# DELINEATION OF THE EXTENT OF MILLING-RELATED CONTAMINATION IN A NATURALLY CONTAMINATED AQUIFER SYSTEM

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## ABSTRACT

Uranium mill tailings from the Susquehanna-Western mill near Falls City, Texas, were pumped to tailings ponds located in abandoned open pit uranium mines. The ores from these mines were oxidized. Uranium and the associated hazardous constituents were present in these ores as relatively soluble secondary minerals. Because the tailings piles are located on the outcrops of the units designated as the uppermost aquifer, there is no upgradient aquifer from which to establish "background" water quality. The widespread mineralization in the area naturally imposes a large variability in water quality in these units. It was necessary to demonstrate to State and Federal regulators that selected downgradient wells were beyond the influence of milling operations, and to develop a series of "indicator parameters" that could be used to differentiate milling contaminated groundwater from that native to the aquifer.

## INTRODUCTION

The Susquehanna-Western uranium mill near Falls City, Texas, was operated between April 1961 and August 1973. The mill was constructed in the vicinity of open pit uranium mines. The area was mined in 1959 and 1960, and the cutoff grade at that time was about 0.2 percent $U_3O_8$. Subsequent exploration drilling has blocked out several hundred thousand tons of ore with a tenor in excess of 0.1 percent $U_3O_8$ (Fig. 1). The ores in the these near-surface deposits were totally oxidized, with autinite ($Ca(UO_2)_2(PO_4)_2 \cdot 10\text{-}12H_2O$) and meta-autinite ($Ca(UO_2)_2(PO_4)_2 \cdot 2\text{-}6H_2O$) being the major ore minerals (1). These oxidized, secondary minerals have higher solubilities than do primary ore minerals.

The mined ore bodies were located at the base of the Deweesville sandstone in contact with the underlying Conquista Clay. Both units are within the Whitsett member of the Eocene Jackson Formation (2). The Deweesville sandstone is a very silty unit with a significant clay content. As a consequence, the hydraulic conductivity of the unit is low and fluids contained within the aquifer are stagnant. In situations where groundwater is free to migrate, oxidized minerals are found only as an alteration rind on the primary ore, and their components are flushed away with the migrating groundwater.

The mine pits were open and exposed to meteoric precipitation for varying amounts of time until, during milling operations, three of them were used as tailings impoundments. In the immediate vicinity of the mill, tailings piles four and five were emplaced in mine pits (Fig. 2). Tailings pore fluids have spread from the piles and have contaminated groundwater in the Deweesville/Conquista aquifer. The challenge is to distinguish the influence of the tailings pore fluids from the water quality of the background fluids in the mineralized aquifers. The milling of uranium ores from the mines in the local ore trend had the same effect as did the weathering of the ores beneath the mill site. The situation is further complicated because the tailings piles are located on or very near the outcrops of the water-bearing units (Fig. 3). Thus, up-dip samples for characterization of background water quality cannot be obtained.

Exploration activities in the vicinity of the mill left over 2,000 rotary drill holes to a depth of up to 300 feet (4). As with most exploration drilling efforts, these boreholes were left standing open and allowed to cave in. Because the potential for communication exists via the abandoned exploration boreholes, the upper three water-bearing units are combined into the "uppermost aquifer" as defined by the Uranium Mill Tailings Remedial Action Control Act of 1978 (Fig. 4).

## BACKGROUND WATER QUALITY

The Deweesville/Conquista aquifer is unconfined in the vicinity of the Falls City UMTRA Project site. Infiltration through mine pits causes a mound in the potentiometric surface that controls the direction of flow away from the site (Fig. 5). Because either downgradient or crossgradient groundwaters had to be used to establish background water quality, the technical staff was required to estimate maximum limits of contamination.

Several pump tests were conducted on monitor wells within the Deweesville/Conquista aquifer, and the hydraulic conductivities ranged over two orders of magnitude (0.01 to 2.7 feet/day). Statistical analysis showed that the 99 percent confidence limit hydraulic conductivity was 1.2 feet/day. This very conservative value was used to delineate a zone of maximum contaminant migration in the direction of groundwater flow for each tailings pile. The first test that a well had to pass in order to be considered background was that it lie beyond this zone.

