Appendix A

S-SX Tank Farm Stratigraphy and Geologic Setting

A.1 General Stratigraphy

The S-SX Tank Farm was constructed in a sequence of sedimentary units that overlie the Columbia River Basalt Group on the north limb of the Cold Creek syncline. These sedimentary units include the upper Miocene to Pliocene Ringold Formation, the Plio-Pleistocene unit, Pleistocene cataclysmic flood gravels and slack water sediments of the Hanford formation, and Holocene eolian deposits.

The Ringold Formation consists of semi-indurated clay, silt, pedogenically altered sediment, fine- to coarse-grained sand, and granule to cobble gravel. The lower half of the Ringold Formation is the main unconfined aquifer under Hanford and contains five separate stratigraphic beds dominated by fluvial gravels. These gravels are separated by intervals containing deposits typical of the overbank and lacustrine facies (Lindsey 1991). The lowermost of the fine-grained sequences is designated the lower mud sequence. The uppermost gravel unit, unit E, grades upwards into interbedded fluvial sand and overbank deposits that are in turn overlain by lacustrine-dominated strata. The fluvial sand and gravel facies is the principal facies of the upper part of the Ringold Formation under the 200 West tank farms.

Late Cenozoic age sediments, as much as 100 m thick within the Pasco Basin, overlie the Ringold Formation and are the main vadose zone units under the tank farms. The most extensive of these is the Pleistocene-aged Hanford formation (Fig. A.1). Locally the Hanford formation and underlying Ringold Formation are separated by two laterally discontinuous and informally defined units. They are the Plio-Pleistocene unit and the pre-Missoula gravels (near 200 East Area) (Fig. A.1). The Plio-Pleistocene unit unconformably overlies a tilted and truncated Ringold Formation in the vicinity of 200 West Area. The Plio-Pleistocene unit appears to be correlative to other sidestream alluvial and pedogenic deposits found near the base of the ridges bounding the Pasco Basin on the north, west, and south. These sidestream alluvial and pedogenic deposits are inferred to have a late Pliocene to early Pleistocene age on the basis of stratigraphic position and magnetic polarity of intercalating loess units.

The Hanford formation is the informal name given to all cataclysmic flood deposits of the Pleistocene. The Hanford formation consists of pebble- to boulder-gravel, fine- to coarse-grained sand, and silt- to clayey-silt. These deposits are divided into three facies: 1) gravel-dominated, 2) sand-dominated, and 3) silt. These same facies are referred to as coarse-grained deposits, plane-laminated sand facies, and rhythmite facies, respectively in Bjornstad et al. (1987). The rhythmites also are referred to as the "Touchet Beds." The Hanford formation is thickest in the vicinity of 200 West and 200 East Areas where it is up to 65 m thick.

1) **Gravel-Dominated Facies**. This facies generally consists of coarse-grained basaltic sand and granule to boulder gravel. These deposits display an open framework texture, massive bedding, plane to low-angle bedding, and large-scale planar cross-bedding in outcrop. The gravel-dominated facies was deposited by high-energy flood waters in or immediately adjacent to the main cataclysmic flood channelways.

2) **Sand-Dominated Facies**. This facies consists of fine- to coarse-grained sand and granule gravel displaying plane lamination and bedding and less commonly plane bedding and channel-fill sequences in outcrop. These sands may contain small pebbles and rip-up clasts in addition to pebble-gravel interbeds and silty interbeds less than 1 m (3 ft) thick. The silt content of these sands is variable, but where it is low a well sorted and open framework texture is common. These sands typically are basaltic, commonly being referred to as black, gray, or salt-and-pepper sands. The laminated sand facies was deposited adjacent to main flood channelways during the waning stages of flooding. The facies is transitional between the gravel-dominated facies and the rhythmite facies.

3) **Silty Facies**. This facies consists of thinly bedded, plane laminated and ripple cross-laminated silt and fine- to coarse-grained sand that commonly display normally graded rhythmites a few centimeters to several tens of centimeters thick (Myers et al. 1979, Bjornstad et al. 1987, DOE 1988). Locally clay-rich beds occur in this facies. These sediments were deposited under slack water conditions and in back flooded areas (DOE 1988).

A.2 S-SX Tank Farm Vadose Zone Geology

In the S-SX Tank Farm the vadose zone is approximately 64 m (200 ft) thick. It consists of the Ringold Formation unit E, the Plio-Pleistocene, the Hanford formation, and Holocene deposits. The vadose zone stratigraphy of the S-SX Tank Farm is illustrated in an east-to-west cross section (Fig. A.2) through the central portion of the SX Tank Farm, and a northwest-southeast cross section (Fig. A.3) through the SX Tank Farm, and an east-west cross section through the S Tank Farm (Fig. A.4). These sections include gamma log profiles, the depth of cesium-137, and the moisture contents (except A.4) in the soils relative to their stratigraphic position. Together these cross sections provide the most detailed and recent update of stratigraphy at or near the two largest areas of vadose zone contamination (and the largest potential sources of groundwater contamination) in the S and SX tank farms (i.e., near tanks S-104, SX-108/SX-109, and SX-115).

