Preliminary Interpretations of the Lithostratigraphy, Hydrostratigraphy, and Borehole Geophysics of the Westgate Heights Park well site, Albuquerque, New Mexico

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Introduction

This report summarizes the preliminary hydrostratigraphy and lithostratigraphy for the Westgate Heights Park monitoring well site (COA-WHP, Fig. 1). This well was completed in cooperation with the City of Albuquerque (COA), Water Resources Division of the U.S. Geological Survey (USGS), and the New Mexico Bureau of Mines and Mineral Resources (NMBMMR) as part of a regional network of groundwater monitoring wells in the Albuquerque Basin. Historical data for the Westgate Heights Park monitoring well are summarized in Table 1. The well was drilled to a depth of 1300 feet (396 m) below land surface during May, 2000. To minimize caving of unconsolidated sediments near the surface, the upper 38 feet of the well was cased during drilling. Lithologic samples (cuttings) were taken at 10-foot intervals from the well head. Southwest Geophysical Services, Inc. conducted borehole geophysical logging of the open drillhole shortly after the target depth was attained. Borehole geophysical logs and cuttings were used to characterize the lithology of sedimentary deposits encountered in this borehole and to provide qualitative estimates of the lithologic and hydrogeologic character of the regional Santa Fe Group aquifer.

This lithologic log and report are submitted to the COA as partial fulfillment of an intergovernmental service agreement with the NMBMMR. The cuttings and geophysical logs used to prepare this report will be available for inspection at NMBMMR in Socorro, New Mexico. This report has not been reviewed according to NMBMMR standards. ***The contents of this report should not be considered final and complete until it is reviewed and published by the New Mexico Bureau of Mines and Mineral Resources.***

Table 1. Historical Data for the Westgate Heights Park monitoring well

Well Name:	Westgate Heights Park (COA-WHP)
Location:	T.10N, R.2E, Section 32.413 Bernalillo County, Albuquerque West 7.5' Quadrangle (USGS 1960) Latitude: 35' 02" 44° Longitude: 106' 45" 02° UTM: N: 3,879,298 m; E: 340, 335 m (Zone 13, NAD 83)
Elevation:	5230±10 feet (1594±3 m) above mean sea level as estimated from the Albuquerque West topographic map.
Drilling Method:	Mud Rotary
Drillers:	U.S. Geological Survey, Water Resources Division
Drill bit size:	15-in. diameter
Drilling Start:	May 10, 2000
Drilling Completion:	May 31, 2000
Sample Interval:	10 feet intervals sampled by driller at well head.
Screened Intervals:	Shallow: 320-360 feet (97-110 m); Middle: 858-863 feet (261-263 m); Deep: 1280-1285 feet (390-392 m) below land surface (bls)
Casing:	12-in. diameter casing from land surface down to 38 feet
Total Depth:	1300 feet (396 m) below land surface (bls)
Static Water Level:	325 feet (99 m) bls, based on resistivity and porosity logs
Sample Logging:	N.N. Derrick (New Mexico Institute of Mining and Technology), P.B. Jackson Paul (NMBMMR)
Geophysical Logging:	Southwest Geophysical Services, Inc.
Geophysical Logs:	Caliper, Spontaneous Potential, Acoustic, Natural Gamma Ray, 16-in. Resistivity, 64-in. Resistivity, Electrical Conductivity, Single Point Resistance, Neutron Porosity, and Density Porosity.
Log Synthesis:	P.B. Jackson Paul and S.D. Connell (NMBMMR).

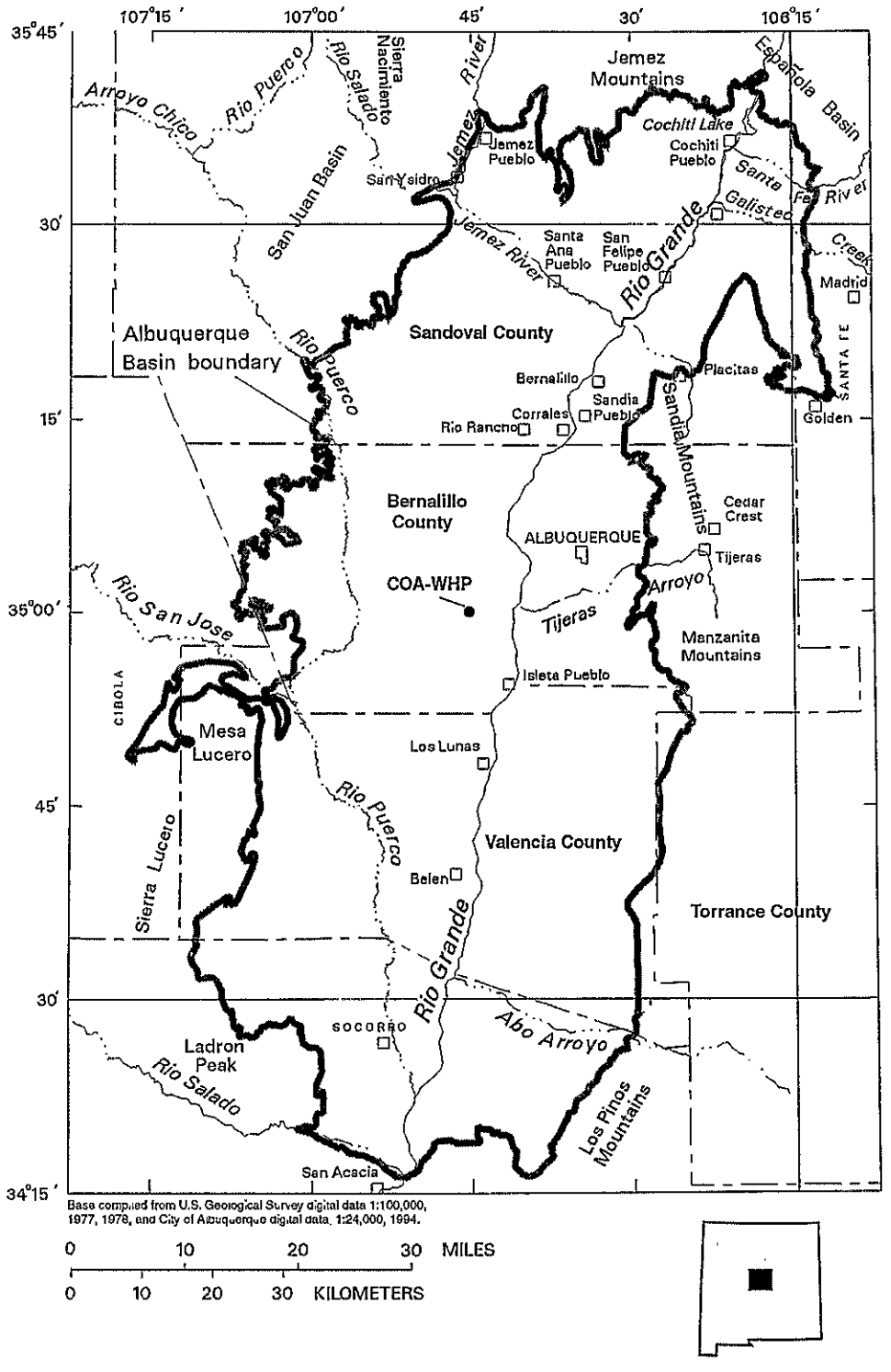

Figure 1. Map of central New Mexico, illustrating the boundary of the Albuquerque Basin and approximate location of the Westgate Heights Park well site (COA-WHP). Base map modified from Bexfield (1998).

Methods

Lithologic descriptions were made by visual examination of mud-rotary cuttings taken from the well head at 10-foot intervals (Appendix A). Drilling methods tend to prevent a complete evaluation of the finer grained fraction (commonly fine-grained sand and silt), which is commonly held in suspension by the drilling fluids. Lithologic descriptions are based on the following criteria:

1. Major textural class;
2. Estimated grain-size distribution by major textural class:
    a.) silt/clay (<0.05 mm)
    b.) sand (0.05-2.00 mm)
    c.) gravel (>2.00 mm)
3. Grain and clast shape;
4. Sorting and approximate range of grain and clast size;
5. Clast composition and approximate relative abundance, in decreasing order of abundance;
6. Color, using Munsell (1992) notation;
7. Other characteristics and selected driller's comments.

