Vadose Zone Geology of Boreholes 299-W10-27 and 299-W11-39 T-TX-TY Waste Management Area Hanford Site, South-Central Washington

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Abstract: This report describes the results of geologic and geophysical logging activities carried out for boreholes 299-W10-27 and 299-W1-1-39. In order to meet the geologic characterization goals, five objectives were defined to guide the logging and interpretation.

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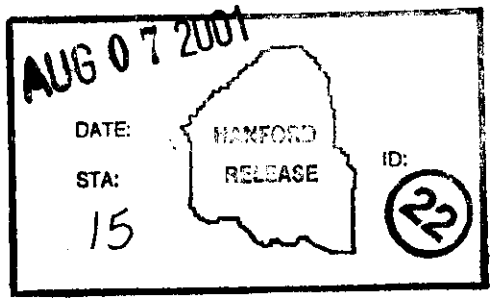

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VADOSE ZONE GEOLOGY OF BOREHOLES 299-W10-27 AND 299-W11-39 T-TX-TY WASTE MANAGEMENT AREA HANFORD SITE, SOUTH-CENTRAL WASHINGTON

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June 2001

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LIST OF TERMS

bgs	below ground surface
cps	counts per second
CRBG	Columbia River Basalt Group
HPGe	high-purity germanium
KUT	potassium, uranium and thorium
msl	mean sea level
PNNL	Pacific Northwest National Laboratory
ROCSAN	Computer program for determining the Wentworth sediment gram size
SPT	split spoon
SSTF	241-T single-shell tank farm
WMA	Waste Management Area

VADOSE ZONE GEOLOGY OF BOREHOLES 299-W10-27 AND 299-W11-39 T-TX-TY WASTE MANAGEMENT AREA HANFORD SITE, SOUTH-CENTRAL WASHINGTON

1.0 INTRODUCTION

In the first half of fiscal year (FY) 2000 two boreholes were drilled in the T-TX-TY Waste Management Area (WMA) in the Hanford Site 200 West Area (Figure 1). A number of split spoon (SPT) samples were collected from these boreholes for vadose zone physical property characterization. These boreholes, which were completed as groundwater monitoring wells, are designated 299-W11-39 (C3117) and 299-W10-27 (C3125). The objective for drilling and sampling these boreholes was to aid in the characterization of vadose zone physical and chemical conditions at a location close to, but largely unaffected by past tank leaks or by waste discharge to facilities adjacent to the tank farms. In both boreholes, SPT samples were collected as continuously as possible from near the surface to near the top of, or into, the Ringold Formation. Information collected from these two boreholes, combined with existing data, provides the opportunity to develop technically strong interpretations of vadose zone physical and chemical conditions beneath the T-TX-TY WMA.

This report describes the results of geologic and geophysical logging activities carried out for the two boreholes. This work was performed by Dr. Kevin Lindsey of Kennedy/Jenks Consultants, Inc., Mr. Kent Reynolds of Duratek Federal Services, Inc., Northwest Operations and Mr. Steven Kos of MACTEC-ERS. In order to meet the geologic characterization goals established for boreholes 299-W10-27 (W10-27) and 299-W11-39 (W11-39), objectives were defined to guide the geologic logging and subsurface interpretation described in this report. These objectives are as follows.

- Briefly describe the general geologic setting of the two boreholes.
- Establish and define geologic logging methodology.
- Geologically log the samples, record observations, and describe subsurface geologic conditions interpreted from the samples.
- Integrate geologic logging results with the results of other geologic investigations and produce a synthesis applicable to the T-TX-TY WMA.
- Present conclusions regarding vadose zone physical geologic conditions beneath the T-TX-TY WMA suggested by this investigation.

This report is subdivided into sections that address these objectives.

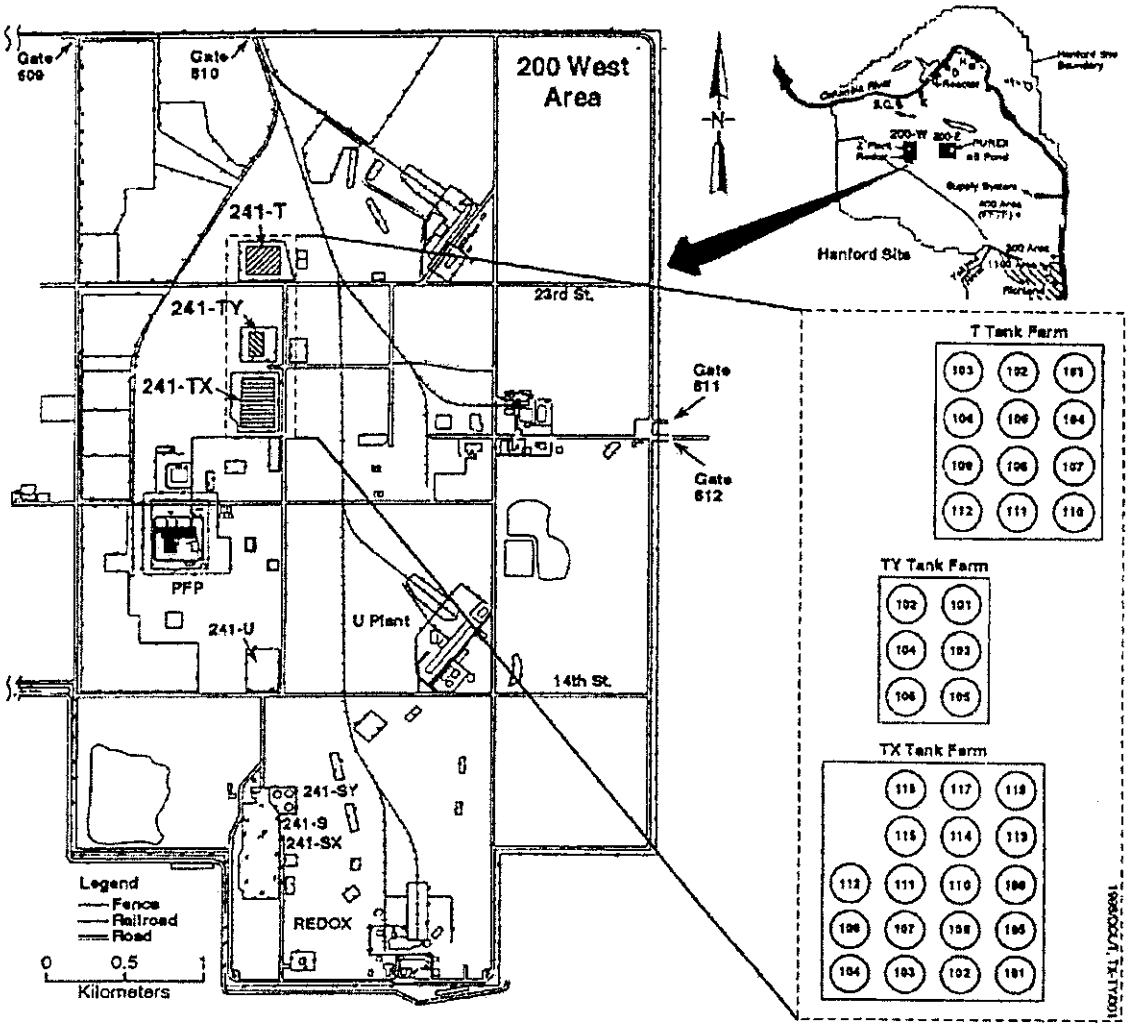

Figure 1. Location of the T-TX-TY WMA in the Hanford Site 200 West Area (from Wood et al. 2001)

2.0 REGIONAL SETTING

The discussions in the following sections were derived from the *TX Tank Farm Report* (DOE-GJPO 1997) and Wood et al. 2001. This information is supplemented by other reports including RL 1993; Caggiano and Goodwin 1993; Lindsey et al. 1992, and Reidel et al. 1989. Additional references are cited as needed.

2.1 REGIONAL GEOLOGY

The Hanford Site is located in the Pasco Basin, which is a physical and structural depression in the Columbia Plateau created by tectonic activity and folding of Columbia River basalt and intercalated and overlying Miocene-Pliocene sediment. The Pasco Basin is bounded on the north by the Saddle Mountains; on the east by the Palouse Slope; on the west by the Umtanum Ridge, the Yakima Ridge, and the Rattlesnake Hills; and on the south by Rattlesnake Mountain and the Rattlesnake Hills. All these uplifts are major structural anticlines within the basalt bedrock. The eastern boundary of the Pasco Basin is a structural monocline with the bedrock dipping to the west and covered with the sediment that constitutes the Palouse Slope. The Hanford Site is underlain by Miocene Age basalt of the Columbia River Basalt Group (CRBG) and Miocene to Pleistocene suprabasalt sediments. Figure 2 illustrates the position of the Hanford Site within the Pasco Basin and identifies major landforms.

2.1.1 Geologic Structure of the Pasco Basin

The Pasco Basin, one of the largest structural basins on the Columbia Plateau, lies near the junction of the Yakima Fold Belt and the Palouse subprovinces. The Yakima Fold Belt is distinguished by a series of segmented, narrow, asymmetrical, generally east-west trending anticlines. The northern limbs of these anticlines generally dip to the north and are steep, vertical, or overturned. The southern limbs generally dip to the south at shallow angles. Broad synclines or basins that may contain thick accumulations of sediment separate the anticlinal ridges. The Umtanum-Gable Mountain anticline divides the Pasco Basin into the Wahluke and Cold Creek synclines. The Cold Creek syncline is asymmetrical and is a relatively flat-bottomed structure. The Hanford Site 200 Areas are located on the northern limb of the Cold Creek syncline where the bedrock dips to the south at an angle of approximately 5 degrees. Anticlines to the north and south create topographic high areas with outcropping basalt flows of Gable Mountain and Rattlesnake Mountain, respectively. Figure 3 shows the structural features of the Pasco Basin in the vicinity of the Hanford Site and also shows the approximate location of the 200 West Area (within which the T-TX-TY WMA is located.

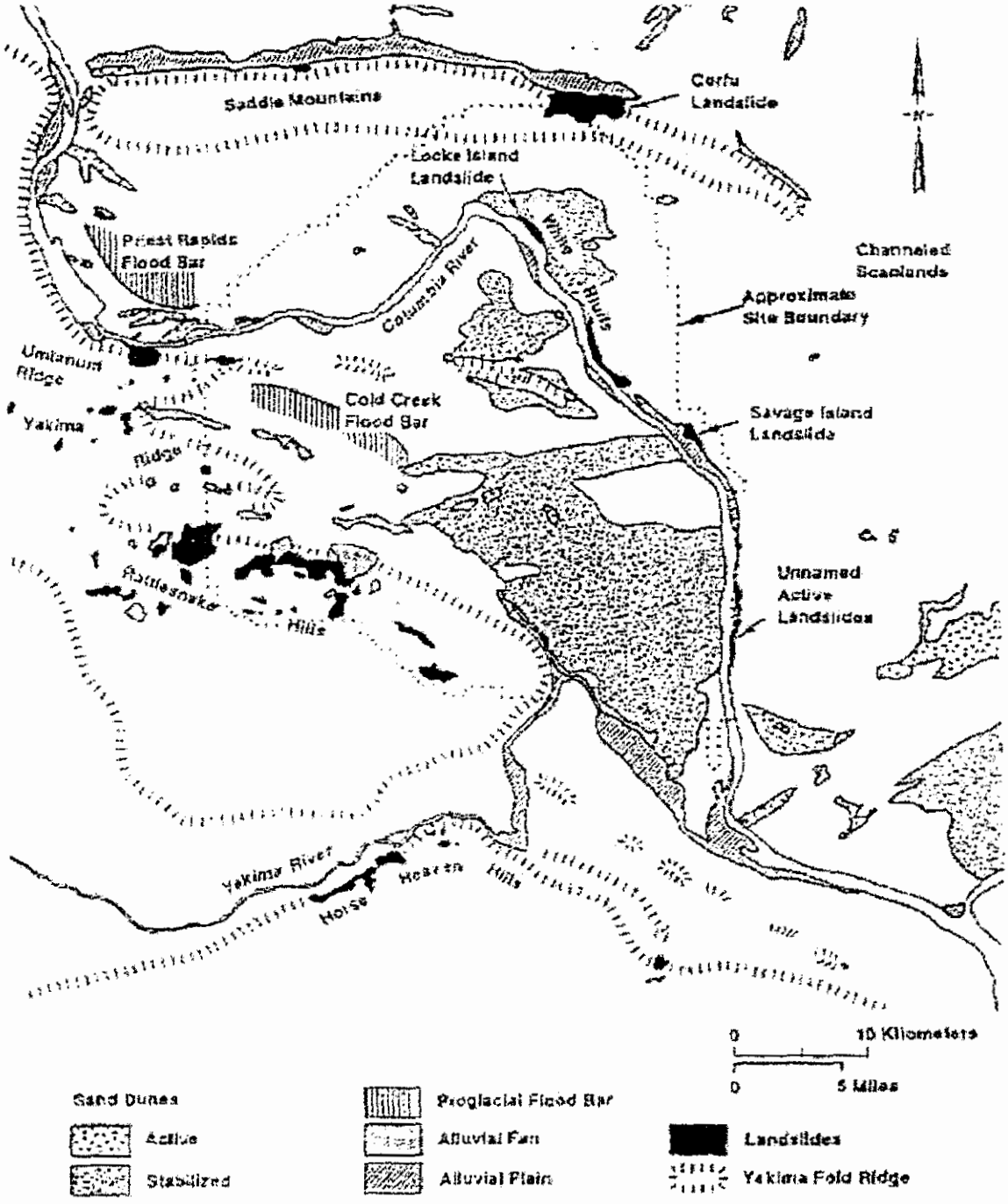

Figure 2. Landforms of the Pasco Basin in the Vicinity of the Hanford Site (from RL 1992)

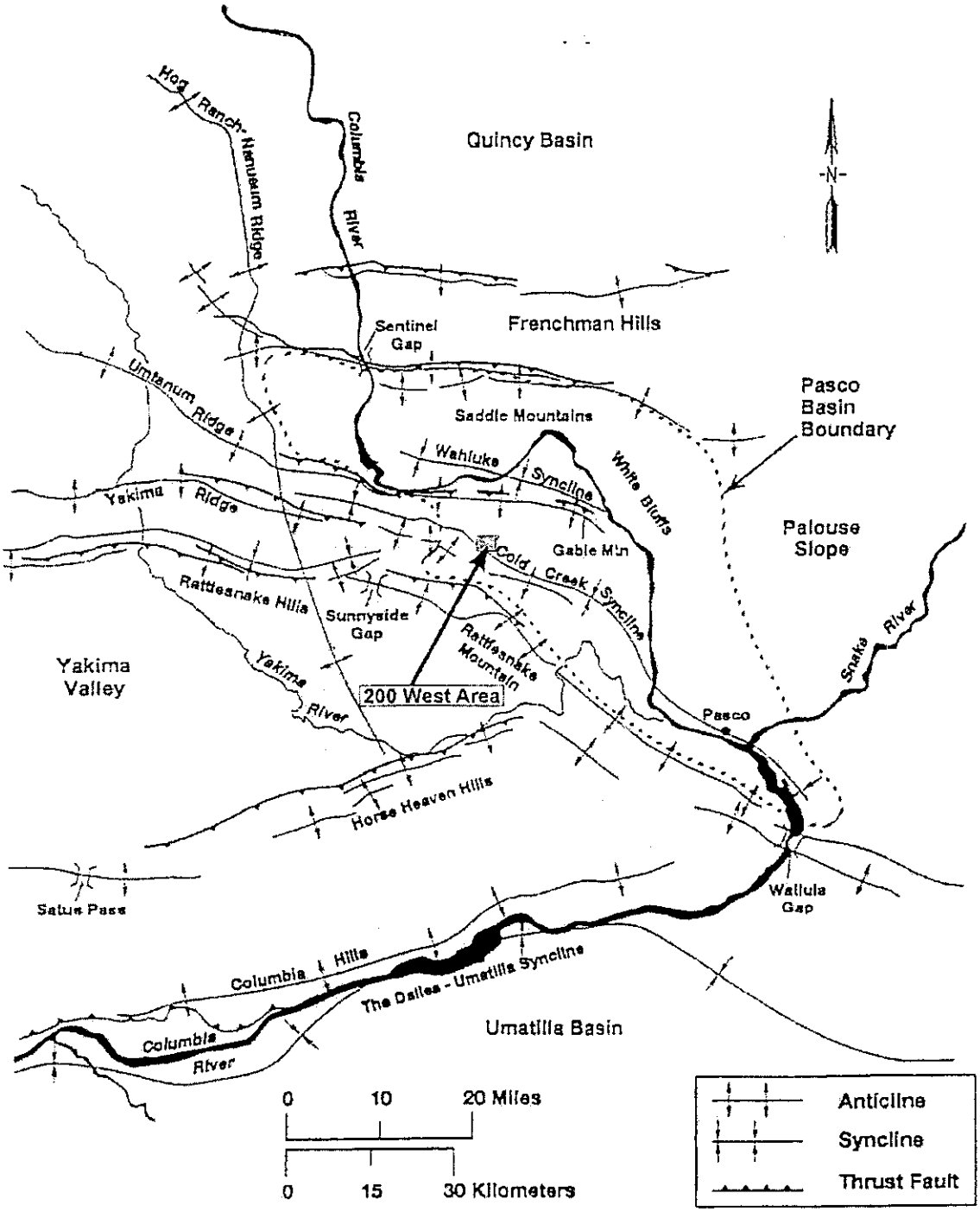

Figure 3. Geologic Structure of the Pasco Basin in the Vicinity of the Hanford Site (from Lindsey 1995).

2.1.2 Stratigraphy of the Pasco Basin

As mentioned previously, the Hanford Site is underlain by Miocene Age basalt of the CRBG, Miocene Age sedimentary interbeds within the CRBG referred to as the Ellensburg Formation, and Miocene to Pleistocene suprabasalt sediments. The bedrock at the Hanford Site consists of a series of CRBG basalt flows. CRBG flows are continental flood basalt that extend from north-central Washington, south into Oregon, and east into Idaho, covering an area of more than 63,000 square miles. They are generally of tholeiitic composition. The thickest flows are more than 30.5 m (100 ft) thick, with sedimentary interbeds occurring between some of the lava flows.

The basalt is overlain by continental sediments, generally referred to as suprabasalt sediments, that are subdivided into the following geologic units:

- Holocene backfill and eolian deposits
- Hanford formation
- Plio-Pleistocene strata
- Ringold Formation.

These geologic units are described in detail in the following sections. A stratigraphic column of the geologic units beneath the T-TX-TY WMA is shown in Figure 4.

Holocene Backfill and Eolian Deposits

Backfill is present at all three of the T-TX-TY WMA tank farms. It generally consists of gravel, sand, and silt removed from, and subsequently returned to, tank farm excavations. Tank farm backfill also intermittently contains construction debris, and it is irregularly compacted. Backfill thickness varies between tank farms. At the 241-T single-shell tank farm (SSTF) it is reported to be approximately 12.2 m (40 ft) thick (DOE-GJPO 1999), at the 241-TX SSTF, it is approximately 15.2 m (50 ft) thick (DOE-GJPO 1997), and at the 241-TY SSTF, it is reported to be approximately 13.7 m (45 ft) thick (DOE-GJPO 1998).

Eolian deposits, consisting of fine sand (DOE 1988; Reidel et al. 1992; Reidel and Fecht 1994), are not typically found within or around the tank farms. These deposits have been largely removed during tank farm and other facility construction, or they have been buried by radiologically "clean" cover materials that were placed to control spread of surface contamination. Eolian sand may be found locally around the periphery of tank farms where it was not removed during construction and waste management activities.

Hanford Formation

The Hanford formation consists of up to 106.4 m (350 ft) of uncemented gravel, sand, and silt deposited by Pleistocene cataclysmic flood waters (Myers et al. 1979; Tallman et al. 1979, 1981; Fecht et al. 1987; DOE 1988; Baker et al. 1991; Reidel et al. 1992; Lindsey et al. 1994a, 1994b; Waitt 1994).

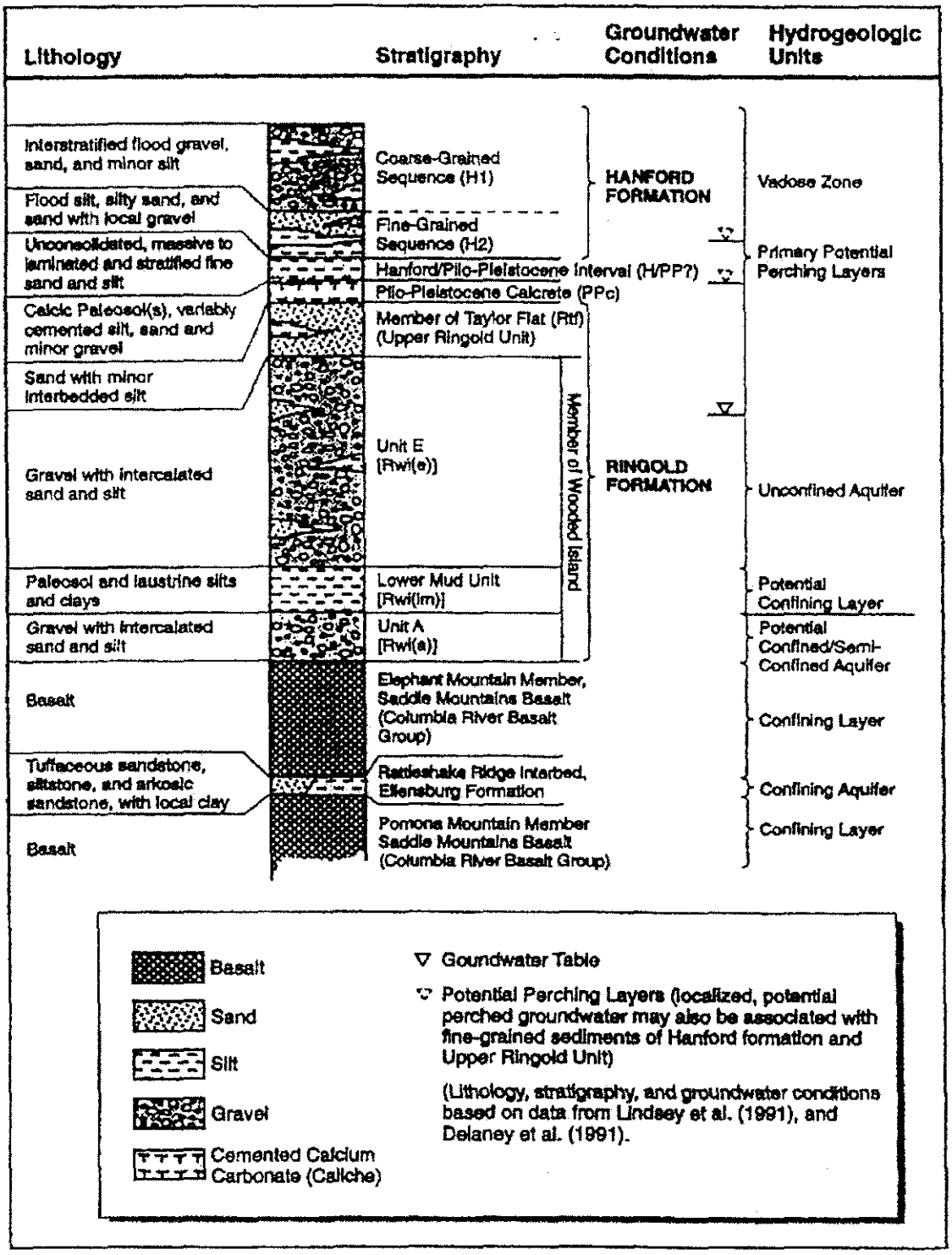

Figure 4. Stratigraphic Column for the T-TX-TY WMA (from Wood et al. 2001).

This is the primary vadose zone geologic unit across the Hanford Site. Strata comprising the Hanford formation generally are described on the basis of three gross-scale facies or sediment types, gravel-, sand-, and silt-dominated (Baker et al. 1991; Reidel et al. 1992; Lindsey et al. 1994a, 1994b). General characteristics of the three gross-scale facies or sediment types are summarized as follows.

Silt-dominated—This sediment type consists of interbedded, brown, tan, and olive, silt and fine-to-coarse sand forming repeated, well stratified, lenticular-to-tabular, normally graded (fining upwards) beds less than 1 m (3 ft) thick (Reidel et al. 1992; Lindsey et al. 1994a). Sand mineralogy is more commonly felsic in the fine-to-medium fractions while it becomes more mafic in the coarse fraction. Individual beds can be traced tens of to several hundred feet, but cannot usually be correlated between outcrops, and from borehole to borehole. Calcium carbonate-rich horizons have been observed in some outcrops. The silty sediment type also is referred to as slackwater deposits, Touchet Beds, rhythmites, and silt facies (Myers et al. 1979; DOE 1988; Last et al. 1989; Baker et al. 1991; Lindsey et al. 1994a, 1994b).

Sand-dominated—Well stratified, fine-to-coarse sand with minor granule gravel characterizes this facies (Reidel et al. 1992, Lindsey et al. 1994a). Silt occurs as minor, laterally discontinuous interbeds. Mineralogy ranges from felsic in silt and fine-to-medium sand to more basaltic in coarse sand and granule gravel. Corresponding colors range from olive, brown, and tan to gray, black, and "salt and pepper." Small pebbles and rip-up clasts may be present in addition to lenticular, pebble-gravel interbeds. Stratification seen in outcrops includes planar lamination, ripple cross lamination, cross bedding, and normal grading. Deposits comprising this facies have also been called the plane-laminated sand, transitional, and sand facies (Myers et al. 1979; DOE 1988; Last et al. 1989; Baker et al. 1991; Lindsey et al. 1994a, 1994b).

Gravel-dominated—These deposits consist of cross-bedded, interstratified, coarse-grained sand and granule-to-boulder gravel in outcrop (Reidel et al. 1992, Lindsey et al. 1994a). Intercalated, lenticular silt-rich horizons are found locally. Clast petrology ranges from felsic to basaltic. Predominant colors are dark brown, gray, and black. Gravelly sediments can occur as isolated beds several meters thick intercalated in other Hanford formation sediment types and as thick amalgamated gravel beds forming intervals up to 20 m (66 ft) thick. This facies is generally uncemented, matrix poor and commonly displays an open framework texture.

Historically, the Hanford formation has been subdivided into two basic map units, gravel-rich strata known as the Pasco Gravel and silt and sand strata referred to as Touchet Beds (Myers et al. 1979). More recent work has lead to the Hanford formation being subdivided into map units correlated to age of deposition (Reidel and Fecht 1994) or lithostratigraphic units correlated on the basis of physical characteristics and stratigraphic position (Last et al. 1989; Lindsey and Law 1993; Lindsey et al. 1994a, 1994b). Following usage in Lindsey and Law (1993) and Lindsey et al. (1994b) Hanford formation units in the vicinity of the T-TX-TY WMA are summarized as follows.

- Unit H1—This unit comprises the upper part of the Hanford formation. It is a gravelly interval of variable thickness that is found across the area and corresponds to the Hanford formation upper sequence of Last et al. (1989).

- Unit H2—A mixed sandy and silty sediment that dominates the lower 1/2 to 2/3 of the formation, although evidence discussed later in this report indicates the unit in the T-TX-TY WMA is coarser than this. Unit H2 generally corresponds to the Hanford formation slack-water sequence of Last et al (1989).

Plio-Pleistocene Strata

A sequence of laterally discontinuous, unnamed fluvial, alluvial, eolian, colluvial, pedogenic carbonate, and lacustrine deposits less than 12 m (40 ft) thick underlies the Hanford formation and overlies the Ringold Formation beneath the 200 West Area. Lithologies that have been described in this interval include:

- Laterally discontinuous pedogenic and groundwater-(?)derived, white, light gray, and light pink colored calcium carbonate forming irregular partings, fracture fill, nodules, and horizons less than 0.3 m (1 ft) thick (Reidel et al. 1992; Lindsey et al. 1994a, 1994b; Slate 1996)

- Interbedded lenses of reworked loess, basaltic sand and gravel, and felsic sand and gravel with intercalated carbonate (Reidel et al. 1992; Lindsey et al. 1994a, 1994b; Slate 1996)

- Thin, planar laminated, interstratified tan, light brown, and olive colored fine sand, silty sand, and sandy silt with interbedded clayey silt (Singleton and Lindsey 1994; Lindsey et al. 1994a, 1994b)

- Massive, loess-like sandy silt to silty sand referred to as early Palouse soil and overlying calcium carbonate deposits (Myers et al. 1979; Tallman et al. 1979, 1981; DOE 1988; Last et al. 1989).

In the T-TX-TY WMA only two of the four main facies appear to be present: (1) interbedded, massive-to-stratified clay, silt, and fine sand, and (2) pedogenic calcium carbonate strata (e.g., caliche). Using the terminology being proposed by B. Bjornstad (B. Bjornstad, personal communication) these facies are grouped into two main subunits, a silty upper unit and a caliche-rich lower unit.

Ringold Formation

The Ringold Formation is approximately 182.9 m (600 ft) thick beneath the Hanford Site. It consists of variably to well-indurated clay, silt, fine- to coarse-grained sand, and pebble to cobble conglomerate. Ringold sediments are felsic to lithic (Goodwin 1993, Lindsey 1996) and are grouped into five facies associations based on lithology, petrology, stratification, and pedogenic alteration (Lindsey 1991, 1996; Lindsey et al. 1994a). Detailed descriptions of the facies associations, I—fluvial gravel, II—fluvial sand, III—overbank-paleosol silt, IV—lacustrine silt and sand, and V—basaltic alluvial sand and gravel are found in Lindsey (1996).

The distribution of facies associations within the Ringold Formation forms the basis for its stratigraphic subdivisions (Lindsey 1996). The lower half of the Ringold Formation, informally called the member of Wooded Island, is subdivided into several subunits (designated A, B, C, D, and E), characterized by strata typical of the fluvial gravel and fluvial sand facies association and separated by deposits of the overbank-paleosol and lacustrine facies association. Interstratified deposits of the fluvial sand and overbank-paleosol facies association, informally called the member of Taylor Flat, and strata dominated by the lacustrine facies association, informally called the member of Savage Island, form the upper half of the Ringold Formation (commonly called the upper unit or upper Ringold). Ringold strata in the vadose zone beneath 200 West Area SSTFs consist of a combination of Unit E of the member of Wooded Island and the lowermost part of the member of Taylor Flat.

Clastic Dikes

Clastic dikes are found in the Hanford formation and locally in other sedimentary units (Black 1979, Fecht and Weekes 1996, Fecht et al. 1999). Clastic dikes are vertical to subhorizontal fissures filled by multiple layers of unconsolidated sand, silt, clay, and minor gravel aligned parallel-to-subparallel to dike walls. Clastic dikes range in vertical extent from 30 cm (1 ft) to 54.8 m (180 ft). In cross section, clastic dikes range from 1 mm to 2 m (.04 in. to 6.54 ft) in thickness, and in plan view clastic dikes extend tens to hundreds of feet along strike. Clastic dikes form a branching pattern that in plan view is manifested as polygons several tens of feet across forming a feature known as patterned ground. They are most abundant in Hanford formation sand-dominated and silt-dominated facies (Fecht et al. 1999). Locally, they also crosscut Plio-Pleistocene carbonate strata (Singleton and Lindsey 1994). Fecht et al. (1999) summarize the locations at Hanford where clastic dikes have been identified.

3.0 VADOSE ZONE GEOLOGY OF BOREHOLES 299-W10-27 AND 299-W11-39

The purpose of this section is to describe the geologic and geophysical data gathered from boreholes W10-27 and W11-39. This section is subdivided into five parts:

- Methodology used in the drilling, sampling, and logging of borehole samples
- Sediment facies descriptions used during the logging
- Geologic logging results and subsurface geology for borehole 299-W10-27
- Geologic logging results and subsurface geology for borehole 299-W11-39
- Geophysical logging used in the analysis of the boreholes.

3.1 METHODOLOGY

This section summarizes the basic methodology used in SPT sample collection, SPT sample geologic logging, and other data collection and analysis.

3.1.1 SPT Sample Collection

Both boreholes were drilled for the Pacific Northwest National Laboratory (PNNL) *Resource Conservation and Recovery Act of 1976* Groundwater Monitoring Program by a drilling contractor managed by Bechtel Hanford, Incorporated. The well site geologist was supplied by Bechtel Hanford, Incorporated. A cable tool drill rig was used to drill both boreholes.

SPT samples were collected from depths of 15.3 and 40.4 m (50 and 132 ft) below ground surface (bgs) in borehole W10-27 and from depths of 6.1 to 28.6 m (20 to 93.5 ft) bgs in borehole W11-39. In both boreholes, continuous SPT sampling was attempted in those depth intervals. Sampling above the SPT interval in each borehole was accomplished by collecting samples from the drive barrel at 1.53 m (5-ft) intervals as drilling progressed. Below the SPT interval samples were collected from hard tool cuttings every 1.53 m (5 ft).

SPT samples were acquired using a .6 m (2-ft) long by 10 cm (4-in.) diameter split spoon sampler containing two, .3 m (1-ft) plastic sleeves. During sampling, the SPT was driven into materials at or near the bottom of the borehole casing. However, field logs do not record the information needed to determine the actual sampling depth(s). This missing information includes amount of casing in the borehole, the actual measured depth of the borehole immediately prior to driving the sampler, and the distance the casing was advanced between each sample. Without this information, it is not possible to locate the borehole bottom prior to each sampling event and to determine the amount, if any, of slough in the borehole.

Once SPTs were brought to the surface, they were opened and the sleeves were removed, capped, taped, and placed in coolers for shipping to PNNL. Descriptions of the sediment contained in the SPT drive shoes were documented by the field geologist. The sediment in the drive shoe was apparently then discarded, rather than being retained and sent to PNNL with the SPT liners.

3.1.2 SPT Sample Geologic Logging

SPT sleeves sent to PNNL for detailed logging were cut open in the lab using a circular saw. The following procedure was used to cut them open.

- A single lengthwise cut was made completely through the sleeve and approximately 3 mm (1/8 in.) into the sample.
- The cut was covered with duct tape.
- A second lengthwise cut was made in the sleeve on the opposite side approximately 180 degrees from the first cut.
- The sleeve was folded open using the taped cut as a hinge. When necessary, a spatula was used to wedge the sample apart into two, nearly equal halves, one in each half of the sleeve.

Generally, sediment contained within the split sleeve broke roughly through the middle, folding over as the split sleeve was folded open. Once opened, sediment in the sleeve was described, moisture samples were collected, and the sample was photographed. Geologic descriptions were made which documented stratification present, grain size as seen in hand sample, color, friability, cohesion, induration, calcium carbonate content, and any other physical properties or structures observed. Upon completion of geologic logging, the sleeves were closed, taped together, and returned to cold storage.

3.1.3 Other Data Collection and Analysis

Subsurface geology across the WMA was interpreted for 106 other boreholes in the area. Interpretations were based on a combination of data, including driller and geologist logs, ROCSAN mud and calcium carbonate values, borehole geophysical logs (most commonly total gamma), examination of saved drill cuttings, and previously compiled and/or published materials.

A series of isopach and structure contour maps of unit tops was also prepared. The maps were built in succession, progressing downwards from a generalized surface elevation grid. Generally, the maps were developed as follows.

- A 16 x 16 meter grid of surface elevations was built.
- An isopach grid for the combined backfill and Holocene deposits interval was built and mapped. This grid was built using borehole data and interpreted control points to constrain unit distribution and thickness.
- The backfill/Holocene isopach grid was subtracted from the surface elevation grid to generate a grid for the top of the next deepest unit, the Hanford formation Unit H1.
- An isopach grid for Unit H1 was generated, mapped, corrected/modified, and subtracted from the H1 top grid to get the next deepest unit top, the Hanford formation Unit H2.

This same general process was repeated from layer-to-layer to the top of the deepest layer in the vadose zone. All isopach grid generation was done using an inverse distance grid model and other grid mapping software in RockWorks99.[1]

3.2 SEDIMENT FACIES DESCRIPTIONS

Sediment facies are defined on the basis of unique physical properties, such as grain size, color, sedimentary structure, and mineralogy and their use allows geologists to consistently characterize sediment properties and interpret sediment origins (Walker 1984, 1994; Reading 1986). This section contains brief descriptions of observed and inferred physical characteristics of the sediment facies identified in the samples logged from the two boreholes and

[1] RockWorks99 is a registered trademark of RockWare, Earth Science Software, Golden, Colorado.

intervals logged on the 106 other boreholes used during interpretation during this investigation. These descriptions include such physical characteristics as dominant and subordinate grain size, stratification, color, friability, cohesion, induration, cement, calcium carbonate reaction, and general mineralogy. Terminology used in these descriptions is based on usage described in Compton (1962), Folk (1974), Collinson (1986), Reading (1986) and Miall (1994). Facies descriptions are summarized below.

Clay/silt—Massive, moderately plastic, cohesive silt with clay; contains little-to-no visible sand; facies is blocky and displays little-to-no observable evidence of bedding; oxidized mottles and dark organic fragments (?) are present; color typically is olive; calcium carbonate reaction is weak to moderate.

Silt—Cohesive, non-plastic, massive-to-crudely stratified mixes of silt and very fine sand; some intervals display poorly developed blocky peds and root casts (paleosols); red/orange tinted stain and mottling also may be present; typical colors include grayish brown, light olive brown, dark grayish brown, and olive brown; calcium carbonate reaction ranges from moderate to strong.

Fine sand/silt—stratified, alternating beds of friable, sandy silt to silty fine sand; individual beds are a less-than-an-inch-to-several-inches-thick planar laminae, ripple-cross lamination, and isolated medium-to-coarse sand layers (<1.3 cm [0.5 in.] thick) are present; colors range from light olive gray to olive; mineralogy is dominantly felsic; calcium carbonate reaction is moderate to strong.

Coarse sand/silt—stratified, friable, very fine-to-medium sand with minor interbedded silty sand; individual beds are a few-centimeters-to-several-centimeters-thick planar laminae, ripple cross lamination, and normally graded intervals several inches thick are present; colors range from olive gray to olive; mineralogy is dominantly arkosic, although basalt lithic grains can locally exceed 25% in coarser fractions (giving a speckled or salt-and-pepper appearance); calcium carbonate reaction is weak to strong.

Fine sand—stratified, friable, very fine-to-medium sand; commonly displays platy bedding cleavage, planar lamination, and normally graded bedding; normally graded intervals are 0.5-to-1 m (1.6-to-3.3 ft) thick, grading upwards from more basaltic to more felsic sand; colors include dark grayish brown, olive brown, and olive; calcium carbonate reaction is weak to strong.

Coarse sand—stratified, very friable, medium-to-very-coarse sand and a trace of granules; planar lamination and normally graded bedding are present; normally graded intervals are 0.5-to-1 m (1.6-to-3.3 ft) thick, grading upwards from more-basaltic-to-more-felsic sand; fine sand occurs as thin (<7.6 cm [3-in.] thick) interbeds throughout the facies; colors include dark grayish brown, olive brown, and olive; calcium carbonate reaction is weak to strong.

Granule sand—stratified, friable, coarse sand, granule sand, and small pebbles; stratification typically planar with layers a few inches thick; minor interstratified fine-to-medium sand and silt present; colors range from light gray to dark gray to dark brown, giving the facies a speckled or

"salt-and-pepper" appearance; granules and small pebbles are predominantly basalt, finer grains are predominantly felsic; calcium carbonate content is variable.

Sand/gravel—very friable, medium-to-very-coarse sand, granules, and pebble gravel; bedding character not well expressed, although grain size and color variations suggest the presence of bedding features a few centimeters to several tens of centimeters thick that are inferred to be associated with larger scale cross-bedded features; pebble content is estimated to generally be less than 25% in hand sample, the largest unbroken pebbles are less than 4 cm (2 in.) in diameter (larger broken pebbles are rare), and gravel is typically matrix supported; coarse sand, granule, and the gravel fraction is basalt dominated; colors range from olive gray to gray and a salt-and-pepper speckling is common due to a high basalt content in the coarse sand fraction; calcium carbonate reaction is weak to moderate.

Sandy caliche—massive, fine-to-very-coarse sand containing calcium carbonate as filaments, clasts, and thin (<2.5 cm [1-in.]) layers (Stage II/III/IV); sand ranges from predominantly basalt (>90%) to felsic; colors range from black to gray; calcium carbonate reaction is variable, from weak-on-clean-grains-to-very-strong-on-calcium-carbonate pieces.

Gravelly caliche—massive, fine-to-very-coarse sand and pebble gravel containing calcium carbonate as filaments, clasts, and thin (<2.5 cm [1-in.]) layers (Stage II/III); sand and gravel ranges from predominantly basalt (>90%) to felsic; colors range from black to gray; calcium carbonate reaction is variable, from weak-on-clean-grains-to-very-strong-on-calcium-carbonate pieces.

Paleosol—massive-to-blocky silt with minor clay and very fine sand; reddish staining is present yielding a mottled appearance; faint remnant bedding, disrupted beds, and root/burrow traces can be present; calcium carbonate reaction is weak to strong.

Overbank/sand—in the Hanford formation consists of massive silty fine sand containing black, possibly organic filaments, mottles suggestive of bioturbation, light olive to brown colors, and strong calcium carbonate reaction; in the Ringold Formation consists of silty-fine-to-silty-coarse sand containing disrupted beds, floating gravel clasts, variable induration, speckled colors ranging from white-gray to gray-brown, and little-to-no calcium carbonate.

Fine and coarse fluvial sand—fine-to-coarse grained, friable sand; where basalt content exceeds 25 percent the facies has a salt-and-pepper look; white mica flakes are common and minor (<10%) pebbles are present; felsic grains are commonly stained yellow brown; induration is slight to moderate; calcium carbonate reaction is very weak to absent.

Fluvial gravel and silty fluvial gravel—variably indurated, fine-to-coarse sand and pebble/cobble gravel typical of Ringold Formation conglomerate (Lindsey 1996); matrix sand typically is felsic and yellow brown in color; clasts are multi-lithologic and range from clast to matrix supported; calcium carbonate reaction is weak to absent; where silt content is greater than 5 to 15 percent commonly referred to as silty fluvial gravel.

Backfill—predominantly non-cohesive fine-to-medium sand with minor silt, coarse sand, and pebble gravel; colors typically range from very dark grayish brown to olive brown; calcium carbonate reaction typically slight to moderate.

Eolian sand—generally fine grained, massive, felsic sand with variable calcium carbonate content.

3.3 VADOSE ZONE GEOLOGY OF BOREHOLE W10-27

The vadose zone portion of borehole W10-27 penetrated strata interpreted to belong to the combined backfill and Holocene deposits unit, Hanford formation, the Plio-Pleistocene Unit, and the Ringold Formation (Figure 5, Plate 1). Physical characteristics observed for each of these units in the borehole are presented in the following section and based on logging notes (Appendix A). Geologic unit descriptions prepared for this report are divided into sections devoted to the Hanford formation (Sec. 3.3.1), the Plio-Pleistocene Unit (Sec. 3.3.2), and the Ringold Formation (Sec. 3.3.3). In addition, sample recovery is summarized in Section 3.3.4.

3.3.1 Hanford Formation

The Hanford formation extends from a depth of 1.4 m (4.5 ft) bgs to 27.7 m (90 ft) bgs. The upper 11.4 m (37 ft) of the unit consists predominantly of the gravel facies, the base of which is found at a depth of 12.8 m (41.5 ft) bgs. This gravelly interval is assigned to Hanford formation Unit H1.

The remainder of the Hanford formation consists predominantly of coarse sand facies and granule sand and sand and gravel facies. This sand-dominated interval is assigned to the Hanford formation Unit H2. Unit H2 in borehole W10-27, with its predominantly coarse and granule sand facies, is unlike correlative strata south of the WMA described in Last et al. (1989) and Lindsey et al. (1994b, 2000) where the unit consists predominantly of a mix of coarse and fine sand facies with intercalated silt. Unit H2 in borehole W10-27 extends to a depth of 24.6 m (80 ft) bgs, at which point the stratigraphy changes to fine-to-medium sand of the fine sand facies.

3.3.2 Plio-Pleistocene Unit

Both subunits of the Plio-Pleistocene Unit are present in borehole W10-27. The silt-rich upper subunit extends from depths of 27.7-to-30.2 m (90-to-98 ft) bgs. As was seen at the S-SX WMA (Lindsey et al. 2000) these strata are sandy and massive to well stratified. Very-fine-to-fine sand interbeds also are present.

The lower, or carbonate, subunit extends from depths of 30.2-to-34.5 m (98-to-112 ft) bgs. In this borehole the carbonate, or caliche, is developed predominantly in

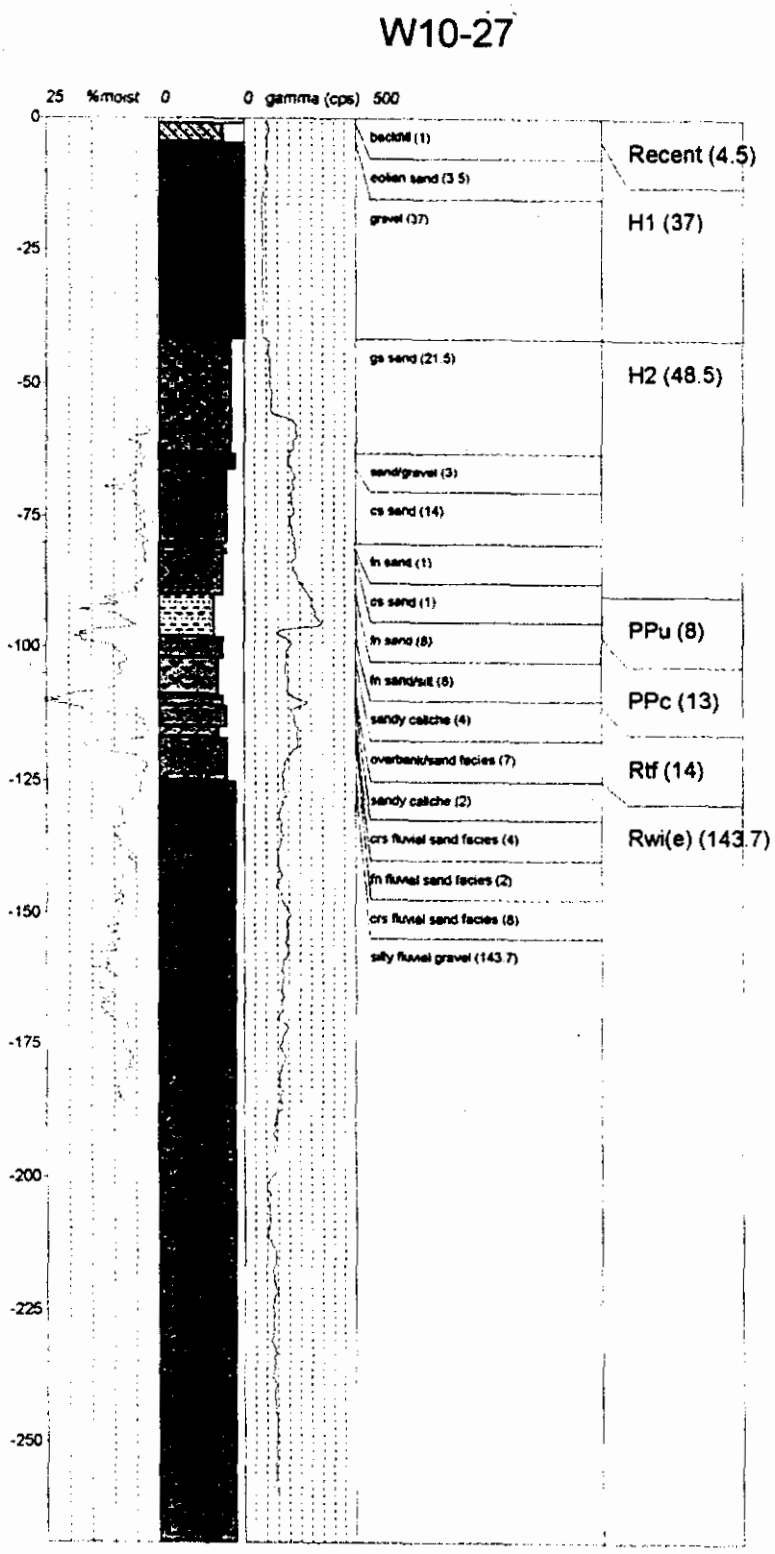

Figure 5. Geologic/Geophysical Log for Borehole 299-W10-27.

sandy lithologies. Two very well developed caliche intervals, stage III and IV of Machette, are found in the subunit, one from depths of 30.2 to 30.9 m (98-to-100.5 ft) bgs and one at depths from 33.6-to-34.2 m (109.3-to-111 ft) bgs. The remainder of the subunit consists predominately of fine-to-medium sand display stage I and II carbonate development.

3.3.3 Ringold Formation

Fourteen feet of coarse sand, comprising the coarse fluvial sand facies, underlies the Plio-Pleistocene Unit. This interval is assigned to the Ringold Formation, member of Taylor Flat. The contact between these two stratigraphic units is placed at the depth at which there is a noticeable decrease in calcium carbonate contact and caliche fragments and below which no more caliche-cemented horizons are found. Identification of this contact is subjective and may vary from borehole to borehole.

The base of the member of Taylor Flat is placed at the top of the first pebble-cobble fluvial gravel facies interval below the caliche subunit of the Plio-Pleistocene Unit. This contact is at a depth of 38.5 m (125 ft) bgs in borehole W10-27. The gravel underlying the member of Taylor Flat is assigned to the Ringold Formation, member of Wooded Island, Unit E. This stratigraphic unit constitutes the remainder of the vadose zone at this location.

3.3.4 Sample Recovery

As a result of the field logging and sampling methodology used during the drilling of this borehole, field logs do not describe the presence of slough in the borehole. Slough was recognized in many SPT samples during the detailed logging performed for this report.

Slough consisted of dark-gray-to-brown, massive, loose-to-compacted sand and occasionally coarser grains. This material, when found in the SPT samples, was consistently found in the upper part of the SPT sleeve. The contact between this dark, massive material and underlying, typically well-stratified and lighter-colored material is very sharp. The consistent location of this material in the upper part of SPT sleeves and its physical appearance leads to the interpretation that slough material remained in the bottom of the borehole prior to sampling. During sampling, this material was the first material that the SPT sampler encountered and it was, therefore, collected in the upper part of the SPT sample. When sloughed material was present in the samples from this borehole it ranged in thickness from .03-to-.3 m (0.1-to-1 ft).

Another factor that impacted sample recovery and the geologic logging performed for this project was the disposal of drive shoe samples. This material was routinely disposed of in the field and, therefore, was not available for detailed logging in the lab. This missing sample material, the presence of slough in the samples, and the sampling methodology used in the field, resulted in less than the 100 percent sample recovery that is documented on field logs.

Actual sample recovery for the SPT-drilled portion of this borehole is summarized as follows:

- Thirty-three .6 m (2-ft) SPTS were attempted between depths of 15.4 and 40.6 m (50 and 132 ft) bgs, for a total of 20.3 m (66 ft) of potential SPT sampling
- Of this total footage, 2.1 m (6.7 ft) was slough. The remaining 18.2 m (59.3-ft) interval of sampling was interpreted to be from intact formation material, for a total recovery of 89.8 percent of the attempted 20.3 m (66 ft) of SPT samples
- Total recovery for the entire 25.2 m (82-ft) interval covered by "continuous" SPT sampling (e.g., 15.4-to-40.6 m [50-to-132 ft] bgs) was 72.3 percent.

3.4 VADOSE ZONE GEOLOGY OF BOREHOLE 299-W11-39

The vadose zone portion of borehole 299-W11-39 penetrated strata interpreted to be backfill materials, and sediments of the Hanford formation, the Plio-Pleistocene Unit, and the Ringold Formation (Figure 6, Plate 2). The following geologic descriptions are based on logging notes collected during split spoon sample logging (Appendix A) and field notes collected by the field geologist. Geologic log descriptions summarized here are divided into sections devoted to backfill (Sec. 3.4.1), the Hanford formation (Sec. 3.4.2), the Plio-Pleistocene Unit (Sec. 3.4.3), and the Ringold Formation (Sec. 3.4.4). Sample recovery data is summarized in Section 3.4.5.

3.4.1 Backfill

Backfill consists of a mix of brown silt, sand, and pebbles extending from the ground surface to 1.5 m (5 ft) bgs.

3.4.2 Hanford Formation

The Hanford formation is 26.2 m (85 ft) thick in this borehole. Unit H1, the upper gravel facies-dominated unit, is 8.9 m (29 ft) thick, with the contact between it and the underlying unit, H2, lying at a depth of 10.5 m (34 ft) bgs. This contact is positioned at the change from pebble-cobble gravel above to coarse-sand and granule-sand facies below.

Unit H2 is 17.2 m (56 ft) thick, extending from depths of 10.5-to-27.7 m (34-to-90 ft) bgs. In borehole W11-39, the unit is predominantly medium-to-coarse sand facies and granule sand facies. This differs from occurrences of the unit south of the WMA where fine-sand-to-coarse-sand facies predominate (Last et al. 1989, Lindsey et al. 1994b). The base of the Hanford formation Unit H2 is sharp and is placed at the top of the first silt-to-silt/sand facies encountered.

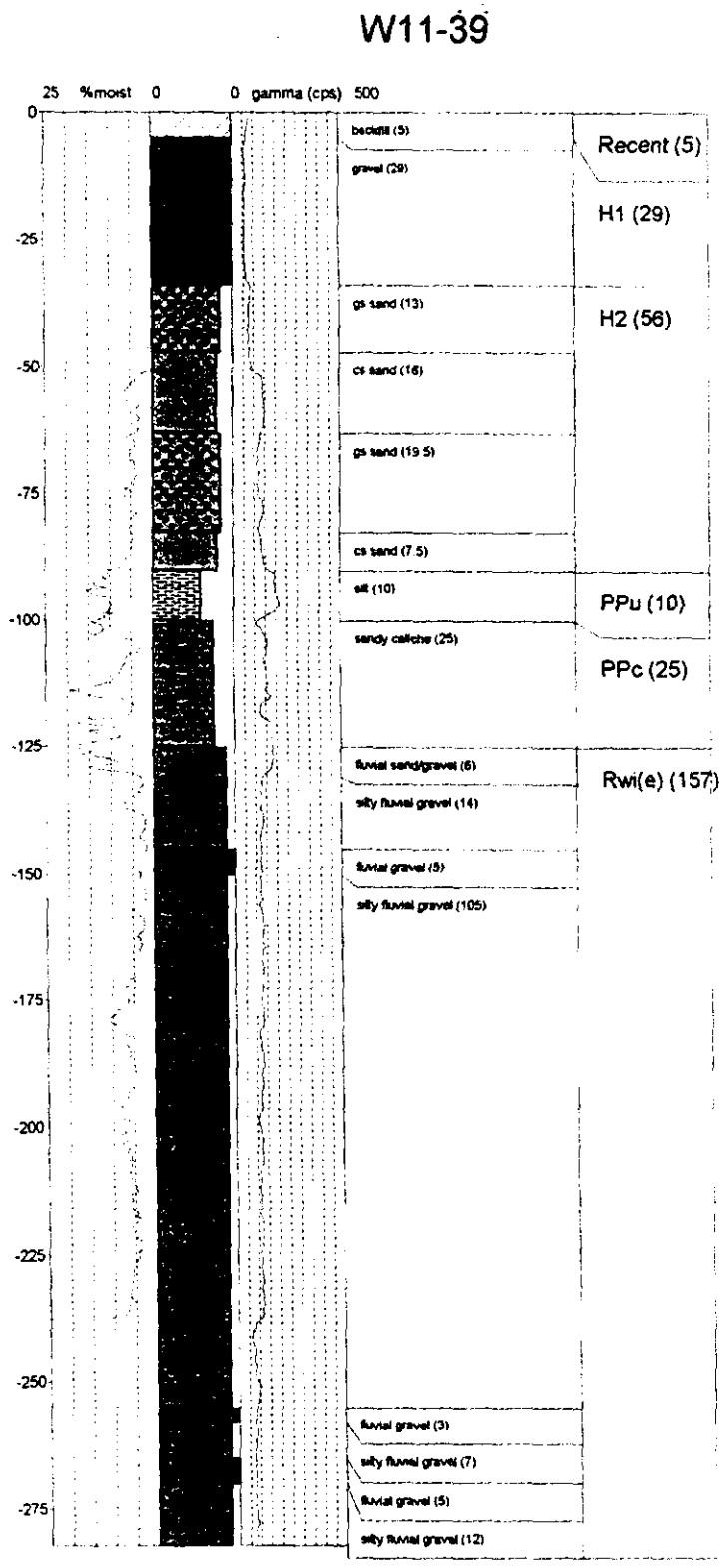

Figure 6. Geologic/Geophysical Log for Borehole 299-W11-39.

3.4.3 Plio-Pleistocene Unit

Both the upper (silty) and lower (caliche) subunits of the Plio-Pleistocene Unit are present. The upper unit extends from depths of 27.7-to-30.8 m (90-to-100 ft) bgs, but only the upper 1.1 m (3.5 ft) of the unit was SPT sampled. Based on SPT and cuttings samples (from below the SPT sample interval), the upper unit is predominantly silt facies with a minor very fine sand fraction.

The remaining 7.4 m (24 ft) of the Plio-Pleistocene Unit consists of sandy caliche facies. Based solely on drill cuttings and field logs, this interval appears to be largely Ringold Formation material overprinted by calcium carbonate. Because the caliche is an overprint on preexisting and reworked Ringold Formation material, placement of the contact can be arbitrary. Following usage described in Lindsey et al. (1994a, 1994b, 2000) and Lindsey (1995, 1996), the contact is placed at-or-near the change from strata containing more than a trace of caliche fragments to strata that do not contain obvious, observable, caliche. Based on borehole log descriptions and drill cuttings, this contact is placed at a depth of 38.5 m (125 ft) bgs.

3.4.4 Ringold Formation

Unit E of the Ringold Formation, member of Wooded Island is the only Ringold Formation stratigraphic unit encountered in this borehole. No SPT samples where collected from this unit. Based on drill cuttings, log descriptions, and other reports (Lindsey 1995, 1996), Ringold Formation Unit E strata in the vicinity of the borehole are interpreted to be predominantly indurated, variably cemented, pebble-cobble gravel with predominantly a fine-to-medium sand matrix. These strata range from clast to matrix supported and silt in the matrix can be at least locally abundant.

3.4.5 Sample Recovery

Similar to the sampling results observed in borehole W10-27, sample recovery was not 100 percent in borehole W11-39. SPT samples were collected using the methodology described earlier in this report. Slough was observed in many of the SPT samples collected from this borehole. Based on observations, sample recovery for this borehole was recalculated as follows.

