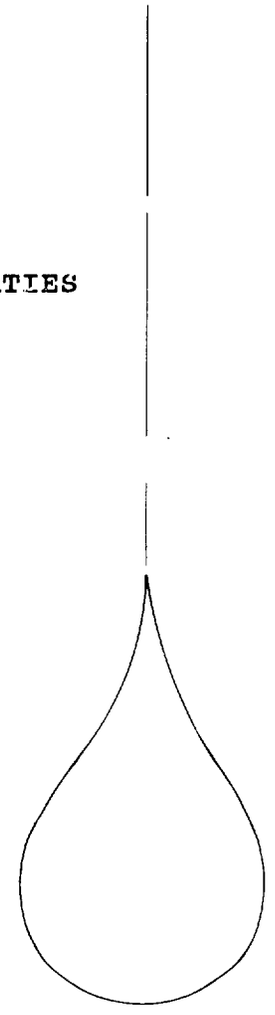
by

Geohydrology Associates, Inc.

ASSESSMENT REPORT FOR LYBROOK AREA PROPERTIES OF BCO, INC. (DUFERS POINT, ESCRITO, LYBROOK AND ALAMITO-GALLUP OIL POOLS) SAN JUAN BASIN, NEW MEXICO



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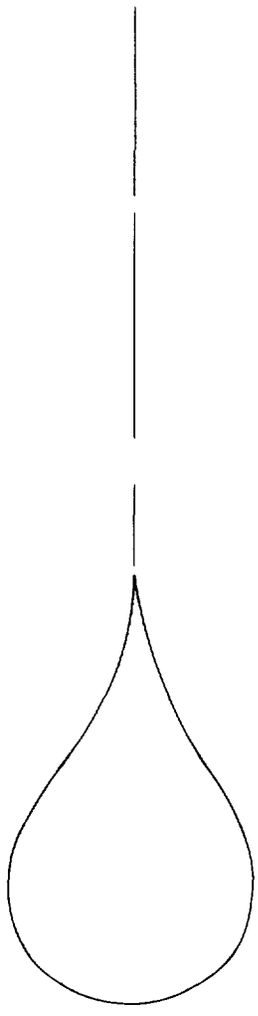
(DUFERS POINT, ESCRITO, LYBROOK AND ALAMITO-GALLUP OIL POOLS)

SAN JUAN BASIN, NEW MEXICO

March 20, 1992



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C O N T E N T S

T A B L E S

I L L U S T R A T I O N S

ASSESSMENT REPORT FOR LYBROOK AREA PROPERTIES OF BCO,INC.

(Dufers Point, Escrito, Lybrook and Alamito-Gallup Oil Pools)

SAN JUAN BASIN, NEW MEXICO

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GEOHYDROLOGY ASSOCIATES,INC.

Albuquerque, New Mexico

RECOMMENDATION

The Lybrook area should be exempted from the expanded vulnerable area designation. Exemption is warranted by the conclusions that follow. The area to be exempted should include Townships 22, 23 and 24 North, Ranges 6, 7 and 8 West.

CONCLUSIONS

1. BCO production facilities in the Lybrook area of New Mexico are located in an area bearing little hydrogeologic resemblance to the study areas forming the basis for the Proposed Vulnerable Area Order. These studies were performed in perennially saturated alluvial valleys having significant susceptibility to surface contamination. There are no alluvial valley deposits in the Lybrook area.

2. The proposed extended vulnerable areas near Lybrook are located on dense shale outcrops of the upper Nacimiento Formation. Near Lybrook, the Nacimiento Formation is characterized by very low permeability and erratic, non-potable ground-water at depths averaging in excess of 200 feet.

3. The Ojo Alamo Sandstone is the only potable aquifer in the Lybrook area. Residents obtain their water from a community well which produces from the Ojo Alamo Sandstone at a depth of approximately 1300 feet. This well produces good water having 630 milligrams per liter dissolved solids.

4. Under the regulations of the State Engineer Office, all water wells constructed in the Ojo Alamo Sandstone must be cased and cemented from the surface to the top of the aquifer. Contamination through the annular space is prevented. There are no old, existing wells tapping the Ojo Alamo Sandstone in the vicinity of the BCO properties.

5. Springs near Lybrook will not be affected by discharges in the vulnerable area extensions because the springs originate at the contact between the Nacimiento shale and overlying sandstones of the San Jose Formation. The springs discharge from locations which are topographically higher than the extended vulnerable areas.

