3.5 Groundwater Resources and Geochemistry

The proposed Hollister Underground Mine Project is described in detail in Section 2.4, Proposed Action. The underground workings would extend approximately 2,000 feet below ground surface (bgs) to a final bottom elevation of 4,570 feet above mean sea level (amsl). As discussed in Section 2.4.3.4, Water Management, groundwater would be removed from the underground workings at an approximate maximum rate of 1,100 gallons per minute (gpm) on a continuous basis for the 20-year mine life. As discussed in Section 2.4.4, Waste Rock Management, waste rock would be disposed of in the existing Rodeo Creek Gold Inc (RCG) waste rock storage facility (WRSF), a new WRSF located in the West Pit, and in underground mined-out areas as backfill. At the conclusion of mining, groundwater removal would cease, and the underground facilities would be allowed to flood over time.

The proposed Hollister underground mining would be in the Vinini Formation and would not involve either the overlying Tertiary volcanic rock (volcanic rock) or the underlying Rodeo Creek unit.

The direct and indirect effects study area and cumulative effects study area (CESA) for groundwater resources are illustrated in **Figure 3.5-1** and include the projected area of the maximum extent of the 10-foot groundwater drawdown contour in the Vinini Formation. The CESA was selected based on the prediction that direct and indirect impacts from groundwater withdrawal from the proposed project would be confined to the maximum extent of the 10-foot groundwater drawdown contour in the Vinini Formation. Other mines on the Carlin Trend are dewatering the carbonate formations and have little effect on water in the Vinini Formation. The other mines in the Carlin Trend (Newmont and Barrick operations) dewater their mining operations by installing wells to constantly pump the groundwater in order to create a cone of depression (area void of groundwater) around the mining operation. The groundwater is pumped and disposed of in various methods to keep the area around the mining operation dry.

At the proposed Hollister Underground Mine the groundwater flows, seeps, or gravity drains into the underground workings. Grouting is utilized to slow or eliminate some of the groundwater seepage into the underground workings. The groundwater that seeps into the underground workings is collected in sumps or pond-like areas and is then pumped to the surface, which is called geotechnical water removal. This water is then disposed of via the pipeline to the rapid infiltration basins (RIBs) or also would be disposed of by the proposed discharge into Little Antelope Creek.

Cumulatively, there would be no overlap with groundwater pumping in the Vinini Formation at Hollister and dewatering at other mines. Past, present, and reasonably foreseeable future actions are summarized in Section 3.2.

3.5.1 Affected Environment

The existing Hollister underground operations are described in detail in Section 2.2. The existing underground exploration workings begin at the existing portal at an elevation of 5,500 feet amsl and extend to a bottom elevation of 5,060 feet amsl.

As discussed in Section 2.2.5, Waste Rock Management, waste rock removed during bulk sampling is transported and placed in the existing RCG WRSF. Material used as backfill may be stored temporarily in the underground workings. The existing West Pit has been partially backfilled. It contains water on a seasonal basis with depths up to 4 feet; this seasonal pit water can be acidic (Brown and Caldwell 2003). The existing Newmont-reclaimed WRSFs contain potentially acid generating (PAG) waste rock; acidic effluent occasionally seeps from the Newmont-reclaimed WRSF during periods of heavy precipitation or snowmelt.

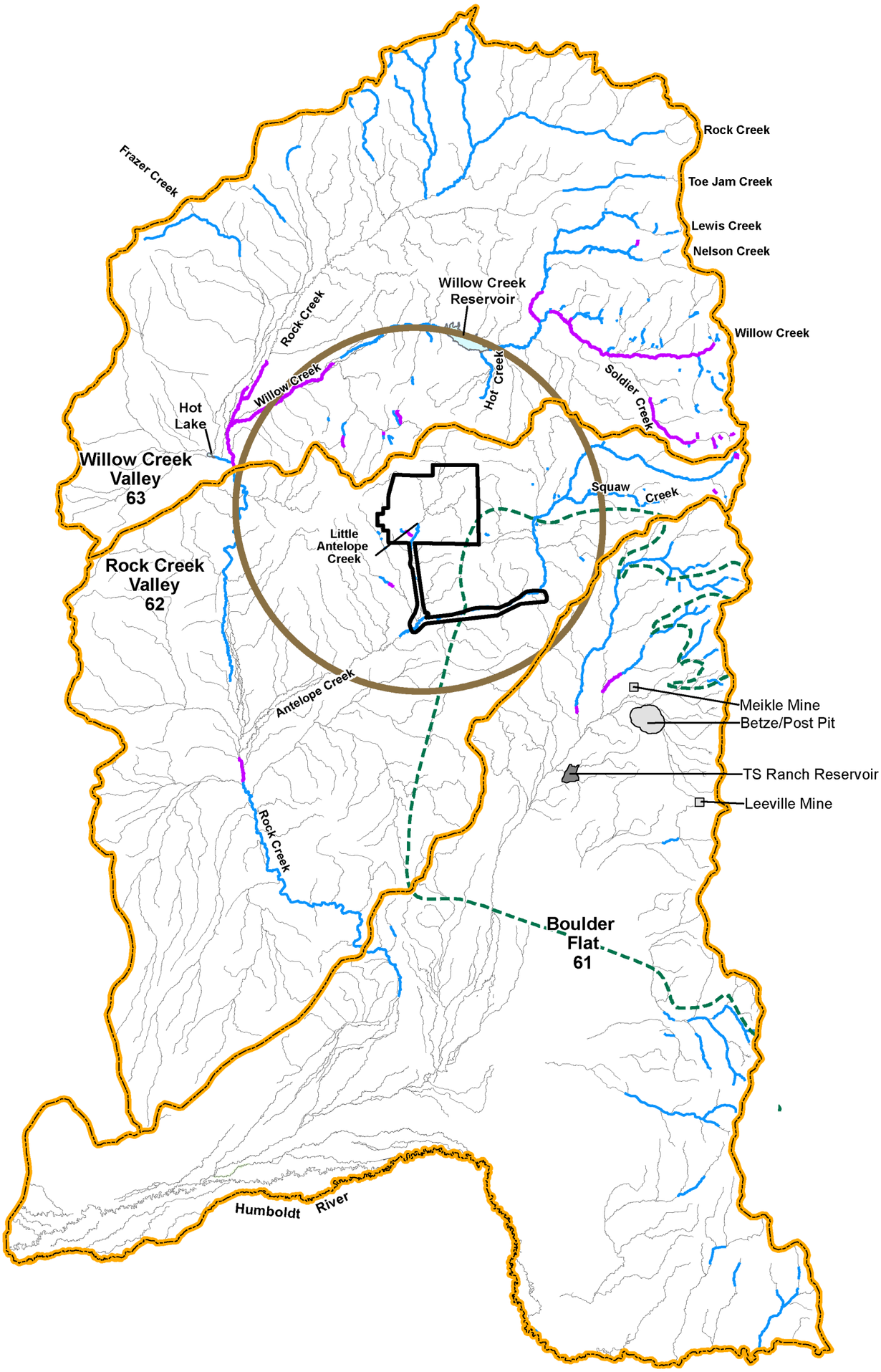
As described in Section 2.2.6, Water Management, RCG grouts water-bearing fractures to reduce water inflow to the underground workings. Water currently is removed from the underground workings at an approximate rate of 400 gpm with a maximum capacity of 700 gpm. Groundwater is pumped to the surface, where it is gravity fed in a pipeline to the existing East Pit water treatment facilities. RCG uses 100 to 150 gpm of the discharge water in operations. Following treatment, excess water is discharged to the existing RIBs.

3.5.1.1 Geologic Setting

The Hollister project area is located within the Carlin Trend mineralized zone of northeastern Nevada, as shown in **Figure 3.2-1**. The geology of the project area is described in Section 3.4, Geology and Minerals, and is shown in **Figure 3.4-1**. The geology of the greater project vicinity is shown in **Figure 3.5-2**. This figure is a composite of several geology maps with varying levels of geologic detail. A cross-sectional view of the geology is shown in **Figure 3.4-4**.

As discussed in Section 3.4 (Geology and Minerals) the geology within the project area comprises Tertiary igneous rocks overlying the Paleozoic Vinini Formation. The volcanic rocks consist of tuffs, tuffaceous sedimentary rocks, andesite, and rhyolite. These rocks cover most of the surface of the study area and form a layer over the Ordovician Vinini Formation that is up to 600 to 700 feet thick (Oelofse et al. 2009). Outside of the Hollister Site, other Paleozoic units, such as the Pennsylvanian/Permian Strathearn Formation, overly the Vinini Formation and are in turn overlain by volcanics. In the Hollister operations area, the volcanic rocks are thinner, approximately 200 to 300 feet thick, and the top of the unconformity between the Vinini Formation and the overlying volcanic rock is exposed in the mine pit (**Figure 3.4-4**). As a result of extensive hot spring activity and hydrothermal alteration, the volcanic rock in the project mine area and the area to the east and southeast has been altered extensively to clay and silica (Brown and Caldwell 2011a), which inhibits the vertical flow of groundwater in the volcanic rock. Horizontal groundwater flow in the volcanic rock primarily is controlled by fractures, faults, and locally by more permeable unaltered volcanic units.

The underlying Vinini Formation, the location of the existing and proposed expansion of the underground mine workings, is composed of quartzite, chert, and argillite (Wallace 2003a); the Vinini Formation is thrust over the Devonian Rodeo Creek unit by the Roberts Mountain Thrust. The estimated thickness of the Vinini Formation in northern Nevada ranges from 500 to 6,000 feet (Western Cordillera 2006). In the project area, the Vinini Formation may be up to 2,000 feet thick (Oelofse et al. 2009; Wallace 2003a). There is a sheeted Breccia zone approximately 1 to 2 miles upgradient from the Hollister Site, and was apparently formed at the time of thrusting of the Vinini Formation. There do not appear to be any characteristics that would differentiate the Breccia zone hydraulically from the Vinini Formation near the Hollister Site or in other locations (Hart 2012; Wallace 2003a). The geologic contact between the volcanic rock and the underlying Vinini Formation is an unconformable contact consisting of re-worked Vinini quartzite and clay (Brown and Caldwell 2010a). The contact zone ranges in thickness from 2 to 50 feet in the project area. The clays in the contact zone and also the hydrothermal clays in the volcanic rock restrict vertical groundwater movement within the volcanic rock and between the Vinini Formation and the overlying volcanic rock. Thick clay zones have been found in groundwater monitoring wells and exploration bore holes at the Hollister Site (**Figure 3.5-3**) (Brown and Caldwell 2011a). In areas more distant from the Hollister Site, substantial clay intervals were documented in the borehole logs of monitoring wells that are part of the Boulder Valley Monitoring Plan associated with the monitoring of dewatering activities at the gold mining operations of Barrick and Newmont. Brown and Caldwell (2011a) summarize the logs for these boreholes that indicate widespread occurrence of clay within the volcanic rock. The data from these wells provide insight to the extent of the clay zones in the project region.



Legend

- Project Area Boundary
- Cumulative Effects Study Area and Direct/Indirect Effects Study Area
- Groundwater Basin Boundary
- Maximum Extent of Cumulative 10-foot Drawdown Contour (2007 Barrick Model)
- Stream (Intermittent or Ephemeral)
- Perennial Stream Reach
- Discontinuous Flowing Stream Reach (interrupted flow that stops and starts)

N

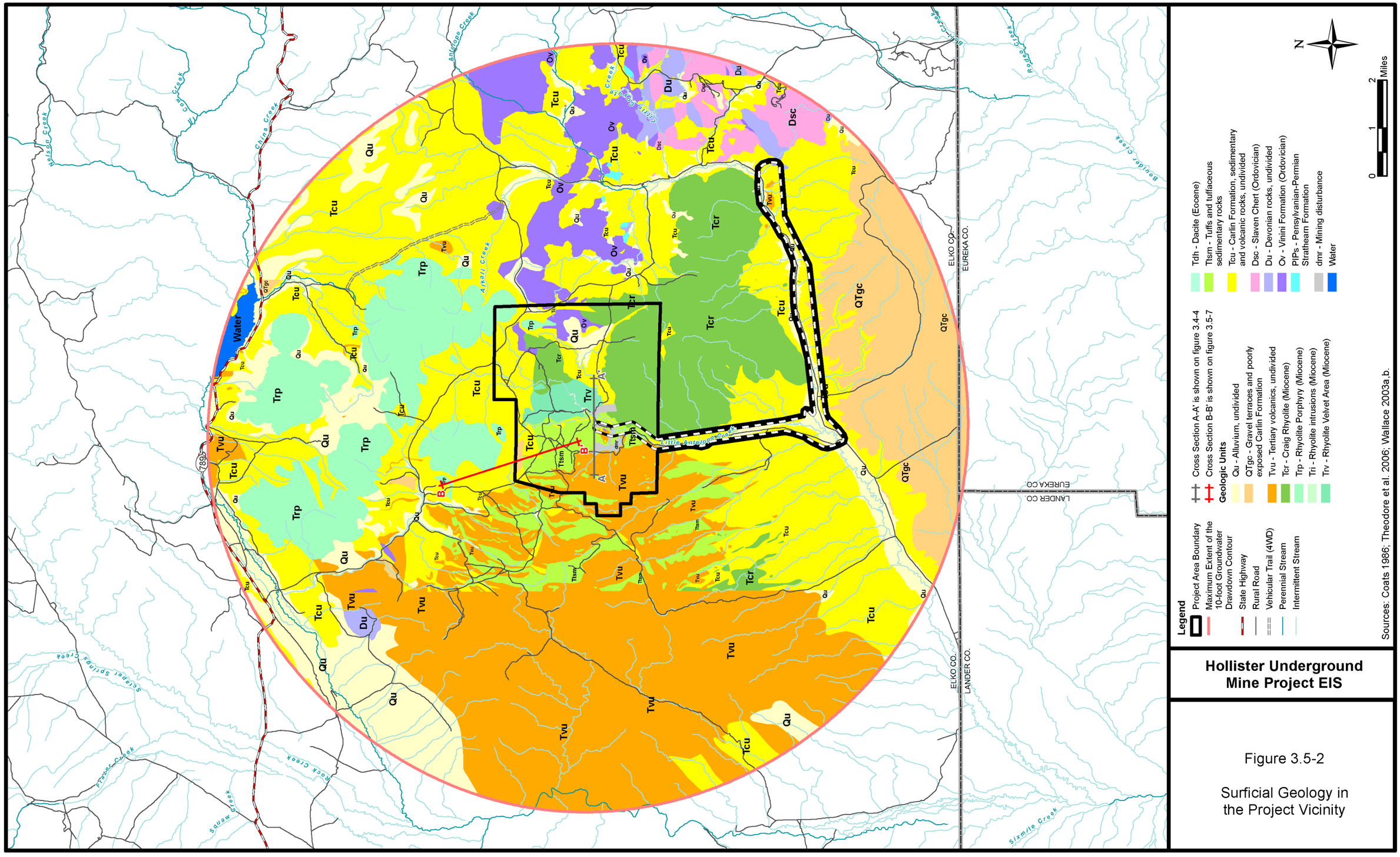
0 2.5 5 Miles

Note: Hydrographic area boundary locations are approximate.
Source: BLM 2000b,c; Brown and Caldwell 2010a.

