HOMESTAKE
Grants Project

Homestake Mining Company of California

Thomas Wohlford
Closure Manager

30 November 2017

40-8903

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RE: Pilot Program for the Installation of Horizontal Wells Near the Large Tailings Pile

Dear Sirs:

Homestake Mining Company (HMC) is proposing a pilot program to install and operate horizontal wells within the alluvial aquifer beneath the Large Tailings Pile (LTP) and within the tailings. The horizontal alluvial aquifer wells would function much like the existing vertical wells in the LTP area and could be operated as a collection or injection well within the ongoing restoration program. The horizontal tailings wells would also function like the existing tailings wells but would only be operated as a tailings dewatering well.

The horizontal wells are being considered both as a supplement to and replacement for a portion of the vertical wells present in the LTP area. For the alluvium, the horizontal wells offer the significant advantage of locating the well head and all necessary well access outside of the footprint of the LTP. This reduces the interference between maintaining and operating wells and other activities such as cover and infrastructure maintenance on the surface of the LTP. The horizontal wells also allow well screen to be installed in areas of the alluvium that are otherwise inaccessible. The capability of installing several hundred feet of horizontal perforated well casing in the alluvial aquifer can also potentially result in a very high yield well when compared with vertical wells with much smaller screen lengths.

NMSS01

The horizontal tailings wells also offer significant advantages for effective dewatering of the tailings. Like the horizontal alluvial wells, the tailings wells can potentially access areas of the LTP without interfering with other activities on the surface of the LTP. Another very significant potential advantage of horizontal tailings dewatering wells with the screened interval at the base of the tailings is that all or most of the screened interval remains within the saturated tailings until the tailings is nearly completely dewatered, and the well yield is expected to be much larger. In contrast, the saturated thickness in a vertical tailings dewatering well declines as the water level in the tailings drops and the corresponding well yield typically declines fairly quickly.

Two types of horizontal wells are under consideration for the pilot program. A continuous or double ended horizontal well is drilled from the surface, extends into the target interval, and then returns to the surface resulting in two access points. The second type of well is a blind or single ended well where the casing terminates below the land surface. The advantages of a continuous well are that it can typically be done with a larger casing and having two access locations increases the flexibility in operation of the well. The disadvantages of a continuous well include the need to span the entire distance from one access location to the next suitable access location. While this can result in a much longer production (screened) well length, this length may also include sections where connection with a well screen is undesirable or counterproductive to the restoration program. The advantages of a blind horizontal well include the ability to screen the well in a target zone without concern for extending the well to a second surface access point. A blind well is also likely to be less expensive to install. The disadvantages of a blind well are practical limitations on well length and maximum casing size.

The following discussion describes the proposed pilot program for installation of the horizontal wells to test and evaluate the installation process and the performance of horizontal wells. The proposed program is conducted in phases with the first phase consisting of installation of two alluvial wells and one tailings well. Additional phases or expansion of the pilot program to include additional wells is contingent upon the success of the first phase and the performance of these wells.

Phase 1 Pilot Horizontal Well Installation Program:

The proposed first phase of the pilot horizontal well includes installation of one continuous alluvial aquifer horizontal well, one blind alluvial aquifer horizontal well and one blind tailings dewatering horizontal well. The locations of these three proposed wells are shown on **Figure 1** with well HWA1 being the continuous alluvial well, well HWA2 being the blind alluvial well and well HWT1 being the blind tailings well. One additional alluvial well location and four additional tailings well locations are shown on **Figure 1** and these wells represent a potential expansion of the pilot program if the Phase 1 installation is successful. The siting and configuration of the wells for the expansion is preliminary and is subject to significant adjustment based upon the results in Phase 1.

Figure 1 shows the continuous horizontal alluvial well HWA1 extending across the northeast corner of the LTP. **Figure 2** shows a cross section for well HWA1 with the proposed entry of the boring on the northwest end of the well. However, the entry and exit points for the well can be reversed based upon drilling contractor recommendations. A length of 300 feet of blank casing is proposed for both ends of the horizontal well, with the intermediate section utilizing perforated casing. The proposed entry and exit angles of 12 and 10 degrees from horizontal, respectively, result in the blank casing extending to within approximately ten feet of the base of the alluvium in the well. The perforated casing as shown in **Figure 2** then generally parallels the base of the alluvium at a level of approximately three to five feet above the base of the

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alluvium. This places the entire screen interval more than fifteen feet below the anticipated water-level elevation in the alluvium.

The maximum vertical displacement along the well is approximately 69 feet. The proposed casing size is six inches but this is subject to limitations imposed by the selected drilling contractor and available equipment. The well casing material may be HDPE, steel, stainless steel, PVC, or a combination material using a dual wall or pipe configuration. The selection of casing material will be based on tensile and compressive strength, flexibility, durability, corrosion resistance, perforation sizes or configurations, and expected ease of installation, development and maintenance.

Figure 1 shows the blind horizontal alluvial well HWA2 extending from north of the LTP a distance of 700 horizontal feet to the south with termination below the LTP. **Figure 3** shows a cross section for well HWA2. Like well HWA1, a length of 300 feet of blank casing is proposed for the entry of the well, and with the proposed entry angle of 13 degrees from horizontal, the blank casing extends to within approximately ten feet of the base of the alluvium in the well. The perforated casing as shown in **Figure 3** then generally parallels the base of the alluvium at a level of approximately three to five feet above the base of the alluvium. This places the entire screen interval more than twenty five feet below the anticipated water-level elevation in the alluvium.

The maximum vertical displacement along the well is approximately 75 feet. The proposed casing size is four inches but this is subject to limitations imposed by the selected drilling contractor and available equipment. The casing material will be selected in a manner similar to that for well HWA1.

Figure 1 shows the blind horizontal tailings well HWT1 extending from north of the LTP a distance of 1000 horizontal feet to the south with termination at the base of the tailings in the LTP. **Figure 4** shows a cross section for well HWT1 and the green base of tailings contours shown in **Figure 1** were used in developing the proposed vertical alignment for the well as shown in **Figure 4**. From the entry point, 200 feet of blank casing is proposed and this extends through the majority of the perched sand layer overlying the alluvial aquifer. The horizontal tailings well is vertically aligned to penetrate to approximately five feet above the base of the perched sand layer beneath the LTP for the horizontal length of approximately 200 feet (see **Figure 4**). After the well boring passes underneath the toe drain corridor, the elevation of the well is gradually raised until it reaches the base of the tailings. The perforated casing then extends parallel to the base of the tailings at a level one to three feet above the base of the tailings to give a total horizontal length of 1000 feet. The installation of perforated casing through the perched sand layer as well as within the tailings will allow the well to extract water from both the perched sand and tailings. The perched sand layer has been impacted by tailings seepage and the water quality is essentially the same as that in the tailings.

The maximum vertical displacement along the well is approximately 31 feet. The casing size and materials are subject to the constraints and considerations described for well HWA2.

The proposed well lengths and completion information are included in Table 1.

