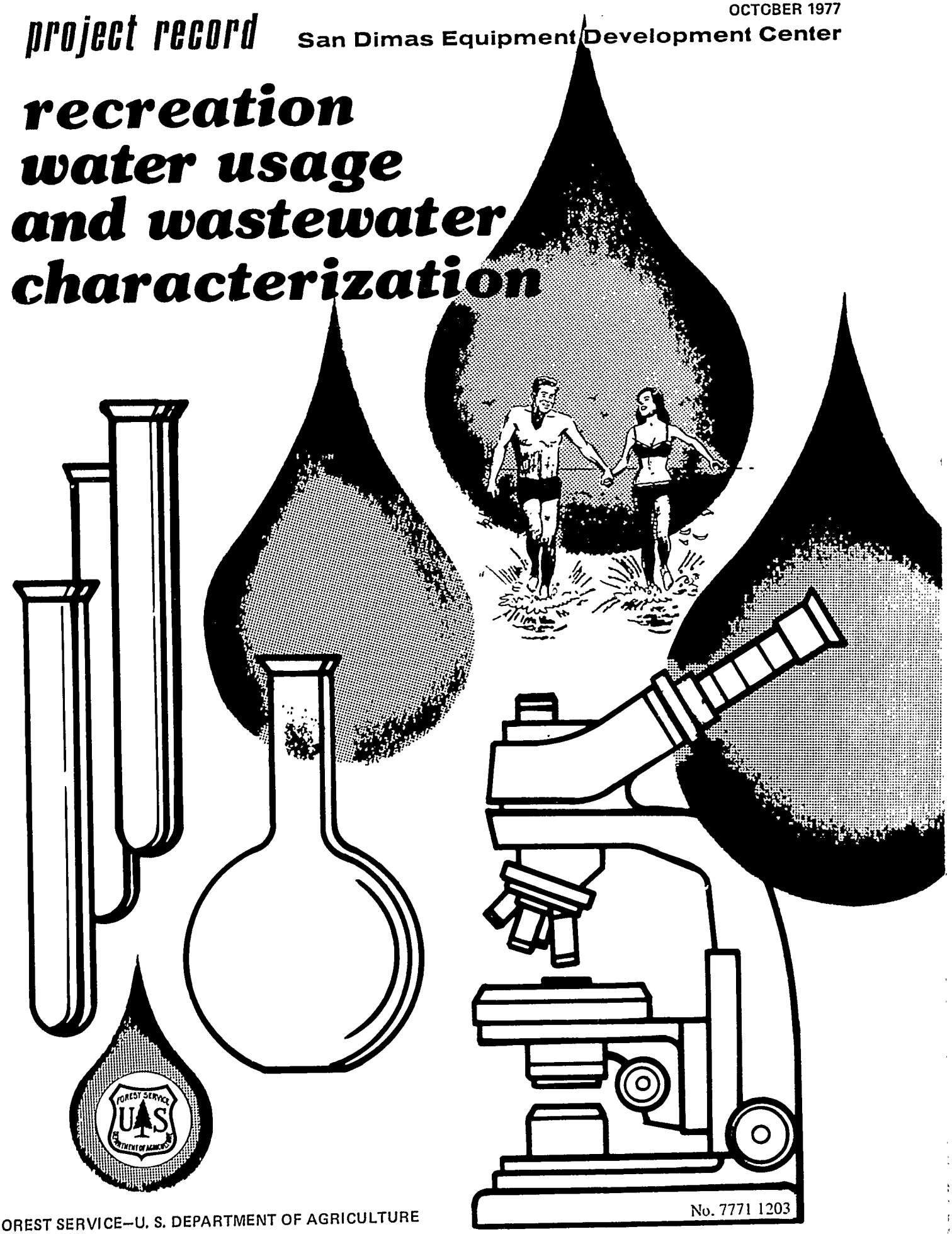
OCTOBER 1977

project record San Dimas Equipment Development Center

recreation water usage and wastewater characterization



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RECREATION WATER USAGE AND WASTEWATER CHARACTERIZATION

by

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ABSTRACT

The Forest Service, in an effort to obtain recreation facility design data for both water and wastewater treatment systems, gathered data from a campground area in Wyoming and a picnic-beach area in California. The data gathered are representative of the study areas and are valid for developing guidelines for design criteria. The study results indicate that the current design values for water usage and wastewater characterization are excessive. The U. S. Army Corps of Engineers performed a similar study in 1975 at a combination campground-picnic area in Mississippi (2).

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INTRODUCTION

The design of water and sewage systems for recreation areas has been difficult because of insufficient data on actual water usage and wastewater characterization. To supplement available data, the San Dimas Equipment Development Center (SDEDC) conducted an extensive field study to determine actual water usage and wastewater characterization at two high-use recreation areas.

The first part of the study was conducted at a 24-hr/day campground with a trailer dump station near the Flaming Gorge Reservoir on the Ashley National Forest, Intermountain Region (August 21 to September 6, 1974). The second part concentrated on a combination 8-hr/day picnic-beach campground site at Pinecrest Lake on the Stanislaus National Forest, California Region (August 18 to September 2, 1975). These sites were selected because their sewage flow could be collected and sampled without undue distortion of chemical and biological analyses of samples due to infiltration flow.

The study sought to determine how much water was used by people entering toilet buildings, and what were the characteristics of the sewage they produced. The water systems at the two sites were metered; electronic counters were installed at the toilet building entrances; and biological and chemical analyses were conducted to determine what differences, if any, in water usage and wastewater characterization exist between 24-hr/day and 8-hr/day recreation areas.

SITE DESCRIPTIONS

Buckboard Campground

The Buckboard Campground on the Ashley National Forest (fig. 1) consists of 2 loops (A and B), each with 34 campsites. Loop A receives more use than loop B because most users find an unoccupied space in loop A and therefore never get to loop B. Each loop has a six-unit water-flush toilet building and two outside faucets, each about 70 ft from the building. The two six-unit buildings each contain the following:

	Regular flush-valve water closet	Wall urinal	Lavatories	Slop sink[1/]	Inside hose bib
Men's side	2	1	2		1
Women's side	3		2		1
Pipe chase				1	

[1/] For recreation vehicle, etc. waste and other miscellaneous uses.

The sewage from the two toilet buildings flows to a manhole immediately ahead of a sewage lift station. The sewage samples were obtained from this manhole.

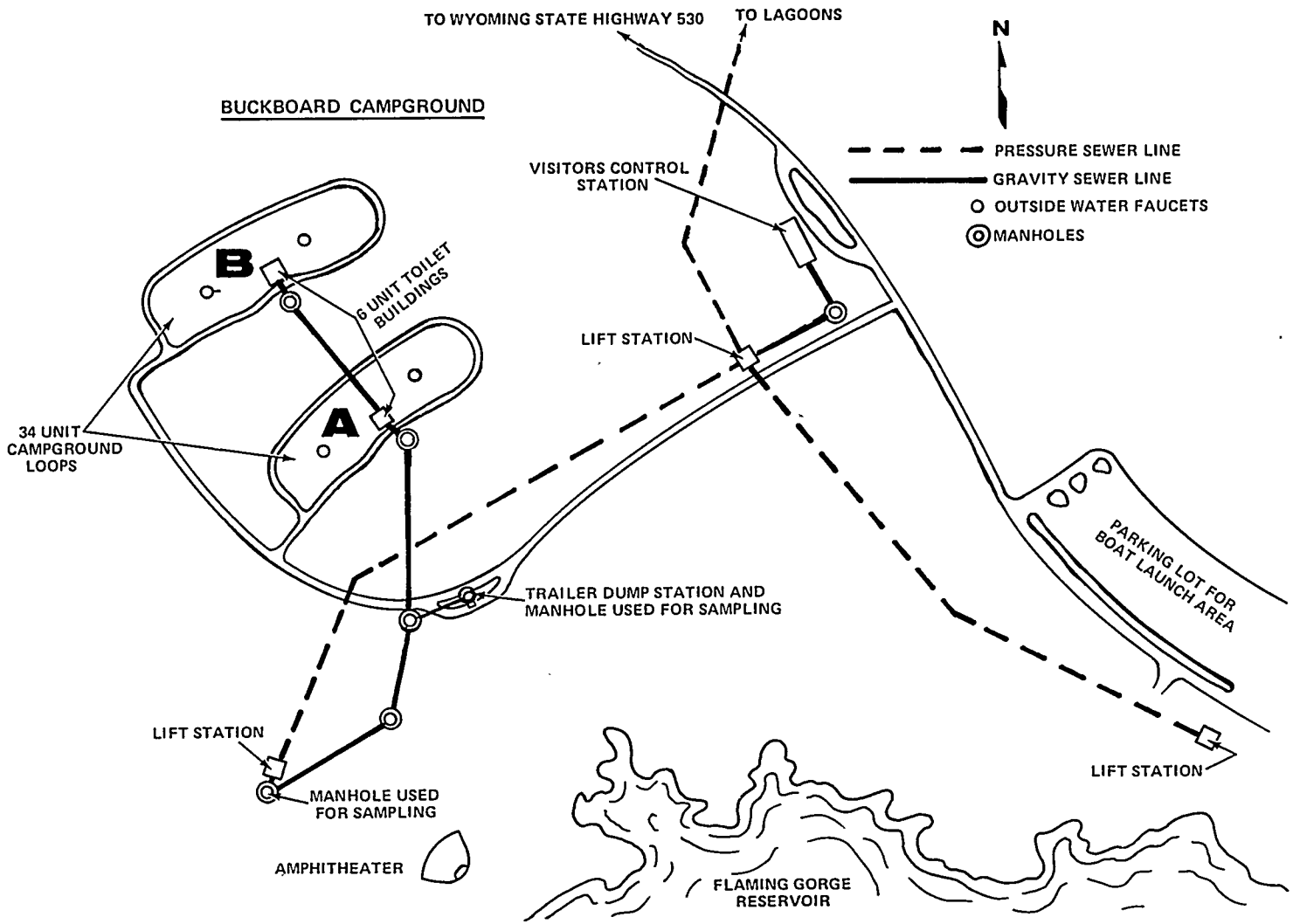

Figure 1. Buckboard Campground.

The trailer dump station is located on the entrance road to the two loops, and is equipped with two water towers—one for cleaning out recreational vehicle sewage holding tanks; the other for potable water. The trailer dump station water supply was not metered during the study. The sewage from the trailer dump station was sampled at the nearest adjacent manhole.

Pinecrest Recreation Area

The Pinecrest Recreation Area on the Stanislaus National Forest (fig. 2) consists of approximately 300 campsites, a boat launch area, and a large picnic and beach area. Within and adjacent to the recreation site are group camping areas and many summer cabins. Figure 3 is an enlarged view of the primary study site, which was divided into three areas with two sampling points.

One four-unit toilet (Beach Expansion Area) served the southern portion of the picnic and beach area; two six-unit toilets (Amphitheater and Lower Dogwood) served the northern portion of the picnic and beach area and one end of a campground loop. One six-unit toilet (Upper Dogwood) served a campground loop adjacent to the immediate study area, and was monitored only for water use and the number of people entering the toilet. The toilet buildings contain the following:

Four-unit toilet

	Handicapped flush-valve water closet	Regular flush-valve water closet	Wall urinal	Lavatory	Clothing change stall	Inside hose bib
Men's side	1		1	1	1	
Women's side	1	1		1	1	
Pipe chase						1

Six-unit toilet

	Regular flush-valve water closet	Wall urinal	Lavatories	Inside hose bib
Men's side	2	1	2	1
Women's side	3		2	1

The sewage from the four-unit toilet flows into a lift station equipped with macerator pumps within 6 ft of the building. The sewage from the two six-unit toilets flows to a common manhole between the two buildings.

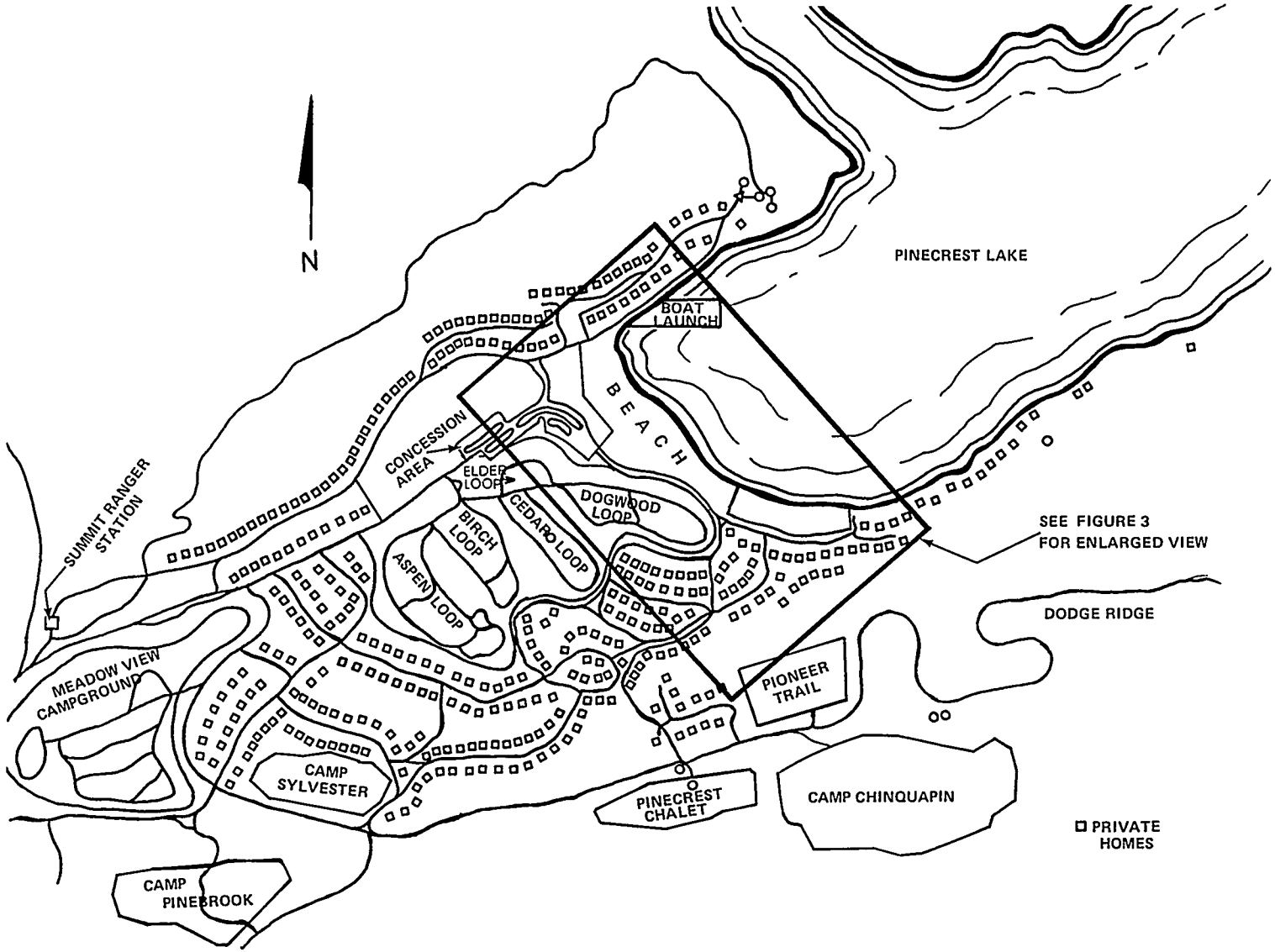

Figure 2. Pinecrest Recreation Area.

