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Harding Lawson Associates

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July 11, 1986

State of New Mexico
Oil Conservation Division
P.O. Box 2088
Land Office Building
Santa Fe, New Mexico 87501

Attention: Mr. David Boyer

Dear Mr. Boyer:

Enclosed please find a copy of our draft report on the hydrogeologic conditions at the Navajo Refinery Company, Artesian Refinery site. The public review copy of the Discharge Plan for Navajo, which you sent me, was extremely useful and, as we agreed, I am sending you our draft report.

I regret that it has taken so long to provide you with a copy of this report. I hope this has not caused you any inconvenience.

Thank you for your assistance.

Yours very truly,

HARDING LAWSON ASSOCIATES

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Geology and Ground Water

Discrepancies in Geologic and Hydrogeologic Information

Geologic and hydrogeologic information available for this review was obtained primarily from two sources, both of which were prepared by consultants retained by Navajo: the 1983 Part B Application and the Discharge Plan* dated July 31, 1985 (16 and 1). Major geologic and hydrogeologic discrepancies between the two sources are as follows:

Nature of Geologic Deposits. The subsurface geology at the Navajo site, as reported in the Part B Application, consists of over 300 feet of alluvial deposits. The alluvium consists of silt, sand, gravel, and cobbles with an underlying quartzose conglomerate unit ranging in thickness from a feather edge to more than 300 feet (16, page III-1-5). In contrast, the Discharge Plan reported that the Navajo site is underlain by evaporites, carbonates, and shales of the Artesia Group deposited in a backreef environment (1, page 4-2).

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*Facilities involved in the production and refining of oil and gas products are required by the New Mexico Water Quality Control Commission to file a Discharge Plan with the Oil Conservation Commission. Such plans are required to include information regarding the character and location of any facility discharges to surface or ground waters.

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<u>Geologic Deposit Nomenclature</u>. The Part B Application identified seven geologic formations/deposits at the Navajo site: San Andres Formation, Chalk Bluff Formation, Quarternary alluvium, Orchard Park Terrace, Lakewood Terrace, Blackdom (sic) Terrace, and quartzose conglomerate unit (16, pages III-1-2 and III-1-5). The Discharge Plan identifies five geologic formations/deposits in the Artesia area: San Andres Formation, Queen Formation, Seven Rivers Formation, Pecos River Valley alluvium, and Bower sand unit (1, page 4-1 and Figure 4-3).

<u>Regional Geomorphology</u>. The Part B Application indicates that Navajo is located in an area of alluvial terraces which includes the Orchard Park Terrace (approximately 40 to 60 feet above the Pecos River) and the Lakewood Terrace (approximately 20 to 30 feet above the Pecos River) (16, page III-1-5). The Discharge Plan states that "The Artesia region is located on a broad, gently sloping plateau which has developed as a result of in-situ weathering of flat-lying carbonate and evaporitic bedrock" (1, page 4-2).

<u>Description of Uppermost Aquifer</u>. The Part B Application states, "The uppermost aquifer is considered to be the thin water-bearing anhydritic sand with cobble seams interbedded with clay, silty clay, sandy clay, and gypsum found at depths ranging from 14 to 22 feet" (16, page III-1-18). In contrast, the Discharge Plan states, "Water is encountered in weathered and fractured anhydrite (so-called gypsum sand) at depths of 15 to 30 feet" and that "This water-bearing unit is confined above by layers of gypsum, anhydrite, and caliche, and below by a continuous layer of clay and anhydrite" (1, page 4-10).

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The above-mentioned discrepancies could not be reconciled during this review. Based on telephone conversations with Ms. Deborah Vaughn-Wright of U.S. EPA Region VI, the geologic and hydrogeologic information provided in the Discharge Plan appears to be the most accurate and is summarized in the following two sections. At EPA's direction, we have used the geologic and hydrogeologic information contained in the Discharge Plan in developing (for each SWMU) the assessments of release pathways and conclusions regarding potential for releases.

Geology

Navajo supplied information regarding four geologic units present in the Roswell-Artesia Basin: the San Andres Formation, the Queen Formation, the Seven Rivers Formation (all part of the Artesia Group), and the Pecos River Valley alluvium. The Artesia Group reportedly consists of carbonates, evaporites, and shales deposited during the Permian period in a backreef environment. Quaternary alluvium deposits overlie the Permian formations.