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Table 1. Proposed Phase 1 Well Installation

Well I.D.	Well Type	Horizontal Length (feet)	Blank Casing Length (feet)	Perforated Casing Length (feet)	Aquifer
HWA1	Continuous	1360	600	772	Alluvial
HWA2	Blind	700	300	408	Alluvial
HWT1	Blind	1000	200	803	Tailings/Perched

Pilot Horizontal Well Installation Program Expansion:

If the installation of wells in Phase 1 of the pilot program indicates that horizontal wells are a cost effective and suitable well installation for the ground-water restoration and/or dewatering programs, additional wells may be installed as shown in **Figure 1**. The proposed additional wells include a continuous tailings dewatering well, three blind tailings wells and a blind alluvial well with a distribution around the LTP. Table 2 presents expected well completion information for the pilot program expansion as depicted in **Figure 1**. However, significant adjustments in the number and configuration of additional horizontal wells may occur after completion of Phase 1.

Table 2. Proposed Horizontal Well Installation Program Expansion

Well I.D.	Well Type	Horizontal Length (feet)	Blank Casing Length (feet)	Perforated Casing Length (feet)	Aquifer
Tailings	Continuous	2510	400	2115	Tailings/Perched
Tailings	Blind	1000	200	803	Tailings/Perched
Alluvial	Blind	700	300	408	Alluvial

Well Installation Considerations:

The wells will be installed according to relevant procedures described in the standard operating procedure for drilling and well installation (SOP 22). It is anticipated that the wells will be drilled with mud rotary techniques. Because the planned entry angles are shallow, it will likely be necessary to install a larger diameter (e.g. twelve inch) conductor casing at the well entry to maintain the hole and facilitate cuttings collection. If a conductor casing is used, it should extend down the boring to provide a minimum of five feet of vertical displacement from the land surface and should be grouted in place. The following listing describes some aspects of the horizontal drilling and well installation that are expected to differ from a typical vertical well installation.

- Borehole Logging - Although borehole logging using cuttings samples will be attempted, the consistency of drilling fluid and cuttings return for the horizontal drilling may limit the utility of the traditional logging approach. Therefore the logging and sampling of cuttings is subject to the discretion of the drilling supervisor. A measurement of well total depth is not applicable for the horizontal well.
- Casing Materials - The well casing material may be HDPE, steel, stainless steel, PVC, or a combination material using a dual wall or dual pipe configuration. Commercial combination pipes such as Enviroflex will be considered. Creating a dual walled casing by installing a sleeve or lining within the primary casing will also be considered.
- Filter Pack - No filter pack is proposed for the horizontal wells. The difficulty in

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conveying a filter pack down the annulus is expected to preclude successful placement in the screened interval.

- Centralizers - No centralizers will be used for the horizontal wells.
- Well Sealing – The sealing of the annular space around the casing will be done by grouting with cement or other suitable sealant to a minimum vertical displacement of five feet from the land surface. This may include grouting of the casing within the conductor pipe. The grouting will be done by inserting a tremie pipe as far as possible into the annulus of the well, but because the annular space in the lower portion of the boring may be very small or the hole may cave around the casing, this insertion distance may be limited.

Prior to the start of drilling, the plans and procedures for the horizontal well installation will be reviewed by HMC and selected drilling contractors to identify and document any modifications of the plans necessary to complete the wells. The drilling cuttings and fluids will be handled according to established procedures described in the Disposal and Decontamination section of SOP 22 and as directed by the site RSO.

Well Operation Considerations:

The operation of horizontal wells will be essentially the same as that of corresponding vertical wells. The horizontal alluvial wells included in Phase 1 of the program would initially be operated as collection wells but could be operated as an injection well in the future. The horizontal tailings wells will only be operated as a dewatering well. An appropriately sized pumping system will be installed and the discharge will be directed to the RO treatment or evaporation pond(s).

Thank you for your time and attention on this matter. If you or anyone on your staff has any questions, please contact me at the Grants office at 505.287.4456, extension 34, or call me directly on my cell phone at 505.290.2187.

Respectfully,

Thomas Wohlford
Closure Manager
Homestake Mining Company of California
Office: 505.287.4456 x34 | Cell: 505.290.2187

Copy To:

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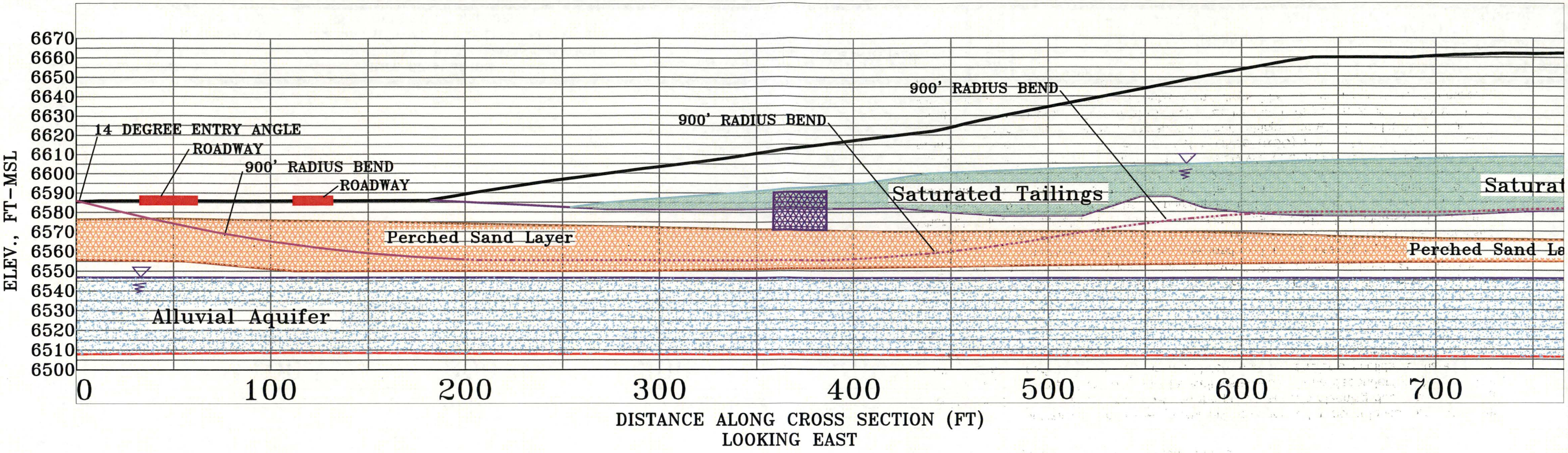