A.2.1 Methodology

The geologic interpretations presented in Figures A.2, A.3, and A.4 were determined by the following method. Initially, the well-site geologist's logs were compared to archived samples from the Hanford Geotechnical Sample Library. The logs were then modified and refined based on the archived samples (the potential for downhole sluffing was taken into consideration). Modified logs were then compared to geophysical logs for the borehole. Geophysical logs (e.g., gross gamma) allow refinement of the geologic data and permit more precise placement of geologic contacts because the geophysical logs are a continuous record whereas the geologic logs are not. Geologic logs are constrained by the drilling method and sample recovery. Sample retrieval in the vadose zone is difficult and typically does not allow the exact depth of samples and contacts to be determined. Changes in drilling blow counts can provide additional information on depth of lithological changes because of differing resistance to drilling by the different lithologies. Archived samples are from 5 ft (1.5 m) intervals and thus can induce as much as a 5 ft (1.5 m) uncertainty in lithology in either direction. Geophysical logs show subtle differences in the amount of gamma emitters in the soils which typically are proportional to clay abundance and typically reflect changes in grain size. When geophysical logs are compared to the well-site geologist's logs, the uncertainty in the depth of lithologic changes is greatly reduced, providing a more accurate representation of the stratigraphy in the borehole. In addition, the signature of the geophysical response from the borehole can provide an additional tool for correlation between boreholes.

Except for new borehole 41-09-39, moisture contents, in weight percent (%), are from (Caggiano 1992, 1993) and are based on gravimetric determination of moisture in samples of drill cuttings collected at 5-ft (1.5 m) intervals. Moisture contents for the new borehole, 41-09-39, are based on neutron probe results (DOE 1997) from 0 to 130 ft (40 m) and gravimetric results from core samples below the 130 ft (40 m) depth (Jeff Serne, personal communication, December 1997). The neutron probe moisture results were read from the original profile in counts per second at 5-ft (1.5 m) intervals. The count rate was converted to volume percent moisture based on interpolation of calibration curves for casing sizes nearest to the borehole 41-09-39 casing (Russ Randall, personal communication, October 1997). The equivalent moisture content in weight % was estimated by dividing volumetric % values by 1.5. Thus, the absolute moisture contents for the 0 - 130 ft (40 m) depth are approximated and may not be directly comparable to the more direct, gravimetric results. Plotting the gravimetric results for the core samples below the 130 ft (40 m) depth also required some judgement in avoiding those samples that were deemed to be impacted by small amounts of water added to facilitate the split spoon coring operation where gravel or highly cemented zones were encountered.

The cesium-137 profile for borehole 41-09-39 was replotted from values read from a log activity vs depth plot (DOE 1997). A linear rather than log concentration scale was used in order to more accurately indicate the depth of penetration of most of the inventory (greatest concentrations) for correlation with potential stratigraphic controls on liquid waste and or cesium-137 movement.

A.2.2 Ringold Formation

The Ringold Formation is up to 185 m (600 ft) thick in the deepest part of the Cold Creek syncline south of the 200 West Area. The vadose zone portion of the Ringold Formation thins from east to west (approximately 16 m (50 ft) to about 13 m (40 ft)) and consists primarily of a slightly silty coarse- to medium-grained sandy gravel (Ringold unit E).

In the S-SX Tank Farm area Slate (1996) interpreted the surface of the Ringold Formation as a trough-like trending northwest-southeast parallel to the Cold Creek syncline and plunging to the southeast (Fig. A.5). This trough contains two smaller troughs, one of which trends directly under the S-SX Tank Farm and one south of 200 West Area (Fig. A.5). Both smaller troughs appear to merge farther southeast. Slate (1996) interpreted the trough as a paleo-Cold Creek drainage developed in the slowly subsiding Cold Creek depression. The net effect of the trough is to give the surface of the Ringold under the tank farm a southeast dip.

A.2.3 Plio-Pleistocene Unit

The Plio-Pleistocene consists of up to 13 m (40 ft) of massive, brown yellow, and compact, silt and minor fine-grained sand and clay. Slate (1996) includes a gravel facies which occurs south of the 200 West Area in the Plio-Pleistocene unit. Granule-sized grains consisting primarily of basalt commonly occur in this unit. The unit is differentiated from overlying graded rhythmites (Hanford formation) by greater calcium carbonate content, massive structure in core, and high natural gamma response in geophysical logs (DOE 1988).

In the vicinity of the S-SX Tank Farm, the surface of the Plio-Pleistocene unit is a trough that resembles the surface of the Ringold Formation (Fig. A.6). There are, however, no obvious smaller troughs within the main trough as in the Ringold and the deepest part of the Plio-Pleistocene trough is under the S-SX Tank Farm. Slate (1996) interpreted this trough as having resulted from a combination of erosion by Cold Creek and post depositional erosion by the Missoula floods. Continued subsidence in the Cold Creek depression probably also contributed to growth of the feature.