6. Water samples from the Nacimiento Formation in Lybrook show that the water is highly mineralized and unacceptable for public supply. The total dissolved solids are greater than 4000 mg/l (milligrams per liter). Spring discharge from the San Jose sandstone is less than 350 mg/l. A sample from Iron Spring contained 2500 mg/l and probably is a mixture of water from the San Jose and Nacimiento.

7. Seventeen water wells are present in the Lybrook area; eleven are completed in the Nacimiento Formation. Five wells, including the Lybrook community well, are completed in the Ojo Alamo Sandstone. The only well completed in the San Jose Formation is located 14,000 feet from the nearest BCO pit located in a vulnerable area.

8. In spite of the fact that oil and gas production in the Lybrook area has been on-going for more than 30 years there is no evidence that contamination of ground-water has occurred.

INTRODUCTION

On January 31, 1992, the Oil Conservation Division (OCD) proposed the expansion of the "vulnerable area" established in 1985 with Order R-7940. The proposed order would eliminate surface disposal of oil and natural gas wastes into unlined pits which are located in the newly delineated vulnerable areas of the San Juan Basin. The proposed definition of the vulnerable area is, "That area which is defined as being within the drainage bottoms of all major perennial and ephemeral surface water drainages which is bounded by the topographic line on either side of the drainage that is 50 vertical feet above the drainage channel measured perpendicularly to the drainage channel . . ." The order proposing expansion also creates "wellhead protection areas" which are defined as, "Those areas that lie within a radius of 1,000 horizontal feet of all fresh water springs and wells."

At the request of Mr. Ernest L. Padilla, Esq. and Neel L. Duncan, Production Manager for BCO, Inc., the staff of Geohydrology Associates, Inc. (GAI) undertook an evaluation of the geohydrologic environment at the BCO properties described above.

The guidelines given to GAI for its evaluation were to determine (1) whether any of the BCO facilities had contaminated any fresh-water sources, (2) whether continued and future BCO operations would have a likelihood of causing contamination to fresh water sources, and (3) whether the proposed regulation, i.e., expansion of the current vulnerable area was appropriate in the area of BCO's operations.

Under the direction of Messrs. Padilla and Duncan, two members of the GAI staff conducted a field reconnaissance of the BCO properties on February 21, 1992. Messrs. L. Clay Kilmer and T. E. Kelly of GAI accompanied Mr. Duncan to springs and wells in the Lybrook area in order to determine the relationship of springs and wells to water-bearing formations in the area. The field reconnaissance was also intended to identify potential areas of shallow ground water having susceptibility to contamination from surface sources. A survey of the geologic formations was made, and water samples were collected for analysis of total dissolved solids and benzene content. A review of the geologic literature also was conducted as part of this investigation, and a listing of the wells near the BCO leases was obtained from the New Mexico State Engineer Office. Maps of the expanded vulnerable area proposed by the OCD were obtained. This report contains a summary of the findings of these investigations.

Supporting documentation for the OCD Order is a report entitled, "Volatile Organic Contamination of Ground Water Around Unlined Produced Water Pits" by William C. Olson (Dec. 1989). This report referenced the studies by Nicholson and Clebsch (1961) and Baker and Brendecke (1983). Most of the conclusions reached by Nicholson and Clebsch were based on an investigation of a brine-pit located in Section 19, Township 21 South, Range 36 East, Lea County, New Mexico, where 1750 bpd (barrels per day) of super-saturated brine was being disposed. At this site there is a thin layer of surficial unconsolidated sand overlying the highly

permeable Ogallala Formation. Baker and Brendecke investigated brine disposal in the Altamont-Bluebell area of the Uinta Basin of northeastern Utah. In this area, "The aquifers considered most important to the study were the unconsolidated surficial deposits formed by stream alluvium, terraces and Pleistocene glacial deposits" (Baker and Brendecke, 1983, p. 318). All of the 13 site evaluations made by Olson (1989, p. 15) were located within the current vulnerable areas defined by New Mexico Oil Conservation Commission Order No. R-7940, ". . . all areas within 100 vertical feet of the San Juan, Animas, and La Plata river channels and within other known shallow ground water areas (Figure 3)." At these sites, perennial ground water was present at depths of 32 feet or less (Olson, 1989, p. 40).

The surficial geologic characteristics of the current vulnerable area are very dissimilar to the surface geology near Lybrook. It is for this reason and others that BCO's operations' area should be exempt from the vulnerable area expansion.