The San Andres Formation, reportedly about 1000 feet thick in the site area, is composed of limestone and dolomite. Navajo reports that it contains solution cavities ranging in diameter from a fraction of an inch to several feet and that the cavernous zones are not confined to certain beds but are extremely irregular and erratic. The San Andres Formation crops out in the western highlands (Sacramento Mountains region) and dips eastward under younger sedimentary rocks in the Roswell Basin. It is found at depths greater than 850 feet below ground surface.

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The Queen Formation overlies the San Andres Formation and reportedly consists of shales, evaporites, and sands. The sands are 10 to 50 feet thick and lie at the top of about 700 feet of relatively impermeable carbonates and evaporites which comprise the bulk of the Queen Formation. The Queen is encountered approximately 150 feet below ground surface, according to Navajo.

The Seven Rivers Formation overlies the Queen Formation and consists of evaporites, carbonates, gypsum, and shale with isolated sand and fractured anhydrite/gypsum lenses. The thickness of this formation (in the vicinity of the Navajo facility) is reported to be approximately 200 feet.

The Pecos River Valley alluvium (Quaternary) is encountered at the surface in the Artesia area adjacent to the Pecos River and generally consists of silty sand. A cross section in the Discharge Plan (1, Figure 4-3) indicates that the westernmost extent of the Pecos River Valley alluvium is approximately 2.5 miles east of the refinery area. No additional geologic information concerning the alluvium was available for this review.

Southeasterly stratigraphic dips of 1 to 3 degrees are reportedly typical in the Permian deposits in the Artesia area. One fault (inferred from subsurface data) is mapped approximately 2.5 miles east of the refinery site. The fault is apparently a normal fault trending approximately N40°E through sections 11, 12, and 14 and has displaced the Seven Rivers, Queen, and San Andres formations. The northwest fault block is reportedly downthrown.

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A unit designated the Bower sand is identified on a cross section in the Discharge Plan but is not addressed in the text of the Plan. A letter by Geoscience Consultants, Ltd. described the sand as the "bottom water sand within the Seven Rivers Formation" (22). This letter states that the sand is discontinuous, but the Discharge Plan cross section clearly indicates that the Bower Sand is an extensive, horizontally continuous deposit (see Figure 3).

Ground Water

The Navajo Refinery is located in the Roswell-Artesia artesian water basin. The San Andres and upper Queen formations are the principal aquifers of the Artesia area; the Seven Rivers Formation and the Pecos River Valley alluvium reportedly produce poor quality water and are generally not used.

The San Andres, known locally as the deep or artesian aquifer, is the major source of ground water in the Artesia area and has been extensively developed for industrial, municipal, and agricultural purposes. The deep aquifer supports most of the large, local agricultural industry. Navajo reports that artesian water, of quality ranging from 500 to over 5000 ppm TDS, is found in the San Andres (and the associated Grayburg Formation) at depths of 850 to 1250 feet below ground surface. The aquifer is recharged along San Andres outcrops in the Sacramento Mountains west of Artesia. According to Navajo, in the early 1900s many wells in this aquifer flowed at 1000 to 3000 gallons per minute, but extensive withdrawals have lowered the piezometric head to about 50 to 80 feet below ground surface. The San Andres aquifer is confined by the impermeable (or slightly permeable) carbonates, shales, and evaporites of the overlying Queen Formation.

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The shallow aquifer, as defined by Navajo, consists of the sands of the upper Queen Formation. This is the second principal ground-water reservoir in the Artesia area. The sand layers of the upper Queen Formation are 10 to 50 feet thick and are encountered at depths of approximately 200 to 250 feet below ground surface.* These sands are confined by the thick anhydrites and shales of the overlying Seven Rivers Formation and are separated from the underlying San Andres Formation by 700 feet of relatively impermeable carbonates, shales, and evaporites which comprise the bulk of the Queen Formation. The upper Queen exhibits nearly 100 feet of artesian head and yields ground-water quality adequate for domestic and irrigation use (500 to 1500 ppm TDS). Water levels in the shallow aquifer wells reportedly range from 40 to 60 feet below ground level.

A map of the shallow aquifer potentiometric surface provided by Navajo indicates that the potentiometric surface typically slopes gently to the east and southeast and follows the regional stratigraphic dips. South of the Artesia area, where extensive agricultural development exists, the potentiometric surface forms a trough due to significant withdrawals from the shallow aquifer. The shallow aquifer's potentiometric surface is generally slightly below the San Andres aquifer's potentiometric surface. Navajo

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*Conflicting information was presented regarding the actual depth of these sands; Navajo also reports that shallow wells typically produce from the sands at depths of 150 to 250 feet.