Samples were placed into cuttings trays, photographed (Appendix B), and visually examined. Hydrostratigraphic subdivisions of the borehole were made using nomenclature developed for alluvial deposits in the Albuquerque Basin by Hawley and Whitworth (1996). In this system deposits are assigned to gravely and sandy fluvial (I-III), eolian (IV), piedmont (V-VIII), and fine-grained basin-floor/playa-lake (IX-X) lithofacies (Table 2). These lithofacies are used to determine hydrostratigraphic units that are subdivided into post-Santa Fe Group and Santa Fe Group deposits. Post-Santa Fe Group units include fluvial-terrace deposits (RA and TA), and piedmont deposits (PA). Santa Fe Group hydrostratigraphic units consist of fluvial and piedmont deposits that are subdivided into upper (USF), middle (MSF), and lower (LSF) hydrostratigraphic units (Table 3). These are further divided into subunits based on inferred sedimentary provenance: eastern piedmont (1), ancestral Rio Grande (2), and western margin fluvial deposits (4).

Table 2. Summary of lithofacies assigned to textural units of the regional Santa Fe Group aquifer, and shallow post-Santa Fe Group aquifer (modified from Hawley and Whitworth, 1996).

Lithofacies	Textural Unit	Interpreted Depositional Setting
Shallow	***Post-Santa Fe Group aquifer***	
A1	Pebble to cobble gravel and sand	River-valley basal channel fluvial deposits
A2	Sand and pebbly sand	River-valley braid-plain fluvial deposits
A3	Silty clay, clay, and sand	Overbank meander belt or oxbow deposits
B	Sand, gravel, silt, and clay (similar to lithofacies V)	Arroyo channel and valley border alluvial fan deposits
Regional	***Santa Fe Group aquifer***	
I	Coarse-grained sand and pebble gravel with minor silt/clay.	Basin-floor fluvial braid plain
II	Fine to coarse-grained sand with lenses of pebbly sand and silty clay.	Basin-floor fluvial and local eolian
III	Interbedded sand and silty clay with lenses of pebbly/granular fine to coarse-grained sand.	Basin-floor fluvial and local eolian
IV	Sand and sandstone with lenses of silty sand to clay.	Mostly eolian
V	Gravel, sand, silt and clay with sand-silt-clay lenses.	a) Distal to medial piedmont-slope alluvial fan deposits associated with large watersheds b) Distal to medial piedmont-slope alluvial fan deposits associated with steep drainages
VI	Coarse gravelly, loamy sand to sandy loam with lenses of sand and cobble to boulder gravel.	a) see Va b) see Vb
VII	Partly indurated (cemented) equivalent of lithofacies V.	See V
VIII	Partly indurated (cemented) equivalent of lithofacies VI.	See VI
IX	Silty clay interbedded with sand, silty sand, or clay.	Basin-floor playa-lake, alluvial-flat, and distal piedmont-slope
X	Partly indurated equivalent of lithofacies IX.	See IX

Table 3. Summary of hydrostratigraphic units in the Albuquerque Basin (modified from Hawley and Whitworth, 1996).

Hydrostratigraphic Unit (*subunit*)		Description
Post-Santa Fe Group Aquifer		
RA		Channel, floodplain and lower river terrace alluvial deposits of the modern Rio Grande and Puerco valleys; typically ≤120 ft thick; Holocene to late Pleistocene in age. Lithofacies A comprises much of this unit.
VA		Tributary-arroyo channel, fan and terrace alluvial deposits in areas bordering inner valleys of the Rio Grande system; ≤ 100 ft thick; Holocene to early(?) or middle Pleistocene in age. Lithofacies B comprises much of this unit. Subdivided into hydrostratigraphic units VAY and VAO.
	VAY	Younger valley border alluvial fans in major arroyo systems.
	VAO	Remnants of older arroyo valley fill deposits.
TA		Channel and floodplain deposits of the ancestral Rio Grande fluvial system (including the Rio Jemez/Guadalupe, Rio Puerco, Rio San Jose, Rio Salado, Santa Fe River, and Jemez River) deposited during a series of at least four stages of valley entrenchment and partial backfilling. Commonly forms ≥100-ft thick deposits that unconformably overlie hydrostratigraphic units of USF, MSF, and locally MSF. Basal contacts are erosional and range from 50 ft below, to 250 ft above, the present floor of the Rio Grande and Rio Puerco; Holocene to early(?) or middle Pleistocene in age. Lithofacies A1-A2 comprise much of this unit.
PA		Coalescing alluvial fan and piedmont deposits extending basinward from the fronts of the Sandia, Manzanita, and Manzano Mountains on the eastern and southwestern margins of the Albuquerque Basin. Includes deposits of the ancestral Tijeras arroyo and mountain-front pediments. Deposits are commonly ≤ 150 ft thick; Holocene to middle Pleistocene in age; Lithofacies V and VI commonly comprise this unit. Locally divided into two subunits.
	PAY	Younger (late Pleistocene and Holocene) alluvial deposits on upper piedmont slopes flanking the Sandia and Manzano Mountains.
	PAO	Older (middle Pleistocene) alluvial deposits flanking the Sandia and Manzano Mountains.

Table 3. *Continued.*

Hydrostratigraphic Unit (*subunit*)	Description
Regional Santa Fe Group Aquifer	
USF	Ancestral Rio Grande and Rio Puerco deposits that interfinger with piedmont-alluvial facies deposits towards the basin margins with volcanic rocks (commonly a mixture of basalt, andesite, rhyolite) and thin eolian deposits present in local areas. Commonly ≤ 1000 ft thick, but locally exceeds 1500 ft in thickness; early Pleistocene to late Miocene (primarily Pliocene) in age; lithofacies I, II, III, V, VI, VII, VIII, IX, X.
1	Alluvial deposits derived from rift flanking uplifts along the eastern margin of the Albuquerque Basin, including the Sandia, Manzanita, and Manzano Mountains.
2	Basin-floor fluvial deposits of the ancestral Rio Grande. Locally interbedded fine to medium-grained alluvial, lacustrine, or eolian deposits.
3	Alluvial deposits derived from rift flanking uplifts along the western margin of the Albuquerque Basin, including the Lucero uplift and the Ladron Mountains.
4	Basin-floor fluvial deposits of the ancestral Rio Jemez/Guadalupe, Rio Puerco, Rio San Jose, and Rio Salado. Underlies much of the Llano de Albuquerque, the topographic divide between the Rio Grande and Rio Puerco valleys. Derived from the Sierra Nacimiento and Colorado Plateau.
MSF	Alluvial, eolian, and playa-lake deposits (MSF-2, 4). Partly indurated piedmont alluvium (MSF-1, 3) interfingers basinward with basin-floor deposits of MSF-2, 4; basaltic and silicic volcanic rocks locally present; in the southwest portion of the basin may be more than 10,000 ft in thickness; in the central portion of the basin deposits may be more than 5,000 ft thick; late to middle Miocene in age; lithofacies III, IV, V, VI, VII, VIII, IX, X.
1	Piedmont alluvium derived from emergent rift flanking uplifts along the eastern margin of the Albuquerque Basin, including the Sandia, Manzano, and Manzanita Mountains.
2	Basin-floor sediments of mixed (alluvial, lacustrine, and/or eolian) origin. Contains deposits of possible ancestral Rio Grande origin.
3	Alluvial deposits derived from emergent rift flanking uplifts along the western margin of the Albuquerque Basin, including the Sierra Lucero, and the Ladron Mountains.
4	Basin-floor fluvial deposits of the ancestral Rio Jemez/Guadalupe, Rio Puerco, Rio San Jose, and Rio Salado. Underlies much of the Llano de Albuquerque, the topographic divide between the Rio Grande and Rio Puerco valleys. Derived from the Sierra Nacimiento and Colorado Plateau.
LSF	Eolian, alluvial, and playa-lake basin-floor deposits interbedded with piedmont deposits near basin margins; generally ≤3500 ft thick in the central basin; middle Miocene to late Oligocene in age; lithofacies III, IV, VII-X.

Hydrostratigraphy and Lithostratigraphy

Major textural and lithologic units encountered in the Westgate Heights Park monitoring well are graphically displayed on Figure 2 and summarized in Table 4. Figure 2 also contains geophysical logs for the well and the various correlations between the geophysical and lithologic logs. Stratigraphic and hydrostratigraphic interpretations (Fig. 2, Table 4) are based on the integration of the lithologic and borehole geophysical data. Prominent shifts in the resistivity, acoustic (not displayed in this report), and porosity geophysical logs indicate that saturated deposits are at about 5020 feet above sea level. The Rio Grande, approximately 5 miles (8 km) west of the site, is at an elevation of 4930±10 feet above mean sea level (based on Albuquerque West 7.5-minute Quadrangle), indicating that the water level slopes east towards the river.

