

Section 3

Physical Characteristics of the Site

This section provides an overview of the site environmental setting. Described in this section are the site's physical characteristics including demography and land use in the vicinity of the site, the associated climate, topography, surface water features, geology, hydrogeology, general ground water quality, and the ecological conditions. The information described herein is based on data collected during the RI (both mobilizations).

3.1 Topography

Las Cruces is situated in the central portion of Doña Ana County, New Mexico. Doña Ana County is located in the south central part of New Mexico, and on its south side borders Mexico and Texas. The site is located on the USGS 7.5 Minute Topographic Quadrangles "Las Cruces" and "Tortugas Mountain." **Figure 3-1** shows the Topographic Quadrangle Maps in the area of the site. The elevation at the site varies from a maximum of about 4,080 ft above MSL to 3,930 ft MSL (**USGS, 1955, and USGS, 1978**). The topography at the site slopes towards the Rio Grande, located west of the site.

The eastern area of the site (between north of East Hadley Avenue and south of East Griggs Avenue, just west of I-25) includes two topographically elevated areas with an arroyo valley extending east-west in between (see **Figure 3-1**). The arroyo once flowed east to west parallel to, and south of the present-day East Hadley Avenue. The topographically elevated areas on either side of this feature were aligned approximately along East Hadley Avenue and East Griggs Avenue. This arroyo no longer serves as a channel for surface water flow, having been intersected by the parks, streets, and storm-water retention basins.

Parts of a separate and larger arroyo (the Las Cruces Arroyo) are still present south of the GWP site (see **Figure 3-1**). The Las Cruces Arroyo trends east-to-west from I-25 to near East Lohman Avenue west of North Walnut Street, with some remnants of the original arroyo running just north and parallel to the Arroyo Plaza Shopping Center. The Las Cruces Flood Control Dam and I-25 intercept the original extent of Las Cruces Arroyo, reducing the flow in this arroyo to that drained from the area west of I-25 (these site features, the dam and I-25, are partially visible in **Figure 3-1**, in the left-most topographic map only).

3.2 Soil

Soil survey information for the GWP site was obtained via the Natural Resources Conservation Survey website at <http://websoilsurvey.nrcs.usda.gov>. Four primary soil types underlie the GWP site: Bluepoint loamy sand, Bluepoint-Caliza-Yturbide Complex, Canutio and Arizo gravelly sandy loams, and Pajarito fine sandy loam. Each soil type is greater than 60 inches in thickness.

The Bluepoint loamy sand is a primarily sandy soil characterized as excessively drained with very low runoff potential. Flooding and ponding of water are rare with this soil type.

The Bluepoint-Caliza-Yturbide Complex is composed of three sub-soil types. The Bluepoint soil is loamy sand characterized as excessively drained with very low runoff potential. Flooding is rare, and there is no potential for ponding of water with this soil type. The Caliza soil is a very gravelly sandy loam characterized as well drained with moderate potential for runoff. There is no potential for flooding or ponding of water with this soil type. The Yturbide soil is a gravelly sandy loam characterized as excessively drained with very low runoff potential. There is no potential for flooding or ponding of water with this soil type.

The Canutio soil is a very gravelly sandy loam characterized as well drained with very low runoff potential. Flooding is rare, and there is no potential for ponding of water with this soil type.

The Arizo soil is a very gravelly sandy loam characterized as excessively drained with negligible runoff potential. This soil type can occasionally flood, and there is no potential for ponding of water. The Pajarito soil is a fine sandy loam characterized as well drained with very low runoff potential. There is no potential for flooding or ponding of water with this soil type.

3.3 Climate

Las Cruces has an arid, continental climate, characterized by light and variable total precipitation, large diurnal and moderate annual temperature ranges, low relative humidity, and abundant sunshine (Malm, N. R., 2003). Climate data from *Climate Guide Las Cruces, 1892 – 2000* (Malm, N. R., 2003) are presented in **Table 3-1**. Additional meteorological data available for the El Paso, Texas, area from the National Oceanic and Atmospheric Administration (NOAA) were obtained via their website at <http://www4.ncdc.noaa.gov>. These data supplement the data from *Climate Guide Las Cruces, 1892 – 2000*, and are presented in **Table 3-1**. Precipitation, temperature, and wind are described in the following paragraphs.

3.3.1 Precipitation

The average annual precipitation in the Mesilla Valley ranges between 8.0 and 9.0 inches per year, with most precipitation in the form of rain. Most rain is limited to brief, sometimes intense thunderstorms, with more than half of the annual precipitation falling during the period July through September. Nearly three-fourths of the annual precipitation occurs in the warmest six months of the year (May through October) (**Malm, N. R., 2003**). Potential evaporation and transpiration greatly exceeds rainfall. Potential evaporation rates measured in an evaporation pan average about 97 inches per year. Potential evaporation and transpiration rates limit the amount of surface water available in the area. This also limits the amount of recharge the aquifer receives from rainfall (**King, et al., 1971**). The end of the rainy season occurs when a high-pressure center weakens in early fall, and winds shift back to the west. Occasionally, remnants of tropical storms or hurricanes can reach New Mexico and cause significant rainfall (**Malm, N. R., 2003**).

November through May is the dry season, with precipitation for each month averaging 0.5 inches or less. April is the driest month, averaging only 0.21 inches of rainfall. The mid-latitude storm track is generally to the north of Las Cruces during the winter, resulting in sunny and dry conditions. Precipitation that occurs in the winter results from Pacific storm systems that track farther south than normal. Snowfall averages only 3.2 inches per year. About one year in three receives no measurable snowfall (**Malm, N. R., 2003**).