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states that if a hydraulic interconnection exists between the two aquifers, ground water would flow upward from the deep to the shallow aquifer.

The Seven Rivers Formation overlies the Queen Formation and consists of evaporites, carbonates, shales, and clay. The formation is nearly impermeable with the exception of local, isolated zones of sand and fractured anhydrite/gypsum. Navajo reports that lithologic logs from monitoring wells installed on site show that water is encountered in weathered and fractured anhydrite (called gypsum sand) at depths of 15 to 30 feet.

Information regarding the thickness of the underlying clay layer, the structural relationship between the underlying clay and anhydrite, and the degree of fracturing/weathering of the anhydrite (if any) was not provided by Navajo. Since the average depth of the on-site monitoring wells is 20 to 24 feet below ground surface, information regarding subsurface geologic conditions below a depth of 30 feet apparently was not developed by Navajo. It is not known whether the Bower sand unit corresponds to the water-bearing zone encountered at depths of 15 to 30 feet or whether it underlies this zone, which would indicate the presence of multiple permeable zones below the Navajo facility.

Ground water in the gypsum sands is under artesian pressure, and typical static water levels are 3 to 5 feet above the saturated zones. The permeable sands and fractured evaporites produce only small quantities of poor quality water. The water-bearing zones are generally less than 5 feet thick, and Navajo reports that they are typically hydraulically connected. However, data from Wells 19, 34, 29, 37, 39, and 40 show that anomalies in the potentiometric surface are present due to complex hydraulic connections in some areas of the plant site, according to Navajo.

Regionally, very shallow (10 to 30 feet), low-production wells may have tapped the gypsum water ("gyp water") in the past and produced water for stock. Many of these wells have been abandoned for various reasons including exhaustion of water or poor quality. These small, stratigraphically trapped accumulations of ground water are highly variable in areal extent, volume, saturated thickness, and quality.

Adjacent to the Pecos River is the Pecos River Valley alluvium, which reportedly is not utilized in this area for any purpose because of its poor water quality. Data from monitoring wells installed by Navajo reportedly show that ground water in the alluvium is typically 6 to 12 feet below ground surface. Although the alluvium is generally silty sand, some 6-inch monitoring wells reportedly are able to maintain a pumping rate of 10 to 15 gpm, suggesting that lenses of higher permeability material may exist. Flow is subparallel to the Pecos River Valley, according to Navajo, generally toward the river. Navajo reports that the water level in the alluvium responds to fluctuations of flow in the Pecos River and that, during periods of high flow, the hydraulic gradient is away from the river into the alluvium (the Pecos River loses water). During low-flow periods, the gradient is reportedly reversed. However, adequate documentation of this phenomenon was not provided by the facility.

<u>Ground Water - Additional Sources</u>

An inspector commented during a 1982 state inspection that all ground water under the Navajo facility is probably contaminated (26). The most recent state inspection (1985) indicated that gasoline from the refinery has contaminated the shallowest aquifer (17 feet), creating a hydrocarbon plume just upgradient of the North Colony landfarm (SWMU 1) (23). This plume is the target of Navajo's aquifer restoration program (23). A monitoring well sample from 10 feet contained phthalate concentrations in the ppb range (36), also indicating that shallow ground water has been contaminated.

Geology - Part B Application

The Navajo refinery is located in the Roswell Artesian Basin. Navajo supplied limited information regarding three geologic units, the San Andres Formation, the Chalk Bluff Formation, and the Quaternary alluvium, which they felt were important to the ground-water supply in the Roswell Basin (16, page 111-1-2). A small amount of information was available in the Part B Application regarding the Orchard Park and Lakewood Terraces and the quartzose conglomerate.

The San Andres Formation, as reported by Navajo, is composed of limestone and dolomite and contains extremely erratic solution cavities ranging in size from inches to feet (16, page 111-1-2). The formation crops out in the western highlands, dips eastward, and is reportedly approximately 1000 feet thick.

Navajo reports that the Chalk Bluff Formation consists of "redbeds", gypsum, and limestone, and overlies the San Andres Formation (16, page 111-1-2). It crops out in a broad area east of the San Andres outcrop area and dips eastward. The thickness of the Chalk Bluff is reportedly approximately 700 feet in the Artesia area.