The upper 0-40 feet contains a succession of arroyo valley alluvial deposits (hydrostratigraphic unit VA; lithofacies B) of Quaternary age (probably late Pleistocene to Holocene in age; Connell et al., 1998a). Between 40-190 ft below land surface (bls), the well is dominated by moderately sorted pink to pinkish-white gravelly coarse-grained sand correlated to hydrostratigraphic unit USF-4. This gravelly interval also is correlated to the Ceja Member of the Arroyo Oijto Formation (Connell et al., 1999). The Ceja Member is the upper part of a thick succession of fluvial deposits interpreted to be derived from the ancestral Rio Puerco fluvial system (Connell et al., 1999). Gravel encountered in this interval contains abundant quartz, potassium-feldspar, chert and volcanic rocks.

Between 190-380 ft bls, and underlying the Ceja Member is 190 ft (58 m) of pink to pinkish-white, moderately sorted, fine to coarse-grained sand. Between 380-890 ft bls is a 510-ft (155-m) thick succession of pink to pinkish-gray and white, moderately sorted, silty sand correlated to the Atrisco unit, which was defined in the 98th Street monitoring well (Allen et al., 1998; Connell et al., 1998b; Stone et al., 1998), located about 4.6 km north of the Westgate Heights Park site. The Atrisco unit has a very distinct geophysical signature on electrical conductivity logs near the 98th Street site (Stone et al., 1998; Allen et al., 1998) and can be correlated to numerous wells in SW Albuquerque (Allen et al., 1998; Connell et al., 1998a, b). The Atrisco unit locally marks to top of the middle Santa Fe Group hydrostratigraphic unit (MSF) and is probably correlative to the Arroyo Ojito Formation. The base of this unit is typically very sharp and abrupt (Allen et al., 1998; Stone et al., 1998). Borehole geophysical logs indicate that the Atrisco unit has an average porosity of 30% by volume. In general this unit is

not a very permeable aquifer unit. Estimates of hydraulic conductivity range from 3.6 to 7.1 ft/d (1.1-2.2 m/d) in wells tested in similar stratigraphic intervals (Thorne and Thomas, 2000).

The lower 890-1300 ft of the well contains 410 ft (125 m) of silty fine to coarse-grained sand and gravelly silty sand with gravel granules up to 4 mm in diameter. Granules are composed of quartz, feldspar, and minor volcanic lithic fragments. Because of the lack of coarser detritus that might clearly indicate provenance, assignment of this interval to MSF-2 or MSF-4 is ambiguous. Thus, this lower unit is assigned to an undivided MSF 2 or 4, and is correlated to either the Arroyo Ojito or Sierra Ladrones Formations.

Table 4. Summary and interpretation of major textural units in the Westgate Heights Park Well. Depth is in feet below land surface (bls). Details of lithologic descriptions are in Appendix A. Gravel and sand composition are based on visual estimates of cuttings and are listed in descending order of abundance.

Depth (ft, bls)	Summary
0-40	**Quaternary alluvial deposits (VA):** coarse-grained sand with granule gravel, moderately sorted, subangular to subrounded grains, pink (7.5 YR 7/3) to pinkish white (7.5 YR 8/2). Gravel composition (listed in order of abundance): quartz, potassium-feldspar, and volcanic rocks. Lithofacies B.
40-190	**Fluvial deposits of the Ceja Member of the Arroyo Oijto Formation (USF-4):** gravelly coarse-grained sand, moderately to well sorted, subangular to subrounded. Gravel clasts are up to 10 mm in diameter and composed of quartz, potassium-feldspar, chert, and volcanic rocks. Color is pink (7.5 YR 7/3) to pinkish white (7.5 YR 8/2). Mostly lithofacies I.
190-380	**Fluvial deposits of the Arroyo Oijto Formation (USF-4):** fine- to coarse-grained sand, minor silt/clay content, moderately sorted, subangular to subrounded grains. Color is pink (7.5 YR 7/3) to pinkish white (7.5 YR 8/2). Mostly lithofacies II.
380-890	**Atrisco unit (MSF-4):** silty sand, moderately sorted, dominantly subrounded grains. Visual estimate of sand composition: quartz, and feldspars (mostly potassium-feldspar), with minor volcanic lithic fragments. Color is pinkish white (7.5 YR 8/2) to pinkish gray (7.5 YR 7/2) to pink (7.5 YR 7/3). Lithofacies IX with interbeds of lithofacies III.
890-1300	**Fluvial deposits (MSF-2(?) or 4):** silty sand to gravelly silty sand, moderately to well sorted, subangular to subrounded. Visual estimate of sand composition: quartz, feldspar (contains less potassium feldspar than in overlying units), and volcanic lithic fragments. Color is very pale brown to brown (10 YR 7/3-8/2), and light-gray (10 YR 7/2) to pinkish gray (7.5 YR 7/2). Mostly lithofacies III.

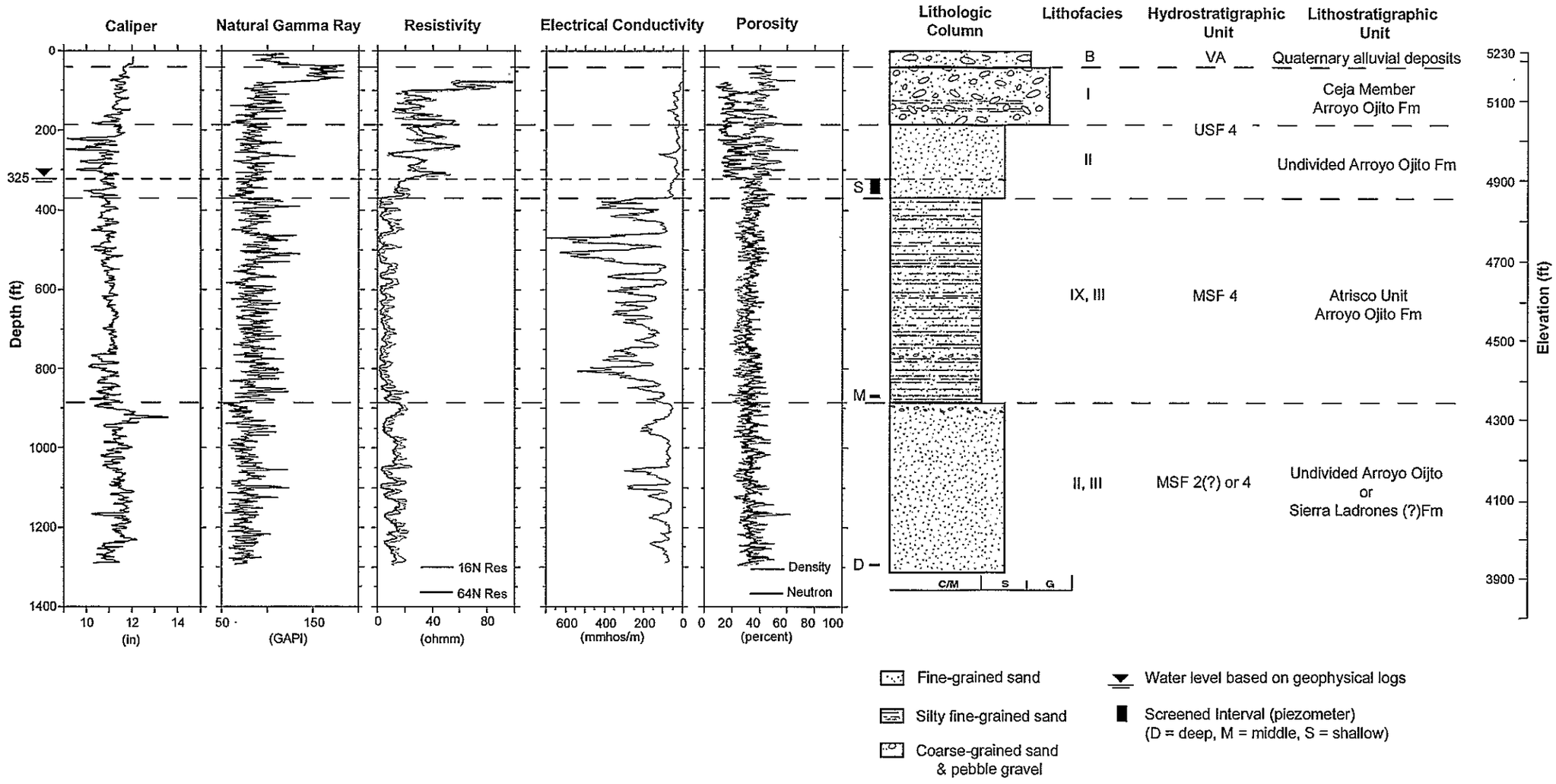

Figure 2: Westgate Heights Park Well Site Geophysical Data Logs, Lithologic Column, Preliminary Hydrostratigraphic & Lithostratigraphic Interpretations
Borehole geophysical survey performed by Southwest Geophysical Services, Inc.