3.3.2 Temperature

The climate in the Las Cruces area is classified as arid. In the Mesilla Valley, temperatures reach 90 degrees Fahrenheit (°F) or greater during an average of 101 days a year. In January, the coolest month, the average daily maximum temperature is 57.7 °F and the average daily minimum temperature is 26.1 °F. The mean annual temperature for Las Cruces is 60.5 °F. Monthly average temperatures vary from 41.9 °F in January to 79.8 °F in July. The average diurnal temperature range is 32.5 °F, which is typical of high elevation deserts. Temperatures of 100 °F or greater occur an average of nine days per year, mostly in June and July (**Malm, N. R., 2003**).

3.3.3 Wind

Winds usually are light, with an annual average speed of 6 miles per hour. Late winter and spring are the windiest periods, and moderately strong winds can cause blowing dust and sand during dry periods. Blowing dust also can occur briefly in advance of thunderstorms with strong gusty winds. Although the general movement of air over Las Cruces is from the southwest, southeast winds are more frequent in summer and fall (**Malm, N. R., 2003**).

3.4 Demography and Land Use

Population data for Las Cruces and Doña Ana County were obtained through the U.S. Census Bureau website at <http://www.census.gov>. The population of Las Cruces, as reported from the 2000 census, was 74,267. The population reported for Doña Ana County from the 2000 census was 174,682. The percent population change for Las Cruces from 1990 to 2000 was an increase of 19.5%, and the percent population change for Doña Ana County from 1990 to 2000 was an increase of 28.9%.

Current land use at and near the GWP site is characterized by a broad mix of commercial, public recreational, light industrial, and residential land uses. Just north of CLC Well No. 18 and extending west to North Solano Drive and east to past North Walnut Street, a large portion of the area is used for public parks. Residential neighborhoods are present west of North Solano Drive, east of North Walnut Street, north of East Hadley Avenue, and south of East Griggs Avenue. The rest of the area along East Hadley Avenue and East Griggs Avenue between North Solano Drive and just east of North Walnut Street is light industrial/commercial. Other commercial and light industrial properties can be found along the major roadways in the vicinity of the site, including East Lohman Avenue, North Solano Drive, and East Spruce Avenue (refer to [Figure 1-1](#) for the layout of the streets).

Past land use at the GWP site is described in detail in the IDRA Report (see [Attachment A](#)). Development in the area of the site has resulted in changes in land uses since the 1950s. This development has resulted in the reworking of soils and importation of fill materials in many areas of the site as development has progressed. Several past land use activities were determined to be relevant to the GWP site and represent potential sources of contamination at the site. These land uses are the historical operations at the Former National Guard Armory, historical operations at the former Crawford Municipal Airport, suspected historical uncontrolled dumping of waste materials west of North Walnut Street along the former arroyo area parallel to and south of the former airport runway (on the same property as the former Crawford Municipal Airport), and historical and/or current operations at the DACTD maintenance facility ([EPA, 2003a](#)).

3.5 Surface Water

Surface water is present in the vicinity of the site only during and immediately after rainfall because of low amounts of precipitation and rapid infiltration rates of area soils. Surface water flow at the site can be characterized as ephemeral. Most surface water flow resulting from rainfall is channeled along streets into the CLC's storm water sewer system. Several storm water retention basins are present throughout the vicinity of the site; these basins accumulate surface runoff during rain events. The arroyo that once flowed east to west parallel to the present-day East Hadley Avenue no longer

serves as a channel to surface water flow, having been intersected by the parks and streets and storm water retention basins. The Las Cruces Arroyo flows east-to-west from about I-25 to near East Lohman Avenue west of North Walnut Street. The Las Cruces Flood Control Dam and I-25 block the majority of stormwater flow from traveling into and along this arroyo into the central areas of Las Cruces.

3.6 Geology

The following paragraphs describe the regional and site-specific geology based on previously documented studies, observations made, and data collected at the site since the first field mobilization.

3.6.1 Regional Geology

Figure 3-2 is a generalized geologic and structural cross-section of the Mesilla Basin in the Las Cruces area. Las Cruces is located in the Mexican Highlands section of the Basin and Range physiographic province. In general, the physiography of the area consists of uplifted fault-block mountain ranges and intermontane basins. The intermontane basins are structurally depressed low areas that have been displaced downward with respect to the mountains. The mountain ranges and intermontane basins generally have a north-south trend. Other mountain types in the area include broad domal uplifts and erosional remnants of igneous intrusive bodies.

The major physiographic features in the Las Cruces area are the entrenched Rio Grande and two intermontane basins, the Jornada del Muerto and the Mesilla Bolson. Las Cruces is located in the Mesilla Valley (located within the Mesilla Bolson) east of the Rio Grande. The Jornada del Muerto is located north and east of Las Cruces. A subsurface high area in the bedrock, known as a horst, separates the two basins. This structural feature is noted as the bedrock high on **Figure 3-2 (King, et al., 1971)**. The horst is located approximately 1 mile east of the GWP site and was not encountered during drilling of any site monitor wells.

The regional geology is composed of the Quaternary flood plain alluvium and the Miocene to Middle Pleistocene Santa Fe Group. The flood plain alluvium was deposited by the Rio Grande. It generally consists of a thick basal sand and gravel channel unit overlain by finer-grained flood plain deposits. The flood plain alluvium is generally about 4 miles wide and 80 ft thick. The Santa Fe Group is a rock stratigraphic unit composed of sequences of unconsolidated to moderately consolidated sedimentary deposits of clay, silt, sand, gravel, some basalts, and minor ash-fall deposits. These deposits have partially filled the intermontane basins along the Rio Grande depression from the San

Luis Valley of Colorado to the lower El Paso Valley of Texas and Chihuahua, Mexico. The Santa Fe Group can be up to 4,000 ft thick (Frenzel, et al., 1990).