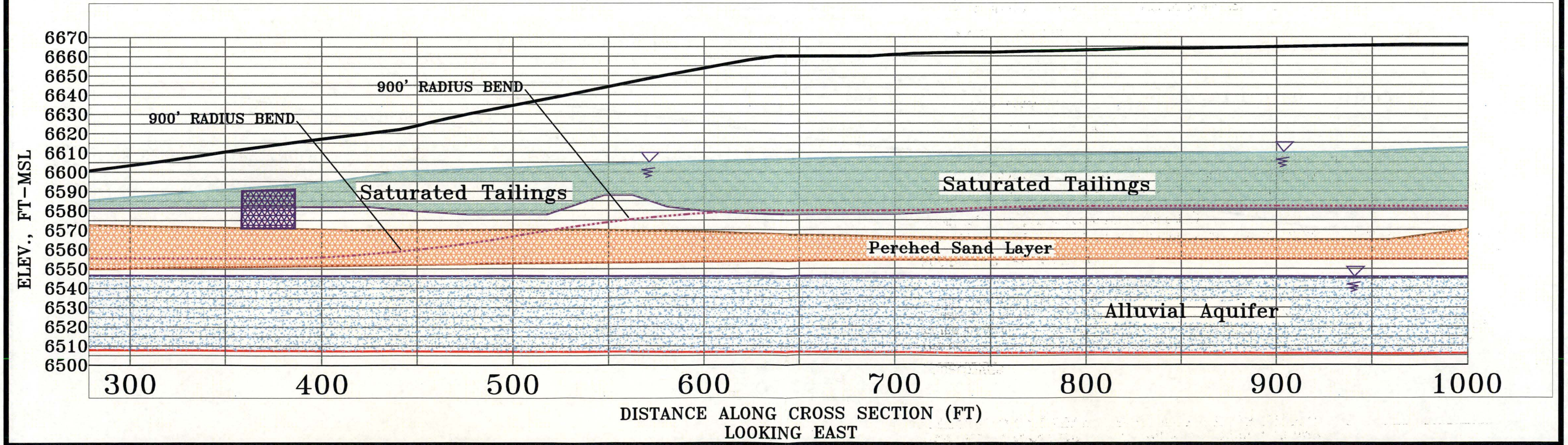

LEGEND

- LAND SURFACE
- BASE OF TAILINGS
- TOP OF PERCHED SAND
- BASE OF PERCHED SAND
- BASE OF ALLUVIUM
- TAILINGS WATER-LEVEL ELEVATION
- ALLUVIAL WATER-LEVEL ELEVATION
- TOE DRAIN CORRIDOR
- HORIZONTAL TAILINGS WELL (Segmented Line Indicates Perforations)
- ROADWAY

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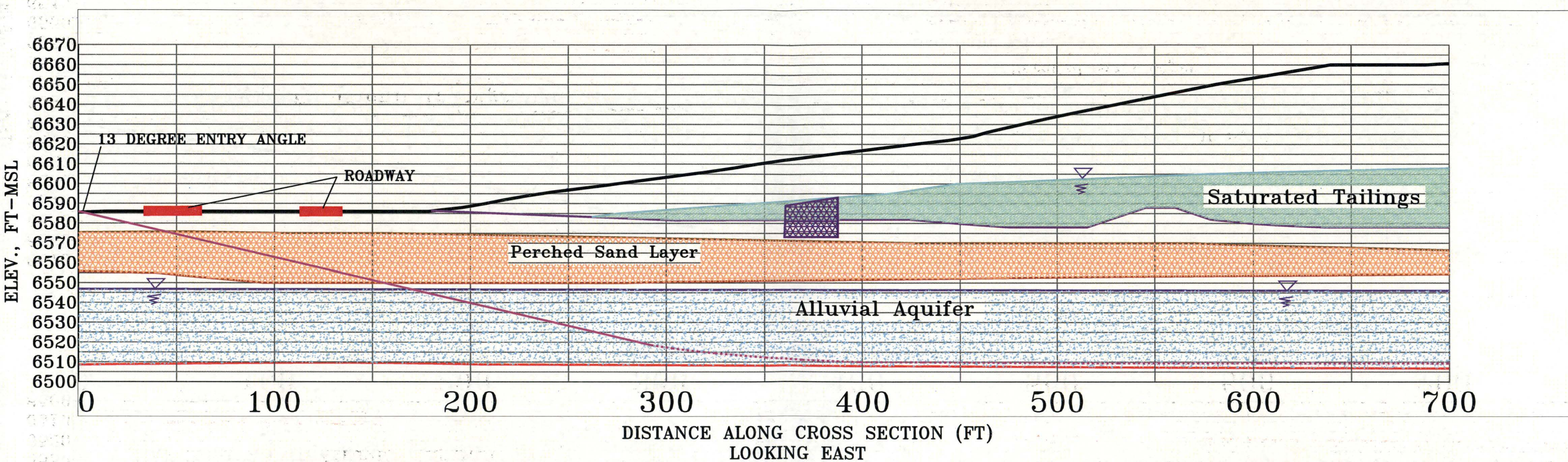
Homestake Mining Company

Grants, New Mexico

Pilot Horizontal Drilling Program

Figure 4

Well HWT1 Proposed Installation



LEGEND

- LAND SURFACE
- BASE OF TAILINGS
- TOP OF PERCHED SAND
- BASE OF PERCHED SAND
- BASE OF ALLUVIUM
- TAILINGS WATER-LEVEL ELEVATION
- ALLUVIAL WATER-LEVEL ELEVATION
- TOE DRAIN CORRIDOR
- HORIZONTAL ALLUVIAL WELL (Segmented Line Indicates Perforations)
- ROADWAY

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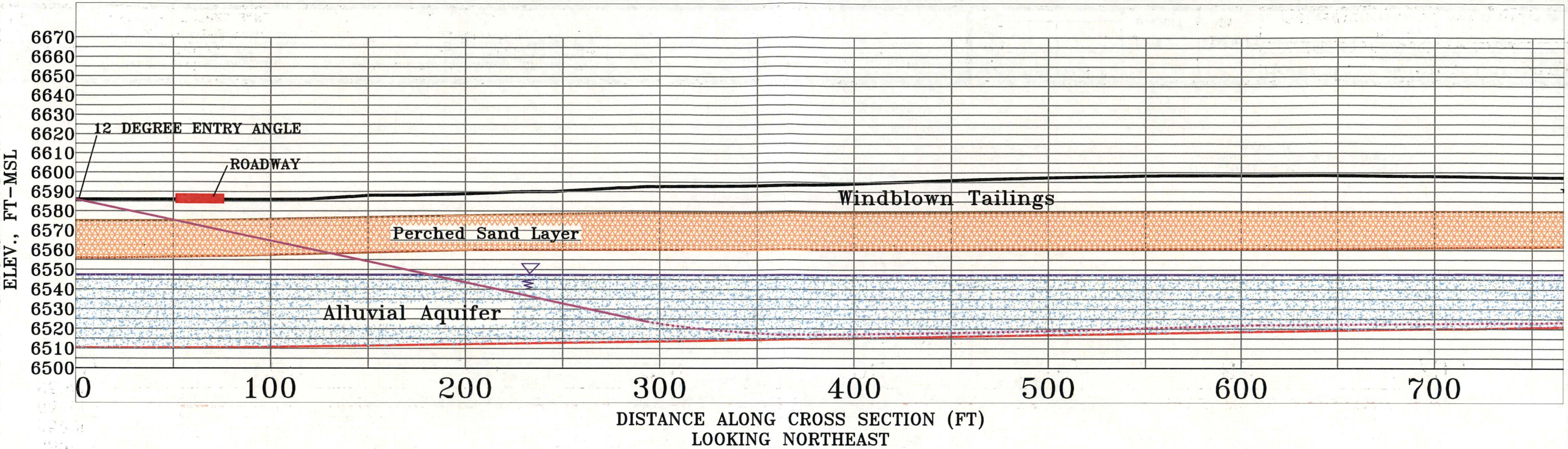
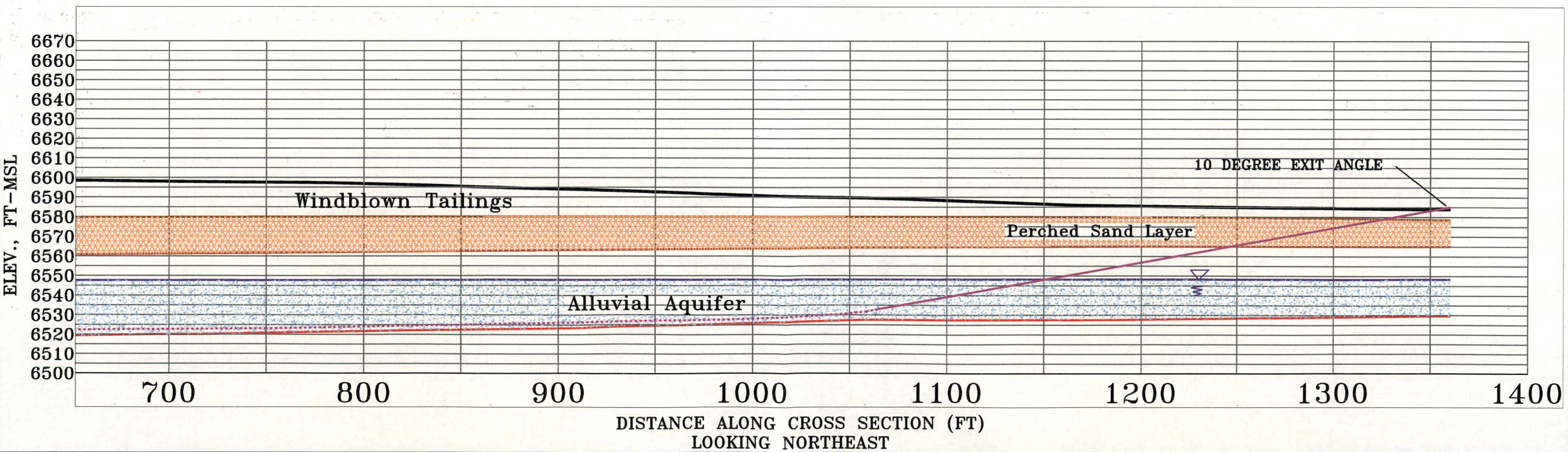
Pilot Horizontal Drilling Program

