT.)
COMPOSITION OF TEST SAMPLES FROM TEST DRUMS

Drum no.	Date	Day *	Gas composition (percent by volume) CO_2	O_2	N_2	CH_4	Drum no.	Date	Day *	Gas composition (percent by volume) CO_2	O_2	N_2	CH_4
	1971							1971					
7	8/6	51	3.5	17.8	78.7	0	8	8/11	51	0	21.0	79.0	0
	8/11	56	0	20.7	79.3	0		8/26	66	3.4	19.4	77.2	0
	8/26	72	2.7	20.3	77.0	0		9/14	85	0	21.1	78.9	0
	9/14	93	11.5	11.5	77.0	0		11/17	148	13.0	10.2	74.8	2.0
	11/17	155	4.7	17.2	78.1	0							
	12/29	195	5.8	14.5	79.7	0.3		1972					
	1972							1/19	211	12.3	9.4	77.1	1.2
	1/19	216	6.8	14.6	78.6	0							
	6/28	377	Inaccurate - Air leak into drum.					6/28	372	19.3	0.1	66.2	14.4
	8/18	428	5.2	12.2	82.6	0		8/18	423	24.5	0.1	55.4	20.0
	9/18	459	2.8	15.7	81.6	0		9/18	454	22.7	1.9	60.6	14.8
	10/20	491	1.8	15.9	82.3	0		10/20	486	14.7	4.4	51.2	24.7
	11/22	524	1.3	18.1	80.6	0		11/22	519	12.0	11.3	61.6	15.1
	12/20	552	2.1	19.6	78.3	0		12/20	547	16.4	3.1	41.0	39.5
	1973							1973					
	2/1	595	2.3	17.7	80.0	0		2/1	590	21.8	5.0	34.7	38.5
	6/28	742	4.3	16.1	79.6	0		6/28	737	3.3	3.6	43.2	49.9
	8/29	804	0.5	19.9	79.6	0		8/29	799	25.8	1.7	12.1	60.4
	10/16	852	0	22.8	77.2	0		10/16	847	17.2	3.7	66.6	12.5

TABLE VI-13 (CONT.)

COMPOSITION OF TEST SAMPLES FROM TEST DRUMS

Drum no.	Date	Day *	Gas composition (percent by volume) CO_2	O_2	N_2	CH_4	Drum no.	Date	Day *	Gas composition (percent by volume) CO_2	O_2	N_2	CH_4
	1971							1971					
9	8/11	51	7.2	17.0	75.8	0	10	8/6	56	29.6	3.4	65.8	1.2
	8/26	66	31.2	4.7	54.0	10.1		8/11	61	12.8	12.4	74.8	0
	9/14	85	7.5	17.2	75.3	0		8/26	76	25.1	2.4	72.5	0
	11/17	148	3.5	19.3	75.8	1.3		9/14	95	25.9	2.1	72.0	0
	12/29	178	4.1	17.8	77.4	0.7		11/17	158	13.3	10.4	76.3	0
	1972							1972					
	1/19	199	3.6	17.9	76.5	2.0		1/19	221	9.8	12.7	77.5	0
	6/28	360	27.2	1.0	24.5	47.4		6/28	382	12.4	1.1	85.9	0.6
	8/18	411	48.8	0.3	41.5	9.4		8/18	433	20.3	1.0	76.2	2.5
	9/18	442	33.4	0	26.4	40.2		9/18	464	23.1	0.4	74.8	1.7
	10/20	474	11.4	11.9	75.4	1.3		10/20	496	12.0	10.5	54.0	23.5
	11/22	507	4.2	27.1	58.1	10.6		11/22	529	17.4	4.6	75.5	2.5
	12/20	535	10.8	12.2	71.5	5.4		12/20	557	16.6	2.4	74.1	6.9
	1973							1973					
	2/1	578	21.5	1.2	18.3	59.0		2/1	600	19.2	0.8	63.5	16.9
	6/28	725	52.9	1.5	6.4	39.2		6/28	747	10.5	5.3	84.2	0
	8/29	787	18.1	10.1	30.3	41.5		8/29	809	14.2	7.4	78.4	0
	10/16	835	6.8	10.8	82.4	0		10/16	857	12.8	8.1	79.1	0

TABLE VI-13 (CONT.)

COMPOSITION OF GAS SAMPLES FROM TEST DRUMS

Drum no.	Date	Day *	Gas composition (percent by volume) CO_2	O_2	N_2	CH_4
	1971					
11	8/6	56	0	20.8	79.2	0
	8/11	61	1.7	22.6	75.7	0
	8/26	76	19.0	9.0	72.0	0
	9/14	95	3.9	18.9	77.2	0
	11/17	158	5.4	16.6	78.0	0
	12/29	200	5.6	18.9	75.5	0
	1972					
	1/19	221	8.2	14.1	77.7	0
	6/29	383	4.3	12.0	83.7	0
	8/18	433	20.0	0.4	79.0	0.6
	9/18	464	18.5	0.9	80.6	0
	10/20	496	5.1	18.1	72.2	4.6
	11/27	544	6.5	11.6	79.1	2.7
	12/20	572	6.9	9.8	80.8	2.5
	1973					
	2/1	615	10.9	5.1	82.8	1.2
	6/28	762	22.6	0.5	18.6	58.3
	8/29	824	11.6	11.9	57.8	18.7
	10/16	872	10.7	4.3	59.1	25.9

Drum no.	Date	Day *	Gas composition (percent by volume) CO_2	O_2	N_2	CH_4
	1971					
12	8/11	61	0	21.8	78.2	0
	8/26	76	20.0	6.0	74.0	0
	9/14	95	13.5	9.5	77.0	0
	11/17	158	5.5	16.1	78.4	0
	1972					
	1/19	179	3.5	18.1	78.4	0
	6/29	341	20.2	1.8	41.6	36.4
	8/18	391	15.8	0.5	83.7	0
	9/18	421	40.0	2.7	17.0	40.3
	10/20	453	0.6	20.5	77.5	1.4
	11/27	491	12.7	4.3	47.8	35.2
	12/20	519	1.2	20.2	77.4	1.2
	1973					
	2/1	562	1.2	20.2	77.4	1.2
	7/9	720	5.2	12.0	82.8	0
	8/29	771	31.5	10.5	12.4	45.6
	10/16	819	11.3	13.4	55.9	19.4

TABLE VI-13 (CONT.)
COMPOSITION OF GAS SAMPLES FROM TEST DRUMS

Drum no.	Date	Day *	Gas composition (percent by volume) CO_2	O_2	N_2	CH_4	Drum no.	Date	Day *	Gas composition (percent by volume) CO_2	O_2	N_2	CH_4
	1971							1971					
13	8/6	56	4.0	19.2	76.8	0	14++	8/6	46	27.2	12.0	48.4	12.4##
	8/11	61	3.7	19.4	76.9	0		8/11	51	5.0	17.2	77.8	0
	8/26	76	8.2	16.2	76.6	0		8/26	66	8.0	18.8	67.7	5.3##
	9/14	95	26.5	3.0	70.5	0		9/14	75	0	20.9	79.1	0
	11/17	158	5.2	16.0	77.9	0.9		11/17	148	0	19.0	81.0	0
	12/29	200	5.2	15.2	79.0	0.6							
	1972												
	1/19	221	3.8	17.6	76.4	2.2		1972					
	6/29	383	26.3	0.3	47.8	25.6		6/29	310	0	21.1	78.9	0
	8/18	433	25.8	0.1	36.1	38.0		8/18	423	2.4	16.7	80.9	0
	9/18	464	39.1	0.1	10.0	50.8		9/18	454	0	20.3	79.7	0
	10/20	496	7.0	10.5	82.5	0		10/20	486	0	19.7	80.3	0
	11/27	534	15.9	1.2	31.1	51.9		11/27	524	0	21.5	78.5	0
	12/20	562	8.4	11.3	62.0	18.3		12/20	552	0	22.0	78.0	0
	1973							1973					
	2/1	605	18.0	1.5	10.3	70.2		2/1	595	0	18.4	81.6	0
	6/28	752	20.5	0.2	8.8	70.5		6/28	742	0	19.0	80.8	0.2
	8/29	814	4.0	16.6	78.7	0.7		8/29	804	0	19.4	80.6	0
	10/16	862	5.2	9.2	65.9	19.7		10/16	852	0	20.4	79.6	0

TABLE VI-13 (CONT.)
COMPOSITION OF GAS SAMPLES FROM TEST DRUMS

Drum no.	Date	Day *	Gas composition (percent by volume) CO_2	O_2	N_2	CH_4
	1971					
15++	8/11	51	0	20.0	80.0	0
	8/26	66	18.0	11.0	66.0	5.0##
	9/14	75	0	18.5	81.5	0
	11/17	148	0	18.9	81.1	0
	12/29	180	0	20.0	80.0	0
	1972					
	6/29	342	0	20.8	79.2	0
	8/14	409	3.2	16.1	80.7	0
	9/18	434	0	20.4	79.6	0
	10/20	466	0	21.5	78.5	0
	11/27	504	0	20.9	79.1	0
	12/20	532	0	20.8	79.2	0
	1973					
	2/1	575	0	19.2	80.8	0
	6/28	722	0	13.2	86.8	0
	8/29	784	0	21.4	78.6	0
	10/16	832	0	21.1	78.9	0

Drum no.	Date	Day *	Gas composition (percent by volume) CO_2	O_2	N_2	CH_4
	1971					
16	8/11	28	8.2	10.6	76.8	4.4
	8/26	43	0	20.8	79.2	0
	9/14	62	3.5	17.3	79.2	0
	11/17	125	6.2	15.9	77.9	0
	12/29	165	4.5	17.2	78.3	0
	1972					
	1/19	186	10.4	12.1	77.5	0
	6/29	348	4.8	10.0	85.2	0
	8/18	398	12.4	1.5	86.1	0
	9/18	429	10.3	8.2	81.5	0
	10/20	461	1.5	19.6	77.0	1.9
	11/27	499	0	21.5	78.5	0
	12/20	527	5.4	12.7	81.8	0
	1973					
	2/1	570	6.0	18.0	76.0	0
	6/28	717	2.9	7.4	89.7	0
	8/29	779	6.4	13.7	71.0	8.9
	10/16	827	3.7	11.0	85.3	0

TABLE VI-13 (CONT.)
COMPOSITION OF GAS SAMPLES FROM TEST DRUMS

Drum no.	Date	Day *	Gas composition (percent by volume) CO_2	O_2	N_2	CH_4
	1971					
17	8/6	50	0	19.2	80.8	0
	8/11	55	0	20.7	79.3	0
	8/26	70	0.5	15.1	84.4	0
	9/14	89	0	20.0	80.0	0
	11/17	152	2.1	19.6	78.3	0
	12/29	194	1.7	19.7	78.6	0
	1972					
	6/29	354	6.7	10.1	83.2	0
	8/14	423	40.7	0.2	30.8	28.3
	9/18	458	30.0	3.3	47.5	19.2
	10/20	490	27.4	6.6	28.3	37.7
	11/27	528	5.0	13.7	77.6	3.7
	12/20	556	5.2	14.2	73.9	6.7
	1973					
	2/1	599	25.9	1.5	5.1	67.5
	6/28	746	7.5	1.8	32.0	58.7
	8/29	808	3.2	17.6	78.5	0.7
	10/16	856	5.3	13.3	81.4	0
	1971					
18**	8/11	63	12.0	12.0	76.0	0
	8/26	78	25.5	1.5	73.0	0
	9/14	97	27.7	1.8	70.5	0
	11/17	160	8.5	14.1	77.4	0
	12/29	202	5.4	15.2	79.4	0
	1972					
	1/19	223	8.8	14.0	77.2	0
	6/29	385	11.2	6.4	82.4	0
	8/14	431	15.8	0.5	83.7	0
	9/18	466	19.7	0.4	79.9	0
	10/20	498	0.7	18.8	80.5	0
	11/27	536	5.7	11.7	82.6	0
	12/20	564	6.4	16.8	75.1	1.7
	1973					
	2/1	607	8.5	8.0	82.1	1.4
	6/28	754	5.2	13.1	78.4	3.3
	8/29	816	10.1	10.5	79.0	0.4
	10/16	864	7.6	8.4	84.0	0

TABLE VI -13 (CONT.)

[*] Days since initial sludge, septic tank pumpings or water application.

[+] Solid waste and sludge mixture; older, denser, and more compact than other drums.

[#] These drums suspected of air leakage.

[**] Dry control drum. No liquids applied.

[++] Forced aeration, through drum from top to bottom. Blower operating cycle five minutes every two hours.

[##] Aeration blower temporarily out of operation at this time.

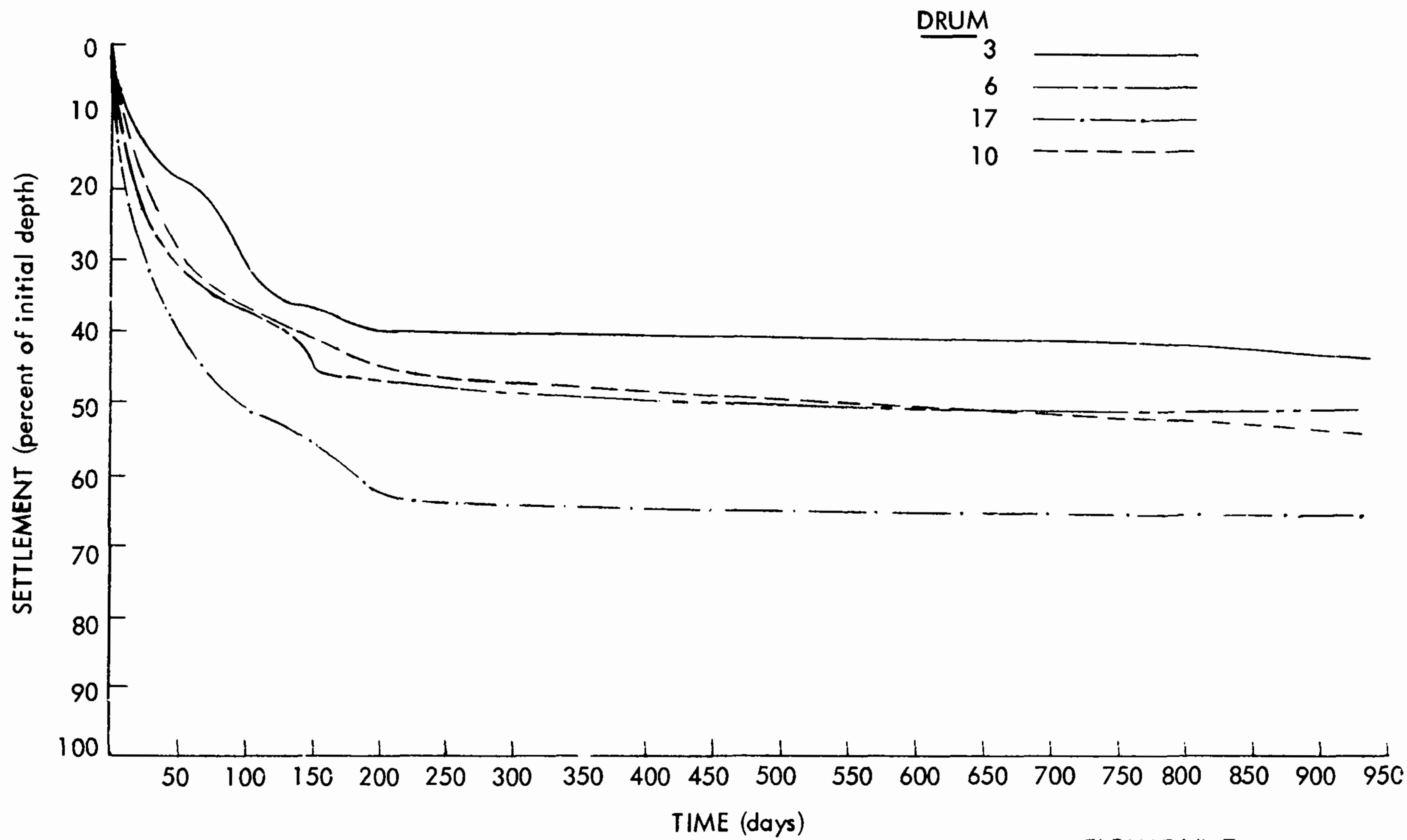

FIGURE VI-7
PILOT TEST DRUM
COMPACTION/SETTLEMENT
LOW RATE

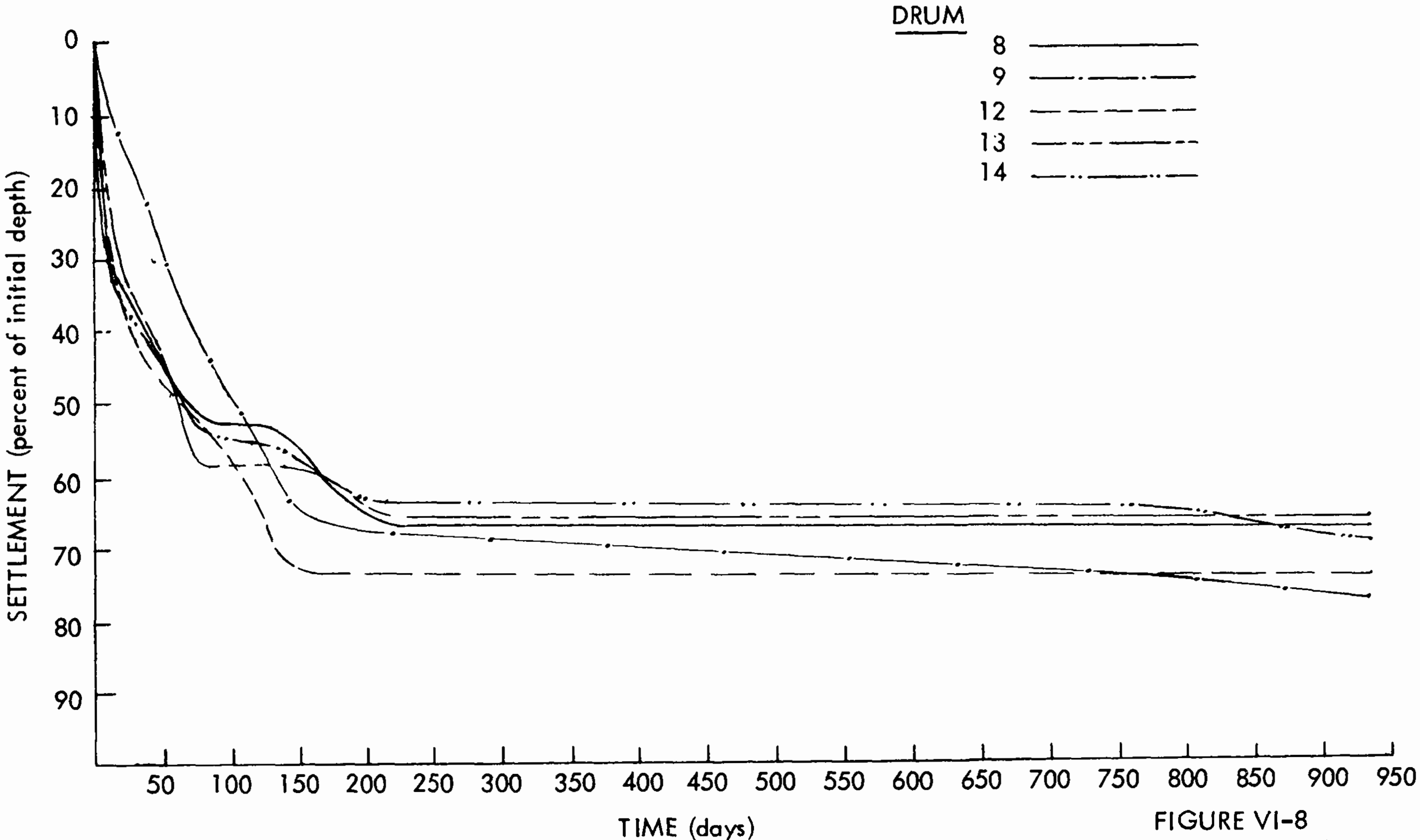

FIGURE VI-8
PILOT TEST DRUM
COMPACTION/SETTLEMENT
HIGH RATE

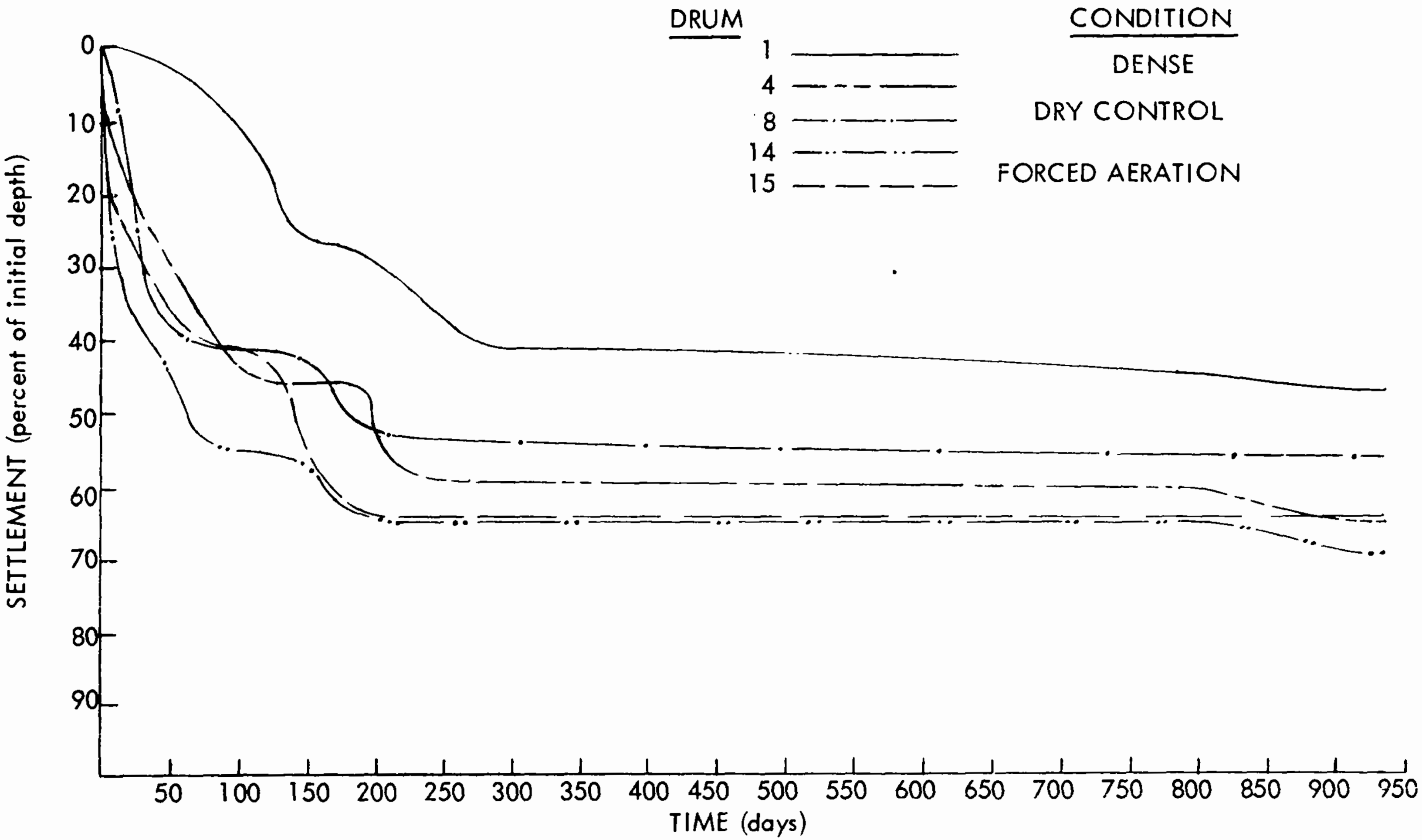

FIGURE VI-9
PILOT TEST DRUM
COMPACTION/SETTLEMENT
SPECIAL CONDITIONS

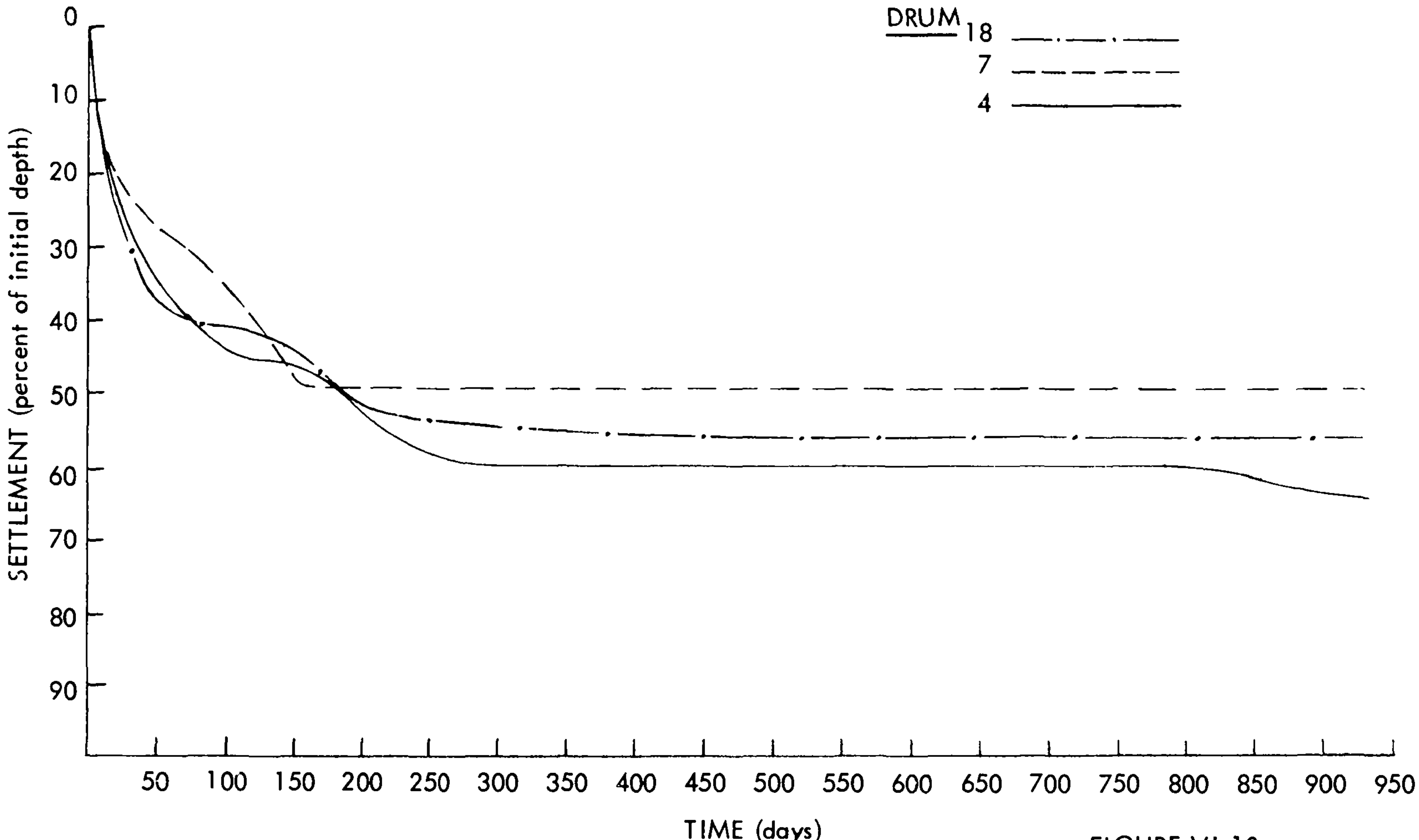

FIGURE VI-10

PILOT TEST DRUM
COMPACTION/SETTLEMENT
LOW RATE

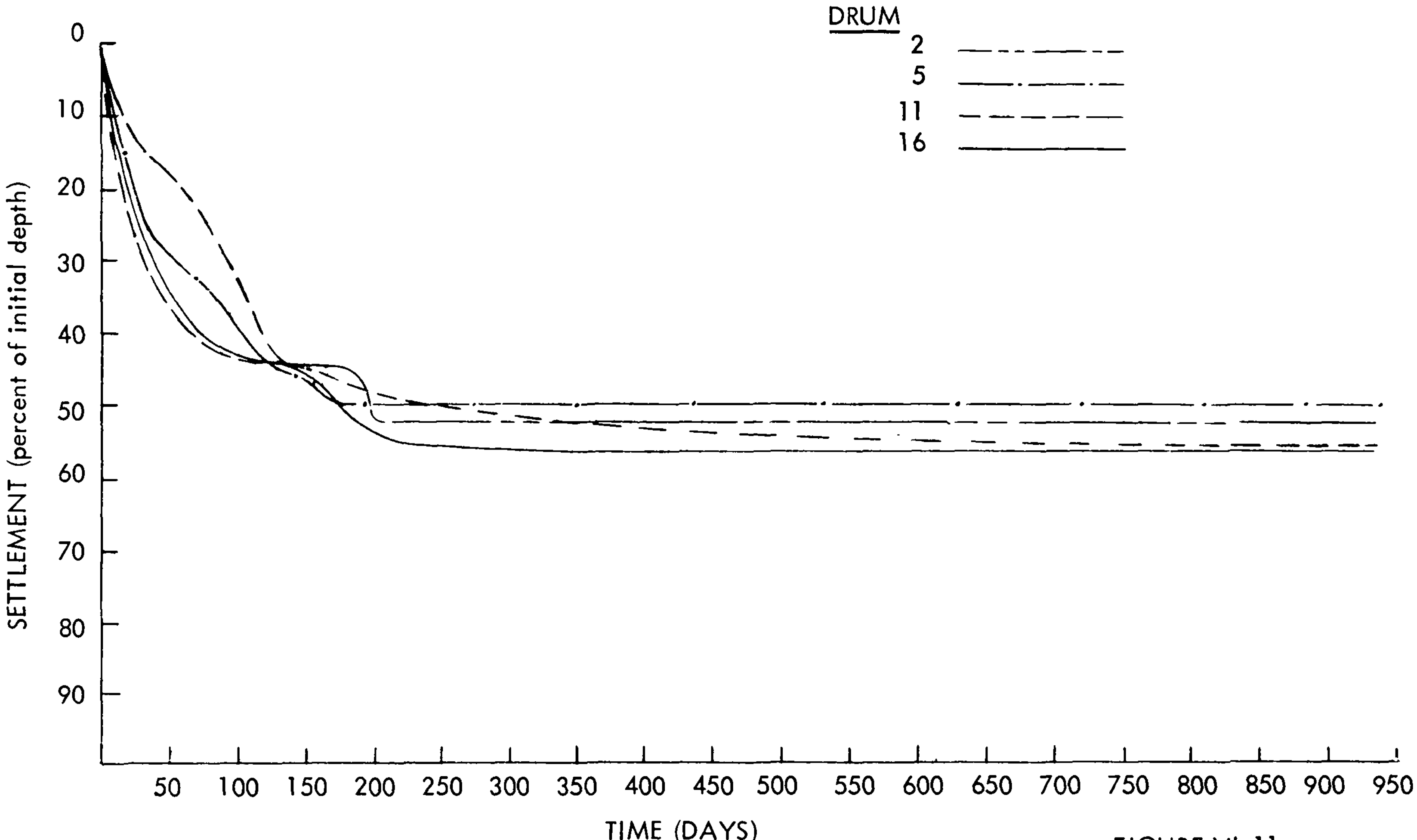

FIGURE VI-11

PILOT TEST DRUM
COMPACTION/SETTLEMENT
LOW RATE

nor any relationship between settlement rates in the dry control drums and settlement rates in those drums receiving liquid applications. Factors possibly related to the size, shape, and arrangement of the larger objects used to make up the solid waste in the drums could have altered settlement. Even though the material initially placed in the drums was carefully selected with respect to composition, quantity and kinds of objects, the relatively small volume of the drums when compared to the size of the solid waste objects precluded attainment of the same degree of "relative homogeneity" which would be expected in a full-scale landfill. In an actual landfill, the dimensions of any single solid waste object are much smaller than the vertical and horizontal dimensions of the landfill, and consequently compaction characteristics are more uniform than those that could be obtained in the test drums. Nevertheless, the pilot plant settlement curves still exhibit the same general form as those of actual landfills (see test cell settlement, Chapter VII).

In conjunction with the compaction measurements, some tests for permeability were conducted in December 1971, March 1972, and from July through September 1972. Three gallons of water were applied over the surface area to each drum in about 5 seconds, and the resulting leachate collected and analyzed. The results of these tests are presented in Figure VI-12. These results should be compared with Table VI-2. As expected, Drums 1 and 9, which had high initial densities, showed far lower permeabilities than any of the other drums. In the case of Drum 12, the low observed permeability, despite its low density, may be attributed to a relatively impervious zone in the vicinity of the drain hole. Drums 14 and 16 may have had high permeabilities, despite their high densities, because of channeling of moisture.

5. Temperature. Plots of temperature measurements are presented in Figures VI-13 through VI-16. The data are grouped by similarity and presented as envelopes, which are compared with ambient temperatures taken at the same hours as the drum temperatures. In general, the variations in temperature closely follow that of ambient air. Some of the variation between drums is attributed to the fraction of the day during which different drums were shaded by the building, and the extent to which some drums were shielded from the wind by the building and by each other. Some of the temperature increment above ambient air temperature in the drums may be attributed to solar heating of the air contained in the drums above the surface of the solid waste.

The test drums are not thermally analogous to any landfill conditions because of their high surface-area-to-volume ratio and the short (l-ft) minimum path for heat conduction to the outside. The same solid waste and sludge buried in a landfill would be better insulated and less affected by sun, wind, or ambient air temperatures. At the same time, the heat generated by bacterial degradation of the organic matter in the solid waste material would not be conducted away so quickly, and higher internal landfill temperatures than those measured from the drums would result.

6. Qualitative and Other Miscellaneous Observations. When the drums were periodically opened for compaction and water addition, they were inspected for odor, insects, and mold growths. The results are summarized as follows.

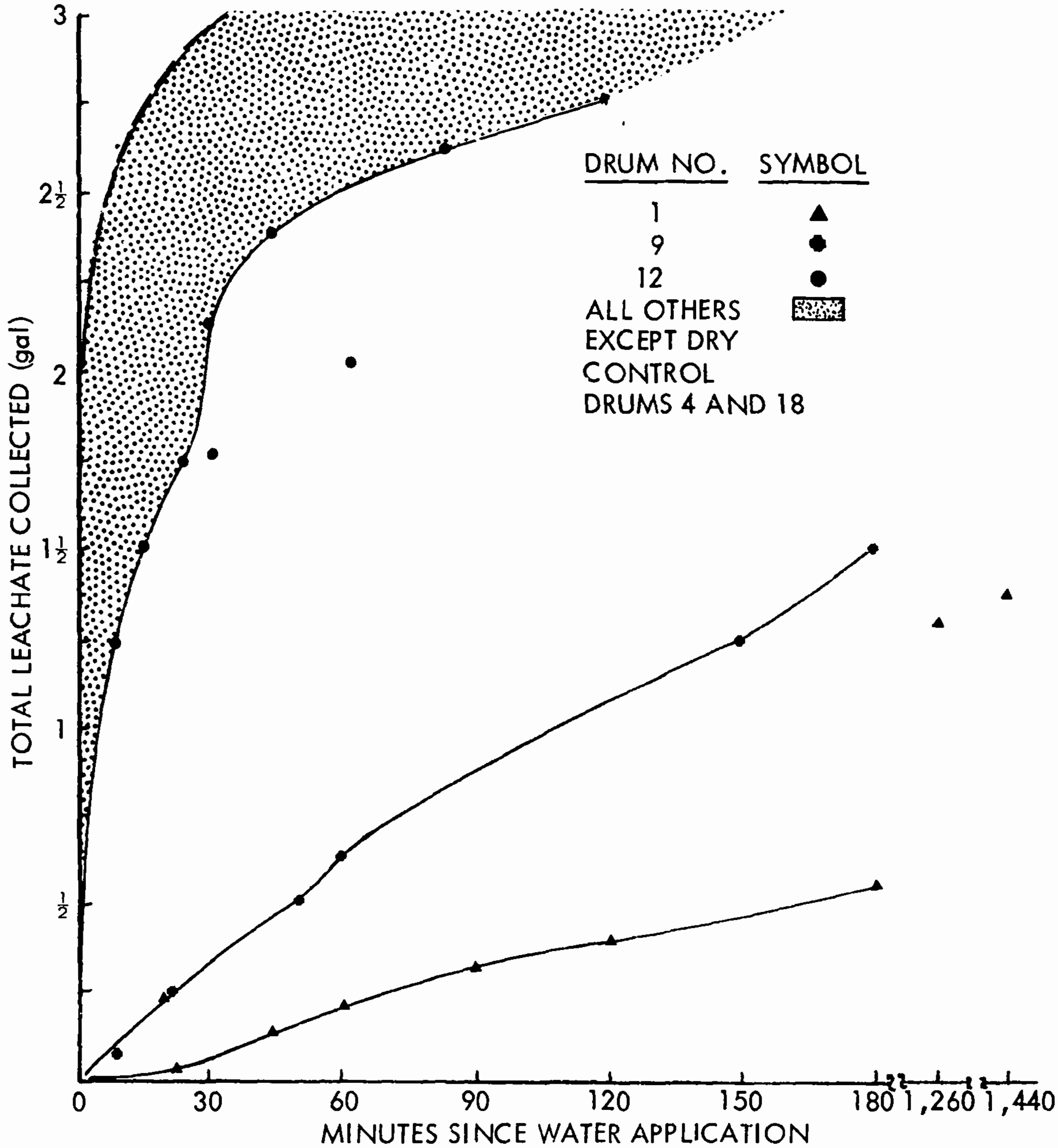

FIGURE VI-12
LEACHATE FLOW RATES
SOLID WASTE PERMEABILITY

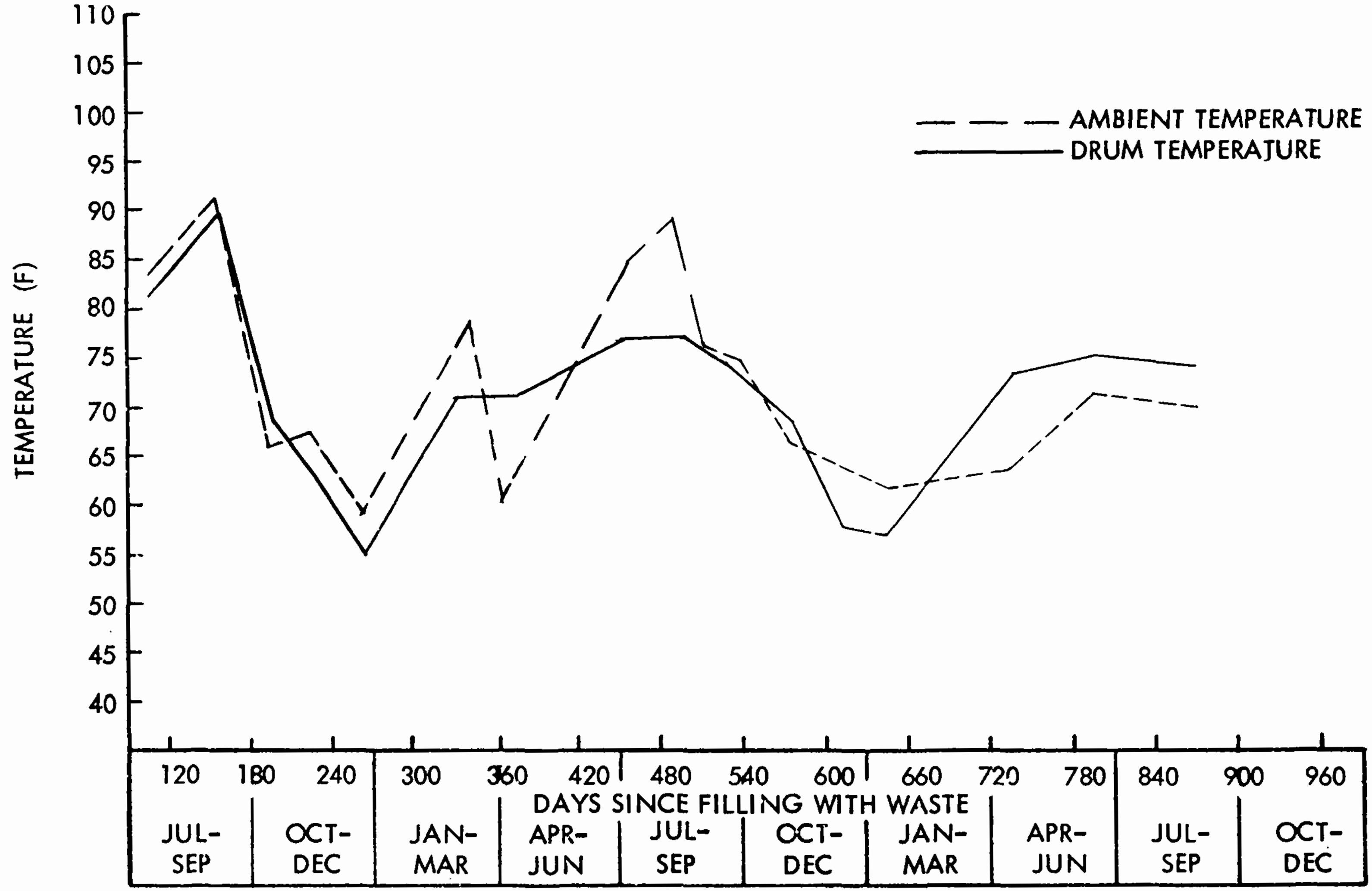

FIGURE VI-13
TEST DRUM 1
TEMPERATURE-TIME CURVE

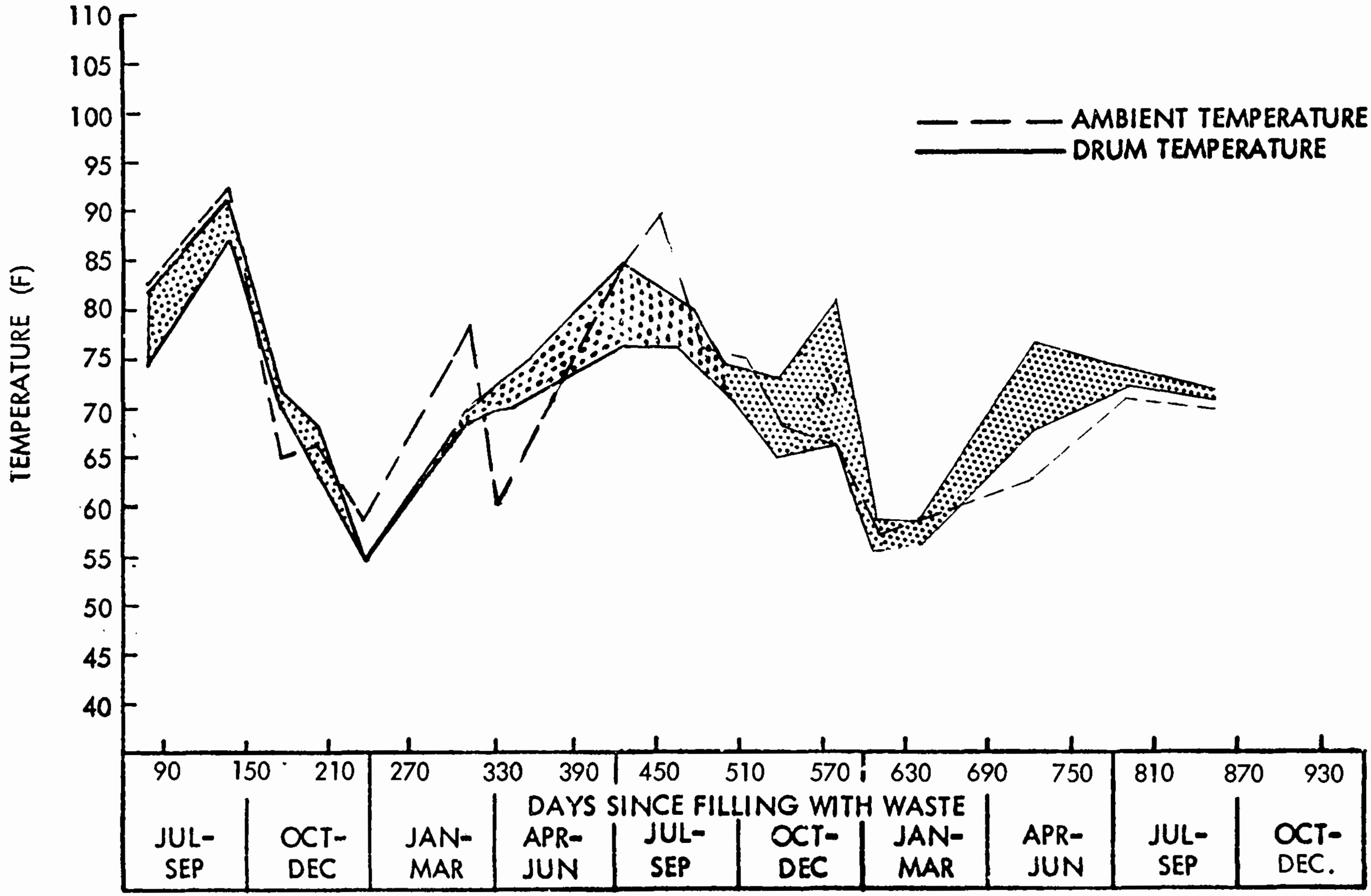

FIGURE VI-14
TEST DRUMS 2, 3, 4, 5
TEMPERATURE-TIME CURVE

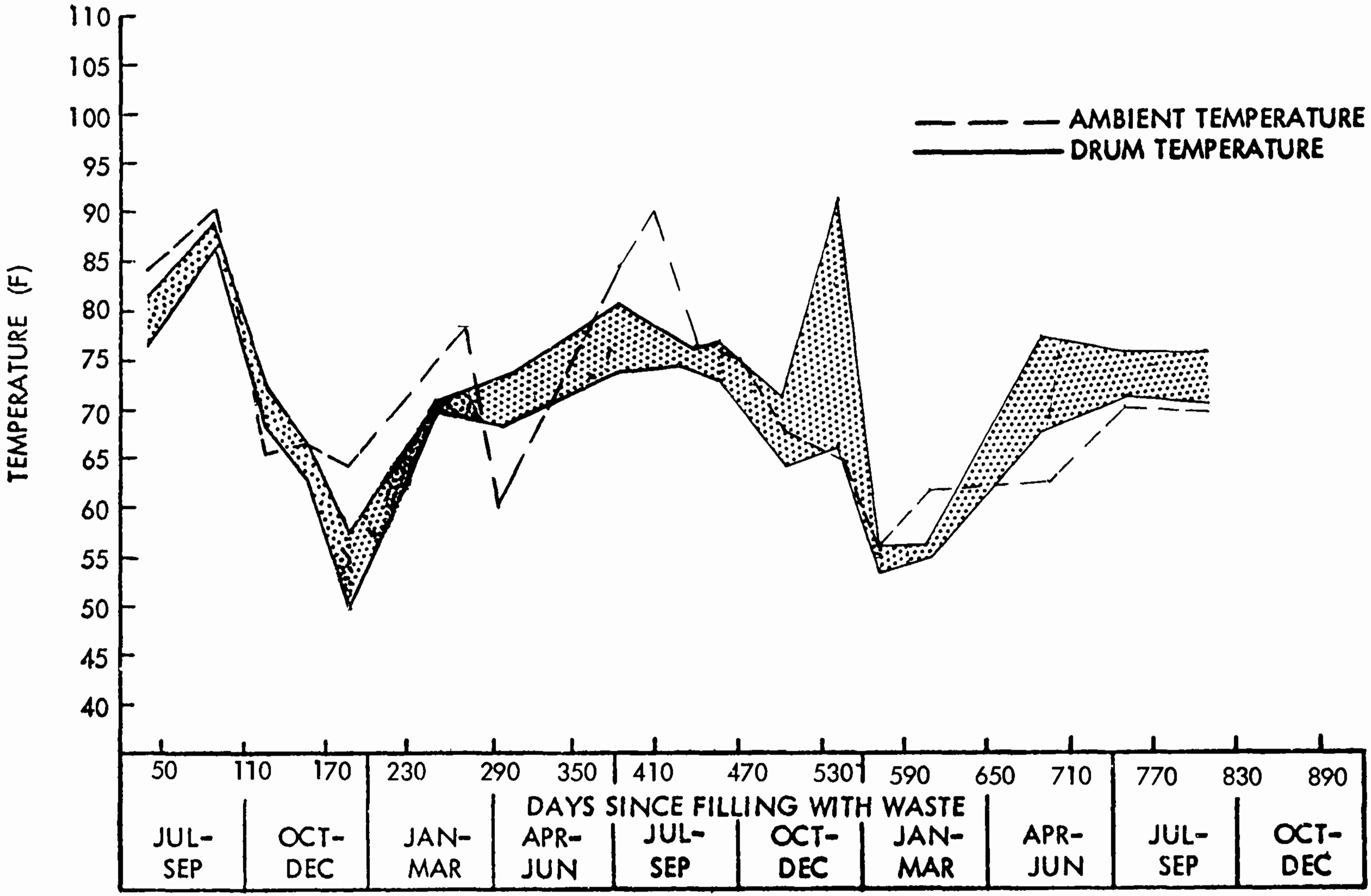

FIGURE VI-15
TEST DRUMS 7, 8, 9, 14, 15, 17, 18
TEMPERATURE-TIME CURVE

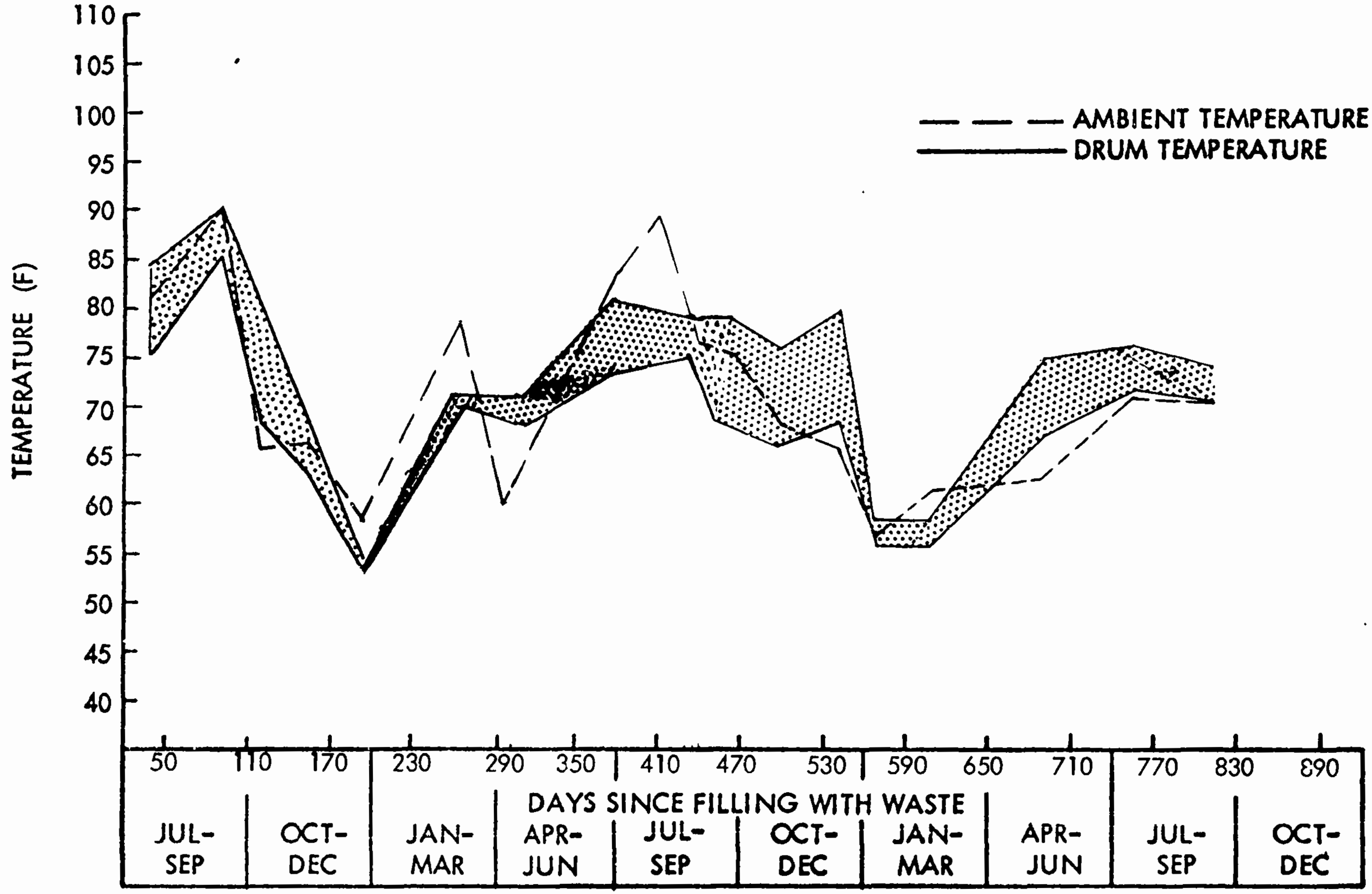

FIGURE VI-16
TEST DRUMS 6, 10, 11, 12, 13, 16
TEMPERATURE-TIME CURVE

a. Odor. Odors followed a predictable pattern and were generally consistent with odors produced by full-scale landfills. Drums filled only with solid waste rapidly developed the smell characteristic of landfills. The odor lessened as drying occurred in the two dry control drums, and intensified in the drum to which water was added. In the other drums, this odor was added to, but not masked by, the septic-sulfide smell of the sludges appplied to them. The strongest and most noxious initial odors were from the two drums to which raw primary sewage sludge was applied. This scent was detectable as a separate component and was sufficiently strong to mask the landfill odor from these two drums.

During the first 100 days after initial sludge or water applications, the odors from all the drums remained relatively intense. After 130 to 170 days, however, the smell from all but one drum was greatly reduced and not overly unpleasant. After 150-205 days, all the drum scents were considerably weak and of an earthy-type similar to wet leaves or dirt. The smells stayed essentially the same for the remainder of the test which continued for over 800 days.

The leachate odors generally paralleled those from the drums, although their evolution to the ultimate weak odor progressed slightly faster. By test completion, the smell of the leachates collected from all except one drum was quite weak, in contrast to the leachate odor of the sample obtained from the Oceanside municipal landfill. These leachates had a putrid scent that was stronger, more sour, and much more displeasing than the odor of the drum leachates.

b. Molds and Plant Growths. Molds were the first surface growth observed on the solid waste; they occurred in Drum 1 (saturated mixed sludges) within the first month after applying sewage sludge. The molds developed a bright red color and grew profusely over a two-week period until they covered about 30 percent of the surface area of the waste in the drum. The mold color changed to grey and the mold diminished until a second cycle of growth started at the end of the third month. The color became white and the mold surface growth continued in Drum 1 until the end of the seventh month after which no growths were observed through month 12. No mold growths were observed at any time in Drums 4 (dry control), and Drums 6 and 7 (digested La Salina sewage sludge). Molds were observed in the other drums on one or at most two occasions during the first 11 months. After the first year, few molds were observed in any of the drums.

Small plant growths were observed in Drums 3, 8, 11, 13, and 16 on one occasion each during the first 11 months, and in Drum 8 on two occasions. Only small sprouts developed less than 1/16 inch in height.

c. Flies, Ants and Other Insects. Flies, spiders, ants, and a few other insects were observed on the pilot drum surfaces at various times. Most of the observations were made during the first twelve months. Thereafter, fewer insects were observed. Flies were by far the most numerous insects and were observed in every drum. The flies observed were small and resembled fruit flies; 24 specimens were obtained and identified as follows:*

Family SCATOPSIDAE, The Minute Black Scavengers, seven specimens: Small, shiny, black flies. Breed in decaying vegetable and animal matter and excrement. They often breed in sewers and privies and frequently become very numerous in houses, where they cause more anxiety than harm."

Family MYCETOPHILIDAE, The Fungus Gnats, nine specimens: "Moderately small, brown, elongated coxae (basal segment of leg)." Breed in "soil, wood, fungi, probably feeding on fungus growth." "Adults are found in moist places, especially about decaying wood. . .moist humus and prefers dark places." Often a pest in houses after fertilizing lawns.

Family PSYCHODIDAE, The Moth Fly or Filter Fly, seven specimens: Smallest of specimens submitted. Light brown. "Thickly haired small flies, wings covered with hairs on sides and folds web-like over the back." The presence of adults in homes indicates breeding in drain pipes or nearby septic condition.

Larva Diptera; Suborder Cyclorrahapha, 1 specimen: Division--Schizophora; Section--Acalyptrate; probably a member of the Family Drosophididae.

7. Production of Leachate Constituents. The quantities of leachate constituents that leached from the pilot test drums per lb of dry solid waste and sludge solids are listed in Tables VI-14 through VI-16. Table VI-14 presents the amounts of magnesium, iron, and zinc in the leachate composites for the entire study. As was mentioned previously, it is believed the iron and zinc analyses were affected by corrosion of the test drums. The largest magnesium production occurred in Drum 17, the wet control drum.

Table VI-15 presents the amounts of sulfate, phosphate, nitrate, chloride, calcium, and organic nitrogen (Kjeldahl) in the drums during each year of the study. Drum 2 had a large amount of sulfate in 1971. Most of the drums were leaching little or no sulfate by 1973. Drums 2 and 10 had the highest phosphate readings in 1971. Phosphate was also being leached in very small quantities by 1973. Drums 5 and 9 exhibited extremely large nitrate concentrations in 1971. Nitrate was still abundantly present in 1973 leachates. Chloride was present in all drum leachates in approximately the same quantity, but chloride levels were much lower in 1973. Both calcium and organic nitrogen were much higher in 1972 than in 1971 and were negligible by 1973. Drum 2 was high in organic nitrogen, while Drums 12 and 13 were high in calcium. With the exception of three high constituent readings in Drum 2, the no sludge added to the solid waste test drums showed leachate constituent concentrations similar to the leachate of drums which received sludge added to the solid waste.

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*The identification of flies was made by Mr. Harvey I. Magy, Southern California Area Representative, California State Department of Public Health, Bureau of Vector Control and Solid Waste Management, Los Angeles, California. Quotations were taken from Curran, C.H., The Families and Genera of North American Diptera, Ballan Press, New York, 1934.

TABLE VI-14

TOTAL METALS IN TEST DRUM LEACHATES
COMPOSITE SAMPLES FOR ENTIRE STUDY

			Quantity, lbs constituents per lb dry wt solid waste*		
Drum	Days after filling	Equiv. rainfall, in.	Mg $\times 10^{-6}$	Fe $\times 10^{-6}$	Zn $\times 10^{-6}$
1	951	84.3	171	5.49	6.50
2	930	81.3	174	19.14	7.87
3	930	86.0	242	6.79	4.74
5	930	80.1	267	6.25	7.04
6	892	80.1	168	3.33	9.06
7	888	86.0	237	6.37	4.64
8	887	86.6	229	8.47	5.92
9	886	87.2	210	6.34	3.75
10	892	81.6	185	4.58	7.26
11	888	86.0	299	14.21	5.72
12	887	86.6	232	7.83	6.65
13	886	86.0	282	5.15	4.66
14	892	81.3	191	3.74	8.31
15	888	86.6	124	5.61	10.30
16	887	82.5	195	10.75	11.81
17	886	86.0	327	6.73	7.35

*Includes sludge solids where applicable.

TABLE VI-15
TOTAL CONSTITUENTS IN TEST DRUM LEACHATES
COMPOSITE SAMPLES
(1971)

Drum	Days after filling	Equivalent rainfall, in.	Quantity, lbs constituents per lb dry wt solid waste*					
			SO_4 $\times 10^{-6}$	PO_4 $\times 10^{-6}$	NO_3 $\times 10^{-6}$	Cl $\times 10^{-6}$	Ca $\times 10^{-6}$	Kj N $\times 10^{-6}$
1	260	52.4	633	8.80	1.92	1860	440	299
2	234	49.4	1540	11.20	5.82	2140	246	503
3	234	54.1	171	9.75	10.00	2270	695	683
5	234	48.2	224	7.13	285.00	1850	845	632
6	191	48.2	727	5.82	7.25	1460	983	780
7	189	54.1	531	6.05	1.33	2250	290	870
8	185	54.7	707	5.49	9.14	2090	658	963
9	185	55.3	326	2.42	280.00	2070	151	206
10	195	49.7	311	11.10	21.30	2280	107	105
11	195	54.1	~0	1.45	1.16	1000	105	182
12	195	54.7	145	0.97	2.62	2150	63	726
13	194	54.1	714	0.95	1.53	2000	104	310
14	193	49.4	206	1.03	3.00	1710	146	319
15	198	54.7	595	1.19	1.29	1040	39	547
16	170	50.6	506	0.57	22.90	2020	56	575
17	189	54.1	269	0.86	19.1	1550	101	505

* Includes sludge solids where applicable.

TABLE VI-15 (CONT.)
TOTAL CONSTITUENTS IN TEST DRUM LEACHATES
COMPOSITE SAMPLES
(1972)

Drum	Days after filling	Equivalent rainfall, in. accumulative*	Quantity, lbs constituents per lb dry wt solid waste+					
			SO_4 x 10^{-6}	PO_4 x 10^{-6}	NO_3 x 10^{-6}	Cl x 10^{-6}	Ca x 10^{-6}	Kj N x 10^{-6}
1	556	75.5	42	.82	.65	130	2430	1240
2	535	72.5	142	4.61	3.85	1380	2490	11300
3	535	77.2	135	5.36	--	560	12400	3960
5	535	72.3	171	3.71	4.90	730	13400	1670
6	497	72.3	113	2.16	13.4	970	5520	4590
7	493	77.2	136	2.36	4.36	1160	10100	2610
8	492	77.8	99	1.12	.048	680	7410	4690
9	491	78.4	226	4.32	2.94	1250	6510	2210
10	497	72.5	115	1.02	12.2	1200	8640	3140
11	493	77.2	106	2.04	10.2	2470	2960	3760
12	492	77.8	151	1.20	.66	1570	16700	5800
13	491	77.2	101	1.64	6.92	660	19400	3910
14	497	72.5	278	1.25	2.95	770	907	6980
15	493	77.8	164	1.73	8.21	720	7800	1730
16	492	73.7	104	1.67	7.62	1690	1240	2810
17	491	77.2	42	1.39	3.89	1170	1130	1640

* All drums received 22 in. of equivalent rainfall in 1972.
\+ Includes sludge solids where applicable.

TABLE VI-15 (CONT.)
TOTAL CONSTITUENTS IN TEST DRUM LEACHATES
COMPOSITE SAMPLES
(1973)

Drum	Days after filling	Equivalent rainfall, in. accumulative*	Quantity, lbs constituents per lb dry wt solid waste+					
			SO_4 x 10^{-6}	PO_4 x 10^{-6}	NO_3 x 10^{-6}	Cl x 10^{-6}	Ca x 10^{-6}	Kj N x 10^{-6}
1	951	84.3	14.4	.311	1.47	156	10.7	8.4
2	930	81.3	48.7	1.72	4.48	357	16.2	45.5
3	930	86.0	0	0	5.13	529	32.1	17.6
5	930	80.1	31.7	0	2.40	528	25.6	2.1
6	892	80.1	33.2	0	21.77	554	15.8	36.4
7	888	86.0	0	.702	8.35	671	52.7	2.6
8	887	86.6	30.2	0	8.73	906	58.8	27.0
9	886	87.2	0	.109	.047	31	3.1	0.5
10	892	81.6	0	0	13.37	635	25.4	8.3
11	888	86.0	0	0	8.85	848	17.6	14.9
12	887	86.6	0	0	1.76	68	15.7	26.7
13	886	86.0	6.3	.314	46.77	597	20.4	1.6
14	892	81.3	158	.518	1.66	936	28.2	26.7
15	888	86.6	85.3	0	5.64	729	23.2	3.4
16	887	82.5	3.2	0	6.13	550	11.3	7.8
17	886	86.0	0	.860	1.72	860	47.1	19.4

*All drums received 8.8 in. equivalent rainfall in 1973.

+Includes sludge solids where applicable.

TABLE VI-16
TOTAL METALS IN TEST DRUM LEACHATES
COMPOSITE SAMPLES
(1971)

Drum	Days after filling	Equivalent rainfall, in.	Quantity, lbs constituents per lb dry wt solid waste* Mg $\times 10^{-6}$	Fe $\times 10^{-6}$	Zn $\times 10^{-6}$	Cu $\times 10^{-6}$	Ba $\times 10^{-6}$	F $\times 10^{-6}$
1	260	52.4	132	0.615	5.28	14.1	1230	1.68
2	234	49.4	131	1.34	5.94	18.5	1680	~ 0
3	234	54.1	149	1.95	2.44	22.6	2140	~ 0
5	234	48.2	149	0.71	3.06	19.9	1630	~ 0
6	191	48.2	127	0.53	5.88	16.0	1600	~ 0
7	189	54.1	172	1.92	2.42	18.1	2060	~ 0
8	185	54.7	173	1.95	2.44	19.5	1650	~ 0
9	185	55.3	182	1.45	3.02	18.1	1940	2.3
10	195	49.7	157	1.78	4.44	17.8	1780	1.22
11	195	54.1	186	1.21	3.02	17.0	1820	4.12
12	195	54.7	72	1.81	2.42	13.9	1630	2.30
13	194	54.1	161	0.83	2.38	19.0	1670	5.24
14	193	49.4	125	0.51	2.06	17.0	1550	1.44
15	198	54.7	73	2.16	2.98	26.8	1670	1.18
16	170	50.6	139	2.30	5.75	23.6	1900	~ 0
17	189	54.1	147	1.97	3.69	24.0	2150	~ 0

*Includes sludge solids where applicable.

TABLE VI-16 (CONT.)
TOTAL METALS IN TEST DRUM LEACHATES
COMPOSITE SAMPLES
(1972)

Drum	Days after filling	Equivalent rainfall, in. accumulative+	Quantity, lbs constituents per lb dry wt solid waste* Mg $\times 10^{-6}$	Fe $\times 10^{-6}$	Zn $\times 10^{-6}$	Cu $\times 10^{-6}$	Ba $\times 10^{-6}$
1	556	75.5	5.9	1.07	.39	0.05	3
2	535	72.5	17.8	89.12	3.04	0.18	11
3	535	77.2	21.4	7.85	.89	0	22
5	535	72.3	31.7	8.17	2.99	0	4
6	497	72.3	41.2	5.55	.92	0	22
7	493	77.2	26.3	9.30	.77	0	8
8	492	77.8	15.9	5.12	.77	0	16
9	491	78.4	39.6	8.44	1.26	0	25
10	497	72.5	13.7	6.48	.72	0.18	14
11	493	77.2	63.5	34.72	1.06	0.21	21
12	492	77.8	43.0	7.39	5.90	0	17
13	491	77.2	24.2	7.13	1.07	0	22
14	497	72.5	25.6	6.98	4.98	0	12
15	493	77.8	3.3	6.64	.91	0	18
16	492	73.7	41.4	18.20	6.42	0	25
17	491	77.2	33.0	6.23	1.50	0	11

*Includes sludge solids where applicable.

+All drums received 22 in. equivalent rainfall in 1972.

TABLE VI-16 (CONT.)
TOTAL METALS IN TEST DRUM LEACHATES
COMPOSITE SAMPLES
(1973)

Drum	Days after filling	Equivalent rainfall, in. accumulative+	Quantity, lbs constituents per lb dry wt solid waste* Mg $\times 10^{-6}$	Fe $\times 10^{-6}$	Zn $\times 10^{-6}$	Cu $\times 10^{-6}$	Ba $\times 10^{-6}$	F $\times 10^{-6}$
1	951	84.3	25	2.3	.26	0.06	0	0
2	930	81.3	41	10.6	1.7	0.53	9	--
3	930	86.0	83	1.4	1.9	0	5	1.7
5	930	80.1	104	2.1	2.7	0	2	.08
6	892	80.1	20	0	1.9	0	2	0
7	888	86.0	54	1.7	.24	3.09	10	0
8	887	86.6	46	4.4	3.0	3.52	8	0
9	886	87.2	6	.17	.01	0	0	0
10	892	81.6	22	.17	2.5	4.79	10	0
11	888	86.0	89	.18	2.3	4.80	10	.04
12	887	86.6	140	2.8	1.5	2.29	5	0
13	886	86.0	110	1.2	1.8	0	3	0
14	892	81.3	52	.16	3.5	0	3	0
15	888	86.6	34	.23	4.1	5.64	9	0
16	887	82.5	40	1.5	.11	2.49	4	0
17	886	86.0	160	1.1	--	7.91	2	0

*Includes sludge solids where applicable.
+All drums received 8.8 in. equivalent rainfall in 1973.

Table VI-16 presents total metals in the leachates for each individual study year. Copper, barium, and fluoride were much lower in 1973 than in 1971, whereas magnesium decreased only slightly.

The BOD_5 of the leachates is presented in Tables VI-17 and VI-18. From Table VI-17 it is evident that Drum 10 had the highest BOD_5 value; Drum 8 was also relatively high. Table VI-18 presents the average BOD_5 for each group of drums. The drums which received raw sludge had the highest BOD_5 in their leachates. Drums receiving digested sludge and domestic septic tank pumpings exhibited the least BOD_5.

Table VI-19 shows the cumulative quantity of water and time required for the BOD_5 values of the leachates to reach a negligible value (60 mg/l). Drum 12 necessitated a relatively large amount of water as well as a long period of time. Drum 16, which received septic tank pumpings, required the least amount of time for BOD_5 to reach 60 mg/l and smallest water addition. The aerated drums (14 and 15) necessitated a relatively short time period and small addition of water. This is to be expected, since aerobic decomposition of solid waste is a faster process than anaerobic decomposition. Drum 17, the wet control, also reached negligible BOD_5 values in a relatively short amount of time. A comparison of Tables VI-19 and VI-17 indicates that the large majority of BOD_5 was leached in the period of time prior to achievement of negligible BOD_5 values. Data in Appendix D indicate the apparently increased concentrations of BOD_5. This is due to the decreased amount of water applied to the test drums, resulting in less dilution of soluble organics and thus their higher concentrations.

8. Comparative Summary of Test Drum Parameters. The following discussion summarizes the results obtained by comparing the three control drums with the drums receiving sewage sludge or septic tank pumpings. The control drums and their conditions were as follows:

Drum No.	Condition
4	Dry control with single water application
17	Water applied - no sludge
18	Dry control - no water applied

a. Absorption Capacity and Leachate Generation. Control Drum 17 absorbed 1.75 lbs water per lb dry wt solid waste before saturation. This absorption capacity for water is near the average value obtained for those drums receiving septic tank pumpings and liquid sewage sludge. It appears, therefore, that water absorption capacity is a valid measure of liquid sewage sludge absorption capacity for solid waste. Also, test drum water retention (see Table VI-6) indicates that Drum 17 retained about the average for drums receiving sludge and septic tank pumpings. Hence, sludge solids do not appear to affect the moisture-holding capacity of solid waste, and so their addition to a solid waste landfill should not by itself cause an increase in the leachate quantity generated.

b. Leachate Characteristics. The BOD_5 of the leachate from control Drum 17 followed the general trend indicated by the average value line shown in Figure VI-3. The maximum BOD_5 value for Drum 17 occurred 40 days after initial water application;

TABLE VI-17
TOTAL BOD_5 IN TEST DRUM LEACHATES
COMPOSITE SAMPLES FOR ENTIRE STUDY

Drum	Days after filling	Equivalent rainfall, in.	Quantity, lbs $BOD_5 \times 10^{-3}$ per lb dry wt solid waste*
1	951	84.3	2.71
2	930	81.3	4.04
3	930	86.0	3.18
5	930	80.1	2.07
6	892	80.1	4.88
7	888	86.0	3.86
8	887	86.6	11.16
9	886	87.2	8.54
10	892	81.6	11.89
11	888	86.0	7.40
12	887	86.6	3.13
13	886	86.0	9.65
14	892	81.3	5.38
15	888	86.6	9.55
16	887	82.5	5.40
17	886	86.0	8.80

*Includes sludge solids where applicable.

TABLE VI-18

GROUP COMPARISONS OF BOD_5
IN TEST DRUM LEACHATE COMPOSITES

Group	Drum	Avg. total $BOD_5 \times 10^{-3}$ in lb per lb dry wt solid waste
Wet control - no sludge	17	8.80
Saturated with sludge	1,8,9	7.47
Domestic septic tank pumpings	3,16	4.29
Digested sludge applied	5,6,7,12,13	4.72
Raw sludge applied	10,11	9.65
Primary sludge applied	10,11,12,13	8.02
Activated sludge applied	6,7,8,9	7.11

TABLE VI-19
QUANTITY OF WATER ADDED TO DRUMS
TO COMPLETE BIO-OXIDATION

Drum	Days to BOD_5 < 60 mg/l	Equivalent rainfall, in.	Water addition, lbs water per lb dry wt solid waste+	Quantity*, lbs $BOD_5 \times 10^{-3}$ per lb dry wt solid waste+
1	265	52.4	8.3	2.66
2	183	35.8	7.7	3.37
3	198	41.6	8.9	2.95
5	218	41.1	8.3	1.55
6	175	41.1	8.7	4.16
7	188	51.8	11.0	3.30
8	169	47.6	10.1	9.24
9	155	58.2	12.1	6.88
10	306	40.5	8.6	11.1
11	171	45.8	9.8	6.37
12	221	58.4	12.2	1.01
13	165	52.2	10.9	8.25
14	138	35.1	7.0	4.31
15	124	35.7	7.4	9.21
16	109	31.0	6.7	3.75
17	153	38.1	8.2	7.80

*Fresh and residual leachate BOD_5 were added in weighted proportion to the volumetric quantity of each obtained from the test drums.

+Includes sludge solids where applicable.

this coincided in time with the BOD_5 peaks for drums receiving sludge and septic tank pumpings. Table VI-19 indicates that the amount of BOD_5 removed from the water control drum (Drum 17) per lb dry wt solid waste was over twice the BOD_5 quantity removed from the drums receiving sludge and domestic septic tank pumpings. The dry sludge solids weight added to Drums 3 and 7 is insufficient to account for the greater quantity of BOD_5 removed from Drum 17. This means there was a greater concentration of biodegradable matter in the leachate collected from Drum 17 than from Drums 3 or 7, suggesting that biological degradation was more complete in the drums to which sludge or septic tank pumpings were applied than in the drum receiving water only.

There are two possible explanations for this phenomenon. The analyses of gas samples taken from Drums 3, 7, and 17 over the course of the test (see Table VI-13) suggest that, in general, Drum 17 was more airtight than Drums 3 or 7, and therefore usually contained less oxygen. If conditions in Drums 3 and 7 were partially aerobic, then biological degradation would occur slightly faster and more completely than in Drum 17. The alternative possibility is that adding sewage sludge or septic tank pumpings to solid waste material adds nutrients not usually available in solid waste (e.g., nitrates), thereby promoting more complete biodegradation.

The pH for Drum 17 leachate ranged between 5.9 and 7.2 units (1.3 unit range), whereas the pH in other drums ranged from 5.0 to 8.6 units $\geq$ 3.6 unit range). Drum 17 pH showed the smallest variation and the second highest average value. This indicates that addition of sewage sludge to solid waste material in a landfill may produce a more acidic leachate and leachate which varies over a wider range of acidic values than would be expected for a normal solid waste landfill. The same result was observed when comparing leachates secured from the old Oceanside landfill (pH 5.1-5.2) with samples obtained from test Cell 1 (pH 4.6 to 5.9 - see Table VI-7). All natural landfill leachates, however, were more acidic than those collected from the test drums. This probably reflects the highly anaerobic natural landfill conditions and the lack of leachate dilution, whereas the test drums were all aerated to some extent.

Turbidity, conductivity, total dissolved salts, and color of Drum 17 leachate showed no variations from the trends observed for the leachates from other drums.

c. Gas Generation. Gas sampling, due to drum sealing failures, was too inaccurate for displaying any significant differences between drums.

d. Settlement. Settlement rates of the three control drums did not vary from the rates observed for the majority of drums receiving sludge.

e. Other Observations. Temperature, odor, and growth of mold, fungi, and plants in the control drums all followed the same trends observed for the other drums. However, Drum 17 consistently contained the greatest number of flies. It is hypothesized that flies preferred Drum 17 due to the presence of food particles that were not contaminated with sewage sludge.

f. Summary. The major effects, derivable from the present study, of disposing sewage sludge or domestic septic tank pumpings into solid waste consist of the following: a decrease in pH of the leachate generated; a possible decrement in leachate BOD_5 through supplying additional nutrients helpful in completing biological activity.

VII. SIMULATION OF SANITARY LANDFILL IN FIELD TEST CELLS

A. Purpose

In order to evaluate the disposal of liquid sludge to a landfill under large-scale controlled conditions, three test cells (described below) were constructed in the City of Oceanside at the new municipal landfill site. These test cells were built so that they permit evaluation of such parameters as landfill settlement, waste decomposition, gas generation, leachate flow, equipment operation, odor development, and attraction of vermin, birds, etc. The test cells have been under observation since filling in February 1972. This chapter describes the test cells and discusses the monitoring results.

B. Method of Study

1. Site Location. The three test cells were constructed adjacent to the new municipal sanitary landfill site that opened November 15, 1971. The landfill site plan noting location of the three test cells is shown on Figure VII-1. The test cells are about 50 feet north of the landfill access road on the rim of the fill canyon. The cells are within observation range of the landfill operator (80 feet) and yet distant enough from the landfill access road traffic so as to remain undisturbed by daily activities. The land area underlying the three test cells is stable and the surrounding surface area has a one to two percent grade sloping away from the test cells, thus minimizing the effects of external drainage. The site is in an exposed position to wind and other normal local weather conditions. It is accessible for routine monitoring.

2. Cell Design Configuration. Figure VII-2 presents the approximate dimensions of the three test cells. The cells (numbered 1, 2, and 3) are located adjacent to each other so as to utilize a common berm between them. Each cell holds solid waste and sewage sludge in volumes equal to the total quantities of each produced in the City during a one-week period. Each cell bottom and side wall is lined with a continuous 10-mil polyethylene membrane with an 8-inch sandy soil overlay to protect the membrane from damage during waste filling. The membrane and cell construction details are shown in Figure VII-3 and Photograph VII-1. A porous sump is installed to accumulate the leachate. The collected leachate is removed through a 1-inch diameter polyvinyl chloride (PVC) drain pipe which extends through the wall of the test cell and is equipped with a valve at its outer end. Air cannot enter through the drain. A concrete valve box is installed over each leachate drain valve to prevent disturbance of the equipment. The leachate collection system is shown in Photograph VII-2.

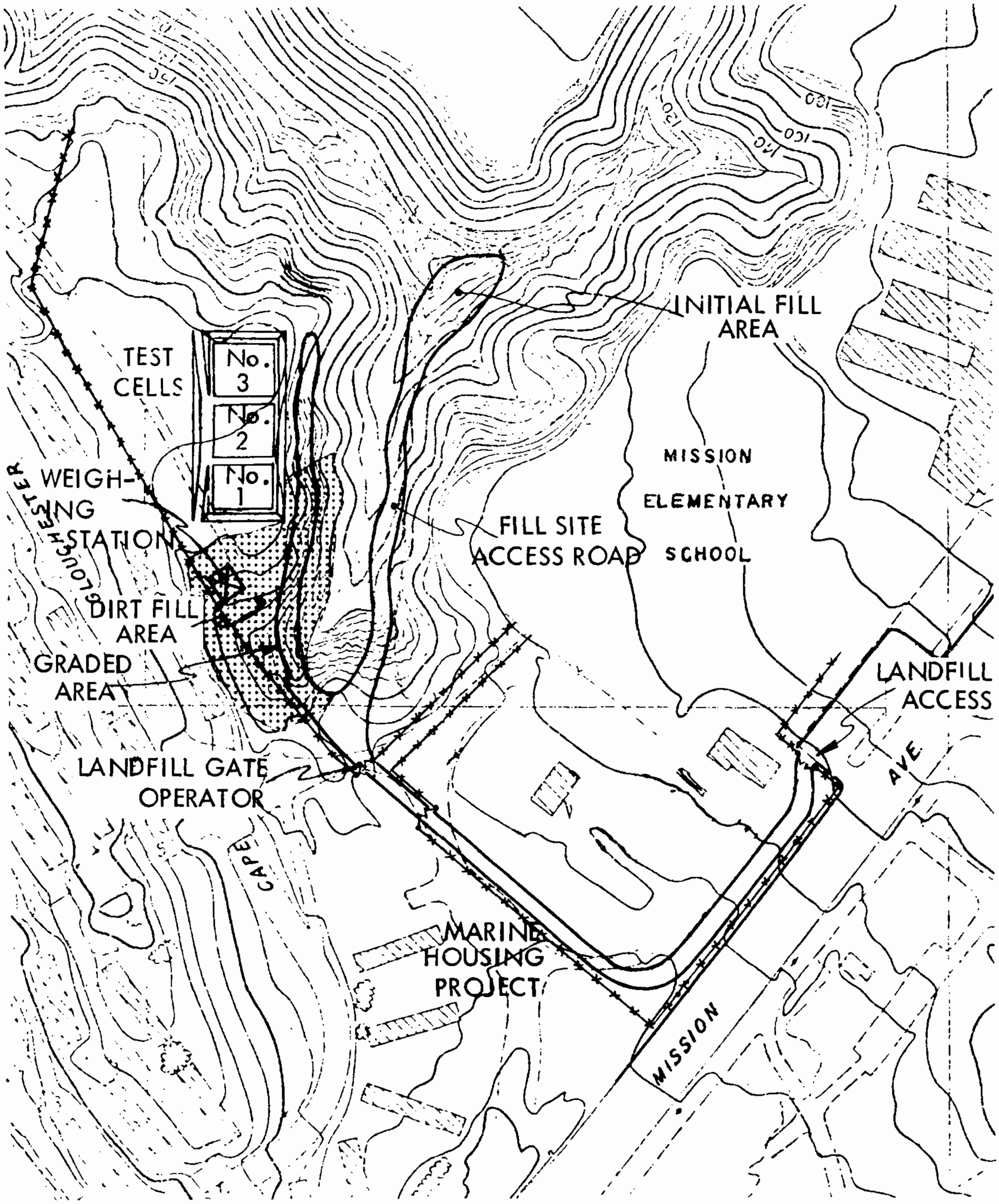
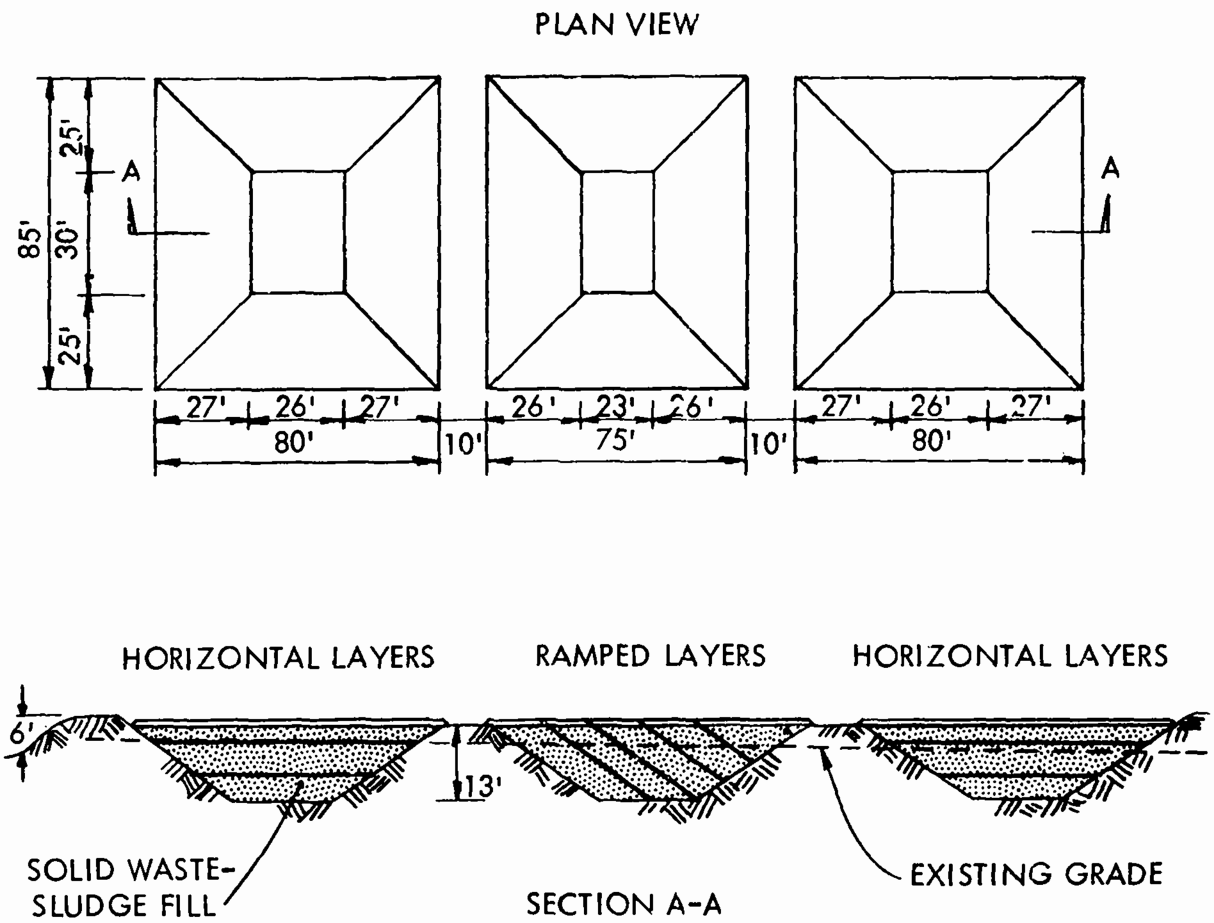


FIGURE VII-1
LOCATION OF TEST CELLS



CELL 3

MIXED PRIMARY AND SECONDARY DIGESTED SLUDGE (LA SALINA, BUENA VISTA, AND SAN LUIS REY PLANTS)

CELL 2

MIXED PRIMARY AND SECONDARY DIGESTED SLUDGE (LA SALINA, BUENA VISTA, AND SAN LUIS REY PLANTS)

CELL 1

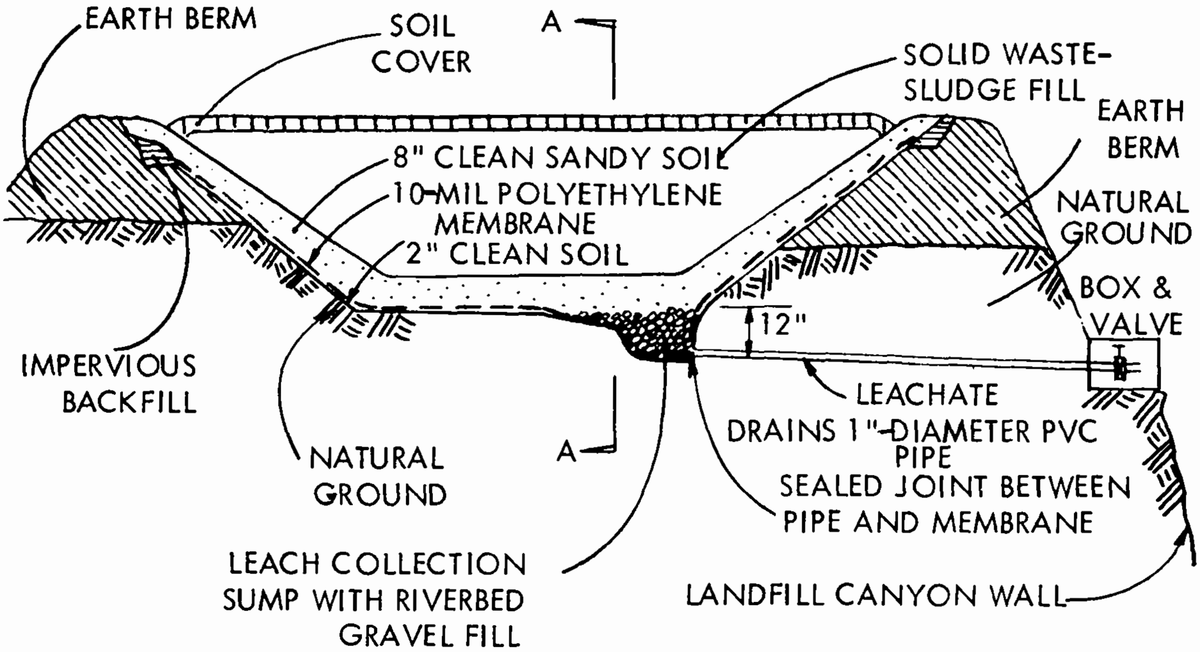
RAW PRIMARY SLUDGE (SAN LUIS REY PLANT)

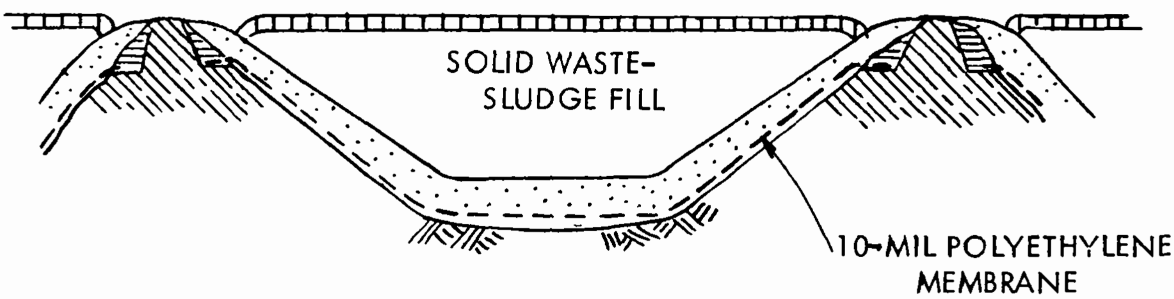
NO SCALE. LINEAR DIMENSIONS SHOWN ARE APPROXIMATE AND VARY ± 5 FEET BETWEEN CELLS.