3.6.2 Site Geology

This section summarizes information on the site-specific geologic conditions. A site stratigraphic model was developed based on data obtained from drilling the 10 deep multi-port ground water monitor wells located throughout the area of affected ground water. The data used to prepare the site stratigraphic model include the soil boring logs and geophysical logs completed for each well (included in [Appendix D](#)).

The boreholes for these wells were drilled to depths comparable to the depths of PCE-affected CLC municipal supply wells. Monitor wells GWMW01, GWMW03, GWMW04, GWMW06, GWMW07, and GWMW08 were drilled to the estimated depth of CLC Well No. 18 (at about 3,460 ft MSL). GWMW09 was drilled to the estimated depth of CLC Well No. 27 (at about 3,325 ft MSL). Based on sample results obtained during drilling of GWMW09, GWMW10 was drilled to a depth of 660 ft bgs (about 3,400 ft MSL). GWMW11 and GWMW15 were drilled to the estimated depth of the plume, based on analytical data collected during the January 2004 sampling event (about 3,420 ft MSL).

The GWP site stratigraphy observed during the monitor well drilling is consistent with the regional stratigraphy documented in published literature for the Rio Grande Alluvium and the Santa Fe Group. Alternating beds of gravels, sands, silts, and clays occur across the vicinity of the site. Many beds can be correlated across most of the area. Hydro-geophysical cross-sections were prepared across the site based on both geologic and hydrogeologic observations from the geophysical logs and boring logs obtained during drilling. Visual descriptions of drill cuttings logged during well construction served to cross-check the geophysical data and confirm the lateral correlations presented on the cross-sections. [Figure 3-3](#) presents a geophysical type section using the geophysical logs obtained from monitor well GWMW01. The type section illustrates the various components presented on the cross-sections. The locations of these cross-sections in plan view are illustrated on [Figure 3-4](#), and the cross-sections themselves are provided in [Figures 3-5, 3-6, and 3-7](#). The CLC municipal supply wells are projected onto these cross-sections to show their screened interval depths relative to the site geology, site hydrogeology, and the screened intervals of the site monitor wells. The completion information for the CLC municipal supply wells is included in [Table 3-2](#).

These cross-sections include a natural gamma log and a 16-inch normal resistivity log. In general, a high resistivity response correlates to coarser grained sediments (sands and gravels). Care must be used when interpreting the natural gamma logs. Usually, a higher natural gamma response correlates

to a finer-grained material such as clay. However, the coarse-grained sediments observed during drilling, especially at deeper depths, contained a high percentage of metamorphic and igneous rock fragments. These materials contain higher amounts of radioactive materials, and this accounts for the higher than normal gamma responses observed on the logs where sands and gravels are interpreted. Consequently, more emphasis was placed upon the resistivity logs, in conjunction with visual descriptions to interpret correlations between strata.

The Rio Grande Alluvium is present across the western portion of the GWP site. Within the area of the site, this alluvium is composed of primarily sand and gravel deposits, with some interbedded clays and silts. The base of the unit consists of a thick sand and gravel deposit that is present at depths of between 80 and 120 ft bgs at approximate elevations between 3,860 and 3,880 ft MSL (all depths bgs are relative to an elevation of 4,100 ft MSL). During drilling, this unit was easily recognizable at wells GWMW03, GWMW04, GWMW06, and GWMW07. This unit appears to pinch out towards the eastern end of the GWP site (see [Figures 3-5](#) and [3-6](#)). The interpretation of the contact between the Rio Grande Alluvium and the Santa Fe Group is based on this observation and the regional interpretation illustrated in [Figure 3-2](#). Where present at the GWP site, the Rio Grande Alluvium is approximately 80 to 120 ft thick, and only the lower 10 to 15 ft is saturated. The water table occurs within the Rio Grande Alluvium beneath the western portion of the site.

The Santa Fe Group sediments are present at the GWP site beneath the Rio Grande Alluvium west of GWMW03 and at the surface east of GWMW03. Along the eastern portion of the GWP site, the upper part of the Santa Fe Group consists of mostly interbedded sand and gravel deposits. Thinner beds of finer grained deposits are also present (see [Figures 3-5](#), [3-6](#), and [3-7](#)). These surficial deposits are between 150 and 260 ft thick and are present down to an approximate depth of 3,850 ft MSL in elevation. This upper portion of the Santa Fe Group is unsaturated.

A thick layer composed of fine sand with varying percentages of silt and clay is present below the upper portion of the Santa Fe Group deposits and the base of the Rio Grande Alluvium. The thickness of this layer is between 50 and 115 ft, is continuous across the site, but thins towards the east (see [Figures 3-5](#) and [3-6](#)). The water table occurs within this unit beneath the eastern portion of the site. At its base, the unit becomes interbedded with silt and clay deposits. These interbedded clay and silt deposits are not present beneath the far eastern portion of the GWP site at monitor well GWMW15 (shown on [Figures 3-5](#) and [3-6](#)).

Below these layers, the Santa Fe Group is composed primarily of fine to coarse sand units ranging in thickness from 10 to 130 ft. These units are commonly separated with thin, interbedded finer grained

units. These finer-grained beds are more numerous in the western portion of the GWP site, with the beds pinching out towards the east. Some gravel beds are present at lower depths. The base of the Santa Fe Group was not encountered in any of the boreholes drilled at the GWP site, down to an elevation of 3,325 ft MSL.

3.7 Hydrogeology

The following paragraphs describe the regional and site-specific hydrogeology. These descriptions are based on previously documented studies and data collected during the RI. Ground water use in the area is also discussed with the regional hydrogeology. For purposes of this report, emphasis is upon the units occurring near or below the water table (80 to 740 ft bgs) in the following sections because these units are the most impacted by PCE releases, pumpage, and transport of contamination. A brief description of the unsaturated zone is also provided in [Section 3.7.2.1](#).

