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WORK PLANS

1977

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September 30, 1977

Mr. William Hagler
Vice President of Marketing
Plateau, Inc.
Post Office Box 108
Farmington, New Mexico 87401

Dear Mr. Hagler:

American Ground Water Consultants has the pleasure to submit herewith our report entitled: Discharge and Monitoring Plan for a Refinery Operated by Plateau, Inc. near Bloomfield, New Mexico.

This document has been prepared to support Plateau's application to the New Mexico Oil Conservation Commission for a permit to discharge waste water from their refinery at Bloomfield, New Mexico.

It has been a privelege serving Plateau in this matter.

Sincerely,

William M. Turner

Dr. William M. Turner
President

WMT:ajs

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1	Correspondance relating to the discharge plan.
2	Well record for the Amoco-Davis Gas Unit F-1 gas well.
3	Lithologic logs for several of the Neutron-Probe Access Holes.
4	Information pertinent to the section of the Hammond ditch passing adjacent to the Plateau refinery.
5	Thermodynamic considerations for determination of waste-water concentration factors necessary for salt precipitation.

SUMMARY

Plateau Inc. operates a petroleum refinery near Bloomfield, New Mexico. Process water for the refinery is obtained directly from the San Juan River. After use in the plant, waste water will be discharged into two solar evaporation ponds totaling approximately five acres in surface area. The estimated rate of waste water discharge is 29,540 gallons per day. It is estimated that the waste water will contain about 4961 milligrams per litre of total dissolved solids.

The solar evaporation ponds are constructed in silt deposits which overlie cobble deposits which in turn overlie an ancient errosional surface developed upon the Nacimiento Formation of Tertiary age. Field investigation indicates that the shale of the Nacimiento Formation is for all intents and purposes impermeable to the downward percolation of water. The bottoms of the solar evaporation ponds have been lined with Wyoming bentonite applied at the rate of about two pounds per square foot of surface area both to the pond bottoms and the sides of the evaporation ponds. The bentonite has not been mixed with the underlying soils. It is overlain by fine-grained borrow material and the bottoms and sides have been compacted with a sheepsfoot roller.

In the event of direct discharge of the plant effluent into either the San Juan River, or the Hammond Ditch which circumvents the the refinery property, the resulting deterioration of the San Juan River water or the Hammond ditch water will be hardly detectable because of the significant level of dilution that will occur.

Based upon the present analysis, it is apparent that precipitation of

dissolved solids will occur thereby providing an additional sealing mechanism. Evaporation and resulting precipitation of dissolved substances will be enhanced by the operation of a spray system which will be constructed peripheral to the evaporation ponds.

To verify the integrity of the pond liner, a monitoring system has been established. The monitoring methodologies include, neutron logging, Thermonics, Zeta-SP, and flourocarbon tracers. Baseline data has already been acquired and a thorough review of all data will be made periodically. The results of data analysis will be submitted to the New Mexico Oil Conservation Commission.

INTRODUCTION

Background

With the promulgation of regulations by the New Mexico Water Quality Control Commission (NMWQCC) entitled: Regulations for Discharges onto or below the Surface of the Ground, no person shall cause or allow effluent or leachate to discharge so that it may move directly or indirectly into ground water unless he is discharging pursuant to a discharge plan approved by the director of the New Mexico Environmental Improvement Agency (NMEIA) or, for dischargers who are involved in the production, transport, and refining of petroleum, the director of the New Mexico Oil Conservation Commission (NMOCC).

The discharge plan shall set forth the methods or processes which the discharger proposes to use or which are expected to occur naturally which will ensure that the quality of the receiving ground water will not be degraded below the standards set forth in Section 3-103 of the regulations. ? To ensure compliance with the regulation, each application for a discharge permit shall indicate suitable monitoring and surveillance methods which the discharger intends to employ.

Present Situation

On April 29, 1977, Plateau, Inc., as a refiner of petroleum, notified the director of the NMOCC in accordance with Section 1-201(A) of the regulations of their intention to make a new contaminatn discharge. Information required by Section 1-201(B) was provided in the letter of notification and subsequent correspondence relating to the notice is included in Attachment 1.

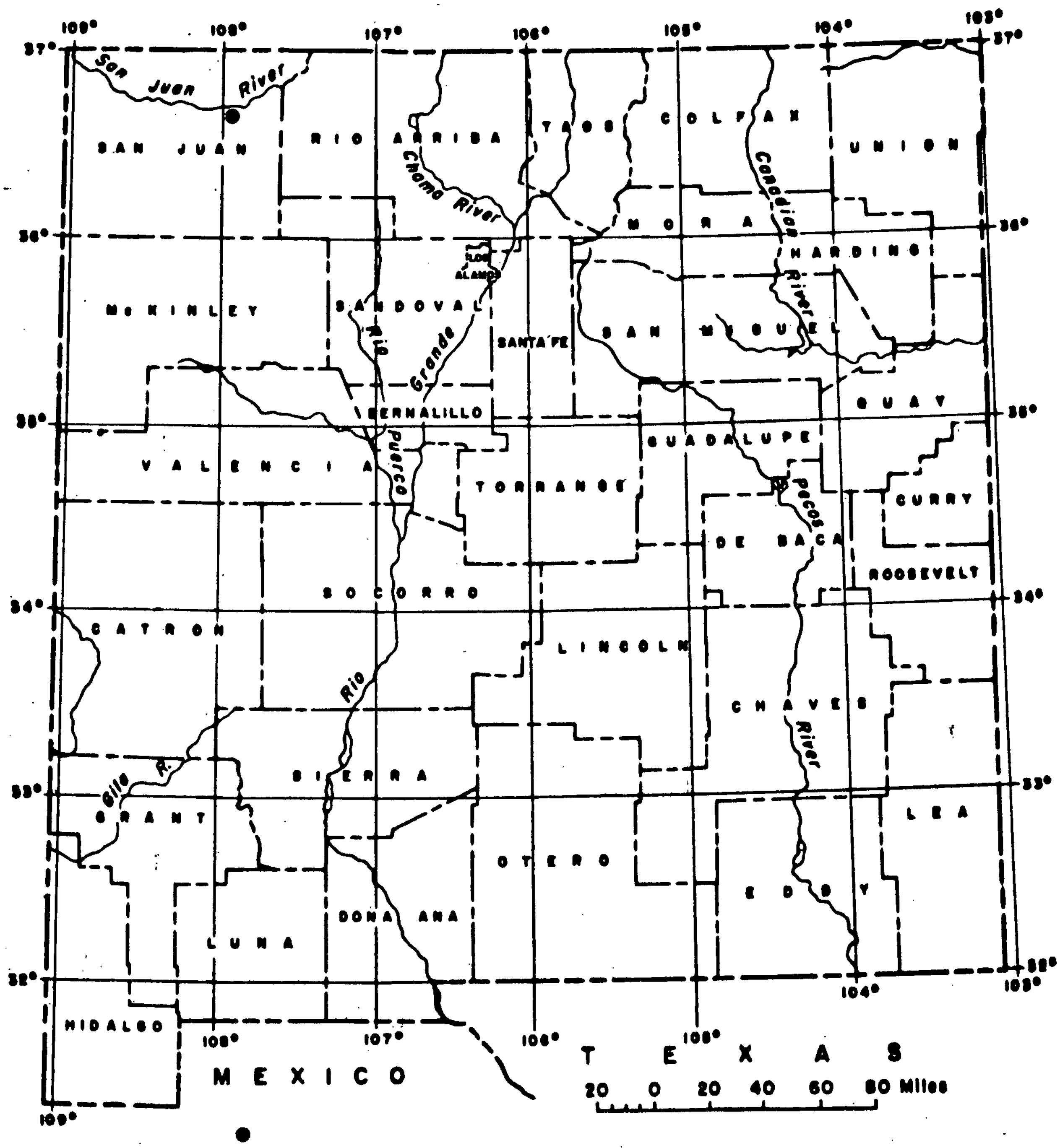

Figure 1. Map showing the location of the project area.

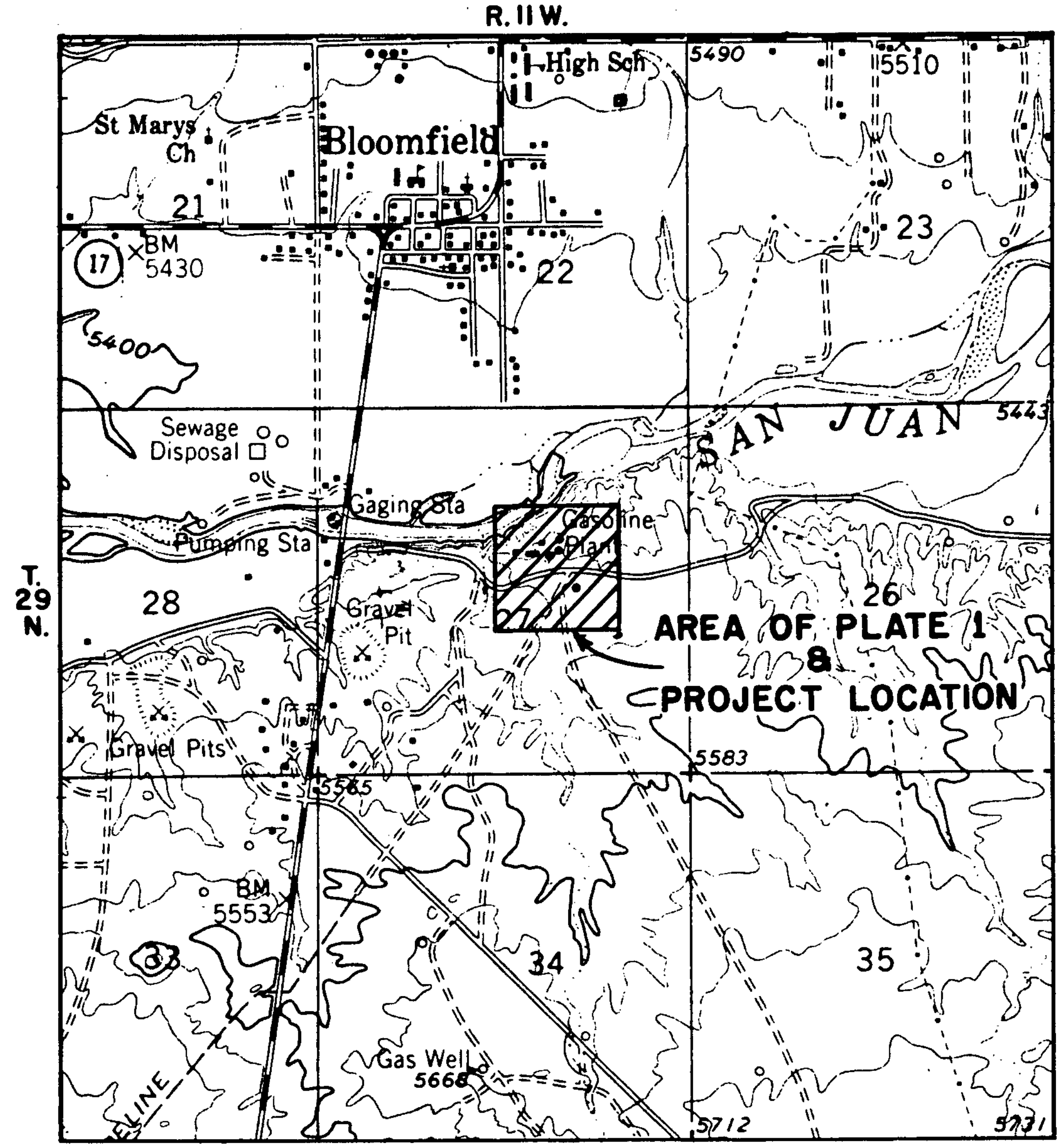

Figure 2. Diagram showing the location of the Plateau Refinery near Bloomfield, New Mexico.

Location and Physiographic Setting

The Plateau refinery is located in the NE 1/4 of Sec. 27, of T. 29 N., R. 11 W. approximately one mile south of Bloomfield, New Mexico. The location of the refinery is shown in figures 1 and 2.

The refinery is situated on an old terrace of the San Juan River approximately 120 feet above the present level of the river. Where the San Juan River passes the refinery, the land surface rises precipitously to the elevation of the river terrace on which the plant is located. At its closest, the refinery is about 500 feet from the river. The setting of the refinery is shown in figure 3 and 4.

The terrace on which the plant is situated has a slightly undulose surface created by intermittent stream channels which drain to the north. The intermittent stream channels are in the process of adjusting to the local base level of the San Juan River and headward erosion is taking place in these intermittent channels. Due north of the plant, the knickpoints in the intermittent channel profiles are generally less than 100 feet from the river and indicate that the surface runoff in channels is from small catchment areas. East of the plant headward erosion of north-flowing intermittent stream channels has progressed further because of the substantially larger surface water catchment areas.

Modification of the land surface at the refinery will prevent surface water runoff from flowing into the channels directly north of the plant, thereby halting headward erosion towards the plant site. — 8

Figure 3. View of the Plateau Refinery situated above the Jackson Lake Terrace. View is to the southeast with the floodplain of the San Juan River in the foreground.

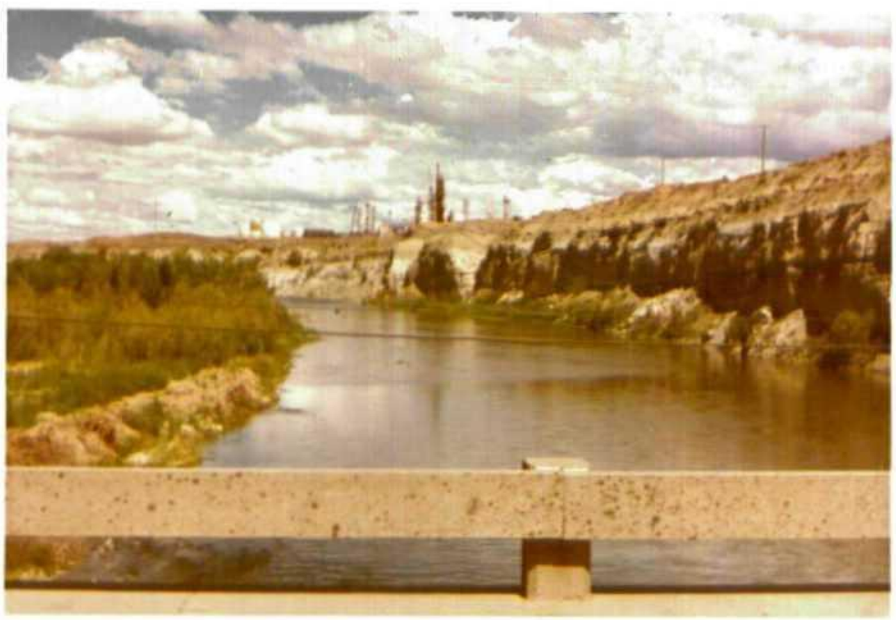

Figure 4. View of the Plateau Refinery situated on the Jackson Lake Terrace. The Nacimiento Formation of Tertiary age overlain by Pleistocene cobble and silt deposits are exposed in the scarp adjacent to the San Juan River. View is to the east looking upstream.

East of the plant site the land surface rises gradually at the rate of about 120 feet per mile.

Geologic Setting

The area of interest occurs within the San Juan structural basin of northwest New Mexico, and more specifically within that smaller part of the basin which received a thick blanket of continental and marine sediment during the Tertiary period. The stratigraphic section encountered in the AMOCO-Davis Gas Unit F-1, which is located near the Plateau truck maintenance facility is given in attachment 2 together with other pertinent information on the well. The location of the AMOCO-Davis Gas Unit F-1 gas well is shown in plate 1 (in pocket).

The Plateau refinery is situated on the Jackson Lake terrace (Pastuzak, 1968) which was formed during the Pleistocene by downcutting of a former valley floor which had been aggraded with cobble and gravel deposits during the last glacial advance. At that time the San Juan River was swollen with meltwater and carried great quantities of glaciofluvial outwash. The Jackson Lake terrace is about 100 feet above the present valley floor and in former times comprised a flood plain three to five miles wide.

During the last glacial retreat, wind-blown sand and silt from the floodplains settled over the coarse clastics to form structurless loess deposits.

The glaciofluvial terrace deposits at the Plateau Refinery consist primarily of a bed of cobble directly overlying the Nacimiento Formation of Tertiary age. The cobble bed is in turn overlain by and interfingers somewhat with fine-grained loess deposits. To the south, within one-half mile of the plant, the cobble bed wedges out leaving only the loess deposits.

The total thickness of Quaternary terrace alluvium is about 30 feet. At the edge of the scarp adjacent to the San Juan River, and in the bore holes drilled through the Quaternary alluvium at the location of the solar evaporation pond, the cobble bed is about 15 feet thick. One-half mile to the southwest a laterally continuous gravel bed is only several feet thick. At the gravel pit on the west side of section 27 the total thickness of gravel and silt is about 10 feet.

As far as can be determined, the Pleistocene cobble bed exists everywhere beneath the refinery, where it is overlain by about 20 feet of fine-grained, wind blown silt and sand. Lithologic logs for monitoring wells drilled in the vicinity of solar evaporation pond 1 are given in attachment 3. Unfortunately samples were not preserved for all of the monitoring wells which were drilled.

