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AN EVALUATION OF THE NAVAJO REFINERY WASTEWATER TREATMENT FACILITIES, ARTESIA, NEW MEXICO

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The New Mexico Water Quality
Control Commission
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I. SUMMARY

On site investigations were conducted of the wastewater treatment facilities at the Navajo Refinery, and drawings of the system were reviewed. A layout of the complete system was prepared, since, at the time of this study, one did not exist.

A determination of the source of wastewater flows from the refinery was made, and the refinery effluent flow was found to be approximately 0.32 mgd. A determination was also made of the COD and suspended solids of the refinery effluent.

In addition, a simultaneous monitoring of the flows entering and leaving the treatment system was conducted. Further, an estimation for the percolation and evaporation rates from the lagoons was made. The strength of the wastewater through various stages of the treatment system was determined, and the reduction in COD was found to be between 25 and 50 per cent. Suspended solids were reduced by 80 to 90 per cent.

Also, test holes were dug to determine the depth of the groundwater, which was found to be five to six feet beneath the bottom of the lagoons. Since groundwater contamination by the lagoons was suspected, the water in the test holes, along with the water from a nearby stockwell, was sampled and tested. However, the test data was inconclusive.

A review of USGS flood flow data for the Pecos River for a period of 1941 to 1965 was conducted and compared with survey elevations of the three lagoons. This comparision illustrated the fact that lagoon three is flooded almost every year by the Pecos River.

A discussion with refinery personnel was held concerning the history of breaks occurring in the system. For example, a December, 1972, break in the effluent ditch resulted in untreated refinery effluent combining with treated domestic sewage from the Artesia sewage treatment plant, and the combined wastewater flowed into the Pecos River. The ensuing publicity focused attention on the Navajo Refinery Wastewater System and helped to precipitate this investigation.

The entire effluent ditch was visually inspected. Photographs were taken at various locations along the ditch. The photographs are included in Appendix B as an integral part of this report.

The proposed effluent regulations for refineries, promulgated under the Federal Water Quality Act Amendments of 1972 (PL 92-500), were reviewed and compared with effluent data obtained in this investigation. The investigation data also were compared to effluent criteria in the proposed New Mexico Permit Regulations.

Also discussed in this report, are the oil spill regulations applicable to the Navajo Refinery situation.

In addition, this report discussed alternatives for improving the effluent from the Navajo Refinery.

II. CONCLUSIONS

1. The Navajo Refinery wastewater treatment system is not a total retention facility. Significant amounts of wastewater effluent finds its way into the Pecos River through seasonal flooding. An additional amount finds its way into the groundwater through percolation.

2. The third lagoon in series (Lagoon 3) in the treatment system is situated at ground level. As a result, it is regularly flooded by the Pecos River. The flooding occurs with sufficient frequency to consider the effluent from Lagoon 2 a surface discharge as defined by the Federal Water Quality Act Amendments of 1972 (PL 92-500). Navajo Refinery is, therefore, legally obligated to obtain a permit to discharge under the Act.

3. Preliminary effluent regulations for oil refineries have been promulgated under PL 92-500. The effluent from lagoon two at Navajo Refinery does not comply with these regulations.

4. Effluent regulations have been proposed as part of a State Discharge Permits Program in New Mexico. The effluent from lagoon number two does not comply with these proposed regulations.

5. The lagoons are situated in very close proximity to the Pecos River, and there has been a history of untreated refinery effluent spills making their way into the Pecos River. Moreover, a reasonable probability exists that the spills will continue to occur, which will necessitate the preparation, by the refinery, of a Spill Prevention Control and Countermeasure (SPCC) Plan in accordance with Federal Regulations published in the Federal Register on December 11, 1973.

6. There is some percolation of wastewater into the soil beneath lagoons one, two, and three. The amount is relatively small compared to the amount of water entering the system each day. However, lagoons one, two, and three are only five to six feet above groundwater. Therefore, it is likely that the groundwater in the immediate area of the lagoons is being contaminated.

Water from a stock well, 100 yards away from lagoon one on the side of the lagoon away from the river, was sampled. The test data indicated that the well was not contaminated. Tests conducted on the groundwater immediately adjacent to the lagoons were inconclusive because of the manner in which they were sampled.

7. The wastewater treatment facilities at Navajo Refinery will have to be improved before they will be capable of meeting effluent regulations.

III. RECOMMENDATIONS

1. The owners of Navajo Refinery must apply for a Federal permit to discharge their wastewater. This permit can be obtained through the Dallas Regional office of the Environmental Protection Agency. Information regarding the permit can be obtained through the New Mexico Environmental Improvement Agency in Santa Fe, New Mexico.

2. The owners of Navajo Refinery must write a spill prevention control and countermeasure plan for the wastewater treatment system. Information regarding this plan can be obtained from the Dallas Regional office of the

Environmental Protection Agency.

3. The owners of Navajo Refinery must take steps to develop a wastewater treatment system at the refinery which will produce a treated wastewater capable of meeting State and Federal wastewater effluent requirements. If it is decided to upgrade the existing total retention facilities, the following should be accomplished:

a. Replace the effluent ditch with a pipeline;

b. Provide sufficient lined lagoon area at the site to retain the wastewater and to prevent any percolation into the soil;

c. Provide lagoon embankments of sufficient height and width to withstand the largest flood on record.

4. Prior to construction of any facilities, the plans, specifications, and design calculations must be submitted to the New Mexico Environmental Improvement Agency, Water Quality Division for review and comment.

IV. INTRODUCTION

The Navajo Refinery is located in Artesia, New Mexico, and consists of two separate plants. The refinery personnel refer to these two plants as the north and south divisions. The present owners purchased the refinery from the Continental Oil Company in May, 1969. This refinery is over 40 years old and originally was an asphalt processing plant during the 1920's. Various processes have been added to the refinery over the years, resulting in an increase in its size.

The refinery processes approximately 19,000 barrels of crude oil every day. The process is uniform and the amount of crude oil processed daily, discounting a shutdown, does not vary.

The principle product of the plant is gasoline, jet fuel, and diesel fuel. Asphalt for road surfacing is also produced. The refinery does not produce lubricating oils, because the crude oil is asphalt based and not suitable for this type of product. Most of the gasoline produced by the refinery is piped to El Paso, Texas, and to Phoenix, Arizona, for out-of-State consumption. A small amount of the refinery's production is shipped to Albuquerque, New Mexico.

A large volume of water is used daily in the refining process. The refinery wastewater contains large amounts of oily solids. The wastewater flows into an open ditch which transports it to three lagoons located three miles from the refinery. The system poses a pollutional threat to both the surface and the groundwater in the area because of the close proximity of the lagoons to the Pecos River and to the groundwater, and because of the close proximity of the ditch to other natural drainage.

In May, 1973, a field inspection of the subject facilities was jointly conducted by Mr. John R. Wright and the writer (both from the New Mexico Environmental Improvement Agency), and by Mr. Dan Nutter and Mr. Pete Porter (both from the New Mexico Oil Conservation Commission). This inspection was conducted to evaluate the water pollution potential of the facilities in question.

Based on the results of the inspection, it was decided to further evaluate the wastewater treatment facilities at the Navajo Refinery. The objective of the additional evaluation was to:

a. obtain details of the refinery wastewater treatment system;

b. determine the quantity, strength, and destination of the effluent from refinery process sources;

c. determine the quantity, strength, and destination of the effluent from the refinery wastewater treatment system;

d. determine the alternatives for regulatory actions should they be necessary; and

e. furnish the New Mexico Water Quality Control Commission with a report.

V. DISCUSSION OF RESULTS

A. System Details

There is no complete updated set of drawings and specifications for the system. To obtain a knowledge of the system, it was necessary to review several documents and interview refinery personnel. The documents included old layouts of portions of the system, old aerial photographs, USGS maps, and sketches prepared by refinery personnel at the request of the writer. The areas of lagoon one and two are obtained by scaling refinery drawings. No information was available on lagoon three.

All of the miscellaneous data available was assembled on a single layout to facilitate the reader's understanding of the system. The layout is shown in Figure 1 (Figure 1 is a 2' x 3' drawing enclosed in the envelope attached to the back cover of this report). To further help in the reader's understanding of the treatment system, several photographs were taken of the system. These photographs are presented in Appendix B.

The Navajo Refinery liquid waste treatment system consists of two oxidation-settling lagoons and a third lagoon which serves as an evaporation-percolation bed. The refinery effluent is carried to the lagoons by a 3.8 mile open unlined ditch. In some segments of its length, the ditch consists of a man-made channel six feet wide at the top, four feet wide at the bottom, and two feet deep. Reference photos taken at locations C and H (in Appendix B) are examples of the man-made segments of the effluent ditch (the key to the photo locations are shown on Figure 1). In other segments, the ditch is simply a shallow depression in otherwise flat terrain through which the refinery effluent meanders. Reference photos taken at locations D and E are examples of these segments of the effluent ditch. The effluent ditch originally was all natural drainage. The exact details of its evolution to its present state are not known. Over the years, the effluent was, for various reasons, diverted away from the natural drainage of Eagle Draw into the man-made channel. The present effluent ditch is totally inadequate for transmission of high strength refinery effluent. It is susceptible to overflows and breaks onto the surrounding farmland and into the Pecos River. (This subject is discussed in more detail in Section V, Part C.)

At the end of the effluent ditch the water flows into lagoon number one. The water in the lagoon is dark and murky at the point at which wastewater flows into the lagoon. At the effluent of lagoon one, the water is noticeably clearer indicating some settling of solids has occurred. A composite photo of lagoon number one is shown in Appendix B. The water in lagoon two is noticeably clearer than the water in lagoon one. It has a very light green tinge indicating that some minimal amount of algae are present. The algae growth is probably limited by the presence of substances in the lagoon which are toxic to the algae.

There is a minimal weed growth around the edge of the lagoons. Some dead tumble weeds were observed, but these probably blew in from other areas. There was little evidence indicating the presence of waterborne insects in the area. The effluent from lagoon two flows into a playa-like percolation/evaporation bed (lagoon three) where it evaporates and percolates into the ground. There are dead salt cedars in and around lagoon three. Grass was observed to be growing in areas adjacent to the lagoon. Lagoon three increases in surface area during the winter when the evaporation rate in the area is low. During the summer, the evaporation rates increase and the size of the playa shrinks accordingly. A photo of lagoon three, taken at location N is shown in Appendix B. Figure 2 is a hydraulic profile of the three lagoons.