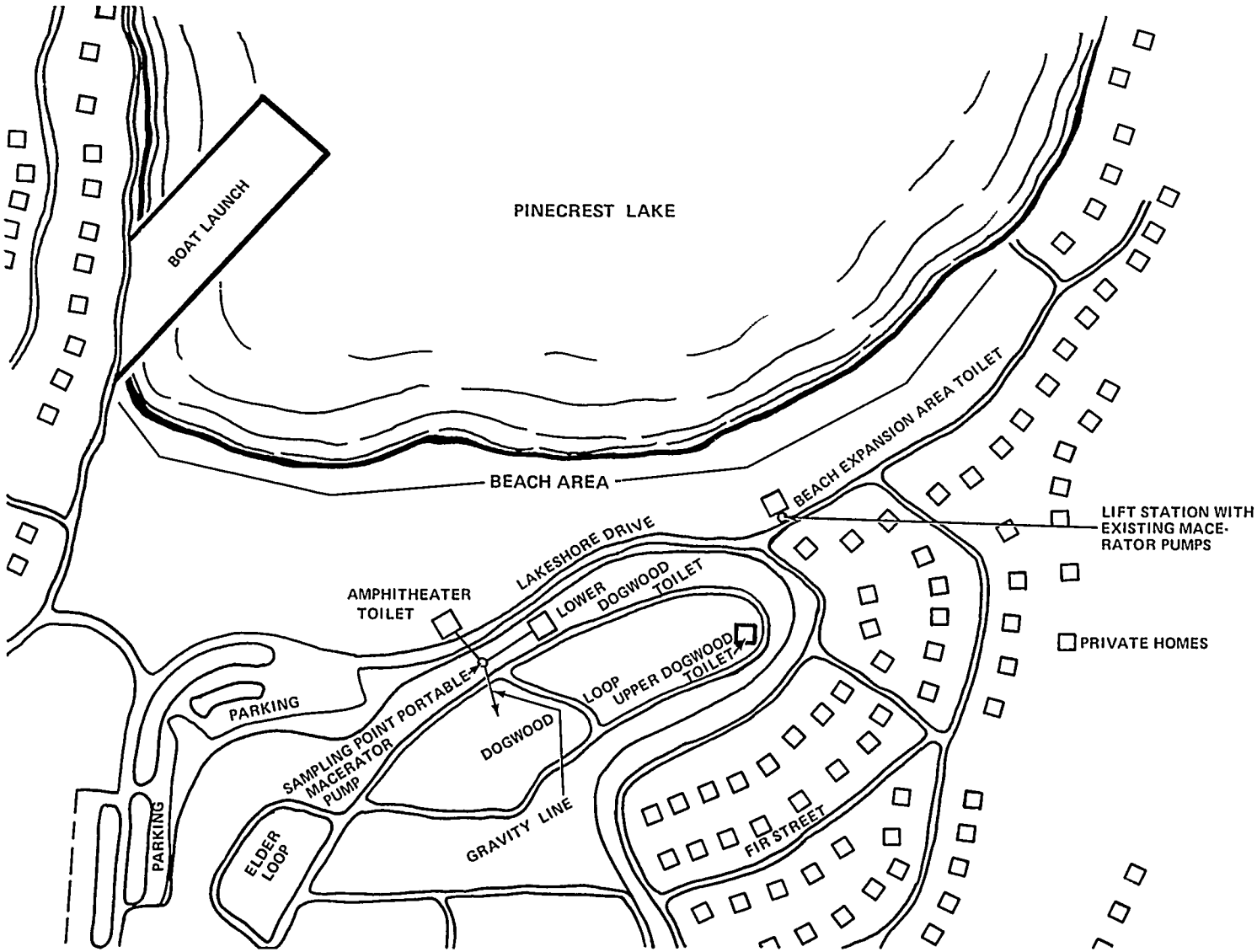

Figure 3. Study site at Pinecrest Recreation Area.

STUDY DESCRIPTION

A 36-ft mobile laboratory was located outside of the immediate study area at both Buckboard and Pinecrest so that the water use and chemical discharge from the laboratory would not affect the sewage being studied. At both sites, the toilet buildings' water usage was accurately metered and electronic counters (see Sept. 1973 MEDC *Equip Tips* "Trail Traffic Counter") were used to record the number of persons entering the buildings. Macerator pumps either existed or were installed at the sampling points to assure well-blended samples.

Sampling Technique

The sampling technique that was used at both sites is detailed in appendix I.

Sample Handling

At both study sites samples were identified by the date and time [1/] the sample was taken. For example, a sample taken on August 21 at 0800 would be sample 21-0800. Immediately after being taken, samples were stored either in a refrigerator set at 4° C or in an ice-packed chest. Nearly all analyses performed in the mobile laboratory occurred within 24 hr after the sample was taken and, with a few exceptions, all samples transported for analyses were analyzed within 36 hr.

Laboratory Control

Two scientists from the Jet Propulsion Laboratory (JPL), Pasadena, Calif., performed most of the biological, and some of the chemical, analyses on samples from both areas in the mobile laboratory. The remainder of the analyses were performed by the Ford Chemical Laboratory (FCL), Salt Lake City, Utah, and the Foothill Laboratory (FL), Jackson, Calif. All analyses were performed in accordance with "Standard Methods for the Examination of Water and Wastewater" (1), except FCL seeded their sewage samples for BOD [2/], which is their standard procedure.

Laboratory Analyses

The three laboratories performed the analyses indicated in the following listings:

JPL (both sites)	FCL (Buckboard)	FL (Pinecrest)
Biochemical oxygen demand (BOD_5)	$BOD_{5, 8, 10, 13, 15, 20}$	$BOD_{5, 10, 15, 20, 24}$
Chemical oxygen demand (COD)	Ammonia nitrogen	Ammonia nitrogen
Total suspended solids	Nitrate nitrogen	Nitrate nitrogen

(Continued)

[1/] All time recorded throughout the study was expressed in 24-hr military time.

[2/] BOD_n = biochemical oxygen demand for "n" days; COD = chemical oxygen demand.

JPL (both sites)	FCL (Buckboard)	FL (Pinecrest)
Total volatile solids	Kjeldahl nitrogen	Kjeldahl nitrogen
Total dissolved solids	Total phosphate	Total phosphate
Settleable solids	Orthophosphate	Orthophosphate
pH	pH	pH
Temperature *(Buckboard only)*	Alkalinity Total organic carbon	Alkalinity
Non-settleable solids *(Pinecrest only)*	Lead	Total suspended solids
Non-filterable solids *(Pinecrest only)*	Zinc	Non-volatile solids
	Mercury	Total volatile solids
	Chrome	Total solids
	Oil and grease	Non-settleable solids
	Formaldehyde	Settleable solids (vol/vol)
		Settleable solids (mass/vol)
		Filterable solids (by test)
		Filterable (by TS-SS)

At both Buckboard and Pinecrest, to determine if there was correlation between the analyses being conducted, JPL performed BOD_5 tests on samples from some batches that had also been analyzed by FCL and FL so that results could be compared.

At Buckboard the heavy metals, formaldehyde, and oil and grease analyses were performed by FCL on the trailer dump waste and also on two campground waste samples known to contain an odor control chemical. No heavy metals test was performed at Pinecrest because recreation vehicle wastes were not dumped into the toilets.

DISCUSSION AND RESULTS

BOD and COD Results

Tables 1, 2, and 3 list the results of the laboratory tests performed on all sewage samples from Buckboard Campground and Pinecrest Recreation Area. The three laboratories reported different results, in some cases, for the BOD_5 tests that were performed on samples taken from the same place at the same time.

Buckboard Campsites

Ten BOD_5 test results pertaining to samples taken at Buckboard (table 1) at the same time showed FCL reporting values that were over twice the values reported by JPL. In an attempt to determine the cause for the discrepancy, JPL performed some additional BOD standard determinations, using 5 ml of a solution containing glucose and glutamate (150 mg/l each) and varying amounts of Buckboard sewage seed. These tests were performed using the same reagents and the same commercial distilled water that was used at Buckboard. Tests were also performed using double-distilled water. Values of only 60 percent of the expected values were found with the commercial distilled water used at Buckboard, while those with double-distilled water approached the expected value. Based upon the results of these additional tests, JPL adjusted the original BOD_5 values.

After averaging the values from the ten samples tested by both laboratories, the corrected JPL BOD_5 mean value was still 85 percent lower than the FCL BOD_5 value. Six out of ten FCL BOD_5 values were also higher than the JPL COD values.[3/] It is not uncommon for the BOD_{20} value to be greater than the COD value in domestic sewage, because the BOD_{20} reflects an ammonia increase during the 20 days of incubation whereas, the 2-hr COD test does not. There does not appear to be an explanation for the FCL BOD_5 values to be higher than the JPL COD values.

Buckboard Trailer Dump Station

The largest BOD and COD discrepancies occurred in the trailer dump samples (table 2). The FCL mean BOD_5 value was approximately 3½ times the JPL mean COD value. After the Buckboard study, JPL thought the error might have occurred because of differences in obtaining the test sample from the main sample. FCL was contacted and their method was compared with the JPL method. JPL used both methods and included a third sampling method in an evaluation (see appendix II). The evaluation of the three tests was within 5 percent, ruling out the sampling technique as the cause for error.

The BOD of vault toilet waste is approximately 20,000 to 25,000 mg/l. Trailer dump waste is diluted when the initial charge of water and chemical is added, when the waste is flushed out of the vehicle holding tank, and when the dump station ramp is washed down with water. As an estimate, the waste is diluted 2:1 to 4:1. This rationale would favor the JPL BOD_5 values and question the FCL BOD_5 values. Comparing the mean values of JPL BOD_5 and COD with results from the Corps of Engineers study (2), also using standard methods analyses (1), the BOD_5 values were within 8 percent and the COD values were within 3 percent:

	BOD (mg/l)	COD (mg/l)
JPL	3,603	6,600
Corps of Engineers	3,320	6,370

3/ FCL seeded all of the BOD samples with local municipal activated sludge seed, so their BOD_5 values would be larger than the unseeded JPL BOD_5 values. This, however, does not explain the 85 percent differential.

Table 1.—Buckboard Campground sewage analysis

	No. of tests	Lowest test result (mg/l)	Highest test result (mg/l)	Mean (mg/l)	Standard deviation
JPL tests					
Biochemical oxygen demand (BOD_5) corrected value	39	98	1043	505	211
Chemical oxygen demand (COD)	49	239	1890	790	375
Total suspended solids (TSS)	46	600	2100	1171	295
Total dissolved solids (TDS)	45	400	1100	757	166
Total volatile solids (TVS)	46	200	1300	644	217
Settleable solids (vol/vol) 1/	46	10	66	29	14
Settleable solids (mass/vol)	43	80	800	282	155
Temperature, °C	28	16	22	19	1.50
pH 2/	54	8.5	9.0	8.73	0.15
FCL tests					
pH	47	6.95	8.85	7.76	0.57
Ammonia nitrogen as N	47	35	360	154	78
Nitrate nitrogen as N	47	1.75	17.8	8.71	4.38
Kjeldahl nitrogen	47	44	371	164	81
Total phosphate as PO_4	47	16	59	31	10
Orthophosphate as PO_4	47	15	58	29	10
Total organic carbon (TOC)	47	84	1642	262	258
Alkalinity	47	48	1044	579	184
Lead (Pb)	4	0.009	0.294	0.12	0.12
Zinc (Zn)	4	0.817	4.78	1.97	1.89
Mercury (Hg)	4	0.001	0.010	0.0043	0.0043
Chrome (Cr)	4	0.002	0.045	0.02	0.02
Oil and grease	5	6	345	80	148
Formaldehyde	4	4	21	13	7
Immediate oxygen demand (BOD_{15})	19	0.35	1.10	0.68	0.22
Biochemical oxygen demand (BOD_5)	18	385	850	603	132
Biochemical oxygen demand (BOD_8)	18	400	880	647	137
Biochemical oxygen demand (BOD_{10})	18	450	910	687	136
Biochemical oxygen demand (BOD_{13})	18	460	980	742	143
Biochemical oxygen demand (BOD_{15})	18	480	1020	798	144
Biochemical oxygen demand (BOD_{20})	18	500	1100	838	151

1/ Here, and in all table entries, this is expressed in ml/l.