Quaternary alluvium, consisting primarily of clay, silt, sand, gravel, and conglomerate, unconformably overlies both the San Andres and the Chalk Bluff formations, according to Navajo. The Quaternary alluvium is reportedly locally slumped and distorted due to solution and collapse of underlying rocks. The facility reports that the thickness of the alluvium ranges from a feather edge in the west to more than 300 feet in places a short distance west of the Pecos River (16, page 111-1-4). However, Navajo's regional geologic cross section (see Figure 2) contradicts this statement. The Quaternary alluvium is reportedly locally slumped and distorted due to solution and collapse of underlying rocks.

Navajo reports that younger alluvium, consisting of undisturbed silt, sand, gravel, and cobbles, was deposited by the Pecos River and its tributaries during Pleistocene time. It reportedly forms a veneer, 5 to 20 feet thick, over the Orchard Park Terrace and underlies the Lakewood Terrace adjacent to the Pecos River to a maximum depth of approximately 40 feet (see Figure 2).

The oldest alluvial deposits appear to be the quartzose conglomerate (late Tertiary) which may be part of the basal Ogallala Formation (see Figure 2) (16, page 111-1-5). The conglomerate reportedly consists of clay, silt, sand, gravel, and caliche conglomerate. However, Navajo did not document the information source for the conglomerate composition. The thickness of the quartzose conglomerate reportedly ranges from zero feet to more than 300 feet. No information on the thickness of the conglomerate beneath the site was available. Apparently no wells or boreholes at the facility have encountered the quartzose conglomerate.

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Subsurface monitoring well borings, drilled by Navajo at the North Colony Landfarm, apparently penetrated the younger alluvium to depths ranging from 19.5 to 24 feet. Four boring logs available for review indicated that the younger alluvium in the North Colony landfarm area consists mainly of tan and brown silty clay with gypsum and anhydrite to a depth of 17 to 22.5 feet overlying predominantly red clay. Interbedded dolomite gravel/pebble and anhydritic sand/pebble seams were encountered at depths average 14 to 20 feet below ground surface. The existence of pebbles in the seams suggests that the dolomite gravel and anhydrite sand are not in situ deposits as the information in the Discharge Plan suggests.

The symbol patterns used in Navajo's regional geologic cross section (see Figure 2) implies that the Orchard Park and Lakewood Terraces are distinct geologic deposits. The Orchard Park Terrace is located about 40 to 60 feet above the Pecos River and overlies the conglomerate in the vicinity of the Navajo facility. The terrace slopes gently toward the Pecos and is reportedly just slightly dissected. Apparently, more than 90 percent of the irrigated farms in the county are located on this terrace. Although Recent alluvium underlies the Lakewood Terrace (16, pg. 111-1-5), the symbol pattern associated with this terrace on Navajo's cross section implies that it differs, perhaps in composition and texture, from the Recent alluvium. The flanks of the Lakewood Terrace are located about 20 to 30 feet above the Pecos River. No information regarding the composition or thickness of either the Orchard Park or Lakewood terraces was provided in the Part B Application. The 1985 state inspection identifies the Orchard Park deposit as terrace gravels (quartzose conglomerates) (36, page 9).

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Ground Water (Part B Application)

Ground water below the Quaternary alluvium reportedly occurs in two geologic formations. The San Andres Formation is the chief artesian aquifer in the Artesia-Roswell Basin. The basal limestone of the Chalk Bluff Formation is an important artesian aquifer in the southern part of the basin.

The water in the San Andres Formation and overlying Chalk Bluff Formation reportedly moves eastward and migrates upward until it eventually discharges into the Pecos River. Except for a few wells drawing water from perched zones, Navajo reports that water-level elevations decline fairly uniformly eastward at a rate of about 3 feet per mile near the northern boundary of the county and about 10 feet per mile near Seven Rivers at the southern boundary. No water-level elevations for wells penetrating the San Andres and Chalk Bluff formations were provided in the Part B Application.

Discharge from the San Andres is reportedly by wells, by upward migration through the shaly beds of the Chalk Bluff into the alluvium and to springs, and by leakage through poorly cased wells (16, page 111-1-3). The lowering of artesian pressures due to discharge of wells has reportedly decreased the discharge by the other routes, and discharge by wells is reportedly greater now than that by all other routes. The discharge of artesian wells in Eddy and Chaves counties has almost stopped the flow of the large artesian springs near Roswell, which formerly discharged most of the water from the artesian aquifer (16, page 111-1-3). As a result of the lowering of artesian pressures, few artesian wells flow in the summer.