3.7.1 Regional Hydrogeology

The regional hydrogeology is primarily controlled by the structural geology described in [Section 3.6.1](#). The major ground water basins in the Las Cruces area are the Mesilla Ground Water Basin and the Jornada del Muerto Ground Water Basin. Las Cruces is located within the Mesilla Ground Water Basin, and the Jornada del Muerto Basin is located farther to the north and east. The two basins are separated by a subsurface high in the less permeable bedrock (see [Figure 3-2](#)) ([King, et al., 1971](#)). The Mesilla Ground Water Basin is located primarily within Doña Ana County, but it also extends southward into El Paso County, Texas, and the State of Chihuahua, Mexico ([Frenzel, 1992](#)).

The Rio Grande flood plain alluvium and the Santa Fe Group are the two major ground water reservoirs in the area. In the Mesilla Ground Water Basin, the two units form a complex aquifer system. Regionally, recharge to ground water is primarily from the Rio Grande and inter-connected irrigation canals along the Rio Grande into the flood plain alluvium. Minor amounts of recharge also occurs as mountain and slope-front recharge. Mountain-front recharge occurs along the western slopes of the Organ and Franklin Mountains. Slope-front recharge occurs from surface water that has accumulated in arroyos during precipitation events.

Water migrates downward through the shallow alluvium to the upper Santa Fe Group through a series of interconnected gravel, sand, and silt lenses. Vertical flow within the system is limited by thin, interbedded clay lenses in the lower part of the flood plain alluvium and the upper portion of the Santa Fe Group. This vertical heterogeneity indicates that the permeability is greater horizontally than vertically.

Ground water occurs under unconfined conditions within the flood plain alluvium and under unconfined to semi-confined conditions within the Santa Fe Group. Ground water flow within the Mesilla Ground Water Basin is generally to the southeast (**King, et al., 1971**). **Figure 3-8** illustrates the regional potentiometric surface for the Mesilla Ground Water Basin, showing elevations of the potentiometric surface in ft MSL.

Ground water is removed from the aquifer by pumping wells and as discharge along irrigation canals when ground water levels are sufficiently high. Minor amounts of ground water leave the basin through the El Paso Narrows, at the southern end of the basin. The primary use of ground and surface water within the Mesilla Basin is for irrigation. Communities within the basin rely on ground water as the source for municipal and industrial water supplies. During non-drought years, most irrigation water is diverted from the Rio Grande. During years of drought, ground water is used to make up for the shortfall in surface water supplies for irrigation. Prior to about 1975, most irrigation wells were completed within the Rio Grande Alluvium, but after 1975, wells were drilled deeper into the Santa Fe Group to acquire better quality water (**Frenzel, 1992**).

The Mesilla Ground Water Basin aquifer has excellent recharge, transmission, and storage capacity. These characteristics make the aquifer system capable of producing large quantities of high quality water for agricultural, municipal, and industrial uses. Ground water is currently the only source of drinking water for the City of Las Cruces. The City obtains water from both the Mesilla and Jornada Ground Water Basins.

The CLC Municipal Water System is a blended system supplying water from 30 wells. The site location map (**Figure 1-1**) presents the CLC wells within and near the GWP site. CLC's municipal wells are completed within sand and gravel layers in the Santa Fe Group. Most wells are located on the east side of the Rio Grande, but there are also wells located west of the Rio Grande on the West Mesa. No single well supplies more than 40% of the total water within the system, and the system produces approximately 19 million gallons per day on average (**EPA, 2000b**, and **CLC, 2002**). **Appendix I** provides the capacity (in gallons per minute [gpm]) of each water supply well in the vicinity of the GWP site, the actual monthly production volume (in millions of gallons) from January 2000 through December 2005, and the city-wide average production rates. There are few private wells in the area of the GWP site and they are used primarily for residential irrigation purposes.

3.7.2 Site Hydrogeology

At the GWP site, the unsaturated zone is underlain by an aquifer composed of unconsolidated sediments. The aquifer can be subdivided into two general hydrologic zones (see **Figures 3-5, 3-6,**

and 3-7). Both zones are fully saturated and can be correlated across the area of the site. The boundaries between the zones were established from observed water levels and geophysical changes observed with depth. Water levels were obtained from the multi-port and nested monitor wells screened across each zone.

Each zone is identified on the cross-sections included as Figures 3-5, 3-6, and 3-7. The cross-sections include the well screen intervals (port depth for multi-port wells) and water level data collected for each monitor well in December 2005 (all water level data collected since July 2002 are included in Appendix H). Lateral correlation of the site stratigraphy helped further refine the boundaries between the hydrologic zones. As shown on the cross-sections, there are two distinct hydrologic zones, the UHZ and the LHZ, that are differentiated primarily on water level elevations measured in various multi-port and nested monitor wells screened at different depths. The UHZ and LHZ are hydraulically connected across the site, but the degree of hydraulic communication is greater in eastern areas of the site. The water levels in the upper-most screened intervals of multi-port and nested monitor wells in the UHZ are typically 4.5 to 12.5 ft higher than the water levels in wells screened in the LHZ. At the site, the saturated zone extends from the water table, which occurs at elevations between 3,860 and 3,825 ft MSL, down to below an elevation of approximately 3,325 ft MSL, which was the deepest depth drilled. The lower boundary of the aquifer at the GWP site is most likely igneous bedrock, which occurs at a depth not attained during drilling of any of the site monitor wells (see Figure 3-2 for the regional interpretation of bedrock occurrence).

A brief description of the unsaturated and hydrologic zones is provided below (all bgs depths are relative to an approximate surface elevation of 4,100 ft MSL).