2/ A dimensionless property.

NOTE: The tests for lead, zinc, mercury, chrome, oil and grease, and formaldehyde were performed on four toilet waste samples known to contain waste from recreational vehicles.

Table 2.—Buckboard Trailer Dump Station sewage analysis

	No. of tests	Lowest test result (mg/l)	Highest test result (mg/l)	Mean (mg/l)	Standard deviation
JPL tests					
Biochemical oxygen demand (BOD_5) corrected value	4	2,396	6,309	3,603	1,818
Chemical oxygen demand (COD)	7	1,090	20,100	6,600	6,507
Total suspended solids (TSS)	7	4,100	18,500	8,014	4,774
Total volatile solids (TVS)	7	2,700	13,500	5,129	3,806
Total dissolved solids (TDS)	7	2,500	5,700	3,900	1,094
Settleable solids (vol/vol)	7	78	670	227	211
Settleable solids (mass/vol)	7	1,100	10,500	2,857	3,397
pH	7	7.30	8.80	8.24	0.65
FCL tests					
Biochemical oxygen demand (BOD_5)	7	18,700	27,300	22,586	2,825
Ammonia nitrogen as N	7	185	1,050	725	317
Nitrate nitrogen as N	7	13	128	39	41
Kjeldahl nitrogen	7	200	1,200	774	345
Total phosphate as PO_4	7	77	335	198	93
Orthophosphate as PO_4	7	75	327	187	89
Total organic carbon (TOC)	7	659	1,500	1,406	840
Alkalinity	7	1,680	4,840	3,191	1,199
pH	7	7.5	8.8	8.04	0.52
Lead (Pb)	7	0.006	0.150	0.065	0.061
Zinc (Zn)	7	5	154	66	49
Mercury (Hg)	7	0.004	0.080	0.033	0.028
Total chrome (Cr)	7	0.005	0.050	0.026	0.019
Oil and grease	7	18	420	122	138
Formaldehyde	7	1.4	133	37	45

Pinecrest Recreation Area

At Pinecrest neither JPL nor FL seeded the BOD tests and double-distilled water was used at both laboratories (table 3). Only 5 of the 32 tests performed on samples taken at the same time came within 10 percent of each other. The overall results (32 samples by JPL and 51 by FL) came within 28 percent. According to standard methods, "At the present, there is no standard against which the accuracy of the BOD test can be measured. To obtain interlaboratory precision data, a glucose-glutamic acid mixture with a theoretical oxygen demand value of 194 mg/l was analyzed by 73 participants, with each laboratory using its own seed material. The arithmetic mean of all results was 175 mg/l and the standard deviation of that mean was $\pm$ 26 mg/l (15 percent)." (1)

Usage Results

Tables 4 and 5 list the test results in pounds per person per day (lb/person/day) of some of the more commonly used sewage treatment design parameters. These results show that the lb/person/day of nearly all substances were greater in the 24-hr/day campground environment than in the day-use picnic-beach area environment. Campground environments receive a majority of a person's ***total waste*** and certainly the majority of fecal, because most of the people are at the campground in the early morning and back by early evening, while others remain at the campground during the entire 24-hr period. Day-use areas, on the other hand, have a greater daily turnover of people, and many never use the toilet facilities. Generally, more urine is deposited in day-use areas.

Table 6 shows a similarity in gallons of water used per person entering the toilet building at Buckboard and Pinecrest, and a dissimilarity of water used per person per day at each site. The campground study resulted in 2.96 gal of water for each person entering the toilet building and 20.57 gal/person/day in the area. Presently, the Forest Service uses a design guideline of 20 to 30 gal/person/day in a campground without showers. The table shows that at Pinecrest of those persons entering the toilet building an average of 2.60 gal of water was used, and those in the area used 1.67 gal/person/day. Therefore, many did not use the toilets during their stay at the site.

Table 7 shows the combined results of both sites to give some of the more common ratios. Over a wide range of tests, the COD value averaged 2.26 times the BOD_5. The COD test is only a 2-hr test while the BOD_5 is a 5-day test. For domestic sewage a COD test divided by 2.26 will give a quick rough estimate of BOD_5.

One parameter that was difficult to measure was gallons of water used by each person per day. At Buckboard, the data from the electronic counters and water meters were recorded and the total number of campground users were counted, both before and after each sample period. For example, the 1200 sample of any given day was a result of sewage accumulated from 0800 until 1200. The total number of campground users, electronic counters, and water meters data were recorded at 0800 and 1200. During this 4-hr period, some of the users would leave the campground. The numbers recorded then, reflect a differential number of users present within a given time frame, with no practical way of determining departure time. This is explained by sample No. 30-1200—the number of campground users at 0800 was 68 and by 1200 had dropped to 45. During that 4-hr period, 58 users entered the toilet building and used 303 gal of water, or 5.2 gal per person. The difficult part is determining the relationship between the number of users present in the campground and the number of users entering the building. We know that some people used their recreational vehicle toilet facilities.

Table 3.—Pinecrest Recreation Area sewage analysis

	No. of tests	Lowest test result (mg/1)	Highest test result (mg/1)	Mean (mg/1)	Standard deviation
JPL tests					
Biochemical oxygen demand (BOD_5)	32	176	579	330	116
Chemical oxygen demand (COD)	50	340	1420	641	267
Total suspended solids (TSS)	28	443	1090	662	175
Total dissolved solids (TDS)	28	180	687	361	100
Total volatile solids (TVS)	28	140	788	414	179
Settleable solids (vol/vol)	32	18	50	31	8
Settleable solids (mass/vol)	24	40	357	186	83
Nonsettleable solids	16	330	749	479	118
Nonfilterable solids	28	146	680	297	143
pH	46	7.1	9.0	7.87	0.53
FL tests					
Ammonia nitrogen as N	51	15	52	26	11
Nitrate nitrogen as N	51	0.1	0.3	0.18	0.23
Kjeldahl nitrogen as N	51	15	264	93	31
Total phosphate as PO_4	51	8	103	51	18
Orthophosphate as PO_4	51	3	60	30	10
Phenolphthalein alkalinity as $CaCo_3$	22	3	49	23	14
Methyl orange alkalinity as $CaCo_3$	51	68	239	108	41
Total alkalinity as $CaCo_3$	51	67	285	118	52
Nonvolatile solids	23	20	368	148	99
Total volatile solids	23	70	1066	560	246
Total solids	23	330	1394	747	244
Nonsettleable solids	23	15	232	112	63
Settleable solids (vol/vol)	23	32	87	50	16
Settleable solids (mass/vol)	23	73	624	117	126
Filterable solids (by test)	23	155	440	300	73
Filterable solids (by TS-SS)	23	118	842	458	187
Biochemical oxygen demand (BOD_5)	51	60	525	238	100
Biochemical oxygen demand (BOD_{10})	19	249	645	416	125
Biochemical oxygen demand (BOD_{15})	18	253	979	571	225
Biochemical oxygen demand (BOD_{20})	16	307	1037	553	183
Biochemical oxygen demand (BOD_{24})	15	396	1114	625	215

Table 4.—Buckboard Campground sewage analysis (lb/person/day)

	No. of tests	Mean (lb/person/day)	Standard deviation
JPL tests			
BOD corrected	35	0.07	0.03
COD	38	0.11	0.04
FCL tests			
BOD_5	18	0.08	0.03
Ammonia nitrogen	11	0.02	0.01
Nitrate nitrogen	11	0.001	0.0005
Kjeldahl nitrogen	11	0.02	0.01
Orthophosphate	11	0.006	0.004
Total phosphate	11	0.006	0.003

Table 5.—Pinecrest Recreation Area sewage analysis (lb/person/day)

	No. of tests	Mean (lb/person/day)	Standard deviation
JPL tests			
Beach Expansion			
BOD_5	12	0.013	0.010
COD	21	0.027	0.018
Amphitheater & Lower Dogwood			
BOD_5	12	0.006	0.002
COD	21	0.012	0.005
FL tests			
Beach Expansion			
BOD_5	21	0.008	0.005
Ammonia nitrogen	21	0.0010	0.0006
Nitrate nitrogen	21	0.000005	0.000006
Kjeldahl nitrogen	21	0.0028	0.0015
Orthophosphate	21	0.0010	0.0006
Total phosphate	21	0.0018	0.0013
Amphitheater & Lower Dogwood			
BOD_5	21	0.006	0.003
Ammonia nitrogen	21	0.00058	0.0023
Nitrate nitrogen	21	0.000006	0.000009
Kjeldahl nitrogen	21	0.0025	0.0007
Orthophosphate	21	0.0007	0.0003
Total phosphate	21	0.0013	0.0005

Table 6.—Water use at each site.

	Buckboard Campground	Pinecrest Recreation Area
Gallons per person entering toilet building	2.96	2.60
Gal/person/day	20.57	1.67 [1/]

[1/] Upper campground toilet not included.

Table 7.—Ratios of BOD, COD, and TOC combinations

		No. of tests	Mean	Standard deviation
Chemical oxygen demand / Biochemical oxygen demand	$\frac{COD}{BOD_5}$	125	2.26	1.11
Chemical oxygen demand / Total organic carbon	$\frac{COD}{TOC}$	37	4.17	1.55
Biochemical oxygen demand / Total organic carbon	$\frac{BOD}{TOC}$	36	2.55	0.89

By taking frequent meter readings and user counts, the actual gal/person/day is certainly representative of conditions that existed during the study period. The method used to calculate gal/person/day is shown in appendix III.

Laboratory Test Results

The total characteristics of important parameters are graphically presented in appendix IV.

CONCLUSIONS AND RECOMMENDATIONS

Examination of the study test results leads to the following conclusions and recommendations:

1. The values of existing water usage and wastewater characterization design criteria are excessive. Relatively reliable guideline numbers for recreation area design engineers are established by the mean values of the biological and chemical analyses of the present study (see tables 8, 9, and 10). (Some standard deviations were greater than the mean values, due primarily to the frequent sampling periods and the wide variation in hourly sewage quality.)

2. The wastewater characteristics from the around-the-clock campground are considerably higher than from the day-use picnic-beach area. More fecal matter and toilet paper are deposited per person in a 24-hr/day campground.

3. The total water usage at Buckboard Campground (24-hr/day) averaged 20.57 gal/person/day, while at the Pinecrest Recreation Area (8-hr/day) the water usage (toilet buildings only) averaged 1.67 gal/person/day. People entering the toilet buildings at the two sites used 2.96 and 2.60 gal per person respectively. These sites had systems using normal flush-valve toilets and self-closing faucets without flow-control devices. Areas using low-volume, water-flush toilets; waterless toilets; water-flow control devices; or other water-use control methods may use less water per person.

4. If standard methods (1) are followed, seeding of domestic sewage samples for the BOD test should be avoided. Standard methods state (p. 545, sect. h) that, for domestic sewage, "seeding is unnecessary and should not be employed." Trailer dump waste should be considered industrial waste and seeding, here, is recommended.

5. The BOD_5 results from any study should be considered only as rough design guidelines. If critical evaluations are necessary, two independent tests on each sample batch should be identically performed by separate laboratories.

6. Future recreation areas containing amenities such as fish cleaning stations, shower and/or laundry facilities, and trailer dump stations should be designed for easy monitoring. Water usage and wastewater characterization monitoring should be included in the operation and maintenance plan to help gather supplemental data that are lacking.

7. Any further proposed studies, regardless of size, should be reviewed by the Federal Interagency Committee for Recreation Waste Management Research to prevent duplication of effort and avoid incorrect set-up, sampling techniques, and laboratory analyses procedures.

Table 8.—Suggested campground design data

Name of test	No. of tests averages were taken from	Average mg/l
Biochemical oxygen demand (BOD_5)	57	550
Chemical oxygen demand (COD)	49	800
Total residue	46	1,200
Filterable residue	45	750
Total volatile residue	46	650
Settleable matter (vol/vol)	46	30
Settleable matter (mass/vol)	43	280
pH	101	8.25
Ammonia nitrogen as N	47	150
Nitrate nitrogen as N	47	10
Kjeldahl nitrogen	47	160
Total phosphate as PO_4	47	30
Orthophosphate as PO_4	47	30
Total organic carbon (TOC)	47	260
Alkalinity	47	580

Table 9.—Suggested day-use area design data

Name of test	No. of test averages were taken from	Average mg/l
Biochemical oxygen demand (BOD_5)	83	280
Chemical oxygen demand (COD)	50	640
Total residue	51	700
Filterable residue	51	330
Total volatile residue	51	490
Settleable matter (vol/vol)	55	40
Settleable matter (mass/vol)	47	150
Nonsettleable matter	39	300
Nonfilterable residue	28	300
pH		7.9
Ammonia nitrogen as N	51	30
Nitrate nitrogen as N	51	0.18
Kjeldahl nitrogen as N	51	100
Total phosphate as PO_4	51	50
Orthophosphate as PO_4	51	30
Total alkalinity as $CaCO_3$	51	120

Table 10.—Suggested trailer dump waste design data

Name of test	No. of tests averages were taken from	Average mg/l
Biochemical oxygen demand (BOD_5) 1/	4	3,600
Chemical oxygen demand (COD)	7	6,600
Total residue	7	8,000
Filterable residue	7	3,900
Total volatile residue	7	5,100
Settleable matter (vol/vol)	7	230
Settleable matter (mass/vol)	7	2,900
pH	7	8.0
Ammonia nitrogen as N	7	720
Nitrate nitrogen as N	7	40
Kjeldahl nitrogen	7	770
Total phosphate as PO_4	7	200
Orthophosphate as PO_4	7	190
Total organic carbon (TOC)	7	1,400
Alkalinity	7	3,200
Lead	7	0.07
Zinc 2/	7	70
Mercury	7	0.03
Total chrome	7	0.03
Oil and grease	7	120
Formaldehyde	7	40

1/ BOD_5 values will be retested and if this value changes a supplement will be issued.

2/ Zinc is being phased out of the market, but still exists in some areas.