Beneath the Pleistocene terrace deposits occurs the massively bedded, olive green, unctuous clay of the Nacimiento Formation. At least 100 feet of this unit is exposed in the cliff face north of the refinery and adjacent to the San Juan River. The clay at the outcrop is a tight unfractured rock unit. The best exposures of the Nacimiento Formation are in the badlands of nearby Kutz Canyon.

The present-day channel of the San Juan River is incised into the Nacimiento Formation, and younger alluvial material occupies the present river channel.

Figure 3 through 6 show the Tertiary and Quaternary stratigraphy in the vicinity of the plant.

HYDROLOGIC FEATURES

San Juan River

The San Juan River is the only perennial river in the vicinity of the refinery. Along the reach of the San Juan in the vicinity of the refinery, the river is neither a gaining nor a losing stream. Its alluvium-filled channel is incised into relatively impermeable clay of the Nacimiento Formation. The flow of the San Juan River at Bloomfield is regulated by the Navajo Dam. The usual low flow of the river is presently 500 cfs. In cases of emergency, such as drownings, the flow may be reduced to 250 cfs for several hours. (Wayne Everett, Personal Communications)

Figure 5. Photograph showing a small valley formed by headward erosion back into the Pleistocene cobble of the Jackson Lake Terrace. Vegetation in the picture is supported by leakage from the Hammond ditch which is cut into the Pleistocene deposits just beyond the head of the valley.

Figure 6. View of solar evaporation pond #1, taken shortly after the pond was filled with fresh water. The silt of the Jackson Lake Terrace forms the pond embankments.

Hammond Ditch

In addition to the San Juan River and the intermittent stream channels which traverse the area of interest, the Hammond Irrigation ditch passes immediately adjacent to the northern boundary of the refinery property. The Hammond ditch traverses the Quaternary river terrace from east to west as a system of unlined ditches, tunnels and inverted siphons. Figure 7 shows the Hammond ditch system. Attachment 4 shows details of the Hammond ditch in the vicinity of the refinery.

The Hammond ditch conveys water only during the irrigation season from mid-May to early October. The reach of the ditch which passes the refinery is excavated into the cobble bed mentioned above. Although attempts have been made by the Hammond Conservancy District to line the ditch with silt from local borrow pits, leakage from the ditch and into the cobble bed is significant. The valleys of nearly all intermittent stream channels which descend from the Quaternary terrace south of the San Juan River are choked with trees, bullrushes, marsh grass and other vegetation. The source of the water which supports the vegatation is leakage through the bed of the Hammond ditch where it crosses the channels of the intermittent streams. Figure 5 and figures 8 through 11 show the ditch near the refinery and areas of leakage from the ditch.

As may be expected, the Hammond ditch acts as a constant-head, line source, and infiltrating water flows to the south in the cobble bed also.

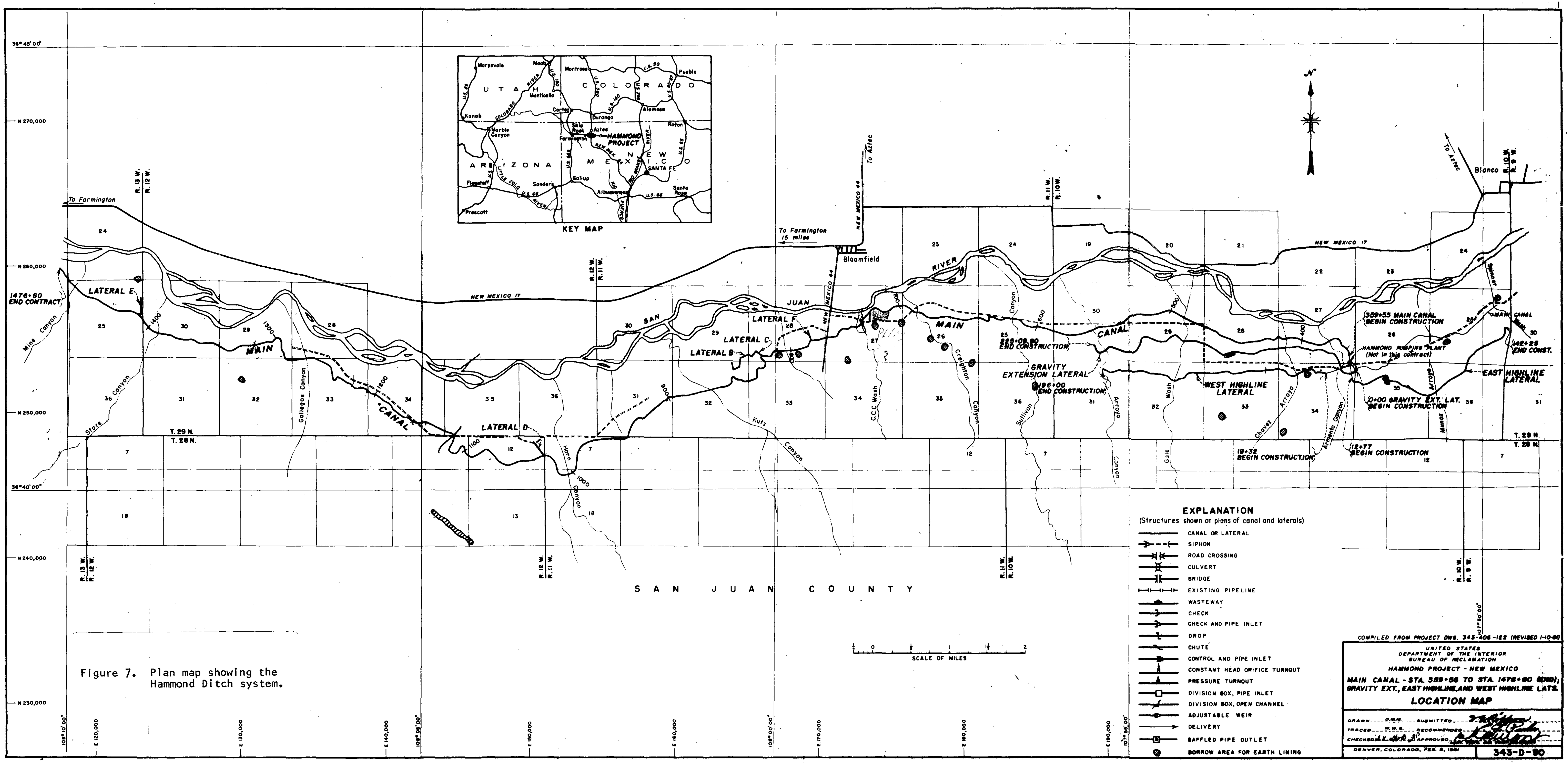

Figure 7. Plan map showing the Hammond Ditch system.

Figure 8. View of the Hammond ditch immediately north of solar evaporation pond #1. Note that the spoil piles on the right hand side of the ditch are primarily comprised of cobble. The spoil piles rest above undisturbed silt.

Figure 9. View of the Hammond ditch immediately west of the Plateau Refinery. The dense vegetation to the right of the ditch is supported by leakage from the ditch.

Figure 10. View to the west immediately north of solar evaporation pond #1 showing leakage from the Hammond ditch. The ditch runs from left to right through the photograph but is hidden by the spoil pile on its right bank. Note the cobble in the spoil pile.

Figure 11. The Hammond ditch is excavated into the terrace in the background and passes directly behind the large tree. The tree is supported by leakage from the ditch.

Observation wells which have been constructed in the vicinity of the solar evaporation ponds indicates that the cobble bed contains some water It is likely that this bank storage will eventually flow back into the ditch when diversion is terminated at the end of the irrigation season.

That the Nacimiento Formation is quite impermeable is demonstrated by the occurrence of ground water seeps at the contact between the cobble bed and the Nacimiento Formation. Commonly it will appear as though water is seeping from the Nacimiento Formation itself well below the contact with the cobble bed. Close examination shows that the seep occurs from a thin regolith of more permeable altered Nacimiento soil. Such a seep of water is shown in figures 12 through 14. The design flow rate of the Hammond ditch at the refinery is given in attachment 4 as 45 cfs or 20,200-gpm.

THE REFINERY

The crude distillation unit can charge approximately 14,000 barrels per day of light, low sulfur crude oil and natural gas condensate produced in the Four Corners area. A three fractionator system produces fuel gas, stabilized (butane removed), light straight run gasoline (an ingredient in finished motor gasoline), naphtha (feed stock to the catalytic reformer via the naphtha hydrotreater), kerosene, diesel fuel, and reduced crude, a portion of which is charged to the fluid catalytic cracking unit (FCCU) as feed stock with the remainder marketed as heavy industrial low sulfur fuel.

Figure 12. Photograph showing gravel pit excavated in the cobble which has exposed the underlying Nacimiento Formation At the contact, oily water is seeping from the cobble bed. The occurrence is on the western side of section 27, T. 29 N., R. 11. W. The area is upgrade on the Nacimiento subcrop from the Plateau Refinery and the oily water is not derived from refinery operations.

Figure 13. Close-up of the contact between the Pleistocene cobble and the Nacimiento Formation, shown in figure 12.

Figure 14. Close up of the contact between the Pleistocene cobble and the Nacimiento Formation shown in figures 13 and 14. The greenish Nacimiento Formation is in the lower part of the picture. View shows the seep of water at the contact.

Figure 15. View of the pump house which provides fresh river water to the Plateau Refinery.

The purpose of the FCCU is to catalytically convert the heavy, high boiling, reduced crude into lighter, more valuable products -- fuel gas, propane, butane, high octane gasoline blending components, diesel fuel or heating oil, and a small amount of fuel oil. Because these products leave the FCCU reactor section in a homogeneous mixture, the FCCU fractionation and gas concentration facilities are employed to separate this mixture into individual product streams.

The purpose of the naphtha hydrotreater unit is to remove sulfur and other impurities from feedstock to the catalytic reformer. This is necessary to protect the catalyst in the reformer. Hydrotreating is accomplished by passing heated naphtha over a cobalt-molybdenum catalyst. H_2S formed in the reaction is separated from the naptha in a fractionator tower (stripper) and sent to the fuel gas system, along with other fuel gas components.

The catalytic reformer rearranges or "reforms" the molecular structure of the naphtha feed in the presence of a catalyst to produce higher octane gasoline blending components and a stream of light hydrocarbon gases. These gases are separated from the liquid product stream by fractionation (stabilizer tower) and sent to the fuel gas system.

A 30,000 lb/hr boiler is employed in the refinery to supply 150 psi steam. This steam is used at various points in the fractionating towers to improve distillation, utilized for driving pumps, and required for heating tanks and some pipelines.

Water Use by Plant

Water used by the Plateau refinery is obtained directly from the San Juan River nearby. Figure 15 shows the pumping plant. It is stored in two fresh water retention ponds pending use. The fresh water ponds are labeled in plate 1. Water used within the refinery is almost entirely for boilers and cooling tower operations. Water is used also for wash-down operations and firefighting purposes. Water for human consumption is purchased from the City of Bloomfield.

Plate 2 (in pocket) is a schematic diagram of the flow of water through the refinery. Waste water includes blowdown from the cooling towers, water from the API separators, surface-water runoff from the plant area, and washdown water.

Oily water is channeled first to the API separator which is a concrete-lined tank. Underflow from the API separator flows to the first of two oily water ponds. Underflow from the first oily water pond then flows to a second oily water pond. Underflow from the second oily water pond will be pumped to the solar evaporation ponds for final disposal. Figures 16 and 17 show the API separation and the oily water ponds. It is estimated that total discharge of wastewater to the solar evaporation ponds will be 29,540 gallons per day.

(20GPM)

CLIMATIC FACTORS

Of prime consideration will be the ability of the ponds to evaporate the daily inflow of wastewater. The rate of evaporation of water from a standing body of water may be estimated by any of several climatologic methods. Results of several evaporation studies are given in table 1.

Table 1. Summary of evaporation data obtained by McIlroy and Angus (1964) at Aspendale, Australia during 1959, 1960, and 1961

Method used to Estimate Evaporation Rate	Evaporation Rate (mm day^{-1})				Annual Total (mm)
	Winter	Spring	Summer	Fall	
Lysimeter					
Grass (6-10 cm) . .	1.53	5.07	5.88	1.74	1,296
Wet Soil.	1.05	3.70	4.30	1.07	939
Water	1.34	4.12	5.10	1.46	1,096
Australian tank . . .	1.66	4.37	5.50	2.04	1,242
Class A pan	2.13	5.85	6.77	2.18	1,543
R/L	1.55	4.63	4.64	1.19	1,096

Figure 16. API separator at the Plateau refinery.

Figure 17. View to the south showing the two oily water ponds at the Plateau Refinery. Pond #1 is in the foreground and pond #2 is in the background. Note the silty soil in the foreground and forming the embankments of the pond.

It can be seen that the Class A Pan evaporation overestimates the evaporation rate of water from a lysimeter, whereas the R/L method (ratio of net radiation at the land surface to latent heat of vaporization of water) yields good agreement. For the Bloomfield area the average net solar radiation for January is 300 langleys per day, and for July it is about 650 langleys per day (Sellers, 1965). These values of radiation neglect the surface albedo which, for a water surface at 30 degrees north latitude, is about 9 percent in the winter and 6 percent in the summer. The evaporation may be estimated from $E = R(1-\alpha)/L$. Results of these calculations are given in table 2.

Table 2. Estimated rates of evaporation for solar evaporation ponds at the Plateau refinery near Bloomfield, New Mexico.

Period	R (langleys/day)	α %	R/L[1] (in/day)	Evaporation Rate[2] (gpm)	(gpd)
January	300	9	0.18	17.2	24,732
July	650	6	0.41	38.4	55,352

[1] L = 595 cal/gm.

[2] Solar evaporation pond area is 5 acres.

Class A Pan evaporation rates for Farmington, New Mexico, have been obtained from the U.S. Weather Service. Average Pan evaporation rates for April through October for 1975 and 1976 are given below in table 3.

Table 3. Average daily Class A Pan evaporation rates from stations at Navajo Dam and Farmington, New Mexico for the period April to October 1975 and 1976. Evaporation rates are in inches of water.

	1975		1976	
	Navajo Dam	Farmington	Navajo Dam	Farmington
April	0.168		0.208	0.234
May	0.322	0.262	0.265	0.271
June	0.312	0.290	0.363	0.344
July	0.306	0.279	0.374	0.340
August	0.297	0.274	0.272	0.271
September	0.222		0.210	0.189
October	0.171		0.155	

From an examination of tables 2 and 3 it is evident that the R/L method is in good agreement with the results obtained from a Class A Pan. For northwestern New Mexico where daily Class A Pan data is sparse the R/L method may be used.

WATER QUALITY

Table 4 are chemical analyses of water from the San Juan River and cooling tower and boiler blowdown. The composition of the mixed blowdown effluent and the standards set forth in Section 3-103 of the NMWQCC regulations are also presented in table 4. The effluent exceeds in composition nearly every item covered by the regulations. Should this effluent enter the San Juan River or water in the Hammond ditch in large quantities, contamination might occur.

Should the effluent stream be discharged directly into the San Juan River, the maximum deterioration of San Juan River water may be estimated from the known composition of the two waters and their flow rates. The estimated flow rate of effluent will be 29,540 gpd or 20.5 gpm. The minimum flow rates of the San Juan River and the Hammond ditch as given above are 250 cfs and 45 cfs respectively (112,200 gpm and 20,196 gpm).

$$Ct = \frac{CrQr + CeQe}{Qt}$$

where,

Cr, Ce, Ct = concentration of ionic constituent for the river, effluent and total.

Qr, Qe, Qt = flow rate of the river, effluent, and total.

Table 4. Quality of San Juan River and Hammond ditch water and Plateau Refinery, wastewater as well as the quality of the San Juan River and Hammond ditch water if wastewater is discharged directly into the San Juan River or the Hammond ditch. Concentrations are in milligrams per litre.

Item	San Juan River and Hammond Ditch	Plant Effluent	San Juan Composite	Hammond Ditch Composite	NMWQCC Standards
Calcium	34	314.9	34.05	34.3	
Magnesium	6.1	101.3	6.1	6.2	
Sodium	19.6	1955.4	20.0	21.6	
Chloride	17.1	600	17.2	17.7	250
Sulphate	52.0	1113.9	52.2	53.1	600
Sulfite		5.1			
Bicarbonate	104.3	207.2	104.3	104.4	
Carbonate		14.6			
Nitrate					44
Iron		2.9			1.0
Phosphorus		6.8			
Zinc	.24	0.8	0.2	0.2	10
Chromium		0.03			0.05
pH	7.7	8.7	7.7	7.7	6-9
Total Dissolved Solids	212.5	4961.7	213.4	217.4	1000

Should effluent be discharged directly into the Hammond ditch during the irrigation season instead, the resulting concentration of ionic components in the mixed water can also be calculated. The results given in table 4 assume the quality of Hammond ditch water is similar to that of the San Juan River from whence it originated, and that the flow rate of water in the ditch is 20,196 gpm.

In both cases, the quality of the composite water streams meet water quality standards set forth in Section 3-103 of the regulations.