Twenty-nine .6 m (2-ft) SPTS were attempted between depths of 6.5 and 28.8 m (21 and 93.5 ft) bgs. Twenty-four of these were attempted in a succession between 10.5 and 28.8 m (34 and 93.5 ft) bgs in an attempt to collect "continuous" samples over an 18.3 m (59.5-ft) interval. Slough accounted for 2.6 m (8.35 ft) of the 14.8 m (48 ft) of collected SPT samples in the 10.5-to-28.8 m (34-to-93.5-ft) depth interval; therefore, sample recovery was 83 percent. Of the total 18.3 m (59.5 ft) drilled during "continuous" SPT sampling, the 12.2 m (39.65 ft) of intact sample collected represents 66.6 percent recovery.

These recoveries do not incorporate the depth interval from 6.5-to-10.5 m (21-to-34 ft) where only 2.2 m (7 ft) of the 4 m (13 ft) drilled was successfully SPT sampled.

3.5 BOREHOLE GEOPHYSICS

This section describes the geophysical logging for the two boreholes, including correlation with the physical descriptions presented in the previous sections. The descriptions in the following sections were taken from the full-scale logs, which provide detail not discernible on the combination geology/geophysical plots shown in Figures 5 and 6. This information is available on the PNNL borehole log database.

3.5.1 Borehole W10-27

Geophysical logging of borehole W10-27 was performed with a high-purity germanium (HPGe) spectral gamma logging tool and a neutron-moisture tool. The results of logging are discussed below.

Spectral Gamma Logging

Borehole W10-27 was logged with a 70-percent-efficiency HPGe detector to identify the specific gamma-emitting radionuclides in the formation surrounding the borehole. Data were acquired at a constant logging speed of .2 m (0.7 ft) per minute (ft/min) at a sample acquisition interval of 0.15 m (0.5 ft). The HPGe spectral gamma log acquired in borehole W10-27 was conducted from ground surface to a depth of 80 m (260 ft) while both the 0.3 m (11.75-in.) diameter and 0.2 m (7.625-in.) diameter casings were installed in the borehole. Processing of the spectral gamma log data allows the identification of gamma-ray emitting man-made radionuclides (if present) and the naturally occurring radionuclides potassium, uranium and thorium (KUT) that are present in earth materials. The total gamma and moisture content profiles show correlation between depths of about 17.5 and 36.9 m (57 and 120 ft) where increases in total gamma and moisture are observed. The total gamma count rate increases in the finer-grained sediments with a corresponding increase in moisture content due to the moisture-retaining properties of these sediments.

No man-made contaminants were detected in borehole W10-27. Throughout most of the borehole, the concentrations of the naturally occurring radionuclides KUT are typical for Hanford formation sediments. The potassium concentrations range between 10 and 20 pCi/g; uranium concentrations range between 0.5 and 1.0 pCi/g (often uranium was not detected); and the thorium concentrations range between 0.5 and 1.0 pCi/g.

Total gamma data is most useful for correlating KUT data with lithologic information. Total gamma is the sum of all gamma rays measured in each 0.15 m (0.5-ft) measurement. In borehole W10-27, as is the case with most log data acquired in Hanford Site boreholes, the profile of the total gamma log plot is most influenced by the potassium concentrations (other than in regions where man-made contaminants are present). Since there was no man-made contamination present in the sediments surrounding this borehole there was no effect to the total gamma count rate from man-made materials.

In borehole W10-27, the total gamma count rate increases sharply at a depth of 17.2 m (56 ft) from slightly over 100 counts per second (cps) to over 200 cps, and the count rate continues to increase to as high as 325 cps at a depth of 29.2 m (95 ft). This trend duplicates changes in the potassium concentration profile; uranium and thorium concentrations reflect little change except near a depth of 29.2 m (95 ft) where thorium concentrations almost double. The borehole intercepts sand and gravel of the Hanford formation to a depth of about 27.7 m (90 ft), where the fine sand and silt of the Plio-Pleistocene are encountered. The highest total gamma count rate (325 cps) was measured in the Plio-Pleistocene sand and silt. Total gamma count rate decrease (with corresponding decreases in potassium, uranium and thorium concentrations) is observed in the Plio-Pleistocene sandy cliché. A narrow peak of total gamma count rate increase occurs at a depth of about 33.8 m (110 ft) in the Plio-Pleistocene overbank facies. This increased count rate reflects increased uranium concentrations to almost 4 pCi/g; thorium concentrations at this depth actually decreased. Total gamma count rate sharply decreases at a depth of 36.9 m (120 ft) where Ringold Formation silty gravels are encountered. Total gamma count rate slowly decreases to about 125 cps in the Ringold Formation gravels to the total depth of the borehole (80 m [260 ft]). Potassium, uranium and thorium concentrations vary slightly from a depth of 36.9 m (120 ft) to the bottom of the borehole.

Neutron-Moisture Logging

The neutron-moisture tool utilizes an americium-beryllium source and a neutron detector to measure hydrogen content in sediments; the hydrogen content is related to hydrogen-bound-in-water as formation moisture. The use of the neutron-moisture log in characterization at Hanford is directed at identifying fine-grained moisture-retaining sediments. These sediments are often thin-bedded and localized, and usually cannot be correlated between widely spaced boreholes. The fine-grained Plio-Pleistocene Unit sediments are an exception; these sediments occur extensively beneath the Hanford Site 200 West Area.

Moisture measurements were acquired at 0.077 m (0.25-ft) depth increments at a logging rate of one foot per minute. The results obtained with the neutron-moisture tool are reported as percent volumetric moisture content. In borehole W10-27, the neutron-moisture survey was conducted from ground surface to a depth of 57.7 m (187.5 ft) (the depth of groundwater at the time of logging). Logging was performed between ground surface and a depth of 17.2 m (56 ft) within both the 0.3 m (11.75-in.) diameter and 0.2 m (7.625-in.) diameter casings. Since the neutron-moisture tool is not calibrated for this casing configuration, the moisture values in this region of the borehole are not valid.

Moisture content in borehole W10-27 ranges between about 3 percent at a depth of 26.5 m (86 ft) to as high as 26 percent at a depth of 33.8 m (110 ft). This range of values does not include moisture values calculated for the data acquired in the double casing or the high moisture values near the water table as the logging tool encountered groundwater. With the exception of a few thin intervals of increased moisture content (to as high as 12 percent) in the Hanford formation sands at depths of 18.5 and 21.5 m (60 and 70 ft) where lenses of finer grained moisture retaining sediments are intersected by the borehole, the highest moisture content occurs between depths of 27.7 and 36.9 m (90 and 120 ft) in Plio-Pleistocene sediments and Ringold Formation silts and sands. Within this depth interval, the borehole intersects several

zones .9-to-1.5 m (3-to-5-ft) thick with moisture content values as high as 26 percent. Below a depth of 36.9 m (120 ft) to groundwater 57.7 m (187.5 ft), moisture values in the Ringold Formation silty gravels range between 8 and 14 percent. Intervals of elevated count rate on the total gamma log correlates with the highest moisture content measurements in the depth interval from about 18.5-to-36.9 m (60-to-120 ft) where finer grained sediments are encountered.

3.5.2 Borehole W11-39

Geophysical logging of borehole W11-39 was performed with a HPGe spectral gamma logging tool and a neutron-moisture tool. The results of logging are discussed below.

Spectral Gamma Logging

Borehole W11-39 was logged with a 35 percent efficiency HPGe detector at a constant logging speed of 0.2 m (0.7 ft) per minute and a sample acquisition interval of 0.15 m (0.5 ft). The HPGe spectral gamma survey in borehole W11-39 was conducted from ground surface to a depth of 86.3 m (280.5 ft) while both 0.3 m (12-in.) diameter and 0.2 m (8-in.) diameter casings were installed in the borehole. The bottom of the 0.3 m (12-in.) diameter casing was at a depth of 15.8 m (51.37 ft), while the 0.2 m (8-in.) diameter casing extended to the total depth of the borehole.

Cesium-137 (^{137}Cs) was detected from ground surface to a depth of .6 m (2.0 ft) at concentrations of about 2 pCi/g. This contamination was most likely deposited by wind from a nearby location. The influence of this contamination on the total gamma profile is shown as the slightly elevated count rate at the top of the borehole.

Potassium concentrations range between 10 and 20 pCi/g; uranium concentrations range between 1 and 2 pCi/g (and up to concentrations of 3 pCi/g in a few narrow peaks); and thorium concentrations range between 0.5 and 1 pCi/g (and up to concentrations of 2 pCi/g in a few narrow peaks). These KUT concentrations are typical of those observed in a majority of Hanford Site borehole logs.

In borehole W11-39, total gamma count rate ranges between 60 and 80 cps from ground surface to a depth of 15.4 m (50 ft) in Hanford formation gravels and gravelly sands. Count rate increases to 150 cps at a depth of 15.4 m (50 ft) where Hanford formation sand is encountered and then decreases slightly between depths of 20 and 27.1 m (65 and 88 ft) in Hanford formation gravelly sand. The potassium, uranium, and thorium profiles are featureless with the exception of a gradual increase in potassium concentrations to slightly over 20 pCi/g at a depth of 19.1 m (62 ft), then a sudden decrease to about 15 pCi/g. A sharp increase in total gamma count rate to over 200 cps occurs between depths of 27.7 and 30.2 m (90 and 98 ft) in the Plio-Pliestocene silt, which corresponds to increases in the potassium, uranium, and thorium concentrations. Total gamma count rate decreases to between 150 and 175 cps between depths of 30.2 and 40 m (98 and 130 ft) in the Plio-Pliestocene carbonates and Ringold Formation sands and gravels. The potassium concentrations mimic the profile of the total gamma count rate in this interval. The uranium and thorium concentration profiles are essentially featureless. From a depth of 40 m

(130 ft) to the bottom of the borehole, total gamma count rate ranges between 75 and 125 cps, and the potassium, uranium, and thorium concentrations gradually decrease. Ringold Formation silty gravels and gravels are present in this region of the borehole.

Neutron-Moisture Logging

The neutron-moisture survey for borehole W11-39 was conducted between depths of 13.8 and 73.2 m (45 and 238 ft). The bottom of the double casing interval was at a depth of 15.8 m (51.37 ft), and since the tool is not calibrated for a double casing configuration, this section was not logged except for a very short section. Moisture content throughout the rest of the borehole ranges between 2 and 19 percent throughout the borehole except for the narrow section logged in the double casings, and at the bottom of the borehole when the moisture content increased as the tool approached ground water. The total gamma and moisture content profiles show correlation between depths of about 16 and 40 m (52 and 130 ft) where increases in both total gamma count rate and moisture content are observed.

Moisture content in Hanford formation gravelly sand and sand is about 5 percent with the exception of the narrow peak at a depth of 23.4 m (76 ft) where the moisture content increases to about 14 percent over a .6 m (2-ft) thick interval. Several thin intervals of moisture content as high as 19 percent occur between depths of 27.7 and 40 m (90 and 130 ft), where the borehole intersects Plio-Pleistocene silt and sandy caliche and Ringold Formation sand and gravel. These intervals range from .3 to .9 m (1 to 3 ft) in thickness. Moisture content in the Ringold Formation sediments below a depth of 40 m (130 ft) ranges between 2 and 11 percent. Some thin intervals of slightly higher moisture content occur at depths of 41.8 (136 ft) and between depths of 52.3 and 55.4 m (170 and 180 ft).

4.0 T-TX-TY VADOSE ZONE PHYSICAL GEOLOGIC CONDITIONS

The geologic and geophysical data and interpretations presented in Section 3.0, the detailed geologic logging notes found in Appendix A, the detailed geologic facies logs shown on Plates 1 and 2, and interpreted borehole logs for over 100 other boreholes in the T-TX-TY WMA (Appendix B) provide detailed information about vadose zone physical conditions beneath the T-TX-TY WMA. Combining the results of this detailed geologic logging with other information describing subsurface physical geologic conditions beneath the WMA offers an opportunity to synthesize technically credible interpretations of vadose zone conditions.

The purpose of this section is to integrate the observations described in the previous sections and the appendixes with other subsurface physical data for T-TX-TY WMA to draw conclusions about subsurface geologic conditions. These interpretations are discussed below and presented in a series of geologic cross sections and structure-contour maps (Figures 7 through 16). Appendix C contains a compilation of thickness and structure-contour data for unit tops from boreholes used in this report. This discussion is subdivided into sections that generally correspond to the main vadose zone stratigraphic units underlying the T-TX-TY WMA, including backfill, the Hanford formation, the Plio-Pleistocene Unit, and the Ringold Formation

4.1 BACKFILL

The logging performed for this report does not provide significant new insights into tank farm backfill physical properties. Consequently, description and analysis of T-TX-TY WMA backfill must rely on previous studies, including Price and Fecht (1976a, 1976b, 1976c). These reports indicate backfill is a mixture of silt, sand, and pebble-to-cobble gravel derived from materials originally excavated when the tank farm sites were constructed. Generally, these materials were derived from Hanford formation Unit H1 and to a lesser extent eolian surficial deposits. Backfill thicknesses in the three T-TX-TY WMA tank farms are approximately as follows:

- 241-T Tank Farm—11.7-to-12.3 m (38-to-40 ft) (Figures 7 and 8)
- 241-TX Tank Farm—13.8-to-16 m (45-to-52 ft) (Figures 9 and 10)
- 241-TY Tank Farm—13.8 m (45 ft) (Figures 11 and 12).

4.2 HANFORD FORMATION

Both Hanford formation Units H1 and H2 are present in and adjacent to the T-TX-TY WMA. However, Unit H1 is locally absent beneath the three tank farms because of its removal during the original excavation of the tank farm sites. Unit H1 shows broad lateral continuity across the WMA where it was not removed during tank farm construction (Figures 7 through 12). In addition, Hanford formation stratigraphy in and around the WMA has few of the complexities found further south in the S-SX WMA as described by Lindsey et al. (2000).

Unit H1 extends across the entire WMA area, ranging in thickness from 0-to-26.2 m (0-to-85 ft). The unit appears to be thickest east and west of the tank farms. The thinnest part of the unit appears to be in a north-south oriented belt on the east side of the WMA.

Unit H2 ranges from 5.2-to-18.5 m (17-to-60 ft) thick and generally thickens from north to south. Although this unit is inferred to be continuous with strata assigned to Unit H2 for areas west and south of the WMA (Lindsey et al. 1994a; 2000), it is coarser grained than strata assigned to the unit in those areas. In the T-TX-TY WMA the unit appears to consist predominantly of coarse sand and granule sand facies. These facies reflect a higher energy depositional system than what is suggested (by the unit) where it is finer grained with predominantly fine and coarse sand facies.

The contact between Units H1 and H2 appears to be irregular. Because the contact between the two units is based solely on physical lithologic changes which were controlled by paleodepositional conditions it is probable that the contact is not at the base of a single, laterally continuous horizon. Instead, it may be at the base of the lowest of a series of laterally discontinuous coarser-grained horizons that form a series of overlapping lenses. Figure 13 presents a structure-contour map of the top of Unit H2 (essentially the contact between Units H1 and H2).

4.3 PLIO-PLEISTOCENE UNIT

Stratigraphic and facies properties described earlier (Section 3.0) and compared to the geologic studies in Reidel et al. (1992), Singleton and Lindsey (1994), Lindsey et al. (1994a, 1994b), and Slate (1996) show the presence of strata overlying Plio-Pleistocene carbonate that differ from the overlying Hanford formation sandy deposits described in the preceding section. This interval, the upper Plio-Pleistocene Unit, as described in Section 3.0 consists of an interstratified sequence of well stratified felsic sand, silty paleosols, and massive/blocky silt/clay that is found in both boreholes. Total gamma logs show a subtle-to-sharp increase across the contact between this subunit and overlying Hanford formation strata.

Examination of borehole geologic and drill logs, grain size data, and published interpretations for other boreholes in the T-TX-TY WMA (Appendix B) indicates the unit is widespread, and probably consists of silty sand and sandy silt containing lesser intercalated and mixed-in clay. Logged samples from this interval provide direct evidence that this unit is not a single, essentially massive, silty sand to sandy silt, but an interstratified sequence of massive-to-laminated silt and well-stratified sand that is finer grained than overlying Hanford formation deposits.

The elevation of the top of the subunit generally dips to the west and southwest, from a high of 178.5-to-181.5 m (580-to-590 ft) msl to 172.3-to-175.4 m (560-to-570 ft) msl (Figure 14). It ranges from 1.2-to-6.2 m (4-to-20 ft) thick. Many of the irregular patterns on the isopach and structure contour maps are artifacts of gridding and uncertainties in unit contact identification and well elevation.

The lower part of the Plio-Pleistocene Unit, the lower or caliche subunit, extends beneath the entire WMA. The elevation of the top of the unit ranges from 178.5 to 181.5 m (580-to-590 ft msl in the north to 169.2-to-172.3 m (550-to-560 ft) msl in the south (Figure 15). Unit thickness is irregular. The cause of this could be due to gridding and/or natural. Because the unit is developed as an overprint on underlying units, these thickness irregularities could be at least in part related to paleoenvironmental conditions that controlled the thickness and distribution of caliche at the time it formed.

4.4 RINGOLD FORMATION

The uppermost Ringold Formation Unit underlying the WMA is the member of Taylor Flat. This unit varies greatly in thickness beneath the WMA, and is absent in several areas, especially in the south and east. The absence of this unit is attributed largely to post-Ringold erosion prior to the formation of the Plio-Pleistocene Unit, which overlies the Ringold Formation across the entire area.

Unit E of the Ringold Formation, member of Wooded Island underlies the entire WMA. The upper surface of Unit E is generally flat to gently undulating beneath the WMA (Figure 16). Irregularities seen in the top of the unit are inferred to be due largely to local facies variations leading to shifts in relative elevation of the lithologies used to identify the contact between the two units and where the member of Taylor Flat is absent, post-Ringold erosion and incision into the unit and variable depth of caliche development related to formation of the Plio-Pleistocene lower subunit.

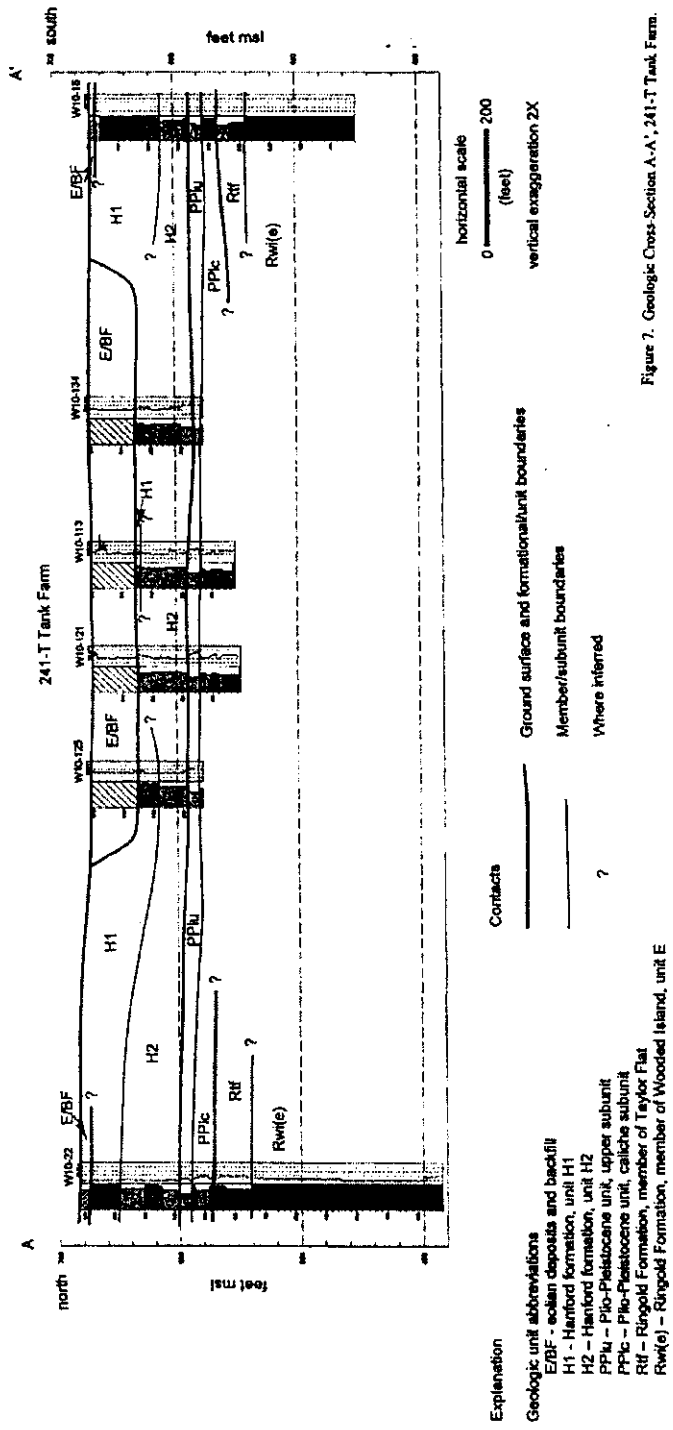

Figure 7. North-South Geologic Cross Section Through the 241-T Tank Farm. See Appendix C for borehole and cross-section locations.

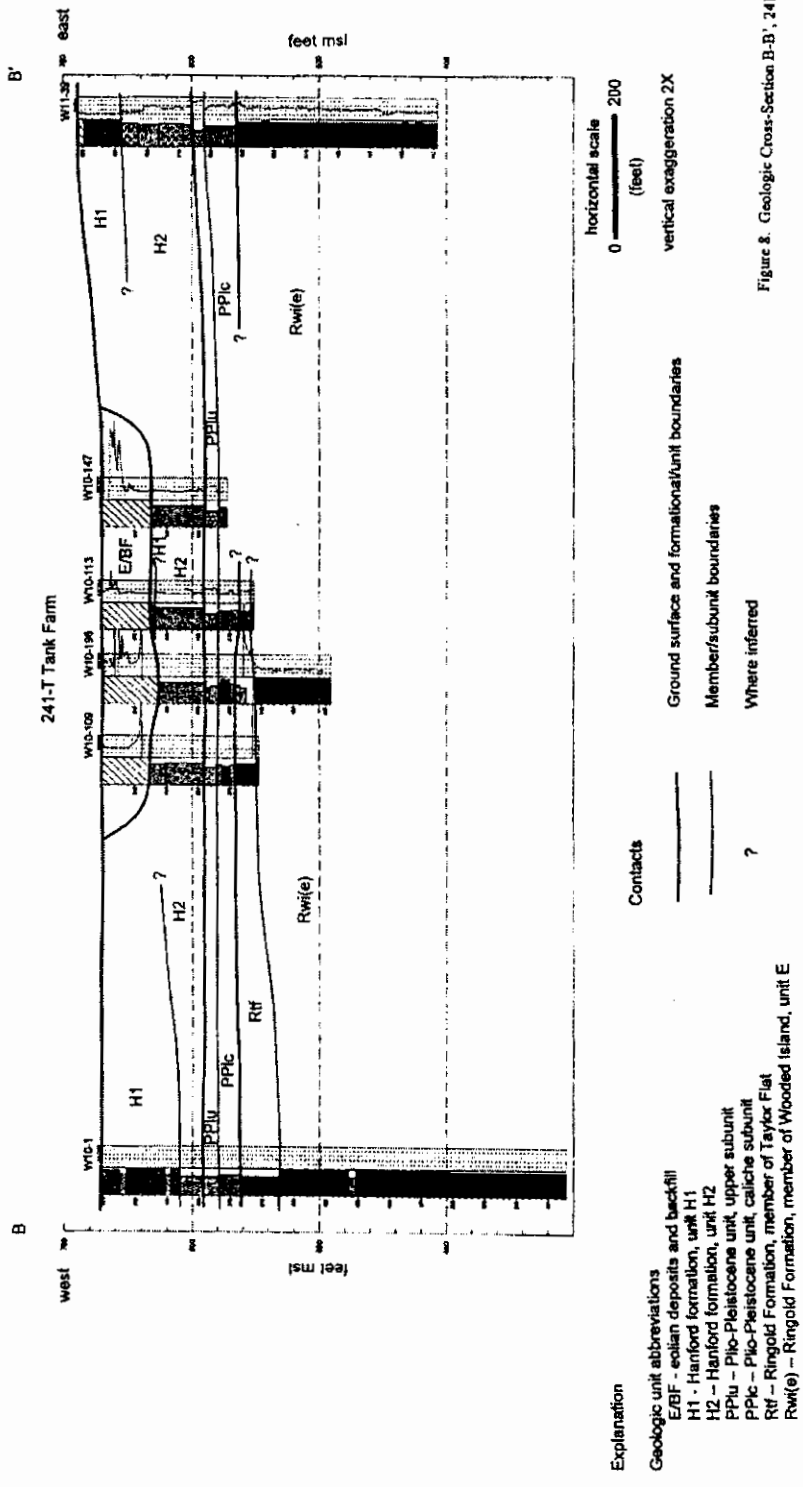

Figure 8. Geologic Cross-Section B-B', 241-T Tank Farm.

Figure 8. East-West Geologic Cross Section Through the 241-T Tank Farm. See Appendix C for borehole and cross section locations.

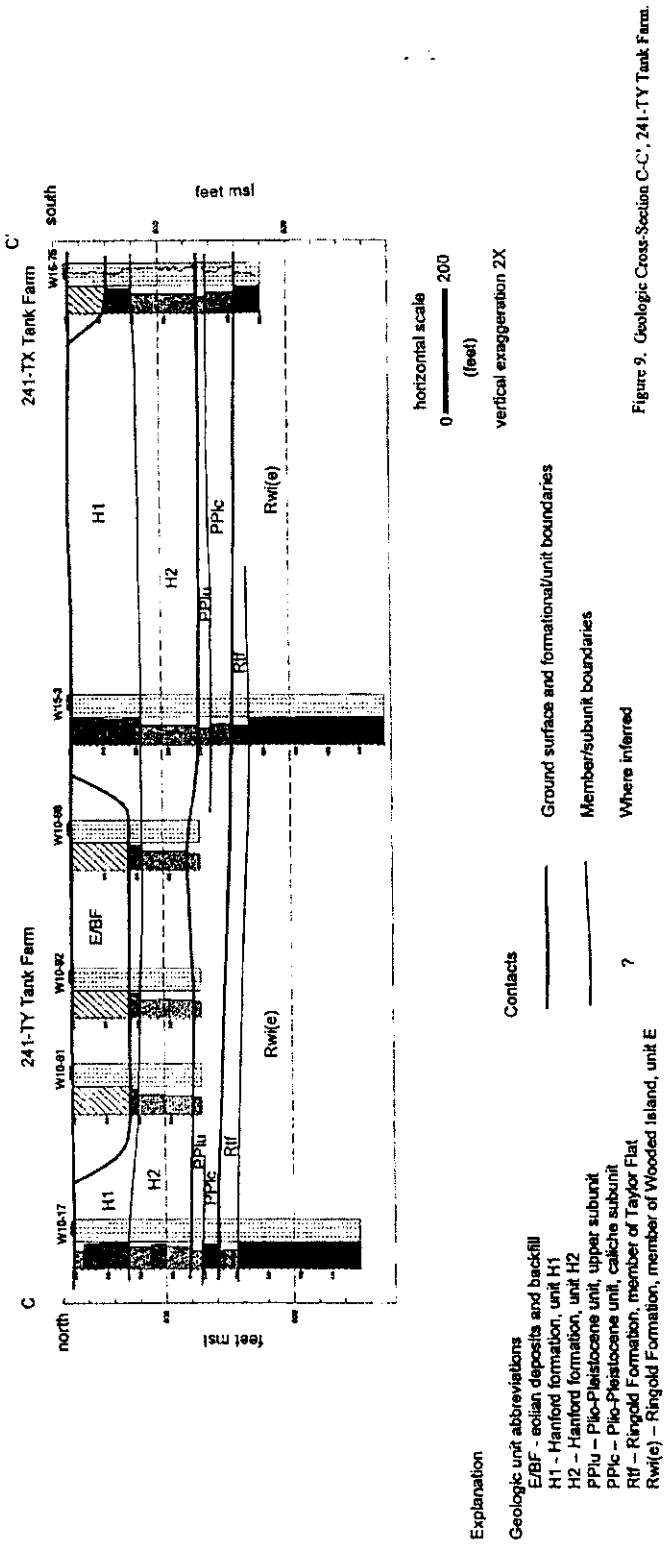

Figure 9. Geologic Cross-Section C-C', 241-TY Tank Farm.

Figure 9. North-South Geologic Cross Section Through the 241-TY Tank Farm. See Appendix C for borehole and cross section locations.

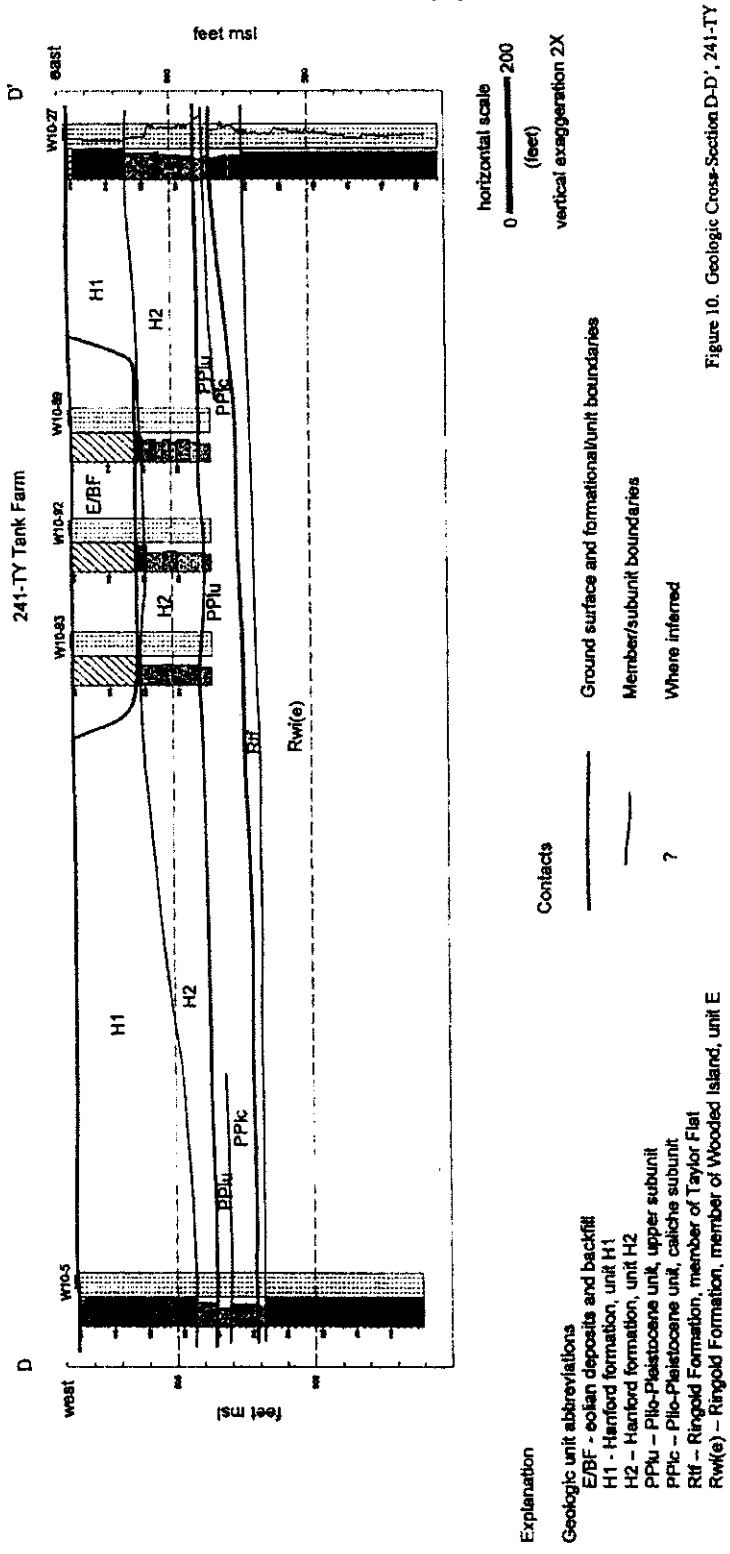

Figure 10. Geologic Cross-Section D-D', 241-TY Tank Farm.

Figure 10. East-West Geologic Cross Section Through the 241-TY Tank Farm. See Appendix C for borehole and cross section locations.

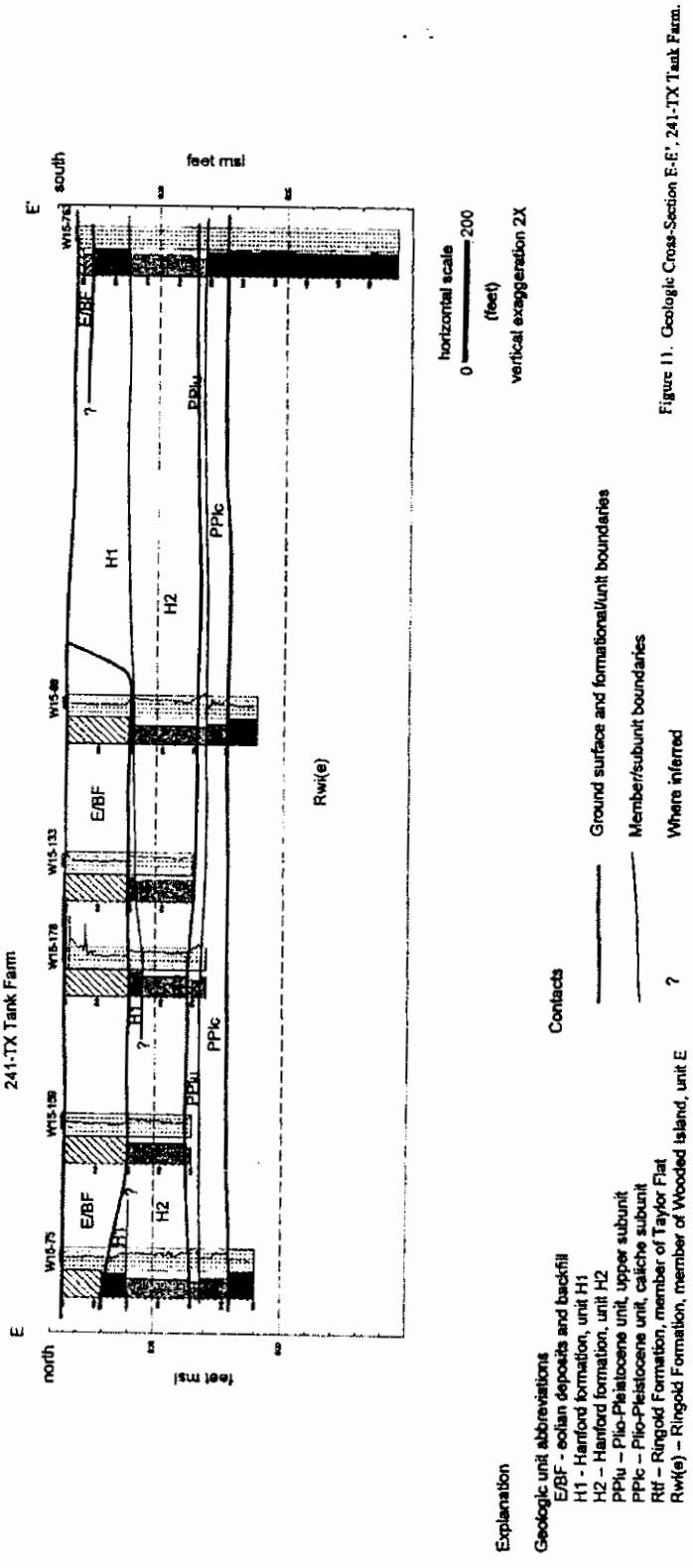

Figure 11. Geologic Cross-Section E-E', 241-TX Tank Farm.

Figure 11. North-South Geologic Cross Section Through the 241-TX Tank Farm. See Appendix C for borehole and cross section locations.

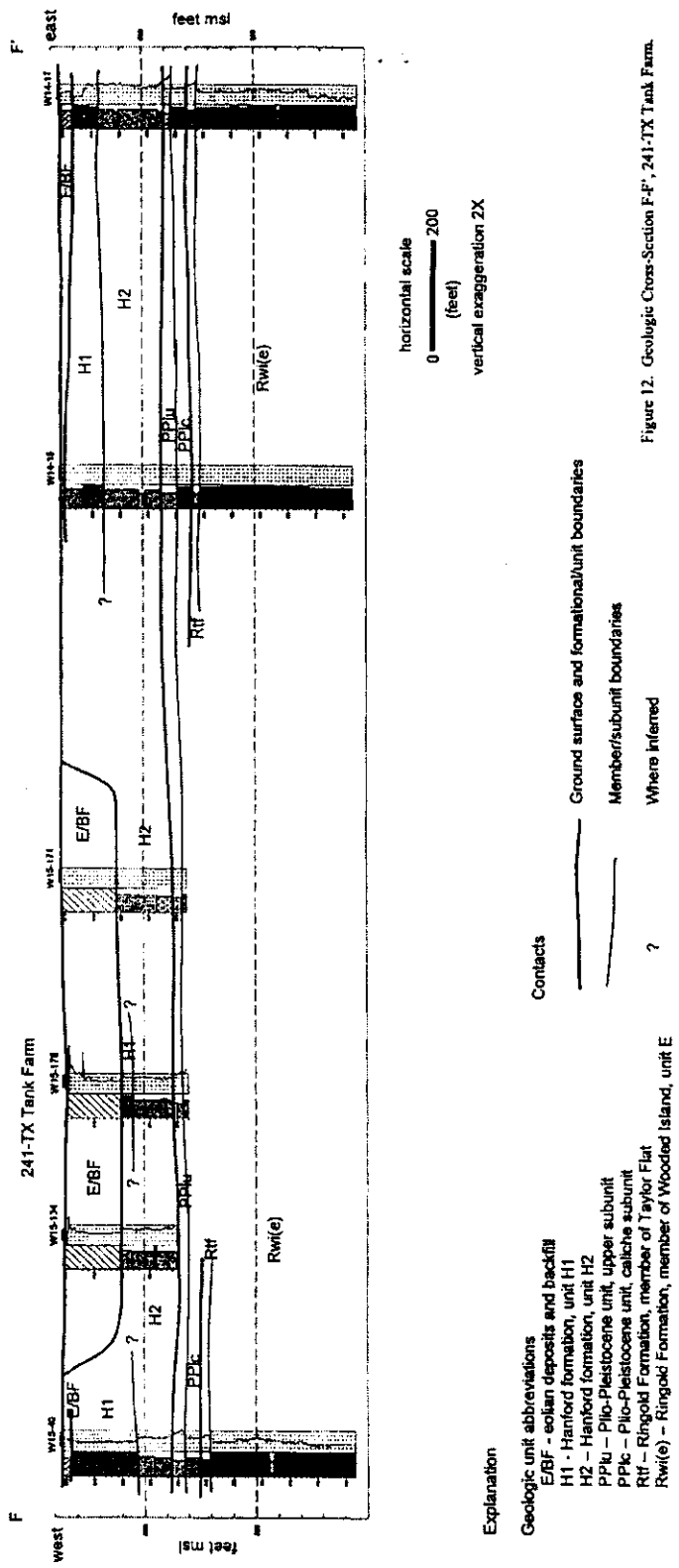

Figure 12. Geologic Cross-Section F-F', 241-TX Tank Farm.

Figure 12. East-West Geologic Cross Section Through the 241-TX Tank Farm. See Appendix C for borehole and cross section locations.

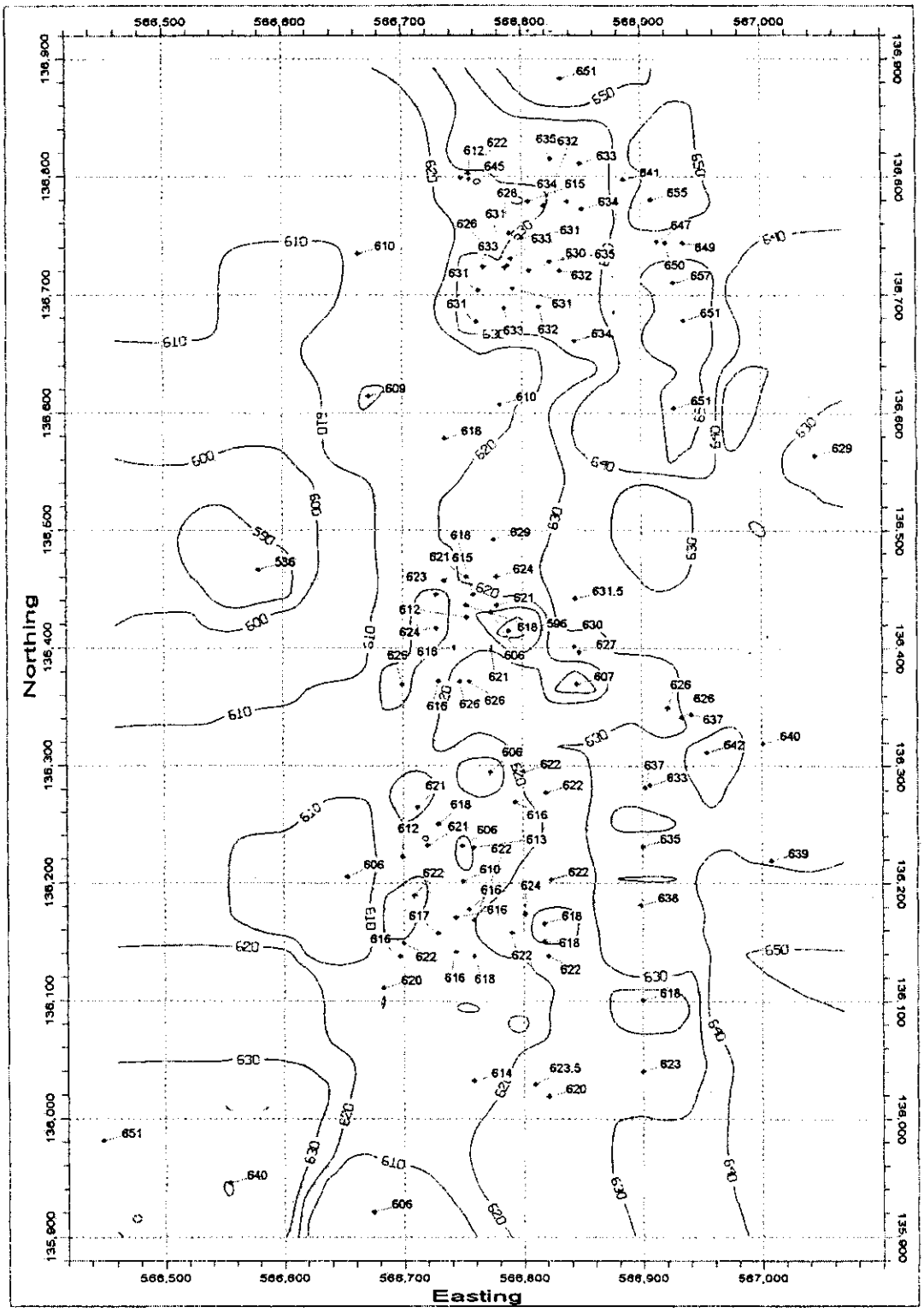

Figure 13. Structure Contour Map of the Top of Hanford Formation Unit H2. See Appendix C for borehole and cross-section locations.

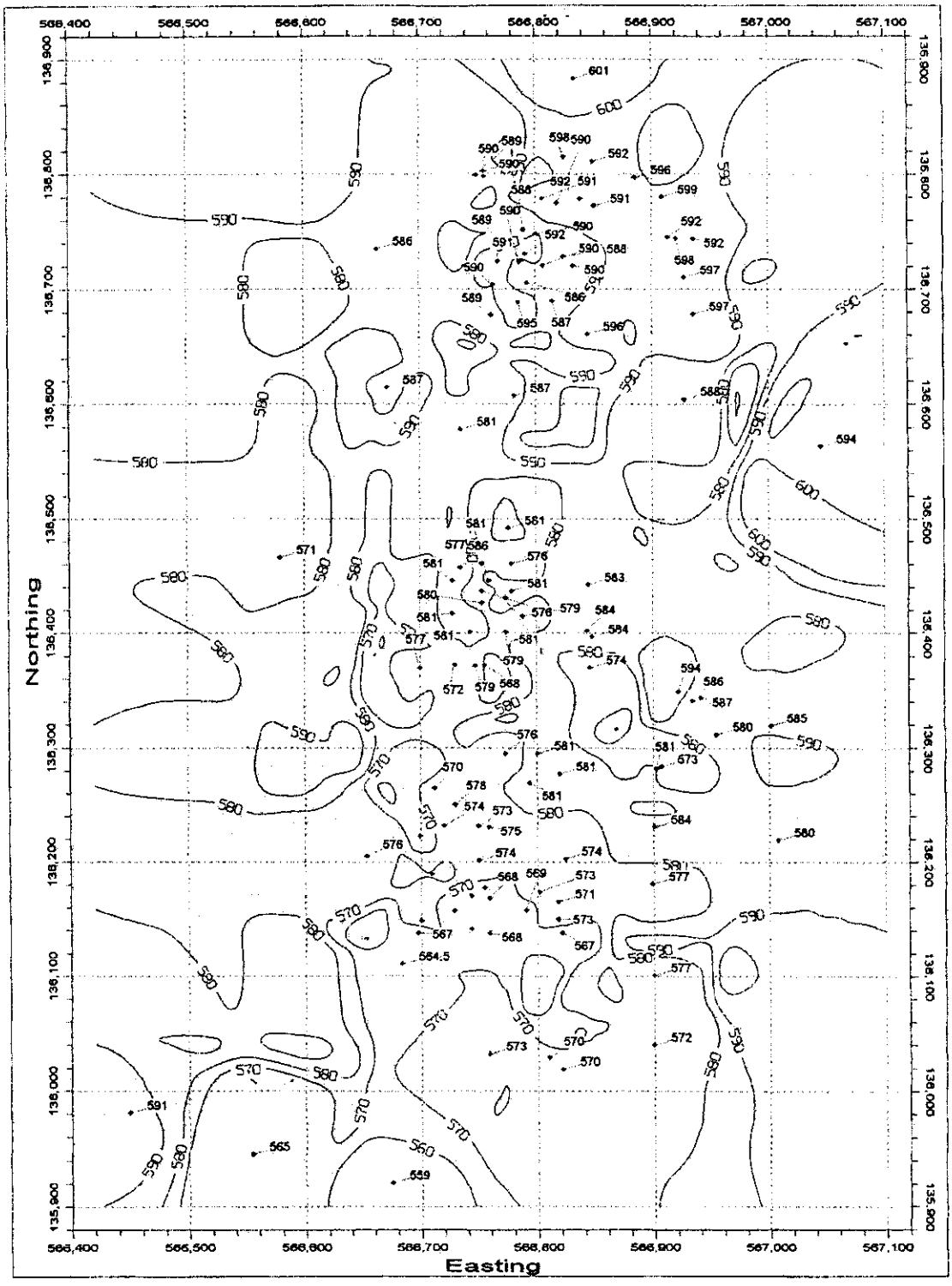

Figure 14. Structure Contour Map of the Top of the Plio-Pleistocene Unit, Upper Subunit. See Appendix C for borehole and cross section locations.

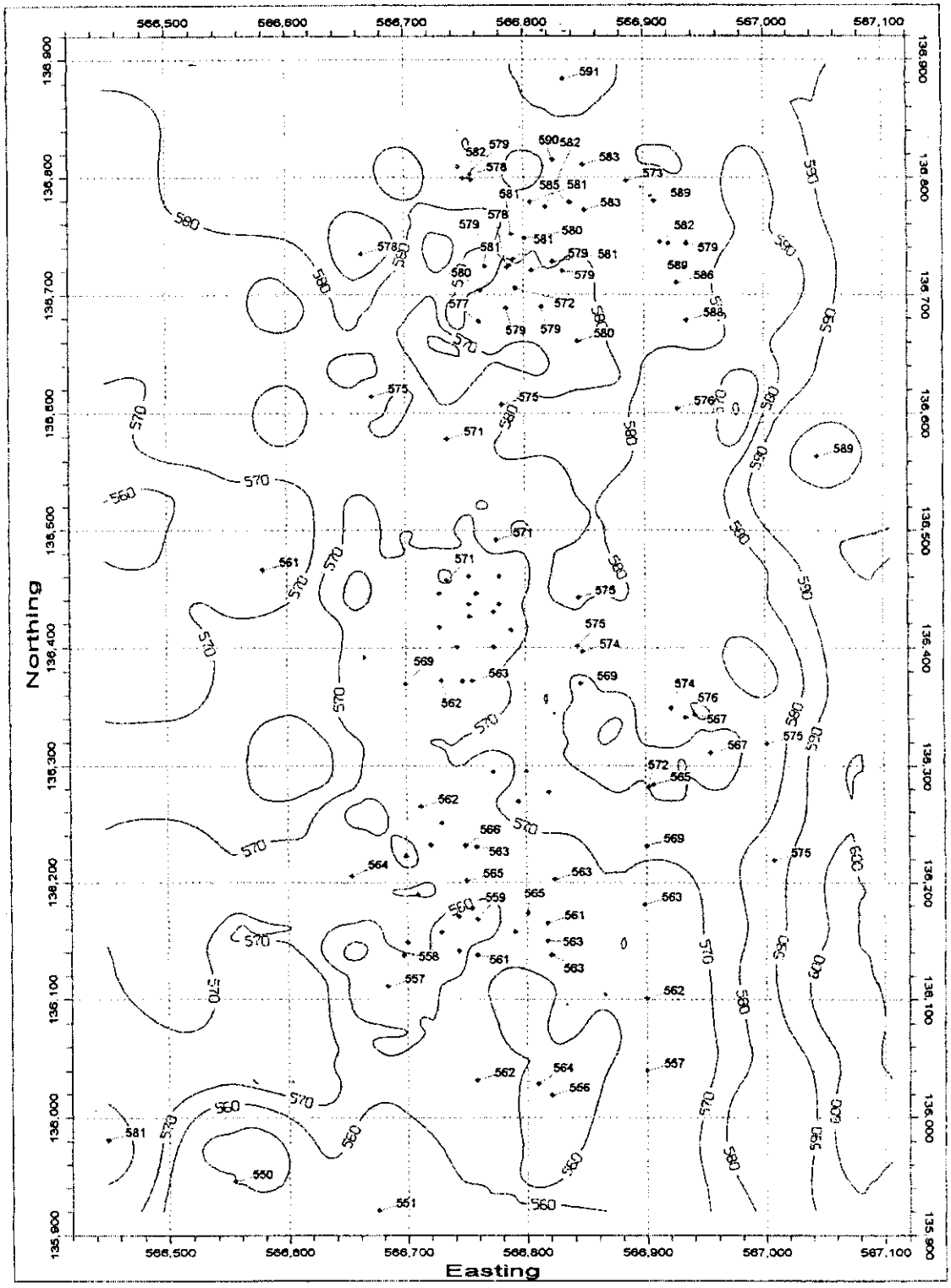

Figure 15. Structure Contour Map of the Top of the Plio-Pleistocene Unit, Caliche Subunit. See Appendix C for borehole and cross section locations.

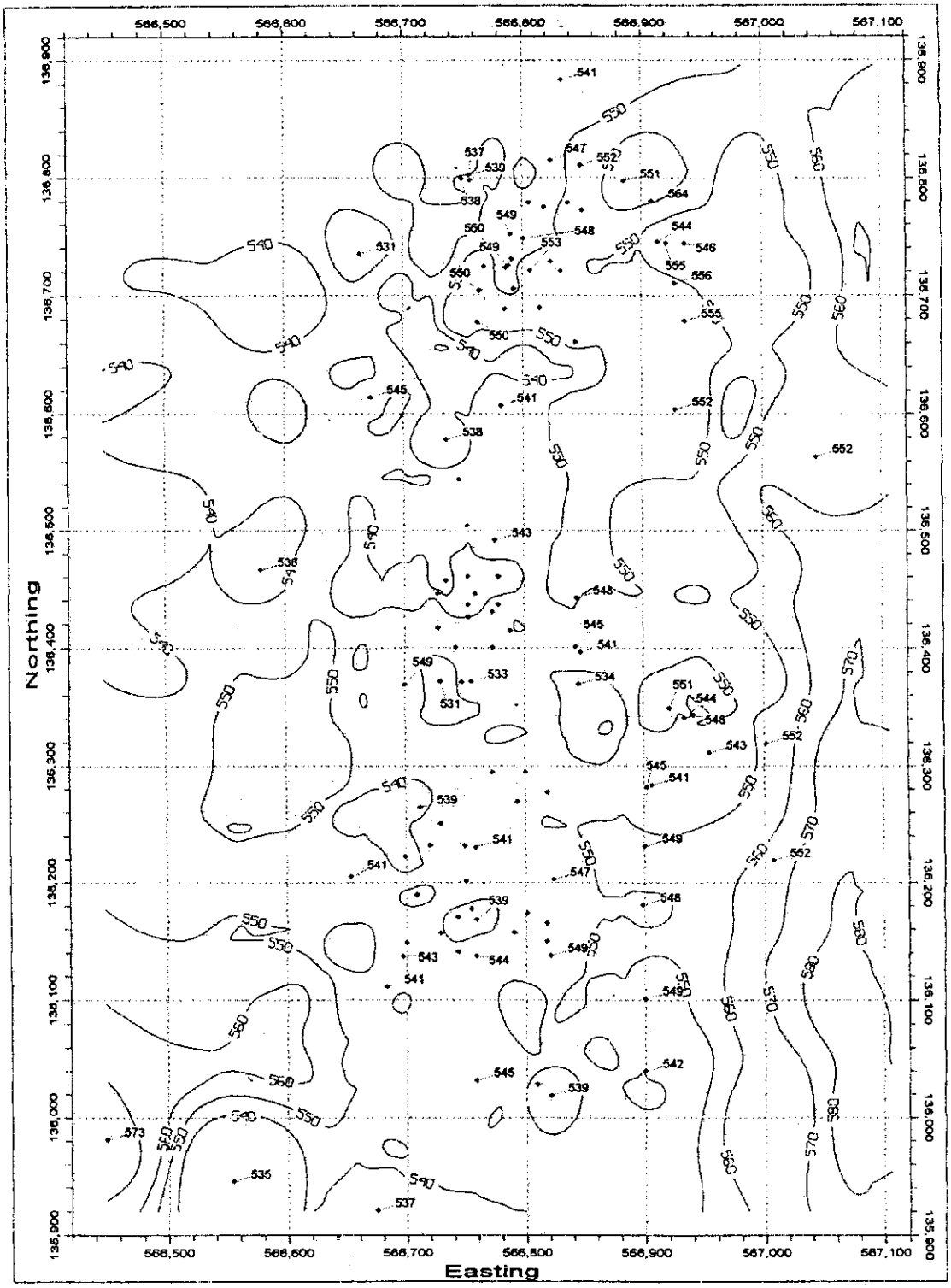

Figure 16. Structure Contour Map of the Top of the Ringold Formation, Member of Wooded Island, Unit E. See Appendix C for borehole and cross-section locations.

5.0 CONCLUSIONS

Based on information derived from logging of W10-27 and W11-39 samples, from previously reported data and information, and stratigraphic interpretations described in this report, the T-TX-TY WMA vadose zone consists generally of the following.

- Backfill in the tank farm excavations consists of mixtures of silt, sand, and pebble-to-cobble gravel derived from the site during tank farm construction. The thickness of this material varies from tank farm to tank farm. The presence of compacted or "hardened" zones in the backfill was not detected, although they could be present.
- Gravel-dominated facies comprising Hanford formation H1 are continuous across the area outside of each tank farm. Beneath the tank farms proper, the unit is locally absent because of removal during site construction. Because of the likelihood of lateral facies variation, the base of this unit may be irregular and not everywhere placed at the same horizon.
- Hanford formation Unit H2 consists of an extremely well-stratified sequence of coarse sand and granule sand facies. Interbedded lenticular silty sand layers are rare. Beneath the T-TX-TY WMA this unit is much coarser grained than is typically described further south beneath the 200 West Area. This trend is interpreted to simply represent lateral facies changes from higher energy deposition in the T-TX-TY area to lower energy deposition further south.
- As was found in the S-SX WMA (Lindsey et al. 2000), the silt-rich interval overlying the Plio-Pleistocene caliche interval consists of a mixture of interstratified clayey silt, silt, sandy silt, and silty very fine sand. These strata range from massive to well stratified. This interval is referred to as the upper subunit of the Plio-Pleistocene Unit.
- The caliche-rich lower subunit of the Plio-Pleistocene Unit underlies the entire T-TW-TY WMA. It is quite variable in thickness, which probably reflects the fact that it was developed to variable depths on the eroded top of the underlying Ringold Formation. As is found elsewhere, the caliche unit consists of a mix of interstratified caliche-rich and caliche-poor, lenticular layers and not a single massive carbonate horizon.
- The Ringold Formation, member of Taylor Flat is the uppermost Ringold Unit underlying the site. It is not present everywhere, having been locally removed by post-Ringold/pre-cataclysmic flood erosion. The uppermost Ringold Unit beneath the entire area is Unit E of the member of Wooded Island. This unit is variably cemented and extends through the remainder of the vadose zone to the top of the unconfined aquifer.

Recommendations for future consideration suggested by this investigation are summarized as follows.

- Future characterization activities may include targeting the base of backfill to determine its lateral continuity and assess the effect the hardened and apparently compacted zone may have on moisture movement.
- The degree of interbedding and the nature of the H1/H2 contact beneath the T-TX-TY WMA are of some concern because of irregularities and lateral interfingering along it. Future characterization and interpretations in the area should consider this.
- Hanford formation Unit H2 is much coarser grained at this site than is typically described elsewhere beneath the 200 West Area. This should be considered in all future characterization and interpretation of site conditions.
- The lithologic variability and degree of interstratification seen in the Plio-Pleistocene in the S-SX WMA was also found in the T-TX-TY WMA. Future interpretation and characterization should account for this variability.
- Because split spoon sampling largely ceased at, or near, the top of the Ringold Formation, few new insights into Ringold vadose zone geology can be derived. Future vadose characterization of Ringold strata, if needed, will require sampling techniques different than those employed in the drilling of W22-50 and W23-19.
- The sampling methodology employed in the field during SPT collection needs to be revised. Hole depths, length of casing in the ground, the presence of slough, and actual sample recovery need to be recorded in field notes prior to each SPT sampling.

6.0 ACKNOWLEDGEMENTS

The authors would like to thank Ray Clayton and the rest of the staff of PNNL's 3720 Building Applied Geology and Geochemistry Laboratory for their support and help during the logging of W10-27 and W11-39 samples.