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Appendix A. Field lithologic descriptions of cuttings from the Westgate Heights Park (WHP) monitoring well.

Sample No.	Depth Interval (ft, bls)	Description
WHP-1	0-10	Gravelly sand (80% sand (cL-vcU), 20% gravel), well sorted, subangular. Gravel granules are up to 8 mm in diameter, composed of quartz, Potassium-feldspar, and possible volcanic rocks. Color is pink (7.5 YR 7/3).
WHP-2	10-20	Gravelly sand (80% sand (cL-vcU), 20% gravel), well sorted, subangular. Gravel granules are up to 8 mm in diameter, composed of quartz, Potassium-feldspar, and possible volcanic rocks. Color is pink (7.5 YR 7/3).
WHP-3	20-30	Gravelly sand (5% silt/clay, 80% sand (mU-vcU), 15% gravel), moderately sorted, subangular to subrounded. Gravel granules are up to 8 mm in diameter, composed of quartz, Potassium-feldspar and possible volcanic rocks. Color is pink (7.5 YR 7/3).
WHP-4	30-40	Gravelly sand (5% silt/clay, 80% sand (mL-vcU),15% gravel), moderately sorted, subangular. Gravel granules are up to 8 mm in diameter, composed of quartz, Potassium-feldspar and possible volcanic rocks. Color is pink (7.5 YR 7/3).
WHP-5	40-50	Gravelly sand (5% silt/clay, 75% sand (cL-vcU), 20% gravel), well sorted, subangular to subrounded. Gravel granules are up to 8 mm in diameter, composed of quartz, Potassium-feldspar, chert, and possible volcanic rocks. Color is pink (7.5 YR 7/3).
WHP-6	50-60	Gravelly sand (5% silt/clay, 75% sand (cL-vcU), 20% gravel), well sorted, subangular to subrounded. Gravel granules are up to 10 mm in diameter, composed of quartz, Potassium-feldspar, chert, and possible volcanic rocks. Color is pink (7.5 YR 7/3).
WHP-7	60-70	Gravelly sand (5% silt/clay, 80% sand (cL-vcU), 15% gravel), well sorted, subrounded. Gravel granules are up to 7 mm in diameter, composed of quartz, Potassium-feldspar, chert, and possible volcanic rocks. Color is pink (7.5 YR 7/3).
WHP-8	70-80	Gravelly sand (5% silt/clay, 80% sand (cL-vcU), 15% gravel), well sorted, subrounded. Gravel granules are up to 5 mm in diameter, composed of quartz, Potassium-feldspar, chert, and possible volcanic rocks. Color is pink (7.5 YR 7/3).
WHP-9	80-90	Gravelly sand (5% silt/clay, 80% sand (cL-vcU), 15% gravel), well sorted, subrounded. Gravel granules are up to 5 mm in diameter, composed of quartz, Potassium-feldspar, chert, and possible volcanic rocks. Color is pink (7.5 YR 7/3).
WHP-10	90-100	Gravelly sand (5% silt/clay, 80% sand (cL-vcU), 15% gravel), well sorted, subrounded. Gravel granules are up to 4 mm in diameter, composed of quartz, Potassium-feldspar, chert, and possible volcanic rocks. Color is pink (7.5 YR 7/3).

WHP-11	100-110	Gravelly sand (5% silt/clay, 80% sand (cL-vcU), 15% gravel), well sorted, subrounded. Gravel granules are up to 4 mm in diameter, composed of quartz, Potassium-feldspar, chert, and possible volcanic rocks. Color is pink (7.5 YR 7/3).
WHP-12	110-120	Gravelly sand (5% silt/clay, 80% sand (cL-vcU), 15% gravel), well sorted, subrounded. Gravel granules are up to 4 mm in diameter, composed of quartz, Potassium-feldspar, chert, and possible volcanic rocks. Color is pink (7.5 YR 7/3).
WHP-13	120-130	Gravelly sand (5% silt/clay, 90% sand (fU-vcU), 5% gravel), moderately sorted, subrounded. Gravel granules are up to 4 mm in diameter, composed of quartz, Potassium-feldspar, chert, and possible volcanic rocks. Color is pink (7.5 YR 7/3).
WHP-14	130-140	Gravelly sand (5% silt/clay, 80% sand (cL-vcU), 15% gravel), well sorted, subrounded. Gravel granules are up to 4 mm in diameter, composed of quartz, Potassium-feldspar, chert, and possible volcanic rocks. Color is pink (7.5 YR 7/3).
WHP-15	140-150	Gravelly sand (5% silt/clay, 90% sand (fU-vcU), 5% gravel), moderately sorted, subrounded. Gravel granules are up to 4 mm in diameter, composed of quartz, Potassium-feldspar, chert, and possible volcanic rocks. Color is pink (7.5 YR 7/3).
WHP-16	150-160	Gravelly sand (5% silt/clay, 80% sand (cL-vcU), 15% gravel), well sorted, subrounded. Gravel granules are up to 4 mm in diameter, composed of quartz, Potassium-feldspar, chert, and possible volcanic rocks. Color is pink (7.5 YR 7/3).
WHP-17	160-170	Gravelly sand (5% silt/clay, 80% sand (cL-vcU), 15% gravel), well sorted, subrounded. Gravel granules are up to 4 mm in diameter, composed of quartz, Potassium-feldspar, chert, and possible volcanic rocks. Color is pink (7.5 YR 7/3).
WHP-18	170-180	Gravelly sand (5% silt/clay, 80% sand (cL-vcU), 15% gravel), well sorted, subrounded. Gravel granules are up to 4 mm in diameter, composed of quartz, Potassium-feldspar, chert, and possible volcanic rocks. Color is pinkish white (7.5 YR 8/2).
WHP-19	180-190	Sand (5% silt/clay, 95% sand (fU-cU)), well sorted, subrounded. Composed of quartz and feldspars (especially Potassium-feldspar), and volcanic lithic fragments. Color is pinkish white (7.5 YR 8/2).
WHP-20	190-200	Sand (5% silt/clay, 95% sand (fU-cU)), well sorted, subrounded. Color is pinkish white (7.5 YR 8/2).
WHP-21	200-210	Sand with minor silt (10% silt/clay, 90% sand (fU-cU)), moderately sorted, subrounded. Color is pinkish gray (7.5 YR 7/2).
WHP-22	210-220	Sand with minor silt (10% silt/clay, 90% sand (mL-vcU)), moderately sorted, subangular to subrounded. Color is pinkish white (7.5 YR 8/2).
WHP-23	220-230	Sand with minor silt (10% silt/clay, 90% sand (fU-cL)), well sorted, subangular to subrounded. Color is pink (7.5 YR 7/3).