NOTE: FOR DETAILS OF CELL STRUCTURE SEE FIGURE VII-3.

FIGURE VII-2
CELL DESIGN CONFIGURATION

TEST CELL PROFILE



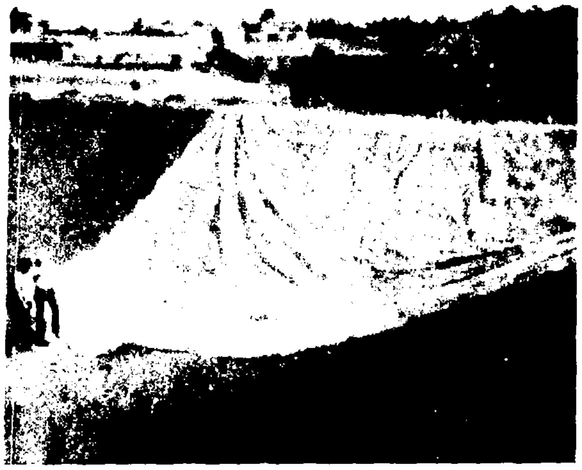


SECTION A-A

NO SCALE.

NOTE: FOR CELL DIMENSIONS, SEE FIGURE VII-2.

FIGURE VII-3
TEST CELL MEMBRANE
AND LEACHATE
COLLECTION INSTALLATIONS



a. PLACEMENT OF TEST CELL 10-MIL POLYETHYLENE MEMBRANE LINER.

b. PROTECTIVE SOIL COVER FOR MEMBRANE LINER.

c. FINISHED GRADED TEST CELL.

PHOTOGRAPH VII-1

FIELD TEST CELL PREPARATION

a. LEACHATE COLLECTION SUMP.

b. LEACHATE DRAIN INSTALLATION.

c. LEACHATE SAMPLE DRAIN PIPE AND VALVE.

PHOTOGRAPH VII-2

TEST CELL LEACHATE COLLECTION SYSTEM

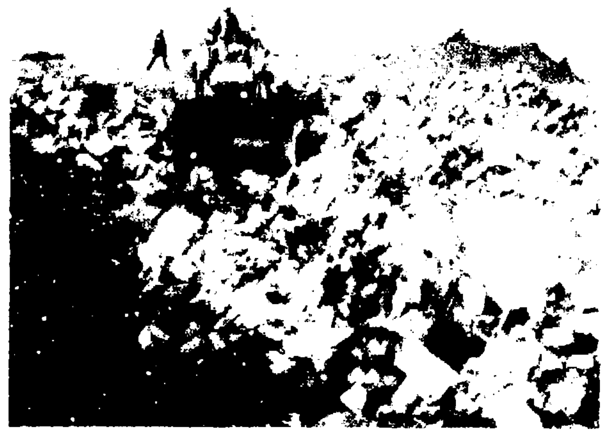
3. Filling of the Test Cells. Each cell was filled with solid waste and sewage sludge over a period of seven days (Cell 1: February 9-15, 1972; Cell 2: February 3-9, 1972; Cell 3: January 26-February 2, 1972). As shown in Figure VII-2, Cell 1 was filled in horizontal layers with the application of raw primary sludge from San Luis Rey Plant. Cell 2 was filled in ramped layers and Cell 3 was built up in horizontal layers each with the application of mixed primary-secondary digested sludge from the three treatment plants. The test cell filling sequence is illustrated in Photograph VII-3. The sewage sludge was admixed evenly by pumping into each cell in the ratio of one 3,500-gallon truck load for every seven solid waste collection truck loads. This one-to-seven truck load ratio is equivalent to the 1971 ratio of generation of sewage sludge to solid waste in the City of Oceanside. Two methods of sludge application are shown in Photograph VII-4. The actual quantities of solid waste and sludge placed in each cell are given in Tables VII-1, VII-2, and VII-3. The solid waste loads deposited in Cell 3 were all weighed, and the number of full truck loads deposited in Cells 1 and 2 were counted during the filling. The average weight per load deposited in Cell 3 was used to estimate the total solid waste placed in Cells 1 and 2. The filling of each cell was completed under continuous supervision to assure proper admixture of liquid sewage sludge. The average sludge to solid waste ratio was 0.6 lb per 1.0 lb (dry wt).

During filling of each cell representative daily samples of sewage sludge and solid waste were taken. A composite sludge sample was made by combining 100-ml portions of separate sludge samples in the ratio of the number of loads from the individual sludge source deposited into each cell. Table VII-4 presents partial analysis of the composite sludge samples. Random grab samples of the solid waste deposited in each cell were also taken daily. These samples were sorted into standard categories to determine their compositions. The samples were tested for moisture and organic content. Table VII-5 presents data on the in-place volumes of the waste and initial densities of the solid waste and combined sludge-solid waste for each cell.

4. Monitoring of the Test Cells. The monitoring program for the test cells included the following: a) measurement of ambient temperature; b) measurement of all temperatures at three different depths (near surface, mid-depth, and bottom--see Figure VII-4); c) analysis of gas samples from the cell bottom and from a depth of about 6 to 7½ ft; d) leachate characterization; e) settlement measurements; and f) analysis of periodic core samples from each cell. The frequency of each measurement and the agency responsible for each test are listed in Table VII-6. The placement of monitoring probes is shown in Photograph VII-5. The following is a brief description of each measurement.

a. Cell Temperature. Measurement of test cell temperatures is accomplished by lowering a glass test tube filled with water to the bottom of each temperature probe by means of a string. When the water temperature reaches a constant value, it is recorded as the cell temperature at that particular depth. (Fifteen years' prior experience with all types of devices monitoring solid waste landfills has indicated that sophisticated measuring devices such as thermocouples and thermisters failed eventually in the highly corrosive landfill environment.) Temperature probes are shown in Photograph VII-6.

a. COLLECTION TRUCK UNLOADING WASTE AT START OF FILLING.



b. COMPACTING WASTE.

c. PLACING SOIL COVER ON TEST CELL.

PHOTOGRAPH VII-3

PLACING SOLID WASTE IN TEST CELLS

a. SPREADING PUMPED SLUDGE FROM
A DOZER BLADE.

b. SPREADING PUMPED SLUDGE BY
MANUAL TIE-LINE.

PHOTOGRAPH VII-4

APPLICATION OF SEWAGE
SLUDGE TO TEST CELLS

TABLE VII-1
SOLID WASTE AND SEWAGE SLUDGE PLACED
IN TEST CELL 1

Waste category	Composition*	Percent dry wt	
		Moisture	Organics
Newsprint	17.7	10.4	98.0
Cardboard	4.7	6.7	98.3
Misc. paper	24.9	15.6	92.5
Food	2.5	233.0	91.0
Glass	5.0	-	-
Metals	7.9	-	-
Tree & shrub prunings	11.5	-	-
Textiles	3.9	4.9	90.0
Plastic, solid	6.4	3.5	98.5
Plastic, soft	0.3	0.0	97.5
Wood	0.9	-	-
Fines, pass a 2" sieve	14.3	11.4	50.2
Total	100.0	13.9	64.5
Sewage sludge applied:	45,500 gallons of raw primary from San Luis Rey Plant		Ratio of liquid sludge to solid waste: 0.46 lb/lb dry wt solid waste

*Total solid waste: 473 tons.

Note: Total dry weight of solids - 412 tons; solid waste - 407 tons; dry sludge solids - 5 tons.

TABLE VII-2
SOLID WASTE AND SEWAGE SLUDGE PLACED
IN TEST CELL 2

Waste category	Composition*	Percent dry wt Moisture	Percent dry wt Organics
Newsprint	11.1	16.0	88.0
Cardboard	4.7	15.1	90.5
Misc. paper	37.9	12.5	87.5
Food	0.8	352.0	88.2
Glass	9.4	-	-
Metals	9.3	-	-
Leaves	1.1	309.0	90.2
Textiles	1.5	14.4	97.6
Plastic, solid	2.2	1.0	99.2
Plastic, soft	0.1	0.0	96.3
Fines, pass a 2" sieve	21.9	56.8	67.2
Total	100.0	26.4	64.3

Sewage sludge applied from treatment plant:			Ratio of sludge to solid waste: 0.55 lb/lb dry wt solid waste
	La Salina	17,500 gallons	
	Buena Vista	14,000 gallons	
	San Luis Rey	7,000 gallons	
	Total	38,500 gallons	

*Total solid waste: 394 tons.
Note: Total dry weight of solids - 299 tons; solid waste - 290 tons; dry sludge solids - 9 tons.

TABLE VII-3
SOLID WASTE AND SEWAGE SLUDGE PLACED
IN TEST CELL 3

Waste category	Composition *	Percent dry wt Moisture	Percent dry wt Organics
Newsprint	15.3	1.1	85.6
Cardboard	3.7	15.2	87.8
Misc. paper	23.4	15.0	91.0
Food	1.2	632.0	87.0
Glass	7.2	-	-
Metals	7.8	-	-
Tree & shrub prunings	3.4	640.0	88.8
Grass	0.9	116.5	70.6
Textiles	2.1	2.3	94.5
Plastic, solid	4.0	1.8	99.0
Plastic, soft	0.1	4.7	98.1
Fines, pass a 2" sieve	30.8	10.2	26.7
Total	100.0	37.9	56.6

Sewage sludge applied from treatment plant:			Ratio of sludge to solid waste: 0.77 lb/lb dry wt solid waste
	La Salina	31,500 gallons	
	Buena Vista	7,000 gallons	
	San Luis Rey	17,500 gallons	
	Total	56,000 gallons	

* Total solid waste: 486 tons.

Note: Total dry weight of solids - 312 tons; solid waste - 302 tons; dry sludge solids - 10 tons.

TABLE VII-4

ANALYSIS OF COMPOSITE SAMPLES OF SLUDGES APPLIED TO TEST CELLS*

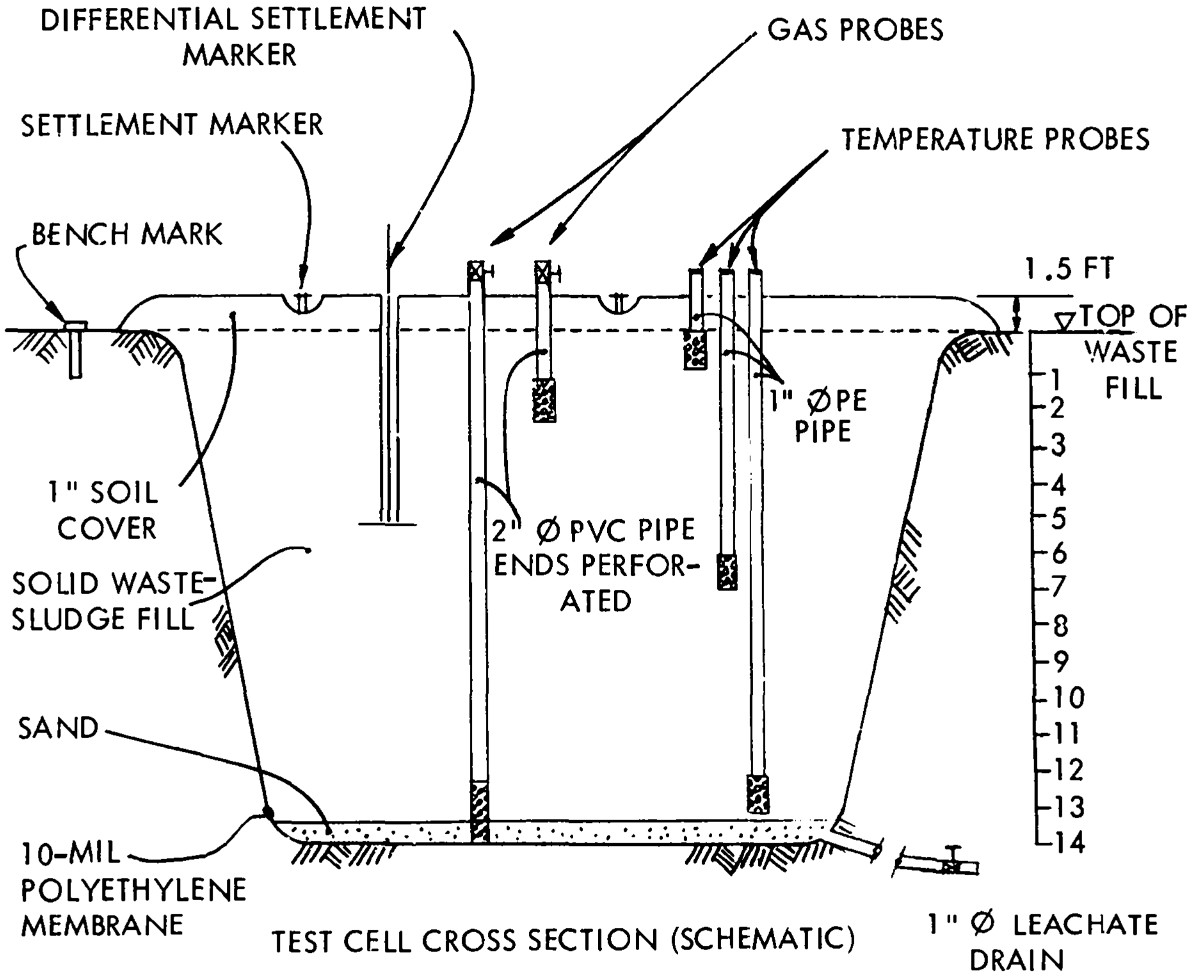
	Test cell		
	1	2	3
pH (units)	6.70	6.80	6.85
Conductivity (micromhos/cm)	1200	1950	2300
Total solids (% wet wt)	2.48	5.45	4.42
Total organics (% dry wt)	69.7	47.8	45.2
Chloride (mg/l)	220	350	385
Phosphate (mg/l)	400	85	94
BOD_5 (mg/l)	7220	1900	4300
Organic nitrogen (% dry wt)	2.2	1.06	1.20

* Analyses made on composite sample representative of all sludge added to a single test cell.

TABLE VII-5
TEST CELL IN-PLACE WASTE/SLUDGE DENSITIES

Measurement	Test cell 1	Test cell 2	Test cell 3
Cell volume (cu yd)*	1,512	1,231	1,560
Density solid waste (lb/cu yd)	626	640	623
Density solid waste and sewage sludge (lb/cu yd)	876	902	923

* Excludes earth cover.



TEST CELL CROSS SECTION (SCHEMATIC)

NO SCALE

NOTE: INSTRUMENTATION FOR THE SECOND AND THIRD YEAR LANDFILL OPERATION TESTS.

FIGURE VII-4
TEST CELL
INSTRUMENTATION

TABLE VII-6
FIELD TEST CELL MONITORING SCHEDULE

Monitoring parameter	Frequency	Performed by
Temperature	Daily - 1st month Weekly - 2nd month and after	Waste Disposal Department*
Gas sampling and analysis	Weekly - 1st quarter Monthly - thereafter	Ralph Stone & Company, Inc.
Leachate - quantity	Weekly (or after rainfall)	Sewer Department*
Standard analyses	Weekly - 1st month Monthly - thereafter	Sewer Department*
Special analysis	Quarterly composite	Sewer Department*
Composite	Bi-yearly	Ralph Stone & Company, Inc.
Settlement measurements	Monthly	Waste Disposal Department*
Core samples of solid waste	Quarterly	Ralph Stone & Company, Inc.

*City of Oceanside municipal departments.

a. PLACING CELL MONITORING PROBES.

b. CELL MONITORING PROBES IN-PLACE.

c. FINISHED CELL WITH MONITORING PROBES AND BENCH MARK.

PHOTOGRAPH VII-5

PLACING SETTLEMENT MARKERS, TEMPERATURE AND GAS PROBES

a. MID-DEPTH SETTLEMENT BENCH MARK PLATE.

b. GAS AND TEMPERATURE PROBE SENSOR ENDS.

c. GAS SAMPLING FOR METHANE.

d. GAS SAMPLING FOR GAS ANALYSIS.

PHOTOGRAPH VII-6

TEST CELL
MONITORING APPARATUS

b. Gas Sampling and Analysis. The gas sampling procedure used was that developed by Ralph Stone and Company, Inc. in previous landfill studies. Basically, the procedure consists of evacuating a 250- or 500-ml sample bottle and connecting it to the test cell gas sample probe and utilizing a hand-operated suction-pressure pump. The actual equipment sequence is as follows:

gas sample probe → moisture trap → vacuum-pressure pump → gas sample bottle

Prior to sample taking, the valved probe is opened, then the probe and clean evacuated bottle is purged by passing approximately 2,500 ml of sample gas through. The bottle is then pressurized by additional pumping. Special methane and sulfide field tests were also run in-situ. The gas probes and gas sampling bottle are then resealed; Photograph VII-6 illustrates the sampling apparatus.

The gas samples were analyzed for CO_2, O_2, N_2, CH_4, and CO on a Varian Aerograph Model A90-P3 Gas Chromatograph in the Ralph Stone and Company, Inc. laboratory.

c. Leachate Characterization. The leachate sampling was as follows. When a leachate drainage pipe was found to contain leachate, the leachate valve was opened until the leachate ceased running out and began slow dripping. The leachate quantity was measured in a calibrated bucket, then mixed thoroughly, and a one-quart sample was taken for chemical analysis. The refrigerated weekly/monthly samples were tested for BOD_5, total dissolved solids, coliform (MPN), chlorides, nitrogen, and conductivity. The quarterly leachate samples were given a comprehensive analysis (see Table VII-7). Composite samples accumulated from 100-ml portions of the weekly/monthly samples from each test cell were tested for calcium, sodium, magnesium, potassium, iron, fluoride, total dissolved solids, and pesticides/herbicides.

d. Settlement Measurements. Monthly surface and differential settlement measurements were made for each test cell. The test cell bench mark elevations were determined immediately after filling for base points; the bench mark elevations were then checked relative to the natural ground reference bench mark using standard surveying equipment. The bench mark plate is shown in Photograph VII-6.

5. Core Sampling and Testing. Bore hole drillings were completed quarterly at each test cell to obtain core samples of the soil and sludge-solid waste admixture. Care was taken to avoid drilling and puncturing the cell membrane. Core samples were taken of surface soils, and sludge-solid waste at two-foot intervals to a depth of 10 feet below the waste fill surface (about 12 feet below the cover soil surface). The bore holes were drilled a minimum of 10 feet distance from the gas and temperature probes in each test cell. Starting in the easterly quadrants, holes were drilled about 10 feet apart in successive quarters proceeding in a clockwise direction around the probes.

A 12-inch auger drill bit mounred on a 40-foot Texoma Drill Rig was used to drill the bore holes. The drilling equipment is illustrated in Photograph VII-7.

Soil, sludge/waste admixed, and solid waste samples were taken in one-quart sealed mason sample jars and returned to the Ralph Stone and Company, Inc. laboratory to determine moisture and organic content, and the remaining moisture absorption capacity. The first quarterly core samples at the 2- and 10-foot depths into the waste were taken in sterile mason jars for subsequent analyses for fecal coliform, fecal streptococci and Psuedomonas aeruginosa. Analytical methods used to determine the bacterial content of the core samples are described in Appendix A.

During sampling at 2-foot depth intervals, observations were made of weather, air temperature, waste temperature, odor, color, readability, appearance and biodegradability. A copy of the core sample data sheet is included in Appendix B, and sample observation procedures are described in Appendix A.

Core samples from each hole with the highest and lowest moisture contents were selected for saturation and leaching tests. The saturation and leaching methods are described in Appendix A.

C. Results and Discussion

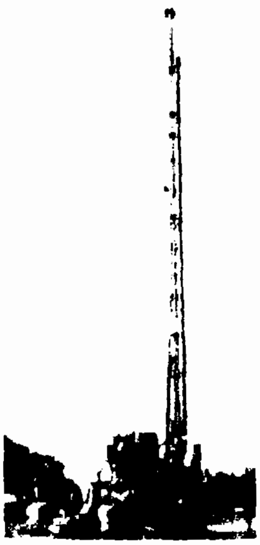
The field test cells were placed in operation in February 1972 and have been continuously monitored at least once each week.

1. Leachates. During the period from February 1972 through June 1973, cumulative rainfall in Oceanside was 12.9 inches onto each cell. Total rainfall onto each cell calculated from surface areas was: Cells 1 and 3 - 55,566 gallons; Cell 2 - 51,262 gallons. These quantities are not adjusted for drainage off of the cells (little drainage occurred since most of the cell surface area will not drain). Similarly, there is no correction for evapotranspiration (there is insignificant plant growth on the cells) or evaporation of surface water. Daily and cumulative rainfall onto Cells 1 and 3 are given in Figure VII-5, and onto Cell 2 in Figure VII-6. Cells 1 and 3 have the same surface area and therefore receive equal rainfall. Cell 2 has a smaller surface area and therefore receives less volume of rainfall.

In addition to rainfall, the following quantities of water in the liquid sludge were applied to each cell during filling: Cell 1 - 44,370 gallons; Cell 2 - 36,400 gallons; and Cell 3 - 53,530 gallons.

Total water into each cell (sludge liquid plus rainfall) from February 1972 through June 1973 was: Cell 1 - 99,936 gallons; Cell 2 - 87,662 gallons; and Cell 3 - 109,096 gallons.

The calculated ratio of lb water (sludge plus rainfall) to lb dry weight solid waste and dry sludge solids in each cell through June 1973 were: Cell 1 - 1.01; Cell 2 - 1.22; and Cell 3 - 1.46. All were within the laboratory-estimated saturation range of 0.6 to 1.8 lb per lb for the solid waste, dry weight.



a. DRILL RIG.

b. AUGER BIT - 12-INCH DIAMETER.

c. MEASURING TEMPERATURE AND SAMPLING CORED MATERIAL.

PHOTOGRAPH VII-7

CORE DRILLING EQUIPMENT

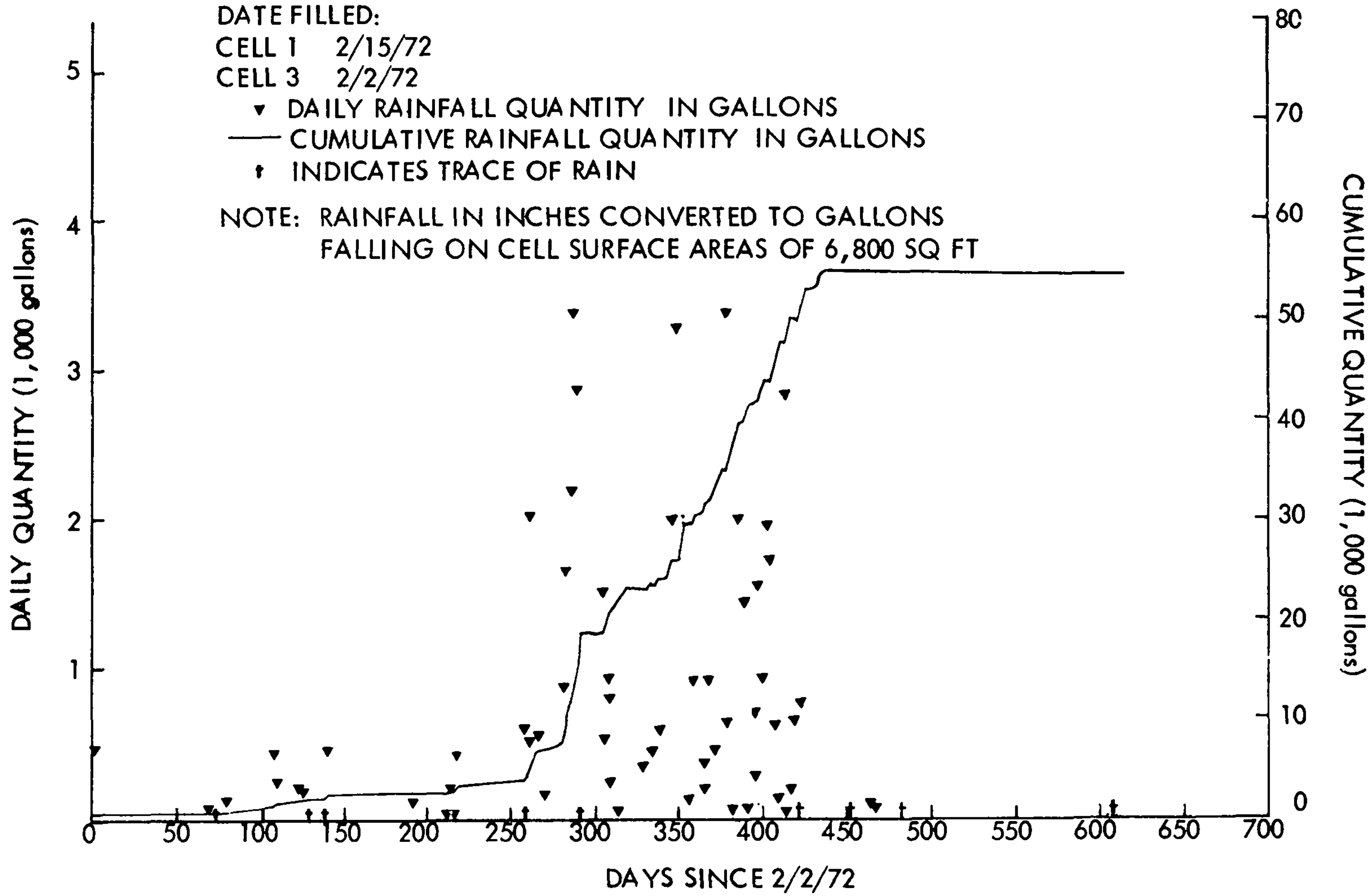


FIGURE VII-5

TEST CELLS 1 AND 3
DAILY AND CUMULATIVE RAINFALL

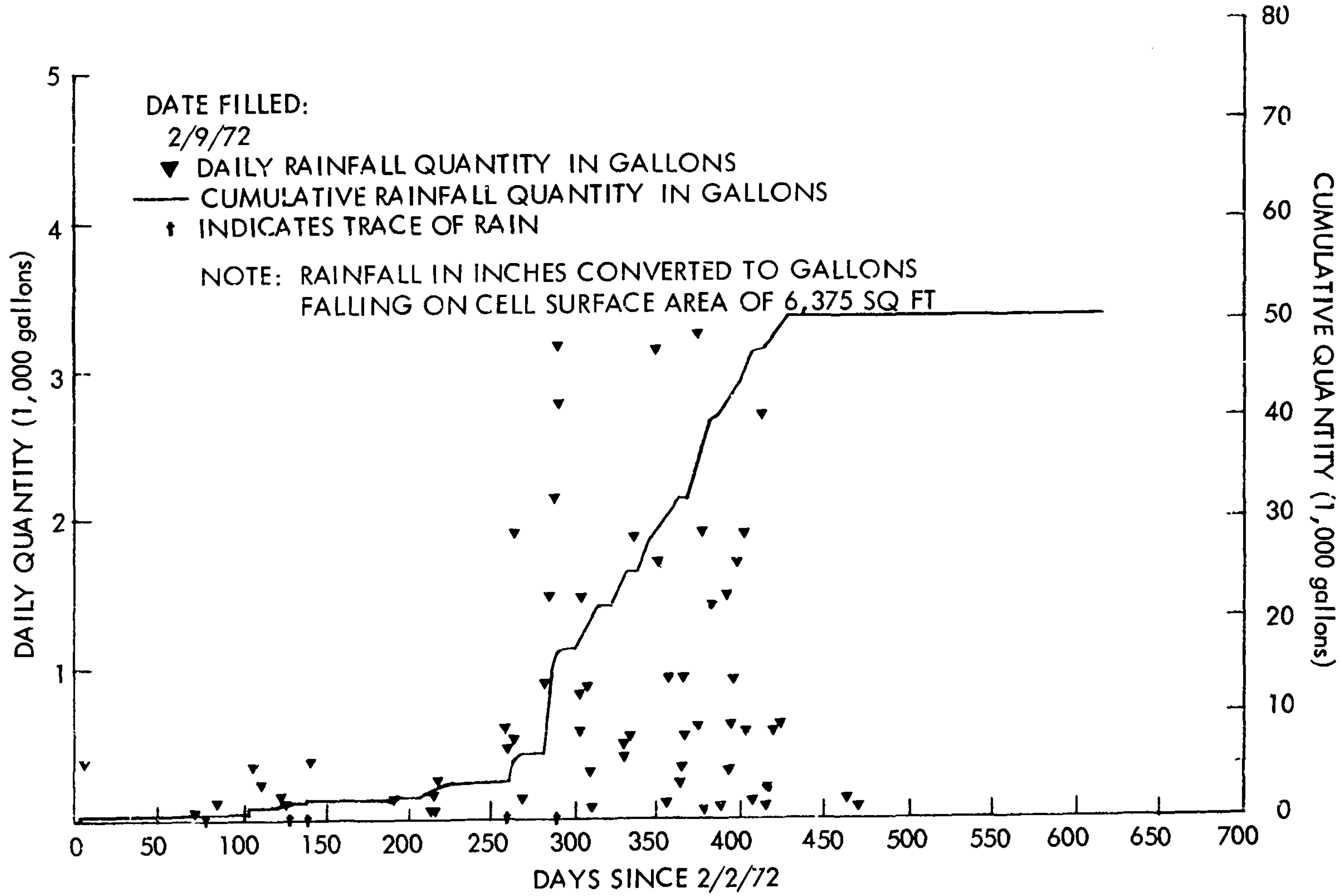


FIGURE VII-6
TEST CELL 2
DAILY AND CUMULATIVE RAINFALL

The daily and cumulative quantities of leachate obtained from Cells 1 and 3 are given in Figures VII-7 and VII-8, respectively. No leachate was obtained from Cell 2. Leachate has been obtained from Cell 1 since the cell was filled. The raw primary sludge applied to Cell 1 had relatively non-viscous, fast settling solids (non-homogenous). This permits the liquid to separate from the solid fraction and percolate through the solid waste. The observation that the test cell with the raw primary sludge tended to produce more leachate than the cells with admixed secondary digested sludges is in agreement with the results of pilot drum tests (see Chapter VI). The total quantity of leachate obtained from Cell 1 through July 23, 1973 was 86.2 gallons, which is negligible when compared with the 45,500 gallons of raw primary sludge put into Cell 1.

The first leachate was obtained from Cell 3 after 2.63 inches of rainfall during the period November 8 through 18, 1972. A total of 2,197 gallons of leachate were obtained from Cell 3 through July 23, 1973. Since no change in leachate production was observed during the same period in Cells 1 or 2, a short-circuit in Cell 3 was suspected. It was observed that the surface of Cell 3 had settled to form a shallow bowl. An eight-inch deep, two-by-two-foot depression was found near the Cell 3 gas and temperature probes through which the storm drainage short-circuiting was thought to have occurred. The depression was subsequently filled with compacted soil and this eliminated the short-circuiting.

Near the end of July 1973, a program to simulate intense rainfall conditions began. Cells 1 and 3 were saturated with water on July 23 and 24. The amount of water necessary for saturation of each cell was determined from laboratory studies of the most recent core drilling; Cell 1 solid waste required 0.137 lbs of water per lb dry weight solid waste, and Cell 3 solid waste required 0.22 lbs of water per lb dry weight solid waste. A 3/4-inch hose delivering 40 gpm was used to apply 13,000 gallons of water to Cell 1 and 15,000 gallons of water to Cell 3.

The leachate production of both cells increased considerably upon saturation, as is illustrated in Figures VII-7 and VII-8. (The saturation date was the 527th day for Cell 1, and the 540th day for Cell 3.) Following saturation, the cells produced leachate in quantities approximately equal to the amount of water applied. Applying 5,000 gallons of water to Cell 1 on November 6, 1973 resulted in over 3,500 gallons of leachate on November 8 and an additional 800 gallons of leachate during the rest of November. (Rainfall during November 1973 was 1.71 inches.) Cell 3 received 3,000 gallons of water twice per month from August 28 to November 5, for a total of 18,000 gallons of water. A total of 17,855 gallons of leachate was produced between August 28 and November 27. For Cell 3, leachate and simulated rainfall after saturation are shown in Figure VII-9.

The analyses of the weekly/monthly leachate samples from Cell 1 are given in Figures VII-10 through VII-17. Except for the sample collected on day 43, all leachate samples were fairly similar in physical and chemical characteristics. The day 43 sample had a straw color, and had higher total dissolved salts and conductivity, and a lower turbidity content. No explanation is available for the atypical characteristics of this sample.

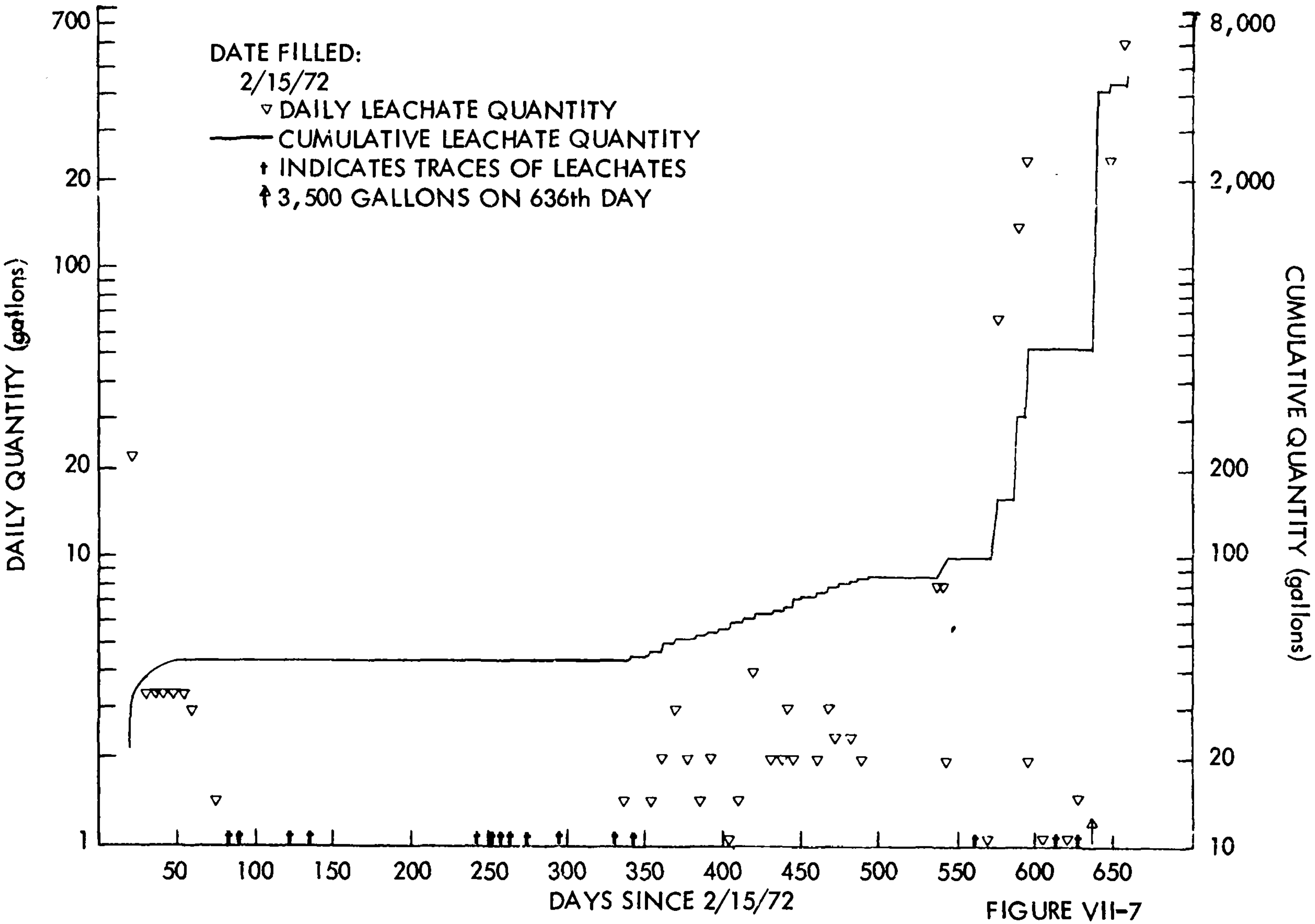


FIGURE VII-7
TEST CELL 1
DAILY AND CUMULATIVE LEACHATE

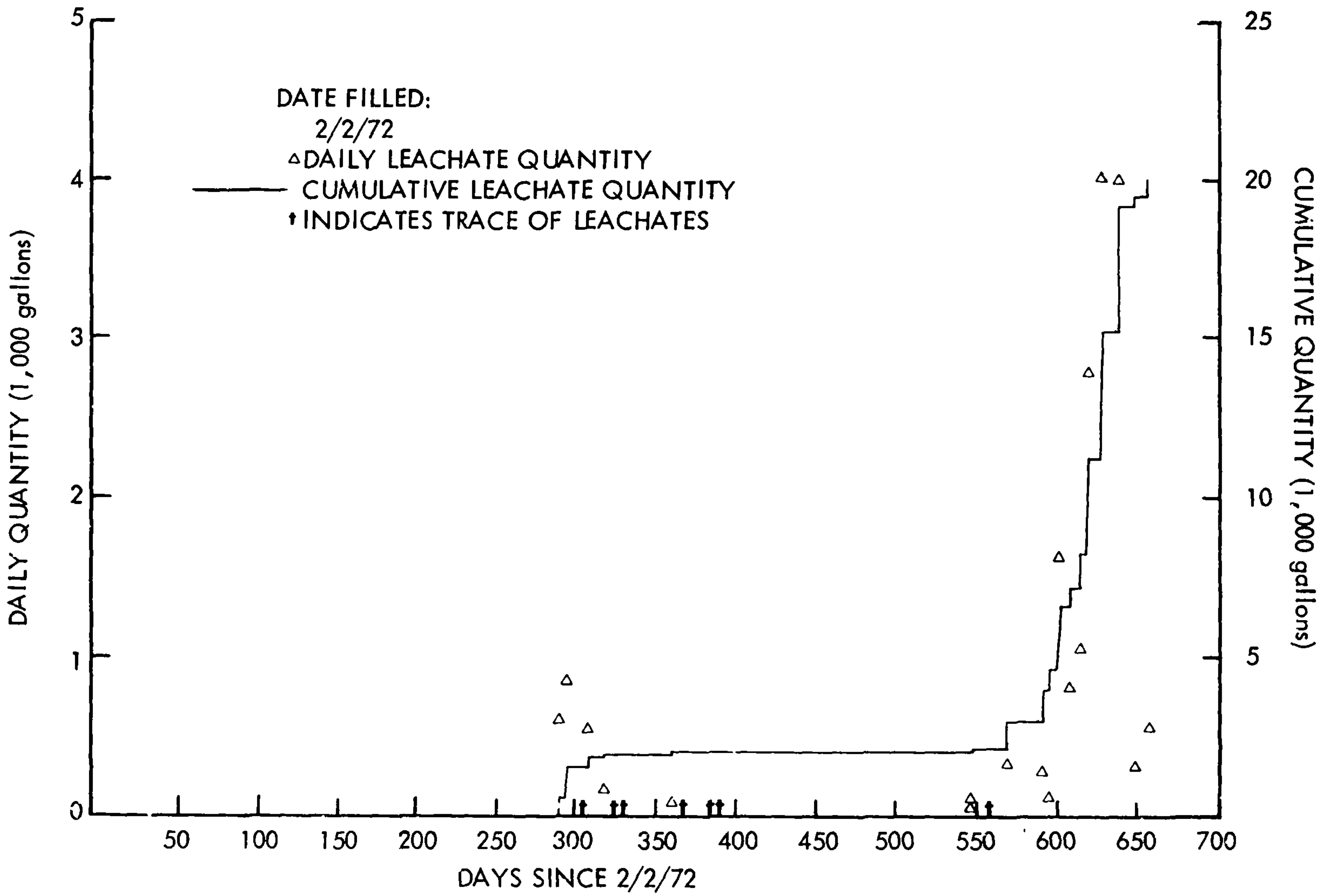
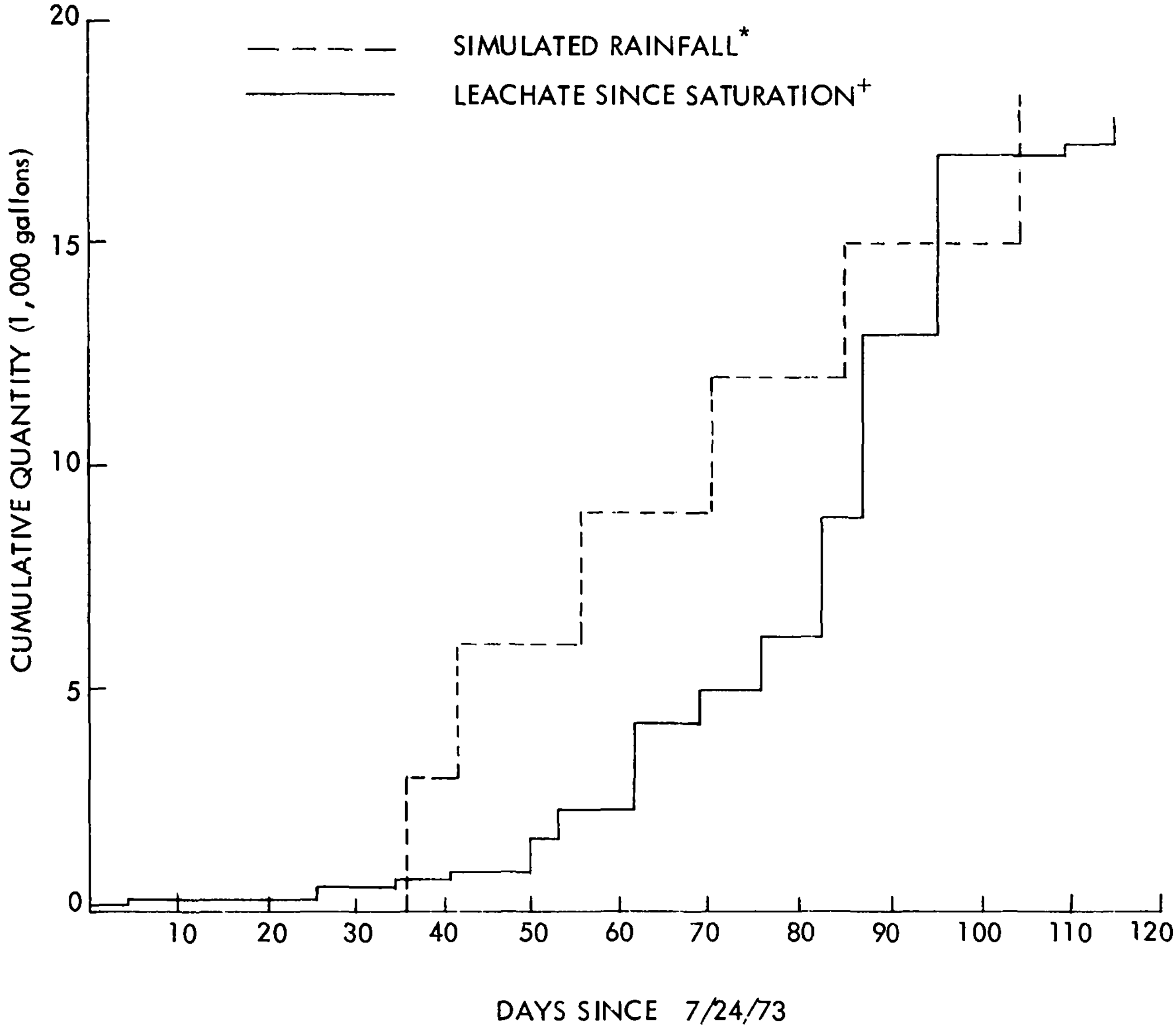


FIGURE VII-8
TEST CELL 3
DAILY AND CUMULATIVE LEACHATE

DATE FILLED: 2/2/72



*Natural rainfall during this period insignificant.

+Cell saturated on July 24, 1973.

FIGURE VII-9
CUMULATIVE LEACHATE RESULTING FROM SIMULATED RAINFALL

DATE FILLED:
2/15/72
NOTE: ANALYSES PERFORMED BY
CITY OF OCEANSIDE

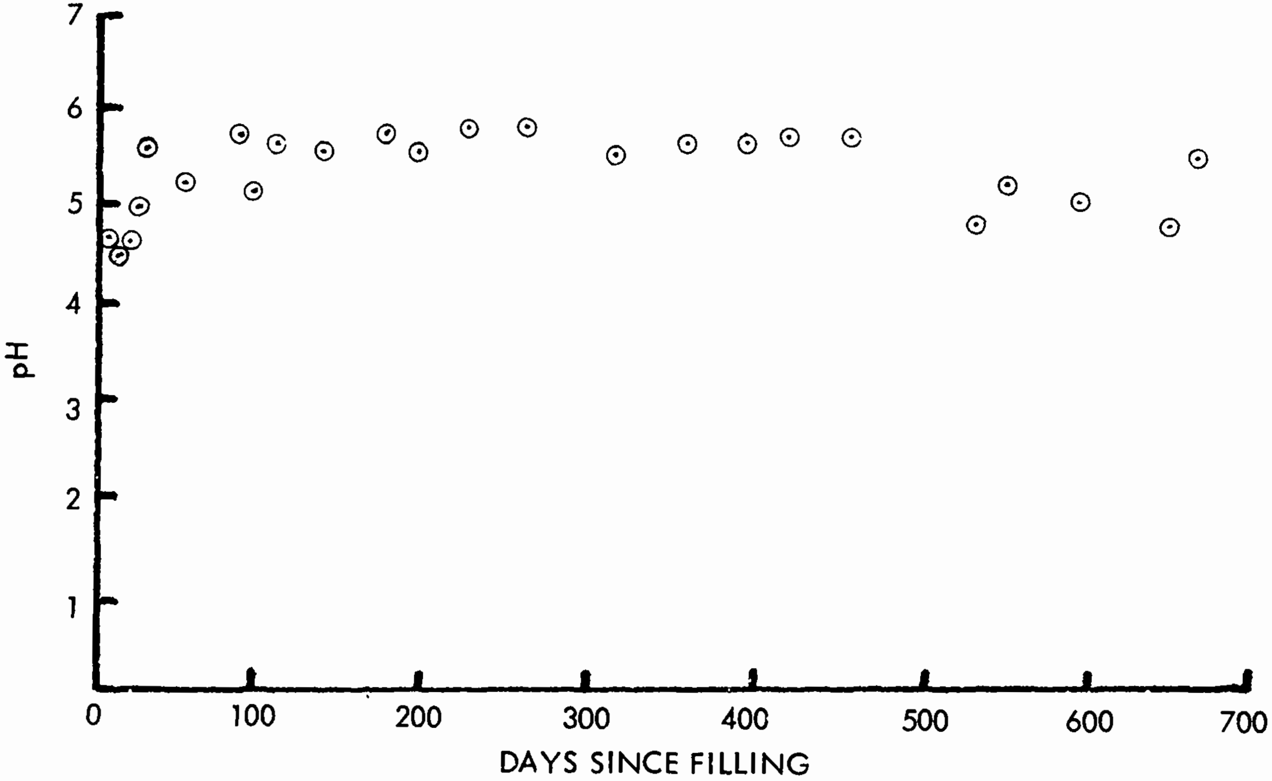


FIGURE VII-10
TEST CELL 1
LEACHATE pH

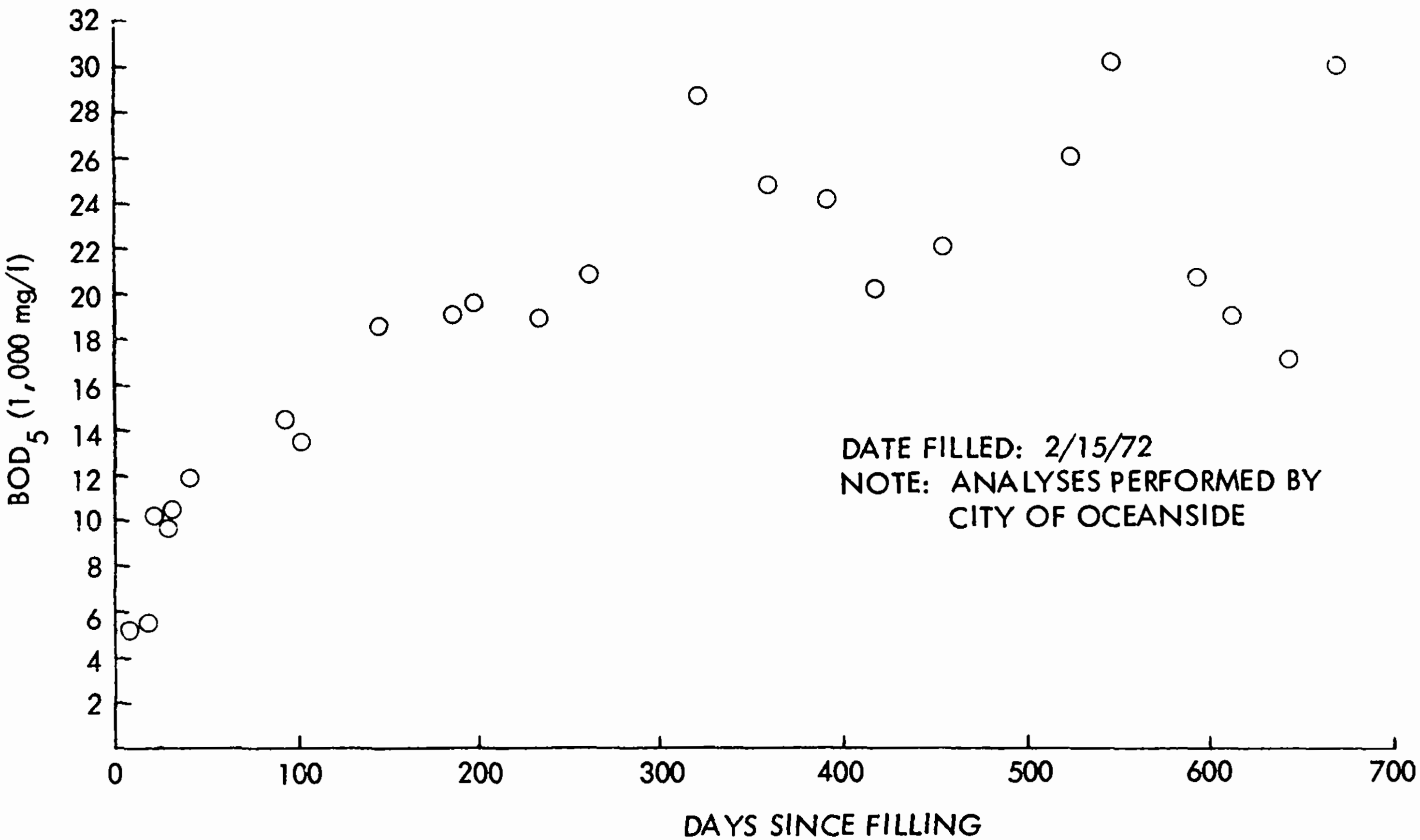


FIGURE VII-11
TEST CELL 1
LEACHATE BOD_5

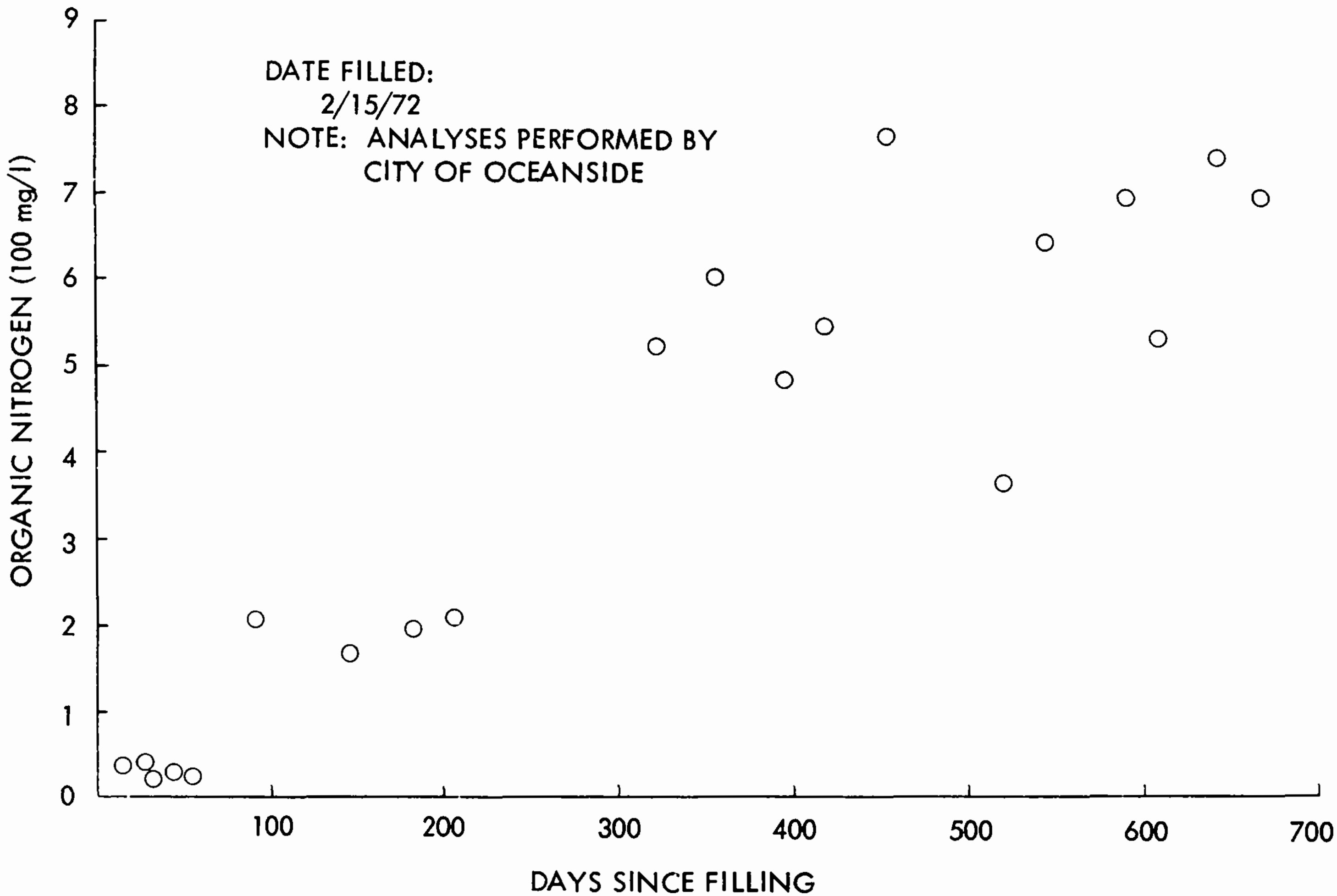


FIGURE VII-12
TEST CELL 1
LEACHATE ORGANIC NITROGEN

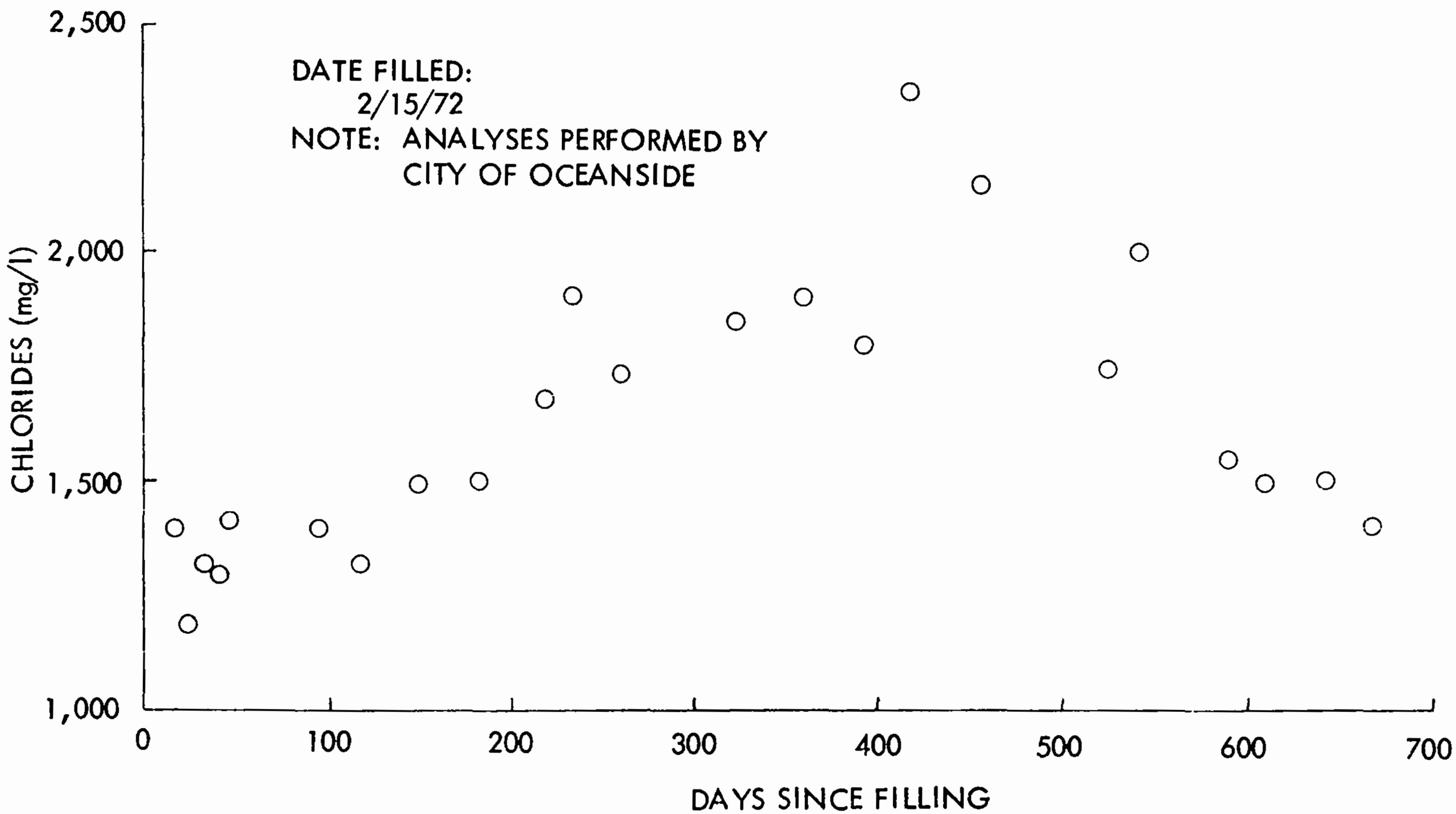


FIGURE VII-13
TEST CELL 1
LEACHATE CHLORIDES

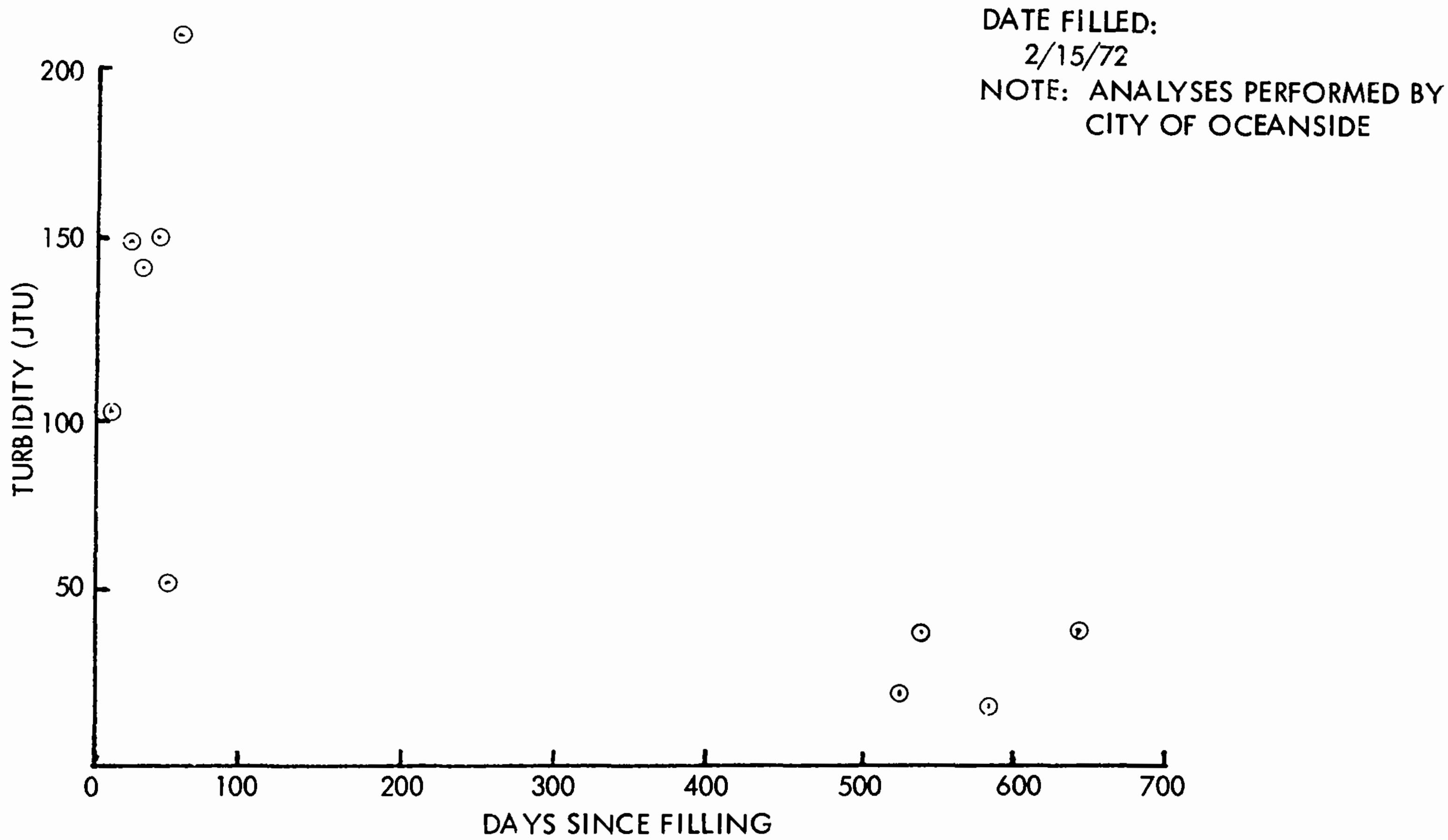


FIGURE VII-14
TEST CELL 1
LEACHATE TURBIDITY

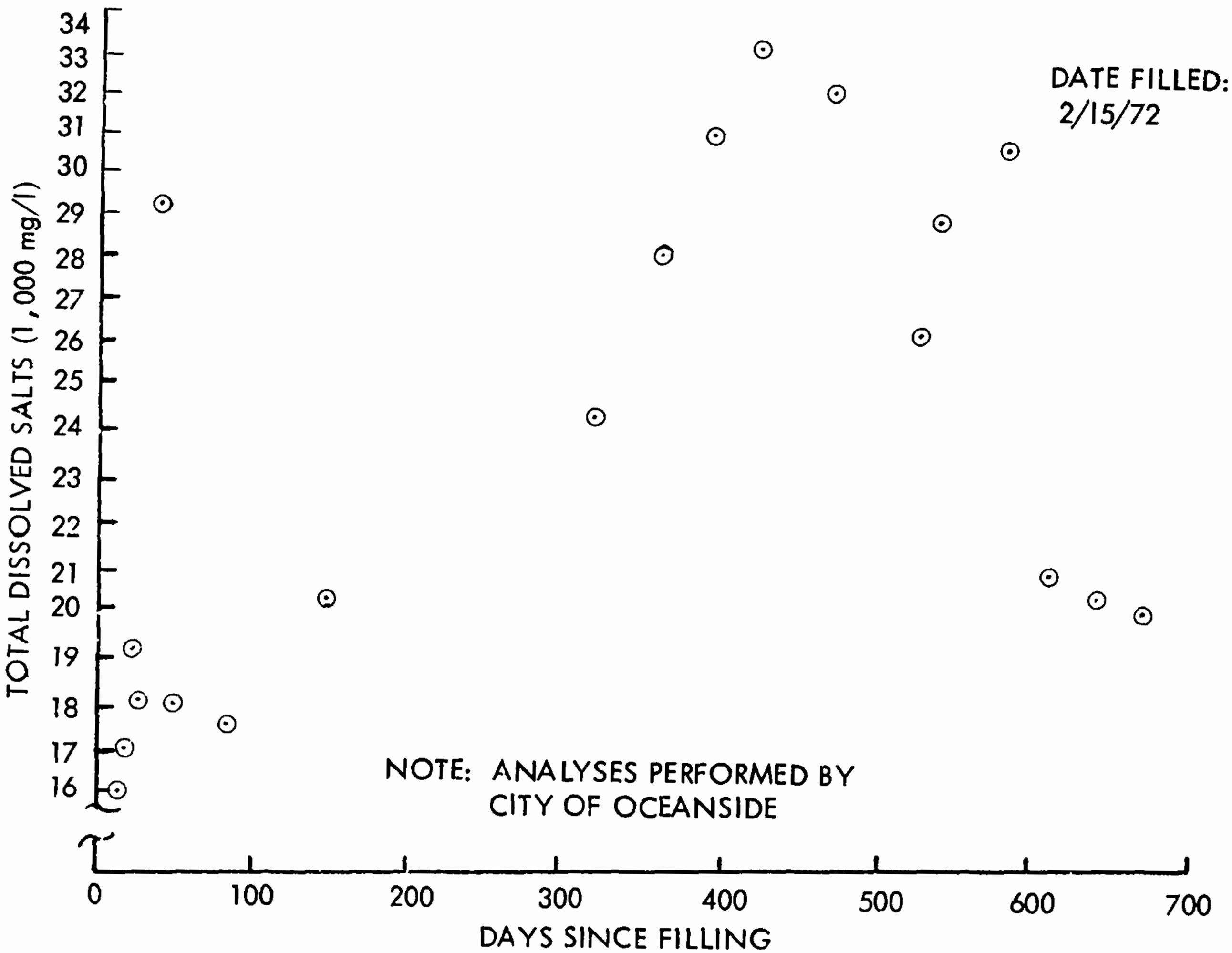


FIGURE VII-15

TEST CELL 1
LEACHATE TOTAL DISSOLVED SALTS

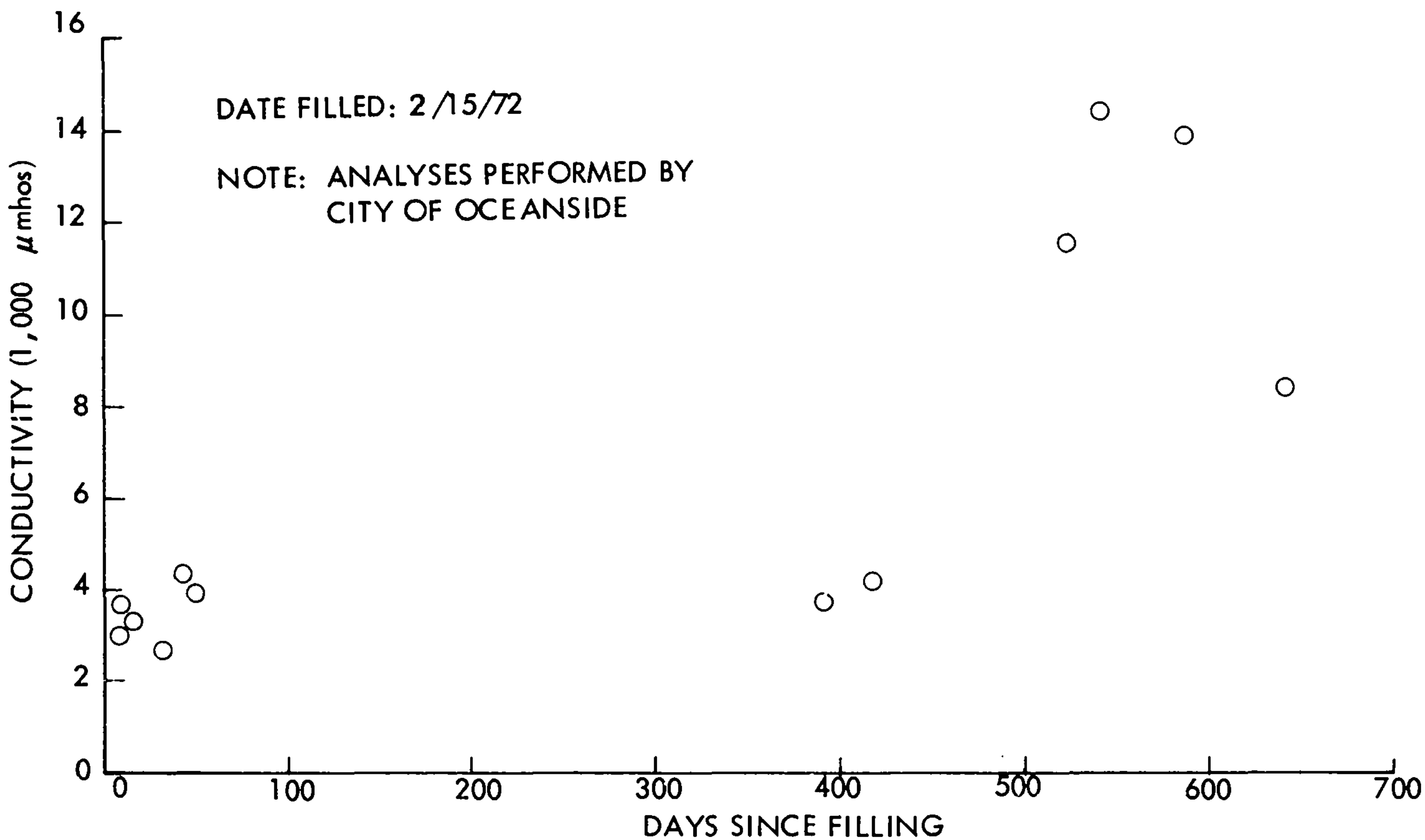


FIGURE VII-16
TEST CELL 1
LEACHATE CONDUCTIVITY

DATE FILLED:
2/15/72
NOTE: ANALYSES PERFORMED BY
CITY OF OCEANSIDE

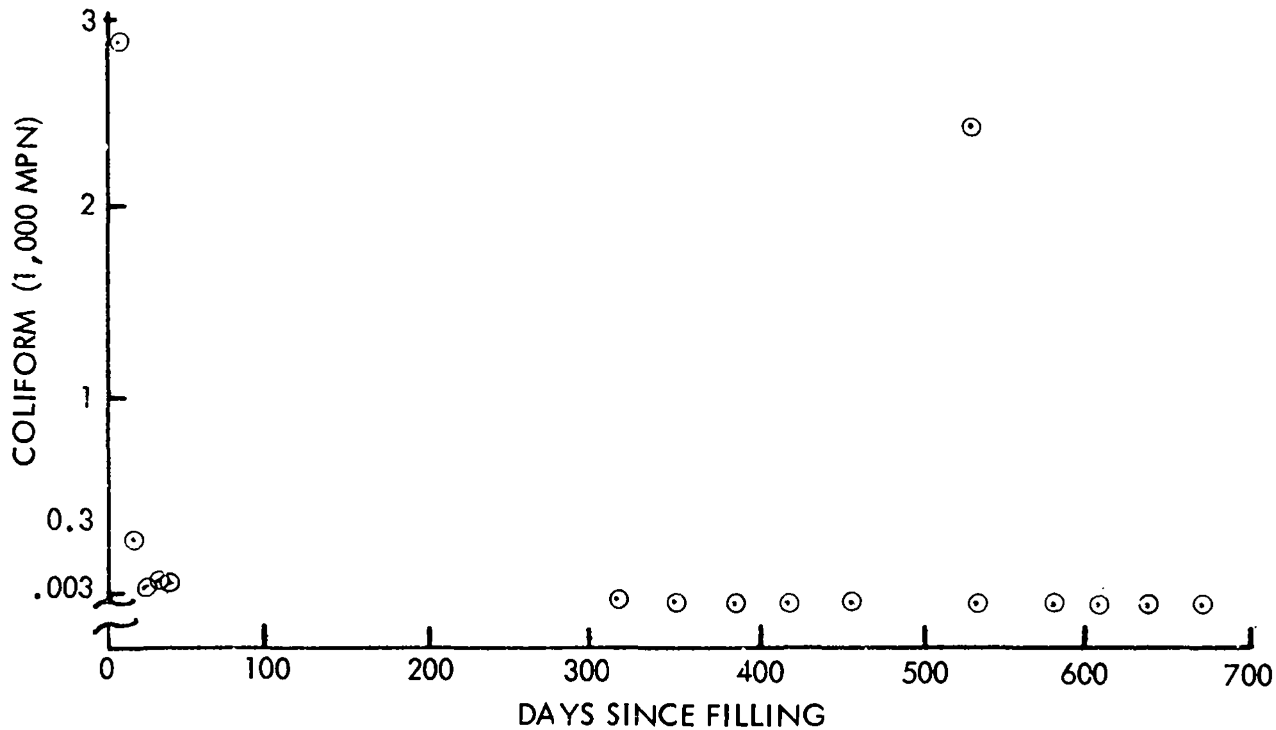


FIGURE VII-17
TEST CELL I
LEACHATE COLIFORM

The data in Figure VII-10 indicate an acidic pH for all leachate samples. The acidic pH may be attributed to the anaerobic decomposition of the sludge and solid waste organic acids. The data also indicate that after the third sample a small but noticeable rise in pH occurred. Figure VII-11 indicates initial BOD_5 levels of 5,000-6,000 mg/l. After the second sample, however, the BOD_5 rose to a level of 19,600 mg/l. A relatively low level of initial BOD_5 and a subsequent rise in BOD_5 has also been observed in the pilot drum tests (see Chapter VI). The initial low BOD_5 levels may correspond to an "acclimation" period during which the proper biological community becomes established. After the biological organism acclimates (the growth/"lag" phase), the degradation of organics proceeds at a faster rate and, hence, more nutrients and microorganisms enter into solution in the leachate, producing a rise in the leachate BOD_5 levels.

Organic Kjeldahl nitrogen levels given in Figure VII-12 show an initial level trend followed by a rise corresponding to the BOD_5 increase. Chlorides (see Figure VII-12) have remained fairly constant between 1,160 and 1,630 mg/l with a slightly increasing trend with time. Analyses vary for turbidity, total dissolved salts, and conductivity (see Figures VII-13 to VII-16); they show no consistent trends. Analyses for coliform (see Figure VII-17) showed an initial MPN greater than 3,000, with subsequent MPN less than 3, with one exception on the 518th day, occurring after the initial water application. The applied water apparently carried coliform from the cell surface or periphery,[39] or alternatively was simply a bad sample.

Table VII-7 presents the comprehensive analyses for quarterly leachate samples for Cells 1 and 3. Of particular interest is the very low concentration of heavy metals. In many cases, these metals were in such low concentrations that they could not be detected by the analytical techniques used. The pesticide aldrin that had been detected in April 1972 subsequently reduced in levels and eventually became undetectable.

The large amounts of leachate generated in 1973 required more frequent analyses. The results of these analyses are presented in Table VII-8. The erratic nature of the data is attributable to the varying amounts of water received, resulting in dilution of many samples.

2. <u>Temperature</u>. A summary of temperature data collected at three different depths within each cell is given in Table VII-9. The temperature trends are plotted in Figures VII-18 to VII-20.

The average temperatures and maximum variations from the average in each test cell since filling through November 28, 1972 were as follows:

Depth, ft	Temperature (F)					
	Cell 1		Cell 2		Cell 3	
	Avg	Max var	Avg	Max var	Avg	Max var
7-8	80	-12	77	-13	76	-20
8-10.5	76	+6	76	-10	77	-17
15-17.8	71	-6	70	-6	73	+19

TABLE VII-7

CELL 1 COMPREHENSIVE QUARTERLY LEACHATE ANALYSES *

(APRIL 1972)

Constituent	Concentration (mg/l)+	Constituent	Concentration (mg/l)+
Cations:		Metals:	
Calcium	1,380	Boron	17
Magnesium	425	Iron	4.7
Sodium	1,320	Manganese	0
Potassium	700	Hexavalent chromium	<0.05
		Arsenic	0
Anions:		Lead	<0.05
Hydroxide	0	Copper	<0.05
Carbonate	0		
Bicarbonate	6,771	Others:	
Sulfate	1,047	Phenols	0.01
Chloride	1,600	Silica	93
Nitrate, NO_3	3.2	Orthophosphate	0.37
		Nitrate, N	0.71
Oxygen consumed	25,000	Total alkalinity ($CaCO_3$)	5,550
Herbicide	None	Total hardness ($CaCO_3$)	5,200
Pesticide - aldrin	0.015	Dissolved solids	17,956
pH (units)	6.1	Conductivity (μmhos/cm)	18,000

*Composite sample taken April 6, 1972. Analyses performed by Environmental Engineering Laboratory, San Diego, California at the request of the City of Oceanside. Metals analyses were done by atomic absorption spectrophotometry.

+Except where noted.

TABLE VII-7 (CONT.)
CELL 1 COMPREHENSIVE QUARTERLY LEACHATE ANALYSES*
(APRIL 1973)

Constituent	Concentration (mg/l)+	Constituent	Concentration (mg/l)+
Cations:		Metals:	
Calcium	1,960	Boron	11
Magnesium	802	Iron	2.4
Sodium	1,750	Manganese	0
Potassium	610	Hexavalent chromium	0.08
Ammonia	699	Arsenic	0.02
		Lead	0.20
Anions:		Copper	0.78
Hydroxide	0		
Carbonate	0	Others:	
Bicarbonate	14,030	Phenols	21
Sulfate	723	Orthophosphate	1.3
Chloride	227	Nitrate, N	2.2
Nitrate, NO_3	9.8	Ammonia, N	538
Fluoride	0.74	Total alkalinity ($CaCO_3$)	11,500
		Total hardness ($CaCO_3$)	8,200
Chlorinated hydrocarbons-aldrin	0.0053	Dissolved solids	25,208
pH (units)	8.3	Conductivity (μ mhos/cm)	29,500

* Composite sample taken April 12, 1973. Analyses performed by Environmental Engineering Laboratory, San Diego, California at the request of the City of Oceanside. Metals analyses were done by atomic absorption spectrophotometry.

\+ Except where noted.

TABLE VII-7 (CONT.)
CELL 1 COMPREHENSIVE QUARTERLY LEACHATE ANALYSES*
(JULY 1973)

Constituent	Concentration (mg/l)+	Constituent	Concentration (mg/l)+
Cations:		Metals:	
Calcium	1,888	Boron	11
Magnesium	748	Iron	113
Sodium	1,275	Manganese	0
Potassium	630	Total chromium	0.10
		Arsenic	<0.10
Anions:		Lead	0.20
Hydroxide	0	Copper	0.81
Carbonate	0		
Bicarbonate	10,248	Others:	
Sulfate	967	Phenols	0.15
Chloride	1,377	Silica	60
Nitrate, NO_3	13	Orthophosphate	4.9
Floride	1.2	Nitrate, N	2.9
Chlorinated hydrocarbons	Not detected	Total alkalinity ($CaCO_3$)	8,400
pH (units)	5.2	Total hardness ($CaCO_3$)	7,800
		Dissolved solids	10,650
		Conductivity (μ mhos/cm)	22,700

* Composite sample taken July 31, 1973. Analyses performed by Environmental Engineering Laboratory, San Diego, California at the request of the City of Oceanside. Metals analyses were done by atomic absorption spectrophotometry.

\+ Except where noted.

TABLE VII-7 (CONT.)
CELL 3 COMPREHENSIVE QUARTERLY LEACHATE ANALYSES*
(JULY 1973)

Constituent	Concentration (mg/l)+	Constituent	Concentration (mg/l)+
Cations:		Metals:	
Calcium	1,400	Boron	7.0
Magnesium	583	Iron	107
Sodium	1,260	Manganese	0
Potassium	375	Total chromium	0.08
		Arsenic	<0.01
Anions:		Lead	0.18
Hydroxide	0	Copper	0.79
Carbonate	0		
Bicarbonate	8,015	Others:	
Sulfate	689	Phenols	0.059
Chloride	1,400	Silica	40
Nitrate, NO_3	3.8	Orthophosphate	0.72
Fluoride	1.1	Nitrate, N	0.85
		Total alkalinity ($CaCO_3$)	6,570
Chlorinated hydrocarbons	Not detected	Total hardness ($CaCO_3$)	5,900
pH (units)	5.4	Dissolved solids	16,896
		Conductivity (μ mhos/cm)	18,200

* Composite sample taken July 31, 1973. Analyses performed by Environmental Engineering Laboratory, San Diego, California at the request of the City of Oceanside. Metals analyses were done by atomic absorption spectrophotometry.

\+ Except where noted.

TABLE VII-8
CELL 1 LEACHATE ANALYSES*
(1973)

Analysis	Date of analysis and days since filling+					
	(Mar 14) 393	(Apr 11) 421	(July 24) 525	(Aug 8) 540	(Sep 26) 589	(Nov 21) 645
Color	Dark brown-gray	Dark gray	Dark gray, opaque	Dark gray-green, opaque	Dark gray-green, opaque	Dark gray-green
pH (units)	5.20	5.29	4.8	5.15	5.0	4.80
Conductivity (μmhos)	3,850	4,150	11,400	14,300	13,900	7,850
Turbidity (JTU)	54	19	21	38	17	59
BOD_5 (mg/l)	15,500	9,200	12,050	12,500	34,800	17,000
Chlorides (mg/l)	5,944.3	3,854.5	1,344	1,973	1,540	1,200
Organic nitrogen (mg/l)	585.5	597.2	819	700	787	734

* Analyses performed by Ralph Stone and Company, Inc.

+ Cell 1 completed filling February 15, 1972.