Figure 3.5-1
Groundwater Resources and Geochemistry Direct/Indirect Effects and Cumulative Effects Study Areas

Hollister Underground Mine Project EIS

3/23/2012



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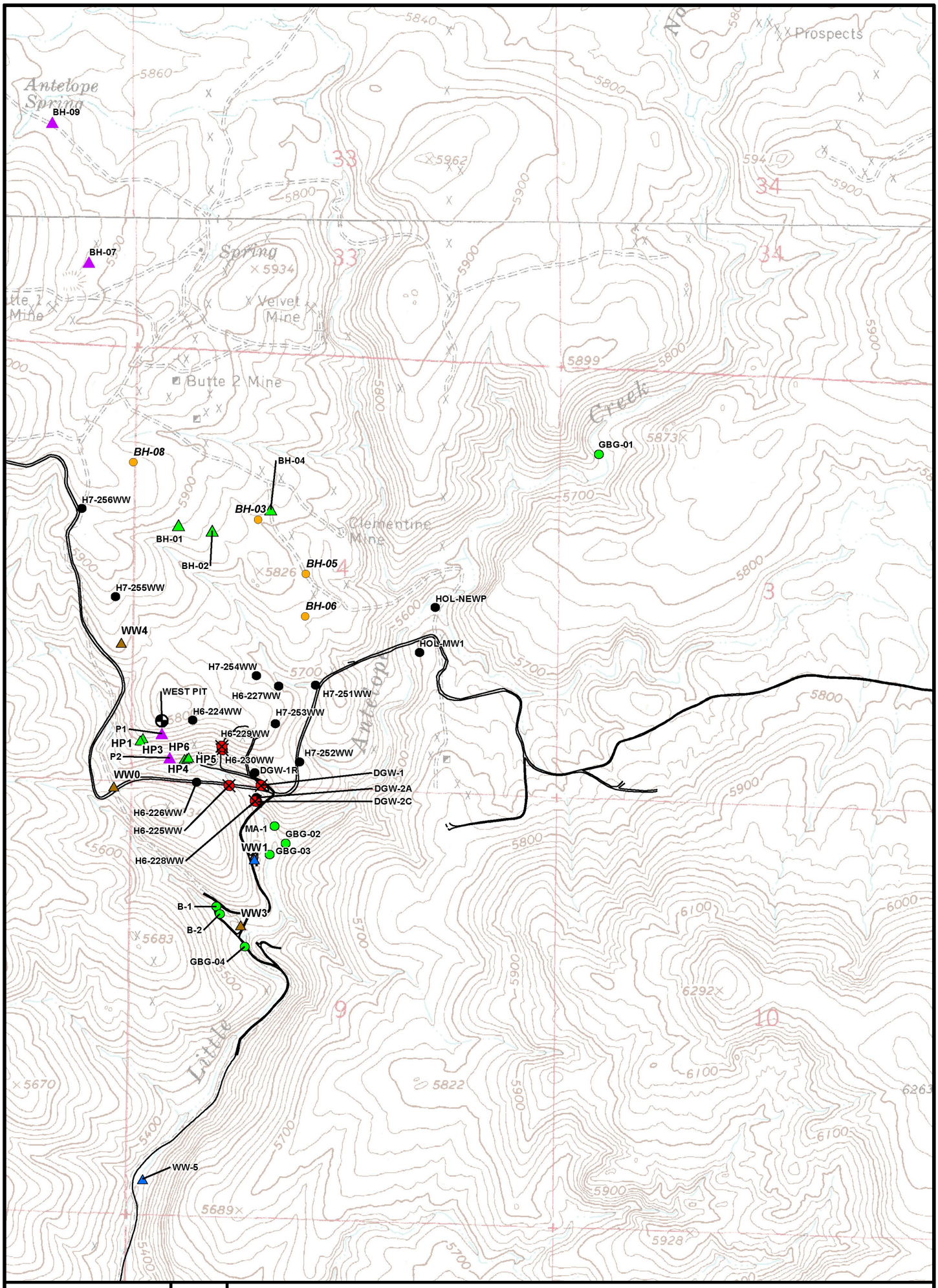


Legend

Roads

Boreholes (Brown and Caldwell 2003)

- 2002 Piezometer and Groundwater Level Elevation
- 2002 Hydrogeologic Test Borehole and Groundwater Level Elevation

Wells (Brown and Caldwell 2003)

- West Pit Monitoring Well (HP)
- Water Production Well (WW)
- Abandoned Water Production Well (WW)

Monitoring Sites (Montgomery and Associates 2010)

- Abandoned Monitor Well
- Monitor Well
- Piezometer, Vinini Aquifer
- Piezometer, Tertiary Volcanic Aquifer
- Stream Sample
- West Pit Staff Gauge

Source: Brown and Caldwell 2010a, 2003; Montgomery and Associates 2010a.

Hollister Underground Mine Project EIS

Figure 3.5-3

Groundwater and Suface Water Monitoring Sites

3/19/2012

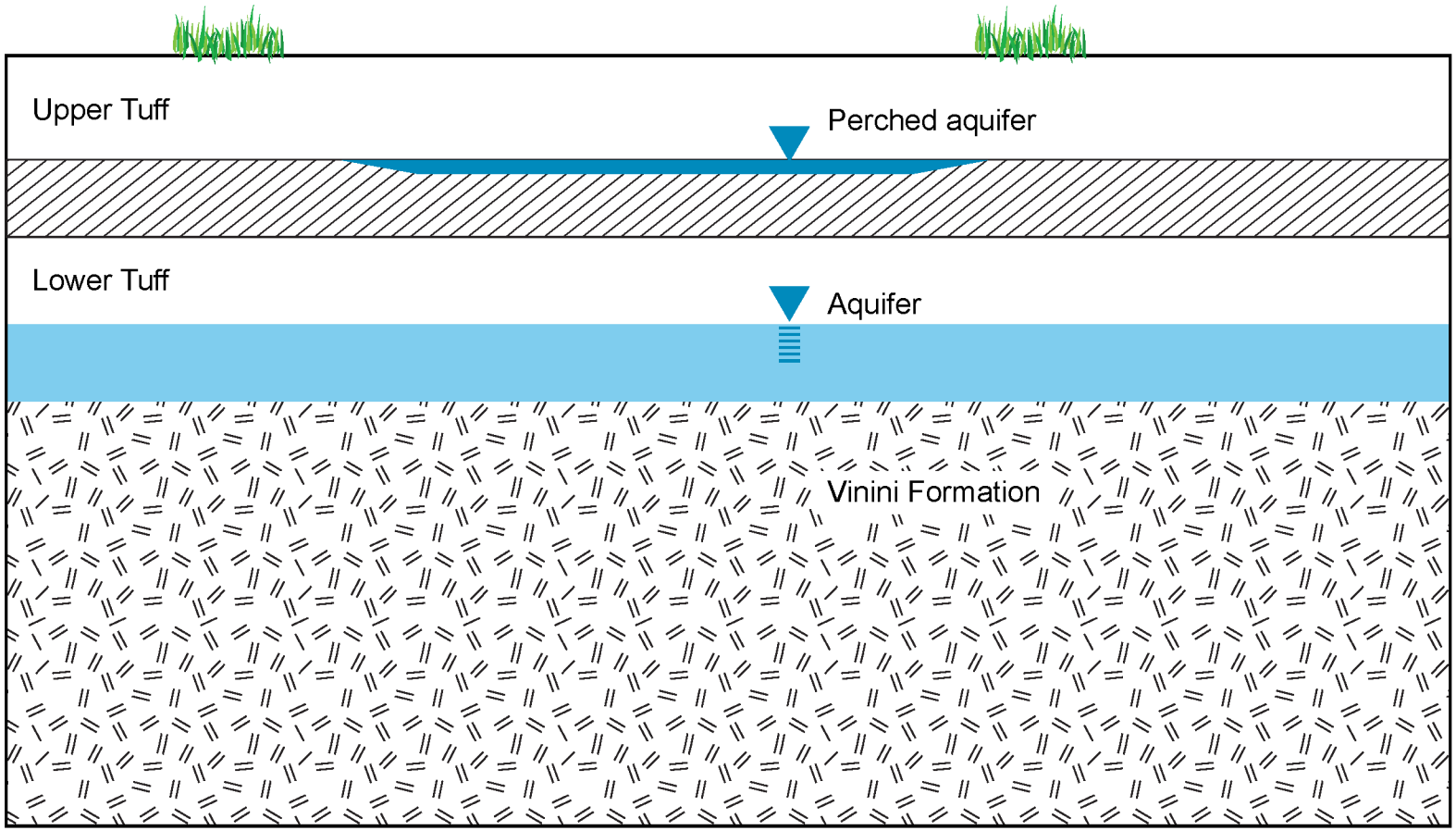
3.5.1.2 Hydrogeology

There are two main aquifers in the project area and a third local "perched" aquifer in the area of former open-pit mining (Brown and Caldwell 2010a). The aquifer in the volcanic rock is separate from the aquifer in the Vinini Formation, and vertical flow between these two aquifers is restricted by a clay alteration in the lower volcanic rock that separates it from the underlying Vinini Formation. The perched aquifer consists of altered and mineralized volcanic rock and overlying alluvial material and is limited mainly to the area of former open-pit mining. **Figure 3.5-4** shows schematically the relationship between the perched aquifer and the Vinini Formation aquifer (Hart 2012). The geotechnical water removal occurs in the Vinini Formation.

Hydro-Search, Inc. installed five water production wells (WW series wells) for the open- pit mining operation in the 1990s; the WW-0, WW-3, and WW-4 wells have been abandoned. HCI installed a series of monitor wells in the area of the West Pit (HP series wells), and Brown and Caldwell installed borehole test wells at the Hollister Site into the Vinini Formation (BH series wells) (Brown and Caldwell 2003), as shown in **Figure 3.5-3**. The results of aquifer testing in these wells showed that water in both the volcanic rock and the Vinini Formation comes mostly from fractures, joints, and faults. Water production in WW-1 increased from 15 to 60 gpm when a fault was intersected. Aquifer testing of the WW series wells showed that the Vinini Formation aquifer has transmissivity values ranging up to 50 to 60 square feet per day (feet^2/day). In the HP series wells, transmissivity in the Vinini Formation ranged from 0.4 to 8.0 feet^2/day, while transmissivity in the volcanic rock ranged from 0.3 to 1.0 feet^2/day. The reworked Vinini quartzite found at the base of the volcanic rock had a transmissivity of 10 to 14 feet^2/day. The BH series wells in the Vinini Formation gave a range of 0.7 to 812 feet^2/day. Transmissivity is the ability of an aquifer to transmit water. The higher the transmissivity, the more volume of water an aquifer can transmit per unit area of the aquifer. The reworked Vinini quartzite, for example, transmits water at a rate about 10 times that in the volcanic aquifer, based on these aquifer tests. But the Vinini Formation, can transmit large quantities of water in the fractures (areas with high transmissivity), and yet transmit much less water in the matrix of the aquifer where the transmissivity is considerably lower.

HCI (1997) estimated, based on aquifer tests, that the hydraulic conductivity of the lower tuff in the volcanic rock ranged from 0.03 to 0.10 feet/day. Brown and Caldwell (2011a) have shown that based on 16 single well tests, the average value for hydraulic conductivity in the volcanic rock is approximately 0.45 feet/day with a mean value of 0.22 feet/day. The Vinini Formation has a hydraulic conductivity ranging from 0.03 to 2.4 feet/day, and the reworked Vinini quartzite has a hydraulic conductivity of approximately 1.0 feet/day. **Figure 3.5-3** shows the location of the monitoring wells and boreholes tested by Brown and Caldwell (2003), and **Table 3.5-1** shows the aquifer parameter data from Brown and Caldwell (2003) measured at the monitoring wells and boreholes. Hydraulic conductivity is the rate at which groundwater can be transmitted and is similar in concept to electrical conductivity. Aquifers with higher hydraulic conductivity values transmit water faster, Hydraulic conductivity is related to transmissivity in that hydraulic conductivity is the transmissivty divided by the saturated thickness of the aquifer. As these aquifer test results show, the Vinini Formation transmits groundwater somewhat faster than the volcanic rock.

RCG installed the H6 and H7 series of wells, and the results of their aquifer tests are shown in **Table 3.5-2** (RCG 2010c); the locations of the wells are shown in **Figure 3.5-3**. The aquifer tests gave a transmissivity for the volcanic rock ranging from 3 to 95 feet^2/day and a transmissivity for the Vinini Formation of 95 feet^2/day. The volcanic rock appears to have a transmissivity up to 44 feet^2/day but it can have a much lower value of approximately 1.0 feet^2/day, except in the reworked Vinini quartzite that lies at the base of the volcanic rock (RCG 2010c). The Vinini Formation can have transmissivity values up to 95 feet^2/day in faults and fracture systems, but often shows a value below 20 feet^2/day (RCG 2010c). Exceptional values can be as high as 320 feet^2/day in large fracture systems (RCG 2010c).



Legend

- Water Level
- Ground Surface
- Low Permeability Zone
- Aquifer
- Perched Aquifer
- Vinini Formation

Source: Hart 2012.

Hollister Underground Mine Project EIS

Figure 3.5-4

Conceptual Diagram of Aquifers in the Hollister Area

Table 3.5-1 Aquifer Parameter Data

Monitor Well	Geologic Unit	Test Type	Discharge Rate (gpm)	Transmissivity ($feet^2$/day)	Hydraulic Conductivity (feet/day)
HP-1	Vinini Formation	Drawdown	7.0	--	--
		Recovery	--	0.4	0.03
		Drawdown	1.2	--	--
		Recovery	--	0.7	0.05
HP-3	Lower Tuff	Drawdown	3.3	--	--
		Recovery	--	0.3	0.03
		Drawdown	1.0	--	--
HP-4	Vinini Formation	Drawdown	2.4	4	0.3
		Recovery	--	--	--
		Drawdown	10.6	8	0.5
		Recovery	--	--	--
HP-5	Reworked Vinini Quartzite	Drawdown	1.8	--	--
		Recovery	--	12	1
		Drawdown	11.9	14	1
		Recovery	--	10	1
HP-6	Lower Tuff	Drawdown	3.0	--	--
		Recovery	--	1	0.1
		Drawdown	3.0	--	--

2002 Drilling Information

Borehole	Transmissivity ($feet^2$/day)	Saturated Thickness (feet)	Hydraulic Conductivity (feet/day)
BH-01	320	411	0.78
BH-02	52	257	0.20
BH-03	0.7	317	0.002
BH-04	812	345	2.4

cm/sec = centimeter per second.

Source: Brown and Caldwell 2003.

Table 3.5-2 Summary of Hydrologic Data from Constant-rate Pumping Tests for Monitor Wells

Well Identifier	Casing Perforated Interval (feet, bgs)[1]	Date Pumping Test Started	Duration of pumping Period (hours)	Average Pumping Rate (gpm)[2]	Pre-Pumping Water Level (feet, bgs)	Maximum Water Level Drawdown Near End of Pumping Period (feet)	Specific Capacity (gpm/ft)[3]	Temperature (°F)[4]	Specific Electrical Conductance (µS/cm)[5]	pH (standard units)	Cooper-Jacob (1946) Drawdown Method Transmissivity (feet^2/day)[6]	Theis (1935) Recovery Method Transmissivity (feet^2/day)[6]	Lithology Tested[7]
H6-224WW	166-221	10-Dec-2006	8	0.8	179.5	17.93	0.045	57.7	1,141	5.69	---24.2	24.1	Tv
H6-225WW	62-127	6-Dec-2006	8	2.0	83.53	8.86	0.23	51.6	1,270	6.10	21.4	53.6	Tv
H6-226WW	75-130	4-Dec-2006	8	7.0	84.66	9.62	0.73	57.7	1,559	6.81	84.4	95.1	Tv
H6-227WW	18-133	12-Dec-2006	8	0.7	28.77	59.25	0.0012	57.7	5,824	3.24	5.3	NA	Tv
H6-228WW	129-184	8-Dec-2006	8	4.0	134.44	13.00	0.31	55.6	3,273	6.56	96.5	NA	Ov
H6-229WW	50-85	14-Dec-2006	8	2.7	24.32	19.34	0.14	56.5	15,060	2.87	23.4	NA	WR/Tv
H6-230WW	15-35	15-Dec-2006	1.8	9.0	22.98	0.05	**	52.0	8,665	2.74	NA	NA	Ov
H6-251WW	172-227	25-Oct-2007	8	1.1	186.91	16.76	0.066	70.0	1,039	6.46	8.0	13.4	Fill
H6-252WW	208-268	23-Oct-2007	6	1.0	216.48	25.14	0.040	69.6	5,325	3.66	4.7	3.1	Tv
H6-254WW	25-85	22-Oct-2007	3	6.2	37.8	39.71	0.15	60.0	1,439	3.97	12.1	44.2	Tv
H6-255WW	230-540[8]	18-Oct-2007	8	8.7	243.52	30.1	0.289	63.0	653	7.19	46.9	42.9	Tv
H6-256WW	22-430	19-Oct-2007	8	4.3	199.65	84.69	0.051	61.2	392	7.31	6.0	24.1	Tv

1 bgs = below ground surface.