A number of different water quality parameters were used in an attempt to delineate the extent of contamination. The mill tailings pore fluids (collected from lysimeters within

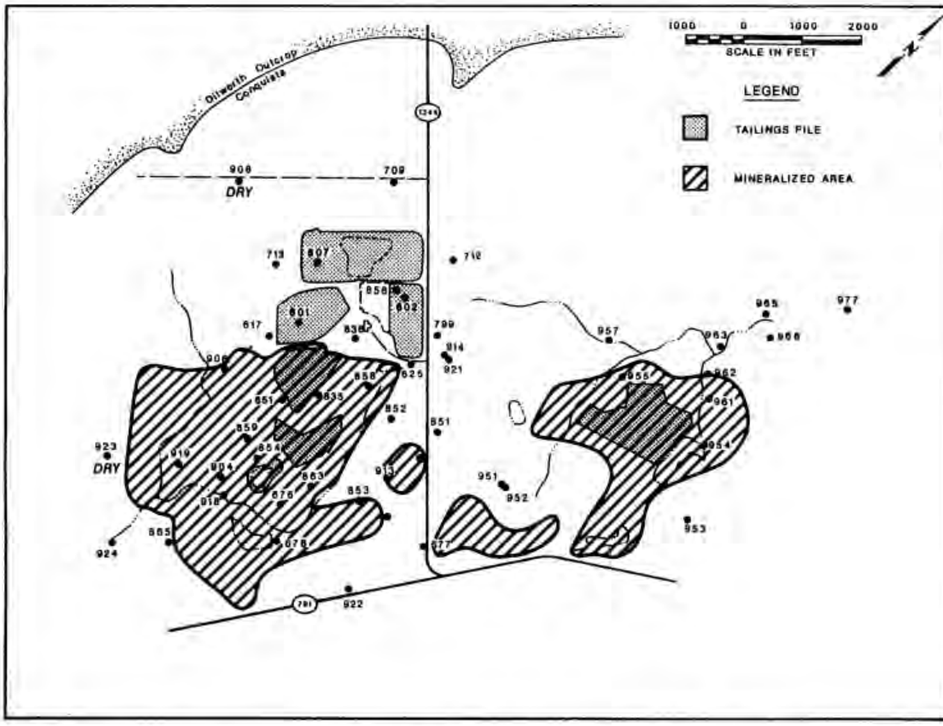


Fig. 1. Identified ore deposits and mineralization Falls City, Texas site.

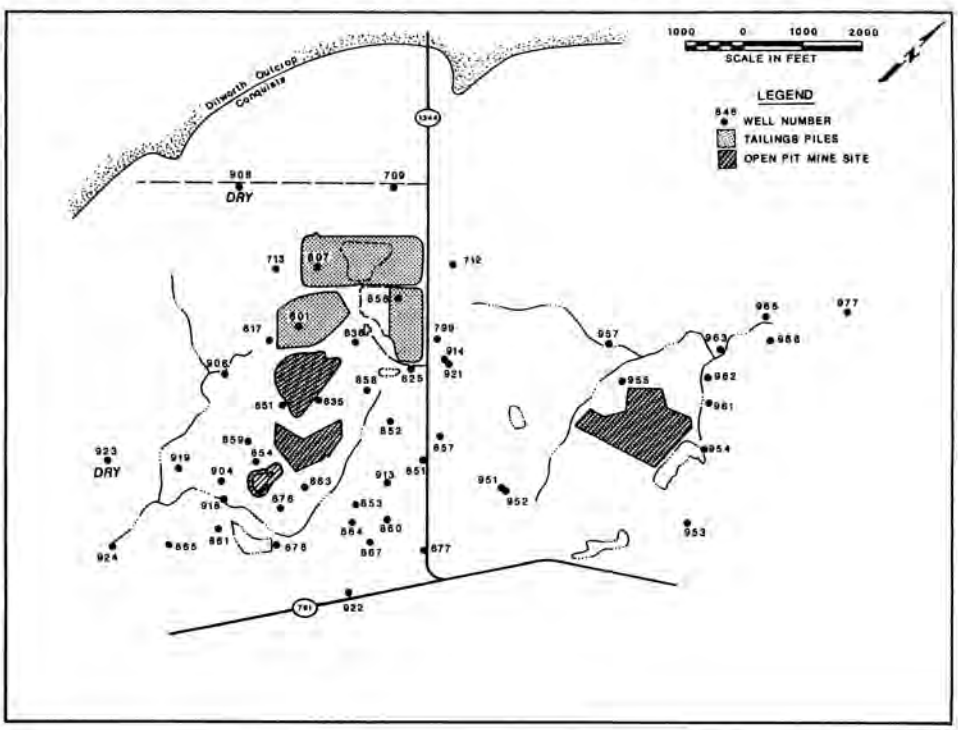


Fig. 2. Location of tailings piles, mines, and Deweesbille/Conquista monitor wells Falls City, Texas, UMTRA site.