TABLE VII-8 (CONT.)
CELL 3 LEACHATE ANALYSES*
(1973)

Analysis	Date of analysis and days since filling+			
	(July 25) 539	(Aug 8) 553	(Sep 26) 602	(Nov 21) 658
Color	Dark gray-green, opaque	Dark gray-green, opaque	Dark gray-green	Dark gray-green
pH (units)	4.9	5.15	4.80	4.80
Conductivity (μ mhos)	9,900	10,400	9,100	7,850
Turbidity (JTU)	45	50	30	59
BOD_5 (mg/l)	18,400	10,900	28,700	17,000
Chlorides (mg/l)	566	1,589	921	1,200
Organic nitrogen (mg/l)	985	736	650	734

* Analyses performed by Ralph Stone and Company, Inc.

+ Cell 3 completed filling February 2, 1972.

TABLE VII-9
OCEANSIDE TEST CELL TEMPERATURE RECORD

		Temperature (F) by day since filling											
	Ambient	Days since	Cell 1 - depth			Days since	Cell 2 - depth			Days since	Cell 3 - depth		
Date	max/min	filling	7'-8"	10'-6"	15'-2"	filling	7'-0"	9'-5"	17'-9"	filling	6'-0"	8'-4"	15'-5"
1972													
2/23	64/50	8	79	74	66	14	70	75	64	21	78	80	66
2/24	59/45	9	80	76	68	15	78	77	-	22	81	84	66
2/25	60/41	10	80	74	65	16	70	77	-	23	80	84	66
2/28	58/47	13	82	76	65	19	72	76	64	26	80	80	-
2/29	65/51	14	82	76	66	20	74	78	68	27	80	84	66
3/7	61/52	21	82	76	67	27	74	78	70	34	79	83	68
3/14	62/54	28	83	76	66	34	74	78	66	41	80	82	67
3/21	68/55	35	84	78	68	41	76	78	72	48	79	82	68
3/30	67/42	44	82	78	68	50	78	78	69	57	81	82	69
4/4	70/53	49	82	76	68	55	78	78	70	62	80	84	69
4/11	68/49	56	83	76	68	62	80	78	70	69	86	84	68
4/18	63/52	63	82	76	68	69	78	78	70	76	82	84	70
4/25	68/51	70	82	76	68	76	78	78	70	83	82	82	70
5/2	71/54	77	82	76	69	83	80	78	72	90	82	82	70
5/9	71/52	84	82	76	68	90	80	78	72	97	82	82	70
5/16	71/58	91	82	76	69	97	80	78	68	104	84	82	72
5/23	71/52	98	83	76	70	104	80	78	68	111	84	83	71
5/30	76/60	105	84	76	70	111	82	80	69	118	86	84	72
6/6	73/63	112	84	76	70	118	82	80	69	125	86	84	72
6/13	74/61	119	84	76	70	125	82	--	70	132	86	80	72
6/20	75/62	126	84	76	70	132	82	80	70	139	86	84	72
6/27	74/56	133	84	76	70	139	82	--	70	146	88	86	74
7/5	75/56	141	85	78	70	147	84	80	70	154	88	86	74
7/11	77/61	147	84	78	70	153	84	80	70	160	88	86	74
7/18	80/67	154	86	78	72	160	85	80	70	167	90	88	74

TABLE VII-9 (CONT.)
OCEANSIDE TEST CELL TEMPERATURE RECORD

		Temperature (F) by day since filling											
		Days since filling	Cell 1 - depth			Days since filling	Cell 2 - depth			Days since filling	Cell 3 - depth		
Date	Ambient max/min		7'-8"	10'-6"	15'-2"		7'-0"	9'-5"	17'-9"		6'-0"	8'-4"	15'-5"
7/25	80/68	161	86	78	72	167	86	80	70	174	90	88	74
8/1	86/65	168	86	78	72	174	86	82	70	181	92	88	76
8/8	79/66	175	88	80	72	181	88	82	72	188	94	90	76
8/15	80/64	182	88	78	72	188	88	82	72	195	96	90	76
8/22	87/62	189	88	78	72	195	88	82	72	202	92	90	78
8/29	78/65	196	88	78	72	202	88	82	72	209	90	90	76
9/5	82/64	203	88	78	72	209	88	82	72	216	94	90	74
9/12	76/55	210	84	80	74	216	83	83	73	223	94	88	74
9/19	76/57	217	88	80	72	223	83	82	73	230	94	90	74
9/26	76/54	224	86	80	72	230	84	82	72	237	92	88	74
10/3	77/53	231	84	80	74	237	84	82	74	244	92	74	78
10/10	75/57	238	90	82	72	244	84	84	72	251	86	90	92
10/17	70/55	245	88	80	72	251	84	82	72	258	90	86	79
10/24	82/54	252	86	80	74	258	82	80	72	265	78	76	74
10/31	69/47	259	86	80	74	265	82	80	72	272	80	80	74
11/7	67/51	266	84	80	74	272	80	82	73	279	80	80	74
11/14	62/47	273	84	80	74	279	78	80	72	286	60	60	70
11/21	72/43	280	82	80	74	286	76	80	72	293	62	62	68
11/28	73/50	287	80	80	74	293	74	78	72	300	64	62	70
12/5	61/39	294	80	60	74	300	72	78	72	307	58	60	70
12/12	61/33	301	78	78	74	307	68	76	72	314	58	62	70
12/20	68/47	309	78	72	74	315	68	76	72	322	60	62	72
12/26	75/48	315	76	78	74	321	68	76	72	328	62	64	72

TABLE VII-9 (CONT.)
OCEANSIDE TEST CELL TEMPERATURE RECORD

		Temperature (F) by day since filling											
	Ambient	Days since	Cell 1 - depth			Days since	Cell 2 - depth			Days since	Cell 3 - depth		
Date	max/min	filling	7'-8"	10'-6"	15'-2"	filling	7'-0"	9'-5"	17'-9"	filling	6'-0"	8'-4"	15'-5"
1973													
1/2	67/40	322	74	76	74	328	68	72	72	335	66	64	72
1/10	59/47	330	72	76	74	336	66	72	72	343	63	64	72
1/16	61/54	336	72	76	74	342	66	72	72	349	66	66	72
1/23	70/40	343	70	76	74	349	64	70	72	356	62	60	72
2/6	65/51	357	70	74	74	363	64	68	72	370	64	64	72
2/13	64/46	364	70	74	74	370	64	68	70	377	64	64	72
2/20	76/41	371	70	74	76	377	64	68	72	384	65	66	72
2/27	67/49	378	70	74	74	384	64	70	72	391	66	66	72
3/6	64/48	385	70	72	72	391	64	68	72	398	66	66	72
3/13	63/45	392	68	72	73	398	64	68	72	405	66	66	74
3/20	61/47	399	70	72	73	405	64	68	72	412	64	66	72
3/27	58/50	406	70	72	72	412	64	66	72	419	66	66	72
4/3	74/42	413	70	72	72	419	64	66	72	426	66	66	74
4/10	73/47	420	70	72	72	426	64	66	72	433	68	66	75
4/15	--	427	70	72	72	433	64	66	72	440	68	68	74
5/1	67/50	434	70	72	72	440	68	66	--	447	68	68	72
5/8	66/46	441	70	72	72	447	--	66	72	454	70	68	72
5/15	70/57	448	70	72	72	454	--	68	72	461	72	70	72
5/23	70/54	456	70	72	72	462	--	67	72	469	72	70	73
5/29	--	462	70	72	72	468	--	68	72	475	72	70	72
6/6	69/58	470	74	72	72	476	75	70	--	483	72	70	74
6/12	73/63	476	78	73	72	482	--	70	72	489	72	72	74
6/19	79/61	483	78	74	72	489	78	72	72	496	74	72	74
6/26	75/61	490	80	74	72	496	80	72	72	503	76	74	73

TABLE VII-9 (CONT.)
OCEANSIDE TEST CELL TEMPERATURE RECORD

		Temperature (F) by day since filling											
	Ambient	Days since	Cell 1 - depth			Days since	Cell 2 - depth			Days since	Cell 3 - depth		
Date	max/min	filling	7'-8"	10'-6"	15'-2"	filling	7'-0"	9'-5"	17'-9"	filling	6'-0"	8'-4"	15'-5"
7/3	--	497	82	74	72	503	82	74	72	510	80	78	73
7/10	71/62	504	82	74	72	510	82	74	72	517	80	80	73
7/17	75/63	511	82	76	72	517	82	76	72	524	78	80	73
7/31	78/63	525	84	78	72	531	82	78	72	538	80	80	74
8/7	76/59	532	84	78	70	538	84	78	72	545	80	80	74
8/14	76/63	539	82	78	70	545	84	78	72	552	78	80	74
8/21	78/65	546	82	78	72	550	84	78	72	557	80	80	74
9/4	73/63	560	80	80	70	566	84	78	72	573	82	78	72
9/11	75/64	567	82	80	72	573	84	80	72	580	78	80	72
9/18	73/57	574	82	80	74	580	84	80	72	587	78	78	74
10/9	74/56	595	80	78	74	601	82	80	72	608	76	76	74

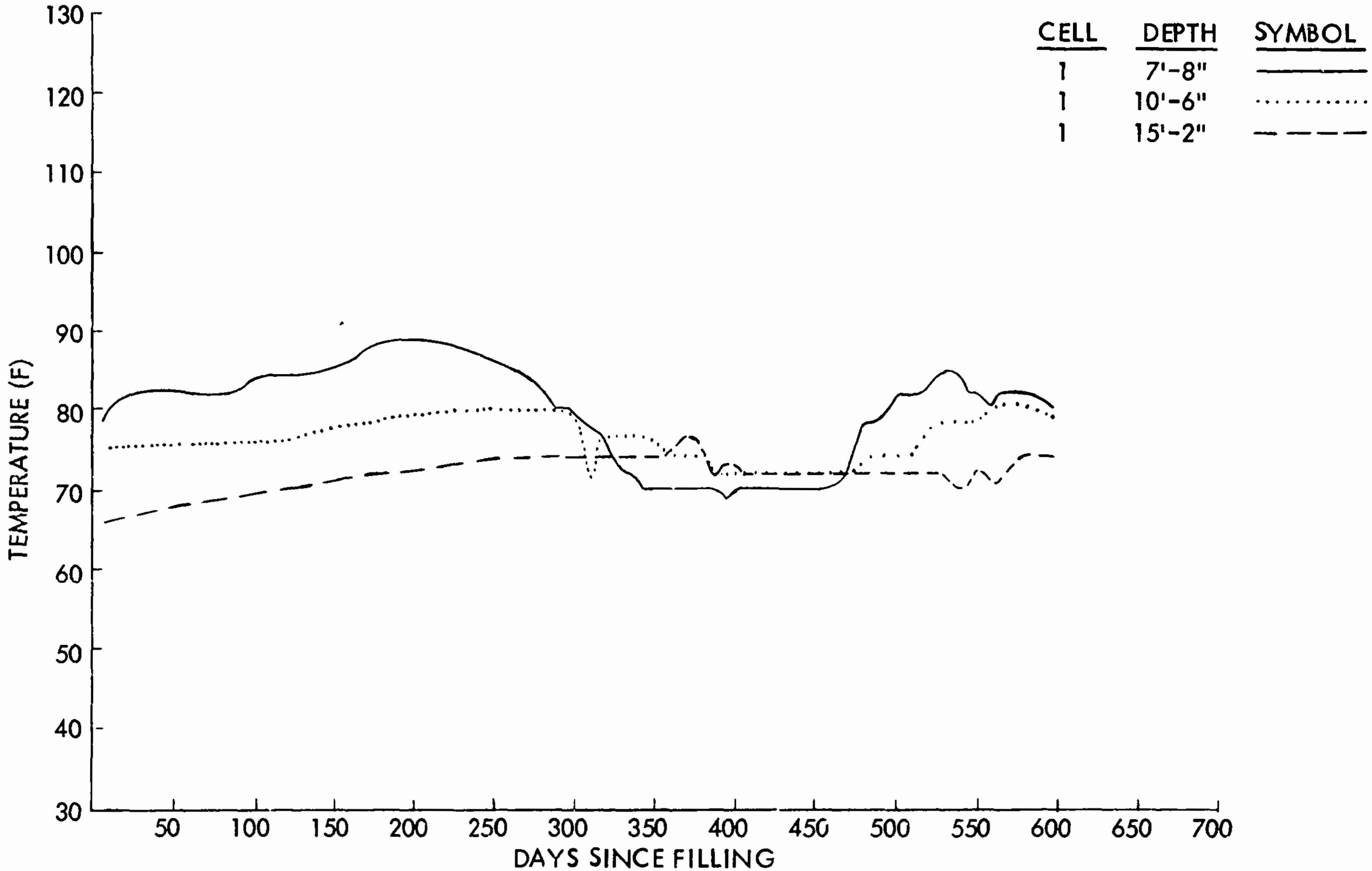


FIGURE VII-18
OCEANSIDE TEST
CELL 1 TEMPERATURE

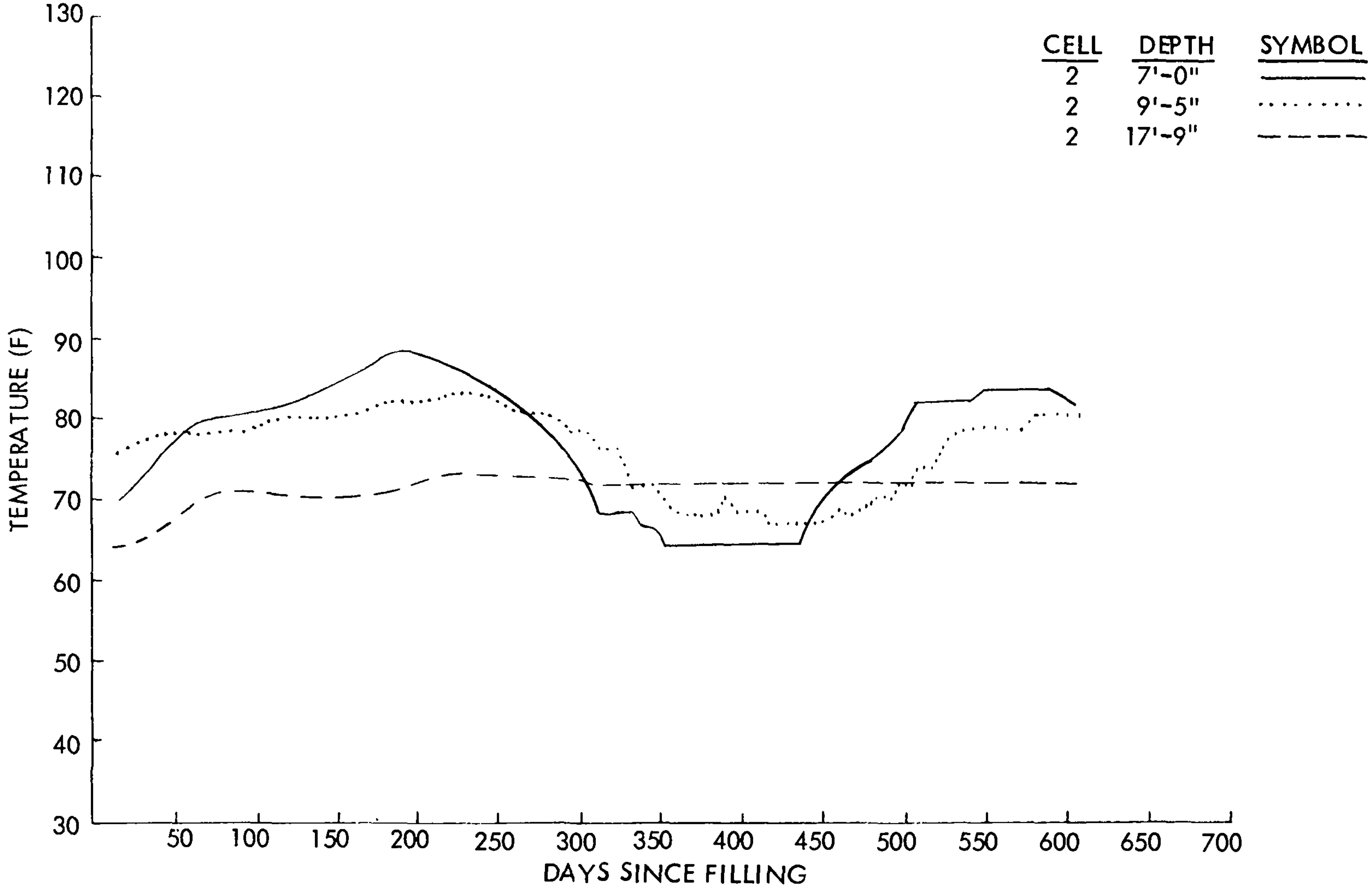


FIGURE VII-19
OCEANSIDE TEST
CELL 2 TEMPERATURE

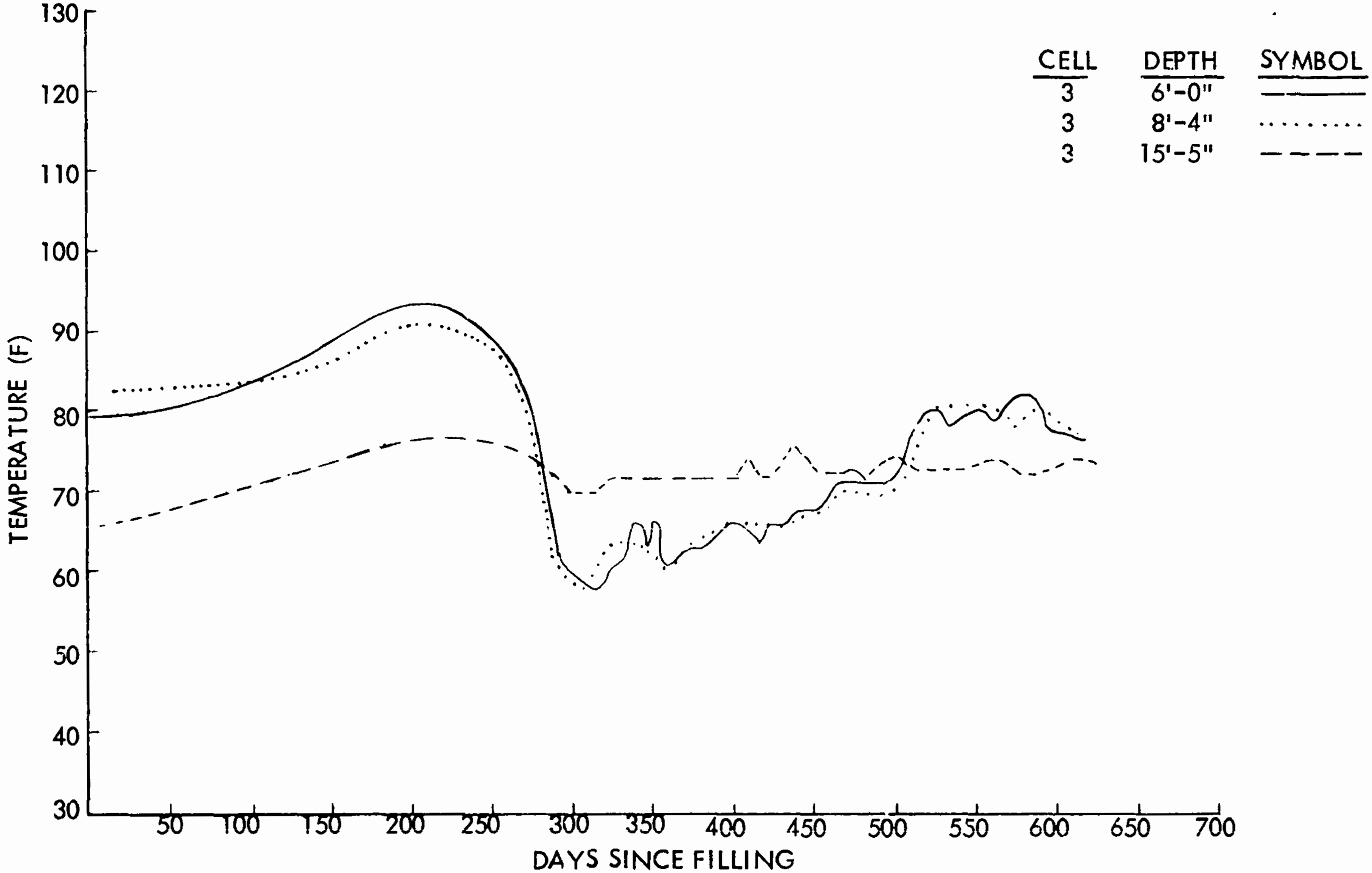


FIGURE VII-20
OCEANSIDE TEST
CELL 3 TEMPERATURE

In all three cells, the temperatures at the 7- to 8-foot depth tended to follow ambient temperatures. Temperatures at the 8- to 10-foot depth in Cell 3 also followed ambient temperatures. In Cells 1 and 2, temperatures at the 8- to 10-foot depth followed a pattern similar to that of the test drums: below ambient temperature in summer and above that in winter. In each cell, the 15- to 18-foot depth temperatures rose to a relatively low temperature and remained there, exhibiting little variation from ambient temperatures. Cell 3 showed large temperature variations. The most notable period of variation occurred in November 1972 (day 250 plus) when 2.63 in. of rainfall short-circuited through Cell 3 in the vicinity of the temperature probes.

3. Gas Analyses. Gas analysis results are presented in Figures VII-21 through VII-26. The methane concentrations at mid-depth and bottom probes in all the cells show generally increasing trends. Oxygen and carbon dioxide show generally decreasing trends, once the carbon dioxide peak is reached. Carbon dioxide content in Cell 2 differs from trends in Cells 1 and 3 in that the CO_2 level did not drop to a low of two percent after the initial peak. The reason for this is unknown. The low two percent CO_2 readings in Cells 1 and 3 were probably erroneous gas samples. Data collected prior to May 1972 were considered less accurate than subsequent data due to problems in field sampling procedures. These problems were minimized after the end of May 1972 by replacing plastic tape gas probe seals with airtight screw plastic caps and plastic valves to eliminate air contamination.

Reports were received from personnel taking temperature measurements that odors were emitted from the temperature probes when opened. Several tests were made for hydrogen sulfide (H_2S) gas in June and July 1972. Hydrogen sulfide was detected in the concentrations on days since filling as shown in Table VII-10.

The H_2S concentration in Cell 1 was initially greater than found in Cells 2 and 3, probably as a result of the raw primary sludge admixed in Cell 1. The H_2S odor was not detectable when the gas and temperature probes were sealed. Some fine cracks 1/8 in. by 6 in. were observed in the cell soil cover during June 1972, but no odors were detected escaping through these cracks.

4. Settlement. Settlement curves are given for the three test cells in Figure VII-27. Though the initial settlement rates varied considerably, the settlement rates were similar by the end of the third year. The wide variations in settlement between the cells is probably due to the variable compaction during placement and the rainfall infiltration; the in-place initial densities (see Table VII-5) do not indicate overall variations in cell densities sufficient to account for the settlement difference. The total settlement for the study period was: Cell 1 - 3.8 percent; Cell 2 - 3.2 percent; and Cell 3 - 3.9 percent.

5. Core Sampling. The results of the seven quarterly test cell core samplings are discussed in the following paragraphs. The cell corings were delayed due to unforeseen funding and scheduling factors.

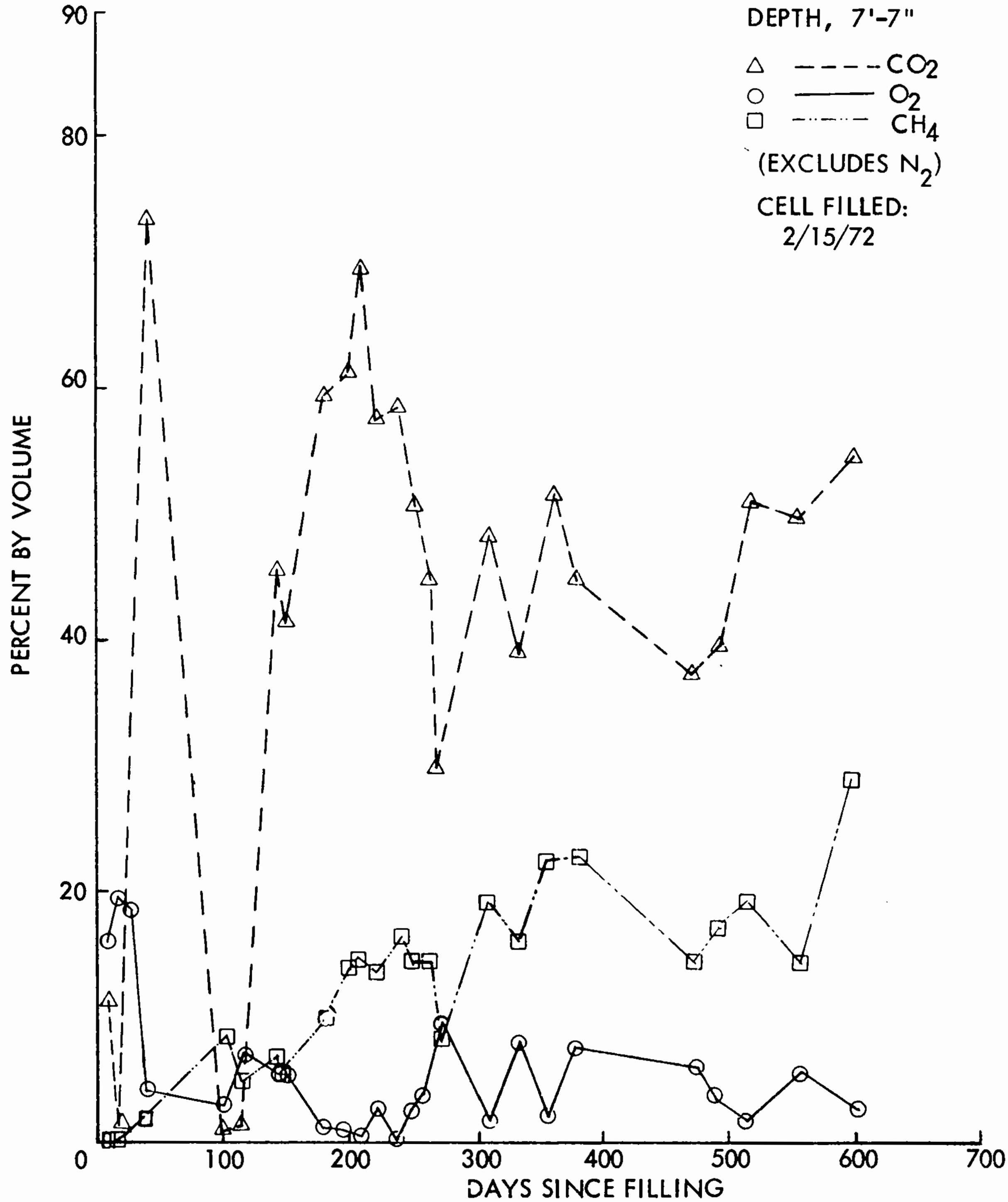


FIGURE VII -21

GAS ANALYSIS
TEST CELL 1

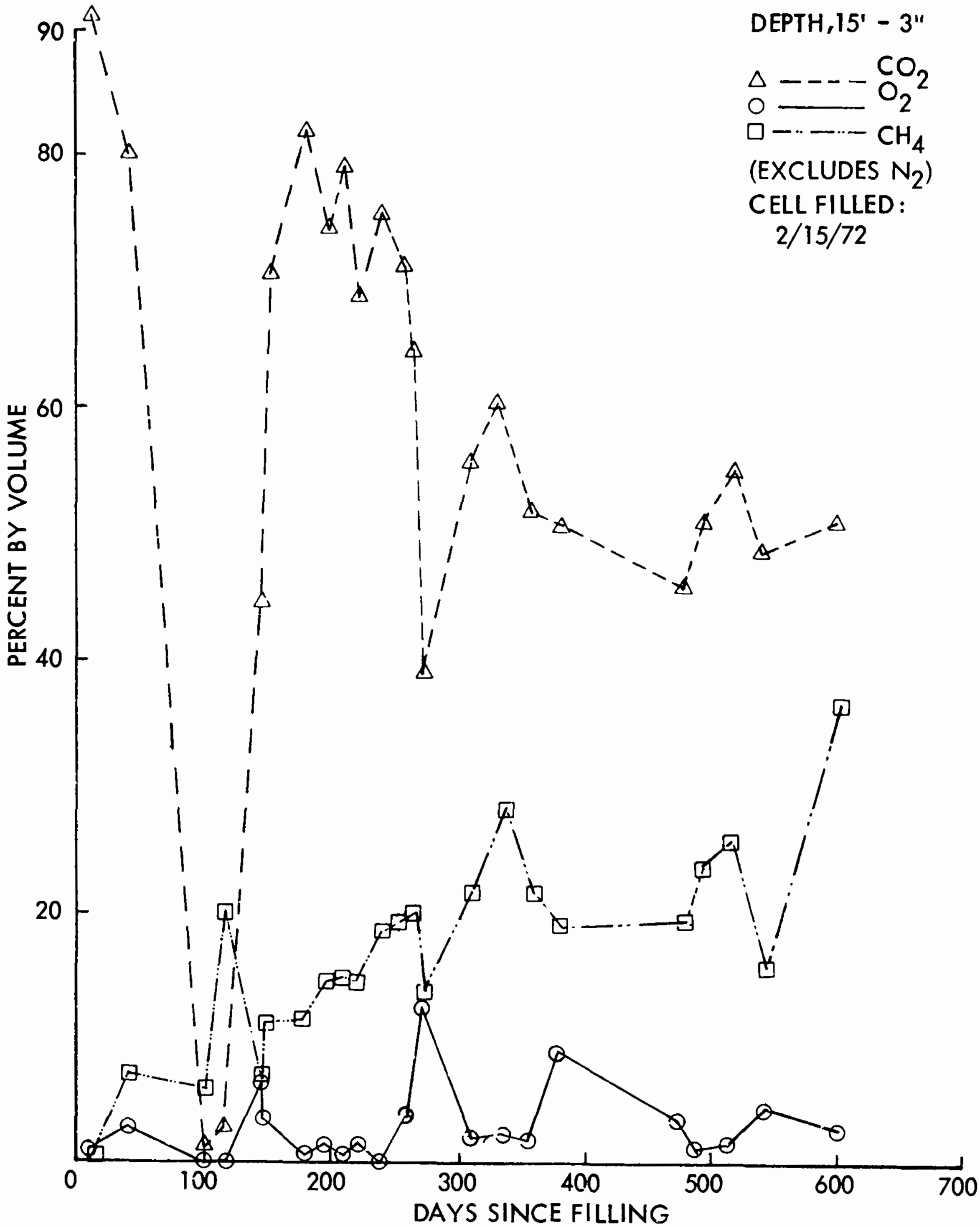


FIGURE VII-22

GAS ANALYSIS
TEST CELL 1

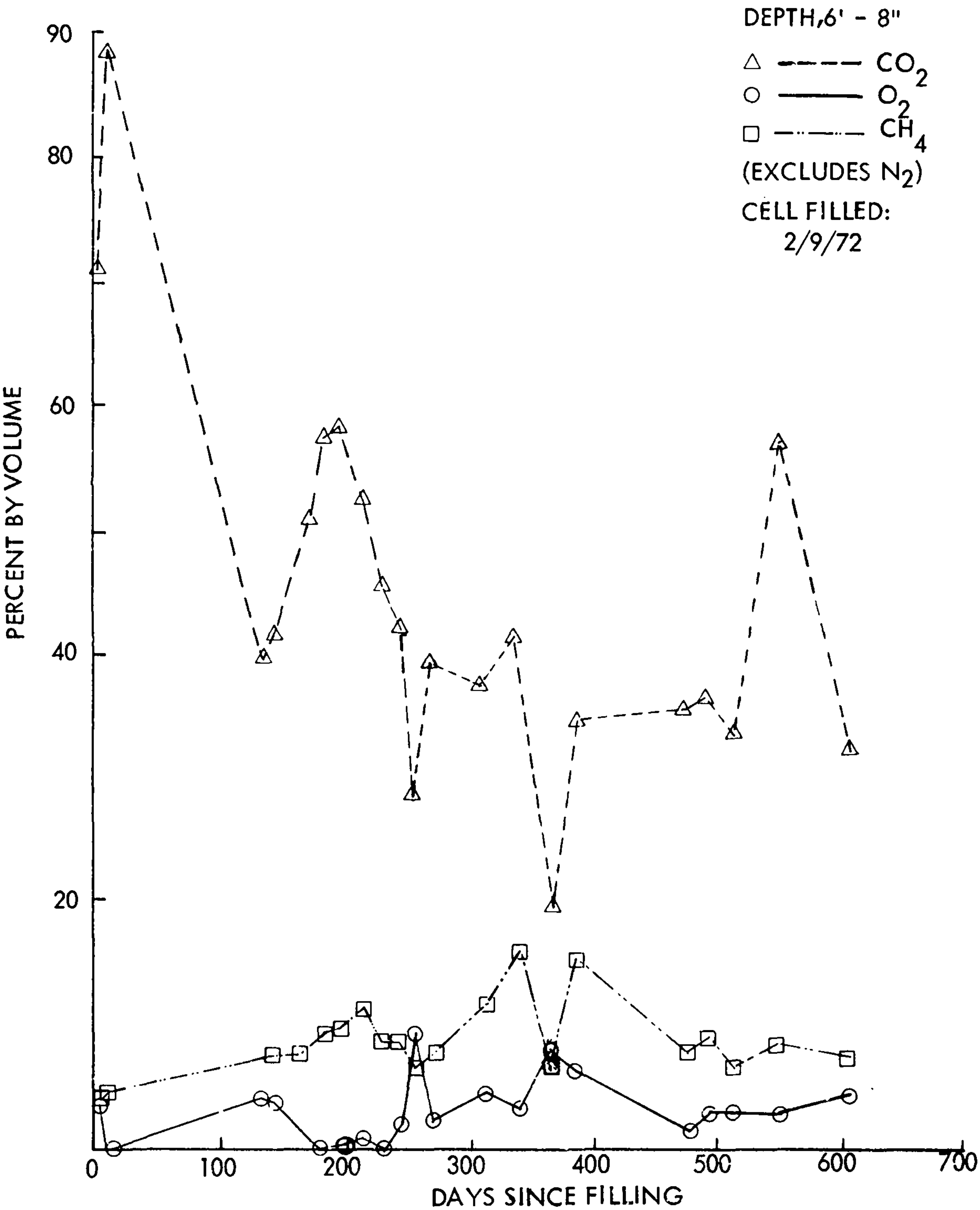


FIGURE VII-23

GAS ANALYSIS
TEST CELL 2

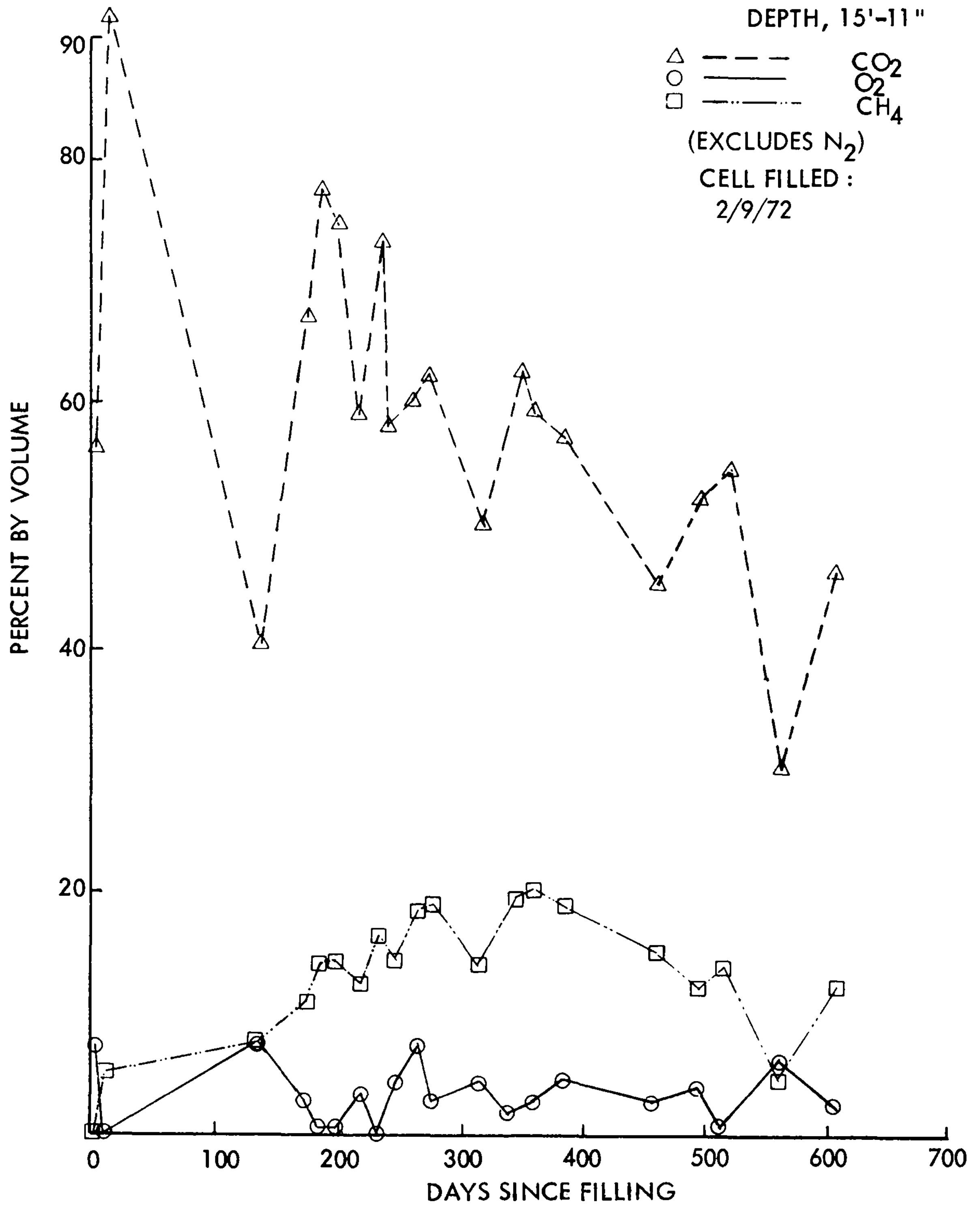


FIGURE VII-24

GAS ANALYSIS
TEST CELL 2

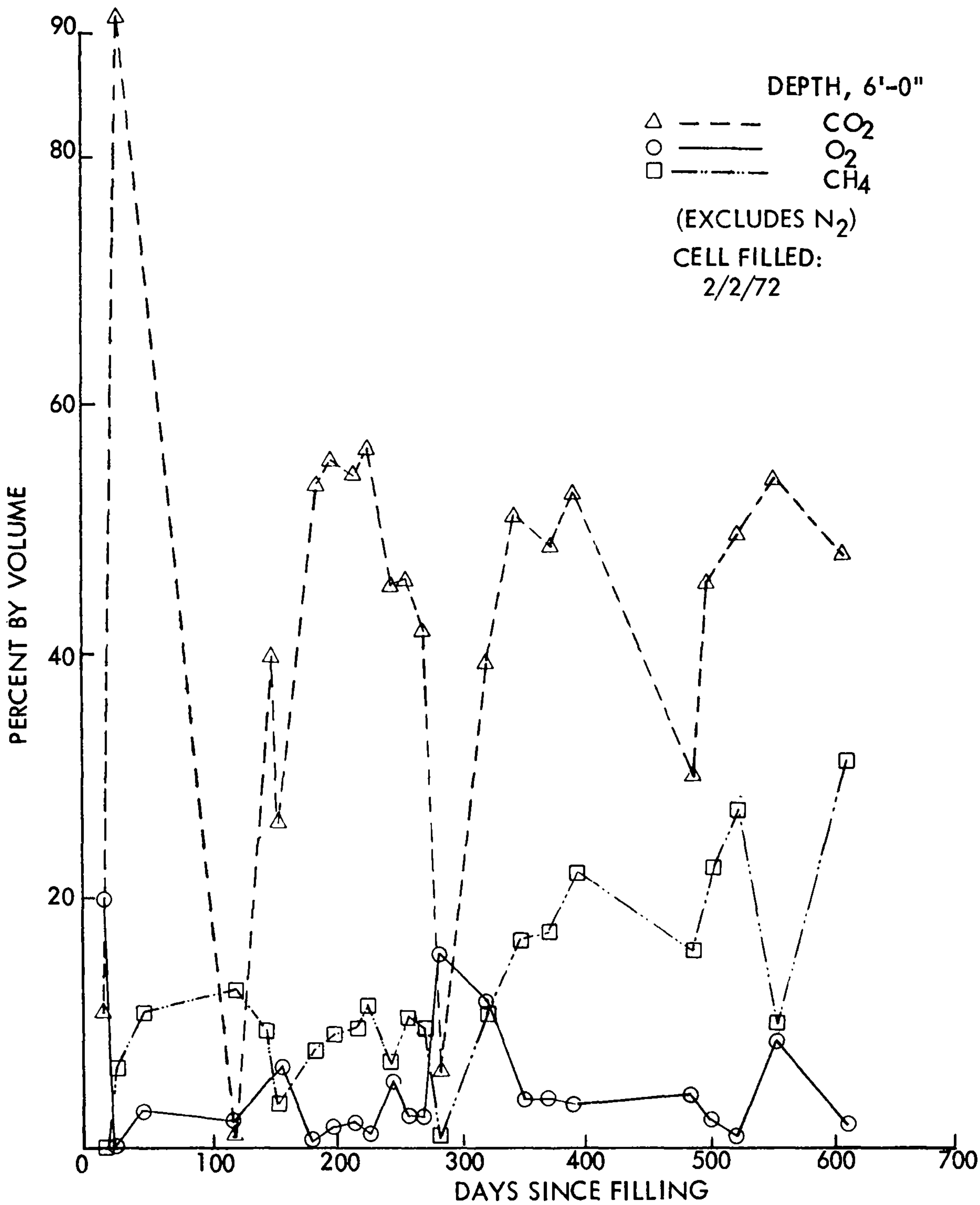


FIGURE VII-25

GAS ANALYSIS
TEST CELL 3

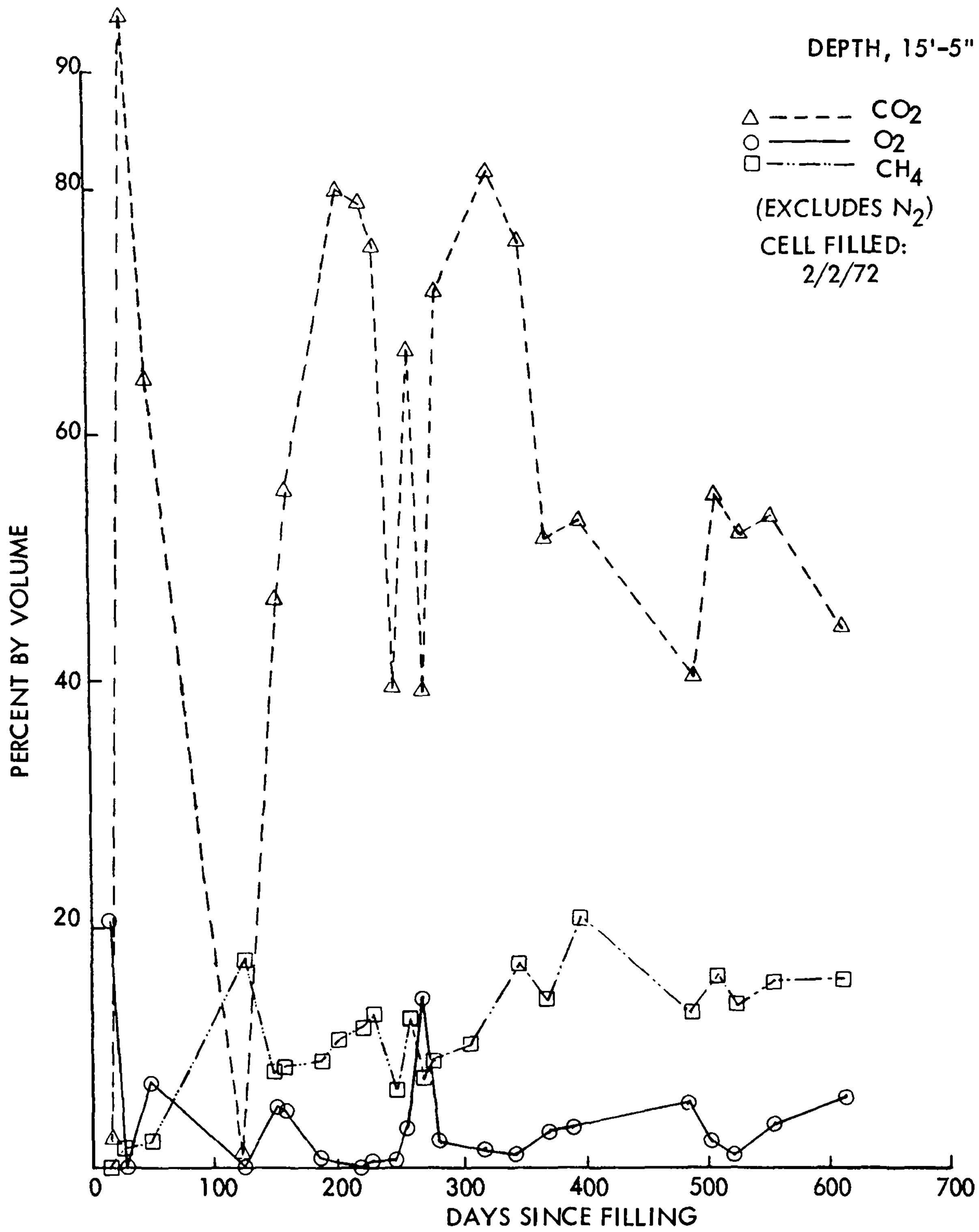


FIGURE VII-26

GAS ANALYSIS
TEST CELL 3

TABLE VII-10

TEST CELL HYDROGEN SULFIDE CONCENTRATIONS*

Days since filling	Cell 1		Cell 2		Cell 3	
	Mid-depth	Bottom	Mid-depth	Bottom	Mid-depth	Bottom
135 - 148	25	750	25	10	5	1
141 - 154	5	9	5	5	5	8
155 - 168	10	100	8	8	5	5
334 - 347	5	20	0	0	50	60
354 - 367	6	30	2	1	50	25
375 - 388	10	40	3	0	25	40
473 - 486	5	22	4	2	20	30
487 - 500	9	22	3	2	22	22
509 - 522	3	25	4	< 4	40	12
547 - 560	30	70	6	Trace	60	50
610 - 623	40	7	3	Trace	100	700
667 - 680	Yes+	No	No	No	Yes+	Yes+

* Values in ppm.

\+ Odor detected; meter not used.

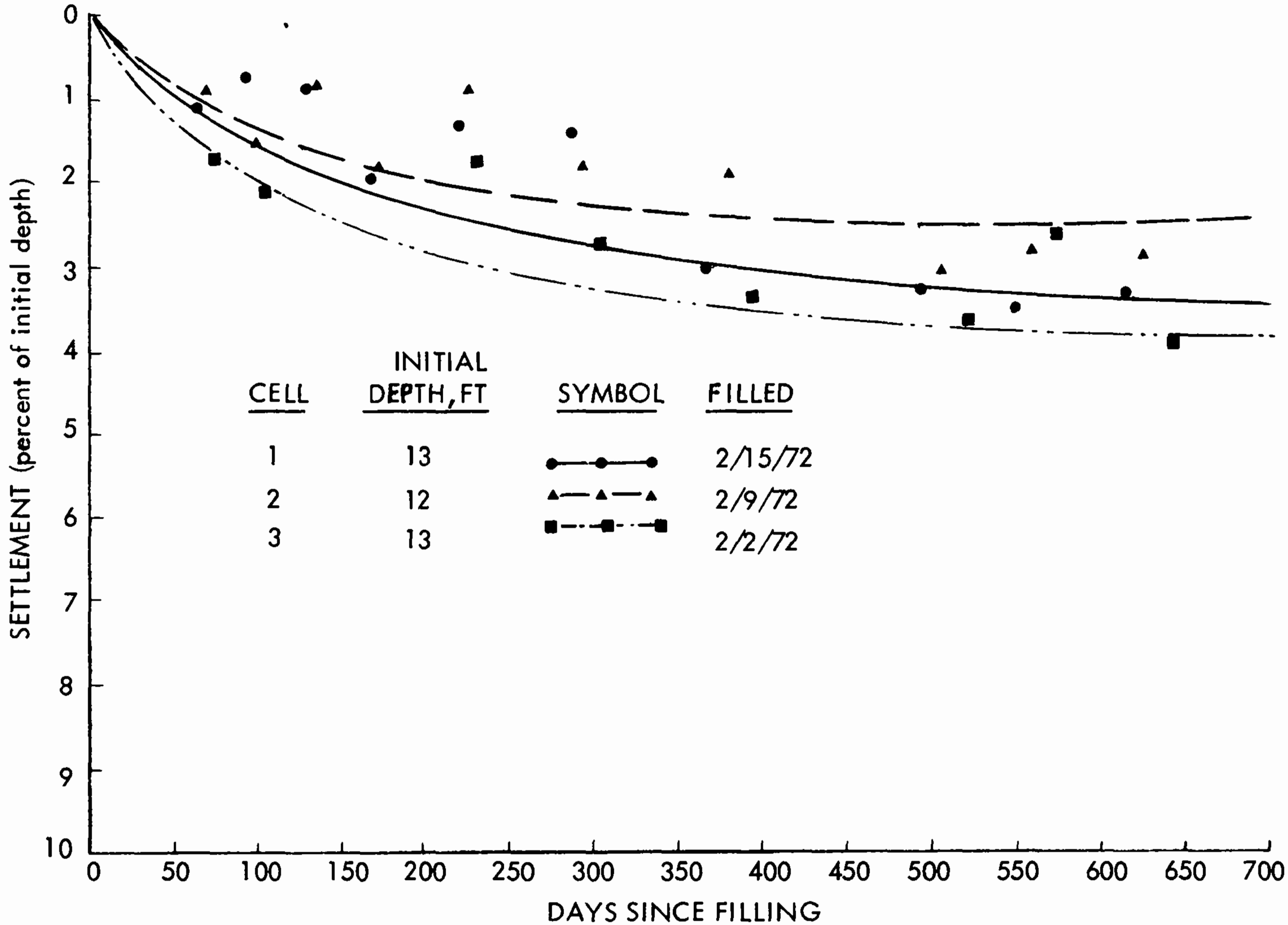


FIGURE VII-27
OCEANSIDE TEST CELL
SETTLEMENT

a. Temperature Profiles. The temperature profiles by depth and ambient air temperatures are given in Tables VII-11 through VII-13 for Cells 1 through 3, respectively. The low ambient air temperature for the first sampling is due to the fact that the drilling was done in the morning; the later two drillings were performed in the afternoon when higher air temperatures prevailed. The average temperature in each cell tended to follow ambient temperatures in the upper two feet of the cell fill; they generally increased with depth. The average temperatures for all depths in each cell were: Cell 1 - 82 F; Cell 2 - 81 F; and Cell 3 - 79 F. The highest temperatures recorded were in Cell 1 at the first sampling; temperatures above 100 F were encountered. Cell 1 received raw primary sludge, which may have undergone more active biodegradation than the digested sludges applied to Cells 2 and 3.

b. Organic Content. Organic analyses by depth are given in Tables VII-14 through VII-16. No trend is visible; thus variations in organic contents of the solid waste-sludge are attributable to random factors. Of interest, however, is the cover soil organic content which increased significantly during the course of the study in Cells 1 and 2. Cell 3 cover soil organics increased at first, then dropped off. The original cover soil was clean, inert fill with minimum organic content. Apparently the presence of landfill gases provided nutrients for various organisms. Various yellow and reddish organisms were observed in proximity to soil cover cracks. The identity of the organisms was not established. Growth of various plants occurred on the cells' surfaces which may also have contributed to the organic content of the soil.

c. Moisture Content. Moisture content of corings from the three test cells are given in Tables VII-17 through VII-19. The cover soil moisture content is rainfall dependent; lower in summer months (first, fourth, and fifth samplings) and higher in the rainy season. Generally the moisture was greater in the lower part of the fill than on top.

d. Moisture Absorption. Special laboratory tests to determine remaining moisture capacities were done on core samples from each cell having the highest and lowest moisture contents and a representative organic contents. The results, given in Table VII-20, include the initial as-received sample moisture content, the moisture added to reach saturation, and the total moisture content at saturation. The data is given in percent, which is convertible to lb water per lb dry weight solid waste when divided by 100. The additional moisture absorbed was below the laboratory estimate of 60 percent minimum as-received absorptive capacity for 88 percent of the samples. The final saturation values are within the 60 to 180 percent saturation range estimated from the laboratory moisture absorption studies for 53 percent of the samples. The samples below this range had considerably lower as-received moisture contents than all the other samples tested. Apparently the material in these samples consisted of less absorbent solid waste constituents.

e. Core Sample Leachate BOD_5. The samples used in the moisture saturation tests described above were also used to generate leachate for BOD_5 analysis. The BOD_5 for the leachates is given in Table VII-21. The BOD_5 values dropped considerably during the study period, with only two samples in the latter part of the study significantly high in BOD_5.

TABLE VII-11

TEST CELL 1 BORE HOLE TEMPERATURE PROFILE

	Depth, ft below soil surface	Temperature (F) Days since filling was completed *						
		162	230	288	473	547	610	667
Ambient air		75	81	74	69	86	75	67
Soil	0	90	82	59	78	75	72	62
	2					77	79	66
Solid waste-sludge	4	94	87	73	81	76	82	70
	6	102	84	82	77	74	80	71
	8	104	84	84	85	80	80	78
	10	89	75	83	83	80	81	77
	12	103	83	83	82	--	--	--
Average +		98	83	81	81	77	79	74

* Cell filling completed February 15, 1972.

\+ Average for solid waste-sludge.

TABLE VII-12

TEST CELL 2 BORE HOLE TEMPERATURE PROFILE

Depth, ft below soil surface		Temperature (F) Days since filling was completed * 168	236	294	479	553	616	667
Ambient air		75	80	76	70	84	70	69
Soil	0	86	82	67	72	80	77	65
	2	90				81	83	64
Solid waste-sludge	4	90	84	77	80	82	83	72
	6	90	83	--	74	80	83	72
	8	92	82	81	78	81	80	80
	10	82	81	85	78	80	82	80
	12	84	86	79	73	--	--	--
Average +		88	83	80	76	81	81	76

* Cell filling completed February 9, 1972.

\+ Average for solid waste-sludge.

TABLE VII-13

TEST CELL 3 BORE HOLE TEMPERATURE PROFILE

Depth, ft below soil surface		Temperature (F) Days since filling was completed *						
		175	243	301	486	560	623	667
Ambient air		78	83	78	70	80	71	74
Soil	0	72	82	67	80	--	69	62
	2	84				73	74	62
Solid waste-sludge	4	85	84	76	78	77	81	67
	6	90	85	82	75	70	82	68
	8	89	88	87	82	72	82	70
	10	87	86	85	74	73	82	75
	12	93	80	83	76	--	--	--
Average +		89	84	83	77.5	74	78	70

* Cell filling completed February 2, 1972.

\+ Average for solid waste-sludge.

TABLE VII- 14

TEST CELL 1 CORE SAMPLE ORGANIC CONTENT

Sample depth, ft below soil surface		Organic content, percent dry wt Days since filling was completed *						
		162	230	288	473	547	610	667
Soil	0	1.7	1.7	3.6	4.2	3.5	3.6	4.6
———	2					56.1	58.5	20.5
Solid waste-sludge	4	38.0	32.6	75.2	34.0	25.5	14.6	12.4
	6	41.9	6.7	59.2	6.2	61.5	71.8	8.1
	8	18.4	44.7	55.8	23.8	23.1	22.6	16.4
	10	44.2	30.7	5.5	20.0	26.4	50.5	54.1
	12	20.4	37.7	34.3	4.7	--	--	--
Average +		32.6	30.5	46.0	17.7	38.5	39.9	22.8

* Cell filling completed February 15, 1972.

\+ Average for solid waste-sludge.

TABLE VII-15

TEST CELL 2 CORE SAMPLE ORGANIC CONTENT

	Sample depth, ft below soil surface	Organic content, percent dry wt Days since filling was completed *						
		168	236	294	479	553	606	673
Soil	0	1.2	1.2	3.0	3.1	3.8	2.2	2.6
	2					19.8	29.5	13.0
Solid waste-sludge	4	33.5	22.0	26.3	66.9	14.3	52.3	15.8
	6	29.3	48.0		28.1	13.5	40.5	5.4
	8	57.5	19.1	40.5	22.9	30.1	74.6	18.2
	10	36.6	66.5	22.4	34.3	19.8	69.6	16.0
	12	30.3	53.4	68.2	8.8	--	--	--
Average +		37.4	41.8	39.4	32.2	19.5	59.3	13.9

* Cell filling completed February 9, 1972.

+ Average for solid waste-sludge.

TABLE VII-16

TEST CELL 3 CORE SAMPLE ORGANIC CONTENT

	Sample depth, ft below soil surface	Organic content, percent dry wt — Days since filling was completed *						
		175	243	301	486	560	623	680
Soil	0	1.8	1.8	4.0	2.8	2.2	1.8	1.9
	2					1.6	69.5	9.5
Solid waste-sludge	4	22.8	76.0	65.7	37.1	28.9	25.9	44.9
	6	28.6	21.0	46.8	22.8	85.4	62.4	35.7
	8	34.0	61.3	86.8	62.5	18.8	86.0	25.9
	10	27.2	65.2	63.6	66.4	30.8	22.5	47.7
	12	38.9	56.5	51.1	16.4	--	--	--
Average +		30.3	56.0	62.8	41.0	33.0	49.2	38.6

* Cell filling completed February 2, 1972.

+ Average for solid waste-sludge.

TABLE VII-17

TEST CELL 1 CORE SAMPLE MOISTURE CONTENT

Sample depth, ft below soil surface		Moisture content, percent dry wt Days since filling was completed * 162	230	288	473	547	610	667
Soil	0	7.6	7.6	9.5	3.2	11.3	16.3	19.1
	2					73.2	82.1	25.2
Solid waste-sludge	4	16.1	33.1	44.0	30.9	66.1	45.1	21.6
	6	19.2	15.0	46.0	18.1	182.0	58.5	18.2
	8	13.5	56.8	39.5	32.2	30.0	46.6	28.7
	10	28.4	46.8	70.5	64.1	49.4	128.4	110.0
	12	34.5	28.1	62.5	15.9	--	--	--
Average +		22.3	35.9	52.5	32.0	80.0	69.7	44.6

* Cell filling completed February 15, 1972.

+ Average for solid waste-sludge.

TABLE VII-18

TEST CELL 2 CORE SAMPLE MOISTURE CONTENT

Sample depth, ft below soil surface		Moisture content, percent dry wt Days since filling was completed *						
		168	236	294	479	553	616	673
Soil	0	3.8	3.8	11.7	3.1	2.7	7.2	8.6
	2					17.5	40.7	16.0
Solid waste-sludge	4	67.1	33.6	24.5	60.2	19.2	21.9	15.0
	6	38.0	42.1		42.8	16.6	38.1	8.4
	8	24.2	17.8	44.0	31.9	53.8	60.6	23.5
	10	68.3	47.9	50.5	43.2	24.3	73.4	11.3
	12	69.0	27.0	58.7	18.4	--	--	--
Average +		53.3	33.6	44.4	39.0	26.0	48.5	14.6

* Cell filling completed February 9, 1972.

\+ Average for solid waste-sludge.

TABLE VII-19

TEST CELL 3 CORE SAMPLE MOISTURE CONTENT

Sample depth, ft below soil surface		Moisture content, percent dry wt Days since filling was completed *						
		175	243	301	486	560	623	680
Soil	0	9.8	9.8	12.9	6.2	4.7	13.9	12.1
	2					11.6	85.3	18.5
Solid waste-sludge	4	25.0	13.6	61.5	43.1	35.8	24.7	103.8
	6	46.3	43.3	46.0	26.4	99.8	230.0	60.1
	8	70.5	36.3	66.3	87.6	42.8	44.7	42.7
	10	92.1	52.5	32.2	115.5	55.0	101.0	86.9
	12	94.3	49.6	69.5	30.9	--	--	--
Average+		65.6	39.1	55.1	60.7	49.0	100.1	73.4

* Cell filling completed February 2, 1972.

+ Average for solid waste-sludge.

TABLE VII-20

MOISTURE ABSORPTION CAPACITY OF SELECTED CORE SAMPLES

Moisture content, percent dry wt*

Days since filling completed/depth, ft

Cell 1	230		288			473			547		610		667		
	4	8	6	8	10	6	10	12	6	8	4	10	CS+	6	10
Sample moisture content	15.0	46.8	39.5	70.5	62.5	18.1	64.1	15.9	182.0	30.0	45.1	128.4	19.1	18.2	110.0
Additional moisture absorbed	9.2	54.7	30.6	11.8	51.7	6.1	21.3	35.4	277.8	73.1	77.0	56.1	19.2	22.5	40.7
Total moisture at saturation	24.2	101.5	70.1	82.3	114.2	24.2	85.4	51.3	459.8	103.1	122.0	186.0	38.3	40.7	139.1

Cell 2	236		294		479			553		616	673		
	6	8	3.5	10	4	8	12	6	8	4	CS+	6	8
Sample moisture content	17.8	47.9	24.5	58.7	60.2	31.9	18.4	16.6	53.8	21.9	8.6	23.4	24.3
Additional moisture absorbed	21.2	39.2	26.7	50.4	65.2	45.3	42.3	102.8	95.5	80.5	8.4	13.9	22.3
Total moisture at saturation	39.0	87.1	51.2	109.1	125.4	77.2	60.7	119.4	149.3	102.0	23.5	14.1	37.6

Cell 3	243		301		486			560		680		
	6	8	8	9	6	10	12	2	6	CS+	2	4
Sample moisture content	36.3	52.5	32.2	69.5	26.4	115.5	30.9	11.6	99.8	12.1	18.5	103.8
Additional moisture absorbed	15.0	51.3	23.2	27.8	23.4	18.0	6.8	13.9	253.9	26.6	20.1	41.0
Total moisture at saturation	51.3	104.8	55.4	97.3	49.8	133.5	37.7	25.5	253.7	38.7	38.6	144.8

* Percent dry wt is equivalent to lb of water per 100 lb of dry wt solid waste. + CS = cover soil.

TABLE VII-21

BOD5 OF LEACHATES FROM SELECTED TEST CELL CORE SAMPLES*

Cell 1			Cell 2			Cell 3		
Days since filling	Depth, ft	BOD_5, mg/l	Days since filling	Depth, ft	BOD_5, mg/l	Days since filling	Depth, ft	BOD_5, mg/l
230	4	680	236	6	660	243	6	170
	8	1,170		8	4,250		8	3,070
288	6	106	294	3.5	28	301	8	138
	8	133		10	92		9	67
	10	561						
473	6	380	479	4	380	486	6	110
	10	300		8	505		10	196
	12	330		12	540		12	140
547	6	594	553	6	407	560	2	181
	8	165		8	495		6	715
610	4	10						
	10	0						

* Samples used to determine moisture absorption were leached to obtain about 157 ml of leachate for BOD_5 analysis.

f. Bacteriological Analysis. During the July 2, 1972 core sampling, core samples at the 4- and 10-foot depths were taken in sterile containers using aseptic collection techniques. Analyses made in duplicate for fecal coliform, fecal streptococci and Pseudomonas aeruginosa on these samples are presented in Table VII-22. The analyses detected fecal coliform and Pseudomonas at 4-foot depths, and none at 12-foot depths. No fecal streptococci were detected at either depth. One hypothesis for the difference in results between the 4- and 12-foot depths is that the test cell environment at 4 feet may be aerobic, and at 12 feet anaerobic. The absence of fecal streptococci may be due to a lack of fecal material in the samples or a shorter survival time (sampling occurred 5.5 months after sludge and solid waste placement). Also, the core samples were extracted for analysis in liquid form; the sample extract appearance for 4-foot depths was earthy yellow, and blackish grey for 12-foot depths.

These results are similar to findings in another report[26] on bacteria survival in soil. Coliform bacteria were reported to be seldom found below 4-foot depths in soil, and were never found below 7 feet.

g. Odor. Odor was determined in terms of strength and type at each 2-foot core sample depth. Odors were generally strong to moderate on the first core sampling (July 1972), and then became moderate to weak on the two subsequent core samplings. Odor in Cell 1 was predominantly strong, and was stronger than for Cells 2 and 3 on the first sampling. This was attributed to the more odoriferous raw primary sludge placed in Cell 1. No difference in odor strength was detected on subsequent samplings.

The type of odor predominating during the first borings was a strong, sweet, septic condition in Cell 1 and putrid, pig pen, or normal landfill in Cells 2 and 3. Odors in the next two samplings were identified as strong sour smells in all cells. In subsequent samplings, earthy and slight sour odors predominated.

h. Core Sample Appearance. Appearance of samples was observed to be agglomerated when highly moist and when mixed with large quantities of sludge. When dry, the samples were loose. During the first year, the agglomerated material required a screwdriver or similar probe to remove strongly adhering samples from the large 12-inch diameter auger drill bit. The majority of the samples were moderately to highly agglomerated in all three cells each time they were sampled. Occassionally, lumps of moist sludge were identified in the solid waste. During the second year of core sampling, the solid waste ranged between dry and slightly moist; it was also quite loose. Following the application of large quantities of water to Cells I and 3 in accordance with the simulated rainfall study, solid waste in these cells became very moist and agglomerated. Cell 2 solid waste remained dry and loose until the first rainfall.

i. Color. Colors in metals, plastic, rubber, glass, ceramics, leather, textiles and wood were similar to those originally disposed except that they were obviously dirty. Paper appeared unchanged in all three cells during the first sampling, but was faded or bleached white in Cells 1 and 2 in subsequent samplings. In Cell 3, paper

TABLE VII-22

SUMMARY OF BACTERIOLOGICAL ANALYSIS OF TEST CELL SAMPLES

Sample: Test cell BH* no.	Sample: Depth, ft	Replicate	Standard plate count per gram	Fecal coliform MPN/g	Fecal coliform %	*Pseudomonas aeruginosa* MPN/g	*Pseudomonas aeruginosa* %	Fecal streptococci MPN/g	Fecal streptococci %	Appearance of sample extract
1	4	A	3.0×10^6	3.3×10^2	.011	40	≈ 0	< 0.2	0	Earthy
		B	2.0×10^6	3.3×10^2	.017	70	≈ 0	< 0.2	0	yellow
1	12	A	1.4×10^5	< 0.2	0	< 0.2	0	< 0.2	0	Blackish-
		B	1.3×10^5	< 0.2	0	< 0.2	0	< 0.2	0	gray
2	4	A	2.0×10^7	9.2×10^4	0.46	2.4×10^3	.012	< 0.2	0	Earthy
		B	1.8×10^7	5.4×10^4	0.3	2.4×10^3	.013	< 0.2	0	yellow
2	11	A	1.3×10^6	< 0.2	0	< 0.2	0	< 0.2	0	Blackish-
		B	1.4×10^6	< 0.2	0	< 0.2	0	< 0.2	0	gray
3	4	A	7.5×10^6	4.6×10^2	.0061	3.3×10^2	.0044	< 0.2	0	Earthy
		B	8.0×10^6	4.6×10^2	.0058	3.3×10^2	.0041	< 0.2	0	yellow
3	12	A	4.0×10^6	< 0.2	0	< 0.2	0	< 0.2	0	Blackish-
		B	3.0×10^6	< 0.2	0	< 0.2	0	< 0.2	0	gray

Note: Any piece of paper in all samples shredded into tiny fibers of cellulose upon manual shaking in dilution bottles.

* BH = bore hole.

was yellowish in the last sampling. Grass, leaves, tree and shrub prunings decomposition rates varied considerably between samples; there was no consistent pattern. Vegetation colors observed included light to dark green, faded green, faded yellow, yellowish-green, yellowish-brown, brown, and black.

j. Readability. The core samples were observed to see if printed paper and container labels were readable. In general, newsprint and paper printing, glass, metal, and plastic labels were readable. Wet paper with printing tended to be blurred. No variations between cells or depth were detected.

k. Biodegradation. During the first sampling, the sample materials were observed to be none or slightly degraded. In subsequent samplings, the core materials were observed to be none to moderately degraded. Food wastes were detected in about 10 percent of the samples, and consisted of fruit peelings and isolated fragments. The peelings were not noticeably degraded.

6. <u>Comparison of Sludge-Admixed Solid Waste with Normal Solid Waste.</u> The three field test cells (lysimeters) at Oceanside closely simulate conditions in a landfill. Other studies on large test cells under conditions comparable in scope and data collected were conducted by Ralph Stone and Robert C. Merz during 1964-1966 at the Los Angeles County Sanitation District's Spadra Landfill in Walnut, California.[27] Three test cells were initially constructed, one of which simulated golf course irrigation, the second simulated heavy (Seattle, Washington) rainfalls, and the third was aerated. The Spadra cells were larger in size (19-foot depth of solid waste, two-foot soil cover, and 70-foot by 130-foot in surface area) than the Oceanside cells. They were in a similar climate, and therefore suitable for comparison with Oceanside test cell data. Data from the two anaerobic Spadra cells will be used for comparison.

A study by Fungaroli[28] on landfill leachate pollution of subsurface water consisted of monitoring a laboratory lysimeter and landfill test plot in Pennsylvania during the period 1966 through 1968. The landfill test plot contained eight feet of solid waste, a two-foot soil cover, and was 50 feet by 50 feet in surface area (similar in size to the Oceanside cells). This test plot provides comparative data for different (Pennsylvania) climatic conditions.

Data from other landfills studied by Ralph Stone and Company, Inc. will also be cited for comparison.

a. Leachate Generation. The quantity of leachate obtained from the Oceanside test cells and estimated quantity of rain into the cells was shown in Figures VII-5 through VII-8. The insignificant amount of leachate obtained during the first 300 days since filling is similar to results reported by Fungaroli. During the first 400 days, he obtained 17 gallons of leachate which was significantly less than the 383 gallons of water added to his lysimeter. The initial moisture content of Fungaroli's lysimeter was 26.6 percent wet weight (36.2 percent dry weight), which was in the range for the three Oceanside field test cells. The leachate obtained from Oceanside test cells as a percentage of total moisture (solid waste moisture plus liquid in the sludge) was for Cell 1 - 0.07 percent, for Cell 3 - 1.9 percent, and for Cell 2 - zero. This is less than the 4.4 percent leachate recovered from water added to solid waste by Fungaroli. The ratios of weight of water added to dry weight of solid waste were: Fungaroli - 2.9; Cell 1 - 0.45; and Cell 3 - 0.71. This accounts for the greater percentage of leachate obtained by Fungaroli. Fungaroli attributed leachate production to the following landfill behavior characteristics.

1. Leachate from Solid Waste - The source is moist organic matter and other liquids in the waste released by decomposition and compaction.

2. Leachate from Channeling - Water running through interstitial channels thus short-circuiting the absorption mechanism.

3. Differential Advancement of the Wetting Front - The more absorptive areas of solid waste become saturated with moisture and then leachate may develop before the entire waste fill is saturated.

4. Saturated Wetting Front - When the entire waste fill reaches field moisture saturation capacity, water application and leachate quantities then become nearly equal.

It was probable that leachate from the Oceanside Cell 1 resulted from a combination of sludge-waste initial moisture and sludge channeling, and that leachate from Cell 3 resulted from subsequent differential settlement enabling rainfall drainage channeling to occur.

The leachate production from sludge admixed solid waste does not appear to differ in mechanism or quantity from that of normal solid waste leachate without sludge.

b. Leachate Characteristics. The range of landfill leachate characteristics reported from 11 landfills and lysimeters in California are given in Table VII-23. The climatic conditions and solid waste characteristics of the landfills in Table VII-23 are somewhat similar to those in Oceanside and will therefore serve as the primary basis for assessing the effects of sludge admixture. The Sonoma cells in Table VII-23 received high quantities of water and septic tank pumpings, and therefore should behave similar to the Oceanside test cells.

The range of pH values for landfill leachates given in Table VII-23 (excluding Sonoma) is 5.6 to 7.8, and for Oceanside Cells 1 and 3 the leachate pH ranged from 4.6 to 5.9. The Sonoma cells leachate pH value was also low (4.6 to 6.5). It appears that admixing sewage sludge (and septic tank pumpings) into solid waste can produce a more acidic leachate. The ages of the fills which data in Table VII-23 cover varies considerably from the age of the Oceanside test cells. Fungaroli reported lysimeter leachate studies at Drexel University with a fill age similar to the Oceanside cells. He obtained leachate pH values in the range 5.1 to 7.1. This agrees with the above

TABLE VII-23

SUMMARY OF LANDFILL LEACHATE CHARACTERISTICS

Leachate components	Landfill site			
	Riverside Landfill* (Bin #1)	Scholl Canyon Landfill+	Puente Canyon Landfill+	
			(2-13-62)	(3-5-62)
pH (units)	5.60-7.63	7.1-7.8	6.0	7.2
BOD_5	81-33,100	97-1200	2200	9200
Nitrogen - Kjeldahl	2.4-550			
Copper		3.3-24		
TDS		1452-2664	18,154	12,530
Alkalinity ($CaCO_3$)	730-9500	1259-2516	3260	5730
Calcium	115-2570	95-567	1340	560
Chloride	96-2350	67-344	1100	1330
Hardness ($CaCO_3$)	650-8120	1085-2075	5600	3260
Iron - total	6.5-305	5.4-260	135	150
Lead		3.3-5.0		.125
Magnesium	64-410	30-265	547	455
Manganese		200-1400	18	13
Nitrogen - NO_3		0-4.0	4.5	
Potassium	28-1860	6.5-13	340	700
Sodium	85-1805	87-115	620	810
Sulfate	39-730	1.0-40	1370	
Total phosphate	.16-29			
Zinc		20-1000		20

Note: All figures in mg/l unless otherwise noted.

TABLE VII-23 (CONT.)

SUMMARY OF LANDFILL LEACHATE CHARACTERISTICS

Leachate components	Landfill site: Mission Canyon Landfill[#] 3-18-68	Mission Canyon Landfill[#] 3-24-71	Central Disposal Site, Sonoma, California** Cell B	Cell C	Cell D	Cell E	Range of values
pH (units)	5.75	7.4	4.2-4.5	4.9-5.2	4.6-5.2	5.8-6.5	4.2-7.8
BOD_5	10,900	908	13,500-32,400	14,700-28,200	19,800-33,600	1020-1730	908-33,600
Nitrogen - Kjeldahl	104	92.4	20-170	174-800	182-864	350-558	2.4-864
Chloride	660	2355	998-1800	530-1200	920-1210	170-210	67-2350
TDS	44,900	13,409	15,970-42,270	9180-19,336	14,196-21,010	2186-2948	1452-44,900
Alkalinity ($CaCO_3$)	9860	8677	0-2360	0-5480	3050-5950	626-704	0-9860
Calcium	7200	216	200-2950	700-1600	900-1800	170-200	81-2950
Copper			3.6	0-0.6	0-0.4	.45	0-24
Hardness ($CaCO_3$)	22,800	8930					650-22,800
Iron - total	2820	4.75					4.75-2820
Lead			3.0	0-0.8	0-2.0	2.0	0-5
Magnesium	15,600	8714	320-924	200-760	360-600	120-150	30-15,600
Manganese							13-1,400
Nitrogen - NO_3			2.5-66	1.8-4.6	1.90-6.34	.87-1.0	0-66
Potassium	68	440	1500	560-845	727-910	24	6.5-1860
Sodium	767	1160	1325	550-950	860-1020	115	85-1805
Sulfate	1190	19		340-880	794-1040		1-1370
Total phosphate	.24	.65	0-83	9.8-41.9	17.8-79.2	.35-2.3	0-83
Zinc			140	22-42	30-95	.15	0.15-1000

Note: All figures in mg/l unless otherwise noted.

TABLE VII-23 (CONT.)

SUMMARY OF LANDFILL LEACHATE CHARACTERISTICS

* Report on the investigation of leaching of a sanitary landfill, State Water Pollution Control Board, Sacramento, California, Publication No. 10, 1954. (Robert C. Merz, Ralph Stone, et. al.)

\+ Sanitary landfill studies, Appendix A. Summary of Selected Previous Investigations, State of California, Department of Water Resources, Bulletin No. 147-5, July 1969.

\# T. M. Meichtry. Leachate control systems. Paper presented at the Los Angeles Regional Forum on Solid Wate Management, May 25, 1971.

** Test cells demonstration grant. EPA Grant No. 1-G06-EC-00351-01 AL. Central Disposal Site, Sonoma County, California. Current report.

higher pH values for normal landfills. The pilot test drum leachate analyses (see Chapter VI.C.7) agree with these results.

The range of BOD_5 values for leachate from normal landfills given in Table VII-23, except for the high range at Riverside, is significantly lower than the Oceanside Cells 1 and 3 and the Sonoma cells.

The quarterly comprehensive analyses of leachate from Oceanside Cells 1 and 3 were given in Table VII-7. The Oceanside cell analyses show values of copper, iron (total), lead, and manganese generally well below the lower limits of the data ranges for landfills shown in Table VII-23. Values of other leachate components showed no discernible difference.

c. *Gas Composition.* A comparison of gas composition in the Oceanside test cells with gas compositions reported by Merz and Stone is given in Figure VII-28. The CO_2 trends are quite similar, but CH_4 concentrations in the Oceanside test cells are lower than concentrations reported by Merz and Stone. The gas concentrations in the Oceanside test cells appear to follow typical trends for normal landfills. Fungaroli obtained similar patterns, but significantly lower concentrations; CO_2 increased to 45 percent at the lysimeter bottom and to 75 percent at mid-depth within 40 days after filling, and then decreased to 15 and 30 percent, respectively. Fungaroli obtained little CH_4, generally less than one percent by volume.

d. Temperature. Initial peak temperatures in landfills have been shown to be a linear function of the solid waste (and weather) temperature at the time of placement of the solid waste. This relationship, as illustrated by Farquhar, is given in Figure VII-29, which shows the Oceanside test cells and the Spadra (California) cells. The three Oceanside test cells fit the landfill temperature curve well, thus indicating that the liquid sewage sludge did not significantly affect the peak temperature behavior. Comparisons of temperature trends in the Oceanside test cells with the Merz and Stone Spadra cells are given in Figures VII-30 and VII-31. The temperature trends from the Oceanside cells are converging with the trends reported by Merz and Stone.

e. Settlement. A comparison of surface settlement trends as a percentage of initial depth is given in Figure VII-32 for the Oceanside and Spadra test cells. Settlement rates in the Oceanside cells were greater than in the Spadra cell during the first 100 days after filling. These different initial settlement rates are attributable to the original differences in the density of the Oceanside cells (623 to 640 lb per cu yd) and the Spadra cell (1,200 lb per cu yd). The total settlement during the study period for the Oceanside and Spadra cells were all within the range of 2 to 4 percent of initial depth. A review of landfill settlement at Coyote Canyon landfill in Orange County, California (about 30 miles north of Oceanside) indicated average annual settlements of 1.0 to 1.1 percent. Compaction density at Coyote Canyon is reported to be 1,200 lb per cu yd, which is identical to the Spadra cell. The Spadra cell received water at a rate triple the normal rainfall experienced at Coyote Canyon; thus the higher settlement at Spadra resulted.

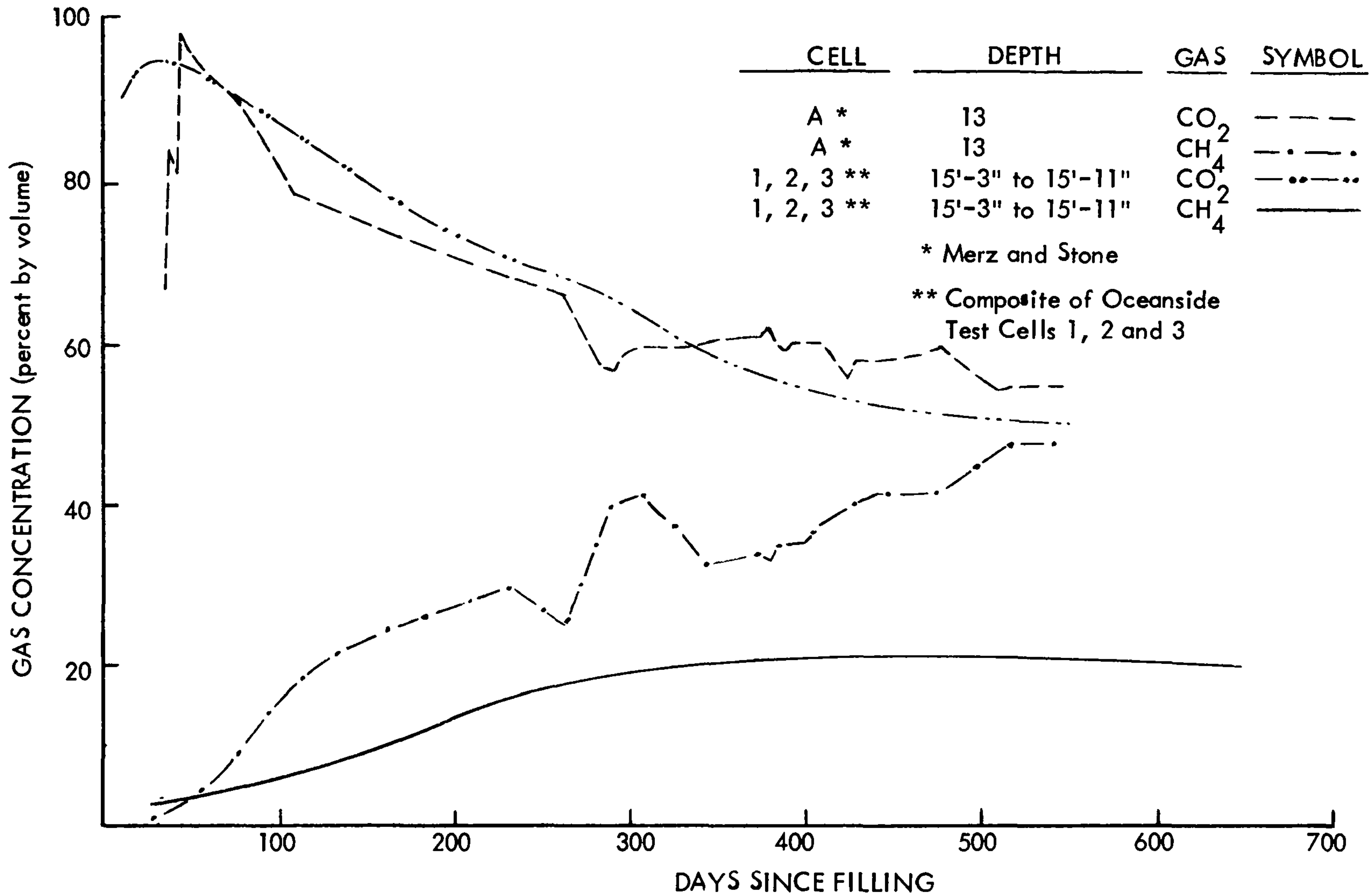
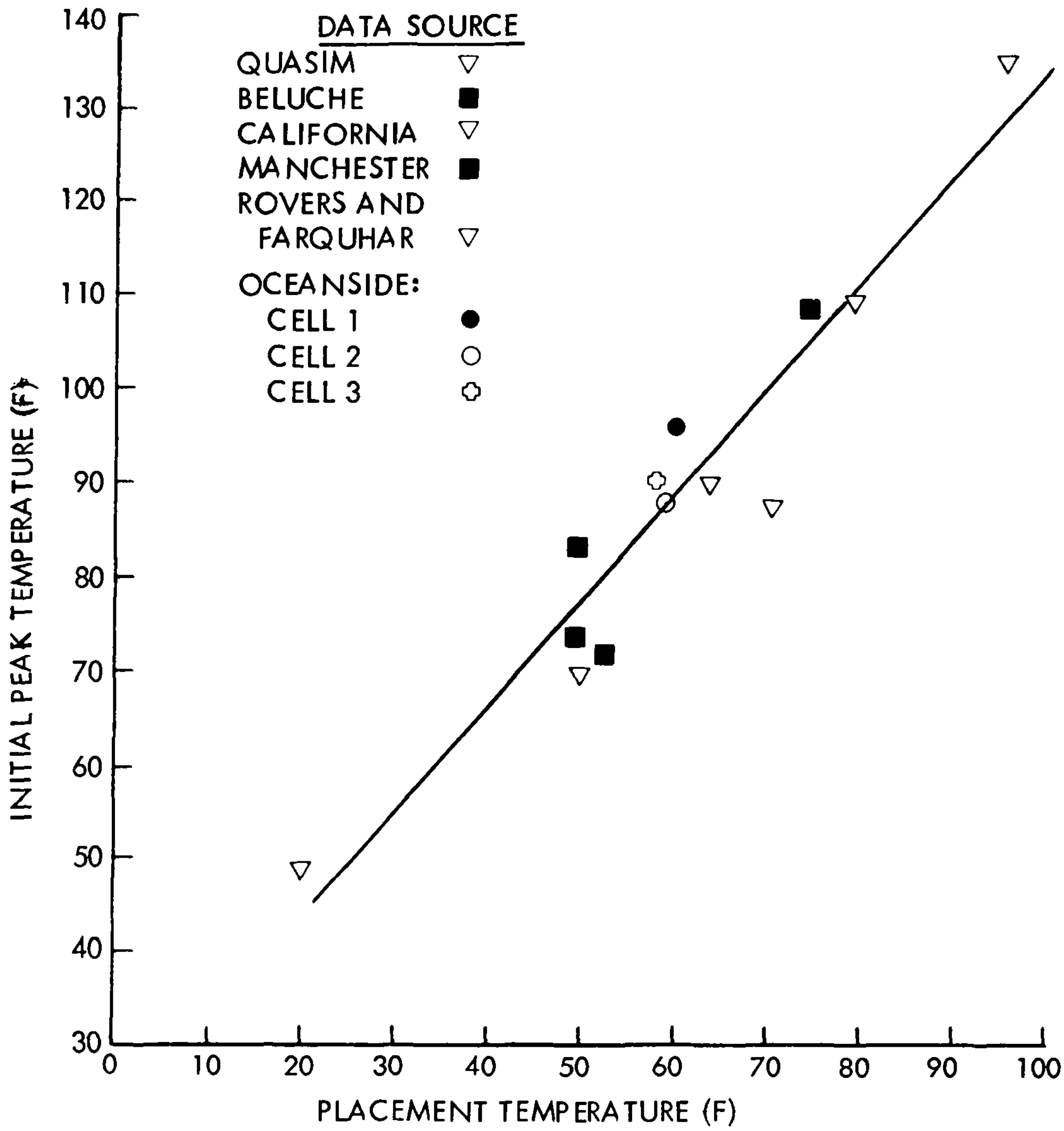


FIGURE VII-28
COMPARISON OF GAS
COMPOSITION IN OCEANSIDE
TEST CELLS WITH NORMAL SOLID WASTE



FROM: Farquhar, G. University of Waterloo, Department of Civil Engineering, Waterloo, Canada, presented at Engineering Foundation Conference, 1972.