WHP-24	230-240	Sand with minor silt (10% silt/clay, 90% sand (fU-cL)), moderately sorted, subangular. Composed of quartz and feldspars (mostly Potassium-feldspar) and minor volcanic lithic fragments. Color is pink (7.5 YR 7/3).
WHP-25	240-250	Silty sand (10% silt/clay, 90% sand (fU-cL)), moderately sorted, subangular to subrounded. Color is pinkish white (7.5 YR 8/2).
WHP-26	250-260	Sand with minor silt (10% silt/clay, 90% sand (mU-cU)), well sorted, subrounded. Color is pink (7.5 YR 8/3).
WHP-27	260-270	Sand with minor silt (10% silt/clay, 90% sand (fU-cU)), moderately sorted, subrounded. Color is pink (7.5 YR 7/3).
WHP-28	270-280	Sand with minor silt (10% silt/clay, 90% sand (fU-cU)), moderately sorted, subrounded. Color is pink (7.5 YR 7/3).
WHP-29	280-290	Sand with minor silt (10% silt/clay, 90% sand (fU-cU)), moderately sorted, subrounded. Color is pink (7.5 YR 7/3).
WHP-30	290-300	Sand with minor silt (10% silt/clay, 90% sand (fU-cU)), moderately sorted, subrounded. Color is pink (7.5 YR 7/3).
WHP-31	300-310	Sand with minor silt (10% silt/clay, 90% sand (fU-cU)), moderately sorted, subrounded. Composed of quartz and feldspars (mostly Potassium-feldspar) and minor volcanic lithic fragments. Color is pink (7.5 YR 7/3).
WHP-32	310-320	Sand with minor silt (10% silt/clay, 90% sand (fU-cU)), moderately sorted, subrounded. Color is pink (7.5 YR 7/3)
WHP-33	320-330	Sand with minor silt (10% silt/clay, 90% sand (fU-cU)), moderately sorted, subrounded. Color is pink (7.5 YR 7/3).
WHP-34	330-340	Sand with minor silt (10% silt/clay, 90% sand (fL-cU)), moderately sorted, subrounded. Color is pinkish white (7.5 YR 8/2).
WHP-35	340-350	Sand with minor silt (10% silt/clay, 90% sand (fL-cL)), moderately sorted, subrounded. Composed of quartz, feldspars, and volcanic-lithic fragments. Color is pinkish white (7.5 YR 8/2).
WHP-36	350-360	Sand with minor silt (10% silt/clay, 90% sand (fU-cL)), moderately sorted, subrounded. Color is pink (7.5 YR 7/3).
WHP-37	360-370	Sand with minor silt (10% silt/clay, 90% sand (mL-mU)), well sorted, subrounded. Color is very pale brown (10 YR 8/3).
WHP-38	370-380	Sand with minor silt (10% silt/clay, 90% sand (mL-cU)), well sorted, subrounded. Color is very pale brown (10 YR 8/3).
WHP-39	380-390	Silty sand (20% silt/clay, 80% sand (fU-cU)), moderately sorted, subrounded. Color is pink (7.5 YR 7/4).
WHP-40	390-400	Silty sand (20% silt/clay, 80% sand (fU-cU)), moderately sorted, subrounded. Composed of quartz and feldspars and minor volcanic lithic fragments. Color is pink (7.5 YR 7/4).
WHP-41	400-410	Silty sand (20% silt/clay, 80% sand (fU-cL)), moderately sorted, subrounded. Color is pink (7.5 YR 7/3).
WHP-42	410-420	Silty sand (20% silt/clay, 80% sand (fU-cL)), moderately sorted, subrounded. Color is pink (7.5 YR 7/3).
WHP-43	420-430	Silty sand (20% silt/clay, 80% sand (fU-mU)), well sorted, subrounded. Color is pink (7.5 YR 7/3).

WHP-44	430-440	Silty sand (20% silt/clay, 80% sand (fU-vcL)), moderately sorted, subrounded. Color is pink (7.5 YR 7/3).
WHP-45	440-450	Silty sand (20% silt/clay, 80% sand (fL-cL)), moderately sorted, subrounded. Color is pink (7.5 YR 7/3).
WHP-46	450-460	Silty sand (30% silt/clay, 70% sand (fU-vcL)), moderately sorted, subrounded. Color is pink (7.5 YR 7/3).
WHP-47	460-470	Silty sand (30% silt/clay, 70% sand (mL-cU)), moderately sorted, subrounded. Color is pink (7.5 YR 7/3).
WHP-48	470-480	Silty sand (30% silt/clay, 70% sand (mL-cU)), moderately sorted, subrounded. Color is pink (7.5 YR 7/3).
WHP-49	480-490	Silty sand (30% silt/clay, 70% sand (mL-cU)), moderately sorted, subrounded. Color is pink (7.5 YR 7/3).
WHP-50	490-500	Silty sand (30% silt/clay, 70% sand (mL-cL)), moderately sorted, subrounded. Composed of quartz and feldspars and minor volcanic lithic fragments. Color is pink (7.5 YR 7/3).
WHP-51	500-510	Silty sand (30% silt/clay, 70% sand (fU-mU)), well sorted, subrounded. Color is Pinkish white (7.5 YR 8/2).
WHP-52	510-520	Silty sand (30% silt/clay, 70% sand (fU-cU)), moderately sorted, subrounded. Composed of quartz, feldspars, and volcanic lithic fragments. Color is pinkish white (7.5 YR 8/2).
WHP-53	520-530	Silty sand (40% silt/clay, 60% sand (vfL-fL)), well sorted, subrounded. Color is pink (7.5 YR 7/3).
WHP-54	530-540	Silty sand (20% silt/clay, 80% sand (fL-mL)), moderately sorted, subrounded. Color is pink (7.5 YR 7/3).
WHP-55	540-550	Silty sand (30% silt/clay, 70% sand (fU-mU)), moderately sorted, subrounded. Color is pink (7.5 YR 7/3).
WHP-56	550-560	Silty sand (30% silt/clay, 70% sand (fU-mU)), moderately sorted, subrounded. Color is pink (7.5 YR 7/3).
WHP-57	560-570	Silty sand (30% silt/clay, 70% sand (fL-mL)), moderately sorted, subrounded. Color is pink (7.5 YR 7/3).
WHP-58	570-580	Silty sand (20% silt/clay, 80% sand (fL-cL)), moderately sorted, subrounded. Color is pink (7.5 YR 7/3).
WHP-59	580-590	Silty sand (20% silt/clay, 80% sand (fL-cL)), moderately sorted, subrounded. Color is pink (7.5 YR 7/3).
WHP-60	590-600	Silty sand (20% silt/clay, 80% sand (fL-mU)), moderately sorted, subrounded. Color is pink (7.5 YR 7/3).
WHP-61	600-610	Silty sand (20% silt/clay, 80% sand (fL-cL)), moderately sorted, subrounded. Color is pink (7.5 YR 7/3).
WHP-62	610-620	Silty sand (20% silt/clay, 80% sand (fU-vcU)), moderately sorted, subrounded to rounded. Color is pink (7.5 YR 7/3).
WHP-63	620-630	Silty sand (20% silt/clay, 80% sand (fL-cU)), moderately sorted, subrounded to rounded. Color is pink (7.5 YR 7/3).
WHP-64	630-640	Silty sand (20% silt/clay, 80% sand (fL-cU)), moderately sorted, subrounded to rounded. Color is pink (7.5 YR 7/3).
WHP-65	640-650	Silty sand (20% silt/clay, 80% sand (fL-cU)), moderately sorted, subrounded to rounded. Color is pink (7.5 YR 7/3).