Figure 3
Well HWA2 Proposed Installation





LEGEND

- LAND SURFACE
- BASE OF TAILINGS
- TOP OF PERCHED SAND
- BASE OF PERCHED SAND
- BASE OF ALLUVIUM
- TAILINGS WATER-LEVEL ELEVATION
- ALLUVIAL WATER-LEVEL ELEVATION
- TOE DRAIN CORRIDOR
- HORIZONTAL ALLUVIAL WELL (Segmented Line Indicates Perforations)
- ROADWAY

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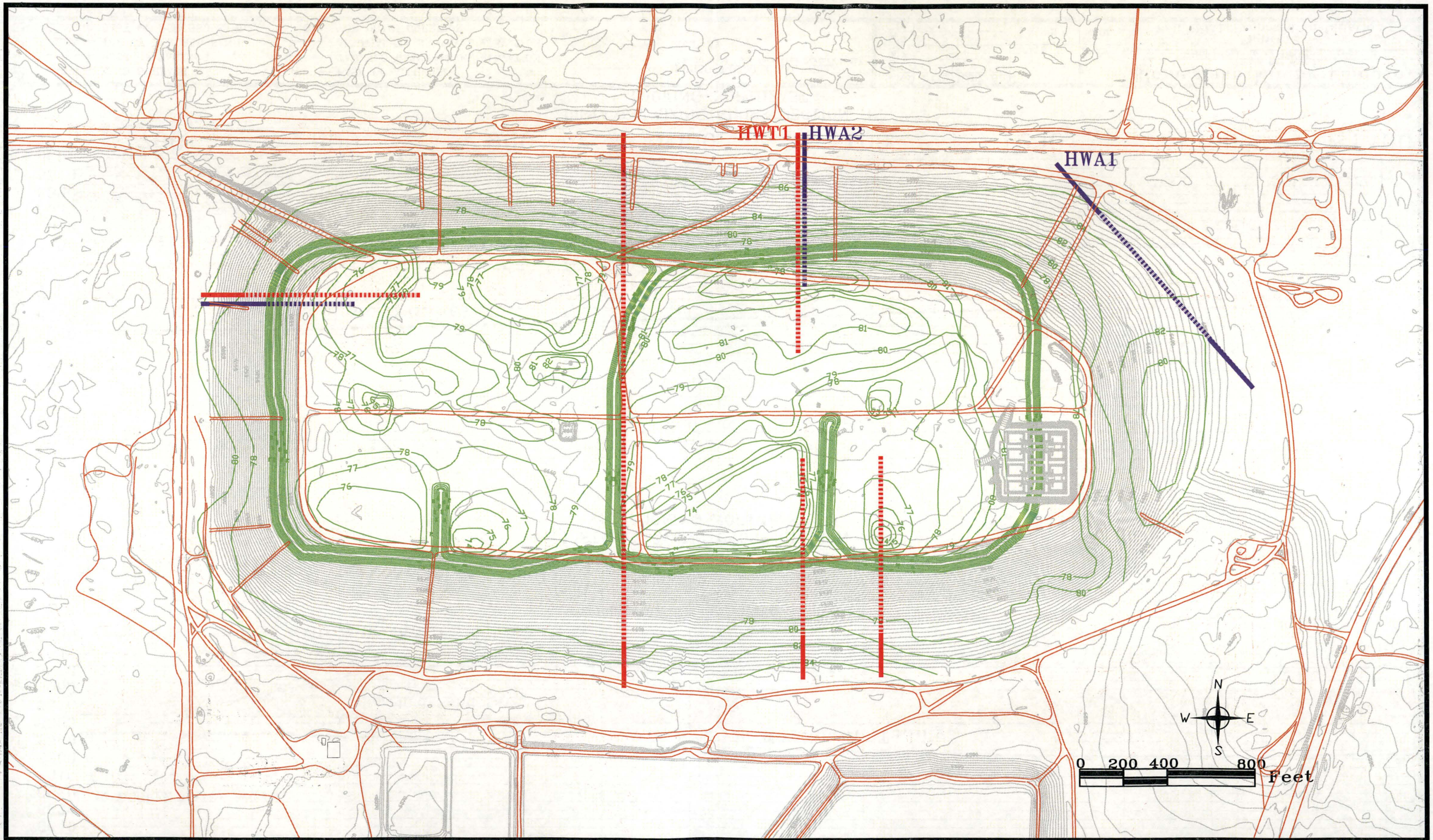
Pilot Horizontal Drilling Program
Figure 2
Well HWA1 Proposed Installation



LEGEND

- Land Surface Contours (ft above MSL)
- Base of Tailings Contours (ft above MSL minus 6500)
- Roads
- Horizontal Alluvial Well (Segmented Line Indicates Perforations)
- Horizontal Tailings Well (Segmented Line Indicates Perforations)

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Pilot Horizontal Drilling Program

Figure 1
Proposed Horizontal Well Locations

SOP 22 – Procedure for Drilling and Well Installation

[Potentially Applicable Regulatory Basis or Bases: SUA-1471, Conditions 23 and 24].

OBJECTIVES

The objective of this standard operating procedure (SOP) is to provide the methods to be used for the installation and development of groundwater wells, and to provide standardized reporting formats for documentation of data. This SOP has been specifically designed with the objective of installing and developing wells.

SCOPE AND APPLICABILITY

This procedure is intended for use for the installation, development, and documentation of monitoring, collection, injection and water supply wells.

Specific well design and installation procedures depend on project-specific objectives and subsurface conditions, and should be discussed in project-specific planning documents. The following aspects will need to be determined when planning a well installation:

- Borehole drilling method
- Construction materials
- Well depth
- Screen length
- Well construction materials
- Location, thickness, and composition of annular seals
- Well completion and protection requirements.