The facies relationships in the Plio-Pleistocene have been interpreted by Slate (1996) as indicating deposition along a northwest-to-southeast trending stream channel. The gravel facies is restricted to the central portion of the trough. The eastern edge of the gravel facies occurs along the southwest boundary of 200 West Area. The S-SX Tank Farm lies above the finest grained facies which probably represents overbank deposits (Fig. A.7). It consists of mainly silty to very-fine silty sand and clay deposits.

The Plio-Pleistocene unit thins from southwest to northeast and varies from about 6 to 13 m (20 to 40 ft) in thickness across the tank farms (Figs. A.2, A.3, and A.4). This unit contains a series of paleosols with pedogenetic carbonate (caliche) zones (Slate 1996). The pedogenic carbonate zones are thought to have formed in the subsurface during hiatuses in deposition; the caliche zones can be as much as 20 m (66 ft) thick but under the S-SX Tank Farm only one has been recognized.

A.2.4 Hanford Formation

The Hanford formation at the S-SX Tank Farm consists of a series of primarily massive sands intercalated with beds of coarse sand and gravel, and thinner lens of silts and clayey silts. The basal portion of the unit consists of sandy to silty sands. Gravel lenses dominate the middle portion which are overlain by principally coarser sands with minor silt and gravel lenses.

The lower portion consists primarily of sands-to silty-sands. This sequence thins from east to west across the S and SX tank farms (Figs. A.2, A.3, and A.4) which may be the result of later scouring. A prominent silty clay bed is found at relatively the same stratigraphic position on both the west and east sides of the SX Tank Farm; how far this extends under the tank farm and if it is continuous is not presently known.

The lower sandy sequence is bounded above by one to two gravel lens and intercalated sands that can be correlated under the tank farms (Figs. A.2 and A.4). There are two gravel lens to the west but they either merge or the upper one pinches out to the east (see Fig. A.2). The sequence ranges in thickness from 3 m to 10 m (10 to 30 ft) in the SX Tank Farm but little thinning is seen under the S Tank Farm. In the S Tank Farm this gravel sequence was intersected during excavation for the tanks (Fig. A.4) and is now in contact with the backfill.

Above the gravel lenses lies an upper sandy- to silty-sand sequence. This sequence thins to the east. A thin, sandy silt, 1 to 1.5 m (3 to 5 ft) thick directly overlying the gravel forms the base of this sequence on the east and north side of the tank farms. A thin, coarse sandy unit about ten feet above the gravel is intercalated with this sequence on the west side only (Figs. A.2 and A.4).

Holocene deposits and backfill material overlie the Hanford formation.

A.3 Subsurface Moisture Distribution Beneath the SX Tank Farm

Moisture profiles are plotted in Figures A.2 and A.3 along with the lithologic profiles. While qualitative at best, the moisture correlations appear to be consistent with the stratigraphy across the tank farm and indicate that gravimetric moisture content increases with decreasing grain size. Several high moisture zones can be identified in the vadose zone.

The uppermost moisture zone occurs at approximately 25 m (80 ft drilled depth) in the Hanford formation in borehole W23-14. This zone correlates with the continuous upper sandy silt sequence above the gravel lenses. A high moisture zone occurs at the same horizon on the east side of the tank farm (Fig. A.2, W22-39). Although stratigraphically similar, this high moisture horizon does not appear to be present in borehole 41-09-39 which was drilled next to tank S-109. This suggests a discontinuity in the moisture content of this stratigraphic unit across the tank farm; higher moisture concentrations in this stratigraphic unit occur away from the tank farm. Gamma logging indicates that this stratigraphic unit has high cesium-137 activity near the S 109 tank.

A second high moisture zone occurs in well W23-14 about 2 m (7 ft) below the gravel lenses and appears to be controlled by a clayey silt zone. There is a similar high moisture zone on the east side of the tank farm at 30 m (90 ft) in well W22-39 but it is not known if this is the same horizon or just a localized bed. Similar to the upper high moisture zone, there is no high moisture zone at a similar horizon in the tank farm (see 41-09-39).

The deepest high moisture zone occurs in a clay- to silty-clay horizon at a depth of approximately 40 m (125 ft in borehole W23-14, Fig. A.2) and corresponds to the Plio-Pleistocene unit. This is the only “high” moisture zone encountered in 41-09-39 below a depth of 3 m (10 ft). Elevated Cs-137 contamination was detected at the surface of the Plio-Pleistocene in this borehole. The surface of the Plio-Pleistocene plunges southeast directly under the tank farm. Any moisture and Cs-137 reaching the Plio-Pleistocene horizon probably will have a tendency to migrate southeast along the axis of the trough.

A.4 References

Bjornstad, B. N., K. R. Fecht, and A. M Tallman. 1987. Quaternary Geology of the Pasco Basin, Washington: Rockwell Hanford Operations. Report RHO-BW-SA-563A.

Caggiano, J. A. 1992. *Borehole Completion Package, WHC-SD-EN-DP-041.* Westinghouse Hanford Company, Richland, Washington.