POND CONSTRUCTION

Fresh Water Ponds

The two fresh water ponds shown in plate 1 occupy an area of five acres. They have been constructed by building earthen embankments. The earthen material forming the embankments has been borrowed from the pond area itself and is generally fine-grained silt which overlies the cobble bed. Earthen material is applied by scraper and compacted with a sheeps-foot roller. During the construction phase all surfaces undergoing compaction were wetted with water from the oily water ponds. The foundation of the fresh-water pond 1 is covered with a hypalon membrane liner to eliminate percolation of fresh-water into the underlying cobble bed. Fresh-water pond 2 has been covered with bentonite and polymer. 15

Oily Water Ponds

The oily water ponds have been in existence for a number of years. 16 They were probably constructed in a manner similar to the fresh water ponds. They too are constructed in the fine-grained silt deposits which overlie the cobble bed. The bottoms of the oily water ponds have been treated with bentonite to retard percolation of contained water. Treatment consisted of floating bentonite on the surface of the ponds and allowing it to settle to the bottom. This work was carried out several years ago.

Solar Evaporation Ponds

The two solar evaporation ponds, which together occupy about five acres, were constructed by building earthen embankments from silt and sand borrowed from the pond bottoms. The bottoms of the ponds were treated with about two pounds of Wyoming bentonite per square foot to retard seepage of contaminated water. The western ends of the ponds were originally deeper than the eastern ends. However, because of the desirability of complete and immediate evaporation of effluent, the pond bottoms are level.

SOLAR EVAPORATION POND OPERATION

The boiler water and cooling tower blowdown and water from other miscellaneous sources is discharged into the evaporation ponds at the rate of ~20.5 gal/min. Total dissolved solid content of the influent is about 4961.6 milligrams per litre. The influent carries about 0.61 tons of solids (dry weight) per day into the ponds. The evaporation ponds are designed to retain all residual solids for more than 40 years.

Due to the continuous evaporation process from the ponds, a continuous buildup of solids results in a progressive decrease in the evaporation rate. Evaporation from salt solution was studied by Rohwer (1933) and Adams (1934). It was found that the evaporation rate decreases about one percent for each one percent increase in the specific gravity of the solution. Evaporation is about two to three percent less from sea water than from fresh water. Based upon the estimated minimum daily evaporation rate for a fresh water body of 24,732 gallons per day, evaporation rates for different levels of concentration of evaporation pond effluent are given in table 5 below, and the maximum estimated evaporation rate is 55,131 gallons per day. The effect of wind upon the evaporation rates has not been considered.

Table 5. Estimated January and July evaporation rates for water solutions of various specific gravities.

Concentration Factor	Sp.Gr.	E_{oJan} (gpd)	E_{oJul} (gpd)
1	1.004	24,633	55,131
10	1.05	23,554	52,716
100	1.50	16,488	36,901
200	1.99	12,428	27,815

To determine the level of concentration required to cause the precipitation of several common salts, solubility product constants, Ks, were calculated from thermodynamic considerations. The activities of the pertinent ionic species were obtained from Garrells and Christ (1965). The concentration factor sufficient to cause the ion product to exceed the solubility products were determined. This procedure is described in attachment 5. The results are given in table 6.

Table 6. Concentration factors required to cause various common salts to precipitate from influent to the evaporation ponds.

Salt	Concentration Factor
$CaSO_4$	8
NaCl	173
Na_2SO_4	187

A concentration factor of 10 implies the volume of influent has been reduced to one-tenth its original volume. Evaporation rates necessary to achieve various concentration factors are given below.

Table 7. Evaporation rates necessary to achieve indicated concentration factor based upon an influx of 29,540 gallons per day.

C	Q (gpd)
10	26,586
100	29,245
200	29,392

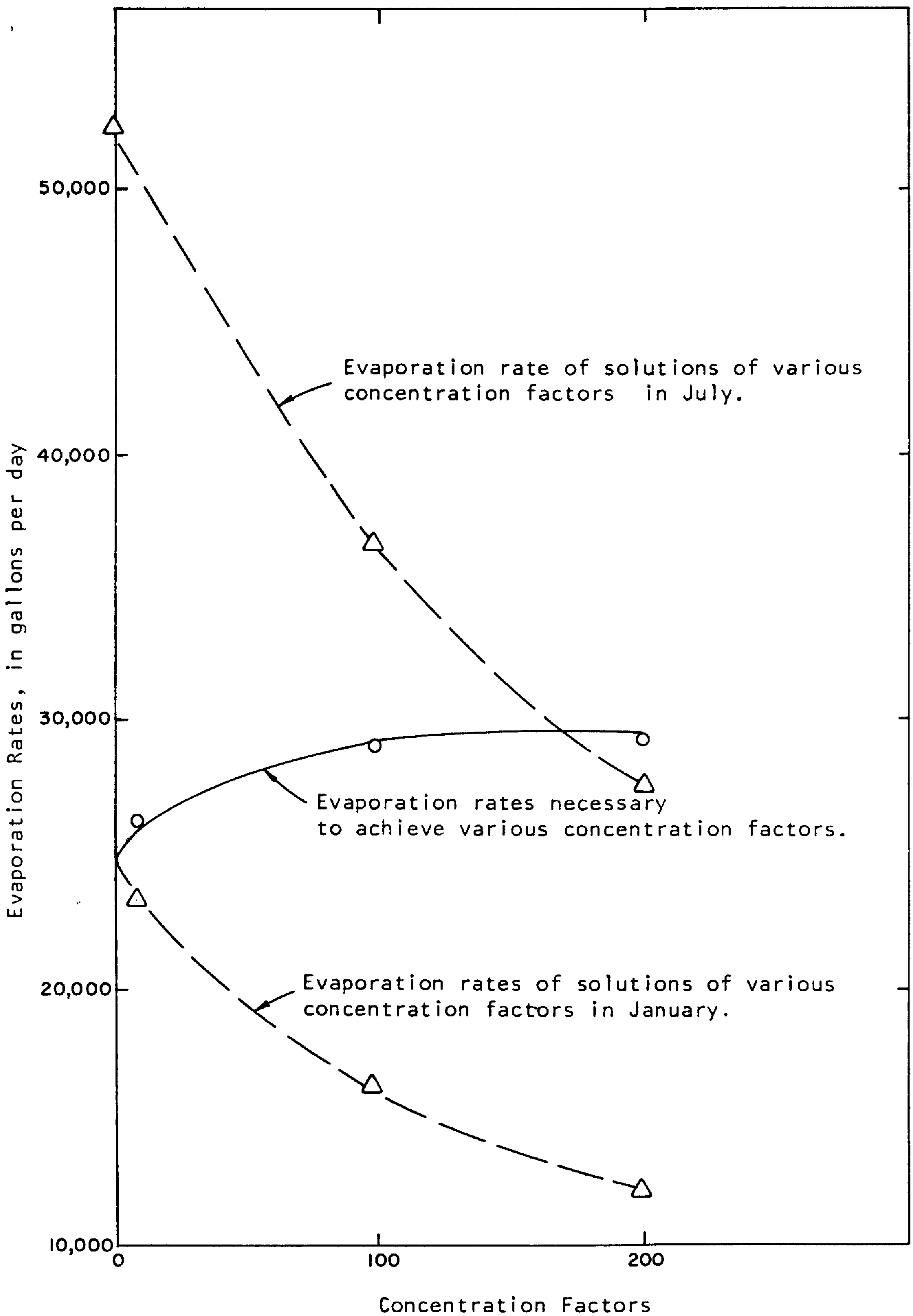

Figure 18. Diagram showing January and July evaporation rates for solutions of various concentrations formed by concentrating waste-water from the Plateau refinery. Diagram also shows the evaporation rates needed to achieve various levels of concentration.

Data in table 6 and 7 has been used to construct figure 18. Figure 18 shows that the evaporation rates in January are not sufficient to produce any significant concentration of influent. Consequently, very little precipitation of solids will occur. In July, however, evaporation rates are sufficient to concentrate the influent up to 175 times, which should cause precipitation of some of the more soluble components.

To enhance evaporation at all times of the year, Plateau intends to install a spray system which will consist of a series of nozzels situated along the embankment of the ponds. Influent waste water will be sprayed as a fine mist onto the surface of the ponds. During the winter when natural surface evaporation is low, waste water may also be taken from the ponds and passed through the spray system to facilitate evaporation. Details of the spray system are given in plate 3 (in pocket). NO PLATE 3

MONITORING METHODOLOGIES

Many methods exist for the quantitative determination of seepage from reservoirs such as solar evaporation ponds. Among these methods are flow net analysis, water budgets, neutron logging, Thermonics, Zeta-SP, (and microflow surveys) and tracers. To detect possible leakage from the solar evaporation ponds constructed by Plateau, Plateau will pursue several monitoring strategies. Specifically, Plateau will pursue all of the above with the exception of the water budget method. All of the methods which Plateau proposes to utilize are methods in which seepage or the direct effects of seepage will be measured directly. Each proposed monitoring method is discussed briefly below.

Flow Net Analysis

A body of water which is impounded on the land surface constitutes a potential source of groundwater recharge. When water seeps through the foundation of such a reservoir and percolates to the groundwater table beneath the reservoir, a slight mound develops on the local water table. The mound develops because in order for the recharge to flow away in the saturated zone a potential gradient must exist away from the zone of recharge. By measuring water levels very accurately in monitoring holes constructed in proximity to the solar evaporation ponds it is possible to define the extent of any mound which may develop and to quantify the rates of ground water flow away from the solar evaporation ponds. This quantification will be of considerable importance if the ground water becomes contaminated and subsequently enters the Hammond ditch. To determine the magnitude of the dilution, the chemical quality and flow rates of both the ground water and ditch water must be known. An alternative and completely unambiguous method utilizes man-made tracers which are discussed below.

In practice water levels are measured in all monitoring holes constructed within the project area by means of a Lufkin etched steel tape graduated in 100ths of a foot.

Neutron Logging

The neutron logging method is a non-destructive field method in which a probe containing a neutron source and detector is lowered to specified depths in suitable access tubes. A single site can be monitored continually. More commonly, the probe is used at several depths in each of several access tubes.

The neutron source emits a cloud of high energy neutrons which samples a spherical volume of soil from 12 to 28 inches in diameter (decreasing with increasing moisture content). When the high energy neutrons encounter hydrogen atoms, they lose some of their energy and become thermalized. The soil moisture content in volume percent is calculated from the measured flux of thermalized neutrons.

In practice, neutron-probe-access tubes are constructed and baseline data is collected prior to filling the solar-evaporation ponds. The original soil-moisture profiles are then compared to neutron-probe data taken after the pond has been filled. Should seepage occur, an increase in the soil moisture content of the unsaturated zone may be detected. The absence of any increase in the soil moisture content indicates that no seepage is taking place past the point intercepted by the neutron access tube.

Thermonics

Thermonics is the analysis of groundwater-flow systems based upon the redistribution of geothermal heat and/or shallow soil heat by moving ground water. Because ground water is usually in motion, it may act as a moving heat sink or heat source, the strength of which is related to the mass-rate of ground-water movement. The flow of geothermal heat through a porous medium which contains a moving fluid is given by the Stallman Equation

$$\frac{\partial^2 T}{\partial x^2} + \frac{\partial^2 T}{\partial y^2} + \frac{\partial^2 T}{\partial z^2} - \frac{c_w \rho_w}{K}\left[\frac{\partial (v_x T)}{\partial x} + \frac{\partial (v_y T)}{\partial y} + \frac{\partial (v_z T)}{\partial z}\right] = \frac{c\rho \partial T}{K\, \partial t}$$

where,

t = time since flow started

T = temperature at any point at time t

v = velocity of fluid flow, direction specified by subscripts x, y, and z.

x, y, z = Cartesian coordinates

k = thermal conductivity of the rock-fluid complex

c_w, c = specific heat of water and the solid-fluid complex

p_w, p = density of water and the solid-fluid complex

The Stallman equation is generally only solvable by analytic methods for steady state cases. Several solutions already developed by Stallman (1959) and by Bredehoeft and Papadopoulos (1965) are useful in determining the rates of ground water flow through both the saturated and unsaturated zones.

In practice, temperature measurements are made in shallow monitoring holes, before the solar evaporation ponds are filled and the normal thermal profile is established. Should seepage occur, the normal thermal profiles will be altered first by the moving fluid which was recharged at some temperature which is different from the temperature encountered in the observation holes and secondly by increasing the thermal diffusivity of the soil-water medium, the depth of penetration of the seasonal heat wave will be greater, also giving rise to an abnormal temperature profile. With the re-establishment of equilibrium conditions, the various analytical solutions of the Stallman equation may be applied to quantitatively determine the rate of seepage.

Zeta-SP

The use of natural electrical current to study water leakage from reservoirs is based upon the well known phenomenan of electric fields formed by the flow of water through a porous medium. The theortetical basis for streaming potentials was first worked out by Helmholtz. The generation of the electric current is caused by the "double layer" boundary between mineral particles and water. The surface of the mineral phase has an excess of negative electrical charge which attracts and partially fixes the positive pole of the dipolar water molecule. The rapid flow of water past the "double layer" dislodges the weakly bonded water molecule leaving an electrical charge deficiency towards which other dipolar water molecules and mono and divalent cations flow. The Helmholtz equation

$$V = \frac{\rho \varepsilon \zeta \ \Delta P}{4 \pi \eta}$$

where,

V = streaming potential

ε = dielectric constant of the fluid

ζ = zeta potential

ρ = resistivity of the liquid

ΔP = difference in head

η = fluid viscosity

relates the magnitude of the electric potential to the driving head for fluid flow.

In practice, the electrical potential on the bottom of a reservoir is measured at many discrete locations. These values are then contoured to show the areas of greatest seepage through the porous material of the reservoir foundation.

Flourocarbon Tracers

Flourocarbon tracers are man-made compounds which have no measureable background in natural waters. Flourocarbon tracers are ideally suited as an environmental tracer for several reasons. They are detectable at concentrations as low as one-hundredth of a part per trillion, that is, one cubic centimeter of the tracer is detectable in one cubic kilometer of water. At the concentration levels used in actual practice they are considered as completely non-toxic substances by OSHA. In addition, they are highly inert, inexpensive, non-sorbitive on sediment and easily handled. Because flourocarbon tracers are man-made, there is no ambiguity in the interpretation of the results as there may be if natural tracers such as chloride, nitrates, sulphates or other components of ground-water or surface water are used. Natural components of the ground water are unsatisfactory because they experience natural fluctuations in concentration. The flourocarbon tracer concentration will fluctuate only as a function of the input program.

THE MONITORING NETWORK

Plate 1 shows the location of all contaminated water handling facilities at the Plateau refinery. At present nine neutron probe access holes have been constructed on the western embankment of solar evaporation pond 1. The nuetron-probe-access tubes were installed in 6-inch diameter holes which were drilled to a depth of 50 feet by mud-rotary methods. To prevent drilling fluid from entering the unsaturated soils, a 100-second viscosity bentonite-base drilling mud was used. Drispack with WI-100 were used to control filtrate loss. Upon completion, the holes were flushed with water and blown with air. Two-inch schedule 40 PVC pipe was run to the bottom of each hole and the annular space was backfilled with a mixture of dry bentonite and soil. The backfill material will prevent leakage of water down the annulus. The PVC casing is open at the bottom to permit groundwater to enter the tubes and groundwater levels may be measured and water samples collected if desired.

Ideally, holes for this purpose should be either augered or drilled by air rotary methods. Air rotary methods were tried on the present project but holes would not remain open due to caving of the boulders in the cobble bed underlying the solar evaporation pond. Drillers logs for most of the holes are given in attachment 3. Samples were not preserved by the drillers for all the holes which were drilled. However, the lithologic logs from those holes in which the samples were preserved indicates that they are all similar. The elevations of the tops of the neutron access tubes are given in Table 8.

Table 8. Elevations above mean sea level of the neutron-probe-access hole PVC-casing collars.

Hole No.	Elevation (ft)
1	5521.82
2	5520.67
3	5521.13
4	5521.17
5	5521.13
6	5520.94
7	5520.97
8	5521.29
9	5520.90

MONITORING SCHEDULE

Neutron logging, Thermonic and Zeta-SP monitoring has already been initiated at the Plateau refinery. Dates of data acquisition tegether with the types of data collected are given below in table 9.

Table 9. Dates of monitoring activity at the Plateau refinery and the types of data collected.

Date	Data Collected[1]
26 April, 1977	N.W.
6 May, 1977	N.W.
21 May, 1977	N.W.T.
15 July, 1977	N.W.T.Z.

[1]N = Neutron logging, W = Water level measurements, T = Thermonics, Z = Zeta-SP.

In the very near future, a flourocarbon injection system will be installed to spike the water in the solar evaporation pond with fluorocarbon tracer.

At the present time, it is expected that monitoring will take place quarterly for at least one year. At the end of this period of time, all data will be thoroughly reviewed to determine the frequency of future monitoring activities.

REFERENCES

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Garrels, R. M. and Christ, C. L., 1965, Solutions, Minerals, and Equilibria, Harper & Row, New York, New York, 450 pp.

Pastuzak, R. A., 1968, Geomorphology of part of the La Plata and San Juan Rivers, San Juan County, New Mexico, Univ. New Mexico, unpub. Masters thesis, 85 pp.