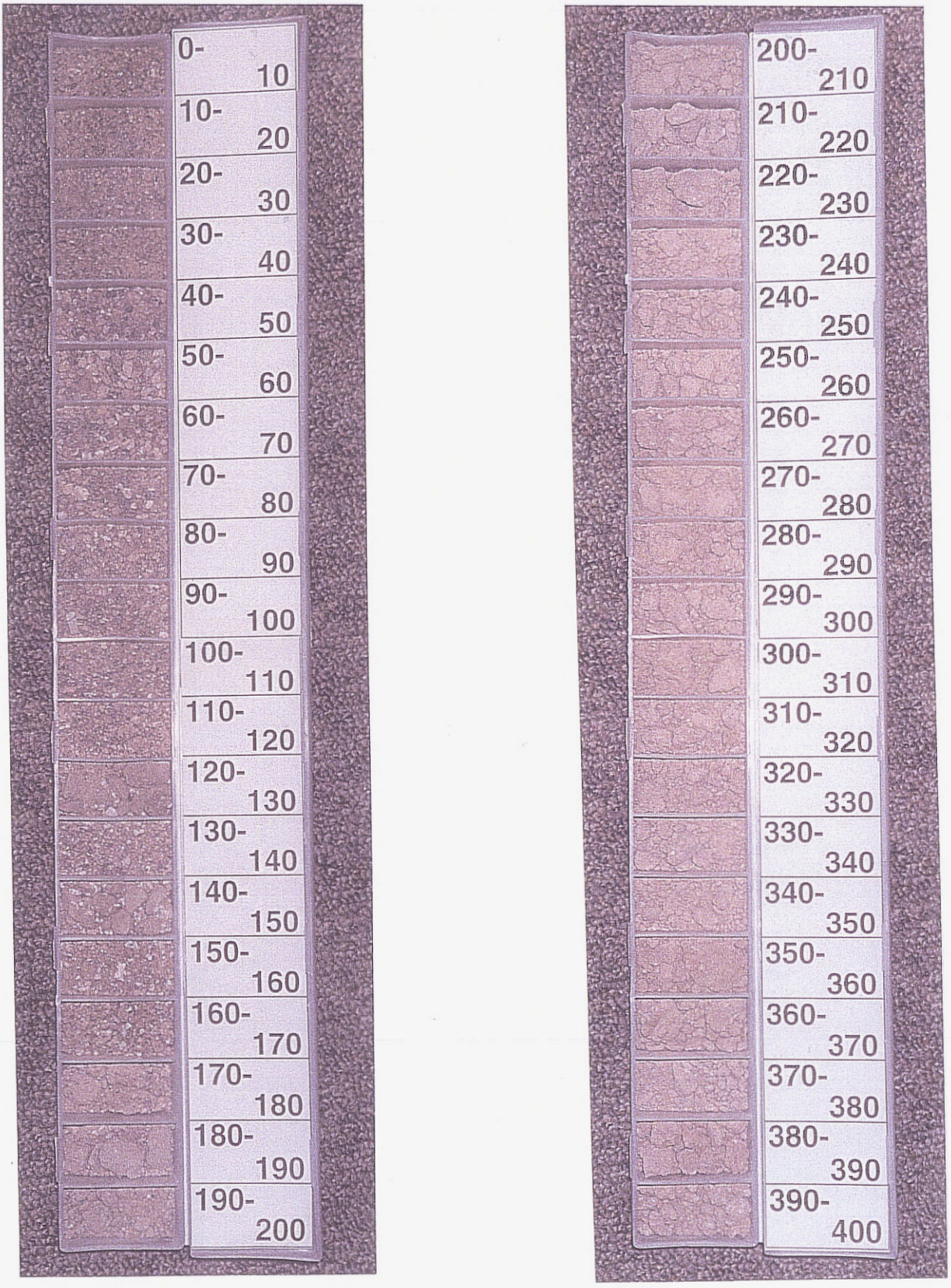
WHP-66	650-660	Silty sand (20% silt/clay, 80% sand (fL-cU)), moderately sorted, subrounded to rounded. Color is pink (7.5 YR 7/3).
WHP-67	660-670	Silty sand (20% silt/clay, 80% sand (vfU-cU)), moderately sorted, subrounded to rounded. Color is pink (7.5 YR 7/3).
WHP-68	670-680	Silty sand (20% silt/clay, 80% sand (vfU-cU)), moderately sorted, subrounded to rounded. Color is pink (7.5 YR 7/3).
WHP-69	680-690	Silty sand (20% silt/clay, 80% sand (fL-cU)), moderately sorted, subrounded to rounded. Color is pink (7.5 YR 7/3).
WHP-70	690-700	Silty sand (20% silt/clay, 80% sand (fL-cU)), moderately sorted, subrounded to rounded. Color is pink (7.5 YR 7/3).
WHP-71	700-710	Silty sand (20% silt/clay, 80% sand (fL-cU)), moderately sorted, subrounded to rounded. Composed of quartz and feldspars and minor volcanic lithic fragments. Color is pink (7.5 YR 7/3).
WHP-72	710-720	Silty sand (20% silt/clay, 80% sand (fL-cU)), moderately sorted, subrounded to rounded. Color is pink (7.5 YR 7/3).
WHP-73	720-730	Silty sand (20% silt/clay, 80% sand (fL-cU)), moderately sorted, subangular to subrounded. Color is pinkish white (7.5 YR 8/2).
WHP-74	730-740	Silty sand (20% silt/clay, 80% sand (fL-cU)), moderately sorted, subangular to subrounded. Color is pinkish white (7.5 YR 8/2).
WHP-75	740-750	Silty sand (20% silt/clay, 80% sand (fL-cU)), moderately sorted, subangular to subrounded. Color is pinkish white (7.5 YR 8/2).
WHP-76	750-760	Silty sand (20% silt/clay, 80% sand (fL-cU)), moderately sorted, subangular to subrounded. Color is pinkish white (7.5 YR 8/2).
WHP-77	760-770	Silty sand (20% silt/clay, 80% sand (fL-cU)), moderately sorted, subangular to subrounded. Color is pinkish white (7.5 YR 8/2).
WHP-78	770-780	Silty sand (20% silt/clay, 80% sand (fL-cL)), moderately sorted, subrounded. Color is pinkish white (7.5 YR 8/2).
WHP-79	780-790	Silty sand (20% silt/clay, 80% sand (fL-cL)), moderately sorted, subrounded. Color is pinkish white (7.5 YR 8/2).
WHP-80	790-800	Silty sand (20% silt/clay, 80% sand (fL-cL)), moderately sorted, subrounded. Color is pinkish white (7.5 YR 8/2).
WHP-81	800-810	Silty sand (20% silt/clay, 80% sand (fL-mU)), well sorted, subangular to Subrounded. Composed of quartz and feldspars and minor volcanic lithic fragments. Color is pink (7.5 YR 7/3).
WHP-82	810-820	Silty sand (20% silt/clay, 80% sand (fL-mU)), well sorted, subangular to subrounded. Color is pink (7.5 YR 7/3).
WHP-83	820-830	Silty sand (20% silt/clay, 80% sand (fL-cU)), moderately sorted, subangular to subrounded. Composed of quartz and feldspars (less Potassium-feldspar than in upper units) and volcanic lithic fragments. Color is very pale brown (10 YR 7/3).
WHP-84	830-840	No Sample
WHP-85	840-850	Silty sand (20% silt/clay, 80% sand (fL-cU)), well sorted, subangular to subrounded. Color is very pale brown (10 YR 7/3).
WHP-86	850-860	Silty sand (20% silt/clay, 80% sand (fL-cL)), well sorted, subangular to subrounded. Color is very pale brown (10 YR 7/3).

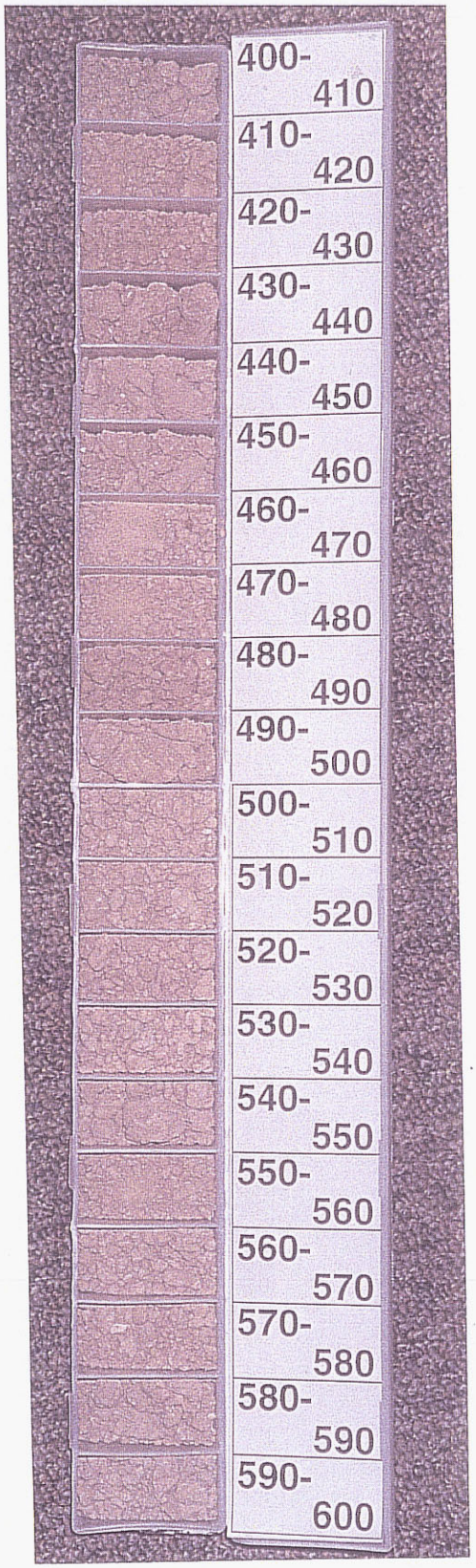
WHP-87	860-870	Gravelly silty sand (20% silt/clay, 75% sand (fU-vcU), 5% gravel), well sorted, subangular. Gravel granules up to 4 mm in diameters. Composed of quartz, feldspar, minor volcanic lithic fragments and chert. Color is very pale brown (10 YR 7/3).
WHP-88	870-880	Gravelly silty sand (20% silt/clay, 75% sand (fU-vcU), 5% gravel), moderately sorted, subangular to subrounded. Gravel granules up to 4 mm in diameters. Composed of quartz, feldspar, minor volcanic lithic fragments and chert. Color is very pale brown (10 YR 7/3).
WHP-89	880-890	Silty sand (20% silt/clay, 80% sand (fL-vcU)), moderately sorted, subrounded. Color is very pale brown (10 YR 7/3).
WHP-90	890-900	Gravelly silty sand (10% silt/clay, 85% sand (fL-vcU), 5% gravel), moderately sorted, subangular to subrounded. Gravel granules up to 5 mm in diameters. Composed of quartz, feldspar, minor volcanic lithic fragments and chert. Color is very pale brown (10 YR 7/3).
WHP-91	900-910	Gravelly silty sand (10% silt/clay, 85% sand (fU-vcU), 5% gravel), moderately sorted, subangular. Gravel granules up to 4 mm in diameters. Composed of quartz, feldspar, minor volcanic lithic fragments and chert. Color is pink (7.5 YR 7/3).
WHP-92	910-920	No Sample
WHP-93	920-930	Sand with minor silt (10% silt/clay, 90% sand (fL-mU)), well sorted, subrounded. Color is very pale brown (10 YR 8/2).
WHP-94	930-940	Sand with minor silt (10% silt/clay, 90% sand (fL-mU)), well sorted, subrounded. Color is very pale brown (10 YR 8/2).
WHP-95	940-950	No Sample
WHP-96	950-960	Sand with minor silt (10% silt/clay, 90% sand (fL-mU)), well sorted, subrounded. Color is very pale brown (10 YR 8/2).
WHP-97	960-970	Sand with minor silt (10% silt/clay, 90% sand (fU-vcL)), moderately sorted, subangular to subrounded. Color is light gray (10 YR 7/2).
WHP-98	970-980	Sand with minor silt (10% silt/clay, 90% sand (fU-vcL)), moderately sorted, subangular to subrounded. Color is light gray (10 YR 7/2).
WHP-99	980-990	No Sample
WHP-100	990-1000	Sand with minor silt (10% silt/clay, 90% sand (fU-vcU)), moderately sorted, subrounded. Color is very pale brown (10 YR 8/2).
WHP-101	1000-1010	Sand with minor silt (10% silt/clay, 90% sand (mL-vcU)), moderately sorted, subrounded. Color is very pale brown (10 YR 8/2).
WHP-102	1010-1020	Sand with minor silt (10% silt/clay, 90% sand (fU-vcL)), moderately sorted, subangular to subrounded. Color is very pale brown (10 YR 8/2).
WHP-103	1020-1030	Sand with minor silt (10% silt/clay, 90% sand (fL-vcU)), moderately sorted, subangular to subrounded. Color is very pale brown (10 YR 8/2).
WHP-104	1030-1040	Sand with minor silt (10% silt/clay, 90% sand (fL-vcU)), moderately sorted, subangular to subrounded. Color is very pale brown (10 YR 8/2).
WHP-105	1040-1050	Sand with minor silt (10% silt/clay, 90% sand (fU-vcU)), moderately sorted, subangular to subrounded. Color is light gray (10 YR 7/2).