FIGURE VII-29
RELATIONSHIP BETWEEN INITIAL PEAK TEMPERATURE AND PLACEMENT TEMPERATURE

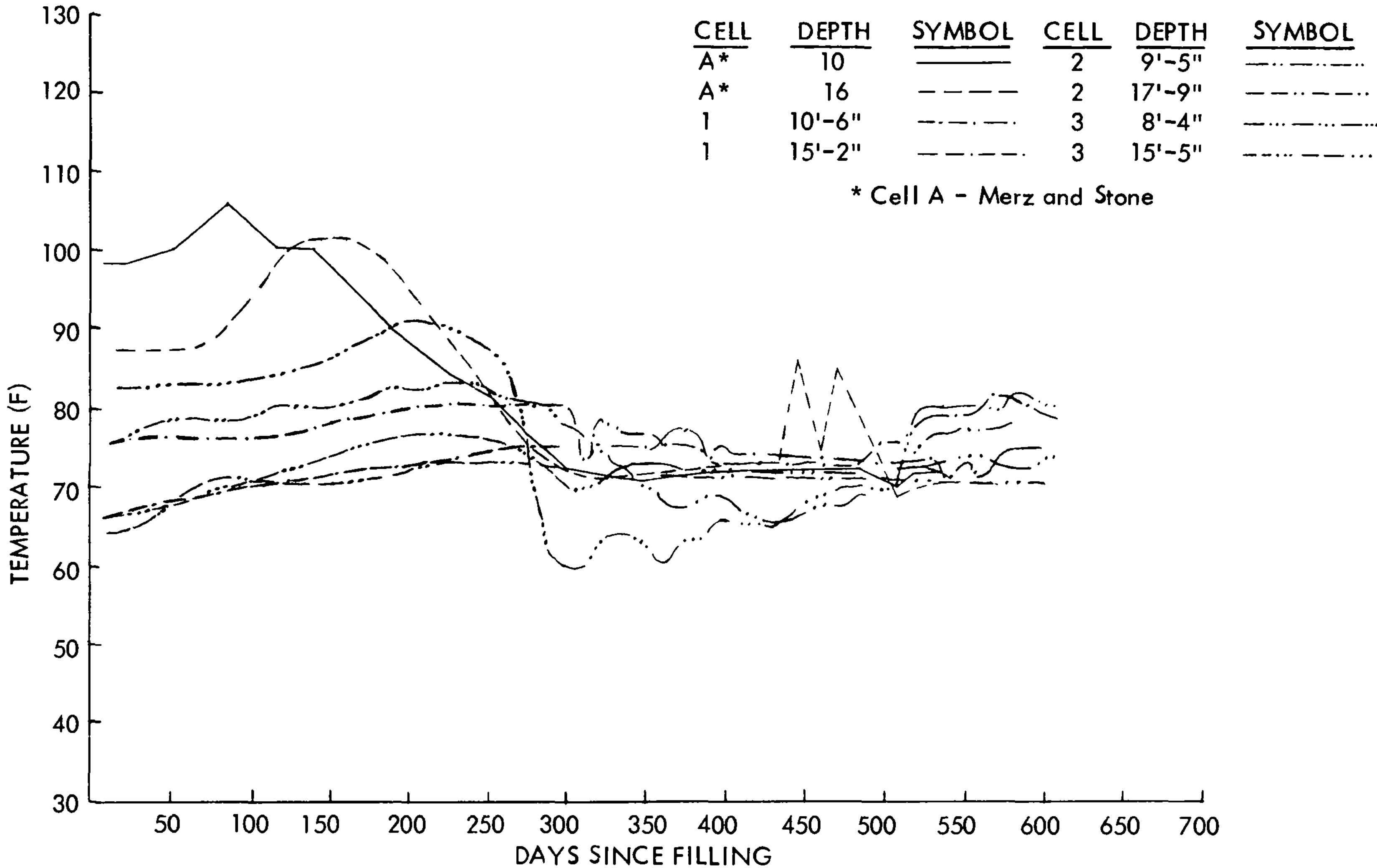


FIGURE VII-30
COMPARISON OF
TEMPERATURES

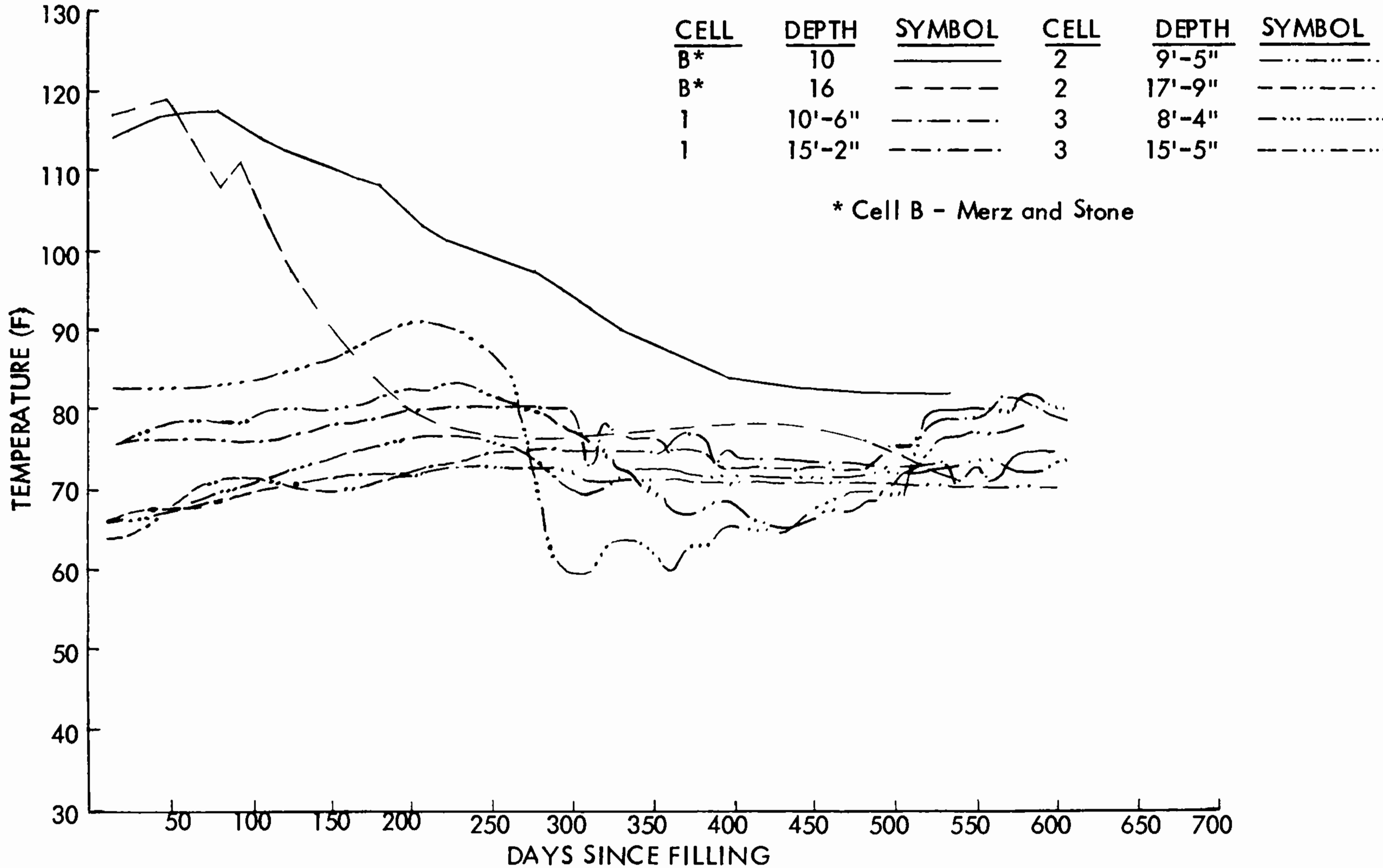


FIGURE VII-31
COMPARISON OF
TEMPERATURES

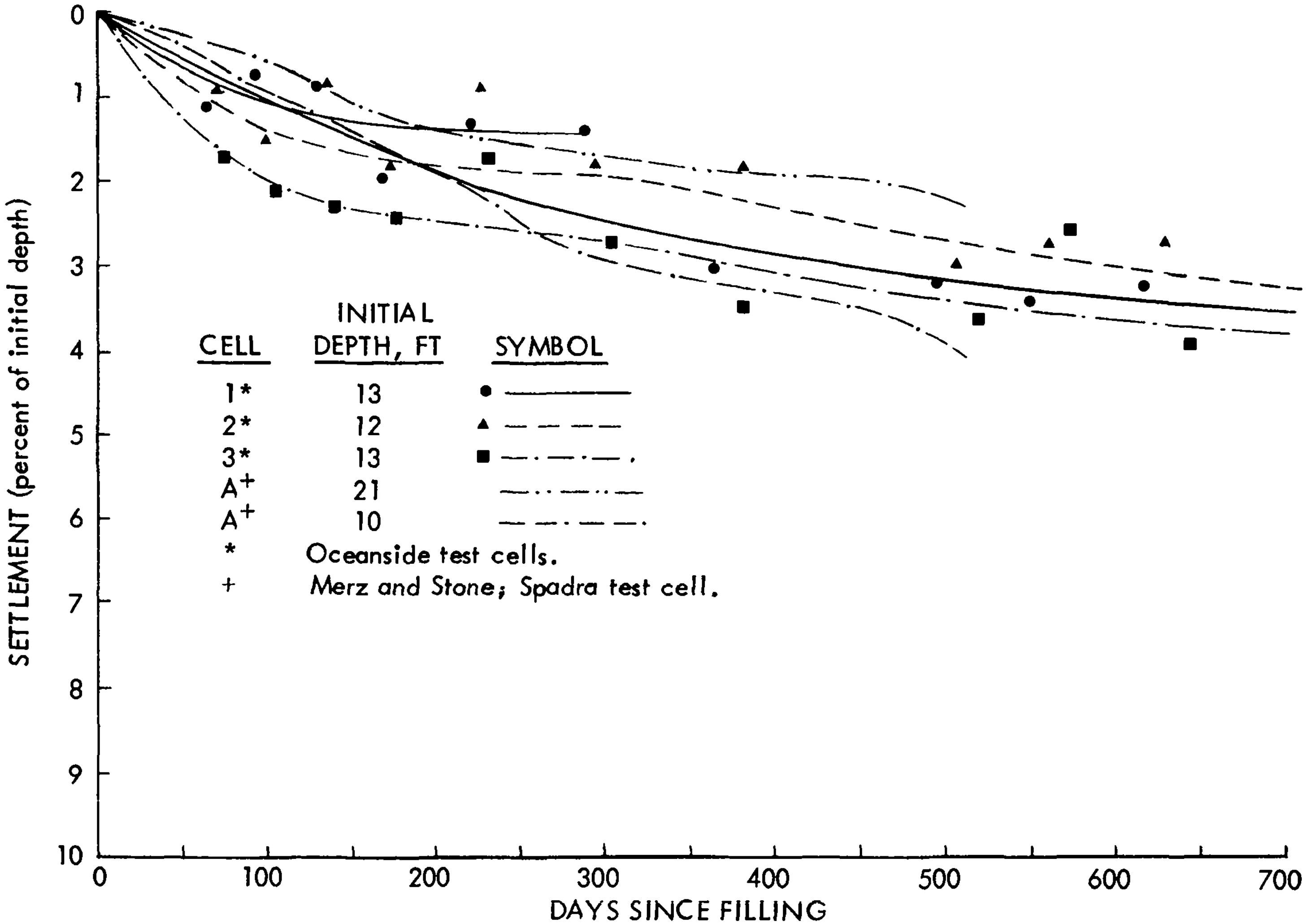


FIGURE VII-32
COMPARISON OF SETTLEMENT --
OCEANSIDE TEST CELLS AND NORMAL
LANDFILL CELLS

f. Microorganisms. There appears to be little or no difference between the pathogenic bacteria content of normal landfill solid waste and sludge-admixed solid waste. Since normal landfill solid waste is contaminated with fecal material (e.g., from disposable diapers, pet and other animal excrement, dead animals, etc.), no major difference in pathogenic bacteria types would be expected. The decrease in fecal organisms with depth and time is a common characteristic, possibly caused by temperature, anaerobiosis, or both. In short, sewage sludge-admixed solid waste is no more hazardous regarding pathogen content than normal landfill solid waste.

g. Summary. The significant differences noted between sludge admixed with solid waste (Oceanside cells) and normal landfills were that sludge-admixed waste had lower leachate pH, higher leachate BOD_5 values and higher Kjeldahl organic nitrogen. The higher BOD_5 values of Oceanside test cell leachate could be attributable to a high soluble organic content in the liquid sewage sludges admixed into the test cell solid waste. These sludge organics would be readily soluble in rainfall or other liquid passing through the fill. The higher Kjeldahl organic nitrogen in the Oceanside cell leachate obviously resulted from the high concentration of nitrogen compounds in the sludge.

The lack of significant differences in temperature, settlement and gas composition between sludge-admixed solid waste and normal landfill solid waste indicates that the effects of the sludge on these parameters are minimal.

VIII. FIELD DEMONSTRATION OF LANDFILL OPERATIONS AND LIQUID SLUDGE DISPOSAL

A. Purpose

The disposal of liquid digested sewage sludge into a sanitary landfill may not only create certain environmental difficulties but it may also present certain operational opportunities and challenges. Operational aspects to be considered are related to equipment, personnel, landfilling methods, soil cover techniques, compaction, drainage, leachate discharge, gas generation, etc. Landfill environmental nuisances which must be controlled include odors, litter, dust, flies (and other insect vectors), birds, rats (and other vermin), and fires.

The operational aspects of sludge disposal into a sanitary landfill were evaluated in special demonstration field studies conducted at the Oceanside landfills. The results obtained and the problems observed to date are presented and discussed in the following text. Site geology, soil and groundwater conditions are described in Appendix F .

B. Method of Study

1. Landfill Site. The preliminary landfill studies were conducted in a selected area at the old Oceanside sanitary landfill. These preliminary studies with liquid sludge were initiated in May 1971 and were continued through November 15 at which time the City closed its old landfill site and opened a new landfill site. The field study was interrupted for three weeks until sufficient deposited solid waste spreading area became available at the new landfill site. In February 1972 (at the start of the second year demonstration program), the City commenced disposing of all digested liquid sewage sludge generated at its three treatment plants into the municipal landfill. This full-scale demonstration operation permitted a comprehensive evaluation of the practical aspects of liquid sludge-solid waste landfill disposal.

2. Parameters Evaluated. The parameters evaluated in the field tests included: sludge and solid waste composition; sludge application techniques; solid waste fill/sludge admixture; personnel; equipment operation and maintenance; odors; gas emissions; blowing of litter and dust; presence of flies, birds, rats, and other vectors; and waste bio-degradation. Table VIII-1 is a summary of the landfill operation monitoring. The landfill monitoring data sheets are shown in Appendix B. A brief description of the various tasks performed through June 1972 is presented. A sample of seagulls at the landfill is shown in Photograph VIII-1a.

The sludge application methods evaluated included the use of different spreading techniques, application of different weight ratios of sludge to solid waste,

TABLE VIII-1
LANDFILL OPERATIONS MONITORING SCHEDULE

Task	Frequency	Performed by
Performance:		
Time and motion studies	Weekly	Ralph Stone and Company, Inc.
Analysis of sludge application effects	Weekly	
Landfill equipment O & M (time)	Weekly	Waste Disposal Department*
Environmental effects:		
Blowing litter and dust, odor, flies, vermin, birds	Daily	Waste Disposal Department*
Operating hazards	Weekly	Ralph Stone and Company, Inc.
Waste core samples (moisture content, decomposition)	Quarterly	Ralph Stone and Company, Inc.
Sludge application studies:		
Spreading sludge with and without soil and refuse cover	Continuously during the year	Waste Disposal and Sewer Depts.*
Spreading sludge on compacted/ uncompacted waste	Continuously during the year	Waste Disposal and Sewer Depts.*
Evaluations of different methods of sludge application (pumping, gravity feed, single nozzle hose, splash plates, etc.)	Continuously during the year	Ralph Stone and Company, Inc.
Temperature, gas sampling (H_2S)	Periodically during landfill studies	Sewer Department* and Ralph Stone and Company, Inc.

*City of Oceanside municipal departments.

a. SEA GULLS FORAGING ON SLUDGE-FREE SOLID WASTE.

b. TRUCK APPLYING LIQUID SLUDGE TO FLAT TEST AREA. NOTE SPREADING PLATES.

c. DOZER MOVING SLUDGE-WASTE ADMIXTURE.

PHOTOGRAPH VIII-1

INITIAL SLUDGE-SOLID WASTE FIELD TESTS

and deposition of various thicknesses of sludge on different solid waste landfill surfaces. Relatively simple, inexpensive methods for spreading trucked sludge over solid waste were demonstrated using direct discharge from the transportation truck. These were: gravity flow from a single 4-in. diameter pipe; gravity flow from similar piping using single and double splash plates; mechanical pumping through a standard fire hose to improve distribution; and gravity flow from a 4-in. diameter flexible hose mounted on an 8-foot boom.

The effect of fill construction on sludge handling capacity was evaluated through: a) application of liquid sludge to uncompacted and compacted waste, and completed landfill b) varying the slope of the fill surface from 1:2 to level; and c) building up the waste and earth cover into dikes to pool the sludge so that the solid waste could be directly discharged into the sludge pool. The effects of excessive moisture were determined by conducting operating tests during rainfalls.

Landfill equipment studies involved reviewing the records for operation and maintenance of the landfill tractor dozers. The City of Oceanside Waste Disposal Department operates two tractor dozers with straight buckets at its landfill, a CAT 977 and a 977 K. The 977 K serves as a backup. Random time and motion studies were conducted to determine the efficiency of the dozer in working the solid waste-sludge mixture under various disposal methods used. The major operating parameters considered were traction and load moving capability on the waste fill surface. Samples of equipment data sheets used in the field are presented in Appendix B. In addition to monitoring dozers, tests were made to evaluate the driving performance of a rubber-tired sludge tank truck while spreading sludge on the fill surface. In order to determine the effects of admixing sludge into solid waste on personnel health and safety, records of illness and accidents from the City of Oceanside were analyzed.

3. Filling and Spreading Operations. The demonstration operations at the old landfill consisted of an initial trial run and a subsequent "extended" operation. In the trial run, three truck loads of solid waste (about 25,000 lb) were unloaded in a flat section at the foot of the landfill working face. The wastes were worked by a CAT 977 K tractor dozer to a 1.5 foot depth within a 60 by 80 foot diked rectangular test area. A 1,250 gallon rubber-tired tank truck was used to apply the secondary digested sludge from the Buena Vista Treatment Plant by gravity feed through a double nozzle splash plate. The ratio of 1,250 gallons of sludge to three truck loads of waste was slightly less than the proportion in which these wastes are generated in Oceanside (1,750 gallons of liquid sludge per three truck loads of solid wastes). Photographs VIII- 1b and c show sludge application and waste-sludge working.

The "extended" field demonstration operation was conducted for seven months at the old landfill and for two months at the new landfill. A total of 30 days (about one per week) of sludge disposal operations were made, 11 of which were at the new landfill. During the tests, the temperature ranged from a low of 46 F to a high of 92 F and the wind intensity ranged from "calm" to "moderate". The temperature remained above 70 F until October 26, 1971; thereafter it was 70 F or lower until the end of the test program in January 1972. During this period, only one day of rainfall occurred when liquid sludge was disposed.

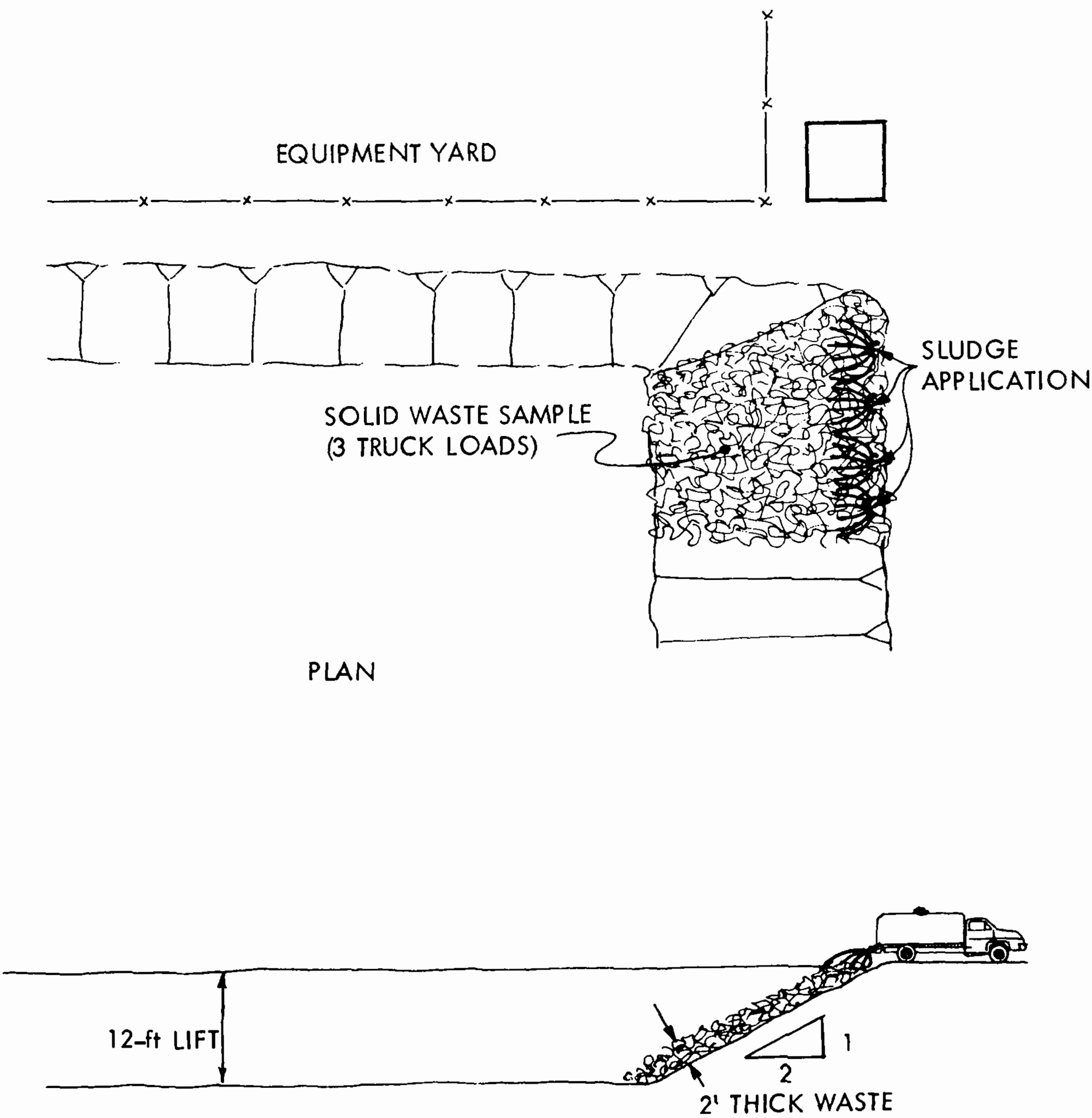
Initially, 1,250 gallons of sludge and two truck loads (32 cu yd capacity) of solid waste were applied to the test site once every week. After an additional two weeks, the weekly demonstration quantities were increased to 1,750 gallons of sludge and three truck loads of solid waste. These quantities were further increased to 3,500 gallons of sludge and six truck loads of solid waste per week.

Figure VIII-1 schematically describes the solid waste placement and sludge application. The solid waste was unloaded at the top of the fill slope, pushed onto the face of the slope, and worked by the dozer to a depth of about 2 ft. A variation of this procedure was also tested. It consisted of pushing the waste onto the slope without working to compact it. In all cases, the sludge was applied evenly across the top of the slope. A daily soil cover of about 6 in. was applied to the fill slope and a 1- to 2-ft soil cover was provided at the top of the slope on the flat portion of the fill lift.

During the full-scale operation at the new landfill site, sludge handling was initially on a two-day per week basis (Monday and Thursday). This was later increased first to three days per week (Monday, Wednesday and Friday), and then to five days per week. During the test period, the temperature ranged from 60 F to 78 F, the wind intensity varied from "calm" to "moderate," and showers occurred on four days. Other information pertaining to the operation at the new landfill is discussed below in connection with the results.

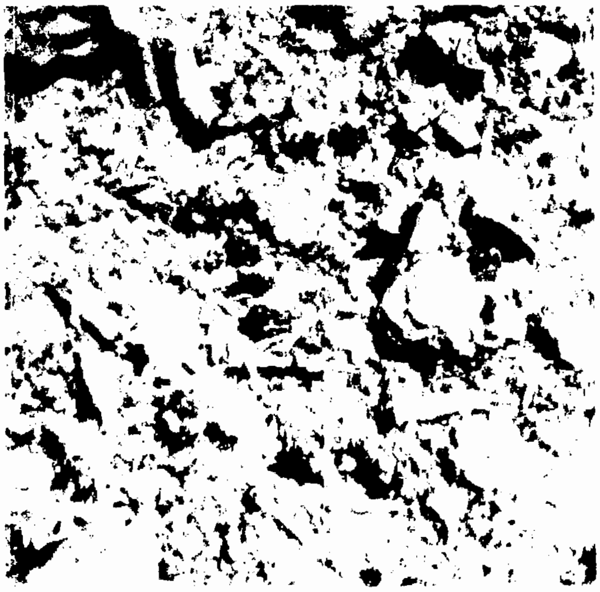
4. Core Sampling. Quarterly bore hole drilling was completed at the existing Oceanside demonstration landfill in areas representing three conditions: 1) the current working face with fresh admixed sludge-solid waste; 2) an older fill area that had received admixed sludge-solid waste; and 3) an older area that had received only solid waste. For the latter two fill conditions, areas were selected that were filled at about the same time as the three test cells. Each time drilling was conducted, bore holes for the latter two landfill conditions were drilled in the same place to obtain continuous data. Bore holes were drilled to a depth of 20 feet or to the bottom of the fill wherever feasible. Samples were taken at two-foot depth intervals. The drilling equipment, sampling methodology, sample analyses and coring observations were done as described in Section VII. B. 5. and Appendix A. Prior to backfilling the bore holes with the waste material removed, 10-foot long 0.25-inch I. D. polyethylene gas sample probes were placed into the holes as shown in Photograph VIII-2 c.

5. Vector Studies. Special studies of fly emergence were begun in August 1972. Dr. John H. Poorbaugh, Jr., Ph. D., Vector Control Specialist of the State of California Department of Public Health, Bureau of Vector Control and Solid Waste Management, assisted in providing guidelines by which to conduct the fly emergence studies. Mr. Harvey I. Magy, Southern California Region, of the same State Department, also assisted in the fly test program and provided 14 modified eye-gnat emergence traps

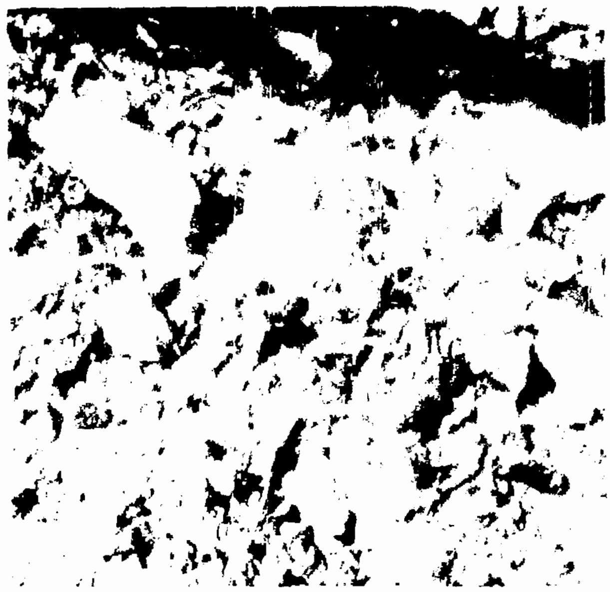


APPLY THE SEWAGE SLUDGE ACROSS THE TOP OF THE WASTE SURFACE.
WORK THE WASTE UNTIL IT IS 2 FT THICK ON THE SLOPE AS SHOWN.

FIGURE VIII-1
SOLID WASTE AND
SLUDGE PLACEMENT



a. CORED SLUDGE-WASTE ADMIXED FILL MATERIAL.



b. CORED SOLID WASTE FILL MATERIAL (NO SLUDGE).

c. PLACING GAS PROBE IN BORE HOLE.

PHOTOGRAPH VIII-2

CORE MATERIALS AND GAS PROBE

to conduct the study. Mr. Daniel Bergman, Vector Ecologist with the San Diego County Department of Public Health, assisted in setting up the fly emergence test plots and traps, and helped monitor and identify flies on the first two tests completed in August and September 1972. The routine monthly tests were conducted by Ralph Stone and Company, Inc. and Oceanside Waste Disposal Department personnel thereafter.

To conduct the studies, two separate test plots were prepared each month, approximately 15 feet by 15 feet in area, with a three-foot depth of solid waste. One area received digested liquid sewage sludge, while the second area contained only solid waste. A six-to twelve-inch moist cover soil layer was applied and compacted as is done on the regular landfill. Four fly emergence traps, each three feet by three feet wide and one foot high, were placed three to five feet apart on each of the two test plots (eight traps total). A schematic of the fly emergence traps is shown in Figure VIII-2. The emerging flies were attracted to the light in the glass jar in which they were trapped and collected daily, counted and identified by species. Flies entering the jar were prevented from leaving by the screen. A tightly packed two-inch seal of soil was placed along the bottom edges of each trap to prevent light entrance and fly escape. Emergence tests were conducted for two-week periods to cover the maximum possible time for egg hatching, larvae stages and emergence as adult flies.

C. Results and Discussion

1. Initial Trial Run at the Old Landfill. The following are highlights of the results of the initial trial run at the old landfill:

a. It was impractical to drive a heavy rubber-tired tank truck over newly deposited solid wastes to distribute sewage sludge. The truck had difficulty traversing the waste and broke a rear axle on its third pass. It was towed through the waste thereafter by the CAT 977 K until it unloaded the 1,250 gallons of sludge. A total of two passes was made in each of three paths across the waste.

b. It was observed that approximately 50 sea gulls were feeding on the exposed solid waste prior to applying the sludge. After application none of the sea gulls would feed on nor traverse the wastes coated with digested dewage sludge. Some sparrows approached the sludge but did not appear to feed in the sludge admixture.

c. The earthy odor of well-digested sewage sludge was observed during sludge disposal and for approximately 30 minutes thereafter within 30 feet of the area. When the liquid soaked into the solid waste and the sludge surface dried, the odor was reduced until it was noticeable only when standing next to the waste. The normal solid waste landfill pig-pen odor was apparently masked by the earthy odor of the digested sludge.

d. The test area was subsequently worked into the face of the regular landfill by pushing and working up the slope of the fill face.

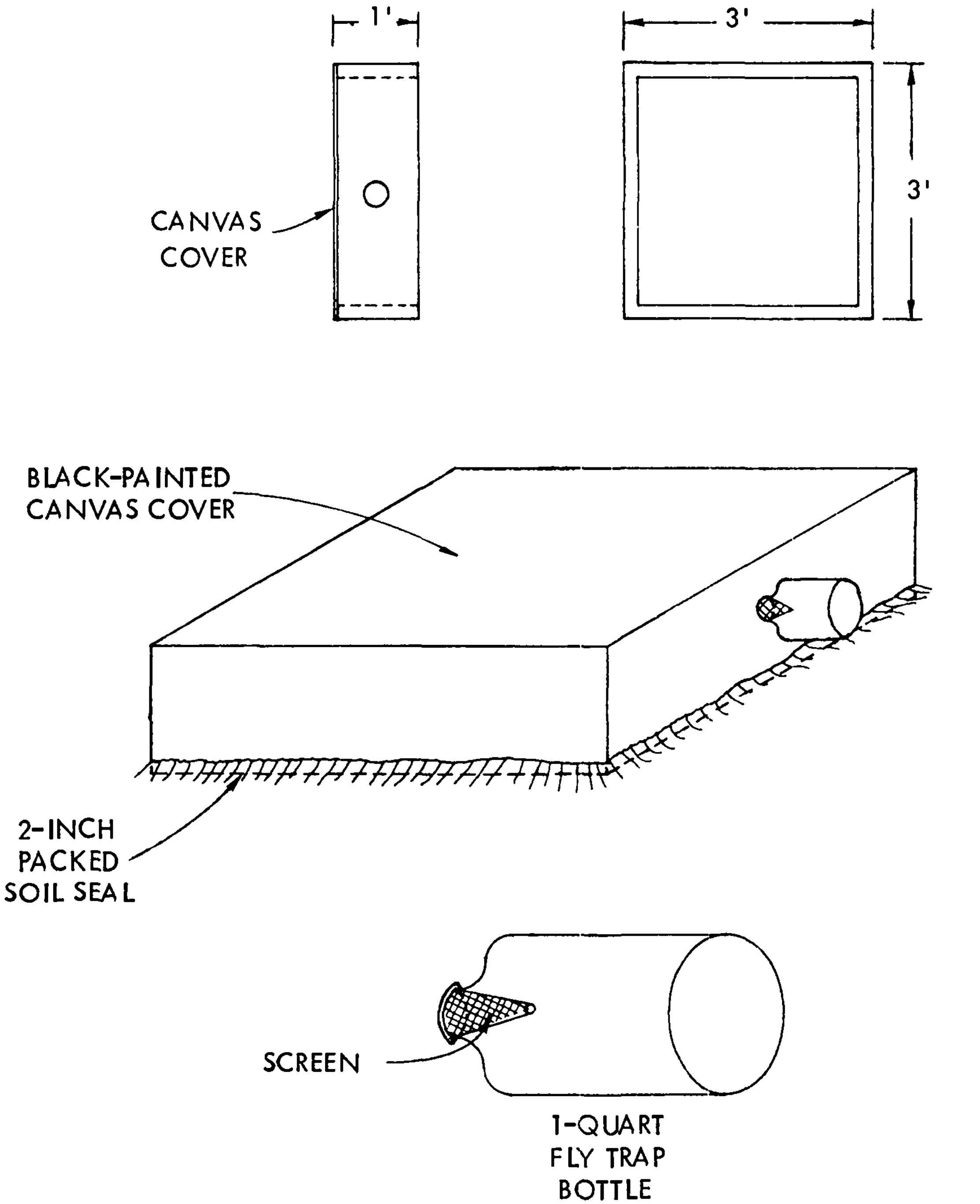


FIGURE VIII-2

SCHEMATIC OF FLY EMERGENCE TRAPS

e. When the test waste-sludge mixture was removed from the test area it was observed that about 70 percent of the surface area was dry. Very little sludge bypass drainage or run-through had occurred.

2. "Extended" Field Tests. The results of the extended demonstration tests are presented below in summary form.

a. Equipment Operation. The CAT 977 K Dozer landfill equipment operator reported it appeared easier to work the solid waste-liquid sludge mixture than regular waste. It compacted better and gave off less dust. Some slippage of the dozer tracks occurred occasionally when working on the slope face in areas where sludge pools had formed.

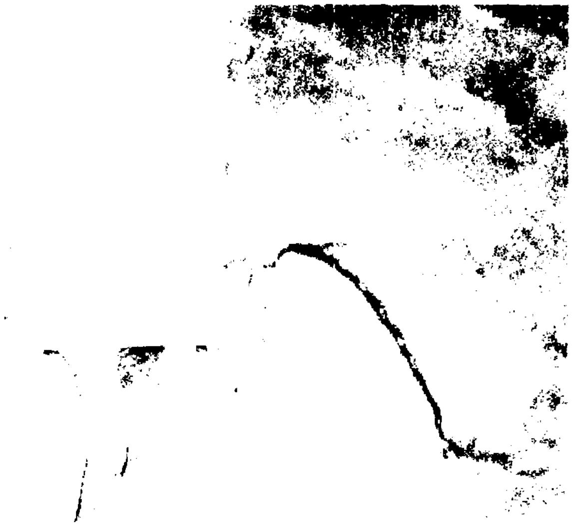
b. Sludge Disposal. It was difficult to achieve uniform liquid sludge spreading from the single 4-in. gravity-feed tank truck discharge pipe. The concentrated high velocity flow discharge tended to channelize the solid waste, and the sludge bypassed along to the bottom of the new lift-old lift interface, creating minor runoff. A new splash plate assembly was ordered for the large 3,500 gallon tank truck, but it did not arrive until full-scale sludge disposal was under way. At times as much as 50 or 60 gallons of sludge bypass runoff was observed from one 3,500 gallon tank-truck sludge load. The runoff was contained by earthen dikes along the foot of the new fill face. (See Photograph VIII-3 a.)

In order to prevent runoff, solid waste dikes were formed on the sloped base of the working face of the fill. The dikes proved effective if the sludge was worked into the solid waste by the tractor dozer to achieve suitable admixture and compaction. Additional solid waste was admixed into the sludge pools behind the dikes. It was found difficult to work the solid waste immediately with pooled sludge due to poor dozer traction. After the liquid sludge soaked into the solid waste for about one hour, however, it was easily worked.

After spreading the liquid sludge, steam was observed in an uncovered area one to two feet below the landfill surface. Routine observations were made once a week for 33 days during the seven-month preliminary field demonstrations. The landfill operator's observations are tabulated in Appendix E and summarized below.

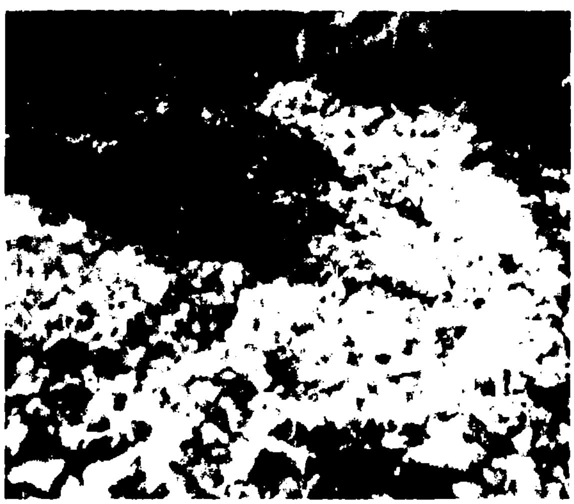
c. Odor. Earthy sewage sludge odors were noted 5 days (17 percent); normal landfill odors, 13 days (43 percent); and no odors, 12 days (40 percent) of the time.

d. Blowing Litter. Windy days in Oceanside are rare. Blowing litter was reported during only one day (3 percent of the observed period) in the landfill site. It occurred during a day when a moderate wind was blowing. The sludge which covered the surface of the test area apparently held the waste down. Water truck irrigation was used to restrain litter from blowing in the regular landfill area. It appears that the sludge can provide an effective control for blowing litter in the working landfill face, but not for the truck roadway and dumping access areas.



a. GRAVITY SLUDGE DISCHARGE.

b. GRAVITY SLUDGE DISCHARGE THROUGH A FLEXIBLE HOSE.



c. SOLID WASTE DIKES FOR SLUDGE CONTAINMENT.

PHOTOGRAPH VIII-3

FIELD DEMONSTRATION
SLUDGE DISPOSAL IN THE LANDFILL--
SLUDGE APPLICATION METHODOLOGIES

e. Animals and Flies. Sea gulls were the most abundant animals observed foraging in the solid waste. They were observed in the sludge test area on five occasions, but only on wastes that were not coated with sludge. A few small birds were noted in the sludged area on two days and lizards on one day. Flies were always present in the sludge-solid waste admixtures.

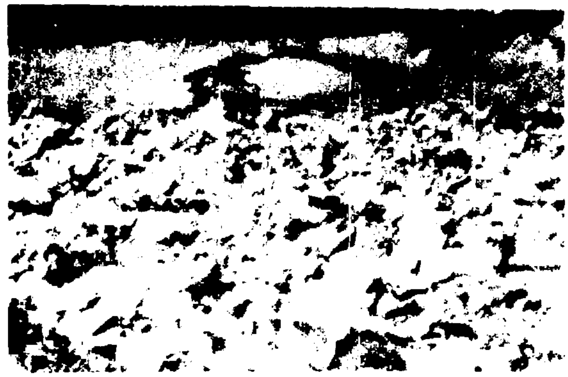
f. Sludge Spreading. Poor spreading and solid waste admixing were noted on two days (6 percent) and some sludge runoff occurred on six days (18 percent of the observations over the seven-month period).

3. Full-Scale Demonstration at the New Landfill. The major problems encountered in the full-scale demonstration wherein all of the City's liquid digested sludge was disposed into the available solid waste were those of sludge admixture and operator acceptance. The field observation data is included in Appendix E and summarized below.

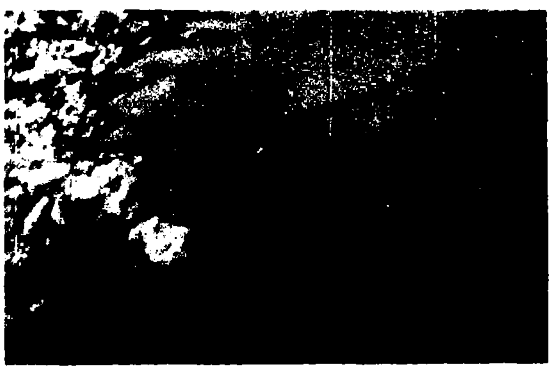
a. Sludge Runoff. Initially when the sludge was hauled and spread on a two-days per week basis, some appreciable runoff occurred. Significantly smaller quantities of runoff, however, resulted when better admixture was provided by a 5-days per week sludge spreading schedule. The use of solid waste diking to prevent sludge runoff was tested. The effort, however, did not prove completely satisfactory since it was difficult to work the pooled sludge-solid waste mixture until most of the liquid had been absorbed by the solid waste. When the runoff volume was large (50 to 100 gallons) an earth dike was maintained below the foot of the new fill face slope to contain runoff and allow it to be absorbed into the older lift. (See Photographs VIII-3c, and VIII-4 a, b, and c.)

A third approach to the problem of runoff control which was investigated in June 1972 was that of reducing the slope of the fill working face. It appeared, however, very difficult to get adequate spreading of the sludge onto a flat surface with gravity discharge unless the truck is actually driven over the fill surface. This is not practical with normal truck equipment and, hence, provides an added cost. A modification of the flat-spreading approach which was also tested (and found undesirable) consisted of digging trenches through the soil cover on top of the completed fill lift. The sludge was discharged into these trenches, and the trenches were subsequently ripped through to allow for sludge spreading. This procedure, however, resulted in a severe odor nuisance and complaints were received from a school 300 feet away. Direct liquid sludge spreading on the flat surface of a completed fill using small berms worked well with a 3- to 6-in. depth sludge application drying in a day or less. (See Photograph VIII-5.) Pumping through movable pipes would be a superior way of spreading sludge on flat or other surfaces. However, it costs more than gravity feed. Costs for sludge pumping are incorporated into the truck transportation costs described in Chapter IX.

a. LANDFILL FACE SLUDGE-SPREADING FLOW PATTERN.



b. SLUDGE RUNOFF.



c. FLIES AND FLY MAGGOTS ENTRAPPED IN SLUDGE RUNOFF.

d. SLUDGE-SOLID WASTE ACCUMULATION IN DOZER TRACK DRIVE.

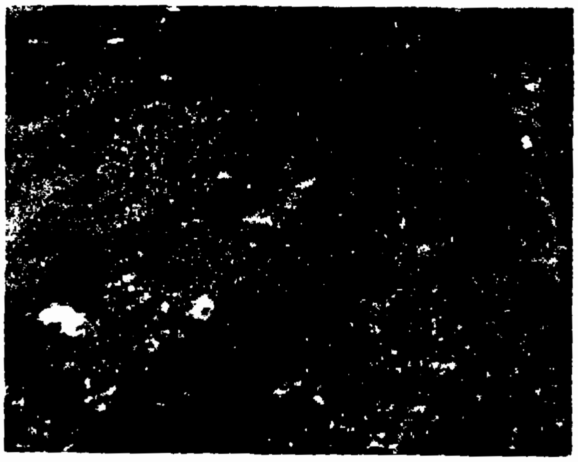
PHOTOGRAPH VIII-4

SLUDGE DISPOSAL FIELD OBSERVATIONS

a. DOZER RIPPING LANDFILL LIFT COVER SOIL PRIOR TO SLUDGE APPLICATION.

b. SLUDGE APPLIED TO COVER SOIL OF LANDFILL LIFT.

c. LIQUID SLUDGE ON LANDFILL LIFT COVER SOIL.



d. DRIED SLUDGE ON LANDFILL LIFT COVER SOIL.

PHOTOGRAPH VIII-5

SPECIAL TESTS OF SLUDGE ADMIXTURE INTO FILL COVER SOIL FOR DRYING

During July and August of 1972, an eight-foot truck boom suspending a four-inch diameter eight-foot long flexible hose was used to spread sludge by gravity feed. Although the spreading was improved over single nozzle discharge, handling the hose was found to be troublesome due to sludge spillage. Also, sludge odor emanated from the hose after disposal. During 10 days of observation in July 1972, runoff occurred on seven days in quantities of 20 gallons or less.

In September 1972 and thereafter, a double splash-plate assembly was used for gravity spreading of sludge. The double splash-plate distributed sludge over an estimated area about 12 feet wide and six feet deep. The double splash-plate assembly was superior in spreading sludge more uniformly over the surface of the working face of the solid waste fill. The truck had to be moved a minimum of three times across the top of the working face to avoid channeling and resultant runoff when using the double splash-plates.

Prior to September 1972, when cover soil was not placed on the working face at the end of each day, the sludge truck began disposal at about 6 A.M. With the initiation of daily cover soil placement on the working face in September 1972, there was no longer any exposed solid waste to admix with the sludge until the first load of solid waste was disposed. This resulted in a change in the sludge disposal schedule. During operation without daily soil cover no external environmental problems with odor or public health were encountered, although a large fly population was observed.

Initially, the sludge disposal truck operated from 5:30 A.M. to about 1 P.M. It was found that all of the sludge was disposed onto one-third to one-half the daily solid waste quantities. Daily solid waste disposal began primarily after 10 A.M. and continued up to 7 P.M. On the revised sludge disposal schedule, sludge was taken to the landfill after 10 A.M. after the first several loads of solid waste were disposed. A reduction in sludge runoff was noted in that runoff quantities generally never exceeded 50 gallons.

Other steps taken to minimize sludge runoff, control vectors and conserve cover soil included the following: 1) providing better solid waste compaction; 2) reducing the width of the landfill working face by up to one-third. The working face was normally 150 to 200 feet wide on a side; this was reduced to about a 30-foot width, 70- to 80- foot length and 12- to 15-foot lift. The resultant proportionally thicker and denser solid waste layers provided additional absorptive capacity and better dozer footing conditions. Sludge runoff has been negligible with the smaller working face. Four tank-truck loads of sludge (14,000 gallons) can be readily disposed daily without significant runoff if scheduled for unloading in proportion (about 0.6 lb sludge per lb solid waste) to solid waste deliveries. The few gallons of sludge runoff at the toe of the working face, if present, are easily covered with refuse or dirt as part of the normal sanitary landfill activity. Since the working face is on a prior lift, for runoff into ground or surface water to occur, liquid must pass through the absorbent solid waste in lower lifts. A working face slope of from 25 to 30 percent was considered best for minimizing runoff and providing suitable dozer traction.

b. Sludge Disposal During Rainfall. Observations were made on two days of rainfall. On November 7, 1972, 0.21 inches of rain fell at the Oceanside landfill. Sludge was deposited on the uncovered face of solid waste which had been thoroughly wetted by the rainfall. Within a couple of minutes after sluge unloading began (800 gallons unloaded), some sludge runoff was observed at the toe of the working face. Sludge unloading was suspended and the truck moved to a newly started working face to unload the remaining 2700 gallons. No runoff occurred from the new working face.

On December 4, 1972, 0.36 inches of rain fell. The landfill was inspected for runoff. It was observed that rainfall drainage from two storm drain pipes, one from the adjacent elementary school and another from the adjacent junior high school track field, flowed uncontrolled over the landfill access roads and onto the fill working face. It is not uncommon to have a "design" storm in the semi-arid Oceanside area which floods out the normally dry San Luis Rey River. The point of this discussion is that even though the Oceanside annual rainfall is relatively low (12 in./year), the individual storm intensity periods may be excessive and, hence, a very fair test of the sludge absorption problems during wet weather was obtained. Corrective action was subsequently taken by grading to re-route the runoff along earthen channels paralleling the edge of the canyon and away from the landfill. Three loads of sludge were disposed on December 4. Some runoff was observed along the toe of the working face toward the end of the third unloading operation. The runoff consisted of a diluted mixture of sludge and rain water.

Obviously, if the solid waste fill is brought to field capacity with enough rainfall the liquid sludge runs off more easily. Since runoff did not occur on December 4, 1972 until the third load of sludge, it appears that the solid waste must be saturated to near its moisture absorption capacity before runoff results.

A number of solid waste disposal trucks became stuck in mud on the landfill unloading area during heavy rain, but no problems occurred with the sludge truck.

c. Odors. Daily surveillance for odor during the period from May 1 through July 31, 1972 indicated the in-situ presence of normal refuse odors for 36 percent of the time and the presence of earthy digested sludge odor for 19 percent of the time. No specific odors were identified during the remaining 45 percent of the observations (see Appendix E for data). During 1973, odor surveillance conducted while sludge disposal was taking place indicated an earthy odor 90 percent of the time. During a warm period in the last week of October 1972, the landfill working face was in a position about 80 feet directly below the adjacent Mission Elementary School cafeteria. A complaint was received by the Oceanside Public Works Director from the school authorities that a "musty odor of old unwashed dirty clothes" pervaded the cafeteria. The landfill working face was promptly moved to another section of the canyon site; no other public complaints have been received before or afterwards. The area below the school cafeteria was filled with solid waste thereafter only when school was not in session. Observations by the Ralph Stone and Company, Inc. Field Engineer verified the existence of a strong "pig pen" type of odor from restaurant garbage, etc. at the landfill when the complaint was received.

d. Operator Problems. During April and May 1972 (second and third months of the demonstration) the dozer operator continually reported strong noxious odors being emitted from the sludge-admixed fill. These reports were investigated by the Consultant's Field Engineer and other staff personnel who conducted qualitative and quantitative tests. Hydrogen sulfide field tests were made, and gas samples were collected for analysis by gas chromatography. The field tests and gas chromatographic analysis for hydrogen sulfide proved negative. It is possible that the odors noted by the dozer operator may have been from a load(s) of partially digested sludge which had been inadvertently disposed. Also, the operator routinely ate his lunch directly in the fill face area and he was advised to eat away from the fill. The dozer operator was examined by medical doctors and found to be healthy. The operator was offered the opportunity to transfer his work and be a truck driver in the refuse collection system. He has elected to continue to operate the dozer tractor full time on the demonstration landfill. The experience with the dozer operator illustrates a key factor in liquid sludge disposal into a sanitary landfill. Special training and further incentives may be required to obtain employee acceptance of working with sludge in the proper manner.

e. Blowing of Litter. From May 1 to July 31, 1972 small amounts of blowing litter were reported at the landfill on three days (7 percent of the observations). Blowing litter was not reported for 1973 observations. Water was applied to the fill working face and over unloaded solid waste primarily when sludge was not being spread. Water application during full-scale sludge disposal in 1972 averaged 8,318 gallons per week (34.7 tons per week), or 1,540 gallons per day (6.4 tons per day based on 5.4 days per week). Water application in 1971 prior to sludge disposal into the landfill averaged 22,360 gallons per week, which indicated a 63 percent reduction in the amount of water used in conjunction with full-scale sludge disposal. Water application rates showed no relationship to weather. Sludge was deemed unacceptable for controlling litter and dust on the access road and solid waste unloading areas. Thus, some use of water is necessary on these latter areas, especially toward the end of the working day after the daily sludge quantity is disposed.

f. Observations of Birds and Animals. Sea gulls were the most common animal life observed at the landfill, being sighted on 16 observation days (36 percent); up to 100 gulls were observed on two occasions. Pigeons, blackbirds, sparrows, rabbits, rats and squirrels were also occasionally sighted; up to 30 pigeons and a like number of crows were observed on separate days. The birds and other animal life initially avoided foraging on solid waste areas covered with wet sewage sludge. It was observed after about seven months of full-scale sludge disposal (about mid-September 1972) that sea gulls and other birds had adapted and were foraging in the wet sludge-waste admixture after the dozer had worked the waste. While foraging, the birds appeared to avoid the particles of waste that were completely covered with wet sludge. After working the refuse, the dozer exposed underlying solid waste that was not covered with wet sludge, thus providing the birds with unoffensive foraging areas. On one occasion, four sea gulls were observed walking in pooled sludge. The sea gulls by December 1972 had overcome their initial aversion to foraging in the wet sewage sludge. Thereafter hundreds of sea gulls were commonplace at the landfill.

g. Fly Studies. Flies are not usually associated with digested wet sewage sludge per se, but it was observed that they will forage in solid waste wetted with sludge. (See Photograph VIII-4 c which illustrates flies and maggots entrapped in sludge runoff.) Observations indicate that houseflies and their larvae do not prefer sludge, but they forage in it and thereby are exposed. Counts of the density of flies in the sludge-solid waste fill indicated densities of five to ten flies per square foot. Since the entire landfill was used for sludge disposal, data on solid waste fill was not obtained.

Special inquiries indicate that no increase in flies was observed or reported from the adjacent school or residential housing projects. No migration of flies was observed. It is known that houseflies are attracted by the odors of food, and in this case the landfill appeared to maintain their attention. Blowflies and houseflies are reportedly wide-ranging (1/2 to 6 miles) and, therefore, the potential for migration may exist if there is a lack of suitable food items at the landfill. Daily compacted earth cover is needed to maintain sanitary landfill conditions.

Flies were collected for identification on three occasions. In August 1972 flies were collected over a 14-day period in fly emergence traps placed on top of covered solid waste. These flies were identified by State of California Department of Public Health Ecologists to be: Cochliomyia macellaria, three specimens; Phaenicia sericata, five specimens; Phaenicia cuprino, 10 specimens; Ophyra leucostoma, two specimens; and Sepsidae, one specimen. In June 1973 flies were collected on the fill face in a sludge-solid waste area and in an area with solid waste only. These flies were identified by the same personnel to be: Phaenicia sericata, 32 specimens; Cochliomyia macellaria, 12 specimens; Musca domestica, 14 specimens; and other species, 13 specimens on the solid waste fill face. Also Phaenicia sericata, 33 specimens; Musca domestica, 12 specimens; Chrysomyza demandata, 5 specimens; and other species, 1 specimen on the sludge-solid waste fill face.

Flies collected in traps placed on covered solid waste for two tests performed in June and August 1973 were identified as: Phaenicia sericata, 54 specimens; Musca domestica, 3 specimens; Haematobia irritans, 3 specimens; Muscina stabulars, 4 specimens; Drosophila immigrans, 6 specimens; Ophyra leucostoma, 2 specimens; and Chrysomyza demandata, 2 specimens.

These species observed at the landfill were different from the flies found in the test drums (see Chapter VI). No large domestic houseflies were found in the test drums, only varieties of small flies the size of gnats.

The August 1972 fly collection was the first of seven fly emergence studies. In theory, a six-inch layer of well-compacted soil will prevent fly emergence from solid waste fill without regard to the composition of the waste fill (in this case, admixture with wet sewage sludge). The efficacy of the cover, however, may vary with local soil type, compaction technique and soil moisture content.[29] The large number of flies which emerged on the August 1972 test was not anticipated. No provision was made to kill flies when they entered the collection jars, nor were they collected daily.

It was suspected that ants may have removed flies that died in the collection jars, and that flies escaped through the disturbed dirt seals. As a result of the above, there are no quantitative results for the first emergence test.

Additional fly emergence tests conducted in November and December 1972 with eight to twelve inches of cover soil resulted in no fly emergence. It was observed that fly larvae were in the solid waste disposed during these tests, although the fly population at the landfill was several orders of magnitude less than during the August-September 1972 tests (the peak fly season). The lack of emergence was attributed to a combination of better compacted soil cover, and a more hostile (cooler) landfill environment that was less conducive to propagation of fly larvae and adults.

Four more fly emergence tests were conducted during 1973. In the June test, solid waste and sludge covered with soil produced 30 emergent flies, while soil-covered solid waste only yielded 16 flies. In August, both types of test cells produced 31 emergent flies. The final two tests of 1973 were control tests. In October, uncovered solid waste admixed with sludge yielded 116 flies, but soil-covered sludge-solid waste produced no emergent flies. In November and early December, a test was run in which uncovered solid waste was compared with uncovered sludge-solid waste; the test cells produced 122 and 60 emergent flies, respectively.

Based on the emergence tests results, the following speculative conclusions may be drawn:

1. Six to eight inches of sand as soil cover will reduce, but not eliminate, fly emergence.

2. The cover soil available at the site (coarse to fine sand) is a rather poor barrier. During the peak fly season, emergence occurred despite six to eight inches of compacted soil.

3. Climatic conditions affect fly emergence by affecting the number of existing flies (i.e., fly seasons). Soil cover which may be ineffective in August may be effective in October due to the smaller number of flies in October.

4. Sewage sludge admixed with solid waste has no detectable influence on fly propagation and emergence.

h. Landfill Accidents. A summary of observed accidents and injuries incurred by Waste Disposal Department personnel and others at the Oceanside landfill is given in Table VIII-2. It is apparent from the nature and causes of injuries that none were attributable to the disposal of sewage sludge.

i. Disinfection.[1] Sewage sludge can be disinfected by storage as well as by various physical, chemical and biological processes. Heating, chemical addition, and drying of raw sludge can also provide disinfection. Pathogenic organisms include

TABLE VIII-2
LANDFILL OPERATING PERSONNEL INJURIES

Date	Nature of injury	Cause of injury
1969		
Oct	Sprained right arm and shoulder.	Stepped on end of can in a trash pile and other end of can tripped him.
1970		
Aug	Twisted right ankle.	Stepped on ridge at landfill and twisted ankle.
Oct	Stepped on nail (left foot).	Guiding truck back to dump and stepped on nail.
Oct	Injured right knee.	After washing dozer he started to climb on, slipped on step, hitting knee on tracks.
Oct	Sprained ankle.	Sprained ankle getting off dozer.
1971		
Jan	Sprained knee.	Sprained knee getting on and off dozer.
Apr	Blow on side of head (right). (Sludge disposal initiated.)	Hit on side of head with lever of rear truck door when opening it.
Nov	Pulled muscle of left shoulder.	Pulling cables and wires from dozer tracks.
Nov	Twisted right knee.	While doing some plumbing, wrench slipped and he fell on knee, twisting it.
Dec	Injured back of right hand.	Injured hand while closing gate at end of day.
1972		
Apr	Pain in lower abdomen (right).	Hit himself on right lower abdomen with lever of tailgate on dump truck.
May	Mashed little finger (left).	Caught little finger between throttle lever and spring on dozer (he was being trained on dozer).
July	Sprained right thumb.	Opening door of truck, lever hit thumb, injuring it.
Aug	Chest.	Pressure caused door to hit him in chest while opening back door of truck.

TABLE VIII-2 (CONT.)
LANDFILL OPERATING PERSONNEL INJURIES

Date	Nature of injury	Cause of injury
1972		
Aug	Bruised 2 fingers (left hand).	While operating dozer ran over some steel cable and piece of cable hit him on left hand.
Aug	Stepped on nail (right foot).	Cleaning out track and stepped on nail.
Oct	Bruised skin (left leg).	Left his post at gate and climbed on dozer to see operator service it. Slipped off track bruising left leg. (Sludge not noted as cause of slip.)

bacteria, viruses, protozoa, worms, and other microorganisms. (The following paragraph is quoted from Reference 1.)

"A study of the survival of E. coli in digested primary sludge showed that they survived for 7 weeks at 37 C and for 2 weeks at 22 C. The coliform organisms apparently disappeared because of competition from other microorganisms better adapted to the digestion environment.[30] Disease organisms such as typhoid-dysentery bacilli, polio virus, anthrax, ova of parasitic worms, and brucella have been throught to have a rapid mortality rate due to their sensitivity to the unacceptable digestion environment. One study where raw and digested sludge was exposed to 55C for two hours resulted in 100 percent destruction or inactivation of Ascaris lumbricoides ova.[31] Keller reported that thermophilic digestion destroyed all ova of parasitic worms and cysts of amoebae parasitic to man in 24 hours.[32]"

Studies completed to determine pathogenic bacteria counts present in solid waste without sewage sludge have indicated that bacteria populations vary widely between samples. Total viable coliform densitites ranged from $3.4 (10)^5$ to $5.1 (10)^7$ organisms per gram of solid waste, and fecal coliform in the same samples ranged from $1.5 (10)^4$ to $8.1 (10)^6$ organisms per gram in samples from eight solid waste disposal systems studied by Environmental Protection Agency personnel. The presence of fecal coliform groups in large numbers indicates extensive normal contamination of solid waste by fecal matter of either human or animal origin.[33]

While the existence of pathogenic bacteria in solid waste is generally known, the exposure of landfill personnel to the pathogens has not been quantified. It is not known if pathogenic bacteria or viral densitites in Oceanside municipal solid waste are in the range of the high densities noted above. In the absence of quantitative data, an indicator of hazard may be illnesses incurred by landfill operating personnel due to exposure to solid waste-borne pathogens.

No illnesses of landfill personnel have been attributed to the landfill disposal of sewage sludge and solid waste throughout the study. No illnesses were reported in the literature or in the Ralph Stone and Company, Inc. nationwide survey on sludge disposal into landfills.

4. Auger Sampling. The results of bore samplings completed quarterly beginning July 1972 are discussed in the following paragraphs. Each auger sampling program provided one bore hole each in: freshly placed sludge-solid waste up to 14 days old; sludge-solid waste placed within one month of the test cell completion; and solid waste only placed within one month of test cell completion.

a. Temperature Profiles. The temperature profiles by depth from the cover soil surface are given in Tables VIII-3 through VIII-5. The average temperatures in the freshly placed sludge-solid waste bore hole were significantly higher than in the other bore holes. Steam was observed escaping from the bore holes in freshly placed fill during the first two drillings. Average temperatures in the older fill without sludge (see Table VIII-5) were higher than in older fill with sludge (see Table VIII-4). One explanation for this may be that the higher moisture (see Tables VIII-9 through VIII-11) in the fill with sludge tended to keep temperatures lower. In Table VIII-5, during the November 1972 drilling, the first 12 feet of fill was newly filled with sludge; the 12- to 20-foot depths were old fill without sludge. The old fill had a higher average temperature than the newer fill above. Under each waste-fill condition, it is evident from Tables VIII-3 through VIII-5 that ambient temperatures had influenced the fill temperatures down to a depth of four to six feet. Even so, the average temperature in the two bore holes in the older fill did not decrease with ambient temperature.

b. Organic Content. The organic contents by depth are given in Tables VIII-6 through VIII-8. The average organic contents are very similar for all three bore holes. No trends were evident over time or by depth in the fill material.

The organic content of the cover soil was apparently rainfall dependent. The higher organic contents were detected in the winter months; summer months produced lower organic contents.

Soil samples from the landfill bottom and an intermediate lift (see Tables VIII-6 to VII-8) indicate organic contents significantly greater than found in the respective cover soils. Also, bottom soil organic content (see Table VIII-8, day 263 at the 12-foot depth) showed this same characteristic. This could have resulted from leaching of organic materials from the overlaying sludge-waste fill, or sludge runoff during landfilling.

c. Moisture Content. Moisture contents in the bore samples are given in Tables VIII-9 through VIII-11. The average moisture content in old sludge-solid waste fill had the greatest average moisture content. Old solid waste fill had the lowest average moisture content. No consistent trend in moisture content by depth was evident.

Moisture contents in the cover soils increased as a result of rainfall in the week prior to sampling in November 1972. Moisture contents in bottom soil and intermediate lift soil were well below moisture saturation levels for fine sandy soils of 42.3 percent dry weight (see Table IV-2). Bottom soil in fresh sludge-waste had a maximum moisture content of 28.4 percent in the November 1972 borings. Since this occurred one week after 2.63 inches of rainfall fell, and the average moisture content for the bore hole was higher than during previous sampling in fresh sludge-waste, it appears that rain water infiltration occurred. Since the bottom soil was not saturated in any of the above cases, it also appears that water has not infiltrated to the bottom to any significant extent, further suggesting that leachate has been at most minimal.

TABLE VIII-3

LANDFILL BORE HOLE TEMPERATURE PROFILE - FRESH SLUDGE-WASTE FILL (0 - 2 WEEKS OLD)

Depth, ft below soil surface		Temperature (F) Days since landfilling completed * Jul 72 0-7	Oct 72 0-7	Nov 72 14	Jun 73 7-14	Aug 73 0-4	Oct 73 0-7	Dec 73 0-7
Ambient air		81	77	80	66	71	--	54
Soil	0				74			54
	2	89	86	68	87	82	78	62
Solid waste-sludge	4	103	88	68	82	85	84	63
	6	116	104	72	90	84	86	72
	8	122	109	77	86	81	85	69
	10	104	108	80	90	84	90	68
	12	119	114	79	81	BOF #	84	70
	14	124	112	BOF #	86		89	
	16	109	115		83		87	
	18	118	113		85		90	
	20	116	109		BOF #		89	
	22	116	111				89	
	25		109					
Average +		115	108	75	86	83.5	86	68

* Approximate number of days. + Average for solid waste-sludge. # BOF = bottom of fill.

TABLE VIII-4
LANDFILL BORE HOLE TEMPERATURE PROFILE - SLUDGE-WASTE
FILLED MARCH 1972

Depth, ft below soil surface	Temperature (F) Days since landfilling completed * Jul 72 140	Oct 72 208	Nov 72 276	June 73 461	Aug 73 535	Oct 73 598	Dec 73 654
Ambient air	77	72	66	65	70	--	67
0				72		70	55
Soil	88	71	59	72	80	74	67
2				79			
Solid waste-sludge 4	92	86	62	79	90	77	78
6	89	84	69	74	89	80	76
8	78	88	81	74	98	81	78
10	82	87	86	81	100	78	No sludge 90
12	71	86	89	75	85	79	94
14	74	88	92 / BOF #		90		92
16	74	81		73	95	78 / BOF #	90
18	75 / BOF #	79		76	94		88
20		73		83	95		88
22					82 / BOF #		
24				85			
27				80 / BOF #			
Average +	79	82	79	78	92	78	86

* Approximate number of days. + Average for solid waste-sludge. # BOF = bottom of fill.

TABLE VIII-5
LANDFILL BORE HOLE TEMPERATURE PROFILE - SOLID WASTE FILLED
JANUARY 1972

Depth, ft below soil surface		Temperature (F) Days since landfilling completed * Jul 72 195	Oct 72 263	Nov 72 321	Jun 73 506	Aug 73 530	Oct 73 743	Dec 73 699
Ambient air		78	74	80	63	70	--	67
Soil	0				74	80	70	62
	2	84	2	New sludge-waste 71	74		82	64
Solid waste	4	89	86	76	74	77	83	73
	6	90	82	87	77	80	86	78
	8	96	86	88	73	79	87	79
	10	95	80 BOF #	87	67	80	88	88
	12	77		91 ++	74	80	89	84
	14	106 BOF #		83	72 BOF #	79	90	89
	16					82	93	94
	18			92		80	90	82
	20			94 Refusal		79	80 BOF #	86
	24					82 ++		
Average +		92	83	85/90 **	73	80	87	84

* Approximate number of days.
\+ Average for solid waste-sludge.
\# BOF = bottom of fill.
** Sludge waste temp/waste only temp.
++ Intermediate lift cover soil.

TABLE VIII-6
LANDFILL BORE HOLE ORGANIC CONTENT - FRESH SLUDGE-WASTE FILL (0-2 WEEKS OLD)

Sample depth, ft below soil surface		Organic content, percent dry wt						
		Days since landfilling completed *						
		Jul 72	Oct 72	Nov 72	Jun 73	Aug 73	Oct 73	Dec 73
		0-7	0-7	14	7-14	0-4	0-7	0-7
Soil	0	2.0	2.0	5.9	3.8	2.0	2.1	2.9
	2						44.8	14.2
Solid waste-sludge	4	29.4	63.0	50.7	26.7	29.3	23.6	15.4
	6	36.3	56.1	56.2	9.8	13.8	26.7	30.2
	8	50.0	59.7	32.5	44.3	20.6	22.2	28.6
	10	45.6	21.5	33.8	31.7	20.8	25.5	51.0
	12	16.2	50.3	40.9	6.3	2.5	26.9	30.9
	14	26.2	63.4	7.4 ** BOF #	20.9		54.1	29.6
	16	34.7	18.4		3.5		25.5	23.1
	18	28.9	55.8		1.3		37.8	19.1
	20	26.5	60.0				41.3	14.6
	22	26.9	31.7				2.3** BOF#	
	25		27.0					
Average +		32.1	46.0	36.9	18.1	17.4	31.5	26.9

* Approximate number of days. # BOF = bottom of fill. ** Bottom soil under fill.

+ Average for solid waste-sludge.

TABLE VIII-7
LANDFILL BORE HOLE ORGANIC CONTENT - SLUDGE-WASTE
FILLED MARCH 1972

	Sample depth, ft below soil surface	Organic content, percent dry wt — Days since landfilling completed * 140	208	276	461	535	598	654
Soil	0	3.2	3.2	2.4	2.2	13.2	2.2	2.7
	2						30.0	14.8
Solid waste-sludge	4	30.5	6.9	44.2	65.9	54.0	37.5	9.6
	6	23.8	19.2	13.8	20.8	52.8	71.8	13.4
	8	25.0	19.4	50.3	10.5	16.0	38.7	21.7
	10	27.0	30.4	48.0	59.0	23.5	45.2	3.5
	12	25.3	30.1	55.7	27.3	48.3	23.4	28.9
	14	18.3	45.6	13.3 BOF #	5.5	43.5	2.4 ++ BOF #	37.3
	16	29.3	36.8			21.9		32.1
	18	38.2 BOF #	8.0		17.9	37.4		22.1
	20		6.1 ++		30.2	20.2		13.4
	24				29.7	10.2		
	27				6.0			
Average +		27.2	22.5	37.6	27.3	32.8	43.3	20.2

* Approximate number of days. # BOF = bottom of fill. ++ Bottom soil under fill.
\+ Average for solid waste-sludge.

TABLE VIII-8
LANDFILL BORE HOLE ORGANIC CONTENT - SOLID WASTE FILLED JANUARY 1972

Sample depth, ft below soil surface		Organic content, percent dry wt — Days since landfilling completed* 195	263	321	506	580	643	699
	0				2.6	1.35		
Soil	2	1.9	1.9	3.7		4.0	2.8	2.3
							8.9	11.0
Solid waste-sludge	4	43.2	45.6	Sludge-waste 58.8	19.4	61.5	33.7	5.1
	6	42.6	33.7	56.7	26.1	55.7	15.9	17.6
	8	36.2	20.7	79.6	19.6	48.7	38.3	27.4
	10	39.9	7.3	29.7	11.6	22.9	63.8	14.3
	12	31.5	7.3++ BOF #	19.1	5.9	35.1	5.2**	6.7
	14	30.7		8.7**	3.0	53.2	7.0**	
	16	31.1 BOF #		40.4		54.8	4.1**	
	18			42.5		61.1	40.6	
	20			Refusal		66.5	35.4	
Average +		36.4	22.9	56.2/27.7 ##	14.3	43.0	38.0	14.2

* Approximate number of days.
\+ Average for solid waste-sludge.
\# BOF = bottom of fill.
** Soil-intermediate lift cover soil.
++ Bottom soil under fill.
\## Sludge waste %/waste only %.

TABLE VIII-9
LANDFILL BORE HOLE MOISTURE CONTENT - FRESH SLUDGE-WASTE FILL (0-2 WEEKS OLD)

Sample depth, ft below soil surface		Moisture content, percent dry wt						
		Days since landfilling completed *						
		Jul 72	Oct 72	Nov 72	Jun 73	Aug 73	Oct 73	Dec 73
		0-7	0-7	14	7-14	0-4	0-7	0-7
	0							
Soil		6.1	6.1	14.5	3.1	6.6	6.1	8.9
	2						122.0	25.3
Solid waste-sludge	4	36.4	9.9	46.7	45.3	20.8	91.0	28.5
	6	26.9	55.6	52.7	29.9	15.0	23.1	46.9
	8	20.3	48.6	68.1	113.7	19.1	39.0	48.0
	10	14.3	25.8	52.1	55.6	14.8	44.8	79.1
	12	25.3	47.3	35.0	10.7	4.8	27.0	55.6
	14	59.2	33.3	28.4 ** BOF #	39.8		55.5	37.5
	16	55.7	32.6		11.9		67.4	25.2
	18	70.6	39.1		4.4		86.0	20.8
	20	65.5	27.0				57.4	27.6
	22	63.1	24.5				7.6** BOF #	
	25		22.2					
Average +		43.7	33.3	47.2	38.9	14.9	54.6	41.0

* Approximate number of days.

\+ Average for solid waste-sludge.

\# BOF = bottom of fill.

** Bottom soil under fill.

TABLE VIII-10
LANDFILL BORE HOLE MOISTURE CONTENT - SLUDGE-WASTE
FILLED MARCH 1972

	Sample depth, ft below soil surface	Moisture content, percent dry wt — Days since landfilling completed *						
		140	208	276	461	535	598	654
	0							
Soil	2	7.1	7.1	15.3	8.1	21.5	6.4 89.5	7.0 35.1
Solid waste-sludge	4	36.8	13.9	90.4	142.0	53.9	67.1	11.4
	6	67.2	16.8	25.9	92.4	62.8	88.6	14.6
	8	67.9	16.1	75.3	22.7	15.9	97.1	33.7
	10	55.5	28.4	62.2	80.1	40.5	110.0	5.7
	12	93.6	19.9	59.4	46.2	48.6	69.8	46.3
	14	59.9	34.8	98.8 BOF #	12.3	21.8	12.2 ++ BOF #	32.4
	16	56.3	37.5			26.4		28.5
	18	25.1 BOF #	22.4		43.1	67.7		26.2
	20		14.5		51.1	43.6		24.5
	24				39.8	22.4		
	27				8.5			
Average +		57.8	22.7	68.7	53.8	40.4	86.5	24.8

* Approximate number of days.
\+ Average for solid waste-sludge.
\# BOF = bottom of fill.
++ Bottom soil under fill.

TABLE VIII-11
LANDFILL BORE HOLE MOISTURE CONTENT - SOLID WASTE
FILLED JANUARY 1972

	Sample depth, ft below soil surface	Moisture content, percent dry wt — Days since landfilling completed *						
		195	263	321	506	580	643	699
	0							
Soil	2	6.2	6.2	7.8	9.6	3.2	8.3 7.1	6.6 13.6
Solid waste	4	42.0	24.1	Sludge-waste 43.0	27.5	166.0	22.8	8.2
	6	19.4	30.4	35.1	41.4	127.0	25.5	13.4
	8	23.3	24.8	54.1	45.6	66.6	50.7	28.8
	10	36.0	13.2	22.8	27.5	21.5	40.7	19.0
	12	15.3	6.5++ BOF #	7.6	15.4	33.2	15.5**	14.0
	14	21.3		31.7	6.5	36.0	19.4**	
	16	21.2 BOF #		17.7		61.0	8.3**	
	18			28.4 Refusal		137.0	25.5	
	20					38.1		
	24					18.2	36.8	
Average+		25.5	19.8	38.8/21.4 ##	27.3	64.6	33.7	16.7

* Approximate number of days.
\+ Average for solid waste-sludge.
\# BOF = bottom of fill.
** Soil-intermediate lift cover soil.
\++ Bottom soil under fill.
\## Sludge waste %/waste only %.

d. Moisture Absorption. Moisture absorption capacities remaining in auger samples having the highest and lowest in-situ moisture content, and representative of the range of organic contents, are given in Table VIII-12. The data in Table VIII-12 are given in percent dry weight which is convertible to pounds of water per pound of solid waste by dividing by 100. The additional absorption capacity remaining in solid waste samples collected during the summer was greater than for samples taken in the rainy season. The data appear to be random with regard to moisture contents, material, and depth of the sample. This was most likely due to the variability in the organic composition of solid waste in the core samples.

The additional moisture absorbed varied from a low of 0.104 lb water per lb of solid waste (dry wt) to a high of 2.43 lb per lb. These values fall outside the laboratory predicted range of 0.6 to 1.8 per lb (dry weight).

e. Bore Sample Leachate BOD_5. The samples used to determine the moisture absorption capacities in Table VIII-12 were used to generate leachate for the BOD_5 analyses presented in Table VIII-13. The BOD_5 values apparently vary according to the type of organic material and bacteria present, but are not correlated with organic content (see Tables VIII-6 through VIII-8).

f. Odor. Odors were determined during drilling in terms of strength and type at each two-foot sample depth interval. Odors were generally moderate to strong in fresh sludge fill, and weak to moderate in old fill with and without sludge. Odors in both the old fill areas generally became weaker with increasing fill age (on each subsequent sampling).

The most prevalent type of odor detected was classified as sour, the second most common was sweet and the third major odor was of normal landfill. The landfill odor was predominant in the area without sludge, as might be expected.

g. Appearance. In general, the material in fill with sludge was partially or highly agglomerated and required a screwdriver or other sharp probe to dislodge samples from the auger drill bit. The fill material that did not receive sludge was found to be loose and powdery; waste constituents were easily separated and identified. The agglomeration in bore holes with sludge appeared to result from the sludge which was slightly to moderately moist and tended to form a pasty bond with soil and waste particles. Occasionally, random lumps of moist black sludge were encountered.

h. Color. The color of materials in freshly placed fill was perhaps dirty, but natural (as-received). The colors of textiles, plastic, rubber, leather, wood, metal, glass and ceramics were natural, i.e., unaffected by the landfill environment. Food and paper at times appeared bleached or otherwise altered in color in the fill with sludge. Grass, leaves,and tree and shrub prunings were often bleached or more intense in color. Since these color changes often occur when vegetation is stored other than in a landfill, it is not certain what changes in vegetation could be attributed to the landfill.

TABLE VIII-12
MOISTURE ABSORPTION CAPACITY OF SELECTED CORE SAMPLES

Moisture content, percent dry wt — Days since landfilling completed/depth, ft

Fresh sludge-waste	0-7					0-7			14	
	4	8	14	16	20	4	6	22	6	12
Sample moisture content	26.9	14.3	55.7	70.6	63.1	9.9	55.6	24.5	68.1	28.4
Additional moisture absorbed	55.9	71.4	75.1	65.5	90.6	64.3	32.5	15.9	27.3	30.7
Total moisture at saturation	82.8	85.7	130.8	136.1	123.7	74.2	88.1	40.4	95.4	69.1

Sludge-waste - old fill	140				208			276	
	4	10	12	18	4	10	16	4	12
Sample moisture content	36.8	55.5	93.6	25.1	13.9	28.4	37.5	25.9	98.8
Additional moisture absorbed	95.8	60.0	70.7	56.8	30.5	27.1	23.1	10.4	36.7
Total moisture at saturation	132.6	115.5	164.3	81.9	44.4	56.0	60.6	36.3	135.0

Solid waste only	195			263		321		
	4	8	12	4	10	6	8	12
Sample moisture content	42.0	23.3	15.3	30.4	6.6	54.1	7.6	31.7
Additional moisture absorbed	136.9	81.4	145.0	20.4	35.3	21.2	29.1	28.9
Total moisture at saturation	178.9	104.7	160.3	50.8	41.8	75.3	36.8	60.6

TABLE VIII-12 (CONT.)
MOISTURE ABSORPTION CAPACITY OF SELECTED CORE SAMPLES

Moisture content, percent dry wt — Days since landfilling completed/depth, ft

Fresh sludge-waste	7-14			0.4			0-7		0-7		
	8	12	13	4	10	IS*	2	6	CS+	4	8
Sample moisture content	113.7	10.7	4.4	20.8	14.8	4.8	122.0	23.1	6.6	8.2	28.8
Additional moisture absorbed	55.6	10.1	15.8	113.6	92.0	22.1	135.0	78.0	24.2	16.5	24.9
Total moisture at saturation	169.3	20.8	20.2	134.4	106.8	27.9	258.0	102.0	30.8	24.7	53.7

Sludge-waste - old fill	461			535			598				655		
	4	15	27	8	18	BS#	CS+	4	10	BS#	CS+	10	18
Sample moisture content	142.0	12.3	8.5	15.9	67.7	22.4	6.43	67.1	110.0	12.2	8.9	79.1	20.8
Additional moisture absorbed	47.1	11.5	30.9	67.8	105.3	25.4	30.2	147.0	187.0	11.0	26.3	41.1	32.2
Total moisture at saturation	189.1	23.8	39.4	83.7	173.0	47.8	36.5	213.0	298.0	23.2	35.2	120.2	53.0

Solid waste only	506			580				643				700		
	8	12	14	4	10	IS*	BS#	CS+	2	8	16	CS+	10	12
Sample moisture content	45.6	28.7	74.3	166.0	21.5	7.1	18.2	8.3	7.1	50.7	8.3	7.0	5.7	46.3
Additional moisture absorbed	15.4	17.0	32.4	243.5	132.6	7.1	34.9	60.2	151.0	229.0	18.7	24.3	34.9	26.2
Total moisture at saturation	6.5	25.6	32.1	409.5	154.1	14.2	53.1	67.5	158.0	276.0	26.9	31.3	40.6	72.5

*IS = intermediate cover soil. +CS = cover soil. #BS = bottom soil.

TABLE VIII-13
BOD_5 OF LEACHATES FROM SELECTED LANDFILL CORE SAMPLES

Fresh sludge-waste			Sludge-waste - old fill			Solid waste only		
Days since landfilled	Sample depth, ft	BOD_5, mg/l	Days since landfilled	Sample depth, ft	BOD_5, mg/l	Days since landfilled	Sample depth, ft	BOD_5, mg/l
0-7	4	498	140	4	37 #	195	4	407
	8	173		10	207		8	283
	14	253		12	234		12	253
	16	70 *		18	215			
	20	399 +						
0-7	4	620	208	4	450	263	4	380
	6	500		10	300		10	750
	22	600		16	900			
14	6	133	276	4	116	321	6	28
	12	68		12	31		8	106
							12	49

* Sample had weak odor. Material consisted of paper, grass and twigs.

+ Sample had strong, sweet odor. Contained large amount of sludge and mixed dirt.

\# Sample was dry and had negligible odor.

TABLE VIII-13 (CONT.)
BOD_5 OF LEACHATES FROM SELECTED LANDFILL CORE SAMPLES

Fresh sludge-waste			Sludge-waste - old fill			Solid waste only		
Days since landfilled	Sample depth, ft	BOD_5, mg/l	Days since landfilled	Sample depth, ft	BOD_5, mg/l	Days since landfilled	Sample depth, ft	BOD_5, mg/l
7-14	8	713	461	4	410	506	8	373
	12	200		15	40		12	10
	18	495		27	140		14	0
0-4	4	129	535	8	72	580	4	5
	10	26					10	72
	18	57						
0-7	6	185	598	CS*	95	643	CS*	0
				10	100		BS+	175
				BS+	40			

*CS = cover soil.

+BS = bottom soil.

i. Readability. The readability of printed matter (newsprint, paper container labels, can labels, glass labels, etc.) was not significantly altered. In some cases, newsprint and paper print were blurred due to moisture.

j. Biodegradation. No evidence of biodegradation nor oxidation was observed for textiles, plastic, leather, wood, metal, glass and ceramics. Newsprint, cardboard and miscellaneous paper exhibited a slight to moderate decrease in strength when pulled by hand. Grass, leaves, and tree and shrub prunings showed slight to moderate biodegradation. Food was seldom found and was deteriorated when observed. No observable difference was detected in biodegradation between bore holes with different fill materials.

k. Gas Analyses. Analyses of gas samples taken from landfill bore holes (until the probes were destroyed during filling) are given in Table VIII-14. The November 1972 fresh sludge-waste fill showed the greatest production of CO_2. The probe was inserted at the fill working face and was destroyed prior to the next sampling period. The gas analyses from the 1973 borings show higher concentrations of CH_4 than the 1972 borings.

5. Compaction Studies. A special field test was conducted to compare compaction of combined solid waste-liquid sludge mixture with normal solid waste. Two test cell areas were designated in two small, narrow canyons in the northeast corner of the Oceanside landfill. For a one-week period these test cells received the full load of solid waste collected by Oceanside. During one test, the cells received solid waste only (June 26 to July 2, 1973), and during a second test, the cells received solid waste admixed with sludge (June 18 to June 25, 1973) at a ratio of 0.3 lb liquid sludge per lb solid waste (wet wt). In both cells, each truckload of solid waste received four passes from the 977K track dozer to provide uniform compaction.