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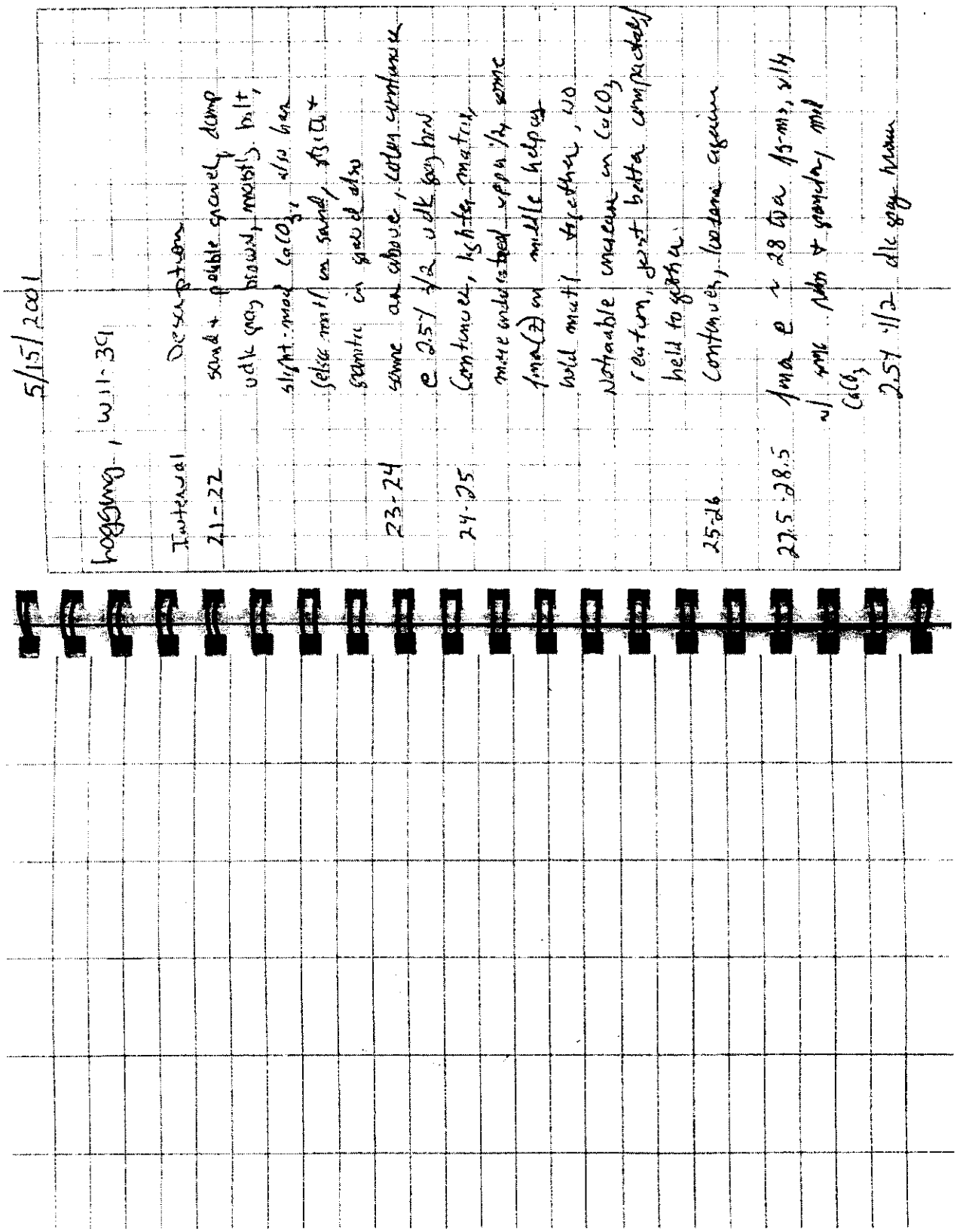
APPENDIX A

LABORATORY GEOLOGIC LOGGING NOTES FOR BOREHOLES 299-W10-27 AND 299-W11-39


5/15/2001
Logging - well 31
Interval Description
21-22 sand + pebble gravel, damp
dark gray brown, moist, halite,
slight mod CaCO3, v/s lam
(selec mtl) in sand, ~5% +
granite in gravel also
23-24 same as above, calcium carbonate
e 25% 1/2 dk gy brn
24-25 Continues, lighter matrix
more indurated very few/1/4 some
mod(2) on middle half
wtd mottl strathm, no
noticable macrom in CaCO3
return, dirt batts comp/packed/
held together
25-26 Continues, random agglom
27.5-28.5 mod e ~ 28 dpm 1/3-m2, v/14
w/ some lam & granular mtl
CaCO3
25Y 1/2 dk gy brn

(2) 5/15

31.5-32.5 gravel continues, w/ a hard ca, more CaCO3 rich zone 1/cm 31.7 to 32.2 ft, sand matrix in lenticular more 1/clue, bld still a bit like, grey, brn olive still dom, some oxidized coatings, little of bit w/ fair amount of ftg sd matrix clay

32.5-33.5 Decr in pebble/cobble content, gran sand, cs, w/ pebbs, looks more bedded, lower 2" zone to a 1/clue cs, w/ 25% bld & slight/low CaCO3 throughout lower laga, little more cohesion, lots of ftg granules & <1cm pebs

Cover layer ~ 2.5Y 4/4 olv brn

5/5 (3)

34-35 31-34.25, gravel w/ fs/ms matrix, sharp base, over well bedded ms-cs, some ss beds, few floating granules, olive 5Y 4/4 olive

35-36 cs/gs and base of previous continues sm, well bedded, stacked and bedded on 3-5" scale, olive color continues

36.5-37.5 cs/gs continues to 36.75, @ thin pt /unc slightly + grd more mottled, less bedded, carb content increases, @ 37.25 CaCO3 goes up again, CaCO3 may be largely in grains in this layer

olive on lower 1/3(?) layer

2.5Y-6/2 ltgy, more to 5Y 6/2 ltolv gry

lower zone looks pretty well bedded

(4) 5/15

37.5-38.5 $CaCO_3$ sand continues to 37.65, then back to cs/gs w/ sand, some pebbles, + S+P appearance, well stratified S+P character makes color difficult to read clean, colors range from olive to grey brown

oxidized color band @ contact

34-40 39-39.45 - mottled coarse silty sand, sharp contact @ well bedded cs, gs, sm pebs, upper 2' is high in the carb debris like above interval, also more compact, softens w/ depth the mottled zone is very compact

40-41 S+P, cs/gs w/ some pebs continue, some bedding & v slight to $CaCO_3$

(5) 5/15

41.5-42.5 To 41.75, more mottled, silty, mussive cs/gs Below, sed into more cs/gs/ pebble 5-15% < 1.5 cm pebbles, some bedding, more stratified below contact

42.5-43.5 @ 42.5' + 2" contact above is fine S+P cs/gs w/ pebbles Below, well stratified but somewhat drilling disrupted cs/ss, upper 1/2 of the is more cs, lower 1/2 is more gs, color back to olive

44-45 Back to S+P, cs/gs in upper 0.6 ft. Low @ 0.4 ft, alt beds of ms/ cs/gs/ ms, w pebs Some sand, slight to mod $CaCO_3$ olive colors to brown colors

A-3

RPP-8531, Rev. 0

(6) 5/15

45-46 Well strat ms/cs, $CaCO_3$ modrate, str appearance but w/ lots of the white/gray $CaCO_3$ particles, in upper 1/2
2 < 1/4" silt, fs stringers @ top 2"
Cord bedding, some hyssertim of XB ~ non ∥ deformed layers

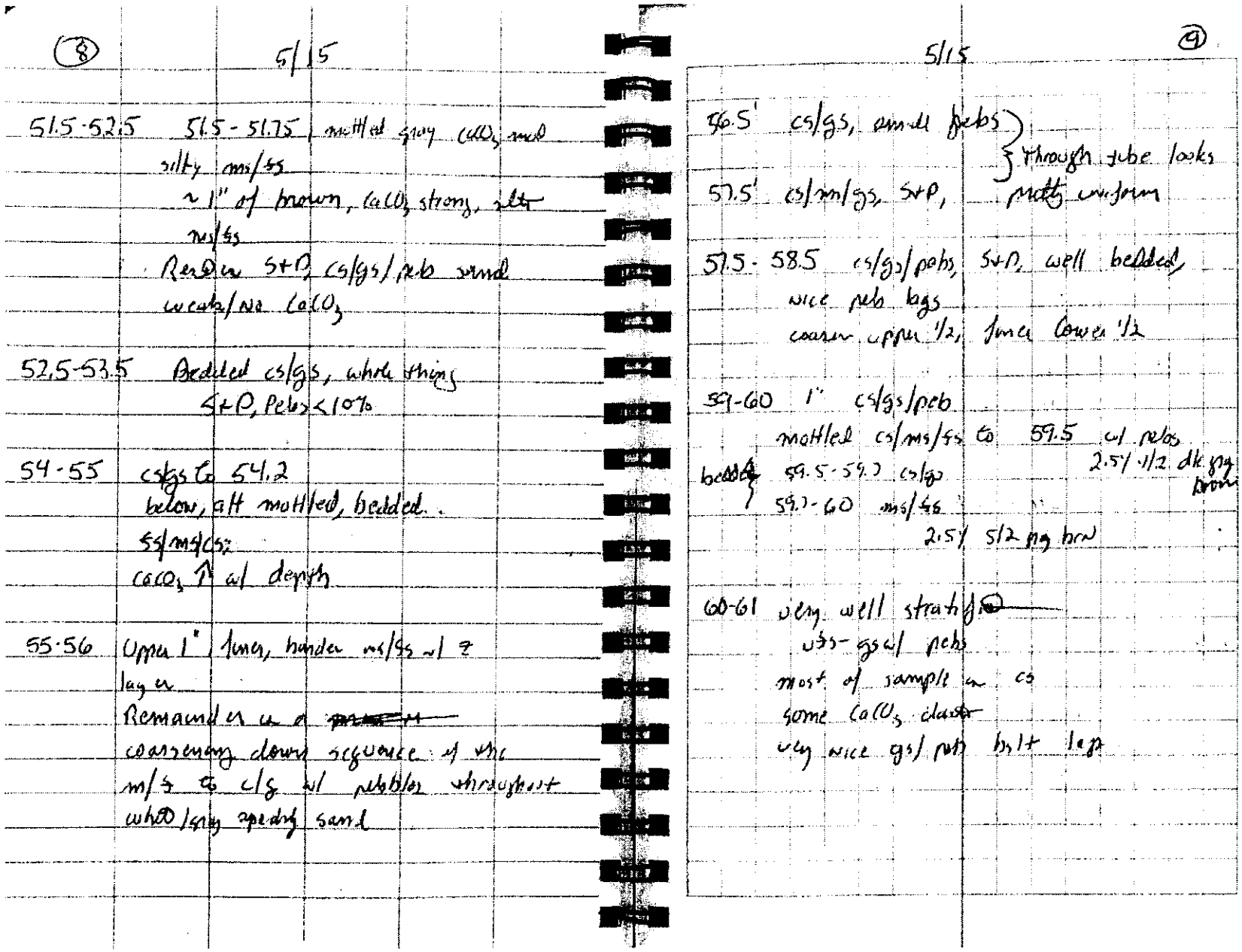
46.5-47.5
To ~ 47.25, str, cs/gs/pebbles @ 47.25 back to Bedded, mottled ms/cs white gray ⇄, ss/ms. The white/gray ss/ms - lots of $CaCO_3$

47.5-48.5 upper ½ the fs/ms fizzy wht/gray specks - stuff
Below wkly str ss ms/cs
some stratification @ base

5/15 (1)

49-50
Very well stratified sand, 49
mottled cs/ms 2 slight mod $CaCO_3$
cs/gs 2
slight $CaCO_3$ ↓ ss w/ z 2 49.5 2.5Y 4/4 olive brn
ss/ms 1
ms/cs 5 50 5
ms/cs @ str, olive + browns
prct strong bedding contacts w/ a lot of grading

50-51 well bedded ms, str, mica, continue to 50.6, hd thing contact + str, cs/gs w/ < 10% pebbles
ms - mod $CaCO_3$, fine dissemin particles
cs/gs - no Ca ∪ slight $CaCO_3$
colors are olive/grays - hvy still mstly str



(8) 5/15

51.5-52.5 51.5 - 51.75 mottled gray $CaCO_3$ rich silty ms/ss
~1" of brown, $CaCO_3$ strong, silty ms/ss
Remain S+P cs/gs/peb sand weak/No $CaCO_3$

52.5-53.5 Bedded cs/gs, whole thing S+P, Peb > < 10%

54-55 cs/gs to 54.2
below, alt mottled, bedded.
ss/ms/cs;
$CaCO_3$ ↑ w/ depth

55-56 Upper 1" finer, harder ms/ss ~1 ? layer
Remainder is a ~~[illegible]~~ coarsening down sequence of the m/s to c/g w/ pebbles throughout white/gray sandy sand

(9) 5/15

56.5' cs/gs, small pebs } through tube looks
57.5' cs/ms/gs, S+P, } pretty uniform

57.5 - 58.5 cs/gs/pebs, S+P, well bedded, nice peb lags
coarser upper 1/2, finer lower 1/2

59-60 1" cs/gs/peb
mottled cs/ms/ss to 59.5 w/ pebs 2.5Y 5/2 dk gray brown
bedded 59.5 - 59.7 cs/gs
59.7 - 60 ms/ss 2.5Y 5/2 gray brown

60-61 very well stratified
vfs - gs w/ pebs
most of sample is cs
some $CaCO_3$ clasts
very nice gs/peb bslt lag

(10) 5/15

NOTE: look for an water, upper part of SSP heavy massive/mottled, if so slough ~ 62.5 suggestion

61.5-62.5
to 62.1, massive, mottled, darker olive brown color
At 62.1 unit harder, more white/gray speckled bs, very $CaCO_3$-rich w/ gs/cs layers

62.5-63.5 well stratified, cs/gs/peb SSP, $CaCO_3$ clasts present a few lots of bslt granules

64-65
to 64.8, faintly massive cs/gs/peb
@ 64.8-65 better bedded w/ $CaCO_3$ clasts in addition to bslt, also some red brown oxidized looking clay/zslt clasts
also visual diff in moisture appearence between halfs

5/15 (11)

65-66, very well stratified SSP, cs/gs/peb throughout

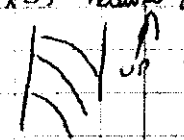
66.5 - cs/gs/peb slough

67.5 - intact cs/gs/peb

67.5-68.5 ⇒ cs/gs/peb continues, well bedded SSP

69-70 upper .25' sharp w/ the SSP cs/gs/peb clast, hard layer @ 69.9 - stay

70-71 very well bedded w/ bslt sand/peb layer forming very nice bands maybe XBs because of the shape



(12)

71.5-72.5
Upper 1/3 - slough? massive hard
debris
~~Lower~~
middle 1/3 the whole spectrum sty/fl
lower 1/3 SHP cs/gs/ped layer

72.5-73.5
well stratified, SHP
cs/gs/ped

~~73-74~~
74-75 crudely stratified to massive looking
at fine structure zone
slough?
Right at bottom ~~old~~ clean bedding
character returns

75-76 well bedded cs/gs/ped SHP
facies

(13)

76.5-77.5 @ 0.1 ft of slough
0.1-0.3, silty fs-vfs, well laminated
olive brown color.
Below to bottom 1B fs/cs, tr pebbles

77.5-78.5, coarsen down, continues
from above, to cs/gs and base w/
sharp contact over sandy silt,
olive brn 2.5Y 4/4, soft
scd deformed contact
↙ massive/fizz
2 to 0.2' thick, thin wisped
coarsening down into cs/ms @
base of tube.

79-80 upper 1/3 sloughs: massive,
mottled debris
Then to white/gray speckled
ms/cs, mod-strong $CaCO_3$ content
incl of ~~cut~~ strata suggests XB

(14) 5/15

80-81 well stnd cs/gs, trace pebs, lots of $CaCO_3$ debris

81.5-82.5
80 82.1, darker, more massive, unstructured below with sparkle banded mud'k lots of $CaCO_3$ debris

82.5-83.5 inclined layers well developed (XBs) stp cs/gs, tr pebs

84-85 well bedded, stp cs/gs, few more pebs than below upper 2", massive rough

85-86 Sand continues cs/gs, tr pebs, bedded

86.5-87.5, from 0.4' is massive, darker, stuff ~ slough?
lower 0.6' is the same cs/gs/ms as above, bedded cs-ms

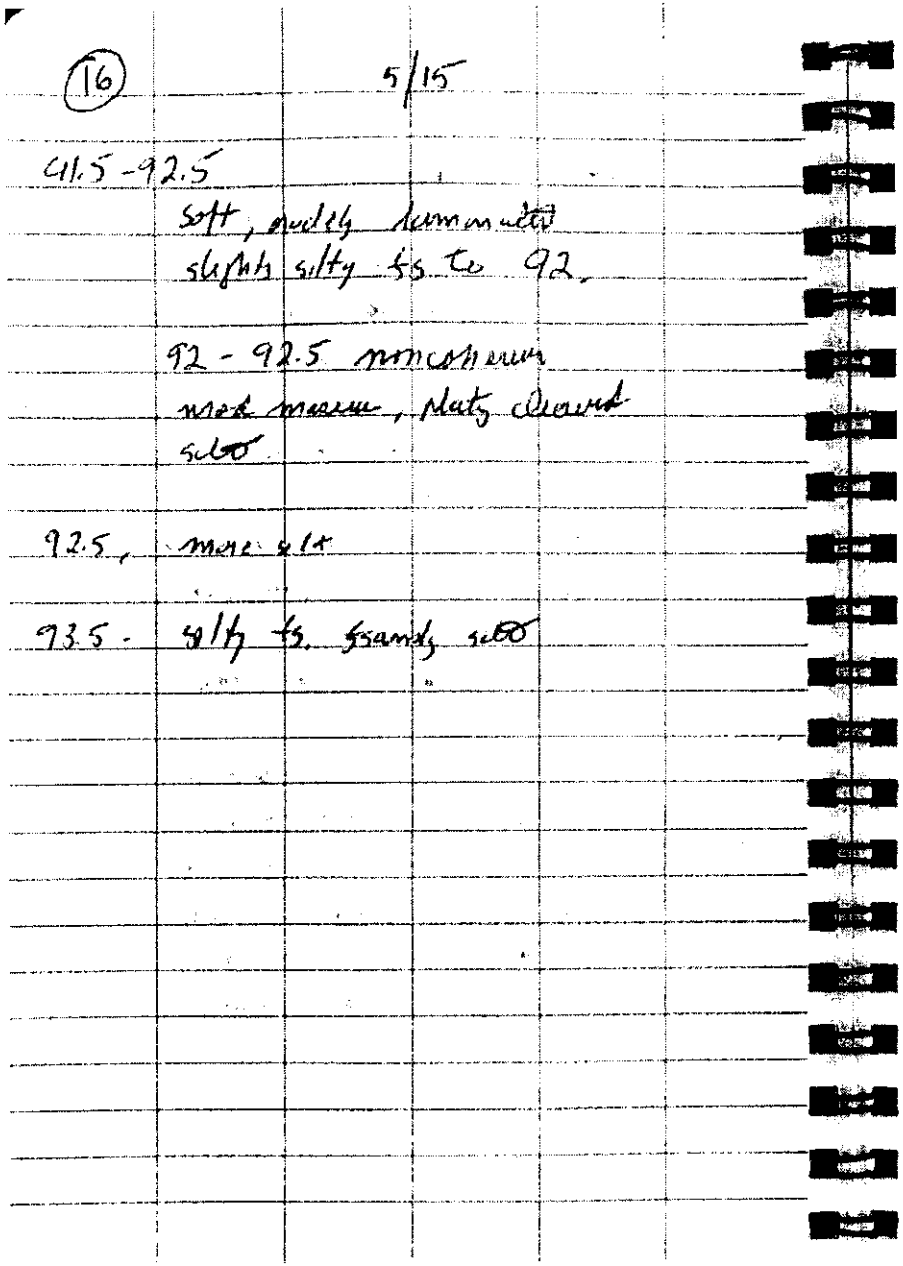
5/15 (15)

87.5-88.5
87.5 → 87.8 cs/gs w/ tr pebs
87.8-88.2 ms/cs
88.2-88.5 ms/f
pretty sharp contact

mass looks similar stp

89-90
To 89.5, the massive, dk zone again
89.5-89.9 stp speckled ms w/ cs + gr mixed in
89.9 sharp contact, non coherent silty s, sandy silt
2.5Y 4/4 olive brn, mod $CaCO_3$ lam in silt

90-91
90-90.3 comes down to silty ss, ripple x lam
90.3-91 massive slightly siltier silt, lower 0.2 ft hyena & crayon + pebs up bedding



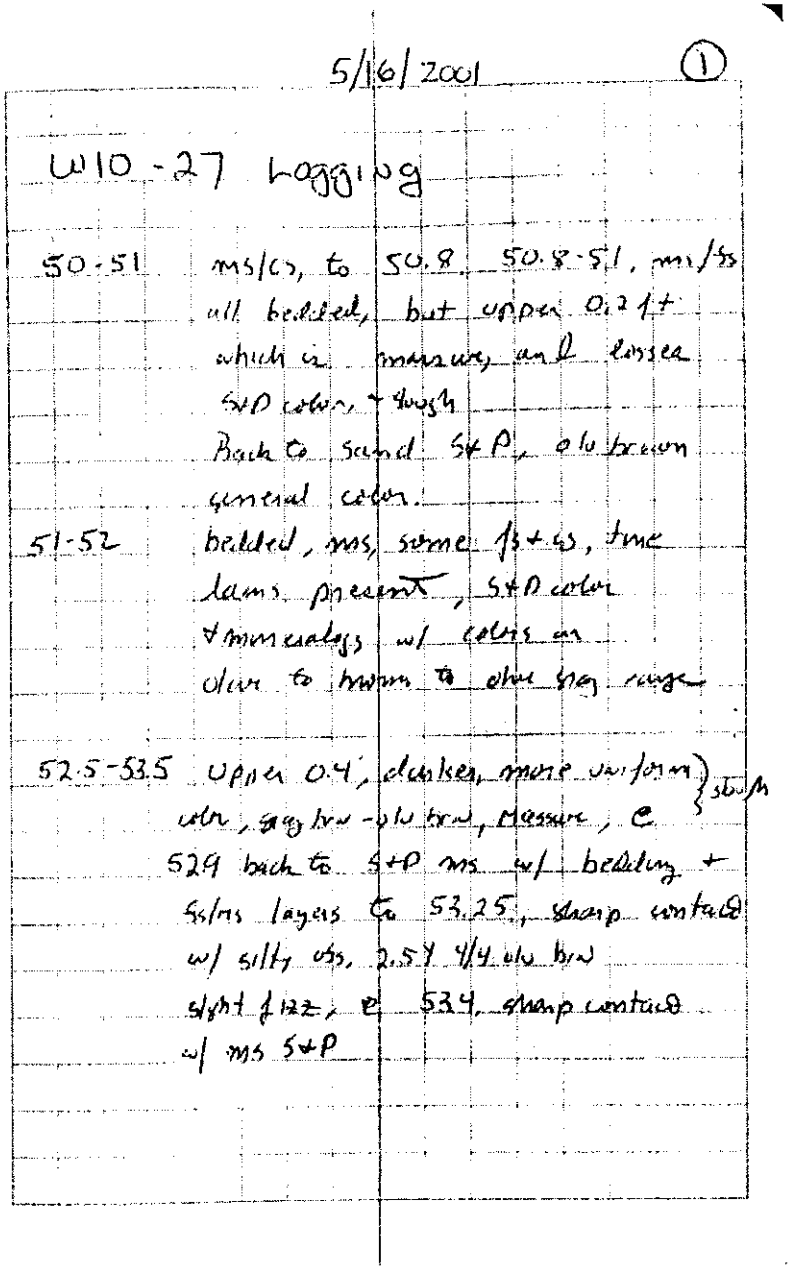
(16) 5/15

91.5 - 92.5
soft, evenly laminated
slightly silty fs to 92.

92 - 92.5 nonlaminated
med massive, platy clasts
sub

92.5, more silt

93.5 - s/lty fs, fsandy sub



5/16/2001 (1)

W10-27 Logging

50-51 ms/cs, to 50.8 50.8-51, ms/ss
all bedded, but upper 0.2 ft
which is massive, and lowest
S+P color, + wash
Back to sand S+P, olv brown
general color.

51-52 bedded, ms, some fs+cs, fine
lams present, S+P color
+ mm scales w/ colors on
olive to brown to olive gray range

52.5-53.5 upper 0.4, darker, more uniform } sub/m
color, gray brn - olv brn, massive, c
529 back to S+P ms w/ bedding +
ss/ms layers to 53.25, sharp contact
w/ silty vfs, 2.5Y 4/4 olv brn
slight fizz, c 534, sharp contact
w/ ms S+P

(2) 5/16

53.5 - 54.5, 53.5 - 54. S+P cs/gs, sharp contact 0.1 ft of well lam ms/ss @ 2.5Y 4/4 olv brn w/ mod fizz, then back to well bedded ms w/ ss/cs variations

55-56 upper 0.2' massive, uniform gray olive colored sand - slough?
Rest is a bedded S+P cs/gs w/ 10%-20% small (<1cm) pebs slight to mod fizz, on seams?

56-57 bedded S+P, cs/gs w pebs, <15%

57.5-58.5 upper 0.28' massive, uniform color pebs
Below well bedded S+P, cs/gs w/ <15% pebbles, some hints of normal gradings

58.5-59.5 well bedded S+P cs/gs w pebs continues

60-61 Upper 1/3, coarse cs/gs, mlow, back to cs/gs dayered matrix, @ 60.3 into a more silty-layered sand w/ pebs

(3)

61-62 & 61.3, the silty cs/gs continues
61.3-61.1 - pebble bed, below, well bedded S+P cs/gs w/ pebbles, contains well dev darkened ss/ms layers < 1cm thick

62.5-63.5 upper 0.2' is massive, hd, uniform colored sand matrix
62.7-631, well bedded ms w/ pebs + cs+ss
631-635, sharp top small pebble gravel w/ CaCO3 cloth, very bubbly, also lots of yellowed brown oxidized stain/clasts (Rumford rpt?). Lower 1' back to cs/gs
635-64.5 cs/gs/peb continues, <15% pebs, S+P, bedded etc, Middle 0.2' is ms/cs w/ a <1cm ss layer
The occasional oxidized spot present
65-66, upper 0.1' the massive stuff
Below, bedded, cs/gs/peb, S+P, as above w/ carb, ox spots, lots of gs mix

(4)

66-67 Just below top ego with bedded ms/cs, bslt ↓, < 30°, still very speckly + colors on olive/brn range still how to pebbles though

67.5-68.5 Fuzzy 2.5" fine massive stuff, Then 2" of compact silty ms/cs w/ pebs, thicker bslts in CaCO3, Below to 68.25 SrP cs/gs - well developed oxidized horizon layered, Then bedded ms/cs/ss

68.5-69.5, bedded ms cont. to 68.25, below back to SrP, bedded cs/gs w/ pebs

70-71, Upper 0.2', massive, uniform color stuff
~1" of bedded SrP cs/gs
~2" olive brn ss/ms silty/very silty
~1" SrP cs/gs
~1" ss laminated
~ silty sand/sandy silt } several wedge shaped structures
~1" v.f.g silty SrP cs/gs + discontinuities
All colors w/ mod fizz in liner manifestations of dust storms?

(5)

72-71 Bedded, ms/cs, SrP sand, some finer, mixed w/ tuff to bedding

72.5-73.5 Upper 1/4 is loose, next 1/4 more massive, yet compact, Then wtr bedded stuff for lower 1/2, SrP ms/cs w/ lots of CaCO3 debris + several clayey stringers/layers in upper 1/2

73.5-74.5, speckly SrP ms/cs w/ ss to 74.1 w/ good bedding, below more cs/gs + pebs

75-76 massive, uniform colored stuff

76 loose homogeneous stuff

77 loose, coarse cs/gs

77.5-78.5 Upper 0.35' questionable middle to lower back to layered ms w/ cs + fs, some silty debris content

78.5-79.5 bedded, SrP, coarse sand

(6)

80-81 Homogenous stuff to 80.5
Below, predominantly, , bedded,
specky ss/ms, mican
· oxy band @ 80.75.

81-82 stP ms/cs, well bedded.
mica common in this stuff,

82.5-83.5 Upper 1/2, loose to homogenous stuff
Lower 1/2 micaceous ss/ms, still
specky, basalt present in all sizes
plus os
very $CaCO_3$-rich, lots of frzz

83.5-84.5 bedded ms/cs, stP, oxy hue
+ spots occasionally fn granules

85-86 Upper 1/2 is massive + homogenized,
There's compacted layer
Lower 1/3 OK, specky, silty ss/ms,
layered

86-87 Coarsens down from fs/ms specky
stuff to stP cs/ms some bedding
but not well expressed.

(7)

87.5-88.5 massive homogenous stuff to
87.75
Below 87.75-88.2 stP, bedded,
cs/ ms/ss, w/ some cs
88.2-88.4 well laminated vfss w/ z
olive-brown color
88.4-88.5 ms/cs layer
88.5-89.5 to 89.25 ms/ss, well laminated
2.5Y 5/4 lt olv brn, more uni/cr micrology
(below)
Couple of layers defined by $CaCO_3$
up of concentrations
89.25-89.5 laminated vfss, gray brn-
lt yellow brown color (2.5Y rg)

90-91 Upper 1/4 is rough - lone debris
2.5Y 4/4 olive brown, laminated
noncoherent; silty vfss, fine sandy silt
sand laminated; ss @ 90.5, some
micrology color banding

91 - slightly cohesive silt

92 - vfss w/ silt

(8)

92.5-93.5 silty vfs sand, sdo from 92.75 ss 93.35 & 93.35 sharp contact to sdo, wherein, b.t non plastic silt from worm mold - some $CaCO_3$ throughout

93.5 cohesive, non plastic silt

94.5 vfs w/ silt to silty vfs to sandy silt

95-96 2.5Y 4/4 to 4/2 olive brn to dk grayish brown, strong $CaCO_3$ vfs silt & silty vfs, massive, slightly mottled, very uniform color.

96- same as above

97 - vfs silt to silty vfs w/ $CaCO_3$ chunks were typ bigger than 1/4"

96-97 massive silty sand/sandy silt as above w/ $CaCO_3$ chunks in lower 2"

97.5-98.5 silty sand/sandy silt to 98. @ 98 @ top of Calcb

Calcb @ predom 5Y 7/2 lt gray 10-15% bslt pebs mixed in.

(9)

98.5 Calcb as above end

99.5 Calcb as above ends, as above

100-101 Calcb as above, grades downwards into felsic/lithic sand w/ scattered bslt, very carbonaceous, w/ some pebble chunks (< 1/2") floating in massive, unstructured 10YR 6/2-6/3 lt brn/gry to pl brn

101 - as above sandy $CaCO_3$

102 " " " "

102.5-103.5 As above, w/ some $CaCO_3$ stringers in middle portion

103.5 as above

104.5 Big chunks of $CaCO_3$ and bslt granules in felsic/lithic sand groundmass

105-106 10YR 5/4 yellow brn massive felsic/lithic ss. w/ bslt granules (<10%) + few calcb pieces (<1%), very strong $CaCO_3$

106-107, As above, massive felsic/lithic ss/sm w/ calcb + tr bslt granules

(10)

107.5 - 108.5 As above, more carb debris + chunks below 108

108.5 oxidized fn/ms, brown, strong brown, yellow brn

109.5 Caliche on end of sleeve

110-111 Massive caliche w/ stringers + globs of other matl (clay?) 7.5YR 7/2 pink/gry lots of sand mixed in, especially at bottom

111 ms, very calc

112 ms, w/ bslt granules, caliche chunks, lots of fizz, color same

112.5 - 113.5 ms/cs, Selce w/ 25% bslt, qtz/feld grains mostly white w/ some oxy staining; Trace pebs, massive, 10YR 5/3 - 5/2 brn - gry brn No Carb reaction

113.5 - 114.5 Sand continues, w/ a rock w/ oxidized coating/stain in middle of sample, mostly ms

115-116 Continues, sand fines ms/fs, few more stained pebbles - upper 0.25' is loose sludge no $CaCO_3$

(11)

116-117, ms/fs continues, some segregation of bedding

117.5 - 118.5 Upper 0.4' loose sand (sloughed) below, sand to 118.45, Selce w/ 25% bslt, ms, no $CaCO_3$

@ 118.45, fizzy silt layer (clay?)

118.5 - alt sand/silt ms in interbedded layers

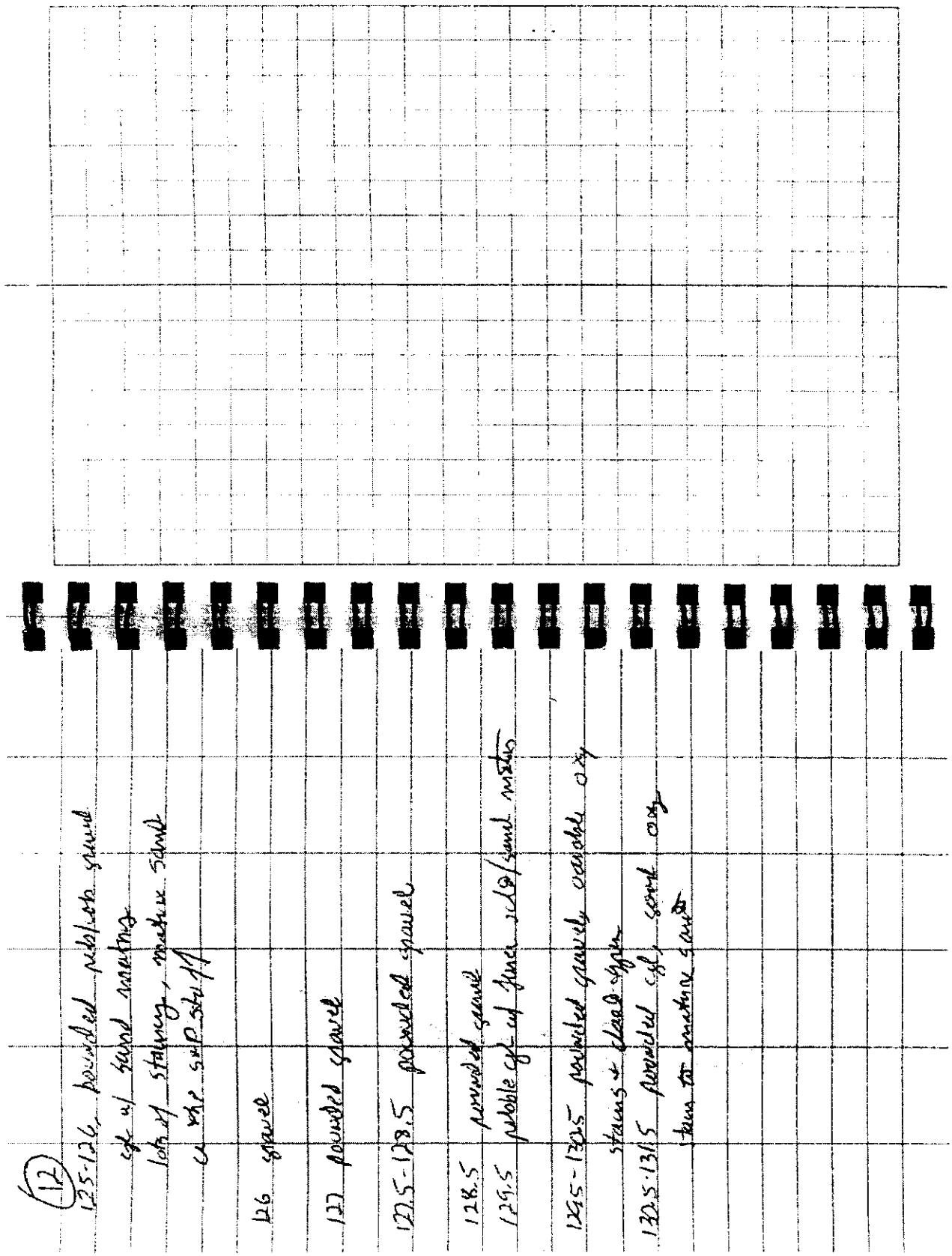
119.5 silt, olv brn color, part of clay?

120-121 to 120.5 cs, S+P, 120.5 - 120.7 cs, olv-brown, 120.7 - 121 - S+P cs

121 - 122 S+P cs, bslt > Selce

122.5 - 123.5 continues, slough on upper 0.15', pebble/cobble beds @ 122.9 to 123.1

123.5 - 124.5 medium S+P cs, bslt w/ moderate supp gravel in upper 1/2 gravel bed on lower 0.15' slight fizz on some light sand grains qtz pebs w/ stain


(12)
125-126 basaltic rubble sand
cgl w/ sand matrix
lots of staining, matrix sand
& silt, some silt
26 gravel
127 rounded gravel
127.5-128.5 rounded gravel
128.5 rounded sand
129.5 rubble cgl of fine rock/sand matrix
129.5-130.5 rounded gravely cobble cgl
stains & clast open
130.5-131.5 rounded cgl, sand matrix
stains at matrix sand

APPENDIX B

INTERPRETED BOREHOLE GEOLOGIC LOGS FOR BOREHOLES USED IN THIS INVESTIGATION

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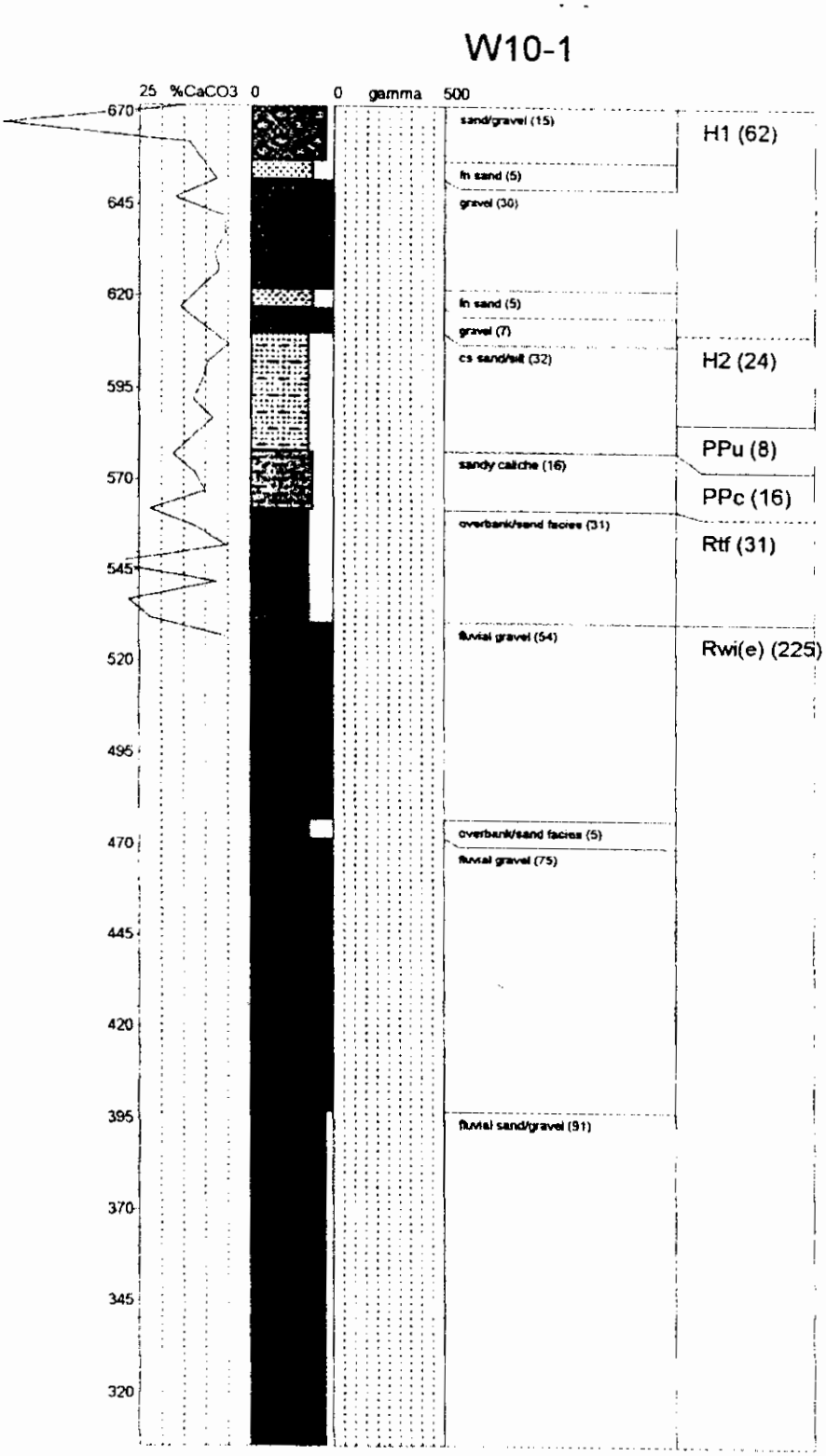
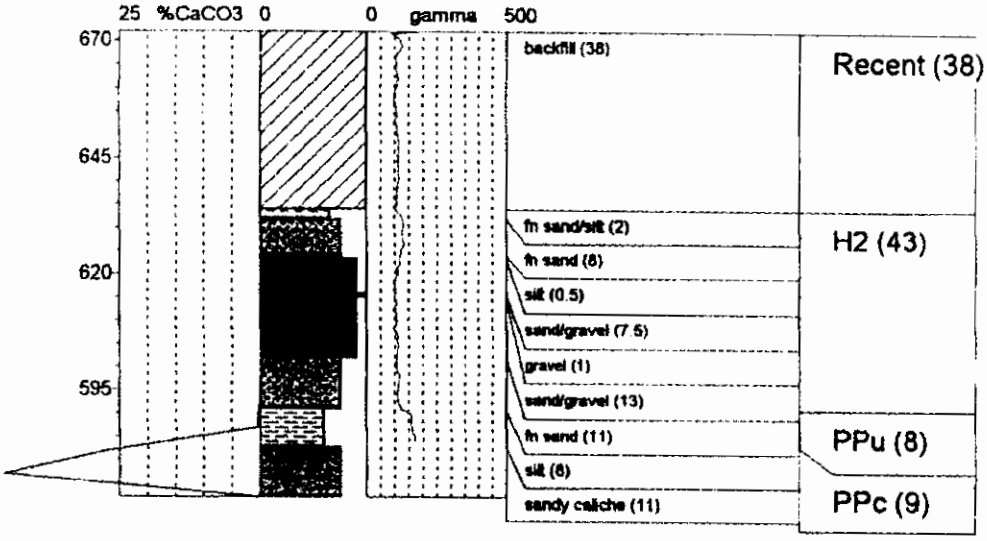
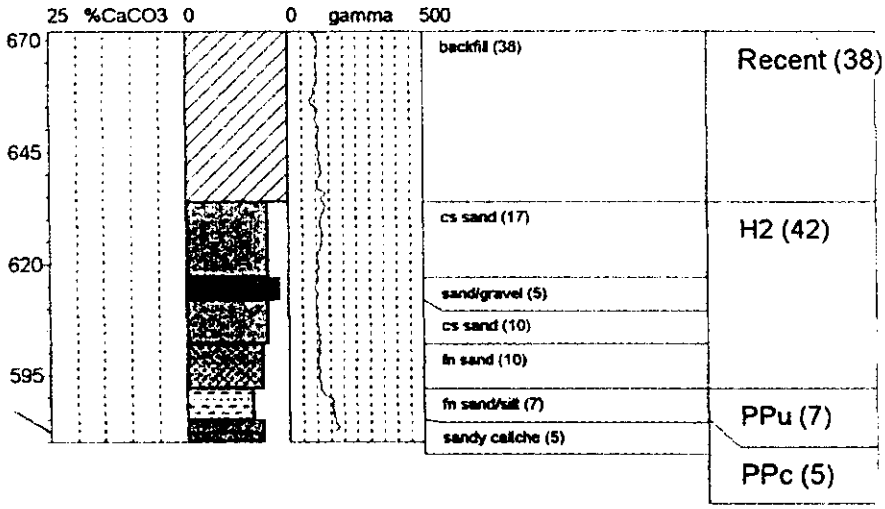
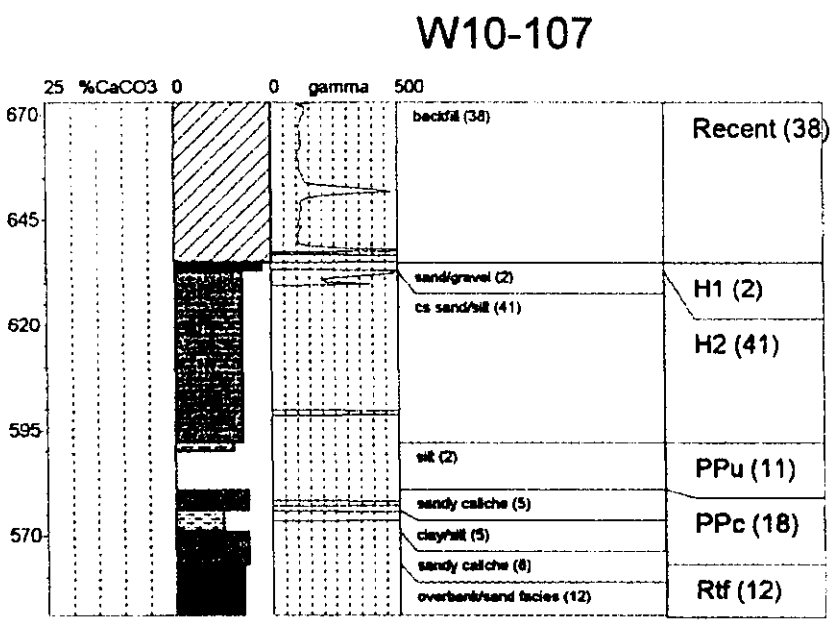

W10-1
25 %CaCO3 0
0 gamma 500
670
645
620
595
570
545
520
495
470
445
420
395
370
345
320
sand/gravel (15)
fn sand (5)
gravel (30)
fn sand (5)
gravel (7)
cs sand/silt (32)
sandy caliche (16)
overbank/sand facies (31)
fluvial gravel (54)
overbank/sand facies (5)
fluvial gravel (75)
fluvial sand/gravel (91)
H1 (62)
H2 (24)
PPu (8)
PPc (16)
Rtf (31)
Rwi(e) (225)

W10-101

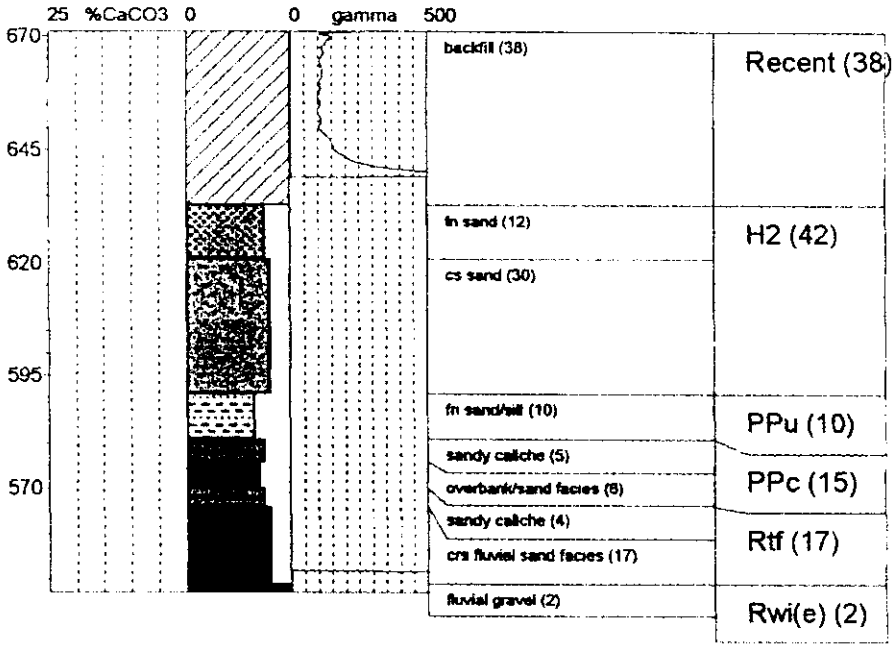

25 %CaCO3 0
0 gamma 500
670
645
620
595
backfill (38)
fn sand/silt (2)
fn sand (8)
silt (0.5)
sand/gravel (7.5)
gravel (1)
sand/gravel (13)
fn sand (11)
silt (8)
sandy caliche (11)
Recent (38)
H2 (43)
PPu (8)
PPc (9)

W10-105

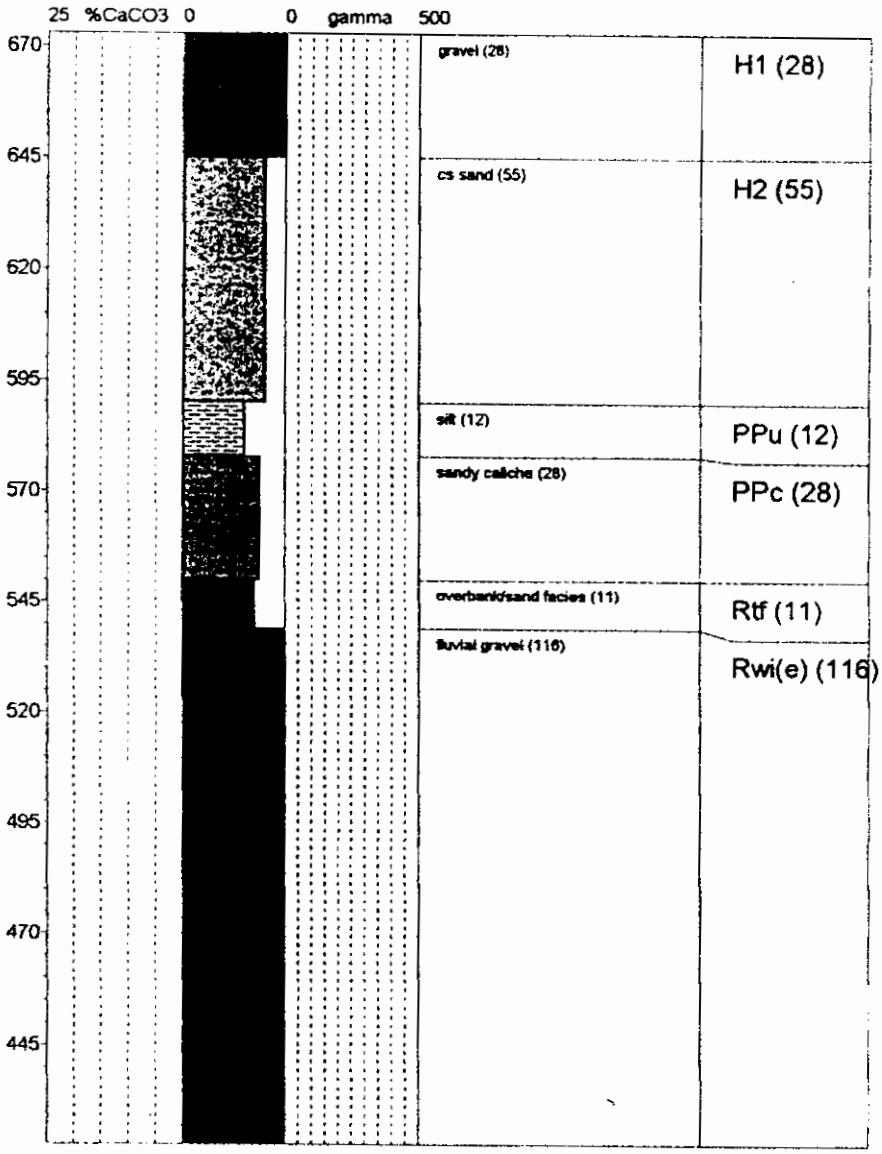

25 %CaCO3 0
0 gamma 500
670
645
620
595
backfill (38)
cs sand (17)
sand/gravel (5)
cs sand (10)
fn sand (10)
fn sand/silt (7)
sandy caliche (5)
Recent (38)
H2 (42)
PPu (7)
PPc (5)


W10-107
25 %CaCO3 0
0 gamma 500
670
645
620
595
570
backfill (38)
sand/gravel (2)
cs sand/silt (41)
silt (2)
sandy caliche (5)
clay/silt (5)
sandy caliche (8)
overbank/sand facies (12)
Recent (38)
H1 (2)
H2 (41)
PPu (11)
PPc (18)
Rtf (12)

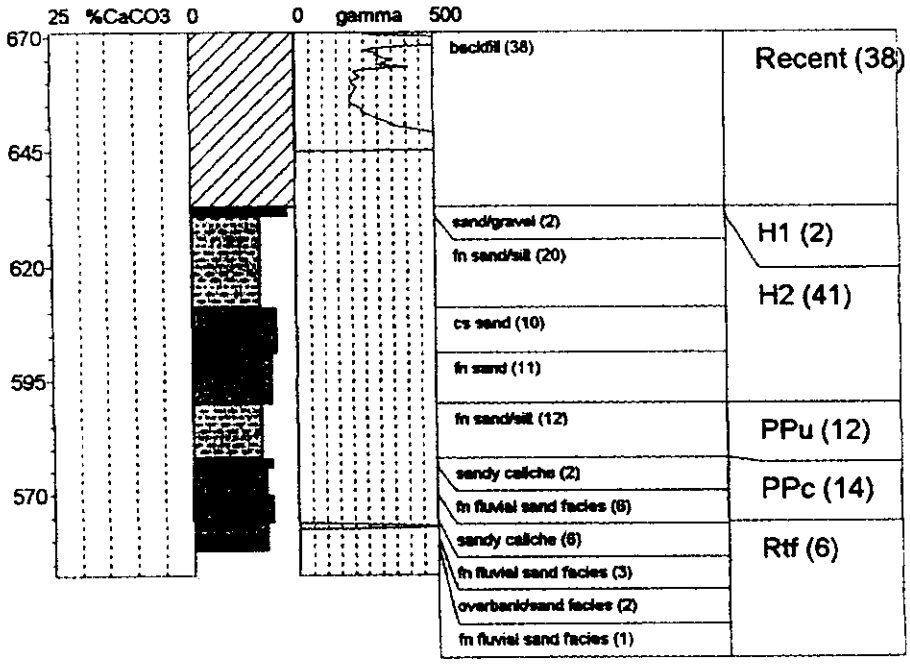
W10-109


25 %CaCO3 0
0 gamma 500
670
645
620
595
570
backfill (38)
fn sand (12)
cs sand (30)
fn sand/silt (10)
sandy caliche (5)
overbank/sand facies (8)
sandy caliche (4)
crs fluvial sand facies (17)
fluvial gravel (2)
Recent (38)
H2 (42)
PPu (10)
PPc (15)
Rtf (17)
Rwi(e) (2)

W10-11


25 %CaCO3 0
0 gamma 500
670
645
620
595
570
545
520
495
470
445
gravel (28)
cs sand (55)
silt (12)
sandy caliche (28)
overbank/sand facies (11)
fluvial gravel (116)
H1 (28)
H2 (55)
PPu (12)
PPc (28)
Rtf (11)
Rwi(e) (116)

W10-111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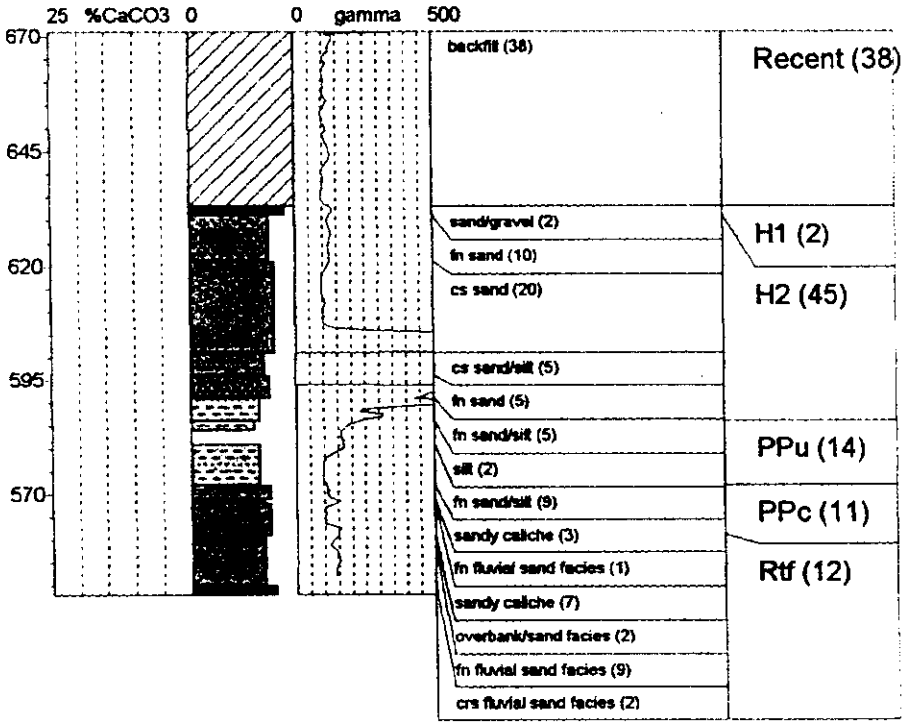
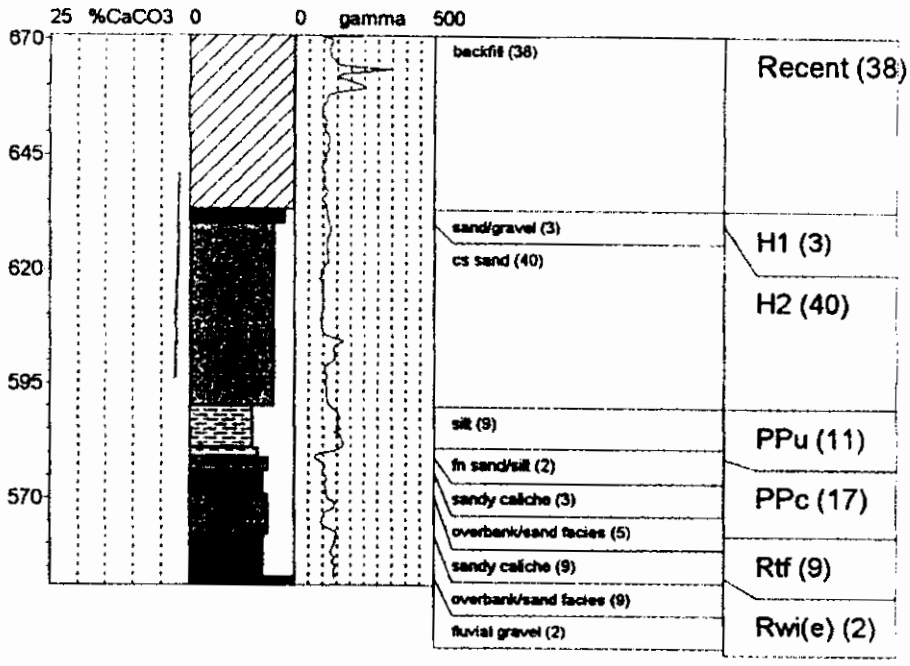
0 gamma 500
670
645
620
595
570
backfill (38)
sand/gravel (2)
fn sand/silt (20)
cs sand (10)
fn sand (11)
fn sand/silt (12)
sandy caliche (2)
fn fluvial sand facies (6)
sandy caliche (6)
fn fluvial sand facies (3)
overbank/sand facies (2)
fn fluvial sand facies (1)
Recent (38)
H1 (2)
H2 (41)
PPu (12)
PPc (14)
Rtf (6)