The lagoons and lagoon embankments do not have the appearance of a facility which was conceived in a well-though-out design prior to being constructed. The embankments are of varying heights and width. The entire lagoon complex has the appearance of having been constructed in a haphazard manner by randomly shoving soil into place with a bulldozer. The lagoons are not lined. The flow structure between lagoons one and two is not visible but appears to be locked in an open position. The flow structure from lagoon two to three is a combination pipe and channel. The pipe portion is shown in a photo adjacent to the composite sampler in Appendix B.

B. Quantity and Strength of Refinery Effluent

The sources of refinery wastewater flows were determined through interviews with refinery personnel. (1)

The extent of contaminants was determined through conversations with refinery personnel and through evaluation of refinery test data.

Figure 3 is a layout of the south plant showing locations of the various processes. Figure 4 is a similar layout of the north plant. Table I gives the sources of estimated flow and type of contaminants for each of the processes contributing to the daily wastewater flow.

The source of Navajo Refinery's process water is the Artesia water supply. This water was sampled and analyzed during this evaluation. The data are reported in Table II. The Artesia water is very hard with high dissolved solids.

The major source of wastewater flow from the refinery is the cooling towers. They contribute approximately 0.19 mgd or 60 per cent of the daily flow. These units are large heat exchanges which circulate cool water over small one-inch pipes through which the hot oil is circulated. Heat is transferred from the oil through the pipes to the water. The heated water is pumped to the top of the cooling tower where it is allowed to fall back to the tank at the bottom of the tower. A great deal of water is lost through evaporation in this process. Fresh water is continually added to the towers and higher salt content water is continually removed. The salts which accumulate in the water are $Na\ SO_4$ and $Ca(HCO_3)_2$. These salts are found in fairly large concentrations in the Artesia water supply to begin with (reference Table II). In addition, sulfuric acid (H_2SO_4), organic phosphates, and chromate compounds are added to the water to prevent scale deposits. Derivatives of these compounds show up in the refinery wastewater effluent.

The boiler blowdown water contributes .026 mgd or eight per cent to the daily flow. The water in the four boilers must occasionally be changed by blowing down or discharging part of the water. This is done to keep the salt levels from becoming too concentrated. The boiler feedwater is softened by ion exchange units. The backwash water from the ion exchange units is high in calcium sodium carbonates, sulfates, and magnesium which contribute to the refinery wastewater flow. After softening, chemicals are added to the water to further protect against scale deposition. These chemicals include sulfides to scavenge dissolved oxygen, organic phosphates to complex calcium and other conditioners. All of these chemicals show up in one form or another in the boiler blowdown water.