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ATTACHMENT 1. CORRESPONDANCE RELATING TO THE DISCHARGE PLAN.

AMERICAN
GROUND WATER
CONSULTANTS, INC.

2300 CANDELARIA ROAD, N.E.
ALBUQUERQUE, NEW MEXICO 87107
TELE: (505) 345-9505 CABLE: HYDROCONSULT
TELEX: 66-0422 TELECOPIER (505) 247-0155

April 29, 1977

Mr. Joe D. Ramey
Secretary-Director
New Mexico Oil Conservation Commission
State Land Office Building
Santa Fe, New Mexico 87503

Dear Mr. Ramey:

American Ground-Water Consultants has been retained by Plateau, Inc. to assist them in complying with the New Mexico Water Quality Control Commission Regualations (NMWQCCR) as ammended.

At the present time, we should like to bring to your attention plans by Plateau to make a new contaminant discharge and to alter the character or location of an existing discharge from their refinery as required by Part 1, Section 201 (A) of the Regulations. The information required under 1-201 (B) is as follows:

1. Plateau, Inc.
2. Post Office Box 108
   Farmington, New Mexico 87401
3. NE 1/4, Sec. 27, T. 29 N., R. 11 W. The refinery location is shown in figure 1. The discharge will be made into two three-acre evaporation ponds.
4. The quality of the wastewater from the boilers and from the existing and new cooling towers as well as the quality of the composite wastewater stream is given in table 1. As additional data becomes available, it will be forwarded to the OCC.
5. Total discharge will be 29,540 gallons per day.
6. Discharge is intended to begin in August, 1977.

In compliance with Part 1, Sections 202 (A) and (B) of the Regulations, we are enclosing herewith, a copy of the Water and Drainage Diagram for the Plateau refinery. This diagram shows the path of water flow from its source, the San Juan River, through all existing and newly constructed facilities to its ultimate disposal in the evaporation ponds. In addition, this diagram shows the normal (N) and design (D) rates of water flow throughout the refinery.

Plateau, Inc. is presently preparing its application for a discharge permit as required by Part 3, Section 104 of the Regulations and intends to submit its application to the OCC in the near future.

Should you have any questions regarding this notice, please direct your inquiries in writing to Mr. William Hagler, Vice President of Marketing for Plateau with copies going to Mr. James Weith, also of Plateau, and myself.

Sincerely,

William M. Turner

Dr. William M. Turner
President

WMT jj

cc: William Hagler, Plateau
James Weith, Plateau
Joseph Pierce, N.M.E.I.A. (w/o Water and Drainage Diagram)

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

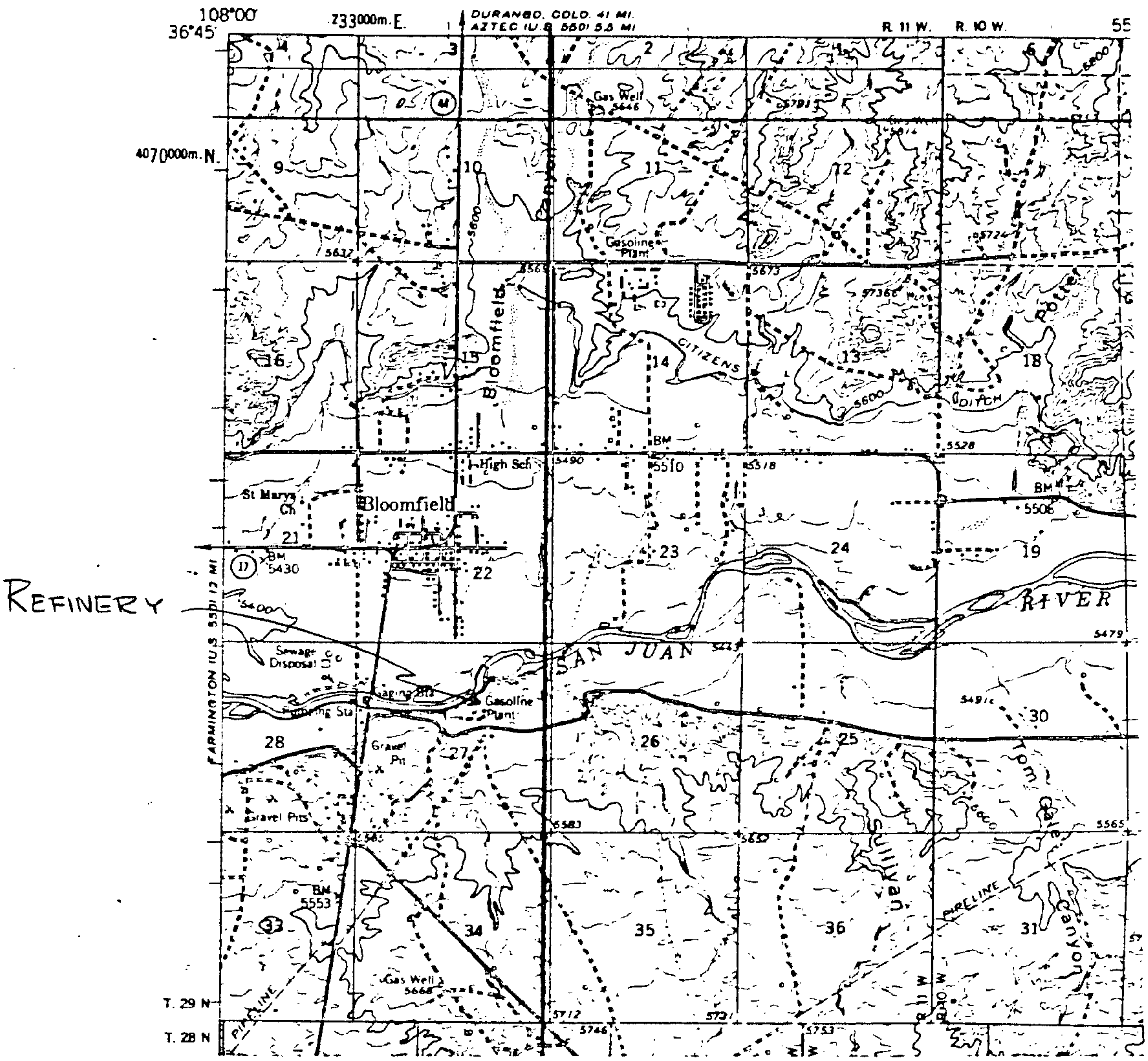


Figure 1. Map showing the location of the Plateau refinery near Bloomfield, New Mexico

OIL CONSERVATION COMMISSION

STATE OF NEW MEXICO
P. O. BOX 2088 - SANTA FE
87501

DIRECTOR
JOE D. RAMEY

LAND COMMISSIONER
PHIL R. LUCERO

STATE GEOLOGIST
EMERY C. ARNOLD

December 13, 1977

American Ground Water Consultants, Inc.
2300 Candelaria Road, N.E.
Albuquerque, New Mexico 87107

Attention: Dr. William M. Turner

Dear Dr. Turner:

I am attaching for your information a copy of a letter from Mr. Bruce Gallaher of the NMEIA.

This letter is self-explanatory and should aid you in the submission of your discharge plan for the Plateau Refinery.

Yours very truly,

JOE D. RAMEY
Director

JDR/fd
enc.

STATE OF NEW MEXICO
JERRY APODACA, Governor
FERNANDO E.C. DE BACA, Executive Director
ENVIRONMENTAL IMPROVEMENT AGENCY
P.O. Box 2348 - Crown Building
Santa Fe, New Mexico 87503
(505) 827-5271 Ext. 371

HEALTH and SOCIAL SERVICES department

December 8, 1977

Mr. Joe D. Ramey
Secretary-Director
New Mexico Oil Conservation Commission
State Land Office Building
Santa Fe, New Mexico 87503

Dear Mr. Ramey:

I have completed a cursory review of Plateau's preliminary discharge plan submitted to O.C.C. for the Bloomfield refinery. It must be noted that this review considered hydrogeologic and water quality conditions exclusively as they pertained to the operation of the new solar evaporation ponds.

The plan reflects considerable employment of state-of-the art pond seepage detection and monitoring techniques. Plateau and its consultants should be commended for their use of a multiple faceted monitoring approach. Most of these techniques are intended for examination of the unsaturated zone beneath the ponds.

It is clear that protection of the ground water resource is the prime motivation behind the discharge plan requirement. Before the plan's adequacy in safeguarding the saturated zone can be completely assessed, additional information and clarification is needed. This information should be included within a modified discharge plan when formal submission transpires. The following material is required pursuant to sections 3-106C and 3-107 of the Water Quality Control Commission Regulations.

Information Lacking from 3-106C Requirements

1. (3-106C.3) "depth to and TDS concentration of the ground water most likely to be affected by the discharge".

2. (3-106C.4) "Flooding potential at the site".

General Ground Water Information

1. Although it is inferred, no specific evidence of the shallow ground water flow direction is presented. This is critical in locating the saturated zone monitoring wells. A water table contour map could be such supportive evidence.

2. Similarly, it is unknown what is the background quality of the ground water most likely to be affected.

Construction and Location of Monitor Wells

1. The applicant should provide detailed construction information about the proposed ground water sampling wells. This should include bore hole diameter, total depth, screened or perforated interval(s), and completion depth in the saturated zone. This information should be provided with specific reference to known or projected static water levels. Will these wells be capable of being pumped?

2. Presently, all monitoring efforts seem to be focused on pond #1. Is it the intention of Plateau not to monitor solar evaporation in pond #2? If so, the company should provide discussion as to the worth of the present design for pond 2 seepage evaluation.

Sampling, Reporting, and Contingency

1. It is unclear what the sampling frequency of the proposed ground water sampling wells. What parameters will be analyzed for?

2. Does the applicant intend to periodically submit to the NMEIA or NMOCC results obtained via the monitoring program? The frequency should be set forth.

3. If the monitoring indicates significant seepage and related deterioration of the ground water system, what remedial measures can be implemented to cope with the failure?

I hope these comments help both the O.C.C. and Plateau, Inc. at this preliminary stage.

Sincerely,

Bruce Gallaher

Bruce Gallaher,
Geohydrologist

BG/jeb

cc: EIA Files

AMERICAN
GROUND WATER
CONSULTANTS, INC.

2300 CANDELARIA ROAD, N.E
ALBUQUERQUE, NEW MEXICO 87107
TELE: (505) 345-9505 CABLE: HYDROCONSULT
TELEX: 66-0422 TELECOPIER: (505) 247-0155

May 23, 1977

Mr. Joe D. Ramey
Secretary-Director
Oil Conservation Commission
Post Office Box 2088
Santa Fe, New Mexico 87501

Dear Mr. Ramey:

This letter is intended to aknowledge receipt of your letter of May 13, 1977 to Mr. William Hagler, Vice President of Marketing for Plateau, Inc..

American Ground Water Consultants is presently in the process of preparing the discharge plan required by the New Mexico Water Quality Control Commission Regulations and hope to have it to you by early July.

Sincerely,

William M. Turner

Dr. William M. Turner
President

WMT:rrt

cc: William Hagler
James Weith
Joe Pierce

OIL CONSERVATION COMMISSION
P. O. BOX 2088
SANTA FE, NEW MEXICO 87501

May 13, 1977

CERTIFIED - RETURN
RECEIPT REQUESTED

Mr. William Hagler
Vice President of Marketing
Plateau, Inc.
P. O. Box 108
Farmington, New Mexico 87401

Dear Mr. Hagler:

I am in receipt of your letter of 4-29-77 from American Ground Water Consultants, Inc. concerning your intent to make a new contaminant discharge and to alter an existing discharge from the Plateau Refinery in Section 27, Township 29 North, Range 11 West, San Juan County, New Mexico.

After reviewing the information submitted with the letter, it is apparent that a discharge plan approval will be required. Therefore, pursuant to New Mexico Water Quality Control Commission requirements, you are hereby notified that a discharge plan as defined in Section 1-101.I is required of the Plateau Refinery.

This notification of Discharge plan required is pursuant to Sections 3-104 and 3-106.

Yours very truly,

JOE D. RAMEY,
Secretary-Director

JDR/dr

cc: Mr. James Weith
✓Dr. William M. Turner
Mr. Joe Pierce

ATTACHMENT 2. WELL RECORD FOR THE AMOCO DAVIS GAS UNIT F-1 GAS WELL.

NEW MEXICO OIL CONSERVATION COMMISSION

Santa Fe, New Mexico

WELL RECORD

AREA 640 ACRES
LOCATE WELL CORRECTLY

Mail to District Office, Oil Conservation Commission, to which Form C-101 was sent not later than twenty days after completion of well. Follow instructions in Rules and Regulations of the Commission. Submit in QUINTUPLICATE. If State Land submit 6 Copies

Pan American Petroleum Corporation (Company or Operator) Davis Gas Unit "F" (Lease)

Well No. 1, in NE ¼ of SE ¼, of Sec. 27, T. 29N, R. 11W, NMPM.

Undesignated Dakota Pool, San Juan County.

Well is 1850 feet from South line and 1190 feet from East line of Section 27. If State Land the Oil and Gas Lease No. is —

Drilling Commenced October 4, 1960 Drilling was Completed October 24, 1960

Name of Drilling Contractor Brinkerhoff Drilling Company

Address 870 Denver Club Building, Denver 2, Colorado

Elevation above sea level at Top of Tubing Head 5565 (RDB) The information given is to be kept confidential until not confidential, 19

OIL SANDS OR ZONES

No. 1, from 6213 to 6250 No. 4, from to

No. 2, from to No. 5, from to

No. 3, from to No. 6, from to

IMPORTANT WATER SANDS

Include data on rate of water inflow and elevation to which water rose in hole.

No. 1, from to feet.

No. 2, from to feet.

No. 3, from to feet.

No. 4, from to feet.

CASING RECORD

SIZE	WEIGHT PER FOOT	NEW OR USED	AMOUNT	KIND OF SHOE	CUT AND PULLED FROM	PERFORATIONS	PURPOSE
8-5/8"	22.7	New	323	Guido			Surface
4-1/2"	9.5	New	6390	Guido			Oil String

MUDDING AND CEMENTING RECORD

SIZE OF HOLE	SIZE OF CASING	WHERE SET	NO. SACKS OF CEMENT	METHOD USED	MUD GRAVITY	AMOUNT OF MUD USED
12-1/4"	8-5/8"	332	225	Halliburton 2 plug		
7-7/8"	4-1/2"	6365	675	2-stage		

OIL CON. COM. DIST.

RECORD OF PRODUCTION AND STIMULATION

(Record the Process used, No. of Qts. or Gals. used, interval treated or shot.)

Spotted 500 gallons 15% BDA. Perforated 6215-19, 6227-29, 6236-40, with 6 shots per foot. Sand water fracked with 40,000 gallons water and 40,000 pounds sand. Breakdown pressure 1500 psi, average treating pressure 2500 psi, average injection rate 39 barrels per minute.

Result of Production Stimulation Completed as Undesignated Dakota field development well November 7, 1960. Preliminary test flowed 4653 MCFPD.

Depth Cleaned Out 6332

RECORD OF DRILL-STEM AND SPECIAL TESTS

If drill-stem or other special tests or deviation surveys were made, submit report on separate sheet and attach hereto

TOOLS USED

Rotary tools were used from 0 feet to 6365 feet, and from .... feet to .... feet.
Cable tools were used from .... feet to .... feet, and from .... feet to .... feet.

PRODUCTION

Put to Producing November 7, 19 60 (Shut in for pipeline connection.)

OIL WELL: The production during the first 24 hours was .... barrels of liquid of which .... % was was oil; .... % was emulsion; .... % water; and .... % was sediment. A.P.I. Gravity ....

GAS WELL: The production during the first 24 hours was Preliminary test 4653 M.C.F. plus .... barrels of liquid Hydrocarbon. Shut in Pressure .... lbs.

Length of Time Shut in Potential test will be submitted on Sundry Notice when available.

PLEASE INDICATE BELOW FORMATION TOPS (IN CONFORMANCE WITH GEOGRAPHICAL SECTION OF STATE):

Southeastern New Mexico				Northwestern New Mexico	
T. Anhy		T. Devonian		T. Ojo Alamo	495
T. Salt		T. Silurian		T. Kirtland-Fruitland	650
B. Salt		T. Montoya		T. Farmington	
T. Yates		T. Simpson		T. Pictured Cliffs	1716
T. 7 Rivers		T. McKee		T. Menefee	
T. Queen		T. Ellenburger		T. Point Lookout	4143
T. Grayburg		T. Gr. Wash		T. Mancos	4410
T. San Andres		T. Granite		T. Dakota	6156
T. Glorieta		T.		T. Morrison	
T. Drinkard		T.		T. Penn	
T. Tubbs		T.		T.	
T. Abo		T.		T.	
T. Penn		T.		T.	
T. Miss		T.		T.	