2 gpm = gallons per minute.

3 gpm/ft = gallons per minute per foot of drawdown.

4 °F = degrees Fahrenheit.

5 µS/cm = microSiemens per centimeter.

6,7 Tv =Tertiary volcanic; Ov = Paleozoic Vinini quartzite/argillite; WR = waste rock.

8 Alternating blank and perforated sections.

NA – Not Analyzed ** – Not Computed

Source: RCG 2010c.

In summary, the aquifer test results from various investigators conducted at different times show that the range in transmissivity of the Vinini Formation is from low values around 0.4 to 8.0 feet^2/day to high values associated with faults and fractures in the range of 52 to 812 feet^2/day. For the volcanics, the range in transmissivity is from 0.3 to 95 feet^2/day with many values falling in the range of 1.0 to 50 feet^2/day. In the fractured areas, the volume of water transmitted by the Vinini Formation can be 10 times the volume in the unfractured part of the formation.

Regional composite groundwater elevations and flow in the Boulder Valley area are shown in **Figure 3.5-5**. In this figure, groundwater elevations in all aquifers ranging from bedrock Paleozoic units to Quaternary alluvium are lumped together and contoured as if they represent one single aquifer. In the Hollister project area, these regional groundwater elevations are associated with the Vinini Formation because the monitor wells used for the water levels are screened in the Vinini Formation. Groundwater flow in the Vinini Formation in the project area is towards the southwest. Local groundwater elevations and flow in the volcanic rock, the uppermost aquifer in the project area, are shown in **Figure 3.5-6**. Because of limited data, the contours are truncated and limited to the immediate area around the monitor well in this figure. Groundwater flow in the volcanic rock is towards the southeast. Hydrogeologic cross-sections showing the water table in both the volcanic rock and the Vinini Formation are shown in **Figure 3.5-7**. The cross-section location is shown in **Figure 3.5-2**. The water table in the volcanic rock is 100 to 200 feet bgs and thus lies below Antelope Spring (**Figure 3.5-7**). Antelope Spring and both Ivanhoe and Buttercup springs (**Figure 3.5-7**) are above the water levels in both the volcanic rock and the Vinini Formation. In general, the shallowest groundwater in the project area is at an elevation of approximately 5,400 to 5,500 feet amsl (Brown and Caldwell 2003). Groundwater in the Vinini Formation is recharged from the Tuscarora Mountains to the east of the project area. Groundwater flow is controlled by fractures and faults, and the estimated flow into the proposed underground workings by Brown and Caldwell (2003) using an analytical groundwater model was approximately 335 to 385 gpm. Current measured flow rates to the underground workings are approximately 400 gpm.

The third aquifer in the project area is a perched aquifer in the volcanic rock that exists in the area of past open-pit mining and provides groundwater flow to the West Pit and to Little Antelope Creek, as suggested by the groundwater elevation data depicted in **Figure 3.5-8** (MWH Americas, Inc. 2007). This aquifer exists in the area of fractured volcanic rock and overlying alluvial material, mainly between the East and West pits, that was disturbed by past mining. **Figure 3.5-8** shows the projected piezometric surface (water levels) and flow lines for 2007 in this perched aquifer. Groundwater generally flows towards the east in the perched aquifer. The West Pit serves as a hydraulic sink, and groundwater in this aquifer flows to the pit at a rate of approximately 5 gpm (MWH Americas, Inc. 2007). Just east of the eastern rim of the West Pit, there is a groundwater divide in the perched aquifer, and groundwater east of that divide flows eastward toward Little Antelope Creek. Oxidized sulfides in the walls of the West Pit contribute acidic groundwater to the West Pit during periods of intense precipitation, due to both groundwater inflow and surface water flushing materials from the pit walls. This water seeps into the perched aquifer.

The West Pit had a pit bottom elevation at the end of mining of 5,505 feet amsl (MWH Americas, Inc. 2007). This pit was backfilled between 1992 and 1997 to an elevation of 5,543 feet amsl with 380 tons of lime and local oxide material and capped with 2 feet of topsoil. Seasonal inflow of groundwater and surface water sometimes produces a pond of water up to 2 feet in depth that lasts from November to July with a near neutral pH (MWH Americas, Inc. 2007). In 2005, exceptionally heavy precipitation resulted in increased flow to the West Pit. Between June 2006 and April 2007, the West Pit pond was approximately 4 feet in depth and turned acidic with a pH of approximately 4.0 standard units. The acidic water in the West Pit pond had total dissolved solids (TDS) ranging from 2,620 to 3,730 milligrams per liter (mg/L) and a sulfate content from 1,680 to 2,450 mg/L. During February and March of 2007, monitor well WP-P1 had a pH of 5.39 standard units and a TDS of 2,190 mg/L with sulfate at 1,510 mg/L. Monitor well WP-P2, which is farther to the south and thus at a greater distance from the West Pit, had a pH of 6.93 standard units and a TDS of 1,225 mg/L with sulfate at 376 mg/L. This suggests that the

majority of the acidity in the West Pit may be derived from the flushing of the oxidized sulfide material in the pit walls (MWH Americas, Inc. 2007). If the water level in the West Pit rises too high, due to exceptionally high rainfall, the West Pit could become a flow-through pit, and water could flow out of the pit and into the perched aquifer (HCI 1997).

Geotechnical groundwater removal from the current underground workings at the Hollister Site using mine sumps has resulted in drawdown in the water levels of monitor wells screened in the Vinini Formation, but not in the overlying volcanic rock. **Figure 3.5-9** shows the extent of current drawdown in the Vinini Formation due to underground water removal at the current Hollister Site (Brown and Caldwell 2011a). **Figure 3.5-10** shows the change in water levels with time in both the Vinini Formation monitoring wells and the monitoring wells in the overlying volcanic rock. The water levels in the volcanic rock show only seasonal fluctuations and have not been affected by drawdown in the Vinini Formation due to geotechnical water removal, further supporting the concept based on geology that the Vinini aquifer is separate from the volcanic aquifer (Brown and Caldwell 2011a).

3.5.1.3 Groundwater Quality

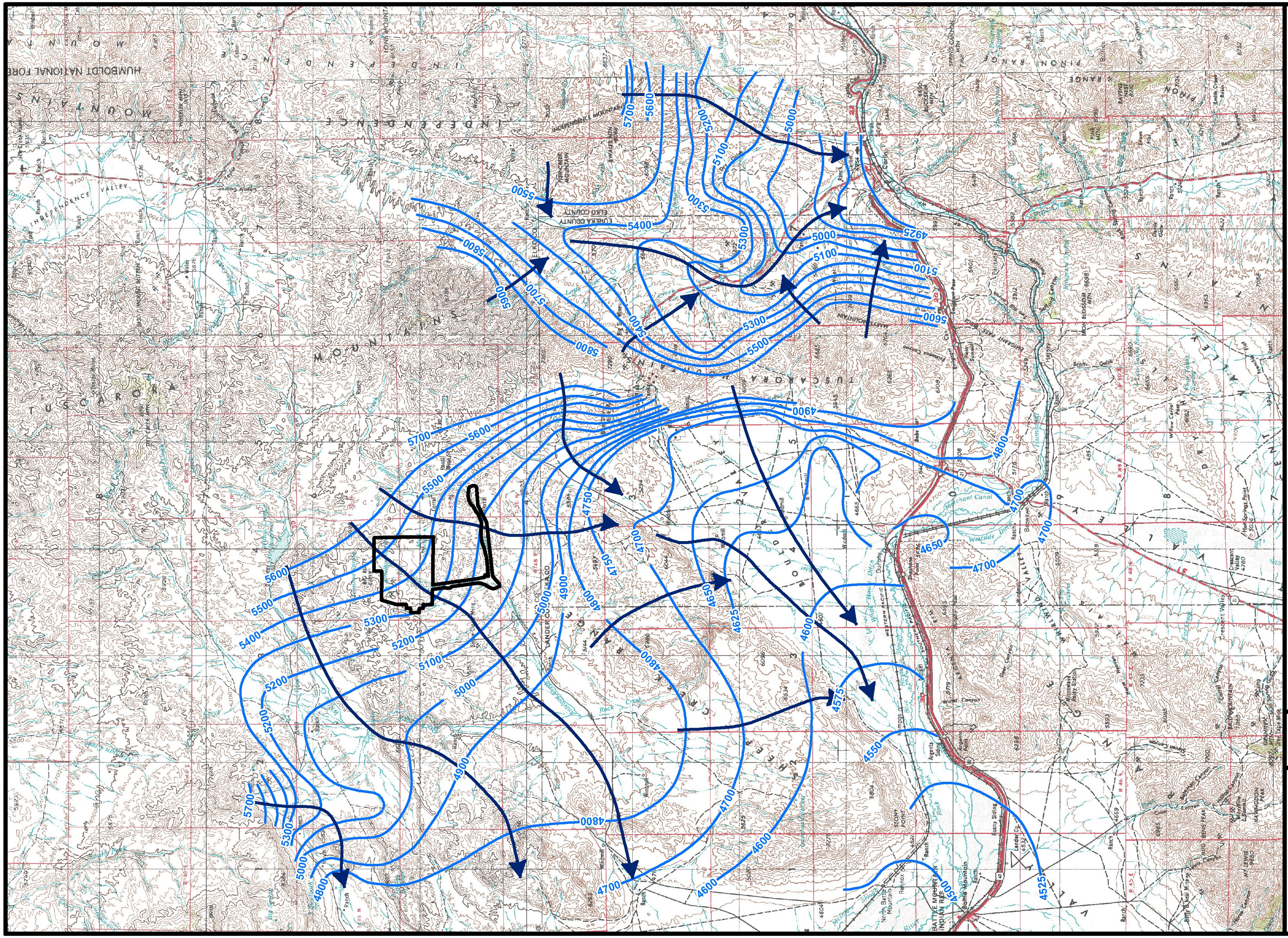
The Nevada Administrative Code (NAC) 445A establishes primary and secondary water quality standards. Nevada water standards applicable to this EIS are summarized in **Appendix B1, Table B1-1**. Primary standards are based on the potential use of groundwater for drinking water and are established to protect human health; secondary standards are for aesthetic qualities. Because groundwater in the project area has the potential to be used for drinking water and by wildlife (Bureau of Land Management [BLM] 2010c), the Nevada primary standards would apply to mine-related activities that affect groundwater.

Water quality data from Brown and Caldwell (2003) and Montgomery and Associates (2010a) are summarized in **Appendix B1, Table B1-2**. **Figure 3.5-11** illustrates the variation in water quality using Stiff diagrams. The majority of exceedences of Nevada water quality standards are found in the wells screened in the perched aquifer in the area of historic open-pit mining.

The WW series of water wells, shown in **Figure 3.5-3**, are located mostly south and southeast of the West Pit and the Newmont-reclaimed South WRSF. Well WW-1 is screened in the Vinini Formation and has TDS in the range of 300 to 400 mg/L with sulfate ranging from 140 to 160 mg/L. Arsenic and iron are the main exceedences in the Vinini Formation in this well. Well WW-5 is screened in the volcanic rock and show TDS ranging from 230 up to 898 mg/L with sulfate in the range of 136 to 392 mg/L. Arsenic, iron, and manganese are the main exceedences in these wells for the volcanic rock. Abandoned well WW-4, screened across both the Vinini Formation and the volcanic rock, showed similar ranges for TDS and sulfate and the same exceedences as WW-1 and WW-5.

The BH series of wells shown in **Figure 3.5-3** are located in the area of the underground workings and are screened in the Vinini Formation (wells BH-1, BH-2, BH-4) and the volcanic rock (wells BH-7 and BH-9). The TDS in the Vinini Formation near the workings is less than 500 mg/L, with the water being dominated by calcium-sodium bicarbonate. The BH wells in the volcanic rock show TDS less than 200 mg/L, sulfate less than 100 mg/L, and the water is dominated by calcium-sodium bicarbonate.

The HP series of wells are all located south and downgradient of the West Pit, as shown in **Figure 3.5-3**. HP wells screened in the Vinini Formation show TDS in the range of 250 to 458 mg/L with sulfate up to 181 mg/L. Exceedences of Nevada water quality standards are for arsenic and the water in the Vinini Formation is calcium-sodium bicarbonate dominated in HP-1, which is a background well in the Vinini Formation, and calcium-magnesium sulfate water in HP-4, which is downgradient of the West Pit and screened in the Vinini Formation. HP wells screened in the volcanic rock have TDS values up to 304 mg/L, and sulfate up to 127 mg/L. Both the upgradient background well HP-1 and the well downgradient of the West Pit (HP-6) show good water quality in the volcanic rock.



Miles
0 2.5 5
N

Legend
Project Area Boundary
Water Table Contour
Regional Groundwater Flow

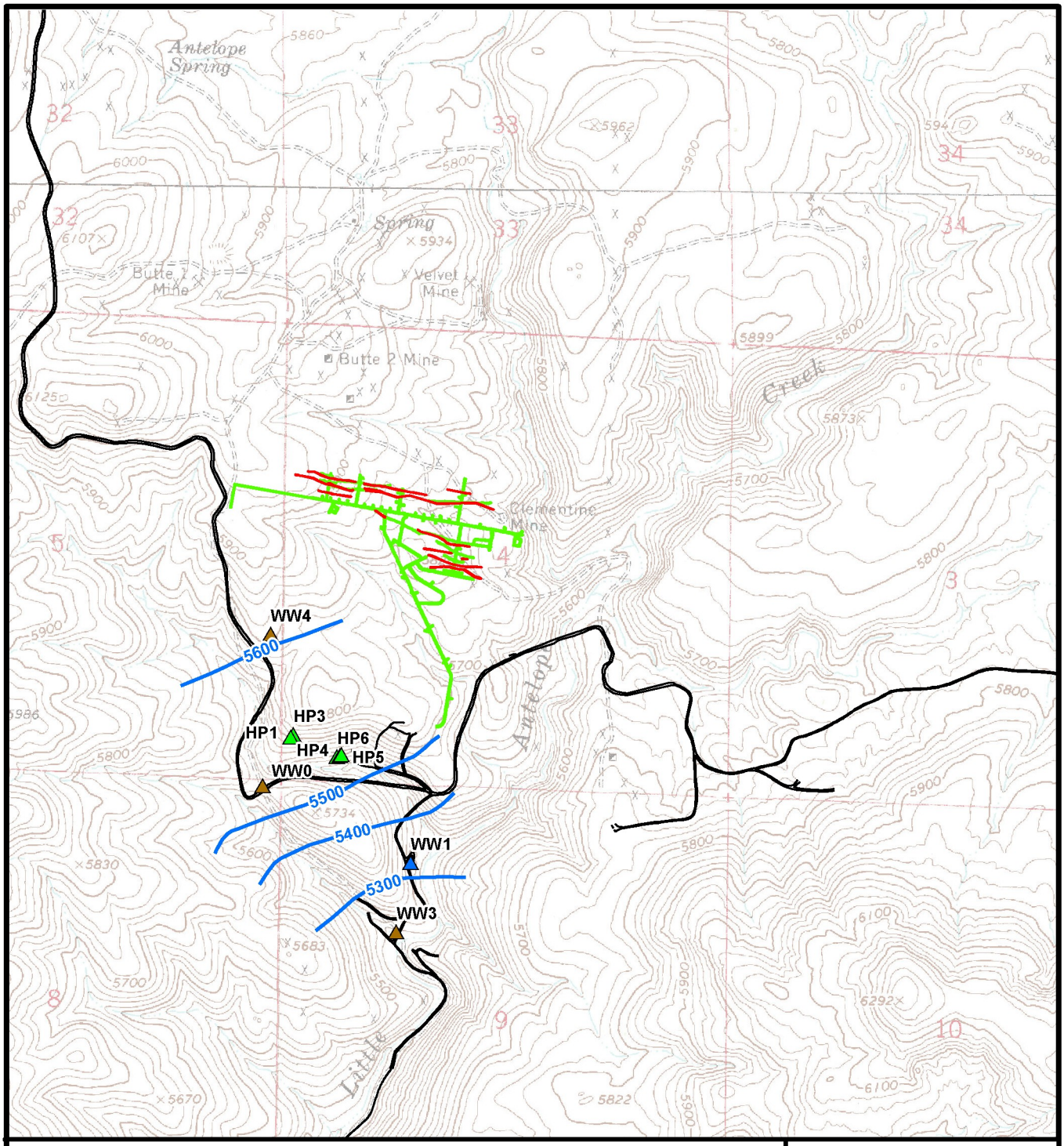
Source: BLM 2000b; Brown and Caldwell 2003.