8. The SDEDC Environmental Staff Engineer was reminded again, as the data from this study were under review, that the gal/person/day varies significantly from recreation area to recreation area, depending on the type of campsite, amenities supplied, remoteness of the site, affluence of users, climatic conditions, and facility characteristics such as self-closing faucets, flush-valve or flush-tank toilets, whether faucets and toilet flush valves are properly maintained, the water pressure, and waterline sizes within the buildings.

LITERATURE CITED

1. American Public Health Association, et. al.

   1975. Standard methods for the examination of water and wastewater. 14th ed. Am. Pub. Health Assoc., Washington, D.C.

2. Francingues, Norman R., Jr., and Andrew J. Green, Jr.

   1976. Water usage and wastewater characterization at a Corps of Engineers recreation area. Misc. Pap. Y-76-1. U. S. Army Engr. Waterways Exp. Sta., Vicksburg, Miss.

APPENDIX I

WASTEWATER SAMPLING PROCEDURE

Buckboard Campground

Campground visitors were visually counted, water meters and electronic counters were read, and sewage samples were taken four times daily (0800, 1200, 1800, and 2200). During the first week, the gate valve located on the inlet line to the pump station was closed daily at 0630 to allow the sewage to accumulate in the manhole immediately before the pump station. At this time, the electronic counters, water meters, and campground visitors were recorded. At 0800 a sewage sample was taken, and the gate valve was opened to allow the accumulated sewage to discharge; then, the gate valve was closed to accumulate sewage for the next sampling and the counters, meters, and visitors were recorded. Then, after the 2200 sampling, the gate valve was left open until 0630.

After the first week, the water meter readings indicated very little water was used from 2200 to 0630; thereafter, the gate valve was closed at 2200 to allow the sewage to accumulate until 0800.

During collection of samples, the macerator pump was turned on and operated for 5 to 10 min. While the pump was operating, a stainless steel bucket was thrown into the manhole to collect a sample. When the bucket picked up floating solids, the solids were returned to the manhole to prevent concentrating the sample. One man stirred the contents of the bucket while the other man filled each 1-gal sample bottle half-full. The sample remaining in the bucket would then be returned to the manhole; a few minutes later another bucketful was taken. Again, one man would stir the bucket contents while the other filled the sample bottles. The 1-gal sample bottles were filled each sampling period. One sample was analyzed at the JPL on-site laboratory and the other sample was sent to FCL.

One peculiarity should be mentioned about the manhole adjacent to the lift station. The sewage enters the manhole through a drop inlet (see fig. I-1). The straight-through pipe enters the manhole about 3 ft from the bottom. When the sewage was at level A, the sampling technique changed. The first half of the sample was taken as described before. Then, the gate valve was opened and the sewage discharged, with the macerator pump running continuously, until the sewage reached level B. With the pump still running, the second half of the sample was taken. By following this procedure a representative sample was obtained of all the waste in the manhole and in the sewer line. The remainder of the waste was discharged and the gate valve closed to accumulate the sewage for the next sampling period.

Buckboard Trailer Dump Station

The manhole used for sampling the trailer dump waste was about 40 ft from the trailer dump station. By plugging the downstream pipe in the manhole, the trailer dump waste accumulated in the manhole. When the level of waste reached the intake of the macerator pump, the waste was macerated and sampled. The sample procedure was the same as for the campground sewage.

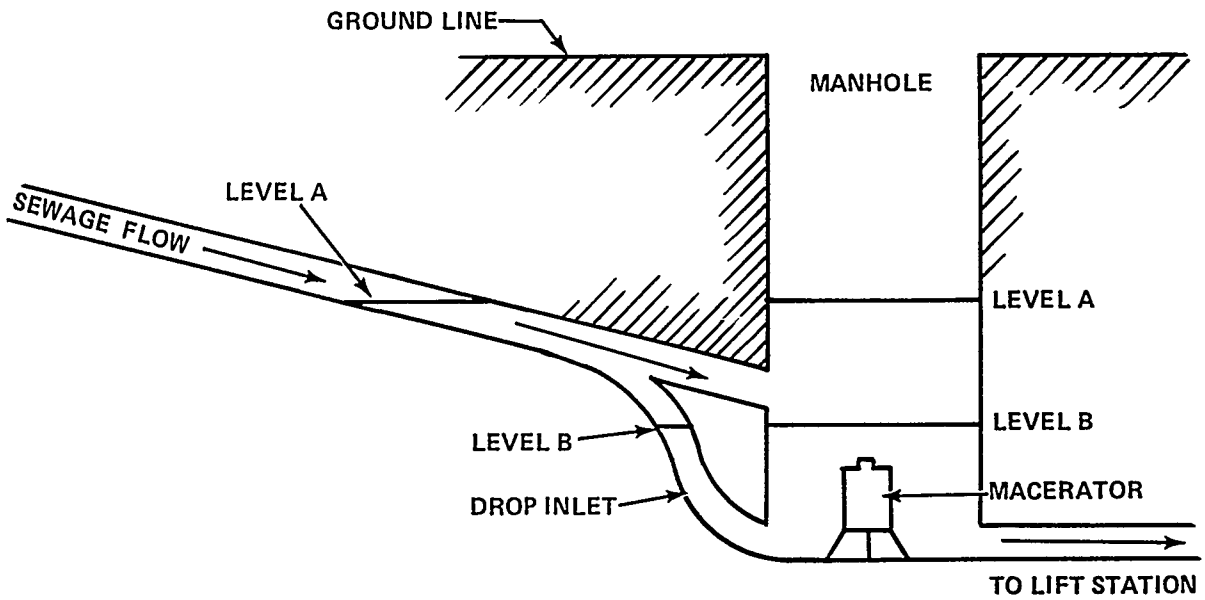

Figure I-1. Manhole adjacent to lift station.

When it was time to take a trailer dump sample, the gate valve at the lift station was left open. After taking the sample, the downstream plug in the trailer dump manhole was removed. Water at the trailer dump station and water turned on at the toilet building in loop A was used to flush the trailer dump water through to the pump station. After approximately 30 min, the gate valve at the lift station was turned off and the meters, counters, and campground users were recorded in preparation for the next campground waste sampling period. This procedure helped assure that no chemicals from the trailer dump waste entered the normal campground waste being sampled.

Pinecrest Recreation Area

Beach area visitors were visually counted, and water meters and electronic counters were read at 1000, 1200, 1400, 1600, and 1800. Sewage samples were taken as often as the manholes filled up.

At one location, two six-unit toilets joined sewer lines at one manhole. One toilet served the beach area and a small portion of campground users. The other toilet served the campground users and some beach area users.

An air plug was inserted in the 6-in manhole discharge line to contain all wastewater from the two toilets. A submersible macerator pump was installed to completely mix the contents of the manhole. As soon as the waste reached a designated level, the macerator pump was turned on and allowed to run until the waste was uniform in appearance. A 12-oz (355 ml) glass taped to a stick was used to extract a sample of the wastewater and the sample was added to two 2,000-ml plastic containers. The sample was then put in an insulated chest

with ice. If the sample containers were filled before the day ended, then the container was thoroughly shaken and approximately 12 oz (355 ml) of the contents were poured back into the manhole while the macerator pump was running. Then a 12-oz (355 ml) sample was taken to refill the 2,000-ml plastic container. After sampling, the air plug was released to discharge the waste and then replaced to accumulate sewage for the next sample.

The second sample location was adjacent to the four-unit toilet. There are two macerator pumps located in the lift station as part of the original design. A gate valve was installed on the discharge line and by opening the drain line and closing the gate valve on the discharge line, the macerator pumps would pump the waste from the bottom of the lift station through the discharge line, back through the drain line in the top of the lift station. A complete mix was quickly accomplished.

The sampling procedure was the same as above. After the samples were taken, the gate valve on the main line was opened and the drain lines closed to allow the wastewater to be pumped to an upper manhole. The same process was used throughout.

The sampling period, 1000 to 1800, was divided into two 4-hr segments, 1000 to 1400 and 1400 to 1800. Two sample containers were filled at each of the two sampling locations during each 4-hr segment. JPL and FL each received one of the sample containers from each location during each sampling segment.

APPENDIX II

CONTROLS ON BUCKBOARD SAMPLING PROCEDURES

Objective

To determine if the sampling procedures used in the Buckboard study gave analyses representative of the actual composition.

Procedures

A sample of oil-flush toilet wastes was obtained. The excess oil was removed from the top and a portion of the concentrated waste was withdrawn (approximately 2 liters). This portion was blended for 30 sec at high speed in the same blender used in the Buckboard study. Residual oil which formed a floating emulsion was removed and the remaining blended sewage was diluted to approximate the consistency of a trailer dump sample encountered in the Buckboard study. Total residues of the blended sewage sample were determined by three sampling methods. The first two were used in the Buckboard study and the third in an alternate method which was chosen as the best possible attempt at representative sampling. These methods are as follows:

Method No. 1

The blender was started and stopped as quickly as possible in order to mix the sample, and about 100 to 200 ml were poured into a glass sampling bottle. The contents of this bottle were swirled vigorously and a portion of the swirling sample was poured into a crucible. The remainder of the sample was returned to the blender. This procedure was repeated to obtain quadruplicate samples.

Method No. 2

The contents of the blending container were stirred with a glass rod while pouring into the glass sampling bottle instead of momentary blender activation. The rest of the procedure was identical to that described in method No. 1.

Method No. 3

After the above residues were prepared, the entire contents of the blending cup (approximately 1.5 liters) were transferred to a 3.0-liter beaker. This was stirred with a 2 x 3/8-in magnetic bar until a vortex indentation of about ½ in was observed in the liquid surface. This level of stirring visually appeared sufficient to completely suspend all settleable material. Total residues of this stirring sample were prepared by removing liquid halfway between the top and bottom of the liquid at a point midway between the vortex center and the wall of the beaker to ensure representative sampling. Material was removed with a 10-ml pipette and the entire contents were delivered into a crucible to avoid any possibility of settling. Withdrawal was repeated until the crucible was filled with sample.

Results and Discussion

Comparison of sampling methods:

Method	TSS average (mg/l) 1/
1	6,640
2	6,360
3	6,660

1/ Each value is an average of four determinations.

The close agreement among the above results eliminates the possibility of large sampling errors in the JPL analyses from the Buckboard study. The procedures were scrutinized and no problems were found (except BOD, as discussed) which would question those data. A level of confidence was established to indicate that the analyses were representative of the actual sample composition.

APPENDIX III

GAL/PERSON/DAY CONSUMPTION

Buckboard Campground

Campground users were counted four times daily at the beginning and the end of each sampling period. An empirical assumption was used in plotting these data.

Example: Assume 200 users were present at 2200 and 100 users were present at 0800. It would be incorrect to draw a straight line from 200 to 100 over the 10-hr period because it was known that the users stayed the night and began to depart around 0600. Therefore, a parallel line was drawn from 200 to 0600 and then a straight line from 200 to 100 over a 2-hr period. This type of assumption was used for the whole day. By using the trapezoid rule, the average number of campground users per day was calculated. The sum of these average daily campground users was divided into the total number of gallons used during the study period. Table III-1 illustrates these averages and the resulting average gal/person/day.

Table III-1.—Gal/person/day at Buckboard

1974 date		Average daily campground users	Total daily gallons used	Gal/person/day
Sun	Aug 25	49.16	1183.1	24.07
Mon	Aug 26	67.60	1420.0	21.01
Tues	Aug 27	61.88	1386.3	22.40
Wed	Aug 28	31.81	599.4	18.84
Thurs	Aug 29	54.84	1506.0	27.48
Fri	Aug 30	62.54	1925.5	30.79
Sat	Aug 31	154.63	3271.6	21.15
Sun	Sept 1	174.23	3327.1	19.09
Mon	Sept 2	137.0	2199.6	16.06
Tues	Sept 3	40.13	629.6	15.69
Wed	Sept 4	43.5	776.5	17.85
Thurs	Sept 5	46.86	783.6	16.72
	TOTAL	924.14	19,008.3	

Average gallons per person per day = total gallons of water ÷ total average daily campground users
= 19,008.3 ÷ 924.14 = 20.57 gal/person/day

Pinecrest Recreation Area

Recreation area users were counted every 2 hr, starting at 1000 and ending at 1800. An average was taken of the people counted between each 2-hr period. The sum of the averages were divided into the total number of gallons of water used during the entire study period.

Example: Total gallons used ÷ sum of average people present
32,275 ÷ 21,142 = 1.67 average gal/person/day.

Also, the gallons per person entering the toilet buildings were calculated (Upper Dogwood toilet included).

Total gallons used = 41,452
No. of people entering toilets = 15,932
41,452 ÷ 15,932 = 2.60 gal per person entering toilet buildings.

The gallons of water used and the number of people entering the toilets from 1800 until 1000 are now shown in these calculations. The total 24-hr water usage at each building is shown in table III-2.

Tables III-3 through III-5 give a breakdown of the hourly water use at Pinecrest Recreation Area during the daily 8-hr sampling period.