GEOHYDROLOGY CONDITIONS

The terrain in the Lybrook area and the BCO properties is highly dissected and could best be described as a canyon and mesa topography. The mesas are capped by a basal sandstone in the San Jose Formation and the canyons are eroded into the Nacimiento Formation which has a total thickness of about 1300 feet. There is no alluvium in these canyons near the BCO properties. The Nacimiento is underlain by the Ojo Alamo Sandstone which is not exposed at the surface near Lybrook.

There are no alluvial deposits in the arroyos which drain the BCO properties. The cliff-forming San Jose sandstones weather by mass-wasting throughout most of the year. During the summer months, characterized by localized thunderstorms, the weathered material is transported by storm runoff through the canyons to the lower reaches of the Chaco Wash and Gobernador Canyon. This scouring action also removes any weathered Nacimiento shale from the arroyos. Thus the canyons and arroyos near the BCO properties are eroded into virtually unweathered shale.

The San Jose Formation consists predominately of buff to yellow, conglomeratic, coarse to very coarse grained, thick-bedded sandstone. The sandstone is moderately lithified and forms steep cliffs in most places. There are thin strata of interbedded shale, and both the sandstone and the shale units may be lenticular and localized. Most of the thicker units are continuous and can be traced in the outcrop for two to three

miles. According to Brown and Stone (1979), springs are common in the San Jose Formation, and these discharge 2 gpm (gallons per minute) or less. During the field investigation, three springs located along the contact between the San Jose sandstone and underlying shales of the Nacimiento Formation were examined and sampled (Table 1). One stock well was identified as tapping the San Jose, but it is 14,000 feet from the nearest BCO disposal location in the expanded vulnerable area. Many springs in this area are seasonal; seeps are common in the spring and following periods of heavy rainfall.

The Nacimiento Formation generally consists of gray, olive-green, and purple shales with minor amounts of thin, discontinuous strata of light colored silty sandstone. In the vicinity of Lybrook, this predominately shale formation is approximately 1300 feet thick. Although the Nacimiento is not considered to be an aquifer, it is tapped by small capacity stock wells in the area. A total of 17 water wells have been identified in the study area, and 11 of these wells tap the Nacimiento deposits (Table 1). All of the Nacimiento wells are small capacity stock wells; two of which are located on BCO's private property and have been capped.

The Ojo Alamo Sandstone underlies the Nacimiento Formation at a depth of approximately 1300 feet. Near the outcrop, approximately 12 miles southwest of Lybrook, the formation is thick-bedded, coarse-grained to very coarse grained, crossbedded, conglomeratic sandstone (Kilmer and Kelly, 1992, in press). Although the thickness of the Ojo Alamo Sandstone is quite variable, it ranges from about 25 feet to more than 300 feet.

Locally the formation consists of two distinct sandstone deposits separated by a shaly interval. The Lybrook community well taps the Ojo Alamo Sandstone (Table 1).

Table 1.--Records of wells and springs in the Lybrook area.

Location	Name	Depth (ft)	Producing Formation
T23N R6W S. 7.13	Well No. 3	160	Tsj
18.122	Largo Ranch Well	1500	Toa
T23N R7W S. 3.22	Iron Spring	surface	Tsj, Tn
10.34	Escrito Spring	surface	Tsj
10.43	Lybrook comm. well	±1300	Toa
15.22a	Rincon well	152	Tn
15.22b	Andress well 1	252	Tn
25.11	unnamed spring 1	surface	Tsj
T23N R8W S. 1.1	Rafael Well	60	Tn
T24N R6W S.18.31	Windmill	C.N.M.	Tn
7.34	Windmill	C.N.M.	?
T24N R7W S. 1.33	Windmill	C.N.M.	Tn
1.44	Windmill 3	180	Tn
13.42	Windmill 5	155	Tn
19.	Crow Mesa Well 1	1700	Toa
22.33	Windmill 6	508	Tn
34.23	Windmill 8	210	Tn
36.22	Windmill 7	190	Tn
T25N R7W S.31.14	Windmill 2	620	Tn

Explanation: Tsj - San Jose Formation
Tn - Nacimiento Formation
Toa - Ojo Alamo Sandstone
C.N.M.- Could not measure

FIELD RECONNAISSANCE

Figure 1 is a map showing the proposed vulnerable areas and the locations of BCO operated oil and gas wells in the Dufer's Point, Escrito, Lybrook, and Alamito-Gallup gas pools. The locations of water wells and springs in the vicinity are also shown. The proposed vulnerable areas are located in the drainages. All of the drainages in the area are ephemeral, having water primarily during brief periods of runoff following storms. In the Lybrook area, these erosional features could best be described as "badlands".