Caggiano, J. A. 1993. *Borehole Completion Package, WHC-SD-EN-DP-042*. Westinghouse Hanford Company, Richland, Washington.

DOE. 1988. Consultation Draft Site Characterization Plan: U.S. Department of Energy, Report DOE/RW-0164, 9 volumes.

DOE. 1997. *TWRS Vadose Zone Contamination Issue, Expert Panel Status Report.* DOE/RL-97-49, U.S. Department of Energy, Richland, Washington.

Lindsey, K. A. 1991. Revised Stratigraphy for the Ringold Formation, Hanford Site, South-Central Washington. Westinghouse Hanford Report WHC-SD-EN-EE-004.

Myers, C. W.; and others. 1979. Geologic Studies of the Columbia Plateau -- a Status Report: Richland, Washington, Rockwell Hanford Operations Report RHO-BWI-ST-4, Richland, Washington, 326 p., 10 plates.

Slate, J. L. 1996. Buried Carbonate Paleosols Developed in Pliocene-Pleistocene Deposits of the Pasco Basin, South-Central Washington, USA: Quaternary International, Vol 34-36, pp. 191-196.

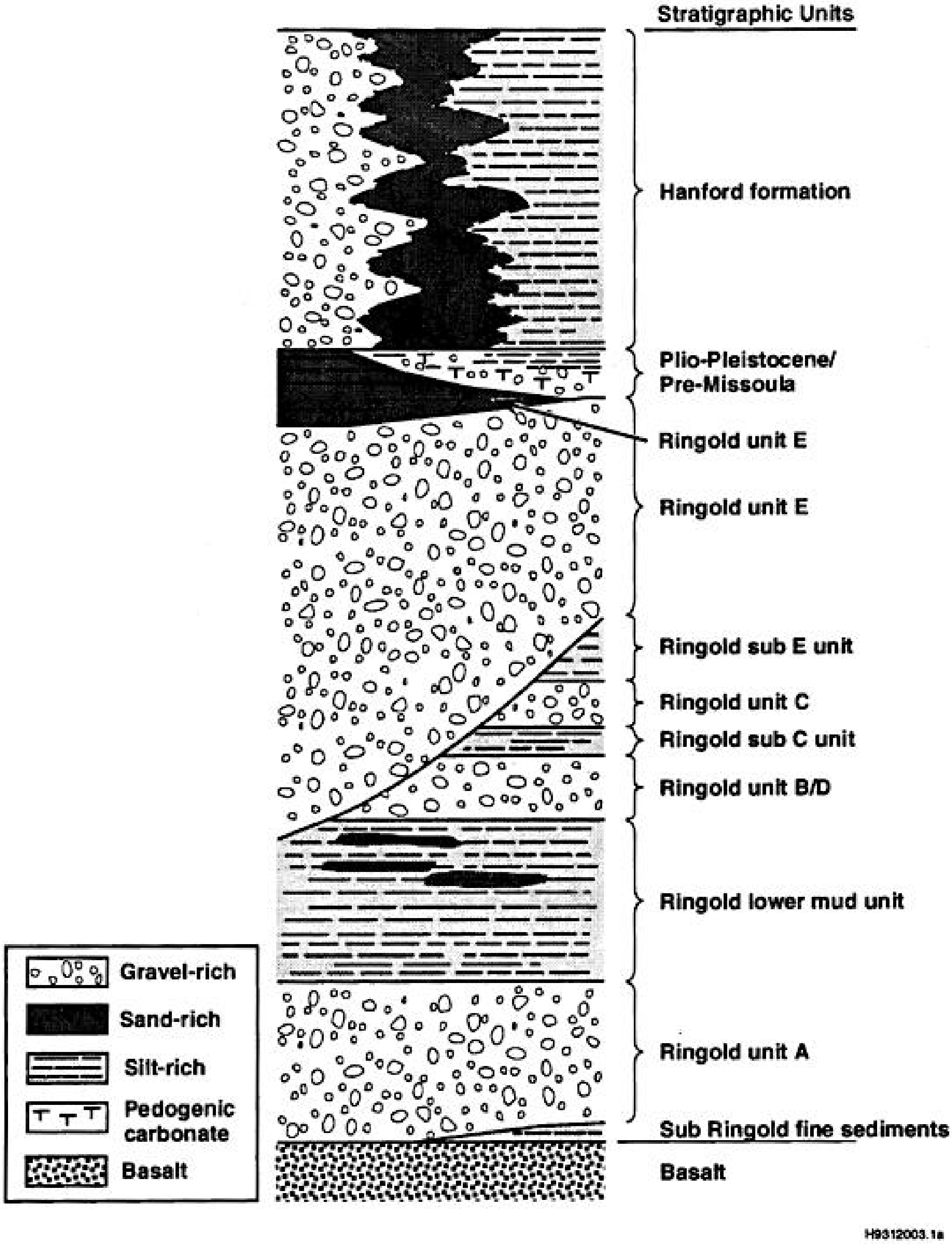

Figure A.1. Generalized, Composite Stratigraphy for the Late Cenozoic Sediments Overlying the Columbia River Basalt Group on the Hanford Site. Typically the Hanford formation forms the majority of the vadose zone and the Ringold Formation dominates the saturated zone.