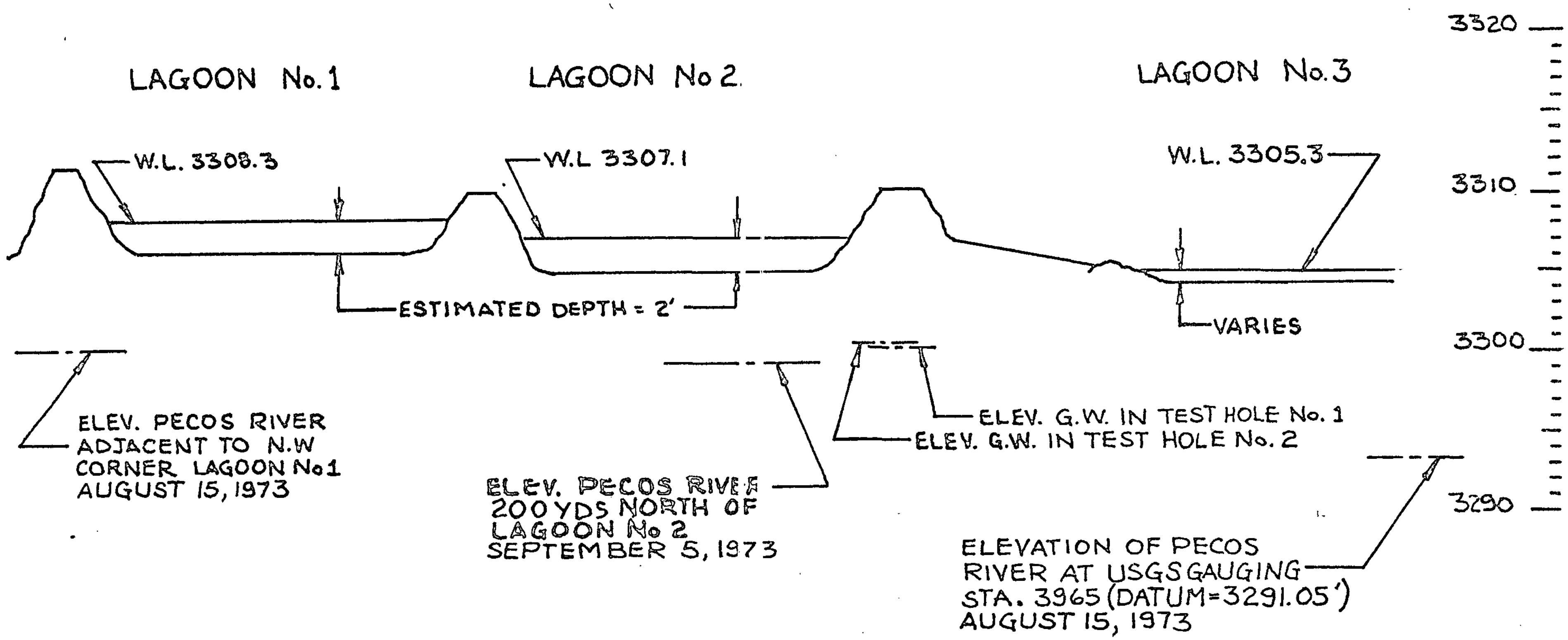

FIGURE 2

NAVAJO REFINERY WASTEWATER
TREATMENT FACILITY
HYDRAULIC PROFILE

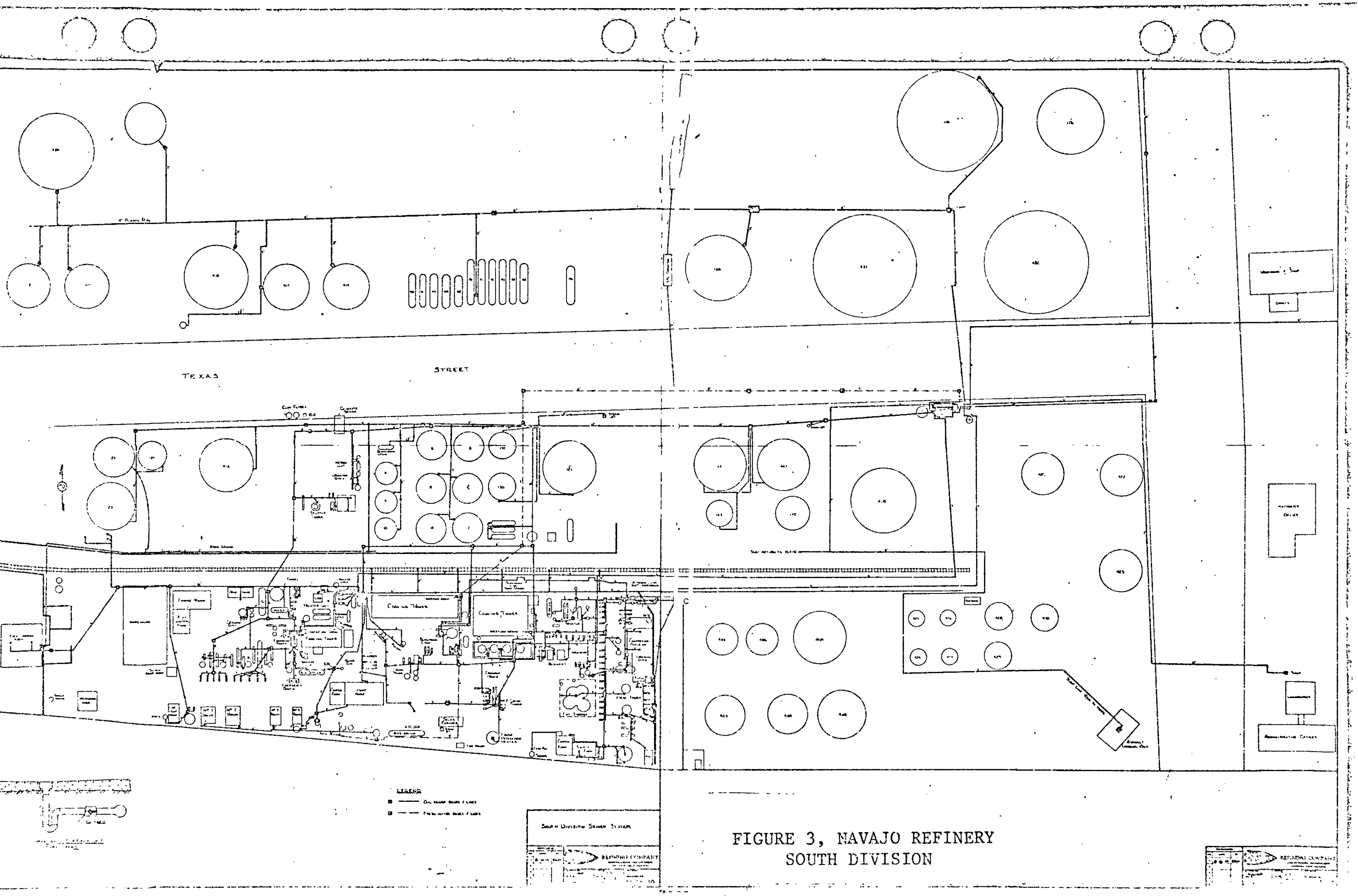

FIGURE 3, NAVAJO REFINERY
SOUTH DIVISION

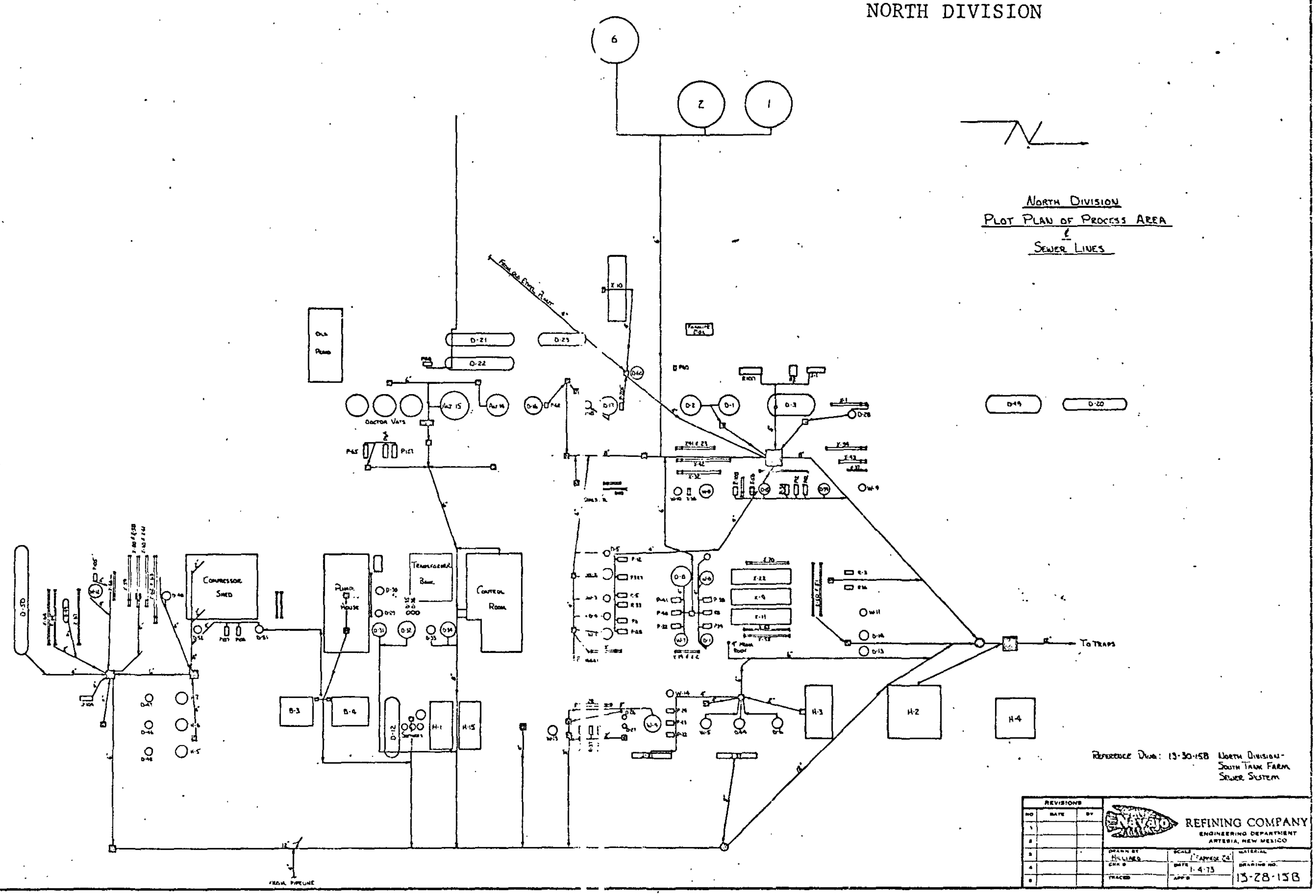

FIGURE 4, NAVAJO REFINERY
NORTH DIVISION

TABLE I

SOURCE OF WASTEWATER FLOW AND
WASTEWATER CONTAMINANTS FROM NAVAJO REFINERY

Source	Flow Mgd	Flow Per Cent	Type of Contaminant
South Boiler Blowdown	.023		Na^{+} $SO_4^{=}$ Cl^{-} $PO_4^{\equiv}$
North Boiler Blowdown	.003		
Subtotal	.026	8.0	
Cooling Towers	.193	60.3	Organic Materials Na^{+}, $SO_4^{=}$, Mg^{++}, HCO_3^{-} Cr, $PO_4^{\equiv}$,
Desalting Water	.04	12.5	NaCl, Crude Oil Components
Steam Stripping	Balance	19.2	Organic Materials
Treaters Caustic Scrubbers Perco Unit Inhibitor Sweetening			Organic Materials Sodium Napthenate, Phenols, H_2S, Mercaptans
Alky Unit Tar Neutralization			NaF
Softeners Backwash Water			Ca^{++}, Na^{+}, $CO_3^{=}$, $SO_4^{=}$
Wash-up Water (to floor drains)			
TOTAL	.32	100	

TABLE II

ARTESIA WATER SUPPLY ANALYSIS

Paramter	Units	Artesia Water Supply**	USPHS Standards 1
Arsenic	mg/l	< 0.04	0.01
Barium		1.0	1.0
Boron		< 0.5	1.0
Cadmium		< 0.01	0.01
Chloride		11.6	250
*Chromium		< 0.01	
Copper		< 0.25	1.0
Fluoride		0.80	1.2
Iron		< 0.25	1.0
Lead		< 0.03	0.05
Manganese		< 0.05	0.05
Nitrate		2.0	45.0
Phenols		none	0.001
Selenium		0.02	0.01
Silver		< 0.05	0.05
Sulfate		450	250.0
Total Dissolved Residue		940	500.0
Zinc		0.03	5.0
Dosium		15.4	
Potassium		1.2	
Calcium		174.0	
Magnesium		47.6	
Bicarbonate		236.2	
Alkalinity		193.6	
Total Hardness		630	
Mercury		0.0008	
Molybdenum		< 0.01	
Nickel		< 0.1	
Carbonate		0.0	

** Stand Pipe Well, Depth 1100 Feet
* Total

Desalting water is another major contributor to the wastewater flow. Hot water is mixed with the crude oil in the primary stages of the refinery process to wash salt (NaCl) out of the crude oil. This process contributes approximately 0.4 mgd or 12 per cent to the daily wastewater flow.

The remainder of the water making up the daily discharge comes from a variety of processes within the refinery. The stream strippers and treaters use water that actually comes into contact with some component of the petroleum. The wash-up water is used to clean up equipment. Water accumulates at the bottom of storage tanks and is drained periodically. The wastewater from all of these sources is extremely oily.

Process water and cooling tower water from the south division is sent through an oil-water separator (API separator) in an effort to salvage and recycle some of the oil, but the oil recovery efficiency is not very high. Effluent from the separator was observed to be very oily (reference photos Appendix B) and flows to a small settling pond and from there into the effluent ditch. Boiler blowdown water from the south division is not contaminated by the oil and is routed directly to the effluent ditch.

All process water from the north division (including boiler blowdown water) is channeled directly to a separator at the north division. Effluent from the separator flows into the small settling pond where it meets with effluent from the north division, and the combined wastewater flows to the lagoons.

The refinery effluent flow was measured with a six-inch portable parshall flume. The flume was installed in the effluent ditch leading from the refinery to the treatment lagoons. The location of the flume is indicated on Figure 1 and photographs of the flume installed in the ditch are shown in Appendix B. Flows ranged from 0.30 to 0.40 mgd. The average flow was calculated to be 0.32 mgd. Refinery personnel stated that the flow remains fairly constant twenty-four hours a day, 365 days a year (reference Figure 5).

A composite sample was taken of the refinery effluent immediately upstream of the six-inch parshall flume. The sample was tested for chemical oxygen demand and also for total, suspended and dissolved residue (2). The results show that the refinery effluent is very high in COD, solids, and pH (reference Table III).

C. Strength and Destination of Treatment System Effluent

A good deal of time in this evaluation was spent in determining the final destination of the water from the refinery wastewater treatment system. The owners of the refinery were under the impression that it is a total retention lagoon system; that is, all waters entering the lagoons are evaporated. The discussion in the following section will show that this is not the actual case. A small amount of water percolates into the soil and into the shallow groundwater from the bottoms of lagoons one and two and three.

It will also be shown that lagoon three is routinely flooded by the Pecos River. Recognizing this, the effluent from lagoon two was considered to be the surface discharge from the system. The strength and magnitude of the lagoon two discharge is discussed along with the reduction in wastewater strength through the system. Tests conducted on the groundwater are also discussed.