the tailings) were characterized by high acidity (low pH), high redox potentials, and elevated concentrations of sulfate, phosphate, molybdenum, uranium, and total organic carbon. For each of these indicator parameters, however, at least one well would prove to be an exception to the rule. For example, some wells located away from the tailings piles had low pH and high uranium concentrations. Other wells located in the immediate vicinity of the tailings piles had a high pH, low redox potential, and low concentrations of uranium.

Because no single indicator parameter or pair of parameters could be relied upon to distinguish contamination, all seven indicator parameters were used. Groundwaters were considered to be contaminated when three or more of them were elevated (Table I). By deduction, groundwaters with two or fewer of the indicator parameters elevated were not

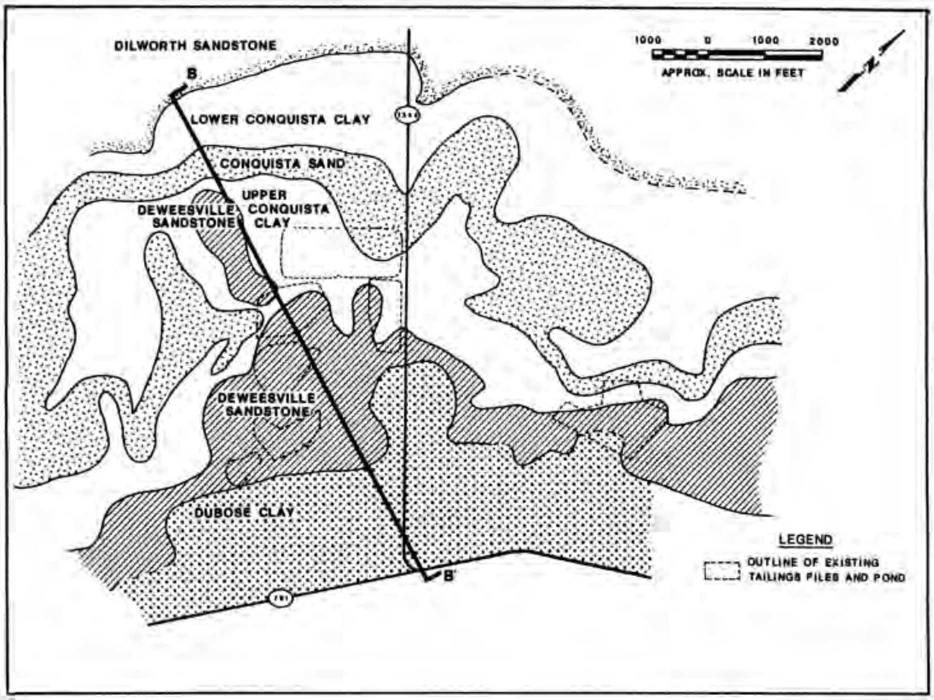


Fig. 3. Surface geology and cross section locations Falls City, Texas site.