Hollister Underground Mine Project EIS

Figure 3.5-5

Regional Groundwater Elevation Contours Prior to Dewatering at Carlin Trend Mines

3/19/2012



Legend

- Existing HP Monitoring Well
- Existing Production Well
- Abandoned Production Well
- Vein
- Existing Underground Exploration Workings
- Groundwater Elevation Contour

Note: Contour interval 10 feet.
Source: Brown and Caldwell 2003.

N

0 1,000 2,000 Feet

Hollister Underground Mine Project EIS

Figure 3.5-6

Groundwater Elevation Contours in the Volcanic Rock

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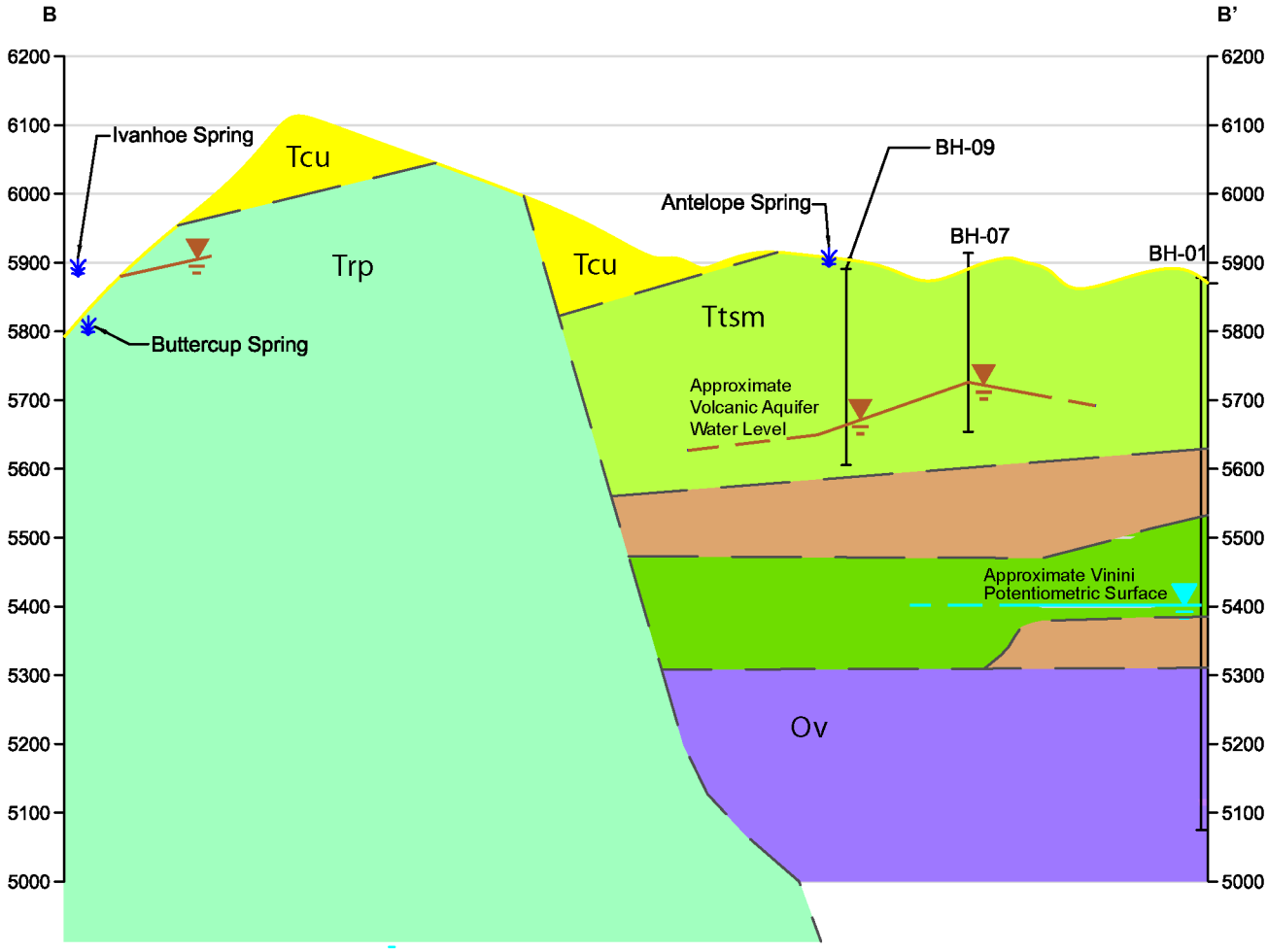
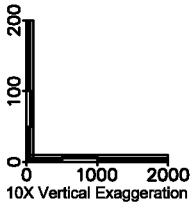


Legend

- Tcu - Carlin Formation, sedimentary and volcanic rocks, undivided
- Trp - Rhyolite Porphyry (Miocene)
- Ttsm - Tuffs and tuffaceous sedimentary rocks
- Basaltic Andesite
- Clay Zone/Lower Tuff (from exploration and piezometer drilling)
- Ov - Vinini Formation (Ordovician)
- Water Table Level in Volcanic Rock
- Potentiometric Surface in Vinini Formation
- Approximate Contacts

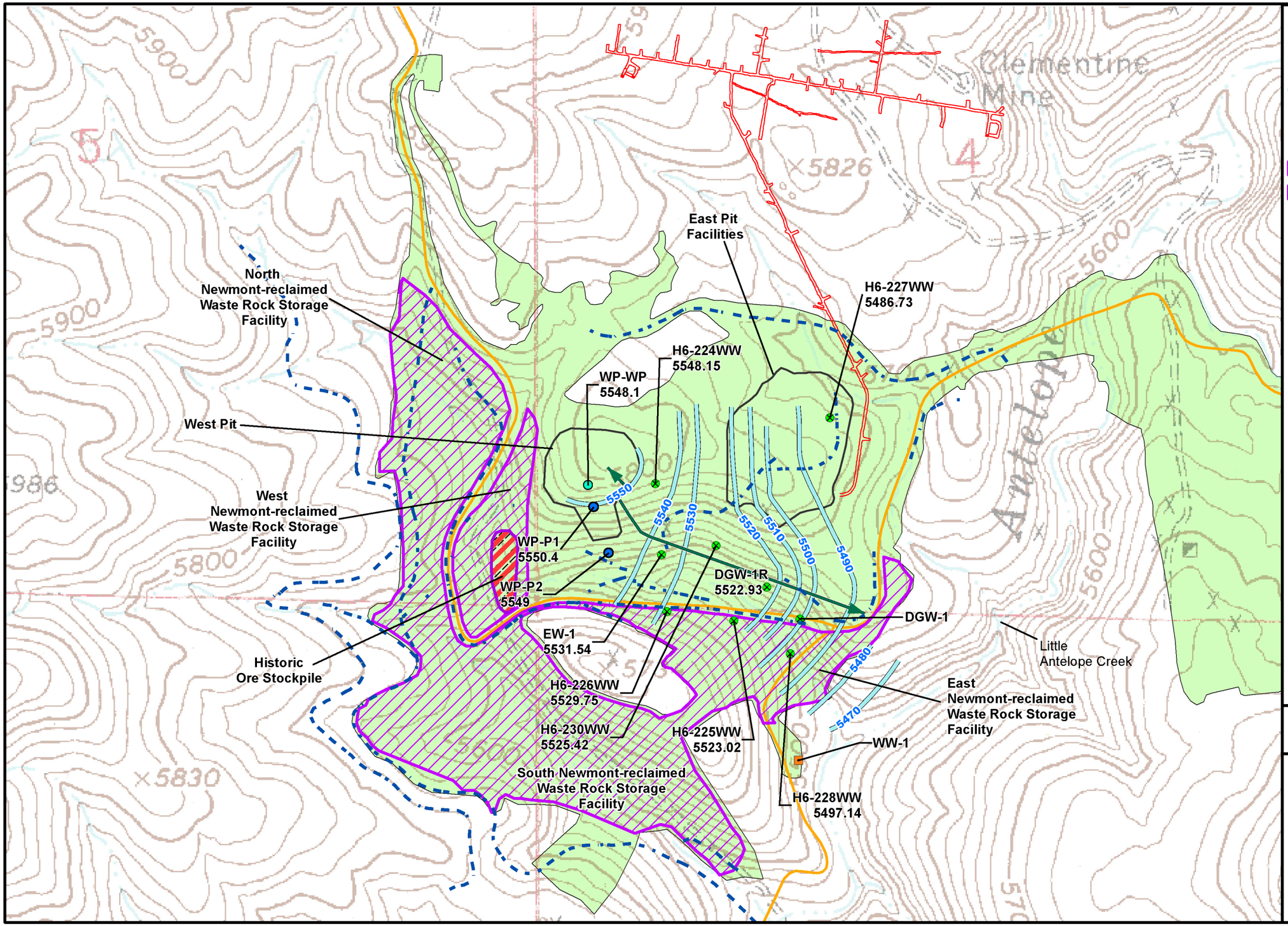


Source: Brown and Caldwell 2003.
Note: The cross-section B-B' is shown on Figure 3.5-2.

Hollister Underground Mine Project EIS

Figure 3.5-7

Hydrogeologic Cross-sections from the Exploration Decline to Buttercup and Ivanhoe Springs



Legend

Existing/Authorized Surface Disturbance or Facilities

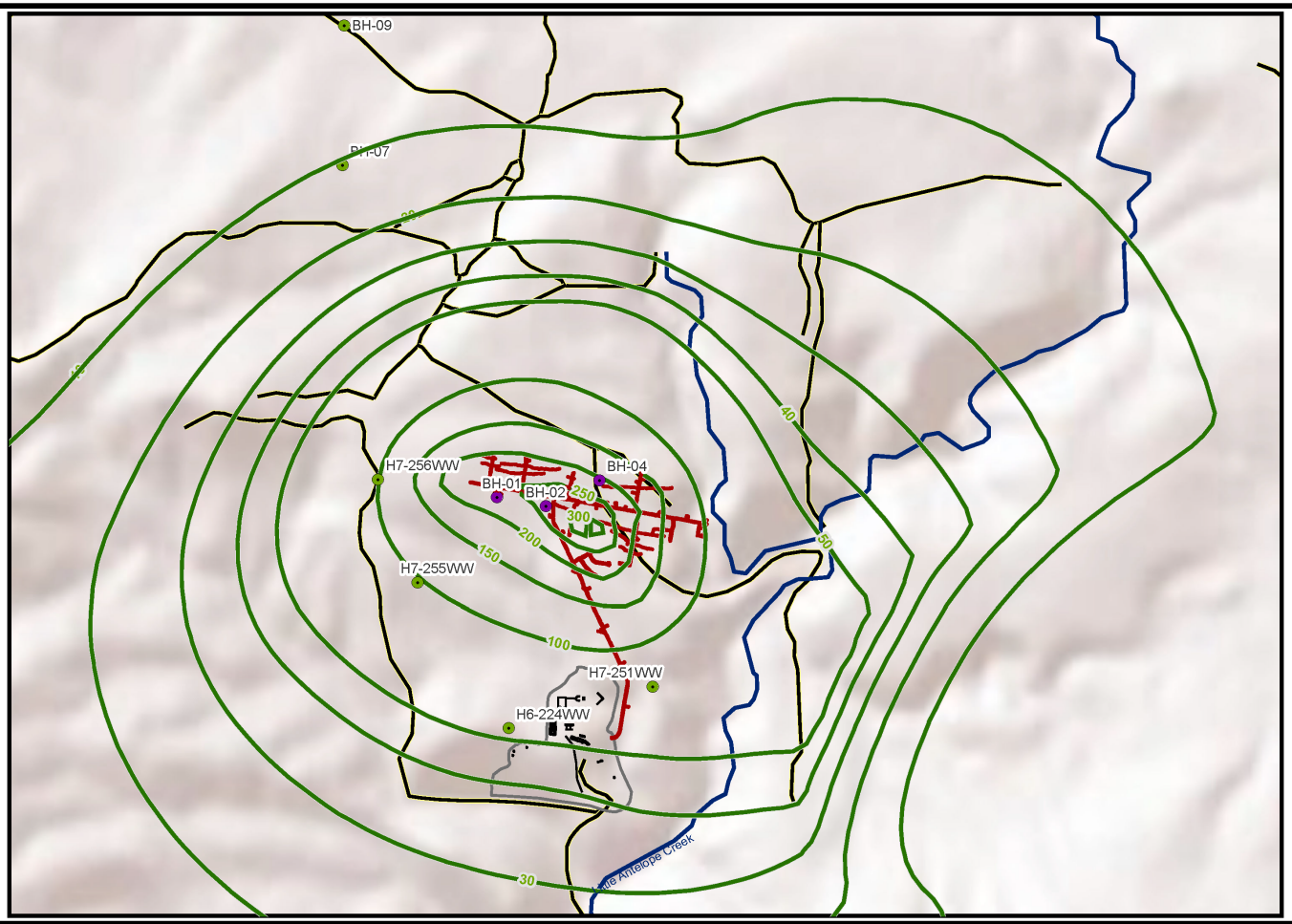
- Mining Disturbance
- Storm Water Diversion Channel
- Road
- Existing Underground Exploration Workings
- Newmont-reclaimed WRSF Stockpile
- Historic Ore Stockpile
- Monitoring Well
- Piezometer
- Piezometer/Staff Gauge
- Water Supply Well
- Inferred Groundwater Flow Direction
- Piezometric Surface Contour

Sources: MWH Americas, Inc. 2007; RCG 2009a.