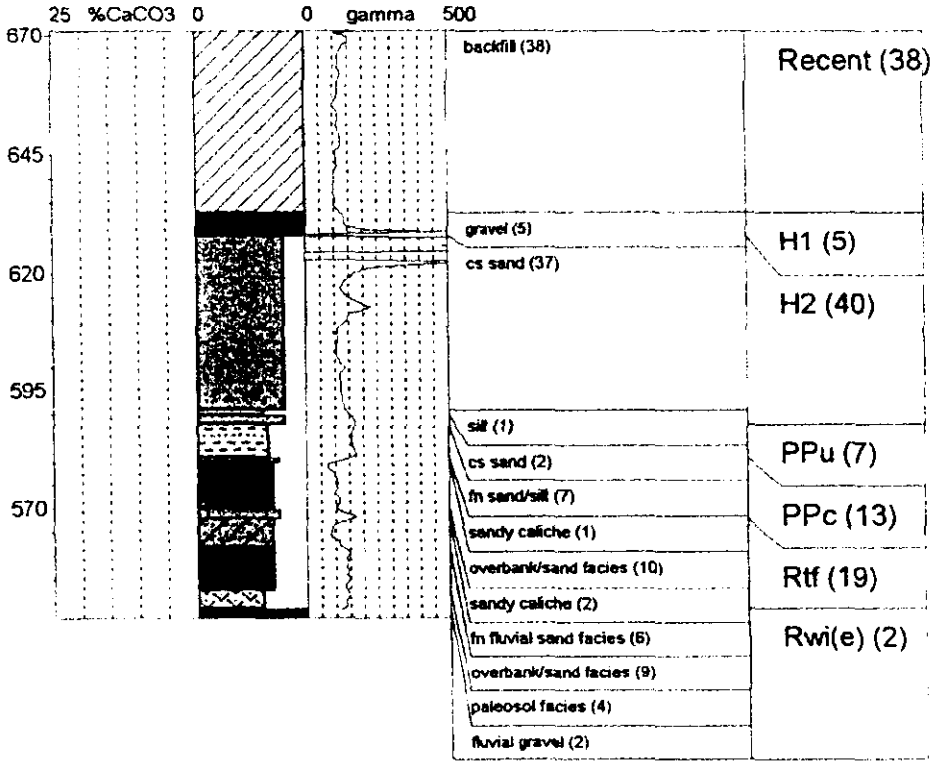
W10-112


25 %CaCO3 0
0 gamma 500
670
645
620
595
570
backfill (38)
sand/gravel (2)
fn sand (10)
cs sand (20)
cs sand/silt (5)
fn sand (5)
fn sand/silt (5)
silt (2)
fn sand/silt (9)
sandy caliche (3)
fn fluvial sand facies (1)
sandy caliche (7)
overbank/sand facies (2)
fn fluvial sand facies (9)
crs fluvial sand facies (2)
Recent (38)
H1 (2)
H2 (45)
PPu (14)
PPc (11)
Rtf (12)

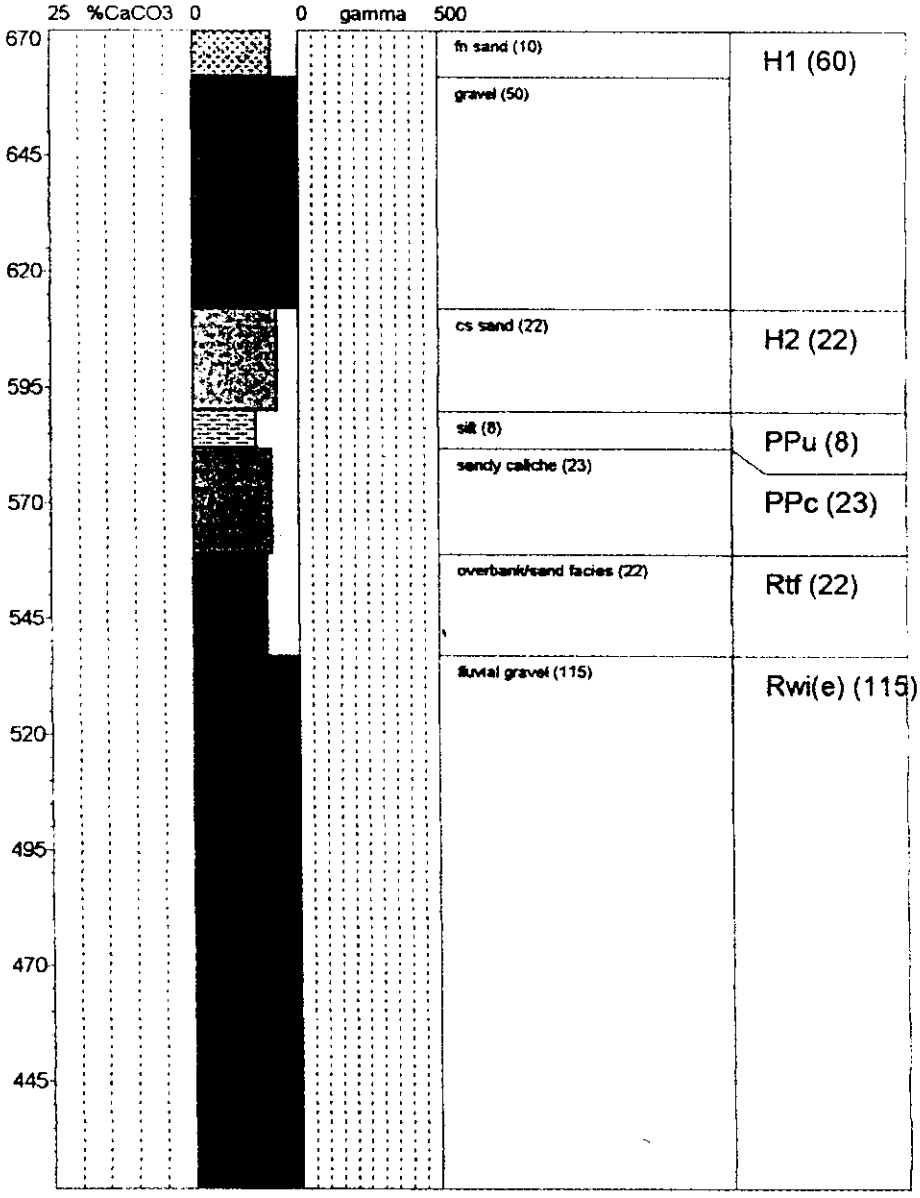
W10-113


25 %CaCO3 0
0 gamma 500
670
645
620
595
570
backfill (38)
sand/gravel (3)
cs sand (40)
silt (9)
fn sand/silt (2)
sandy caliche (3)
overbank/sand facies (5)
sandy caliche (9)
overbank/sand facies (9)
fluvial gravel (2)
Recent (38)
H1 (3)
H2 (40)
PPu (11)
PPc (17)
Rtf (9)
Rwi(e) (2)

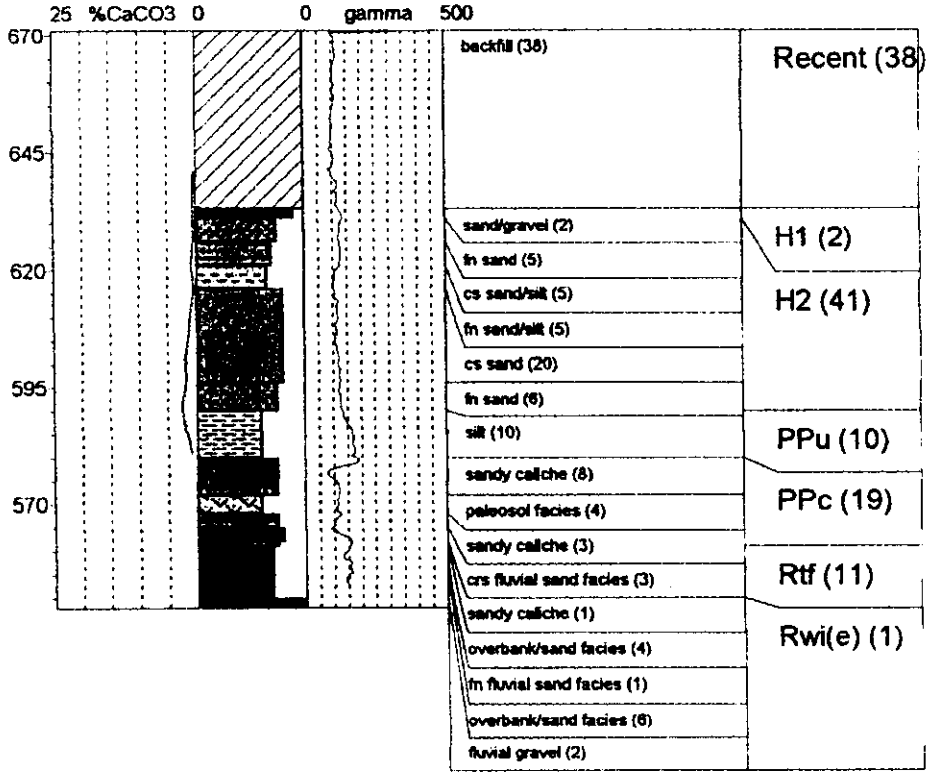
W10-117


25 %CaCO3 0
0 gamma 500
670
645
620
595
570
backfill (38)
gravel (5)
cs sand (37)
silt (1)
cs sand (2)
fn sand/silt (7)
sandy caliche (1)
overbank/sand facies (10)
sandy caliche (2)
fn fluvial sand facies (6)
overbank/sand facies (9)
paleosol facies (4)
fluvial gravel (2)
Recent (38)
H1 (5)
H2 (40)
PPu (7)
PPc (13)
Rtf (19)
Rwi(e) (2)

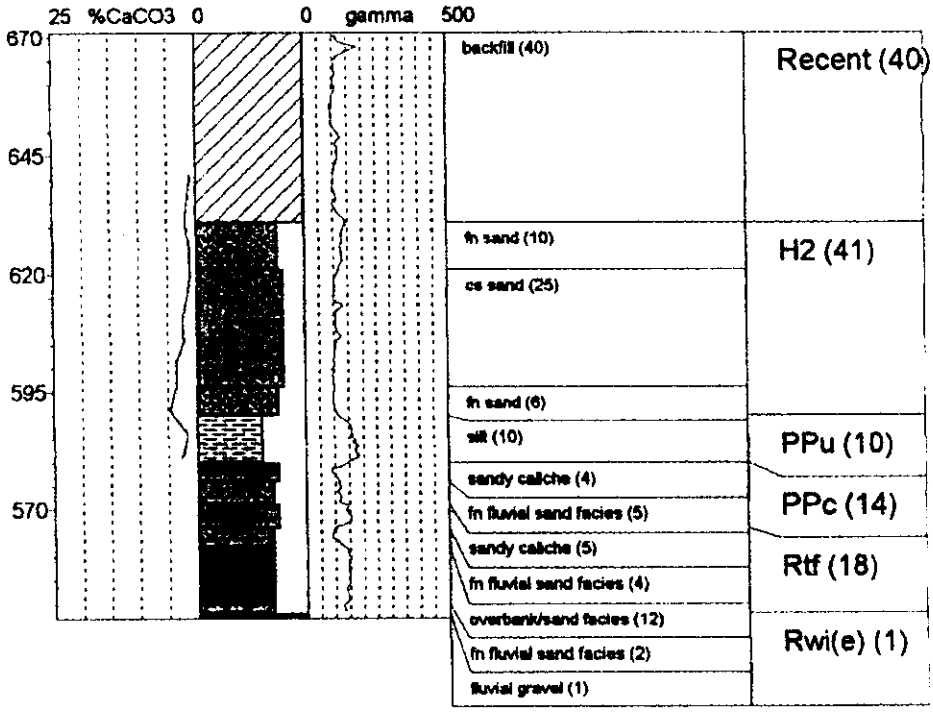
W10-12


25 %CaCO3 0
0 gamma 500
670
645
620
595
570
545
520
495
470
445
fn sand (10)
gravel (50)
cs sand (22)
silt (8)
sandy caliche (23)
overbank/sand facies (22)
fluvial gravel (115)
H1 (60)
H2 (22)
PPu (8)
PPc (23)
Rtf (22)
Rwi(e) (115)

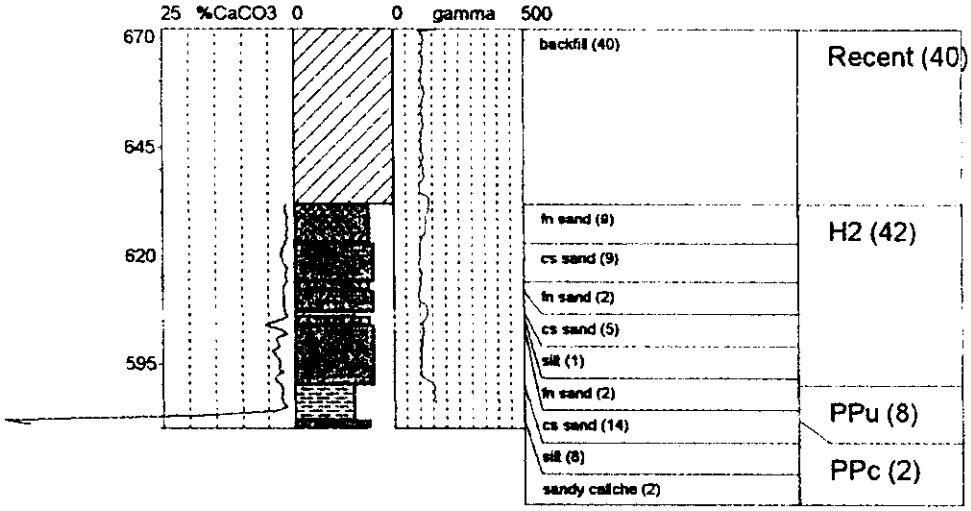
W10-120

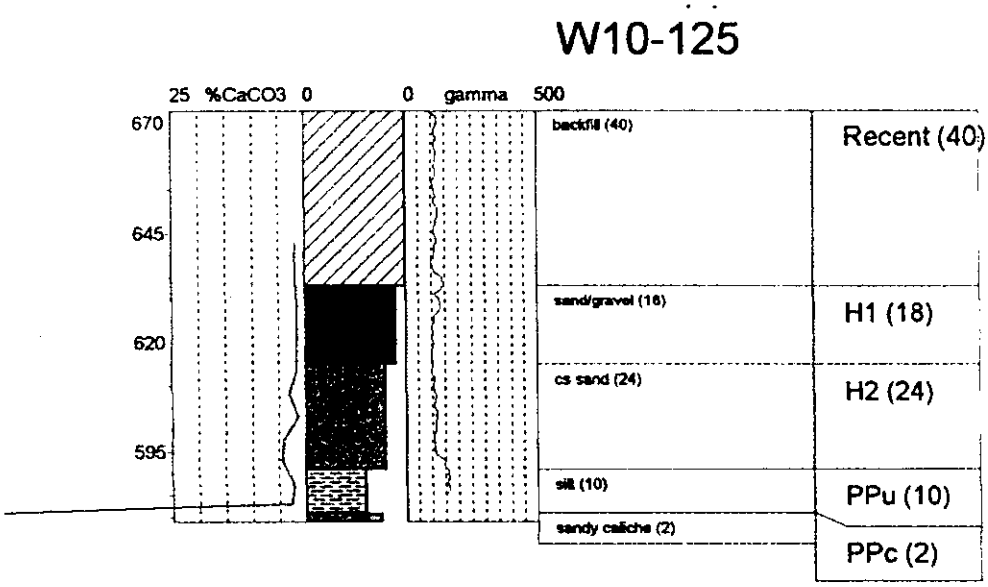

25 %CaCO3 0
0 gamma 500
670
645
620
595
570
backfill (38)
sand/gravel (2)
fn sand (5)
cs sand/silt (5)
fn sand/silt (5)
cs sand (20)
fn sand (6)
silt (10)
sandy caliche (8)
paleosol facies (4)
sandy caliche (3)
crs fluvial sand facies (3)
sandy caliche (1)
overbank/sand facies (4)
fn fluvial sand facies (1)
overbank/sand facies (6)
fluvial gravel (2)
Recent (38)
H1 (2)
H2 (41)
PPu (10)
PPc (19)
Rtf (11)
Rwi(e) (1)

W10-121

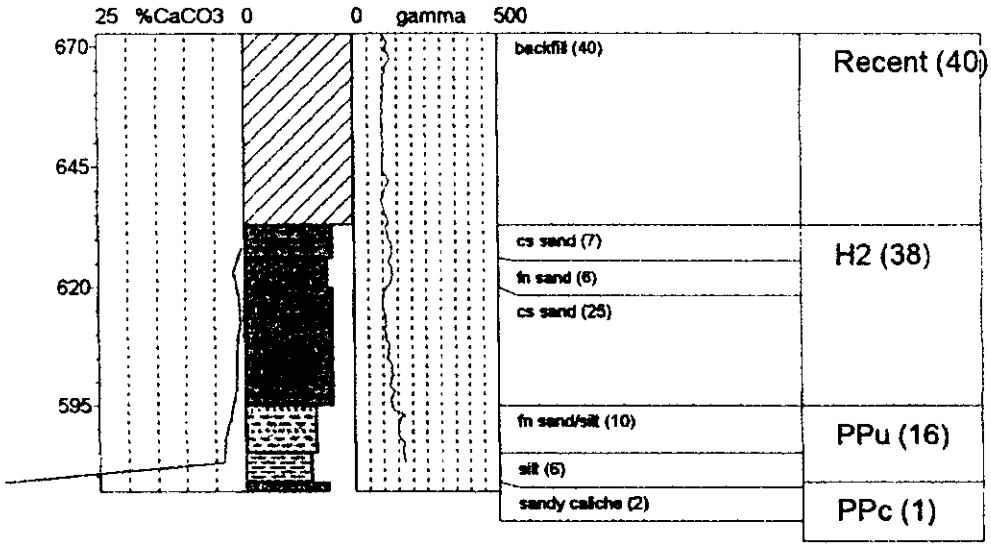

25 %CaCO3 0
0 gamma 500
670
645
620
595
570
backfill (40)
fn sand (10)
cs sand (25)
fn sand (6)
silt (10)
sandy caliche (4)
fn fluvial sand facies (5)
sandy caliche (5)
fn fluvial sand facies (4)
overbank/sand facies (12)
fn fluvial sand facies (2)
fluvial gravel (1)
Recent (40)
H2 (41)
PPu (10)
PPc (14)
Rtf (18)
Rwi(e) (1)

W10-122

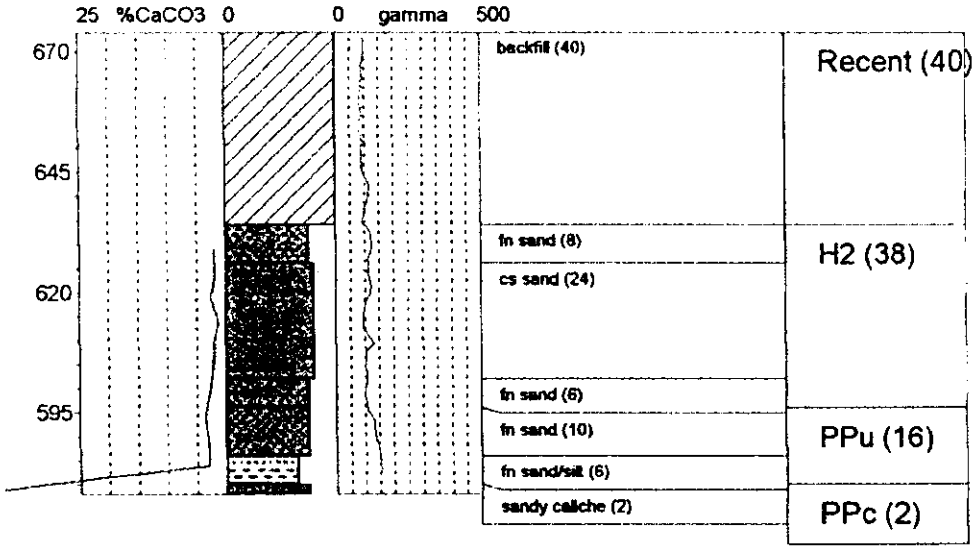

25 %CaCO3 0
0 gamma 500
670
645
620
595
backfill (40)
fn sand (9)
cs sand (9)
fn sand (2)
cs sand (5)
silt (1)
fn sand (2)
cs sand (14)
silt (8)
sandy caliche (2)
Recent (40)
H2 (42)
PPu (8)
PPc (2)


W10-125
25 %CaCO3 0
0 gamma 500
670
645
620
595
backfill (40)
sand/gravel (18)
cs sand (24)
silt (10)
sandy caliche (2)
Recent (40)
H1 (18)
H2 (24)
PPu (10)
PPc (2)

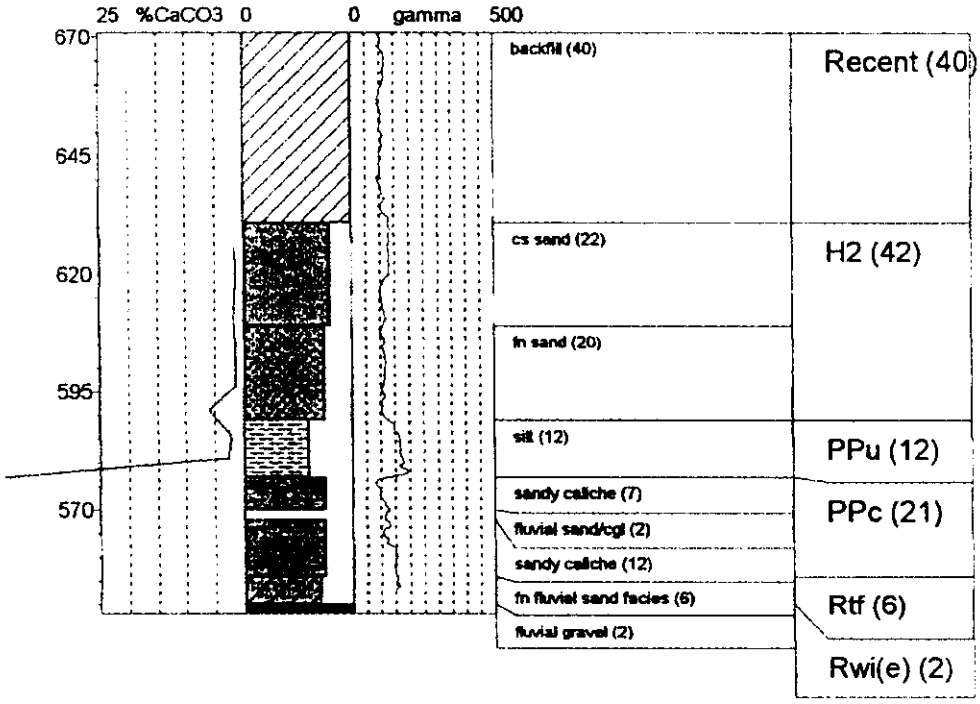
W10-134


25 %CaCO3 0
0 gamma 500
670
645
620
595
backfill (40)
cs sand (7)
fn sand (6)
cs sand (25)
fn sand/silt (10)
silt (6)
sandy caliche (2)
Recent (40)
H2 (38)
PPu (16)
PPc (1)

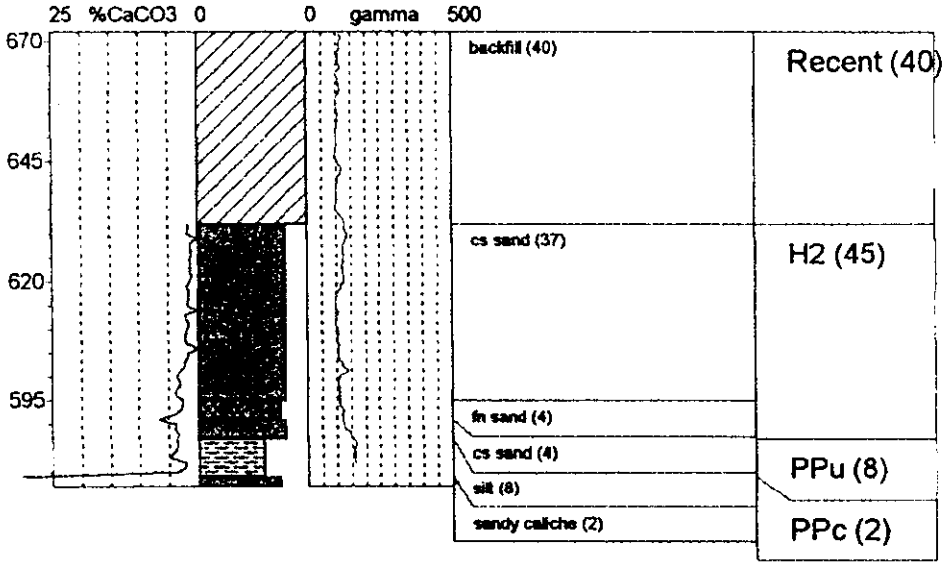
W10-135


25 %CaCO3 0
0 gamma 500
670
645
620
595
backfill (40)
fn sand (8)
cs sand (24)
fn sand (6)
fn sand (10)
fn sand/silt (6)
sandy caliche (2)
Recent (40)
H2 (38)
PPu (16)
PPc (2)

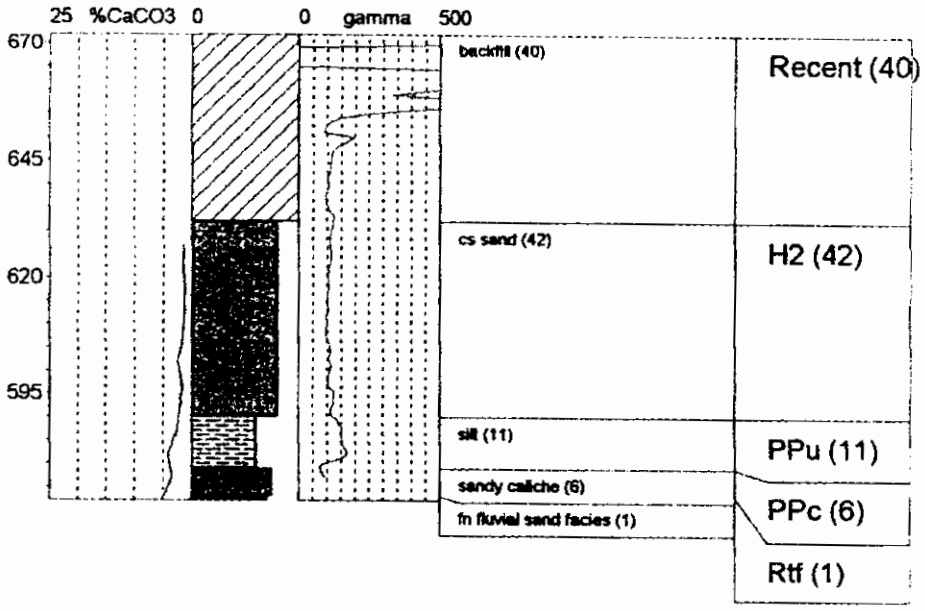
W10-141


25 %CaCO3 0
0 gamma 500
670
645
620
595
570
backfill (40)
cs sand (22)
fn sand (20)
slt (12)
sandy caliche (7)
fluvial sand/cgl (2)
sandy caliche (12)
fn fluvial sand facies (6)
fluvial gravel (2)
Recent (40)
H2 (42)
PPu (12)
PPc (21)
Rtf (6)
Rwi(e) (2)

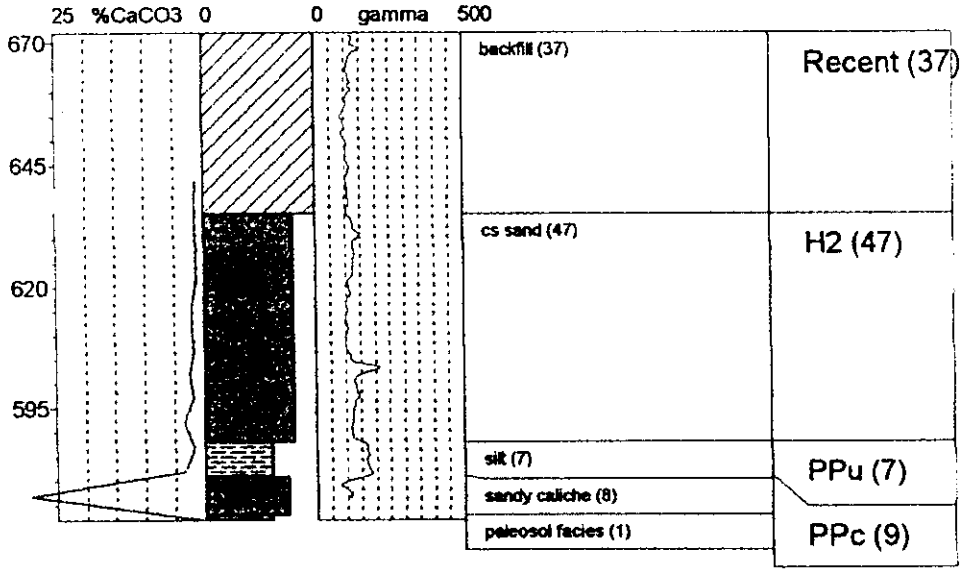
W10-143


25 %CaCO3 0
0 gamma 500
670
645
620
595
backfill (40)
cs sand (37)
fn sand (4)
cs sand (4)
silt (8)
sandy caliche (2)
Recent (40)
H2 (45)
PPu (8)
PPc (2)

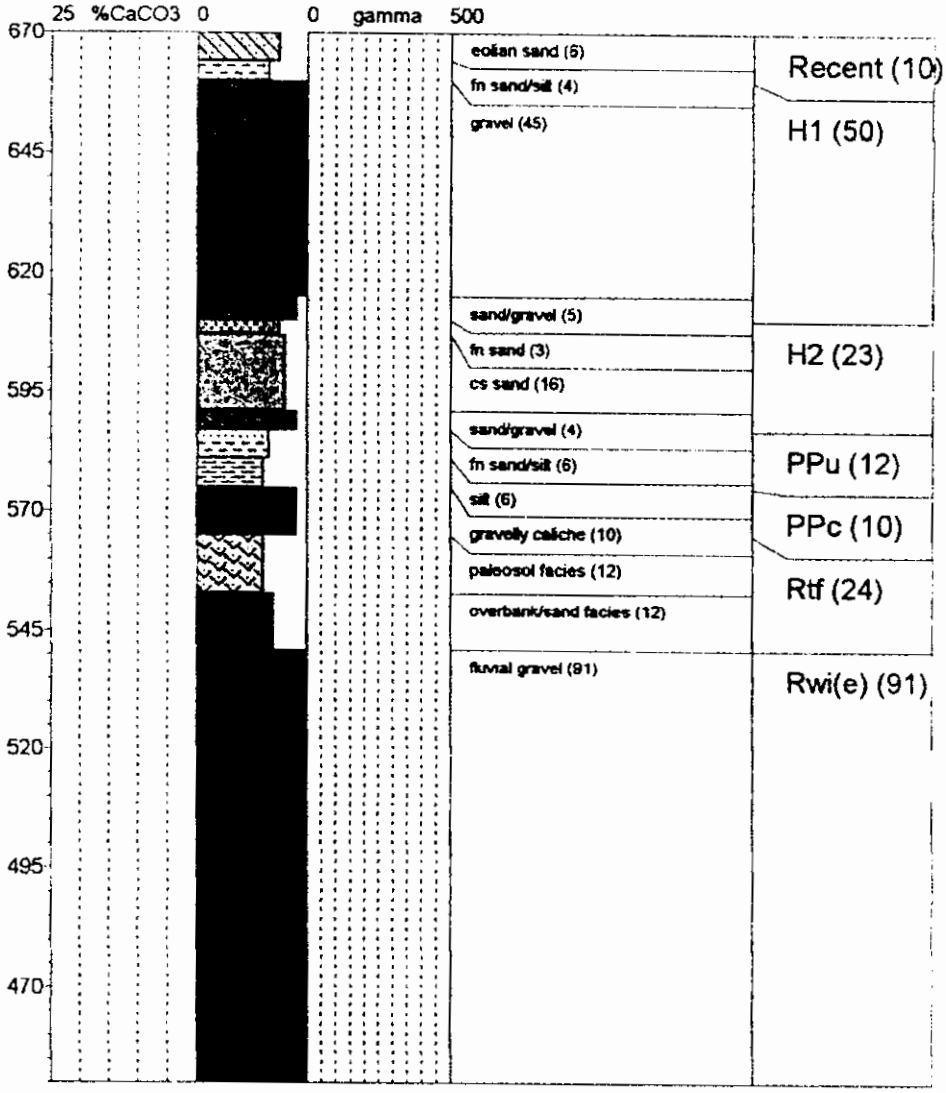
W10-147


25 %CaCO3 0
0 gamma 500
670
645
620
595
backfill (40)
cs sand (42)
silt (11)
sandy caliche (6)
fn fluvial sand facies (1)
Recent (40)
H2 (42)
PPu (11)
PPc (6)
Rtf (1)

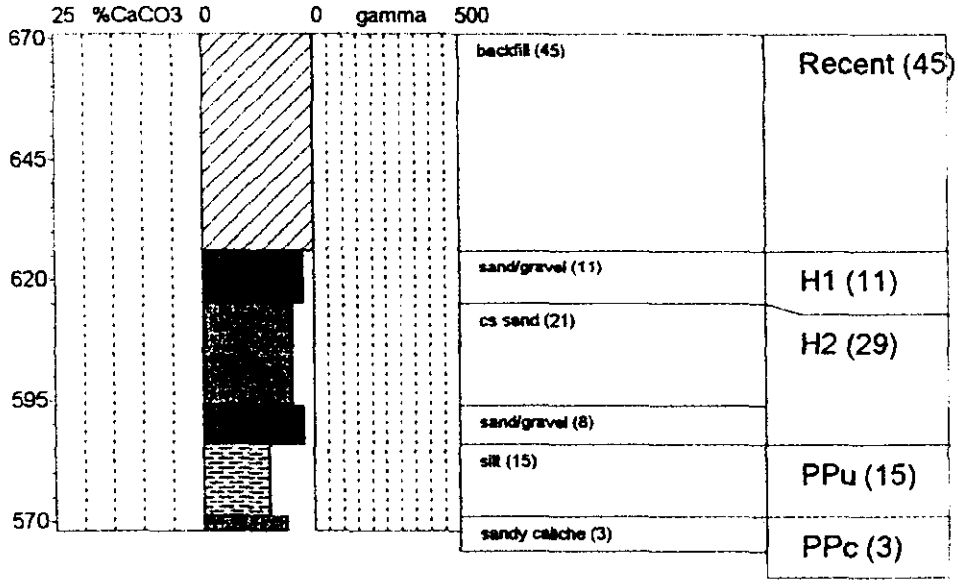
W10-148


25 %CaCO3 0
0 gamma 500
670
645
620
595
backfill (37)
cs sand (47)
silt (7)
sandy caliche (8)
paleosol facies (1)
Recent (37)
H2 (47)
PPu (7)
PPc (9)

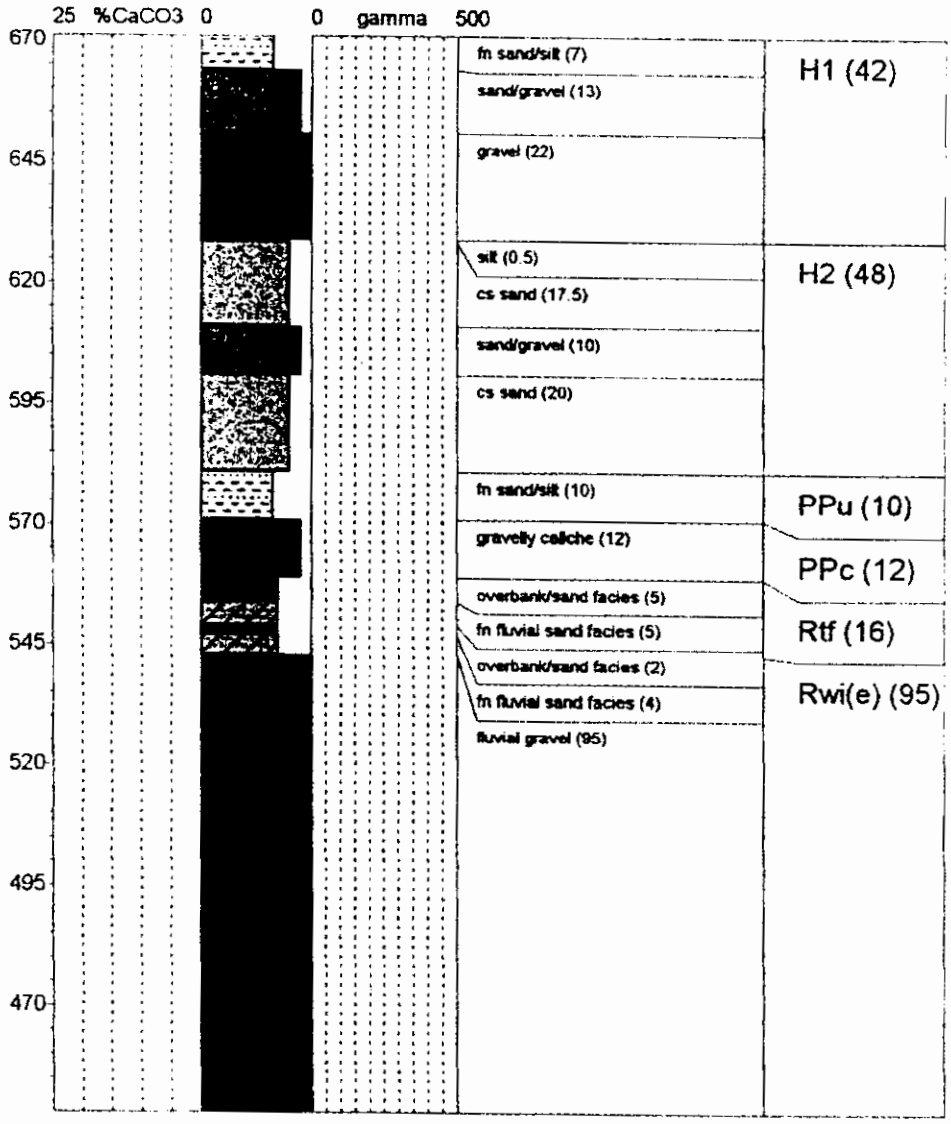
W10-16


25 %CaCO3 0
0 gamma 500
670
645
620
595
570
545
520
495
470
eolian sand (6)
fn sand/silt (4)
gravel (45)
sand/gravel (5)
fn sand (3)
cs sand (16)
sand/gravel (4)
fn sand/silt (6)
silt (6)
gravelly caliche (10)
paleosol facies (12)
overbank/sand facies (12)
fluvial gravel (91)
Recent (10)
H1 (50)
H2 (23)
PPu (12)
PPc (10)
Rtf (24)
Rwi(e) (91)

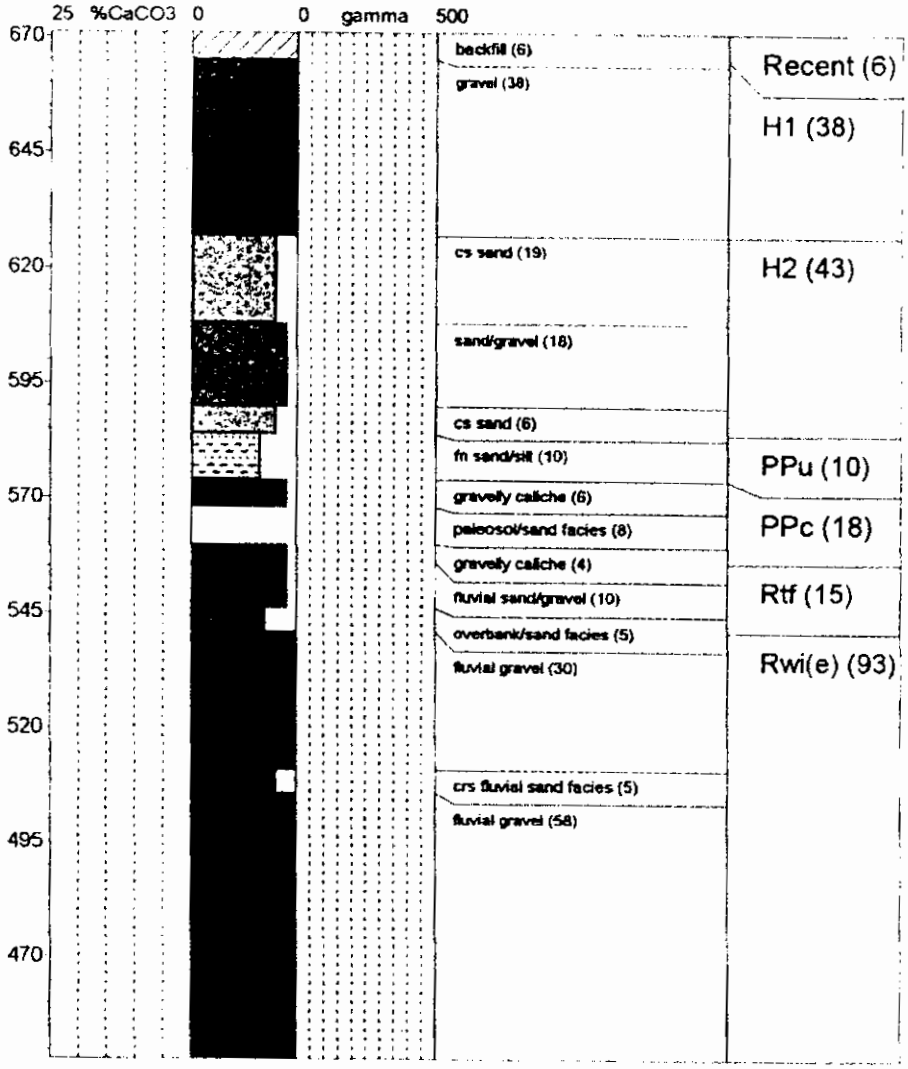
W10-161


25 %CaCO3 0
0 gamma 500
670
645
620
595
570
backfill (45)
sand/gravel (11)
cs sand (21)
sand/gravel (8)
silt (15)
sandy caliche (3)
Recent (45)
H1 (11)
H2 (29)
PPu (15)
PPc (3)

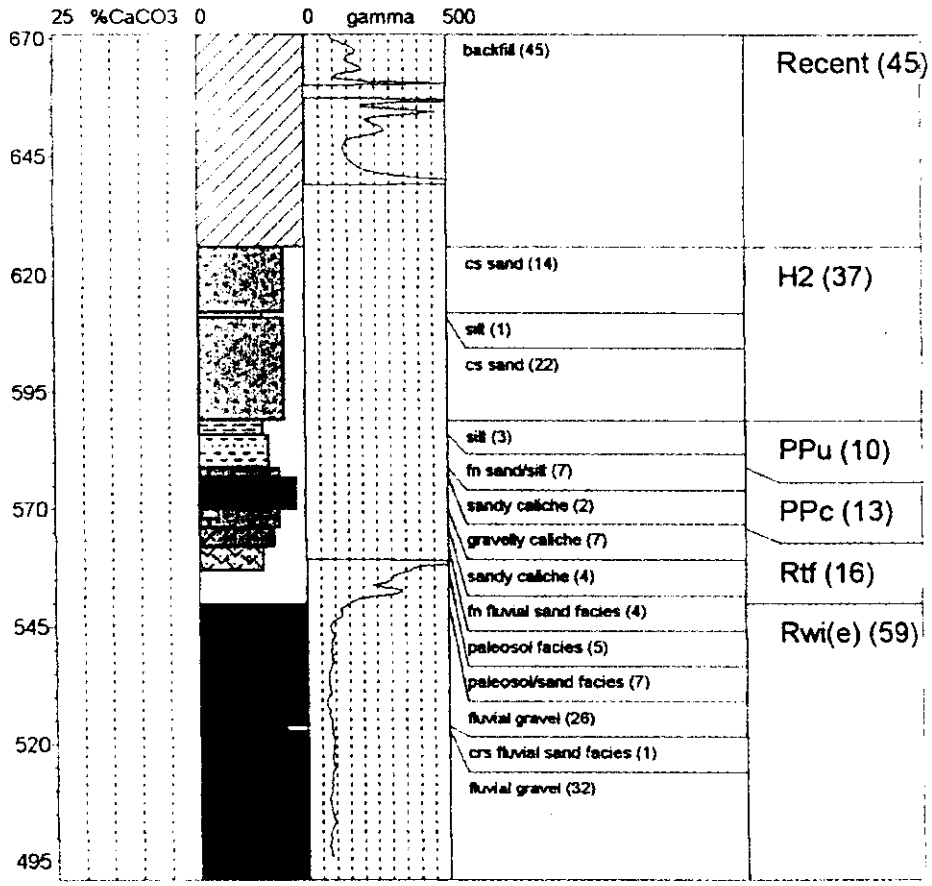
W10-17

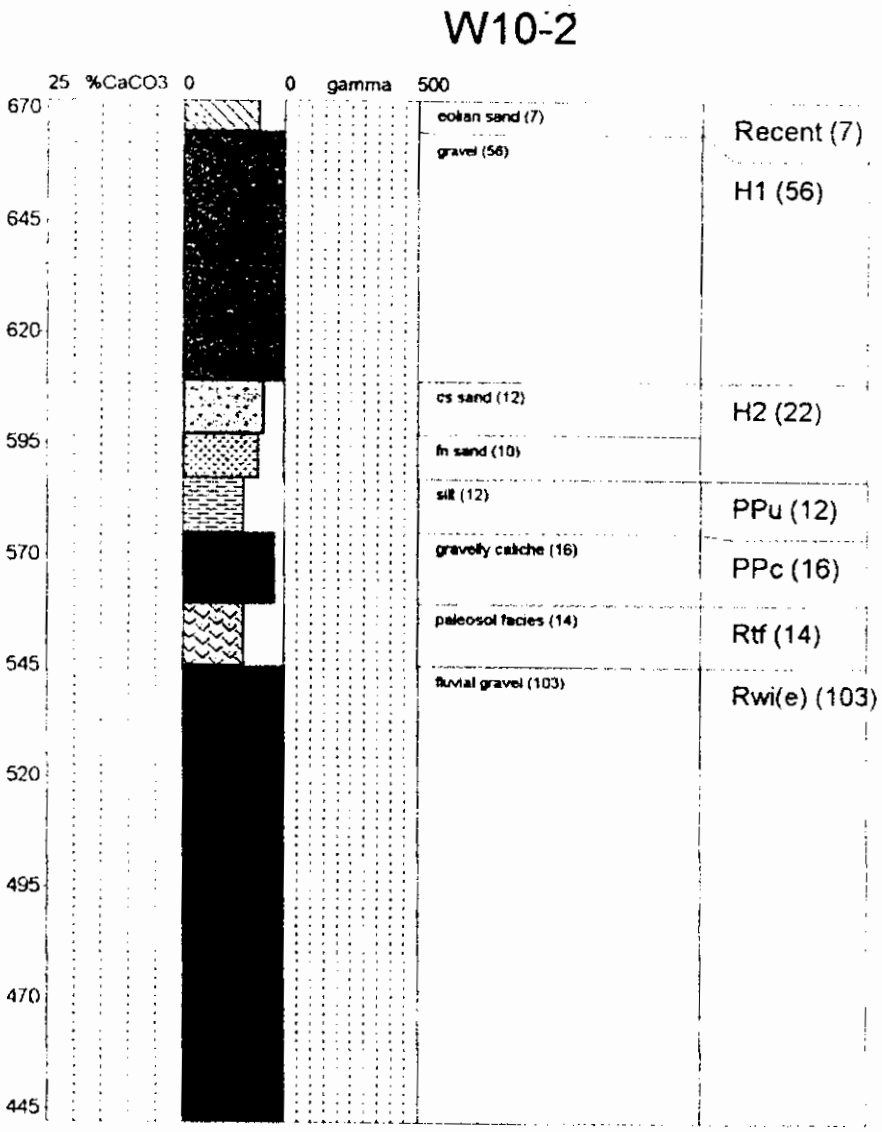

25 %CaCO3 0
0 gamma 500
670
645
620
595
570
545
520
495
470
fn sand/silt (7)
sand/gravel (13)
gravel (22)
silt (0.5)
cs sand (17.5)
sand/gravel (10)
cs sand (20)
fn sand/silt (10)
gravelly caliche (12)
overbank/sand facies (5)
fn fluvial sand facies (5)
overbank/sand facies (2)
fn fluvial sand facies (4)
fluvial gravel (95)
H1 (42)
H2 (48)
PPu (10)
PPc (12)
Rtf (16)
Rwi(e) (95)

W10-18

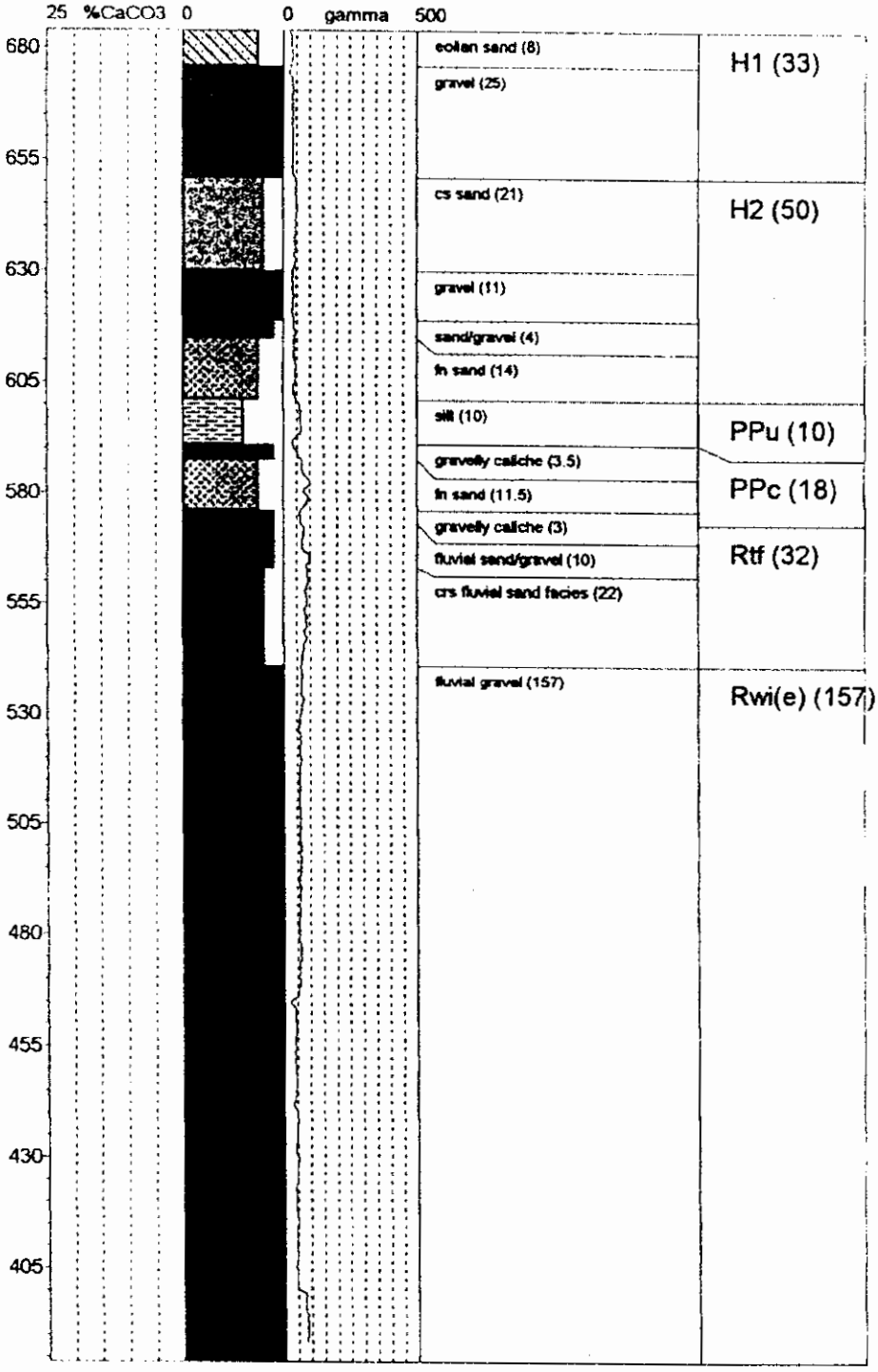

25 %CaCO3 0
0 gamma 500
670
645
620
595
570
545
520
495
470
backfill (6)
gravel (38)
cs sand (19)
sand/gravel (18)
cs sand (6)
fn sand/silt (10)
gravelly caliche (6)
paleosol/sand facies (8)
gravelly caliche (4)
fluvial sand/gravel (10)
overbank/sand facies (5)
fluvial gravel (30)
crs fluvial sand facies (5)
fluvial gravel (58)
Recent (6)
H1 (38)
H2 (43)
PPu (10)
PPc (18)
Rtf (15)
Rwi(e) (93)

W10-196

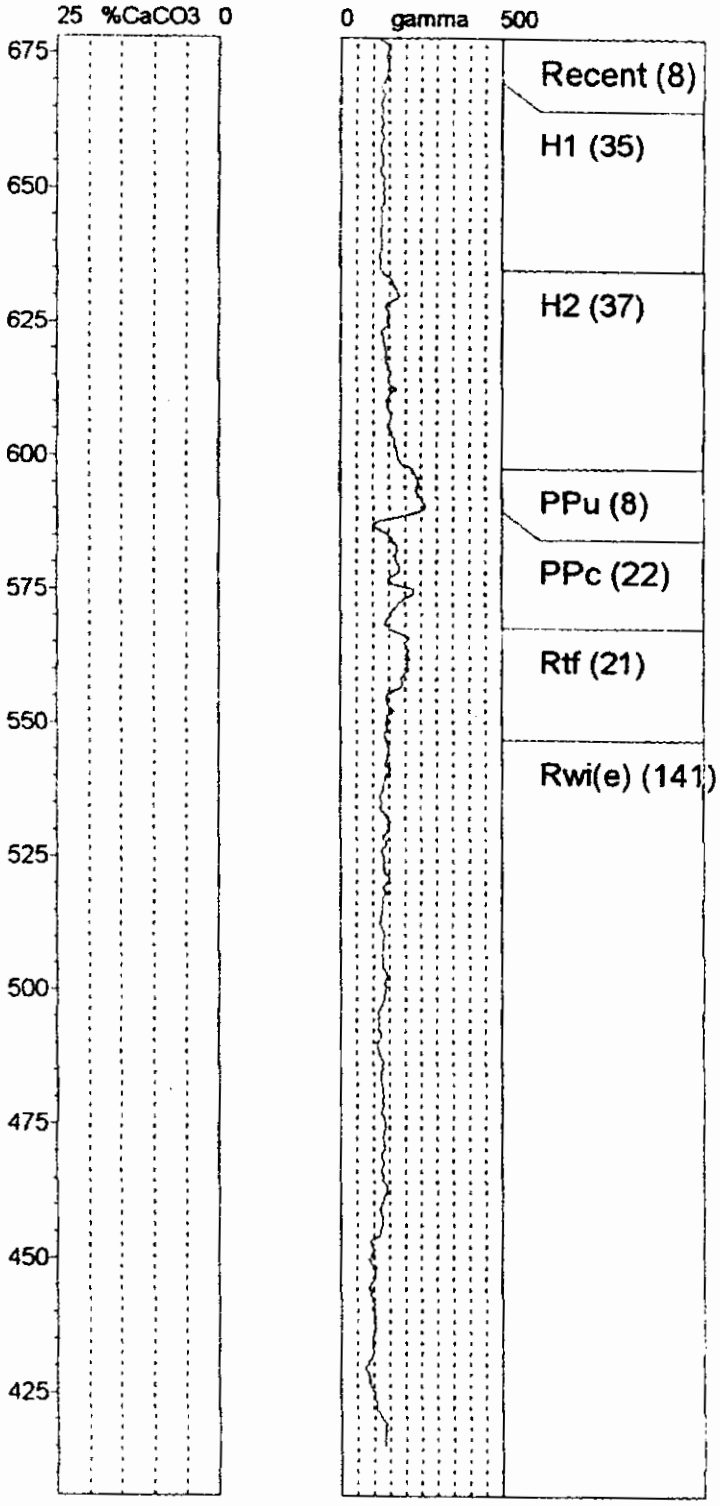

25 %CaCO3 0
0 gamma 500
670
645
620
595
570
545
520
495
backfill (45)
cs sand (14)
slt (1)
cs sand (22)
slt (3)
fn sand/slt (7)
sandy caliche (2)
gravelly caliche (7)
sandy caliche (4)
fn fluvial sand facies (4)
paleosol facies (5)
paleosol/sand facies (7)
fluvial gravel (26)
crs fluvial sand facies (1)
fluvial gravel (32)
Recent (45)
H2 (37)
PPu (10)
PPc (13)
Rtf (16)
Rwi(e) (59)


W10-2
25 %CaCO3 0
0 gamma 500
670
645
620
595
570
545
520
495
470
445
eolian sand (7)
gravel (56)
cs sand (12)
fn sand (10)
silt (12)
gravelly caliche (16)
paleosol facies (14)
fluvial gravel (103)
Recent (7)
H1 (56)
H2 (22)
PPu (12)
PPc (16)
Rtf (14)
Rwi(e) (103)