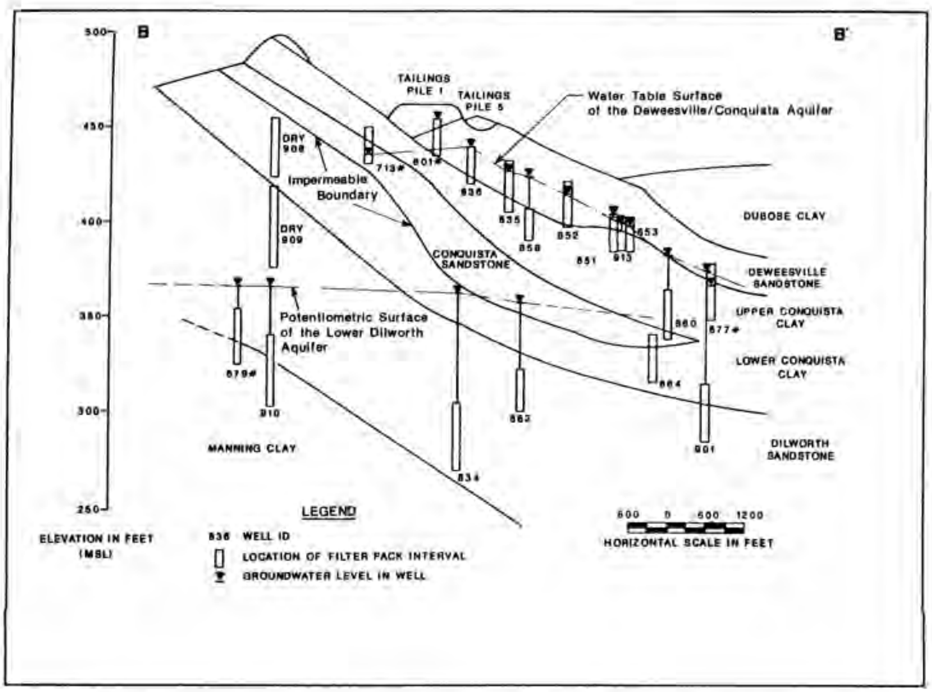


Fig. 4. Cross section of uppermost aquifer B-B' Falls City, Texas site.

considered to be contaminated with tailings pore fluids. Monitor wells 922, 924, and 951 were designated as background water quality (Fig. 3).

High natural variability of hazardous constituents within the Deweesville/Conquista aquifer was supported by historical data from two other sources. Conoco had installed a series of monitor wells in the vicinity of their Conquista Uranium Mill in 1976. Because the procedures used to install and document the construction of these wells no longer exist, the staff of the U.S. Nuclear Regulatory Commission (NRC) would not allow data from these wells to be used as a basis for making decisions. However, the data were allowed to support the argument of widespread natural contamination. The second source of historical data was Texaco's Hobson in situ uranium mine. To establish a baseline for groundwater restoration at the termination of mining, background water quality

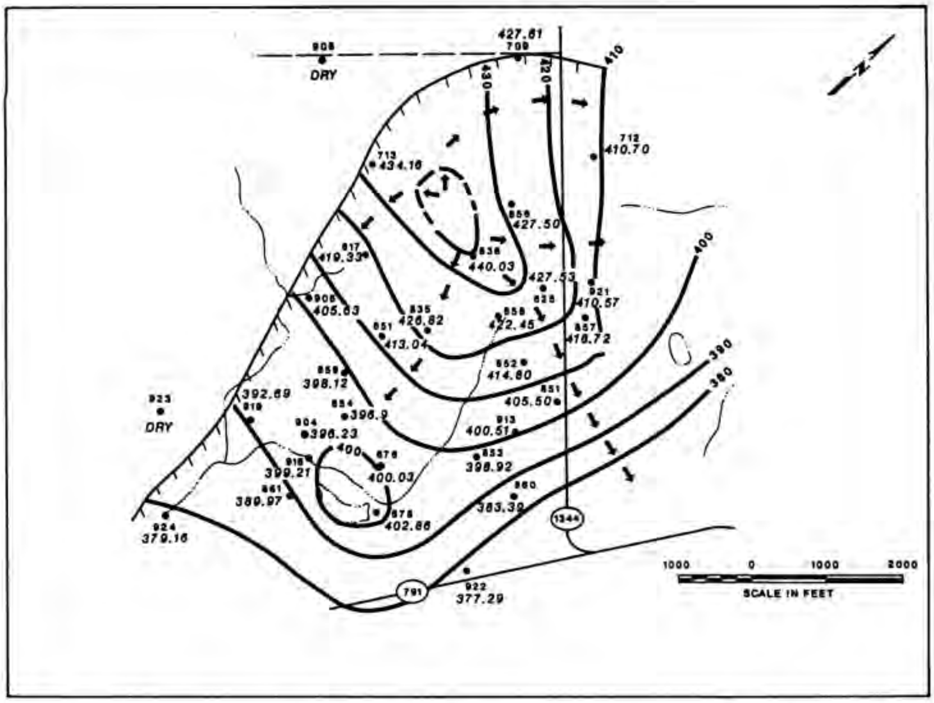


Fig. 5. Extent of saturation of the Deweesville/Conquista aquifer and potentiometric surface of the uppermost aquifer.