Hollister Underground Mine Project EIS

Figure 3.5-8

Perched Aquifer Flow



Legend

- Monitor Well - Vinini Formation
- Monitor Well - Volcanic Rock
- Drawdown in the Vinini Formation (Simulated, December 2009)
- Existing Underground Exploration Workings
- Roads
- Little Antelope Creek

N

0 500 1,000 2,000 Feet

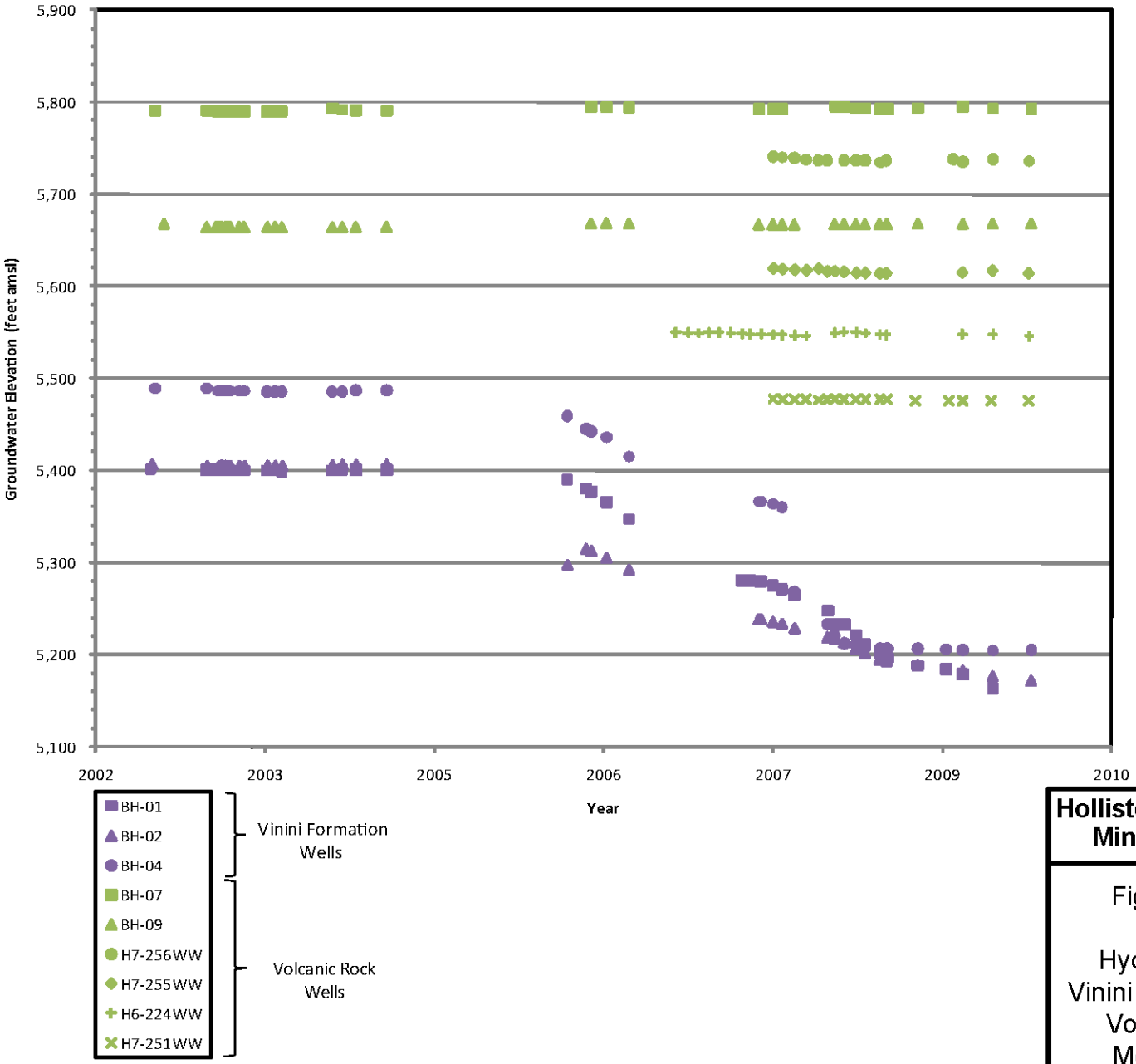
Source: Brown and Caldwell 2011a.

Hollister Underground Mine Project EIS

Figure 3.5-9

Current Vinini Formation Drawdown

03/20/2012



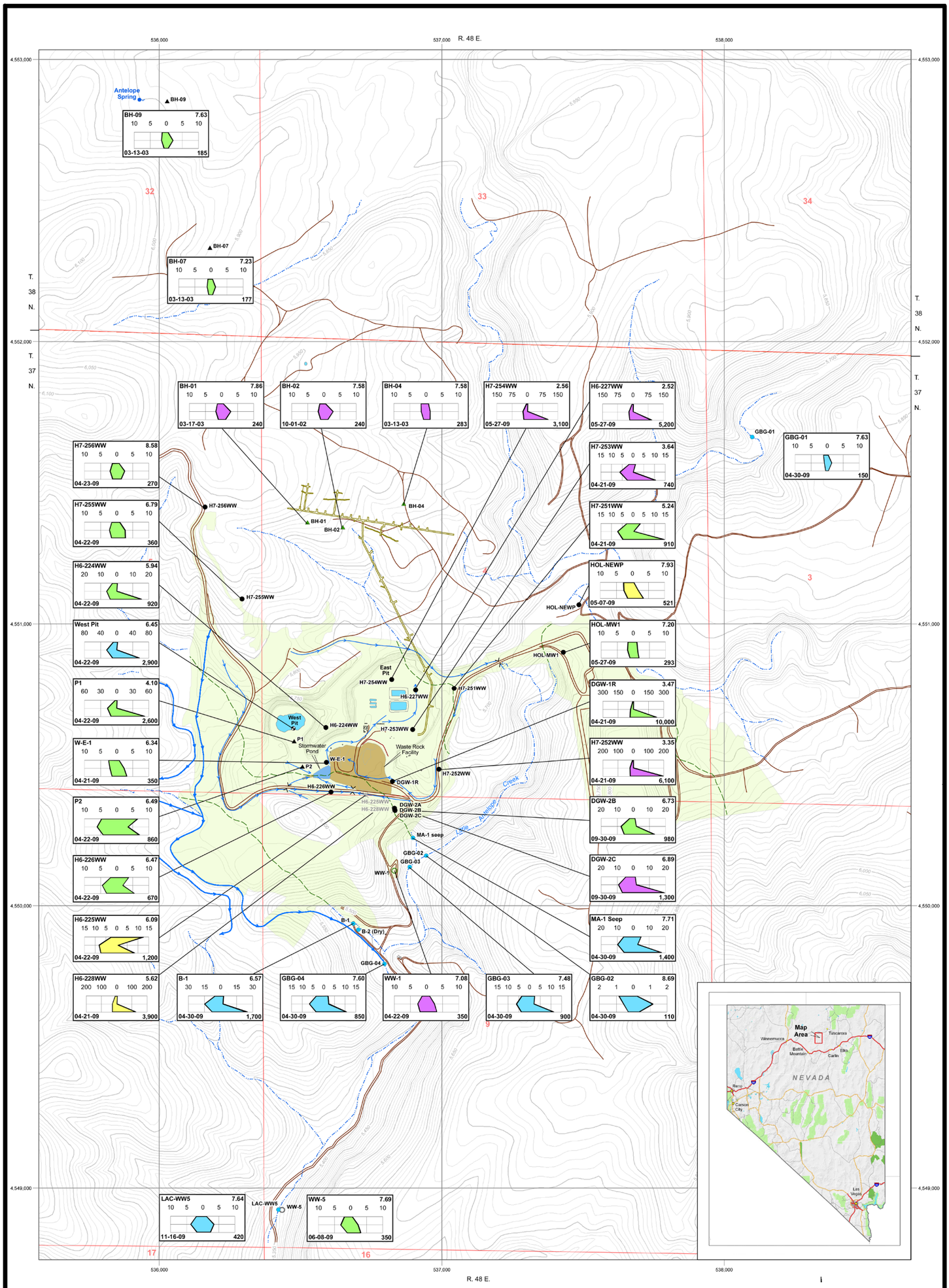
Source: Brown and Caldwell 2011a.

Hollister Underground Mine Project EIS

Figure 3.5-10

Hydrographs of Vinini Formation and Volcanic Rock Monitor Wells

03/21/2012



Legend

- Water Supply Well Location, Vinini Aquifer
- Water Supply Well Location, Tertiary Volcanic Aquifer
- Piezometer Location, Vinini Aquifer
- Piezometer Location, Tertiary Volcanic Aquifer
- Monitor Well Location
- Abandoned Monitor Well Location
- West Pit Staff Gauge Location
- Stream Sample Location
- Surface Water Diversion Channel
- Surface Water
- Pre-mining Stream Channel (Covered By Waste Rock)
- Previous Disturbance by Historic Surface Mining (Approximate Location)

Stiff Diagram

Site Identifier — pH
WW-5 7.69
Cations: Na+K, Ca, Mg — Anions: Cl, HCO_3, SO_4
06-08-09 350
Date Sampled — Total Dissolved Solids in milligrams per liter

- Green fill indicates well/ piezometer completed in Tertiary Volcanic units
- Purple fill indicates well/ piezometer completed in Ordovician sedimentary units
- Yellow fill indicates well/ piezometer completed in waste rock and/ or waste rock and Tertiary volcanic units
- Blue fill indicates surface water sample

Source: Montgomery and Associates 2010a.

Hollister Underground Mine Project EIS

Figure 3.5-11
Project Area Water Quality

03/20/2012

Overall, wells screened in the Vinini Formation away from the area of past mining show water quality generally within Nevada water quality standards with occasional exceedences of primary standards for arsenic and iron. Wells screened in the unaltered volcanic rock away from the area of past historic mining also show water quality generally within Nevada water quality standards with occasional local exceedences of primary standards for arsenic, iron, and manganese.

Groundwater quality in the area of past historic mining, both in the volcanic rock and the Vinini Formation has elevated TDS and sulfate. The groundwater in the area of past mining has been referred to as the perched aquifer (MWH Americas, Inc. 2007). The H6 and H7 series of wells are located mainly within and adjacent to the historic mined area of the West Pit and the East Pit along with the waste rock piles developed during that period of open-pit mining. Two wells screened in the volcanic rock, H7-255 and H7-256, serve as background wells and are located north and upgradient of the former mined area, as shown in **Figure 3.5-3**. These two wells have TDS less than 500 mg/L with calcium and sodium dominating the cations and sulfate and bicarbonate being about equal in concentration, making the water calcium-sodium sulfate/bicarbonate water. Iron is elevated above Nevada primary standards and arsenic ranges up to 0.4 mg/L (**Appendix B1, Table B1-2**). These background wells are within Nevada water quality guidelines for wildlife propagation.

The H6 and H7 wells screened in the area of past historic open-pit mining show the influence of pyrite oxidation on groundwater quality. TDS ranges from 800 to 39,000 mg/L, with most values between 800 and 5,000 mg/L. The groundwater is calcium sulfate water with exceedences of Nevada primary water quality standards for aluminum, arsenic, iron, manganese, and fluoride. Locally in a few wells, exceedences for thallium, mercury, cadmium, nickel, and selenium are found. The pH ranges from 2.6 to 8.0, with many values in the range of 4.0 to 7.0 standard units. These pH values are mostly below Nevada water quality guidelines for wildlife propagation. Overall, these wells indicate that groundwater in the previously mined area in both the volcanic rock and the Vinini Formation has been affected by the oxidation of pyrite.

Groundwater in the volcanic rock in the area of the West Pit, as shown in wells P1 and P2, has TDS well above 1,000 mg/L, is dominated by calcium sulfate, and has exceedences of Nevada primary water quality standards for aluminum, arsenic, iron, manganese, nickel and mercury. The pH ranges from 4.0 to 6.9 standard units and thus is below Nevada guidelines for wildlife propagation. When water is present, water quality in the West Pit pond has a TDS ranging from 1,800 to 5,800 mg/L and is calcium sulfate water with a pH ranging from 4.0 to 7.0 standard units. This area is part of the altered volcanic rock in the area of past historic mining. Sulfate and pH concentrations in the perched aquifer water are shown in **Figure 3.5-12**.

The HOL-MW-1 well screened in the volcanic rock by the reclaimed leach pad shows good water quality with TDS below 500 mg/L and no exceedences of Nevada water quality standards. The MA-1 seep located downgradient to the southeast from the area of past historic mining shows elevated TDS in the range of 1,100 to 1,360 mg/L, with sulfate slightly greater than bicarbonate and neutral pH.

In summary, groundwater in the Vinini Formation and the volcanic rock away from the area of past historic mining between the West Pit and the East Pit is generally within Nevada primary water quality standards, with local exceedences for arsenic, iron, and manganese. Within the area of past open-pit gold mining, the groundwater in the volcanic rock and the Vinini Formation shows elevated TDS, sulfate, and exceedences for many metals. This water does not meet Nevada water quality guidelines for wildlife propagation.

3.5.1.4 Waste Rock Geochemistry

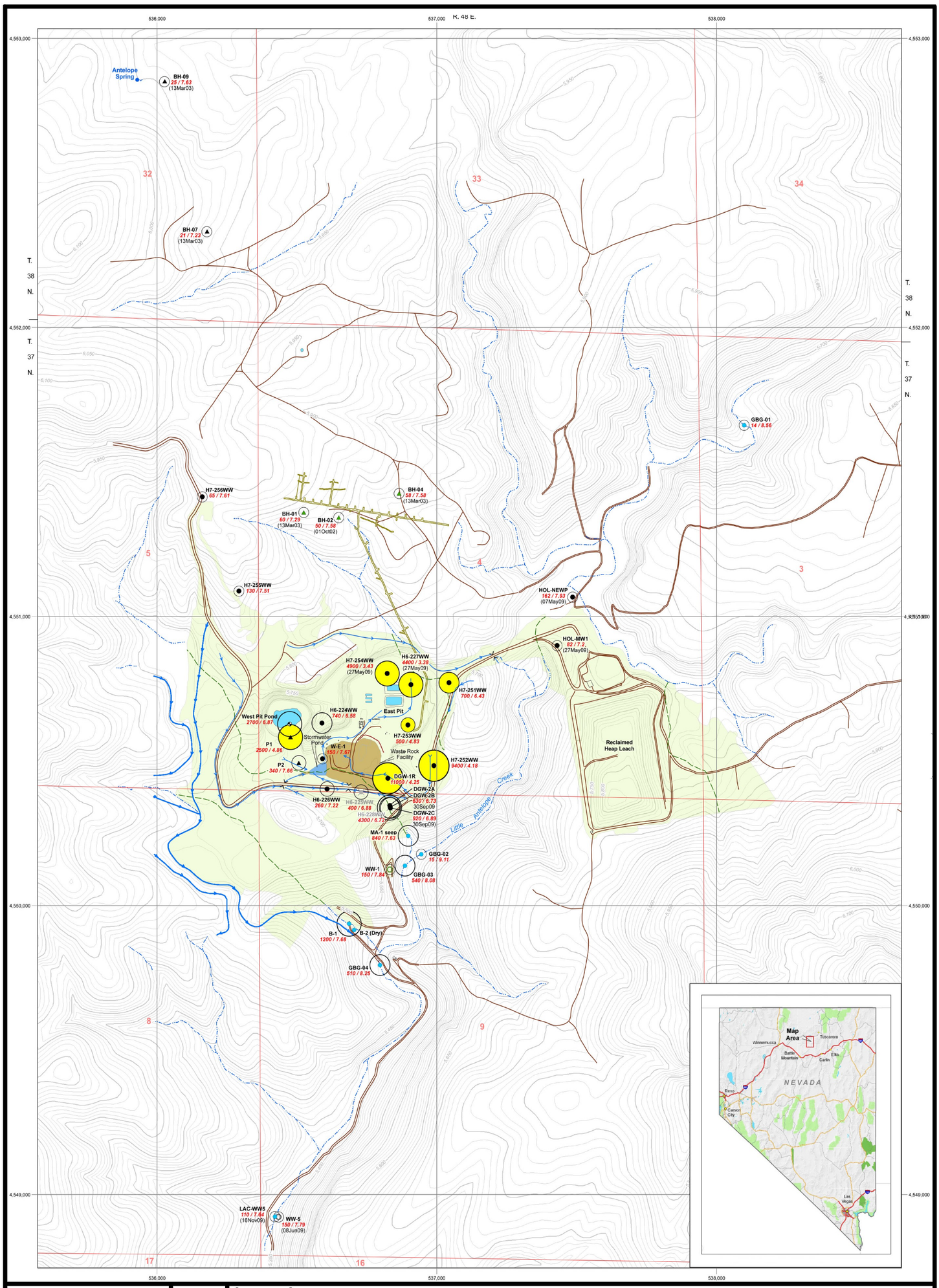
Walker and Associates (2003) completed static acid-base accounting (ABA) tests, Nevada meteoric water mobility procedure (MWMP) tests, and humidity cell tests (HCTs) on lithologies from the Vinini Formation that are expected to be involved in the proposed expansion of the underground workings. No tests were conducted in the volcanic rock because RCG was not planning to conduct mining in the volcanic rock. The lithologic types tested were quartzite, siltite, argillite, and andesite that are found in the Vinini Formation. All rock tested showed hydrothermal alteration in the form of silicification, pervasive alteration to clays and chlorite, and locally alunite and pyrite up to 3 percent. Gold occurs in the Vinini Formation as gold-quartz veins surrounded by hydrothermally altered wall rock. The samples tested came from drill holes and ranged in depth from 128 feet to 1,050 feet bgs.