3.7.2.1 Unsaturated Zone

The unsaturated zone (also known as the vadose zone) overlying the aquifer at the site is the soil and sediment that extends from the ground surface to the water table, which occurs at elevations between 3,860 and 3,835 ft MSL. Its thickness ranges from about 80 ft in the western part of the site to over 200 ft in the east (Figures 3-5, 3-6, and 3-7). This zone is typically a permeable layer of sediments through which water infiltrates to the aquifer. Air and other vapors can migrate in horizontal and vertical directions in the unsaturated zone through physical processes such as diffusion. Figures 3-5, 3-6, and 3-7 indicate porous material within the unsaturated zone at the site. The lithology of the unsaturated zone varies from fine sand with silt and clay to coarse sand and gravel. Sediments exposed at land surface and in the shallow subsurface are mostly fine to coarse sand. Small lenses of clay and silt exist, but are predominantly present at depth in the eastern portion of the site.

3.7.2.2 Upper Hydrologic Zone (UHZ)

The UHZ is composed of the lower portions of the Rio Grande Alluvium and the upper portion of the Santa Fe Group (**Figures 3-5, 3-6, and 3-7**). It represents the uppermost portion of the aquifer and is over 100 ft thick along the western portion of the GWP site. Representative thicknesses of the UHZ in the eastern part of the site range from 20 ft at GWMW09 to 50 ft at GWMW15. The UHZ extends from the water table down to an elevation of 3,810 ft MSL at GWMW09 (where the UHZ is thinnest) and to an elevation of 3,750 ft MSL at GWMW07 (where the UHZ is thickest). In general, this zone is wedge shaped. The zone is thicker in the western portions of the GWP site, but becomes thinner towards the east. Ground water in this zone occurs under unconfined or water-table conditions.

Along the western portion of the GWP site, the upper portion of this zone is composed of a gravel and coarse sand layer that marks the base of the Rio Grande Alluvium (**Figures 3-5, 3-6, and 3-7**). Below this layer, and along the eastern portions of the GWP site, this zone is composed of fine sand that contains varying percentages of silt and clay. During drilling, this zone was often classified as a clay unit with a lower percentage of sand and silt. However, fine sand and silt were difficult to observe in the drill cuttings because of the mud rotary drilling method utilized during monitor well construction. This drilling method was necessary in order to achieve the depths attained during installation of the boreholes. As a result, there could be portions of this zone that contain less silt and clay than fine sand when compared with estimates determined during the lithologic logging process. Overall, sediments in this zone are finer grained than sediments in the LHZ.

Because of the differences in grain sizes (and the resultant effects on permeability), the hydraulic conductivity of this zone is less than the hydraulic conductivity of the LHZ. The lower portion of the UHZ is not as clearly distinguished from the LHZ in the easternmost portion of the site, where the finer grained materials separating the UHZ from the LHZ are thinner or not present. In addition, the water level differences between the UHZ and LHZ are less pronounced (such as at monitor well GWMW10, see **Figures 3-5, 3-6, and 3-7**) indicating greater hydraulic communication between the LHZ and the UHZ to the east.

3.7.2.3 Lower Hydrologic Zone (LHZ)

Most of the LHZ is composed of fine to coarse sand with some fine gravel. The boundary between LHZ and the UHZ is marked by interfingering layers of fine sand with clay and silt, clay, and silt that are present across most of the site (**Figures 3-5, 3-6, and 3-7**). These finer grained sediment layers appear to pinch out east of monitor wells GWMW09 and GWMW10. The LHZ is divided into upper and lower portions based primarily on contaminant concentration differences between ports 3 & 4 at

wells GWMW01 and GWMW10 (discussed in [Section 4.2.2.3](#)) and lithologic differences that occur in areas of the Site west of monitor wells GWMW09 and GWMW10. Some subtle hydrologic differences also occur between the units, particularly with respect to ground water flow direction, described later in this section. Fine-grained layers represent the upper portion of the LHZ. For the purposes of this report, the upper portion of the LHZ is considered the portion of the aquifer from an elevation of 3,675 ft MSL up to the base of the UHZ, which occurs between elevations of 3,750 ft MSL and 3,810 ft MSL. The lower part of the upper portion of the LHZ contains sediments composed of fine to coarse sand. The lower portion of the LHZ is considered the portion of the aquifer below an elevation of 3,675 ft MSL. Interfingered within the zone are thin layers (10 to 20 ft) of fine sand, silt, and clay. These fine-grained lenticular beds are more prevalent in the western portion of the site. Layers containing coarse sand and gravel were noted in the deeper intervals logged during monitor well construction.

While the total thickness of the LHZ is unknown, it does extend from the base of the UHZ to at least 800 ft bgs at an elevation of 3,300 ft MSL. The bottom of the LHZ was not encountered in any of the boreholes drilled at the GWP site. This zone is the primary ground water production interval for the CLC municipal supply wells in the study area. The screened intervals of CLC municipal supply wells are shown on [Figures 3-5, 3-6, and 3-7](#).

The entire LHZ is fully saturated. As discussed further in [Section 3.7.2.5](#), water level responses to peak periods of pumping and water level trends within the upper and lower portions of the LHZ are similar. Qualitative assessment of lithologic descriptions and geophysical data indicate that the horizontal hydraulic conductivity is significantly greater than the vertical hydraulic conductivity as a result of the interbedded nature of this zone, especially in the western portion of the site. Pumping data from the City's wells, compared with water level responses in monitor wells, indicates a hydraulic connection between the UHZ and LHZ.

3.7.2.4 Comparison of the Site Hydrogeology to the JSP Site Model

The ground water model developed by the JSP further refines the site hydrogeologic model. The JSP model divides the site hydrogeology into five model layers. The five model layers are based on the hydrostratigraphic units and lithofacies assemblages presented by Hawley and Kennedy (**Hawley and Kennedy, 2004**). The ground water modeling report further details how the JSP model and hydrogeologic framework were determined and explains each model layer (**JSAI, 2006a**).