**TABLE I**

**Concentrations of Indicator Parameters in Background and On-site Contaminated Monitor Wells (mg/l except as noted, BDL - below detection limit)**

| Background Wells | | | | | | | |
|---|---|---|---|---|---|---|---|
| Well # | pH[1] | ORP[2] | Mo | $PO_4^{3-}$ | $SO_4^{2-}$ | TOC | U |
| 922 | 5.80 | 351.5 | BDL | 0.3 | 2470 | 5 | BDL |
| 924 | 6.19 | 335.3 | BDL | 0.4 | 2850 | 9 | 0.011 |
| 951 | 6.69 | 335.7 | BDL | 0.1 | 833 | 12 | 0.052 |
| On-site Wells | | | | | | | |
| Well # | pH[1] | ORP[2] | Mo | $PO_4^{3-}$ | $SO_4^{2-}$ | TOC | U |
| 835 | 3.02 | 551.9 | 1.10 | 0.61 | 5530 | 41 | 9.75 |
| 836 | 6.88 | 448.0 | 57.0 | 2.5 | 9000 | 36 | 6.53 |
| 913 | 6.60 | 454.6 | 0.01 | 0.1 | 1580 | 7 | 3.56 |

[1] Standard Units
[2] mV

was determined within the well field before mining began. The Hobson deposit was located in the Deweesville sandstone about 8.5 miles from the UMTRA Project site at Deweesville. The Hobson ores were not as oxidized as those mined at Deweesville, so the concentrations of hazardous constituents were lower; however, they still showed wide variability. The NRC staff also allowed these data to be used to support the ambient contamination argument.

Thus, the designation of background wells was based on a combination of the estimated maximum extent of contamination (calculated from measured hydrologic parameters) and the concentrations of the indicator parameters. Water quality data from the designated background wells were used to specify the uppermost aquifer as limited use, and to develop the groundwater protection strategy for the remediation of the tailings piles. While the State and Federal regulatory agencies did not allow data from wells that were not installed to EPA specifications to be used for decision making, these data were allowed in support of the general conclusion of widespread ambient contamination.

## DELINEATION OF CONTAMINATION

Figures 6 through 11 are plots of the distribution of pH, sulfate, cadmium, selenium, molybdenum, and uranium,

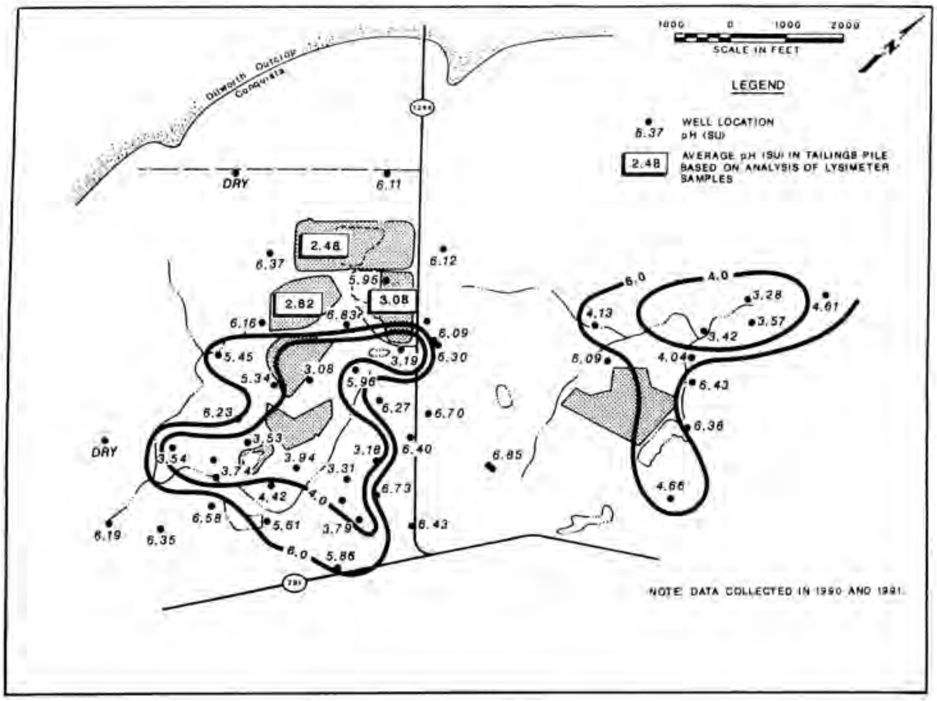


Fig. 6. Distribution of pH in the Deweesbille/Conquista aquifer Falls City, Texas site.