WHP-106	1050-1060	Sand with minor silt (10% silt/clay, 90% sand (fU-vcU)), moderately sorted, subangular to subrounded. Color is light gray (10 YR 7/2).
WHP-107	1060-1070	Sand with minor silt (10% silt/clay, 90% sand (fL-cU)), moderately sorted, subrounded. Color is light gray (10 YR 7/2).
WHP-108	1070-1080	Silty sand (10% silt/clay, 90% sand (fU-cU)), moderately sorted, subrounded. Color is light gray (10 YR 7/2).
WHP-109	1080-1090	Sand with minor silt (10% silt/clay, 90% sand (fU-cU)), moderately sorted, subrounded to rounded. Color is light gray (10 YR 7/2).
WHP-110	1090-1100	Sand with minor silt (10% silt/clay, 90% sand (fU-cU)), moderately sorted, subrounded. Color is light gray (10 YR 7/2).
WHP-111	1100-1110	Sand with minor silt (10% silt/clay, 90% sand (fU-vcL)), poorly sorted, subrounded. Color is light gray (10 YR 7/2).
WHP-112	1110-1120	No sample.
WHP-113	1120-1130	Sand with minor silt (10% silt/clay, 90% sand (fL-cU)), moderately sorted, subangular to subrounded. Color is light gray (10 YR 7/2).
WHP-114	1130-1140	Sand with minor silt (10% silt/clay, 90% sand (mL-vcL)), moderately sorted, subangular to subrounded. Color is light gray (10 YR 7/2).
WHP-115	1140-1150	Sand with minor silt (10% silt/clay, 90% sand (mL-cU)), moderately sorted, subangular. Color is light gray (10 YR 7/2).
WHP-116	1150-1160	Sand with minor silt (10% silt/clay, 90% sand (fL-cL)), moderately sorted, subangular. Color is light gray (10 YR 7/2).
WHP-117	1160-1170	Sand with minor silt (10% silt/clay, 90% sand (fL-cL)), moderately sorted, subangular. Color is light gray (10 YR 7/1).
WHP-118	1170-1180	Sand with minor silt (10% silt/clay, 90% sand (fL-cL)), moderately sorted, subangular to subrounded. Color is light gray (10 YR 7/2).
WHP-119	1180-1190	Sand with minor silt (10% silt/clay, 90% sand (fL-cL)), well sorted, subrounded to rounded. Color is light gray (10 YR 7/2).
WHP-120	1190-1200	Sand with minor silt (10% silt/clay, 90% sand (fL-cL)), well sorted, subrounded. Color is light gray (10 YR 7/2).
WHP-121	1200-1210	Sand with minor silt (10% silt/clay, 90% sand (fL-mU)), well sorted, subrounded to rounded. Composed of quartz, feldspar, minor volcanic lithic fragments and chert. Color is very pale brown (10 YR 8/2).
WHP-122	1210-1220	Sand with minor silt (10% silt/clay, 90% sand (fL-vcL)), moderately sorted, subangular to subrounded. Color is very pale brown (10 YR 8/2).
WHP-123	1220-1230	Sand with minor silt and scattered granules (10% silt/clay, 85% sand (fU-vcU), 5% gravel), moderately sorted, angular to subangular. Scattered gravel granules are up to 4 mm in diameter. Composed of quartz, feldspar, minor volcanic lithic fragments and chert. Color is pinkish gray (7.5 YR 7/2).
WHP-124	1230-1240	Sand with minor silt and scattered granules (10% silt/clay, 85% sand (fU-vcU), 5% gravel), moderately sorted, angular to subangular. Gravel granules are up to 4 mm in diameter. Composed of quartz, feldspar, minor volcanic lithic fragments and chert. Color is pinkish gray (7.5 YR 7/2).

WHP-125	1240-1250	Sand with minor silt (10% silt/clay, 90% sand (fU-cL)), moderately sorted, subangular to subrounded. Color is pinkish gray (7.5 YR 7/2).
WHP-126	1250-1260	Sand with minor silt (10% silt/clay, 90% sand (fU-cL)), moderately sorted, subangular to subrounded. Color is pinkish gray (7.5 YR 7/2).
WHP-127	1260-1270	Sand with minor silt (10% silt/clay, 90% sand (fU-cL)), well sorted, subrounded to rounded. Color is pinkish gray (7.5 YR 7/2).
WHP-128	1270-1280	Sand with minor silt (10% silt/clay, 90% sand (fU-cL)), well sorted, subrounded. Composed of quartz, feldspar, and minor volcanic lithic fragments and chert. Color is pinkish gray (7.5 YR 7/2).
WHP-129	1280-1290	Sand with minor silt (10% silt/clay, 90% sand (fU-cU)), moderately sorted, subangular to subrounded. Color is very pale brown (10 YR 8/2).
WHP-130	1290-1300	Sand with minor silt (10% silt/clay, 90% sand (fU-cU)), moderately sorted, subangular to subrounded. Composed of quartz, feldspar, and minor volcanic lithic fragments and chert. Color is very pale brown (10 YR 8/2).