Groundwater well installation and development will be performed in accordance with applicable New Mexico State regulations, this SOP and the project-specific planning documents. Drilling methods employed to pilot the borehole for well installation will be dependent on the physical nature of the subsurface materials (unconsolidated materials and/or consolidated materials) at the site. The drilling contractor shall be a licensed water well driller, in accordance with local and state requirements.

Health and Safety

All workers on the Grants Reclamation Site must wear Level D Personal Protective Equipment (PPE) when outside the main office enclosure. Level D PPE consists of hard hat, high-visibility vest or clothing, long-sleeved shirt, pants, steel-toed work boots, hearing (in high decibel noise areas) and eye protection. Potential physical and chemical hazards will need to be addressed when planning well installation. A health and safety plan (HASP) that addresses known and anticipated field conditions must be prepared prior to field work and be followed during well installation. On the Grants Reclamation Project, the primary radiological constituents of concern of uranium, thorium-230, radium-226 and radium-228 may be encountered especially if drilling on top of the Large Tailings Pile (LTP). A Radiation Safety Work Permit (RSWP) may be applicable if tailings will be encountered. The Radiation Safety Officer (RSO) must review the proposed scope of work to decide how to deal with contaminated drill cuttings and whether a RSWP is required. All staff must wear proper Personnel Protective Equipment (PPE) such as long-sleeved shirts, work pants and gloves to avoid skin contact with tailings. The drill cuttings must be kept moist to prevent wind-blown dust exposure.

RESPONSIBILITES

The *Project Manager* is responsible for ensuring that the project involving well installation is properly planned and executed, and that safety of personnel is provided from chemical and physical hazards associated with drilling and well installation activities.

The *Radiation Safety Officer* is responsible for ensuring that the project involving potential radiological hazards is safe to perform and determining what applicable mitigation is required to maintain ALARA (As Low As Reasonably Achievable) standards.

The *Field Geologist or Engineer* is responsible for directly overseeing the construction and installation of the wells by the driller, ensuring that the well installation specifications defined in the project-specific planning documents are followed, and that pertinent data are recorded on appropriate forms and in the field notebook. Well construction and boring completion will be conducted under the supervision of an appropriately-qualified and registered person as defined by local regulations.

The *Site Safety Officer (SSO)*, typically the field geologist or engineer, is responsible for overseeing the health and safety of employees and for stopping work if necessary to fix unsafe conditions observed in the field. If a subcontracted firm conducts installation and documentation activities, then the firm will designate an SSO.

WELL PERMIT

Prior to initiating any drilling operation on the Grants Reclamation Site, a well permit must be obtained from the Office of State Engineer (OSE). Typically a small fee such as $5 is required to be submitted for each well to be installed. This permit must be obtained before scheduling the work.

ARTESIAN WELL PLAN

For any well to be drilled and installed in a confined aquifer in the State of New Mexico, the OSE is requiring completion and submittal of an Artesian Well Plan with the well permit application. The Artesian Well Plan requires that all surface aquifers, such as the alluvial aquifer at the Grants site, be cased off first with surface casing prior to proceeding to drill into the lower confined aquifer(s). The Artesian Well Plan identifies the type of casing and other materials to be used in the well installation operations.

REQUIRED MATERIALS

Many materials are required for successfully completing the installation and development of wells. The drilling Subcontractor often supplies much of the material. However, the field personnel should be aware of what is required to conduct the work so they have their own supplies (if needed) and can provide complete Subcontractor oversight. The following is a general list of materials that are needed for performing the tasks outlined in this SOP.

Geologist

- Hand lens for mineral and grain size identification
- Health and Safety supplies (e.g., steel-toed boots, gloves, hard hat, etc.)
- Lithologic Logs and Well Completion forms
- Logbook
- Logging assistance tools (e.g., grain-size charts, color charts)
- Measuring tapes (both long weighted cloth type and small measuring tape, preferably marked in tenths and hundredths of a foot)

Drilling Subcontractor

- Drilling equipment (depends upon the type of drilling, e.g., drill stem, auger, generators, compressors, steam cleaners, etc.)
- Well drilling supplies (drilling mud)
- Decontamination pad construction supplies
- Well construction supplies (screen, well casing, sand pack, bentonite chips, bentonite/cement mixture, water)
- Health and safety records required for working on-site
- Ancillary support vehicles

METHODS

The borehole diameter must be a minimum of four (4) inches greater than the outside diameter of the well screen or riser pipe used to construct the well. This is necessary so that sufficient annular space is available to install filter packs and grout seals. All boreholes will be cleared for shallow obstructions by following the SOP for Utility Clearance. In New Mexico, it is required to place an 811 call for underground utility mark-out. After placing the call, the caller typically receives a response from *all* utility companies in the area *whether they have a service in the area or not.*

Drilling Methods

Several drilling methods are available for use in creating a borehole for well installation. These methods include hollow-stem, air rotary, mud rotary, and cable tool, among others. The drilling method selected will be based on the physical properties of the subsurface materials.

Hollow-Stem Auger Methods

Hollow-stem auger uses continuous-flight hollow-stem augers with a bit on the bottom to drill and maintain an open borehole. The continuous-flight auger drives the drill cuttings to the surface as drilling progresses. The walls of the auger minimize the amount of unconsolidated materials entering into the space inside the casing. Intact soil samples are collected by pounding a steel split-spoon sampler ahead of the auger. The well casing, filter pack and seal are installed inside the auger. The auger is removed slightly ahead of backfilling as filter pack and grout are added. Careful recording of the amount of each material used should be recorded in the field logbook.

Mud Rotary Methods

Mud rotary drilling uses drilling fluids or synthetic gels to circulate drill cuttings to the surface. Drilling fluid will consist of water mixed with bentonite. Powdered bentonite or an approved equivalent will be used as an additive in the drilling fluid. Bentonite will be mixed into the drilling fluid using a mud mixer and a portable mud tank. Drilling fluid density and viscosity will be maintained at appropriate levels for the various lithology encountered and in accordance with material specifications.

A shale-shaker and de-sanding system will be used to maintain the density and viscosity of the drilling fluid. Sand content will be minimized to the degree possible by maintaining no greater than four (4) percent (%) sand by mud volume.

If water or other drilling fluids have been introduced into the borehole during drilling or well installation, samples of these fluids should be obtained and analyzed for chemical constituents that may be of interest at the site. Also, an attempt should be made to recover the quantity of fluid or water introduced by flushing the borehole before well installation and/or by pumping the well during development.

Air Drilling Methods

The following are descriptions of air rotary, "down-the-hole", Air Rotary Casing Hammer (ARCH) method, and dual-wall reverse-circulation air rotary methods. Air rotary uses air as a primary means of transporting drill cuttings to the surface. A large compressor provides filtered air that is piped to the swivel hose connected to the top of the Kelly bushing or drill pipe. The air, forced down the drill pipe, escapes through small ports at the bottom of the drill bit, thereby lifting the cuttings and cooling the bit. The cuttings are blown out the top of the hole and are collected at the surface in a cyclone unit and a container or pit. Injection of a small volume of clean water into the air system controls dust and lowers the temperature of the air so that the swivel is cooled. Air drilling is effective in semi-consolidated or consolidated materials.