[Table 3-3](#) provides a cross-reference of the UHZ, upper portion of the LHZ, and lower portion of the LHZ to the JSP's ground water model layers and the hydrostratigraphic units and lithofacies

assemblages from Hawley and Kennedy. The UHZ is equivalent to the ground water model layer 1. The upper portion of the LHZ is equivalent to the ground water model layer 2 and the uppermost portion of the ground water model layer 3. The lower portion of the LHZ is equivalent to the majority of the ground water model layer 3 and layers 4 and 5.

3.7.2.5 Horizontal and Vertical Ground Water Flow

Ground water levels have been monitored at the GWP site since the first mobilization (July 2002). These data were used to evaluate temporal water level trends at the GWP site. A round of water level measurements was collected in December 2005 during the second field mobilization to provide data for potentiometric mapping of both the UHZ and LHZ. Water level data were also used to assess potentiometric head differences between zones. All water level measurements collected since July 2002 are included in [Appendix H](#).

Water level data were evaluated for analysis of both temporal and spatial water level trends at the GWP site, beginning in July 2002. During most water level monitoring events, water levels were collected from the multi-port monitor wells only. Water levels were collected from all site monitor wells prior to site wide ground water sampling events conducted in December 2002, January 2004, and December 2005. [Figures 3-9](#) through [3-11](#) present the temporal water level trends and a comparison of the trends to monthly production volumes in CLC municipal supply wells for selected site monitor wells. Figures showing the temporal water level trends for all site monitor wells are included in [Appendix H](#). These figures also include the monthly production volumes from several CLC municipal supply wells located near the site using the production data included in [Appendix I](#). CLC Well Nos. 10, 19, 20, and 21 were selected based on their close proximity to the site. In addition, monthly production trends at CLC Wells Nos. 10, 20, and 21 are similar to the trends of the municipal water supply system as a whole. CLC Well No. 19 was included because this well was part of the water distribution system until a mechanical failure occurred in July 2005. CLC Well Nos. 18 and 27 are not included on these figures because they were not pumping most months during the period covered by these data (2002 through 2005).

3.7.2.5.1 Upper Hydrologic Zone Water Level Trends

Water level elevations in the UHZ ranged from approximately 3,862 to 3,835 ft MSL, during the period July 2002 to December 2005. During this period, water levels in most wells within the UHZ generally fluctuated between 1.1 and 3.4 ft. However, fluctuations in monitor wells MW-SF10, GWMW08, and GWMW10 (4.5 ft, 6.8 ft, and 7.3 ft, respectively) exceeded this fluctuation range over the 39-month period (see [Appendix H](#) for the water level data).

Over the entire water level monitoring period, the water level trends in the UHZ wells tended to vary depending on each well's location. As shown in **Figure 3-9**, wells in the western portion of the site show a decreasing trend. Wells in the central and eastern portion of the site, generally closest to the City's production wells, demonstrated increasing water level trends over the period of record. At the same time however, subtle water level declines in central and eastern wells are noted to coincide with periods of peak production in the CLC wells, generally beginning in April of each year. **Figure 3-9** shows that greater ground water production from the municipal supply wells occurs primarily in the months of April through September. Water level trends in the multi-port wells, which were monitored more frequently than the water table monitor wells, were used to evaluate the relation between pumping and water level responses at the site. Water levels in the UHZ in the area extending from the DACTD maintenance facility towards the east do show a slight response to pumping. This is demonstrated by slight decreases in water levels at monitor wells GWMW01 (port 01), GWMW08 (port 01), and GWMW10 (port 01) in response to increased production at CLC Well Nos. 10, 20, and 21 (see **Figure 3-9**). Although somewhat affected by local pumping, water level trends for the central and eastern parts of the site indicate increasing trends over the period of record (**Figure 3-9**). Water levels in the UHZ west of the DACTD maintenance facility do not show a response to pumping, as demonstrated by the water level trends at monitor wells GWMW03, GWMW04, GWMW06, and GWMW07 (port 1 in each well, see **Figure 3-9**). The water level trends west of the DACTD maintenance facility over the period of record were decreasing.

3.7.2.5.2 Lower Hydrologic Zone Water Level Trends

The influence from the CLC well field production is more evident in the water level data for the LHZ. **Figure 3-10** presents water levels from port 3 of several multi-port monitor wells. These ports reflect potentiometric conditions in the upper portion of the LHZ. As the figure shows, water levels across the GWP site, during the period from October 2002 to December 2002, decreased during periods of peak ground water production from the municipal wells (**Figure 3-10**). The trends of representative wells in **Figure 3-10** are the same as those in the UHZ (**Figure 3-9**). Wells in the western portion of the site exhibit decreasing historical trends compared with increasing trends in the central and eastern areas of the site.

Figure 3-11 presents similar data, only from deeper ports within the same multi-port monitor wells. As such, these wells reflect potentiometric conditions within the lower portion of the LHZ. The responses seen in the monitor wells are very similar to those presented in **Figure 3-10**. These trends demonstrate that water levels throughout all levels of the LHZ are directly influenced by pumping at the CLC municipal supply wells. The water levels decline in the LHZ as the amount of pumping

increases during the summer months. Although the water levels fluctuated seasonally over the course of the monitored period, water levels in wells located in the LHZ in the central and eastern portions of the site exhibited increasing trends during the period October 2002 through December 2005.