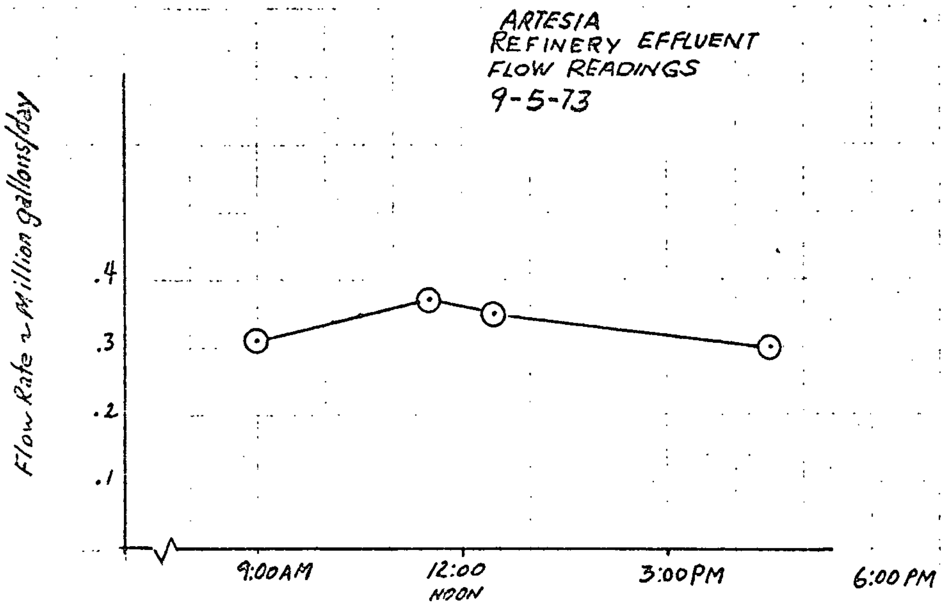

Figure a

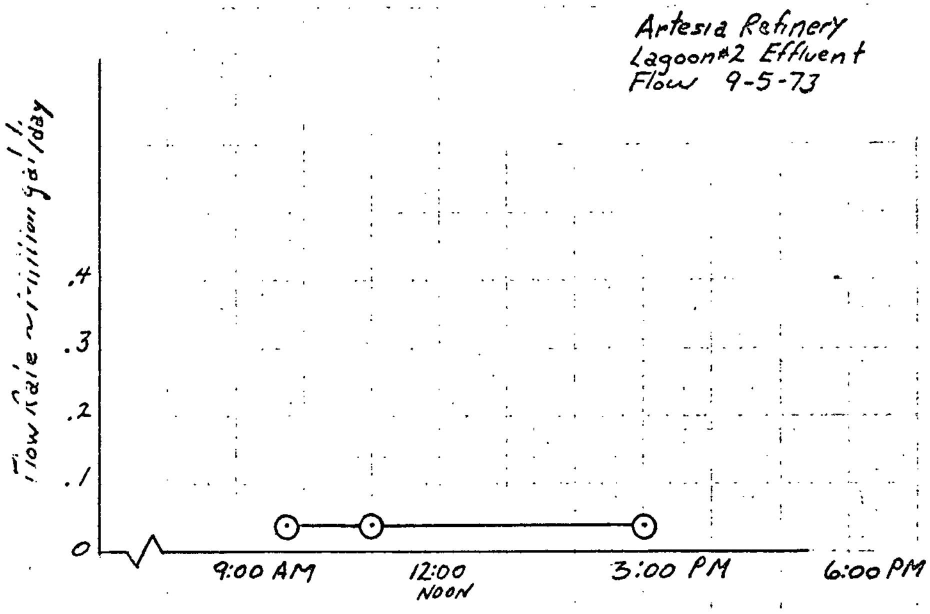

Figure b

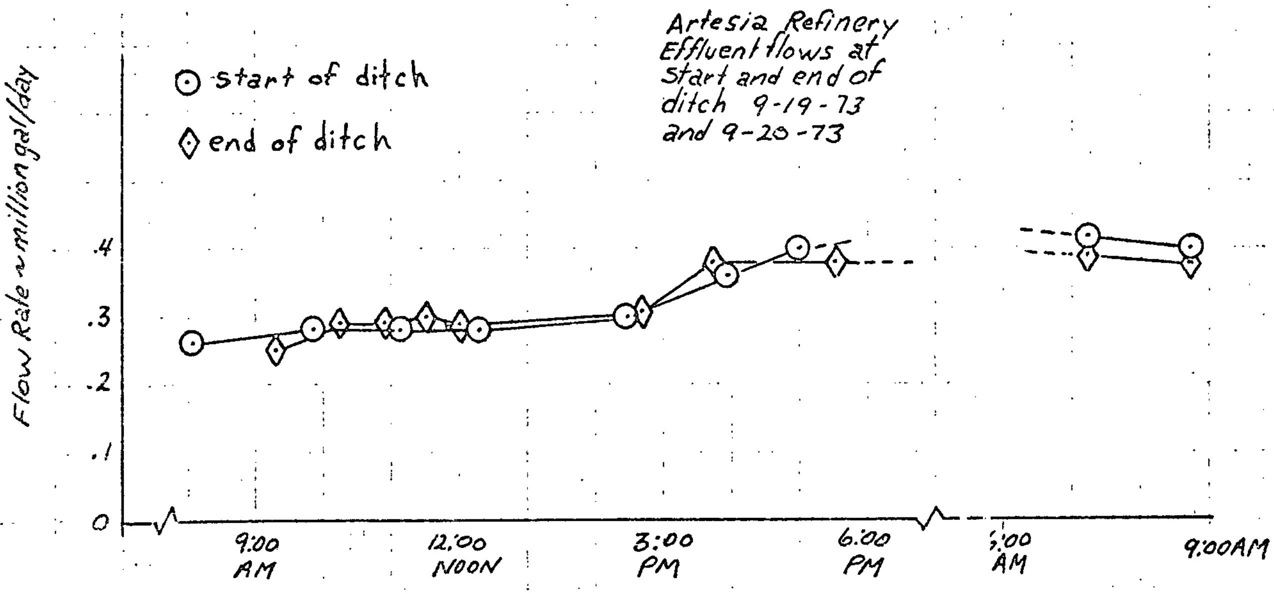

Figure c

FIGURE 5
REFINERY WASTEWATER FLOW DATA

TABLE III

Test Data; Navajo Refinery Wastewater Treatment System

Sample Location and Sampling Method	Sampling Date	COD mg/l	Total Residue mg/l	Dissolved Residue mg/l	Suspended Residue mg/l	Chromium mg/l	Lead mg/l	Phenol mg/l	pH***
Refinery Effluent 24 hr. composite grab	6/28-29/73 9/20/73	752	12065	6864	5201	0.10			9.32
First Lagoon Influent grab grab	6/29/73 8/15/73	740 500	12523	7500	5023			>10**	
Second Lagoon Influent grab grab grab	6/29/73 8/15/73 9/5/73	356 350 375	12541	12033	508				5.95
Second Lagoon Effluent 24 hr. composite 24 hr. composite grab grab	6/29/73 8/15/73 9/5/73 9/20/73	500 340 375	13141	12501	640	0.05	0.230	0.010 0.024	7.12
Third Lagoon grab grab	9/5/73 9/20/73	436						0.004	
Groundwater Test Hole 1**** grab	8/16/73					0.05*	0.220*	0.010*	
Groundwater Test Hole 2**** grab	8/16/73					0.10*	0.220*	0.016*	
Groundwater Test Hole 3 **** grab	9/20/73							< 0.001*	
Pecos River 3 1/2 miles north of bridge on US 82 grab	9/20/73					< 0.05		< 0.001	
Pecos River at bridge on US Highway 82 grab	9/20/73					< 0.05		< 0.001	

* Questionable data
** Too high to read
*** Ph run by refinery personnel
**** Invalid Sampling Procedure

The lagoon two discharge was tested for COD, total dissolved and suspended residue, phenols, chromium and lead.

All samples were tested at the Environmental Improvement Agency Laboratory in Albuquerque. The test methods used were in accordance with Standard Methods for Water and Wastewater Analysis, Volume 13. (2)

Table III is a tabulation of data from the treatment system. The COD is reduced from 752 mg/l in the refinery effluent to an average 420 mg/l in the effluent from lagoon two.

The increase in dissolved residue across the system, particularly from lagoon one influent to lagoon two influent is due to evaporation. Tables IV, V, and VI were prepared from data furnished by Navajo Refinery. Comparison of data for lagoons one and two shows an increase in hardness, alkalinity, and NaCl. This is due to the high amount of evaporation taking place in the lagoons, particularly in the summer months. The drop in suspended residue across lagoon one is due to settling.

Lead and chromium are present in the effluent from lagoon number two. The concentrations of both metals in the effluent is somewhat higher than the concentrations of these same metals in the city water supply. Lead and chromium are undoubtedly being increased in the water by evaporation which takes place in the refining and wastewater treatment processes. Also, chromates are added to the cooling tower water. It is likely that other heavy metals are present in high concentrations in the effluent from lagoon two due to concentration by evaporation. The concentrations of these metals would be higher except that the metal ions probably combine with anions already present in the water (sulfate for example) to form low solubility salts. A complete heavy metals analysis should be conducted on the lagoon two effluent during the months of peak evaporation to determine if any of the heavy metals are being raised to dangerous concentrations through evaporation.

The concentration of phenols is reduced through lagoons one and two from greater than 10 mg/l at the influent to 0.01 mg/l at the effluent. The phenol content in lagoon number three was found to be 0.004 mg/l.

The impact of the effluent strength from lagoon two in regards to regulatory Agency effluent limitations is discussed in Section VI.

The average flow from lagoon two was measured with a three-inch parshall flume on September 5, 1973. The flow remained constant at 0.04 mgd (Reference Figure 5). However, the amount of flow from lagoon two will vary considerably with evaporation. (3) (4) (5) In the summer, when evaporation rates are very high, the discharge may go to zero for a short time. In the winter, when evaporation rates are low, the discharge will increase. The area of lagoon three will decrease and increase corresponding to fluctuations in evaporation.

The daily net evaporation from the effluent ditch, lagoon one and lagoon two, was estimated by multiplying the combined surface area of the ditch and the lagoons by the daily average evaporation for the area. (3) (4) (5) (Reference calculations in Appendix A.)

Table IV

Wastewater Analyses

West Evaporation Pond Results in ppm
(Lagoon #1)

Date	P. Alk.*	M. Alk.**	Acidity	pH	NaCl	Hardness	Fluoride	Sulfide
2/2/73	0	102	0	6.30	1230	950	18.24	0
2/16/73	0	116	0	7.15	1140	940	20.9	0
3/8/73	0	134	0	7.85	1290	1000	20.14	0
3/21/73	0	136	0	7.05	1160	990	21.28	0
4/6/73	0	108	0	6.55	1290	990	22.80	0
4/23/73	0	106	0	6.75	1380	1230	25.08	0
5/11/73	0	96	0	7.04	1380	1250	24.0	0
5/24/73	0	106	0	6.90	1290	1070	20.90	0
6/5/73	0	100	0	6.48	1380	1200	25.08	0
6/29/73	0	22	0	5.95	1380	1230	30.40	0
8/2/73	0	94	0		980	830	30.02	0

* Phenophthalen alkalinity

** Methyl orange alkalinity

Table V

Wastewater Analyses

Middle Evaporation Pond Results in ppm
(Lagoon #2)

Date	P. Alk.*	M. Alk.**	Acidity	pH	NaCl	Hardness	Fluoride	Sulfide
2/2/73	0	58	0	6.32	1250	1100	20.52	0
2/16/73	0	56	0	6.75	1260	1130	20.2	0
3/8/73	0	42	0	7.20	1230	1120	23.56	0
3/21/73	0	56	0	6.78	1250	1250	24.70	0
4/6/73	0	54	0	6.65	1300	1240	22.40	0
4/23/73	0	60	0	6.75	1520	1420	21.66	0
5/11/73	0	54	0	7.75	1780	1600	25.08	0
5/24/73	0	38	0	7.22	1800	1570	24.70	0
6/5/73	0	36	0	7.00	1960	1700	20.50	0
6/29/73	0	24	0	7.12	2300	1950	25.46	0
8/2/73	0	10	0		2510	2180	25.84	0

* Phenophthalen alkalinity

** Methyl orange alkalinity

Table VI

Wastewater Analyses

East Evaporation Pond Results in ppm
(Lagoon #3)

Date	P. Alk.*	M. Alk.**	Acidity	pH	NaCl	Hardness	Fluoride	Sulfide
2/2/73	0	50	0	6.30	1230	1150	17.48	0
2/16/73	0	56	0	6.70	1250	1170	19.0	0
3/8/73	0	44	0	7.15	1240	1380	22.04	0
3/21/73	0	70	0	6.80	1500	1500	24.70	0
4/6/73	0	50	0	6.75	1390	1370	19.00	0
4/23/73	0	40	0	7.25	2020	1820	20.14	0
5/11/73	0	26	0	7.15	3380	3000	19.76	0
5/24/73	0	38	0	7.37	1850	1600	25.08	0
6/5/73	0	34	0	7.45	2280	1960	28.12	0
6/29/73	0	24	0	7.08	2290	1940	24.70	0
8/2/73	0	10	0		2600	2200	24.32	0

* Phenophthalen alkalinity

** Methyl orange alkalinity

A corresponding percolation rate for the lagoons and ditch was estimated by subtracting the evaporation from the difference in flows in and out of the system. The combined percolation rate was estimated to be 27 gpm. This is very low considering the amount of water entering the system every day and the surface area over which it is absorbed. However, the bottoms of the lagoons are within five to six feet of the groundwater table. Whatever water is percolating into the soil is going directly into the groundwater.