Table III-2.—Pinecrest daily water use

1975 date	Beach Expansion toilet (gal)	Amphitheater toilet (gal)	Lower Dogwood toilet (gal)	Upper Dogwood toilet (gal)
Tues Aug 19	675	1732	Meters not installed yet	1047
Wed Aug 20	817	2121	1241	1588
Thurs Aug 21	658	1910	1314	1245
Fri Aug 22	978	2150	1614	1555
Sat Aug 23	1111	2881	2321	1605
Sun Aug 24	991	3153	1658	1200
Mon Aug 25	640	1870	1969	1140
Tues Aug 26	765	2299	1422	990
Wed Aug 27	776	2495	1258	1070
Thurs Aug 28	680	2186	1115	1120
Fri Aug 29	753	1815	1382	1160
Sat Aug 30	1122	3837	1758	1270
Sun Aug 31	1850	4027	2155	1290
Mon Sept 1 (1000 to 1400)	243	864	171	Not taken
TOTAL	12,059	33,802	19,378	16,280

GRAND TOTAL = 81,519 gal

Table III-3.—Hourly water use—Amphitheater and Lower Dogwood toilets combined

Date / Time	Gallons used	Avg. No. of people in area	People entering toilets	Gal per person in area	Gal per person entering toilets
Fri 8/22/75					
1000-1200	421	236	161	1.78	2.61
1200-1400	880	615	336	1.43	2.62
1400-1600	682	653	270	1.04	2.53
1600-1800	555	350	208	1.59	2.67
Sat 8/23/75					
1000-1200	681	284	227	2.40	3.00
1200-1400	993	625	345	1.59	2.88
1400-1600	990	718	407	1.38	2.43
1600-1800	586	387	286	1.51	2.05
Sun 8/24/75					
1000-1200	783	178	347	4.40	2.26
1200-1400	1130	531	428	2.13	2.64
1400-1600	962	656	371	1.47	2.59
1600-1800	516	314	195	1.64	2.65
Mon 8/25/75					
1000-1200	305	143	102	2.13	2.99
1200-1400	499	358	167	1.39	2.99
1400-1600	622	507	289	1.23	2.15
1600-1800	341	320	158	1.07	2.16
Tues 8/26/75					
1000-1200	369	234	158	1.58	2.34
1200-1400	724	527	252	1.37	2.87
1400-1600	894	640	370	1.40	2.42
1600-1800	349	332	169	1.05	2.07
Wed 8/27/75					
1000-1200	470	229	180	2.05	2.61
1200-1400	630	454	235	1.39	2.68
1400-1600	914	535	404	1.71	2.26
1600-1800	350	307	153	1.14	2.29
Thurs 8/28/75					
1000-1200	386	187	151	2.06	2.56
1200-1400	604	384	165	1.57	3.66
1400-1600	590	407	174	1.45	3.39
1600-1800	332	234	93	1.42	3.57
Fri 8/29/75					
1000-1200	214	148	102	1.45	2.10
1200-1400	622	373	214	1.67	2.91
1400-1600	546	453	191	1.21	2.86
1600-1800	398	238	172	1.67	2.31

(Continued next page)

Table III-3.—Continued

Date / Time	Gallons used	Avg. No. of people in area	People entering toilets	Gal per person in area	Gal per person entering toilets
Sat 8/30/75					
1000-1200	612	200	208	3.06	2.94
1200-1400	695	543	265	1.28	2.62
1400-1600	1142	695	379	1.64	3.01
1600-1800	928	374	315	2.48	2.95
Sun 8/31/75					
1000-1200	856	199	321	4.30	2.67
1200-1400	1277	583	482	2.19	2.65
1400-1600	1704	732	661	2.33	2.58
1600-1800	661	412	288	1.60	2.30
Mon 9/1/75					
1000-1200	484	169	174	2.86	2.78
1200-1400	795	370	335	2.15	2.37
TOTAL	28,492	16,834	10,908		

$$\frac{\text{Gallons used}}{\text{people entering toilets}} = \frac{28,492}{10,908} = 2.61 \text{ gallons per person entering toilets}$$

$$\frac{\text{Gallons used}}{\text{Average people in area}} = \frac{28,492}{16,834} = 1.69 \text{ gallons per person in area}$$

Table III-4.–Hourly water use–Beach Expansion Area toilet

Date / Time	Gallons used	Avg. No. of people in area	People entering toilets	Gal per person in area	Gal per person entering toilets
Fri 8/22/75					
1000-1200	119	65	35	1.83	3.40
1200-1400	186	140	63	1.33	2.95
1400-1600	236	180	110	1.31	2.15
1600-1800	84	105	42	0.80	2.00
Sat 8/23/75					
1000-1200	97	67	47	1.45	2.06
1200-1400	284	152	136	1.87	2.09
1400-1600	230	185	110	1.24	2.09
1600-1800	162	112	76	1.45	2.13
Sun 8/24/75					
1000-1200	108	37	52	2.92	2.08
1200-1400	248	125	106	1.98	2.34
1400-1600	280	170	113	1.65	2.48
1600-1800	170	93	64	1.83	2.66
Mon 8/25/75					
1000-1200	80	27	51	2.96	1.57
1200-1400	114	95	53	1.20	2.15
1400-1600	119	122	50	0.98	2.38
1600-1800	64	67	43	0.96	1.49
Tues 8/26/75					
1000-1200	67	27	35	2.48	1.91
1200-1400	110	112	49	0.98	2.24
1400-1600	183	147	83	1.24	2.20
1600-1800	115	95	60	1.21	1.92
Wed 8/27/75					
1000-1200	61	48	36	1.27	1.69
1200-1400	125	95	50	1.32	2.50
1400-1600	290	137	144	2.12	2.01
1600-1800	70	80	29	0.88	2.41
Thurs 8/28/75					
1000-1200	75	17	33	4.41	2.27
1200-1400	85	57	27	1.49	3.15
1400-1600	158	65	74	2.43	2.14
1600-1800	22	32	18	0.69	1.22
Fri 8/29/75					
1000-1200	65	25	24	2.60	2.71
1200-1400	111	65	54	1.71	2.06
1400-1600	154	102	59	1.51	2.61
1600-1800	70	65	30	1.08	2.33

(Continued next page)

Table III-4.—Continued

Date / Time	Gallons used	Avg. No. of people in area	People entering toilets	Gal per person in area	Gal per person entering toilets
Sat 8/30/75					
1000-1200	95	61	51	1.56	1.86
1200-1400	197	149	94	1.32	2.10
1400-1600	185	220	117	0.84	1.58
1600-1800	275	142	64	1.94	4.30
Sun 8/31/75					
1000-1200	147	62	78	2.37	1.88
1200-1400	450	177	159	1.54	2.83
1400-1600	497	270	208	1.84	2.39
1600-1800	352	172	82	2.05	4.29
Mon 9/1/75					
1000-1200	93	42	37	2.21	2.51
1200-1400	150	95	50	1.58	3.00
TOTAL	6,783	4,308	2,942		

$$\frac{\text{Gallons used}}{\text{people entering toilets}} = \frac{6{,}783}{2{,}942} = 2.31$$

$$\frac{\text{Gallons used}}{\text{Average people in area}} = \frac{6{,}783}{4{,}308} = 1.57$$

Table III-5.—Hourly water use—Upper Dogwood toilet

Date / Time	Gallons used	Avg. No. of people in area	People entering toilets	Gal per person in area	Gal per person entering toilets
Mon 8/18/75					
No time	371	—	150	—	2.47
Tues 8/19/75					
1000-1400	165	—	67	—	2.46
1400-1600	75	—	29	—	2.59
1600-1800	131	—	57	—	2.30
Wed 8/20/75					
1000-1200	204	—	93	—	2.19
1200-1400	225	—	72	—	3.13
Thurs 8/21/75					
1200-1400	132	—	52	—	2.54
1400-1600	78	—	19	—	4.11
1600-1800	65	—	32	—	2.03
Fri 8/22/75					
1000-1200	195	—	56	—	3.48
1200-1400	142	—	54	—	2.63
1400-1600	143	—	38	—	3.76
1600-1800	87	—	37	—	2.35
Sat 8/23/75					
1000-1200	155	—	49	—	3.16
1200-1400	272	—	72	—	3.78
1400-1600	78	—	26	—	3.00
1600-1800	78	—	34	—	2.29
Sun 8/24/75					
1000-1200	170	—	51	—	3.33
1200-1400	110	—	31	—	3.55
1400-1600	155	—	37	—	4.19
1600-1800	97	—	21	—	4.62
Mon 8/25/75					
1000-1200	110	—	42	—	2.62
1200-1400	100	—	34	—	2.94
1400-1600	120	—	42	—	2.86
1600-1800	65	—	34	—	1.91
Tues 8/26/75					
1000-1200	60	—	21	—	2.86
1200-1400	110	—	28	—	3.93
1400-1600	100	—	20	—	5.00
1600-1800	90	—	18	—	3.21
Wed 8/27/75					
1000-1200	100	—	27	—	3.70
1200-1400	113	—	31	—	3.65
1400-1600	135	—	55	—	2.45
1600-1800	82	—	25	—	3.28

(Continued next page)

Table III-5.—Continued

Date / Time	Gallons used	Avg. No. of people in area	People entering toilets	Gal per person in area	Gal per person entering toilets
Thurs 8/28/75	125	—	49	—	2.55
1000-1200	125	—	49	—	2.55
1200-1400	65	—	82	—	0.79
1400-1600	146	—	30	—	4.87
1600-1800	70	—	23	—	3.04
Fri 8/29/75					
1000-1200	160	—	61	—	2.62
1200-1400	150	—	26	—	5.77
1400-1600	190	—	43	—	4.41
1600-1800	30	—	10	—	3.00
Sat 8/30/75					
1000-1200	170	—	55	—	3.09
1200-1400	100	—	45	—	2.22
1400-1600	105	—	24	—	4.38
1600-1800	63	—	14	—	4.50
Sun 8/31/75					
1000-1200	113	—	48	—	2.35
1200-1400	187	—	52	—	3.60
1400-1600	100	—	21	—	4.76
1600-1800	90	—	35	—	2.57
TOTAL	6,177		2,082		

$$\frac{\text{Gallons used}}{\text{people entering toilets}} = \frac{6,177}{2,082} = 2.97$$

APPENDIX IV

LABORATORY TEST RESULTS

Figures IV-1 through IV-17 present the graphical printouts of the laboratory test results from both recreation sites where the study was performed.

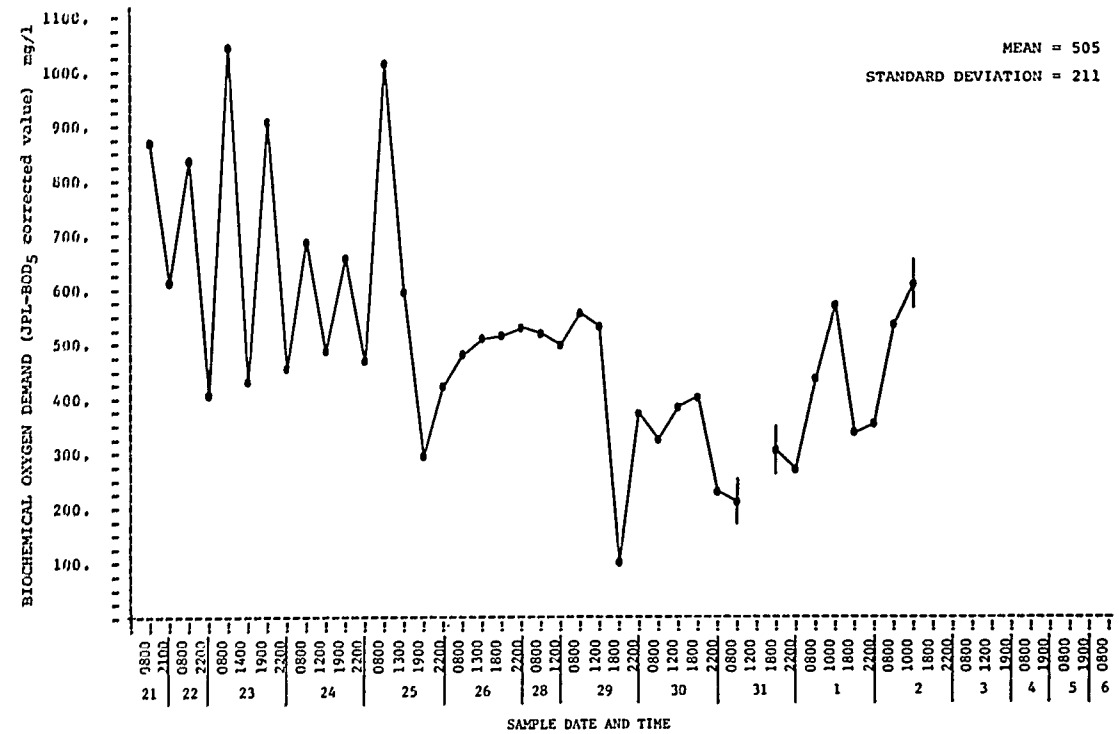

Figure IV-1. JPL–Buckboard biochemical oxygen demand (5-day corrected value).

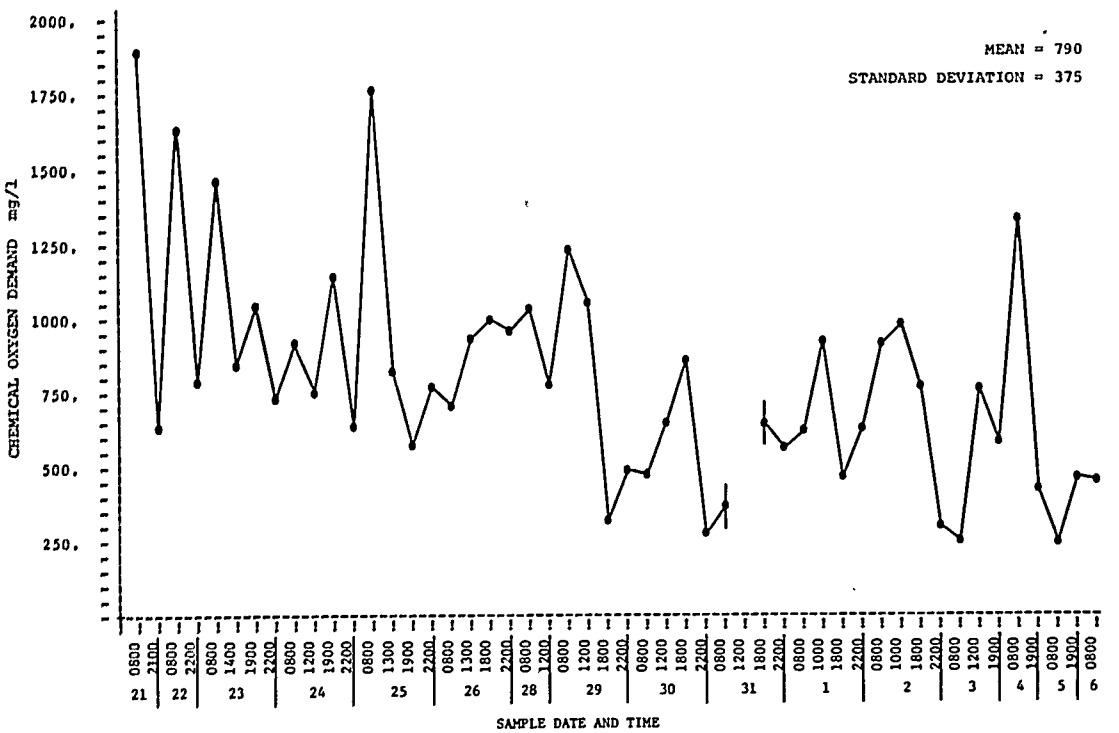

Figure IV-2. JPL–Buckboard chemical oxygen demand.