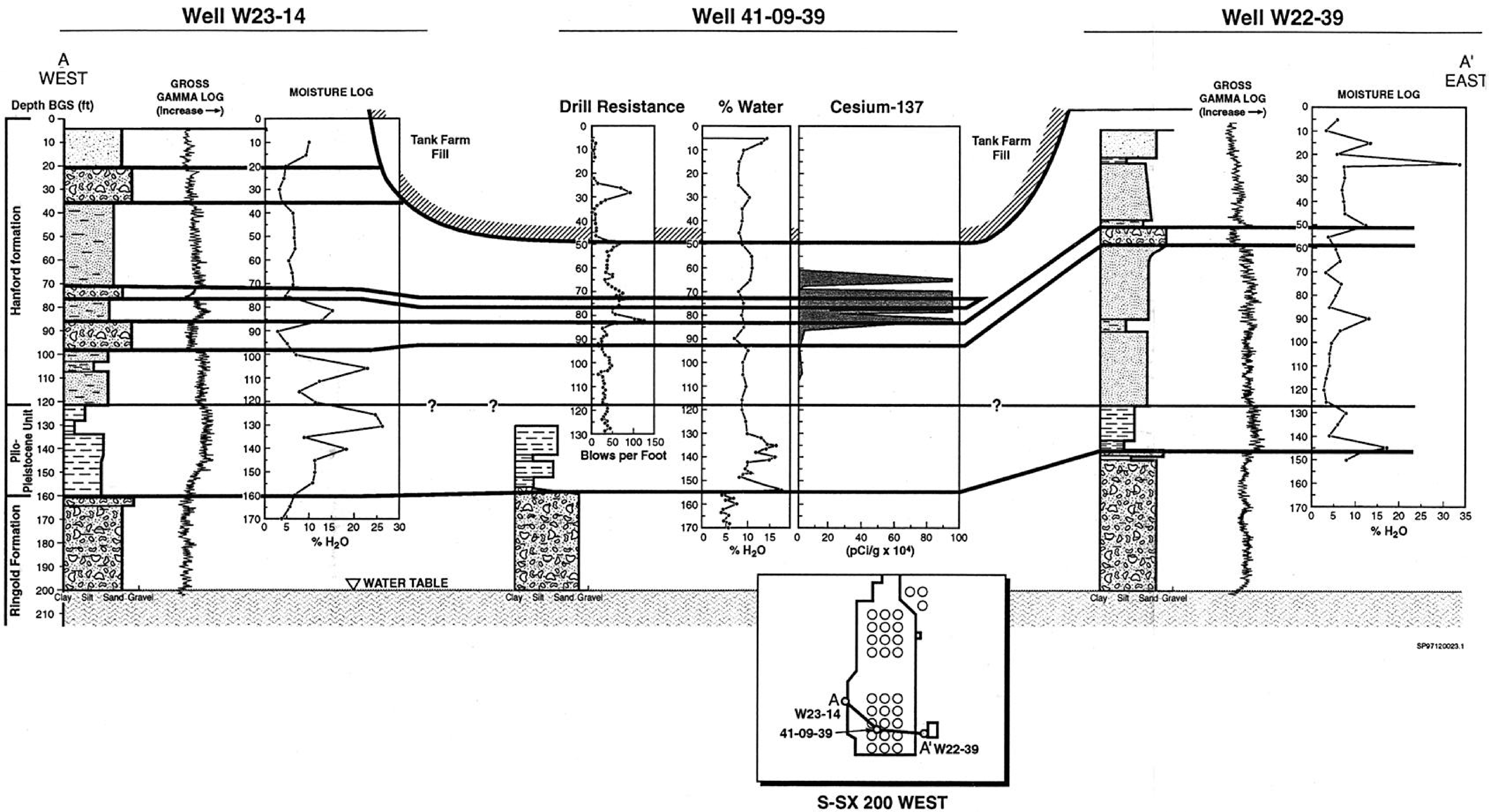

Figure A.2. East-West Cross Section Through SX Tank Farm. Shown are selected logs for the stratigraphic units from Figure A.1, texture, moisture content, drilling resistance, and gamma profiles. The logs for each well are grouped together under each well. Horizontal lines between the wells show correlation of units.