A second direct rotary method using air is called the "down-the-hole" or percussion down-hole hammer drilling system. A pneumatic drill operated at the end of the drill pipe rapidly strikes the rock while the drill pipe is slowly rotated. The percussive effect is similar to the blows delivered by a cable tool bit. Cuttings are removed continuously by the air used to drive the hammer.

A third direct air rotary method called the ARCH method is used where an outer steel casing is advanced slightly behind the drill bit. The drill bit reams material in front of the casing and then the casing is advanced with a pneumatic hammer down the hole to prevent hole collapse. Cuttings are collected in a tube system that conveys them into a cyclone at the surface.

The dual-wall reverse-circulation air rotary method uses flush-jointed, double-wall pipe in which the air moves by reverse circulation. The airflow is contained between the two walls of the dual-wall pipe and only contacts the walls of the borehole near the bit. Dual-wall pipe can be driven into place in loosely-consolidated materials by a pile hammer as a drive bit is cutting the formation. Downhole air hammers and tricone bits can also be used to cut the formation. The air lifts the cuttings to the surface through the inner pipe. Dual-wall methods can be applied in consolidated and unconsolidated formations.

Rotosonic Drilling

Rotosonic is a core drilling method that employs simultaneous high-frequency vibration and low-speed rotational motion along with downward pressure to advance the core barrel without use of drilling fluid or air. The core barrel can generally advance from five to 20 feet at one time, depending on the length of the core barrel. The drill cuttings are brought to the surface by removal of the entire core barrel from the borehole and the cuttings are vibrated out of the barrel. If required for logging purposes, the cuttings are collected in plastic sleeves. An outer casing is generally washed-down with water to stabilize the borehole from collapse and heaving sand. The outer casing prevents cross-contamination and formation mixing. The advantage of rotosonic core drilling is that no drilling fluids or muds are required to bring the cuttings to the surface and the aquifer is less likely to be contaminated by the drilling method.

Borehole logging

Boreholes will be logged using cuttings and samples collected during drilling activities. Soil or rock samples will be collected as described in the SOP for Soil Sampling (SOP-23). Cuttings, soil and rock samples will be described at the frequency presented in the project-specific planning documents following the procedures outlined in SOP for Soil and Rock Descriptions (SOP-24).

After drilling has been completed, the field geologist/engineer will measure the total open depth of the borehole with a weighted, calibrated tape measure and document the depth. The field geologist will then collaborate with the supervising geologist by reviewing lithologic units encountered, water levels, if any, and other logged information to determine the well construction details.

Boreholes/well locations should be clearly designated in the field notes using notes and a hand-sketched layout, and should include the following information:

- Measurements of each boring/sample point relative to fixed objects (building, structures, etc),
- Boring/sample location with the identification number noted,
- North arrow or other compass directional indicator, and
- Other essential site features and/or investigation features (underground storage tanks, piping, above-ground tanks, etc.).

WELL CONSTRUCTION PROCEDURES

Wells will be constructed in accordance with state and local agency requirements, and will include at a minimum the following materials:

- Borehole backfill for over-drilled boreholes prior to well installation,
- Well casing and screen
- Filter pack materials
- Well sealing materials (e.g., bentonite pellets, cement, powdered bentonite), and
- Surface seals and materials for well surface completion (e.g., concrete, protective steel casing, steel posts, surface boxes).

A discussion of these materials and how they are used is provided in more detail in the following sections.

Backfilling

If backfilling the borehole to the appropriate well installation depth is necessary, neat cement, bentonite grout, bentonite pellets or filter pack sand may be used. The backfill material selected for use will depend on site conditions, lithology, and project-specific requirements. Most often, the borehole requires complete sealing with lower layers, so neat cement, bentonite grout, or bentonite pellets are used. The setup time should be a minimum of 48 hours for neat cement and 24 hours for bentonite grout and bentonite pellets prior to beginning well construction. Field personnel should remeasure and verify that the bottom of the borehole is exactly where it should be set before proceeding with well construction. The necessary setup times may be reduced if manufacturer-approved additives are mixed with the grout to accelerate the cure time.

If neat cement or bentonite grout is used, a tremie pipe will be required to place the grout in the bottom of the hole. Grouting the borehole may be difficult to accomplish, if the portion of the borehole to be grouted is significantly lower than the groundwater level. Provisions will be necessary to support the screen and riser pipe to prevent sinking into the grout. Care will be taken to frequently measure the total borehole depth when adding grout to the bottom of the hole. Grout should have thickened to a hardened state before proceeding. The thickness of the grout will be calculated based on depth readings and recorded. If a well has been backfilled too much, it may require reaming to clear out the overfilled material.

Depending upon the lithology, some distance should be planned between the fill in a borehole and the bottom of the screened interval. Unless this distance would result in a breach of a confining layer, or the well screen requires setting directly on the impermeable zone due to site requirements, the bottom of the well screen should be set at a maximum of six inches above the top of any backfill. The distance between the top of fill and the bottom of the well screen should be filled with a fine sand buffer.

Bentonite pellets should be carefully dropped into the borehole to minimize the risk of pellets sticking to the side of the borehole when dropped through a water column. Pellets are generally easier to place than bentonite chips because pellets do not hydrate as quickly; hence pellets are the preferred method for small backfill jobs where significant confining zones have not been breached.

Well Casing and Screen

The well will consist of factory-sealed commercially-available well screen and casing. Well screens and casing will typically be constructed of polyvinyl chloride (PVC), a type of plastic, but may also be constructed of stainless-steel or Teflon® depending on subsurface conditions or other project requirements. Stainless-steel casing shall meet one of the following standards: American Society For Testing Materials (ASTM) A-53-93A or B, A-589-93, or American Petroleum Institute 5L, March 1982 Edition to conform to the minimum standards given in Table A of that document.

Plastic casing and liners shall meet the requirements of ASTM Standard F480-94 and the National Sanitation Foundation (NSF) International Standard Number 14-1990, Plastic Piping System Components and Related Materials. Evidence of compliance shall be included in the current NSF listing, display of the NSF seal on each section of casing, and marking the casing in accordance with the requirements of ASTM Standard F-480-94. Plastic well casing and liners must be Standard Dimension Ratio (SDR)-rated and conform to the minimum requirements given in Table B of the above-referenced document.

Well screens shall be constructed of non-corrosive and non-reactive material. Well screens shall be permanently joined to the well casing and shall be centered in the borehole. The anticipated length of screen and the reasoning behind choosing the length of screen will be determined when developing the project-specific planning documents. Modification can be made in the field, but will be done in consultation with the PM, or their designee such as the Project Technical Manager or Responsible Geologist.

Screen slot type and size will be dependent on the sand pack material and the aquifer formation material. Casing will be connected by flush-threads or coupled-joints, and will be completed with a bottom cap. A collection sump may be installed below the screen and will vary in length depending on lithology and project needs. The collection sump and bottom cap will be connected to the well screen by flush-threaded or coupled-joints. Plastic casing must have threaded joints and O-ring seals. Solvent, glue, or anti-seize compounds will not be used on the joints. With deep wells (greater than approximately 100 feet below grade), centralizers should be used to keep the well casing plumb and straight in the borehole. Centralizers should be placed at approximately 20-foot intervals in the screen interval and 40-foot intervals throughout the blank casing interval.

For water table wells, well screens should be placed such that some of the screened interval is above the water table, and some section is below the water table. This allows for seasonal water level fluctuations. The amount of split should be determined by the lead responsible geologist and be based upon local conditions.