FORMATION RECORD

From	To	Thickness in Feet	Formation	From	To	Thickness in Feet	Formation
0	495	495	Surface sands & shales.				
495	650	155	Ojo Alamo sand.				
650	1523	873	Kirtland shales & sands, including Farmington.				
1523	1716	193	Fruitland sands, shales & coals.				
1716	1840	124	Pictured Cliffs sands & shales.				
1840	3300	1460	Lewis shales & sands.				
3300	4410	1110	Mesaverde sands & shales.				
4410	5304	894	Mancos shale.				
5304	6060	756	Gallup sands & shales.				
6060	6100	40	Greenhorn shaly sand.				
6100	6156	56	Graneros sands & shales.				
6156	6213	57	Dakota sands & shales.				
6213	6365	152	Dakota pay sands & shales.				
			(Tops from E log)				

STATE OF NEW MEXICO
OIL CONSERVATION COMMISSION
AZTEC DISTRICT OFFICE
NUMBER OF COPIES RECEIVED
SANTA FE
FILE
U.S.G.S.
LAND OFFICE
TRANSPORTER OIL / GAS
PRORATION OFFICE
OPERATOR

ATTACH SEPARATE SHEET IF ADDITIONAL SPACE IS NEEDED

I hereby swear or affirm that the information given herewith is a complete and correct record of the well and all work done on it so far as can be determined from available records.

November 9, 1960
(Date)

Company or Operator Pan American Petroleum Corporation Address Box 480, Farmington, New Mexico

Name ORIGINAL SIGNED BY R. M. Bauer, Jr. Position or Title Area Engineer

ATTACHMENT 3. LITHOLOGIC LOGS FOR SEVERAL OF THE NEUTRON-PROBE ACCESS HOLES.

LITHOLOGY	INTERVAL (ft)
Neutron Access Hole 1	
Samples missing	0-5
Samples missing	5-10
Samples missing	10-15
Samples missing	15-20
Cobble and large pebbles	20-25
Pebbles and cobble	25-30
Brownish silt and pebbles	30-35
Brownish green silty clay	35-40
Bluish gray silty clay	40-45
Grayish silty clay	45-50
Neutron Access Hole 2	
Samples missing	0-5
Samples missing	5-10
Samples missing	10-15
Samples missing	15-20
Brownish silt and pebbles	20-25
Greenish clay	25-30
Greenish gray silty clay	30-35
Grayish silty clay	35-40
Grayish silty caly	40-45
Grayish silty clay	45-50
Neutron Access Hole 3	
Samples missing	0-5
Samples missing	5-10
Samples missing	10-15
Brown silt, and pebbles and cobble	15-20
Pebbles and cobble	20-25
Green shale	25-30
Greenish gray clay	30-35
Greenish gray silty clay	35-40
Bluish gray silty clay	40-45
Bluish gray sandy clay	45-50

LITHOLOGY	INTERVAL (ft)

<u>Neutron Access Hole 5</u>

Samples missing	0-5
Samples missing	5-10
Samples missing	10-15
Samples missing	15-20
Gravel and pebbles	20-25
Pebbles	25-30
Greenish gray silty clay	30-35
Grayish silty clay	35-40
Grayish silty clay	40-45
Grayish silty clay	45-50

<u>Neutron Access Hole 6</u>

Gray sand	0-5
Gray sand	5-10
Gray sand	10-15
Gray sand	15-20
Pebbles and cobble	20-25
Pebbles	25-30
Buff silt	30-35
Buff silty clay	35-40
Buff sand	40-45
Buff sand	45-50

(40-45, 45-50:) SS in Sacramento

<u>Neutron Access Hole 7</u>

Samples missing	0-5
Brownish sand	5-10
Silt and pebbles	10-15
Pebbles	15-20
Pebbles and cobble	20-25
Pebbles and cobble	25-30
Pebbles and cobble	30-35
Grayish clayey sand	35-40
Grayish clayey sand	40-45
Grayish clayey sand	45-50

(35-40, 40-45, 45-50:) sand in Sacramento

LITHOLOGY	INTERVAL (ft)	
Neutron Access Hole 9		
Samples missing	0-5	
Samples missing	5-10	
Samples missing	10-15	
Samples missing	15-20	
Samples missing	20-25	
Samples missing	25-30	
Samples missing	30-35	
Buff silt	35-40	
Gray sand	40-45	sand in top [illegible]
Gray sand	45-50	

ATTACHMENT 4. INFORMATION PERTINENT TO THE SECTION OF THE HAMMOND DITCH PASSING ADJACENT TO THE PLATEAU REFINERY.

AP 156
EL 5496.0

0' – 3' – 4' – 13' – 14'; 7-26-57

SAND, silty, about 70% soft, fine-grained, #50 max. size; about 30% slightly plastic silt fines; quick dilatancy, firm and moist in place (SM)

SAND, poorly graded, about 95% medium hard, subangular, skip-graded, #16 max. size; about 5% nonplastic silt fines; firm and damp in place, small amount of hard, subrounded, fine gravel (SP)

SAND, silty, about 80% soft, fine-grained, #50 max. size; about 20% nonplastic silt fines; quick dilatancy, firm and damp in place (SM)

SAND, poorly graded, about 95% medium hard, subangular, fine-grained, #30 max. size; about 5% nonplastic silt fines; firm and damp in place (SP)

AP 157
EL 5500.2

0' – 2' – 5'; 7-26-57

SAND, silty, about 80% soft, fine-grained, #50 max. size; about 20% slightly plastic silt fines; quick dilatancy, firm and moist in place (SM)

SAND, silty, about 70% soft, fine-grained, #50 max. size; about 30% slightly plastic silt fines; firm and damp in place, white mottled with black from 3' - 5'; some cementation, outcrops nearby (SM)

AP 158
EL 5494.0

0' – 5' – 10'; 7-26-57

SAND, poorly graded to silty sand; about 80% medium hard, medium- to fine-grained, #16 max. size; about 10% hard, subrounded, predominantly coarse gravel, 2" max. size; about 10% nonplastic silt fines; firm and moist in place (SP-SM)

SAND, silty, about 70% medium hard, subangular, medium- to fine-grained, #30 max. size; about 10% hard, subrounded, predominantly coarse gravel, 2" max. size; about 20% slightly plastic silt fines; thin streaks of clay with alkali, medium dilatancy, firm and moist in place (SM)

NOTE: Stopped due to caving and encountering large cobbles.

AP 159
EL 5503.0

0' – 2' – 6' – 8'; 7-26-57

SAND, silty, about 70% medium hard, subangular, medium- to fine-grained, #16 max. size; about 30% slightly plastic silt fines; small amount of coarse gravel and cobbles, quick dilatancy, firm and damp in place (SM)

SAND, poorly graded to silty sand, about 70% medium hard, subangular, medium- to fine-grained, #16 max. size; about 20% hard, subrounded, fairly well graded gravel and cobbles, 5" max. size; about 10% nonplastic silt fines; gravel coated with lime, firm and damp in place (SP-SM)

SAND, silty, about 80% medium hard, subangular, fine-grained, #30 max. size; about 20% slightly plastic silt fines; quick dilatancy, small amount of hard, subrounded, fine gravel (SM)

AP 160
EL 5496.0

0' – 5'; 7-26-57

SAND, silty, about 90% soft, fine-grained, #50 max. size; about 10% slightly plastic silt fines; firm and moist in place (SP-SM)

AP 12-S
EL 5505.0

0' – 2.5' – 9'; 6-6-57

SAND, poorly graded, medium, slightly silty, 45% gravel, max. size 4", subrounded, smooth surface, very hard (SP)

SHALE, very soft, gray, augered easily. When pulverized this shale turns into a clay, moderately plastic, trace of silt and very fine sand (CL)

AP 161 ATS·PHON EAST OF PLANT
EL 5461.0

0' – 2' – 11' – 13'; W.L. 7-29-57; 7-29-57

SAND, silty, orange and gray varied with black, about 80% soft, fine-grained, #30 max. size; about 20% slightly plastic silt fines; quick dilatancy, very firm and moist in place, some cementation, outcrops nearby (SM)

SAND, silty, about 70% soft, fine-grained, #50 max. size; about 30% slightly plastic silt fines; quick dilatancy, very firm and moist in place, considerable cementation, thin lenses of shale, sand size increases to #30 max. size at 8.5' and back to #50 at 10' (SM)

CLAY, sandy, (highly weathered sandy shale), about 70% medium plastic clay; about 30% soft, fine-grained sand, #100 max. size; medium toughness, no dilatancy, firm and very moist in place (CL)

AP 162 EL PASO W RIGT TO F WAY
EL 5499.5

0' – 3.5'; 7-29-57

GRAVEL, silty, about 50% hard, subrounded, skip-graded gravel and cobbles, 6" max. size; about 35% medium hard, subangular, medium- to fine-grained sand, #16 max. size; about 15% slightly plastic silt fines, trace of clay; firm and damp in place (GM)

NOTE: Stopped due to caving and large cobbles.

AP 13-S
EL 5518.8

0' – 12.5' – 23.5'; 6-6-57

SAND, silty, slightly plastic, fine, trace of clay, a few thin layers of SP medium and SC present (SM)

GRAVEL, well graded, 60% gravel, max. size 5" subrounded, smooth surface, very hard, some lime coated; minus 1/4" is slightly dirty and contains an abundance of medium sand (GW)

NOTE: Augering stopped at 12.5' because of difficulties due to contacting gravel.

Log from 12.5' to 23.5' obtained from cut 20'± from auger hole.

AP 163
EL 5499.0

0' – 4' – 7'; 7-29-57

SAND, silty, about 70% soft, very fine-grained, #100 max. size; about 30% slightly plastic silt fines; quick dilatancy, firm and dry in place; small amount of hard, subrounded gravel, 1" max. size from 0 to 2' (SM)

SAND, silty, about 70% soft, fine-grained, #50 max. size; about 10% hard, subrounded, fine gravel, 3/4" max. size; about 20% slightly plastic silt fines; quick dilatancy, firm and dry in place (SM)

NOTE: Stopped due to caving.

AP 164
EL 5503.5

0' – 2.5' – 3.5' – 6'; 7-29-57

SAND, silty, about 80% soft, fine-grained, #50 max. size; about 20% slightly plastic silt fines; quick dilatancy, firm and damp in place (SM)

SAND, clayey, about 60% soft, very fine-grained, #100 max. size; about 40% medium plastic clay fines, trace of silt; medium toughness, slow dilatancy, firm and dry in place (SC)

SAND, silty, about 45% medium hard, subangular, medium- to fine-grained, #16 max. size; about 40% hard, subrounded, fairly well graded gravel, 1-1/2" max. size; about 15% slightly plastic silt fines; firm and dry in place (SM)

NOTE: Stopped due to caving.

AP 165
EL 5502.5

0' – 2' – 3' – 6.5'; 7-30-57

SAND, silty, about 80% soft, fine-grained, #30 max. size; about 20% slightly plastic silt fines; quick dilatancy, firm and moist in place (SM)

SAND, silty, about 60% soft, fine-grained, #50 max. size; about 10% hard, subrounded, fine gravel, ½" max. size; about 30% slightly plastic silt fines; quick dilatancy, firm and damp in place (SM)

SAND, poorly graded, silty, about 70% medium hard, subangular, fine-grained, #30 max. size; about 10% hard, subrounded, lime coated, fine gravel, 1" max. size; about 10% nonplastic silt fines; firm and dry in place, a few cobbles 3" max. size (SP-SM)

NOTE: Stopped due to caving and large cobbles.

AP 166
EL 5474.4

0' – 2' – 3'; 7-30-57

SAND, poorly graded, about 95% medium hard, subangular, medium- to fine-grained, #30 max. size; about 5% nonplastic silt fines; firm and moist in place (SP)

SAND, poorly graded to silty sand, about 80% medium hard, subangular, medium- to fine-grained, #30 max. size; about 10% hard, subrounded, lime coated, fine gravel, 1" max. size, few cobbles 5" max. size; about 10% slightly plastic silt fines; firm and moist in place (SP-SM)

NOTE: Stopped due to encountering large cobbles. Tried several locations but could not get down.

AP 167
EL 5496.7

0' – 4' – 8'; 7-30-57

SAND, silty, about 70%-80% soft, fine-grained, #50 max. size; about 30% (20% from 3' - 4') slightly plastic silt fines; trace of clay from 0 - 3'; quick dilatancy, firm and damp in place (SM)

GRAVEL, poorly graded to silty gravel, about 60% hard, subrounded, lime coated, skip-graded, fine and coarse, 5" max. size; about 30% medium hard, subangular, medium- to fine-grained sand, #16 max. size; about 10% nonplastic silt fines; firm and damp in place (GP-GM)

AP 168
EL 5498.4

0' – 2' – 3' – 4' – 8.5'; 7-30-57

SAND, clayey, about 60% soft, very fine-grained, #100 max. size; about 40% medium plastic clay fines; medium toughness, firm and damp in place (SC)

SAND, clayey, about 80% soft, very fine-grained, #100 max. size, about 20% medium plastic clay fines; firm and damp in place, lime crystals (SC)

SAND, silty, about 80% soft, fine-grained, #50 max. size; about 20% slightly plastic silt fines; quick dilatancy, firm and damp in place, lime crystals (SM)

GRAVEL, poorly graded to silty gravel, about 60% hard, subrounded, lime coated, skip-graded, fine and coarse, 5" max. size; about 30% medium hard, subangular, medium- to fine-grained sand, #16 max. size; about 10% nonplastic silt fines; firm and damp in place, streaks of alkali (GP-GM)

AP 169
EL 5493.6

0' – 4' – 6' – 9'; 7-30-57

SAND, silty to clayey, about 60% soft, very fine-grained, #100 max. size; about 20% silt fines; about 20% medium plastic clay fines; medium toughness and dilatancy, firm and damp in place, alkali streaks (SM-SC)

SAND, silty, about 80% medium hard, subangular, fine-grained, #30 max. size; about 20% nonplastic silt fines; quick dilatancy, firm and damp in place, alkali streaks (SM)

SAND, poorly graded, about 85% medium hard, subangular, medium- to fine-grained, #16 max. size; about 10% hard, subrounded, lime coated fine gravel, 1" max. size; about 5% nonplastic silt fines; firm and damp in place (SP)

AP 14-S
EL 5495.0

0' – 5' – 10'; 6-6-57

SAND, clayey, moderately plastic, very fine, some silt (SC)

SAND, silty, slightly plastic, fine, trace of clay, considerable lime between 9' and 10' (SM)

NOTE: Contacted gravel at 10'. Stopped because of gravel and caving.

AP 170
EL 5491.1

0' – 3' – 6' – 7'; 7-30-57

SAND, silty, about 70% soft, very fine-grained, #100 max. size; about 20% silt fines; about 10% medium plastic clay fines; firm and damp in place, alkali streaks (SM)

SAND, silty, about 80% medium hard, subangular, fine-grained, #50 max. size; about 20% nonplastic silt fines; quick dilatancy, firm and dry in place (SM)

SAND, silty, about 70% medium hard, subangular, medium- to fine-grained, #16 max. size; about 10% hard, subrounded, lime coated, fine gravel, 1" max. size; about 20% nonplastic silt fines; firm and dry in place (SM)

AP 171
EL 5494.

0' – 2' – 3' – 4' – 10'; 8-1-57

SAND, silty, about 70% soft, fine-grained, #50 max. size; about 30% slightly plastic silt fines; some hard, subrounded, fine gravel, 1" max size; quick dilatancy, firm and damp in place (SM)

SAND, silty, about 70% soft, fine-grained, #50 max. size; about 15% hard, subrounded, lime coated, skip-graded gravel, 1-1/2" max size; about 15% slightly plastic silt fines; firm and damp in place (SM)

SAND, silty, about 80% soft, fine-grained, #100 max. size; about 20% slightly plastic silt fines; quick dilatancy, firm and damp in place (SM)

SAND, poorly graded to silty sand, about 90% soft, very fine-grained, #100 max. size; about 10% nonplastic silt fines; firm and damp in place (SP-SM)

AP 172
EL 5493.7

0' – 3' – 6' – 10'; 8-1-57

SAND, silty to clayey, about 60% soft, very fine-grained, #100 max. size; about 20% silt fines; about 20% medium plastic clay fines; medium toughness and dilatancy, firm and damp in place, lime streaks (SM-SC)

CLAY, sandy, about 40% soft, very fine-grained sand, #100 max. size; about 60% medium plastic clay fines; medium toughness, firm and damp in place, lime streaks (CL)

SAND, silty, about 80% soft, very fine-grained, #100 max. size; about 20% slightly plastic silt fines; trace of clay 6' to 8', considerable cementation from 8' to 10', quick dilatancy, firm and damp in place (SM)

AP 173
EL 5490.3

0' – 9'; 8-1-57

SAND, silty, about 80% soft, very fine-grained, #100 max. size; about 20% slightly plastic silt fines; quick dilatancy, firm and damp in place (SM)

AH 867+60
EL 5407.5

0' – 9'; 11-30-60

SAND

NOTE: Hole hand augered to depth shown. A steel rod was then driven to depth of 13'; rod stopped by hard material.