It was not possible to estimate the percolation rate from lagoon three because there was no information available for determining surface area. However, it is being assumed that the percolation rate for lagoon three is higher than for the rest of the system. By the time the wastewater gets to the third lagoon, it has lower settleable solids to seal the bottom. Also, the bottom is dried out periodically due to fluctuations in lagoon area which enables the soil to absorb more water.

The percolation losses in the effluent ditch could be significant. The ditch passes through soil types ranging from silty loam to silty clay loam having water intake rates ranging from moderate to slow. Sealing of the bottom of the ditch would not occur to the same extent as in a lagoon because the velocity of the wastewater would be sufficient to keep some of the particles in suspension. Thus, it is possible that significant percolation is occurring in the ditch. This presents an undesirable situation due to the close proximity of groundwater in the area.

An attempt was made to determine flow losses in the ditch. Flows were measured at the beginning and end of the ditch on September 19 and September 20 (reference Figure 5). The flows recorded the nineteenth showed an increase rather than a decrease in flow from the beginning to the end of the ditch. The increase is attributed to rainfall and surface runoff which occurred in the area on September 18 and 19. The flows recorded for a short time on September 20 indicate a decrease in flow of 0.02 mgd.

Groundwater test holes one, two, and three were dug to determine the depth of groundwater (reference Figure 1 for hole location). Depth to groundwater below the lagoon bottoms was determined to be five to six feet (reference Figure 2). The water in the holes was also sampled and tested for lead, chromium, and phenols. However, after consideration of the method by which the samples were collected, it was concluded that these data were questionable. Contaminants were undoubtedly introduced from the surface into the holes as they were being dug. The data are reported in Table III.

A stockwell adjacent to the southwest corner of lagoon one was also sampled. The well is 100 yards south of the lagoon on the side of the lagoons away from the river. A complete analysis was made on the samples. The data are reported in Table VII. There were no unusually high concentrations of heavy metals or phenols detected.

Flooding potentials were determined by consulting USGS gauging station data and USGS personnel (6, 7). The USGS Pecos River gauging station at Artesia (station No. 3965) is located 6500 feet southeast of the center of lagoon number one (reference Figure 1). The USGS Cottonwood Creek gauging station is located

TABLE VII

STOCK WELL WATER ANALYSIS

Parameter	Units	Stock Well Depth five feet (estimated)
Arsenic	mg/1	0.04
Barium		0.6
Boran		< 0.5
Cadmium		< 0.01
Chloride		893.0
Chromium		< 0.01
Copper		0.25
Fluoride		0.58
Iron		< 0.25
Lead		0.073
Manganese		0.80
Nitrate		0.10
Phenols		none
Selenium		0.02
Silver		< 0.05
Sulfate		1800.0
Total Dissolved Residue		4695.0
Zinc		0.05
Sodium		598.0
Potassium		5.85
Calcium		432.0
Magnesium		216.6
Bicarbonate		215.3
Alkalinity		176.4
Total Hardness		1967.5
Mercury		< 0.0008
Molybdenum		< 0.01
Nickel		< 0.10
Carbonate		0.0

30,380 feet northwest of lagoon number one. The river valley in which the two stations are located is sufficiently broad and flat to justify the assumption that the grade of water between the two stations is uniform during major floods (6). Thus, flood levels at the lagoons were estimated by multiplying the ratio of 6500 ft./30380 ft. by the difference in level of the flood waters at the two stations (reference Appendix A). The water level of the three lagoons and the level of the embankments of lagoons one and two were determined by surveying their elevations in relation to a USGS bench mark located very near to gaging station No. 3965 on the Highway 82 bridge across the Pecos River (reference Figure 1).

Those years where the USGS recorded elevations approached or exceeded the lagoon embankment elevations are tabulated in Table VIII. Data from gauging station 3965 are available from 1941 to 1965. During these years, the elevation of the river has never exceeded the elevation of lagoon one and two embankments. However, in 1941 and 1955, the river rose to within one foot of the top of the embankments. It is probable that water this near to the top of the lagoons would breach the embankments. The embankments are relatively narrow at the top and it wouldn't take much erosion to breach them.

Lagoon three does not have any embankment to speak of. It is situated much lower than lagoons one and two. Comparison of river elevation data with the elevation of lagoon three shows that the lagoon is flooded routinely.

There were breaks in the first two lagoons due to flooding in 1964 and 1966. The refinery effluent ditch was flooded with runoff water which in turn flooded the lagoons. The Eagle Draw drainage ditch was constructed in 1968 to divert runoff.

There have been breaks in the system from time to time resulting in spills. The most recent occurred in December, 1972, when untreated refinery effluent flowed through a break in the refinery effluent ditch into an adjacent ditch which was carrying treated domestic sewage to the Pecos River.

The refinery effluent ditch is very susceptible to spills and breaks. The writer walked the entire length of the ditch and took several photos of the ditch (reference Appendix C, photo locations B through K). Several areas were observed where small spills had occurred onto adjoining pasture-land. One of the photos taken at location E illustrates this. Some evidence of spills were also observed at location H. The photo taken at location I shows the concrete and steel consturcted at the site of the December, 1972, spill to prevent any future spills at this location. The photo taken at location K shows a diversion in the ditch which was apparently constructed to bypass a spill problem area.

The spill problem was discussed with a local rancher (8) who owns irrigated land along the last two miles of the ditch. He stated that spills occur routinely along the ditch onto his land. He has complained to the refinery with limited success.

In the writer's opinion, the spills from the ditch will continue to occur until the ditch is eliminated. It should be replaced by a pipeline completely protected from any exfiltration or infiltration.

TABLE VIII

ELEVATIONS OF NAVAJO REFINERY WASTEWATER
FACILITIES RELATIVE TO FLOOD LEVELS
ATTAINED BY PECOS RIVER SINCE 1941*

Year	Elevation at Gaging Station No. 3965 Feet	Min. Est. Elevation of River at Lagoons Feet	Minimum No. Years Flooding Occurs: Yrs. Lagoon 1 & 2 Embankments Possibly Breached (elev. 3,305.3) Feet	Yrs. Lagoon 3 Flooded (elev. 3,305.3) Feet
1941	13.32	3309.1	(x)	x
1942	12.46	3308.3		x
1943	11.22	3307.0		x
1944	7.98	3303.8		x
1945	7.40	3303.2		
1946	10.41	3306.2		x
1947	7.48	3303.3		
1948	11.80	3307.6		x
1949	12.01	3308.8		x
1950	12.23	3308.0		x
1951	10.38	3306.2		x
1952	10.35	3306.2		x
1953	11.82	3307.6		x
1954	12.23	3308.0		x
1955	13.76	3309.5	(x)	x
1956	12.11	3307.9		x
1957	12.33	3308.1		x
1958	11.70	3307.5		x
1959	10.14	3305.9		x
1960	12.56	3308.3		x
1961	12.38	3308.2		x
1962	10.43	3306.2		x
1963	12.14	3307.9		x
1964	6.80	3302.5		
1965	12.34	3308.1		x

*Gage #3965 has been at present location at 3291.05 Datum since April 4, 1941
x - River exceeded elevation of lagoon
(x) - River within 1' of top of embankment

VI. REGULATORY ALTERNATIVES

The efffluent from the Navajo Refinery wastewater treatment system, both surface and subsurface is subject to regulation by the Federal Water Pollution Control Act Amendments of 1972 (Pl 92-500).

Sections 401 and 402 of the Act require that industrial, municipal, and other point source dischargers obtain permits for the discharge of any pollutants into the waters of the United States. The conditions of the permit must be certified by the State before the permit can be granted. To obtain a permit, the discharger must produce an effluent typical of "best practicable control technology" by July, 1977. By 1983, effluent requirements which represent "best available technology economically achievable" must be met.

Recognizing the need for standard discharge limits within industrial categories, the Environmental Protection Agency contracted for research and studies to determine what the "best practicable" and "best available" equivalent effluent was for 20 industrial categories. The proposed effluent limitations for oil refineries were published in the December 14, 1973, issue of the "Federal Register." There are five categories of refineries. The Navajo Refinery falls into category B "Low Cracking."

At the time the tests were run on the effluent, it was not known what criteria would be used in the Federal Regulations to characterize refinery effluents. Included in the Federal criteria, are standards for COD, suspended solids, phenols, and total chromium. The effluent from the Navajo Refinery Treatment system was tested for these items. The levels for COD. suspended solids, total chromium and phenols found in the effluent from the Navajo Refinery wastewater treatment system were compared to Federal criteria. These data are shown on Table IX.

The monthly discharges were estimated by the calculations shown in Appendix A. Flow readings taken September 5, and effluent testing accomplished from June through September were used as a basis for these calculations. The writer recognizes that some of the assumptions used in calculating the monthly flows may not be entirely valid, and that the resulting estimated flows and flow strengths may be only roughly approximate at best. However, the estimated monthly discharges illustrate the point that some parameters such as COD and suspended solids will exceed Federal limitations many times during the year, depending on the evaporation. Other criteria such as total chromium and phenols may be well below Federal criteria all year.