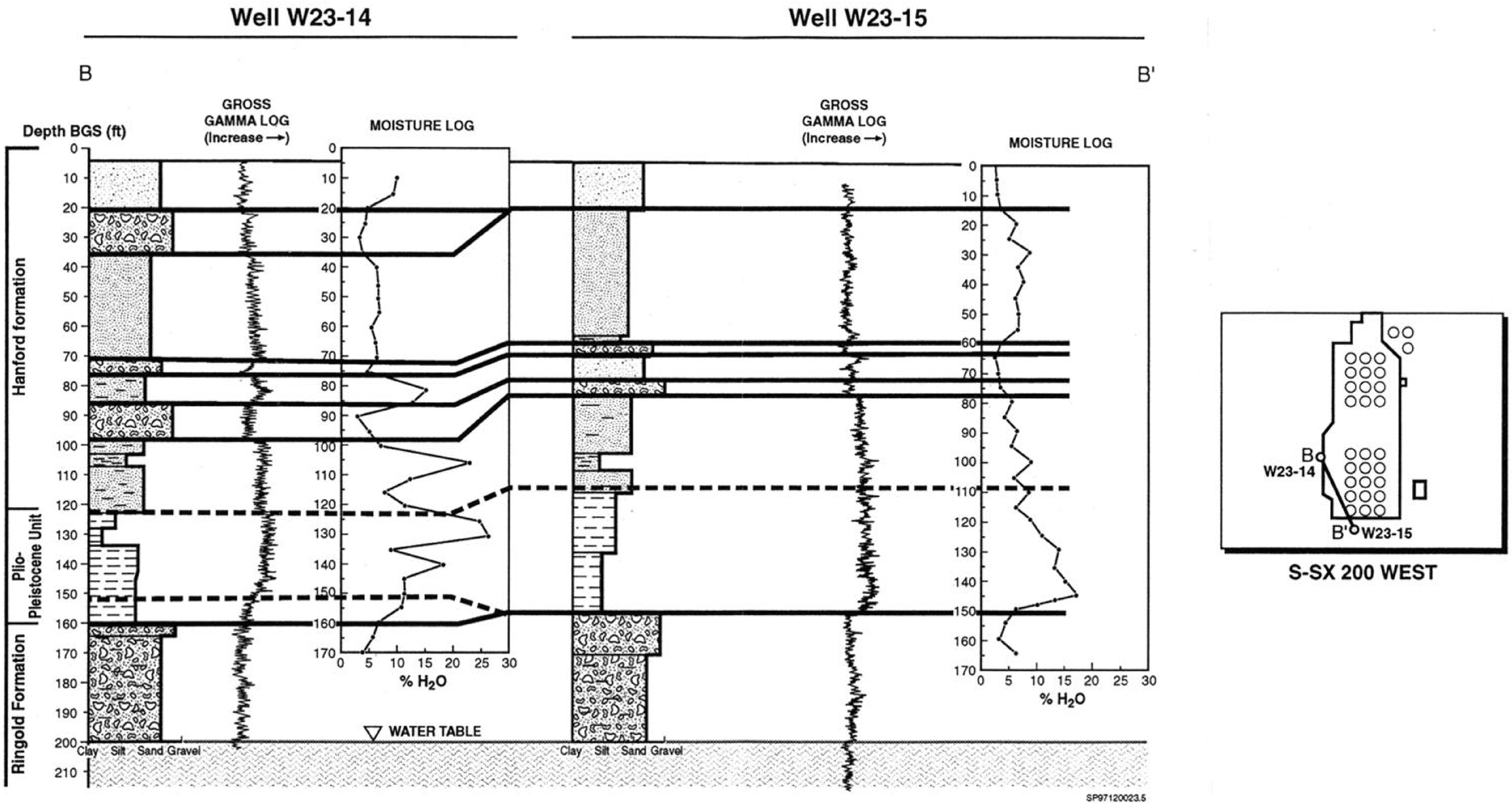

Figure A.3. Northwest-Southeast Cross Section Through SX Tank Farm. Shown are selected logs for the stratigraphic units from Figure A.1, texture, moisture content, and gamma profiles. The logs for each well are grouped together. Horizontal lines between the wells show correlation of units.