AP 15-S
EL 5414.9

0' – 2' – 8' – 15' – 17' – 19'; W.L. 6-7-57; 6-7-57

SAND, silty, slightly plastic, fine, some clay, a few thin layers of SC present (SM)

SAND, poorly graded, fine to medium, some silt, thin layer of shaly material at 8' (SP)

SAND, poorly graded, medium- to coarse-grained, about 5% gravel of 3/4" max. size, slight trace of silt (SP)

GRAVEL, clayey, poorly graded gravel-sand-clay mixture; about 50% hard, subangular gravel, max. size 3"; about 30% coarse- to medium-grained, hard, subangular sand; about 20% highly plastic, fine clay, mainly in lumps, derived from shale (GC)

CLAY, fat, considerable amount of very fine sand, derived from shale, highly plastic; material in sample coated with sand and gravel caving from above (CH)

NOTE: Stopped due to caving.

AP 174
EL 5436.1

0 – 13'; 7-31-57

SAND, silty, about 70% - 80% soft, fine-grained #50 (#30 from 0-5') max. size; about 30% (20% from 0-5' and 8' - 11') slightly plastic silt fines; quick dilatancy, firm and damp in place (SM)

NOTE

For explanation and note see Dwg. 343-D-171.

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

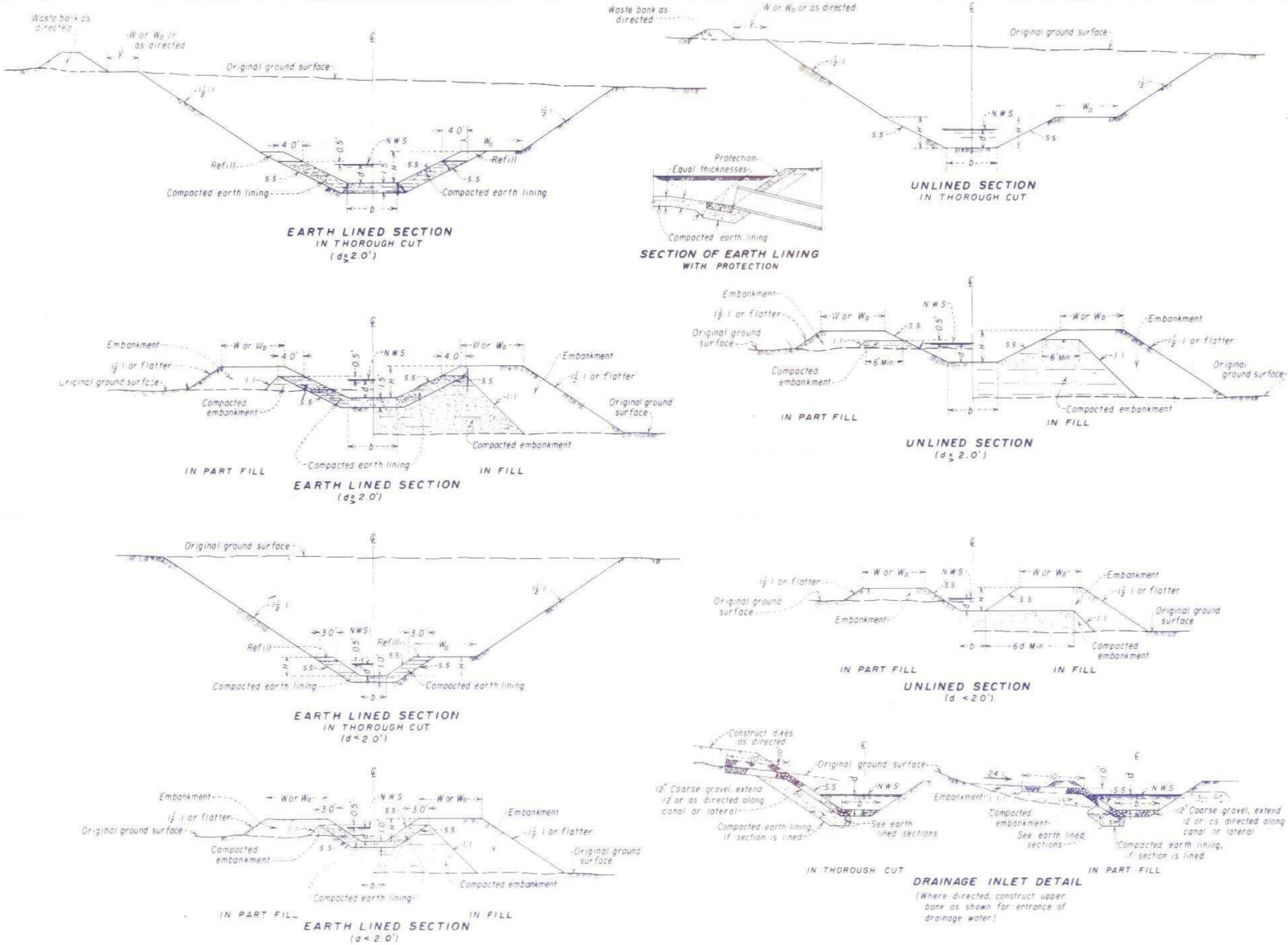
HAMMOND PROJECT—NEW MEXICO

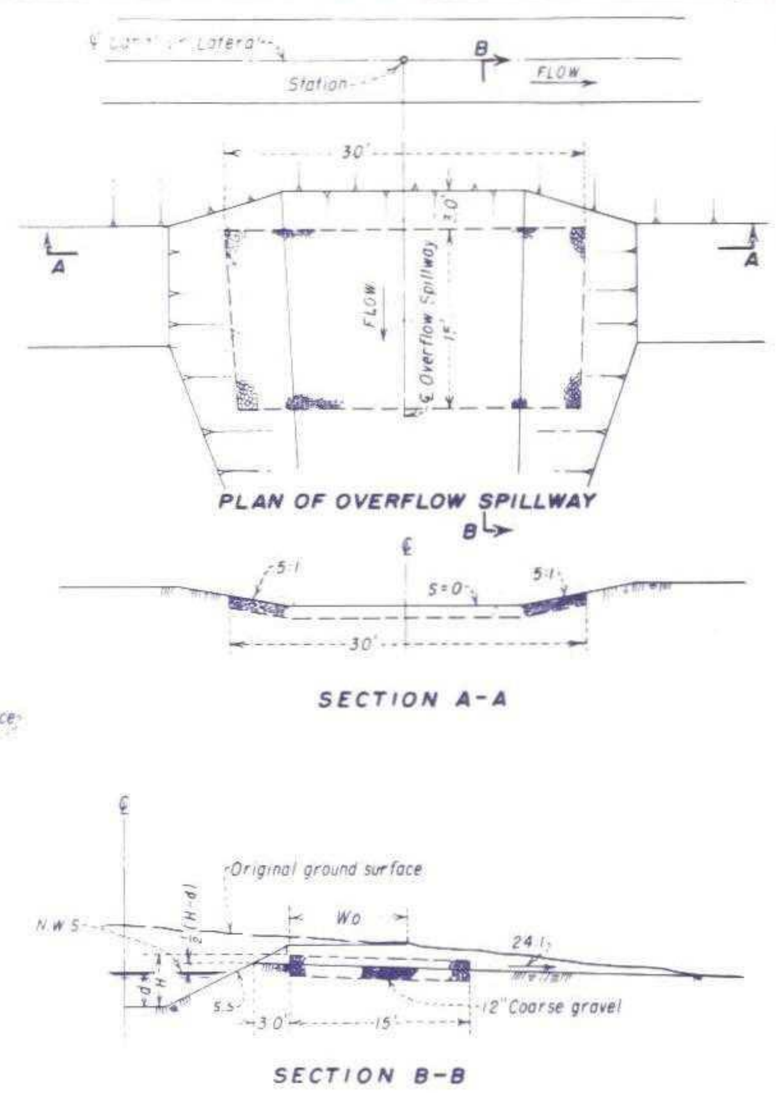
MAIN CANAL
STA. 359+55 TO STA. 1476+60
LOGS OF EXPLORATION

DRAWN	J.R.D.-W.M.S.	SUBMITTED	[illegible]
TRACED	R.B.S.	RECOMMENDED	William H. [illegible]
CHECKED	[illegible]	APPROVED	[illegible] CHIEF DESIGNING ENGINEER

DENVER, COLORADO, FEBRUARY 21, 1961
SHEET 5 OF 5

343-D-173





NOTES

For values of b, d, and s.s., minimum values of H, w, and W_o, see Plan and Profile Drawings

W = Minimum bank width, W_o = Minimum bank width for O & M road. For location of O & M roads, see Plan and Profile Drawings

For location of Overflow Spillways, see Plan and Profile Drawings

Where an earth-lined section adjoins an earth transition, the transition shall be lined with the same material of the same thickness as the earth-lined section

Earth lining placed under protection shall have the same thickness as the adjoining lining without protection

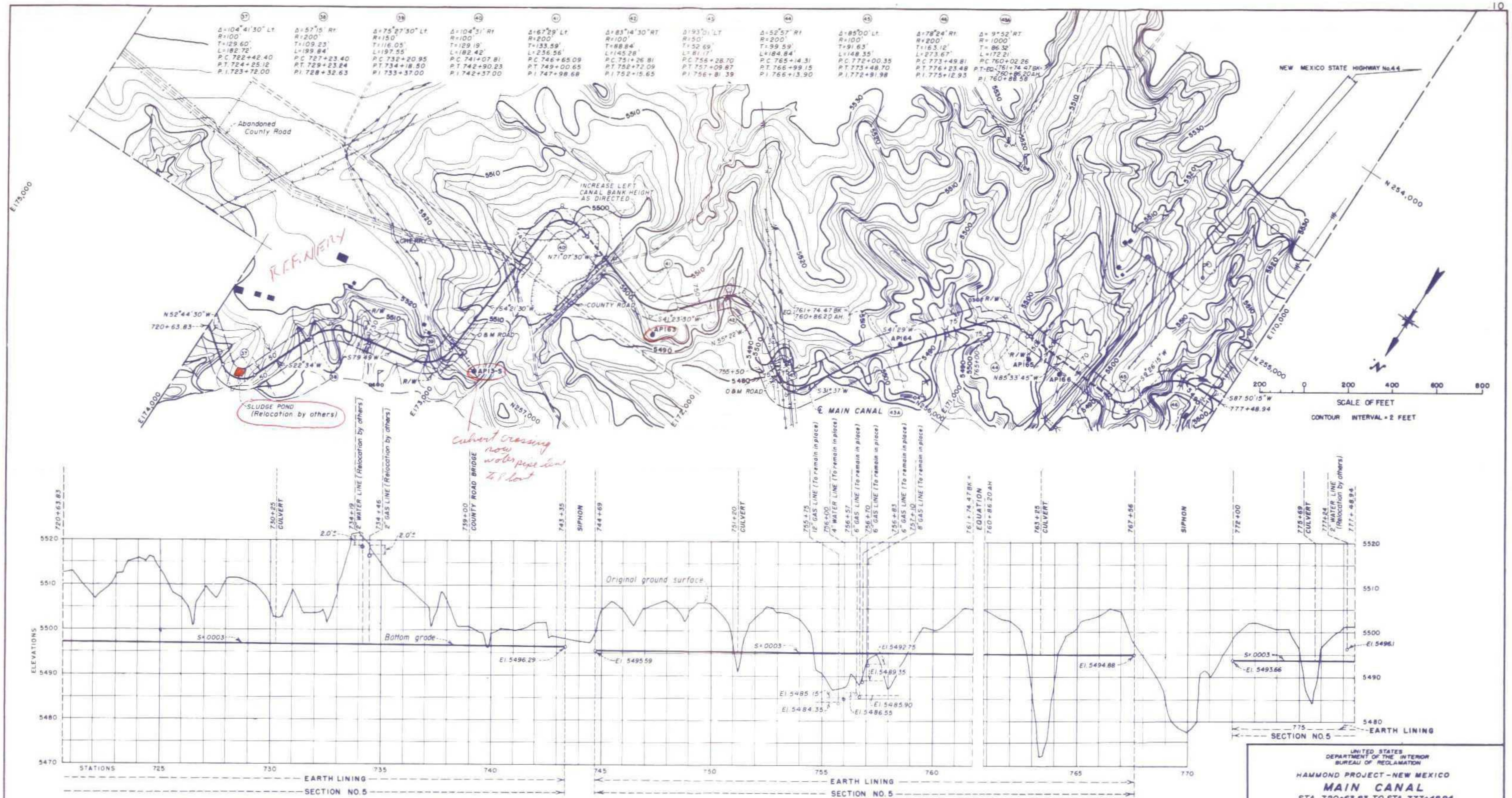
UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
HAMMOND PROJECT - NEW MEXICO

MAIN CANAL - STA. 359+55 TO STA. 1476+60 (END); GRAVITY EXT., EAST HIGHLINE, AND WEST HIGHLINE LATS.

TYPICAL SECTIONS

DRAWN J.O.G. — SUBMITTED W. T. [signature]
TRACED H.M.G. — RECOMMENDED [signature]
CHECKED [initials] — APPROVED [signature] CHIEF DESIGNING ENGINEER

DENVER, COLORADO, FEB 8, 1961 | 343-D-91



HYDRAULIC PROPERTIES

SECTION	Q	A	V	b	d	r	n	S	H	W	W_0	S.S.
No. 5	45	29.84	1.51	7	2.70	1.78	.025	.0003	4.2	5	.10	$1\frac{1}{2}$:1

NOTES

For typical canal sections, see Dwg. 343-D-91
For logs of geologic exploration, see Dwg. 343-D-173

COMPILED FROM PROJECT DWG. 343-422-22
THIS DRAWING SUPERSEDES DWG. 343-406-150

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

HAMMOND PROJECT – NEW MEXICO

MAIN CANAL

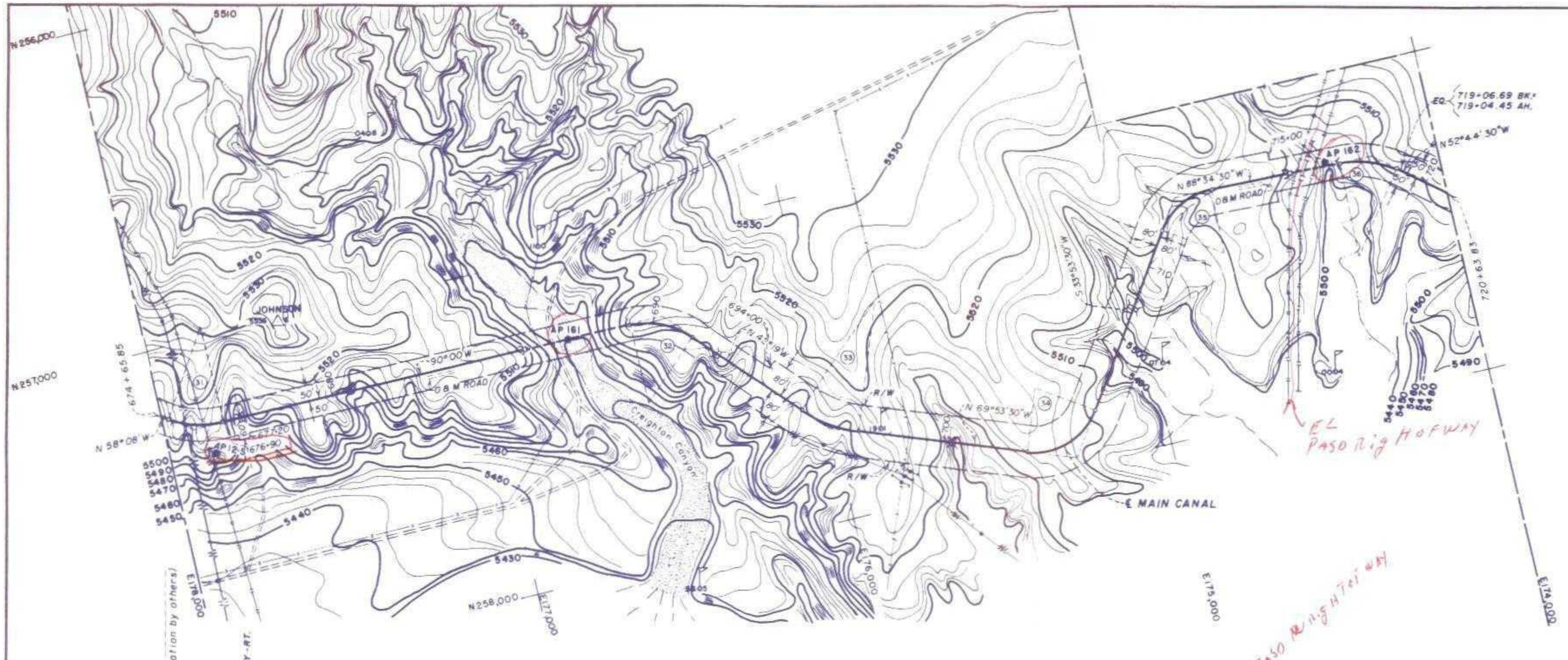
STA. 720+63.83 TO STA. 777+48.94

PLAN AND PROFILE

DRAWN D.M.M. SUBMITTED [signature]
TRACED D.R.H. RECOMMENDED [signature]
CHECKED [initials] APPROVED [signature]
CHIEF DESIGNING ENGINEER