The solid waste admixed with sludge had a density of 884 lb/cu yd compared to 849 for solid waste only, which is 4 percent better compaction. This figure is based on a correction for the cover soil volume. Prior to the cover soil correction, the solid waste admixed with sludge indicated a 16 percent improved compaction (753 lb/cu yd versus 657 lb/cu yd). This is because the solid waste-sludge cell received much less cover soil (358 cubic yards versus 290 cubic yards). Possibly the solid waste-sludge cell had fewer voids in the solid waste due to reduction in paper wet strength. Less cover soil would, therefore, be required since less soil would seep into the voids. Hence, the 16 percent improved compaction value may yield a better indication of the effect of the liquid sewage sludge.

The above study was conducted under controlled conditions; only solid waste collected by City of Oceanside waste disposal vehicles was disposed to the test cells. Also, bulldozer operations were controlled to provide uniform compaction in the cells. These controls probably affected the final compaction achieved in the test cells. Therefore, the compaction attained in the test cells is not indicative of normal compaction achieved at the landfill.

TABLE VIII-14

LANDFILL BORE HOLE GAS ANALYSES

	Concentration, percent by volume*														
	Fresh sludge-waste fill					Old sludge-waste fill					Old solid waste fill				
Date sampled	Days since placing fill	CO_2	O_2	N_2	CH_4	Days since placing fill+	CO_2	O_2	N_2	CH_4	Days since placing fill+	CO_2	O_2	N_2	CH_4
1972															
7-26#	0-7	75.6	1.6	6.9	15.0	140	42.2	6.6	49.0	2.2	195	28.6	4.6	66.4	0.4
8-11		Probe destroyed				156	63.4	4.8	28.6	3.2	211	45.1	0.8	53.2	0.9
8-18						163	70.7	0.6	20.4	8.3	218	44.6	1.6	52.2	1.6
9-1						177	66.5	2.5	23.6	7.4	232	50.2	2.0	43.2	4.6
9-15						191	70.2	0.4	17.4	12.0	246	52.0	2.9	34.1	11.0
10-2						208	70.3	0.0	13.7	16.0	263	Probe destroyed			
10-27						233	57.1	4.4	19.4	19.1					
1973															
1-13		56.6	4.4	22.1	16.8	313					368	56.4	1.9	15.6	26.2
2-2		48.5	8.2	28.5	14.8	380					385	55.0	7.0	20.4	17.6
2-23		69.6	2.1	4.3	24.0	351					404	58.0	3.6	16.7	21.7
6-11						459	66.0	2.0	10.0	22.0					
6-15						463	68.0	1.3	4.4	26.3					
10-16	0-7	57.1	2.2	17.2	23.5	586	49.9	0.8	5.6	43.7	641	49.7	0.8	5.7	43.8
12-12	0-14	76.6	0.3	20.4	1.5	643	32.1	3.4	23.1	21.5	698	31.8	2.1	16.5	25.5

* All samples taken from a depth of 10 feet below the cover soil surface.

\+ Estimated.

\# Probes placed July 26, 1972.

A second study was conducted to determine more normal landfill compaction. The landfill was operated under normal conditions without restrictions on solid waste received or bulldozer operations. The two northeast canyons received all incoming solid waste for one month (August 6 to September 7, 1973). The incoming solid waste was recorded on a load count data sheet (see Appendix B). A form known as tractor operations data (also included in Appendix B) was employed for recording the amount of cover soil used. The volume of utilized cover soil was subtracted from the total volume filled. During the study, 85 truckloads of debris (mostly cement) were received from the demolition of a commercial clothes-cleaning establishment. The volume displaced by these 85 truckloads of debris (approximately 1,000 cubic yards) was subtracted from the total volume filled to avoid the abnormal effect that the high-density material would have had on the study results. The sludge solids resulting from an admixture ratio of 0.3 lb liquid sludge per lb solid waste (wet wt) were included in the calculation. The resulting compaction under these conditions was 1,119 lbs per cubic yard. This figure extends well into the upper range of landfill compaction densities.

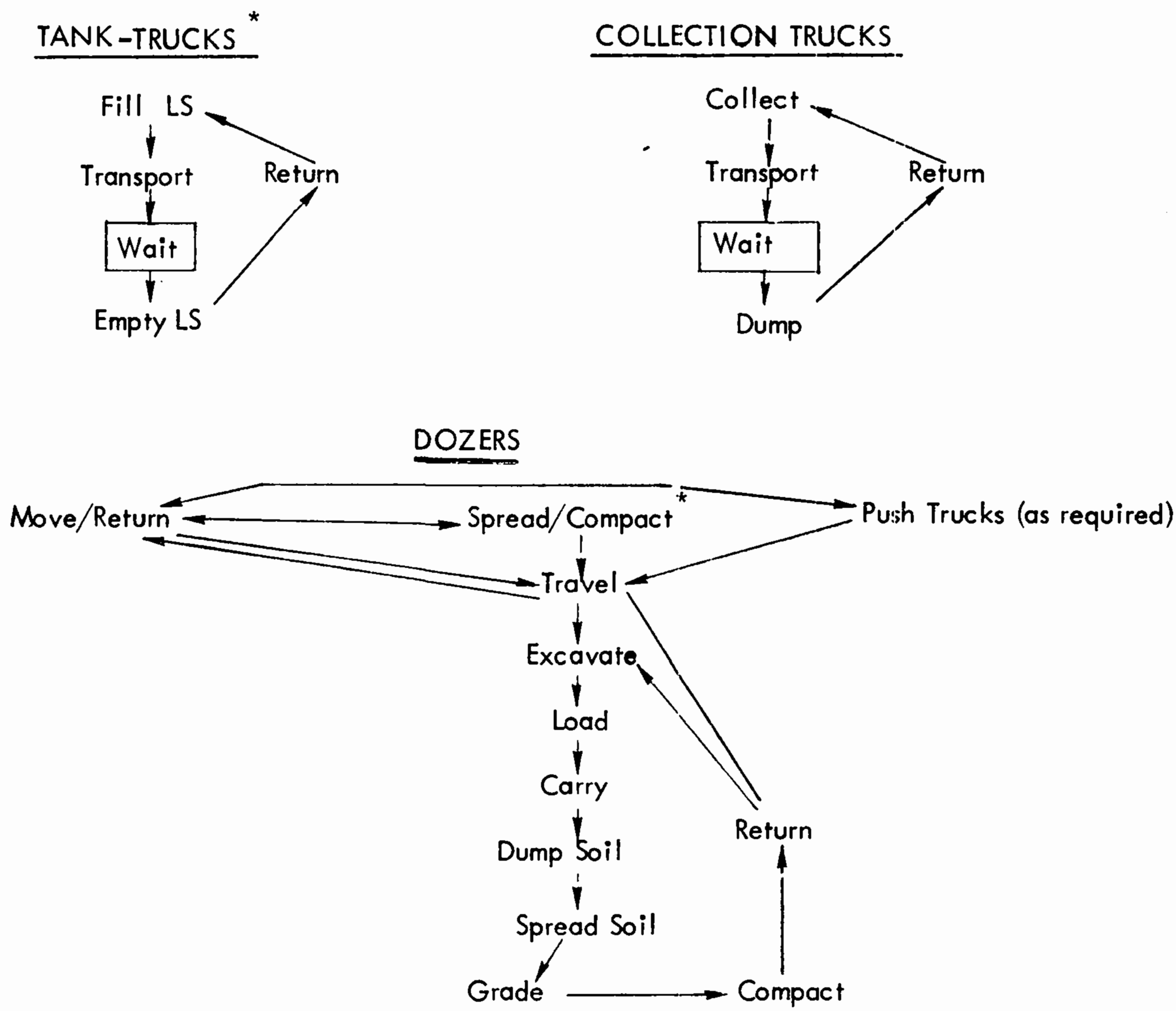
6. Time and Motion Studies. Studies were conducted evaluating the observable differences between normal solid waste landfilling and landfilling which involved admixing sludge with the solid waste. These studies measured the rate of working refuse with dozers; evaluated the operating cycle of sludge trucks; and measured the average period collection trucks had to wait before dumping.

The time measurements for these studies required definition of a set of measurable operations. Figure VIII-3 presents operating cycles for the equipment studied. Figure VIII-4 shows the interdependence of equipment in the processing of liquid sludge, solid waste, and cover soil. The measured tasks referred to in the following results are all measured within these networks.

a. Dozers. Sludge admixing affects dozer operations on the working face in a number of ways. For example, traction is decreased by the presence of water and the lubricating quality of sludge; refuse workability is improved by soaking; and negative attitudes of drivers toward working with solid waste-sludge admixtures reduced driver efficiency. Time observations measured the net result of these and other factors without identifying individual changes.

Stopwatch measurements of "moving," "returning," "spreading," and "compacting" operations for 1972 and 1973 are the statistical bases for Table VIII-15. The table includes total observation time, sample size, mean duration, standard deviation, and a time index for each operation under seven distinct conditions of drivers and refuse. Each time index is the ratio of total observation time for an operation to total time observed for "moving" (under the same conditions); this index closely follows the working time spent per refuse unit weight. Changes in mean duration and time index should indicate any changes in operating times.

In the model, spreading and compacting refer to dozer time on the slope of the working face. Spreading occurs when the blade is down on refuse, and compacting



*Operations affected by admixing sludge and solid waste.

FIGURE VIII-3
SANITARY LANDFILL
EQUIPMENT WORK TASKS

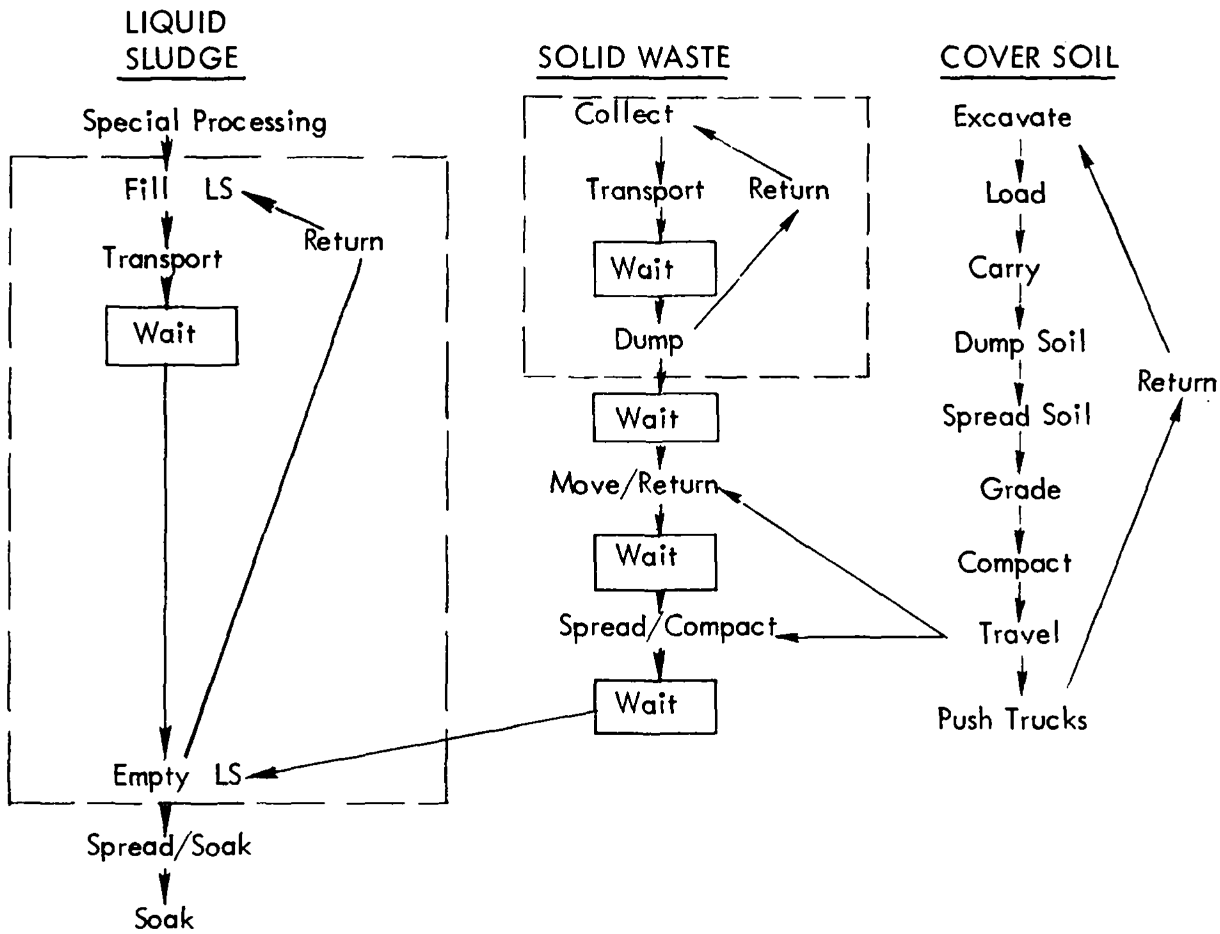


FIGURE VIII-4
LIQUID SLUDGE, SOLID WASTE
SANITARY LANDFILL MODEL

TABLE VIII-15
MEASURED OPERATING TIMES IN HUNDREDTHS OF MINUTES
UNDER FOUR CONDITIONS TABULATED SEPARATELY FOR TWO DRIVERS

Condition		Operation								
		Returning		Moving		Spreading		Compacting		Spreading/ compacting
		A	B	A	B	A	B	A	B	B
Dry	$\sum x_i$	9,043	5,850	7,187	3,879	4,023	2,059	6,648	4,821	6,880
	N	272	258	254	205	180	105	189	128	128
	$\bar{X}$	33	23	28	19	22	20	35	38	54
	s.d.	18	13	14	9	12	9	24	58	-
	Index	1.26	1.51	1	1	0.56	0.53	0.93	1.24	1.77
Wet	$\sum x_i$	3,635	265	2,906	202	1,052	319	2,339	555	874
	N	125	15	99	13	56	14	66	14	14
	$\bar{X}$	29	18	29	16	19	23	35	40	62
	s.d.	16	8	12	7	8	6	24	34	-
	Index	1.25	1.31	1	1	0.36	1.58	0.81	2.75	4.33
Sludge (0.5-0.6 lb sludge per lb solid waste)	$\sum x_i$	5,095	3,067	3,879	1,633	979	457	1,875	2,950	3,407
	N	165	120	138	73	53	33	59	56	56
	$\bar{X}$	31	26	28	22	18	14	32	53	61
	s.d.	13	16	13	10	10	7	24	58	-
	Index	1.31	1.88	1	1	0.25	0.28	0.48	1.81	2.09
Double sludge (1.0-1.2 lb sludge per lb solid waste)	$\sum x_i$		884		527					1,163+
	N		39		31					19
	$\bar{X}$	-	23	-	17	-	*	-	*	61
	s.d.		14		6					47
	Index		1.68		1					2.21

Note: $\sum x_i$ = sum of all observed times; N = sample size; $\bar{X}$ = sample mean; s.d. = standard deviation; Index = ratio of corresponding operation's total time to total time for "moving."

* Spreading and compacting were combined on these data sheets.

\+ Observed slipping and failure to climb some areas of the slope.

when the blade is up in the air. Moving and returning refer to time spent above the slope on the level top of the lift. Moving occurs when the dozer blade pushes refuse from dump-piles over onto the sloped face, and returning when the dozer is on the level top with the blade up, heading back to move more refuse. Admixing sludge with solid waste does not affect moving or returning operations, since the dozer is located away from the sludge. Under constant working-face conditions, both moving and returning operating times are assumed to be constant per unit weight of refuse.

Once every week for about two hours, a member of the Ralph Stone and Company, Inc. staff recorded all dozer activities, one dozer at a time. About half the recorded data are useless since they reflect changed factors other than drivers, sludge, or wetness. The number of measurements is listed for each of the twenty-six categories.

The results in Table VIII-15 are ambiguous, since the effects of water and sludge vary by driver. Using mean duration or time index the same changes occur. Generally driver A speeded up under wet or sludge-admixed conditions, while driver B slowed down. The below conclusions may be derived from Table VIII-15.

1. Under double-admixed conditions (1.0 to 1.2 lb sludge per lb solid waste), the index of time spent working refuse increased significantly. With a 20 to 30 degree slope, double admixture increased time working a unit refuse weight by over 40 percent.

2. One driver definitely increased his working rate and the second driver slowed down. This difference between the men appears valid because data here are complete and accurate enough to draw trend distinctions. The difference in performance is partly due to physiological and human performance factors and to a small sample for driver B.

3. Under single-admixed ratios (between 0.5 and 0.6 lb sludge per lb solid waste), no decrease in physical operations has been observed over two years. Apparently wetness improves refuse workability. After a half-hour soaking period, sludge-admixed refuse is significantly easier to work, with less time needed per weight of refuse.

b. Tank-Trucks. The operating sequence of sludge trucks is presented in Figure VIII-5. This expands the operations shown in Figure VIII-4 into sub-operations. Only tasks dependent on the truck itself were measured for standard times. Transportation, return, and waiting times are largely a function of local conditions and hence were not measured.

The sludge trucks require a tank, drain valve, and dispersal apparatus. Only the dispersal apparatus merits detailing. Gravity flow and pumping are the two methods which can be used for sludge moving. Gravity has proven to be inexpensive, simple, reliable, and sufficiently fast for this purpose. Pumps increase flow, especially near the end of conveyance when force of gravity drops, but require investment and

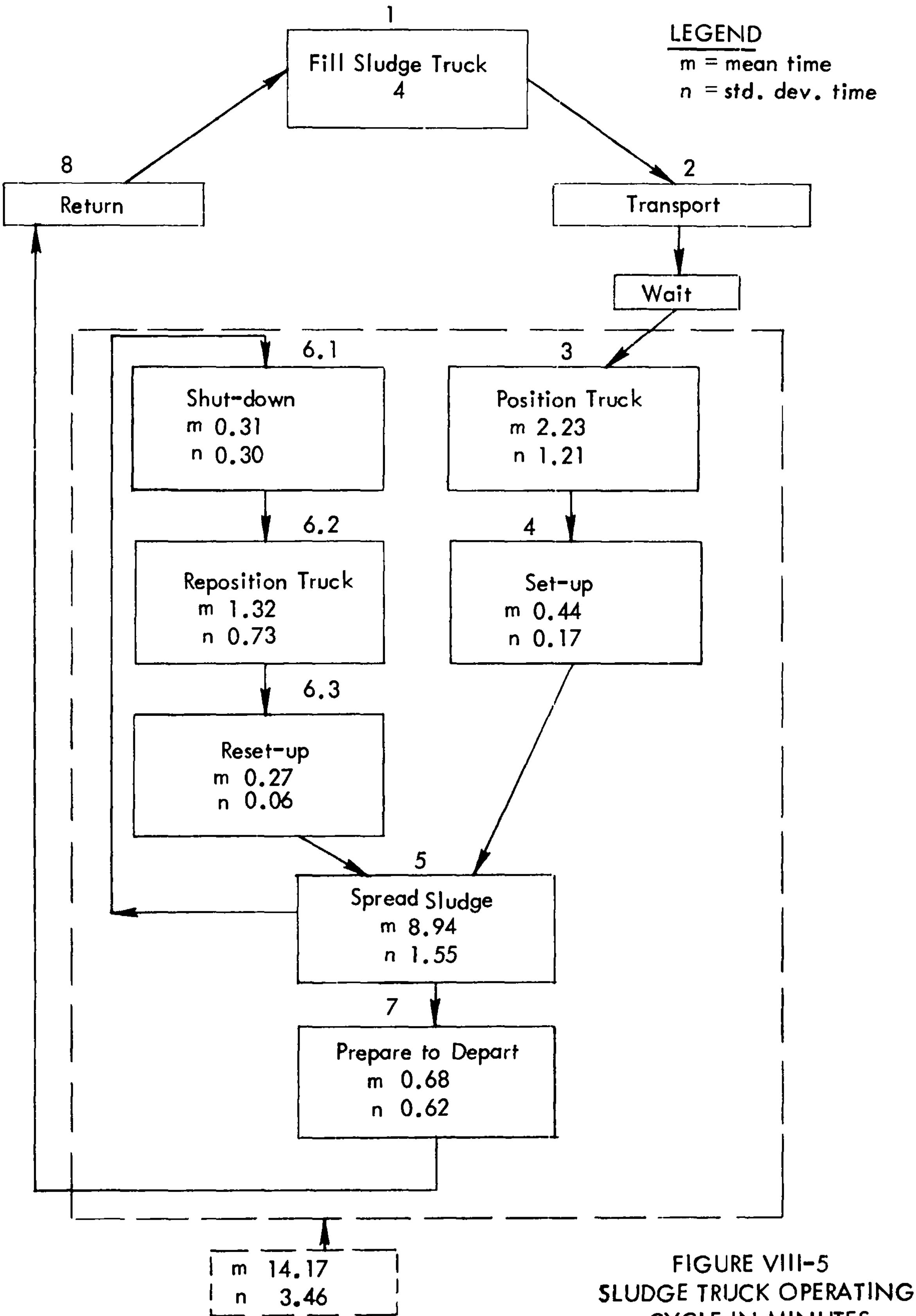


FIGURE VIII-5
SLUDGE TRUCK OPERATING
CYCLE IN MINUTES

SLUDGE COSTS:
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savings. Two techniques exist for
e. Flexible hoses are useful for a wide
operator can direct the flow onto specific
is undesired. However, odor and
ad use. Fixed nozzles entail fast, easy
mit working slope conditions suitable for
ıvolved are controlling short-circuiting
s the sludge truck wheels. Present de-
ıshplates to the rear axle; a suggested
d assume that all sludge flows down
eels causes dumping trucks to become

ed at Oceanside; the sludge truck operator
reflect typical performance and as such

t on collection trucks of admixing sludge
e (see Figure VIII-3) as a result of a
. Unfortunately, this increase in waiting
e there was little traffic and the sludge
truck arrivals were anticipated.

ı be treated as any other truck in the queue
determined by using a standard queuing
a function of the ratio of average dumping
etween arrivals (Γ, in minutes per truck).
ition of a few more sludge loads will not
ıg times will not be measurably affected.

ompares three sets of dozer cost data: 1)
lling; 2) part of 1972 with sludge admixture
and non-sanitary landfilling, ... 1973 with sludge admixture and sanitary landfilling. The costs employed are from Oceanside official records. Dozer operating and maintenance costs are used, while other costs arising from fee collection, etc. are not included in this calculation. Tables VIII-16, VIII-17, and VIII-18 present the data.

The dozer costs per as-received ton are \$0.72 for non-sanitary landfilling, \$0.64 for sludge-admixed non-sanitary landfilling, and \$0.92 for sludge-admixed sanitary landfilling. Sanitary landfilling involves daily use of about six inches of soil covering the day's new refuse. At Oceanside this required use of a second full-time dozer operator; the increased 1973 cost reflects the additional earth moving and cover soil placement.

The data shows sludge admixture alone does not increase landfilling costs. The accuracy is not sufficiently reliable to demonstrate that admixing sludge lowers costs;

TABLE VIII-16
OPERATING AND MAINTENANCE COSTS
FOR DOZERS WD-A AND WD-C IN 1971

Period	Operating labor (hrs)	Operating labor ($)*	Maintenance labor ($)	Diesel fuel (gal)	Diesel fuel ($)	Oil (qts)	Oil ($)	Parts ($)	Subtotal+ ($)	Total ($)
Jan	#	#	128.57	779	101.27	0	0	22.95	252.79	#
Feb			205.29	690	89.70	220	41.30	7.64	343.93	
Mar			271.61	665	86.45	440	65.86	15.07	438.99	
Apr			372.58	588	76.44	220	29.75	10.11	488.88	
May			532.25	775	100.75	440	82.58	401.59	1,117.17	
June			153.56	735	95.55	0	0	6.76	255.87	
July			210.68	825	107.25	220	41.29	51.23	410.45	
Aug			274.80	965	125.45	0	0	50.96	451.21	
Sep			305.42	730	94.90	220	41.29	329.14	770.75	
Oct			266.02	850	110.50	2	0.36	495.45	872.33	
Nov			294.87	712	93.60	227	42.55	51.53	482.55	
Dec			400.42	650	84.50	19	3.42	55.26	543.60	
1971	2,576	10,819.20	3,416.07	8,964	1,166.36	2,008	348.40	1,497.69	6,428.52	17,247.73
/ton wet wt**	0.107	0.451	0.142	0.374	0.049	0.084	0.015	0.062	0.268	0.719

* At 4.20 per hour as the average hourly wage. One full-time operator.

\+ Excludes "operating labor"; sum of costs directly connected with dozer maintenance and fuel.

\# Unavailable by months.

** Based on 23,993 tons wet wt hauled (i.e., 1,999.4 tons/month).

TABLE VIII-17
OPERATING AND MAINTENANCE COSTS FOR DOZERS WD-A AND WD-C IN 1972 (FEBRUARY TO SEPTEMBER)

Period	Operating labor (hrs)	Operating labor ($)*	Maintenance labor ($)	Diesel fuel (gal)	Diesel fuel ($)	Oil (qts)	Oil ($)	Parts ($)	Subtotal+ ($)	Total ($)
Feb	201	844.20	203.21	880	114.40	83	14.94	111.41	443.96	1,288.16
Mar	209	877.80	183.92	546	71.00	0	0	1,149.75	1,404.67	2,282.47
Apr	257	1,079.40	192.46	640	83.20	0	0	33.30	308.96	1,388.36
May	173	726.60	627.81	536	69.63	0	0	275.15	972.59	1,699.19
June	214	898.80	143.86	645	83.85	0	0	89.86	317.57	1,216.37
July	278	1,167.60	135.80	645	83.85	226	42.37	42.04	304.06	1,471.66
Aug	189	793.80	355.50	891	115.77	0	0	81.73	533.00	1,326.80
Sep	206	865.20	191.88	107	13.91	110	20.64	29.45	255.88	1,121.08
Feb to Sep	1,727	7,253.40	2,014.44	4,890	635.61	419	77.95	1,812.69	4,540.69	11,794.09
/ton wet wt#	0.0933	0.392	0.109	0.264	0.0343	0.0226	0.0042	0.0979	0.245	0.637

* At 4.20 per hour as the average hourly wage. One full-time operator.

\+ Excludes "operating labor"; sum of costs directly connected with dozer maintenance and fuel.

\# Based on the average of 1971 and 1973 solid wastes, or approximately 18,520 tons wet wt hauled (i.e., 2,315.5 tons/month).

TABLE VIII-18
OPERATING AND MAINTENANCE COSTS
FOR DOZERS WD-A AND WD-C IN 1973
(APRIL TO DECEMBER)

Period	Operating labor		Maintenance labor	Diesel fuel		Oil		Parts	Subtotal[+]	Total
	(hrs)	($)*	($)	(gal)	($)	(qts)	($)	($)	($)	($)
Apr	448	1,881.60	76.16	1,047	157.00	0	0.0	33.67	266.83	2,148.43
May	429	1,801.80	207.82	867	130.00	0	0.0	299.42	567.24	2,369.04
June	445.5	1,871.10	153.49	888	133.17	0	0.0	75.92	362.58	2,233.68
July	430	1,806.00	264.85	1,016	132.01	440	126.18	84.41	607.45	2,413.45
Aug	534.5	2,244.90	311.93	1,005	130.65	0	0.0	274.30	716.88	2,961.78
Sep	423	1,776.60	143.57	1,157	150.41	0	0.0	18.57	312.55	2,089.15
Oct	502	2,108.40	177.91	1,357	239.61	0	0.0	771.12	1,188.64	3,297.04
Nov	424.5	1,782.90	160.67	974	165.65	0	0.0	280.53	606.85	2,389.75
Dec	388	1,629.60	122.02	789	134.10	360	61.94	8.96	327.02	1,956.62
Apr to Dec	4,024.5	16,902.90	1,618.42	9,100	1,372.60	800	188.12	1,776.90	4,956.04	21,858.94
/ton wet wt#	0.170	0.714	0.068	0.384	0.058	0.034	0.008	0.075	0.209	0.923

* At 4.20 per hour as the average hourly wage. Two full-time operators.

+ Excludes "operating labor"; sum of costs directly connected with dozer maintenance and fuel.

Based on 23,685 tons wet wt hauled (i.e., 2,631.7 tons/month).

Note: *The April to December period is presented because the actual weighed quantity of solid waste was available for these months. A scale was installed at the Oceanside municipal landfill in mid-March 1973.*

however, intensive, stop-watch time measurements as previously-described showed that one operator compacts waste significantly faster following sludge admixture.

8. Sludge Disposal Costs. For truck hauling, sludge disposal costs arise from labor and capital expenses of buying, operating, and maintaining a sludge truck. Oceanside has two tank-trucks used for sludge disposal, but one is small and used only when the larger SD-240 is under repair. The SD-240 is sufficiently large for Oceanside's sludge hauling; hence costs of the SD-190 will be ignored in the following cost analysis.

Tables VIII-19 and VIII-20 list all costs associated with the large 3,500-gal SD-240; these cost data are from the City of Oceanside accounting records. The "equipment rental" column follows the City's accounting method, resulting in very inflated capital recovery payments. To present an accurate amortization figure, the purchase price of $12,247.20 for the truck is amortized over 10 years at 6 percent annually, yielding $139 per month in payments. This significantly reduces amortization cost, with reduced total cost as shown in Table VIII-20. The summary costs presented in Table VIII-21 are a more realistic estimate of truck-hauling disposal costs.

These costs illustrate the effect of inflation from 1972 to 1973. The January 1972 data were excluded because sludge hauling started during this month; hence larger costs were incurred, as seen in total costs. No major changes occurred in routes or procedures during this time, so these costs reflect expected costs under conditions similar to Oceanside: warm, dry climate; approximately 2.5-mile hauls; 3 to 10 percent solids content; and gravity feed drain.

9. Summary. Since large quantities of sewage sludge are used throughout the country as a soil conditioner, numerous people are exposed to it. Much of this sludge is known to contain some raw waste material and pathogens. There is no record of disease transmission to humans as a result of sludge treatment plant activities and use of sludge as a fertilizer. Burd[1] points out that this may be due to existing health department regulations and operator precautions. There does not appear to be an urgent problem regarding disinfection.

The preliminary field demonstration results presented in this chapter indicate that the joint disposal of Oceanside's digested sewage sludge and solid waste into a sanitary landfill can be accomplished successfully without major operational cost increases or difficulties. From the standpoint of landfill operation, the addition of digested sewage sludge to refuse could be beneficial in at least three respects. First, the refuse-sludge mixture could be better compacted by heavy equipment than the solid waste alone. Second, the presence of sludge essentially prevents blowing of litter which normally occurs in a refuse landfill and which may otherwise be controlled by water addition. Third, digested sludge may possibly provide a deterrent to rodents which ordinarily abound in a refuse landfill. The demonstration work at Oceanside has indicated the need for improved sludge-spreading techniques.

TABLE VIII-19
LABOR AND CAPITAL EXPENSES FOR
SLUDGE TRUCK OPERATIONS IN 1972

Period	Operating labor ($)	Maintenance labor ($)	Equipment rental hrs+	Equipment rental Cost ($)	Fuel gal	Fuel Cost ($)	Oil qrt	Oil Cost ($)	Parts ($)	Mileage (mil)	Total sludge (gal)
Jan	131.50	71.22	32.00	256	250*	54.82	0	0.00	0.00		21,000
Feb	524.01	30.48	127.50	1,020	254*	55.56	4	0.72	3.21		203,000
Mar	302.06	19.14	73.50	588	121*	26.58	2	0.36	0.00		171,500
Apr	340.96	20.40	83.00	664	276*	60.41	7	1.26	203.38		238,000
May**	516.89	203.44	126.00	1,008	273*	59.71	5	0.90	380.74		311,500
June**	491.11	118.73	119.50	956	205*	44.83	5	0.90	21.15		231,000
July	617.44	150.06	136.00	1,088	352*	77.00	6	1.08	107.71		346,500
Aug	624.25	173.52	133.75	1,070	371*	81.16	0	0.00	52.39		350,000
Sep	729.30	18.16	127.00	1,016	248	54.14	4	0.72	35.70		367,500
Oct**	817.28	135.53	107.50	860	198	43.49	4	0.72	956.81		140,000
Nov	585.42	0.00	81.00	648	214	46.88	0	0.00	170.44		192,500
Dec	528.67	60.98	75.50	604	175	37.17	0	0.00	0.00		196,000
1972 Total	6,208.89	1,001.66	1,222.25	9,778	2,937	641.75	37	6.66	1,931.53	19,568.49	2,768,500 (2,955,500)++
Excluding Jan	6,077.39	930.44	1,190.25	9,522	2,687	586.93	37	6.66	1,931.53	19,054.95	2,747,500 (2,934,500)++
1972											
Cost/ 1,000 gal	2.24	0.362	3.53		0.232		0.0024		0.698	7.07	
Cost/ton#	14.04	2.270	22.12		1.460		0.0150		4.380	44.30	
Excluding Jan											
Cost/ 1,000 gal	2.21	0.339	3.47		0.214		0.0024		0.703	6.94	
Cost/ton#	13.85	2.120	21.74		1.340		0.0150		4.400	43.48	

TABLE VIII-19 (CONT.)
LABOR AND CAPITAL EXPENSES FOR
SLUDGE TRUCK OPERATIONS IN 1972

* Estimated using 0.219 dollars per gallon.

\+ Based on a rental rate of approximately $8.00 per hour.

\# Based on an average solids content of 3.8 percent with 8.4 lbs per gallon liquid.

** City of Oceanside used two sludge trucks, SD-240 and SD-190; however, sludge data from only the SD-240 is used.

++ Total sludge hauled by both trucks.

TABLE VIII-20
LABOR AND CAPITAL EXPENSES FOR
SLUDGE TRUCK OPERATIONS IN 1973

Period	Operating labor ($)	Mainten- ance labor ($)	Equipment rental hrs+	Equipment rental Cost ($)	Fuel gal	Fuel Cost ($)	Oil qrt	Oil Cost ($)	Parts ($)	Mileage (mil)	Total sludge (gal)
Jan**	576.71	168.73	87.5	700	247	51.89	28	5.04	154.48	196	199,500
Feb	477.22	18.16	75.5	604	198	39.86		0.00	57.75	270	175,000
Mar	484.90	21.07	82.0	656	267*	56.10		0.00	0.00		164,500
Apr	354.70	57.71	51.5	412	183*	40.07		0.00	203.62		105,000
May	582.69	96.54	105.0	840	292*	63.96	19	3.42	31.39		269,500
June**	695.14	0.00	120.5	964	204*	44.71	4	0.76	0.00		196,000
July	788.58	44.70	124.0	992	201	48.75	8	1.52	142.78		287,000
Aug	585.26	197.50	95.0	760	32	7.78	3	0.57	113.21		224,000
Sep**	367.48	392.21	56.5	452	15	3.65		0.00	1,090.85		0
Oct**	703.87	239.05	99.5	796	122	30.05		0.00	231.11	115	52,500
Nov	494.73	24.18	67.0	536	260	61.44	4	0.76	0.00	419	171,500
Dec	579.50	241.72	86.5	692	282	66.60	26	4.94	542.38	523	234,000
1973 Total	6,690.78	1,501.57	1,050.5	8,404	2,303	514.86	84	17.01	2,567.57	19,695.79	2,068,500 (2,391,200)++
1973 Cost/ 1,000 gal	3.23	0.726		4.06		0.249		0.0082	1.24	9.52	
Cost/ton#	16.39	3.68		20.58		1.260		0.0420	6.29	48.23	

* Estimated using 0.219 dollars per gallon (except for August where 0.243 is used).

\+ Based on a rental rate of approximately $8.00 per hour.

\# Based on an average solids content of 4.7 percent with 8.4 lbs per gallon liquid.

** City of Oceanside used two sludge trucks, SD-240 and SD-190; however, sludge data from only the SD-240 is used.

++ Total sludge hauled by both trucks.

TABLE VIII-21
SUMMATION OF LABOR AND CAPITAL EXPENSES FOR SLUDGE TRUCK OPERATIONS

Period	Operating labor ($)	Maintenance labor ($)	Equipment rental* ($)	Fuel ($)	Oil ($)	Parts ($)	Total cost ($)	Total sludge gal (ton)
1972								
Total	6,208.89	1,001.66	1,668.00	641.75	6.66	1,931.53	11,458.49	2,768,500
Cost/ 1,000 gal	2.24	0.362	0.602	0.232	0.0024	0.698	4.14	
Cost/ton	14.04	2.27	3.77	1.46	0.015	4.38	25.93	(441.9)
1972 (except Jan)								
Total	6,077.39	930.44	1,529.00	586.93	6.66	1,931.53	11,061.95	2,747,500
Cost/ 1,000 gal	2.21	0.339	0.557	0.214	0.0024	0.703	4.03	
Cost/ton	13.85	2.12	3.49	1.34	0.015	4.40	25.23	(438.5)
1973								
Total	6,690.78	1,501.57	1,668.00	514.86	17.01	2,567.57	12,959.79	2,068,500
Cost/ 1,000 gal	3.23	0.726	0.806	0.249	0.0082	1.24	6.27	
Cost/ton	16.39	3.68	4.09	1.26	0.042	6.29	31.74	(408.3)

* Based on $12,247.20 amortized over 10 years at 6 percent annually.

Mitigation measures for undesirable aspects of disposing of liquid sewage sludge into landfills were discovered. When undigested or partially digested liquid sewage sludge was disposed into the landfill, severe odor problems resulted. By immediately covering the non-digested sludge with solid waste and a minimum six inches of cover soil, the odors can be controlled. It was discovered that suitable soil cover prevented fly emergence. Landfill temperatures sufficiently high to kill many viruses and pathogens were observed for solid waste fill seven-days old.

IX. ECONOMIC ANALYSIS OF SLUDGE PROCESSING AND TRANSPORTATION ALTERNATIVES

Liquid sludge handling and disposal into a landfill consists of two steps: transportation from the sewage treatment plant to the landfill, and spreading the sludge onto the solid waste fill. The sludge transportation method will depend on whether the sludge is liquid, dewatered or dried prior to disposal. Thus, the feasible transportation methods consist of: pipeline, tank-truck and rail tank car for liquid sludge; dump truck and rail hopper car for dewatered sludge. The costs for handling dewatered sludge include the cost of dewatering.

The cost analysis is developed for the City of Oceanside and in general terms for application in other locales. The two feasible alternatives for Oceanside based on the existing sewage treatment plant and landfill location are via pipeline or truck transportation.

A. Analytical Approaches

1. Oceanside Conditions. Figure IX-1 shows the location of the existing landfill, and the four existing sewage treatment plants. The new sewage treatment plant will replace the Buena Vista and San Luis Rey plants in the fall of 1974, thus leaving two plants, the other being La Salina. The sludge from the two plants will be transported to the new landfill until its estimated completion after 10 years. A new landfill will have to be used after the existing landfill is completed. A useful landfill life of 10 years will be used in the analysis. The most direct potential truck routes are shown in Figure IX-1. Since existing City rights-of-way follow the same routes, it was assumed that a pipeline will also follow these routes to avoid additional costs.

It was also assumed that a new landfill site will be required within 10 years, thus the rerouting of 75 percent of the pipeline will be assumed for costing over a 30-year period. Since no railroad tracks are near the landfill, the sludge quantities are relatively small and the landfill is a short distance from the treatment plants, rail haul is not considered feasible. The two Oceanside treatment plants process sludge by aerobic (new plant) and anaerobic (La Salina plant) digestion. Data on present (1972-74) and projected (1985) sludge quantities from each plant are given in Table IX-1 along with information on sludge solids content and transportation distances.

2. General Cost Conditions. The method of costing the Oceanside sludge operations was based on standard engineering cost analyses. Costs must be determined independently for a given locale according to local conditions. The least costly method, whether it be truck haul, pipeline or combined dewatering and truck haul, must be determined on a case-by-case basis.

The data available to most municipal officials consist of the following: quantity of sludge produced; sludge solids content; distance from sewage treatment plants to landfill sites; and sludge processing and disposal costs.

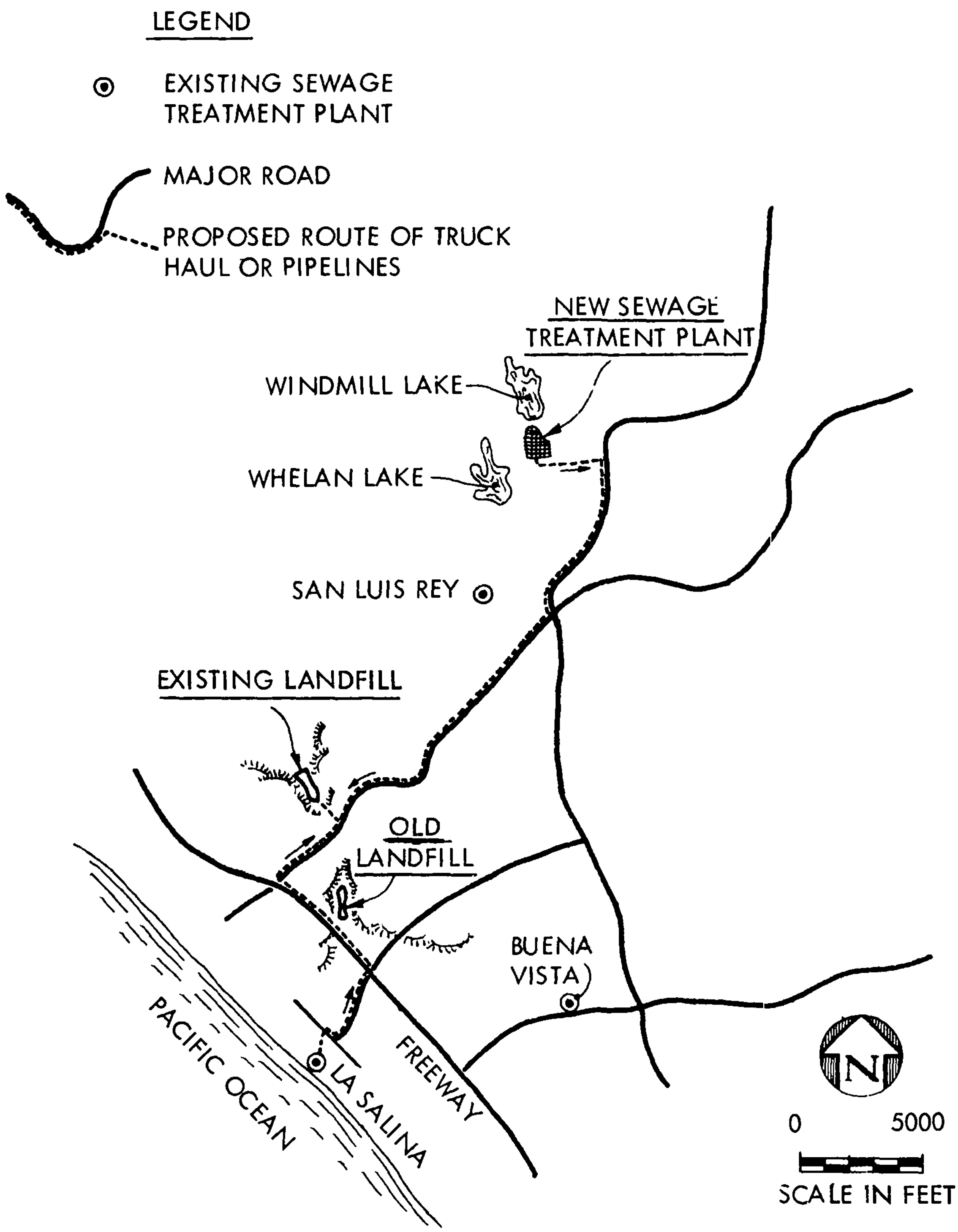

FIGURE IX-1
POSSIBLE ROUTINGS FOR SLUDGE PIPELINE OR TRUCK HAUL

TABLE IX-1
PRESENT AND FUTURE PRODUCTION OF
LIQUID DIGESTED SLUDGE IN OCEANSIDE

Item	La Salina Plant	San Luis Rey and Buena Vista	New plant	Total
1972-1973				
Million gallons/year	1.303	1.292	0	2.595
Percent solids:				
Average	4.5	5.0	-	4.75
Range	3.8-5.6	0.8-11.1	-	0.8-11.1
Projected, 1985				
Million gallons/year	2.2+	0	8.4#	10.6
Percent solids:				
Average	4.5	-	5.5	5.3
Range	-	-	-	5.0-6.0
Tons/year solids	416**	0	1,940**	2,356
Gallons/day liquid	8,460++	0	32,300++	40,720++
Approximate miles to landfill site	2	-	5	4.38
Ton-miles/year (dry weight basis)	554	-	9,700	10,254

From: Reference 7.

+ Present capacity, increased by 15%, rounded off.

By difference.

** Based on average % solids and assumed liquid weight of 8.4 lbs/gal.

++ Based on 5 days/week, 52 weeks/year.

B. Cost Analysis for the City of Oceanside

The cost analysis is for the existing liquid digested sludge produced at the new and the existing La Salina sewage treatment plants. Thus, tank-truck and pipeline transportation of the liquid sludge are evaluated. Rail haul is uneconomical for the small quantities of sludge produced at Oceanside, plus the cost of constructing a railroad spur to the landfill and new treatment plant would be high.

1. Truck Transportation of Liquid Sludge. Three types of tank-trucks were considered in the economic analysis. These are "spreader," "refueler", and "vacuum pumper". The first two types of trucks are manufactured by the Vendoro Company (Los Angeles, California) which produces a wide variety of vehicles for hauling water and fuel. The "spreader" model is a standard water truck whereas the "refueler" is a fuel truck. Both of these vehicles have to be slightly modified for sludge trucking. The modification would consist of replacing the standard water or jet fuel pump with a heavy-duty sludge pump, and providing multiple spreading nozzles. The costs of spreading nozzles and pumps (or elimination of pumps, if gravity loading and discharge are employed) are small compared to the total cost and, hence, were disregarded in this preliminary economic analysis. Currently, there are some 3,000 "vacuum pumper" trucks in operation across the nation, with approximately 150 in Los Angeles County, California, alone.[34] These trucks are commonly used to haul liquid industrial waste residues.

Table IX-2 presents a summary of estimated sludge hauling costs for the three types of trucks considered. A hauling time of 1 hr was assumed (10 min each for loading and unloading, and 40 min for an average round-trip from either the La Salina or the new San Luis Rey Treatment Plant to the new landfill). As indicated in Table IX-2, the total estimated annual capital and operating costs for sludge transportation with "spreader", "refueler", and "vacuum pumper" trucks are about $40,900, $16,900, and $22,400, respectively. The use of a refueler truck thus appears to be economically most advantageous.

2. Pipelines. Table IX-3 presents a summary of the estimated costs for liquid sludge transportation by pipelines. Due to the smaller flow from the La Salina Plant, the cost of the 2-mi pipeline from this plant has been considered separately from that of the 5-mi line from the new plant.

The following assumptions were made:

a) The pipeline follows the same route as the truck hauls (see Figure IX-1).
b) The pipeline will be 8 inches in diameter.
c) The entire daily sludge production will be pumped to the landfill over a sufficiently short period of time (less than 10 percent of the time) so that adequate flow velocities can be maintained to avoid deposition of sludge solids in the pipeline.

TABLE IX-2
COST OF TRUCKING SLUDGE - OCEANSIDE
(1985)

Item	Spreader *	Refueler *	Vacuum pumper +
Capacity (gallons)	3,300	10,000	7,000
Cost range ($1,000):			
Truck	18-25	-	-
Tank & modification	10	-	-
Total	28-35	50	40-50
High average	32	50	45
Loads/day			
La Salina (8,460 gallons/day)	3-	1	2-
New plant (32,300 gallons/day)	11-	3¼	5-
Total	14-	4¼	7-
No. of trucks required	2	½	1
Annual costs ($1,000)			
Depreciation (10-year life at 6 percent)	8.7	6.8 #	6.1
Fuel & maintenance **	8.2	4.1 #	4.3
Driver's salary & fringe, & overhead(5) ++	24.0	6.0 #	12.0
Total annual cost	40.9	16.9	22.4

TABLE IX-2 (CONT.)
COST OF TRUCKING SLUDGE - OCEANSIDE
(1985)

Item	Spreader *	Refueler *	Vacuum pumper +
Average cost/ton, $ per ton of liquid hauled ##	0.92	0.38	0.50
Average cost/ton, $ per ton of dry solids ##	17.36	7.17	9.51
Average cost/ton-mile, dry basis ***	3.95	1.64	2.17

* Characteristic truck data from Klein products.

+ From Reference 7.

It is assumed that the total depreciation on the truck will be charged to the sludge hauling operation, while the driver's salary will only apply for the half of the time that the truck is used to haul sludge.

** Average of 1972 and 1973 maintenance and fuel costs of $3,581.60 and $4,601.01 for a 3,500 gallon truck. Since gravity feed was used, pumps will increase annual costs.

++ Basis: $10,000/man-year + 20% fringe and overhead.

Basis: 44,520 tons/year of liquid sludge and 2,356 tons/year of dry solids.

*** Weighted average haul of 416 tons x 2 miles and 1,940 tons x 5 miles is 4.38 miles.

TABLE IX-3

COSTS OF PIPELINE TRANSPORTATION - OCEANSIDE

Item	La Salina	New plant
Distance from landfill (miles)	2	5
Annual sludge production:		
Million gallons	2.2	8.4
Tons (liquid)	9,240	44,540
Tons (solids only)	416	1,940
Cost of pipeline ($)	105,600	264,000
Cost of pumping station ($)	50,000	50,000
Total	155,600	314,000
Annual depreciation cost ($):		
Pipeline (10-year useful life at 6 percent)	14,350	35,870
Pump station (30-year useful life at 6 percent)	3,630	3,630
Total annual cost	17,980	39,500
Cost per ton ($)		
Liquid sludge basis	1.95	1.12
Dry solids basis	43.22	20.36
Cost per ton-mile ($), dry solids basis	21.61	4.07

d) Sludges from the La Salina and the new plant will contain about 3.0 and 5.5 percent solids, respectively.
e) The pumping station would have a useful operating life of 30 years. The landfill useful life, however, is only 10 years. Thus, the pipeline would only be used for 10 years after which it would be abandoned. The pumping stations would be used for the full 30 years because a pipeline to a new landfill would still be connected to the existing pumps.
f) The maintenance cost for the pipeline would be negligible. The maintenance cost for the pumps was included in the treatment cost at the sewage treatment plants.
g) The pipeline and the pumping station first costs were about $10 per running foot and $50,000, respectively.
h) Sludge would be applied directly to the solid waste without storage at the landfill.

The data in Table IX-3 indicate that the sludge transportation by pipelines would cost $4.07 and $21.61 per ton of dry solids per mile for the new plant and La Salina, respectively. Comparison of these values with the corresponding estimates for truck transportation ($1.64-$3.95 per ton of dry solids per mile) indicates that the pipeline is decidedly not economical.

It should be emphasized that the economic analysis presented here is only preliminary and was based on a large number of assumptions, the validity of which have not been fully established. For example, sludge transportation cost is affected significantly by the sludge solids content and at the present time the solids content of the sludge which will result from the operation in the new plant is not specifically known. It is estimated that an increase in the sludge solids content from 5.5 to 8 percent would reduce the transportation cost (by either trucking or pipeline) by approximately 32 percent.

In recent years several studies have been reported in the literature on sludge transportation costs. One study[1] reports a long-term pipeline transportation cost of $3 to $7 per ton of dry solids of which $1 to $2 is charged to operation and maintenance. This study assumes pipe lengths of 4 to 17 miles and diameters of 8 to 24 inches. A study of sludge transportation in the Chicago area[35] indicates cost of $37.50 and $6.80 per ton of dry solids for truck hauling and pipeline, respectively. The Chicago study was based on employing 14- and 24-in. pipelines flowing at their optimum capacity for 95 percent of the time. Although the sludge quantities and conditions assumed in these studies are significantly different from those used in the preliminary analysis for Oceanside, the reported data are generally in reasonable agreement with those for Oceanside (especially the pipeline transportation costs).

A more recent survey of 68 communities in northwestern Ohio[37] concerned direct land application of sewage sludge. Fourteen of these communities utilize City-owned vehicles (mostly tank-trucks with a 1,000-5,000 gallon capacity) to directly apply sludge to the land. One Cleveland treatment plant pays $5.85 per wet ton of sludge to a private contractor to haul vacuum-filtered sludge (about 80 percent water) a distance of 100 miles. Average disposal costs to the 68 communities, for direct land application of one ton of sewage sludge, including transportation, were: vacuum filtration and centrifuging, $34.41; direct land application by hauling contract, $31.93; drying beds, $14.34; and direct land application by City-owned trucks, $7.73.

In conclusion, the preliminary economic analysis reported here for Oceanside indicates that pipelines are not economically justified for transportation of sludge. As conditions change with time, further analysis should precede the final selection of an appropriate sludge transportation system for Oceanside.

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APPENDIX A

SUMMARY OF ANALYTICAL AND LABORATORY TEST PROGRAMS

TABLE A
ANALYTICAL METHODS

Parameter	Analytical Method (or instrument)	Reference* (page)
Biochemical Oxygen Demand (BOD)	Manometric BOD_5	Hach Manometric BOD Apparatus Hach Chemical Co.
Chemical Oxygen Demand (COD)	Dichromate Reflux	(p. 495)
pH Value	Glass Electrode Method - Analytical Measurements Model 700	(p.276)
Specific Conductance	Conductivity Bridge Method - Yellow Springs Instrument Model 31	(p.323)
Turbidity	Nephelometric Method - Hach Turbidimeter - Model 2100	(p.349)
Metals		
Arsenic Calcium Chromium Copper Iron Lead Magnesium Manganese Zinc	Atomic Absorption Spectroscopy - Perkin-Elmer Model 290 B	Analytical Methods for Atomic Absorption Spectrophotometry Perkin-Elmer Corp. 1968 (also p.211 Standard Methods)

TABLE A (CONT.)

ANALYTICAL METHODS

Parameter	Analytical Method (or instrument)	Reference* (page)
Barium	Turbidimetric Method – Hach DR-Colorimeter	Hach Colorimeter Methods Manual Hach Chemical Co. 1971
Nitrate	Brucine Method	(p. 461)
Phosphate (Total)	Stannous Chloride Method	(p. 530)
Sulfate	Turbidimetric Method	(p. 334)
Chloride	Argentometric Method	(p. 96)
Total Nitrogen (Organic)	Kjeldahl Method	(p. 244)
Total Dissolved Solids	Filtrable Residue, Difference Method	(p. 539)
Total Solids %	Total Residue (%)	(p.540)
Total Organics	Volatile Residue (%)	(p. 540)
Total Volatile Acids	Column - Partition Chromatographic Method	(p. 577
Total Coliforms	Standard Total Coliform - MPN Tests	(p. 664)
Fecal Coliforms	Fecal Coliform MPN Procedure	(p. 669)
Fecal Streptococci	Multiple Tube Technic	(p. 689)
H_2S - Gas	Mine Safety Appliances – Universal Testing Kit #83500 with detector tubes for H_2S #87414	Mine Safety Appliances Co.

TABLE A (CONT.)
ANALYTICAL METHODS

Parameter	Analytical Method (or instrument)	Reference*(page)
Gas: CO_2 CH_4 O_2 N_2	Gas Chromatographic Method - Varian Aerograph Model A90P3	(p. 546)
Hardness	EDTA Titrimetric Method	(p. 179)
Fluoride	SPADNS Method	(p. 174)
CO_2	Nomographic Determination of Free Carbon Dioxide and the Three Forms of Alkalinity	(p. 86)
Nitrogen (Ammonia)	Nesslerization Method	(p. 226)

*Standard Methods for the Examination of Water and Wastewater, 13th Edition, Washington, D.C., APHA, AWWA, WPCF, 1971.

TEST PROCEDURE FOR

MOISTURE CONTENT DETERMINATION

Samples are received in plastic bags with ties to seal airtight.

1. Remove bag tie and tag and obtain weight of sample and bag.

2. If sample is tightly packed, loosen to facilitate drying.

3. Place bag with sample in oven and dry at 102 C for approximately 24 hours.

4. Remove bag from oven and place in dessicator to cool.

5. After bag and sample have cooled (about 30 minutes), remove from dessicator and obtain weight of the dried sample and bag.

6. Remove sample from bag making sure all of sample is removed. Save sample to determine organic content.

7. Determine tare weight of bag.

8. Calculate moisture content using the following formulas:

Moisture content, percent by dry weight=

$$\frac{(\text{tare} + \text{wet sample}) - (\text{tare} + \text{dry sample})}{(\text{tare} + \text{dry sample}) - (\text{tare})} \times 100$$

Moisture content, percent by wet weight=

$$\frac{(\text{tare} + \text{wet sample}) - (\text{tare} + \text{dry sample})}{(\text{tare} + \text{wet sample}) - (\text{tare})} \times 100$$

CITY OF OCEANSIDE/E. P. A. BORE HOLE DRILLING PROGRAM
INSTRUCTIONS

A. Drilling Instructions

1. Drill Site Location. Three sites will be selected on the landfill to include the following conditions: 1) freshly placed sludge-solid waste, 0 to 2 weeks old; 2) older sludge-solid waste placed about the same time as the test cells; and 3) old solid waste without sludge placed about the same time as the test cells. Condition 1) will be on the top of the current working face; conditions 2) and 3) will be selected on the first drilling period and first drilling period and drilling will be done in the same area in subsequent quarterly drilling periods.

One hole in each test cell to be drilled at least 15 feet from the gas and temperature probes. Bore holes to be drilled in a clockwise direction each time starting on the west side of the probes.

a. Test Cells. Drill to a 12-foot depth (10-foot depth excluding soil cover) to stay at least 3 feet above the bottom of each test cell.

b. Landfill. Locate the drill at least 15 feet from nearest canyon wall where feasible. Drill to a 20-foot depth into the waste fill or until either refusal or the bottom of the fill is encountered.

2. Drill Rig. A 12-inch auger drill bit on a 40-foot rig.

3. If obstacles are encountered while drilling in any hole, move the drill rig 5 to 10 feet and drill again.

B. Core Sampling Observations

1. Temperature. Insert thermometer into fresh waste on auger bit at two-foot intervals as bit is withdrawn in two-foot increments.

2. Odor. Describe odor at two-foot intervals as:

a. Strength. Strong, medium, weak, none.
b. Type. Earthy, pig pen, sweet, grassy, sour.

3. Color. Describe components natural if no change has occurred or as they appear if changed (faded, bleached, brightened, dulled, etc.).

4. Readability. Describe if newsprint, paper labels, etc. are readable, blurred, or unreadable.

5. Biodegradability. Note components' (cans, glass, grass, newsprint, polyethylene, sticks, etc.) degradability.

6. Appearance. Describe if waste components are dry, moist, powdery and crumbling, compact and agglomerated.

7. Samples. Fill a 1-quart sample bottle with representative wastes at two-foot intervals and check off on data sheet.

C. Backfilling

Backfill the core holes with the solid waste and soil removed from the same hole. If additional backfill material is needed, use solid waste from the existing fill face. Cover the hole with the original cover soil.

D. Core Sample Removal

The procedure to be followed is to drill into the solid waste a distance of 2 feet and remove the bit for sampling and observation of the material as described under item B above. Clean off the drill bit and drill into the waste and remove the drill for sampling, etc. Mark the auger drill bit with emery cloth at 2-foot intervals (allow for soil cover) so that drill depth can be measured.

E. Gas Detection Tests

Gas detection tests for hydrogen sulfide and methane are at the 10-foot depth in the test cell bore holes and the 20-foot depth in the landfill bore holes. A plastic tube with a permeable material on one end is lowered to the bottom of the hole and the hydrogen sulfide and methane tests made as done on the test cells.

ANALYSIS OF TEST CELL BORE HOLE SAMPLES FOR BACTERIA COLIFORM (E. COLI), FECAL STREPTOCOCCUS, PSEUDOMONAS AERUGINOSA

Preparation of Sample for Bacterial Analysis:

Thirty grams of solid sample were withdrawn from the jar aseptically and added to a sterile 500-ml capacity bottle containing 270 ml of 0.067M cold phosphate buffer, pH 7.2. Contents of the bottle were mixed thoroughly by vigorous shaking of the bottle 50 times. The suspension was then filtered through a four-layered sterile cheese cloth into another sterile empty bottle. This filtrate was used to prepare a series of decimal dilutions.

Preparation of Decimal Dilutions:

The filtered suspension prepared as noted above was diluted 1:10. Ten ml of this suspension was transferred to a dilution bottle containing 90 ml of phosphate buffer. The bottle was stoppered and shaken vigorously 25 times. This gave a 1:100 dilution. Further dilutions were made in a similar fashion up to 1:1,000,000 by transferring 10-ml portions into 90 ml sterile phosphate buffer for each subsequent dilution. These dilutions were used to inoculate a series of selected culture media for detecting various specific microorganisms as well as standard bacterial plate counts.

Bacterial Count by Pour Plate:

Each dilution bottle containing an appropriate dilution of the test sample was shaken vigorously 25 times and 1-ml portions were pipetted into each of the appropriately marked duplicate Petri plates. Fifteen ml of molten agar (Difco) prepared in accordance with Standard Methods was held at 45 C. The test sample was added to the agar in the Petri plate and mixed thoroughly with the agar by rotating and tilting the plate. The plates were allowed to solidify soon after mixing and incubated at 35 $\pm$ 0.5 C for 24 hours in an inverted position.

The bacterial colonies developed after incubation were counted and the bacterial content for each sample was computed from the plates containing 20 to 300 colonies. The colony count was computed per gram of the sample (wet weight).

Determination of Total Coliform Group by MPN Method:

Presumptive Test:

One-ml portions of each decimal dilutions of each sample were inoculated into 5 lactose broth tubes in identical fermentation media (10 ml medium per tube). The range of decimal dilutions used was 10^{-2} to 10^{-5} for each test sample. The fermentation tubes were incubated at 35 $\pm$ 0.5 C for 24 hours and examined for the presence of gas. If no gas was present the tubes were incubated for another 24-hour period. Tubes showing the presence of gas were recorded as being positive in the presumptive test.

Confirmed Test:

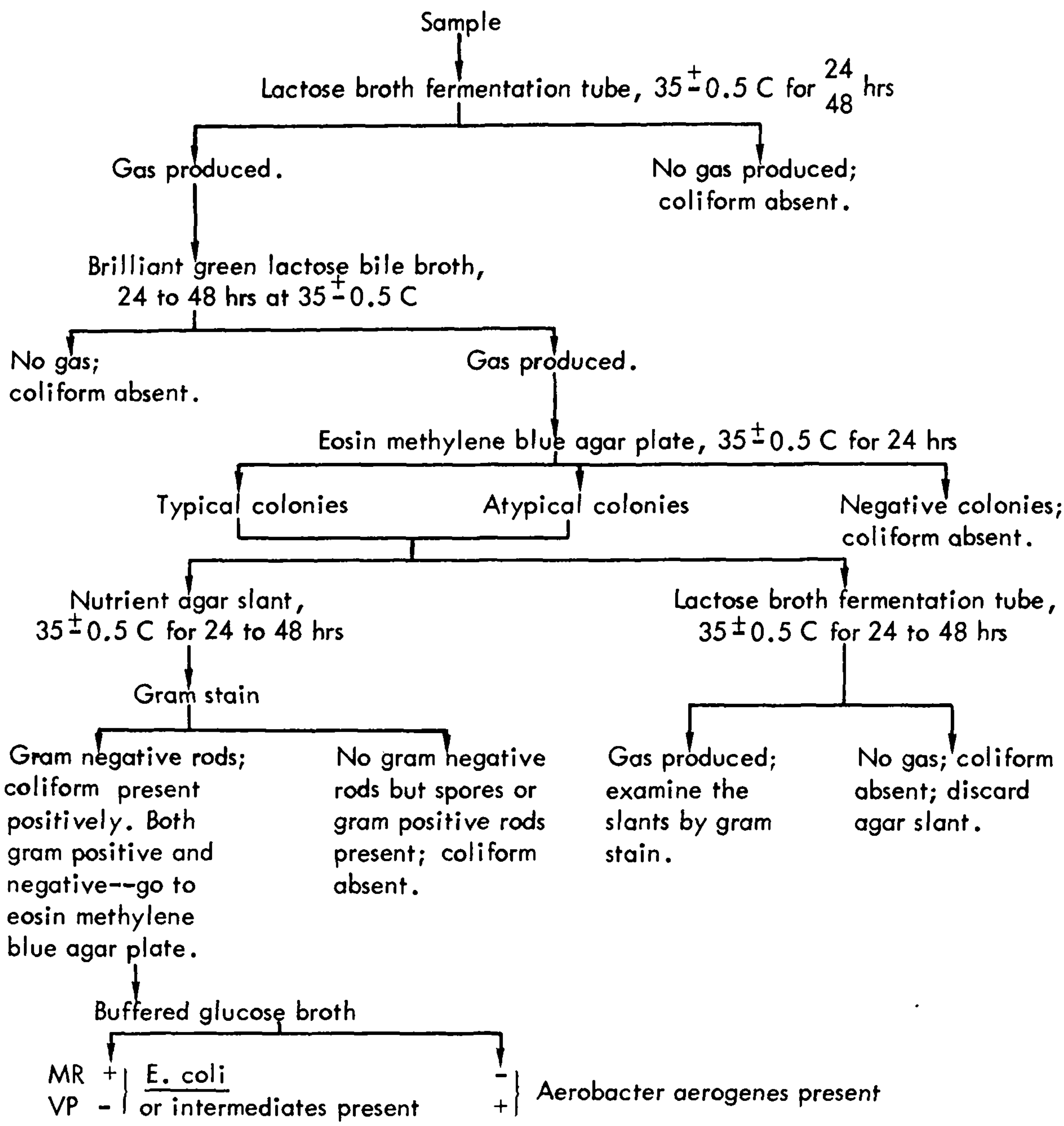
All tubes showing a positive presumptive test were submitted to a confirmation test. For this purpose a loopful (3 mm in diameter)of the culture in the presumptive fermentation tube was transferred to another fermentation tube containing brilliant green lactose bile broth. These tubes were marked appropriately and incubated at 35 $\pm$ 0.5 C. They were examined periodically for the production of gas. Tubes which did not show any gas production after 48 hours of incubation were considered negative (i.e.,coliform were absent) and discarded.

Completed Test:

All brilliant green lactose bile fermentation tubes giving positive reactions within 48 hours were submitted to the confirmation test. A loopful of the culture from the confirmed test tube was streaked onto an appropriately marked eosin methylene blue agar (Levine) plate soon after the production of gas. The plates were incubated in an inverted position for 24 hours at 35 $\pm$ 0.5 C and examined for the presence of typical colonies showing a green metallic sheen; atypical colonies were transferred out from the plate and inoculated into appropriately marked lactose broth fermentation tubes and nutrient agar slants. The tubes and the agar slants were incubated at 35 $\pm$ 0.5 C for 24 to 48 hours. Gram-stained smears were prepared from the agar slants if any amount of gas was produced in the corresponding lactose broth fermentation tubes. If no gas was produced in lactose broth fermentation tubes after 48 hours of incubation, the coliform group was considered to be absent in those tubes and no gram-stained smears were prepared from corresponding tubes. The gram-stained smears prepared from the agar slants were examined in oil immersion under a suitable microscope for the presence or absence of spores. If the smear contained gram negative rods and no spores the test was considered to be completed, i.e.,positively present coliform in the tube. If spores or gram positive rods were found on the smear the test was considered to be negative, i.e.,absence of coliform bacteria in the tube. If both gram positive and gram negative rods and/or spores were found on the smear the test was considered indecisive and the procedure beginning from eosin methylene blue agar (Levine) plate was repeated.

Differential Test:

A small portion from the bacterial growth on nutrient agar slant whose smear showed only gram negative rods was inoculated into appropriately marked tubes in duplicate containing 5 ml of buffered glucose broth and incubated at 35 $\pm$ 0.5 C for 3 to 5 days. After incubation one of the duplicated tubes was treated with 5 drops of methyl red indicator solution (0.1 gram methyl red in 300 ml of 95% ethyl alcohol and diluted to 500 ml with distilled water). Development of a red color was considered as methyl red positive and development of yellow color was considered as methyl red negative.



From: Standard Methods for the Examination of Water and Wastewater, 13th Edition, AWWA, WPCF, et.al, 1971.

FIGURE 1
BACTERIAL ANALYSIS
FLOW SHEET

The other duplicate tube of the buffered glucose broth was incubated for 3 days and tested by the Voges - Proskauer test by adding 3 ml of fresh α -naphthol solution (5g in 100 ml absolute ethanol) and 1.0 ml of 40% KOH solution and incubating at room temperature for 2 to 4 hours. Development of a pink to crimson color in the culture indicated positive V-P test; otherwise the test was considered as negative. A combination of positive methyl red (MR) and negative V-P tests indicated the presence of E. coli and/or its intermediates in the tube. (The flow sheet is shown in Figure 1,)

Quantitative Analysis for Pseudomonas Aeruginosa:

Presumptive Test:

One-ml portions from each decimal dilutions of each sample were inoculated into duplicate sets of 5 tubes of asparagine enrichment broth. The tubes were incubated at 35 ± 0.5 C for 48 hours. The tubes were examined for development of turbidity and/or green or blue-green color. The tubes showing such characteristics were considered as positive presumptive. The negative presumptive tubes were discarded.

Confirmation Test:

The asparagine enrichment tubes, which gave positive presumptive tests, were used to inoculate appropriately marked acetamide broth tubes. The acetamide broth tubes were incubated at 35 ± 0.5 C for 48 hours. Development of violet color in the medium indicated a positive confirmed test for Pseudomonas aeruginosa.

Completed Test:

Culture from positive acetamide broth (confirmation test) tubes was streaked onto appropriately marked "TECH" agar plates for isolated colonies. The plates were incubated at 35 ± 0.5 C for 24 hours. Development of diffusible blue-green color indicated the presence of Pseudomonas aeruginosa. Gram-stained smears were prepared from one of these colonies and viewed in oil immersion under microscope for the presence of gram negative rods to further confirm the presence of Pseudomonas aeruginosa.

Quantitative Analysis for Fecal Streptococci:

Presumptive Test:

One-ml portions of each decimal dilutions were inoculated into a series of appropriately marked azide dextrose broth tubes containing 10 ml of the medium. The tubes were incubated for 24 to 48 hours at 35 ± 0.5 C and examined for growth indicated by turbidity.

Confirmation Test:

Two drops of culture from all positive presumptive test tubes was inoculated into appropriately marked tubes containing 10 ml of ethyl violet azide broth using sterile Pasteur pipets. The tubes were incubated at 35 ± 0.5 C for 24 hours and examined for the formation of a purple button at the bottom (positive confirmation test). If tubes showed a negative confirmation test at this point, they were inoculated with two additional drops of culture from positive presumptive test tubes, which were always saved. The confirmed test tubes were incubated again at 35 ± 0.5 C for 24 hours and examined for positive or negative reactions.

Completed Test:

Tubes of brain heart infusion broth supplemented with 6.5% sodium chloride were inoculated with three loopfuls of culture from positive presumptive tubes corresponding to positively confirmed test tubes. The completed test tubes were incubated at 35 ± 0.5 C for 48 hours and examined for growth. Turbidity in 6.5% NaCl broth constituted a completed test.

As a check, gram-stained smears were prepared from 6.5% NaCl broth and viewed under a microscope.

CORE SAMPLE MOISTURE SATURATION AND LEACHATE GENERATION METHODOLOGY

1. After determination of moisture and organic content in the core samples was completed, the core samples in each bore hole having the highest and lowest moisture contents were selected for saturation and leaching tests.

2. A representative sub-sample of materials in each selected core sample was obtained and weighed.

3. The weighed sub-sample was packed into a 2-inch diameter transparent polyethylene column on top of a 1/8-inch square mesh screen support. The column system was capped at the top and bottom to close the system. A 1/16-inch I. D. glass drain tube was installed through the bottom cap. A 200-ml buret with a stop-cock control was positioned above the column with its nozzle extending through the top cap. A 200-ml graduated flask was placed below the column with the glass column drain tube passing through a rubber stopper in the top of the flask.

4. The buret was filled with 200 ml of distilled water and the stop-cock was opened to allow the water to drip into the column onto the packed solid waste material. The optimum rate of water application was determined in preliminary tests to be about 400 ml per hour. Additional distilled water was added to the buret in 100-ml portions as required to maintain a minimum of 50 ml head in the buret. Water addition required about 30 to 50 minutes to reach saturation. Saturation was indicated when prolonged dripping of water from the bottom of the sample began as determined by observation. The volume of water added to saturation (less any leachate) was determined to calculate the percent dry weight of water absorbed.

5. The water application was continued after saturation until at least 157 ml of leachate was collected in the 100-ml flask.

6. The 157 ml of leachate was used to determine BOD_5 on the HACH Manometric BOD_5 apparatus.

APPENDIX B

DATA SHEETS

WASTE SAMPLE WEIGHTS, LB

OFFICE OF SOLID WASTE MANAGEMENT PROGRAMS
(WASTE CATEGORIES)

OBSERVER ____________
DATE ____________

1. Paper			2.	3.	4.	5. Garden			6.	7. Plastic Rubber Leather		8.	9.		Other
Newsprint	Cardboard (Solid and Corrugated)	Misc. Paper	Food	Glass, Ceramic	Metals	Tree & Shrub Prunnings	Leaves	Grass	Textiles	Plastic, Rubber Leather - Solid	Plastic, Rubber-Foam	Wood	Dirt, Ash, Sand	Concrete, Rock	2 Inch Sieve

Date: ____________________

Observer: ____________________

Title: ____________________

LANDFILL VEHICLE COUNT TALLY SHEET

Type and Size of Vehicle						Type of Waste Load		
			Waste Collection Vehicles					
Auto/ Station Wagon	Pick-up Truck Van 1/4-1 ton	Truck Over 1 ton	Private/ Industrial	Oceanside Municipal	Other Municipal	Domestic Household	Industrial	List Wastes & Comments

Enter check (√) or volume in cu yd if known.

Check (√) appropriate column(s).

OCEANSIDE TEST CELL TEMPERATURE RECORD

Date	Temperature, Deg F									
	Ambient	Cell No. 1			Cell No. 2			Cell No. 3		
		S[1]	M-D[1]	B[1]	S	M-D	B	S	M-D	B

[1] S = surface probe temp; M-D = mid-depth probe temp; and B = bottom probe temp.

MONTHLY OCEANSIDE TEST CELL LEACHATE SAMPLING[1]

Date	Sample No.	Quantity (gal)	BOD (mg/l)	Cl (mg/l)	TDS (mg/l)	N (mg/l)	Coliform (MPN)	EC (μmhos)

[1] Return each data sheet with the listed samples.

LANDFILL EQUIPMENT OPERATIONS
CITY OF OCEANSIDE

Observer ____________________ Driver ____________________

Date ____________________ Dozer ____________________

Time	Weather		Equipment Time/Task, Min. (1/100)					Flies, Rats, Birds
	Temp. °F	Con-dition *	Non-pro-ductive +	Working Refuse	Placing Soil Cover	Moving Earth	Travel	

*Describe weather as: (a) sunny; (b) cloudy; (c) rain; (d) wet ground (not raining).

+Include equipment maintenance, coffee/lunch breaks, breakdown/stuck, talk, etc.

EPA GRANT NO. S-801582

Date ______________ Page _____ of _____

Weather ________________ Observer ________________

LOAD COUNT DATA SHEET

Time	Type of Vehicle					Capacity cu. yd.	Total Vehicle Wt., Lbs.	Bucket Loads Soil, No.	Type of Load						Comments
	Street Sweeper % Full	Pick Up 1/4 to 1 ton % Full	Truck Over 1 ton % Full	Waste Disposal WD No.	Other Specify				Residential	Industrial	Brush & Trees	Dirt	Demolition	Other	

Note: Capacity not needed for WD vehicles. Give capacity and percent full (estimate) for other vehicles, weight is not required. Give load type for all open vehicles.

EPA/CITY OF OCEANSIDE

Observer______________ Page_____of______

TRACTOR OPERATIONS DATA

Date	Cat 977		Cat 977K		Comments
	Hours Used	Buckets of Soil for Cover	Hours Used	Buckets of Soil for Cover	

FIELD TEST OF SLUDGE DISPOSAL

Date	Solid Waste, Lb	Sewage Sludge, Gal	Weather			Odor, Describe	Blowing Litter	Birds, Rats, Other, No.		Comments
			Temp °F	Wind*	Condition+			Test Area	Regular Landfill	

*Enter - Calm, Low, Moderate, or High.
+Enter - Sunny, Cloudy, Overcast, Showers, or Rain.

Date/time ______________ Observer ______________

Temp. ______ Weather ______________

CORE SAMPLE DATA SHEET

Bore hole no. ______ Depth (ft) ______

Check-off when taken: Photo ( ) Sample ( )

(Take at bottom of 10 or 20 ft hole: CH_4 (mg/l) ______ H_2S (mg/l) ______)

Waste material category	Temp. (F)	Odor	Color	Readability	Appearance	Biodegradability
Newsprint						
Miscellaneous paper						
Cardboard						
Food						
Textiles						
Grass						
Leaves						
Tree & shrub prunings						
Plastic, rubber						
Leather						
Wood						
Metal						
Glass & ceramics						
Dirt, ash, sand						
Sewage sludge						

Comments ____

____

____

Continue on back

DS-1: SLUDGE APPLICATION DATA - FIELD TEST OF SLUDGE DISPOSAL Observer________________

Date & time	Loads disposed, no.		Weather			Sludge disposal	Est. qty, gallons	
	Solid waste by type*	Sludge load by type+	Temp. °F	Wind#	Condition**	Describe method of sludge and solid waste placement, and condition of sludge when observed (wet, dry)	Runoff	Leachate (sample when observed)

*Type of load: for WD (Waste disposal collection trucks) enter "WD-no. loads". For other loads indicate "Type-no. loads".

+Indicate type of sludge as: SLR-no.(gallons/load); and for Buena Vista (BV) and La Salina (LS) note primary digested (PD), primary raw (PR) or secondary digested (SD) sludge. Example: LS - 3 (3,500) (SD).

#Enter - calm, low, moderate or high. **Enter - sunny, cloudy, overcast, showers or rain.

DS-2: ENVIRONMENTAL OBSERVATIONS - FIELD TEST OF SLUDGE DISPOSAL Observer________________

Date & time	Sludge test area: ft x ft						(No sludge) Regular landfill area: ft x ft					
	Blowing litter, no. items*	Animals and insects, no/PA+				Odor‡	Blowing litter no. items*	Animals and insects, no/PA+				Odor‡
		Birds	Rats	Flies	Others!			Birds	Rats	Flies	Others!	

*Estimate the number of items travelling in the wind. Do not include items waving or flapping in the wind which are held down at one end.

+Count the number of birds and animals on the waste fill and estimate the total area in square feet (feet). The sludge test area size shall include all solid waste fill surface which is covered with sludge or was mixed with sludge at the time of observation. PA = populated area where 80 percent or more of the observed population is foraging.

#Estimate the area covered by flies and the number of flies, maggots.

‡ Earthy, pig pen, sweet, etc.; none, medium, strong, etc.

! Indicate rats, cats, dogs or other unusual animal or insect or event.

Observer________________
Date/Day________________

DS-3: LANDFILL EQUIPMENT OPERATIONS
CITY OF OCEANSIDE

Driver____________________
Dozer____________________

Clock Time (wait)	Temp (deg F)	Con- dition*	Task time, min/100								Refuse condition, describe
			Equipment								
			Nonpro- ductive	Travel	Moving refuse	Working refuse	Moving soil	Placing soil cover	Apply water#	Unload sludge	As received, dry or wet; (sludge admixed, dry or wet)

*Describe weather as: sunny; cloudy; showers; rain, overcast; wet ground.

+Nonproductive equipment time includes any time dozer motor is running, but dozer is not moving such as: equipment, repair, stuck, driver doing other tasks.

#Note if dozer driver (D) or handyman (H) is watering refuse.

CONFIDENTIAL COOPERATIVE NATIONWIDE SURVEY OF SLUDGE DISPOSAL TO SANITARY LANDFILLS

We are conducting special studies on disposal of sludges and hazardous wastes.
Please complete and return to: Ralph Stone and Company, Inc. 10954 Santa Monica Boulevard Los Angeles, California 90025 Phone: (213) 478-1501

For your cooperation in completing this questionnaire, you will receive a summary of the national results.

Landfill Location(s)________________________Operator (name)______________
Check one: ( ) Public ( ) Private Approx.population served_________
Address______________________________

1. Are any sludges, liquid wastes, or hazardous wastes disposed to the landfill?
( ) Yes (Please complete all questions.) ( ) No (Please complete questions 2, 6, 7, and 8.)

2. Is disposal of sludge, liquid wastes, or hazardous wastes to landfills regulated or inspected? ( ) Locally; ( ) State (Please enclose regulations); ( ) Unregulated; ( ) Seasonal; ( ) Routinely Performed
Comments:____

3. Please estimate the following quantities:

Type of Sludge	Quantity Disposed (gal/yr)	Rate of Disposal (gal/yr)	Sludge Solids Content (%, dry weight)	Solid Waste Disposed (tons/yr)
Municipal Sewage Sludge				
Septic Tank Pumpings				
Industrial* Sludge/Liquid Waste				
Hazardous Waste *				

* Identify types, quantities of waste, and disposal locations, for radioactive, pesticides/ herbicide chemicals, industrial acids and chemicals, hospital, explosives, combustibles in the space at the bottom of this page.

4. Please describe the method for applying sludge to the landfill on the back of this questionnaire.

5. Do procedures exist for the following (describe where applicable):
   a. Catching drainage from sludge overflow ( ) Yes ( ) No______________
   b. Compaction ( ) Yes ( ) No______________________________
   c. Isolating landfill from contact with groundwater______________________
   d. Isolating landfill from surface drainage___________________________

6. Type of landfill operation:
Cut and Cover ( ) Other type___________Remaining Capacity in Fill (%)_____
Canyon or ravine ( ) Fill site area (acres)_________Avg.Annual Rainfall(in.)_____
Pit or Quarry ( ) Fill final depth (avg. ft.)___________

6. (Cont.)

Is refuse covered daily? ( ) Yes Depth of Cover (ft)______________ ( ) No
Do regulations exist on types of solid wastes accepted for landfill disposal?
( ) Yes (enclose copy) ( ) No
Is waste weighed as received at the landfill? ( ) Yes ( ) No
Approximate daily tonnage__________
Has the landfill caused local water pollution problems? ( ) Yes ( ) No
Comments:____
Have tests for leachate drainage from the landfill been made? ( ) Yes ( ) No
Describe quantity (gpd):______________________________________

7. Landfill use:
a. Is the landfill open to the public: ( ) Yes ( ) No b. How close is the nearest residential area_______ c. What is the planned use for the landfill site after filling is completed?______________________________________

8. Landfill Operation Opinion Question
NOTE: If sludge is disposed to your landfill, rate the effects as requested. If sludge is not disposed to your landfill, give your opinion of the effects you would expect if it was disposed. Your opinion is being solicited to learn the prevailing attitudes of landfill operators in the 50 states as a whole.

a. Environmental Impact of Hazardous Waste Disposal
Please rate, in your opinion, the seriousness of problems and hazards associated with handling, transporting, and disposing of the following waste materials:

Type of Waste Material	Anticipated Environmental Problem/ Hazard in Transportation and Disposal Via Landfill										
	None	Little			Moderate				Great		
	0	1	2	3	4	5	6	7	8	9	10
a. Municipal Sewage Sludge											
b. Septic Tank Sludge											
c. Radioactive Waste											
d. Pesticide/Herbicide, etc.											
e. Indus.Petro,chemicals											
f. Hospital Waste											
g. Combustibles											
h. Explosives											

b. Anticipated Sanitary Landfill Effect

Please rate municipal sludge, septic tank sludge, and other liquid and hazardous waste disposal to sanitary landfill relative to sanitary landfilling without disposal of these materials for each of the following conditions·

Landfill Conditions/Factors	Rating										
	Much Worse		Slightly Worse			Same	Slightly Improved			Greatly Improved	
	-5	-4	-3	-2	-1	0	+1	+2	+3	+4	+5
Fires											
Settlement											
Ease of Equipment Operation											
Ease of Compaction											
Compaction Density											
Operating Cost											
Blowing Dust and Litter											
Leachate Quantity											
Ground Water Quality											
Local Surface Water Pollution											
Flies											
Vermin											
Birds											
Gas Production											
Odors											
Fill Operator Health & Safety											
Public Attitudes											

Thank you very much for your assistance. Please use the space below for additional comments. Attach available reports when returning questionnaire.

File No. 219-0

CONFIDENTIAL COOPERATIVE SURVEY OF FIFTY STATES ON DISPOSAL OF SLUDGE, LIQUID OR HAZARDOUS WASTES TO SANITARY LANDFILLS

Please complete and return to: Ralph Stone and Company, Inc. Phone:
10954 Santa Monica Boulevard (213) 478-1501
Los Angeles, California 90025

We are conducting special studies on disposal of sludge and hazardous wastes to landfills. The study objectives include determining public health policy on handling and disposing of sewage sludge, septic tank pumpings, and industrial sludge, liquid and hazardous wastes. Your response to this questionnaire would, therefore, be most helpful. In return for your cooperation, a summary of the questionnaire results will be mailed to your agency upon completion of the study.