Different combinations of the three basic lithologies, quartzite, argillite, and siltite, were found in the drill hole samples. Quartzite contained 0.02 to 2.5 percent pyrite, while the quartzite/siltite combination contained 1.63 to 2.99 percent pyrite. The Quartzite/argillite combination contained an average of 2.04 percent pyrite. Argillite alone contained 0.3 to 1.16 percent pyrite, while argillite/siltite combination contained 1.07 to 1.43 percent pyrite. Siltite alone contained 0.4 percent pyrite (Walker and Associates 2003). Thus, pyrite is quite common in all potential waste rock types, but most common in the lithologies that have interbedded quartzite and siltite or quartzite and argillite.

Table 3.5-3 summarizes the results of the static ABA tests completed by Walker and Associates (2003) on expected waste rock for the Hollister Development Block Project. Sixty-four samples of all rock types were analyzed for ABA testing. Net neutralizing potential (NNP) is the difference between the acid neutralizing potential (ANP) and the acid generating potential (AGP) of a rock and is the measure of whether the rock has the potential to generate acidic effluent when exposed to water and oxygen. An NNP less than +20 tons of calcium carbonate/Kiloton of rock (t/Kt) is suggestive of the potential for generation of acidic effluent (BLM 2010b).

Andesite is a minor component of the waste rock at Hollister and is the only lithology with a positive average NNP. This lithology has an average NNP of 3.05 t/Kt and an average content of 0.03 percent pyrite. The average NNP of the andesite is below 20 t/Kt, making the rock type potentially acid generating. The argillite has an average NNP of –35.2 t/Kt and an average pyrite content of 1.13 percent. The quartzite has an average NNP of –29.4 t/Kt and an average pyrite content of 0.92 percent. The siltite contains the most pyrite at an average of 2.0 percent and has an average NNP of –60.5 t/Kt. Thus, all of the rock types expected to be mined and comprise part of the waste rock for the Hollister project have the potential to be acid generating and can be classified as PAG rock. This was confirmed by Walker and Associates (2003) in HCT tests on 14 samples, which showed rapid oxidation of the pyrite after the first week in tests that were conducted for 11 weeks in some samples and for 3 weeks in others, with pH values for the effluents starting below 5.0 standard units and usually ending below 3.0 standard units.

The Nevada Division of Environmental Protection (NDEP) and the BLM (BLM 2010b) require that all potential waste rock be tested using the Nevada MWMP test methodology to determine the potential for generation of effluent elevated in metals and sulfate if rain or snow melt contacts the waste rock and potentially infiltrates into the waste rock pile. **Appendix B1**, **Table B1-3** contains summary results from the MWMP tests on expected waste rock from the underground operations. The pH in these tests ranged from 3.13 to 6.58 standard units. Most pH values were below 6.0 standard units, indicating the acid generating nature of the waste rock. Overall, pH was generally below NDEP Profile I standards.



Legend

- Water Supply Well Location, Vinini Aquifer
- Water Supply Well Location, Tertiary Volcanic Aquifer
- Piezometer Location, Vinini Aquifer
- Piezometer Location, Tertiary Volcanic Aquifer
- Monitor Well Location
- 1200 / 7.68 — pH; Concentration of Sulfate, in milligrams per liter, April 2009, unless indicated otherwise
- Abandoned Monitor Well Location
- West Pit Staff Gauge Location
- Stream Sample Location
- Surface Water Diversion Channel
- Pre-mining Stream Channel (Covered By Waste Rock)
- Surface Water
- Previous Disturbance by Historic Surface Mining (Approximate Location)

Sulfate Concentrations (milligrams per liter)

- <250
- 251 - 500
- 501 - 1000
- 1001 - 5000
- >5000

Yellow where pH is <6.50

0 500 1,000 1,500 2,000 Feet

Source: Montgomery and Associates 2010a.

Figure 3.5-12
Sulfate and pH Values in Perched Aquifer

Hollister Underground Mine Project EIS

03/19/2012

Table 3.5-3 ABA Summary by Rock Type

Sample Site Units	Rock Type	NNP tons $CaCO_3$/kiloton Rock	Pyritic Sulfur (S) weight %
IH020 330-335	Quartzite	-52.8	1.69
IH020 285-295	Quartzite	-79.1	2.53
IH020 340-350	Quartzite	-6.6	0.21
IH149 198-206	Quartzite	-0.6	0.02
IH149 128-138	Andesite	8.3	-0.01
IH149 181-186	Andesite	-2.2	0.07
DDH88071 A 440-445	Quartzite	-35.9	1.15
DDH88071 A 459-463	Argillite	-36.3	1.16
IH209 1016-1026	Quartzite	-24.8	0.88
IH209 1040-1050	Quartzite	-1.7	0.3
IH-208 514-522-4	Quartzite	-42.2	1.35
IH-208 530-537	Argillite	-50.3	0.71
IH-208 547.9-556	Argillite	-11.6	0.85
IH157 1016-1026	Quartzite	-2	0.53
IH-112 308-318	Quartzite	-63.8	1.36
IH-083 587-596	Quartzite	-81.6	0.31
IH-083 596-605.7	Siltite	-93.4	0.54
IH-070 695-705	Quartzite	-44.7	0.39
IH-059 641-651	Argillite	-33.4	1.07
IH-059 651-661	Argillite	-44.4	1.42
IH-057 528-538	Quartzite	-12.6	0.41
IH-013 700-710	Siltite	-50.4	1.63
IH 013 690-700	Quartzite	-42.8	1.37
BH02 650-655	Siltite	-43.1	1.42
BH02 660-665	Siltite	-48.2	1.7
BH02 665-670	Quartzite	-19.1	0.62
BH02 675-680	Quartzite	-24.2	0.83
BH02 670-675	Quartzite	-21.5	0.83
BH02 680-685	Siltite	-56.8	1.92
BH02 655-660	Siltite	-33.2	1.14
BH03 600-605	Quartzite	-30.3	0.97
BH03 605-610	Quartzite	-20	0.64
BH03 610-615	Quartzite	-15.9	0.51
BH03 615-620	Quartzite	-15.9	0.51
BH03 620-625	Quartzite	-49.7	1.59

Table 3.5-3 ABA Summary by Rock Type

Sample Site Units	Rock Type	NNP tons $CaCO_3$/kiloton Rock	Pyritic Sulfur (S) weight %
BH03 625-630	Quartzite	-26.2	0.95
BH03 630-635	Quartzite	-16.4	0.54
BH05 510-515	Siltite	-71.2	2.55
BH05 515-520	Siltite	-69.6	2.37
BH05 520-525	Siltite	-63.1	2.02
BH05 525-530	Siltite	-73.8	2.36
BH05 530-535	Sillite	-63.5	2.04
BH05 535-540	Siltite	-83.2	2.67
BH05 540-545	Siltite	-95.9	3.07
BH06 400-405	Quartzite	-22.2	0.71
BH06 405-410	Quartzite	-26.6	0.85
BH06 410-415	Quartzite	-16.6	0.53
BH06 415-420	Quartzite	-42.5	1.36
BH06 420-425	Quartzite	-7.44	0.31
BH06 425-430	Quartzite	-10.9	0.54
BH06 430-435	Quartzite	-12.2	0.39
BH08 945-950	Quartzite	-19.9	0.88
BH08 950-955	Siltite	-24.4	0.96
BH08 955-960	Siltite	-31	1.22
BH08 960-965	Quartzite	-48.3	1.78
BH08 965-970	Quartzite	-41.9	1.49
BH08 970-975	Quartzite	-29.7	1.17
BH08 975-980	Quartzite	-21.3	0.95
BH08 980-985	Quartzite	-63.2	2.36

$CaCO_3$ = calcium carbonate.

Source: Walker and Associates 2003.

Arsenic occasionally exceeded the standards, while iron and antimony frequently exceeded the standards. Nevada wildlife propagation standards and stock water standards were exceeded for pH (**Appendix B1, Table B1-1**). Stock water standards also were exceeded occasionally for fluoride. A study completed by Hecla Ventures (2004) evaluated the effectiveness and addition rate of dolomite, which was the material determined to be the most effective in neutralizing the acid generation of Hollister waste rock. These tests were conducted using equal amounts of quartzite and argillite/siltite, which is representative of the Hollister waste rock. Humidity cell tests were run for 20 weeks using various ratios of dolomite additions. All results indicated that the ANP:AGP ratio of 1:2 was sufficient in preventing acid generation. Further, the results indicated there was no additional benefit to increasing the ANP:AGP ratio to greater than 1:2. It also was determined through this test work that the addition of dolomite essentially

eliminated constituent mobility from the waste rock. However, the BLM guidance requires an ANP:AGP ratio of 3:1, which would require dolomite additions to increase from approximately 4 percent by weight to approximately 9.7 percent by weight of dolomite. This policy requires sufficient neutralization potential from carbonate material in the rock to offset the AGP and allows for the carbonate material to be consumed faster than the acid generating material, thus ensuring that the rock would not be acid generating.

3.5.1.5 Existing Open-pit Project Waste Rock Storage Facilities

There are currently four existing Newmont-reclaimed WRSFs from past open-pit mining activities by other operators located at the Hollister Site. These are the Newmont-reclaimed North, South, East, and West WRSFs (**Figure 2-1**). In addition, there is a rinsed and reclaimed spent heap leach facility (MWH Americas, Inc. 2007). The Newmont-reclaimed East WRSF comprises approximately 6 acres and contains mostly oxidized material with an NNP ranging from 4.8 to 19.4 t/Kt (MWH Americas, Inc. 2007). The ANP:AGP ratio is 3:1, so the rock is considered to be non-acid generating. The WRSF is covered with 6 inches of vegetated topsoil. Following a very wet year in 2005, seepage from the Newmont-reclaimed South WRSF was elevated in sulfate in 2006 but had a neutral pH (MWH Americas, Inc. 2007). This seepage drained to Little Antelope Creek, approximately 500 feet from the Newmont-reclaimed South WRSF.

The Newmont-reclaimed South WRSF, also located near Little Antelope Creek, comprises 26 acres and contains both oxide and sulfide waste rock. The NNP for waste rock in this WRSF ranges from –58 to +271 t/Kt (MWH Americas, Inc. 2007). The average NNP is about 1.36, and the average ANP:AGP ratio is about 1.18:1, making this WRSF potentially acid generating (MWH Americas, Inc. 2007). In 1996, acidic water was found seeping from the Newmont-reclaimed South WRSF and was pumped to the West Pit. Limestone was added to the top 12 feet of the WRSF, and this upper limed cap was covered with 12 inches of topsoil and vegetated. The Newmont-reclaimed South WRSF continued to produce seepage with a pH between 4.0 and 6.5 standard units and elevated sulfate, so a passive bioreactor was constructed to intercept and neutralize the seepage before it reached Little Antelope Creek (MWH Americas, Inc. 2007). This bioreactor did not work as planned and is currently not operational. Seepage from the Newmont-reclaimed South WRSF flows through an upland/wetland area. Little Antelope Creek (LAC) downstream from the Newmont-reclaimed South WRSF is currently elevated in sulfate (**Table 3.6-4**).

The reclaimed heap leach pad covers 31 acres and has a 60-mil geocomposite liner underlain by compacted soil (MWH Americas, Inc. 2007). The heap leach pad was rinsed from 1993 to 1996 and is covered by 6 to 12 inches of vegetated topsoil. The long-term draindown rate is 1.0 to 1.6 gpm. The spent material in the reclaimed heap leach pad is potentially acid generating but monitoring data indicates neutral pH and slowly increasing alkalinity over time (MWH Americas, Inc. 2007). The draindown water contains elevated sulfate, selenium, arsenic, mercury, nitrate, and TDS with a neutral pH (MWH Americas, Inc. 2007). In 1999, the draindown water was mixed with organics in an infiltration leach field to reduce the potential influx of contaminants to groundwater. The leach field is monitored by well HOL-NEWP with well HOL-MW-1 as the background well. The HOL-NEWP monitor well samples show elevated pH, TDS, chloride, cyanide, nitrate, sulfate, calcium, potassium, magnesium, sodium, arsenic, boron, barium, and selenium compared to the background monitor well.

3.5.1.6 Existing RCG Waste Rock Storage Facility

There currently is an active RCG WRSF at the Hollister Site that is being used for storage of waste rock generated by the underground workings for exploration. The permitted facility is located in the East Pit (see Chapter 2.0). The design capacity of this facility is 612,000 cubic yards (yd^3) covering 7.2 acres. The facility is lined with a high-density polyethylene liner system and synthetically lined wet well sumps to capture seepage from the facility. Dolomite was placed above the liner to neutralize the acidity of any seepage. Water collected in the wet well sumps is treated in the Hollister reverse osmosis plant or the

de-silting facility, as needed, before the water is discharged to the existing RIBs. Operation of the facility and discharge of treated water is in accordance with NDEP Water Pollution Control Permits, as discussed in Chapter 2.0. Groundwater monitoring wells have been installed downgradient of the facility.

3.5.2 Environmental Consequences

The environmental consequences of the Proposed Action and alternatives relative to water quantity for the proposed project involve the impacts associated with geotechnical water removal from the expanded Hollister underground workings and the proposed Hatter Expansion. To estimate the potential impacts of groundwater removal by the expanded underground workings, RCG contracted with Brown and Caldwell to develop a three-dimensional numerical groundwater flow model for the Hollister Mine and vicinity. The model covers an area of approximately 590 square miles centered on the Hollister Mine workings, as shown in **Appendix B2, Figure 3-2**. The principal geologic unit affected by groundwater removal is the Vinini Formation. Principal surface water features within the model domain are Rock Creek, Willow Creek, Little Antelope Creek, and Antelope Creek. The groundwater model is discussed in detail in **Appendix B2**. Potential impacts to seeps and springs associated with groundwater withdrawal are addressed in Section 3.6.2, Surface Water Resources, Environmental Consequences.

Environmental consequences relative to water quality for the Proposed Action and alternatives consist of: 1) the water quality of the proposed Hollister Mine and Hatter Expansion underground workings as the workings refill with water after cessation of mining; 2) potential water quality impacts related to disposal of PAG waste rock on the surface in the Hollister Mine area; and 3) potential water quality impacts to Little Antelope Creek due to disposal of waste rock on the surface. Water quality impacts due to refilling of the underground workings were assessed with geochemical modeling; this model is described in Section 3.5.2.2, Geochemical Model. Water quality impacts due to waste rock disposal were assessed using standard NDEP- and BLM-required ABA, HCT, and MWMP tests.

3.5.2.1 Groundwater Model

<u>Conceptual Hydrogeologic Model</u>

Groundwater models are designed and constructed based on a conceptual understanding of the geology, hydrogeology, and groundwater flow in the area of the proposed model domain. Details on the geology can be found in Section 3.4.1, Affected Environment. The hydrogeology and groundwater elevations for the hydrostratigraphic units at the Hollister Mine are discussed in Section 3.5.1, Affected Environment. This section focuses on the conceptualization of the hydrogeology for the groundwater model.

There are three main geologic units in the Hollister Mine area: 1) volcanic rock; 2) the Vinini Formation, which contains the gold veins of the Hollister Mine; and 3) the Rodeo Creek unit. The Vinini Formation is thrust over the Rodeo Creek unit by the Roberts Mountain Thrust. The volcanic rock unconformably overlies the Vinini Formation and is separated from the Vinini Formation in the project area by clays and re-worked quartzite that form a low hydraulic permeability layer between groundwater in the volcanic rock and groundwater in the Vinini Formation. The carbonates of the Rodeo Creek unit lie approximately 6,500 feet below the surface and approximately 4,500 feet below the lowest part of the proposed underground workings in the expanded Hollister and the Hatter Expansion areas (Brown and Caldwell 2010a). Slow seepage from the saturated Vinini Formation into the underground workings requires geotechnical groundwater pumping to allow underground access to the gold-bearing Clementine, Gwenivere, and Hatter Expansion area veins. Water levels in the Vinini Formation have declined up to 300 feet due to local geotechnical groundwater removal by mine sumps during underground exploration in the Hollister area, while water levels in the overlying volcanic rock have shown only seasonal fluctuations (**Figure 3.5-10**). The Hatter Graben, which would contain the proposed Hatter Expansion area, is separated from the Hollister area by the Little Antelope Creek Fault

(**Appendix B2, Figure 2-1**), although the two areas are hydraulically connected. On the west, the veins of the Hollister area are bounded by the Butte Fault.