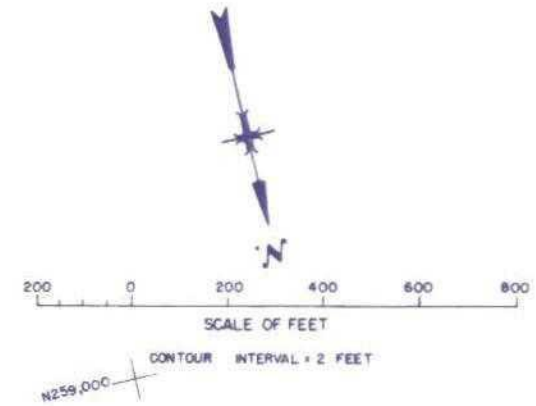
DENVER, COLORADO FEBRUARY 8, 1961
SHEET 8 OF 22

343-D-99



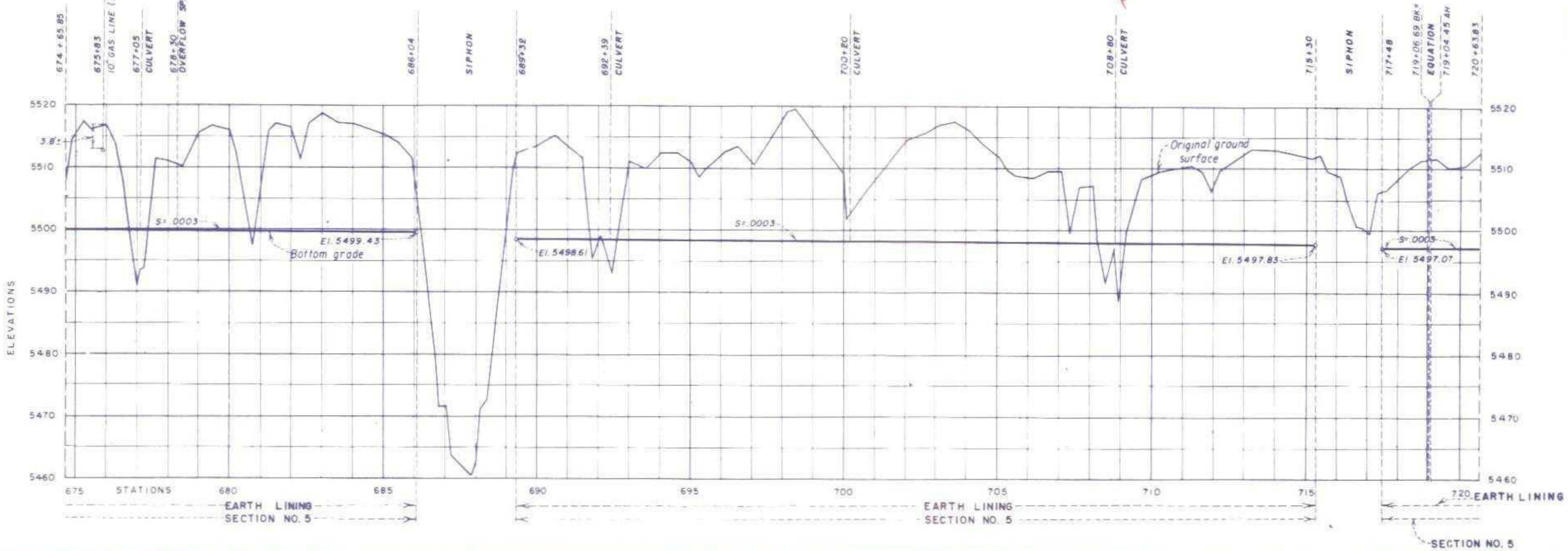
㉛	㉜	㉝
Δ = 31° 52' LT	Δ = 47° 41' RT	Δ = 55° 09' LT
R = 300'	R = 250'	R = 400'
T = 85.65'	T = 110.48'	T = 98.16'
L = 116.85'	L = 208.06'	L = 192.51'
P.C. 674 + 89.90	P.C. 689 + 36.42	P.C. 695 + 41.74
P.T. 676 + 56.75	P.T. 691 + 44.48	P.T. 697 + 34.25
P.I. 675 + 75.55	P.I. 690 + 46.90	P.I. 696 + 39.90

㉞	㉟	㊱
Δ = 76° 13' LT	Δ = 57° 32' RT	Δ = 35° 30' RT
R = 200'	R = 200'	R = 200'
T = 156.87'	T = 109.80'	T = 64.02'
L = 266.05'	L = 200.83'	L = 123.92'
P.C. 702 + 58.93	P.C. 711 + 09.90	P.C. 717 + 49.80
P.T. 705 + 24.98	P.T. 713 + 10.73	P.T. 718 + 73.72
P.I. 704 + 15.80	P.I. 712 + 19.70	P.I. 718 + 13.82



HYDRAULIC PROPERTIES

SECTION	Q	A	V	b	d	r	n	S	H	W	Wo	S.S.
No. 5	45	29.84	1.51	7	2.70	1.78	.025	.0003	4.2	5	10	1½:1



NOTES

For typical canal sections and overflow spillway, see Dwg. 343-D-91
For logs of geologic exploration, see Dwg. 343-D-173

COMPILED FROM PROJECT DWG. 343-422-21
THIS DRAWING SUPERSEDES DWG. 343-406-149

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

HAMMOND PROJECT—NEW MEXICO

MAIN CANAL

STA. 674+65.85 TO STA. 720+63.83

PLAN AND PROFILE

DRAWN D.M.M. SUBMITTED W. F. Schneider
TRACED D.R.H. RECOMMENDED [signature]
CHECKED J.K. APPROVED [signature]
CHIEF DESIGNING ENGINEER

DENVER, COLORADO FEBRUARY 8, 1961
SHEET 7 OF 22

343-D-98

ATTACHMENT 5. THERMODYNAMIC CONSIDERATIONS FOR DETERMINATION OF WASTE-WATER-CONCENTRATION FACTORS NECESSARY FOR SALT PRECIPITATION.

The cornerstone of our ability to calculate the effects of evaporation upon the concentration of dissolved solids in aqueous solutions is the Law of Mass Action. The driving force of a chemical reaction to right or left is related to the concentrations of the reactants and products. When a system is in equilibrium, the rates to the right and left are equal. For a system in equilibrium, the relationship of the concentrations of the reactants and products can be stated, "The product of the activities of the reaction products, each raised to the power indicated by its numerical coefficient, divided by the product of the activities of the reactants, each raised to a corresponding power, is a constant at a given temperature." This constant is the thermodynamic equilibrium constant.

Simply stated if the reaction of b moles of B with c moles of C are in equilibrium with d moles of D and e moles of E

$$bB + cC = dD = eE$$

then:

$$K = \frac{a_D^d \quad a_E^e}{a_B^b \quad a_C^c}$$

here a is the activity or thermodynamic concentrations of the various reactants and products and K is the thermodynamic equilibrium constant.

By definition, the activity of solid is unity. The solubility product constant is that equilibrium constant for which the product of a reaction is a solid which precipitates from solution.

Equilibrium constants and solubility product constants for any particular reaction may be calculated from the standard free energy of the particular reaction. The standard free-energy of reaction is the sum of the free energies of formation of the products in their standard states, minus the free energies of formation of reactants in their standard states.

$$\Delta F_r^\circ = \Sigma F_f^\circ \text{ products} - \Sigma\Delta F_f^\circ \text{ reactants}$$

The standard free-energy of reaction is related to the equilibrium constant by

$$\Delta F_r^\circ = RT \ln K$$

where R is the gas constant, and T the absolute temperature.
At 77° F (25°C)

$$\Delta Fr^\circ \text{ (kcal)} = -0.001987 \text{ kcal/deg} \times 298.15 \ln K$$

$$\Delta F_r^\circ = -0.592 \ln K$$

When a soluble salt, such as sodium chloride, is dissolved in water until the solution is saturated, the equilibrium constant between the solid phase and the completely ionized salt in solution may be expressed as

$$NaCl_s = Na^+ + Cl^-$$

For this process the equilibrium constant is

$$K_s = (a_{Na^+}) \quad (a_{Cl^-})$$

The equilibrium constant in this case is the solubility product of the salt. The solubility product may be calculated from thermodynamic considerations.

$$\Delta F_r^O = \Delta F_{N_a} + \Delta F_{Cl} - \Delta F_{NaCl}$$

$$\Delta F_r^O = (-62.589) = (-31.35) - (-91.785)$$

$$\Delta F_r^o = -2.154 \text{ kcal}$$

$$\ln K_s = -2.154/-0.592$$

$$\ln K_s = 3.636$$

$$K_s = 37.9363$$

From the magnitude of K_s it is evident that sodium chloride is not a difficultly soluble salt.

Precipitation will occur when the product of the activities of the sodium and chloride ions exceed 37.94.

Strictly the activity of a dissolved species is given as

$$a = \gamma m$$

where:

a = activity

γ = activity coefficient

m = molar concentration of species

in dilute solutions the activity coefficient is sensibly equivalent to one. For concentrated solutions the activity coefficient is generally much less than one. Figure 5-1 and 5-2 show the variation in activity coefficients for some typical salts and common ions. Consequently, in concentrated solutions the tendency towards precipitation is supressed by the decrease of the activity coefficient.

To determine the degree of concentrations required to cause K_s to be exceeded for several common salts, the ionic strengths for solutions of specified concentration were determined. Also the corresponding activity

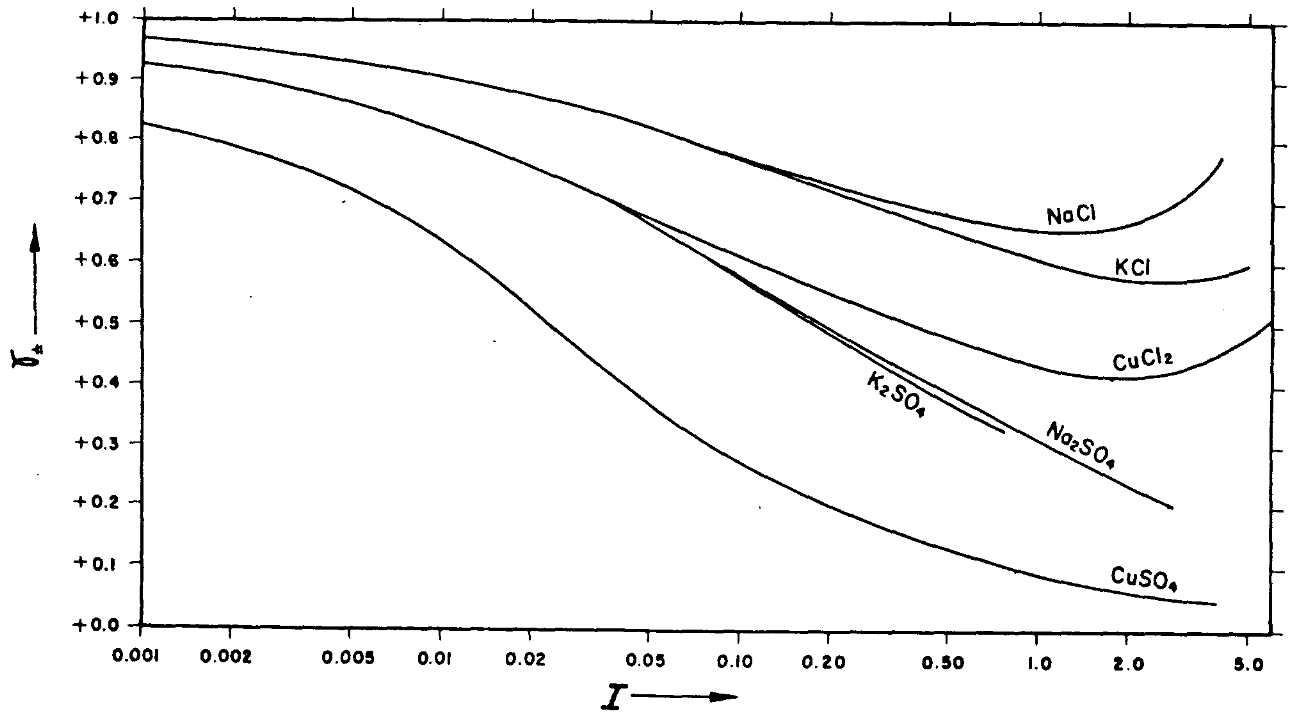


Figure 5-1. Mean activity coefficients of typical salts plotted against the ionic strength (log scale).

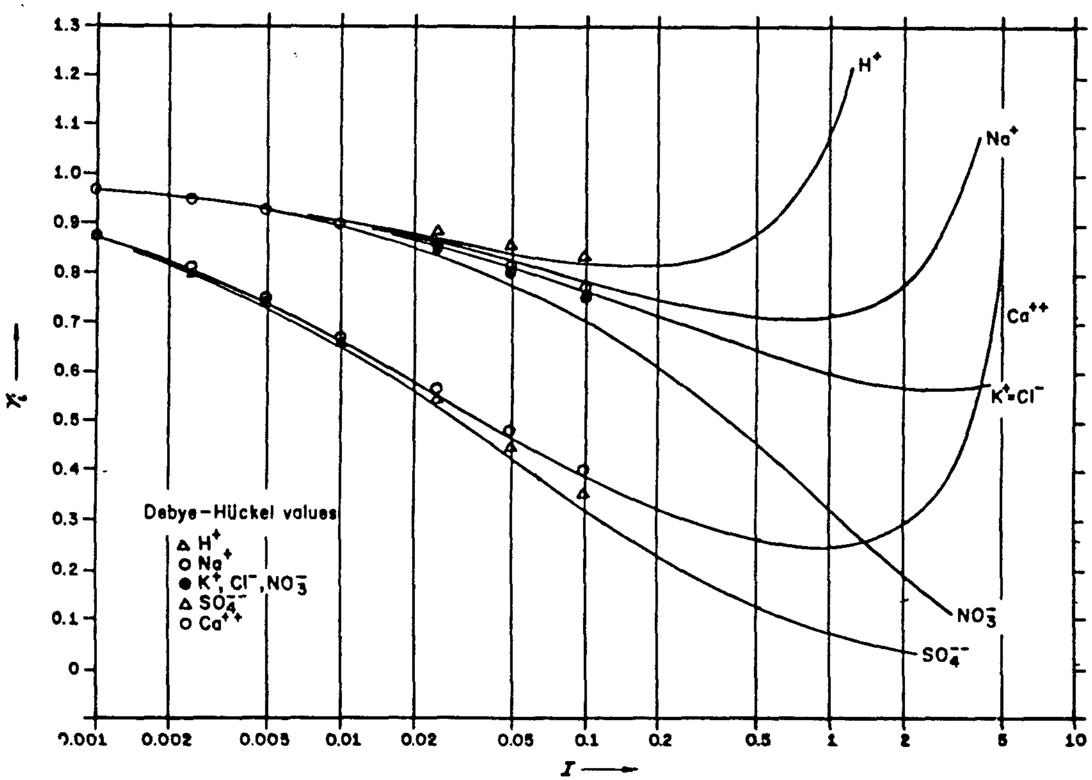


Figure 5-2. Single ion activity coefficients vs. ionic strength for some common ions. Solid lines represent the values calculated by the mean salt method. Debye-Hückel values were calculated with $10^8/\mathring{a}_i=9$ for H^+; 4 for Na^+; 3 for K^+, Cl^-, NO_3^-; 6 for Ca^{++}; and 4 for SO_4^{--}. The Debye-Hückle γ_i values for the monovalent ions converge, within experimental error, for $I < 0.01$.

coefficients were determined and the equilibrium constants calculated. Results of these computations are given below

Concentration Factor	Ionic Strength	γ_{Na^+}	γ_{Cl^-}	m_{Na^+}	m_{Cl^-}	K.
10	1.004	0.72	0.60	0.85	0.17	0.06
20	2.008	0.78	0.58	1.70	0.34	.26
40	4.016	1.07	0.582	3.40	0.68	1.44

When the log of the concentration factor is plotted against the log of the equilibrium constant obtained in the table above figure 5-3 is obtained. The concentration factors necessary to reach the solubility product of 37.94 is read from the log - log plot as 173. That is, the volume of original wastewater would have to be reduced to 1/173 of the original volume before sodium chloride would precipitate.

Solubility products for several common salts are given below together with the concentration which would be required of the Plateau refinery wastewater to cause precipitation. The solubility of calcium carbonate is highly pH dependent but because its solubility product is much less than the solubility product of calcium sulphate, calcium carbonate will precipitate before the calcium sulphate.