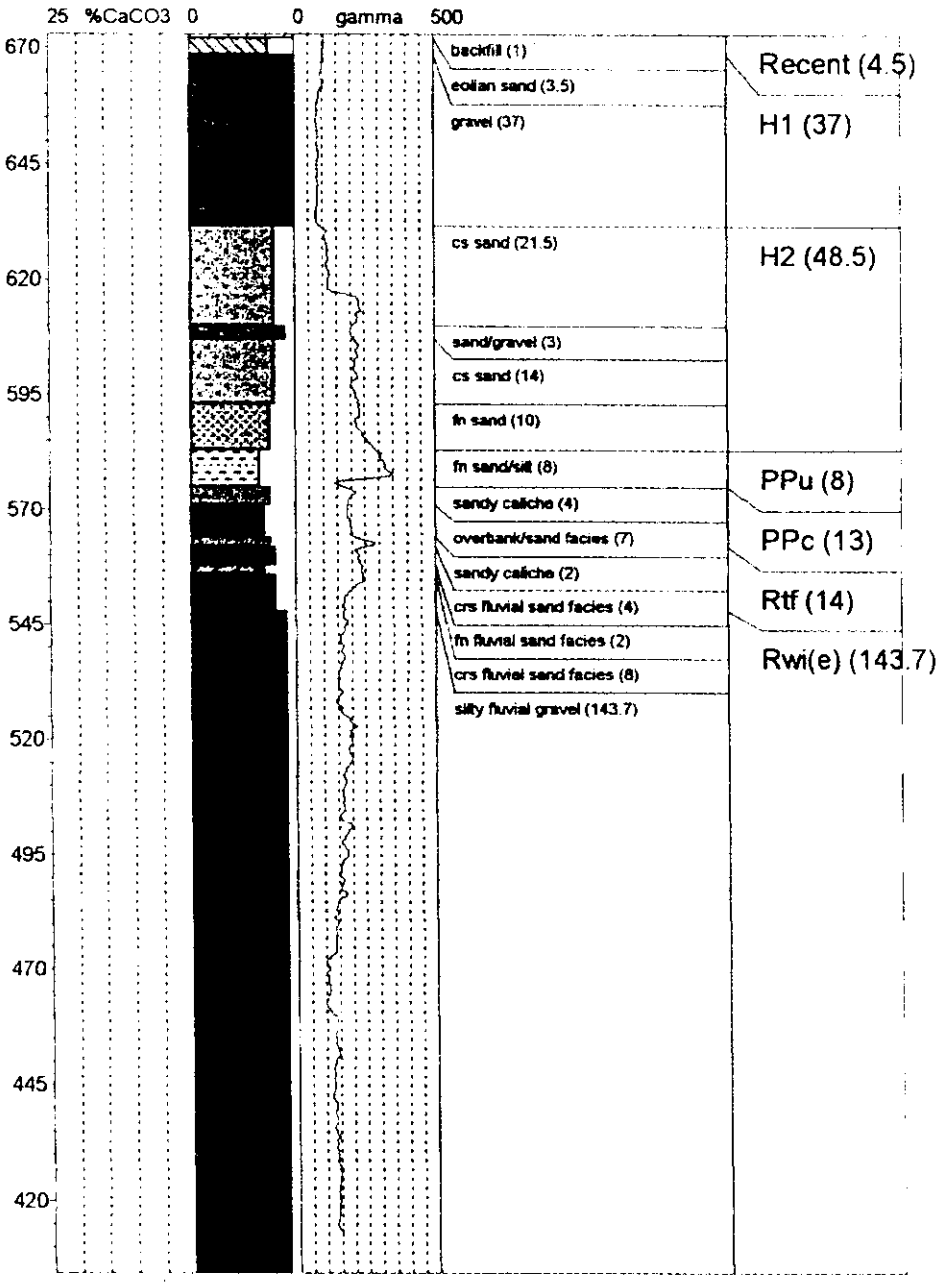
W10-22


25 %CaCO3 0
0 gamma 500
680
655
630
605
580
555
530
505
480
455
430
405
eolian sand (8)
gravel (25)
cs sand (21)
gravel (11)
sand/gravel (4)
fn sand (14)
silt (10)
gravelly caliche (3.5)
fn sand (11.5)
gravelly caliche (3)
fluvial sand/gravel (10)
crs fluvial sand facies (22)
fluvial gravel (157)
H1 (33)
H2 (50)
PPu (10)
PPc (18)
Rtf (32)
Rwi(e) (157)

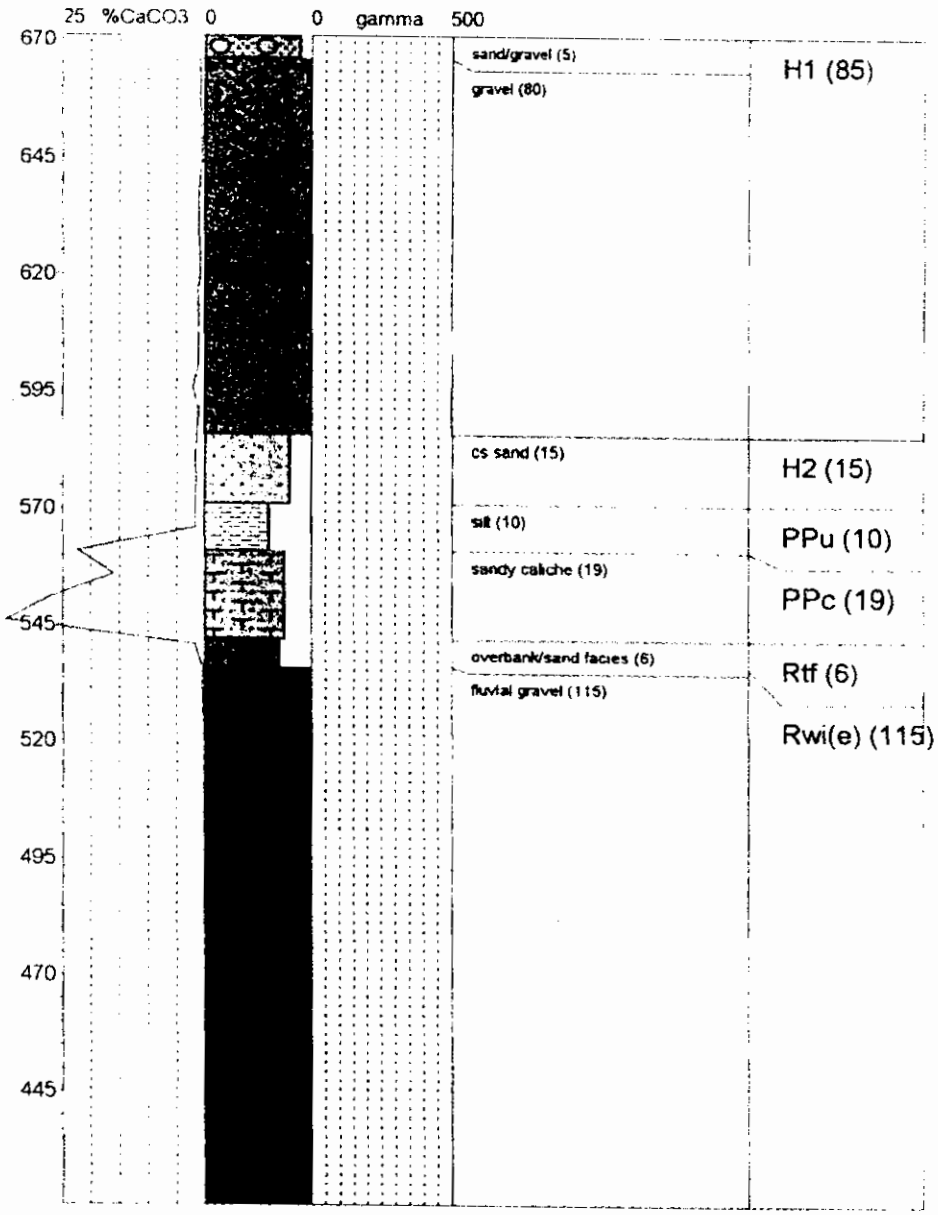
W10-23


25 %CaCO3 0
0 gamma 500
675
650
625
600
575
550
525
500
475
450
425
Recent (8)
H1 (35)
H2 (37)
PPu (8)
PPc (22)
Rtf (21)
Rwi(e) (141)

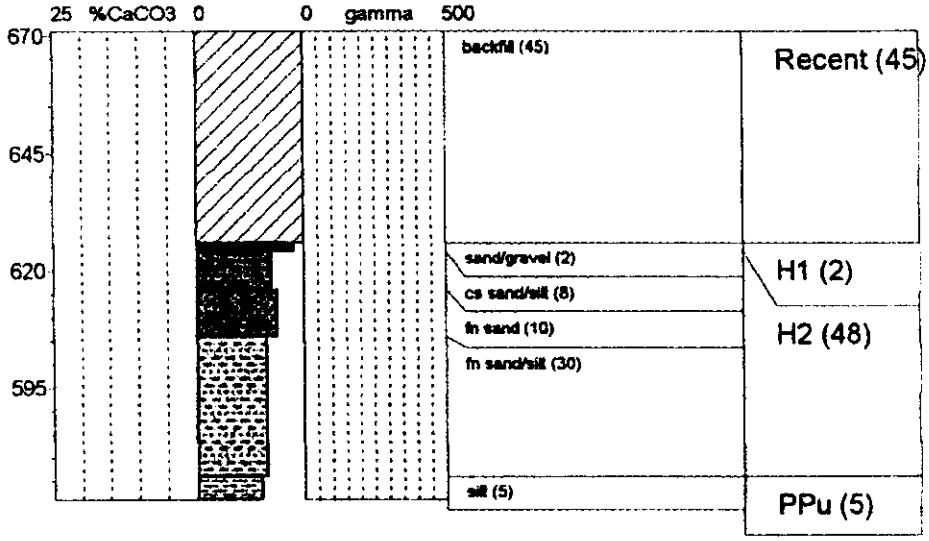
W10-27


25 %CaCO3 0
0 gamma 500
670
645
620
595
570
545
520
495
470
445
420
backfill (1)
eolian sand (3.5)
gravel (37)
cs sand (21.5)
sand/gravel (3)
cs sand (14)
fn sand (10)
fn sand/silt (8)
sandy caliche (4)
overbank/sand facies (7)
sandy caliche (2)
crs fluvial sand facies (4)
fn fluvial sand facies (2)
crs fluvial sand facies (8)
silty fluvial gravel (143.7)
Recent (4.5)
H1 (37)
H2 (48.5)
PPu (8)
PPc (13)
Rtf (14)
Rwi(e) (143.7)

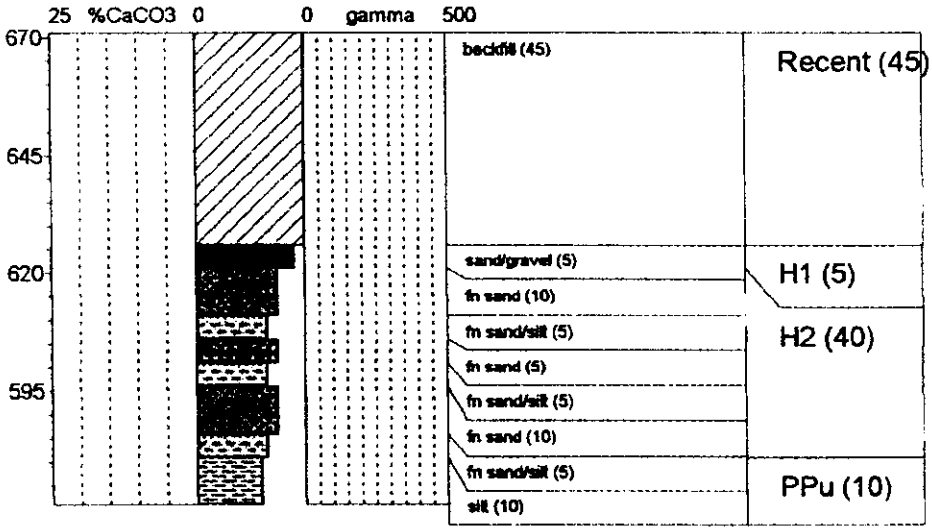
W10-5


25 %CaCO3 0
0 gamma 500
670
645
620
595
570
545
520
495
470
445
sand/gravel (5)
gravel (80)
cs sand (15)
silt (10)
sandy caliche (19)
overbank/sand facies (6)
fluvial gravel (115)
H1 (85)
H2 (15)
PPu (10)
PPc (19)
Rtf (6)
Rwi(e) (115)

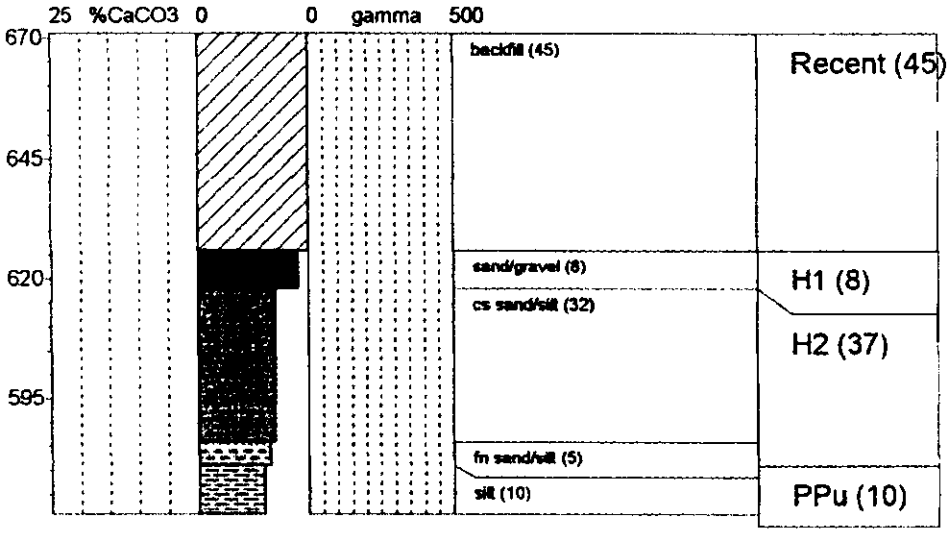
W10-88


25 %CaCO3 0
0 gamma 500
670
645
620
595
backfill (45)
sand/gravel (2)
cs sand/silt (8)
fn sand (10)
fn sand/silt (30)
silt (5)
Recent (45)
H1 (2)
H2 (48)
PPu (5)

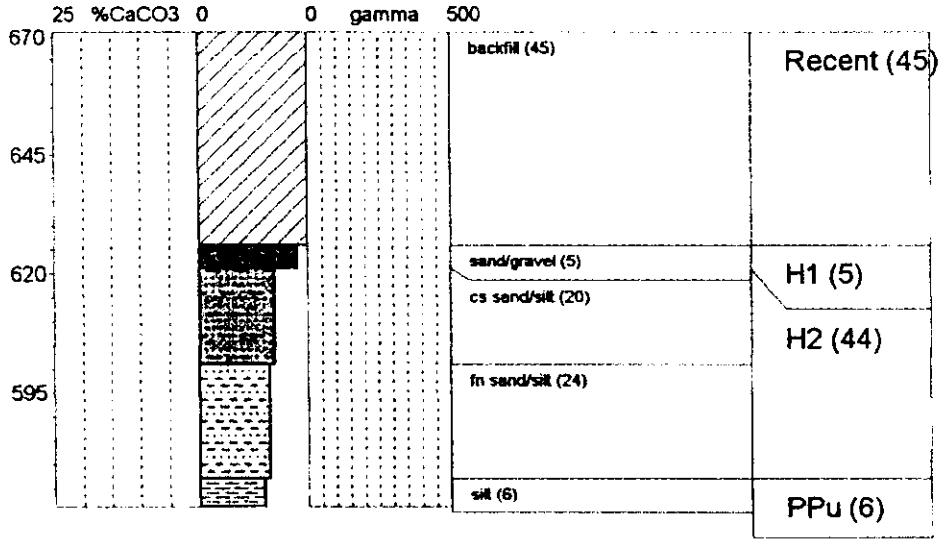
W10-89


25 %CaCO3 0
0 gamma 500
670
645
620
595
backfill (45)
Recent (45)
sand/gravel (5)
fn sand (10)
H1 (5)
fn sand/silt (5)
fn sand (5)
fn sand/silt (5)
fn sand (10)
H2 (40)
fn sand/silt (5)
silt (10)
PPu (10)

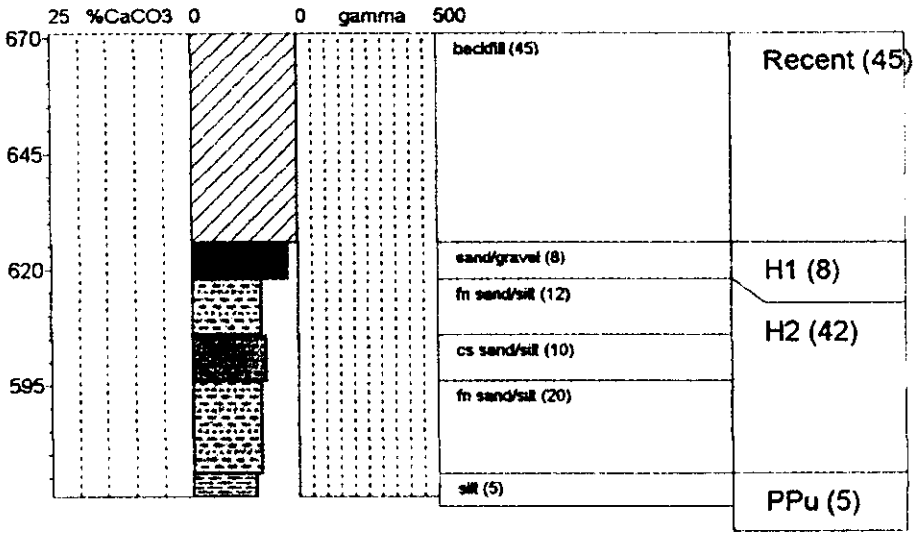
W10-90

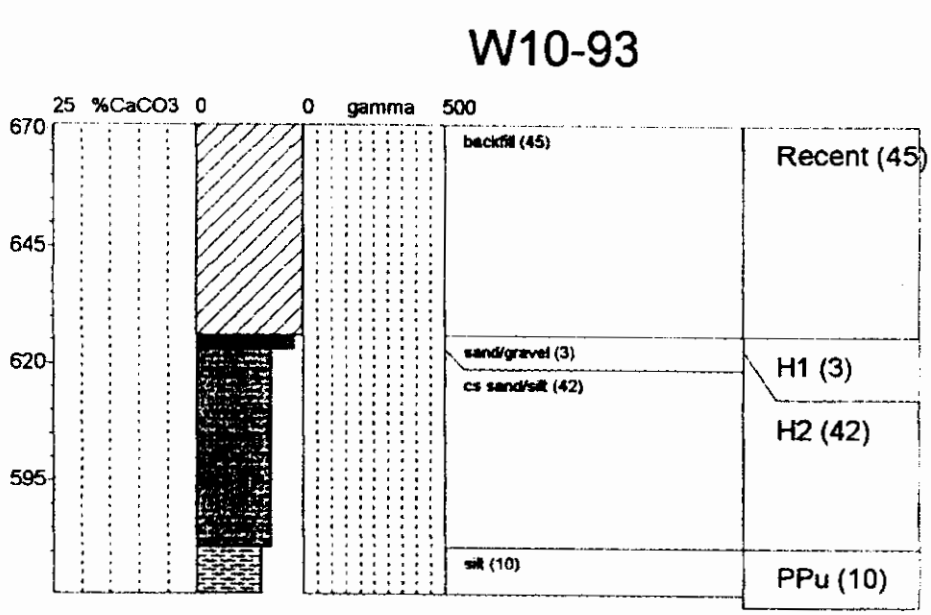

25 %CaCO3 0
0 gamma 500
670
645
620
595
backfill (45)
sand/gravel (8)
cs sand/silt (32)
fn sand/silt (5)
silt (10)
Recent (45)
H1 (8)
H2 (37)
PPu (10)

W10-91

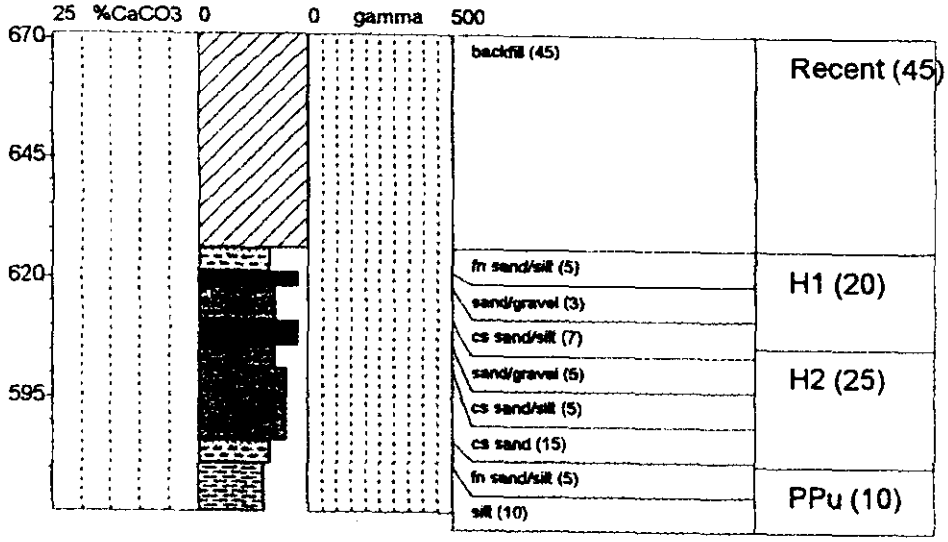

25 %CaCO3 0
0 gamma 500
670
645
620
595
backfill (45)
sand/gravel (5)
cs sand/silt (20)
fn sand/silt (24)
silt (6)
Recent (45)
H1 (5)
H2 (44)
PPu (6)

W10-92

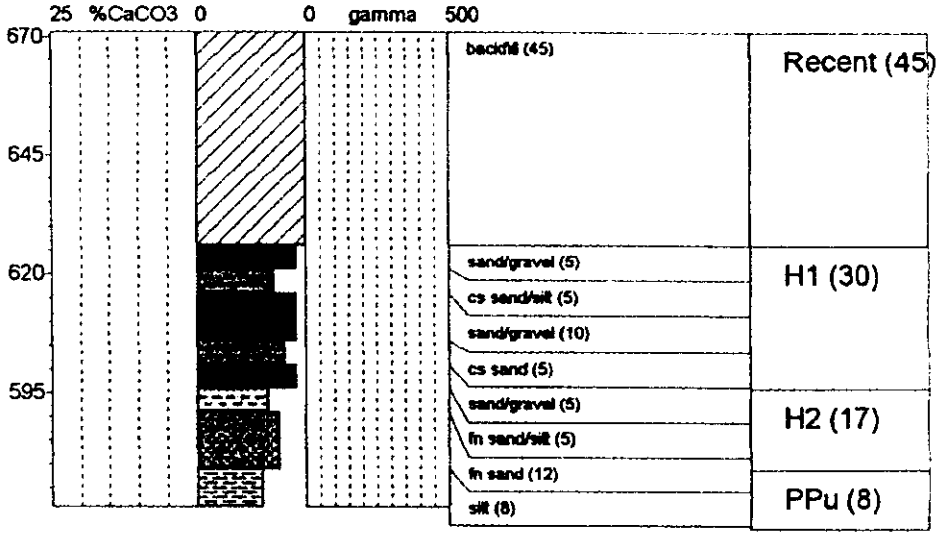

25 %CaCO3 0
0 gamma 500
670
645
620
595
backfill (45)
sand/gravel (8)
fn sand/silt (12)
cs sand/silt (10)
fn sand/silt (20)
silt (5)
Recent (45)
H1 (8)
H2 (42)
PPu (5)


W10-93
25 %CaCO3 0
0 gamma 500
670
645
620
595
backfill (45)
sand/gravel (3)
cs sand/silt (42)
silt (10)
Recent (45)
H1 (3)
H2 (42)
PPu (10)

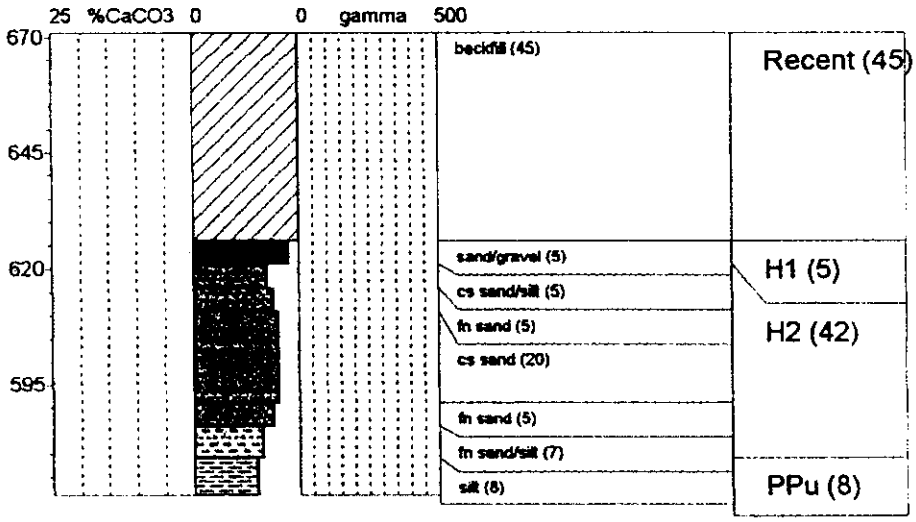
W10-94


25 %CaCO3 0
0 gamma 500
670
645
620
595
backfill (45)
fn sand/silt (5)
sand/gravel (3)
cs sand/silt (7)
sand/gravel (5)
cs sand/silt (5)
cs sand (15)
fn sand/silt (5)
silt (10)
Recent (45)
H1 (20)
H2 (25)
PPu (10)

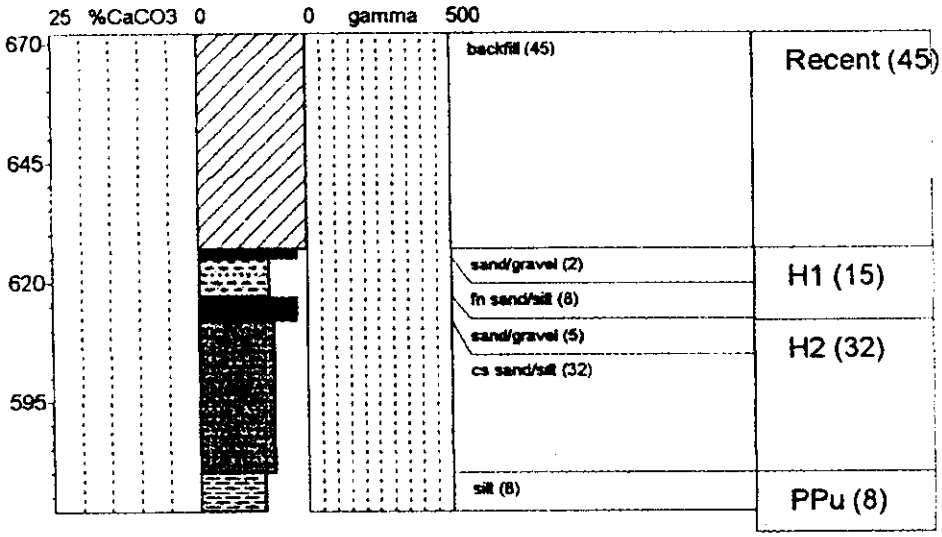
W10-95


25 %CaCO3 0
0 gamma 500
670
645
620
595
backfill (45)
Recent (45)
sand/gravel (5)
cs sand/silt (5)
sand/gravel (10)
cs sand (5)
H1 (30)
sand/gravel (5)
fn sand/silt (5)
H2 (17)
fn sand (12)
silt (8)
PPu (8)

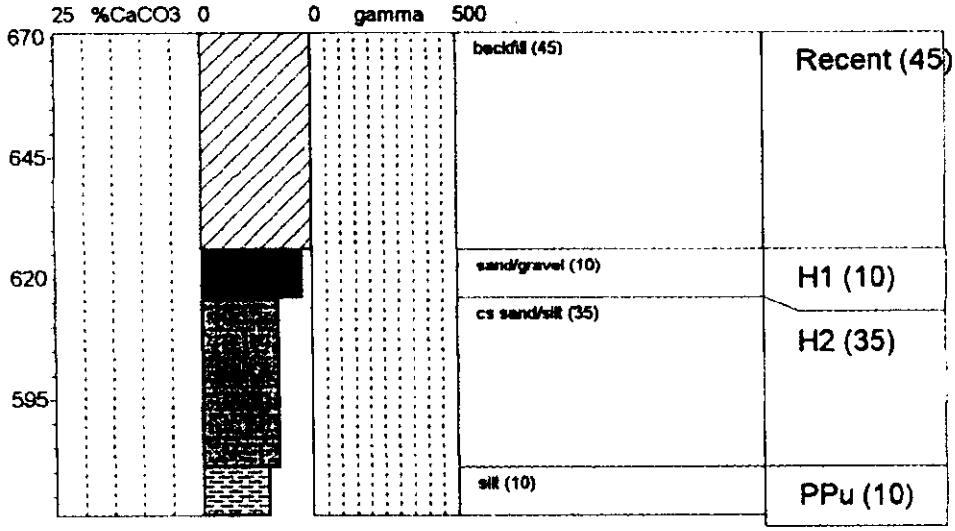
W10-96


25 %CaCO3 0
0 gamma 500
670
645
620
595
backfill (45)
sand/gravel (5)
cs sand/silt (5)
fn sand (5)
cs sand (20)
fn sand (5)
fn sand/silt (7)
silt (8)
Recent (45)
H1 (5)
H2 (42)
PPu (8)

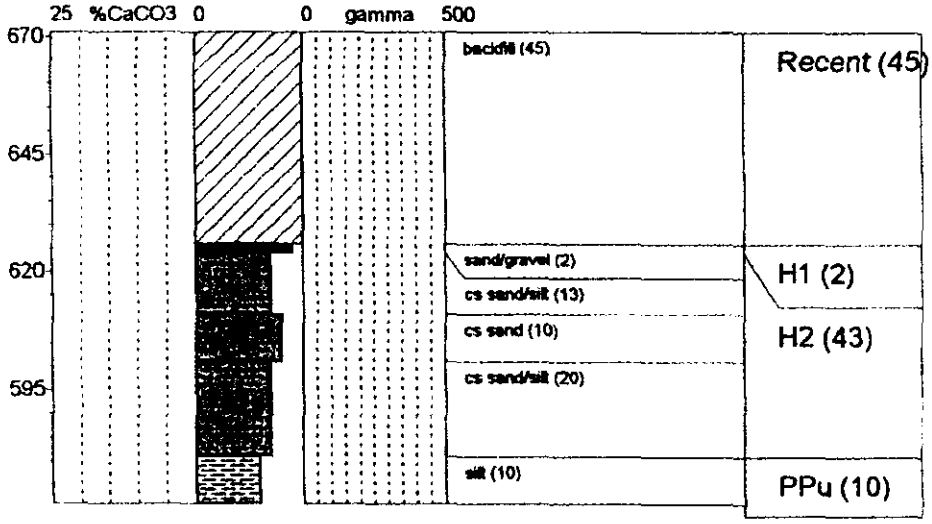
W10-97


25 %CaCO3 0
0 gamma 500
670
645
620
595
backfill (45)
sand/gravel (2)
fn sand/silt (8)
sand/gravel (5)
cs sand/silt (32)
silt (8)
Recent (45)
H1 (15)
H2 (32)
PPu (8)

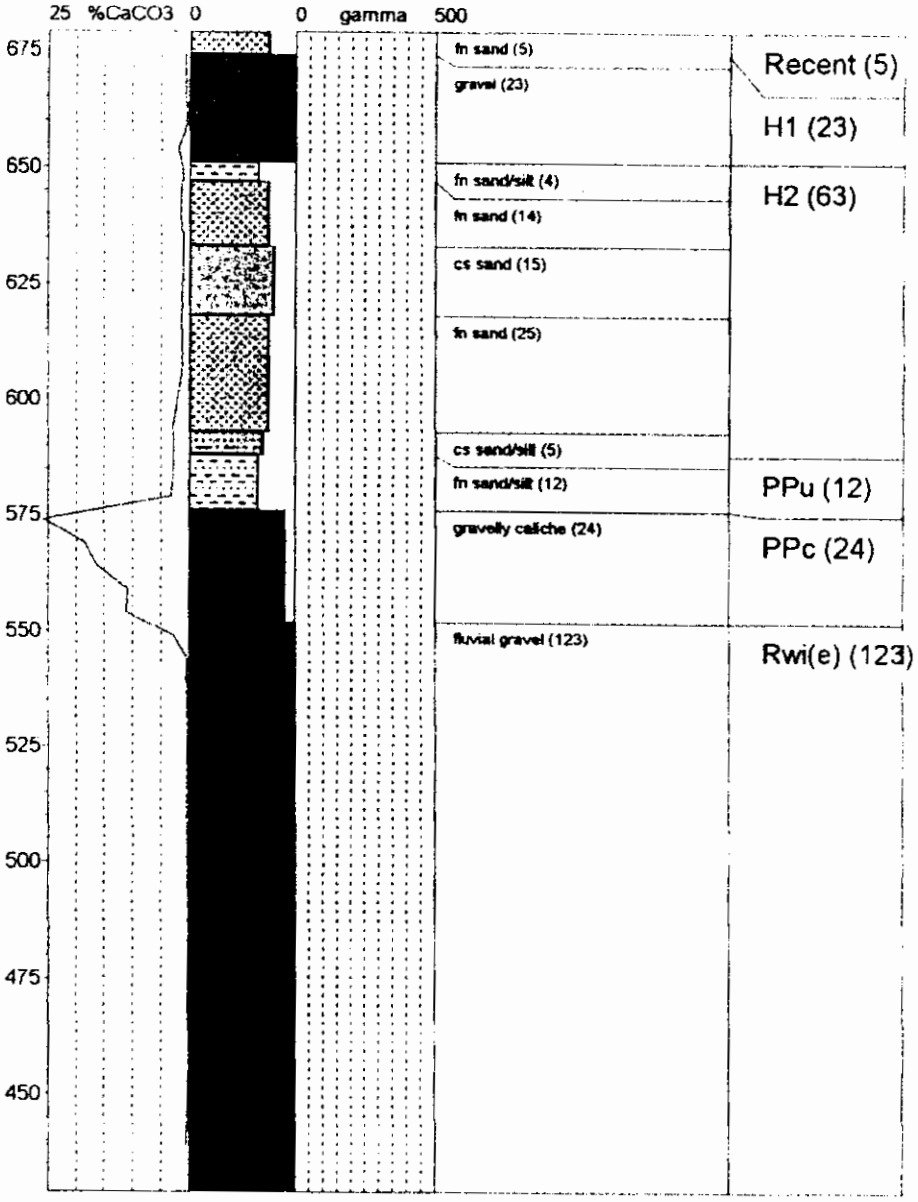
W10-98


25 %CaCO3 0
0 gamma 500
670
645
620
595
backfill (45)
sand/gravel (10)
cs sand/silt (35)
silt (10)
Recent (45)
H1 (10)
H2 (35)
PPu (10)

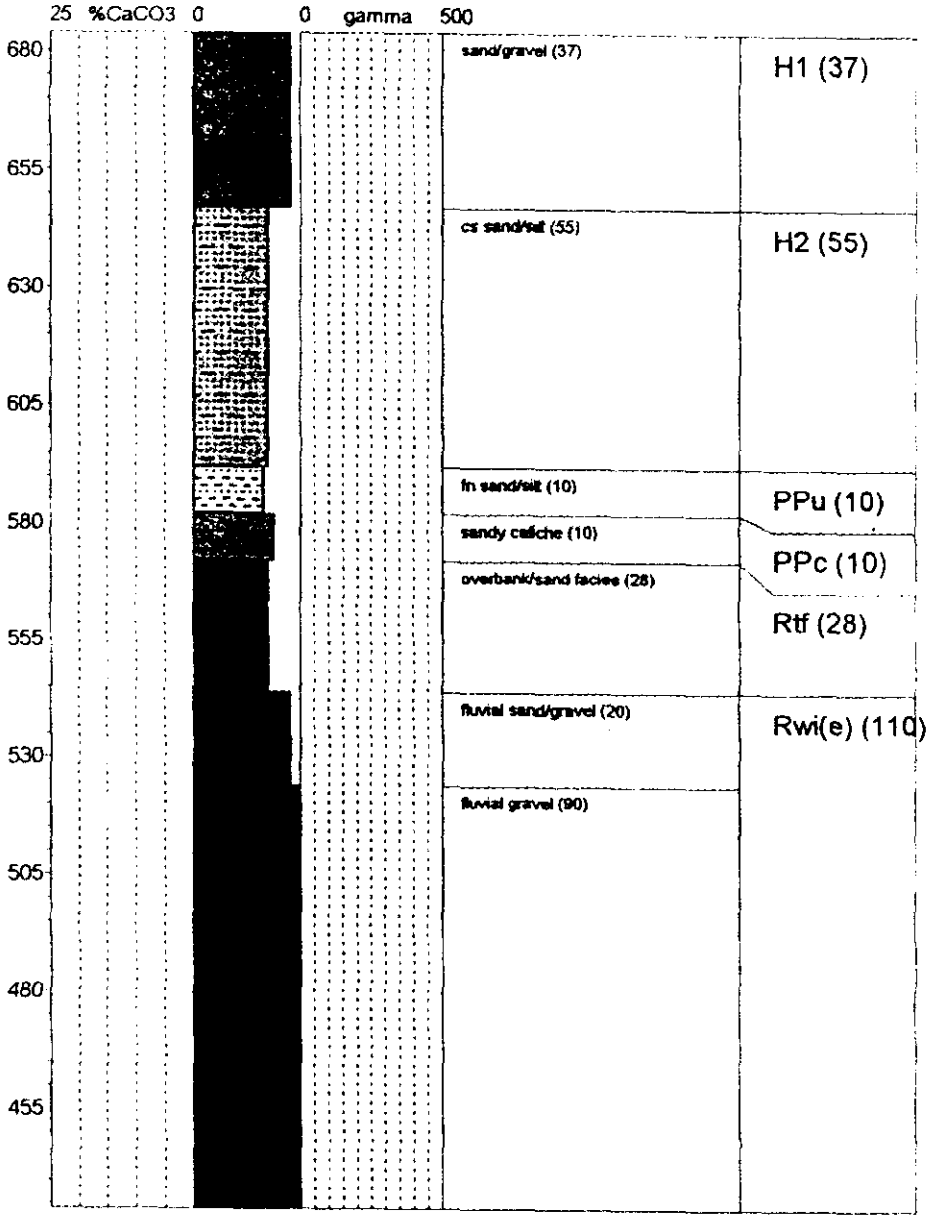
W10-99

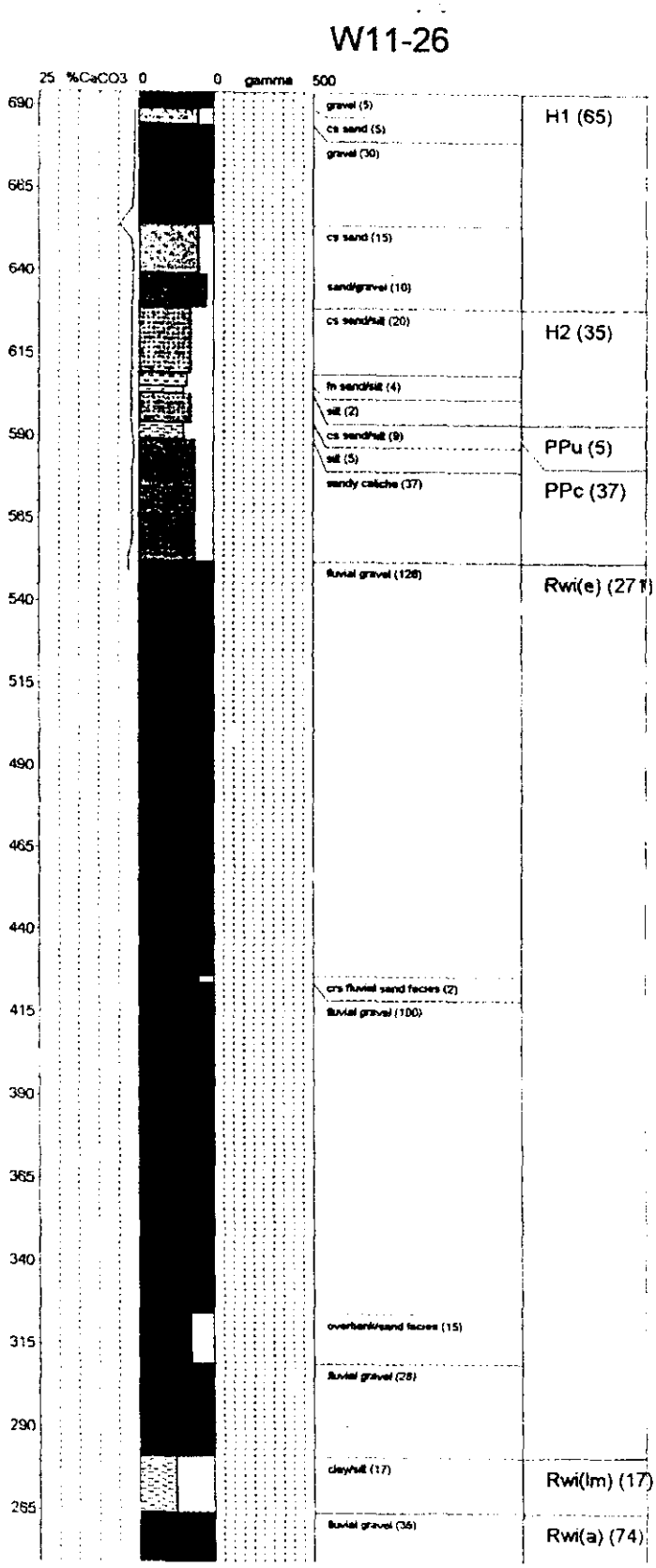

25 %CaCO3 0
0 gamma 500
670
645
620
595
backfill (45)
sand/gravel (2)
cs sand/silt (13)
cs sand (10)
cs sand/silt (20)
silt (10)
Recent (45)
H1 (2)
H2 (43)
PPu (10)

W11-12

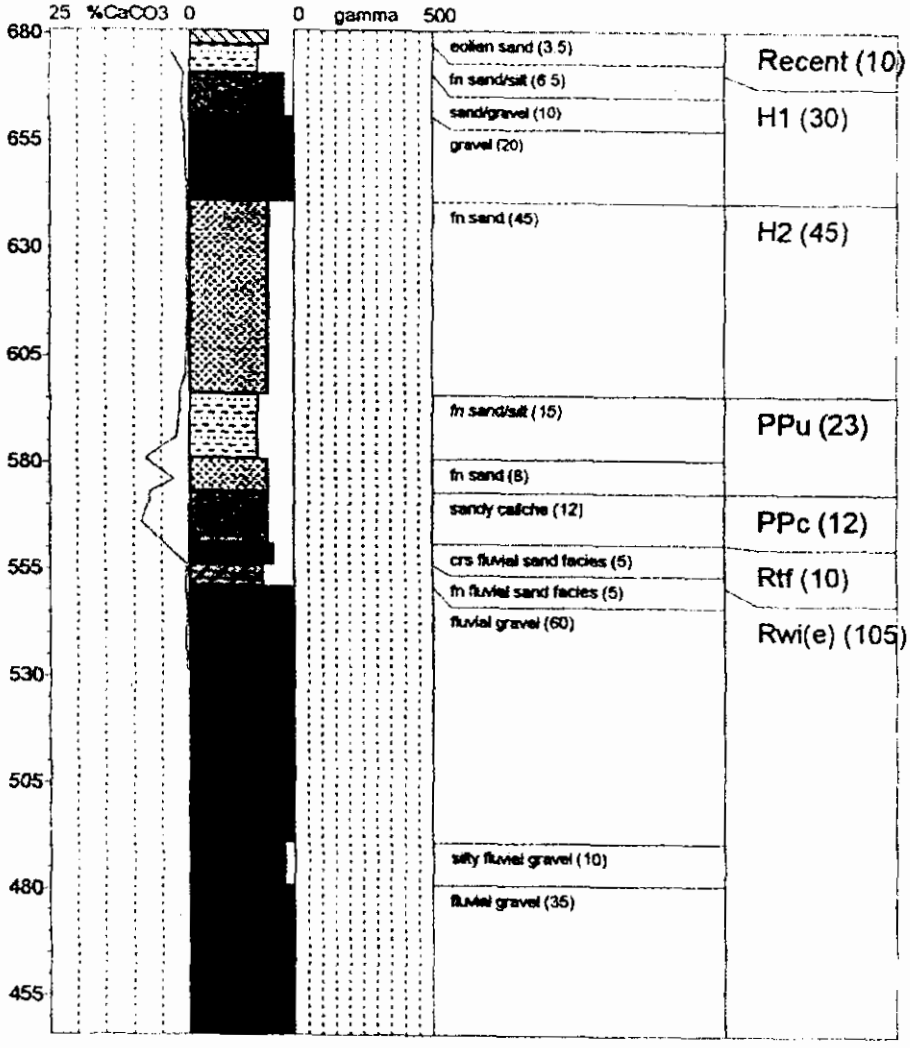

25 %CaCO3 0
0 gamma 500
675
650
625
600
575
550
525
500
475
450
fn sand (5)
gravel (23)
fn sand/silt (4)
fn sand (14)
cs sand (15)
fn sand (25)
cs sand/silt (5)
fn sand/silt (12)
gravelly caliche (24)
fluvial gravel (123)
Recent (5)
H1 (23)
H2 (63)
PPu (12)
PPc (24)
Rwi(e) (123)

W11-24

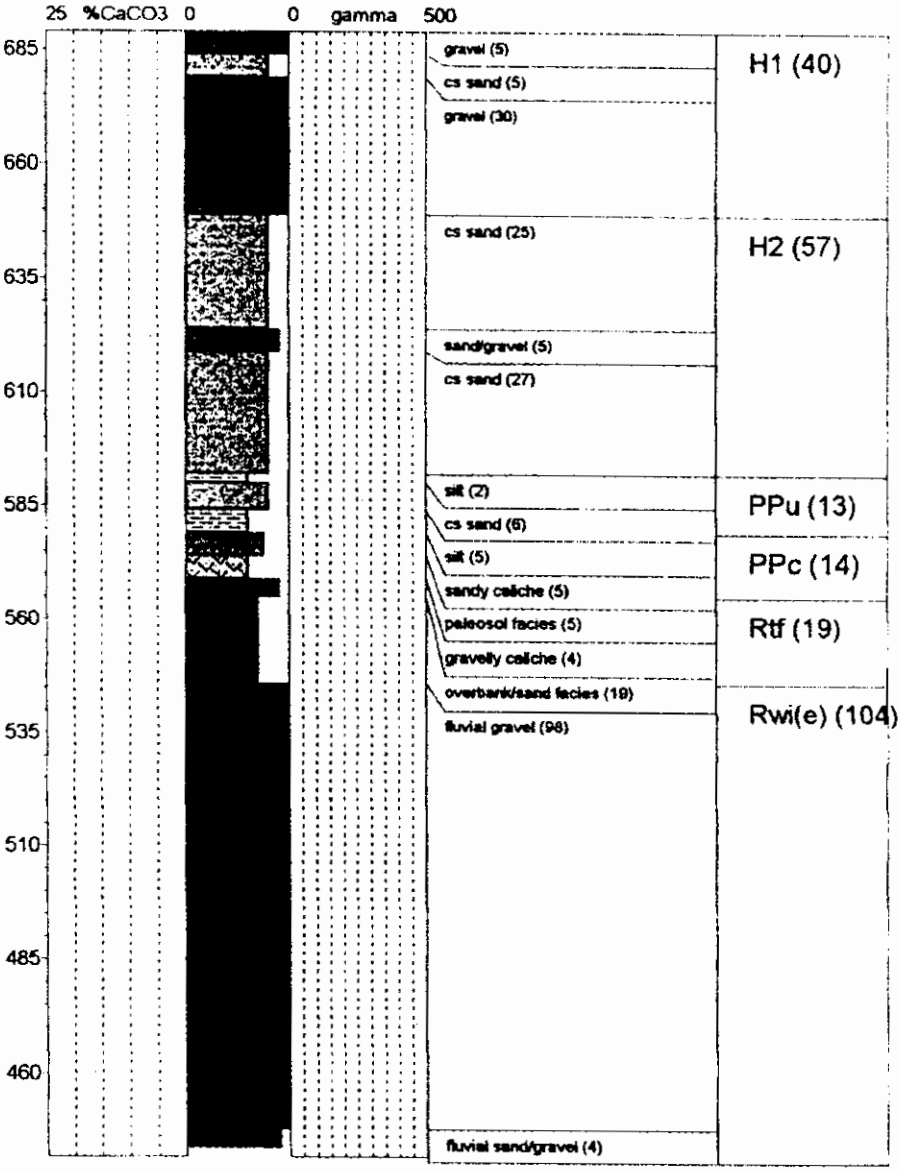

25 %CaCO3 0
0 gamma 500
680
655
630
605
580
555
530
505
480
455
sand/gravel (37)
cs sand/silt (55)
fn sand/silt (10)
sandy caliche (10)
overbank/sand facies (28)
fluvial sand/gravel (20)
fluvial gravel (90)
H1 (37)
H2 (55)
PPu (10)
PPc (10)
Rtf (28)
Rwi(e) (110)


W11-26
25 %CaCO3 0
0 gamma 500
690
685
640
615
590
585
540
515
490
465
440
415
390
365
340
315
290
265
gravel (5)
cs sand (5)
gravel (30)
cs sand (15)
sand/gravel (10)
cs sand/slt (20)
fn sand/slt (4)
slt (2)
cs sand/slt (9)
slt (5)
sandy caliche (37)
fluvial gravel (128)
crs fluvial sand facies (2)
fluvial gravel (100)
overbank/sand facies (15)
fluvial gravel (28)
clay/slt (17)
fluvial gravel (36)
H1 (65)
H2 (35)
PPu (5)
PPc (37)
Rwi(e) (271)
Rwi(lm) (17)
Rwi(a) (74)

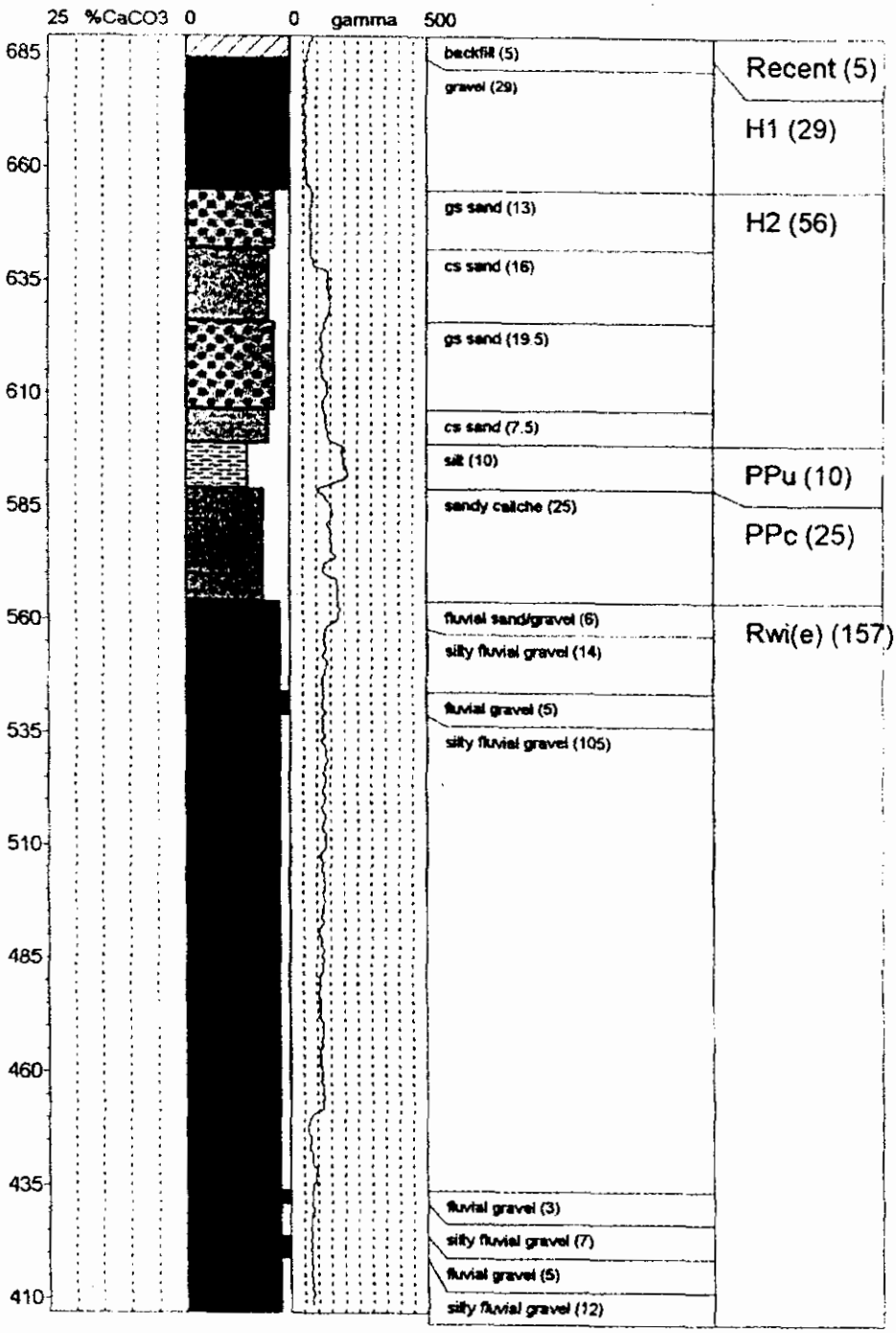
W11-27


25 %CaCO3 0
0 gamma 500
680
655
630
605
580
555
530
505
480
455
eolian sand (3.5)
fn sand/silt (6.5)
sand/gravel (10)
gravel (20)
fn sand (45)
fn sand/silt (15)
fn sand (8)
sandy caliche (12)
crs fluvial sand facies (5)
fn fluvial sand facies (5)
fluvial gravel (60)
silty fluvial gravel (10)
fluvial gravel (35)
Recent (10)
H1 (30)
H2 (45)
PPu (23)
PPc (12)
Rtf (10)
Rwi(e) (105)

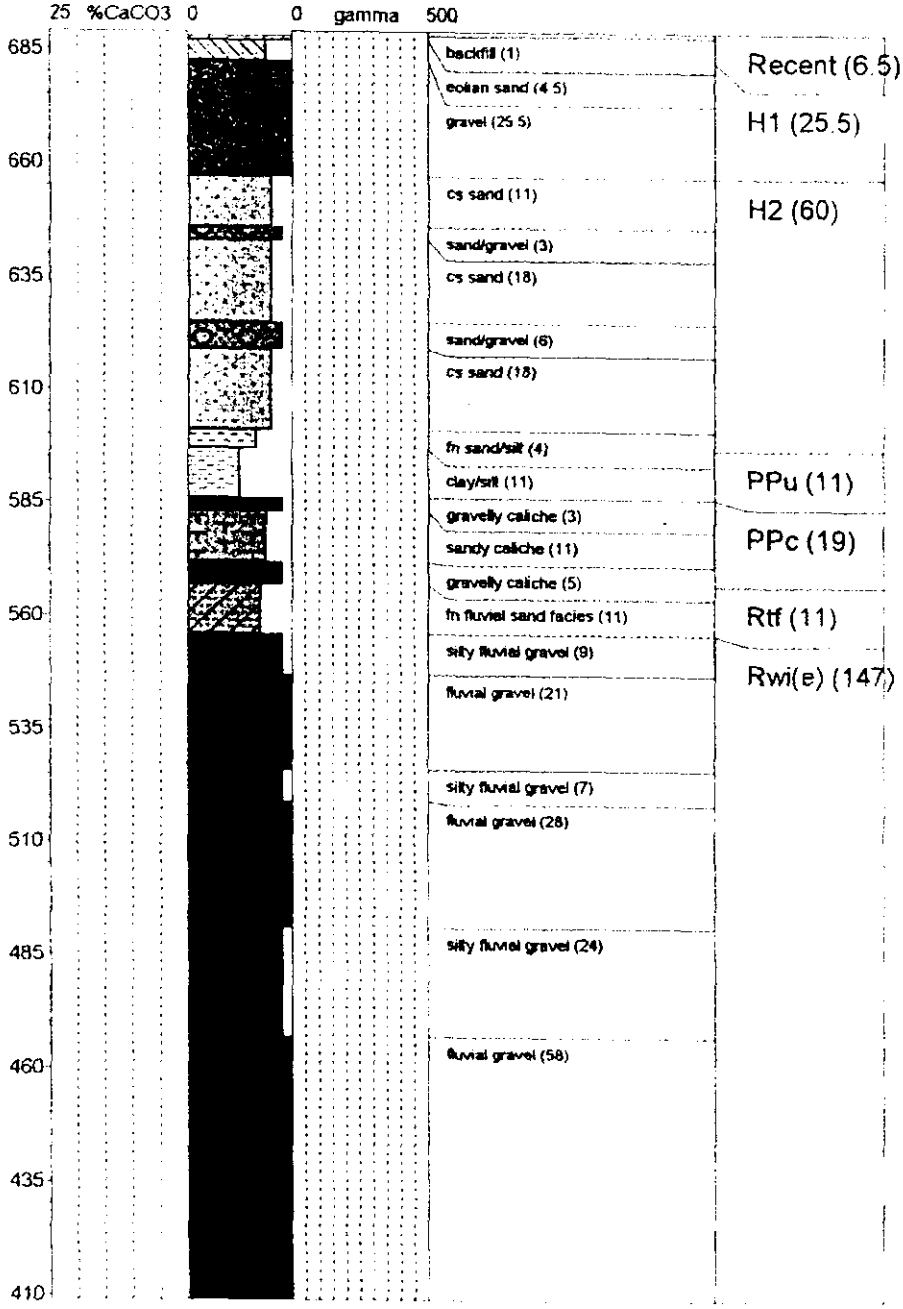
W11-28


25 %CaCO3 0
0 gamma 500
685
660
635
610
585
560
535
510
485
460
gravel (5)
cs sand (5)
gravel (30)
cs sand (25)
sand/gravel (5)
cs sand (27)
silt (2)
cs sand (6)
silt (5)
sandy caliche (5)
paleosol facies (5)
gravelly caliche (4)
overbank/sand facies (19)
fluvial gravel (98)
fluvial sand/gravel (4)
H1 (40)
H2 (57)
PPu (13)
PPc (14)
Rtf (19)
Rwi(e) (104)