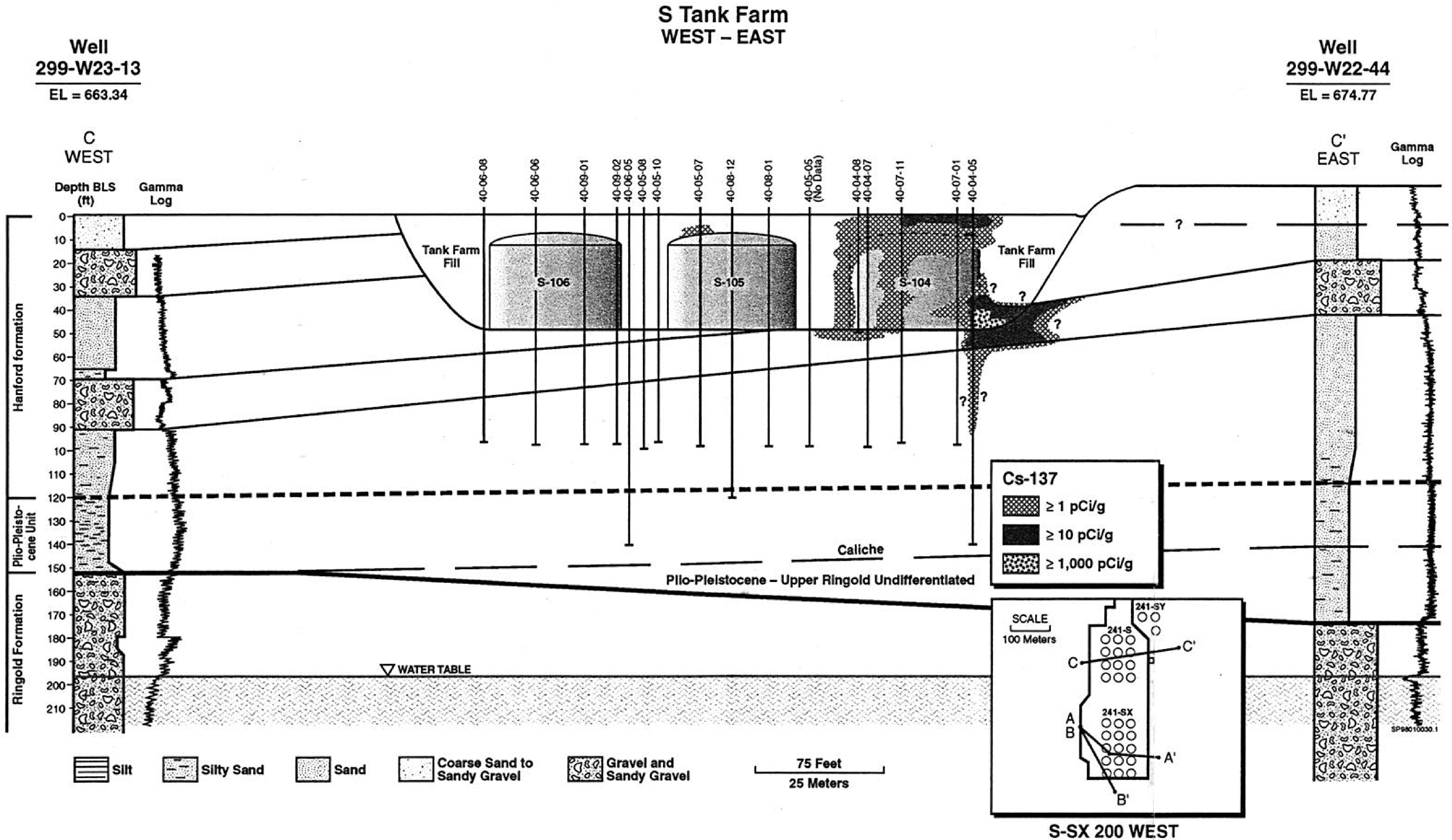

Figure A.4. East-West Cross Section Through S Tank Farm. Shown are selected logs for the stratigraphic units from Figure A.1, texture, gamma profiles, and distribution of Cs-137 in the soil. The logs are grouped together under each well. Horizontal lines between the wells show correlation of units.

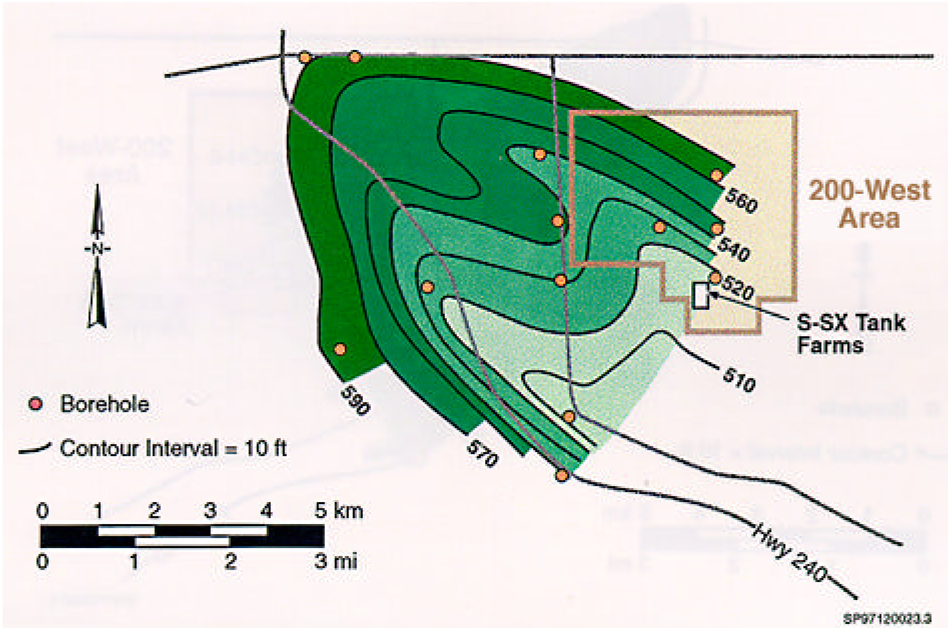

Figure A.5. Contour Map on the Surface of the Ringold Formation in the S-SX Tank Farm and Surrounding Area (from Slate 1997). Note that the surface of the Ringold Formation forms a southeast plunging trough centered under the SX Tank Farm. Depths are in feet above mean sea level.