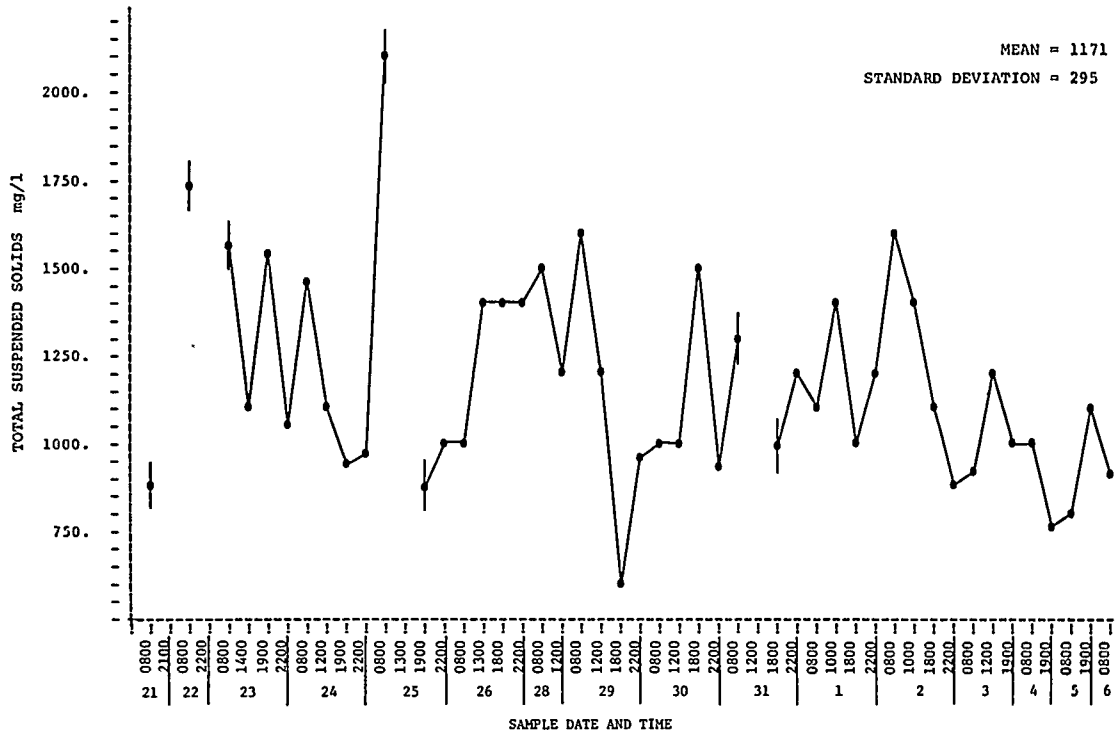

Figure IV-3. JPL–Buckboard total suspended solids.

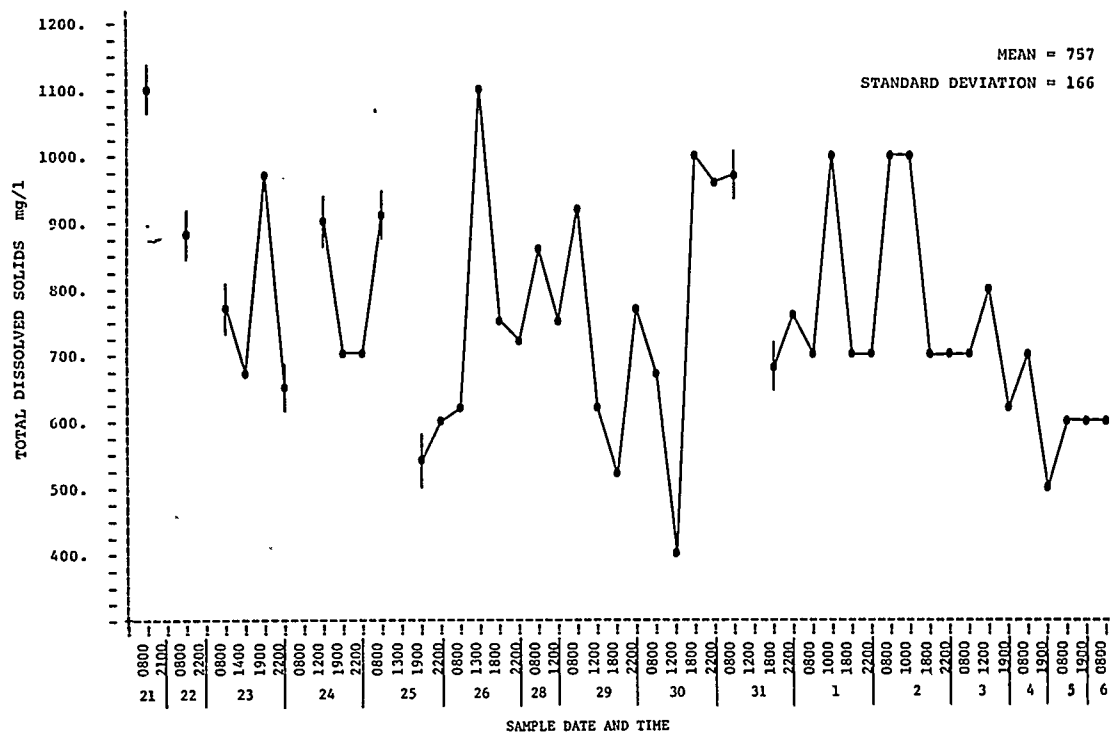

Figure IV-4. JPL–Buckboard total dissolved solids.

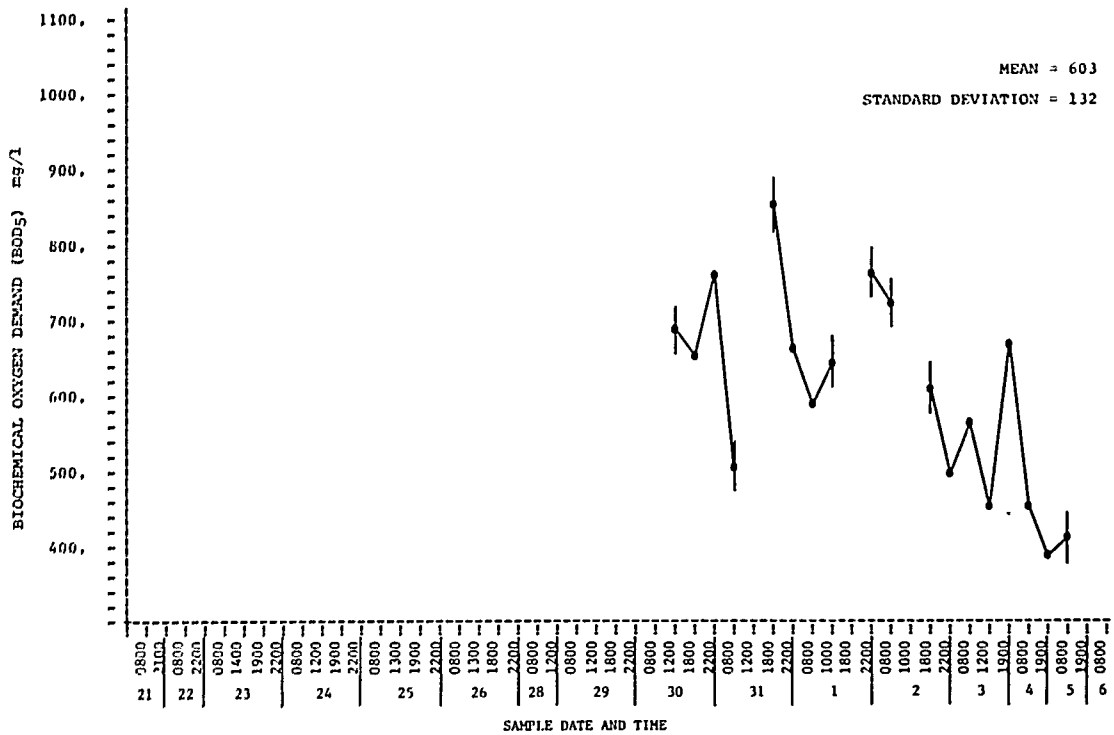

Figure IV-5. FCL–Buckboard biochemical oxygen demand (5-day).

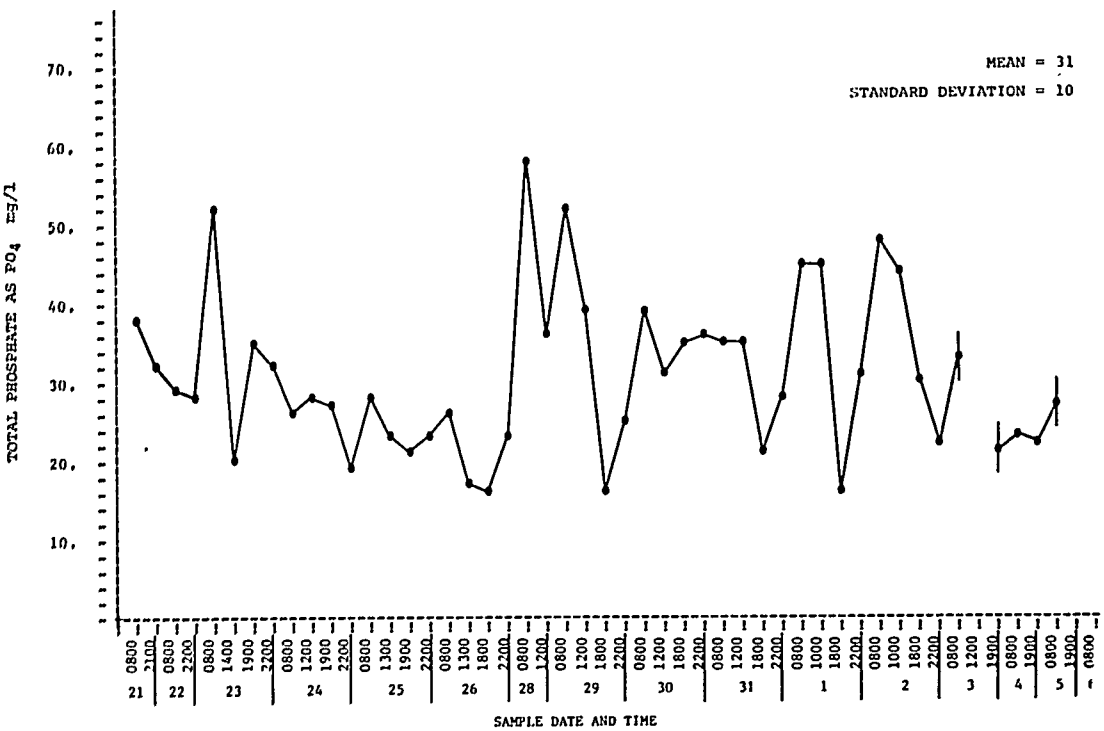

Figure IV-6. FCL–Buckboard total phosphate.

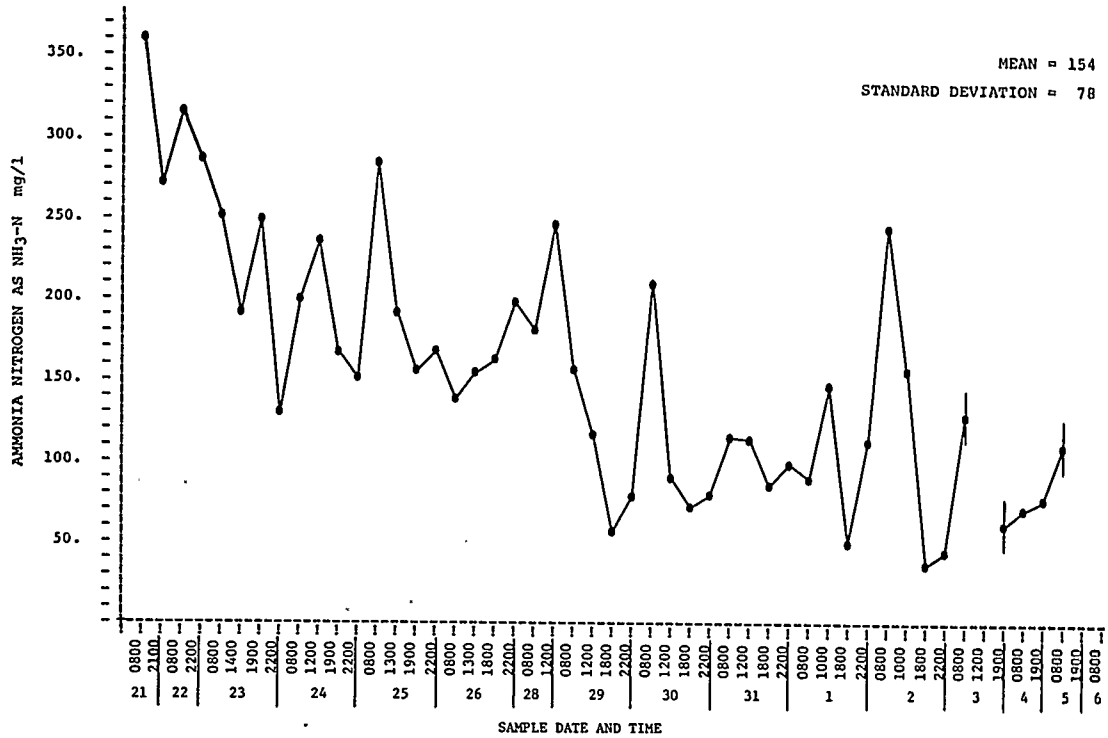

Figure IV-7. FCL–Buckboard ammonia nitrogen.