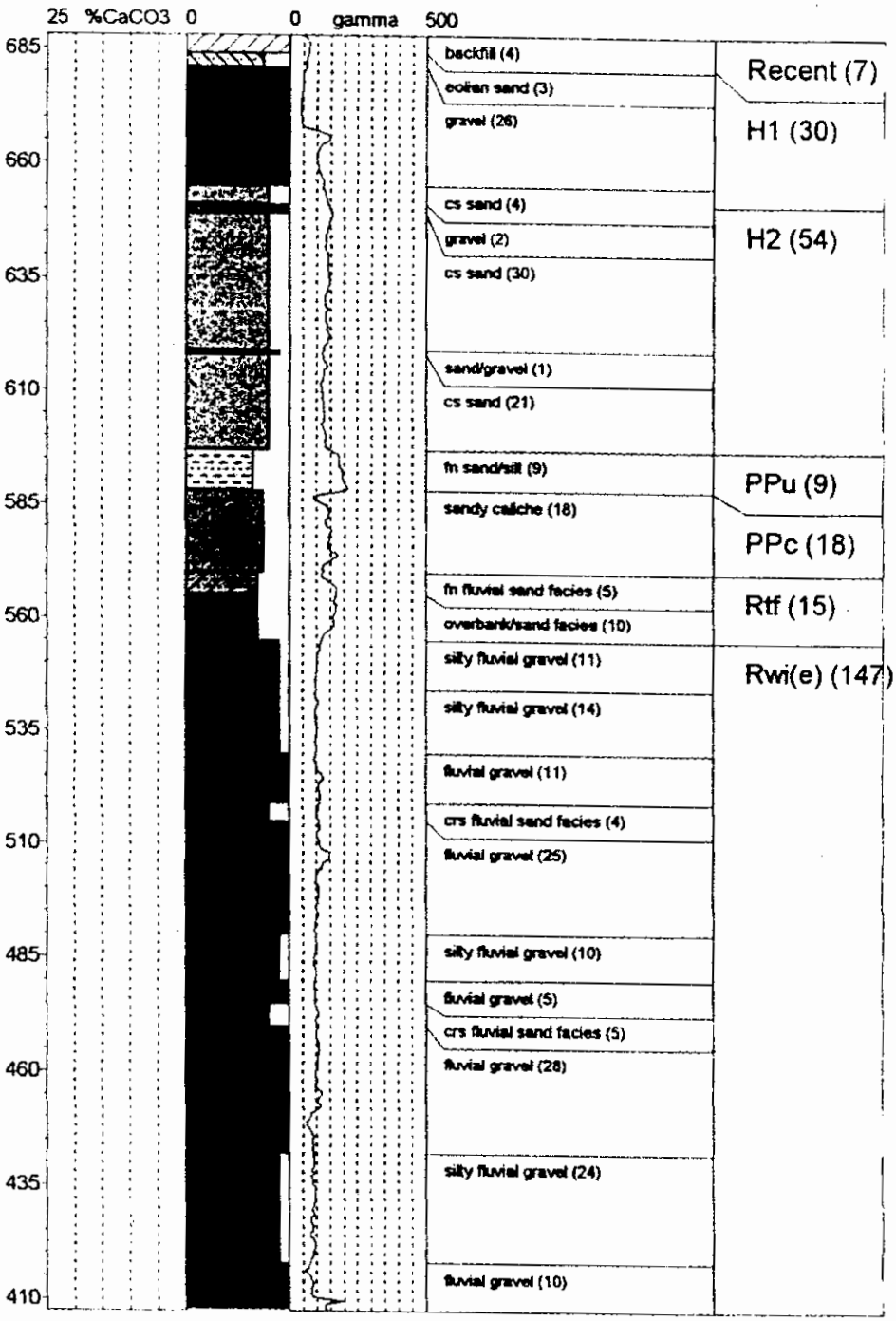
W11-39


25 %CaCO3 0
0 gamma 500
685
660
635
610
585
560
535
510
485
460
435
410
backfill (5)
gravel (29)
gs sand (13)
cs sand (16)
gs sand (19.5)
cs sand (7.5)
silt (10)
sandy caliche (25)
fluvial sand/gravel (6)
silty fluvial gravel (14)
fluvial gravel (5)
silty fluvial gravel (105)
fluvial gravel (3)
silty fluvial gravel (7)
fluvial gravel (5)
silty fluvial gravel (12)
Recent (5)
H1 (29)
H2 (56)
PPu (10)
PPc (25)
Rwi(e) (157)

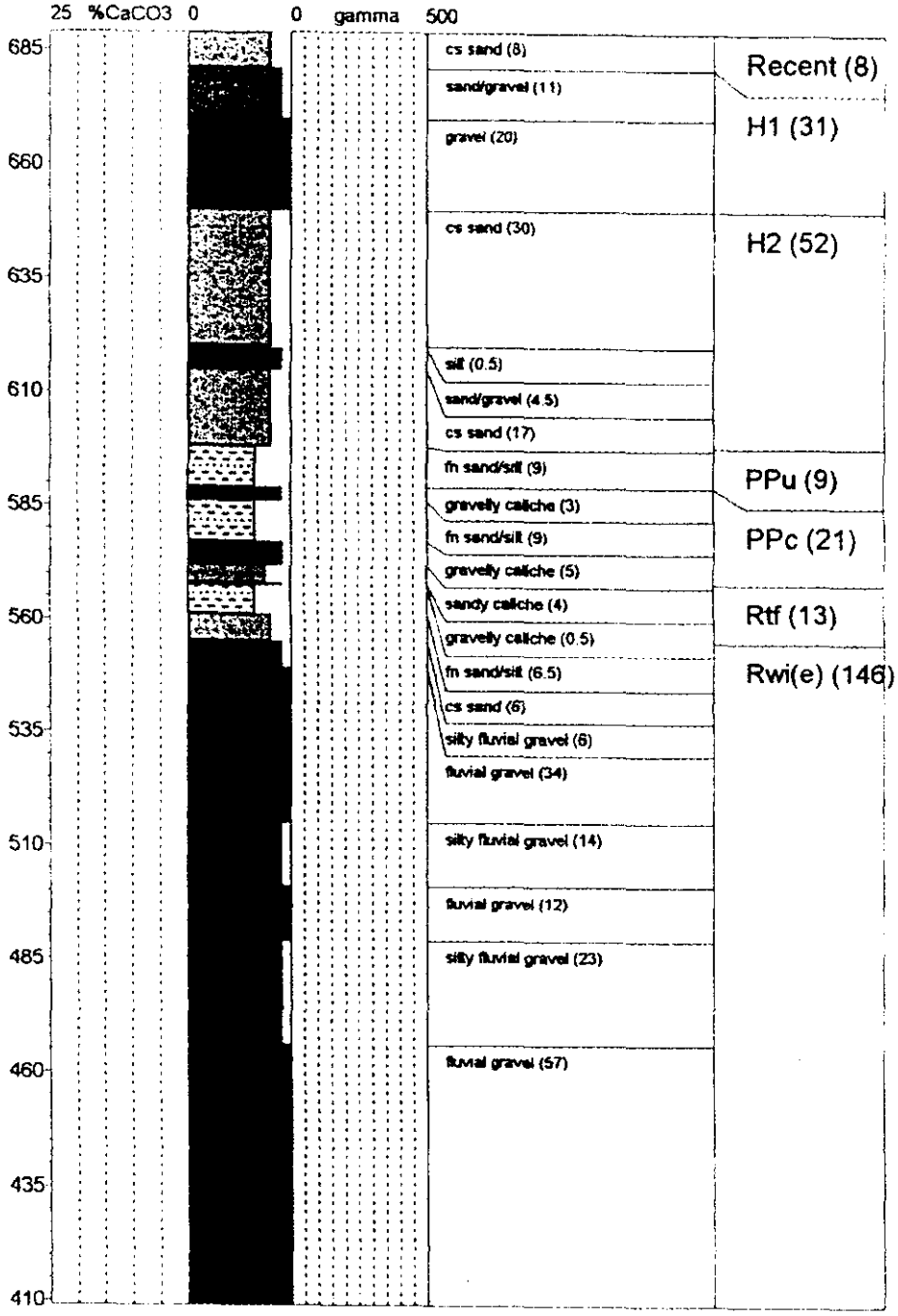
W11-40


25 %CaCO3 0
0 gamma 500
685
660
635
610
585
560
535
510
485
460
435
410
backfill (1)
eolian sand (4.5)
gravel (25.5)
cs sand (11)
sand/gravel (3)
cs sand (18)
sand/gravel (6)
cs sand (18)
fn sand/silt (4)
clay/silt (11)
gravelly caliche (3)
sandy caliche (11)
gravelly caliche (5)
fn fluvial sand facies (11)
silty fluvial gravel (9)
fluvial gravel (21)
silty fluvial gravel (7)
fluvial gravel (28)
silty fluvial gravel (24)
fluvial gravel (58)
Recent (6.5)
H1 (25.5)
H2 (60)
PPu (11)
PPc (19)
Rtf (11)
Rwi(e) (147)

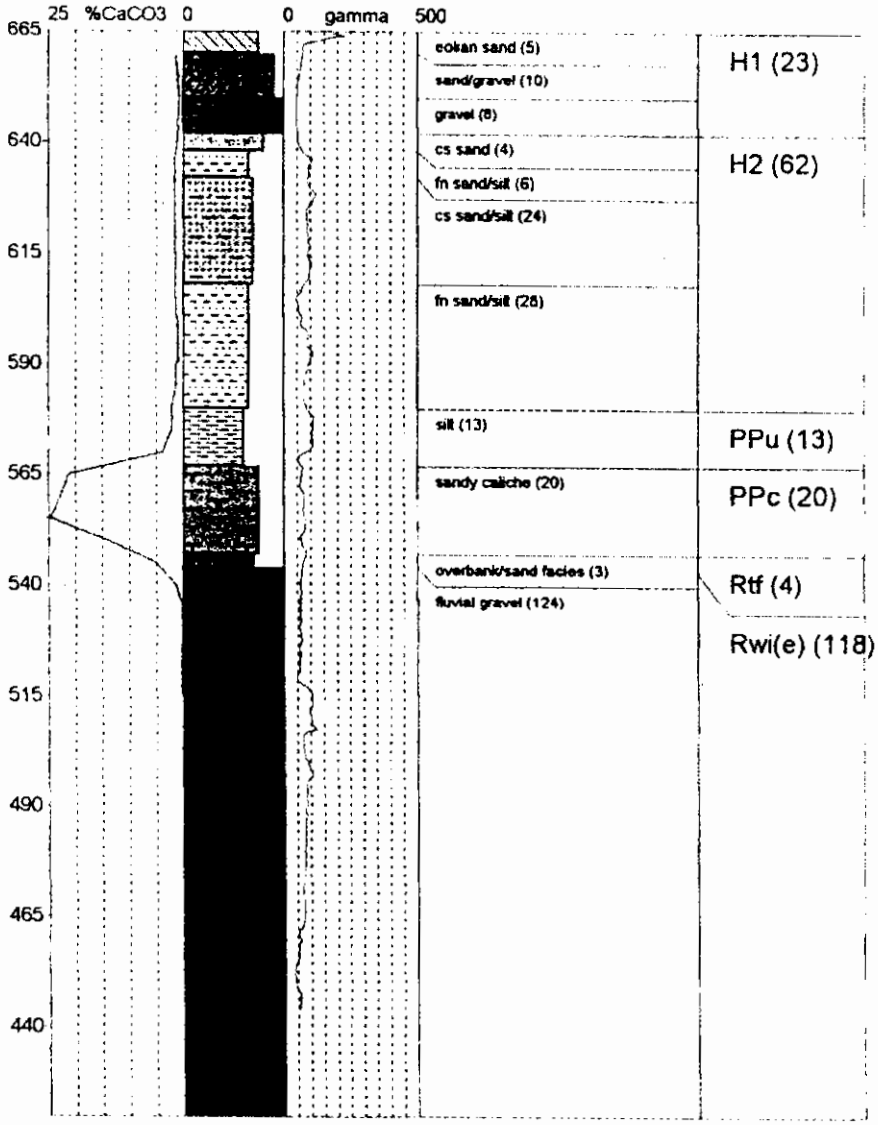
W11-41


25 %CaCO3 0
0 gamma 500
685
660
635
610
585
560
535
510
485
460
435
410
backfill (4)
eolian sand (3)
gravel (26)
cs sand (4)
gravel (2)
cs sand (30)
sand/gravel (1)
cs sand (21)
fn sand/silt (9)
sandy caliche (18)
fn fluvial sand facies (5)
overbank/sand facies (10)
silty fluvial gravel (11)
silty fluvial gravel (14)
fluvial gravel (11)
crs fluvial sand facies (4)
fluvial gravel (25)
silty fluvial gravel (10)
fluvial gravel (5)
crs fluvial sand facies (5)
fluvial gravel (28)
silty fluvial gravel (24)
fluvial gravel (10)
Recent (7)
H1 (30)
H2 (54)
PPu (9)
PPc (18)
Rtf (15)
Rwi(e) (147)

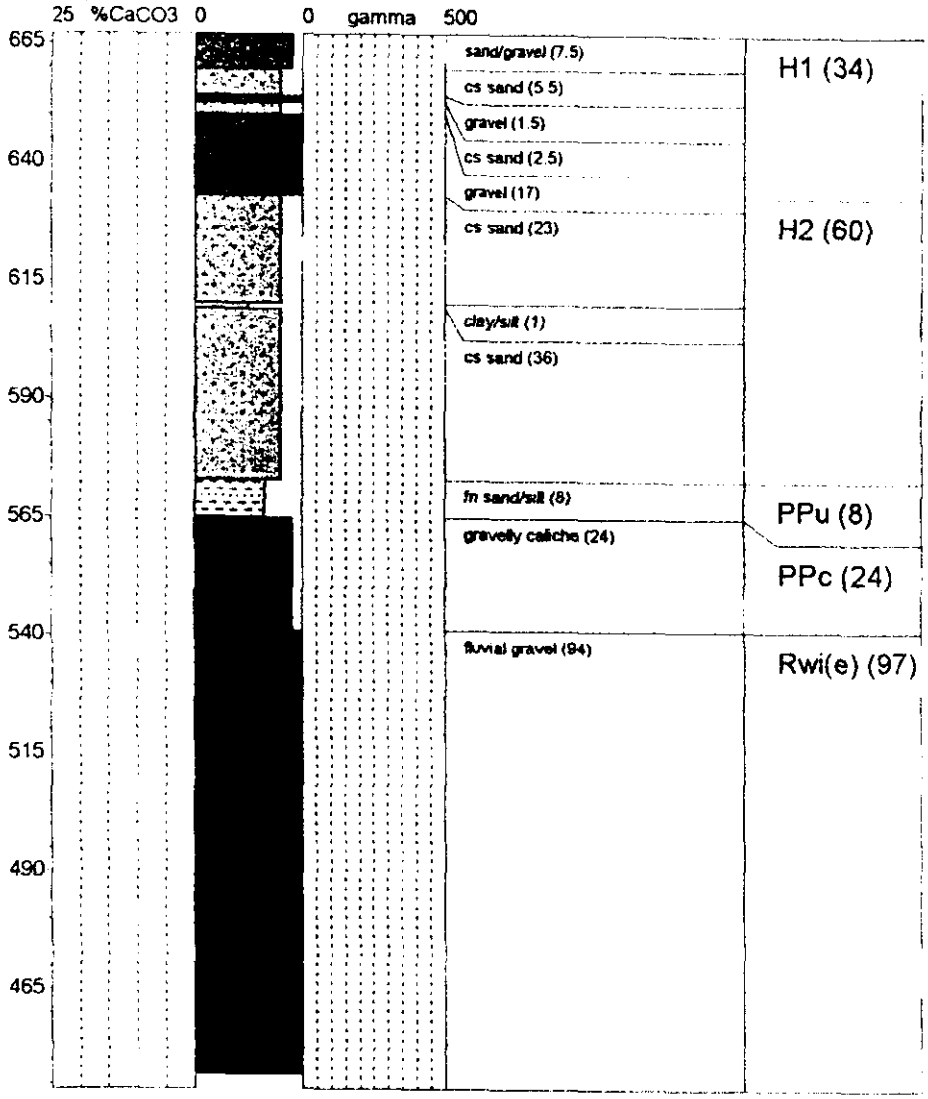
W11-42


25 %CaCO3 0
0 gamma 500
685
660
635
610
585
560
535
510
485
460
435
410
cs sand (8)
sand/gravel (11)
gravel (20)
cs sand (30)
slt (0.5)
sand/gravel (4.5)
cs sand (17)
fn sand/slt (9)
gravelly caliche (3)
fn sand/slt (9)
gravelly caliche (5)
sandy caliche (4)
gravelly caliche (0.5)
fn sand/slt (6.5)
cs sand (6)
silty fluvial gravel (6)
fluvial gravel (34)
silty fluvial gravel (14)
fluvial gravel (12)
silty fluvial gravel (23)
fluvial gravel (57)
Recent (8)
H1 (31)
H2 (52)
PPu (9)
PPc (21)
Rtf (13)
Rwi(e) (146)

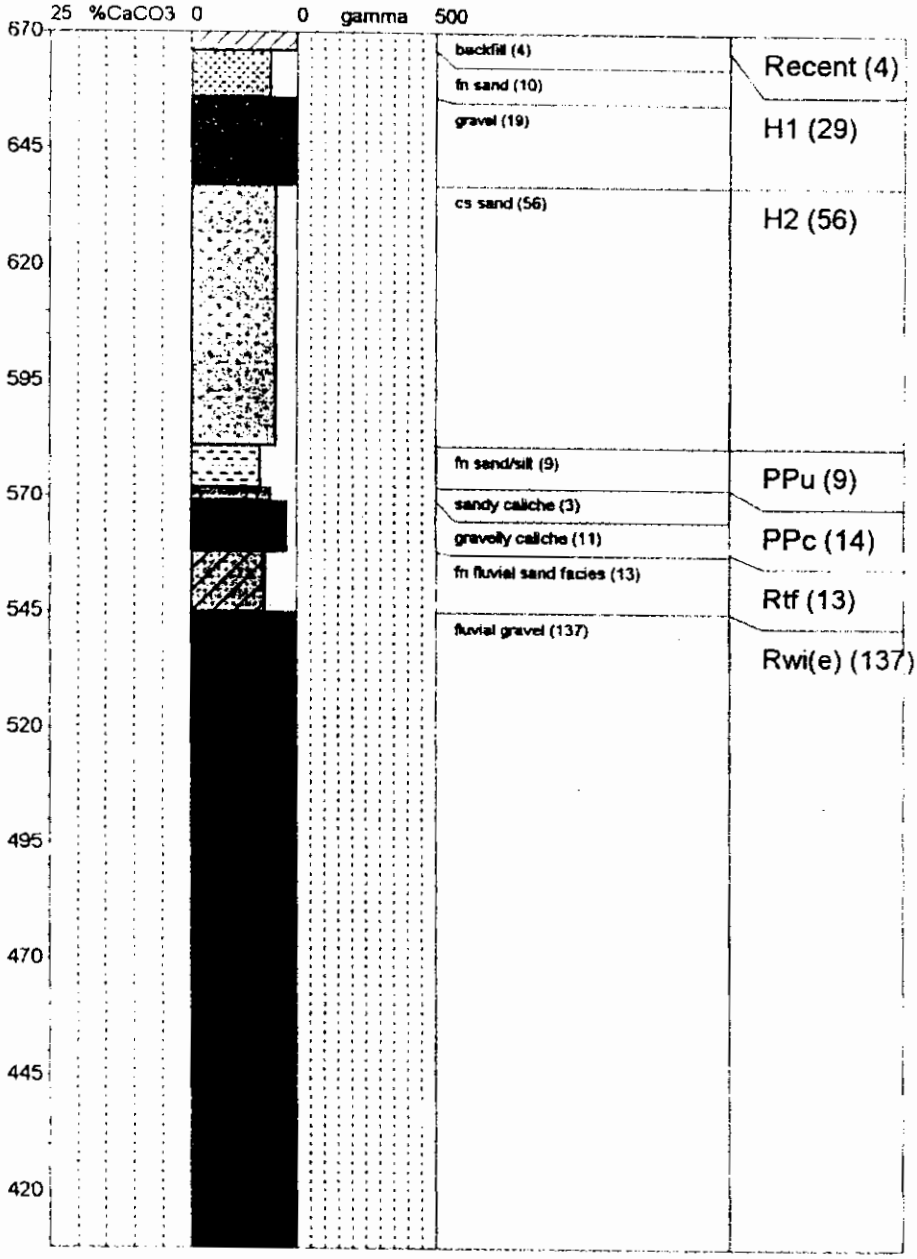
W14-1

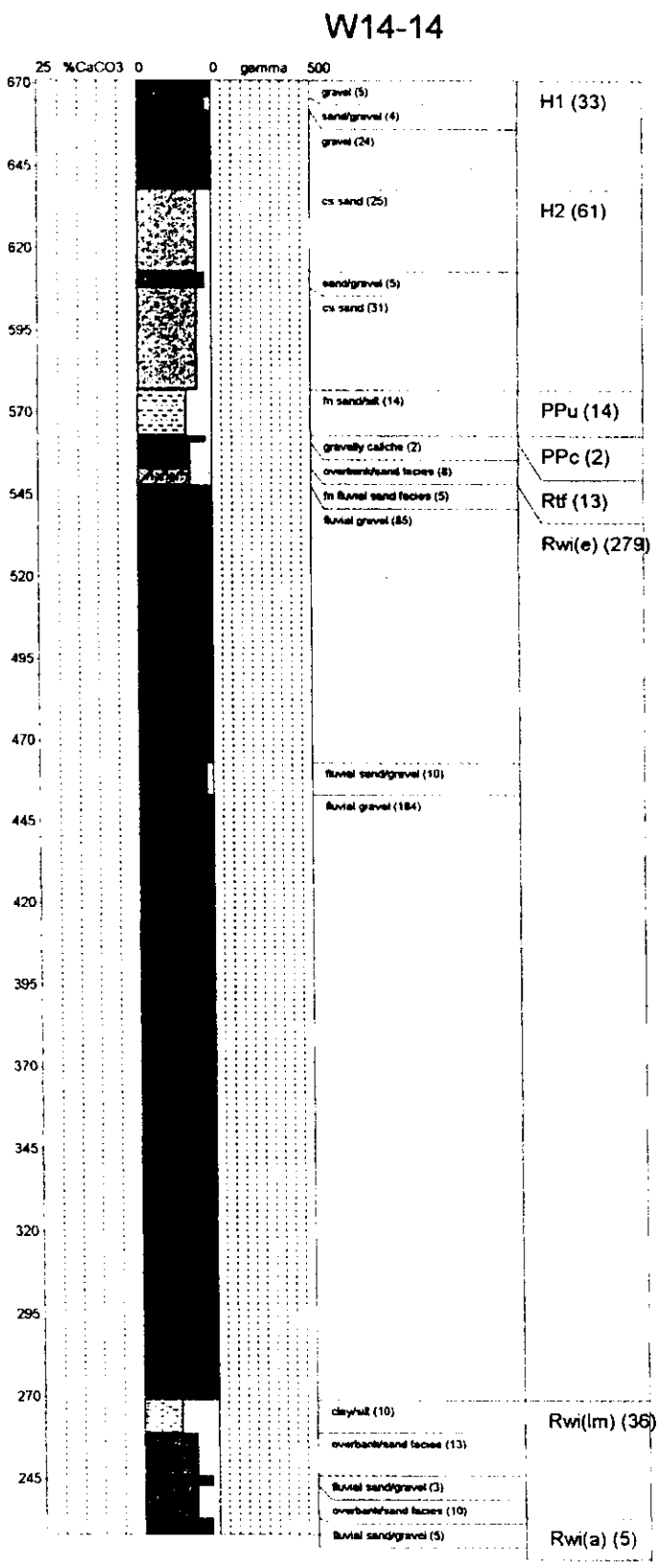

25 %CaCO3 0
0 gamma 500
665
640
615
590
565
540
515
490
465
440
eolian sand (5)
sand/gravel (10)
gravel (8)
cs sand (4)
fn sand/silt (6)
cs sand/silt (24)
fn sand/silt (28)
silt (13)
sandy caliche (20)
overbank/sand facies (3)
fluvial gravel (124)
H1 (23)
H2 (62)
PPu (13)
PPc (20)
Rtf (4)
Rwi(e) (118)

W14-12

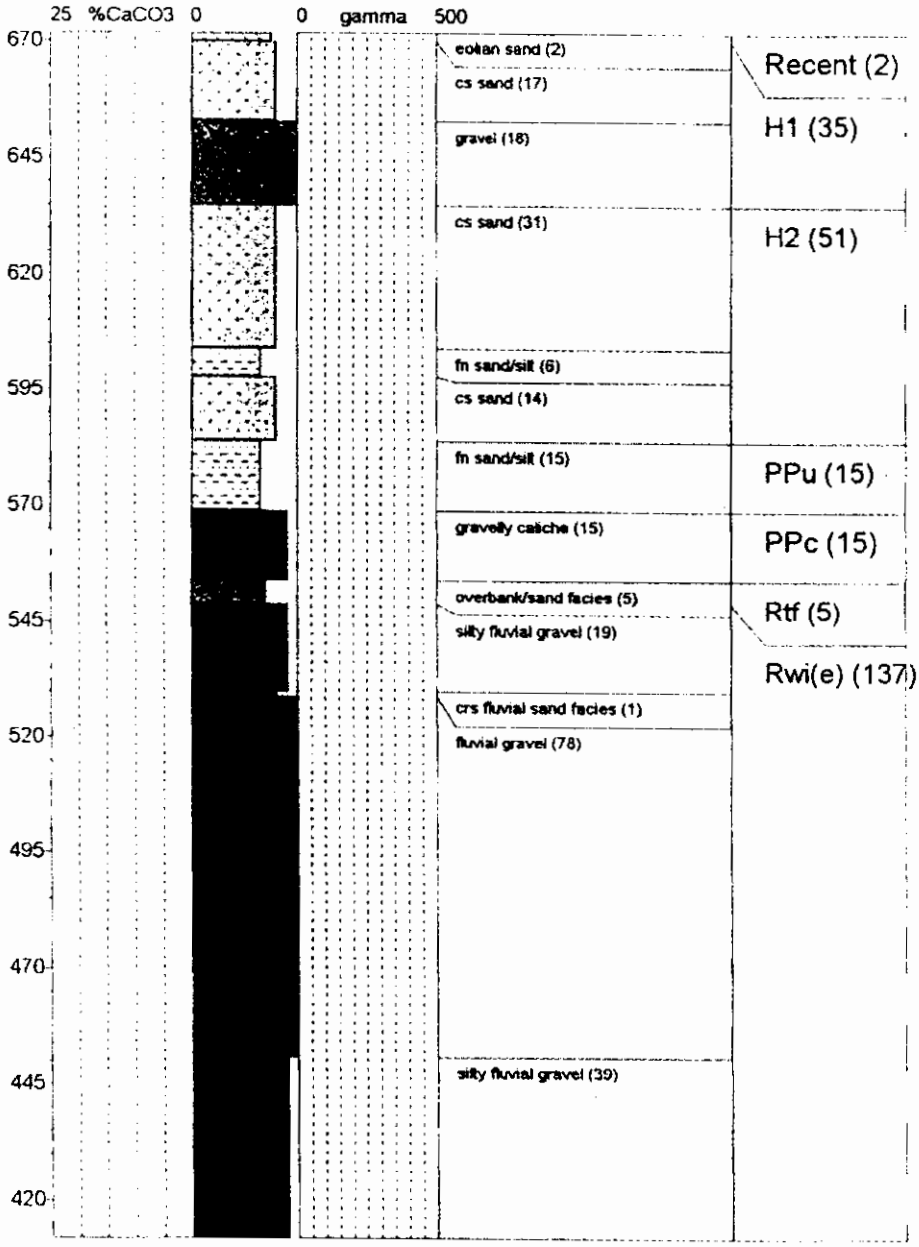

25 %CaCO3 0
0 gamma 500
665
640
615
590
565
540
515
490
465
sand/gravel (7.5)
cs sand (5.5)
gravel (1.5)
cs sand (2.5)
gravel (17)
cs sand (23)
clay/silt (1)
cs sand (36)
fn sand/silt (8)
gravelly caliche (24)
fluvial gravel (94)
H1 (34)
H2 (60)
PPu (8)
PPc (24)
Rwi(e) (97)

W14-13

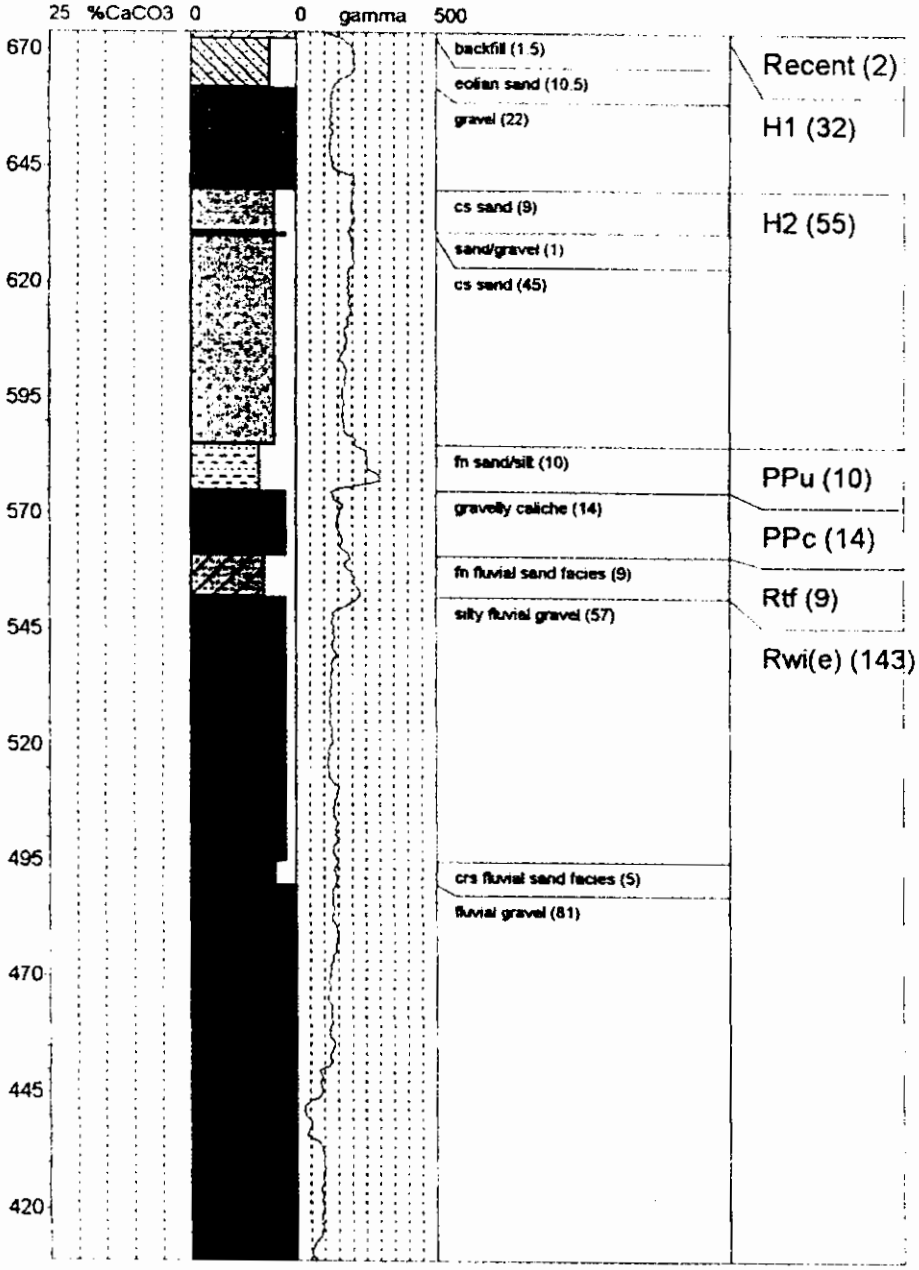

25 %CaCO3 0
0 gamma 500
670
645
620
595
570
545
520
495
470
445
420
backfill (4)
fn sand (10)
gravel (19)
cs sand (56)
fn sand/silt (9)
sandy caliche (3)
gravelly caliche (11)
fn fluvial sand facies (13)
fluvial gravel (137)
Recent (4)
H1 (29)
H2 (56)
PPu (9)
PPc (14)
Rtf (13)
Rwi(e) (137)


W14-14
25 %CaCO3 0
0 gamma 500
670
645
620
595
570
545
520
495
470
445
420
395
370
345
320
295
270
245
gravel (5)
sand/gravel (4)
gravel (24)
cs sand (25)
sand/gravel (5)
cs sand (31)
fn sand/silt (14)
gravelly caliche (2)
overbank/sand facies (8)
fn fluvial sand facies (5)
fluvial gravel (85)
fluvial sand/gravel (10)
fluvial gravel (184)
clay/silt (10)
overbank/sand facies (13)
fluvial sand/gravel (3)
overbank/sand facies (10)
fluvial sand/gravel (5)
H1 (33)
H2 (61)
PPu (14)
PPc (2)
Rtf (13)
Rwi(e) (279)
Rwi(lm) (36)
Rwi(a) (5)

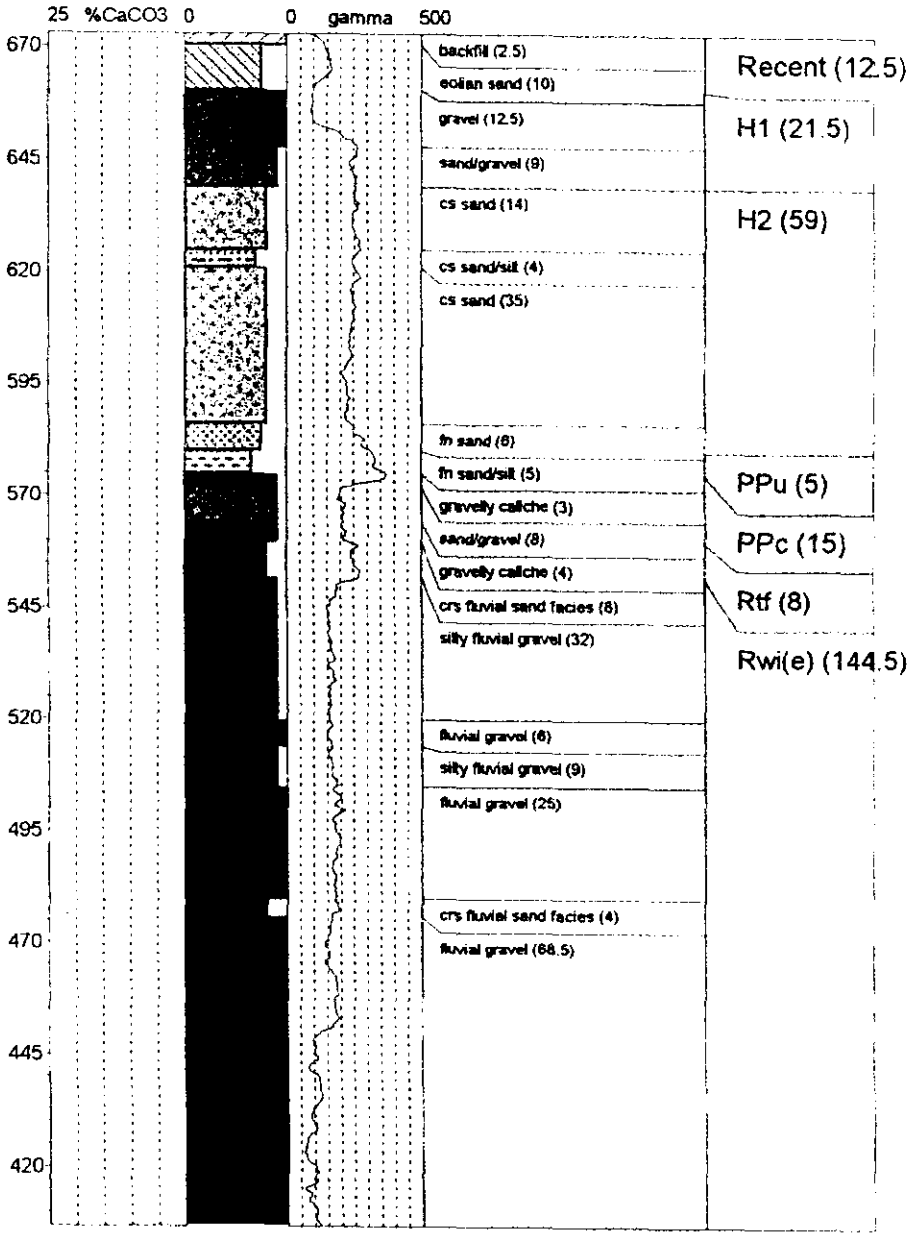
W14-15


25 %CaCO3 0
0 gamma 500
670
645
620
595
570
545
520
495
470
445
420
eolian sand (2)
cs sand (17)
gravel (18)
cs sand (31)
fn sand/silt (6)
cs sand (14)
fn sand/silt (15)
gravelly caliche (15)
overbank/sand facies (5)
silty fluvial gravel (19)
crs fluvial sand facies (1)
fluvial gravel (78)
silty fluvial gravel (39)
Recent (2)
H1 (35)
H2 (51)
PPu (15)
PPc (15)
Rtf (5)
Rwi(e) (137)

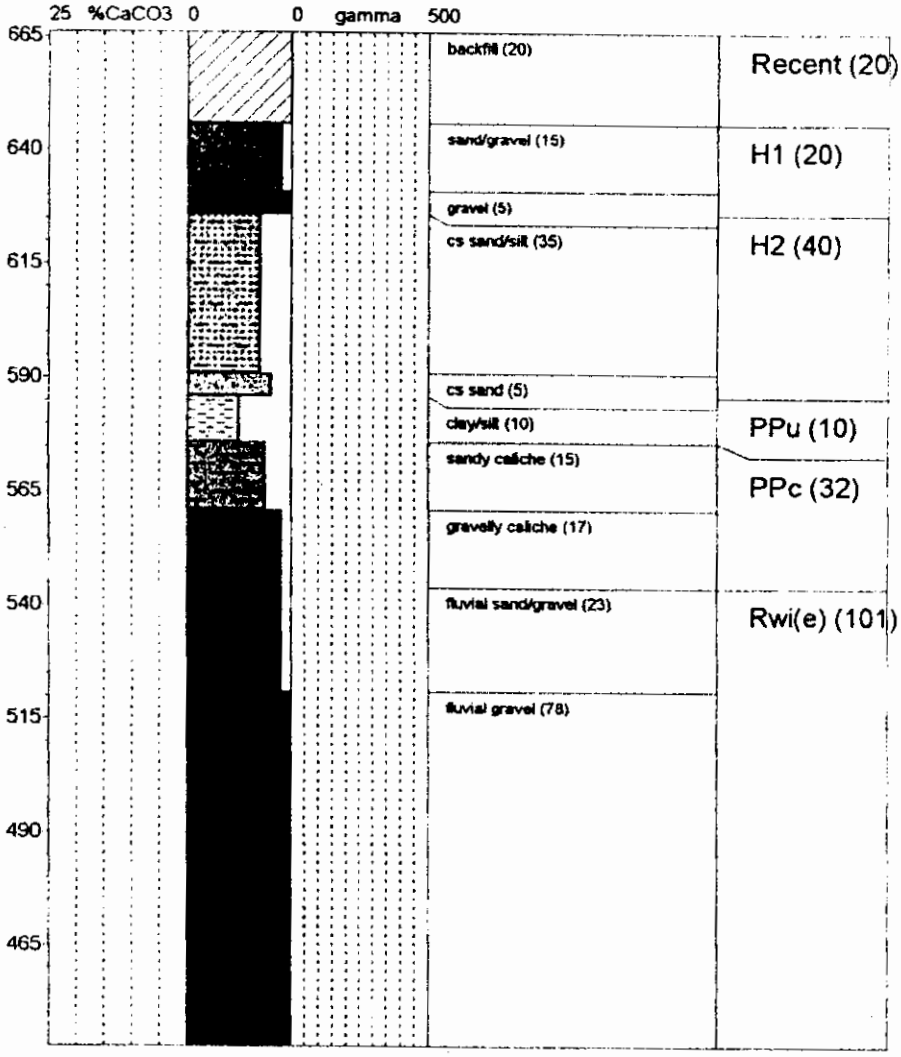
W14-16


25 %CaCO3 0
0 gamma 500
670
645
620
595
570
545
520
495
470
445
420
backfill (1.5)
eolian sand (10.5)
gravel (22)
cs sand (9)
sand/gravel (1)
cs sand (45)
fn sand/silt (10)
gravelly caliche (14)
fn fluvial sand facies (9)
silty fluvial gravel (57)
crs fluvial sand facies (5)
fluvial gravel (81)
Recent (2)
H1 (32)
H2 (55)
PPu (10)
PPc (14)
Rtf (9)
Rwi(e) (143)

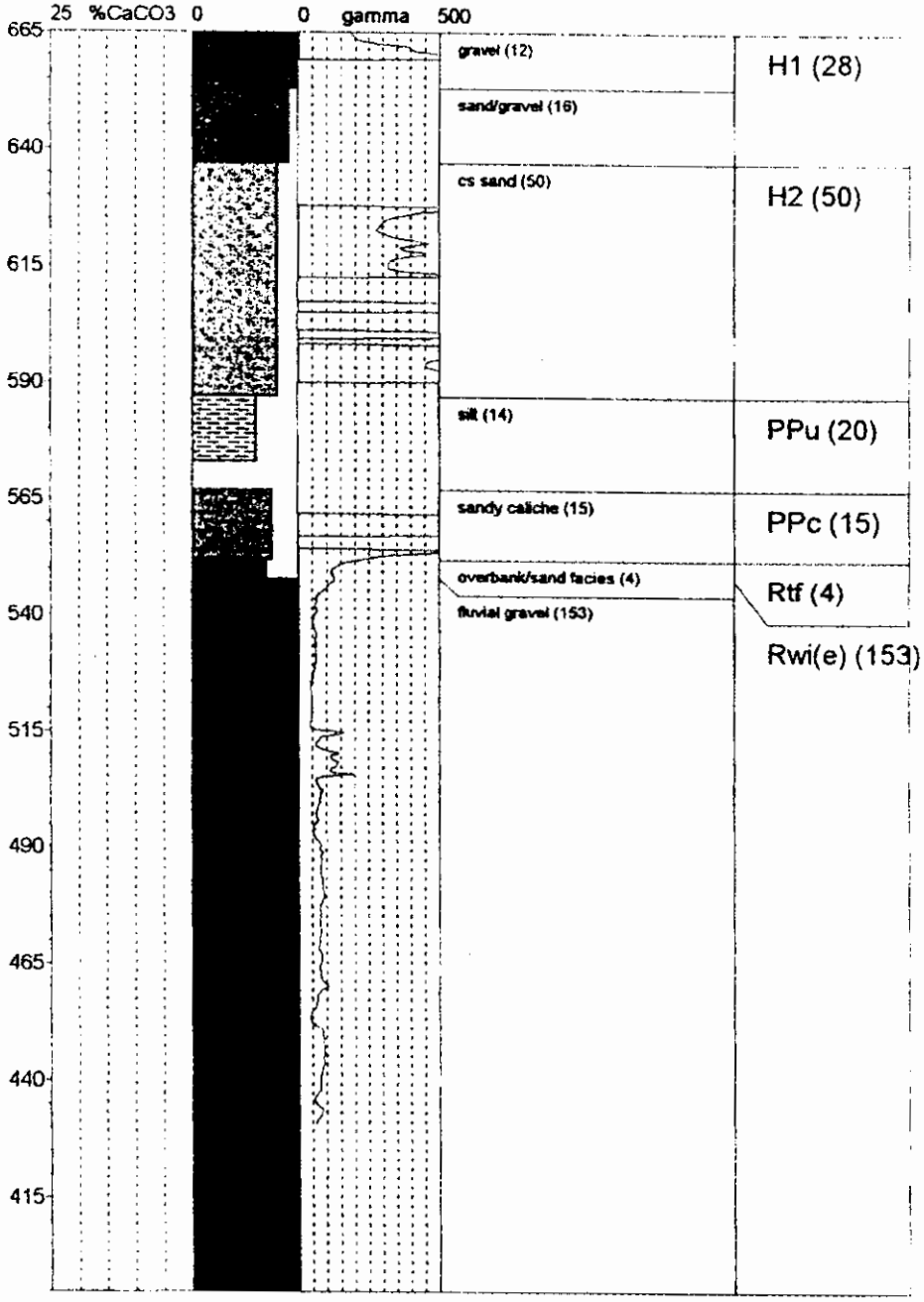
W14-17


25 %CaCO3 0
0 gamma 500
670
645
620
595
570
545
520
495
470
445
420
backfill (2.5)
eolian sand (10)
gravel (12.5)
sand/gravel (9)
cs sand (14)
cs sand/silt (4)
cs sand (35)
fn sand (8)
fn sand/silt (5)
gravelly caliche (3)
sand/gravel (8)
gravelly caliche (4)
crs fluvial sand facies (8)
silty fluvial gravel (32)
fluvial gravel (6)
silty fluvial gravel (9)
fluvial gravel (25)
crs fluvial sand facies (4)
fluvial gravel (68.5)
Recent (12.5)
H1 (21.5)
H2 (59)
PPu (5)
PPc (15)
Rtf (8)
Rwi(e) (144.5)

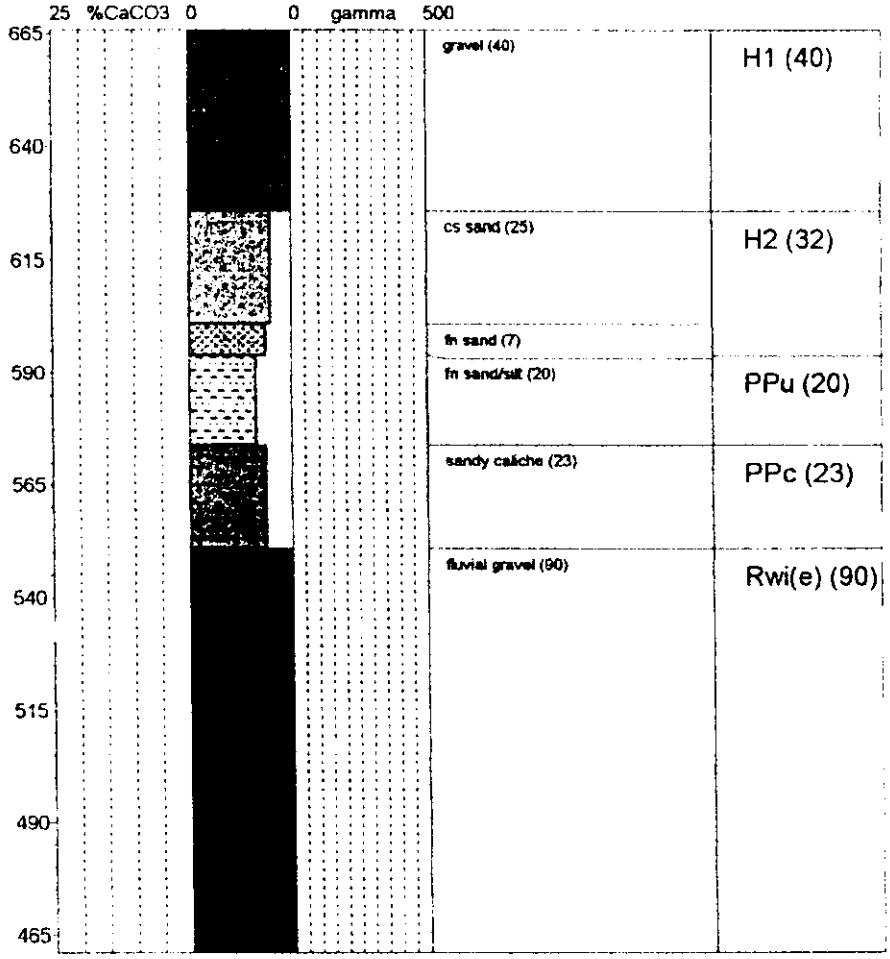
W14-2


25 %CaCO3 0
0 gamma 500
665
640
615
590
565
540
515
490
465
backfill (20)
sand/gravel (15)
gravel (5)
cs sand/silt (35)
cs sand (5)
clay/silt (10)
sandy caliche (15)
gravelly caliche (17)
fluvial sand/gravel (23)
fluvial gravel (78)
Recent (20)
H1 (20)
H2 (40)
PPu (10)
PPc (32)
Rwi(e) (101)

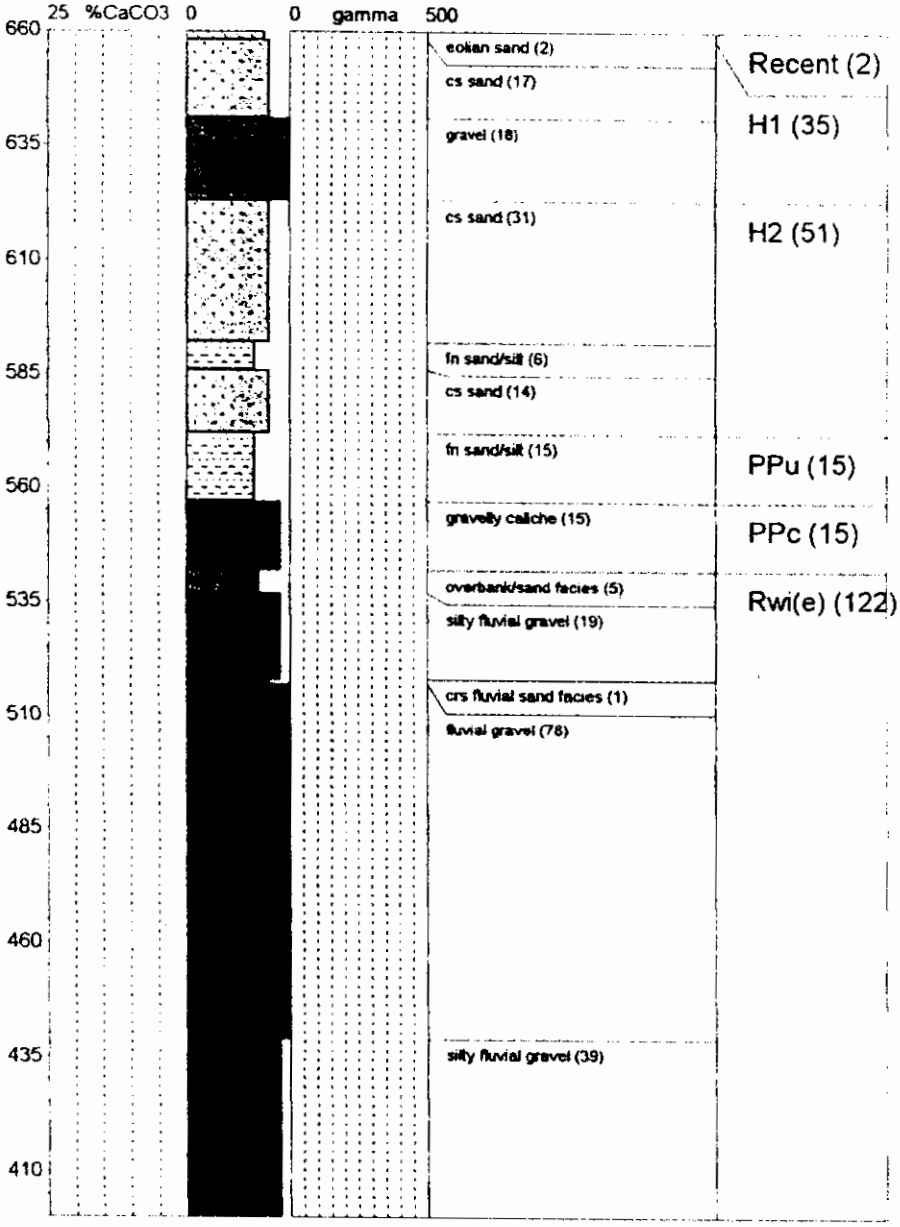
W14-3


25 %CaCO3 0
0 gamma 500
665
640
615
590
565
540
515
490
465
440
415
gravel (12)
sand/gravel (16)
cs sand (50)
silt (14)
sandy caliche (15)
overbank/sand facies (4)
fluvial gravel (153)
H1 (28)
H2 (50)
PPu (20)
PPc (15)
Rtf (4)
Rwi(e) (153)

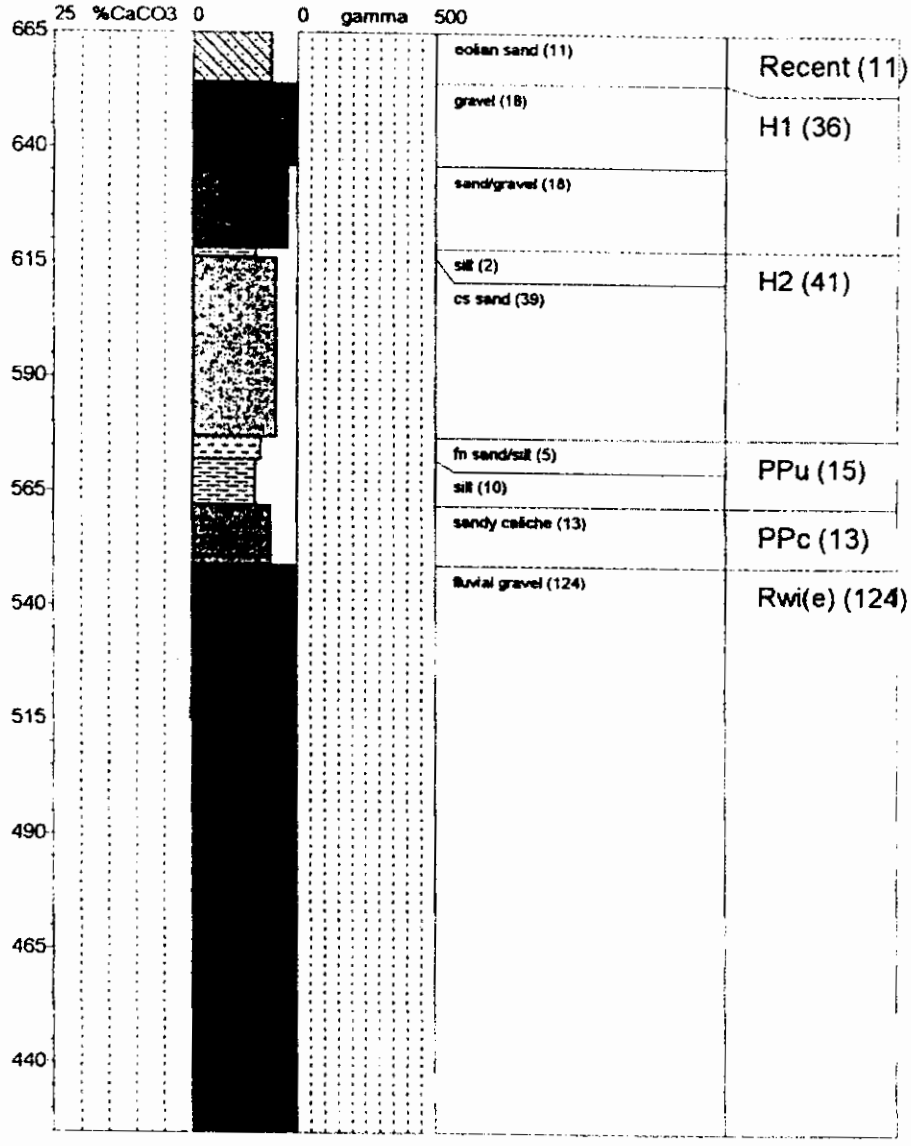
W14-4


25 %CaCO3 0
0 gamma 500
665
640
615
590
565
540
515
490
465
gravel (40)
cs sand (25)
fn sand (7)
fn sand/silt (20)
sandy caliche (23)
fluvial gravel (90)
H1 (40)
H2 (32)
PPu (20)
PPc (23)
Rwi(e) (90)

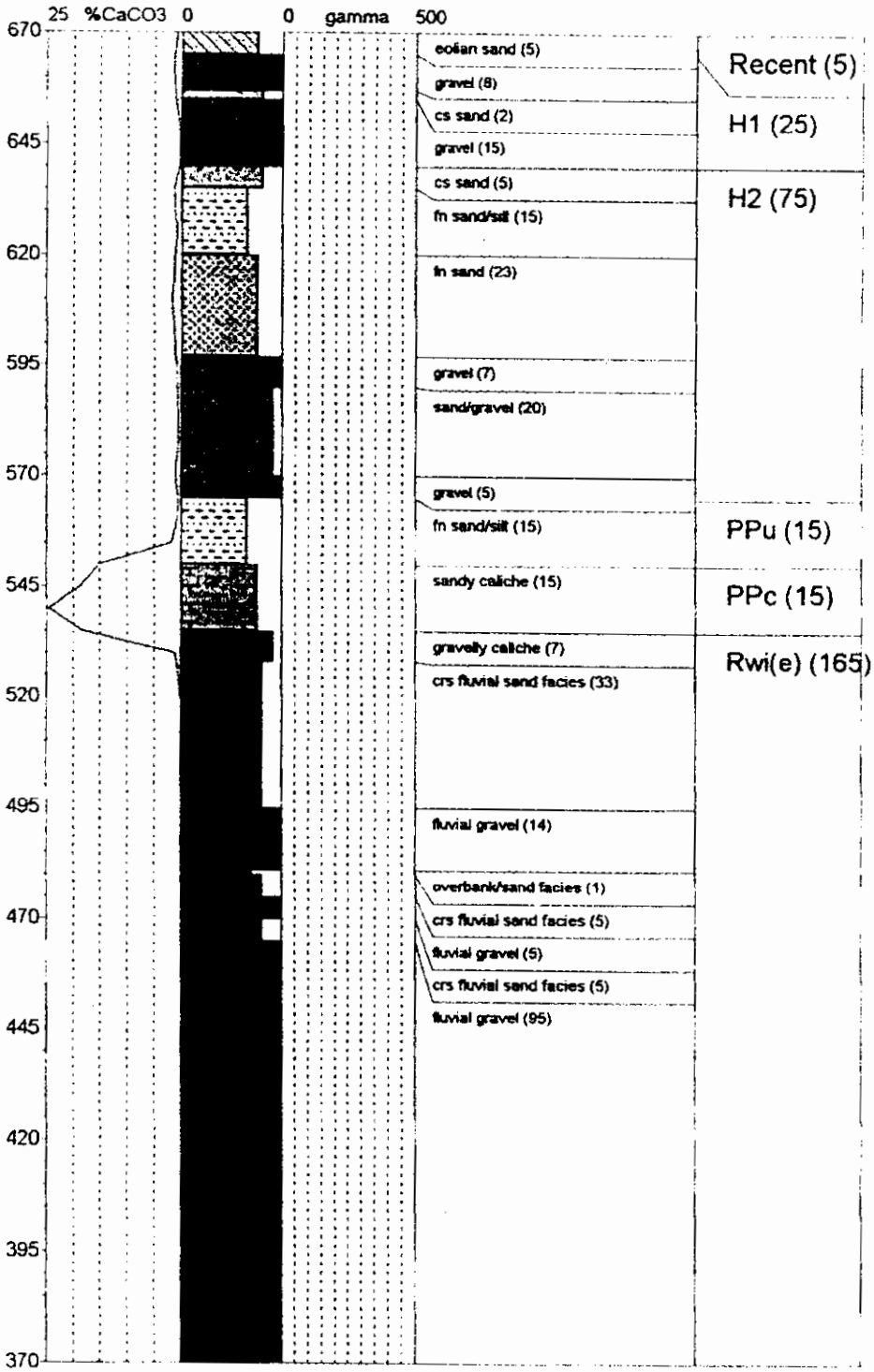
W14-5


25 %CaCO3 0
0 gamma 500
660
635
610
585
560
535
510
485
460
435
410
eolian sand (2)
cs sand (17)
gravel (18)
cs sand (31)
fn sand/silt (6)
cs sand (14)
fn sand/silt (15)
gravelly caliche (15)
overbank/sand facies (5)
silty fluvial gravel (19)
crs fluvial sand facies (1)
fluvial gravel (76)
silty fluvial gravel (39)
Recent (2)
H1 (35)
H2 (51)
PPu (15)
PPc (15)
Rwi(e) (122)