All of the water wells in the area are listed in Table 1. This table lists the wells by location, depths and producing formations. These are stock wells, with the exception of the wells completed in the Ojo Alamo sandstone (Table 1). Most of the wells are located to the northeast of BCO production in the Escrito-Gallup pool.

The results of the water-quality analyses of samples collected from wells and springs in the vicinity are listed in Table 2. The samples are listed by location.

Table 2.--Results of laboratory analyses of water samples from wells and springs in the Lybrook area.

Well or Spring Location (NMPM)	Name of well or spring	Benzene (ug/l)	TDS (mg/l)	Unit
T23N R7W Sec 25.11	unnamed spring	N.D.*	310	Tsj
10.34	Escrito Spring	N.D.	200	Tsj
15.21	Lybrook comm. well	N.D.	630	Toa
15.22a	Rincon well	N.D.	6200	Tn
15.22b	Andress well 1	N.D.	4200	Tn
15.22c	Iron Spring	N.D.	2500	Tsj, Tn

*N.D.: Non-detect at 1.0 micrograms per liter

The water-quality analyses indicate that no contamination of shallow ground water is present in the Lybrook area. It should be stressed that Lybrook lies within a mature oil and gas producing province of the San Juan Basin. The small volume waste water disposal practices employed there today have been on-going for more than 30 years. The lack of contamination after such a long period of operation constitutes strong evidence that shallow ground water is not threatened by the extractive industry in the area. This can be attributed to very low permeability in the Nacimiento Formation. Most hydraulic investigations show that the vertical permeability is only ten percent of horizontal permeability. Thus in shaly formations, such as the Nacimiento, the vertical migration of contaminants is highly improbable.

The information from total dissolved solids obtained in this study indicates that the springs of the San Jose Formation produce the highest quality water available in the area. The Ojo Alamo Sandstone also produces high quality water. Iron Spring produces moderately mineralized water that is likely a mixture of waters from the San Jose and Nacimiento Formations. Water from the Nacimiento Formation is highly mineralized and is not considered to be useful for human consumption.

VULNERABILITY OF GEOLOGIC UNITS

San Jose Formation

The results of the field reconnaissance and file and literature search indicate that outcrops of massive sands in the San Jose Formation are the areas of greatest shallow ground water susceptibility to surface contamination in the Lybrook area. Figure 2 is a geologic cross section showing the relationship of geology and shallow springs near Lybrook. The cross section indicates that local shallow ground water conditions are characterized by spring discharge at or near the contact between a massive basal sandstone unit in the San Jose Formation and shale in the upper Nacimiento Formation. Precipitation infiltrates the massive sand in the San Jose Formation on topographic highs and percolates down to the Nacimiento shale, moving laterally along the contact to discharge as a spring or to be lost to evapotranspiration. Iron Spring, Escrito Spring, and unnamed spring No. 1 are all located at or near this contact. This sandstone sequence crops out along a northwest to southeast trend passing through Lybrook.

Despite the fact that the massive sandstone in the San Jose Formation is widely exposed in the Lybrook area, it rarely produces water to wells. The formation is heavily dissected by arroyos such that recharge is lost to seeps along down dip escarpments and to areal evapotranspiration. The outcrop of the sandstone near Lybrook is comprised largely of erosional outliers surrounded by Nacimiento Formation.

The listing of wells in Table 1 indicates that only one of these wells appears to be completed in the San Jose; the others were completed in the Nacimiento Formation.

Nacimiento and San Jose Formations

Away from the sandstone outcrops described above, the surficial geology is composed primarily of shales in the Nacimiento and San Jose Formations. These units are characterized by low infiltration potential and ground-water depths on the order of two hundred feet. Wells completed in these units produce small amounts of moderately to highly mineralized water. Recharge into and ground-water movement through these units occurs slowly.

During the field reconnaissance, two capped wells completed in the Nacimiento Formation in Lybrook (Table 2) were measured and sampled. These two wells are located approximately 75 feet apart. The water level in the Rincon well was 138.64 feet below land surface and the depth of the well was 152 feet. The water level in the Andress well was 210.97 feet below land surface and the depth of this well was 252 feet. Notable differences in the depths to water and water quality from these two wells indicate that the producing zones are hydrologically distinct and laterally discontinuous in spite of their proximity (Table 2). The total dissolved solids found in the water samples indicate poor overall water quality caused by natural mineralization.

Alluvium

There is no alluvium in the Lybrook area. Erosion has cut the drainages through the lower San Jose Formation and into unweathered shales of the Nacimiento Formation. Intermittent rainfall scours the arroyos and prevents the accumulation of alluvium in the Lybrook area.