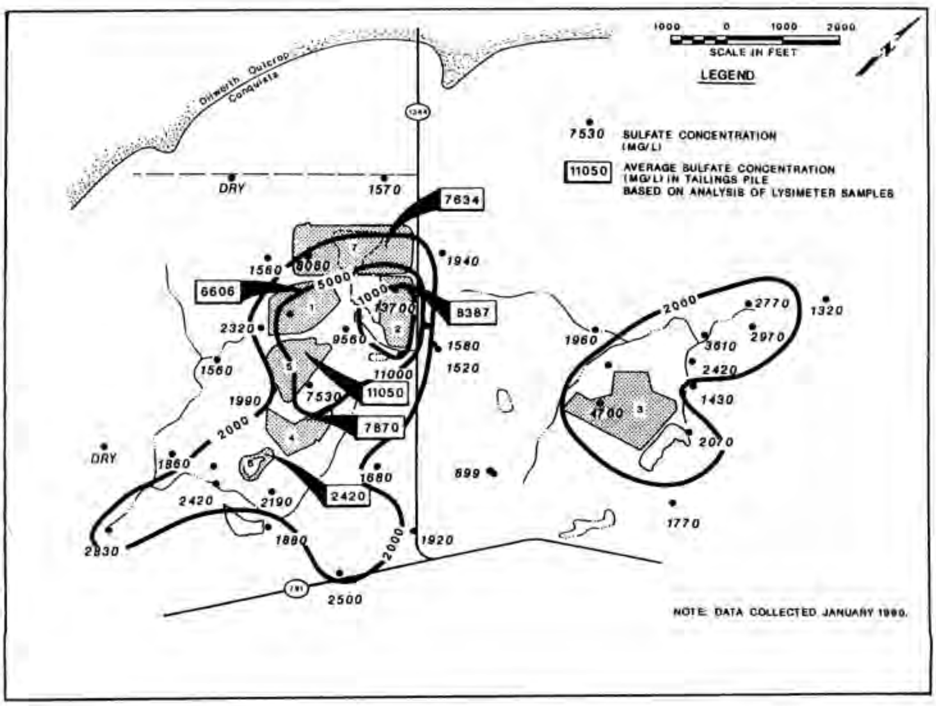


Fig. 7. Distribution of sulfate in the Deweesville/Conquista aquifer Falls City, Texas site.

respectively. The distributions of pH, sulfate, and uranium are concentric around the tailings piles, with maxima within the tailings pore fluids. The molybdenum high is restricted to the area between the tailings piles and seems to have its source at the eastern edge of tailings pile seven. These four constituents were contributed by uranium milling activities, and the imprint of the tailings highs are superimposed on the extremely variable background. The elevated concentrations of cadmium and selenium are isolated and the distribution is sporadic. These hazardous constituents are believed to be contributed to the groundwater by the ambient mineralization. An examination of the historical operations records for the mill indicates that molybdenum was concentrated during the milling process and that this raffinate was disposed of in an unlined pit in the vicinity of tailings pile one ("M" in Fig. 10).