Name of State____________

Optional: Name__________________Title__________Address_________________

1. Does your state permit ( ) regulate ( ) inspect ( ) or prohibit ( ) disposal of the following liquid wastes to landfills:

   Municipal Sewage Sludge__________Industrial Sludge/Liquid Waste *___________

   Septic Tank Pumping _____________Hazardous Waste*_______________________

2. Estimate number of landfill sites disposing of sludge, liquid and hazardous waste*:

   ____

3. What problems, if any, have occurred in your state because of disposing any of the waste listed in item 1 into landfills?____________________________________

   ____

4. Recommended or existing alternative sludge/liquid waste disposal methods _______

   ____

5. Confidential Personal Opinion Question

   NOTE: Only your personal opinion is being solicited. ALL REPLIES TO THE FOLLOWING QUESTIONS WILL REMAIN CONFIDENTIAL. Only summary results will be published. It is understood that your rating will be a subjective, educated guess. We are primarily interested in learning the prevailing attitudes of knowledgeable Public Health/Sanitary Engineers in the 50 States as a whole.

a. Environmental Impact of Hazardous Waste Disposal

   Please rate, in your opinion, the degree of problems and hazards associated with handling and disposing of the following waste materials:

Type of Waste Material	Anticipated Environmental Problems/Hazard										
	None	Little			Moderate				Great		
	0	1	2	3	4	5	6	7	8	9	10
a. Municipal Sewage Sludge											
b. Septic Tank Sludge											
c. Radioactive Waste											
d. Pesticide/Herbicide Chemicals											
e. Industrial Acids, Chemicals, etc.											
f. Hospital Waste											
g. Combustibles											
h. Explosives											

* Identify types: radioactive, pesticides, herbicides, chemicals, industrial acids, hospital, explosives, or combustibles.

Anticipated Sanitary Landfill Effect

Please rate, in your opinion, the effects of disposing domestic sewage sludge, septic tank pumpings, industrial sludges*, liquid and hazardous* waste to landfills on each of the listed landfill factors.

Sanitary Landfill Conditions/Factors	Anticipated Effects of Sludge, Etc. Disposal										
	Much Worse		Slightly Worse			No Change	Slightly Improved			Greatly Improved	
	-5	-4	-3	-2	-1	0	+1	+2	+3	+4	+5
Leachate Quantity											
Ground Water Quality											
Local Surface Water Pollution											
Gas Production											
Odors											
Flies											
Vermin											
Birds											
Fill Operator Health & Safety											
Public Attitudes											
Aquatic Life (fish)											

* We will appreciate receiving a copy of your applicable State, Health and Safety Code Regulations regarding sanitary landfills, sewage sludge, septic tank and hazardous waste disposal. Thank you very much for your assistance.

APPENDIX C

ANALYSES OF SEWAGE SLUDGES FROM OCEANSIDE, CALIFORNIA

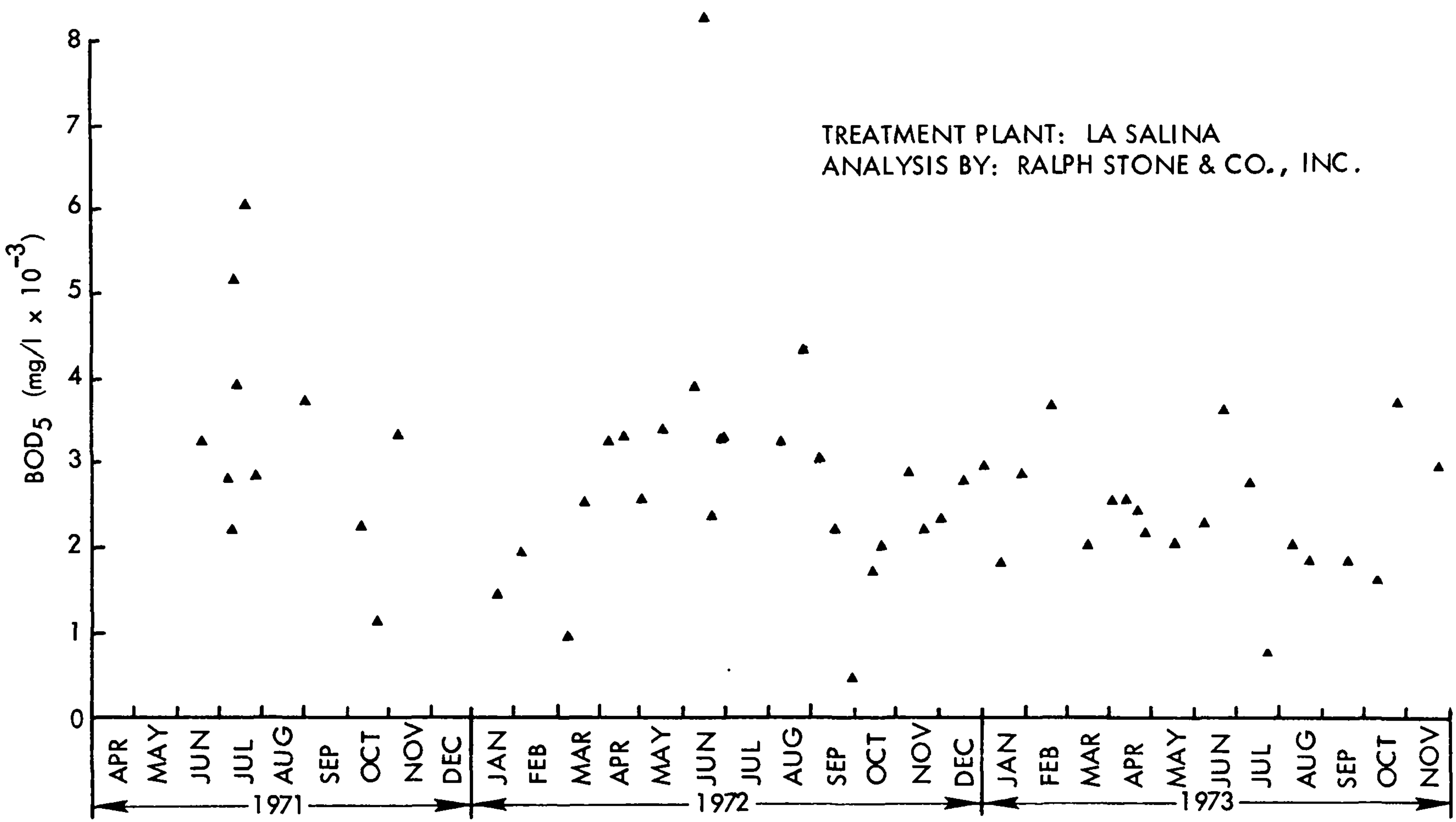


FIGURE C1
PROPERTIES OF SLUDGES
FROM OCEANSIDE, CALIFORNIA

TREATMENT PLANT: BUENA VISTA
ANALYSIS BY: RALPH STONE AND COMPANY, INC.

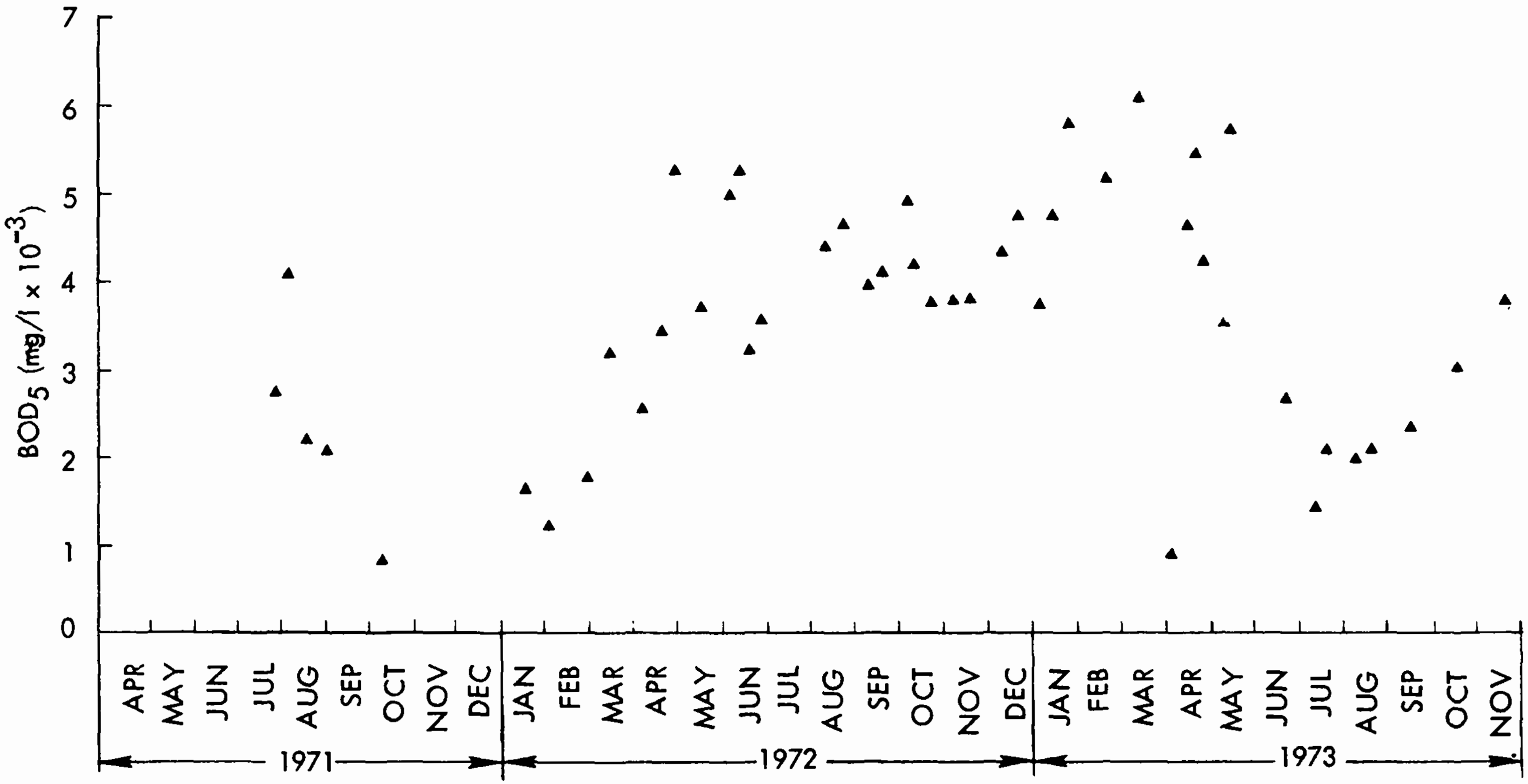


FIGURE C2
PROPERTIES OF SLUDGES
FROM OCEANSIDE, CALIFORNIA

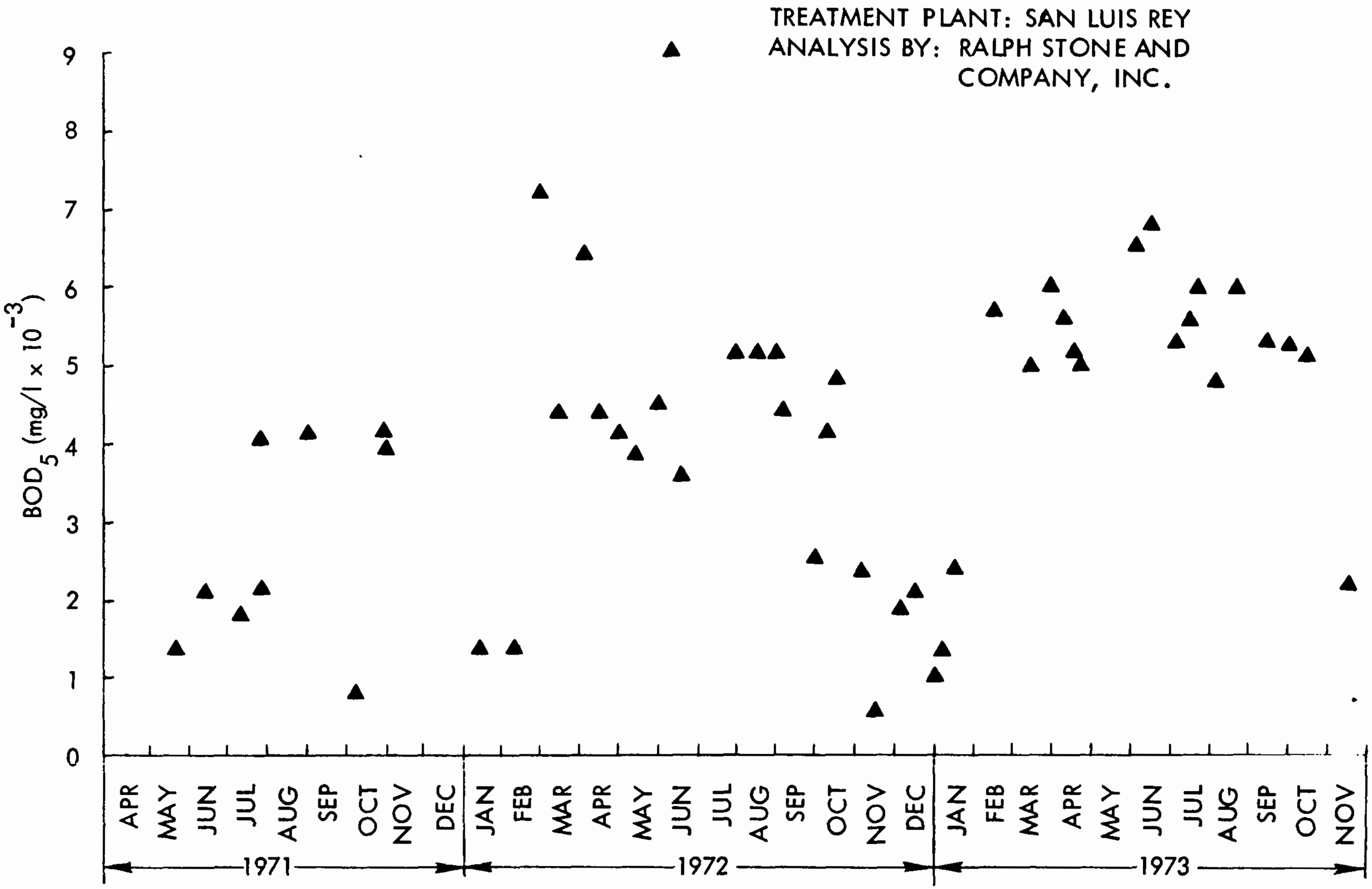


FIGURE C3
PROPERTIES OF SLUDGES
FROM OCEANSIDE, CALIFORNIA

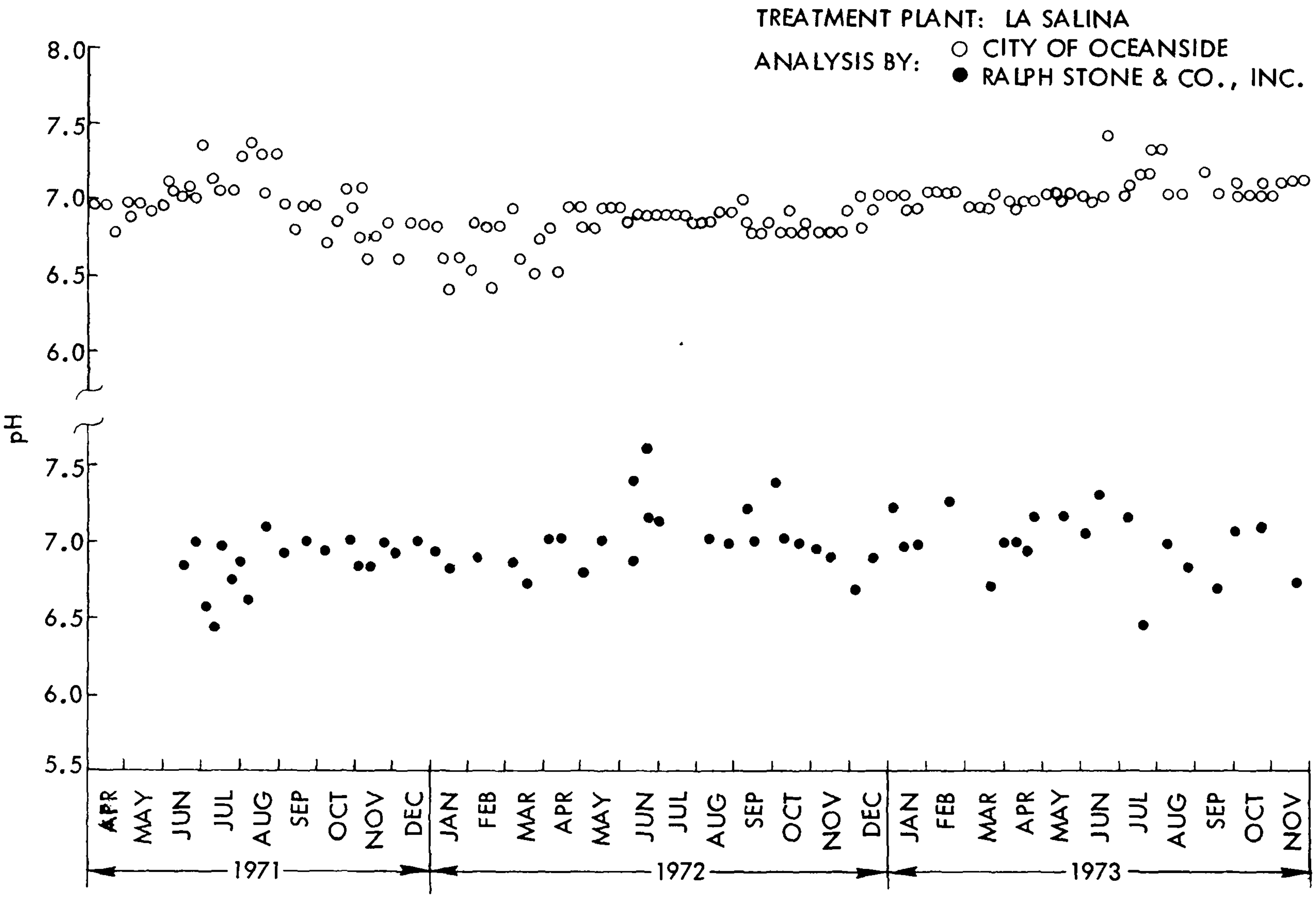


FIGURE C4
PROPERTIES OF SLUDGES
FROM OCEANSIDE, CALIFORNIA

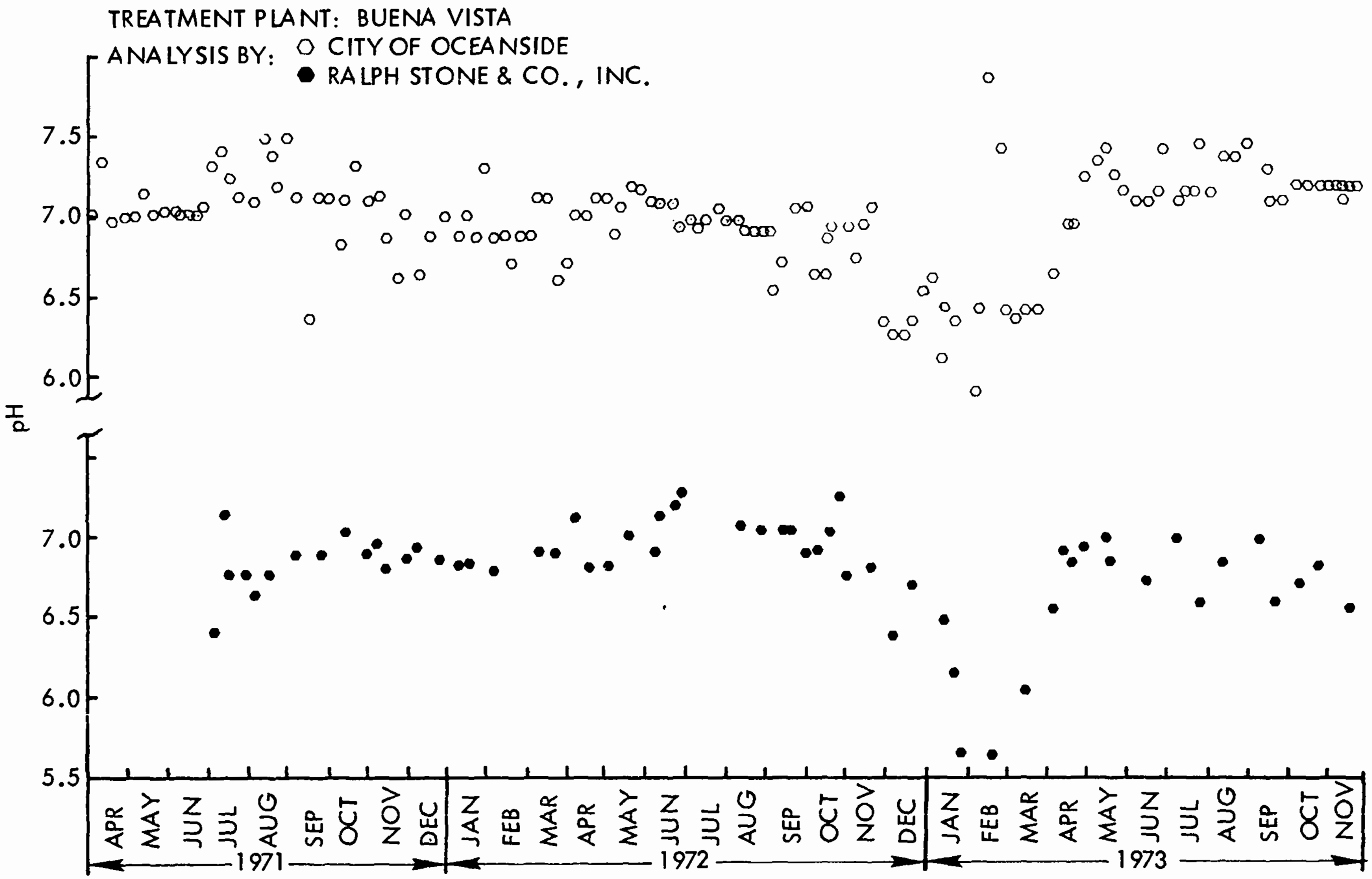


FIGURE C5
PROPERTIES OF SLUDGES
FROM OCEANSIDE, CALIFORNIA

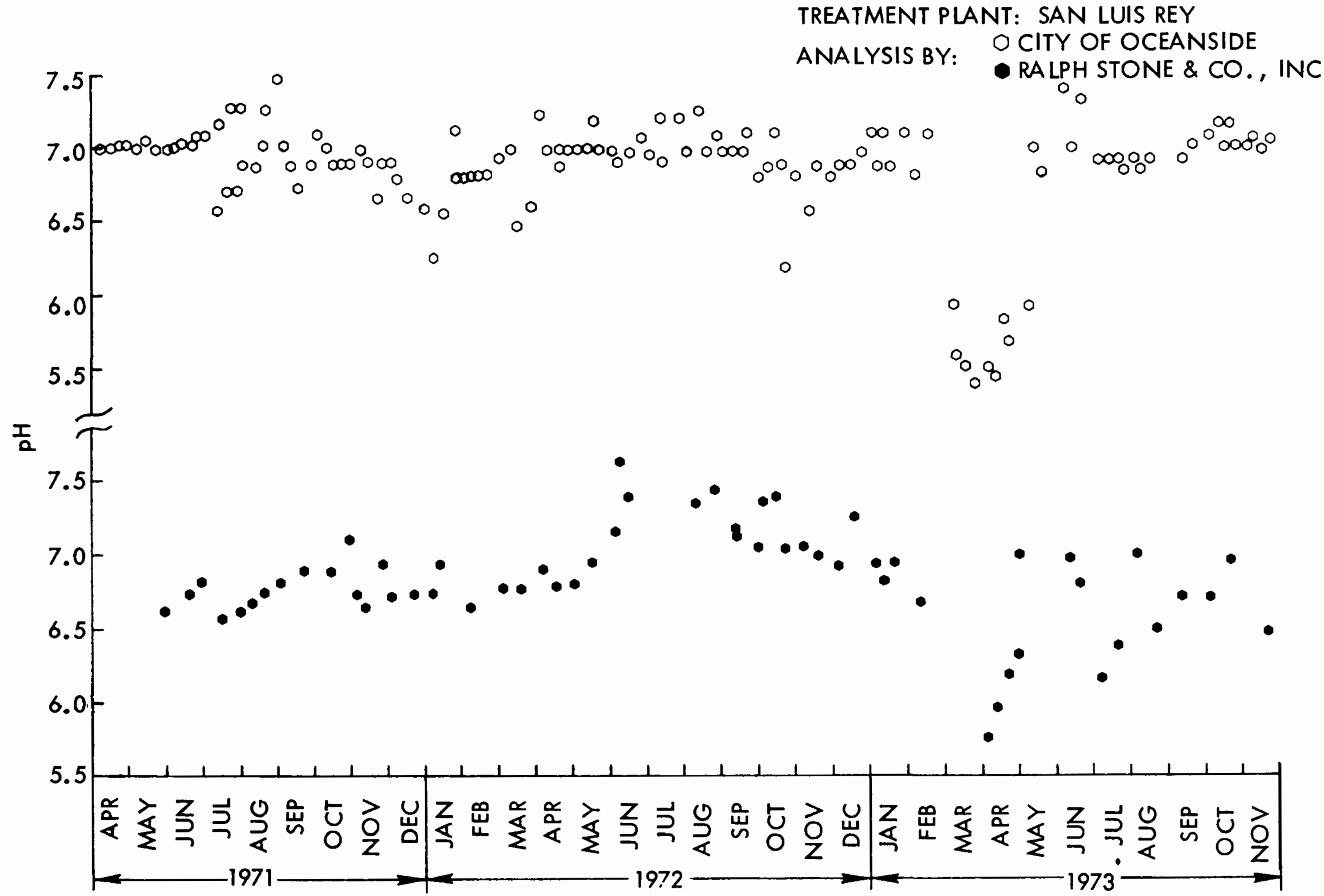


FIGURE C6
PROPERTIES OF SLUDGES
FROM OCEANSIDE, CALIFORNIA

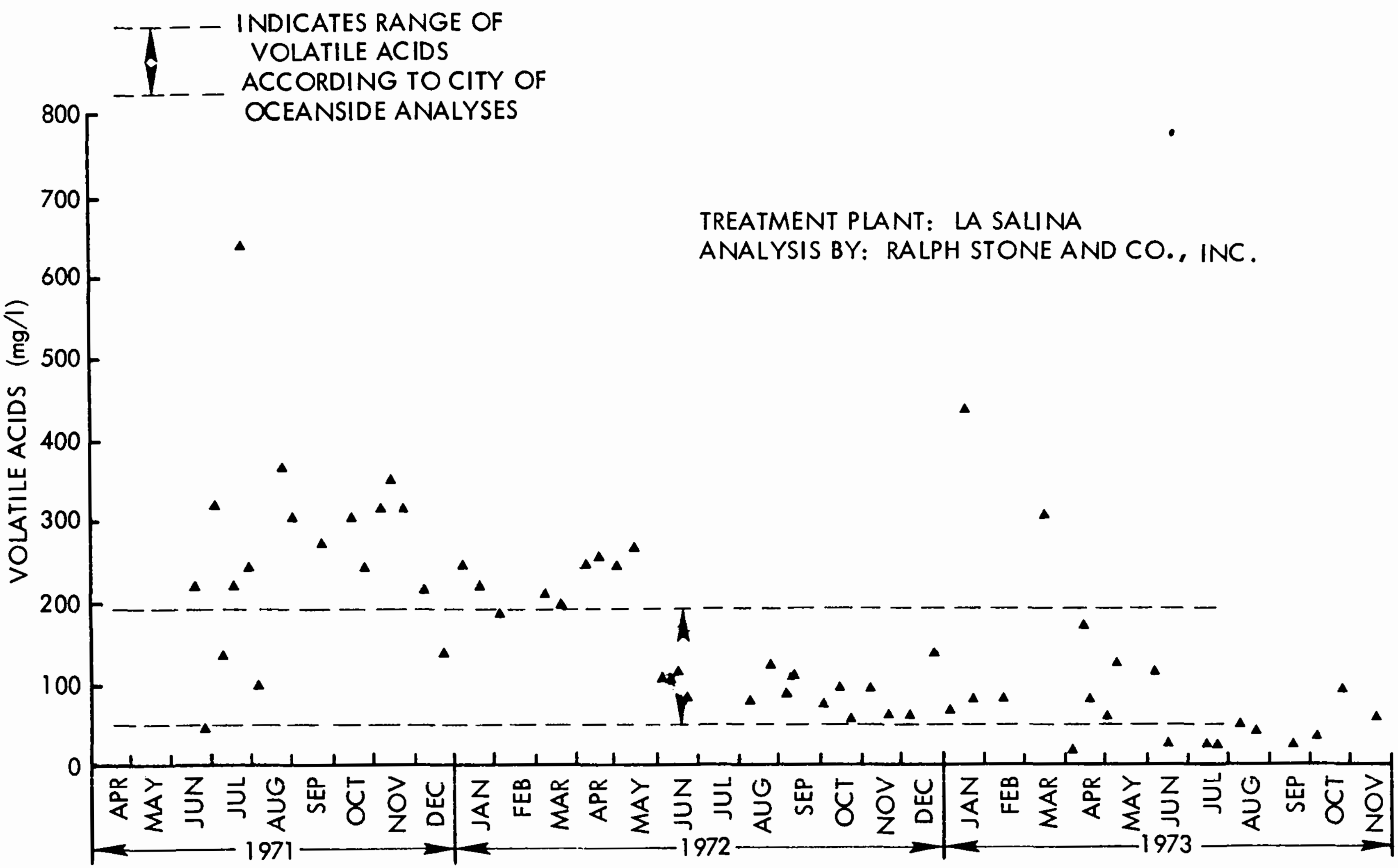


FIGURE C7
PROPERTIES OF SLUDGES
FROM OCEANSIDE, CALIFORNIA

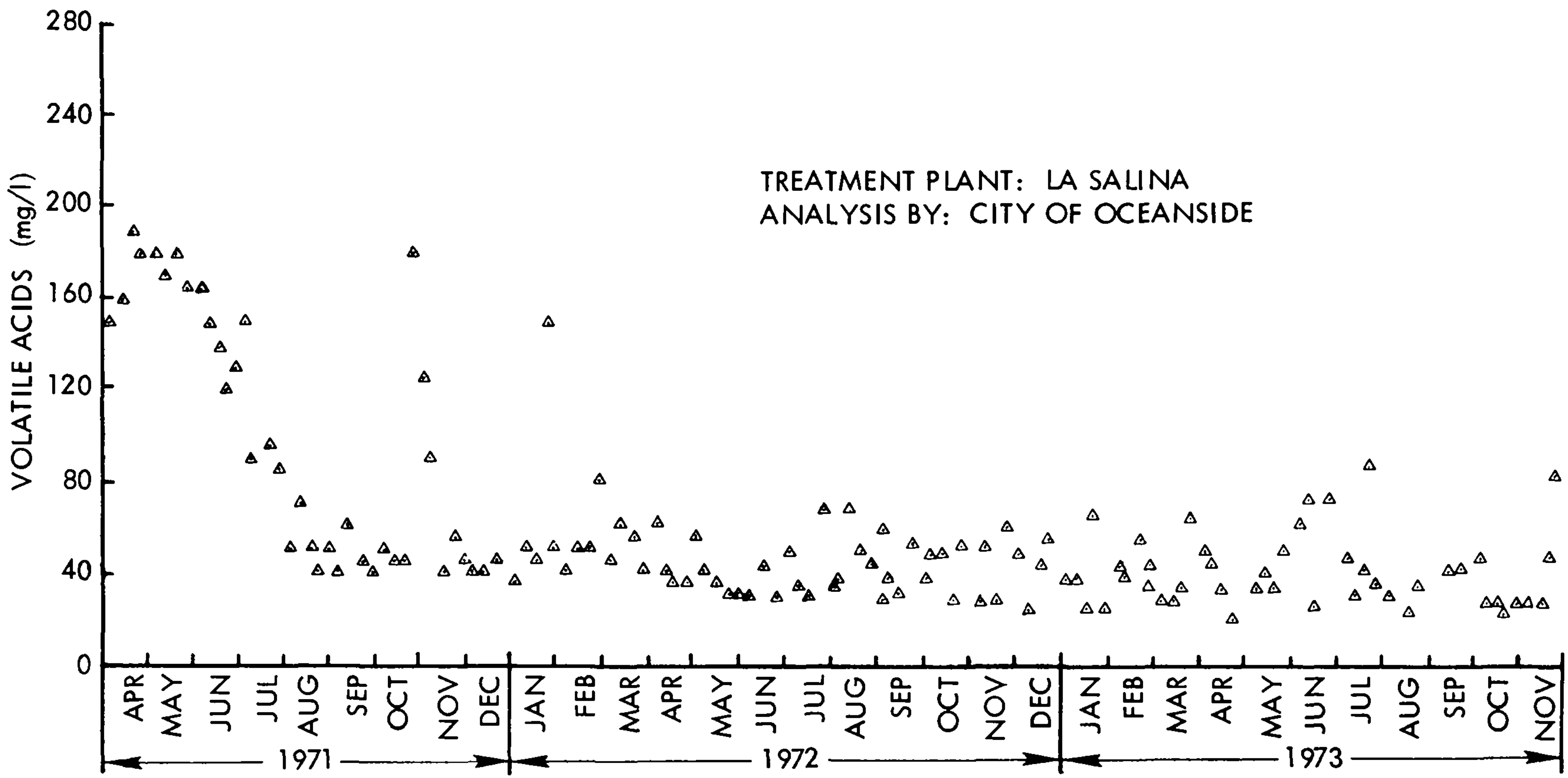


FIGURE C8
PROPERTIES OF SLUDGES
FROM OCEANSIDE, CALIFORNIA

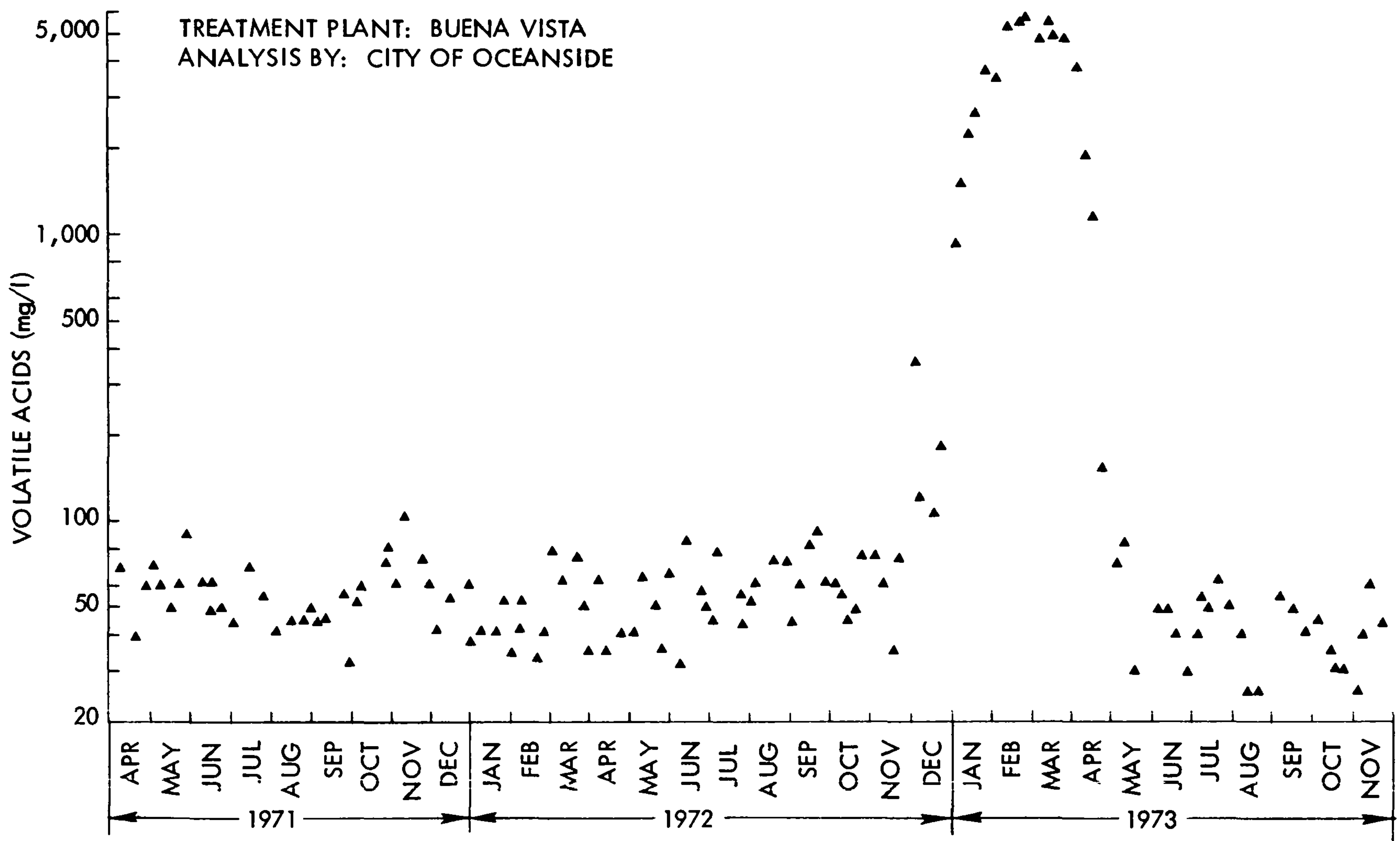


FIGURE C9
PROPERTIES OF SLUDGES
FROM OCEANSIDE, CALIFORNIA

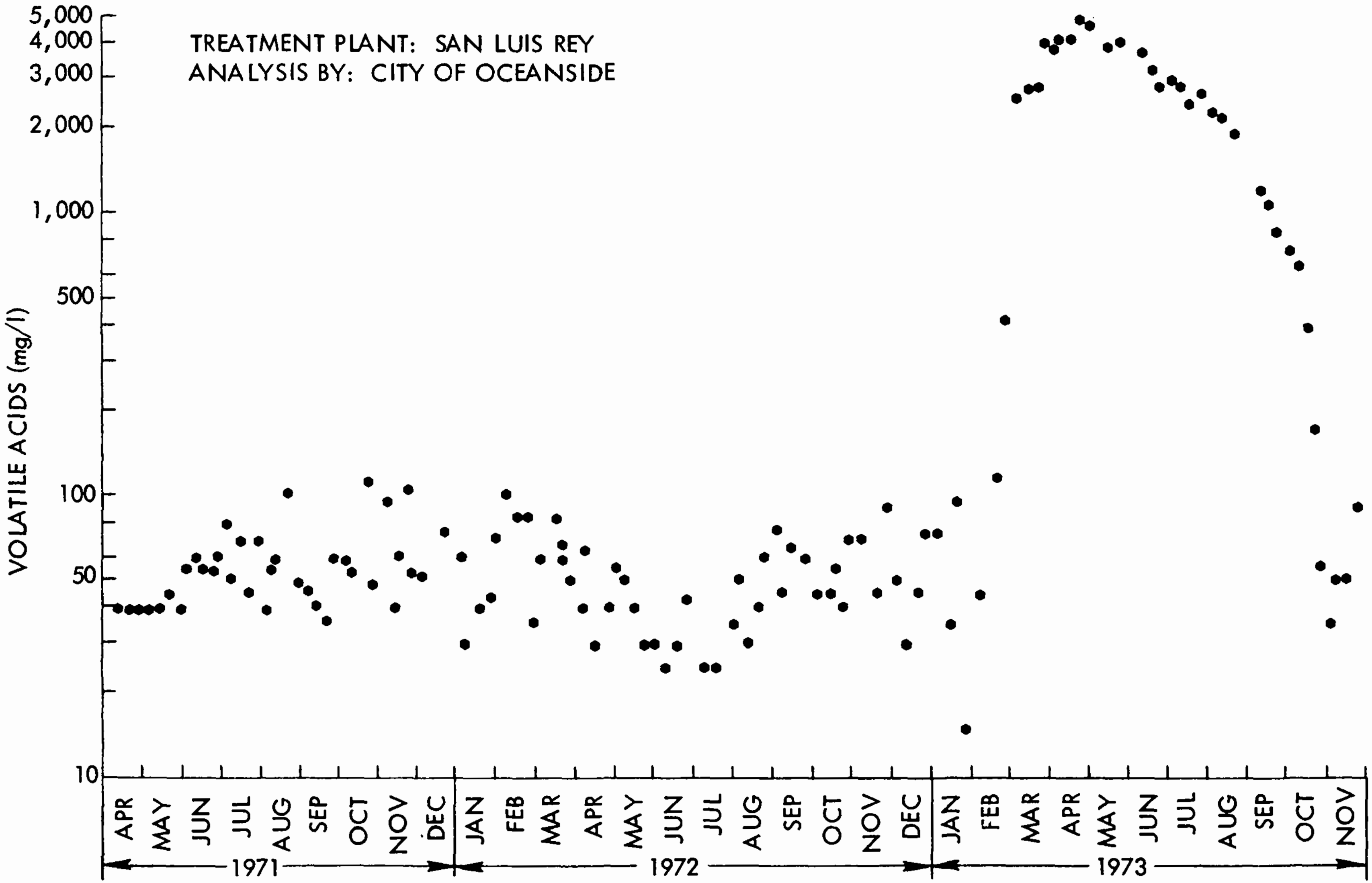


FIGURE C10
PROPERTIES OF SLUDGES
FROM OCEANSIDE, CALIFORNIA

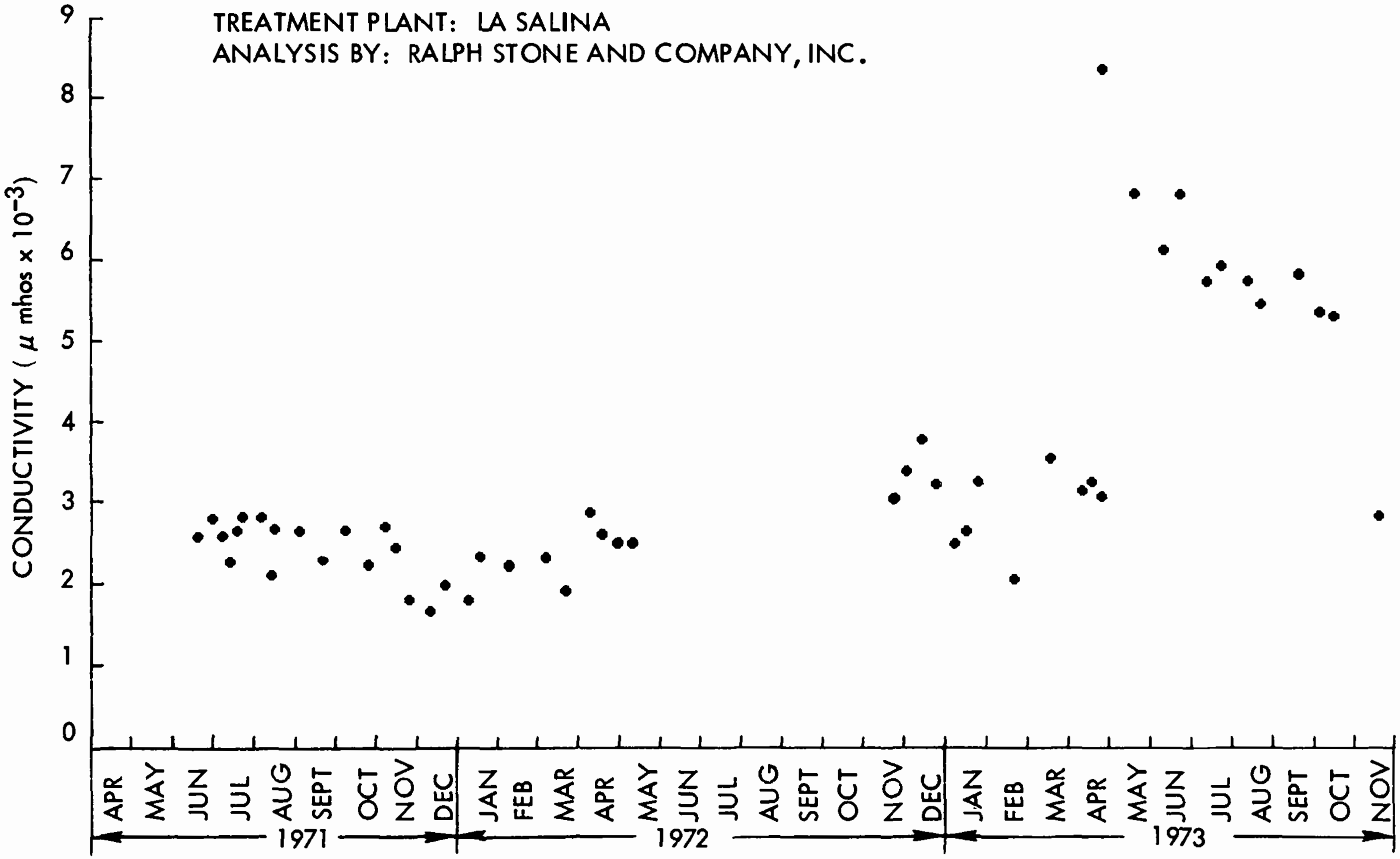


FIGURE C11
PROPERTIES OF SLUDGES
FROM OCEANSIDE, CALIFORNIA

TREATMENT PLANT: BUENA VISTA
ANALYSIS BY: RALPH STONE AND COMPANY, INC.

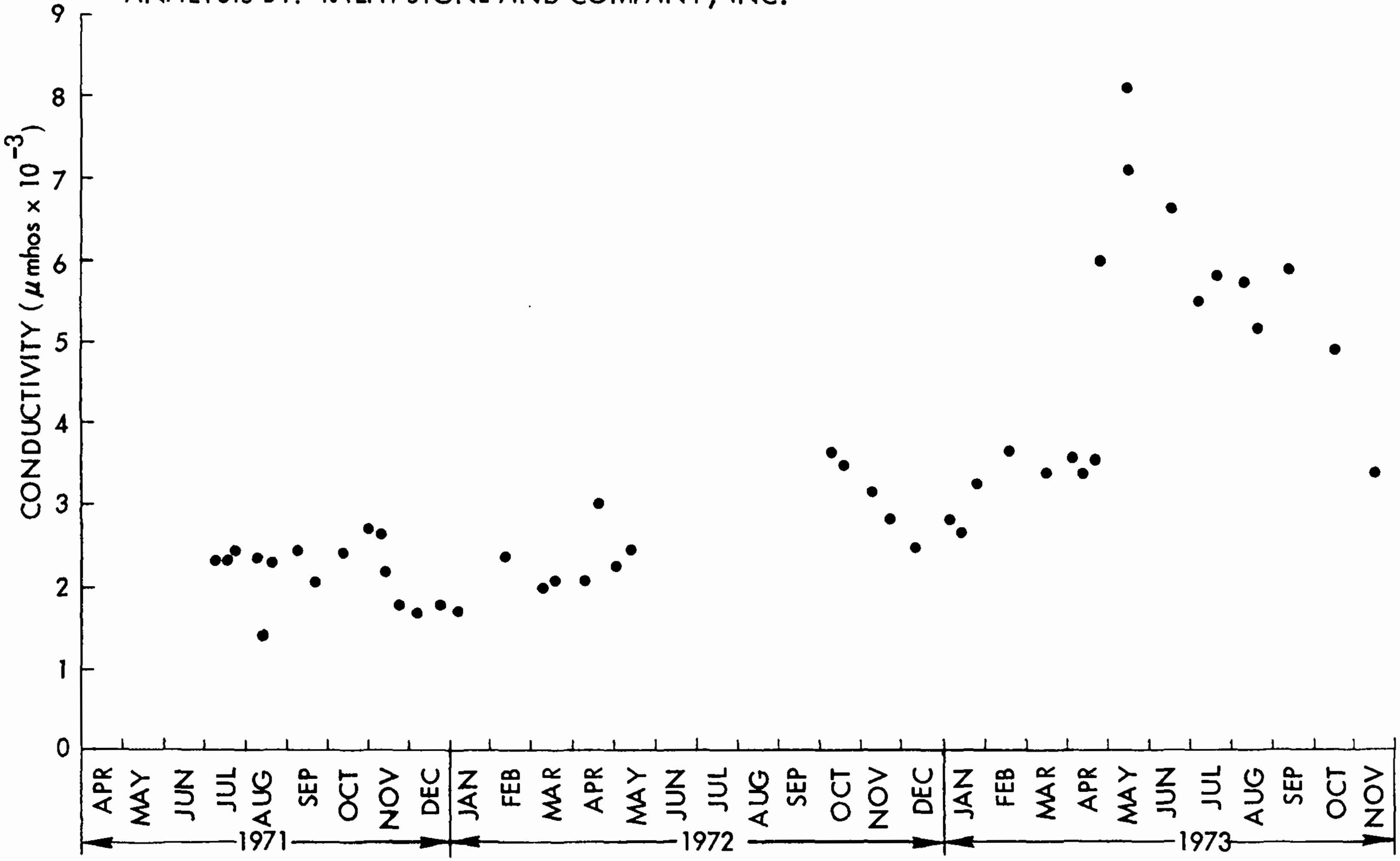


FIGURE C12
PROPERTIES OF SLUDGES
FROM OCEANSIDE, CALIFORNIA

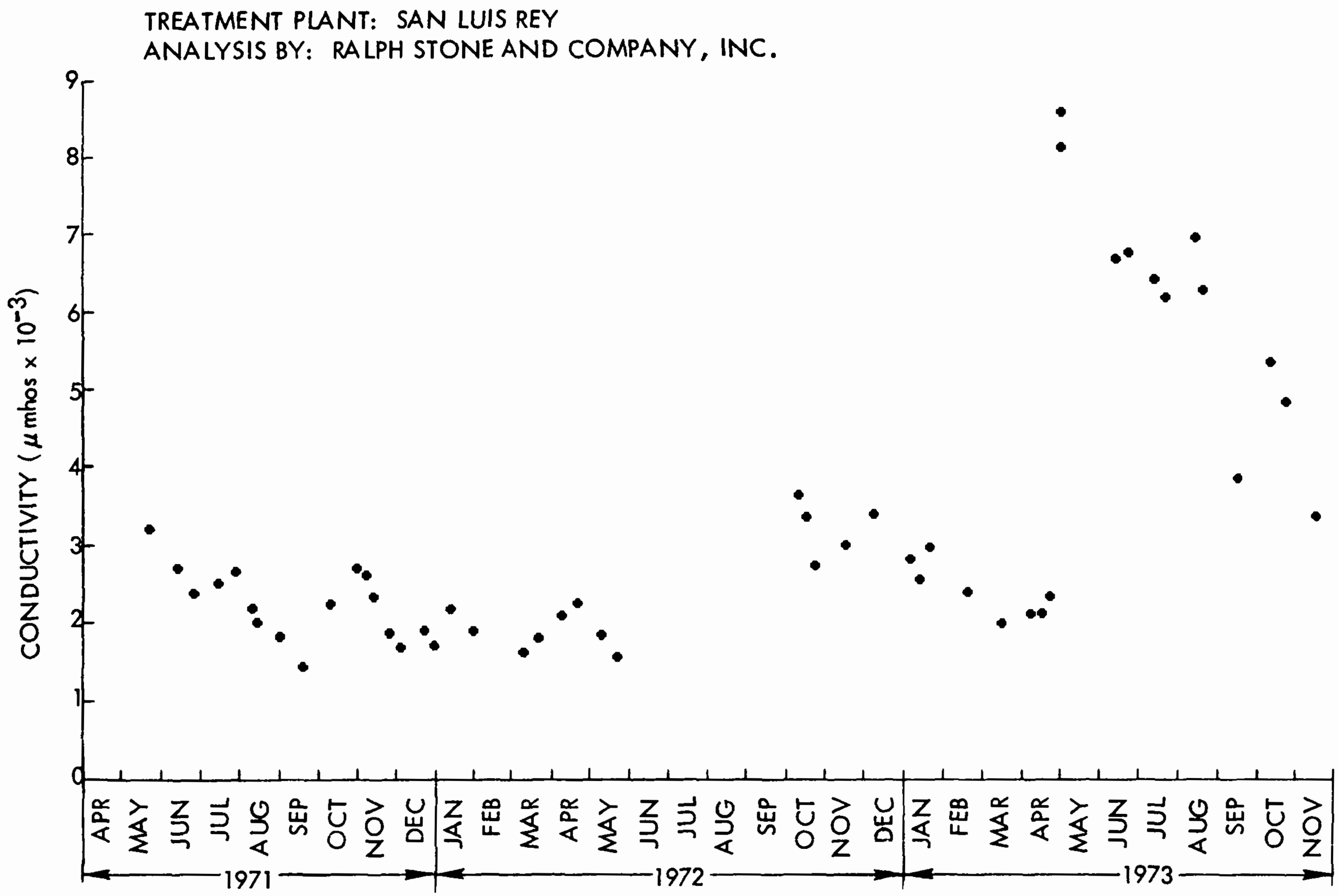


FIGURE C13
PROPERTIES OF SLUDGES
FROM OCEANSIDE, CALIFORNIA

TREATMENT PLANT: LA SALINA
ANALYSIS BY: RALPH STONE & CO., INC.