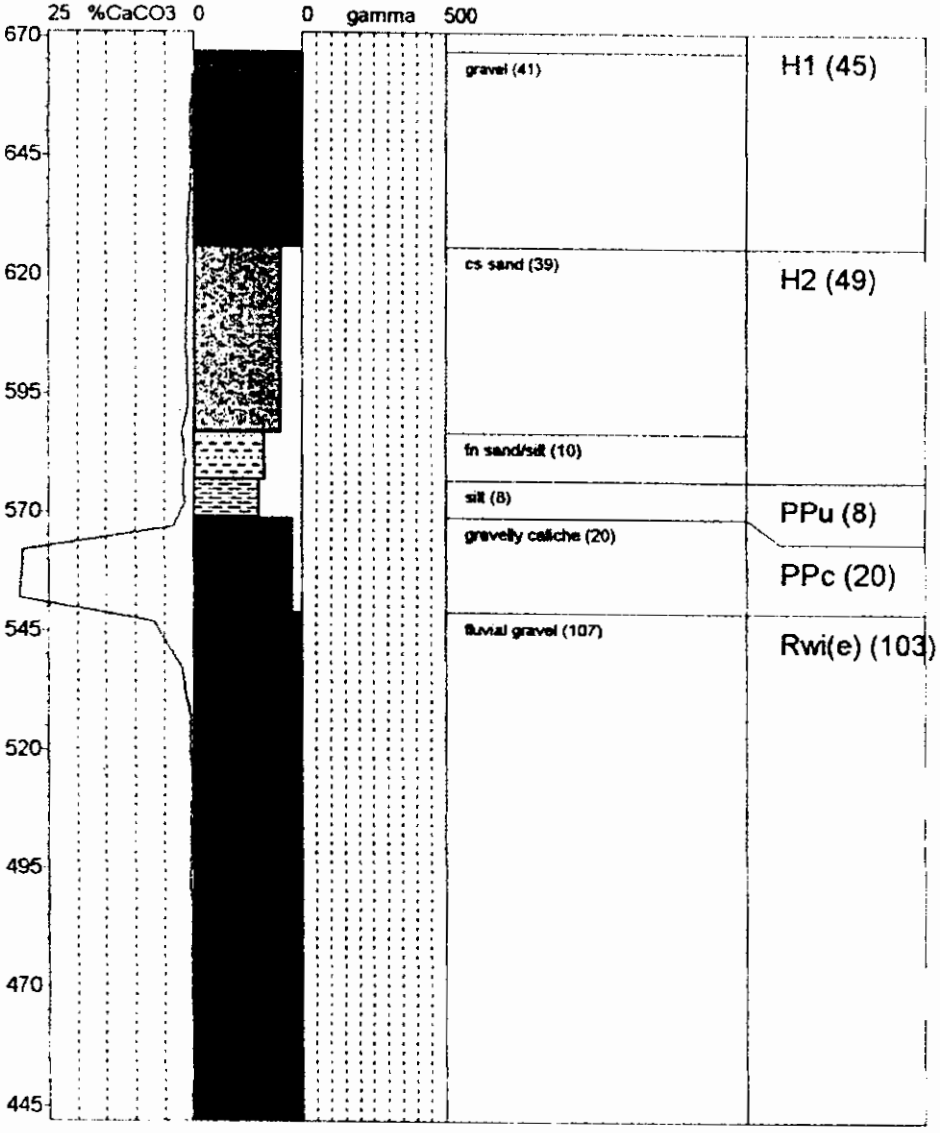
W14-6

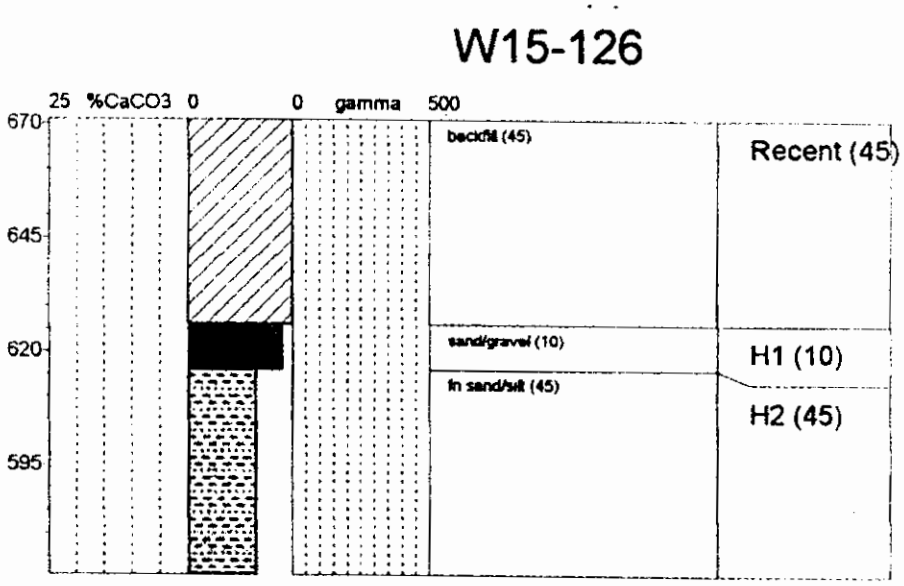

25 %CaCO3 0
0 gamma 500
665
640
615
590
565
540
515
490
465
440
eolian sand (11)
gravel (18)
sand/gravel (18)
silt (2)
cs sand (39)
fn sand/silt (5)
silt (10)
sandy caliche (13)
fluvial gravel (124)
Recent (11)
H1 (36)
H2 (41)
PPu (15)
PPc (13)
Rwi(e) (124)

W15-1

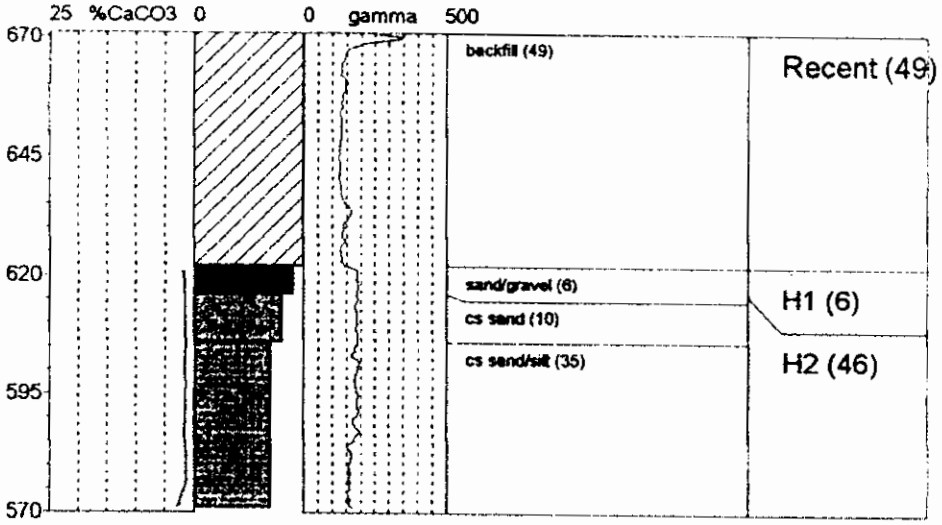

25 %CaCO3 0
0 gamma 500
670
645
620
595
570
545
520
495
470
445
420
395
370
eolian sand (5)
gravel (8)
cs sand (2)
gravel (15)
cs sand (5)
fn sand/silt (15)
fn sand (23)
gravel (7)
sand/gravel (20)
gravel (5)
fn sand/silt (15)
sandy caliche (15)
gravelly caliche (7)
crs fluvial sand facies (33)
fluvial gravel (14)
overbank/sand facies (1)
crs fluvial sand facies (5)
fluvial gravel (5)
crs fluvial sand facies (5)
fluvial gravel (95)
Recent (5)
H1 (25)
H2 (75)
PPu (15)
PPc (15)
Rwi(e) (165)

W15-12

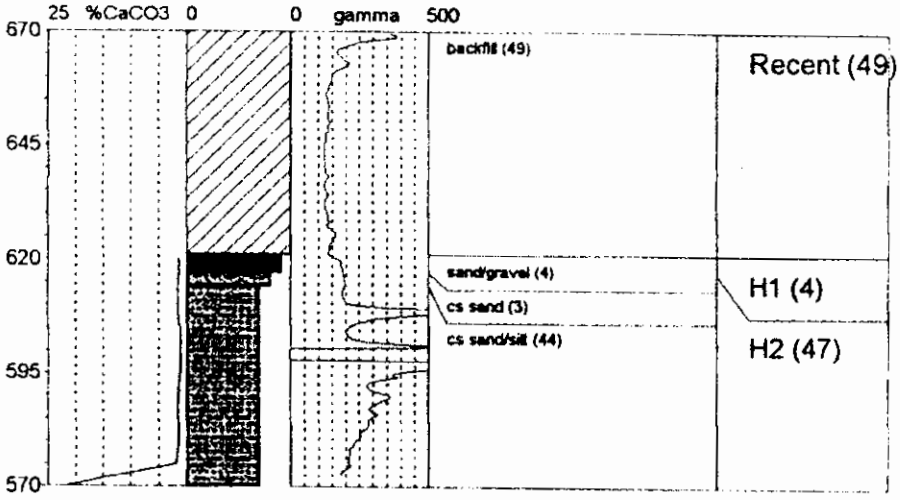

25 %CaCO3 0
0 gamma 500
670
645
620
595
570
545
520
495
470
445
gravel (41)
cs sand (39)
fn sand/slt (10)
slt (8)
gravelly caliche (20)
fluvial gravel (107)
H1 (45)
H2 (49)
PPu (8)
PPc (20)
Rwi(e) (103)

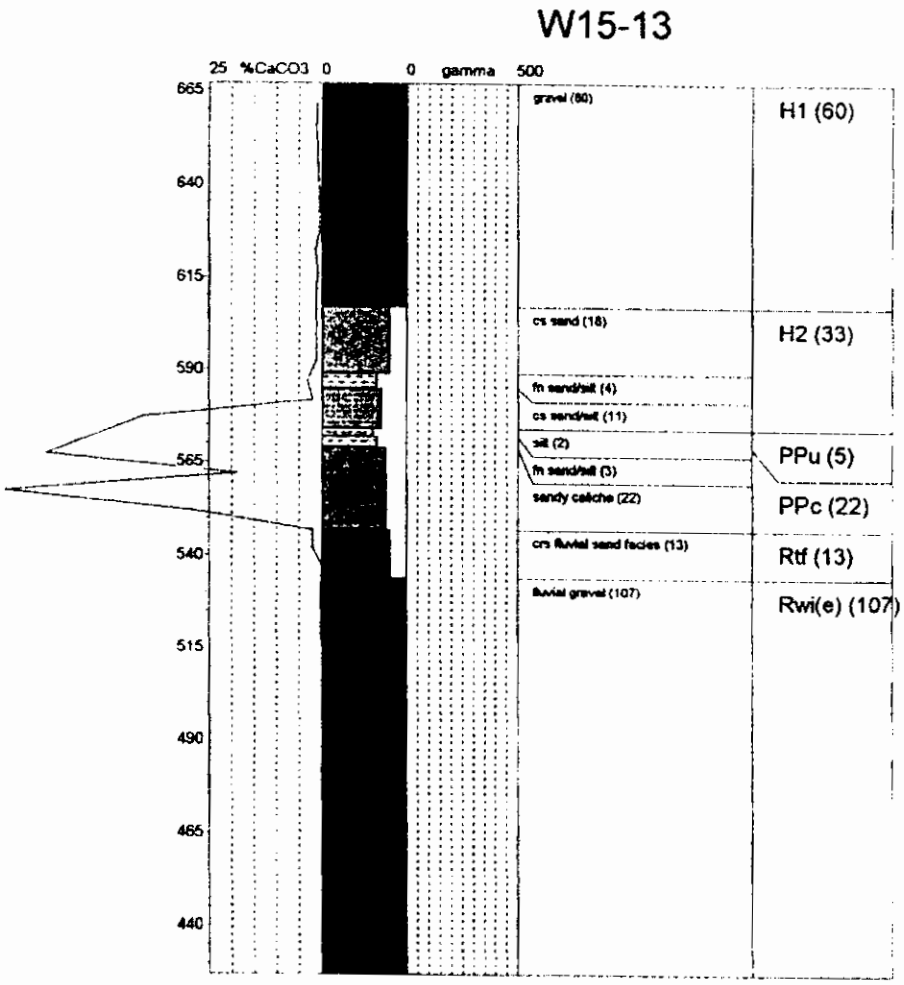

W15-126
25 %CaCO3 0
0 gamma 500
670
645
620
595
backfill (45)
sand/gravel (10)
fn sand/silt (45)
Recent (45)
H1 (10)
H2 (45)

W15-127

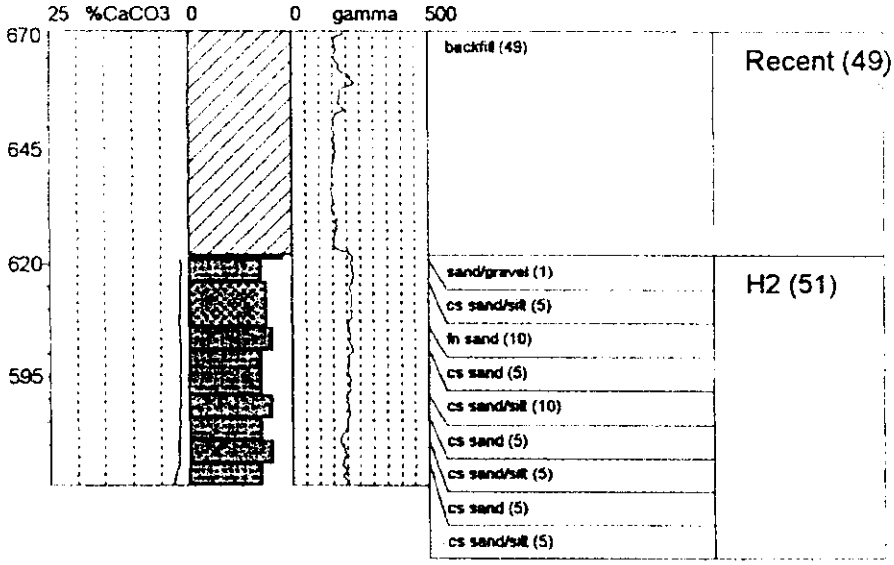

25 %CaCO3 0
0 gamma 500
670
645
620
595
570
backfill (49)
sand/gravel (6)
cs sand (10)
cs sand/silt (35)
Recent (49)
H1 (6)
H2 (46)

W15-128

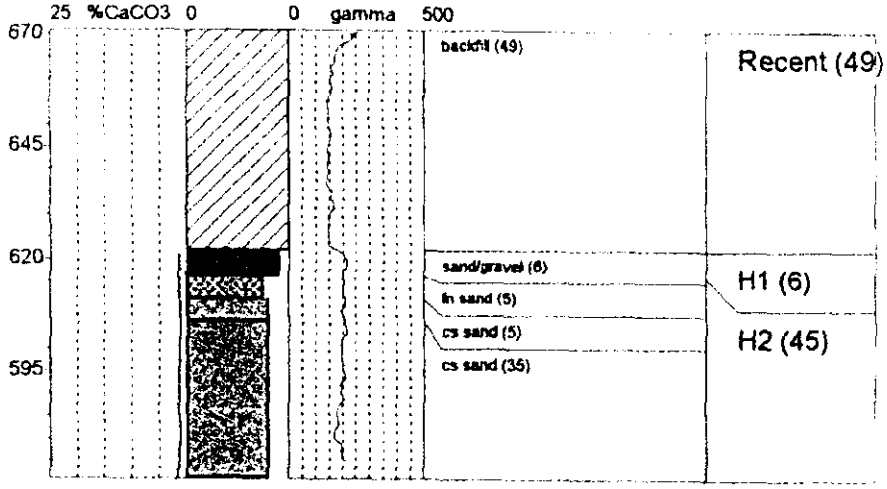

25 %CaCO3 0
0 gamma 500
670
645
620
595
570
backfill (49)
sand/gravel (4)
cs sand (3)
cs sand/silt (44)
Recent (49)
H1 (4)
H2 (47)

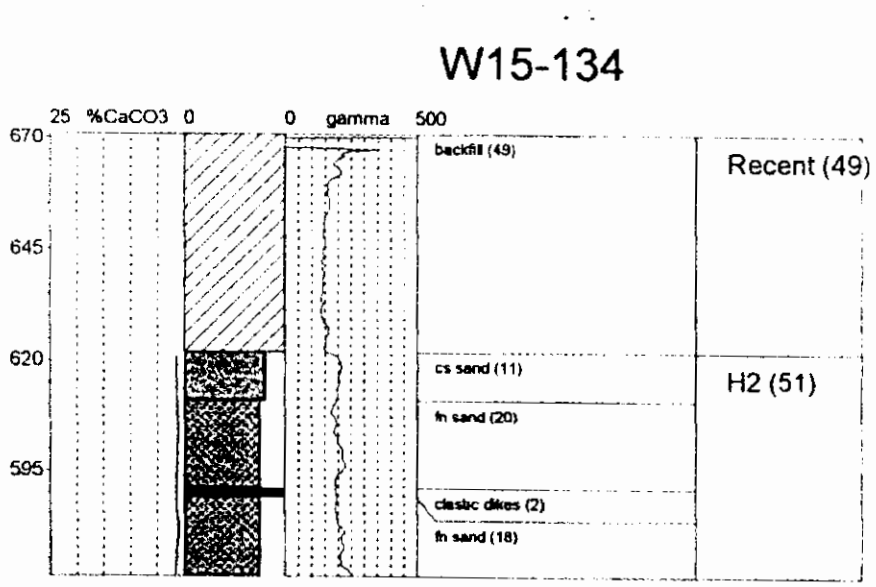

W15-13
25 %CaCO3 0
0 gamma 500
665
640
615
590
565
540
515
490
465
440
gravel (60)
cs sand (18)
fn sand/slt (4)
cs sand/slt (11)
slt (2)
fn sand/slt (3)
sandy caliche (22)
crs fluvial sand facies (13)
fluvial gravel (107)
H1 (60)
H2 (33)
PPu (5)
PPc (22)
Rtf (13)
Rwi(e) (107)

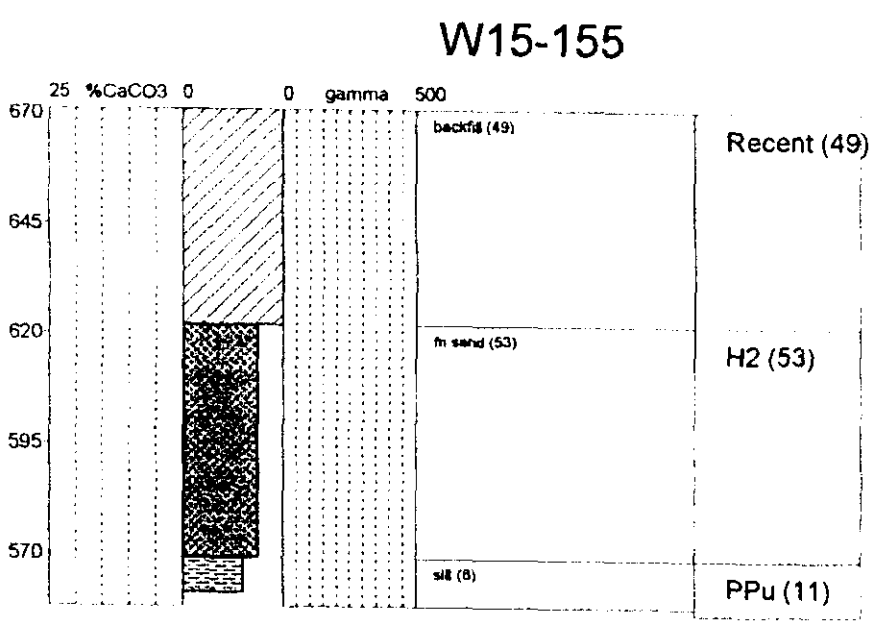
W15-131


25 %CaCO3 0
0 gamma 500
670
645
620
595
backfill (49)
Recent (49)
sand/gravel (1)
cs sand/silt (5)
fn sand (10)
cs sand (5)
cs sand/silt (10)
cs sand (5)
cs sand/silt (5)
cs sand (5)
cs sand/silt (5)
H2 (51)

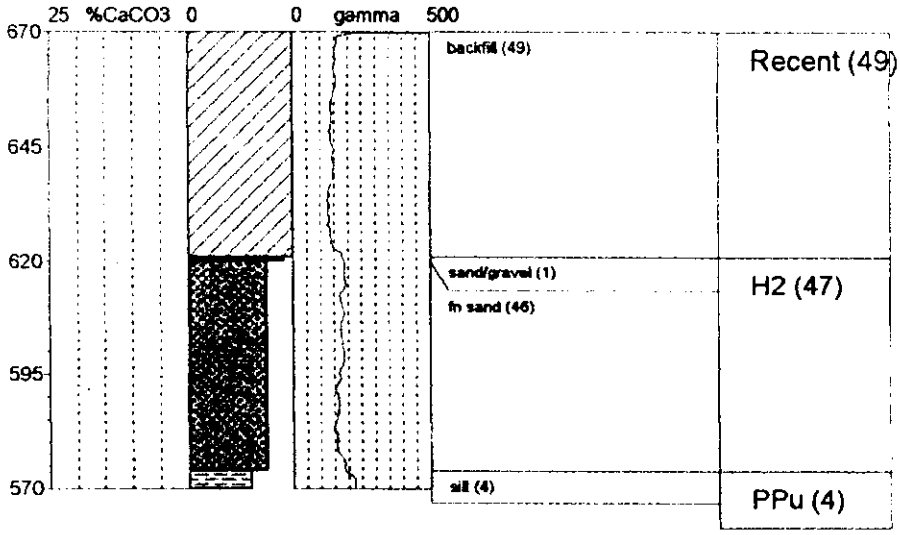
W15-133


25 %CaCO3 0
0 gamma 500
670
645
620
595
backfill (49)
sand/gravel (6)
fn sand (5)
cs sand (5)
cs sand (35)
Recent (49)
H1 (6)
H2 (45)

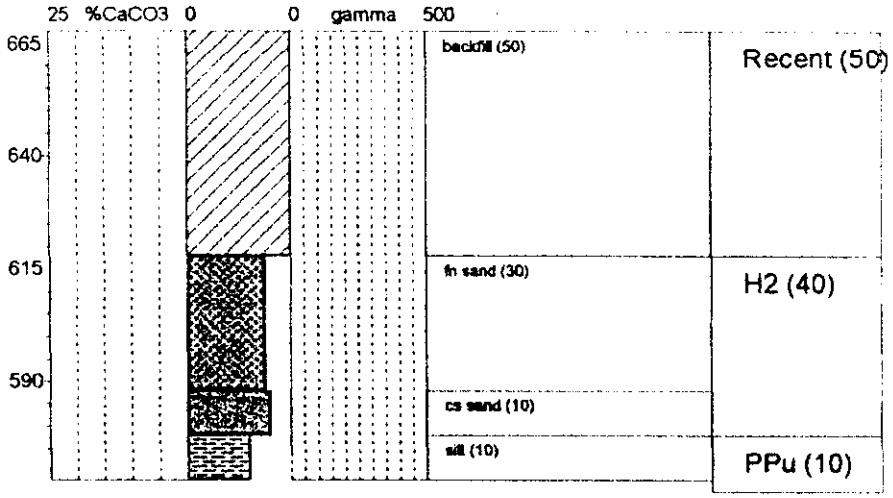

W15-134
25 %CaCO3 0
0 gamma 500
670
645
620
595
backfill (49)
cs sand (11)
fn sand (20)
clastic dikes (2)
fn sand (18)
Recent (49)
H2 (51)


W15-155
25 %CaCO3 0
0 gamma 500
670
645
620
595
570
backfill (49)
fn sand (53)
silt (8)
Recent (49)
H2 (53)
PPu (11)

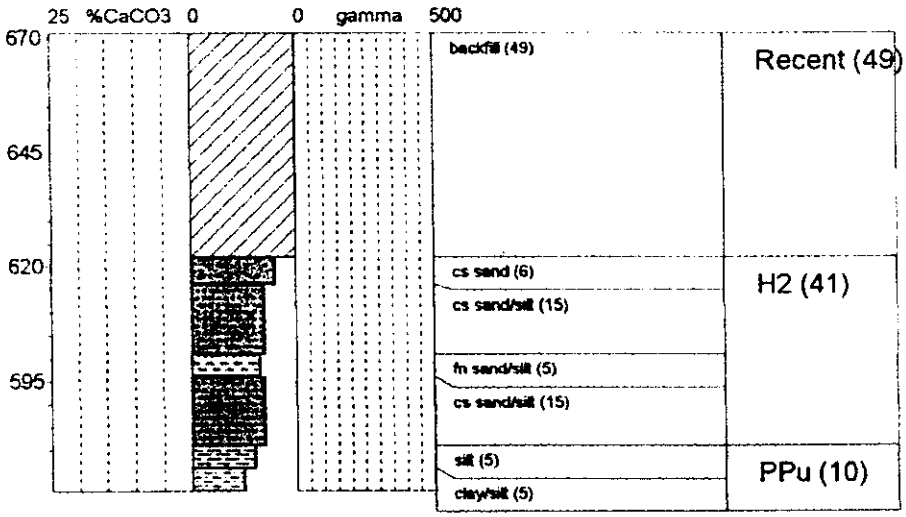
W15-159

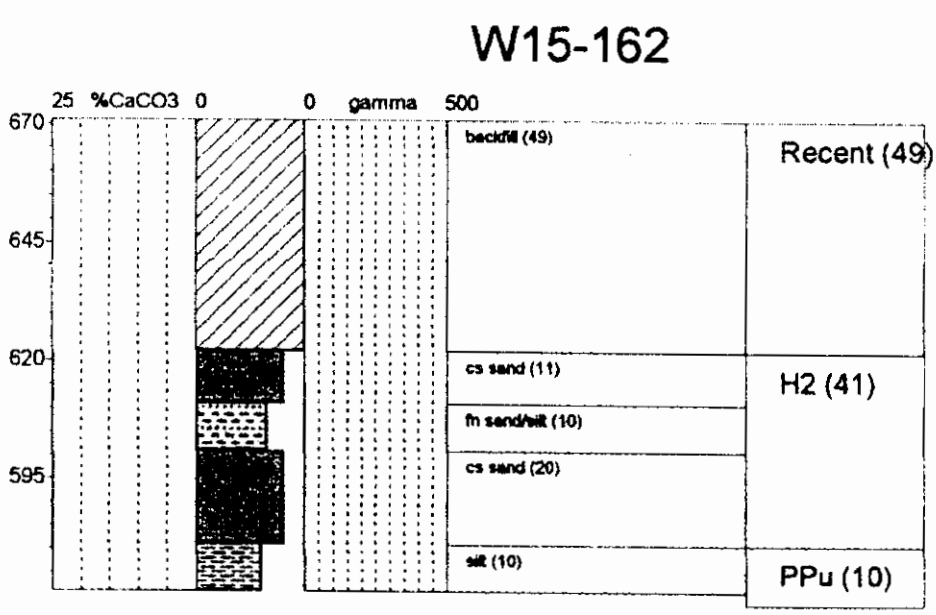

25 %CaCO3 0
0 gamma 500
670
645
620
595
570
backfill (49)
sand/gravel (1)
fn sand (46)
silt (4)
Recent (49)
H2 (47)
PPu (4)

W15-160

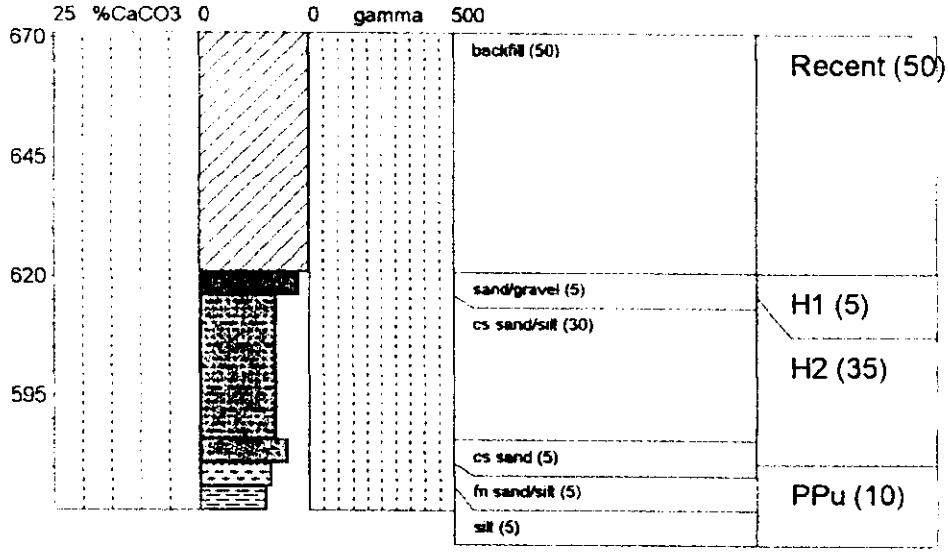

25 %CaCO3 0
0 gamma 500
665
640
615
590
backfill (50)
fn sand (30)
cs sand (10)
silt (10)
Recent (50)
H2 (40)
PPu (10)

W15-161

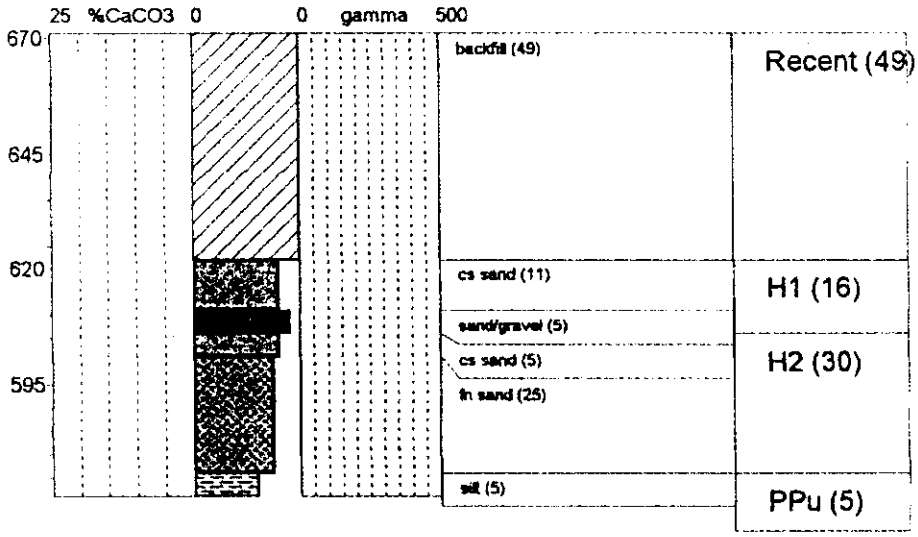

25 %CaCO3 0
0 gamma 500
670
645
620
595
backfill (49)
Recent (49)
cs sand (6)
cs sand/silt (15)
H2 (41)
fn sand/silt (5)
cs sand/silt (15)
silt (5)
clay/silt (5)
PPu (10)


W15-162
25 %CaCO3 0
0 gamma 500
670
645
620
595
backfill (49)
cs sand (11)
fn sand/silt (10)
cs sand (20)
silt (10)
Recent (49)
H2 (41)
PPu (10)

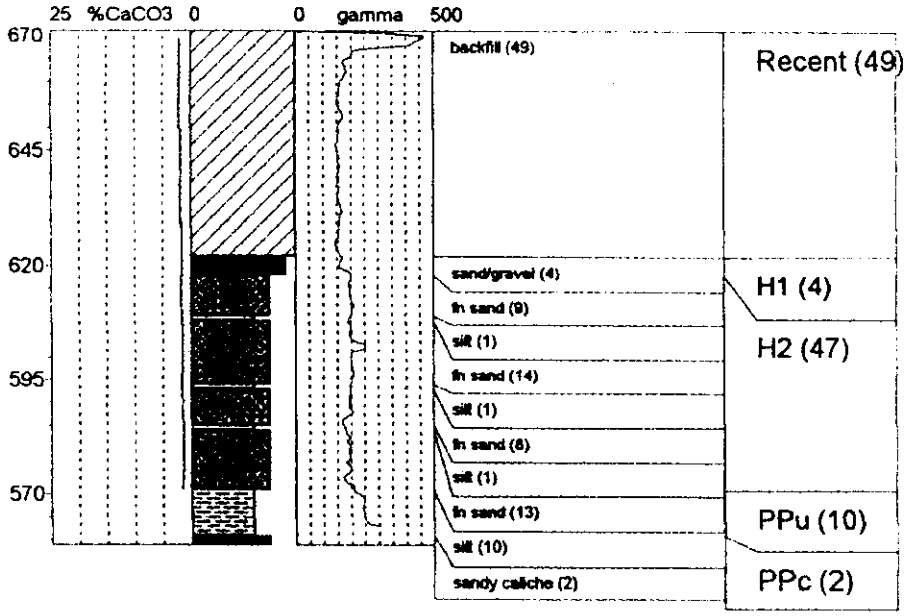
W15-163


25 %CaCO3 0
0 gamma 500
670
645
620
595
backfill (50)
sand/gravel (5)
cs sand/silt (30)
cs sand (5)
fn sand/silt (5)
silt (5)
Recent (50)
H1 (5)
H2 (35)
PPu (10)

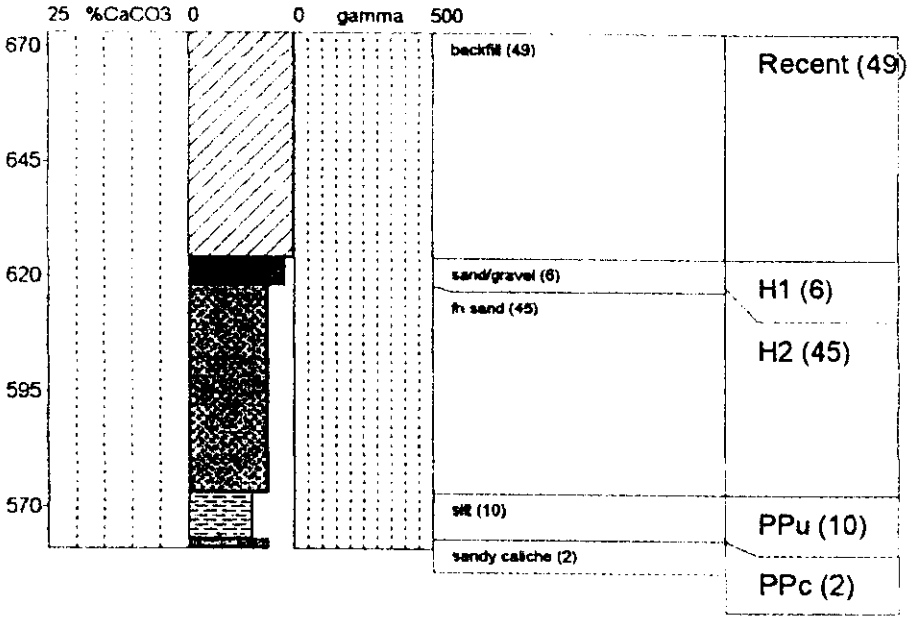
W15-164


25 %CaCO3 0
0 gamma 500
670
645
620
595
backfill (49)
cs sand (11)
sand/gravel (5)
cs sand (5)
fn sand (25)
silt (5)
Recent (49)
H1 (16)
H2 (30)
PPu (5)

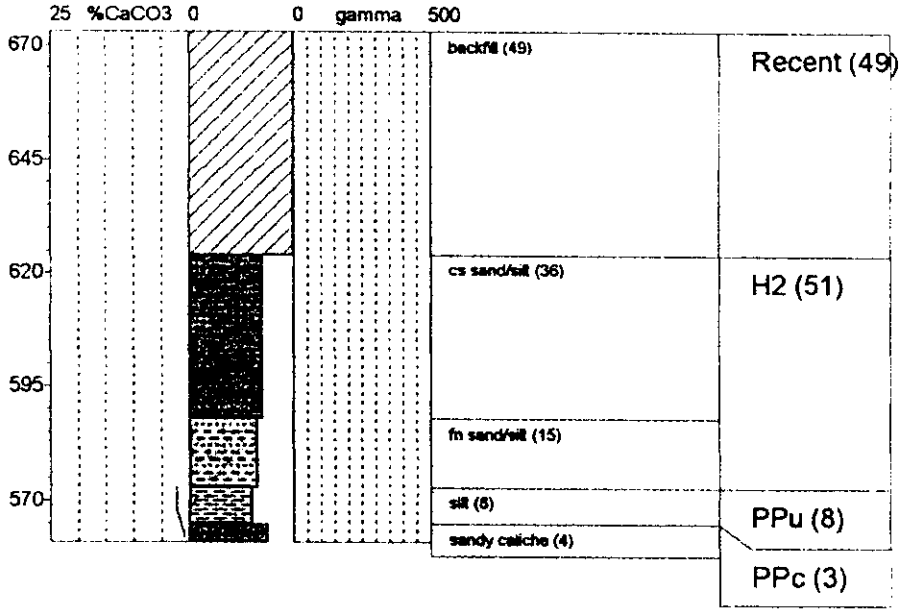
W15-166


25 %CaCO3 0
0 gamma 500
670
645
620
595
570
backfill (49)
sand/gravel (4)
fn sand (9)
silt (1)
fn sand (14)
silt (1)
fn sand (6)
silt (1)
fn sand (13)
silt (10)
sandy caliche (2)
Recent (49)
H1 (4)
H2 (47)
PPu (10)
PPc (2)

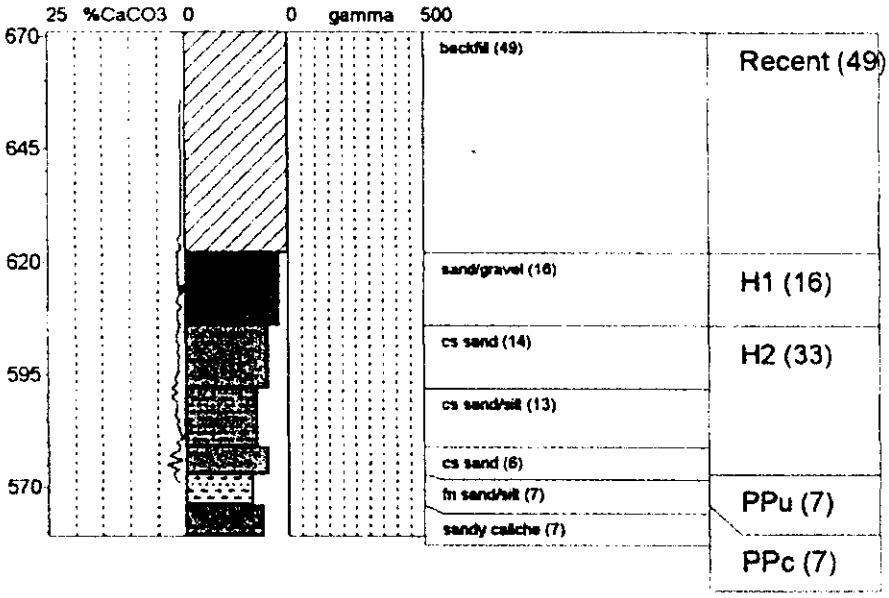
W15-167


25 %CaCO3 0
0 gamma 500
670
645
620
595
570
backfill (49)
sand/gravel (6)
fn sand (45)
silt (10)
sandy caliche (2)
Recent (49)
H1 (6)
H2 (45)
PPu (10)
PPc (2)

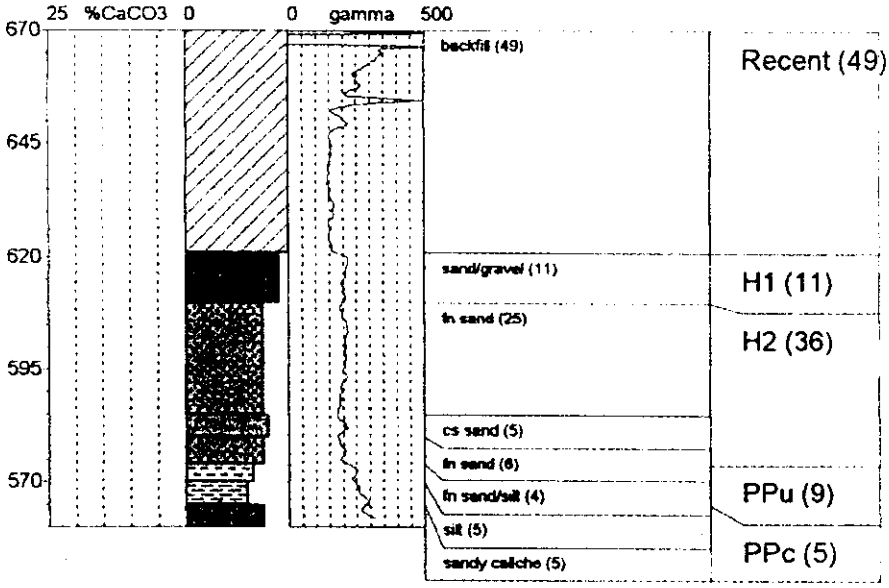
W15-171

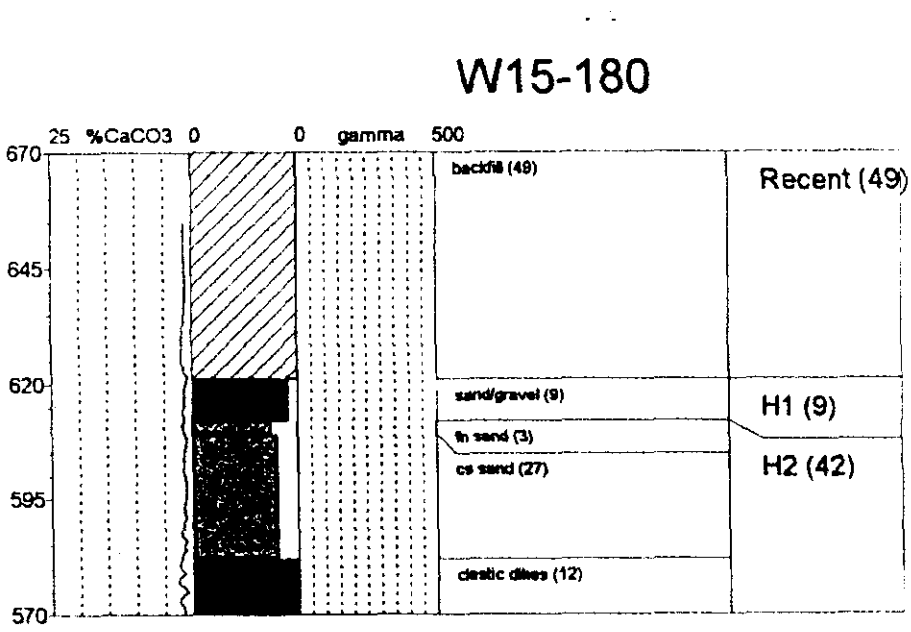

25 %CaCO3 0
0 gamma 500
670
645
620
595
570
backfill (49)
cs sand/silt (36)
fn sand/silt (15)
silt (6)
sandy caliche (4)
Recent (49)
H2 (51)
PPu (8)
PPc (3)

W15-177

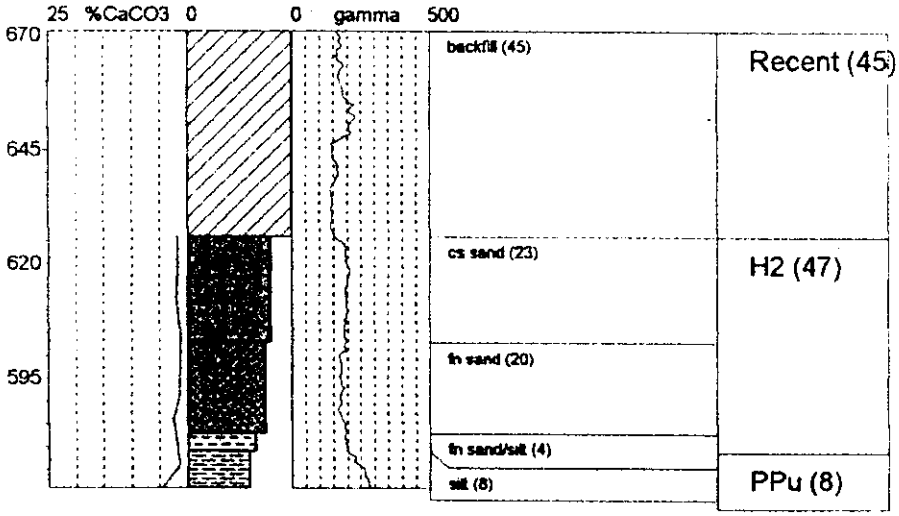

25 %CaCO3 0
0 gamma 500
670
645
620
595
570
backfill (49)
sand/gravel (16)
cs sand (14)
cs sand/silt (13)
cs sand (6)
fn sand/silt (7)
sandy caliche (7)
Recent (49)
H1 (16)
H2 (33)
PPu (7)
PPc (7)

W15-178

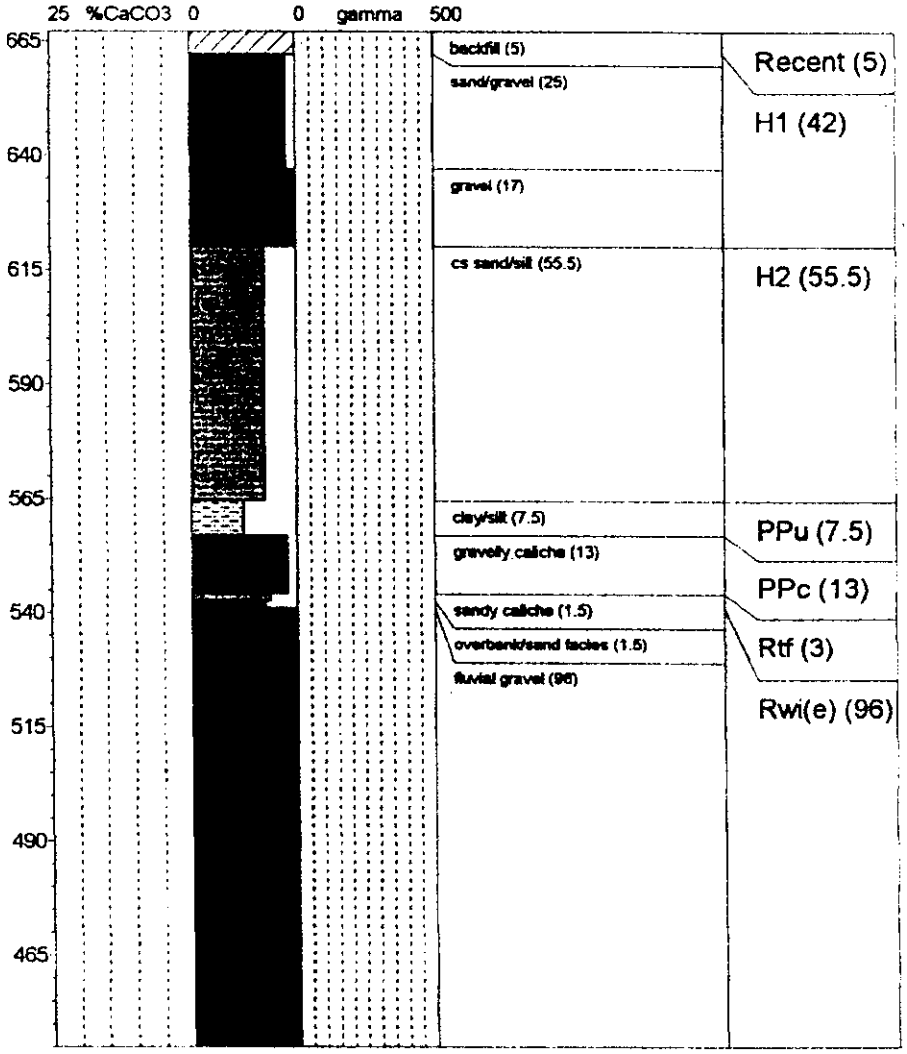

25 %CaCO3 0
0 gamma 500
670
645
620
595
570
backfill (49)
sand/gravel (11)
fn sand (25)
cs sand (5)
fn sand (6)
fn sand/silt (4)
silt (5)
sandy caliche (5)
Recent (49)
H1 (11)
H2 (36)
PPu (9)
PPc (5)


W15-180
25 %CaCO3 0
0 gamma 500
670
645
620
595
570
backfill (49)
sand/gravel (9)
fn sand (3)
cs sand (27)
clastic dikes (12)
Recent (49)
H1 (9)
H2 (42)

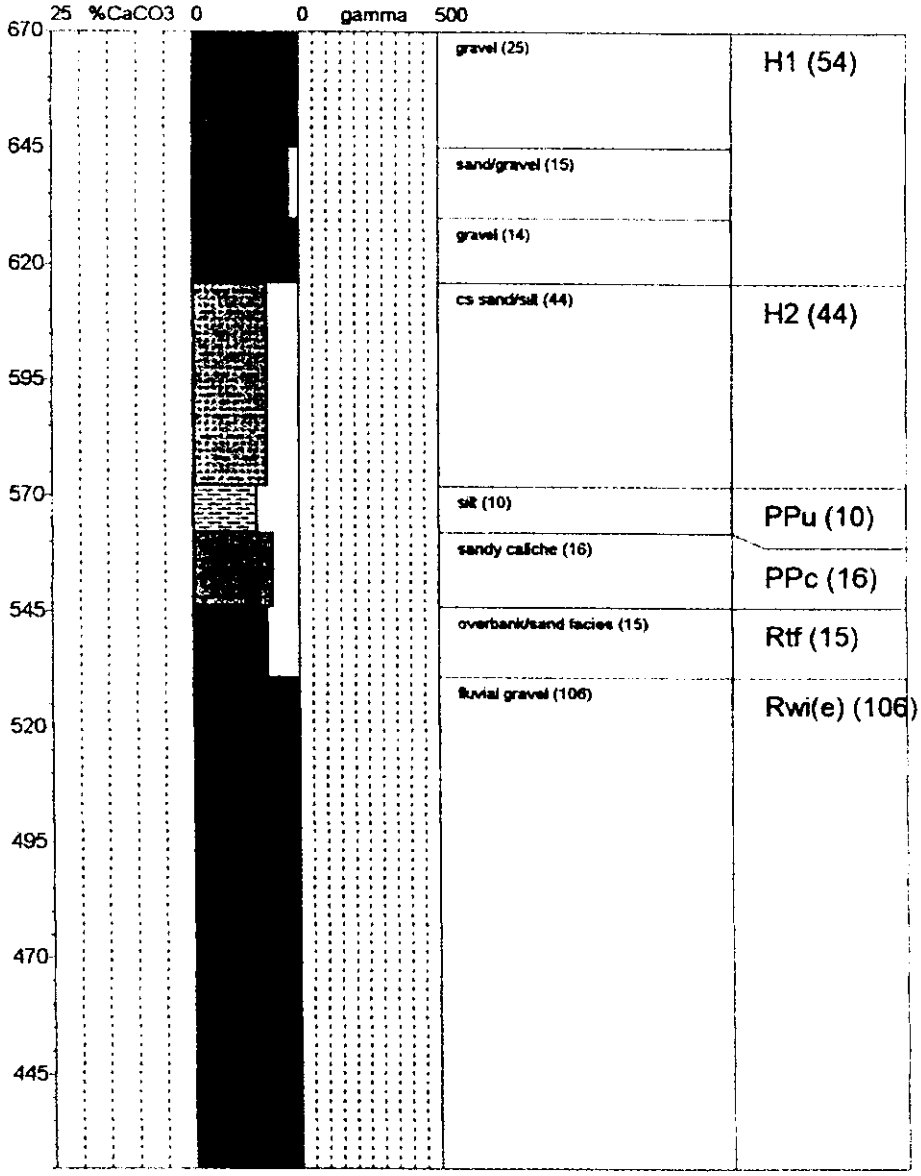
W15-184


25 %CaCO3 0
0 gamma 500
670
645
620
595
backfill (45)
cs sand (23)
fn sand (20)
fn sand/silt (4)
silt (8)
Recent (45)
H2 (47)
PPu (8)

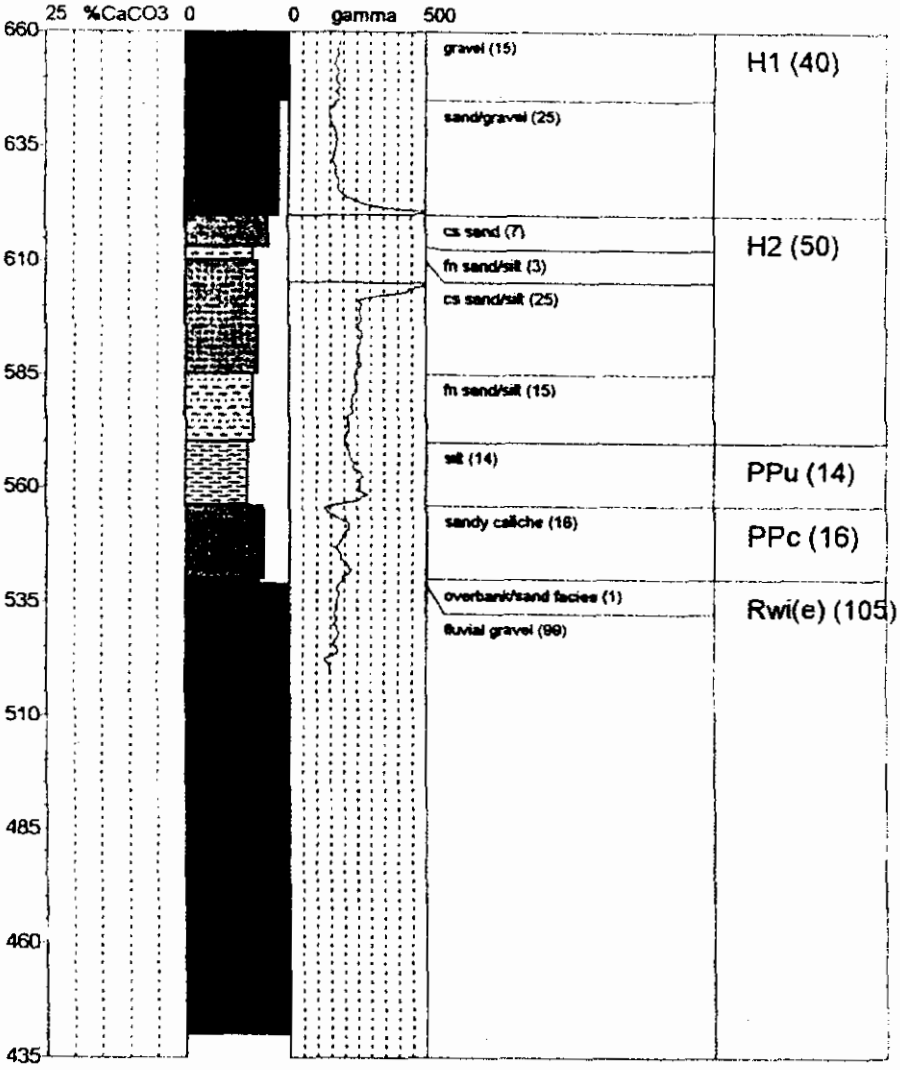
W15-22


25 %CaCO3 0
0 gamma 500
665
640
615
590
565
540
515
490
465
backfill (5)
sand/gravel (25)
gravel (17)
cs sand/silt (55.5)
clay/silt (7.5)
gravelly caliche (13)
sandy caliche (1.5)
overbank/sand facies (1.5)
fluvial gravel (96)
Recent (5)
H1 (42)
H2 (55.5)
PPu (7.5)
PPc (13)
Rtf (3)
Rwi(e) (96)