Compound	K_s	Concentration Factor
$CaCO_3$	8.7×10^{-9}	<8
$CaSO_4$	1.08×10^{-4}	8
Na_2SO_4	1.861	187
Na Cl	37.94	173

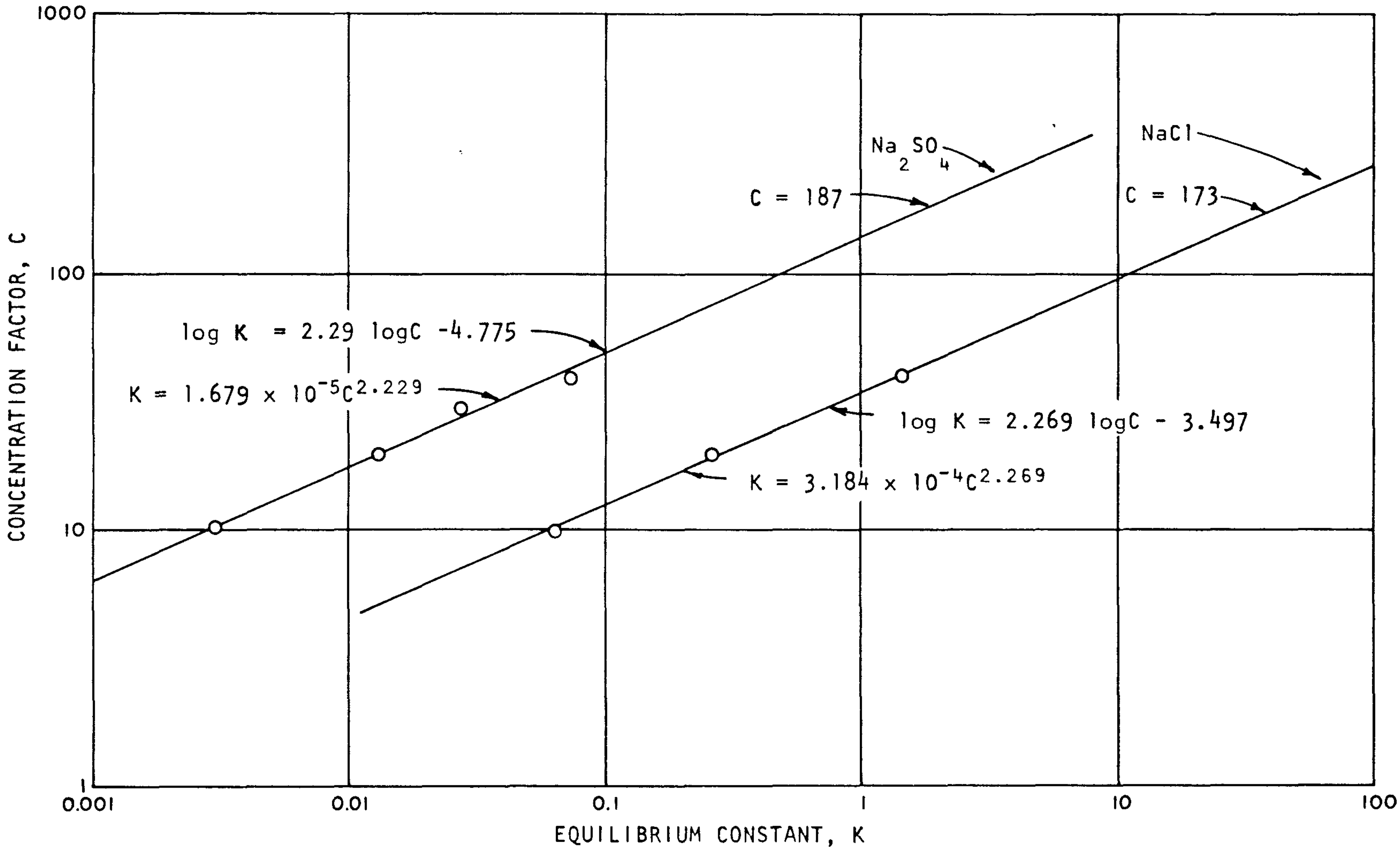


Figure 5-3. Concentration factors of refinery effluent necessary to achieve given equilibrium constants for NaCl and Na_2SO_4.

ADDENDUM TO THE DISCHARGE AND MONITORING PLAN FOR A REFINERY OPERATED BY PLATEAU, INC. NEAR BLOOMFIELD, NEW MEXICO

Submitted to

Plateau, Inc.
Farmington, New Mexico

Submitted by

American Ground Water Consultants, Inc.
Consulting Ground Water Geologists & Hydrologists
Albuquerque, New Mexico

AMERICAN
GROUND WATER
CONSULTANTS, INC.

2300 CANDELARIA ROAD, N.E.
ALBUQUERQUE, NEW MEXICO 87107
TELE: (505) 345-9505 CABLE: HYDROCONSULT
TELEX: 66-0422 TELECOPIER: (505) 247-0155

April 4, 1978

Mr. William Hagler
Vice President of Marketing
Plateau, Inc.
Post Office Box 108
Farmington, New Mexico 87401

Dear Mr. Hagler:

American Ground Water Consultants has the pleasure to submit herewith the Addendum to the Discharge and Monitoring Plan for a Refinery Operated by Plateau, Inc. near Bloomfield, New Mexico. This addendum has been prepared in response to comments raised by the New Mexico Environmental Improvement Agency.

It has been a privelege serving Plateau in this matter.

Sincerely,

Dr. William M. Turner
President

WMT:ajs

TABLE OF CONTENTS

SUMMARY AND CONCLUSIONS

Based upon the hydrogelogy of the refinery site and the spatial occurrence of the cobble bed of the Jackson Lake Terrace it is evident that:

1. There is no naturally occuring ground water within the cobble bed or the underlying Nacimiento Formation which is tributary to either the Hammond ditch or the San Juan River.

2. Any water in the cobble bed derives from seepage from the Hammond ditch.

3. There is no evidence at the present time for seepage from the solar evaporation ponds.

4. Any potential future seepage must discharge either into the Hammond ditch or in the small valleys of the area which drain northward and into the San Juan River.

5. The refinery site is not subject to flooding.

Because of the observations above, it is concluded that:

1. No contamination of local ground water can take place.

2. The monitoring network and the monitoring program currently underway are sufficient to detect leakage of water from the solar evaporation ponds into either the Hammond ditch or the San Juan River.

INTRODUCTION

In October, 1977, Plateau, Inc., submitted to the New Mexico Oil Conservation Commission (NMOCC) a proposed discharge and monitoring plan for its refinery located at Bloomfield, New Mexico. This plan was submitted for informal review and comment by the NMOCC. The NMOCC in turn requested the New Mexico Environmental Improvement Agency (NMEIA) to provide technical comment. On December 8, 1977, the NMEIA responded in writing to the NMOCC. On December 13, 1977, comments on the proposed discharge and monitoring plan were forwarded by the NMOCC to Plateau, Inc. These comments have been included in attachment 1 of the proposed discharge and monitoring plan.

The comments pertain generally to the: 1) quality of ground water in the area of the evaporation ponds and the adequacy of the monitoring program; and, 2) the sampling program. In addition the question of flooding at the Plateau refinery was raised. It is the objective of this addendum to the proposed discharge and monitoring plan to respond to the specific comments made in the December 8, 1977, letter.

LOCAL GROUND WATER

The geologic setting of the plant site is described in the original report where it is mentioned that the refinery is situated upon a deposit of Pleistocene loess which in turn overlies slightly older cobble. The cobble overlies the Nacimiento Formation of Tertiary age. Attachment 2 of the original report contains the drillers log of the AMOCO-Davis Gas Unit F-1 well, located near the refinery. This log indicates that the Nacimiento Formation is about 495 feet thick. At the plant site the Nacimiento Formation is exposed in a northward facing cliff which is about 100 feet in height. The San Juan River is at the base of the cliff and the refinery sits above on the Jackson Lake Terrace.

At the cliff face, the contact between the cobble bed of Pleistocene age and the underlying Nacimiento Formation is easily visible. It is observed that the cobble bed contains no water except where water from the Hammond ditch percolates into the cobble bed and thence into small valleys which have been cut into the terrace. This seepage sustains lush vegetation in these valleys. Wherever these seeps are encountered, the seep is always at the contact between the cobble bed and the Nacimiento Formation. The Nacimiento Formation is for all intents and purposes an impermeable, unctious green shale. It is particularly well exposed in the badlands of Kutz Canyon several miles to the south.

To verify that the cobble bed is void of natural ground water the contact between the cobble bed and the underlying Nacimiento Formation was staked at numerous points shown in addendum figure 1. Elevations of the contact were then levelled. The elevations of the contacts are also shown in figure 1. Elevations shown in italics represent elevations of the contact at points where small seeps of water were observed.

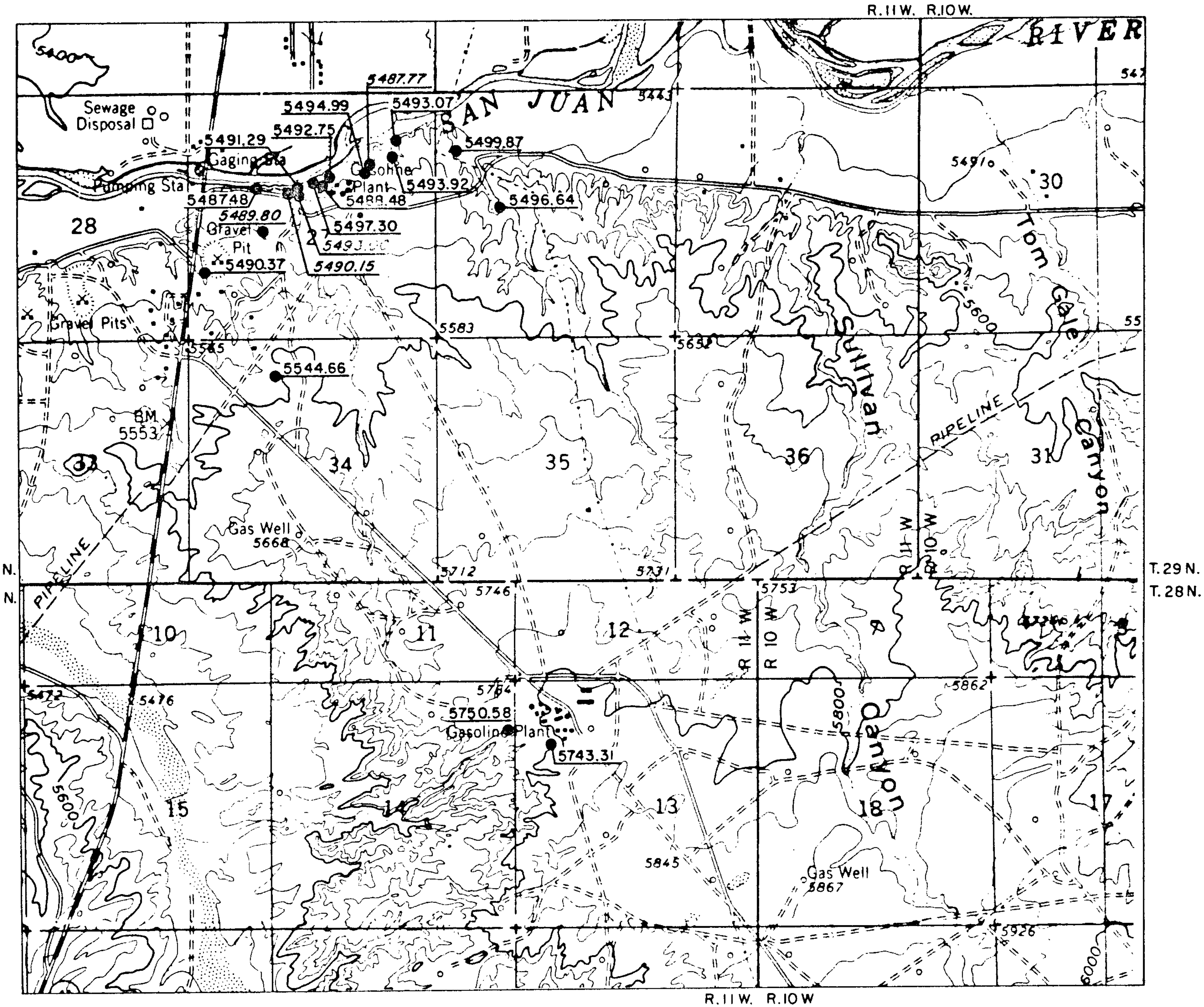


Figure 1. Map of Plateau refinery and vicinity showing elevation of the contact between the Nacimiento Formation and the cobble bed.

It is evident from figure 1 that the slope of the subcrop beneath the cobble bed is to the north or northwest at about 1.2 degrees. It is also evident that the subcrop topography is slightly undulose and this is easily visible in the outcrop. The spatial occurrence of the cobble bed indicates that it is dry. Any natural recharge to the cobble bed would drain to the north and either discharge into one of the southward trending valleys or onto the northward facing cliff immediately north of the refinery. All seeps have been closely observed for nearly one year and for most of that time, solar evaporation pond 1 has been filled with fresh water. During that time and more significantly during the past winter when the Hammond ditch was dry no increase in seepage was observed at any seep; in fact, the amount of seepage has diminished suggesting that the Hammond ditch contributes the water which supports the vegetation in the area. In January, 1978, the Hammond ditch was completely dry and it was walked from the eastern to the western boundary of the refinery. In the vicinity of the solar evaporation ponds no seepage into the ditch was observed. It is important to note that at the time of this visual inspection, solar evaporation pond 1, which is in closest proximity to the ditch was completely full.

It is concluded, therefore, that there is no naturally occurring ground water within the cobble bed capping the Jackson Lake Terrace. This conclusion is supported by the absence of private domestic water wells anywhere on the terrace.

The Nacimiento Formation, as mentioned above, is an impermeable, unctious green clay. It is about 495 feet deep and throughout its thickness is not known to contain any ground water. There are no known sandstone beds within the Nacimiento Formation. The upper 100 feet of the formation which is exposed in the cliff north of the refinery shows no seeps of water from within the Nacimiento Formation.

It is concluded that there is no ground water within the Nacimiento Formation which could be recovered for domestic purposes. Seeps at the contact of the cobble bed with the Nacimiento Formation support the impermeability of the Nacimiento Formation and support the conclusion that the Nacimiento Formation does not contribute ground water to the San Juan River.

With specific reference to the comments made in the December 8, 1977 letter from the NMEIA to the NMOCC, 1) there is no ground water likely to be affected by the proposed discharge; consequently, 2) a water-table-contour map cannot be prepared. Any water in the cobble bed derives from the Hammond ditch and is a very thin zone directly above the Nacimiento Formation. Finally, because there is no naturally occuring ground water in the area, any contained water is most likely to be similar in quality to the water in the Hammond ditch and in the San Juan River, an analysis of which appears in table 4 of the original report.

CONSTRUCTION AND LOCATION OF MONITOR WELLS

Inasmuch as there is no naturally occuring ground water beneath the refinery, no ground water monitoring wells will be constructed. No information can be gained from monitoring wells that cannot be gained from careful monitoring of water in the Hammond ditch and the San Juan River for the tracer which is currently injected into the evaporation pond.

Inasmuch as any seepage which may occur must ultimately drain to the north, the monitoring network which currently exists is sufficient for monitoring any seepage from either solar evaporation ponds 1 or 2.

SAMPLING, REPORTING & CONTINGENCY

At present monitoring is carried out according to the following schedule:

Method	Frequency	Parameter Measured
Neutron Logging	Quarterly	Moisture content of soils
Thermonics	Semi-Annually	Rate of water movement in Unsaturated zone
Zeta SP	Semi-Annually	Leakage through bottom of evaporation ponds
Aquatrace	Monthly	Tracer

The sampling frequency may be decreased if, in the opinion of American Ground Water Consultants little new information is to be gained by more frequent monitoring. On the other hand, the frequency of monitoring may increase if a rapidly changing condition is encountered which requires close attention. Any decision to change the frequency of monitoring will be reviewed with the NMOCC.

Plateau, Inc., will submit any and all monitoring data to the NMOCC at their request and for their independent review.

Because there is no naturally occurring ground water in the area, it follows that no deterioration can take place. The solar evaporation ponds appear to be well sealed and there is no evidence that seepage of fresh water has taken place. It is anticipated that precipitation of salts from the waste-water effluent will further seal the bottoms of the two evaporation ponds. In the event of significant seepage through the pond bottoms, it must flow to either the Hammond ditch or to one of the small valleys which occur in the area. Because there has been no seepage into the ditch while pond 1 has been full, it is difficult to hypothesize the potential magnitude of a seep in the future. A seep of 10 or even 100 gpm into the Hammond ditch would encounter water flowing at 20,000 gpm and the dilution of contaminants would be from 200 to 2,000 to one. The dilution of a similar seep into the San Juan River would be much greater as the flow of the San Juan River is now controlled to 500 cfs (224,415 gpm).

In the unlikely event that serious contamination of surface water took place, it will be possible to construct either interceptor wells to capture the contaminated water before it enters the Hammond ditch or the small valleys of the area, or to construct a cutoff wall between the evaporation ponds and the Hammond ditch. The cutoff wall would involve the emplacement of impermeable materials in a trench oriented so as to form a barrier boundary to the subsurface flow of contaminated water from the evaporation ponds to either the ditch or the small valleys.

FLOODING

The refinery is located on the Jackson Lake Terrace which, for a small area such as is occupied by the refinery, may be considered for all intents and purposes as level. There are no arroyos or other intermittant stream channels developed south of the plant site which would collect large amounts of surface runoff during transient thunderstorms and which would lead to the flooding of the refinery property.

The refinery property itself possesses many small embankments or berms which enclose hydrocarbon storage tanks and other facilities. These embankments are intended to contain any potential accidental hydrocarbon spill. Moreover, they act to contain rainfall on the property and to prevent runoff of rainfall into the nearby Hammond ditch.

As a result of the geomorphologic setting of the refinery and as a consequence of the on-site modification of the land surface, the flooding of the site by natural causes is improbable.