Casing and screen (well string) must be clean, free of rust, grease, oil or contaminants, and be composed of materials that will not affect the quality of the water sample. All casing shall be water-tight. The casing shall be centered in the borehole, be free of any obstructions and allow sampling devices to be lowered into the well. The well string shall be hung in the borehole during installation so that the well is sufficiently plumbed and straight after completion.

Filter Pack

Wells installed in unconsolidated material will be constructed with filter packs. When used, the filter pack will be the only material in contact with the well screen. The filter pack will consist of sand or gravel. The sand or gravel used for filter pack material shall be sized to match the

screen slot size and the surrounding lithology to prevent subsurface materials from penetrating through the sand or filter pack; and preventing the sand or filter pack from entering the well. Sizing of the filter pack material is often conducted using sieve analysis and following interpretative procedures outlined in Driscoll (1986). The sand or gravel shall be free of clay, dust, and organic material. Crushed limestone, dolomite, or any material containing clay or any other material that will adversely affect the performance of the monitoring well shall not be used as filter pack. The filter pack will extend a maximum of six inches below the bottom of the screen to two to three feet above the top of screen. The filter pack material may be placed in the well by pouring the sand into the open borehole, or tremied into place depending upon site-specific criteria. However, in all cases, filter pack material should be added carefully with continuous measurements by the field geologist to prevent bridging of the filter pack material.

Groundwater wells completed into competent bedrock material are often not completed with filter pack material, and can be completed as an open hole over the screened interval. Completion in this manner should be carefully considered and approved by regulatory agencies prior to field mobilization.

The well will be gently bailed and surged with a bailer and surge block or air lifting after the filter pack has been added to the borehole and before the seal is placed in the annular space. A surge block consists of a rubber or leather and metal plunger attached to a rod or pipe of sufficient length to reach the bottom of the screen. Surging should be maintained for at least five minutes and the entire length of saturated screen will be surged to help settle the filter pack. The top of the filter pack will need to be gauged after surging and additional filter pack material may need to be added if settling has occurred.

Sometimes project-specific requirements may identify that a transition sand be emplaced above the main filter pack. This transition sand is usually much smaller grain size than the filter pack, and is emplaced to provide added protection that grout invasion into the filter pack will not occur when deep wells (greater than 200 feet deep) are installed. Transition sands can be emplaced up to 10 or 20 feet above the regular sand pack interval. An alternative to transition sands is to use additional well seal material such as bentonite pellets.

Well Sealing Material

The wells will have an annular space seal that extends from the top of the filter pack to the ground surface. The annular sealing material above the filter pack will prevent the migration of fluids from the surface and between aquifers. Sealing material will be chemically compatible with anticipated contaminants. Hydrated bentonite chips or pellets are typically used as an annular seal directly above the filter pack. The annular seal should be a minimum of three feet-thick unless site-specific requirements dictate otherwise. For example, as mentioned above, deep wells may require additional sealant material (10 to 20 feet thick versus three feet) between the sand pack and cement to prevent grout invasion into the filter pack interval. Cement and/or bentonite grout or bentonite chips are typically used as annular fill above the seal. Above the sealant material, a bentonite grout mixture is often used as an annular fill to complete the well installation to within two feet of the ground surface. Grout will be emplaced using a tremie pipe so that the grout fills the annular space from the bottom to the ground surface without allowing air pockets to form in the filled zone.

Surface Completions

Above-Grade or Monument Surface Well Head Completion

With above-grade well completions, the well casing will extend to two to three feet above the ground surface. A locking cap will be placed at the top of the casing and the cap will be water-tight. The section of casing that sticks up above ground will be protected by a steel protective pipe, set at least two-feet deep into a concrete surface seal. A concrete pad should be constructed around the protective steel pipe. The pad should be square, approximately 1.5-by-1.5 feet to two-by-two feet, sloped slightly away from the well, and the top of the pad should be

approximately four inches off the ground. The top of the protective pipe will have a vented lockable cap. Protective steel posts will be installed in areas where the well could be struck by vehicles or heavy equipment. Also, a "weep" hole should be drilled in the bottom of the protective steel pipe. In areas where freezing may occur, placement of the weep hole is critical; little volume should exist in the protective casing above the weep hole where water could accumulate and freeze thereby damaging the well. A "V" notch or other permanent mark will be placed at the north edge of the top of the well casing that will be used as the reference point for well elevation surveying and water level monitoring.

Ground or Grade Surface Well Head Completion

Well casing may terminate at the ground surface with a flush-mounted traffic-rated road box. Road box installations must use a water-tight well cap for the well riser pipe in addition to a water-tight road box to prevent surface water from entering the well. The well casing should extend approximately three inches above the sealant in the bottom of the well box. The traffic-rated road box and surface concrete completion should meet Class A specifications, which meet a minimum 4000-pound compressive strength. The surface completion should provide positive drainage away from the well box to prevent ponding around the well. In traffic areas and sidewalks, this positive drainage slope away from the box should be minimized to prevent physical hazards. The surface seal around the box should be a minimum of 12 inches around the perimeter of the box. As discussed above, a reference mark should be placed on the top of the well casing for well elevation surveying and water level monitoring.

Well Location and Surveying

Wells will be located by parcel coordinates required by local permit requirements. Each well will be surveyed by a licensed surveyor in the state where the well has been installed and tied to an established state or county benchmark, site conditions permitting. The vertical survey will be accurate to 0.01 foot relative to mean sea level. Both the top of casing and ground surface elevation near the well will be surveyed for vertical control. The "V" notch cut on the north side of each well casing will be used as the surveyor's reference mark. For horizontal control, each well will be tied to an existing site coordinate system and will be surveyed to a horizontal accuracy of 0.1 foot.

Well Development

Well development is necessary to ensure that complete hydraulic connection is made and maintained between the well and the aquifer material surrounding the well screen and filter pack. The appropriate development method will be selected for each project based on the lithology, objectives, and requirements of that project.

Project-specific planning documents will identify the specific development method to be used. In general, most wells will be developed by using surge block and bailing methods to draw the coarse and/or fine material out of the sand pack. Other development methods that may be used include jetting, airlift, and submersible pump methods. These methods are discussed further below. Jetting is typically not used as a development method for environmental investigations, but is commonly used for water resource monitoring wells or production wells.

Well development should begin no sooner than 48 hours after well installation, if the well annulus is cemented. However, if drilling muds are used during well installation, well development should occur less than 24 hours following well installation so that the drilling mud does not set up in the well screen section.

Generally, a phased process is used to develop wells, starting with a gentle bailing phase to remove sand, followed by a surging phase then a pumping or air lifting phase after the well begins to clear up. The following paragraphs provide more detailed information.

After a well is first installed, and in fact, often before the bentonite pellet seal is set, gentle bailing is used to remove water and sand from the well. The purpose of this technique is to settle the sand pack. After further well sealant materials have been added and allowed to set for approximately 48 hours, bailing is resumed as part of well development. The purpose of bailing is to remove any fine material that may have accumulated in the well, and start pulling in natural material into the sand pack. Bailing is often conducted until the sand content in the removed water begins to decrease.