Section 311 of the Act requires that preventive measures be taken against discharges of oil or hazardous substances into or upon the navigable waters of the United States. On December 11, 1973, Oil Pollution Prevention Regulations were published in the Federal Register. They apply to non-transporation related onshore and offshore facilities engaged in drilling, producing, refining, transferring, distributing, or consuming oil and oil products and which, due to their location, could reasonably be expected to discharge oil in harmful quantities into or upon the navigable waters of the United States or adjoining shorelines.

Under these regulations, owners and operators of the above described facilities will be required to prepare a Spill Prevention Control and Countermeasure (SPCC) plan within six months after the effective date of the regulations (January 10,

TABLE IX
Comparison of Navajc I efinery
Effluent to Allowable Federa I egulations

Parameter	Units	Allowable Discharges per Fed. Regulations: Monthly Average (lb/1000/bbl/day)	Allowable Discharges per Fed. Regulations: Daily Maximum (lb/1000/bbl/day)	*Estimated Monthly Effluent Discharges for Navajo Refinery: Jan.	Feb.	March	April	May	June	July	August	Sept.	Oct.	Nov.	Dec.
Flow	mgd			.18	.13	.07	.01	NO EFFLUENT	NO EFFLUENT	NO EFFLUENT	.01	.06	.13	.17	.19
COD	lbs/1000 bbl crude through put/day (lbs/1000/bbl/day)	22.1	27.6	33	24	13	2				2	11	24	31	35
T. Sus. Solids		2.2	2.8	50	37	20	3				3	17	37	48	53
Phenols		0.024	0.034	<.001	<0.001	<0.001	< 0.001				< 0.001	< 0.001	< 0.001	<0.001	< 0.001
Total Cr.		0.056	0.070	<0.01	<0.01	<0.01	<0.01				< 0.01	<0.01	<0.01	<0.01	<0.01
BOD_5		3.6	4.4												
Oil Grease		1.1	1.4												
Ammonia		1.1	1.4												
Sulfide		0.020	0.031												
TOC		4.9	6.1												

*Estimates based on following data taken June-September, 1973

NOTE: Underlined figures represent month's effluent which does not meet Federal Regulations.

COD - 420 mg/l (avg. of two composite samples)
Total Sus. Solids - 640 mg/l
Phenols - 0.01 mg/l
Total Cr. - 0.05 mg/l
Average Daily flow in - .?2 mgd
Average daily crude oil processed - 19,000 barrels

1974.) The plan is to be implemented not later than one year after the effective date.

Navajo Refinery, because of its history of spills and because of its proximity to the Pecos River, will be required to implement a SPCC plan.

There is a provision in Section 402 of the Act whereby the authority to issue permits can be delegated to the State. The State of New Mexico has drafted Proposed Permit Regulations for the purpose of obtaining the authority to issue permits. The proposed program, if adopted, will require a discharger to comply with all State and Federal laws pertaining to Water Quality and Effluent Standards. Minimum acceptable effluent criteria which permit holders must meet or exceed on a routine basis are given in the proposed regulations. Table X is a comparison of the Navajo effluent parameters of COD, chromium, and suspended solids to equivalent proposed State permit effluent criteria. The Navajo effluent falls short of meeting the proposed regulations.

The State standard definition for water addresses all water situated within the borders of New Mexico both surface or subsurface. Thus, any percolation into the groundwater at the Navajo Refinery would be subject to these regulations.

VI. IMPROVEMENTS TO THE TREATMENT SYSTEM

The preceding sections have served to illustrate the need and the obligation of the owners of Navajo Refinery to improve their wastewater treatment system. The refinery owners are aware of the shortcomings of their system and realize something must be done. The following discussions explore some of the alternatives for improvement.

The refinery personnel have suggested a deep disposal well as a solution to their wastewater problem. It is stated in the Act and the proposed State Regulations that a deep disposal well can only be used to dispose of waters generated in the production of crude oil or gas. Both regulations define a well as a point source. Thus, a disposal well cannot be used to dispose of refinery wastewaters.

Much could be accomplished in improving the Navajo wastewater treatment system if the cooling tower and boiler blowdown water were segregated from the process water. Boiler blowdown and cooling water amounts to 68 per cent of the entire refinery wastewater flow. Depending on the quality, these waters could possibly be discharged without further treatment. The separation technique is used routinely throughout the industry.

Another method routinely used is removal and recovery of oil solids from process water by flotation. Tiny air bubbles are introduced into a tank through which the wastewater is continuously fed. As the bubbles rise to the surface, they carry the emulsified oil solids with them to form a scum on the surface. The scum is skimmed off the surface and sent back through the refining process. This process can be very effective. If the cooling tower waters are initially segregated, a correspondingly smaller flotation unit could be used.

The effluent ditch is totally unacceptable. In its present form, it is a very real source of pollution of surface or groundwater through either percolation into the soil or spills. The ditch must be replaced with a lined channel or a pipeline. A force main from the plant to the wastewater treatment area may be the most economical method, especially if the flows are reduced as described earlier.

TABLE X

COMPARISON OF NAVAJO REFINERY LAGOON 2
EFFLUENT DATA TO PROPOSED
NEW MEXICO PERMITS PROGRAM CRITERIA

Paramenter	Units	Lagoon 2 Effluent	N. M. Permit Criteria
BOD	mg/l		30
COD	mg/l	420	125
Suspended Solids	mg/l	640	30
Settleable Solids	ml/l		0.2
Fecal Coliform	*		200
PH	none		6-9
Arsenic	mg/l		0.05
Barium	mg/l		1.0
Boron	mg/l		0.25
Cadmium	mg/l		0.01
Chromium (total)	mg/l	0.05	0.01
Copper	mg/l		0.05
Lead	mg/l	0.23	0.05
Manganese	mg/l		0.1
Mercury	mg/l		0.001
Molybdenum	mg/l		0.01
Nickel	mg/l		0.1
Selenium	mg/l		0.01
Silver	mg/l		0.05
Zinc	mg/l		0.01

*Microorganisms/100 ml

The present lagoon system is unacceptable. If a total retention system is to be used, the present lagoons should be replaced with properly lined lagoons. If the cooling tower water is separated from the wastewater, approximately 20 acres of surface area would be required. The present lagoons have a surface area of 32 acres.

Other forms of treatment may be feasible. Several types of treatment are used in oil refinery wastewater treatment and are considered to be "best practicable treatment" methods. These processes include initial solids and oil removal using clarifiers, dissolved air flotation or filters, activated sludge, trickling filters, activiated carbon, filters, (sand, dual media or multimedia) or various combinations of these processes.

ACKNOWLEDGEMENT

I wish to thank the Personnel of the Navajo Refinery for their cooperation and assistance during the evaluation.

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APPENDIX A. CALCULATIONS

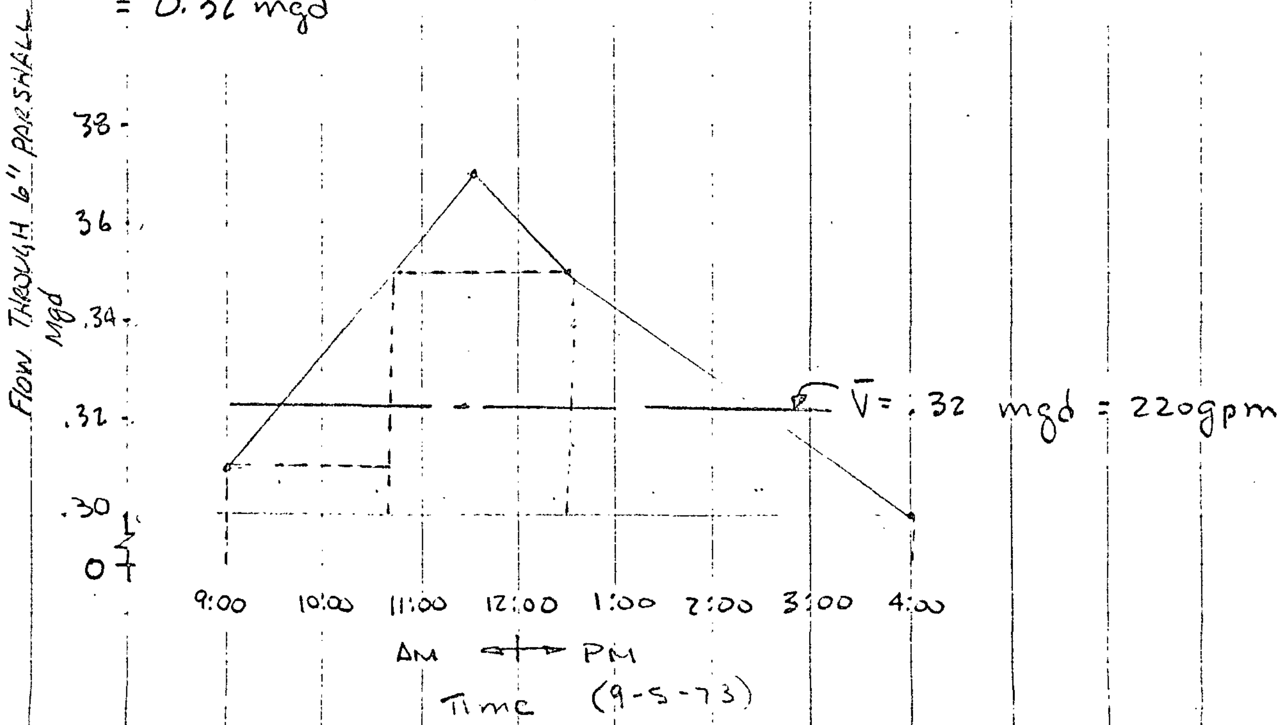
EWB
9-9-73

Navajo Refinery Flow Readings 9-5-73 (Ref figure 5)

Reading	Flume width (in.)	Ht (ft)	Time	flow mgd	flow gpm
1	6	0.40	9:00 AM	.31	220
2	3	0.16	9:45	.04	30
3	3	0.16	11:00	.04	30
4	6	0.45	11:35	.37	260
5	6	0.430	12:30 PM	.35	240
6	3	0.16	3:00	.04	30
7	6	0.39	4:35	.30	210

$$\bar{V} = .3 + .01 \times \frac{\left(1.33 \times \frac{5 \times 7}{2} + 2.5 \times 3.8 \times 5 + 5.7 \times \frac{3.8 \times 2}{2} + 2.33 \times \frac{3.4 \times 4}{2} + .5 \times 3.4 \times 1\right)}{\frac{5 \times 7}{2} + 3.8 \times 5 + \frac{3.8 \times 2}{2} + \frac{3.4 \times 4}{2} + 3.4 \times 1}$$