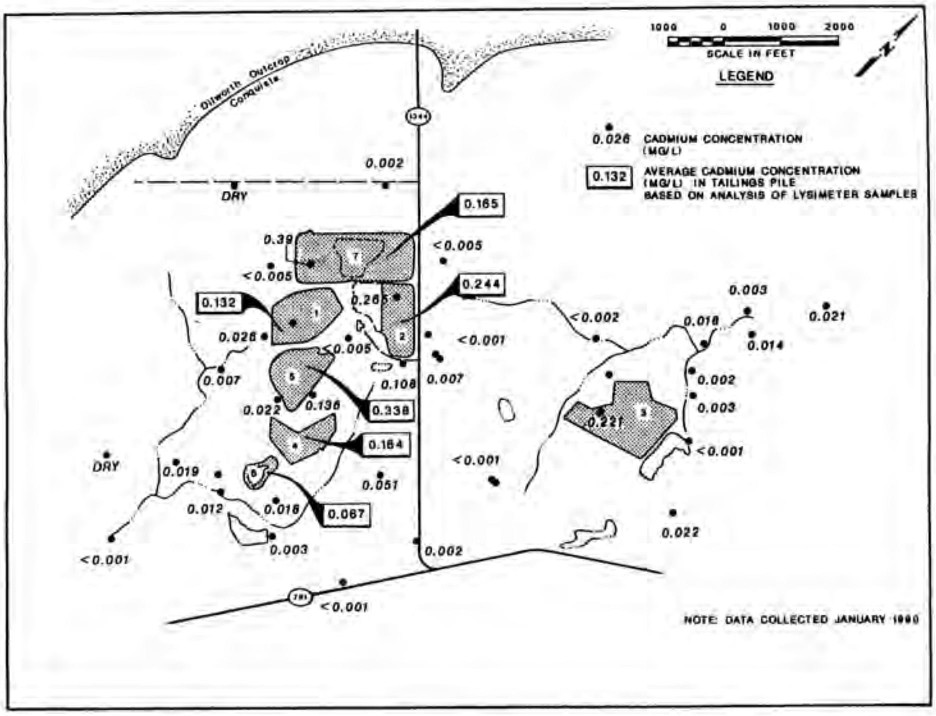


Fig. 8. Distribution of Cadmium in the Deweesville/Conquista aquifer Falls City, Texas site.

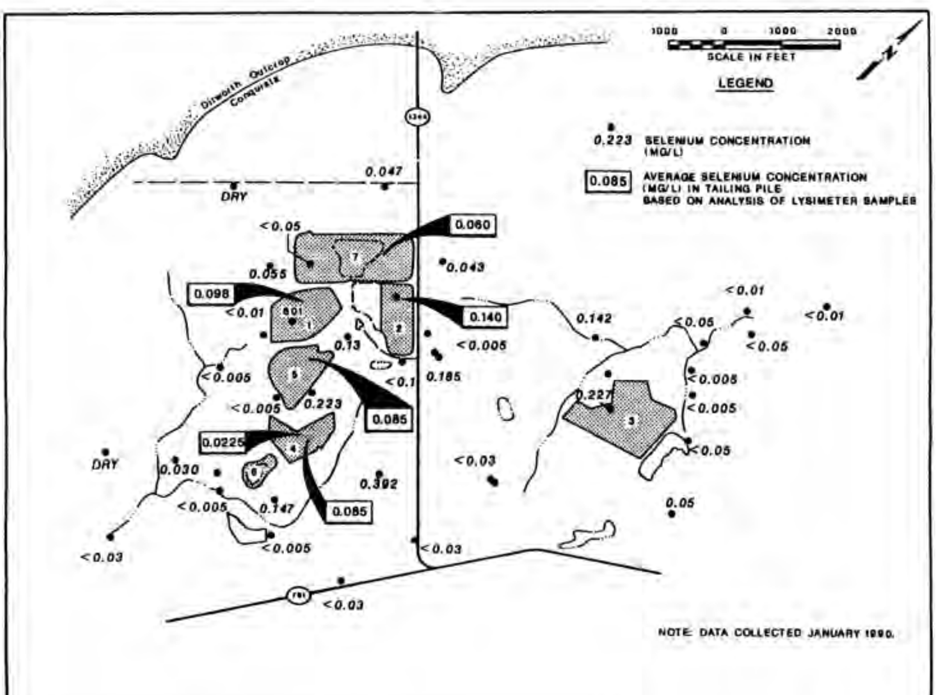


Fig. 9. Distribution of selenium in the Deweesville/Conquista aquifer Falls City, Texas site.

## CONCLUSIONS

By developing an understanding of 1) the hydrologic regime, 2) the distribution of mineralization, and 3) the geochemistry of the potential water-rock interactions, it was possible to select downgradient wells that were unaffected by milling activities to establish background water quality. The widespread *ambient contamination* necessitated the use of multiple indicator parameters and required the stipulation that elevated values of three or more indicated contamination, and two or fewer represented natural conditions.