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As the water in the San Andres Formation moves chiefly through cavities in the limestone, which are irregularly distributed, Navajo reports that the yield of wells differs greatly within short distances. However, yields great enough for irrigation can generally be obtained from wells penetrating the artesian aquifers in most of the Roswell basin (16, page 111-1-3).

No information regarding water quality in the San Andres and Chalk Bluff formations was provided in the Part B Application.

Ground water in the Quaternary alluvium is a shallow-water source used for irrigation in the vicinity of the plant. Navajo reports that regionally the water in the alluvium is from five sources: local precipitation, surface water, losses from leaky artesian wells, natural leakage of artesian water from the underlying artesian aquifers, and irrigation return (16, page 111-1-4). The amount of water from each source is variable and indeterminate; however, the importance of the various sources of shallow ground water can be inferred from the conditions governing each. Navajo reports that the greater part of the shallow ground-water supply is derived directly or indirectly from the deep artesian aquifers, and that direct precipitation and surface drainage on the whole contribute only a small part of the total recharge. Of the recharge from the artesian supply, natural leakage is believed by Navajo to be the primary component.

According to Navajo, movement of the shallow ground water is in general to the east toward the Pecos River, where it discharges. Reportedly, shallow ground water also discharges into most of the lower courses of tributary streams where their channels are cut below the water table; hence, ground water locally moves toward those streams.

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There are a great number of shallow irrigation wells in the irrigated area which, in addition to the artesian irrigation wells, discharge large quantities of water. Introduction of this artificial discharge has apparently altered the local movement of shallow ground water, inducing it to flow to the wells.

Navajo reports that the capacities of the wells drawing water from the alluvium vary widely because of the erratic occurrence of the sand and gravel beds that supply ground water. However, sufficient water for irrigation is available from wells in the valley fill in most of the area. Measured specific capacities of 13 wells distributed throughout the valley in Chaves and Eddy counties reportedly ranged from 12 to 78 gallons per minute per foot of drawdown (16, page 111-1-4). Navajo reports that the average transmissivity of the alluvium has been estimated at 100,000 to 150,000 gpm and the average coefficient of storage at about 10 percent (16, page 111-1-5). The coefficient of storage in the alluvium is much greater than that in the artesian aquifer.

In general, the younger alluvium is above the water table over most of the Orchard Park Terrace. Some wells in the Lakewood Terrace yield water, but the highest yielding wells on the terrace probably tap the underlying quartzose conglomerate, according to Navajo.

The confined water table identified by Navajo at Navajo Refinery from existing monitoring well installations is variously reported to be a thin cobble seam and a pebble seam in the younger alluvium deposits (16, page 111-1-5 and page 111-1-6). Since no cobbles were encountered in any of the monitoring well boreholes at the North Colony landfarm, this report assumes that Navajo is referring to the interbedded dolomite gravel/pebble and anhydritic/pebble seams encountered at an average depth of 14 to 20 feet below ground surface. Navajo reports that it is possible that the water-bearing zone is the seam between the Orchard Park Terrace and the younger alluvium (16, page 111-1-6).

No further description of the "water-bearing seam" is provided by Navajo. If the upper portion of the Orchard Park Terrace consists of red clay, as is suggested by the monitoring well borehole logs, then the "seam" is apparently the basal portion of the younger alluvium. This seam is apparently confined by the overlying silty clay and the underlying clay, and Navajo reports that water-level elevations in the on-site monitoring wells rise above the water-bearing zone. The potentiometric surface of this water-bearing seam reportedly slopes with the land surface to the northeast toward Eagle Draw and the Pecos River. No potentiometric surface map subtantiating this trend was provided by Navajo.

Monitoring well borings were drilled by Navajo in October 1982 adjacent to the North Colony landfarm, the truck bypass landfarm, and the TEL weathering area. Selected Shelby tube soil samples obtained during drilling were reportedly analyzed to determine grain size distribution, vertical permeability, specific gravity, and dry unit density. This information was then used by Navajo to calculate porosity and hydraulic conductivity for various subsurface zones which are presented in Table 111-1 in the Part B Application (16, page 111-1-6). However, Navajo did not clarify which

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subsurface zones the porosity values correspond to and, since no borehole logs were available for the sampled boreholes, no valid conclusions can be drawn from this information.