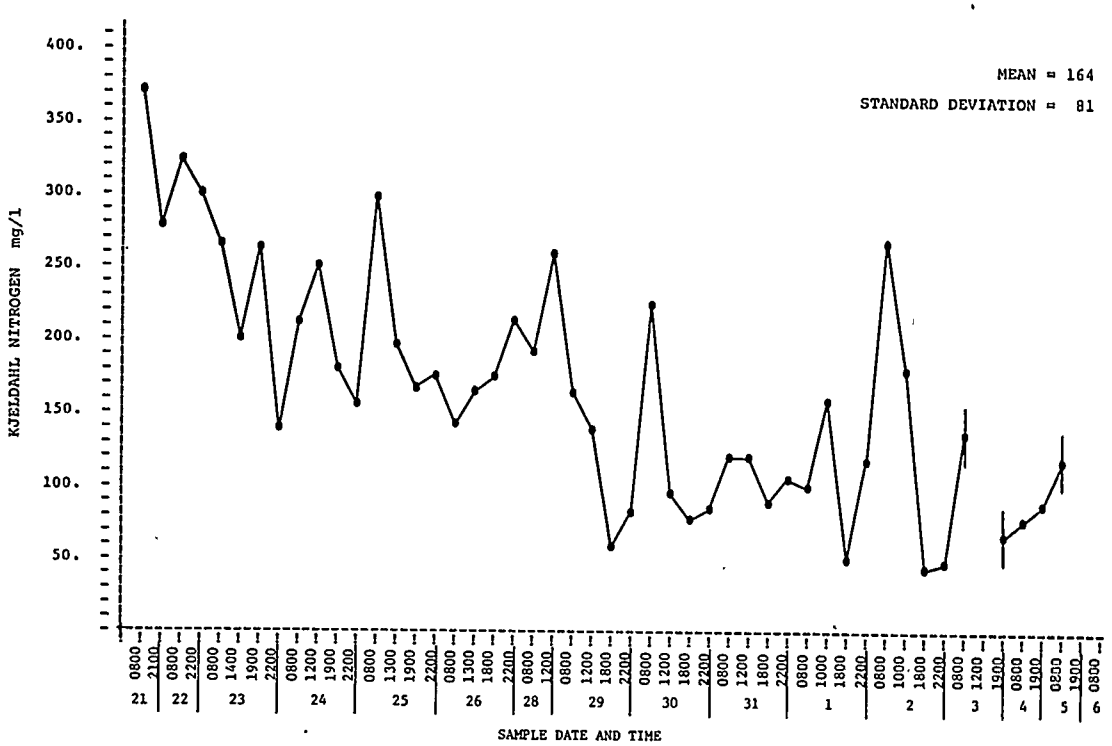

Figure IV-8. FCL–Buckboard Kjeldahl nitrogen.

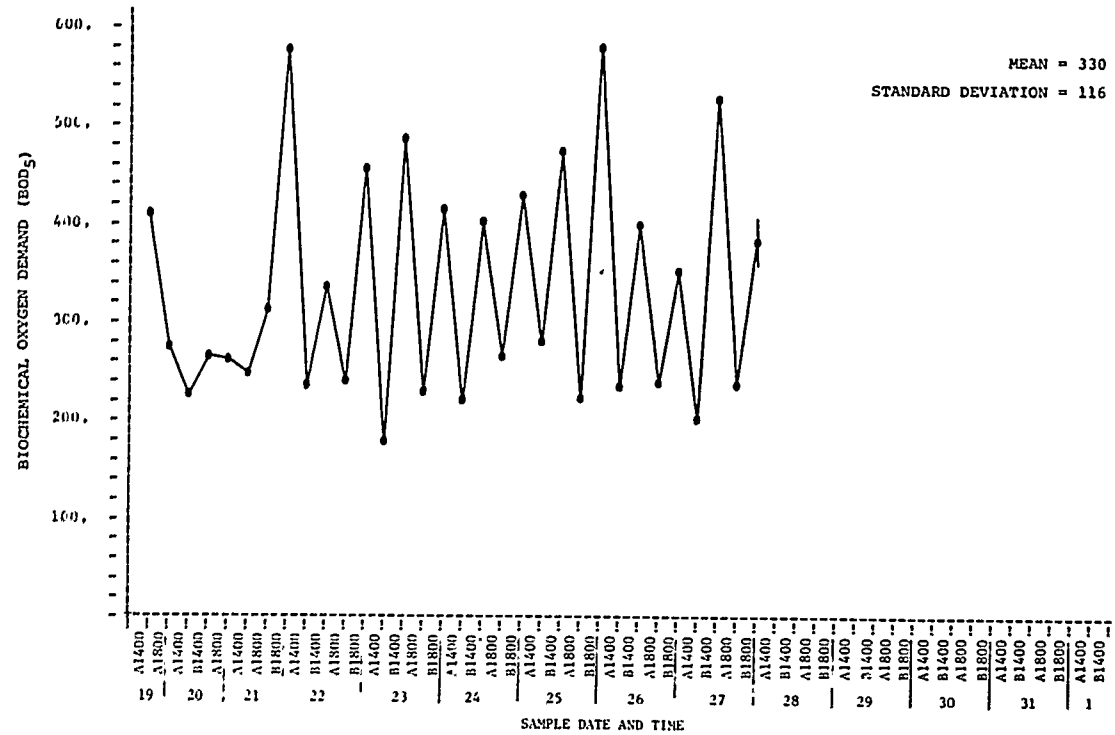

Figure IV-9. JPL–Pinecrest biochemical oxygen demand (5-day).

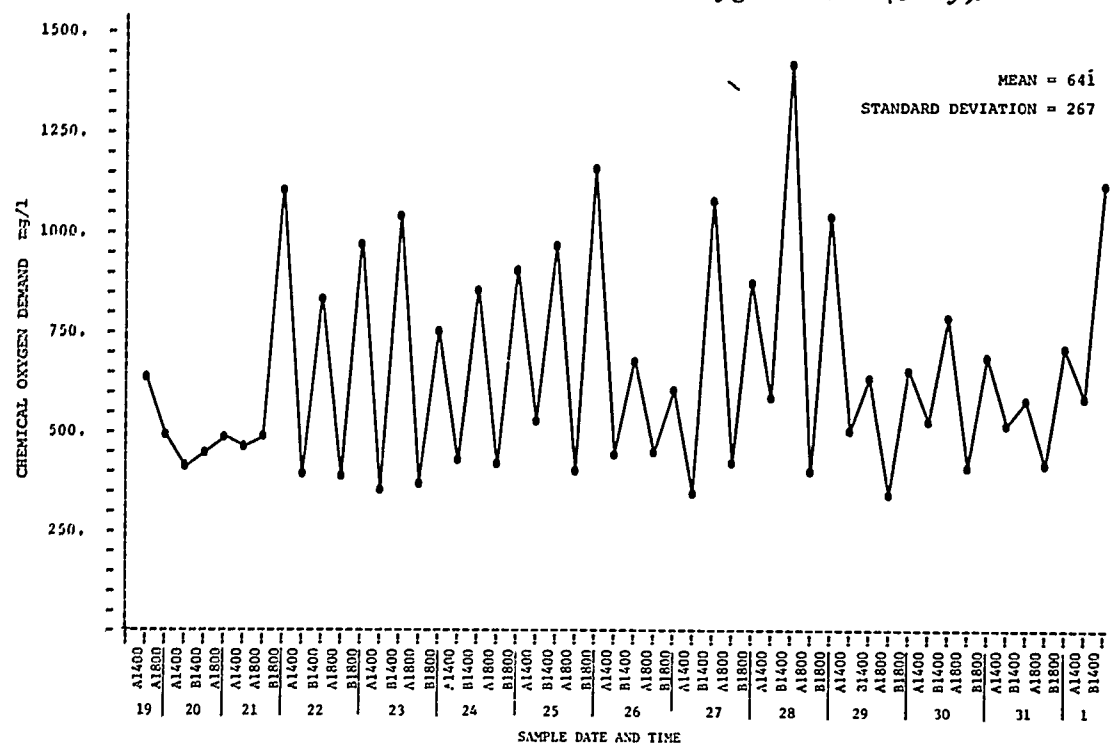

Figure IV-10. JPL–Pinecrest chemical oxygen demand.

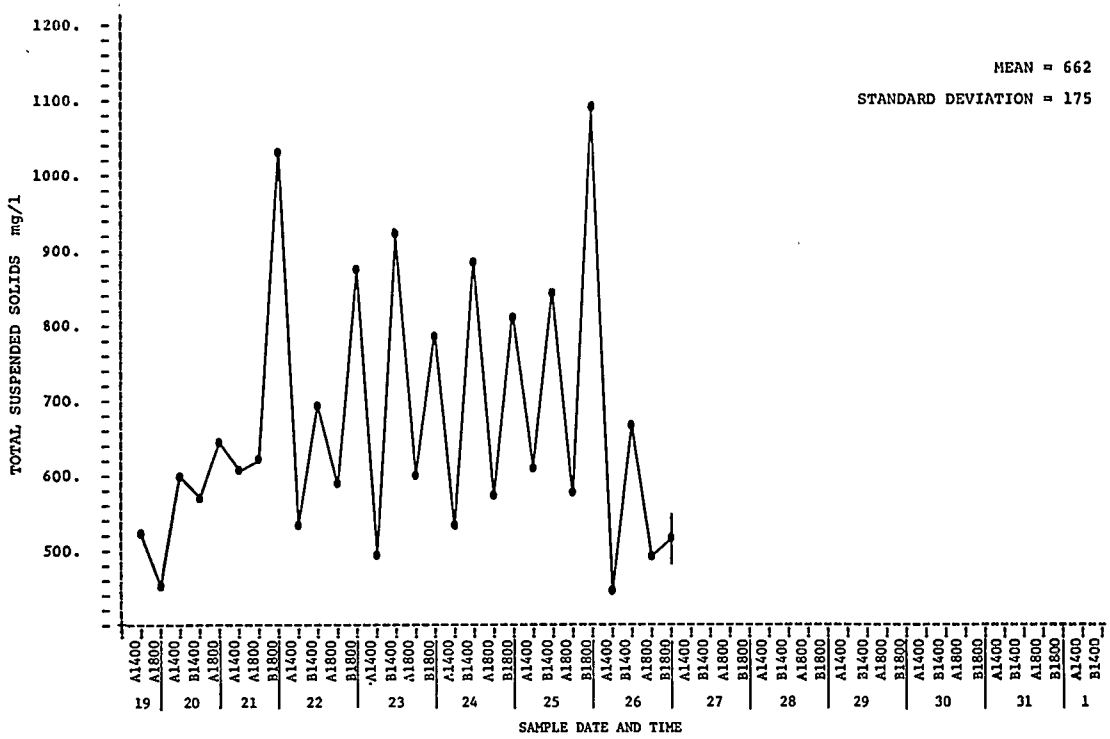

Figure IV-11. JPL—Pinecrest total suspended solids.

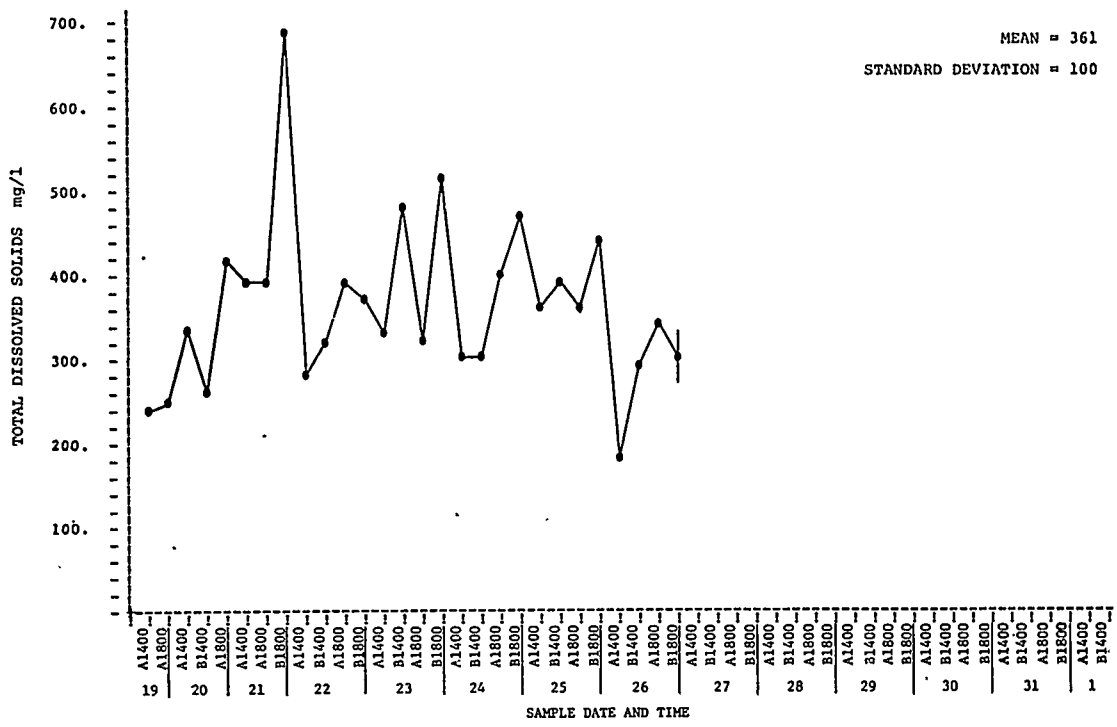

Figure IV-12. JPL—Pinecrest total dissolved solids.