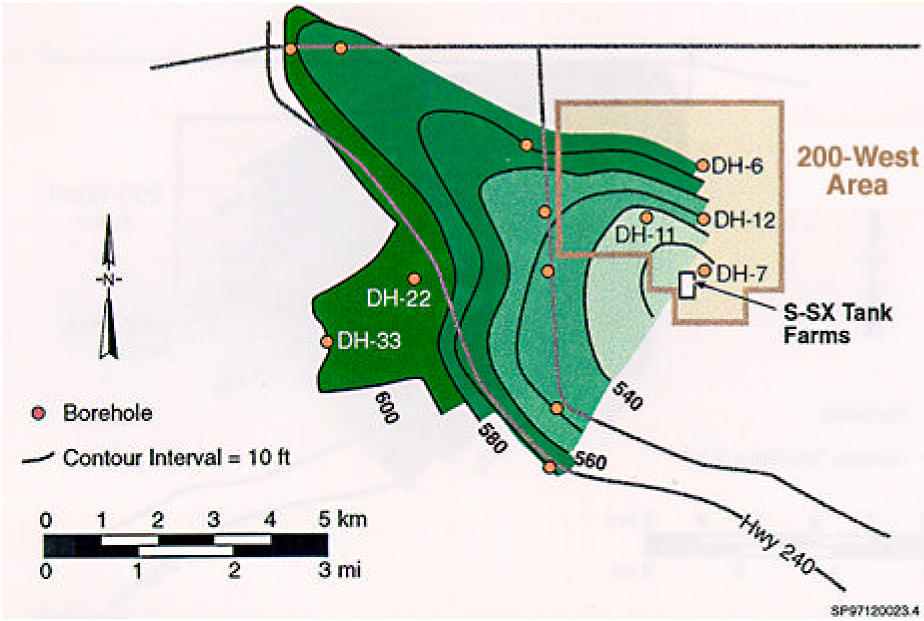

Figure A.6. Contour Map on the Surface of the Plio-Pleistocene Unit in the S-SX Tank Farm Area (from Slate 1997). Note that the surface of the Plio-Pleistocene unit forms a southeast plunging trough under the tank farm. A comparison of Figures A.5 and A.6 shows that the axes of both troughs coincide and provide a potential southeast lateral pathway for contaminant spreading. Depths are in feet above mean sea level.

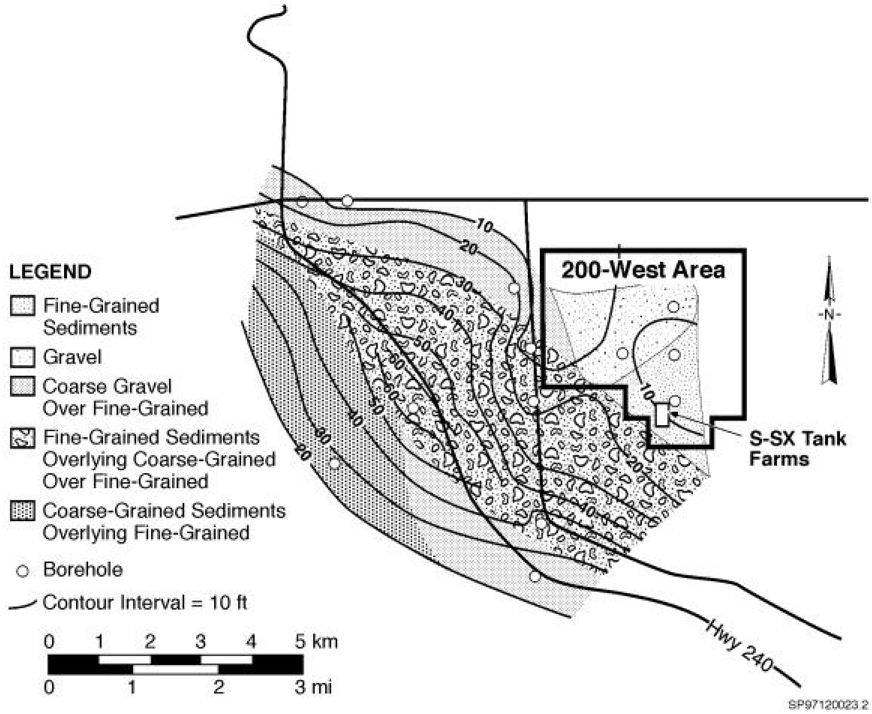

Figure A.7. Plio-Pleistocene Unit Textural Variations in the S-SX Tank Farm Area (from Slate 1997). The Plio-Pleistocene Unit is interpreted to be the sediments from the ancestral Cold Creek. The textural variations through the area are summarized here. Under the S-SX Tank Farm area the Plio-Pleistocene Unit is primarily fine-grained silts and sands deposited as overbank sediments by the ancestral Cold Creek.