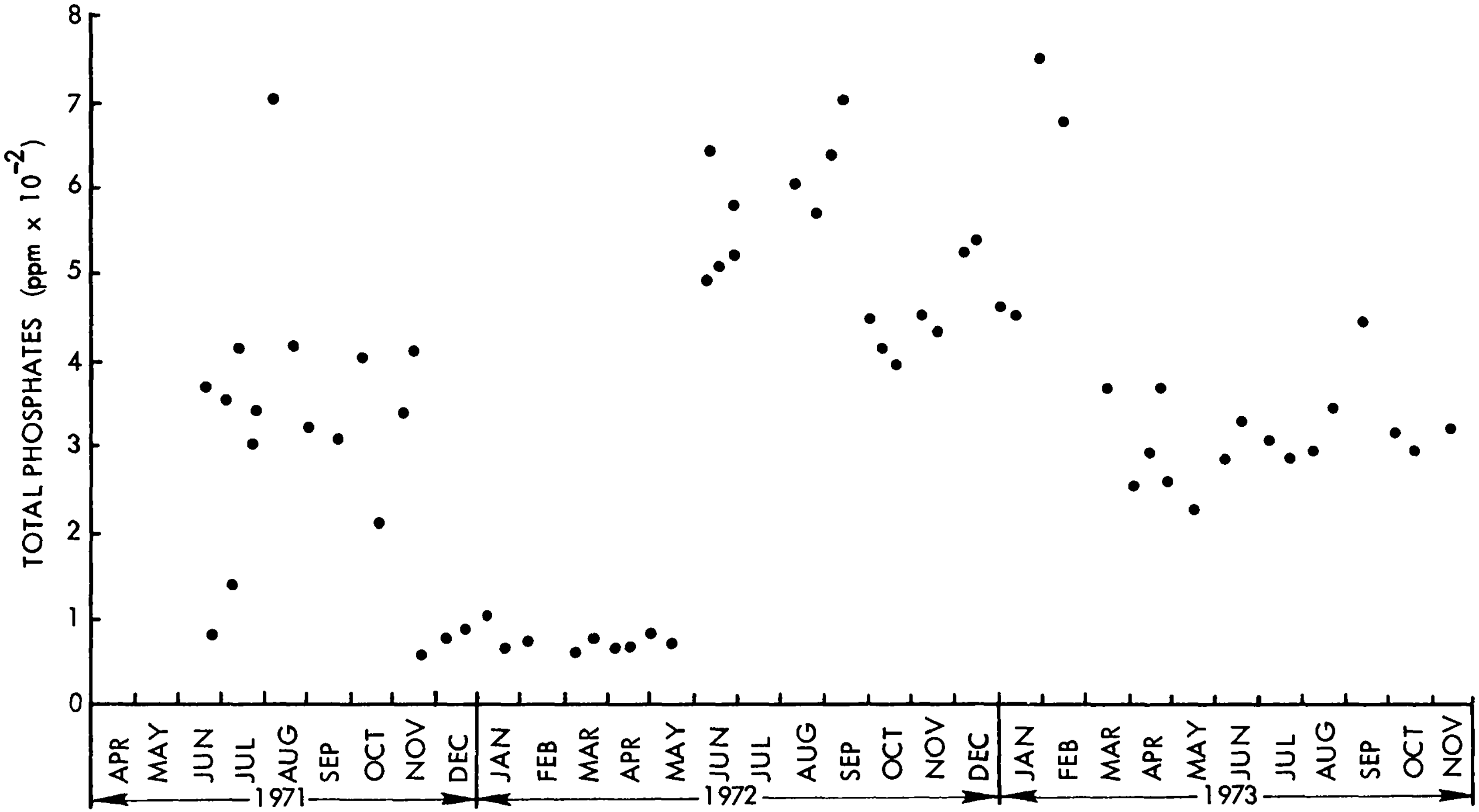


FIGURE C14
PROPERTIES OF SLUDGES
FROM OCEANSIDE, CALIFORNIA

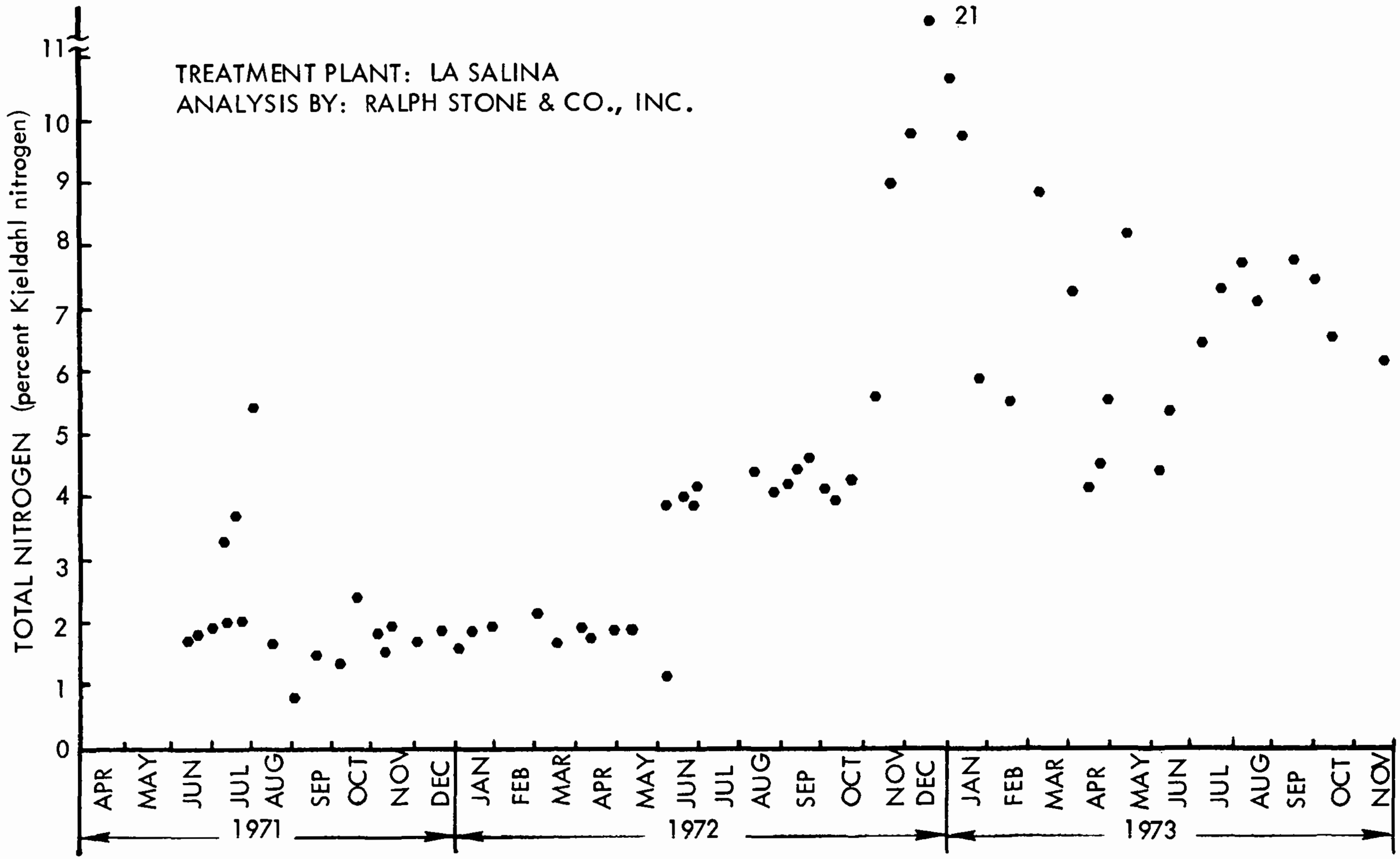


FIGURE C15
PROPERTIES OF SLUDGES
FROM OCEANSIDE, CALIFORNIA

APPENDIX D

LABORATORY ANALYSIS OF LEACHATES FROM PILOT SCALE TEST DRUMS

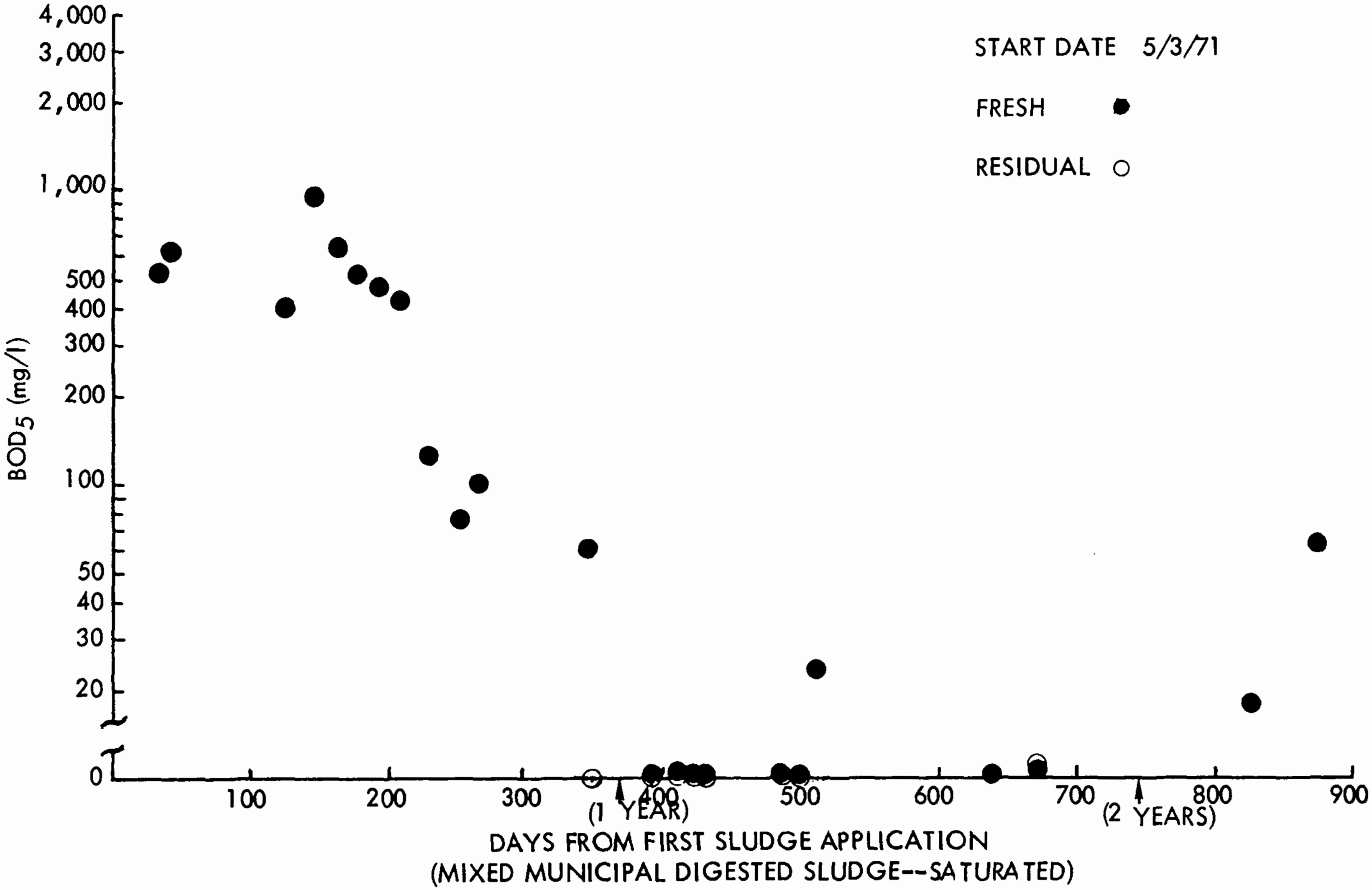


FIGURE D1
LEACHATE BOD_5 VS. TIME
DRUM NO. 1

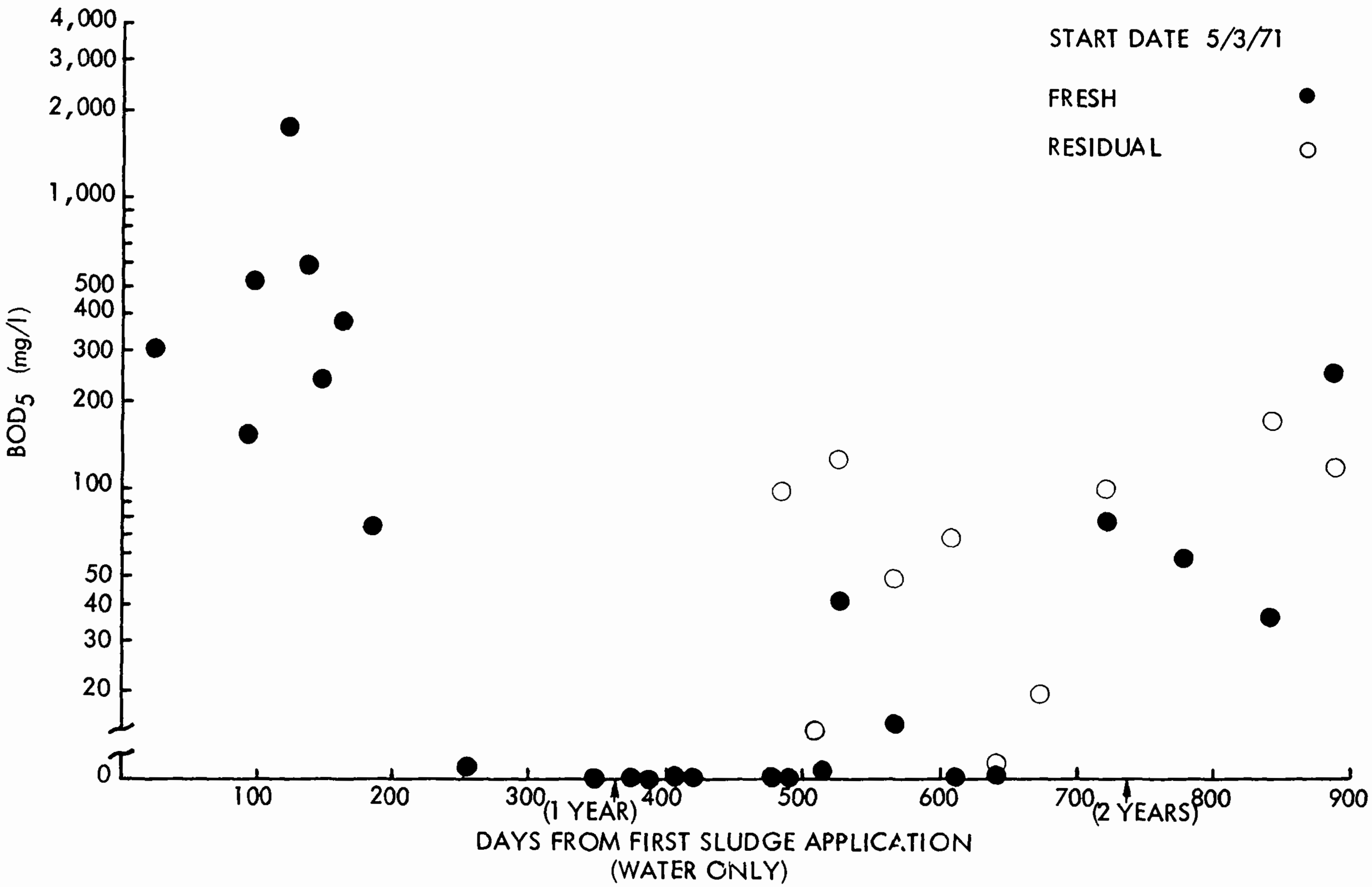


FIGURE D2
LEACHATE BOD_5 VS. TIME
DRUM NO. 2

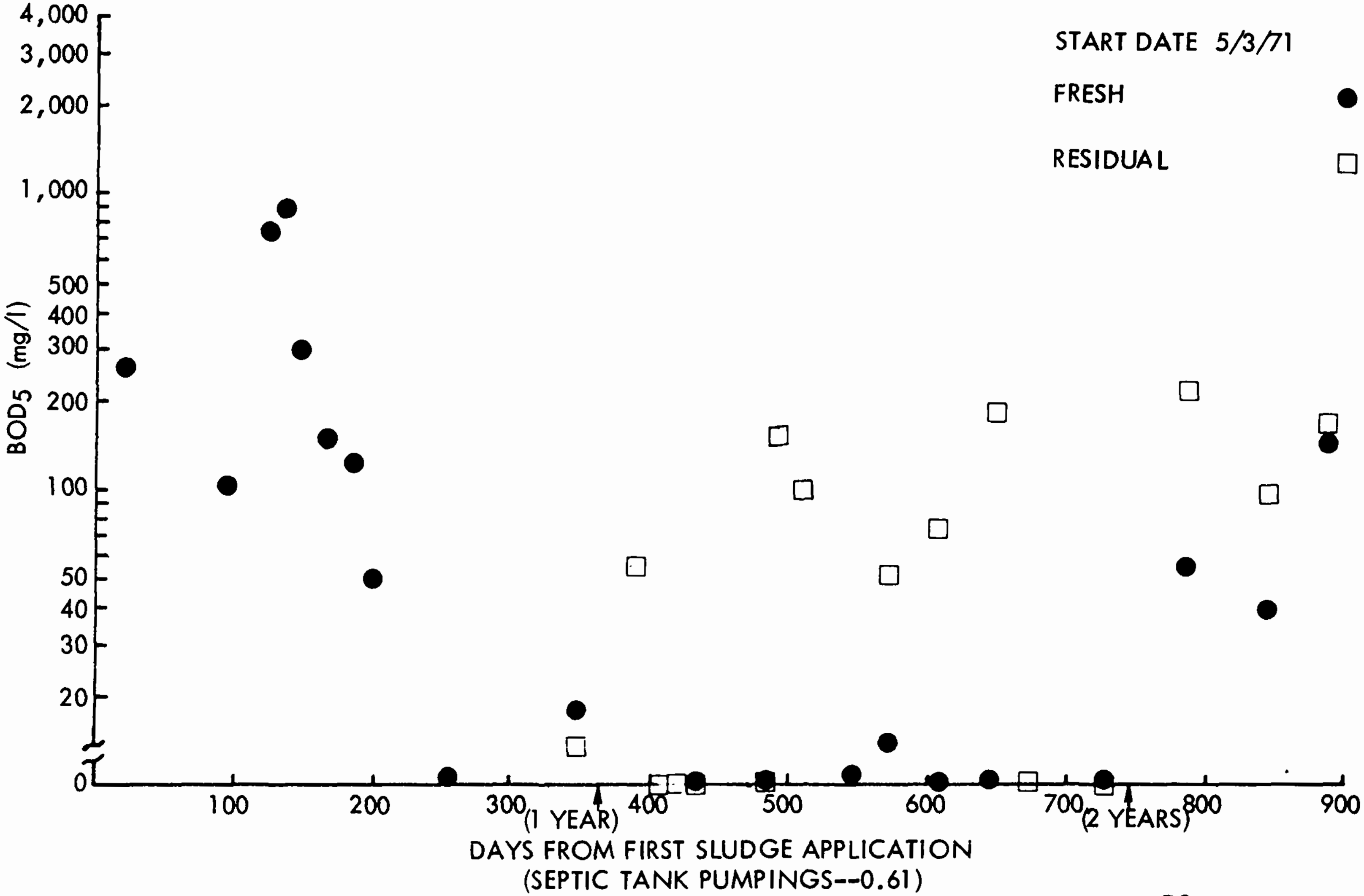


FIGURE D3
LEACHATE BOD_5 VS. TIME
DRUM NO. 3

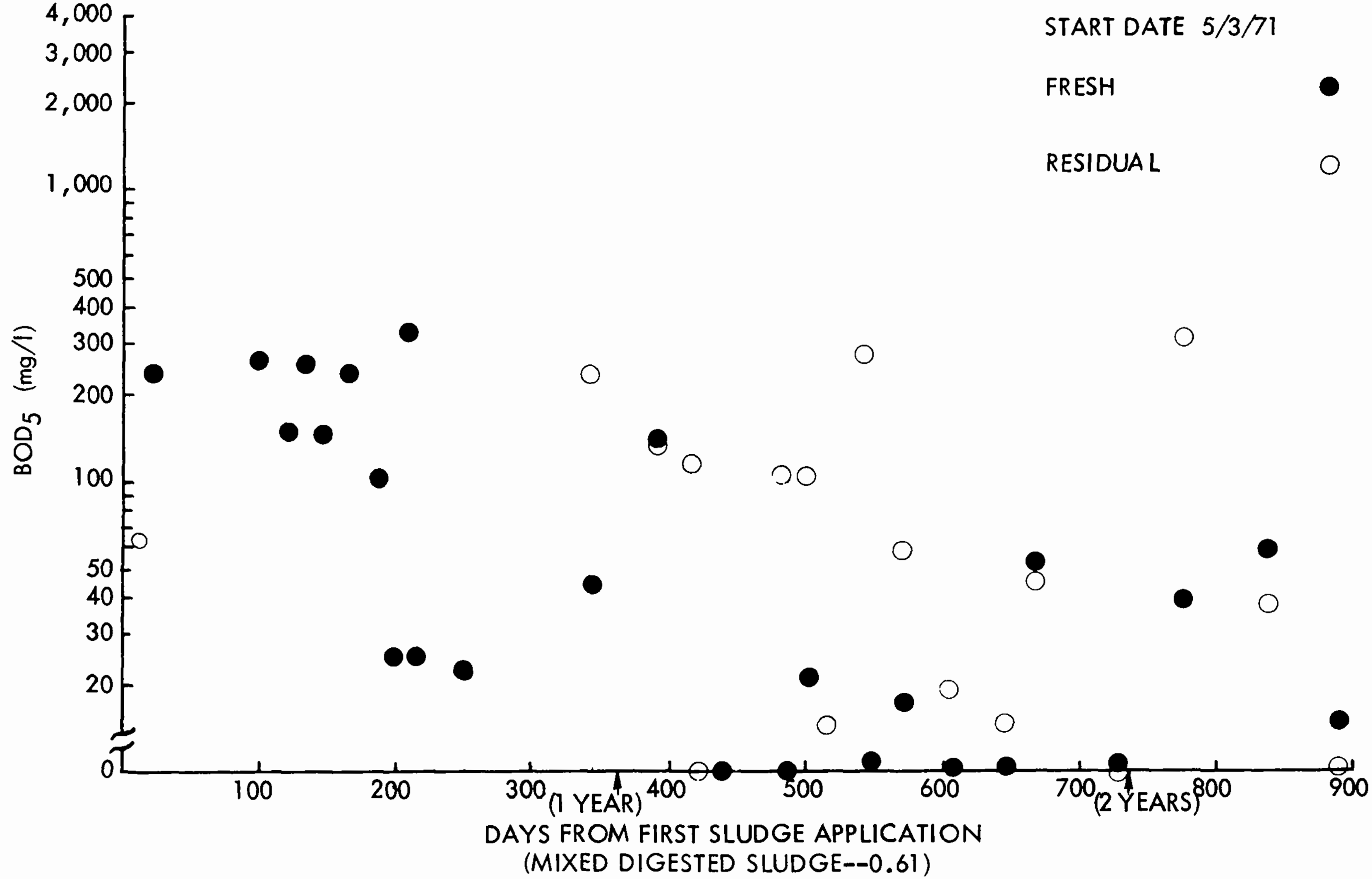


FIGURE D4
LEACHATE BOD_5 VS. TIME
DRUM NO. 5

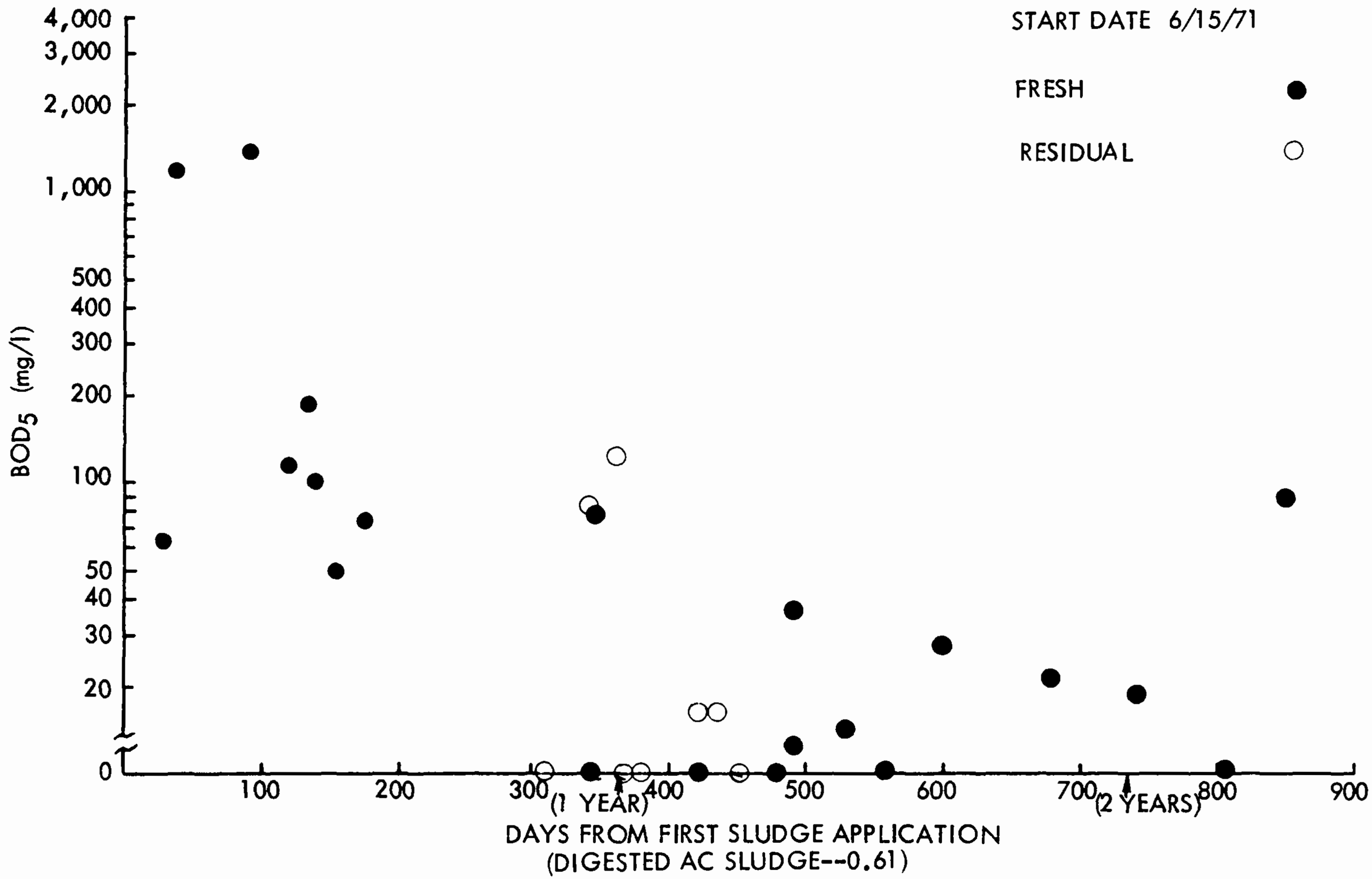


FIGURE D5
LEACHATE BOD_5 VS. TIME
DRUM NO. 6

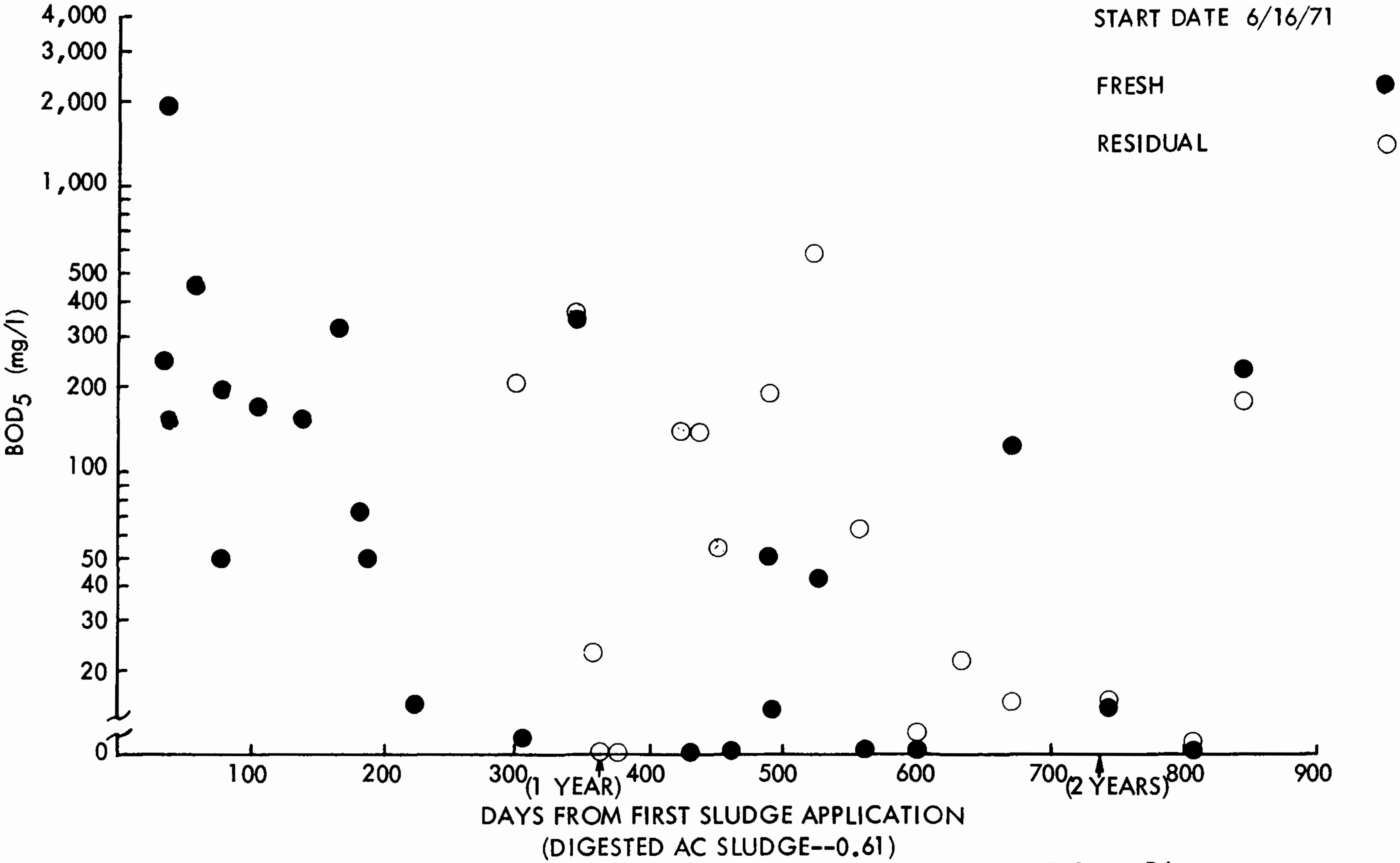


FIGURE D6
LEACHATE BOD_5 VS. TIME
DRUM NO. 7

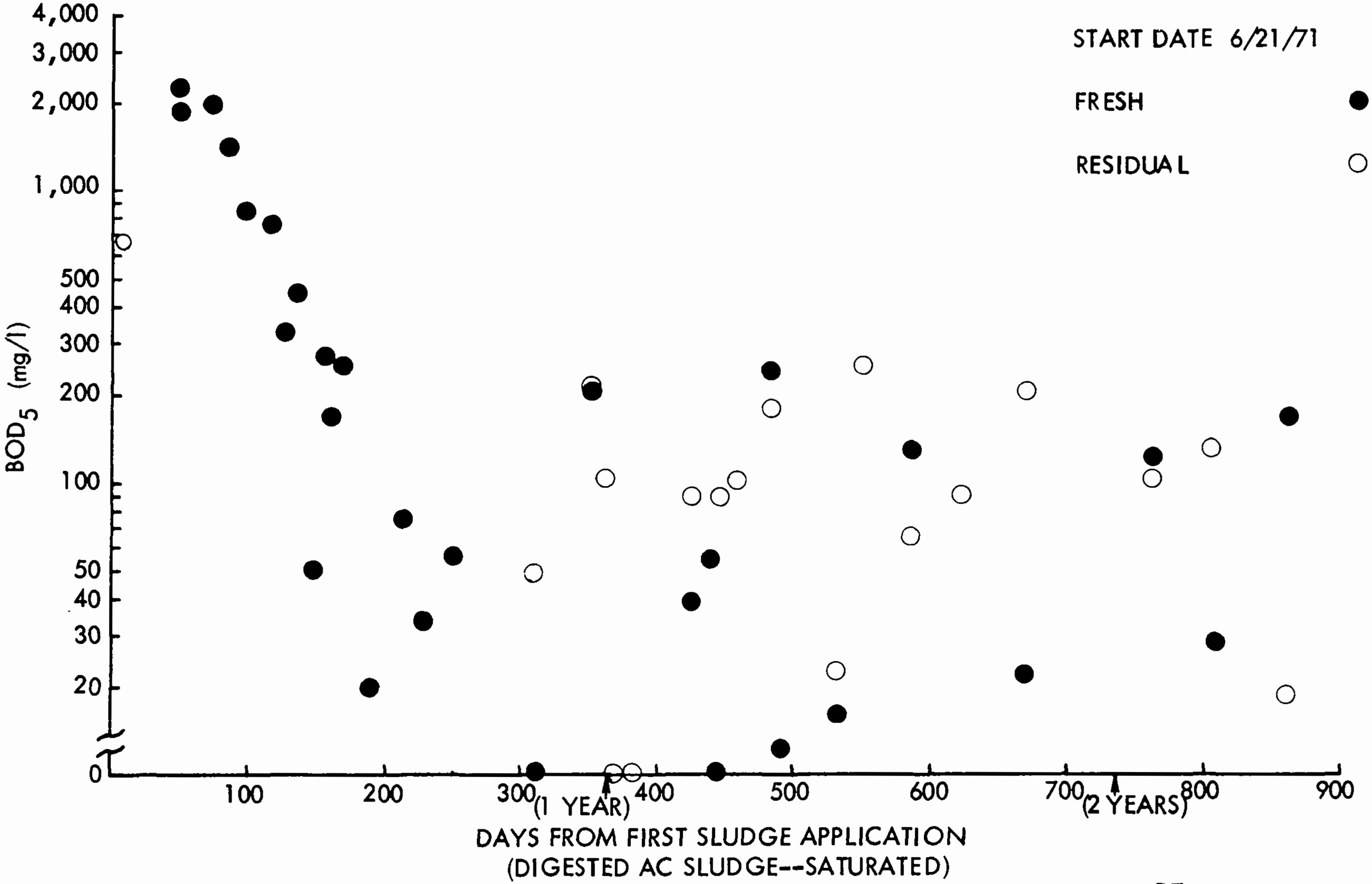


FIGURE D7
LEACHATE BOD_5 VS. TIME
DRUM NO. 8

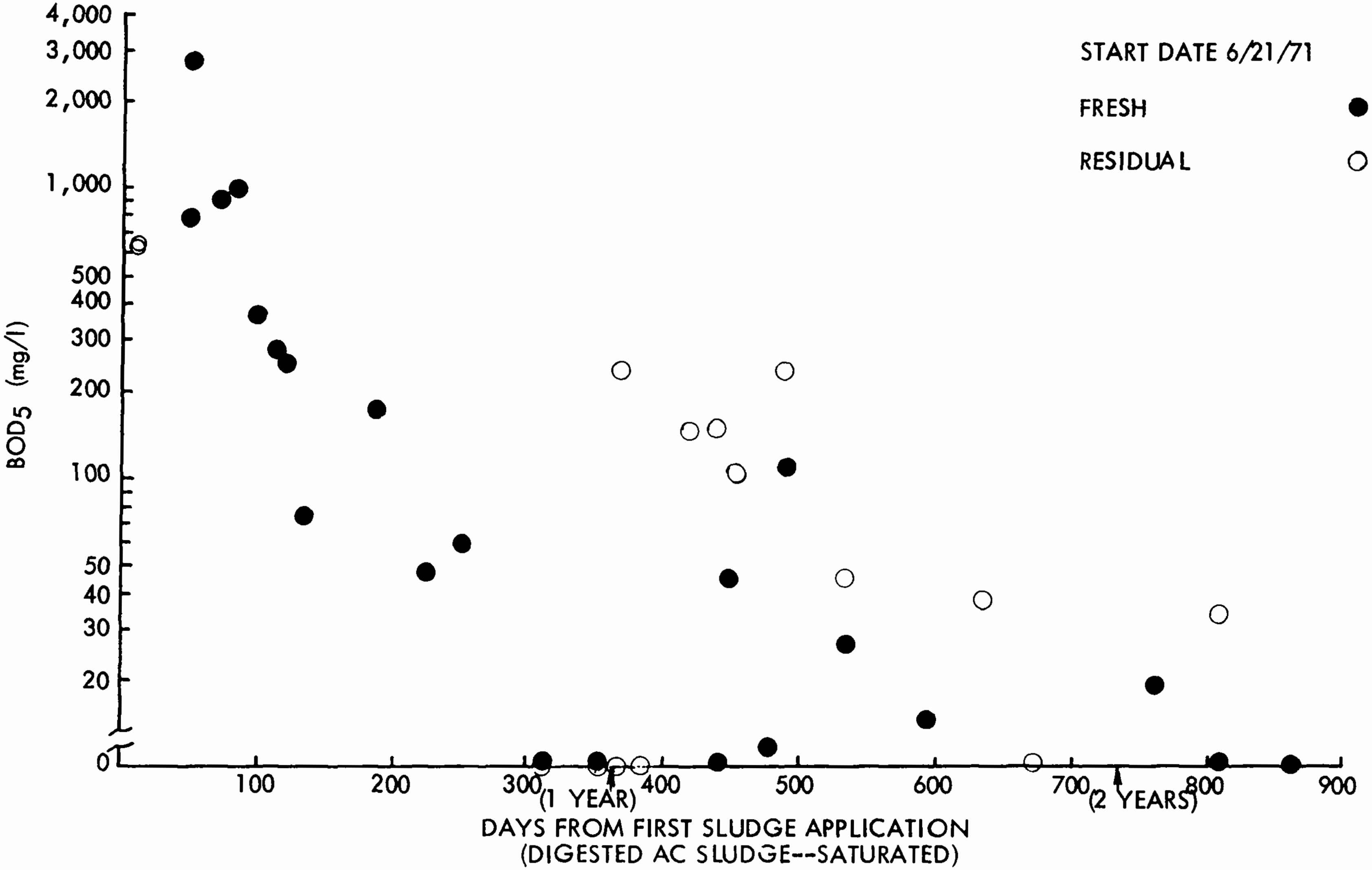


FIGURE D8
LEACHATE BOD_5 VS. TIME
DRUM NO. 9

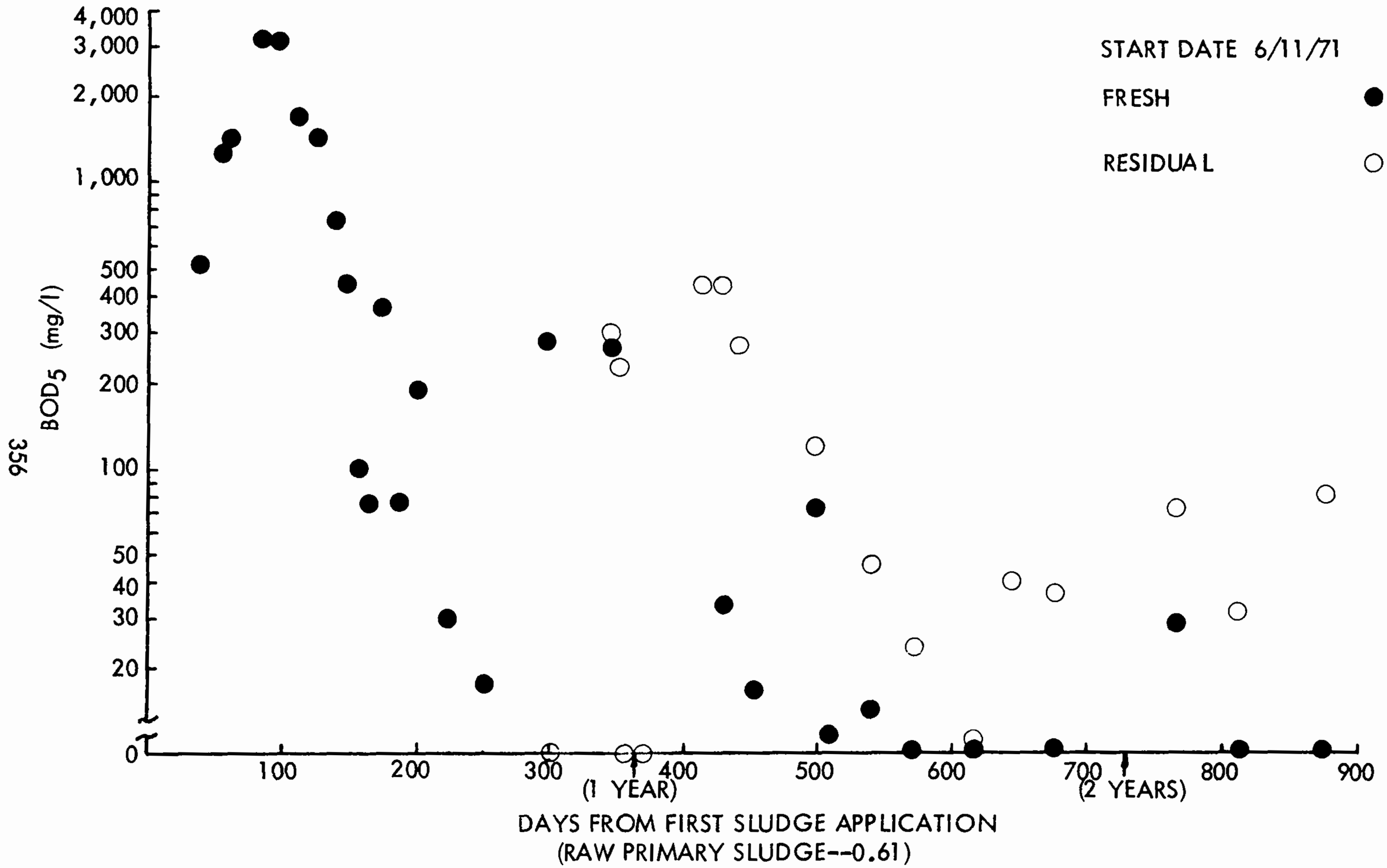


FIGURE D9
LEACHATE BOD5 VS. TIME
DRUM NO. 10

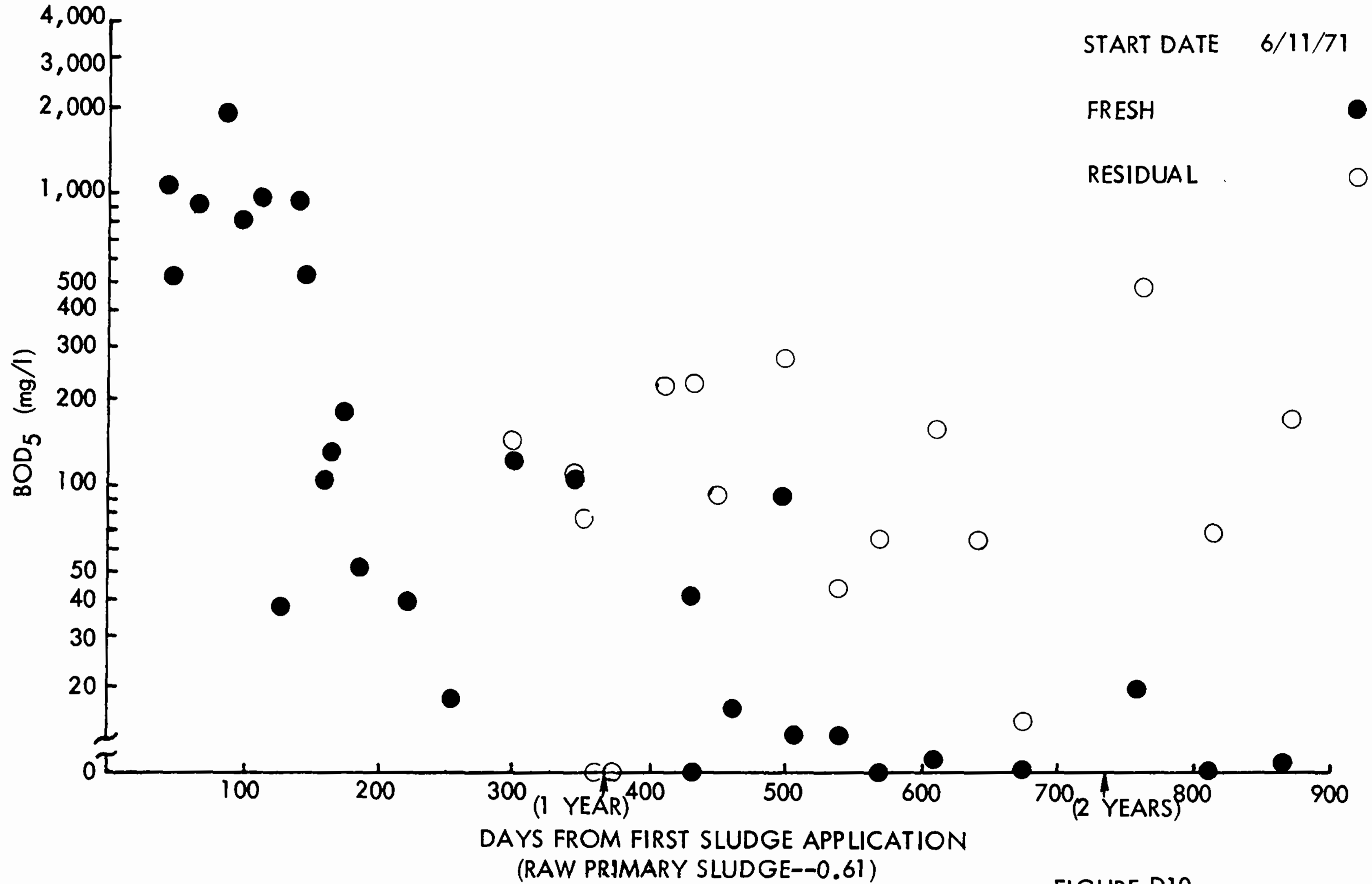


FIGURE D10
LEACHATE BOD_5 VS. TIME
DRUM NO. 11

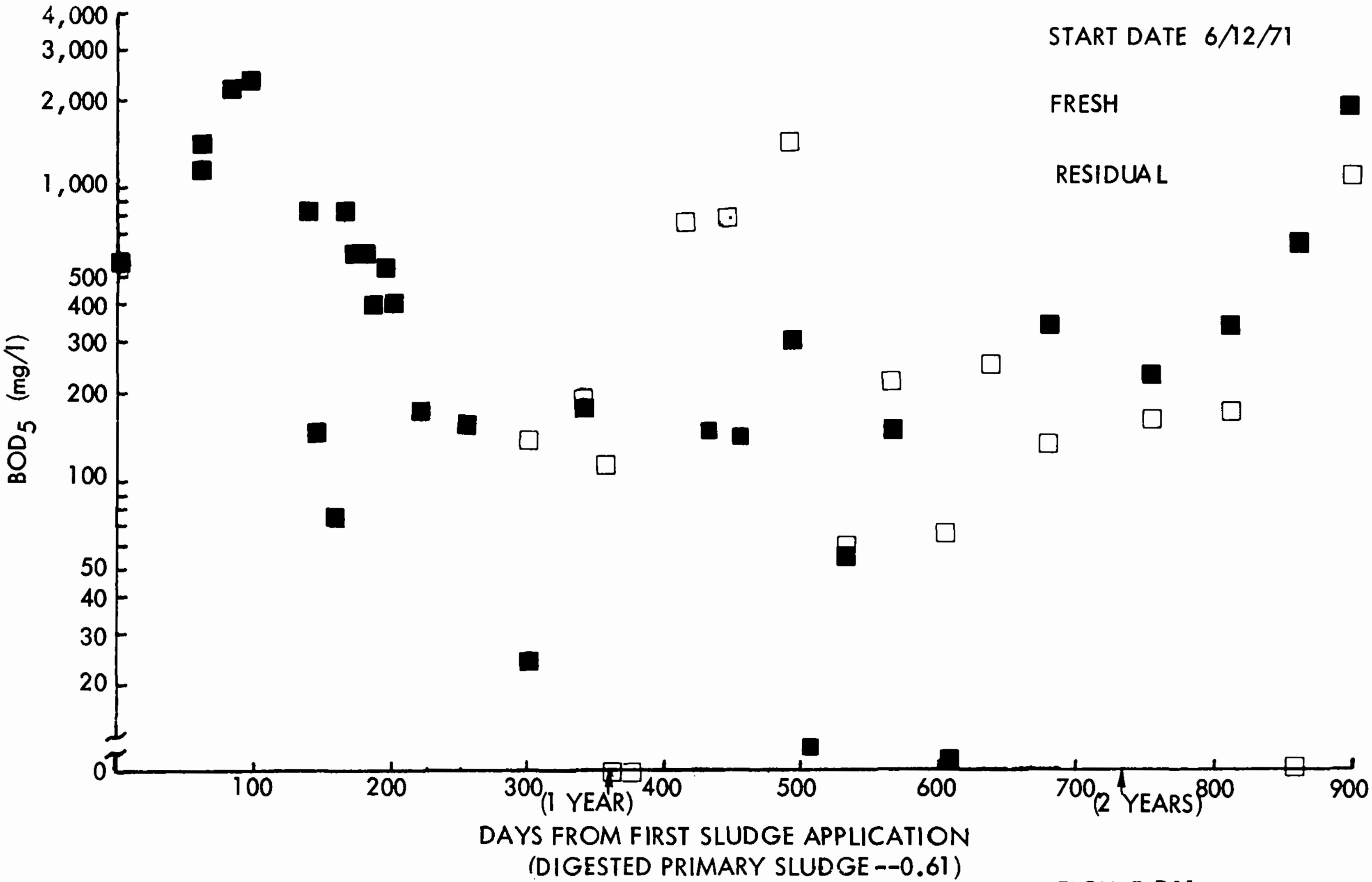


FIGURE D11
LEACHATE BOD_5 VS. TIME
DRUM NO. 12

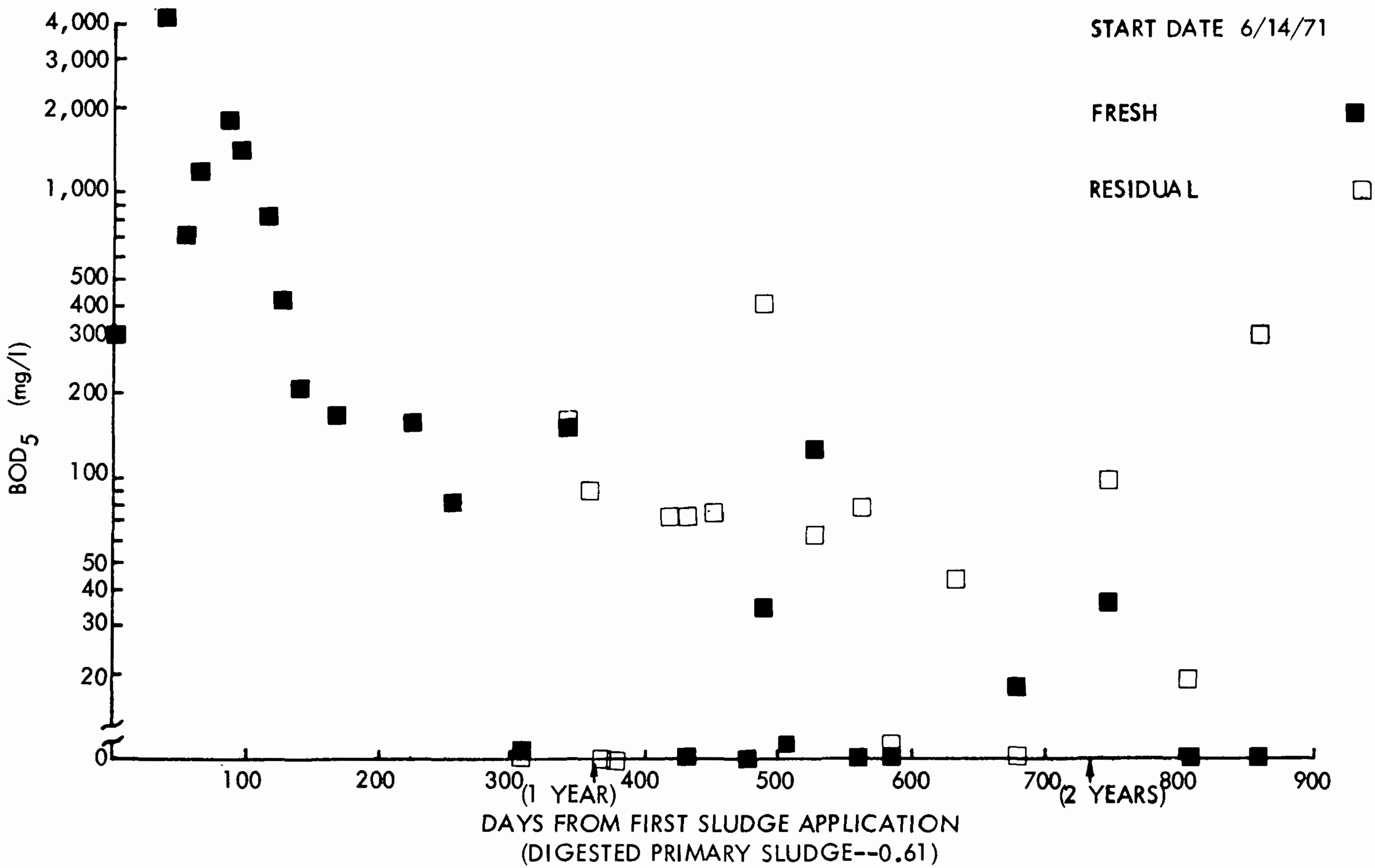


FIGURE D12
LEACHATE BOD_5 VS. TIME
DRUM NO. 13

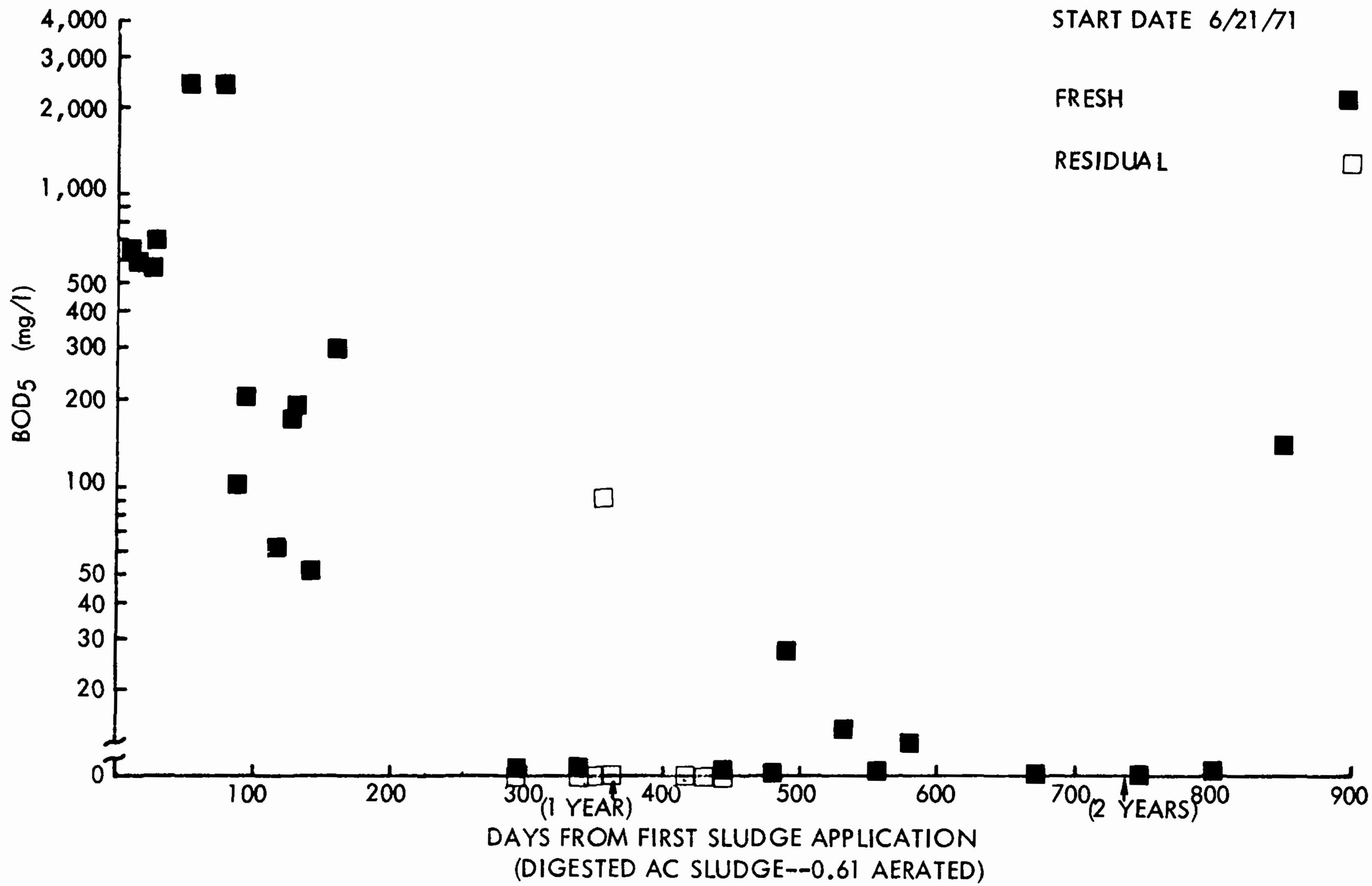


FIGURE D13
LEACHATE BOD_5 VS. TIME
DRUM NO. 14

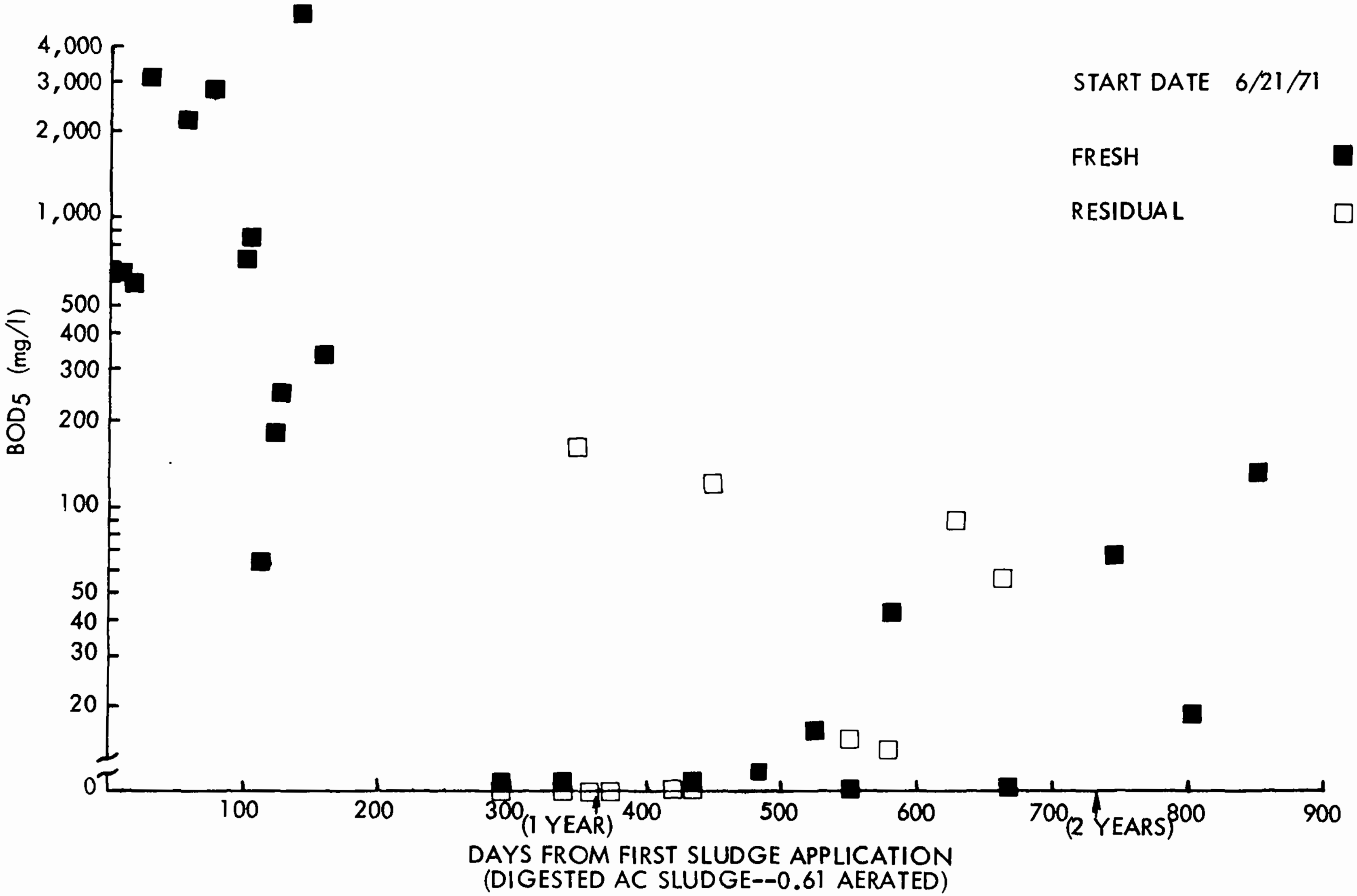


FIGURE D14
LEACHATE BOD_5 VS. TIME
DRUM NO. 15

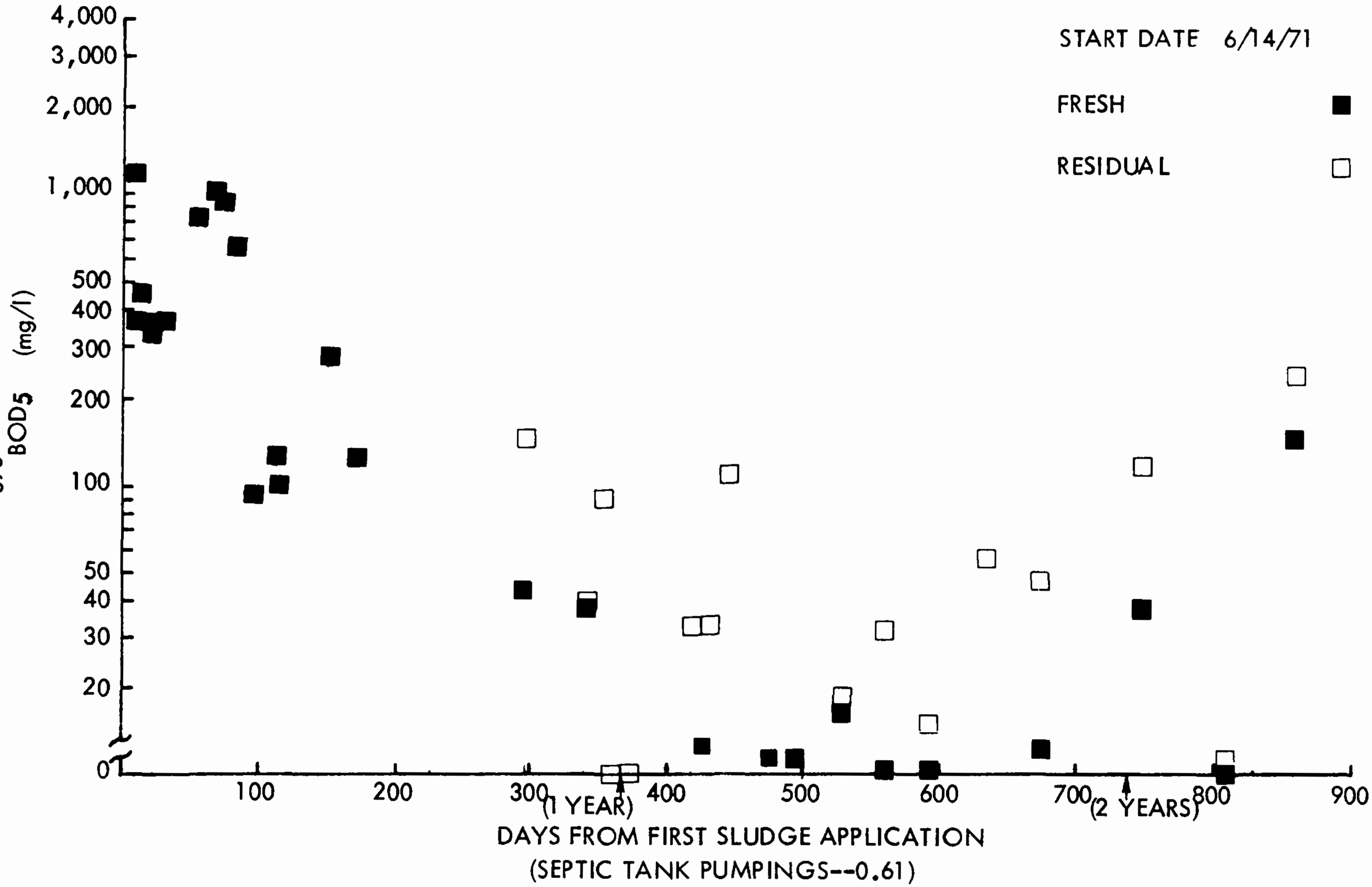


FIGURE D15
LEACHATE BOD_5 VS. TIME
DRUM NO. 16

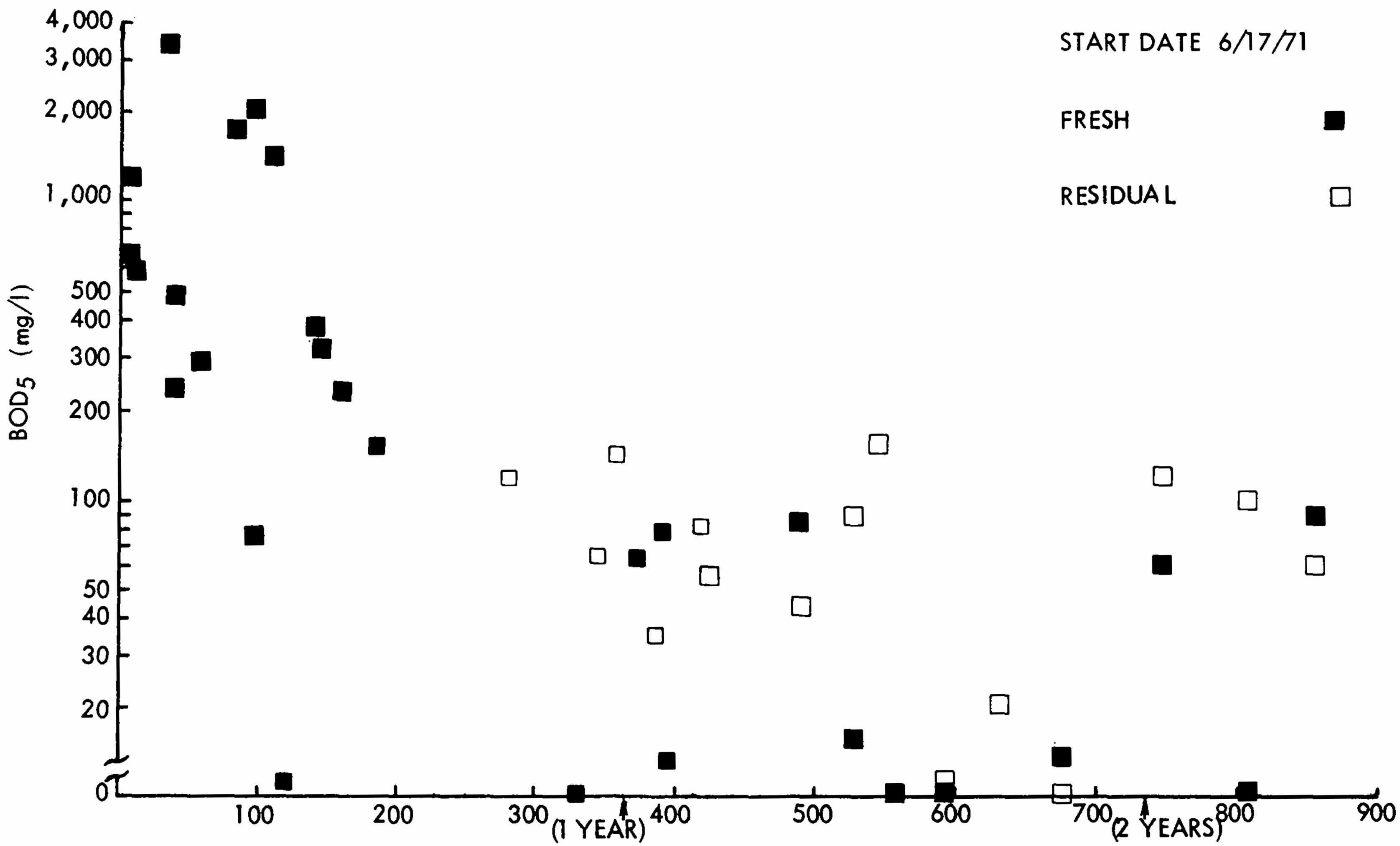


FIGURE D16
LEACHATE BOD_5 VS. TIME
DRUM NO. 17

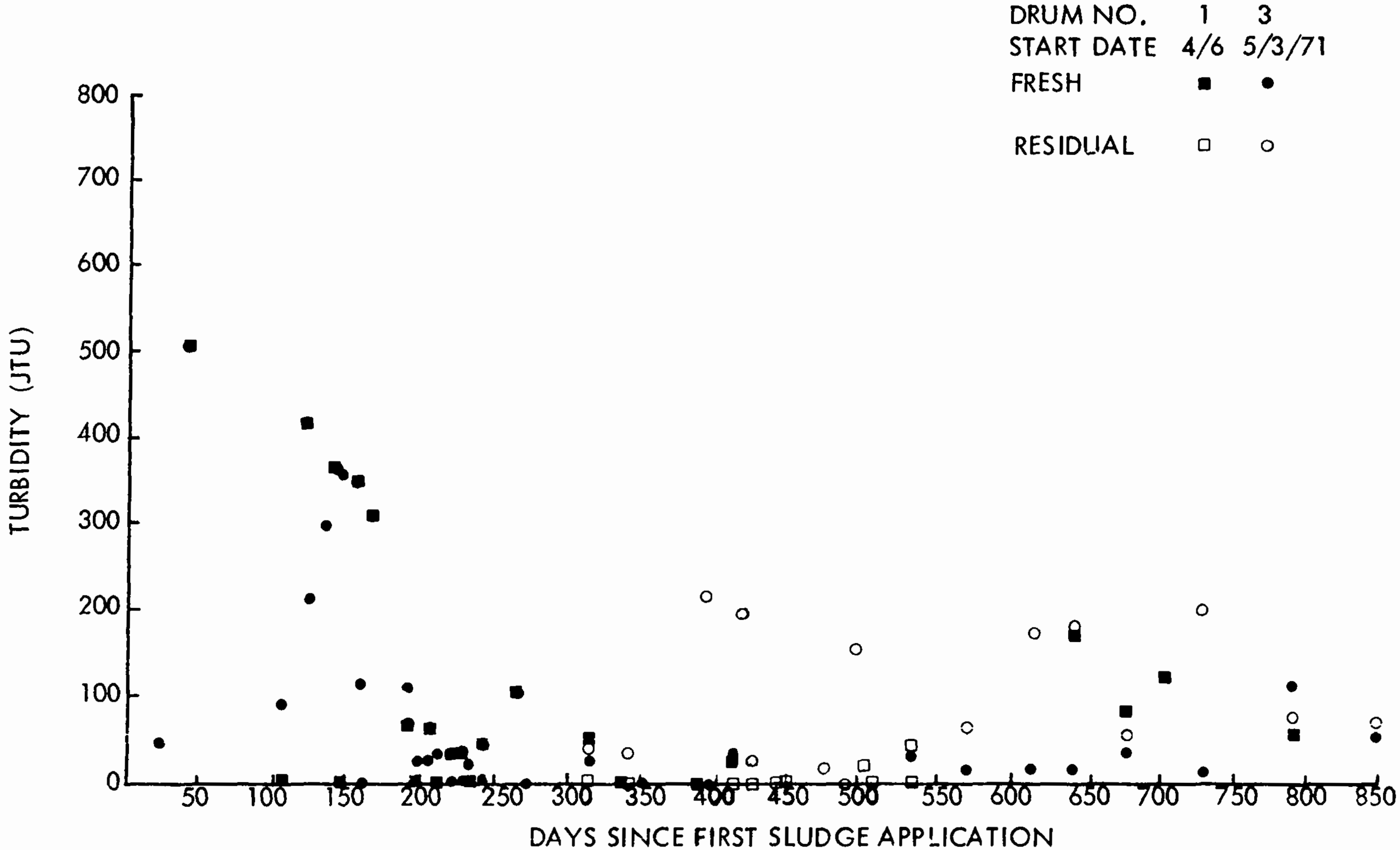


FIGURE D17
TURBIDITY OF LEACHATES

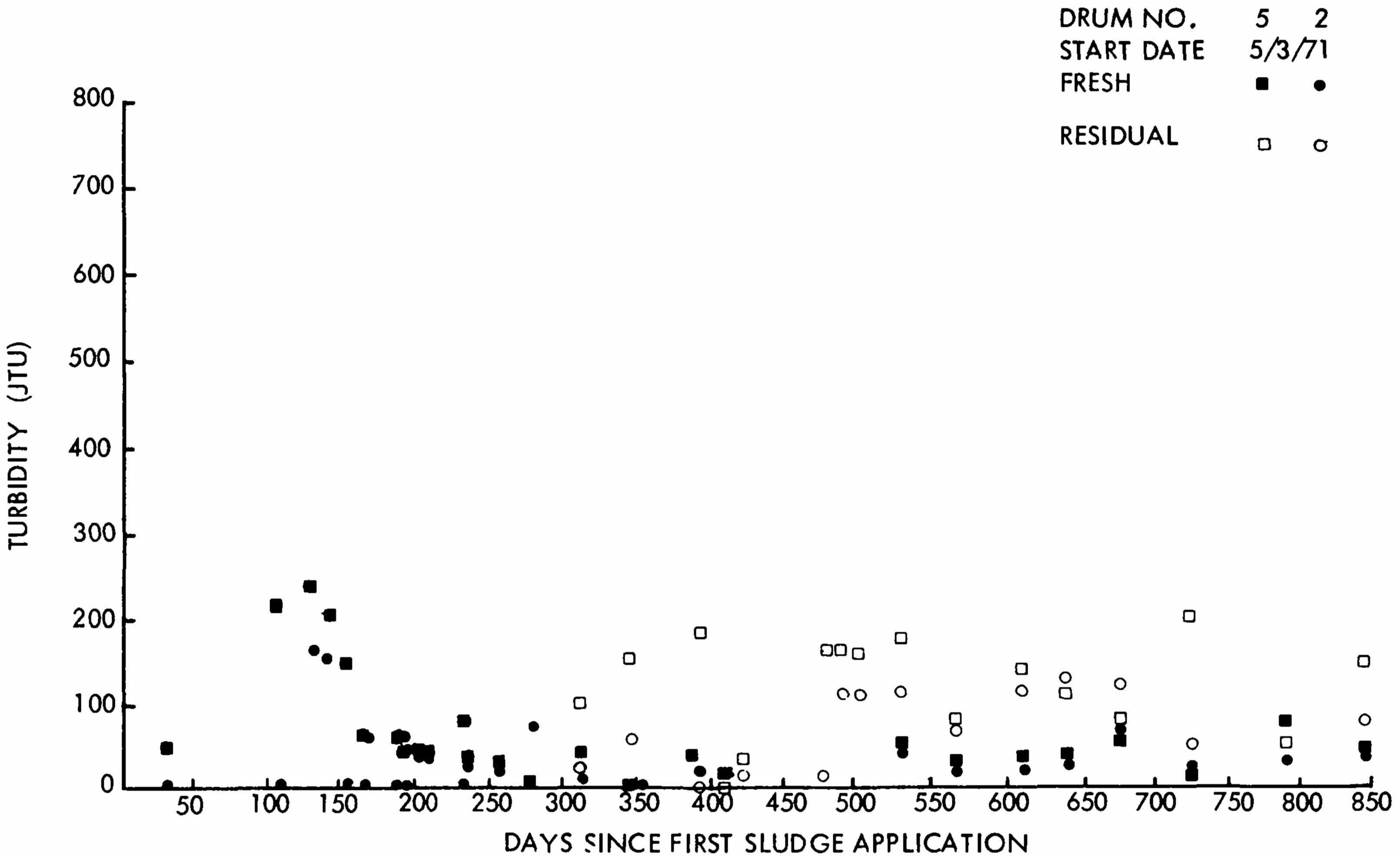


FIGURE D18
TURBIDITY OF LEACHATES

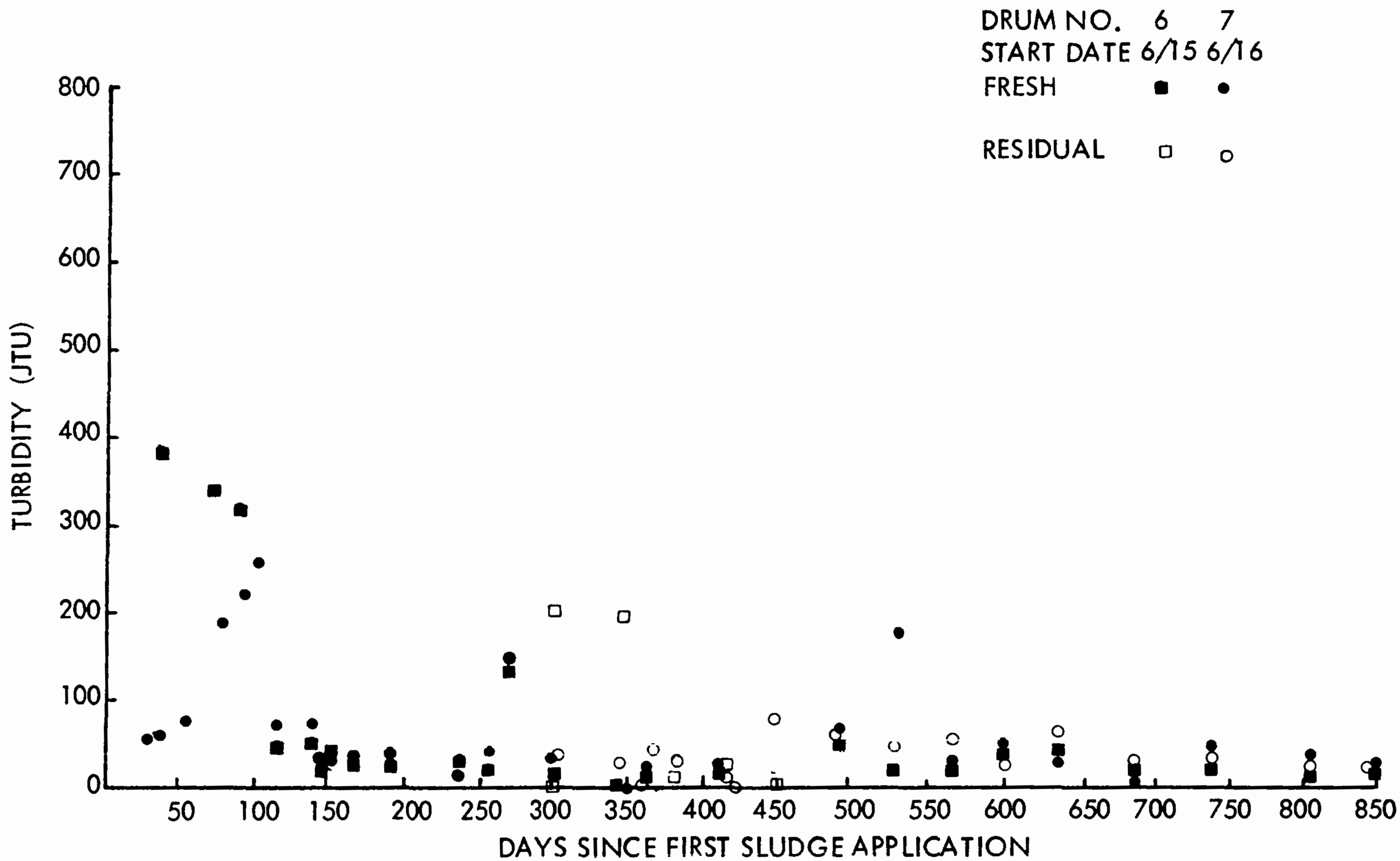


FIGURE D19
TURBIDITY OF LEACHATES

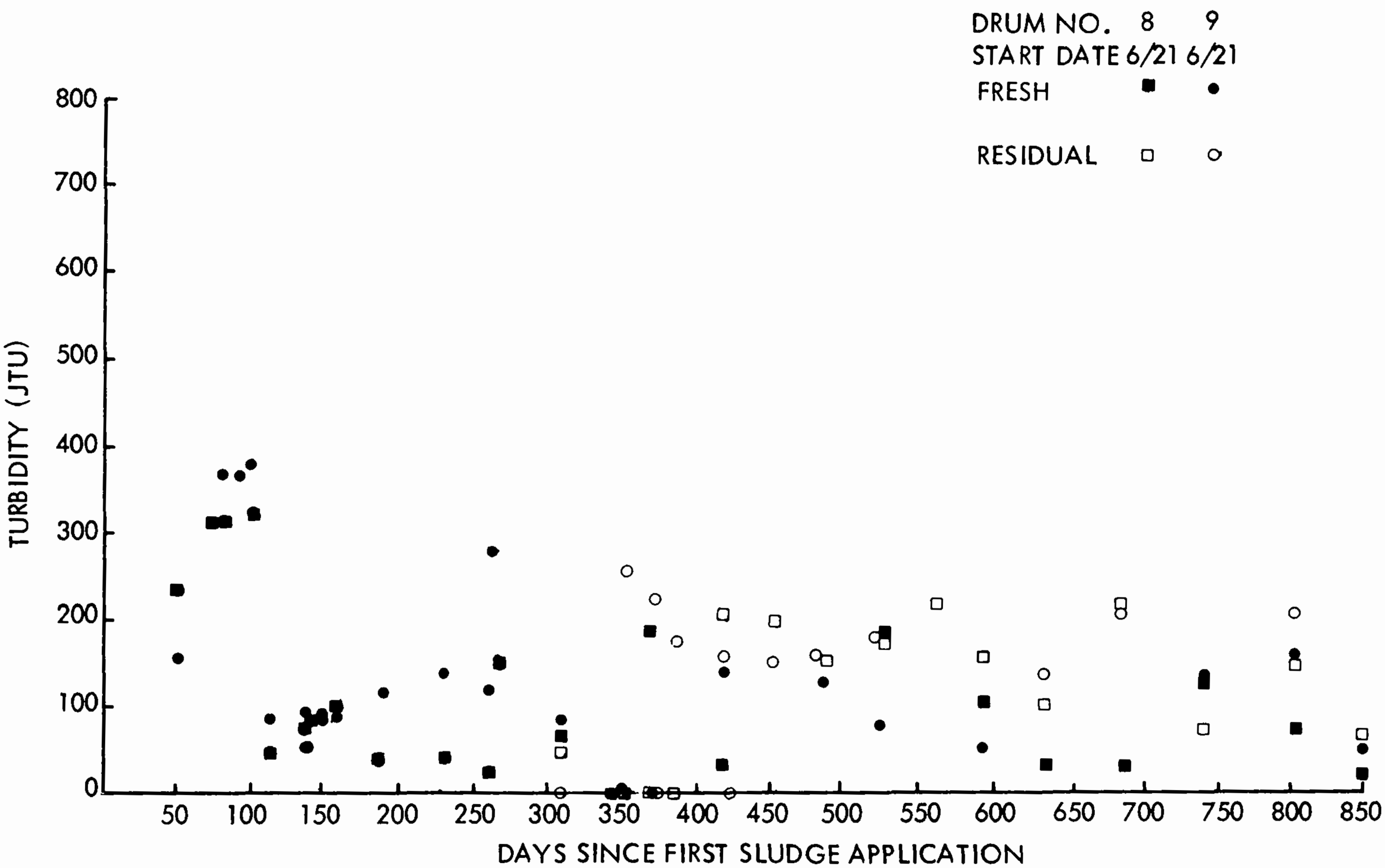


FIGURE D20
TURBIDITY OF LEACHATES

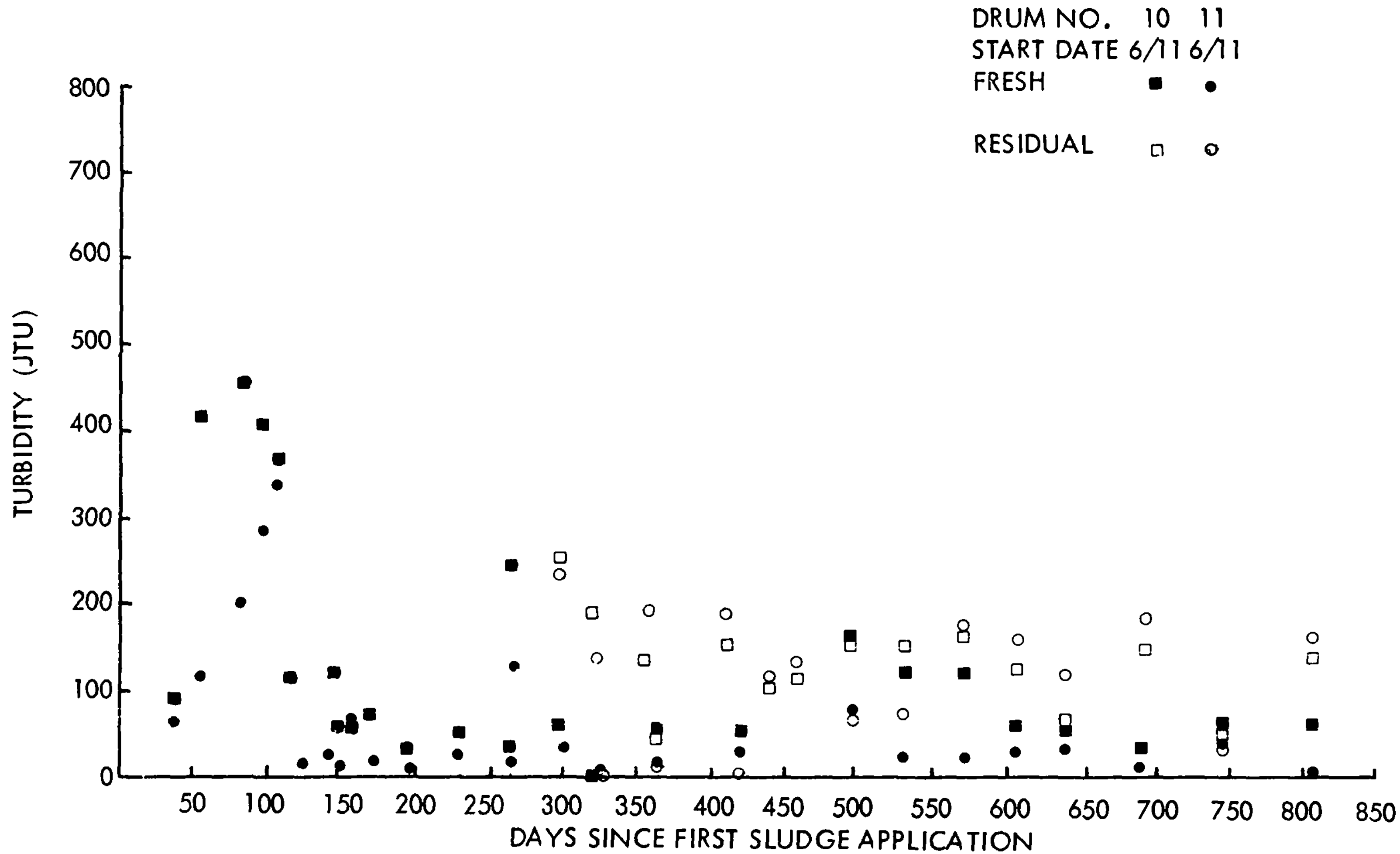


FIGURE D21
TURBIDITY OF LEACHATES

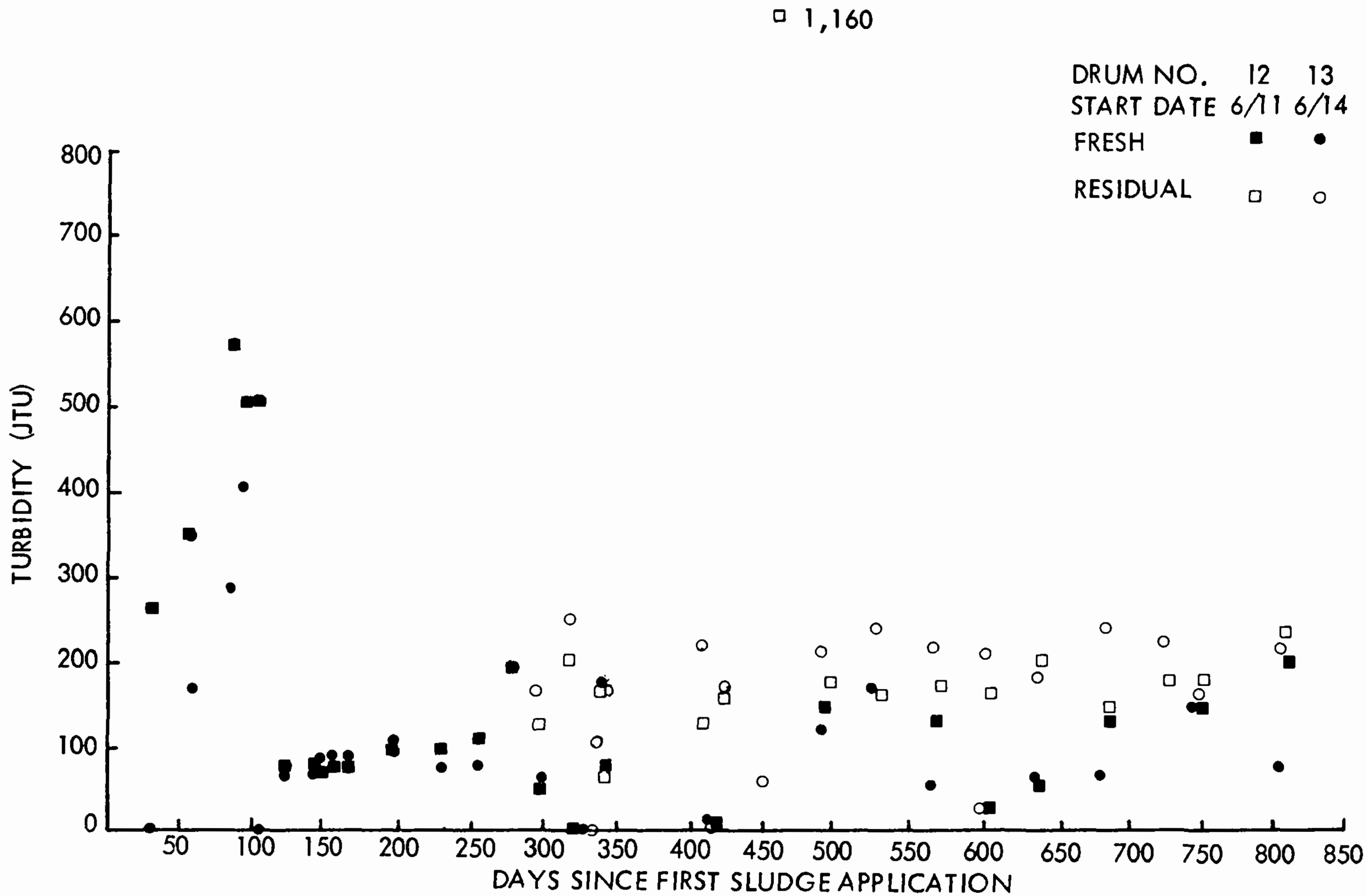


FIGURE D22
TURBIDITY OF LEACHATES

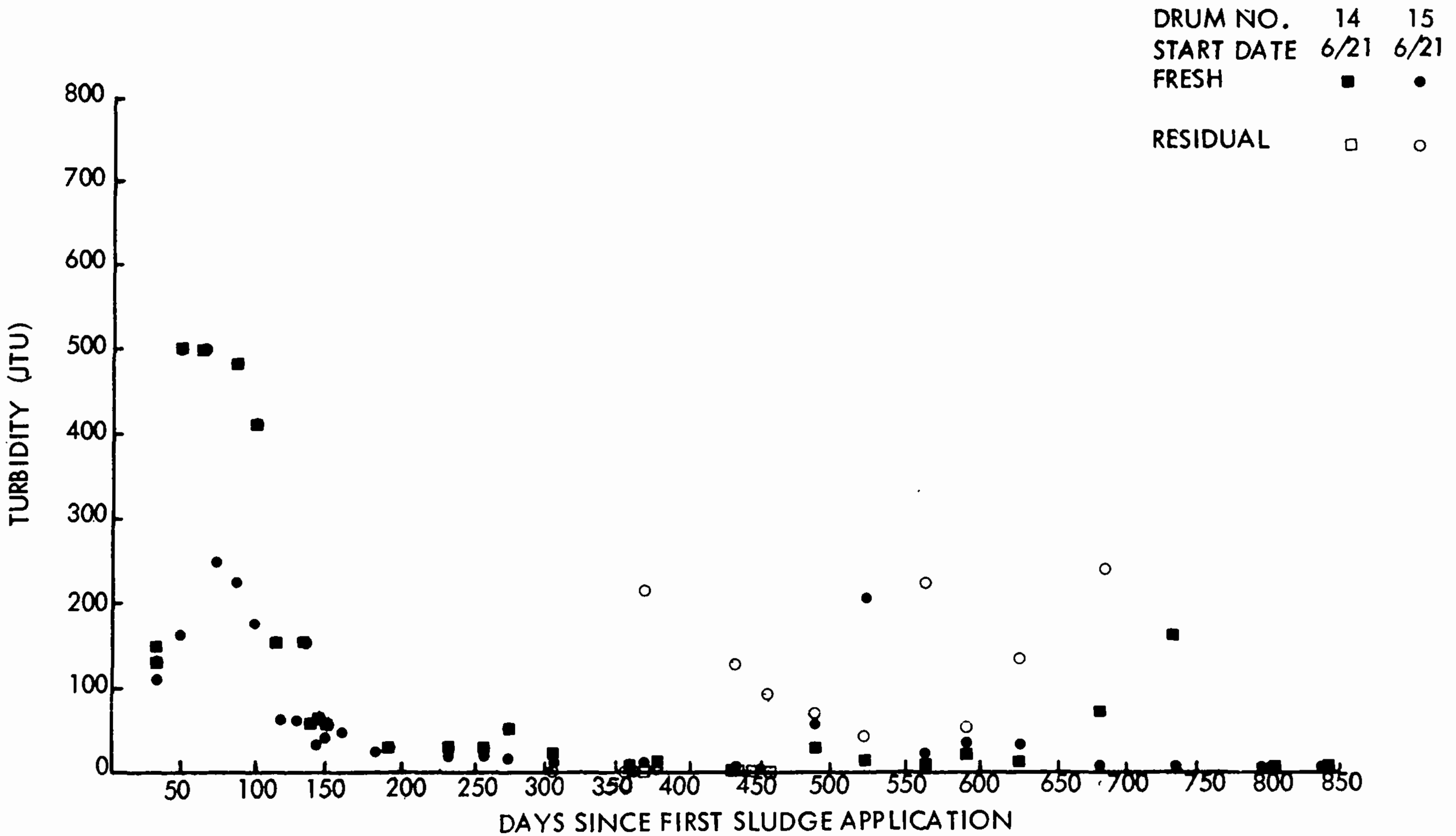


FIGURE D23
TURBIDITY OF LEACHATES

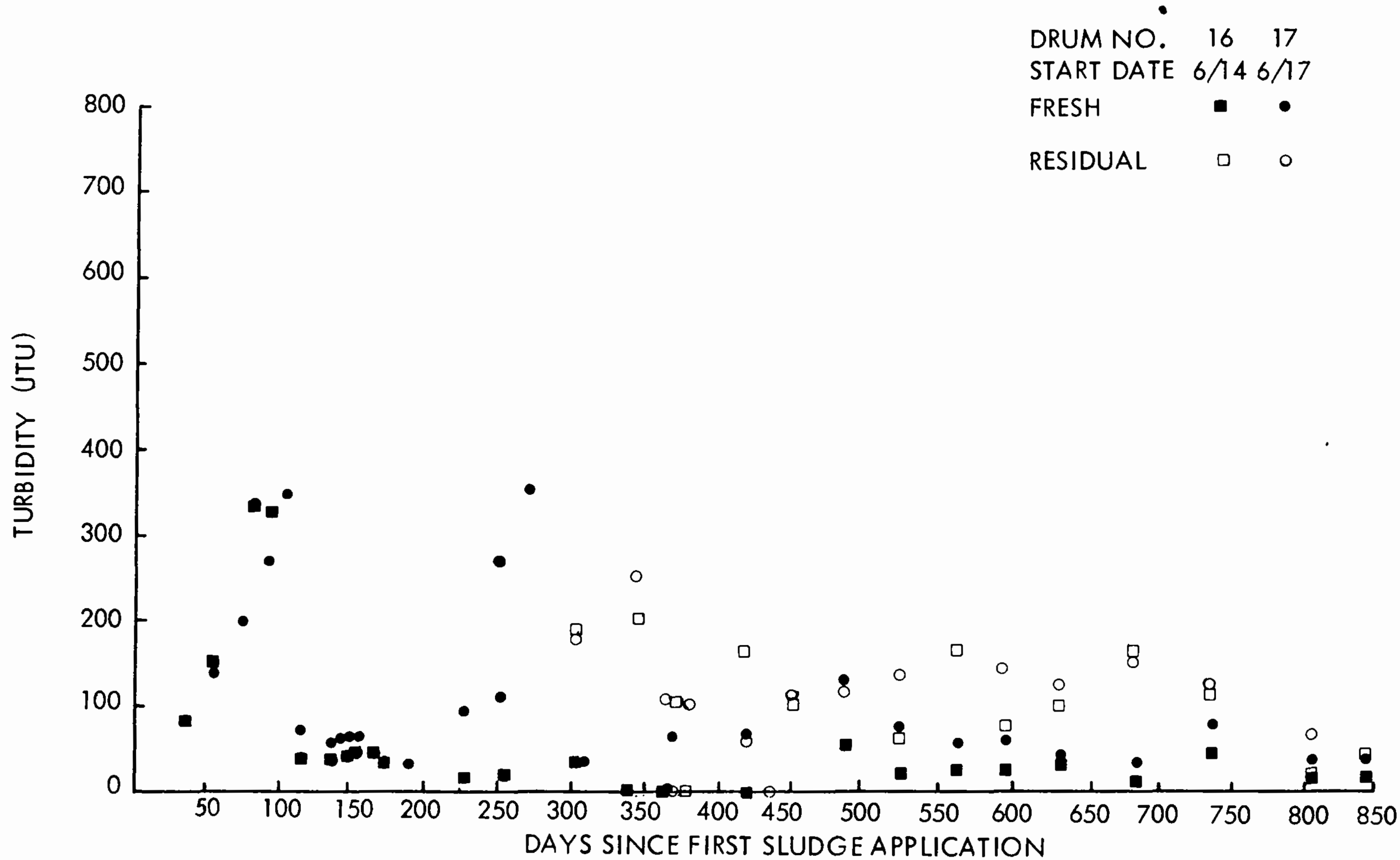


FIGURE D24
TURBIDITY OF LEACHATES

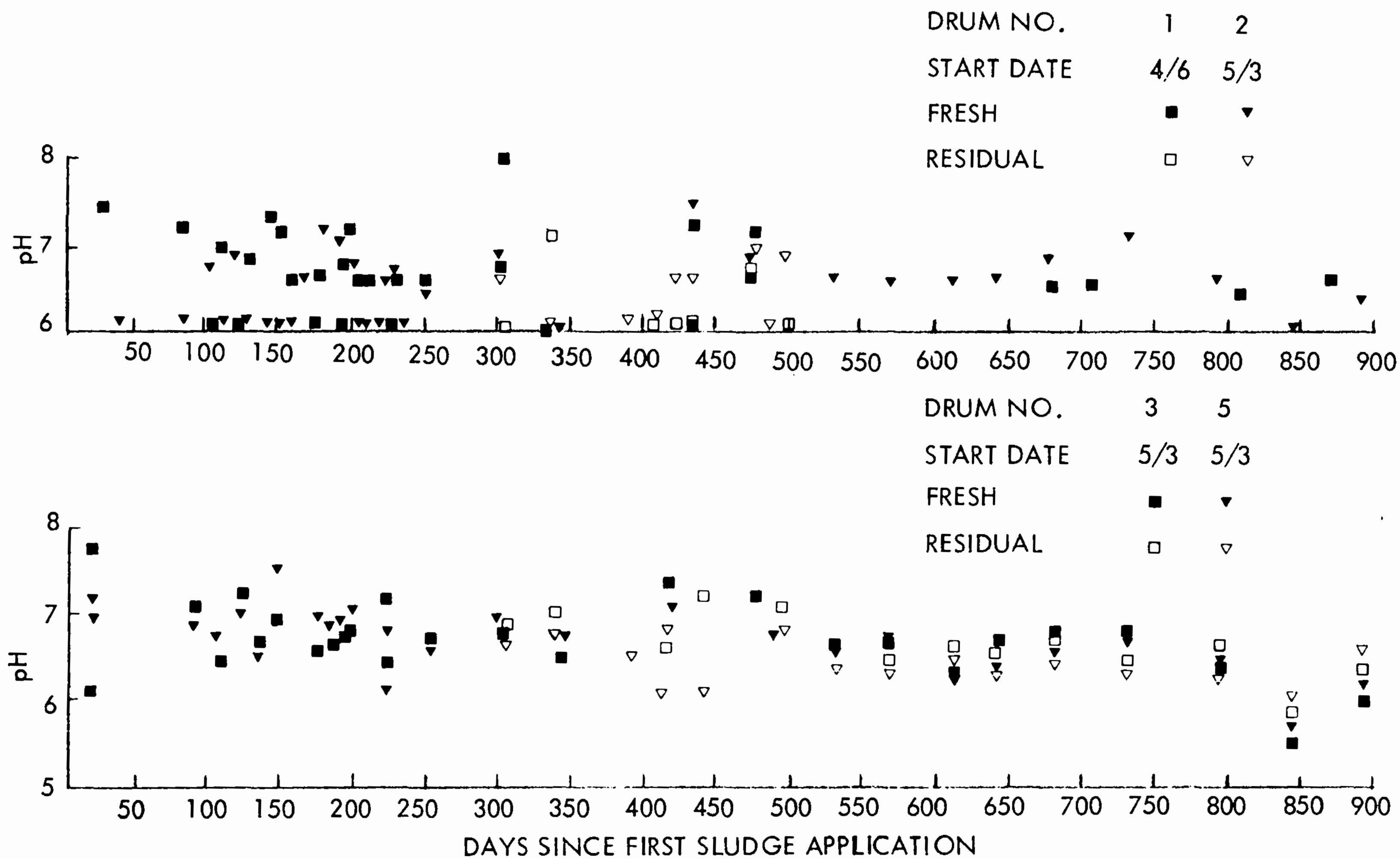


FIGURE D25
pH OF LEACHATES

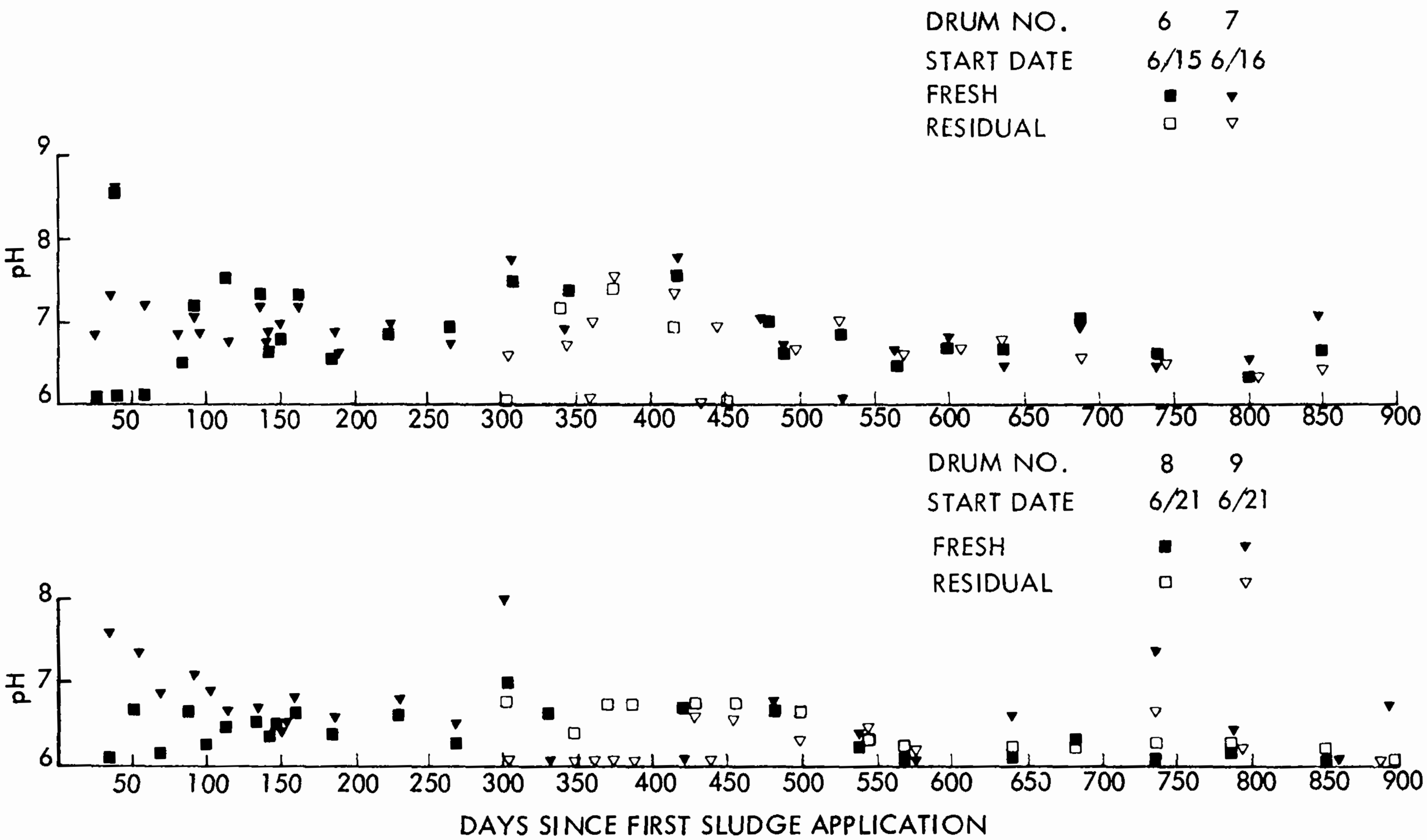


FIGURE D26
pH OF LEACHATES

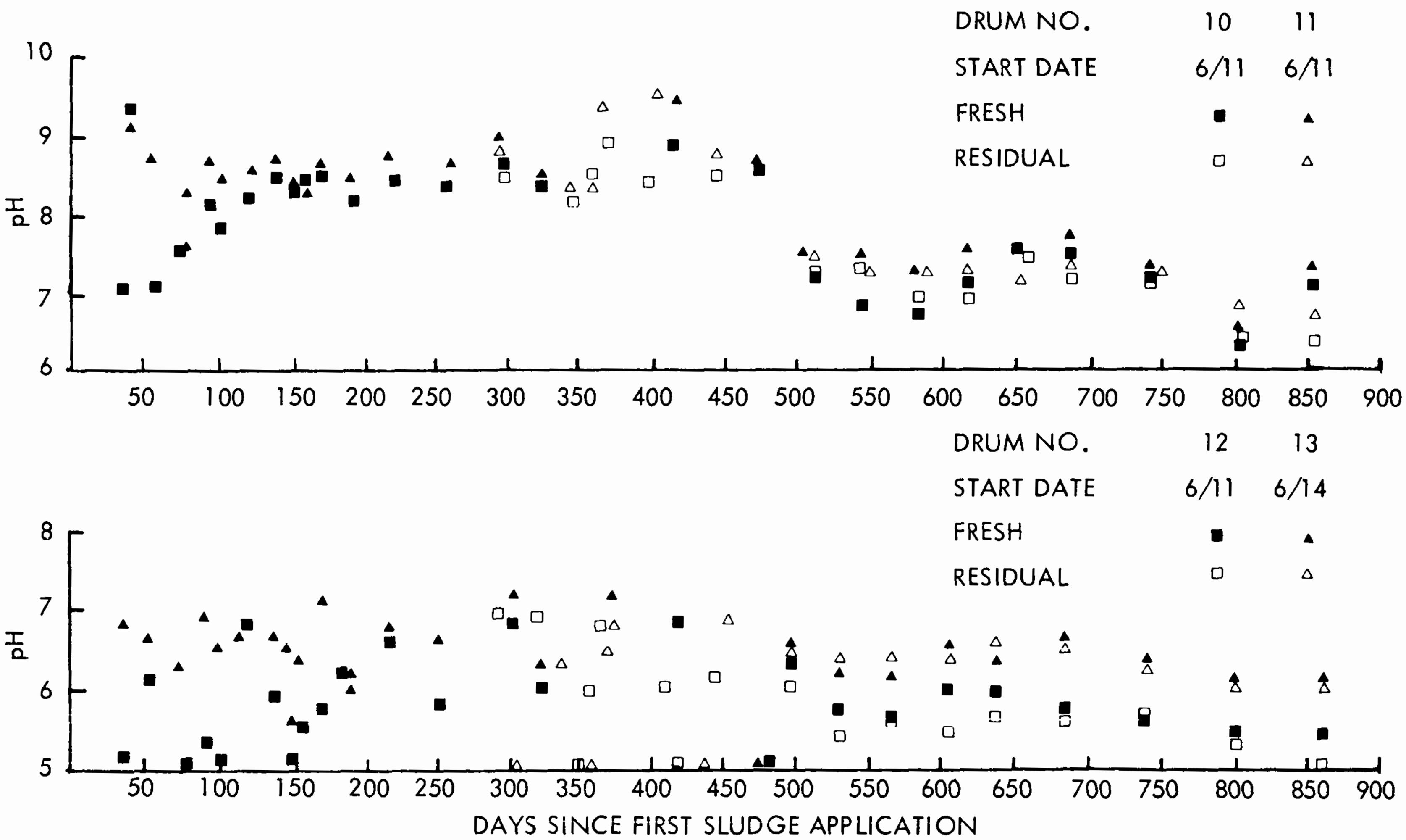


FIGURE D27
pH OF LEACHATES

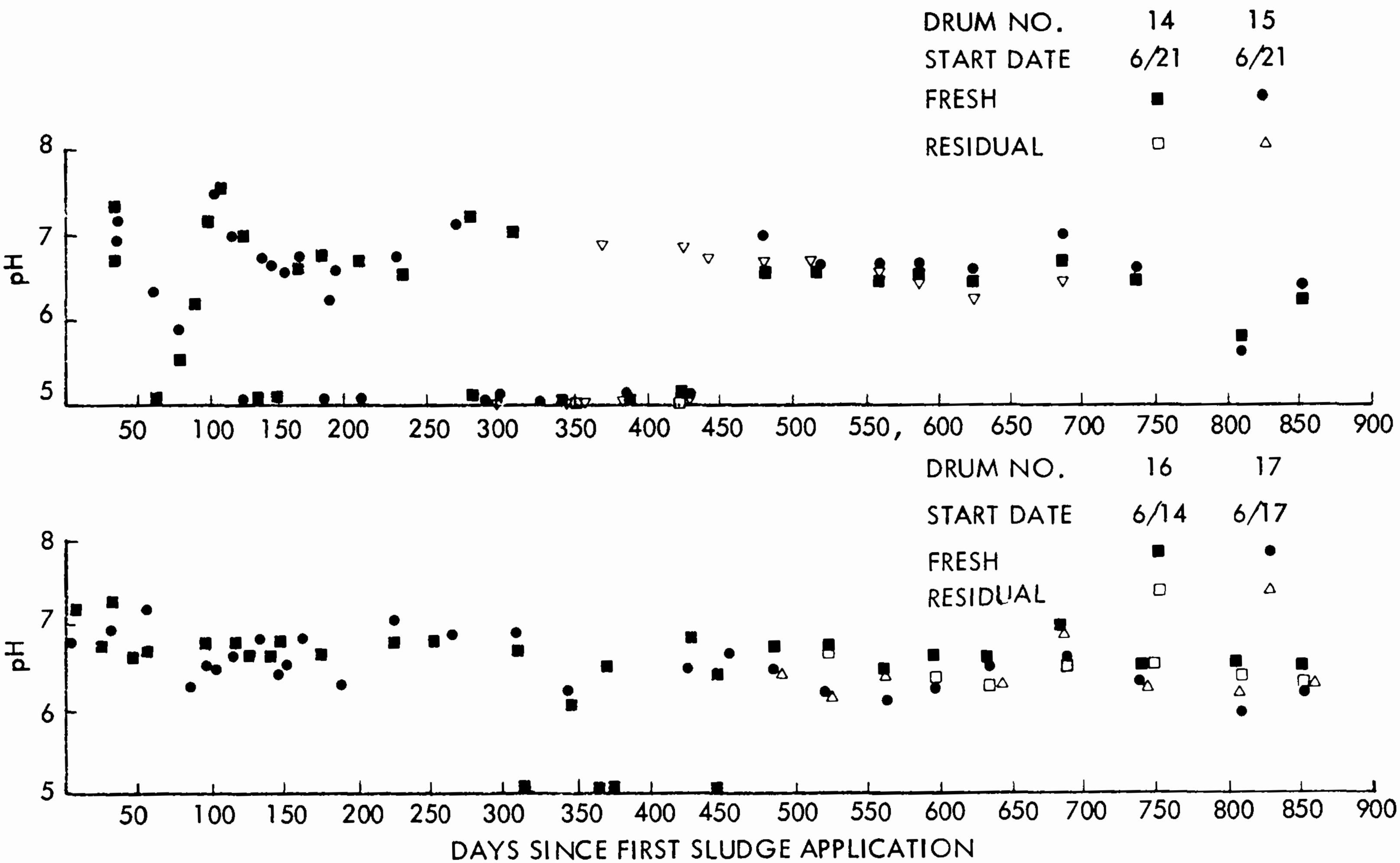


FIGURE D28
pH OF LEACHATES

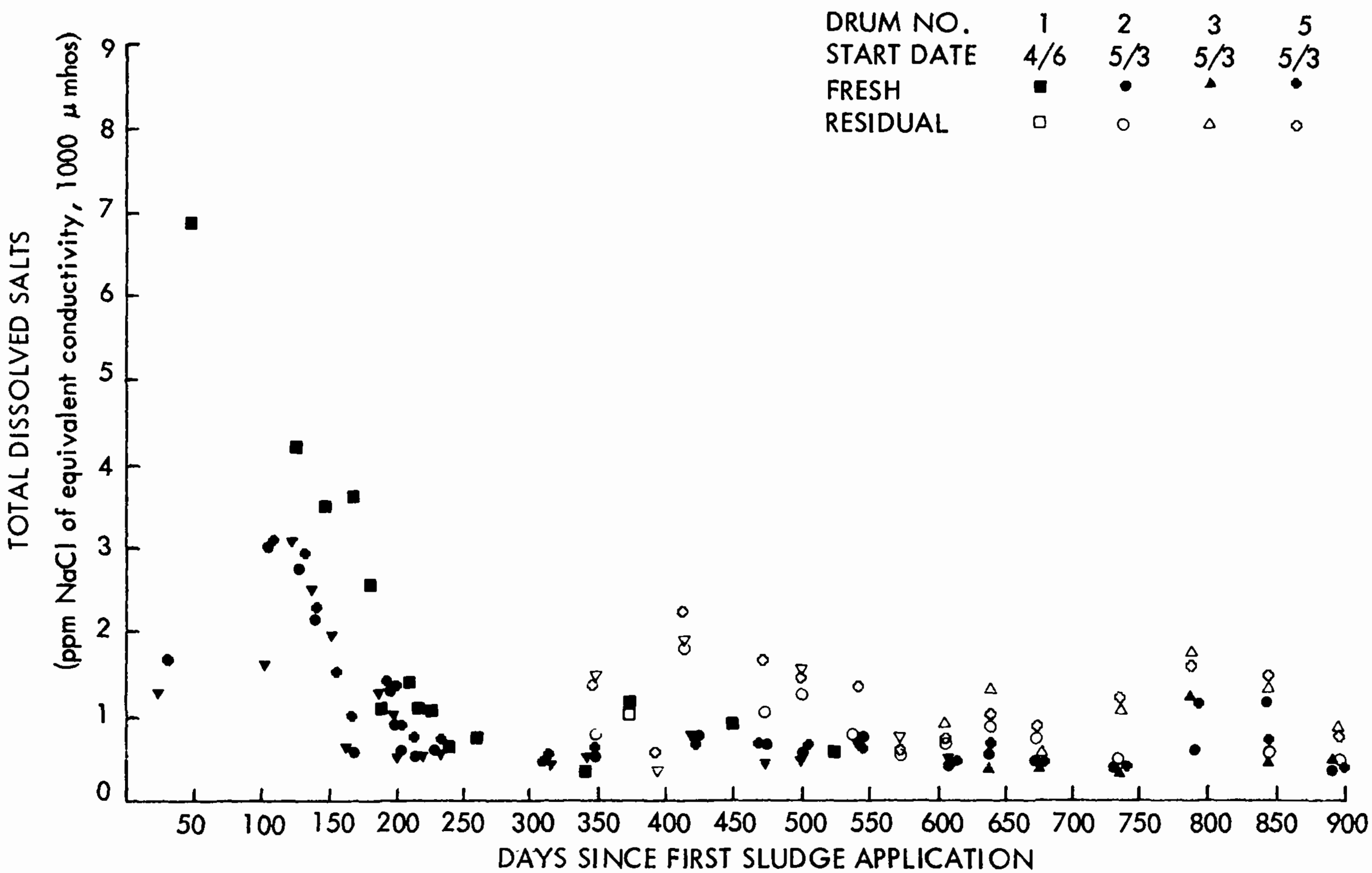


FIGURE D29
TOTAL DISSOLVED SALTS
IN LEACHATES

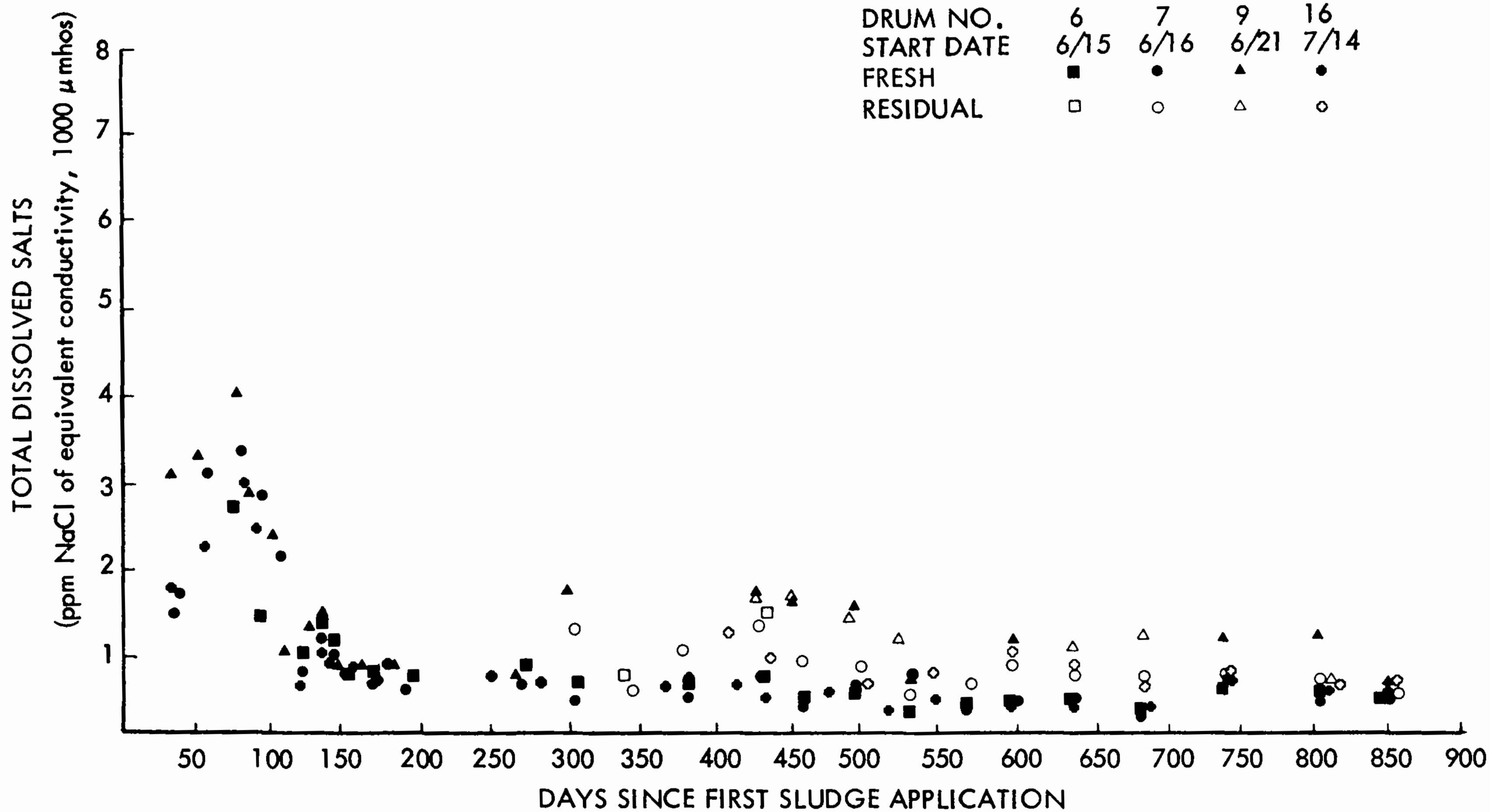


FIGURE D30
TOTAL DISSOLVED SALTS
IN LEACHATES

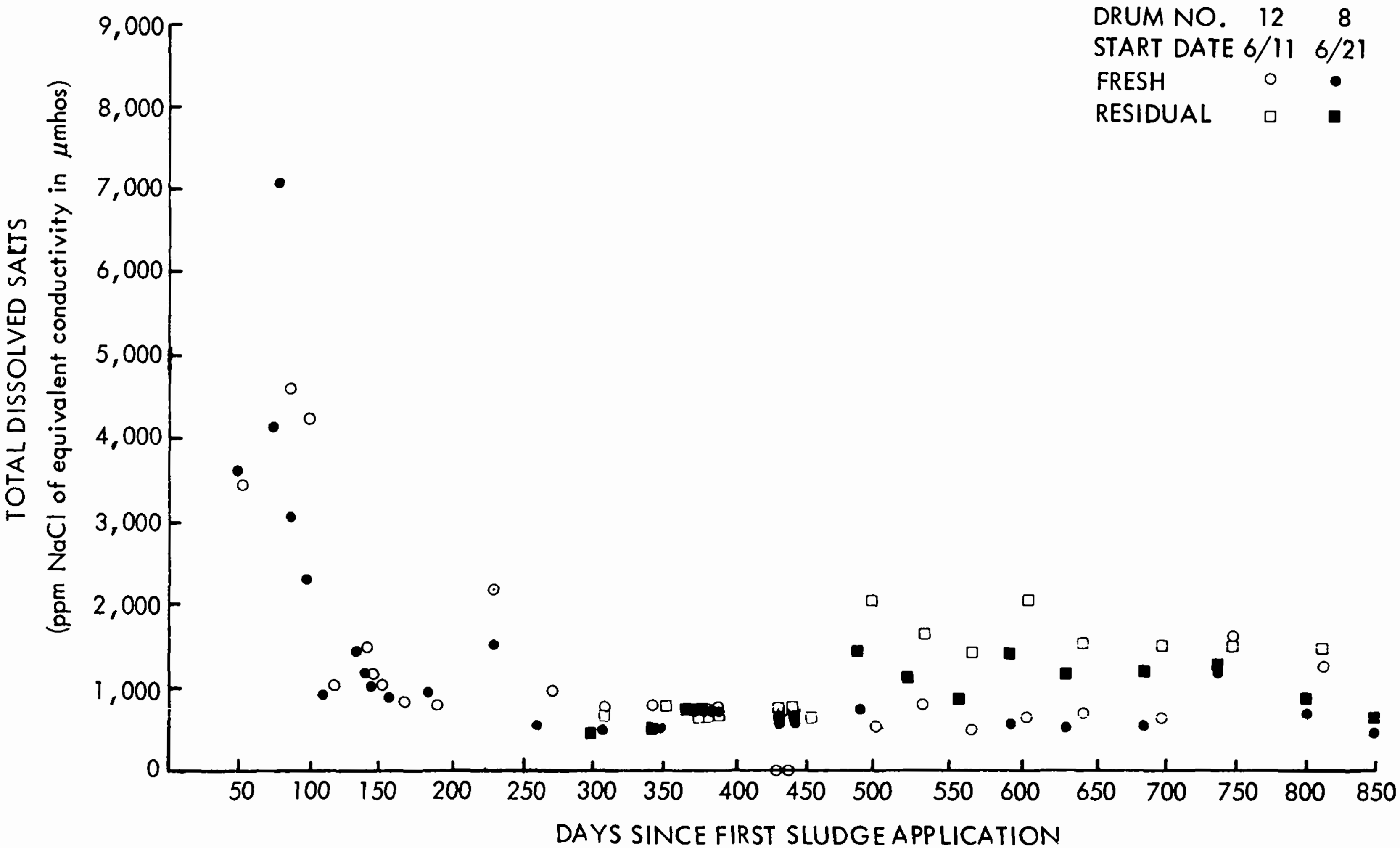


FIGURE D31
TOTAL DISSOLVED SALTS
IN LEACHATES

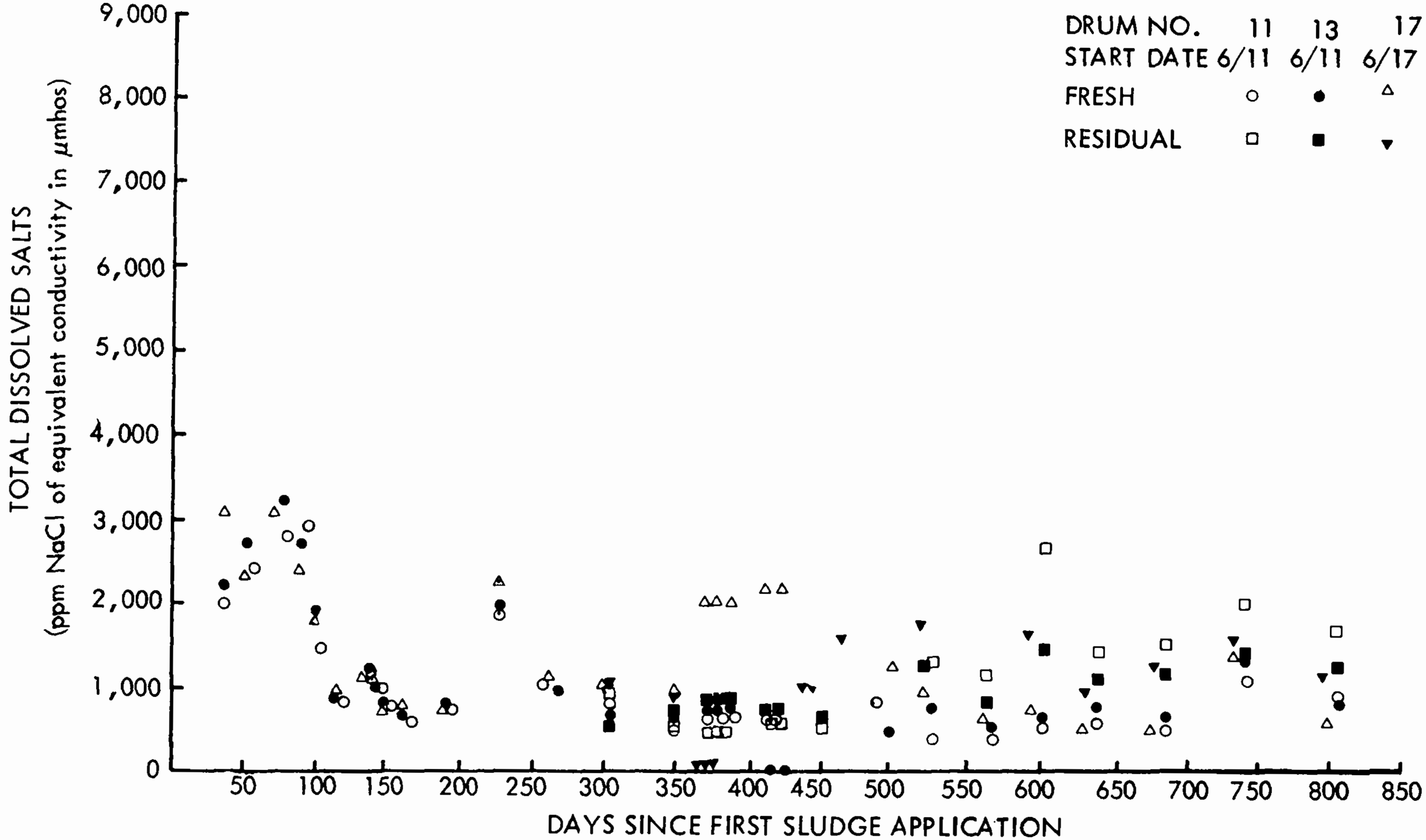


FIGURE D32
TOTAL DISSOLVED SALTS
IN LEACHATES

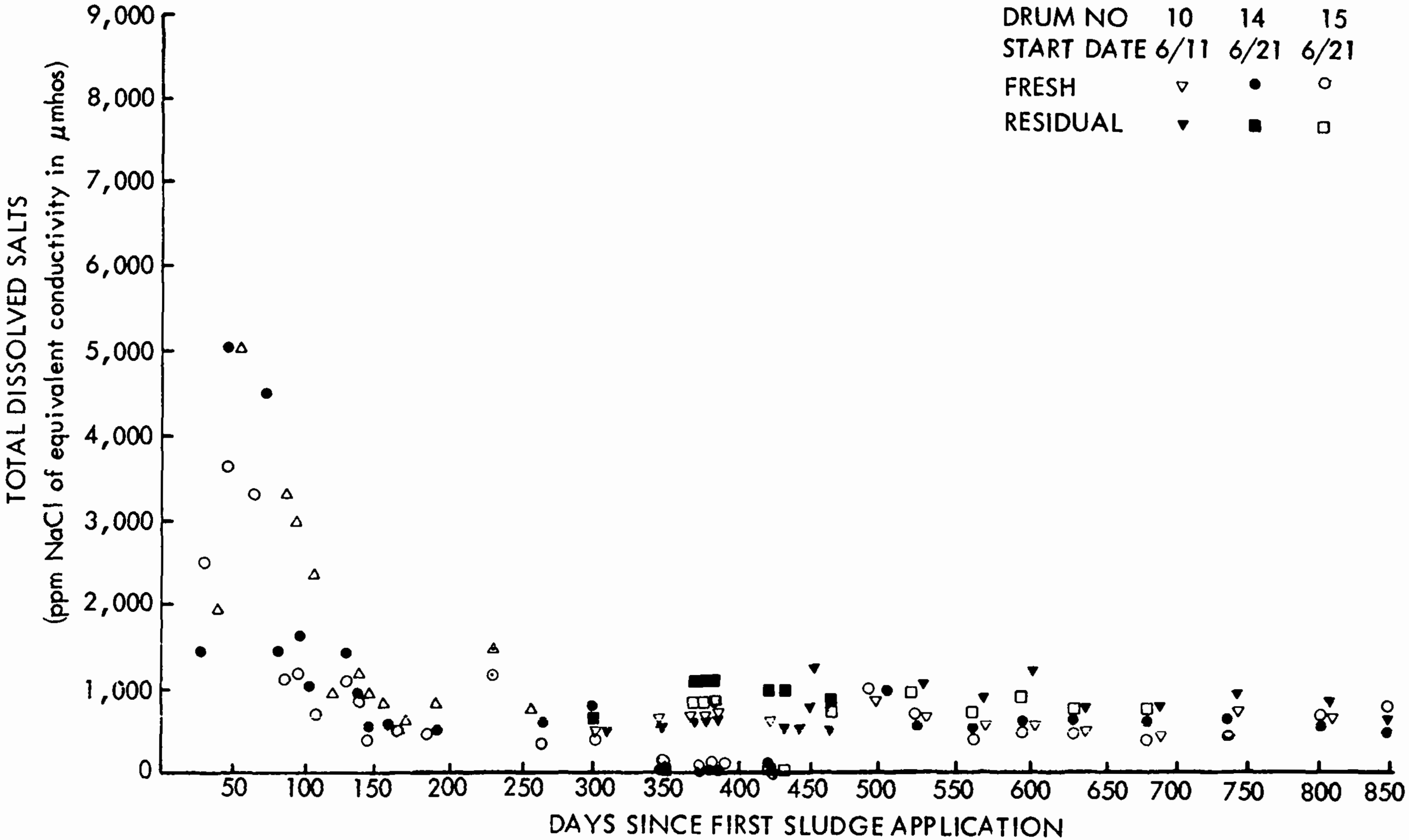


FIGURE D33
TOTAL DISSOLVED SALTS
IN LEACHATES

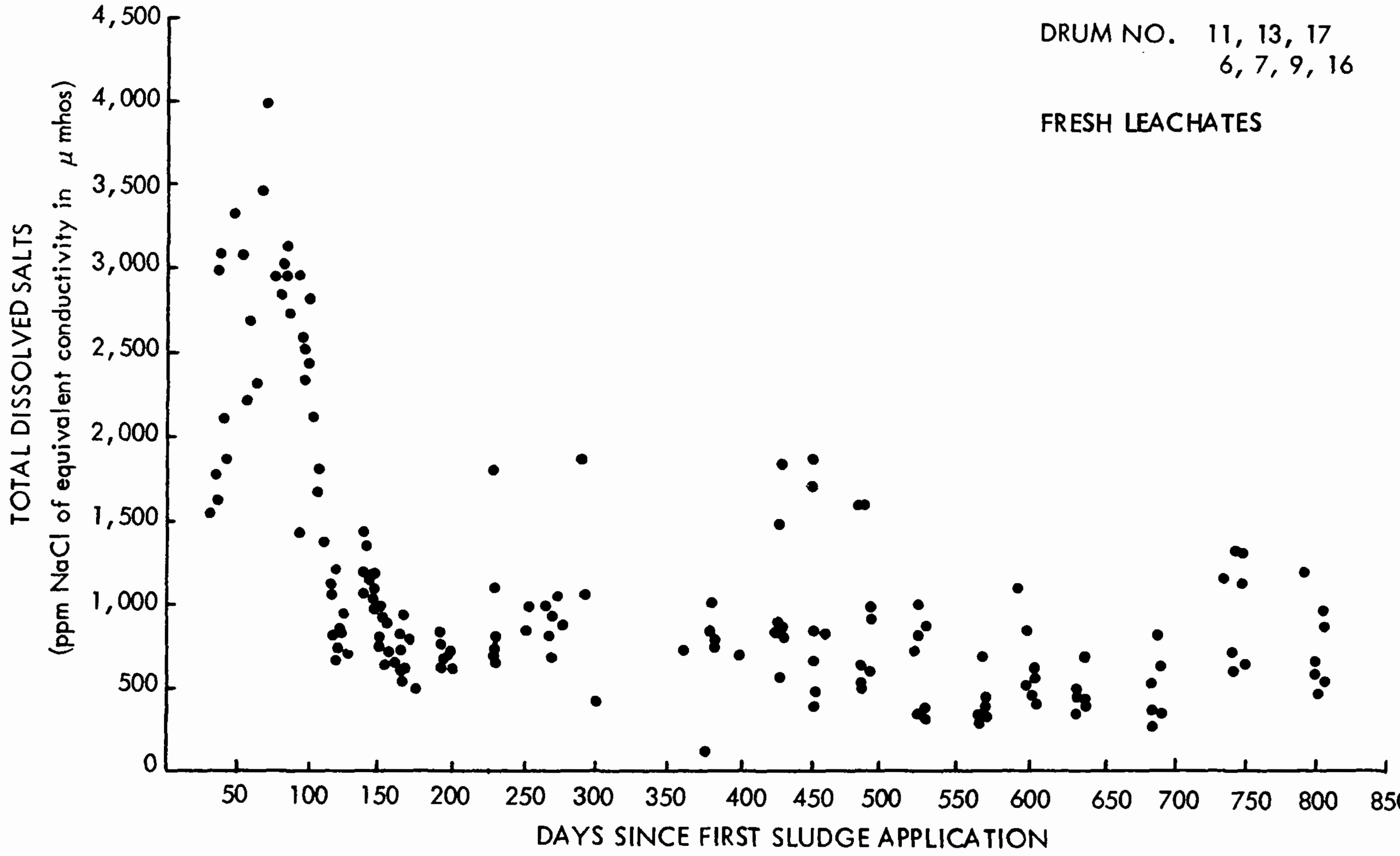


FIGURE D34
TOTAL DISSOLVED SALTS
(COMPOSITE) IN LEACHATES

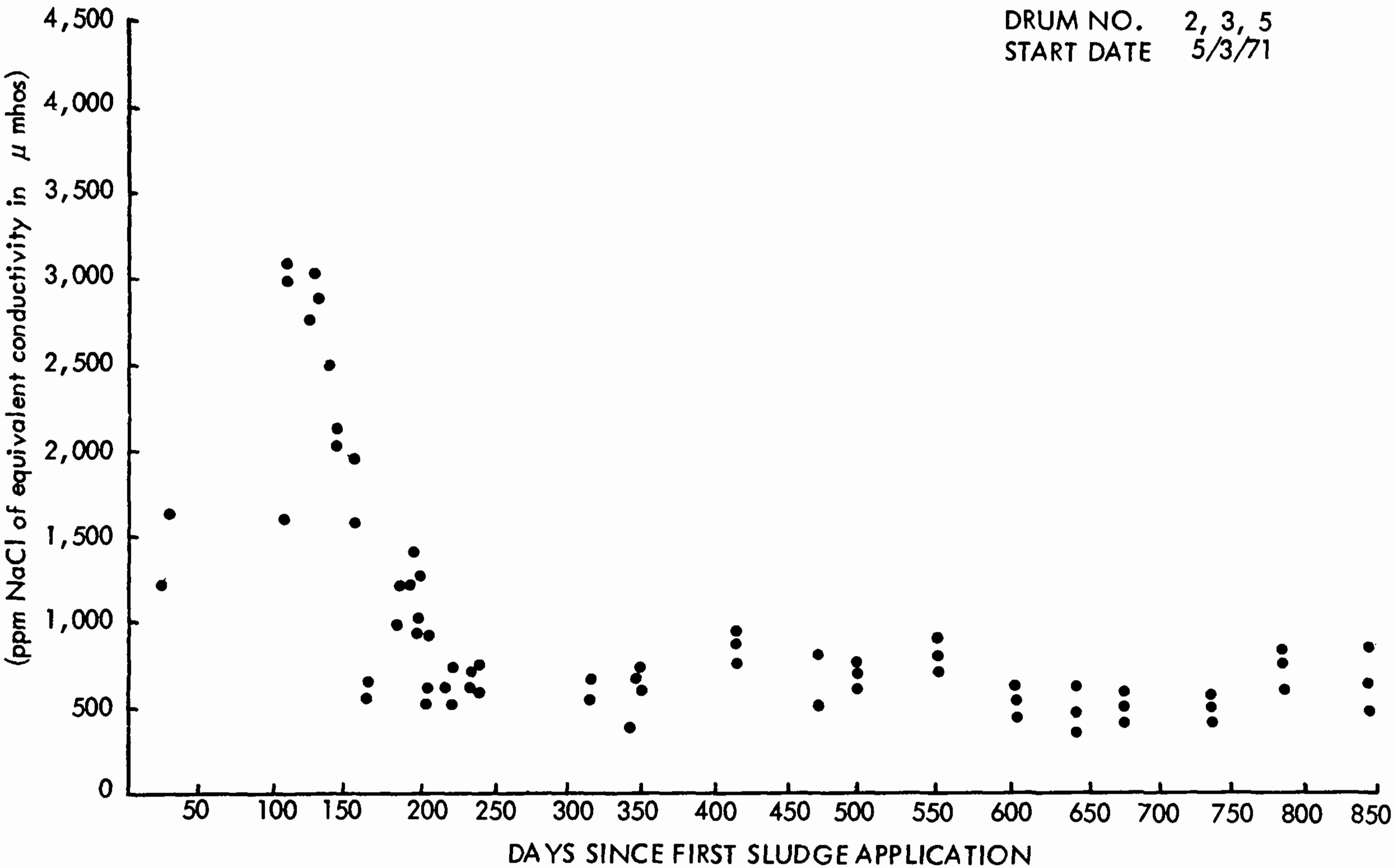


FIGURE D35
TOTAL DISSOLVED SALTS
(COMPOSITE) IN LEACHATES

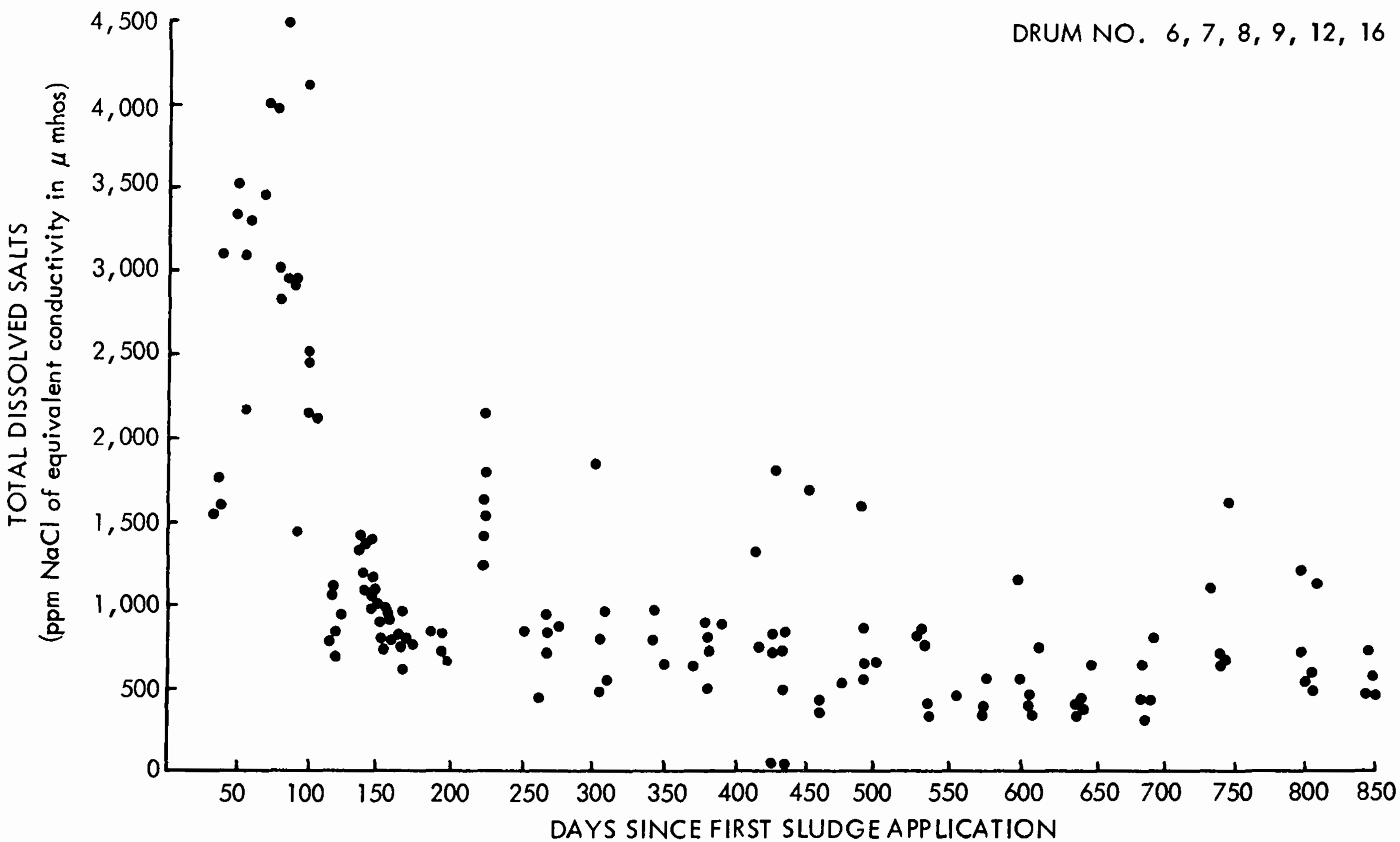


FIGURE D36
TOTAL DISSOLVED SALTS
(COMPOSITE) IN LEACHATES

DRUM NO. 8, 10, 12, 14

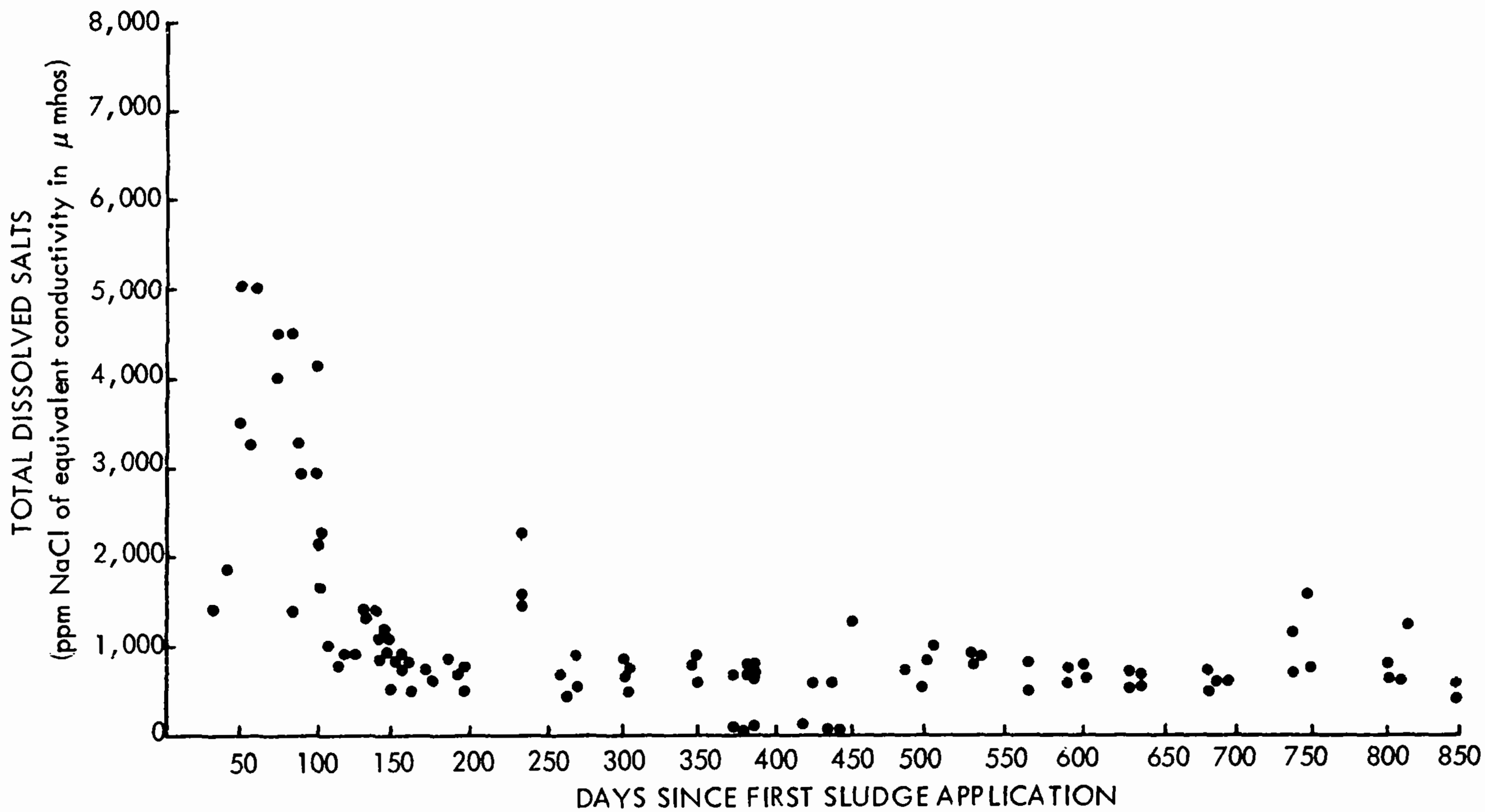


FIGURE D37
TOTAL DISSOLVED SALTS
(COMPOSITE) IN LEACHATES

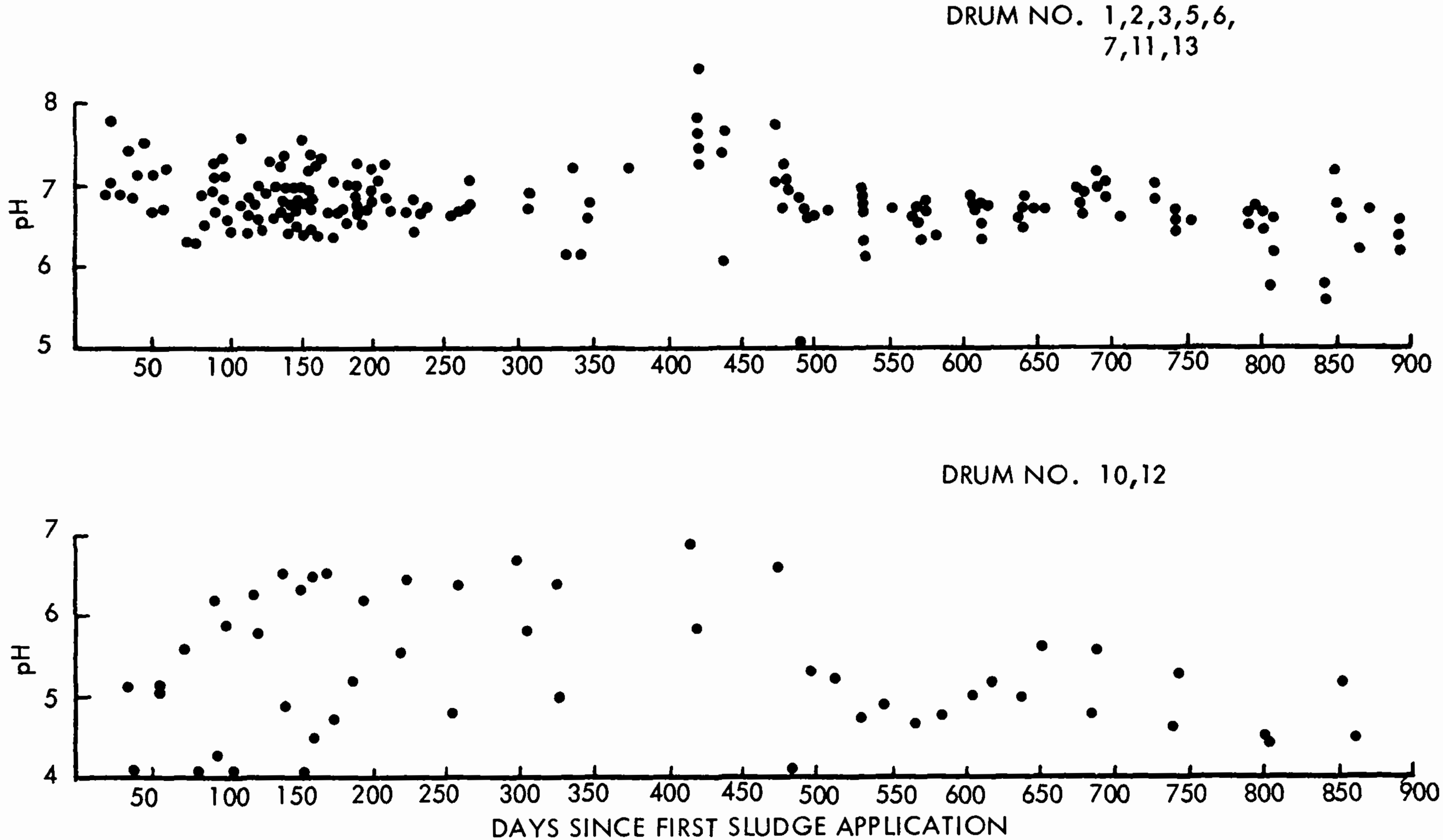


FIGURE D38
pH OF LEACHATES--COMPOSITES

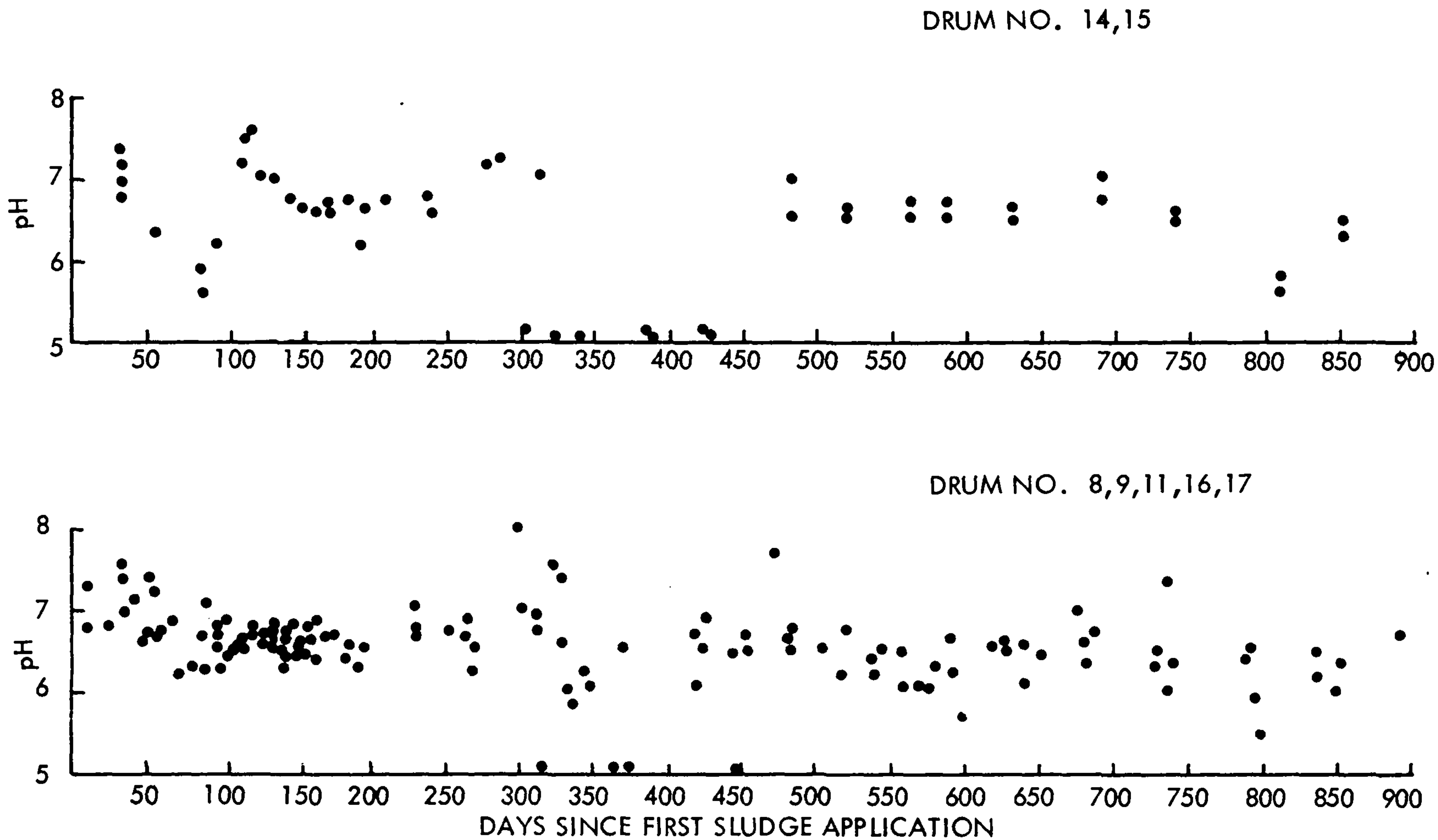


FIGURE D39
pH OF LEACHATES--COMPOSITES

TABLE D1

TOTAL METALS IN TEST DRUM LEACHATES -- COMPOSITE SAMPLES DURING 1972

Drum no.	Days since filling+	Quantity, lbs metals per lb dry wt solid waste* Mg $\times 10^{-5}$	Zn $\times 10^{-7}$	Fe $\times 10^{-6}$
1	267-450	1.44	9.60	2.58
2	241-424	0.15	2.25	7.20
3	241-424	0.96	4.00	3.44
5	241-424	1.36	12.80	3.44
6	198-381	2.14	4.80	2.80
7	196-379	1.09	3.20	2.75
8	192-375	0.99	4.80	3.12
9	192-375	2.24	7.20	4.72
10	192-375	0.61	3.20	2.80
11	192-375	2.40	4.00	13.00
12	201-384	1.92	2.73	3.22
13	201-384	1.09	4.80	3.12
14	200-383	1.35	27.50	3.22
15	192-373	1.65	4.50	3.22
16	177-360	1.60	24.70	6.95
17#	196-379	1.99	9.00	3.66

*Includes sludge solids where applicable.

+The amount of equivalent annual rainfall on all the drums during this time period was 11.9 inches.

#Water only -- this is representative of ordinary landfills.

APPENDIX E

FIELD TEST OF SLUDGE DISPOSAL

APPENDIX E
FIELD TEST OF SLUDGE DISPOSAL

1971 Date	Solid Waste, Lb	Sewage Sludge, Gal	Weather			Odor, Describe	Blowing Litter	Birds, Rats, Other, No.		Comments
			Temp °F	Wind*	Condition+			Test Area	Regular Landfill	
6/25	CONSULTANT 96 cu yd	1,750	70±	Low	Overcast	Septic, sulfide	At regular landfill	None	birds	Sludge ran into fill OK.
7/13	3 loads	5,250	83	Calm	Sunny	No	None	small birds	small birds	After 1½ days uncovered test area begins to give odors. Can't identify other than decaying garbage.
7/20	3 loads	1,750	80	Calm	Overcast	Yes, garbage	None	6 seagulls	None	Sludge is not being spread evenly over trash.
7/20 #	CONSULTANT 96 cu yd	1,750	70	Easterly breeze	Cool	Slight	None or very little	flies walking on refuse and sludge		Counted at least 50 flies. Sludge ran down incline in rivulets and settled in pools at base. Sludge & solid waste already placed.
7/27	3 loads	1,750	84	Calm	Sunny	No	None	None	None	Sludge spread better this time. No runoff.

*Enter - Calm, Low, Moderate, or High.
+Enter - Sunny, Cloudy, Overcast, Showers, or Rain.

APPENDIX E
FIELD TEST OF SLUDGE DISPOSAL

1971 Date	Solid Waste, Lb	Sewage Sludge, Gal	Weather: Temp °F	Weather: Wind*	Weather: Condition+	Odor, Describe	Blowing Litter	Birds, Rats, Other, No.: Test Area	Birds, Rats, Other, No.: Regular Landfill	Comments
7/27	CONSULTANT 96 cu yd	1,750	70	Moderate	Overcast	Downwind sulfide, septic	No	None	50 birds	Ran sludge out in 3 locations from 2 pipes at rear of tank. Some pooled in refuse; most percolated in very fast. Cat operator says bottom layer holds better: top layer runs off faster; lower platform holds sludge best. Also thinks less pressure in 2 openings than before with 1 opening in tank.
8/3	3 loads	1,750	88	Calm	Sunny	Slight sewage odor	None	None	seagulls, small birds	Test area does not seem to attract anything but flies.
8/10	3 loads	1,750	86	Calm	Sunny	Negligible	None	None	None	
8/10	CONSULTANT		88	Moderate	Sunny	No	No	6 seagulls	6 seagulls	Slight leachate.
8/17	3 loads	1,750	73	Moderate	Overcast	Negligible	Some plastic bags	None	birds	Out of room at Brooks St. landfill. Dumped.

*Enter – Calm, Low, Moderate, or High.
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APPENDIX E
FIELD TEST OF SLUDGE DISPOSAL

1971 Date	Solid Waste, Lb	Sewage Sludge, Gal	Weather			Odor, Describe	Blowing Litter	Birds, Rats, Other, No.		Comments
			Temp °F	Wind*	Condition+			Test Area	Regular Landfill	
										These loads at new landfill off Mission Drive.
8/23	CONSULTANT 96 cu yd	1,750	80	Westerly low	Sunny	Digested sludge	None	flies	1 seagull	Leachate from refuse.
8/24	3 loads	1,750	92	Calm	Overcast	Negligible	None	None	few birds	Birds have not yet located new site.
8/30	CONSULTANT	1,700	85	Westerly low	Sunny	Slight	No		seagulls	No upper level leachate. Water below landfill was clear.
8/31	6 loads	3,500	87	Calm	Sunny	Negligible	None	None	birds	Location-West bank. Cannot get to East wall of canyon yet.
9/7	6 loads	3,500	87	Calm	Sunny	None	None	None	None	Everything quiet today. Sludge was emptied before trash was spread.
9/13	Cancelled this week - dozer broke down.									
9/21	6 loads	3,500	78	Calm	Cool	None	None	flies	None	Quiet.
9/21	CONSULTANT 7 trucks	3,500	75	Low	Overcast	Slight	No	flies before sludge applied	None	Dumped Tuesday morning. Thousands of flies.

*Enter - Calm, Low, Moderate, or High.
+Enter - Sunny, Cloudy, Overcast, Showers, or Rain.

APPENDIX E
FIELD TEST OF SLUDGE DISPOSAL

1971 Date	Solid Waste, Lb	Sewage Sludge, Gal	Weather			Odor, Describe	Blowing Litter	Birds, Rats, Other, No.		Comments
			Temp °F	Wind*	Condition+			Test Area	Regular Landfill	
										Green blow flies and large ¼" house fly-type were on the solid waste, with or without sludge on its surface. Flies didn't discriminate between sludge and regular waste.
9/28	Cancelled this week - dozer broke down.									
10/4	6 loads	3,500	86	Calm	Sunny	None	None	flies, lizards	seagulls	None.
10/12	6 loads	3,500	81	Calm	Cloudy	Negligible	No	None	seagulls	
10/19	6 loads	3,500	74	Calm	Sunny	Negligible	No	None	seagulls & other birds	Thin sludges; lots of runoff, 3250 gal
10/26	6 loads	3,500	63	Moderate	Sunny	None	No	None	seagulls & other birds	Regular landfill blowing litter.
11/2	6 loads	3,500	63	Moderate	Sunny	Slight sewage odor for 15 minutes	None	None	seagulls & other birds	Some litter blowing at regular landfill.
11/9	6 loads	35,000	64	Calm	Sunny	No	None	None	birds	

*Enter - Calm, Low, Moderate, or High.
+Enter - Sunny, Cloudy, Overcast, Showers, or Rain.

APPENDIX E
FIELD TEST OF SLUDGE DISPOSAL

1971 Date	Solid Waste, Lb	Sewage Sludge, Gal	Weather: Temp °F	Weather: Wind*	Weather: Condition+	Odor, Describe	Blowing Litter	Birds, Rats, Other, No.: Test Area	Birds, Rats, Other, No.: Regular Landfill	Comments
11/16	6 loads	35,000	70	Low	Sunny	No	None	None	Closed	Old landfill closed 11-13-71; all dumping at new location.
11/23	6 loads	35,000	68	Low	Sunny	No	None	None	Closed	Used shot gun with bird-dispersing shells.
11/30	6 loads	35,000	64	Calm	Sunny	None	None	None	Closed	
12/7	6 loads	35,000	63	Calm	Sunny	No	None	seagulls	Closed	Just a few sea-gulls. Do not settle down as they did at old fill site, but fly high and land when area is un-occupied by men and equipment.
12/14	6 loads	35,000	64	Low	Sunny	No	None	seagulls	Closed	
12/21	6 loads	35,000	55	Calm	Overcast	No	None	seagulls	Closed	
12/21	CONSULTANT Normal	3,500	60	Calm	Overcast	Musty, light	No	No		Sludge was unloaded at 1 spot only and flooded 2/3 down face of fill; went below refuse and exited onto canyon floor (200 gals ±).

*Enter - Calm, Low, Moderate, or High.
+Enter - Sunny, Cloudy, Overcast, Showers, or Rain.

APPENDIX E
FIELD TEST OF SLUDGE DISPOSAL

Date	Solid Waste, Lb	Sewage Sludge, Gal	Weather			Odor, Describe	Blowing Litter	Birds, Rats, Other, No.		Comments
			Temp °F	Wind*	Condition+			Test Area	Regular Landfill	
12/28 1972	6 loads	35,000	54	Calm	Rain	No	No	None		
1/4	6 loads	35,000	55	Low	Sunny	Very slight	No	few birds		Sludge not being spread over trash.
1/11	6 loads	35,000	62	Calm	Sunny	No	No	None		Poor coverage.
1/18	6 loads	35,000	46	Calm	Overcast	No	No	seagulls		
1/25	6 loads	35,000	52	Calm	Sunny	No	No			
2/1	All sludge being dumped on top in test cells (7 to 1 ratio).									
2/15	All test cells filled with trash and sludge and covered. Sludge now being dumped with trash in bottom of canyon.									

*Enter - Calm, Low, Moderate, or High.
+Enter - Sunny, Cloudy, Overcast, Showers, or Rain.

APPENDIX E
FIELD TEST OF SLUDGE DISPOSAL

1972 Date	Solid Waste, Lb	Sewage Sludge, Gal	Weather: Temp °F	Weather: Wind*	Weather: Condition+	Odor, Describe	Blowing Litter	Birds, Rats, Other, No.: Test Area	Birds, Rats, Other, No.: Regular Landfill	Comments
5/1	(truck avg 3¼ ton/ea) 33 loads	(10,500 small truck) 8,500			Hazy	Normal	No	seagulls	flies, blackbird, seagulls	
5/2	22 loads									
5/3	22 loads	7,500	70	Slight	Good	Normal trash smell	No	seagulls	seagulls, blackbird	
5/4	22 loads	10,000	78	None	Overcast		No	seagulls	seagulls, blackbird	
5/5	33 loads	21,000 (big truck)	76					seagulls, pigeons		
5/8	25 loads	10,500	60	Slight	Clear	Normal	No		seagulls, squirrels	
5/8	CONSULTANT		67	Low	Cloudy	None	No	30 seagulls, 20 crows, 25 pigeons, 1 squirrel, 100 birds		Morning sludge dumped on top of fill soil from Sat. Birds avoid sludge-covered areas. 1 jack rabbit, 4 squirrels not in test area.
5/9	20 loads	17,500	62	Slight	Clear	Normal	No	seagulls	squirrels, seagulls	No litter when use water.
5/10	20 loads	14,000		None	Cloudy		No		seagulls, blackbird	Soto on dozer for a few days.

*Enter - Calm, Low, Moderate, or High.
+Enter - Sunny, Cloudy, Overcast, Showers, or Rain.

APPENDIX E
FIELD TEST OF SLUDGE DISPOSAL

1972 Date	Solid Waste, Lb	Sewage Sludge, Gal	Weather			Odor, Describe	Blowing Litter	Birds, Rats, Other, No		Comments
			Temp °F	Wind*	Condition+			Test Area	Regular Landfill	
5/11	22 loads	14,000	63	None		Normal	No	seagulls	seagulls	Using water on litter.
5/11	CONSULTANT		75	Low to moderate	Sunny		None, using water	100 seagulls, chipmunk, 30 pigeons, 20 misc birds		2 walking on sludge.
5/12	33 loads	10,500	64		Cloudy	Normal	No	seagulls,		
5/15	30 loads		63	Calm	Sunny	Normal	None	None	None	At 10:30 a.m. quiet and calm.
5/16	20 loads	21,000	64	Calm	Sunny	Normal	None	None	seagulls	
5/17	22 loads	21,000	63	Moderate	Overcast	Normal trash smell	No	None	seagulls, blackbird	
5/17	CONSULTANT		68	Low	Sunny	Normal	None			A couple sludge loads brought a.m. No sludge visible on face of refuse. Small amount visible on plateau below face in two streamers. Took photos.
5/18	20 loads	17,500	62	Calm	Sunny	Normal	No	None	squirrel, seagulls	
5/19	31 loads	17,500	60	Moderate	Showers	Normal	No	birds	seagulls	

*Enter - Calm, Low, Moderate, or High.
+Enter - Sunny, Cloudy, Overcast, Showers, or Rain.

APPENDIX E

FIELD TEST OF SLUDGE DISPOSAL

1972 Date	Solid Waste, Lb	Sewage Sludge, Gal	Weather			Odor, Describe	Blowing Litter	Birds, Rats, Other, No.		Comments
			Temp °F	Wind*	Condition+			Test Area	Regular Landfill	
5/22	33 loads	17,500	60	Low	Showers	Normal	A little	seagulls	seagulls	Some litter because of wind.
5/23	20 loads	21,000	63	Calm	Overcast	Normal trash odor	No	seagulls	birds, flies, seagulls	
5/24	20 loads	31,500	65	Low	Sunny	Normal	No	seagulls	seagulls	
5/25	21 loads	10,500	62	Moderate	Overcast	Sewer and trash odor	Some	None	blackbirds, seagulls	Litter because of wind coming up canyon.
5/26	33 loads	21,000								
5/29	8 loads	None	65	Calm	Sunny	Normal sewer odor	None	None	seagulls, squirrel, blackbirds	Only 4 trucks as holiday.
5/30	20 loads	24,500			Sunny		None		seagulls, squirrel, birds	
5/31	22 loads	7,000	68	Calm	Sunny					
6/1	30 loads		67	Moderate	Cloudy, sunny	Sewer odor	None	birds	seagulls, flies, squirrels	Ending this lift and will have trouble when start the next level.
6/2	30 loads		63			Trash and sewer odor	None	birds seagulls	seagulls, squirrels, birds	

*Enter - Calm, Low, Moderate, or High.

+Enter - Sunny, Cloudy, Overcast, Showers, or Rain.

APPENDIX E
FIELD TEST OF SLUDGE DISPOSAL

1972 Date	Solid Waste, Lb	Sewage Sludge, Gal	Weather			Odor, Describe	Blowing Litter	Birds, Rats, Other, No.		Comments
			Temp °F	Wind*	Condition+			Test Area	Regular Landfill	
6/3	40 loads	None	66	Moderate	Overcast, hazy	Normal	None	seagulls, birds	seagulls, birds	Make up day for holiday-trash only.
6/5	30 loads		69	Moderate	Cloudy	Normal	None		seagulls, squirrels	
6/6	20 loads		63	Moderate	Overcast, rain	Normal	None		birds, seagulls	Some litter. Short of help to clean up.
6/7	22 loads		62	Moderate	Showers	Sewer odor	None		squirrel, birds, seagulls	

*Enter - Calm, Low, Moderate, or High.
+Enter - Sunny, Cloudy, Overcast, Showers, or Rain.

DS-1: SLUDGE APPLICATION DATA - FIELD TEST OF SLUDGE DISPOSAL Observer Jim Reid

Date & time	Loads disposed, no.		Weather			Sludge disposal	Est. qty, gallons	
	Solid waste by type*	Sludge load by type+	Temp. °F	Wind#	Con-dition**	Describe method of sludge and solid waste placement, and condition of sludge when observed (wet, dry)	Runoff	Leachate (sample when observed)
7/17	WD-6 Other-1	1-LS(2500)	79	Low	Sunny	Truck, gravity feed; single hose w/flat head; truck no motion; wet; slope 45% approximate. Sludge worked in after spreading by use of tractor.	0	
7/18	-	-	-	-	-	(No report) no sludge -		
7/19	-	-	-	-	-	(No report) truck broke down		
7/20 0915	WD-3 Other - 3	2-LS(3500) 2-BV(3500)	77	Low	Cloudy		0	
1330	WD-7 Other - 8	2-LS(3500)	81	Low	Sunny		5	
7/21 0930	WD-2	4-LS(3500)	75	Low	Cloudy		20	

*Type of load: for WD (Waste disposal collection trucks) enter "WD-no. loads". For other loads indicate "Type-no. loads".

+Indicate type of sludge as: SLR-no.(gallons/load); and for Buena Vista (BV) and La Salina (LS) note primary digested (PD), primary raw (PR) or secondary digested (SD) sludge. Example: 3-LS (3,500) (SD).

#Enter - calm, low, moderate or high. **Enter - sunny, cloudy, overcast, showers or rain.

DS-1: SLUDGE APPLICATION DATA - FIELD TEST OF SLUDGE DISPOSAL Observer Jim Reid

Date & time	Loads disposed, no.		Weather			Sludge disposal	Est. qty, gallons	
	Solid waste by type*	Sludge load by type+	Temp. °F	Wind#	Condition**	Describe method of sludge and solid waste placement, and condition of sludge when observed (wet, dry)	Runoff	Leachate (sample when observed)
7/21 1230	WD-6 Other-4	4-LS(3500) 6-BV(3500)	81	Low	Sunny		10	
7/24 1230	WD-4 Other-3	4-LS(3500) 2-BV(3500)	89	Mod	Sunny		20	
7/25 0850	WD-2 Other-1	4-LS(3500) 2-SLR(3500)	80	Low	Overcast		10	
7/25	--	--	--	--	--			
7/26 1100	WD-3 Other-3	4-LS(3500) 2-BV(3500)	80	Low	Sunny		20	
7/26 1300	WD-6 Other-4		81	Low	Sunny		0	
7/27 1100	WD-3 Other-2	4-LS 2-SLR	82	Low	Sunny		0	
1400	WD-7 Other-4	2-SLR	84	Low	Sunny		5	

*Type of load: for WD (Waste disposal collection trucks) enter "WD-no. loads". For other loads indicate "Type-no. loads".