Regional groundwater elevations and flow directions for the bedrock and alluvial aquifers in the Carlin Trend, prior to initiation of dewatering, are shown in **Figure 3.5-5**. These elevations are a composite of water levels in all formations, including alluvial valley fill. In the mountainous areas, the composite water levels reflect the uppermost bedrock units. In the valleys, the water levels reflect groundwater elevations in alluvial valley fill. Recharge for the regional bedrock aquifers is along the Tuscarora Mountains, which are northeast and upgradient from the Hollister Site. In the vicinity of the project area, Vinini Formation groundwater flows southwest with the ridge that contains the Hollister Site acting as a groundwater divide (**Figure 3.5-5**). Groundwater flow in the volcanic rock around the Hollister Site is controlled by local topography and flows to the southeast toward Little Antelope Creek (Brown and Caldwell 2011a). The maximum extent of the 10-foot groundwater drawdown contour in the Vinini Formation in the project area is shown in **Figure 3.5-9**.

Groundwater flow in the Vinini Formation is controlled by faults, fractures, bedding planes and lithology, with the quartzites of the Vinini Formation being more conductive to groundwater flow, especially in the underground workings (Brown and Caldwell 2010a). The Little Antelope Creek Fault is a mixture of shattered rock and areas of ductile deformation, suggesting that it may not be a barrier to groundwater flow (Brown and Caldwell 2010a).

Hydraulic conductivity estimates for the Vinini Formation from constant-rate discharge tests range from approximately 0.10 feet/day for tests conducted with water wells to 2.4 feet/day for estimates from airlift tests. The storage coefficient estimated from the pumping tests is approximately 0.008 (Brown and Caldwell 2010a).

Groundwater Model Development

A detailed description of the numerical groundwater model developed for the proposed Hollister Mine and Hatter Expansion area is included in **Appendix B2**.This model was based on earlier screening-level models used to estimate groundwater flow into the existing underground exploration workings and anticipated additional groundwater flow associated with currently approved operations. These models showed that hydraulic conductivity values for the Vinini Formation of approximately 0.1 feet/day with higher values of approximately 1.12 feet/day in the exploration decline segments were appropriate for estimating the current inflow rates of approximately 335 to 385 gpm. Storage coefficients of approximately 0.008 and a specific yield of approximately 0.01 also were used in the screening-level models to match current groundwater inflow rates into the underground workings (Brown and Caldwell 2010a). Specific details regarding the groundwater model development and calibration are described in **Appendix B2**.

The groundwater model developed for the Proposed Action (Hollister mine area and the Hatter Expansion area) has the expressed purpose of estimating groundwater removal requirements and associated drawdown in the Vinini Formation. Its calibration to existing monitoring wells is limited to a few wells in the Vinini Formation near the current Hollister underground workings. The transient calibration to water levels in these wells and the matching of historic geotechnical water removal requirements in the current underground workings suggest that the model, although limited in nature, is suitably calibrated and sufficient for estimating groundwater drawdown in the Vinini Formation due to projected future mine groundwater removal.

3.5.2.2 Geochemical Model

The underground workings at the proposed Hollister Mine and Hatter Expansion areas would fill with water after the cessation of mining. Water levels eventually would reach a steady-state level close to pre-mining levels. For the proposed project, mining would cease around 2030. For the Hollister Mine, the

underground workings are predicted to be approximately 92 percent filled with water by 2050 and 99 percent recovery of groundwater levels would occur around year 2130 (Enchemica 2010). For the Hatter Expansion area, the underground workings are predicted to be more than 90 percent filled with water by 2060 and 99 percent recovery of groundwater levels would occur around 2115 (Enchemica 2010). The underground workings would be backfilled with waste rock, and the volume of the waste rock would be approximately 25 to 30 percent of the total volume of the underground workings at Hollister and the Hatter Expansion areas by the end of mining. The waste rock would be stabilized with concrete approximately every 6 feet (Enchemica 2010). (Note: the geochemical model assumed that mining would begin in 2010. Therefore, the various dates used through this document should be interpreted as the number of years that have passed since the hypothetical start of mining – 2010.)

Conceptual Geochemical Model

Groundwater from the Vinini Formation seeping into the underground workings at the Hollister and Hatter Expansion areas at the end of mining would react with sulfides and other minerals in the wall rock of the underground workings and the waste rock left in the underground workings, and would react with the concrete used to stabilize the waste rock. These reactions would result in the release of constituents from the wall rock, waste rock, and concrete. Constituents for which solubility has been exceeded would precipitate in the water. Some constituents would adsorb onto ferrihydrite (iron oxyhydroxide) as it precipitates. **Appendix B3, Figure 4-1** summarizes the conceptual reactions that are expected as the underground workings refill with water.

Geochemistry Model

A detailed description of the geochemistry model developed for the proposed Hollister Mine and Hatter Expansion area is included in **Appendix B3**. The geochemical modeling approach used the U.S. Geological Survey equilibrium geochemical modeling code PHREEQC (version 2.17) (Parkhurst and Appelo 1999) to conduct the batch mixing, estimate the reactions that would occur under equilibrium conditions between the inflowing groundwater, wall rock, waste rock, and concrete, and then determine the final water chemistry by precipitating allowed phases and modeling adsorption onto precipitating ferrihydrite.

The approach taken to modeling the post-mining final water quality in the underground workings was that of a fully mixed batch reactor (Enchemica 2010). The inflowing groundwater contains constituents found naturally in the Vinini Formation. This water then reacts with the wall rock of the underground workings. A mass of constituents is released and dissolved by the inflowing water based on the exposed surface area of the wall rock and the reactivity of the minerals in the wall rock. The waste rock left in the underground workings and the concrete also would react with water filling the underground workings due primarily to sulfate in the mine water. The addition of constituents from the wall rock, waste rock, and concrete results in chemical reactions within the inflowing water, and select solid phases precipitate, removing some constituents from solution. Iron precipitates as ferrihydrite (iron oxyhydroxide) and many metals adsorb onto the surface of the ferrihydrite and are removed from solution by precipitation of the ferrihydrite. The final chemistry of the water filling the underground workings is thus determined by chemical reactions between the inflowing groundwater and the wall rock, waste rock, and concrete as well as chemical reactions that occur in the water resulting in removal of some constituents by precipitation and adsorption.

Details regarding the geochemical model approach and background information are provided in **Appendix B3**. The geochemical and groundwater flow models would be updated a minimum of every 5 years throughout the life of the project. As the mining progresses and information from mining operations is obtained, actual data would be utilized in the model recalibrations as applicable to update the models and modeling information. The modeling results per each model would be reported to the BLM. Monitoring and mitigation is discussed in Section 3.5.4.

3.5.2.3 Proposed Action

Water Quantity Impacts

Hollister Mine – Hatter Expansion Area Impacts

Water quantity impacts associated with the Proposed Action were modeled using the given parameters discussed above and in **Appendix B2**. To model the required geotechnical groundwater removal needed to keep the underground mine workings dry as they advance over the course of the proposed development of the Hollister and Hatter Expansion areas, Brown and Caldwell (2010a) utilized the drain package of MODFLOW-SURFACT to simulate the underground workings. **Appendix B2, Figure 5-1** shows the arrangement of the drains used to model water removal by the underground workings. **Appendix B2, Table 5-2** gives the schedule of implementation of the drains in the predictive modeling of groundwater withdrawal. These drains have a length equal to the model cell length (100 feet), a width comparable to the expected underground mine width (20 feet), and a thickness of 1 foot. The hydraulic conductivity used in estimating the conductance of the drains was the same as the hydraulic conductivity used for the layer in which the drain exists.

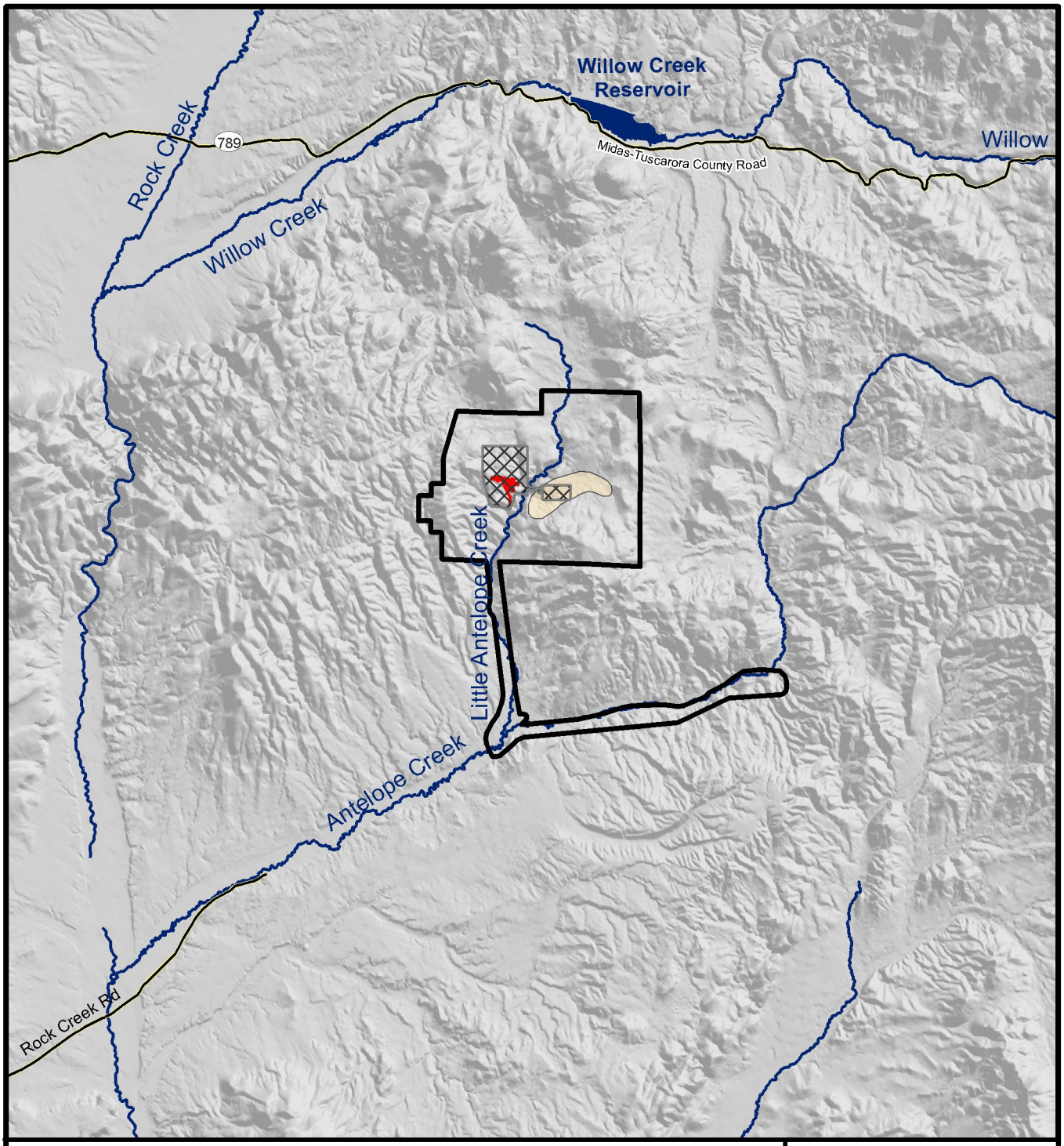
The modeled groundwater removal rate for the life of the proposed Hollister Mine and Hatter Expansion areas is shown in **Appendix B2, Figure 5-8**. The maximum rate of groundwater seepage withdrawal would be approximately 1,100 gpm, and this would occur in approximately year 2015. After that, the rate would drop and stabilize at approximately 600 to 700 gpm for the remainder of the proposed mine life. Currently, groundwater removal is at a rate of approximately 400 gpm.

The simulated drawdown in the Vinini Formation at the end of 2016 is shown in **Appendix B2, Figure A-6**. The predicted drawdown at the end of 2 016 in the Hatter Expansion area is approximately 600 feet. The maximum predicted drawdown in the Hollister Mine area is approximately 550 feet. Simulated water levels in the Vinini Formation at 2016 are shown in **Appendix B2, Figure A-3**. Groundwater would seep into the mine workings rather than continue downgradient to the southwest. The simulated drawdown in the Vinini Formation at the end of mining in 2030 is shown in **Figure 3.5-13**. By the end of mining, drawdown in the Hatter Expansion area is predicted to be approximately 1,400 feet, and drawdown in the Hollister area is predicted to be approximately 200 feet due to refilling of the Hollister workings. Simulated groundwater levels in the Vinini Formation in 2030 are shown in **Figure 3.5-14**. By the end of mining in 2030, groundwater would be seeping into the Hatter Expansion area from a broad area around the project. The Hatter Expansion area would act as a regional sink for groundwater flow in the Vinini Formation.

The maximum extent of the groundwater drawdown contour is predicted to occur in year 2070, approximately 40 years after the cessation of mining, as shown in **Figure 3.5-15**. Water levels in the Vinini Formation at the predicted maximum extent of drawdown in 2070 are shown in **Figure 3.5-16**. The maximum extent of the 10-foot groundwater drawdown contour is predicted to extend just beyond Antelope Creek to the southeast and just beyond Willow Creek to the northwest.

A screening methodology was used to evaluate potential impacts to seeps and springs associated with groundwater drawdown. The following steps were involved in this screening process.

As a first step in the analysis, springs located within the maximum extent of the 10-foot groundwater drawdown contour area within the Vinini Formation were identified. These springs, including an indication of their surface location and geology, are listed in **Appendix C, Table C-1**. Their locations are shown in **Appendix C, Figure C-1**.



Legend

- Project Area Boundary
- 2030 Simulated Drawdown (feet)
- Streams
- Roads
- Intrusive Area (Model Low Permeability Area)
- Existing Underground Exploration Workings
- Proposed Action Conceptual Underground Workings Areas

Note: Mining activities for the Proposed Action are simulated to end in 2030.
Source: Brown and Caldwell 2010a.