3.7.2.5.3 Vertical Potentiometric Head Differences

To evaluate the potentiometric head differences in the aquifer, average vertical gradients between the UHZ and LHZ were calculated using the December 2005 water level data. **Table 3-4** summarizes the average vertical gradients at each monitor well. As shown, a downward vertical gradient range of 0.02 to 0.06 (ft per foot) exists between the UHZ and LHZ at all locations. The lower vertical gradient observed at well GWMW10 may be the result of the well's proximity to CLC Well No. 21. It is likely that horizontal flow to CLC Well 21 lowers the vertical gradients in this area. The lower gradient could also be affected by greater hydraulic communication between the UHZ and LHZ near well GWMW10. The cross-section A-A' (**Figure 3-5**) shows that a single low permeability layer separates the UHZ and LHZ at this location.

Vertical potentiometric head differences are less pronounced within the LHZ. As shown on the cross-sections in **Figures 3-5, 3-6, and 3-7**, the water levels in multi-port wells screened within the LHZ are similar between the upper and lower portions. Therefore, vertical gradients were not calculated between the upper and lower portions of the LHZ.

3.7.2.5.4 Horizontal Ground Water Flow

Water level data from December 2005 were used to create potentiometric surface contour maps. The potentiometric surface for the UHZ (which also represents the water table) is presented in **Figure 3-12**. **Figures 3-13 and 3-14** present potentiometric surfaces for upper and lower portions of the LHZ, respectively. The potentiometric surface for the upper and lower portions of the LHZ are plotted to show that the horizontal ground water flow direction throughout the entire thickness of the LHZ, although slightly different between the upper and lower portions, is towards the areas of pumping.

Ground water flow in the UHZ is towards the east-southeast in the western portion of the GWP site. The ground water flow becomes more eastward near monitor wells GWMW03 and MW-SF6 (**Figure 3-12**). This easterly flow direction is consistent across the eastern portion of the GWP site, flowing towards the CLC's municipal supply wells in the area of I-25. The easterly flow direction is also consistent with previous flow directions observed at the site since December 2002 (**EPA, 2003a**, and **CH2M HILL, 2004**). The ground water flow direction indicates that the UHZ is affected by pumping at the CLC municipal supply wells, especially in areas east of monitor well GWMW03. This observation is consistent with the observations made when comparing the water level trends in

this zone with the monthly production rates at the CLC municipal supply wells (**Figure 3-9**). As stated in **Section 3.7.1**, the regional ground water flow is to the southeast.

Two separate potentiometric surface maps are provided for the LHZ. **Figure 3-13** shows the potentiometric surface for the upper portion of the LHZ, and **Figure 3-14** presents the potentiometric surface for the lower portion of the LHZ. Ground water flow in the upper portion of the LHZ (**Figure 3-13**) is towards the northeast across the entire GWP site. **Figure 3-14** shows that in the lower portion of the LHZ, ground water flows to the east in the western portion of the site, but changes direction near the DACTD maintenance facility. Near the DACTD maintenance facility, the ground water flow direction shifts to the northeast.

The ground water model indicates that ground water flow at the site is towards the south-southeast and southeast within the LHZ (model layers 2 through 5). The ground water model report states that a lack of water level data exists north and east of CLC Well 21 and east of I-25 result in a lack of the current monitor well network to delineate fully the cone-of-depression created by pumping at the CLC Wells. The current monitor well network is limited to a narrow west-to-east area from monitor wells GWMW07 and GWMW06 east to GWMW15. Extension of the monitor well network both north and south of the site in the area east of Solano Drive might indicate a more southeasterly direction of ground water flow.

The CLC supply wells are screened across most of the LHZ. The flow patterns indicate that ground water flow in the LHZ at the GWP site is affected by pumping at the CLC municipal supply wells. This observation is also consistent with the water level trends previously discussed above and presented on **Figures 3-10** and **3-11**.

3.8 Ground Water Quality

Provided below is a summary of general water quality conditions as determined from field parameters measured during the first field mobilization in December 2002, the January 2004 sampling event, and the second field mobilization in December 2005. Limited water quality samples were collected from monitor wells during the second field mobilization in December 2005, and this data is also summarized below. Finally, limited metals samples collected from monitor wells during January 2004 and samples collected by the CLC for uranium concentrations in ground water are also discussed.

3.8.1 Field Instrument Parameters

General water quality parameters were collected using field instruments during the first field mobilization (December 2002), the January 2004 sampling event, and the second field mobilization (December 2005). The parameters were collected during the first field mobilization and the January 2004 sampling event from the multi-port monitor wells only. The parameters were collected from the multi-port monitor wells, nested monitor wells, and selected water table monitor wells during the second field mobilization. General water quality parameters that were measured included pH, temperature, oxidation/reduction potential (ORP – also known as redox potential), conductivity, and DO. In addition, DO field test kits were also used to obtain data during the first and second field mobilizations. The parameters measured from field instruments and the test kit results are included in [Appendix E](#).

During the first field mobilization, the pH measurements ranged from 5.9 to 11.8 (standard units) for all measurements. Measurements above a pH of 8.0 were recorded for most well ports at the multi-port wells. During the January 2004 sampling event, the pH measurements ranged from 5.8 to 12.8 for all measurements, and measurements above a pH of 8.0 were recorded for all the well ports at the multi-port wells. The pH measurements collected during the second mobilization ranged from 5.7 to 11.8 for all measurements. Measurements above a pH of 8.0 were recorded for the well ports at most multi-port monitor wells. The elevated pH measurements observed in these wells are most likely artifacts from the grout used during well construction. The annular space at each multi-port monitor well was grouted from total depth up to ground surface (see [Appendix B](#) for a description of the well construction procedures for these wells). The pH measurements collected during the second mobilization during the low-flow purge sampling of the water table and nested monitor wells ranged from 6 to 7. This pH range is within the normal range of circum-neutral pH encountered in most aquifers, and these pH measurements are probably representative of the actual pH of ground water in the aquifer.