Ojo Alamo Sandstone

The Ojo Alamo Sandstone is the only aquifer in the Lybrook area which consistently produces useful quantities of potable water. This aquifer is the source of water for the Lybrook community water system. The geologic cross section in Figure 2 depicts the relationship of the aquifer to other geologic units and to the surface near Lybrook.

The Ojo Alamo Sandstone is overlain by the Nacimiento Formation and thus is buried beneath approximately 1300 feet of shale at Lybrook. The recharge area for the aquifer is approximately 12 miles southwest of Lybrook at the outcrop (Kilmer and Kelly, 1992). The thick sequence of Nacimiento Formation shales overlying the Ojo Alamo has such low vertical and horizontal hydraulic conductivity that migration of oil and gas well-produced waters into this aquifer is not a threat. Typically the vertical permeability of a stratigraphic unit is about 10 percent of the horizontal permeability. Thus the shale is virtually impervious to the vertical migration of contaminants.

Water wells completed in the Ojo Alamo aquifer are required by the State Engineer Office regulations to have an annular grout seal to prevent upward migration and loss of artesian water into shallow horizons. The required annular seals would prevent produced water disposed at the surface from migrating into the Ojo Alamo aquifer.

Geologic Cross Section of Lybrook, New Mexico

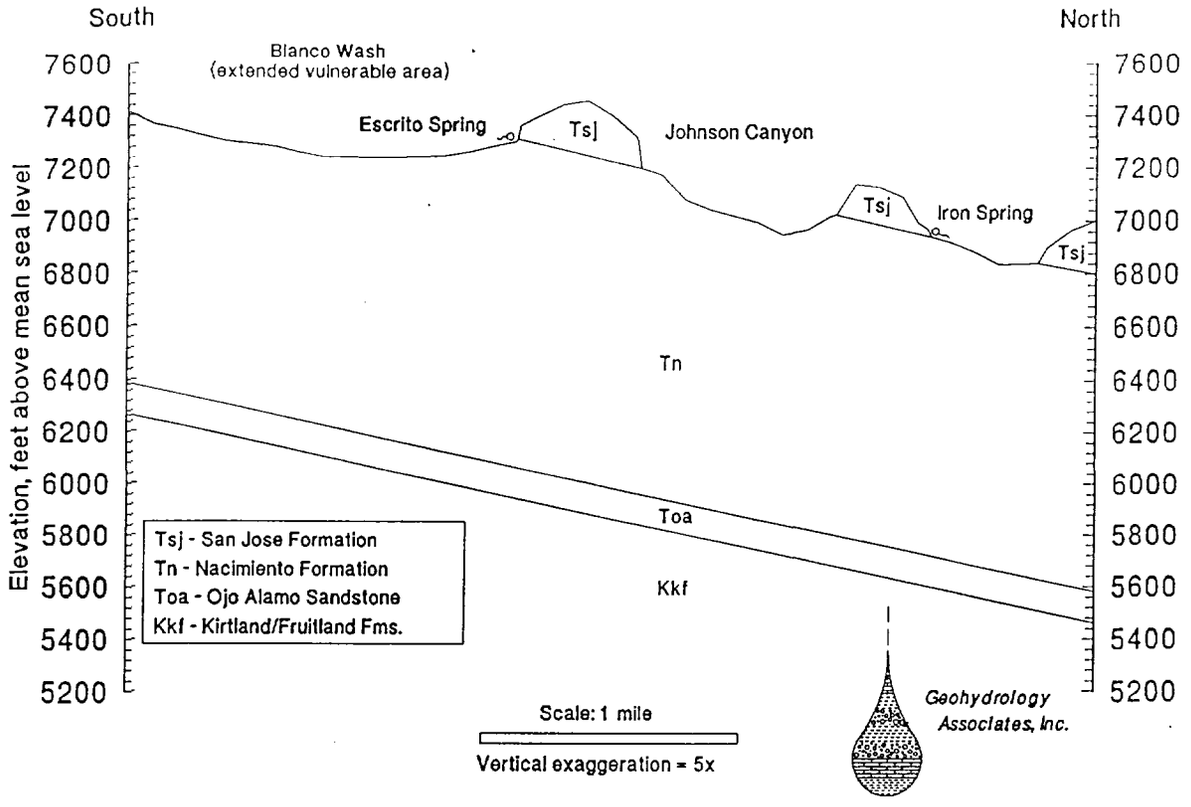

FIGURE 2

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