+Indicate type of sludge as: SLR-no.(gallons/load); and for Buena Vista (BV) and La Salina (LS) note primary digested (PD), primary raw (PR) or secondary digested (SD) sludge. Example: 3-LS (3,500) (SD).

#Enter - calm, low, moderate or high. **Enter - sunny, cloudy, overcast, showers or rain.

DS-1: SLUDGE APPLICATION DATA - FIELD TEST OF SLUDGE DISPOSAL Observer Jim Reid

Date & time	Loads disposed, no.		Weather			Sludge disposal	Est. qty, gallons	
	Solid waste by type*	Sludge load by type+	Temp. °F	Wind#	Con-dition**	Describe method of sludge and solid waste placement, and condition of sludge when observed (wet, dry)	Runoff	Leachate (sample when observed)
7/28 0900	WD-1 Other - 3	4-LS(3500) 2-BV(3500)	85	Low	Sunny			
1400	WD-4		87	Low	Sunny			
7/31 1000	WD-3 Other - 2							

*Type of load: for WD (Waste disposal collection trucks) enter "WD-no. loads". For other loads indicate "Type-no. loads"

+Indicate type of sludge as: SLR-no.(gallons/load); and for Buena Vista (BV) and La Salina (LS) note primary digested (PD), primary raw (PR) or secondary digested (SD) sludge. Example: 3-LS (3,500) (S.D).

#Enter - calm, low, moderate or high. **Enter - sunny, cloudy, overcast, showers or rain.

DS-1: SLUDGE APPLICATION DATA - FIELD TEST OF SLUDGE DISPOSAL   Observer Jim Reid

Date & time	Loads disposed, no.		Weather			Sludge disposal	Est. qty, gallons	
	Solid waste by type*	Sludge load by type+	Temp. °F	Wind#	Condition**	Describe method of sludge and solid waste placement, and condition of sludge when observed (wet, dry)	Runoff	Leachate (sample when observed)
12/11 0800	WD-0	O-SLR	68	Mod	Cloudy	Dry --		
1400	WD-6	3 - 2-LS 1-SLR (3500)	72	Calm	Sunny	Dispersed through fixed nozzle; track moves 3 positions to cover area while unloading.	0	
12/12 1315	WD-8	2-LS (3500)	65	Low	Sunny		0	
12/13 0950	WD-2 Other-2	0	60	Calm	Sunny		0	
12/14 1300	WD-7 Other-2	2-BV(3500) PR	66	Calm	Sunny			
12/15 1130	WD-3 Other-3	2-SLR 1-BV 1-LS	73	Calm	Sunny			
12/16 0930	WD-2 Other-1	0	70	Calm	Sunny			

*Type of load: for WD (Waste disposal collection trucks) enter "WD-no. loads". For other loads indicate "Type-no. loads".

+Indicate type of sludge as: SLR-no.(gallons/load); and for Buena Vista (BV) and La Salina (LS) note primary digested (PD), primary raw (PR) or secondary digested (SD) sludge. Example: LS - 3 (3,500) (SD).

#Enter - calm, low, moderate or high. **Enter - sunny, cloudy, overcast, showers or rain.

DS-1: SLUDGE APPLICATION DATA - FIELD TEST OF SLUDGE DISPOSAL   Observer Jim Reid

Date & time	Loads disposed, no.		Weather			Sludge disposal	Est. qty, gallons	
	Solid waste by type*	Sludge load by type+	Temp. °F	Wind#	Condition**	Describe method of sludge and solid waste placement, and condition of sludge when observed (wet, dry)	Runoff	Leachate (sample when observed)
12/18	--	--	--	--	--	Dispersed through fized nozzle with truck moving to three positions to cover entire area.	0	
12/19 0936	WD-4	2-BV	67	Calm	Sunny			
12/20 1411	WD-8 Other-1	3-BV 3-LS	72	Calm	Sunny			
12/21 900	WD-4 Other-3	--	75	Calm	Sunny			
12/22 1330	WD-6 Other-3	2-BV 2-LS	76	Calm	Sunny			
12/23	--	--	--	--	--			

*Type of load: for WD (Waste disposal collection trucks) enter "WD-no. loads". For other loads indicate "Type-no. loads".

+Indicate type of sludge as: SLR-no.(gallons/load); and for Buena Vista (BV) and La Salina (LS) note primary digested (PD), primary raw (PR) or secondary digested (SD) sludge. Example: LS - 3 (3,500) (SD).

#Enter - calm, low, moderate or high.   **Enter - sunny, cloudy, overcast, showers or rain.

DS-1: SLUDGE APPLICATION DATA - FIELD TEST OF SLUDGE DISPOSAL   Observer Jim Rowlands

Date & time	Loads disposed, no.		Weather			Sludge disposal	Est. qty, gallons	
	Solid waste by type*	Sludge load by type+	Temp. °F	Wind#	Condition**	Describe method of sludge and solid waste placement, and condition of sludge when observed (wet, dry)	Runoff	Leachate (sample when observed)
1-2-73	--	--	--	--	--			
1-4-73 1515	--	3-LS 1-BV	50	Calm	Overcast, very light showers	Solid waste in dry-10' high x 40' wide x 80' long. Fourth load of sludge deposited by spreader plates across face; runoff started on 2nd load. All sludge still wet.	250	
1-9-73								
1100	--	1-BV	55	Low	Showers	Sludge wet and pooled at top of face.	0	
1200	WD-5	1-BV	55	Low	Cloudy	Same as above.	10	
1315	--	--	--	Low	Cloudy	Runoff in tight to base.	50	
1445	--	1-LS	--	Low	Cloudy	--	50	No increase
1535	--	1-LS	--	Low	Cloudy	No new runoff.	50	No increase
1-10-73 1415	WD-10±	2-LS	58	Low	Cloudy	Refuse and wet sludge mixed; some pooled sludge.	100	

*Type of load: for WD (Waste disposal collection trucks) enter "WD-no. loads". For other loads indicate "Type-no. loads"

+Indicate type of sludge as: SLR-no.(gallons/load); and for Buena Vista (BV) and La Salina (LS) note primary digested (PD), primary raw (PR) or secondary digested (SD) sludge. Example: LS - 3 (3,500) (SD).

#Enter - calm, low, moderate or high.   **Enter - sunny, cloudy, overcast, showers or rain.

DS-1: SLUDGE APPLICATION DATA - FIELD TEST OF SLUDGE DISPOSAL Observer Jim Reid

Date & time	Loads disposed, no.		Weather			Sludge disposal	Est. qty, gallons	
	Solid waste by type*	Sludge load by type+	Temp. °F	Wind#	Condition**	Describe method of sludge and solid waste placement, and condition of sludge when observed (wet, dry)	Runoff	Leachate (sample when observed)
1/8/73 1111	WD-8 Other-4	0	68	Calm	Sunny	Dispersed through double nozzle fixed level and moving truck to alternate positions.		
1/9/73	--	--	--	--	--			
1/10/73 1300	WD-6 Other-6	2-BV	72	Calm	Sunny			
1/11/73 1330	WD-8 Other-10	2-LS 2-BV	72	Calm	Sunny			
1/12/73 1100	WD-6	0	80.	Calm	Sunny			
1/15/73 1230	WD-5 Other-2	0	68	Calm	Cloudy			
1/16/73 1310	WD-8 Other-6	2-BV	68	Calm	Cloudy, drizzle			
1/17/73	--	--	--	--	--			

*Type of load: for WD (Waste disposal collection trucks) enter "WD-no. loads". For other loads indicate "Type-no. loads".

+Indicate type of sludge as: SLR-no.(gallons/load); and for Buena Vista (BV) and La Salina (LS) note primary digested (PD), primary raw (PR) or secondary digested (SD) sludge. Example: LS - 3 (3,500) (S.D).

#Enter - calm, low, moderate or high. **Enter - sunny, cloudy, overcast, showers or rain.

DS-2: ENVIRONMENTAL OBSERVATIONS - FIELD TEST OF SLUDGE DISPOSAL Observer Jim Reid

Date & time	Sludge test area: 150 ft x 200 ft						(No sludge) Regular landfill area: 200 ft x 200 ft					
	Blowing litter, no. items*	PA = 30,000 ft.^{2} Animals and insects, no./PA+				Odor‡	Blowing litter no. items*	Animals and insects, no./PA+				Odor‡
		Birds	Rats	Flies	Others!			Birds	Rats	Flies	Others!	
7/17 1100	0	0	0	100	None	Earthy	0	0/ 40,000 ft.^{2}	0/ 4(10^4) ft.^{2}	100/9 ft.^{2}		
7/18	No sludge disposed.											
7/19												
7/20	0	0	0	100	None	None						
7/20	0	0	0	100	None	None						
7/21 0930	0	2	0		None	None						
7/21 1230	0	2	0	100	None	None						
7/24	0	0	0	0	None	None						

*Estimate the number of items travelling in the wind. Do not include items waving or flapping in the wind which are held down at one end.

+Count the number of birds and animals on the waste fill and estimate the total area in square feet (feet). The sludge test area size shall include all solid waste fill surface which is covered with sludge or was mixed with sludge at the time of observation. PA = populated area where 80 percent or more of the observed population is foraging.

#Estimate the area covered by flies and the number of flies, maggots.

‡ Earthy, pig pen, sweet, etc.; none, medium, strong, etc.

! Indicate rats, cats, dogs or other unusual animal or insect or event.

DS-2: ENVIRONMENTAL OBSERVATIONS - FIELD TEST OF SLUDGE DISPOSAL Observer Jim Reid

Date & time	Sludge test area: 200 ft x 200 ft; Blowing litter, no. items*	PA = 40,000 $ft.^2$ Animals and insects, no/PA+: Birds	Rats	Flies	Others!	Odor‡	(No sludge) Regular landfill area: ft x ft; Blowing litter no. items*	Animals and insects, no/PA+: Birds	Rats	Flies	Others!	Odor‡
7/25 0850	0	0	0	50/9	0	None						
7/25 --	--	--	--	--	--	--						
7/26	0	0	0	0		None						
7/27 1100	0	0	0	50/9		None						
1400	0	0	0	0		None						
7/28 0900	0	2	0	20/5		None						
1400												
7/31 1000	0	0	2	100/9		Earthy						

*Estimate the number of items travelling in the wind. Do not include items waving or flapping in the wind which are held down at one end.

+Count the number of birds and animals on the waste fill and estimate the total area in square feet (feet). The sludge test area size shall include all solid waste fill surface which is covered with sludge or was mixed with sludge at the time of observation. PA = populated area where 80 percent or more of the observed population is foraging.

#Estimate the area covered by flies and the number of flies, maggots.

‡ Earthy, pig pen, sweet, etc.; none, medium, strong, etc.

! Indicate rats, cats, dogs or other unusual animal or insect or event.

DS-2: ENVIRONMENTAL OBSERVATIONS - FIELD TEST OF SLUDGE DISPOSAL Observer Jim Reid

Date & time	Sludge test area: ft x ft						(No sludge) Regular landfill area: ft x ft					
	Blowing litter, no. items*	Animals and insects, no/PA+				Odor‡	Blowing litter no. items*	Animals and insects, no/PA+				Odor‡
		Birds	Rats	Flies	Others!			Birds	Rats	Flies	Others!	
12/11 0800	0	0	0	0	0	None						
1400	0	0	0	0	50	Medium						
12/12 1315	0	8	0	0	50	Earthy						
12/13 0950	0	6	0	0	0	None						
12/14 1300	0	12	0	0	0	None						
12/15 1130	0	100 seagulls, 25 pigeons, 20 other	0	0	0	Pig pen						
12/16 0930	0	5	0	0	0	Earthy						

* Estimate the number of items travelling in the wind. Do not include items waving or flapping in the wind which are held down at one end.

\+ Count the number of birds and animals on the waste fill and estimate the total area in square feet (feet). The sludge test area size shall include all solid waste fill surface which is covered with sludge or was mixed with sludge at the time of observation. PA = populated area where 80 percent or more of the observed population is foraging.

\# Estimate the area covered by flies and the number of flies, maggots.

‡ Earthy, pig pen, sweet, etc.; none, medium, strong, etc.

! Indicate rats, cats, dogs or other unusual animal or insect or event.

DS-2: ENVIRONMENTAL OBSERVATIONS - FIELD TEST OF SLUDGE DISPOSAL Observer Jim Reid

Date & time	Sludge test area: ft x ft						(No sludge) Regular landfill area: ft x ft					
	Blowing litter, no. items*	Animals and insects, no/PA+				Odor‡	Blowing litter no. items*	Animals and insects, no/PA+				Odor‡
		Birds	Rats	Flies	Others!			Birds	Rats	Flies	Others!	
12/18	--	--	--	--	--	--						
12/19 0930	0	5	0	0	0	Earthy						
12/20 1400	0	0	0	0	0	Earthy						
12/21 0900	0	12 seagulls	0	0	0	Earthy						
12/22	0	8 pigeons	0	0	0	Pig pen						
12/23	0	0	0	0	0	Earthy						

*Estimate the number of items travelling in the wind. Do not include items waving or flapping in the wind which are held down at one end.

+Count the number of birds and animals on the waste fill and estimate the total area in square feet (feet). The sludge test area size shall include all solid waste fill surface which is covered with sludge or was mixed with sludge at the time of observation. PA = populated area where 80 percent or more of the observed population is foraging.

#Estimate the area covered by flies and the number of flies, maggots.

‡ Earthy, pig pen, sweet, etc.; none, medium, strong, etc.

! Indicate rats, cats, dogs or other unusual animal or insect or event.

DS-2: ENVIRONMENTAL OBSERVATIONS - FIELD TEST OF SLUDGE DISPOSAL   Observer Jim Rowlands

Date & time	Sludge test area: ft x ft						(No sludge) Regular landfill area: ft x ft					
	Blowing litter, no. items*	Animals and insects, no/PA+				Odor‡	Blowing litter no. items*	Animals and insects, no/PA+				Odor‡
		Birds	Rats	Flies	Others!			Birds	Rats	Flies	Others!	
1/4/73 1515	0	0/3200 (200 circling overhead)	0	0	0	Med. earthy						
1/9/73 1045	0	0/2100	0	0	0	Med. earthy						
1/10/73 1400	0	0/2450	0	0	0	Med. earthy						

*Estimate the number of items travelling in the wind. Do not include items waving or flapping in the wind which are held down at one end.

+Count the number of birds and animals on the waste fill and estimate the total area in square feet (feet). The sludge test area size shall include all solid waste fill surface which is covered with sludge or was mixed with sludge at the time of observation. PA = populated area where 80 percent or more of the observed population is foraging.

#Estimate the area covered by flies and the number of flies, maggots.

‡ Earthy, pig pen, sweet, etc.; none, medium, strong, etc.

! Indicate rats, cats, dogs or other unusual animal or insect or event.

DS-2: ENVIRONMENTAL OBSERVATIONS - FIELD TEST OF SLUDGE DISPOSAL Observer Jim Reid

Date & time	Sludge test area: ft x ft						(No sludge) Regular landfill area: ft x ft					
	Blowing litter, no. items*	Animals and insects, no/PA+				Odor‡	Blowing litter no. items*	Animals and insects, no/PA+				Odor‡
		Birds	Rats	Flies	Others!			Birds	Rats	Flies	Others!	
1/8/73 1100	0	200 seagulls	0	0	--	Pig pen						
1/9/73	--	--	--	--	--	--						
1/10/73 1300	0	0	00	0	0	Earthy						
1/11/73 1330	0	0	0	0	0	Earthy						
1/12/73 1100	0	10	0	0	0	Earthy						
1/15/73 1230	0	10	0	0	0	Earthy						
1/16/73 1350	0	60	0	0	0	Sweet						
1/17/73	--	--	--	--	--	--						

*Estimate the number of items travelling in the wind. Do not include items waving or flapping in the wind which are held down at one end.

+Count the number of birds and animals on the waste fill and estimate the total area in square feet (feet). The sludge test area size shall include all solid waste fill surface which is covered with sludge or was mixed with sludge at the time of observation. PA = populated area where 80 percent or more of the observed population is foraging.

#Estimate the area covered by flies and the number of flies, maggots.

‡ Earthy, pig pen, sweet, etc.; none, medium, strong, etc.

! Indicate rats, cats, dogs or other unusual animal or insect or event.

APPENDIX F

OCEANSIDE LANDFILL SITE GEOLOGY
AND GROUNDWATER CONDITIONS

APPENDIX F

Oceanside Demonstration Landfill Site Geology

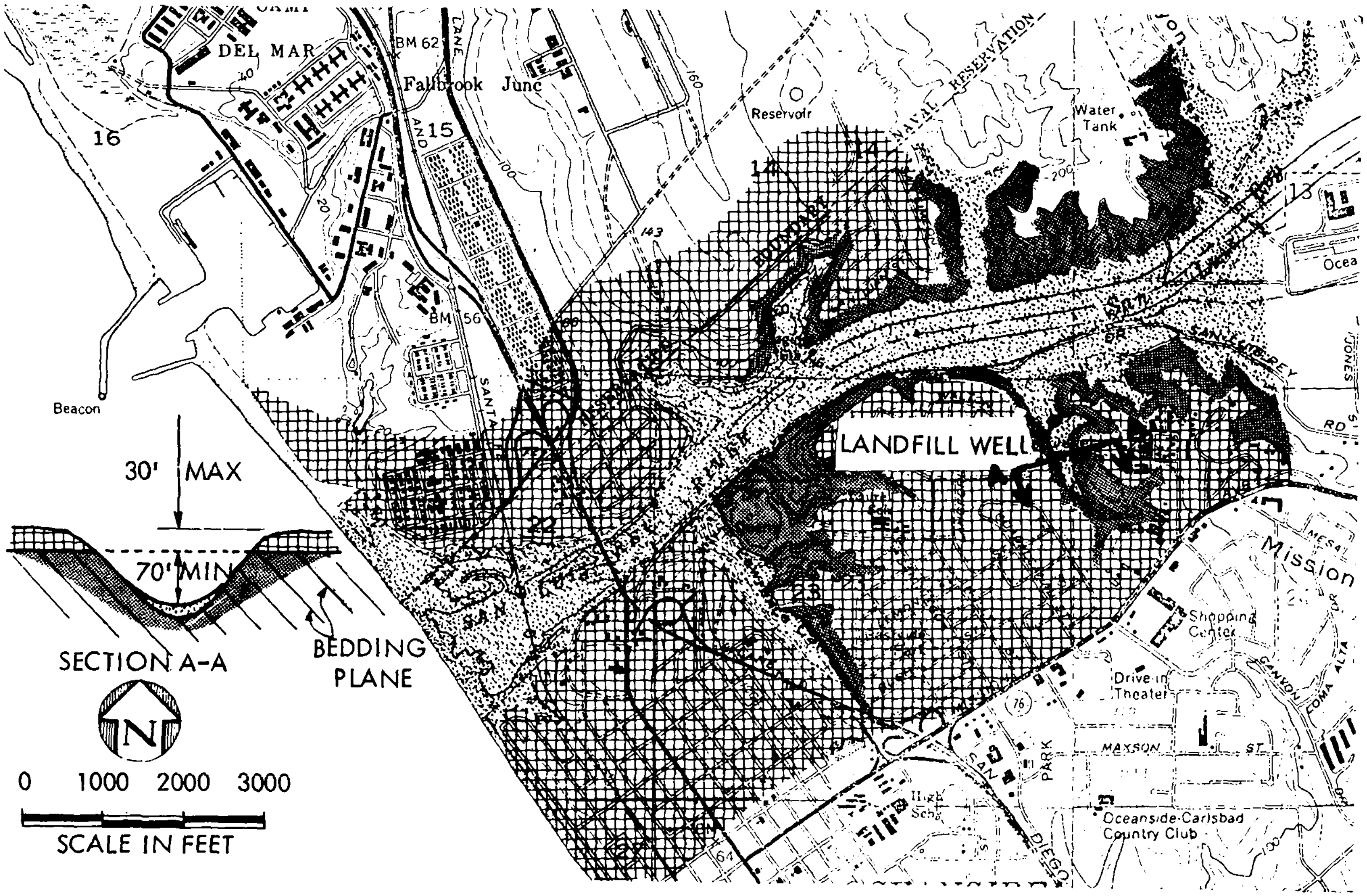
The canyon designated for landfill is underlain by resistant, impermeable bedrock with a layer of fine alluvial deposits of relatively low permeability and undetermined thickness lining the canyon floor. Underground seepage may occur in the bedrock along bedding planes which slope to the southwest (see sketch on Figure F 1), or through the fine alluvium. Marine terrace deposits along the top of the canyon walls are permeable.

Landfill cover soils are coarse to fine sand cut primarily from loose areas of the landfill canyon walls. Additional cover soils are imported. Sieve analyses of cover soil samples from the three test cells and the landfill given in Figures F 2 and F 3 indicate that the soils are coarse to fine sand.

No landslide, mud flow, other mass movements or soil creep were evident at the landfill site. The canyon walls consist of well-consolidated sandstone in the upper-canyon areas, some of which has been difficult to remove for use as landfill cover soil.

Groundwater

No natural groundwater spring or seepage was observed in the landfill canyon. A test well installed approximately two-thirds of the distance from the upper canyon wall to the downstream San Luis Rey River basin (see Figure F 1) indicated a groundwater level of 14 to 17 feet below the surface. Analyses of well water samples are given in Table F 1. The well water quality is not suitable for human or animal consumption due to the presence of coliform. Also, the dissolved solids and sulfate concentrations exceeded drinking water standards in the 1972 sample. The coliform presence may be due to well contamination rather than being from seepage of bacteria into the groundwater aquifer by percolation.



FINE ALLUVIUM — MARINE TERRACE DEPOSITS — SAN ONOFRE BRECCIA

FIGURE F 1
GEOLOGIC MAP
OF LANDFILL SITE

GRAIN SIZE ACCUMULATION CURVE

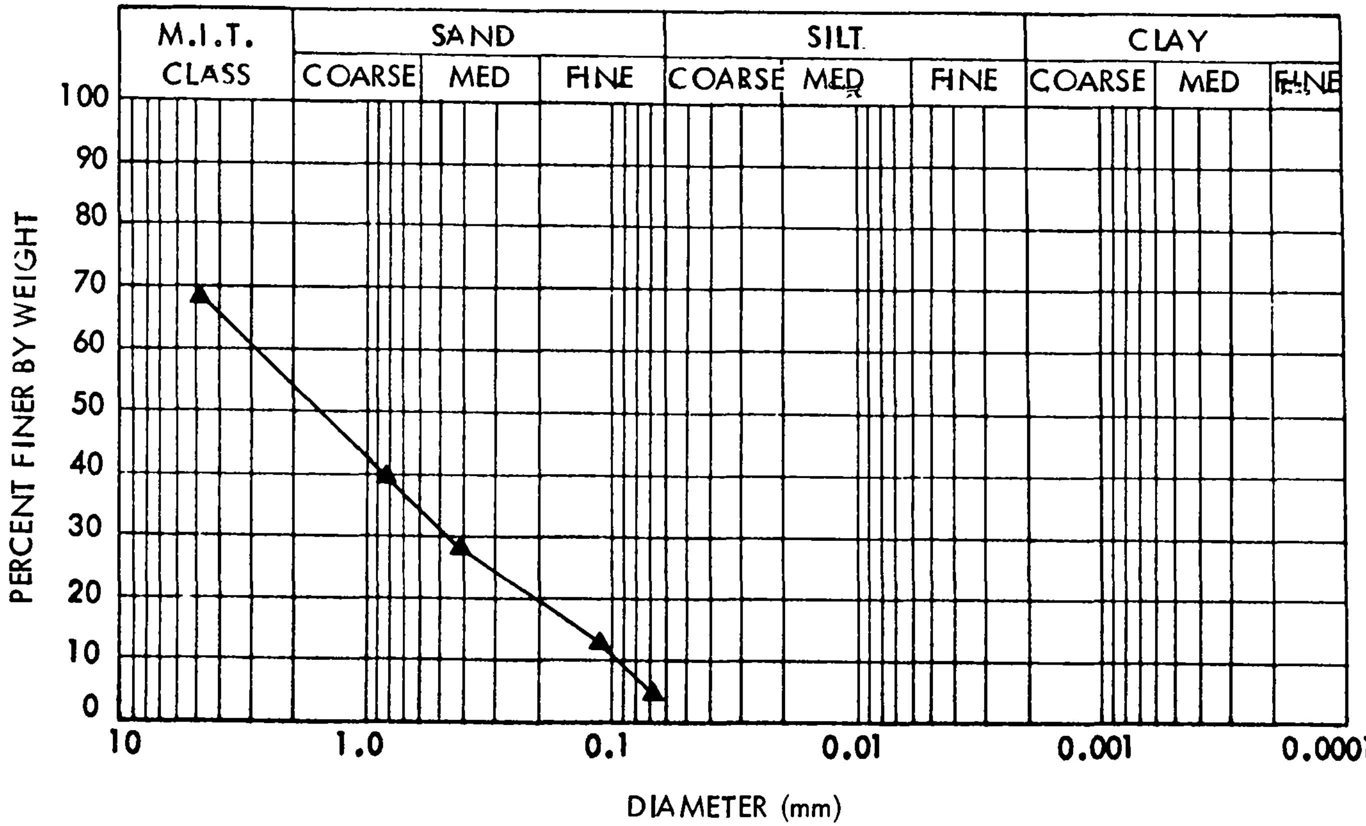


FIGURE F2

FIELD TEST CELL
COVER SOIL COMPOSITE
SAMPLE

GRAIN SIZE ACCUMULATION CURVE

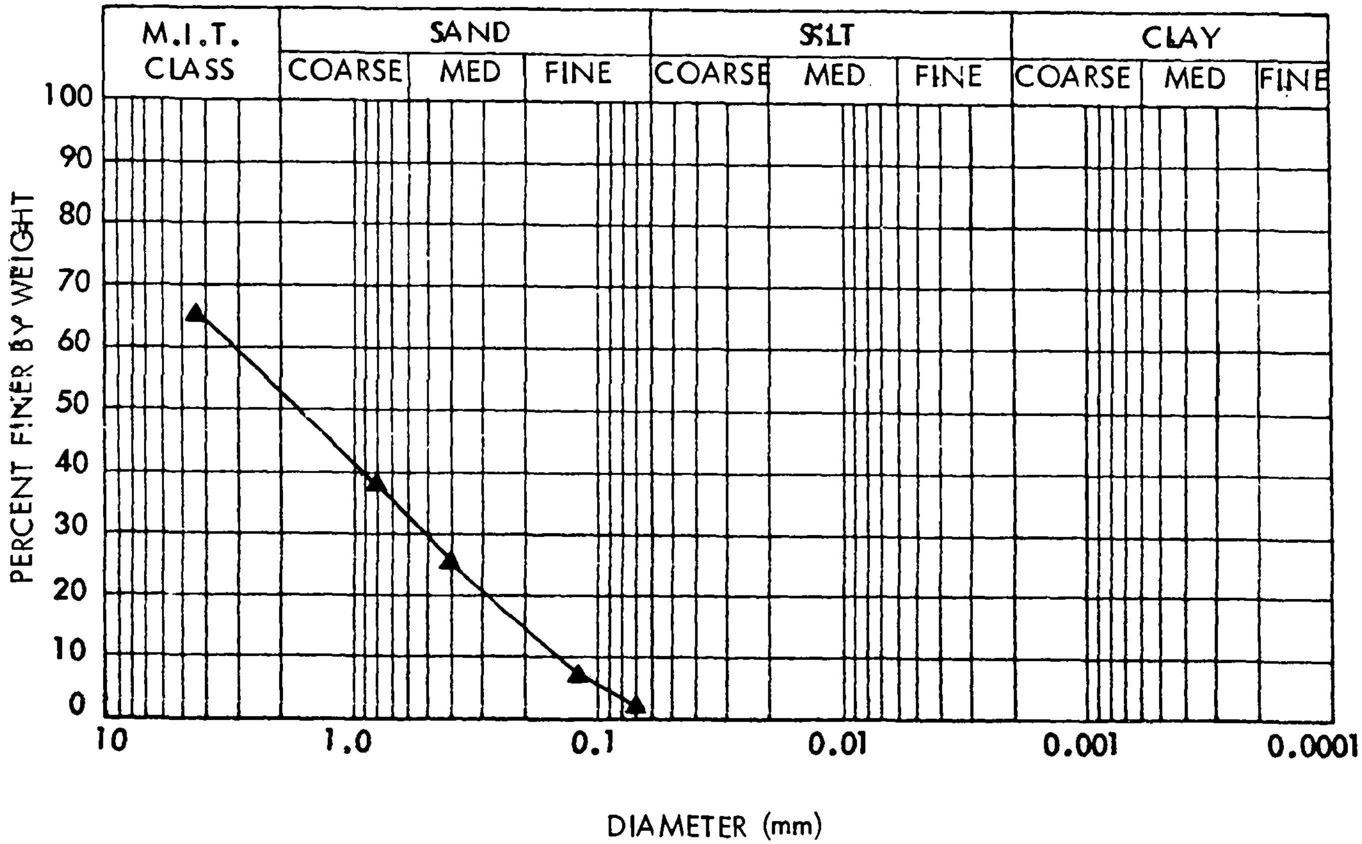


FIGURE F-3

LANDFILL COVER SOIL
COMPOSITE SAMPLE

TABLE F 1

OCEANSIDE LANDFILL WELL WATER ANALYSES

Constituents *	Sample date 3/1/72	Sample date 8/29/73
pH	7.6	7.6
Coliform	43	+
Total solids	740	+
Suspended solids	14	+
Dissolved solids	726	+
Volatile suspended solids	14	+
Calcium	104	160
Sodium	102	112
Ammonia (NH_4)	0.61	0
Carbonate (CO_3)	0	0
Bicarbonate (HCO_3)	37	390
Sulfate (SO_4)	429	67
Chloride	80	+
Fluoride	0.04	+
Total phosphate	1.9	2.0
Nitrite	0.008	0.05
Nitrate	0.01	1.2
Ammonia (N)	0.47	0
Total alkalinity ($CaCO_3$)	412	320
Total hardness ($CaCO_3$)	298	510

*All analyses are in units of mg/l except pH (units) and coliform (MPN/100 ml).

+ Insufficient sample amount to perform analysis.

APPENDIX G

ENGLISH-METRIC EQUIVALENTS

1	ft^3	=	28.32	liter
1	gallon	=	3.785	liter
1	pound	=	0.4536	kilogram
1	ton	=	907.2	kilogram
1	ounce	=	28.35	gram
1	inch	=	2.54	centimeter
1	foot	=	0.3048	meter
1	acre	=	4,047	m^2
1	ft^2	=	929	cm^2
1	gal/min	=	0.06309	liter/sec
1	ft^3/min	=	0.4719	liter/sec
°C		=	5/9 (°F - 32)	

μσ 1061