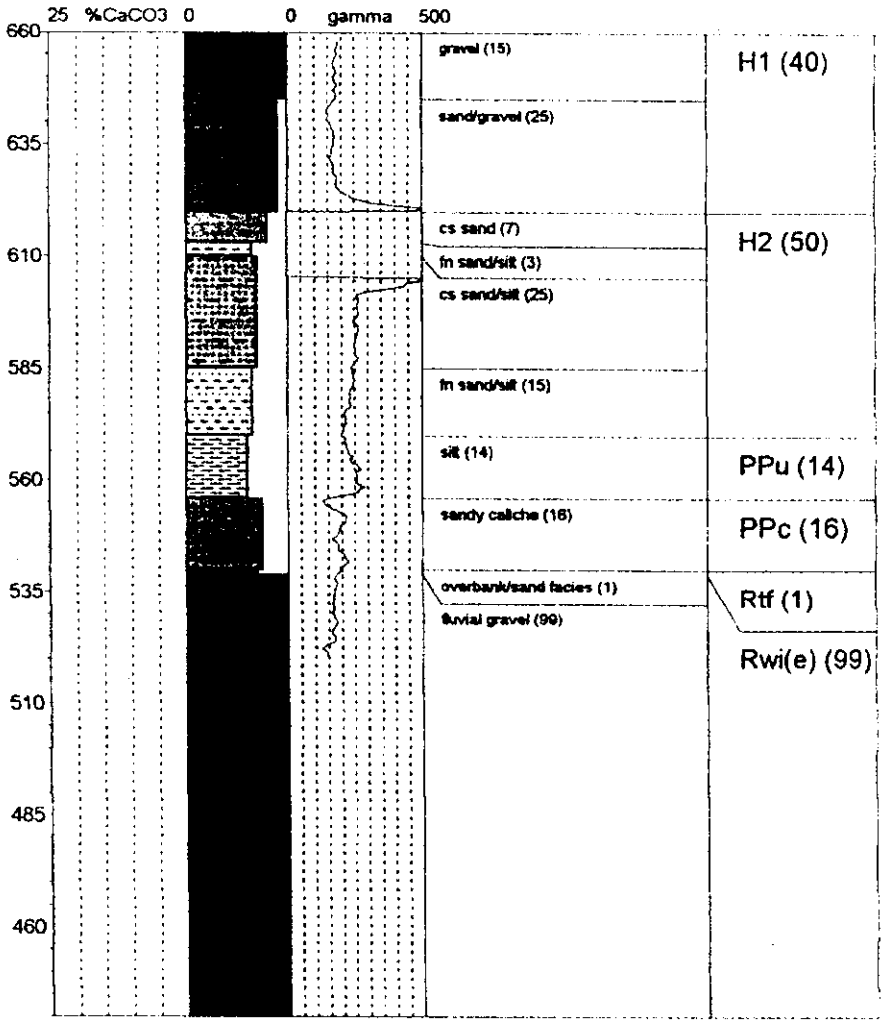
W15-3

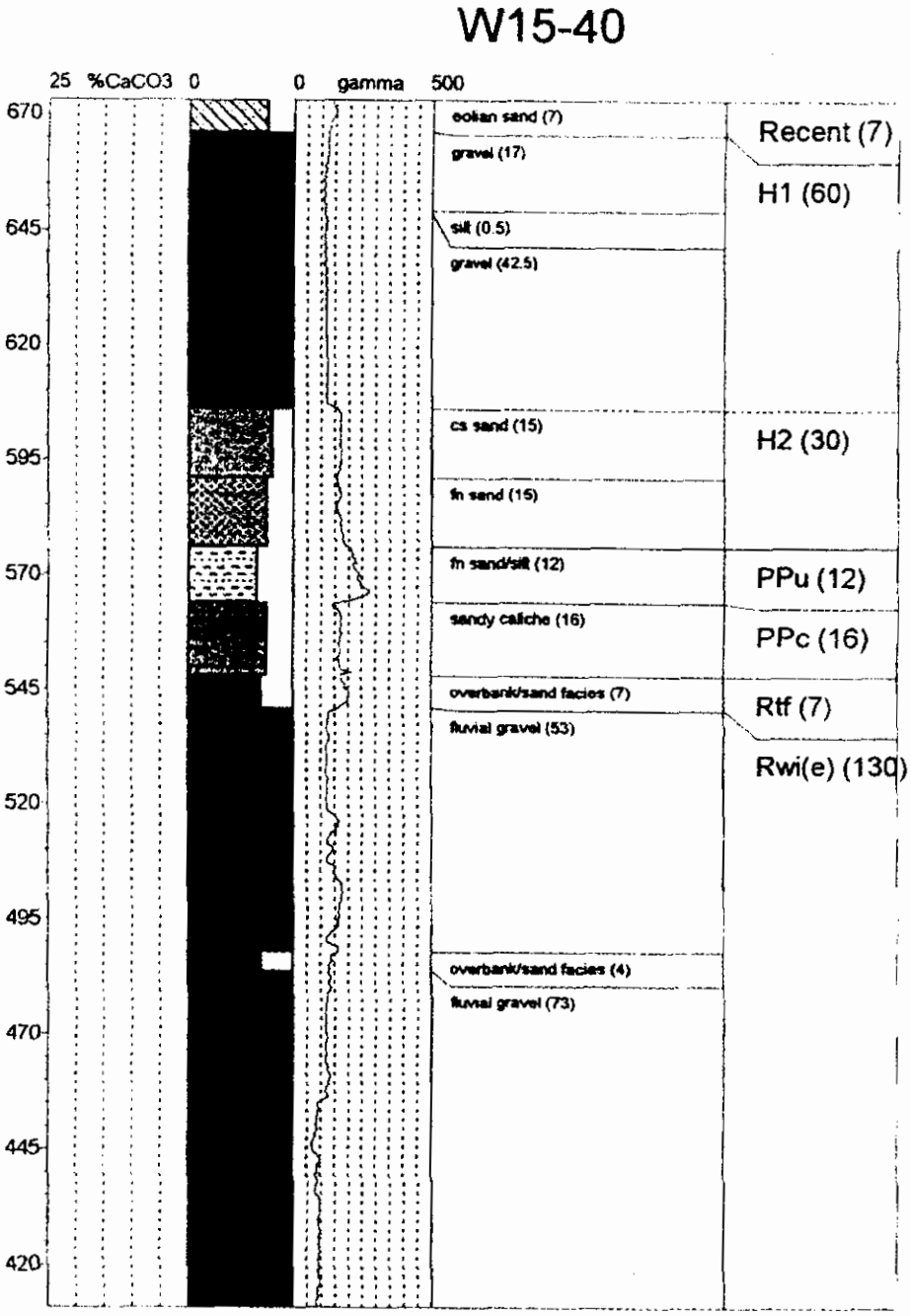

25 %CaCO3 0
0 gamma 500
670
645
620
595
570
545
520
495
470
445
gravel (25)
sand/gravel (15)
gravel (14)
cs sand/slt (44)
slt (10)
sandy caliche (16)
overbank/sand facies (15)
fluvial gravel (106)
H1 (54)
H2 (44)
PPu (10)
PPc (16)
Rtf (15)
Rwi(e) (106)

W15-4

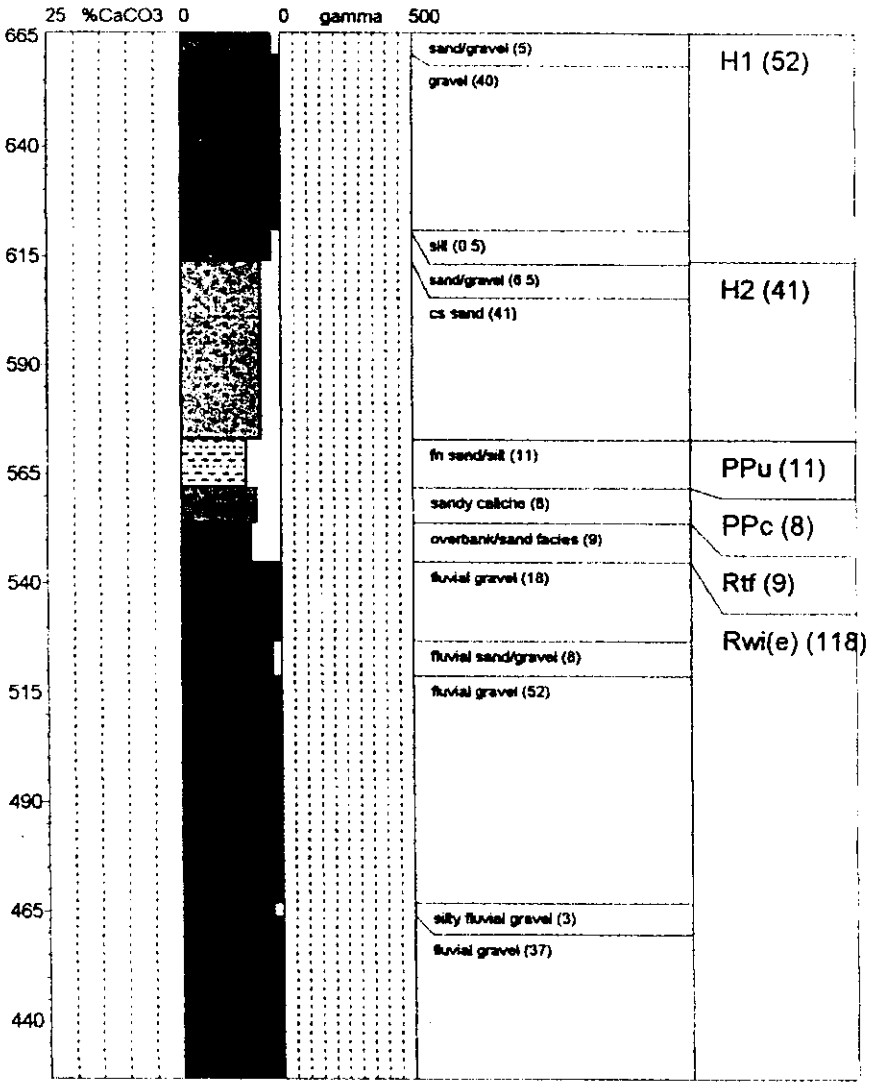

25 %CaCO3 0
0 gamma 500
660
635
610
585
560
535
510
485
460
435
gravel (15)
sand/gravel (25)
cs sand (7)
fn sand/silt (3)
cs sand/silt (25)
fn sand/silt (15)
silt (14)
sandy caliche (16)
overbank/sand facies (1)
fluvial gravel (99)
H1 (40)
H2 (50)
PPu (14)
PPc (16)
Rwi(e) (105)

W15-4

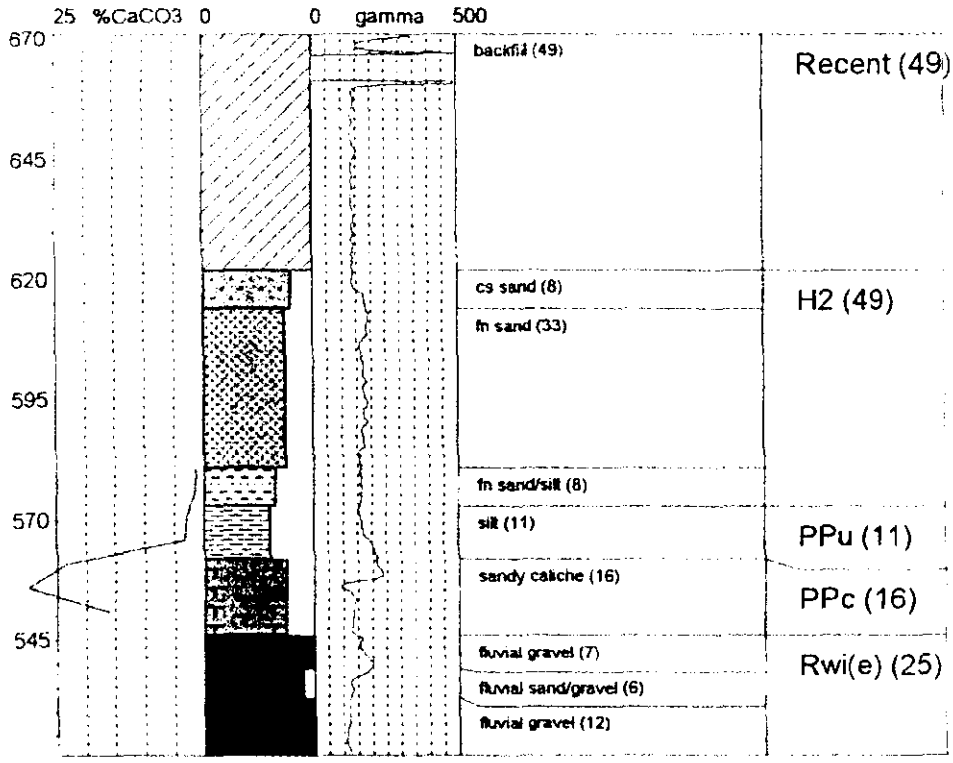

25 %CaCO3 0
0 gamma 500
660
635
610
585
560
535
510
485
460
gravel (15)
sand/gravel (25)
cs sand (7)
fn sand/silt (3)
cs sand/silt (25)
fn sand/silt (15)
silt (14)
sandy caliche (16)
overbank/sand facies (1)
fluvial gravel (99)
H1 (40)
H2 (50)
PPu (14)
PPc (16)
Rtf (1)
Rwi(e) (99)

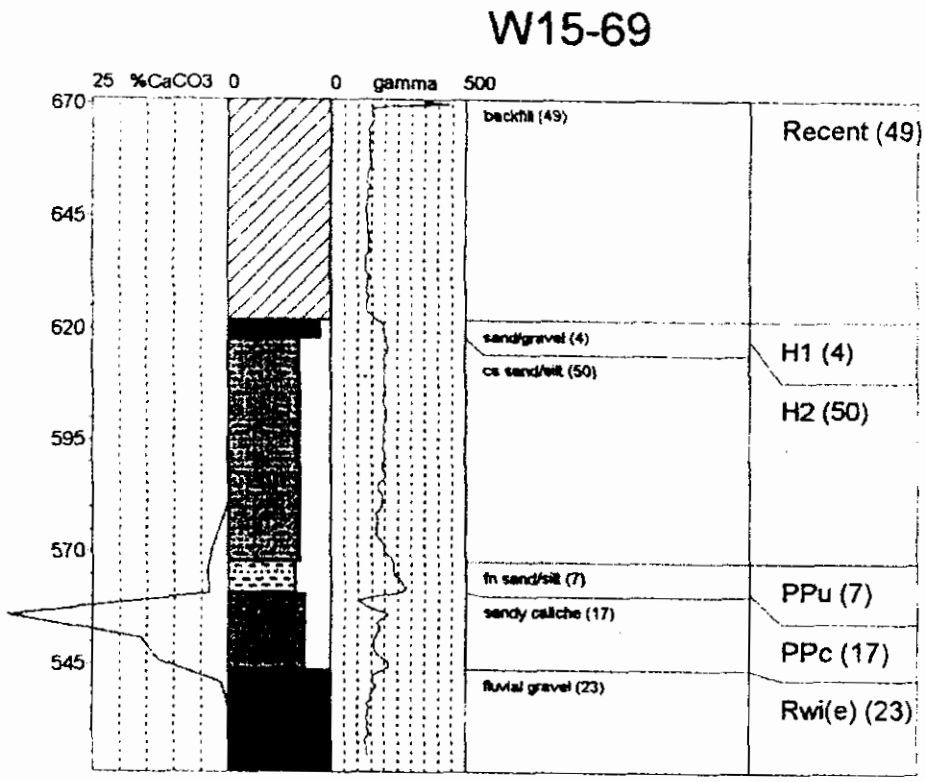

W15-40
25 %CaCO3 0
0 gamma 500
670
645
620
595
570
545
520
495
470
445
420
eolian sand (7)
gravel (17)
silt (0.5)
gravel (42.5)
cs sand (15)
fn sand (15)
fn sand/silt (12)
sandy caliche (16)
overbank/sand facies (7)
fluvial gravel (53)
overbank/sand facies (4)
fluvial gravel (73)
Recent (7)
H1 (60)
H2 (30)
PPu (12)
PPc (16)
Rtf (7)
Rwi(e) (130)

W15-41

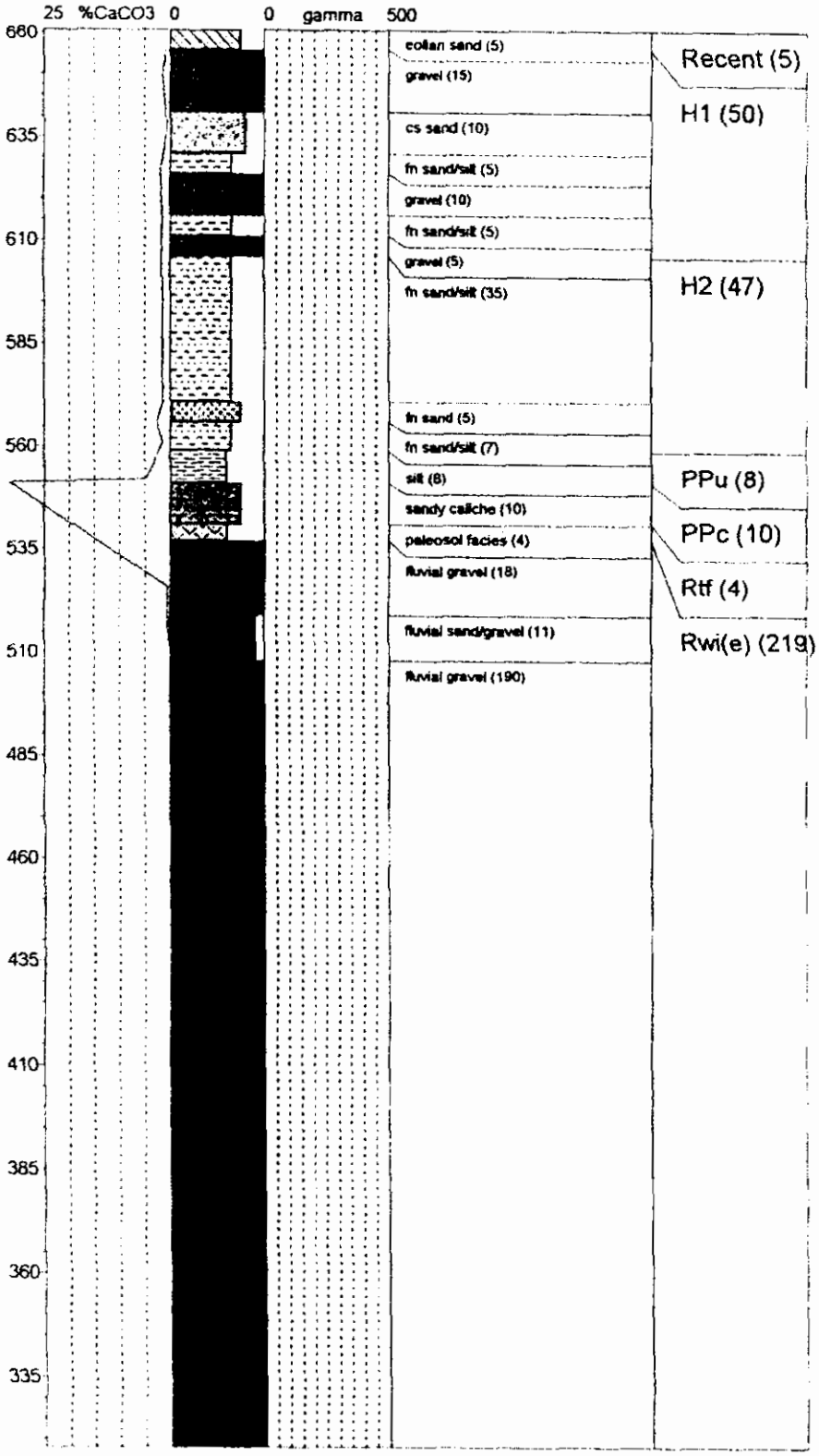

25 %CaCO3 0
0 gamma 500
665
640
615
590
565
540
515
490
465
440
sand/gravel (5)
gravel (40)
silt (0 5)
sand/gravel (6 5)
cs sand (41)
fn sand/silt (11)
sandy caliche (8)
overbank/sand facies (9)
fluvial gravel (18)
fluvial sand/gravel (8)
fluvial gravel (52)
silty fluvial gravel (3)
fluvial gravel (37)
H1 (52)
H2 (41)
PPu (11)
PPc (8)
Rtf (9)
Rwi(e) (118)

W15-67

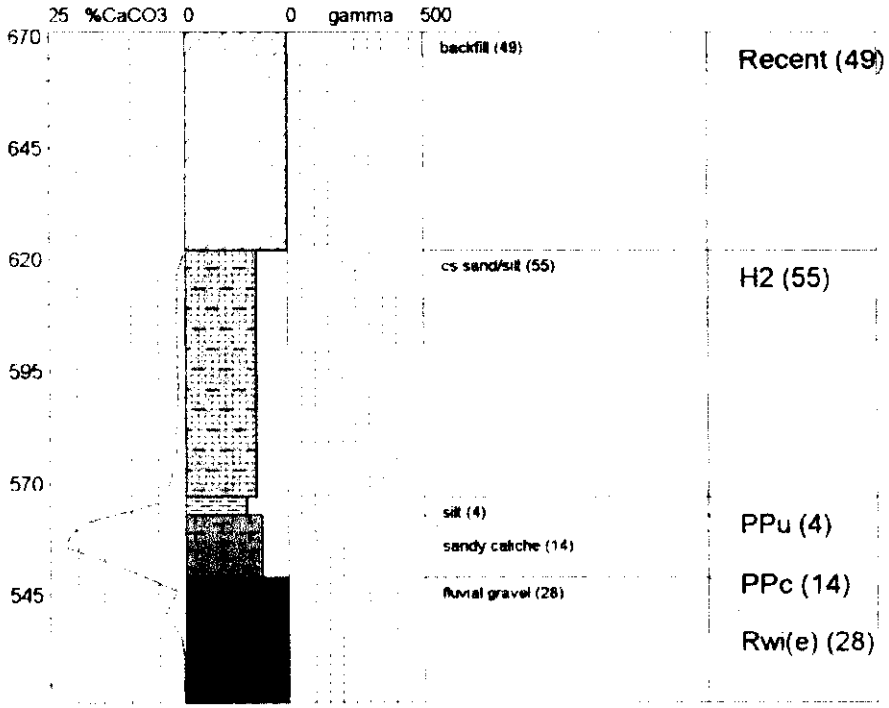

25 %CaCO3 0
0 gamma 500
670
645
620
595
570
545
backfill (49)
cs sand (8)
fn sand (33)
fn sand/silt (8)
silt (11)
sandy caliche (16)
fluvial gravel (7)
fluvial sand/gravel (6)
fluvial gravel (12)
Recent (49)
H2 (49)
PPu (11)
PPc (16)
Rwi(e) (25)


W15-69
25 %CaCO3 0
0 gamma 500
670
645
620
595
570
545
backfill (49)
sand/gravel (4)
cs sand/silt (50)
fn sand/silt (7)
sandy caliche (17)
fluvial gravel (23)
Recent (49)
H1 (4)
H2 (50)
PPu (7)
PPc (17)
Rwi(e) (23)

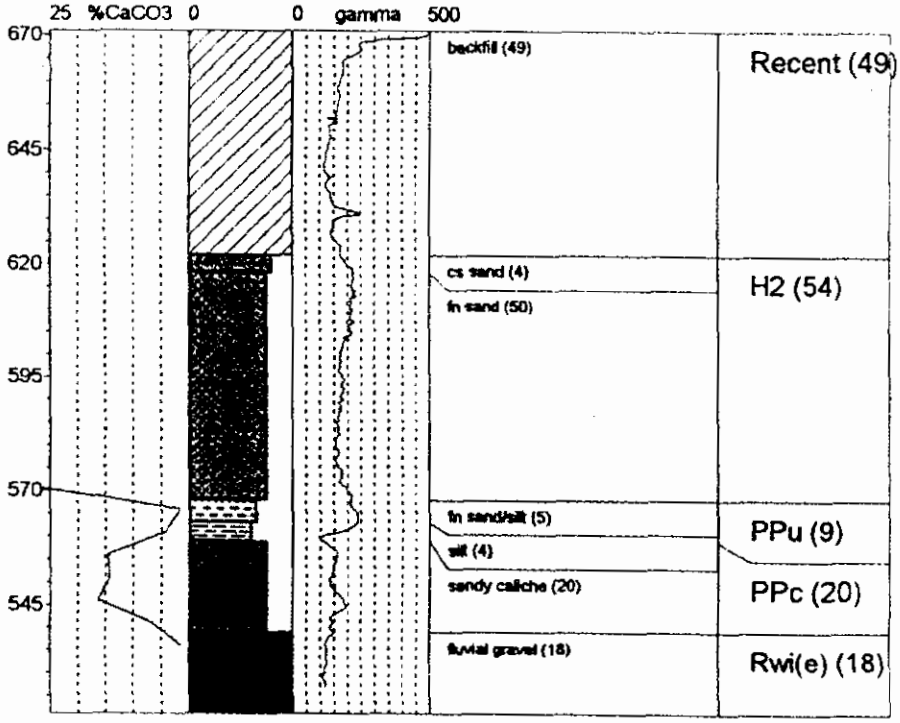
W15-7


25 %CaCO3 0
0 gamma 500
660
635
610
585
560
535
510
485
460
435
410
385
360
335
eolian sand (5)
gravel (15)
cs sand (10)
fn sand/silt (5)
gravel (10)
fn sand/silt (5)
gravel (5)
fn sand/silt (35)
fn sand (5)
fn sand/silt (7)
silt (8)
sandy caliche (10)
paleosol facies (4)
fluvial gravel (18)
fluvial sand/gravel (11)
fluvial gravel (190)
Recent (5)
H1 (50)
H2 (47)
PPu (8)
PPc (10)
Rtf (4)
Rwi(e) (219)

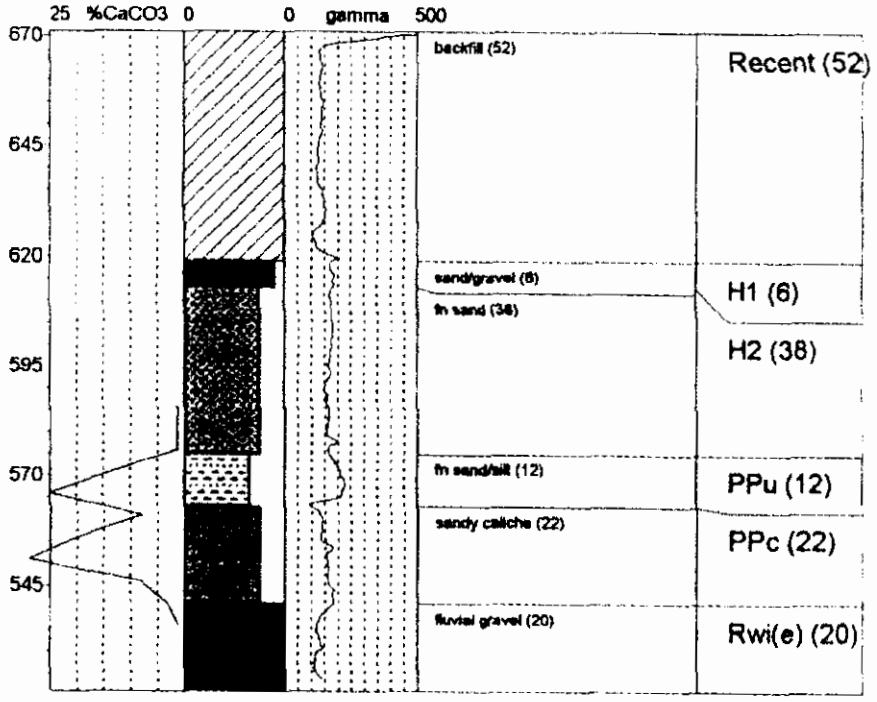
W15-70


25 %CaCO3 0
0 gamma 500
670
645
620
595
570
545
backfill (49)
cs sand/silt (55)
silt (4)
sandy caliche (14)
fluvial gravel (28)
Recent (49)
H2 (55)
PPu (4)
PPc (14)
Rwi(e) (28)

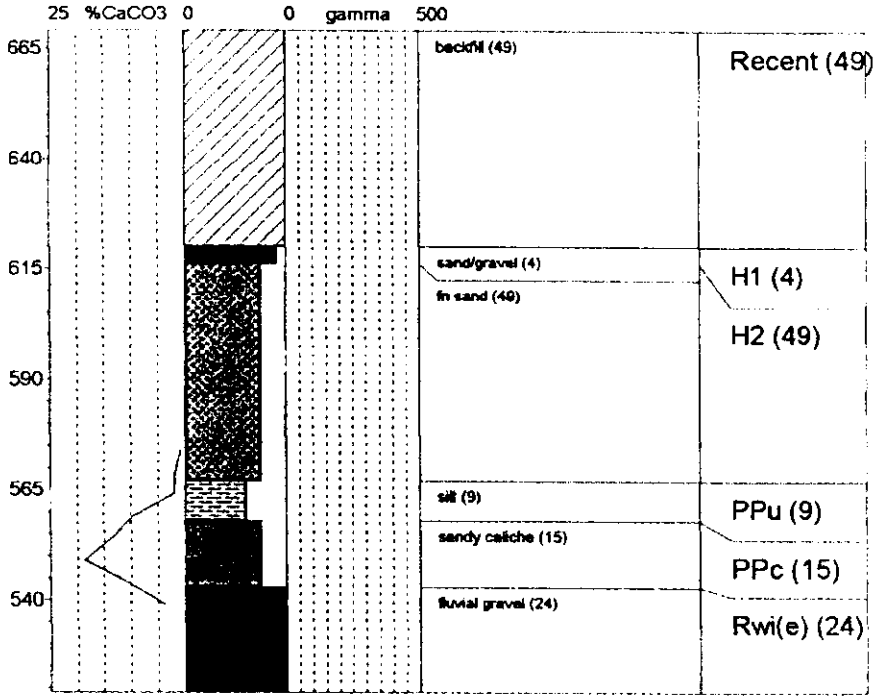
W15-71

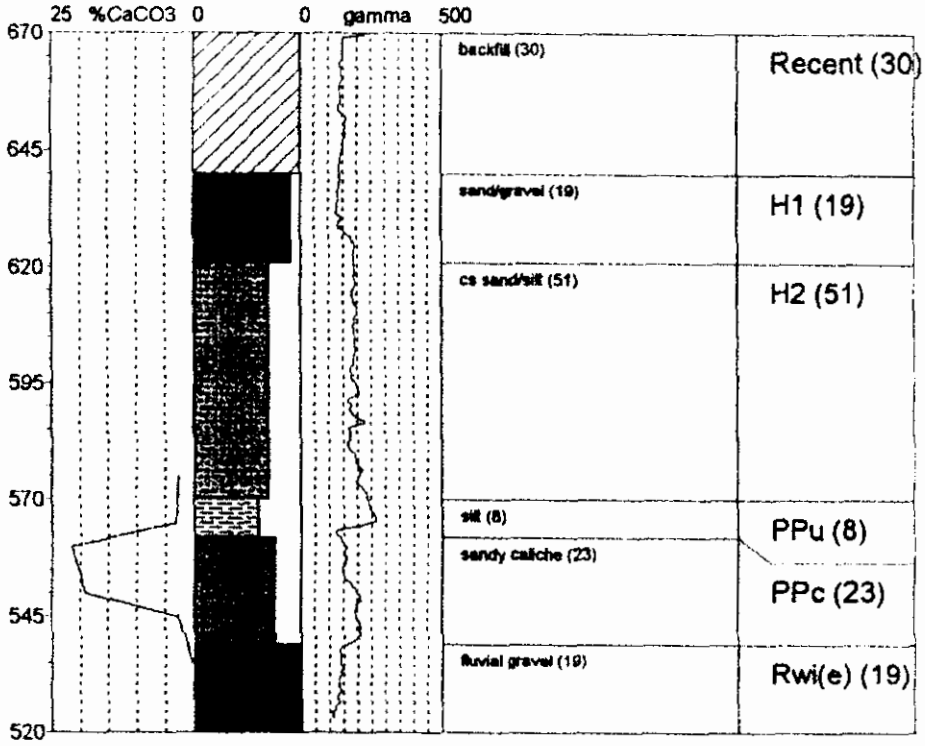

25 %CaCO3 0
0 gamma 500
670
645
620
595
570
545
backfill (49)
cs sand (4)
fn sand (50)
fn sand/silt (5)
silt (4)
sandy caliche (20)
fluvial gravel (18)
Recent (49)
H2 (54)
PPu (9)
PPc (20)
Rwi(e) (18)

W15-72

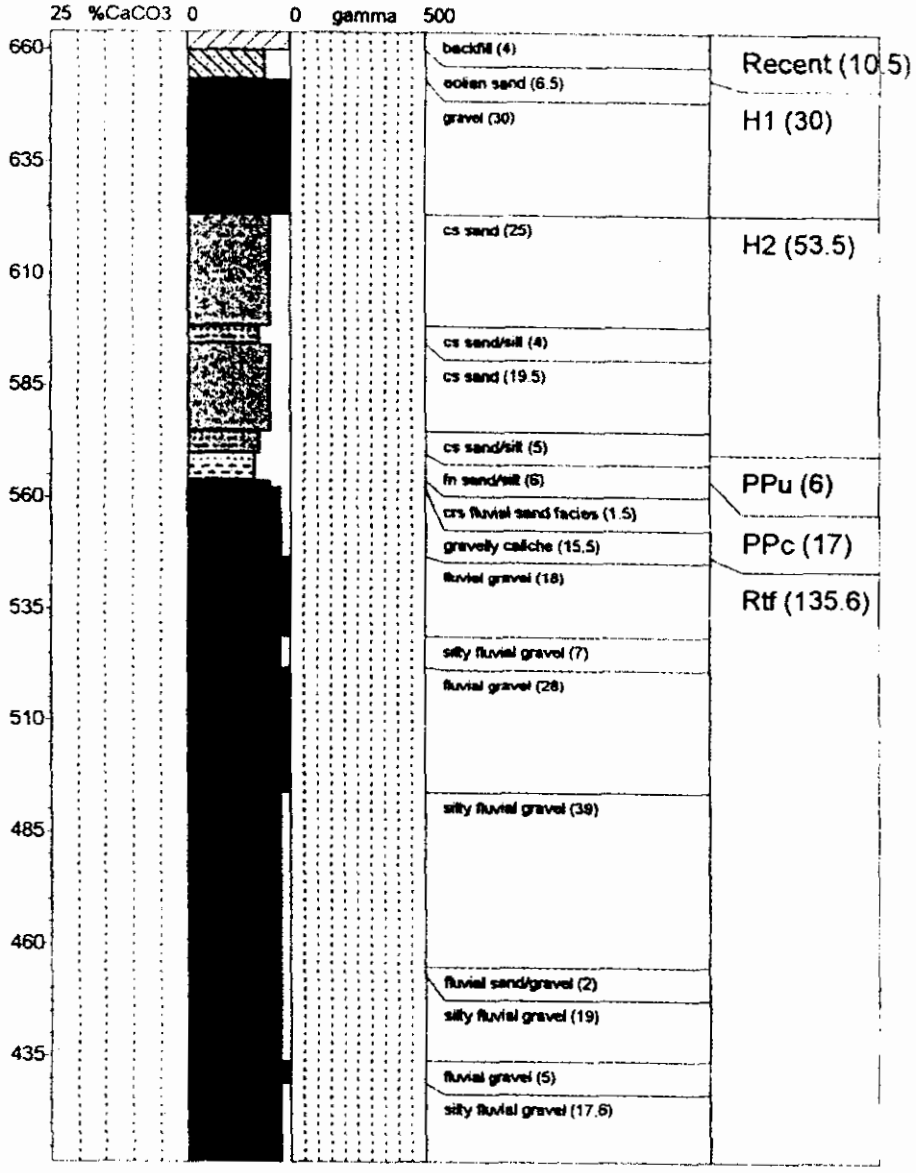

25 %CaCO3 0
0 gamma 500
670
645
620
595
570
545
backfill (52)
sand/gravel (6)
fn sand (38)
fn sand/silt (12)
sandy caliche (22)
fluvial gravel (20)
Recent (52)
H1 (6)
H2 (38)
PPu (12)
PPc (22)
Rwi(e) (20)

W15-73

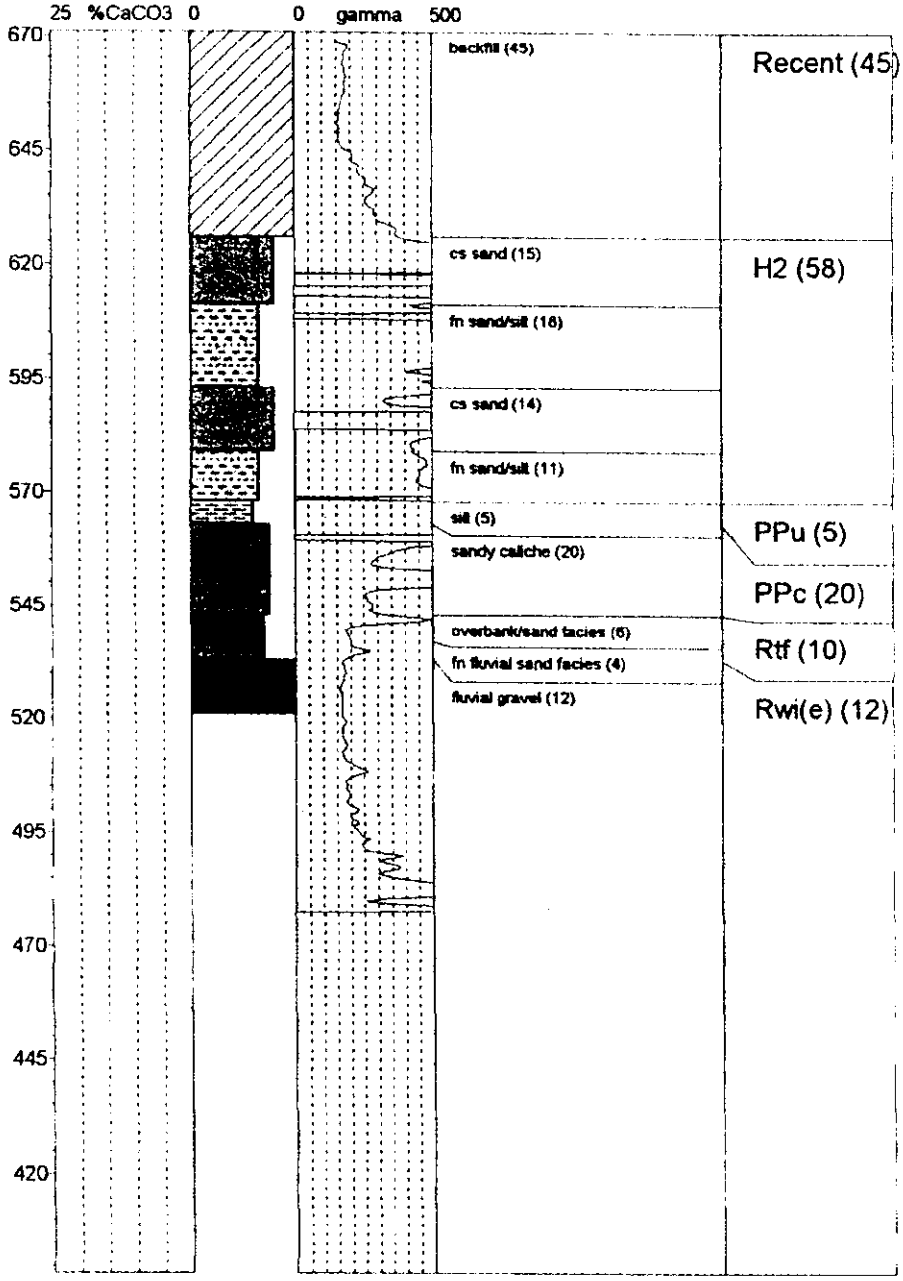

25 %CaCO3 0
0 gamma 500
665
640
615
590
565
540
backfill (49)
sand/gravel (4)
fn sand (49)
silt (9)
sandy caliche (15)
fluvial gravel (24)
Recent (49)
H1 (4)
H2 (49)
PPu (9)
PPc (15)
Rwi(e) (24)


W15-75
25 %CaCO3 0
0 gamma 500
670
645
620
595
570
545
520
backfill (30)
sand/gravel (19)
cs sand/silt (51)
silt (8)
sandy caliche (23)
fluvial gravel (19)
Recent (30)
H1 (19)
H2 (51)
PPu (8)
PPc (23)
Rwi(e) (19)

W15-763


25 %CaCO3 0
0 gamma 500
660
635
610
585
560
535
510
485
460
435
backfill (4)
eolian sand (6.5)
gravel (30)
cs sand (25)
cs sand/silt (4)
cs sand (19.5)
cs sand/silt (5)
fn sand/silt (6)
crs fluvial sand facies (1.5)
gravelly caliche (15.5)
fluvial gravel (18)
silty fluvial gravel (7)
fluvial gravel (28)
silty fluvial gravel (39)
fluvial sand/gravel (2)
silty fluvial gravel (19)
fluvial gravel (5)
silty fluvial gravel (17.6)
Recent (10.5)
H1 (30)
H2 (53.5)
PPu (6)
PPc (17)
Rtf (135.6)

W15-79


25 %CaCO3 0
0 gamma 500
670
645
620
595
570
545
520
495
470
445
420
backfill (45)
cs sand (15)
fn sand/silt (16)
cs sand (14)
fn sand/silt (11)
sil (5)
sandy caliche (20)
overbank/sand facies (5)
fn fluvial sand facies (4)
fluvial gravel (12)
Recent (45)
H2 (58)
PPu (5)
PPc (20)
Rtf (10)
Rwi(e) (12)

APPENDIX C

ISOPACH AND STRUCTURE CONTOUR DATA

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Table C-1. Isopach and Structure Contour Data. (3 sheets total)

Well No.	Northing	Easting	Elevation	Recent	recentiso	H1	H1 iso	H2	H2 iso	PPlu	PPlu iso	PPlc	PPlc iso	Rtf	Rtf iso	Rwi(e)	Rwi(e) iso	Rwi(lm)	Rwi(lm) iso	Rwi(a)	Rwi(a) iso	CRB	TD
W10-1	136734.76	566663.45	672	672	0	672	62	610	24	586	8	578	16	562	31	531							306
W10-101	136772	566850.2	672	672	38	634	0	634	43	591	8	583											574
W10-105	136778.415	566837.971	672	672	38	634	0	634	42	592	7	585											580
W10-107	136730.446	566790.848	673	673	38	635	2	633	41	592	11	581	18	563									551
W10-109	136723.987	566767.395	671	671	38	633	0	633	42	591	10	581	15	566	17	549							547
W10-11	136802.287	566755.313	673	673	0	673	28	645	55	590	12	578	28	550	11	539							423
W10-111	136723.118	566785.685	671	671	38	633	2	631	41	590	12	578	14	564									558
W10-112	136705.152	566792.435	671	671	38	633	2	631	45	586	14	572	11	561									549
W10-113	136720.426	566806.112	671	671	38	633	3	630	40	590	11	579	17	562	9	553							551
W10-117	136751.473	566789.576	671	671	38	633	5	628	40	588	7	581	13	568	19	549							547
W10-12	136797.67	566755.9	672	672	0	672	61	611	22	589	8	581	23	558	22	536							422
W10-120	136703.556	566763.484	671	671	38	633	2	631	41	590	10	580	19	561	11	550							549
W10-121	136747.842	566800.253	671	671	40	631	0	631	41	590	10	580	14	566	18	548							547
W10-122	136774.708	566818.169	672	672	40	632	0	632	42	590	8	582											580
W10-125	136778.639	566805.358	673	673	40	633	18	615	21	594	13	581											579
W10-134	136688.37	566784.857	673	673	40	633	0	633	38	595	16	579											578
W10-135	136660.477	566844.056	674	674	40	634	0	634	38	596	16	580											578
W10-141	136677.035	566761.721	671	671	40	631	0	631	42	589	12	577	21	556	6	550							548
W10-143	136689.357	566814.114	672	672	40	632	0	632	45	587	8	579											577
W10-147	136720.185	566832.02	672	672	40	632	0	632	42	590	11	579	6	573									572
W10-148	136728.089	566823.466	672	672	37	635	0	635	47	588	7	581											572
W10-16	136606.9	566781.2	670	670	10	660	50	610	23	587	12	575	10	565	24	541							450
W10-161	136456.908	566734.23	671	671	45	626	11	615	29	586	15	571											568
W10-17	136491.5	566775.7	671	671	0	671	42	629	48	581	10	571	12	559	16	543							448
W10-18	136396.5	566847.2	671	671	6	665	38	627	43	584	10	574	18	556	15	541							448
W10-196	136725	566788	671	671	45	626	0	626	37	589	10	579	13	566	16	550							491
W10-2	136614	566672	672	672	7	665	56	609	22	587	12	575	16	559	14	545							442
W10-22	136883	566833	684	684	0	684	33	651	50	601	10	591	18	573	32	541							384
W10-23	136815	566824	678	678	8	670	35	635	37	598	8	590	22	568	21	547							406
W10-26	136401	566843	672	672	3	669	39	630	46	584	9	575	13	562	17	545							410
W10-27	136442	566844	673	673	4.5	668.5	37	631.5	48.5	583	8	575	13	562	14	548							404.3
W10-4	136578	566735	670	670	0	670	52	618	37	581	10	571	16	555	17	538							425
W10-5	136465.97	566579.069	671	671	0	671	85	586	15	571	10	561	19	542	6	536							421
W10-8	136811	566849	677	677	0	677	44	633	41	592	9	583	22	561	9	552							426
W10-88	136460.37	566778.111	671	671	45	626	2	624	48	576													571
W10-89	136436.292	566778.171	671	671	45	626	5	621	40	581													571
W10-9	136799	566749	672	672	0	672	50	622	33	589	10	579	41	538	0	538							447
W10-90	136445.387	566758.642	671	671	45	626	8	618	37	581													571
W10-91	136460.307	566752.509	671	671	45	626	5	621	44	577													571
W10-92	136436.228	566752.569	671	671	45	626	8	618	42	576													571
W10-93	136445.31	566727.553	671	671	45	626	3	623	42	581													571
W10-94	136430.184	566773.309	671	671	45	626	20	606	25	581													571
W10-95	136414.372	566787.979	671	671	45	626	30	596	17	579													571
W10-96	136400.315	566773.384	671	671	45	626	5	621	42	579													571
W10-97	136426	566753	672	672	45	627	15	612	32	580													572
W10-98	136400.238	566742.296	671	671	45	626	10	616	35	581													571
W10-99	136416.66	566727.625	671	671	45	626	2	624	43	581													571
W11-12	136604	566927	679	679	5	674	23	651	63	588	12	576	24	552	0	552							429
W11-24	136745	566913	684	684	0	684	37	647	55	592	10	582	10	572	28	544							434
W11-26	136563.7	567044.7	694	694	0	694	65	629	35	594	5	589	37	552	0	552	271	281	17	264	74	190	185

Well No.	Northing	Easting	Elevation	Recent	recentiso	H1	H1 iso	H2	H2 iso	PPlu	PPlu iso	PPlc	PPlc iso	Rtf	Rtf iso	Rwi(e)	Rwi(e) iso	Rwi(lm)	Rwi(lm) iso	Rwi(a)	Rwi(a) iso	CRB	TD
W11-27	136797	566885	681	681	10	671	30	641	45	596	15	581	20	561	10	551							446
W11-28	136743.7	566934.9	689	689	0	689	40	649	57	592	13	579	14	565	19	546							442
W11-39	136780	566908	689	689	5	684	29	655	56	599	10	589	25	564	0	564							407
W11-40	136710	566927	689	689	6.5	682.5	25.5	657	60	597	11	586	19	567	11	556							409
W11-41	136678	566935	688	688	7	681	30	651	57	594	4	590	20	570	15	555							408
W11-42	136744	566920	689	689	8	681	31	650	52	598	9	589	21	568	13	555							409
W14-1	136311.4	566953.6	665	665	0	665	23	642	57	585	18	567	20	547	4	543							425
W14-12	136284	566906	667	667	0	667	34	633	60	573	8	565	24	541	0	541							444
W14-13	136282	566902	670	670	4	666	28	637	56	581	9	572	14	558	13	545							408
W14-14	136181	566898	671	671	0	671	33	638	60.5	577	14	563	2	561	13	548	279	269	36	233			228
W14-15	136231	566900	672	672	2	670	35	635	51	584	15	569	15	554	5	549							412
W14-16	136319	567001	674	674	13.5	660.5	20.5	640	55	585	10	575	14	561	9	552							409
W14-17	136219	567007	673	673	12.5	660.5	21.5	639	59	580	5	575	15	560	8	552							407.5
W14-2	136341	566933	666	666	20	646	20	626	40	586	10	576	32	544	0	544							443
W14-3	136343.2	566940.7	665	665	0	665	28	637	50	587	20	567	15	552	4	548							395
W14-4	136349	566921	666	666	0	666	40	626	32	594	20	574	23	551	0	551							461
W14-5	136040.1	566899.5	660	660	0	660	29	631	51	580	18	562	22	540	0	540							420
W14-6	136101	566899.4	665	665	11	654	36	618	41	577	15	562	13	549	0	549							425
W15-1	135945.5	566553.9	670	670	5	665	25	640	75	565	15	550	15	535	0	535							370
W15-12	136369	566699.5	667	671	0	671	45	626	49	577	8	569	20	549	0	549							446
W15-126	136170.456	566742.882	671	671	45	626	10	616															571
W15-127	136141.198	566742.956	671	671	49	622	6	616															570
W15-128	136157.009	566728.287	670	670	49	621	4	617															570
W15-13	136369.5	566845.4	667	667	0	667	60	607	33	574	5	569	22	547	13	534							427
W15-131	136148.403	566699.66	671	671	49	622	0	622															571
W15-133	136177.494	566754.141	671	671	49	622	6	616															571
W15-134	136189.265	566708.701	671	671	49	622	0	622															571
W15-155	136157.469	566789.849	671	671	49	622	0	622	53	569													558
W15-159	136231.632	566719.552	670	670	49	621	0	621	47	574													570
W15-160	136250.248	566728.954	668	668	50	618	0	618	40	578													568
W15-161	136277.294	566818.799	671	671	49	622	0	622	41	581													571
W15-162	136294.925	566800.163	671	671	49	622	0	622	41	581													571
W15-163	136269	566793.218	671	671	50	621	5	616	35	581													571
W15-164	136294.856	566772.428	671	671	49	622	16	606	30	576													571
W15-166	136165.127	566817.25	671	671	49	622	4	618	47	571	10	561											559
W15-167	136149.92	566817.25	673	673	49	624	6	618	45	573	10	563											560
W15-171	136173.621	566801.075	673	673	49	624	0	624	51	573	8	565											562
W15-177	136231.401	566748.812	671	671	49	622	16	606	33	573	7	566											559
W15-178	136201.254	566749.509	670	670	49	621	11	610	36	574	9	565											560
W15-180	136222.156	566698.865	670	670	49	621	9	612															570
W15-184	136371.295	566747.244	671	671	45	626	0	626	47	579													571
W15-22	136111	566683	667	667	5	662	42	620	55.5	564.5	7.5	557	13	544	3.5	540.5							445
W15-3	136371.7	566729.5	670	670	0	670	54	616	44	572	10	562	16	546	15	531							425
W15-4	136018.9	566820.7	660	660	0	660	40	620	50	570	14	556	16	540	0	540							435
W15-40	136205	566653	673	673	7	666	60	606	30	576	12	564	16	548	7	541							411
W15-41	136032	566758	666	666	0	666	52	614	41	573	11	562	8	554	9	545							427
W15-67	136202.631	566823.253	671	671	49	622	0	622	48	574	8	566	20	546	0	546							521
W15-69	136137.58	566758.508	671	671	49	622	4	618	50	568	7	561	17	544	0	544							521
W15-7	135920.7	566674.6	661	661	5	656	50	606	47	559	8	551	14	537	0	537							311
W15-70	136137.736	566820.376	671	671	49	622	0	622	55	567	4	563	14	549	0	549							521
W15-71	136168.057	566758.431	671	671	49	622	0	622	54	568	9	559	20	539	0	539							521

Well No.	Northing	Easting	Elevation	Recent	recentiso	H1	H1 iso	H2	H2 iso	PPlu	PPlu iso	PPlc	PPlc iso	Rtf	Rtf iso	Rwi(e)	Rwi(e) iso	Rwi(lm)	Rwi(lm) iso	Rwi(a)	Rwi(a) iso	CRB	TD
W15-72	136230.205	566758.264	671	671	52	619	6	613	38	575	12	563	22	541	0	541							521
W15-73	136137.424	566696.64	669	669	49	620	4	616	49	567	9	558	15	543	0	543							519
W15-75	136264.53	566711.545	670	670	30	640	19	621	51	570	8	562	23	539	0	539							520
W15-763	136029	566809	664	664	10.5	653.5	30	623.5	53.5	570	6	564	17	547									411.4
W15-79	136371.62	566755.168	671	671	45	626	0	626	47	579	16	563	20	543	0	533							521

Plate 1. Geologic and Geophysical Logs for Borehole 299-W10-27. See Report Section 3.0 for Facies Descriptions and Appendix C for Borehole Location, Surface Elevation, and Coordinates.

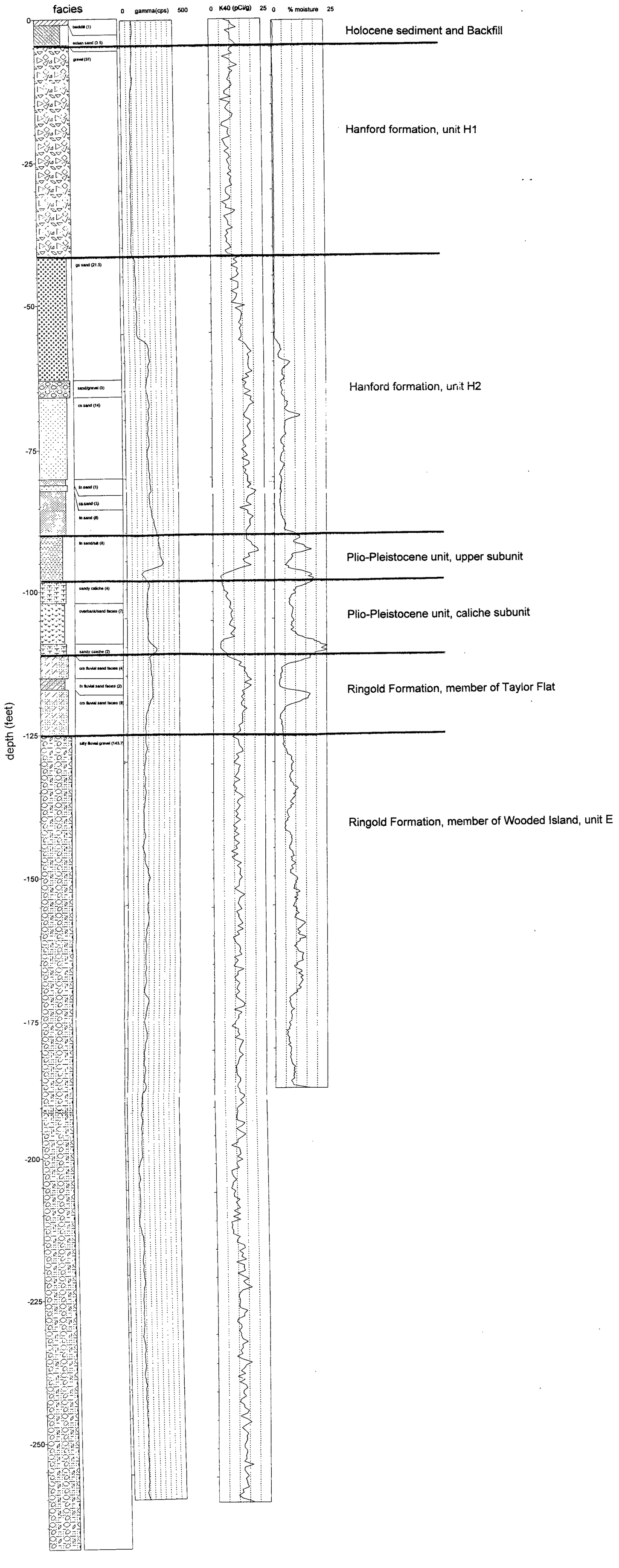
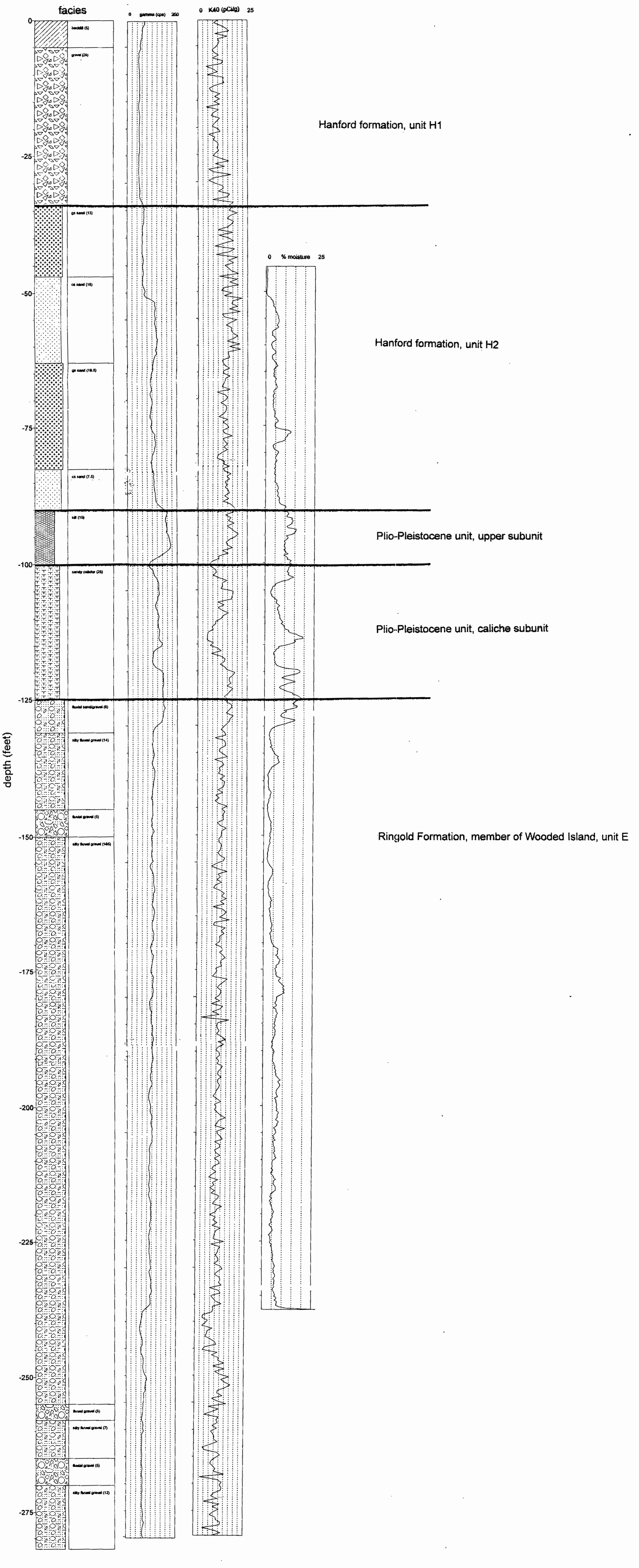
Plate 2. Geologic and Geophysical Logs for Borehole 299-W11-39. See Report Section 3.0 for Facies Descriptions and Appendix C for Borehole Location, Surface Elevation, and Coordinates.