$= 0.32$ mgd



Thus $\bar{V}_{in}$ = .32 mgd, = 223gpm
V_{out} = .04 mgd = 28 gpm

Navajo Refinery Flow Calculations

Evaporation, Lagoon 1, 2, outfall ditch

Gross annual lake evaporation from SCS map M7-0-22432 for region 4 miles east of Artesia

Lake Evap = 80 in/yr

Pan evaporation for Lake Avalon from N.M. State Engr Tech Report 31

Annual Pan = 110.1
August Pan = 12.4
Sept pan = 9.7
Aug/sept avg = 11.6"

Aug/sept % of Annual = 11.6/110.1 · 100 = 10.5%

Then daily lake evaporation around the first of Sept is

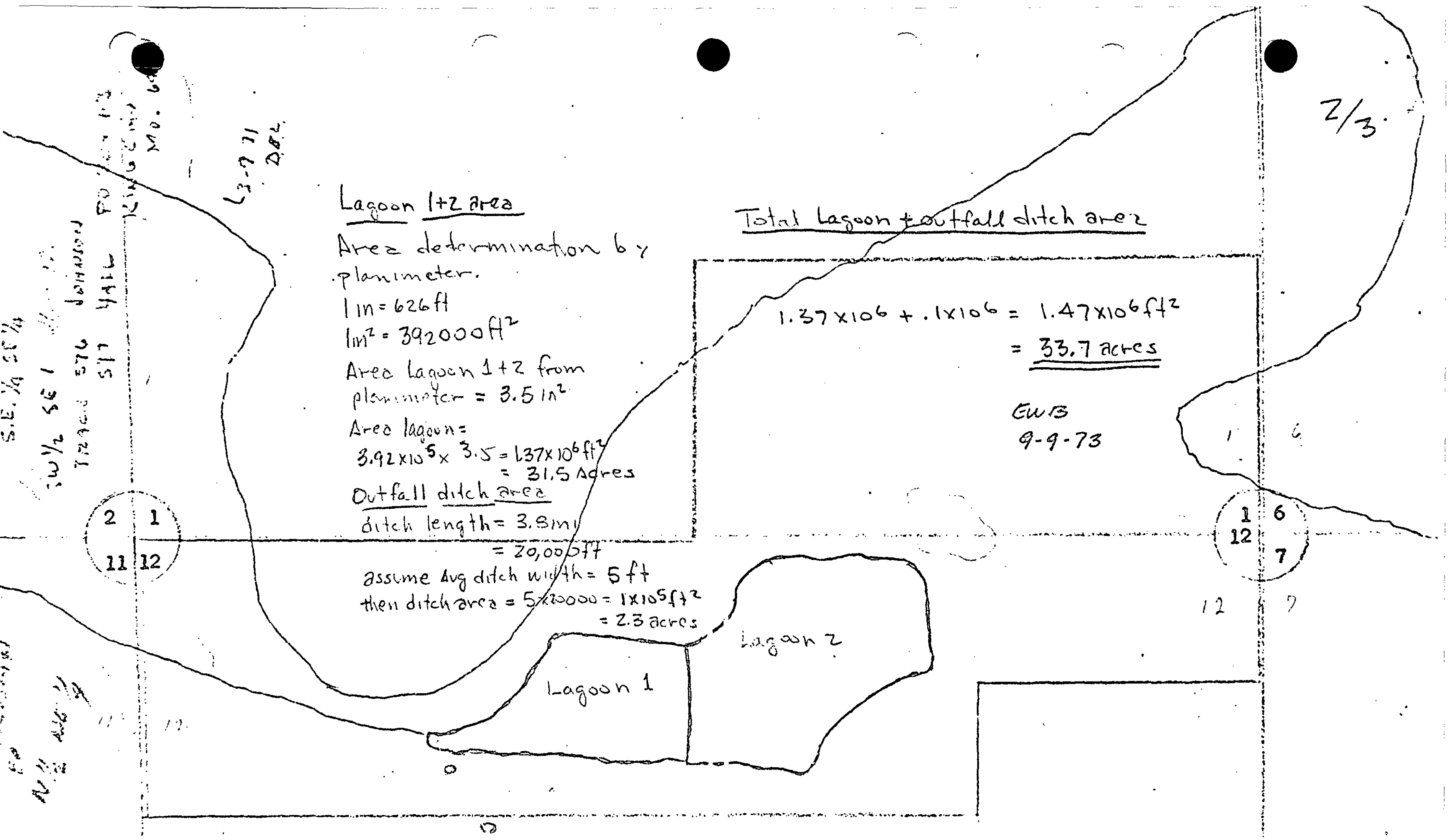
$$0.105 \times 80\text{ in} \times \frac{1\text{ ft}}{12\text{ in}} \times \frac{1\text{ mo}}{31\text{ day}} = 0.022\text{ ft/day}$$

Lagoon-ditch area from 2/3 = 1470000 ft²

Then daily evap = $1.47 \times 10^6\ ft^2 \times 0.022\ ft/day \times 7.48\ \frac{gal}{ft^3} \times \frac{1}{1 \times 10^6}$

= .240 mgd

= 168 gpm



Lagoon 1+2 area

Area determination by planimeter.

1 in = 626 ft

1 in² = 392000 ft²

Area Lagoon 1+2 from planimeter = 3.5 in²

Area lagoon = 3.92×10⁵ × 3.5 = 1.37×10⁶ ft² = 31.5 Acres

Outfall ditch area

ditch length = 3.8 mi = 20,000 ft

assume Avg ditch width = 5 ft

then ditch area = 5×20000 = 1×10⁵ ft² = 2.3 acres

Total Lagoon + outfall ditch area

1.37×10⁶ + .1×10⁶ = 1.47×10⁶ ft² = **33.7 acres**

EWB
9-9-73

The land inclosed within the red line is jointly owned by New Mexico Asphalt and Refining Co. and Continental Oil Co. This land is:

1.	$N\frac{1}{2}$, $NW\frac{1}{4}$ Sec 12 T17S, R26E	80 acres
2.	$NW\frac{1}{4}$, $NE\frac{1}{4}$ Sec 12 T17S, R26E	40 acres
3.	$N\frac{1}{2}$, $NE\frac{1}{4}$, $NE\frac{1}{4}$ Sec 12 T17S, R26E	20 acres
4.	$S\frac{1}{2}$, $NE\frac{1}{4}$ Sec 1 T17S, R26E	80 acres
		220 acres

Navajo Refinery Calculations

Percolation = Lagoon 1, 2, outfall ditch

Percolation = flow in − (flow out + evaporation)

= 223 − (28 + 168) = 27 gpm

use 30 in calculations

EWB
8-20-73

Flood Calculations

Pecos River gaging station data (1)

Datum elev 3291.05 (Sta 3965)
Height above datum recorded for Sept 1941 flood = 13.32' (peak)
Elevation at flood = 3291.05+13.32 = 3304.37

Cottonwood Creek gaging station data (1)

Datum elevation corrected = 3316.3 - 1.5' = 3314.8
Height above datum recorded by USGS during Sept 1941 flood (peak) = 11.72'
Cottonwood Creek elevation at flood = 3314.8 + 11.72 = 3326.52

Δ elev = 3326.52 - 3304.37 = 22.15'

Distance from Cottonwood Creek Gaging Sta to Sta 3965 = 30380' (2,3)
Distance from Pecos River Gaging Station to Center lagoon #1 = 6500' (3)

Estimated elev of Sept 1941 flood at center lagoon #1

$$\left[\frac{6500}{30380} \times 22.15\right] + 3304.37 = 3309.11$$

Difference in elevation between lagoon location and Sta 3965

3309.11 - 3304.37 = 4.73' ⟵ use for adjusting flood elevations from Sta 3965 to lagoon site.

(3) USGS Map "Artesia NE Quadrangle" 1955
(2) USGS Map "Spring Lake Quadrangle", 1955
(1) Lewis Reiland, USGS Santa Fe N.M. Office 7-25-73

DM4
11/30/73

Conversion to EPA Effluent
Quality Limitations Units

	Sept 5
flow	.043
Cod	8.0
Susp Sol	12.
Total Phen	.0002
Total Cr	.0009

*Conversion factor:

lb/1000bbl/day = (mg/l)(mgd)(.439)

	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
flow (gpm)	130	100	50	10	—	—	—	10	40	90	120	130
(mgd)	.18	.13	.07	.01				.01	.06	.13	.17	.19
COD = 420 mg/l (lb/1000bbl/day)	33	24	13	2				2	11	24	31	35
T. Susp. Sol. = 640 mg/l (lb/1000bbl/day)	50	37	20	3				3	17	37	48	53
phenols = .01 mg/l (lb/1000bbl/day)	<.001	<.001	<.001	<.001				<.001	<.001	<.001	<.001	<.001
Total Cr = .05 mg/l (lb/1000bbl/day)	<.01	<.01	<.01	<.01				<.01	<.01	<.01	<.01	<.01

Given: 19-1000 barrels/day of crude oil

Req'd: Convert parameter loading (mg/l) to EPA Effluent Quality Limitation Units (lbs/1000 barrel of crude/day)

$$\text{*Conversion factor} = \text{lbs}/1000\text{bbl}/\text{day} = (\text{mg}/l)\left(\frac{8.34\ \text{lb/gal}}{10^6\ \text{mg}/l}\right)(\text{mgd})\left(\frac{1}{19\cdot 1000\text{bbl}}\right)$$

$$= (\text{mg}/l)(\text{mgd})(.439)$$

DMF
11/30/73

Estimation of Flow-out

Jan. Daily Average

Gross annual lake evaporation from SCS map M7-0-22432 for region east of Artesia near lagoons = 80"/yr

Pan evaporation for Jan. and annual pan evaporation from N.M. State Engr. Tech Report 31 page 18 for Lake Avalon (15 mi north of Artesia)

Annual Pan evap = 110.1"
Jan. Pan evap = 4.2"

Ratio of annual lake evaporation to annual pan evaporation:

$R = 80"/yr \div 110.1"/yr = 0.73 = 73\%$

∴ Avg daily evap for month of January is equal to:

$0.73 \times 4.2" \times 1/12" \times 1 mo/31 day = 8.2 \times 10^{-3}$ ft/day lake evap.