APPENDIX B: Photos of the cuttings from the Westgate Heights Park well site

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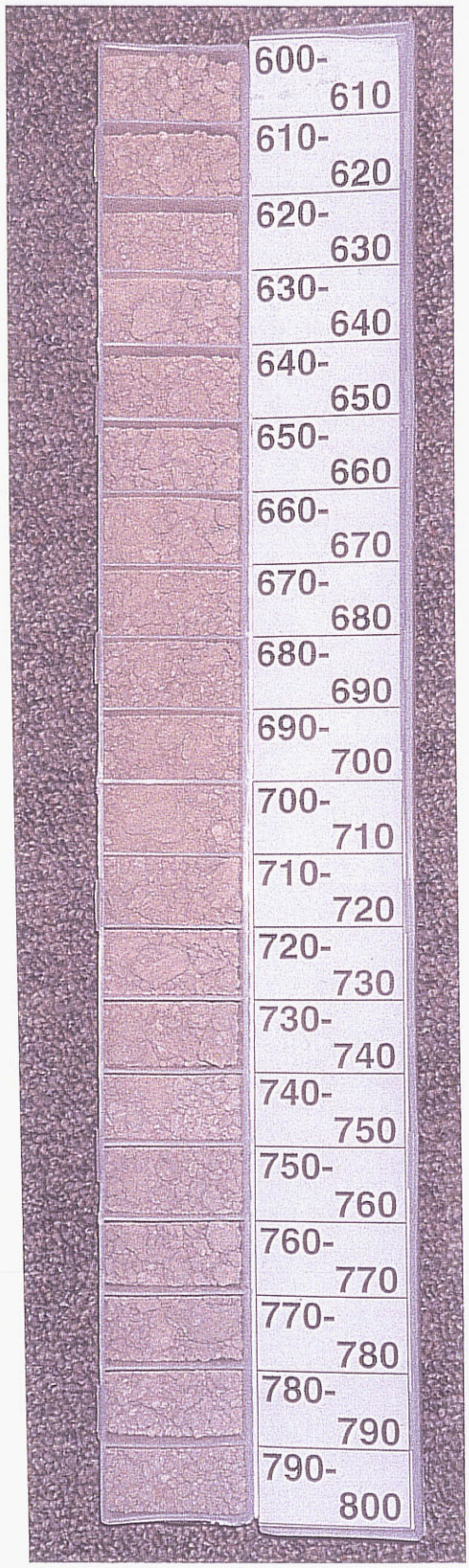
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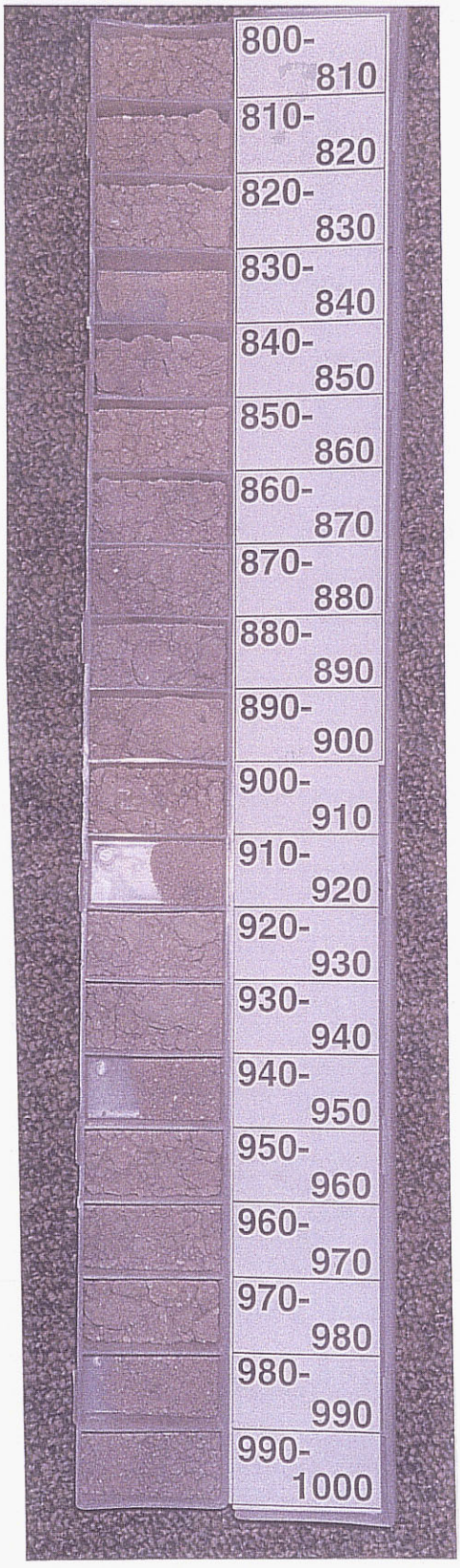
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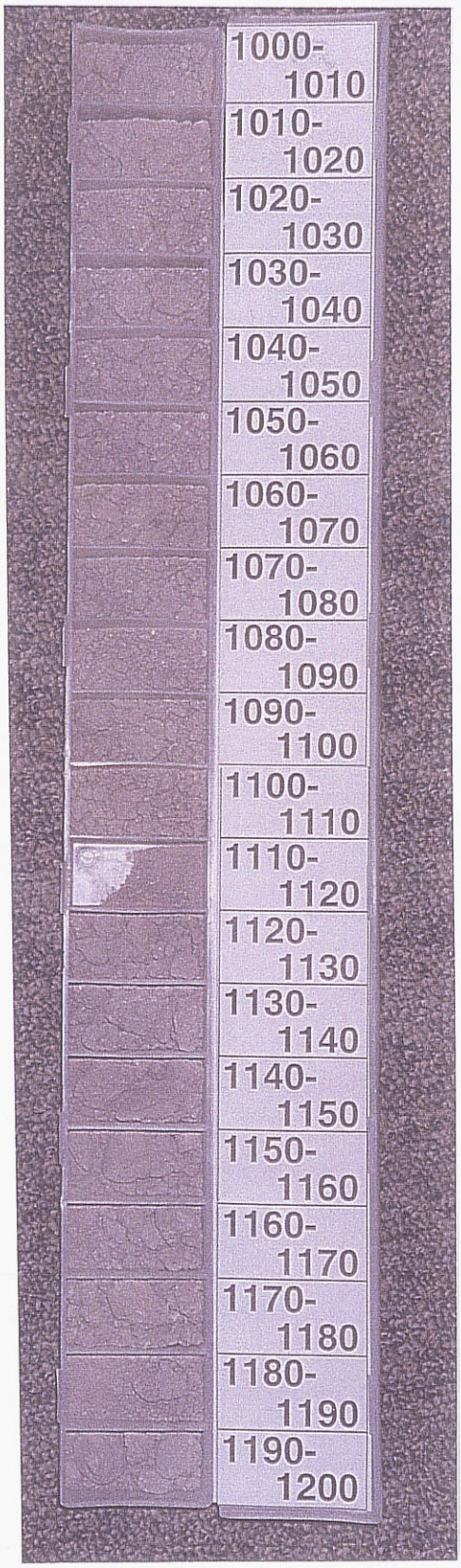
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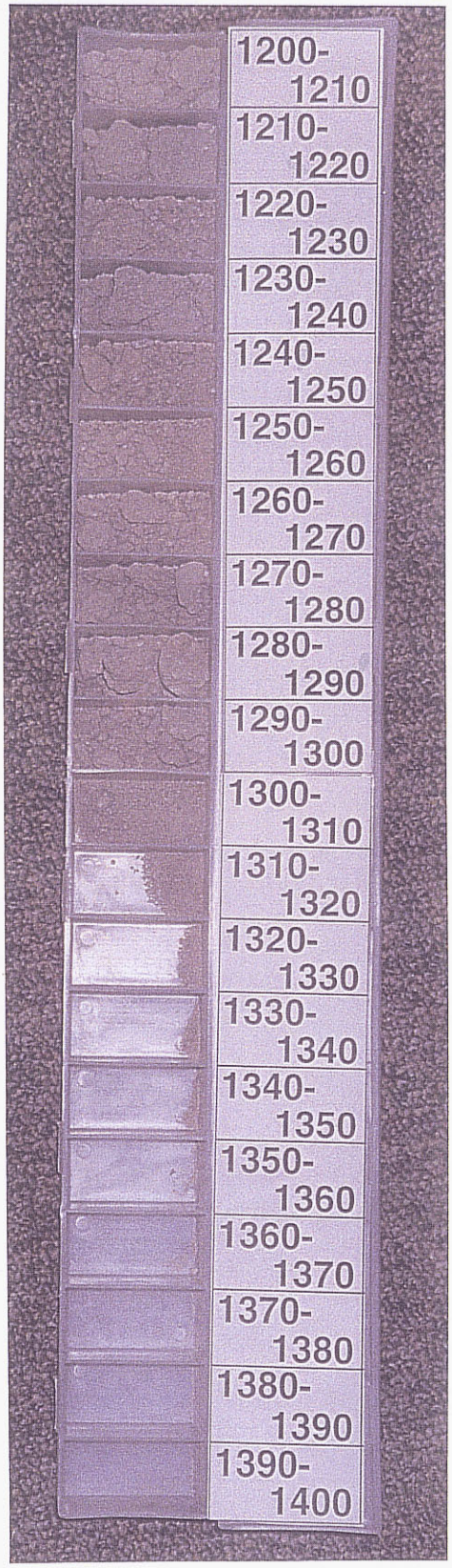
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