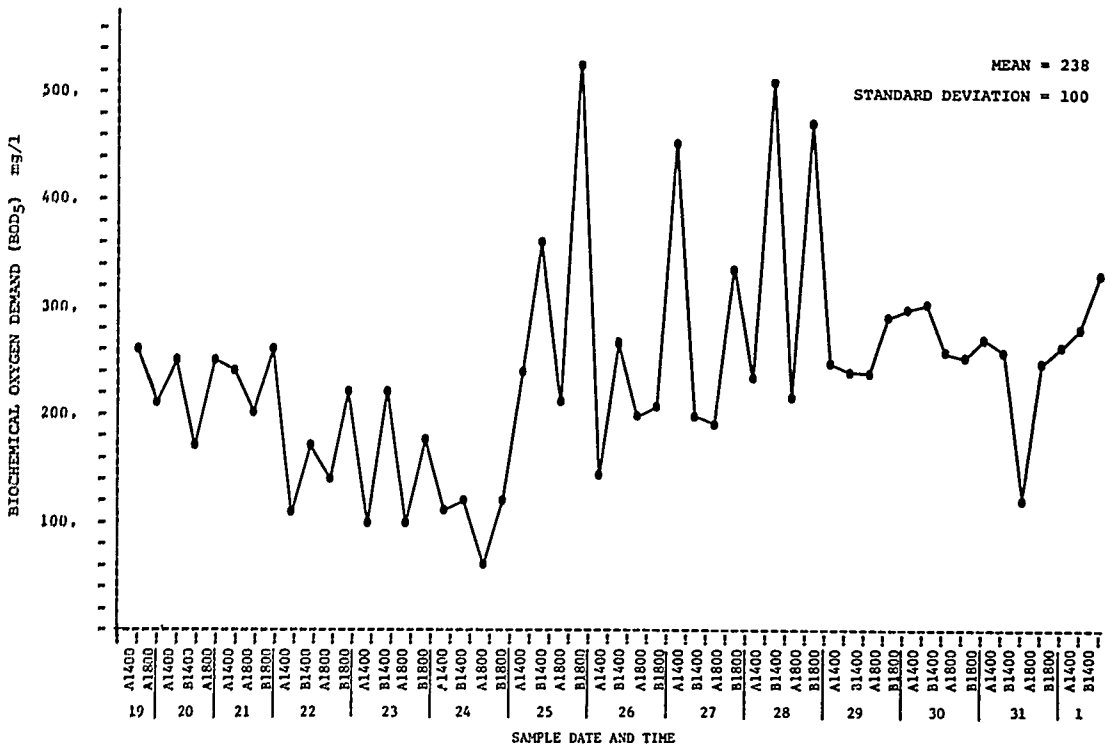

Figure IV-13. FL–Pinecrest biochemical oxygen demand (5-day).

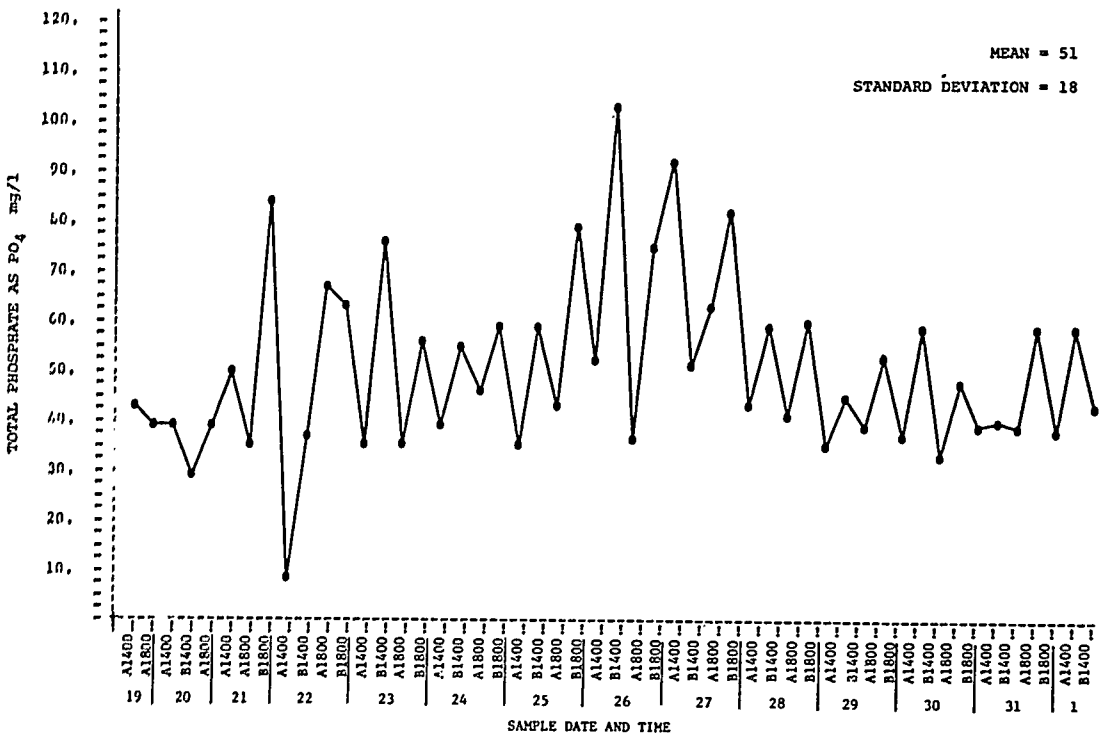

Figure IV-14. FL–Pinecrest total phosphate.

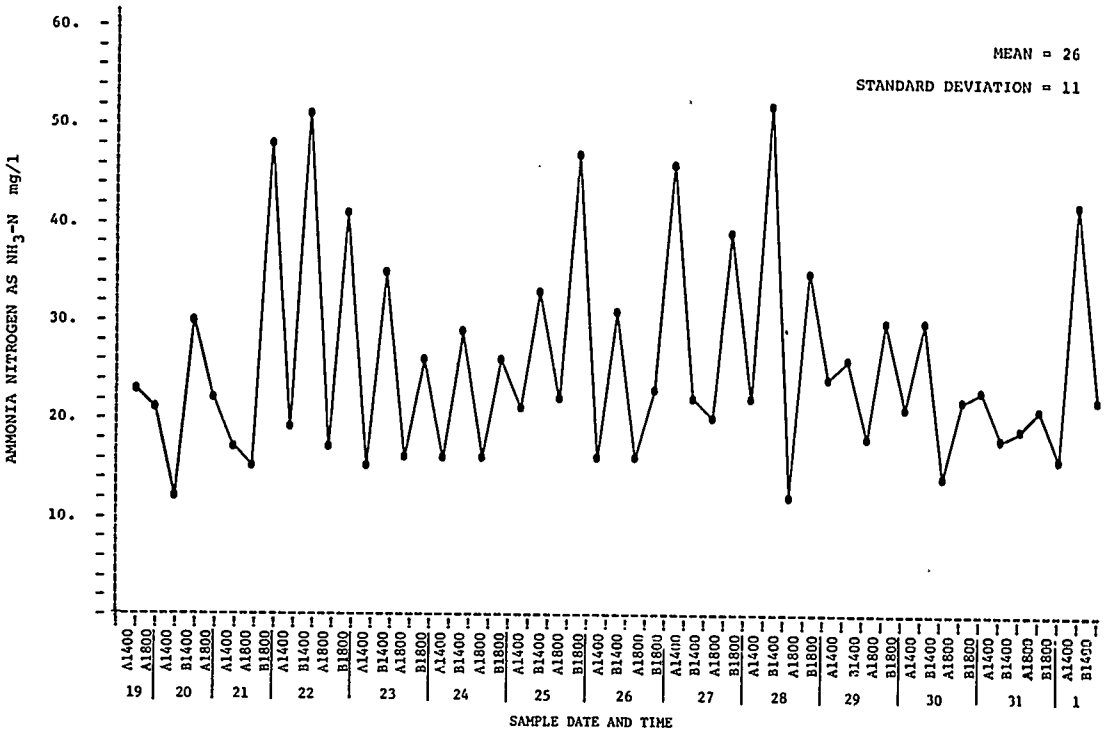

Figure IV-15. FL—Pinecrest ammonia nitrogen.

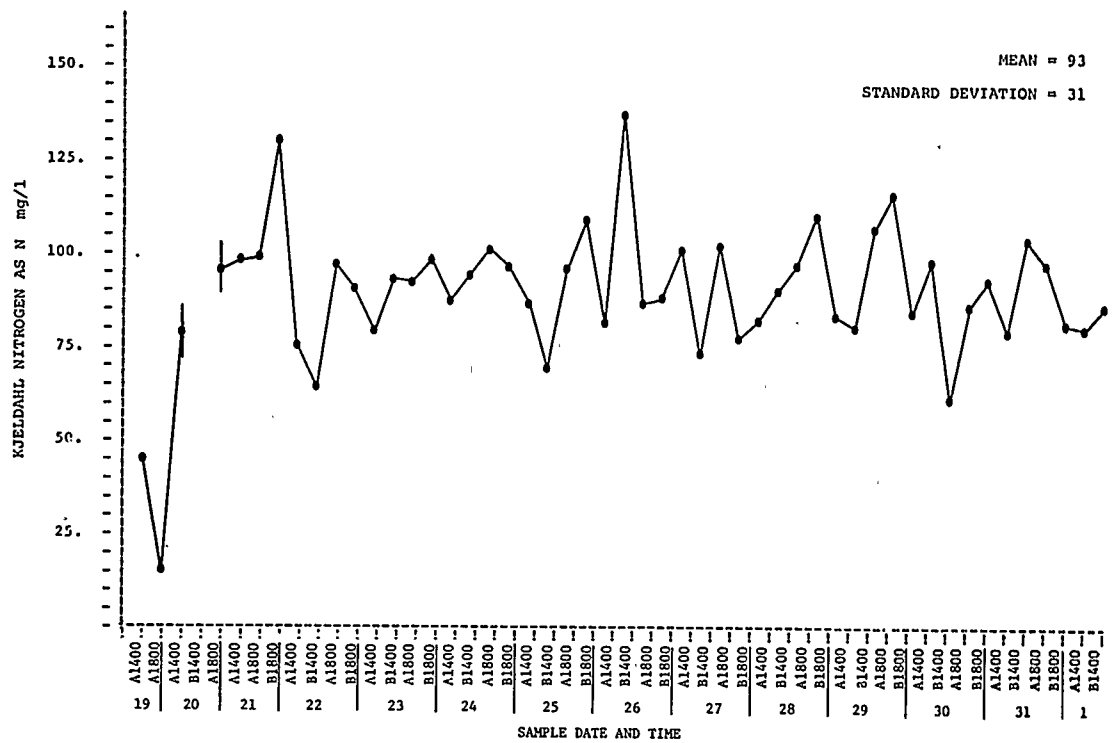

Figure IV-16. FL—Pinecrest Kjeldahl nitrogen.

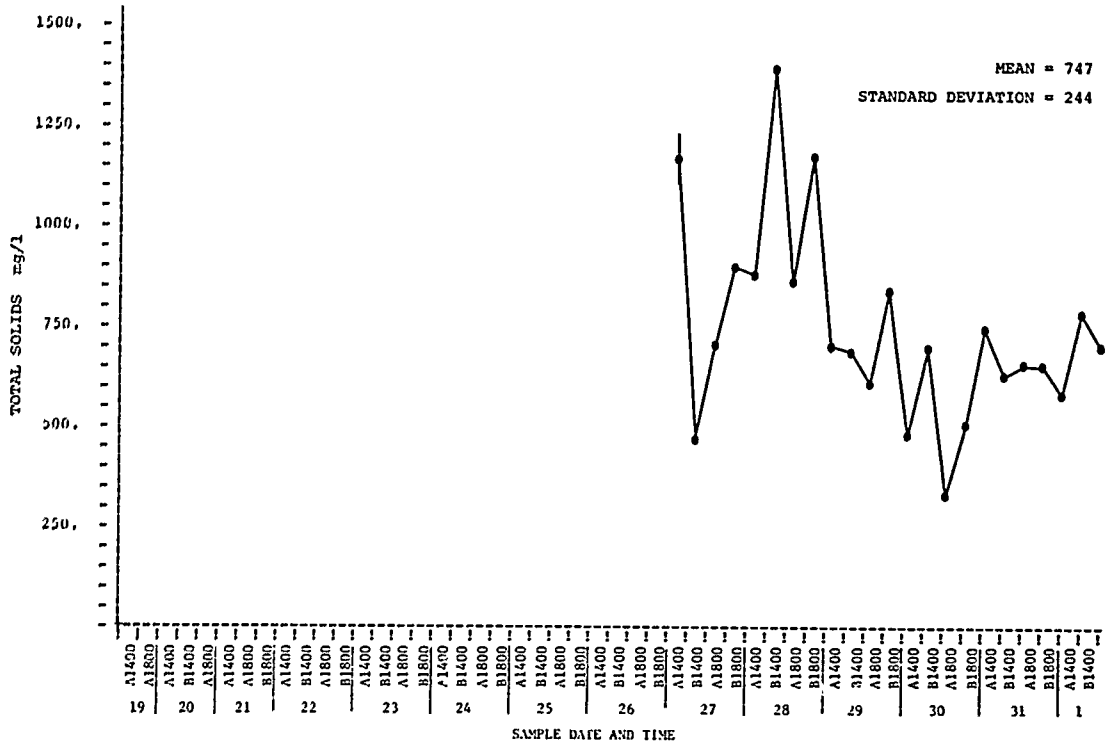

Figure IV-17. FL—Pinecrest total solids.