From previous calculations by EWB percolation ≈ 30 gpm

∴ flow-in = flow-out + evaporation + percolation

lagoon area = 1,470,000 ft^2 = 33.7 acres

daily evap. = $1.47 \times 10^6 ft^2 \times 0.0082$ ft/day 7.48 gal/ft^3 = .090 mgd
= 60 gpm

Flow-in = 220 gpm

∴ flow-out = flow-in − (evap. + perc)
= 220 − (60 + 30) = = 130 gpm
= .18 mgd

D.[illegible]
11-30-73

Estimation of flow-out

Feb. Daily Avg

Pan evaporation for Feb. (from previous quoted source)

Feb. pan evap = 5.8"

R = 0.73 (from before)

∴ Avg daily evap for month of February is equal to:

$0.73 \times 5.8" \times 1/12" \times 1\,mo/28\,day = .013\ ft/day$ lake evap

daily evap $= \frac{1.47\times10^6}{1\times10^6} ft^2 \times .013 ft/day \times 7.48\ gal/ft^3 = .14\ mgd$
$= 100\ gpm$

∴ flow-out = 220 - (100+30) = 90 gpm
= .13 mgd

March Daily Avg

Pan evaporation for March = 9.2"

R = 0.73 (from before)

∴ Avg daily evap for month of March is equal to:

$0.73 \times 9.2" \times 1/12" \times 1\,mo/31\,days = .018\ ft/day$ lake evap

daily evap $= \frac{1.47\times10^6}{1\times10^6} ft^2 \times .018\ ft/day \times 7.48\ gal/ft^3 = .20\ mgd$
$= 140\ gpm$

∴ flow-out = 220 gpm - (140+30) = 50 gpm
= 0.07 mgd

0114
11/30/73

Estimation of flow-out

April Daily Avg

Pan evaporation for April = 11.8"

R = 0.73

∴ Avg daily evap for month of April is equal to:

$0.73 \times 11.8'' \times 1/12'' \times \frac{1\ mo}{30\ days} = .024\ ft/day$ lake evap

daily evap = $\frac{1.47 \times 10^6 ft^2}{1 \times 10^6} \times 0.024\ ft/day \times 7.48\ gal/ft^3 = 0.26$ mgd
= 180 gpm

∴ flow-out = 220 gpm − (180+30) = 10 gpm ←
= .01 mgd

May Daily Avg

Pan evaporation for May = 14.0"

R = 0.73

∴ Avg daily evap for month of May is equal to:

$0.73 \times 14.0'' \times 1'/12'' \times \frac{1\ mo}{31\ days} = .027\ ft/day$ lake evap.

daily evap = $\frac{1.47 \times 10^6 ft^2}{1 \times 10^6} \times .027\ ft/day \times 7.48\ gal/ft^3 = .30$ mgd
= 210 gpm

∴ flow-out = 220 gpm − (210+30) = −20 gpm (0 discharge) ←

June Daily Avg

Pan evaporation for June = 14.8"

flow-out due to evaporation and percolation > flow-in ∴ no effluent for June

DN17
11/30/73

Estimation of flow-out

July Daily Avg

Pan evaporation for July = 13.1"

R = 0.73

∴ Avg daily evap for month of July is equal to:

$0.73 \times 13.1'' \times 1'/12'' \times 1\,mo/31\,days = .026\ ft/day$ lake evap

daily evap $= 1.47 \times 10^6\ ft^2 \times 0.026\ ft/day \times 7.48\ gal/ft^3 = .28\ mgd$
$= 200\ gpm$

∴ flow-out = 220 gpm − (200+30) = −10 (no discharge)

Aug. Daily Avg

Pan evaporation for Aug. = 12.4"

R = 0.73

∴ Avg daily evap for month of Aug is equal to:

$0.73 \times 12.4'' \times 1'/12'' \times 1\,mo/31\,days = .024\ ft/day$ lake evap.

daily evap. $= 1.47 \times 10^6\ ft^2 \times .024\ ft/day \times 7.48\ gal/ft^3 = .26\ mgd$
$= 180\ gpm$

∴ flow-out = 220 gpm − (180+30) = 10 gpm ←
.01 mgd

GML
11/30/73

Estimation of flow-out

Sept. Daily Avg.

Pan evaporation for Sept. = 9.7"

$R = .73$

∴ Avg daily evap. for month of Sept is equal to:

$0.73 \times 9.7'' \times 1'/12'' \times 1\,mo/30\,day = .020$ ft/day Lake evap

daily evap $= 1.47 \times 10^6\ ft^2 \times .020\,ft/day \times 7.48\,gal/ft^3 = .22$ mgd
$= 150$ gpm

∴ flow-out $= 220\,gpm - (150 + 30) = 40$ gpm
$= 0.06$ mgd ←

Oct. Daily Avg.

Pan evaporation for Oct. = 7.0"

$R = .73$

∴ Avg daily evap. for month of Oct. is equal to:

$0.73 \times 7.0'' \times 1'/12'' \times 1\,mo/31\,day = .014$ ft/day lake evap

daily evap. $= 1.47 \times 10^6\ ft^2 \times .014\,ft/day \times 7.48\,ft^3/day = .15$ mgd
$= 100$ gpm

∴ flow-out $= 220\,gpm - (100 + 30) = 90$ gpm
$= .13$ mgd

DM 7
11/30/73

Estimation of flow-out

Nov. Daily Avg

Pan evaporation for month of Nov = 4.5"

R = .73

∴ Avg daily evap. for month of Nov. is equal to:

$.73 \times 4.5'' \times 1'/12'' \times 1mo/30day = .0091$ ft/day lake evap.

daily evap = $1.47 \times 10^6 ft^2 \times .0091 ft/day \times 7.48 gal/ft^3 = .10$ mgd
= 70 gpm

∴ flow-out = 220 gpm − (70 + 30) = 120 gpm
= 0.17 mg

Dec. Daily Avg

Pan evaporation for month of Dec = 3.8"

R = .73

∴ Avg daily evap. for month of Dec. is equal to:

$.73 \times 3.8'' \times 1'/12'' \times 1mo/31day = .0075$ ft/day lake evap.

daily evap = $1.47 \times 10^6 ft^2 \times .0075 ft/day \times 7.48 gal/ft^3 = .08$ mgd
= 60 gpm

∴ flow-out = 220 gpm − (60 gpm + 30 gpm) = 130 gpm
= .16 mgd

APPENDIX B, PHOTOGRAPHS

REFERENCE FIGURE I
For Key to Lettered Locations

API Oil-Water Separator at
South Plant
(Location A)

API Oil-Water Separator at
South Plant
(Location A)

Six-inch Parshall Flume
Looking Upstream
(Location B)

Six-inch Parshall Flume
Looking Downstream
(Location B)

REFERENCE FIGURE I
For Key to Lettered Locations

Effluent Ditch Looking West
(Upstream)
(Location C)

Effluent Ditch looking Northwest
(Upstream)
(Location D)

Area Adjacent to Effluent Ditch
Where Overflow has Occurred
(Location E)

Effluent Dtich Looking Southwest
(Upstream) Catalytic Cracking Tower
at Refinery is in Background
(Location E)

REFERENCE FIGURE I
For Key to Lettered Locations

Effluent Ditch Looking Northeast
(downstream)
(Location E)

Artesia Sewage Treatment Plant Effluent
Going to Farm
(Looking Southwest) (Location F)

Effluent Ditch Looking Southwest
(upstream)
(Location G)

Effluent Ditch Looking Southeast (down-
stream)(Ditch is elevated in this area.
There was evidence of Ditch overflows here.
(Location H)

REFERENCE FIGURE I
For Key to Lettered Locations

Crossover Where December, 1972
Spill Occurred
(Location I)

Irrigation Ditch and Effluent Ditch
(behind fence) Running Parallel
(Location I)

Diversion in Effluent Ditch Looking
Northwest (upstream). There was evidence of overflows here.
(Location K)

REFERENCE FIGURE I
For Key to Lettered Locations

Composite Photo Lagoon Number One
From Southeast Corner
(Location L)

REFERENCE FIGURE I
For Key to Lettered Locations

Composite Sampler set up on Effluent From Number Two Lagoon. (Location M) Looking Southwest

Evaporation-Percolation Bed (Lagoon #3) (Location N) Looking Southwest

Refinery Effluent in Imhoff Cones (Location B)


U.S. HIGHWAY 285
N
CITY of ARTESIA
LOCATION OF 6 IN. PARSHALL FLUME # 1
REFINERY WASTEWATER EFFLUENT LINE AND DITCHES
NAVAJO REFINERY North Plant
South Plant
EAGLE DRAW DRAINAGE DITCH
REFINERY WASTEWATER EFFLUENT DITCH TO LAGOONS
TREATED SEWAGE OUTFALL LINE
ARTESIA SEWAGE TREATMENT PLANT
ditch ends
FARM IRRIGATION DITCH
NATURAL EAGLE DRAW DITCH
LOCATION OF REFINERY EFFLUENT SPILL 12-72
LOCATION, 6 IN. PARSHALL FLUME # 2
PECOS RIVER
BOUNDARY OF LAGOON AREA. PROPERTY OWNED BY NAVAJO REFINERY
GROUND WATER TEST HOLE # 1 W.L. Elev. 3300.2
GROUND WATER TEST HOLE # 2 W.L. Elev 3300.7
LAGOON # 3 W.L. 3305.3
GROUND WATER TEST HOLE # 3
LOCATION, 3 IN. PARSHALL FLUME
3313.4
3310.2
3310.4
3310.4
3311.8
LAGOON # 2. W.L. 3307.1
3311.2
LAGOON # 1. W.L. 3308.3
3310.3
STOCK WELL
3310.2
3310.8
NOTE: Elevations shown around edge of lagoons were taken at top of lagoon embankments.
U.S. HIGHWAY 82
USGS MARKER P-257 Elev 3313.40 (Marker located S.E. corner of bridge)
USGS GAGING STATION NUMBER 3965 Datum Elev 3291.05
PECOS RIVER
NAVAJO REFINERY WASTEWATER TREATMENT FACILITIES
FIGURE 1
SCALE: 1" = 700'
DRAWN: E.W.B.
N.M.E.I.A. 8-18-73