The data validation reports provided from the CLP for all the VOC analytical data did qualify results due to the pH in the samples exceeding the acid preservation requirements. However, the ground water samples were not preserved at the time of sample collection because of concerns that the hydrochloric acid would react with carbonate in the ground water, causing the samples to effervesce (bubble), and resulting in the loss of VOCs. The data validation process appropriately qualified the VOC results, and the data were deemed useable for their intended purpose for the RI/FS.

For the first field mobilization in December 2002, the average temperature measured for all the multi-port wells was 20.1 °C. The average temperature measured for all the multi-port wells during January 2004 was 18.4 °C. For the second field mobilization in December 2005, the average temperature measured for all multi-port wells was 18.6 degrees °C. The average temperature in December 2005 for the water table and nested monitor wells was 16.9 °C.

The conductivity measurements recorded prior to sample collection during December 2002 ranged from 759 microsiemens per centimeter ($\mu\text{S}/\text{cm}$) to 2,790 $\mu\text{S}/\text{cm}$ at GMMW06 port 4 and GMMW01 port 2, respectively. At most wells, conductivities were less than 2,000 $\mu\text{S}/\text{cm}$. The conductivity measurements recorded prior to sample collection during January 2004 ranged from 656 $\mu\text{S}/\text{cm}$ to 4,680 $\mu\text{S}/\text{cm}$ at GMMW08 port 5 and GMMW03 port 4, respectively. At most wells, conductivities were less than 2,000 $\mu\text{S}/\text{cm}$. The conductivity measurements recorded prior to sample collection during December 2005 ranged from 510 $\mu\text{S}/\text{cm}$ to 4,230 $\mu\text{S}/\text{cm}$, at GMMW15-D and GMMW04 Port 5, respectively. At most wells, conductivities were less than 2,000 $\mu\text{S}/\text{cm}$.

ORP measurements were generally negative values at the time of sample collection at the multi-port wells during each sampling event. These low ORP measurements are possibly artifacts of the well installations. Also, field ORP measurements are often an unreliable indicator of an aquifer's true redox condition. The reasons for this include the fact that many oxidation/reduction pairs do not react with the platinum electrodes used to measure ORP and many natural ground water systems are not in chemical equilibrium. For these reasons, ORP data are evaluated in a qualitative manner instead of a quantitative manner. During December 2002, the ORP measurements in ground water ranged from -388 millivolts (mV) and -128 mV. The January 2004 ORP measurements in ground water ranged from -332 mV and -102 mV. During December 2005, the ORP measurements in ground water ranged from -352 mV to 230 mV. In general, of the 63 wells for which ORP was measured, only 9 wells exhibited an ORP greater than 50 mV. Of these 9 wells, eight were screened in the UHZ.

At the multi-port wells, DO measurements collected from field instruments are generally not representative of the actual DO concentrations in ground water because of the purging procedures used. A flow through cell cannot be used. Water was collected into a cup for general water quality data using the field instrument. This leads to direct contact of the water with the atmosphere and results in inaccurate DO measurements.

DO field test kits were used during December 2002 at all multi-well ports and during the December 2005 sampling event at locations where Monitored Natural Attenuation (MNA) data were also collected to obtain more accurate data for DO concentrations. In addition, DO data were collected

using a flow through cell and field instrument during low-flow purging during December 2005. For the field test kits, a small aliquot of the ground water was taken after sample collection at each well. A colorimetric test was then performed to obtain DO concentrations. In December 2002, DO concentrations ranged from 0 milligrams per liter (mg/L) at several multi-port wells to 7.3 mg/L at GWMW04 port 4. In December 2005, DO concentrations ranged from 1 mg/L at several multi-port wells to 5.75 mg/L at water table well MW-5.

3.8.2 Ground Water Quality Analyses

Ground water samples were collected in December 2005 for analysis of general water chemistry, and the analyses included alkalinity (carbonate, bicarbonate, and total as Calcium Bicarbonate [CaCO_3]), calcium, magnesium, chloride, hardness, nitrate/nitrite, sulfate, sulfide, TDS, and TOC. Four samples were collected from well screens or ports completed within the UHZ at monitor wells GWMW01 port 01, GWMW03 port 01, GWMW04 port 01, and MW-SF1. The remaining seven samples were collected from wells GWMW01 port 06, GWMW03 port 05, GWMW04 port 05, GWMW09 port 04, GWMW10 port 02, GWMW15-S, and GWMW15-D completed in the LHZ. **Table 3-5** presents the results from the 11 samples.

With the exception of alkalinity (as CaCO_3) and TOC, the concentrations of analytes were noticeably higher in samples collected from the UHZ. This is particularly evident in multi-port wells GWMW01, GWMW03, GWMW04, and nested well GWMW15, where samples were collected from different depths at the same location. Sulfide was not detected in any of the samples.

3.8.3 Metals and Uranium

Samples were collected at the multi-port monitor wells during January 2004 for analysis of TAL metals (**Table 3-6**). The samples were collected for the analysis of total (unfiltered) metals. The table also shows the frequency of detection for each compound. Inorganics that were detected included aluminum, antimony, arsenic, barium, cadmium, calcium, chromium, cobalt, copper, iron, lead, magnesium, manganese, mercury, nickel, potassium, selenium, sodium, thallium, vanadium, and zinc. Of these inorganics, aluminum, antimony, arsenic, barium, calcium, chromium, cobalt, copper, iron, lead, magnesium, manganese, nickel, potassium, sodium, vanadium, and zinc were detected in more than five percent of the samples.

The NMED collected samples for metals analysis during the Site Inspection activities in 2000. With the exception of arsenic, their analytical results were similar to those obtained for metals in January 2004 from the multi-port wells (**CH2M HILL, 2004**).