After the sand content begins to decrease, surging is conducted. A surge block is used to move sediments from the filter pack into the well casing. A surge block consists of a rubber (or leather) and metal plunger attached to a rod or pipe of sufficient length to reach the bottom of the well. All surge blocks will be constructed of materials that will not introduce contamination into the well. Surge blocks should have some manner of allowing pressure release to prevent casing collapse. The surge block is moved up and down the well screen interval and then removed, followed by a return to bailing to remove any sand brought into the well by the surging action. Care should be taken to not surge too strongly with subsequent casing deformation or collapse; the well screen interval is often the weakest part of a well. Surging should be followed by additional bailing to remove fine materials that may have entered the well during the surging effort.

After surging has been completed and the sand content of the bailed water has decreased, a submersible pump is used to continue well development. The pump should be moved up and down the well screen interval until the obtained water is relatively clear. Well development will continue until the water in the well clarifies and monitoring parameters such as pH, specific conductivity, and temperature stabilize as defined in the project-specific planning documents. It should be noted that where very fine-grained formations are opposite the screened interval, continued well development until clear water is obtained might be impossible. Decisions regarding when to cease development where silty conditions exist should be made between the field supervisor and PM.

During well development pH, specific conductivity, temperature, and turbidity should be monitored frequently to establish natural conditions and evaluate whether the well has been completely developed. The main criteria for well development is clear water (Nephelometric turbidity units or NTU of less than 5). As mentioned above, clear water can often be impossible to obtain with environmental monitoring wells. A further criteria for completed well development is that the other water quality parameters mentioned above stabilize to within 10% between readings over three well volumes.

The minimum volume of water purged from the well during development will be approximately a minimum of three borehole volumes (wells will typically not reach stabilization of water quality parameters before this condition is achieved and may not have reached stability even after this threshold has been achieved). The above is a general guideline for difficult well development - project-specific planning documents should address project constraints on well development. Development water will be temporarily stored in 55-gallon Department of Transportation (DOT)-approved drums, tanks or ground pits depending upon the total volume of purge water removed from the newly installed wells, if the water produced from the well exceeds or is expected to exceed the site standards. Well development water can be discharged to unlined pits if the well is completed in an area where site standards in the completion interval are not exceeded.

Disposal and Decontamination

All drill cuttings and fluids generated during well installation and development will be containerized pending analytical results and determination of disposal options, as site conditions determine unless project-specific requirements specify otherwise. Waste containment and disposal will occur in a manner that will not result in contamination of the immediate area or result in a hazard to individuals who may come in contact with these materials. For borings drilled in specific areas the following disposal procedures apply;

LTP – All drill cuttings are to be left in the drill cuttings disposal pits and a 1-foot thick layer of clean (non-contaminated) soil placed on top. The area of the pit(s) must be physically inspected occasionally after covered to ascertain if settlement has occurred. If so, additional clean soil must be applied.

Off-Site Areas – Groundwater contamination has only potentially impacted the saturated alluvial and bedrock aquifers. Therefore, non-saturated alluvial materials can be disposed of on the land surface. All potentially contaminated alluvial and bedrock aquifer material shall be disposed of in Evaporation Pond No. 1 (EP-1) which will be the final disposal cell for all licensed 11.e (2) material on the Grants site. The material of aquifers that are not impacted can be disposed in a pit adjacent to the drill site. This includes the Chinle shale which is not impacted due to its very small permeability restricting the movement of contaminants in the shale.

On-Site Areas – Groundwater contamination has only potentially impacted the saturated alluvial and bedrock aquifers. Therefore, non-saturated alluvial materials can be disposed of on the land surface or remain in any such drilling cuttings pits that were constructed. All potentially contaminated alluvial and bedrock aquifer material shall be disposed of in EP-1. The material of aquifers that are not impacted and Chinle shale can be disposed in a pit adjacent to the drill site.

Clean non-contaminated water, such as from the San Andres-Glorieta Aquifer, will be allowed to drain naturally on the ground surface as long as there is *no danger of it draining to a surface water* body or *otherwise directed by regulatory authorities*. Contaminated water or fluids will be disposed of in EP-1.

All drilling and well construction equipment that comes into contact with the borehole will be decontaminated by following the Equipment Decontamination SOP-25.

QUALITY ASSURANCE/QUALITY CONTROL

Borehole drilling and well construction details will be documented in detail in the field. Field documentation forms will consist of a lithologic borehole log, a well construction log, and daily field note forms. Deviations from project-specific planning documents will be documented and explained in daily field notes. The program manager will be contacted to discuss project deviations.

Field quality control can be maintained through 1) making sure employees are properly trained to conduct the work being implemented, and 2) performing routine field audits to evaluate how well employees are following procedures. These two aspects of quality assurance/quality control (QA/QC) are detailed in the Quality Assurance Program documentation.

RECORDS

Field notes and logs will be submitted to the Project Manager or designee immediately following the field event for checking and revision purposes. The Project Manager or designee shall review and transmit the completed forms for incorporation into the project file.

HORIZONTAL WELLS

The practices mentioned in this SOP will apply to horizontal well drilling with a few exceptions detailed below:

- The minimum borehole diameter does not have to be 4 inches larger than the casing diameter. The effective minimum borehole diameter is the outer casing diameter plus the smallest annular space that will allow successful installation of the selected well casing.
- Borehole logging using cuttings samples will be attempted. However, the consistency of drilling fluid and cuttings return for the horizontal drilling may limit the utility of the traditional logging approach. Therefore, the logging and sampling of cuttings is subject to the discretion of the drilling supervisor. A measurement of well total depth is not

applicable for the horizontal well.

- In cases of shallow entry angles, a conductor casing is likely to be needed to help maintain the hole and facilitate cuttings collection. If used, the conductor casing should extend down the boring to provide a minimum of five feet of vertical displacement from land surface and be grouted in place.
- The potential casing materials used in horizontal drilling may differ from those used in vertical applications. HDPE or steel may be used as well as stainless steel, PVC, or other suitable material. Commercially available combinations of these materials that incorporate filter pack material or filter fabric between two pipes, such as Enviroflex, may be used as well. Well casing material will be selected at the discretion of the driller and project manager.
- The filter pack requirements do not apply to horizontal drilling due to the difficulty in conveying a filter pack down the annulus.
- The sealing of the annular space around the casing will be done by grouting with cement or other suitable sealant to a minimum vertical displacement of five feet from the land surface. This may include grouting of the casing within the conductor pipe. The grouting will be done by tremie pipe where possible, but given the small annular space, the insertion distance may be limited.
- Well development of the horizontal wells will differ from that of vertical wells. Due to the horizontal orientation of the well, surging and/or bailing of the well are not likely viable options. Jetting, air lifting and/or pumping are expected to be potentially useful methods of well development for horizontal wells.
- Centralizers will not be used in horizontal wells.
- Because of the shallow angle of the well entrance, a typical well vault is generally not a suitable means of well protection. A concrete pad with surface casing around the well casing will be installed. The well and casing access will be configured to prevent entry of surface water and debris. Protective steel posts to protect the well from damage by vehicles and/or heavy equipment will be installed as directed by the drilling supervisor. A suitable well enclosure or protective structure will be installed as directed by the drilling supervisor.

REFERENCES

American Society for Testing Materials (ASTM) A-53-93A or B, A-589-93, or American Petroleum Institute 5L, March 1982 Edition

ASTM Standard F480-94 and the National Sanitation Foundation (NSF) International Standard Number 14-1990, Plastic Piping System Components and Related Materials

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United States Environmental Protection Agency, 1989, Handbook for Suggested Practices for the Design and Installation of Monitoring Wells, EPA 600/4-89/034, Reprinted by the National Ground Water Association.