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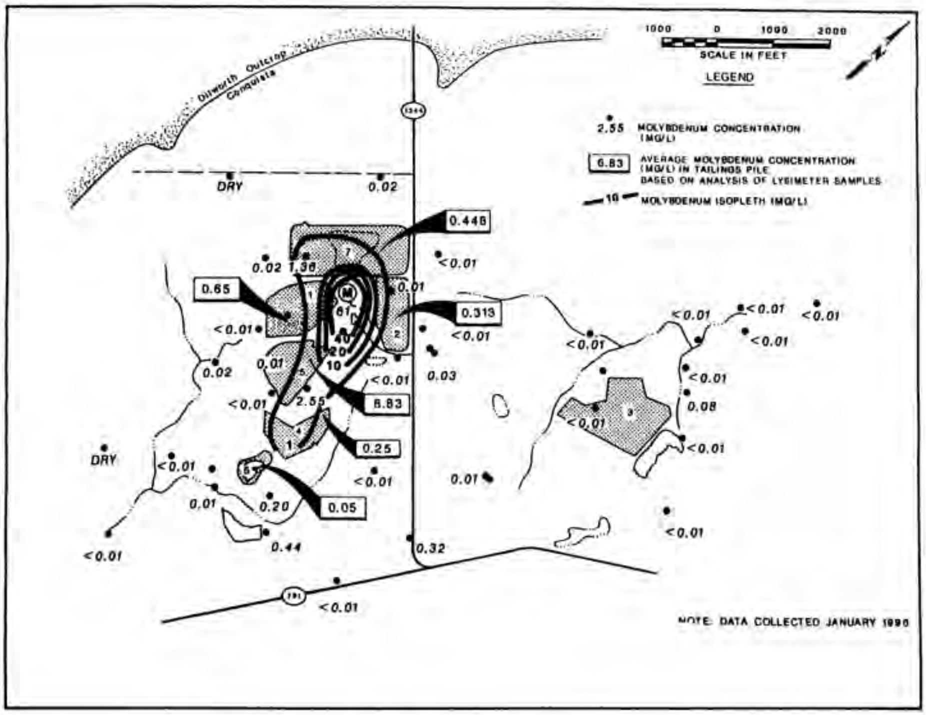


Fig. 10. Distribution of molybdenum in the Deweesville/Conquista aquifer Falls City, Texas site.

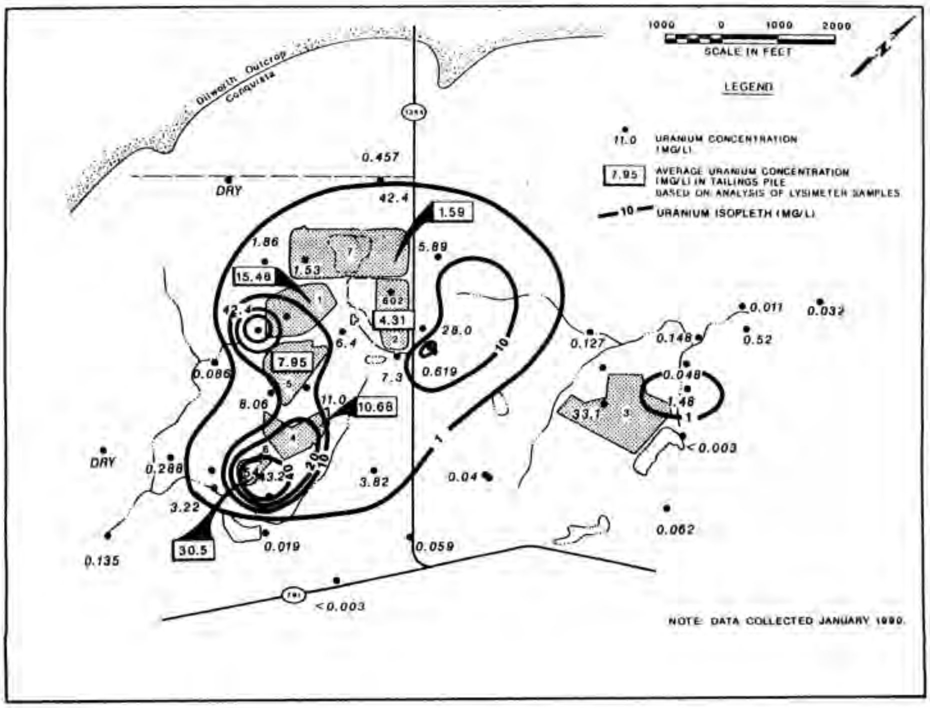


Fig. 11. Distribution of uranium in the Deweesville/Conquista aquifer Falls City, Texas site.


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