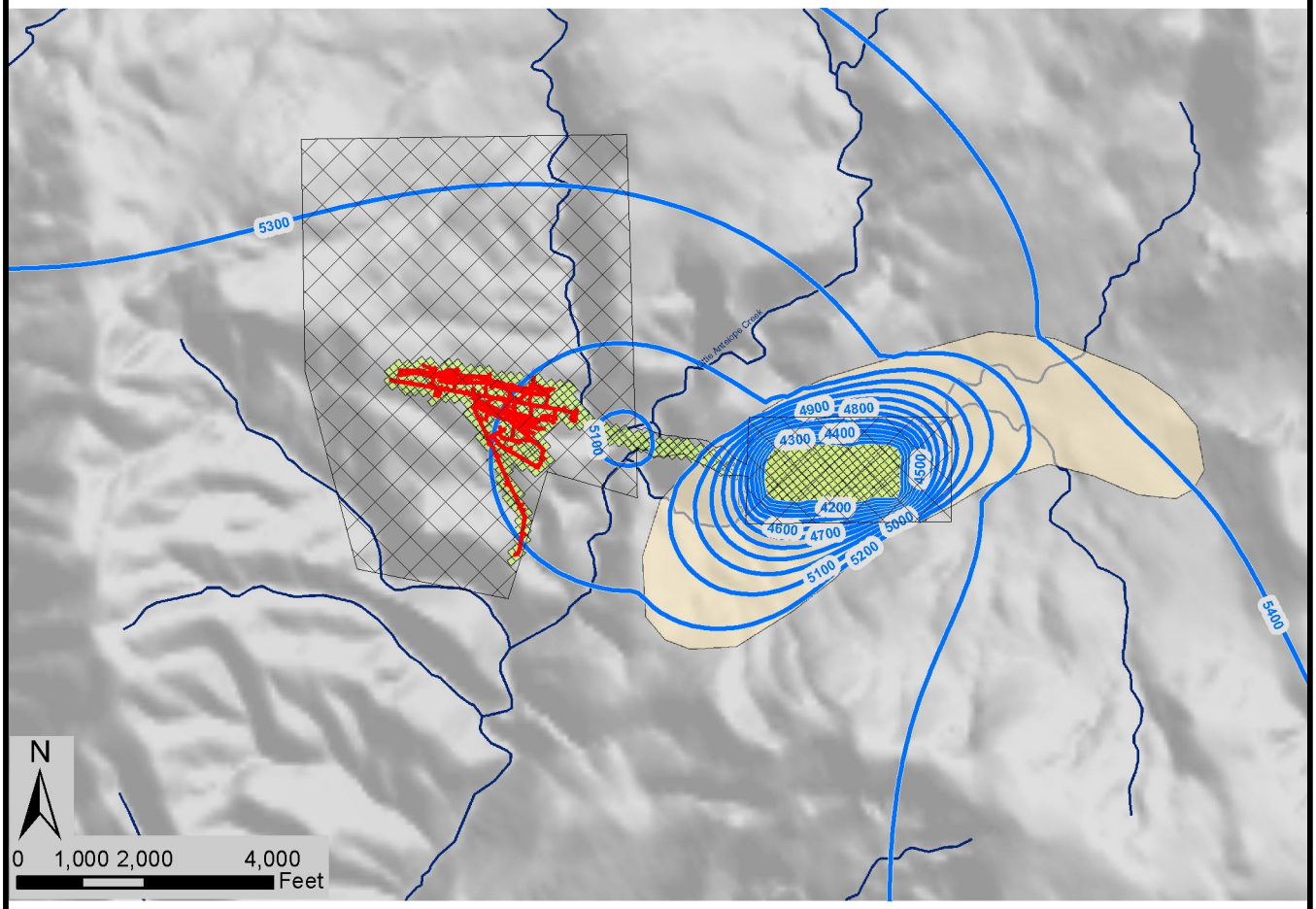
N

0 1.25 2.5 Miles

Hollister Underground Mine Project EIS

Figure 3.5-13

Proposed Action Simulated Drawdown in the Vinini Formation in 2030



Legend

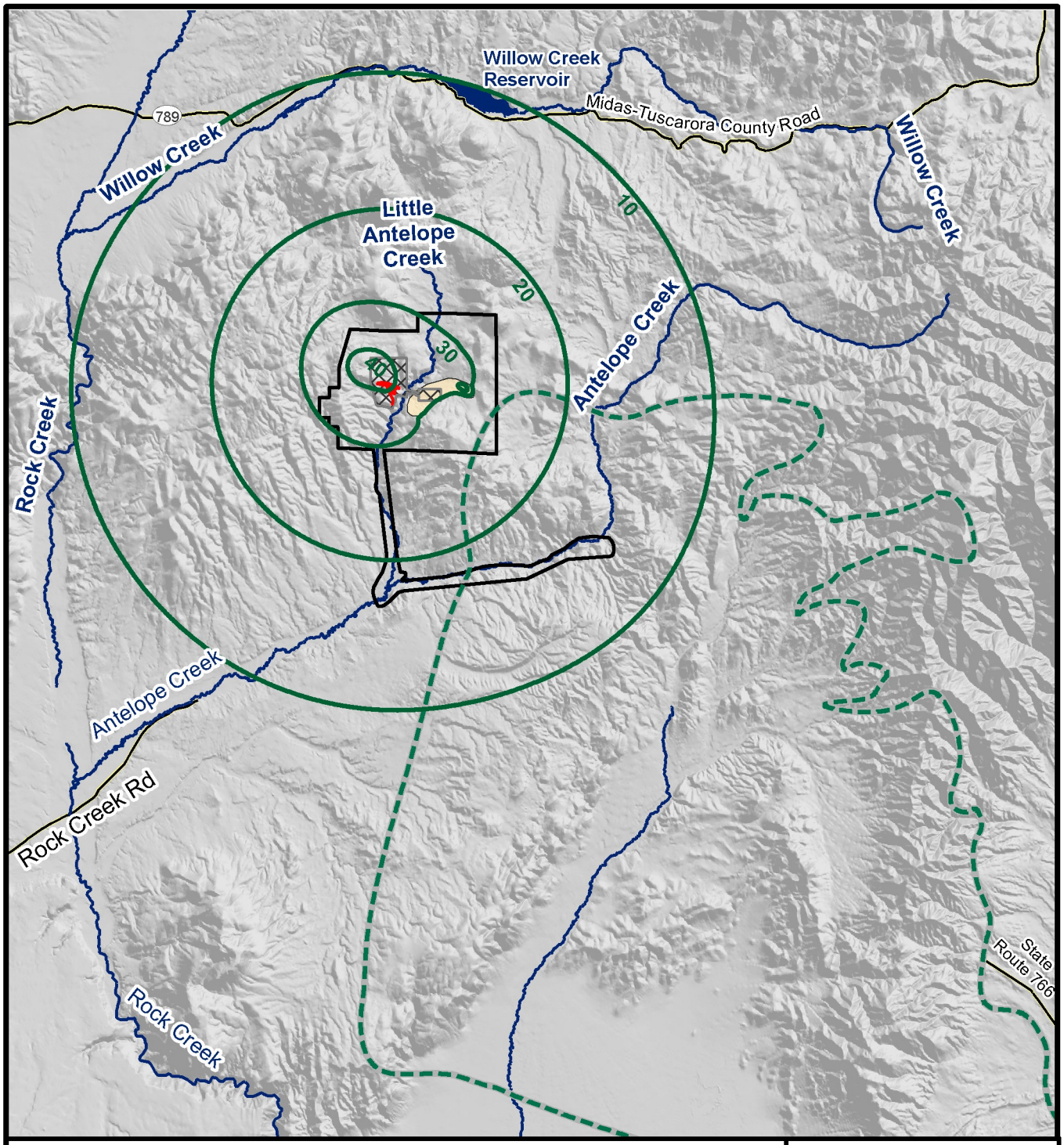
- 2030 Simulated Water Levels (feet amsl)
- Simulated Drain Cells
- Existing Underground Exploration Workings
- Intrusive Area (Model Low Permeability Area)
- Proposed Action Conceptual Underground Workings Area
- Streams

Note: Mining activites for the Proposed Action are simulated to end in 2030.
Source: Brown and Caldwell 2010a.

Hollister Underground Mine Project EIS

Figure 3.5-14

Proposed Action Simulated Water Levels in the Vinini Formation in 2030



Legend

- Project Area Boundary
- Maximum Extent of Drawdown (drawdown in feet)
- Existing Underground Exploration Workings
- Intrusive Area (Model Low Permeability Area)
- Proposed Action Conceptual Underground Workings Areas
- Maximum Extent of Barrick Cumulative 10-foot Drawdown Contour (Barrick 2007 Model)
- Roads

Note: Mining activities at the Hatter Expansion area simulated to stop in 2030.
Source: Brown and Caldwell 2010a.

N

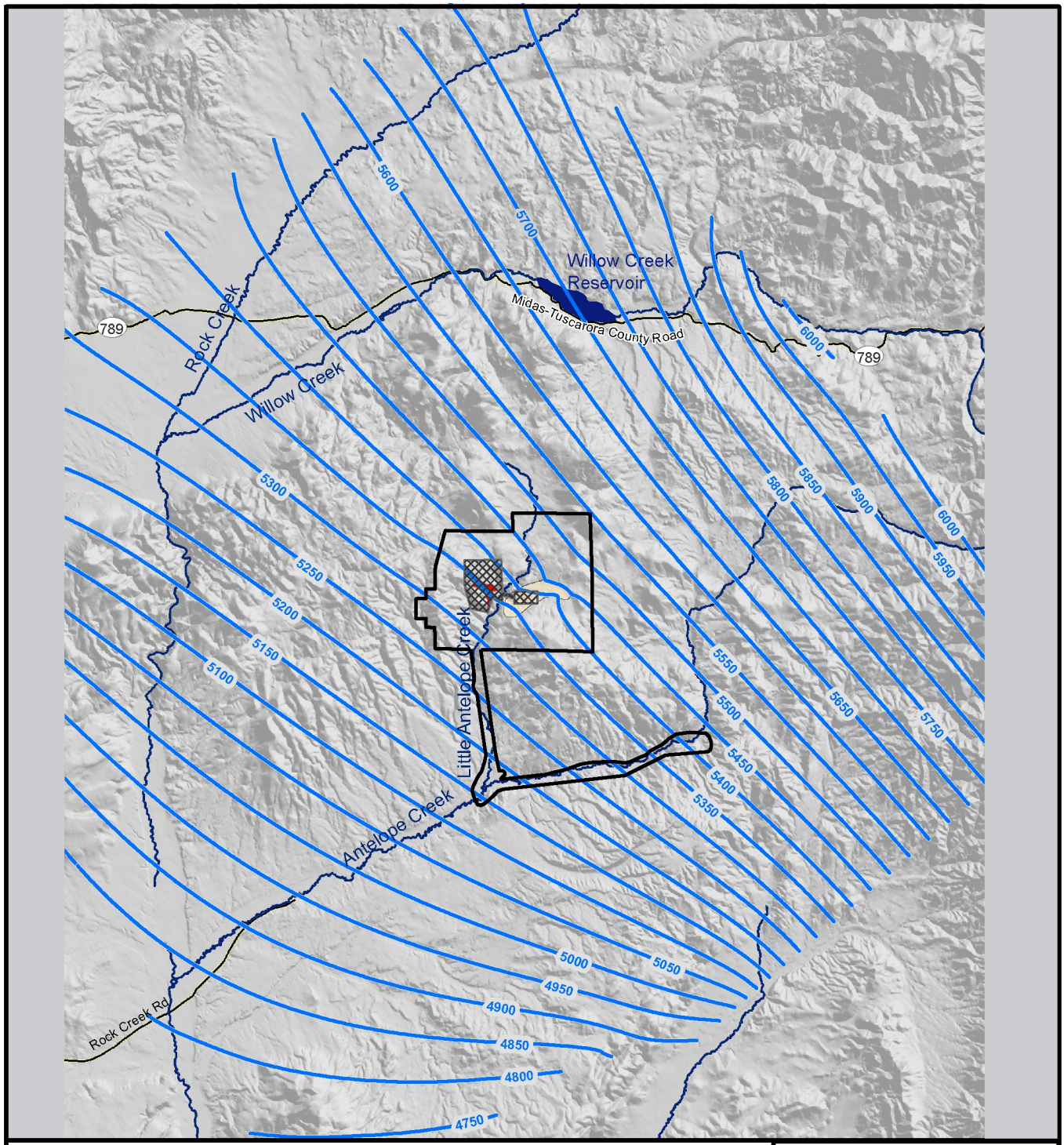
0 2 4 Miles

Hollister Underground Mine Project EIS

Figure 3.5-15

Proposed Action Simulated Maximum Extent of 10-foot Drawdown (2070)

2/29/2012



Legend

- Project Area Boundary
- 2070 Simulated Water Levels (feet amsl)
- Existing Underground Exploration Workings
- Intrusive Area (Model Low Permeability Area)
- Proposed Action Conceptual Underground Workings
- Streams
- Roads

Source: Brown and Caldwell 2010a.
Note: Mining activites for the Proposed Action were simulated to end in 2030.

N

0 1.5 3 Miles

Hollister Underground Mine Project EIS

Figure 3.5-16

Proposed Action Simulated Water Levels in the Vinini Formation at Time of Maximum Extent of Drawdown (2070)

02/29/2012

In the next step, springs within the predicted maximum extent of the 10-foot groundwater drawdown contour were evaluated relative to the geology of the water source. Springs sourced in the Vinini Formation within the maximum extent of the 10-foot groundwater drawdown contour potentially could be affected by drawdown in the Vinini Formation. Springs in Pennsylvanian/Permian units (Strathearn Formation) above the Vinini Formation within the maximum extent of the 10-foot groundwater drawdown contour may be affected by drawdown in the Vinini Formation if there is a hydraulic connection between these geologic units and the Vinini Formation. Springs in volcanic rock are not expected to be affected by drawdown in the Vinini Formation because of the extensive clay and silica alteration in the volcanic rock (Brown and Caldwell 2011a). Springs in the Tertiary Carlin Formation are not anticipated to be affected by drawdown in the Vinini Formation because the Carlin Formation is not likely to have hydraulic connection to the Vinini Formation due to clay in the Carlin Formation. **Appendix C, Table C-1** summarizes the geologic information of the springs, and **Appendix C, Figure C-2** shows all springs in the project vicinity and their geologic associations.

In the third step, springs within the maximum extent of the 10-foot groundwater drawdown contour were classified according to their specific geologic formation, groundwater elevation, and spring elevation. Springs sourced in the Vinini Formation with a spring elevation less than 50 feet above the groundwater elevation potentially would be affected by groundwater drawdown in the Vinini Formation. There also is a potential for springs sourced in the Strathearn Formation to be affected by groundwater drawdown in the Vinini Formation if there is a hydraulic connection between the Vinini and Strathearn formations. The 50-foot criterion (spring elevation less than 50 feet above the groundwater elevation) was selected based on the potential error in projecting the groundwater elevation contours in the Hollister area.

There are four spring complexes with some potential for impact by groundwater drawdown in the Vinini Formation (Section 3.6, Surface Water Resources and Watersheds, **Figures 3.6-4** and **3.6-5**). A spring complex is a local, geographically distinct area that contains one or more springs. A discussion of the specific seeps and springs potentially affected by groundwater drawdown associated with groundwater removal from development of the proposed Hollister Mine and Hatter Expansion area is provided in Section 3.6, Surface Water Resources and Watersheds.

Mining would end around 2030, and groundwater rebound would commence as the pumping is shut down. The simulated rebound of the water table shows recovery to within approximately 100 feet of the pre-mining water levels by 2050 at the Hollister area and by 2060 at the Hatter Expansion area. Ninety-five percent recovery of the water table would occur around 2060 at the Hollister area and 2065 at the Hatter Expansion area. Nearly full recovery of the water table (99 percent) would take until approximately year 2115 for the Hatter Expansion area (Enchemica 2010). Modeled groundwater refilling curves for the Hollister Mine and the Hatter Expansion areas are shown in **Appendix B2, Figures 5-9** and **5-10**, respectively.

Groundwater modeling results predict impacts to water levels in the Vinini Formation in the vicinity of the Hollister Mine with potential impacts to seeps, springs, and other water dependant resources as a result of geotechnical water removal under the Proposed Action.

Potential impacts to water rights are discussed in Section 3.6, Surface Water Resources and Watersheds.

West Pit WRSF Impacts

Under the Proposed Action, waste rock from underground mining at the Hollister and the Hatter Expansion areas would be disposed of by: 1) backfilling the underground workings, 2) surface disposal in the existing WRSF, and 3) surface disposal in the proposed West Pit WRSF. Because waste rock at both Hollister and the Hatter Expansion areas is PAG, the proposed WRSF in the existing West Pit would need to be a zero discharge facility. As discussed in Section 2.4.4.2, the West Pit WRSF would

have a geosynthetic liner on top of a base composed of non-PAG aggregate covered by compacted silt-sized material, and a wet well above the liner to remove any seepage to a facility where the seepage can be routed through the water treatment facility at the Hollister Mine. In addition, the sides of the West Pit would be lined with shotcrete (concrete sprayed onto a surface) over a height of 40 to 50 feet. Dolomite would be mixed with the PAG waste rock in a ANP:AGP ratio of 3:1 following BLM guidelines. The proposed West Pit WRSF would be reclaimed with a soil evapotranspiration cover and 6 to 12 inches of growth media (Section 2.4.4.2). This design would prevent seepage from the West Pit WRSF from reaching groundwater and would thus be protective of the perched aquifer water quantity and quality. No impacts to the perched aquifer are expected from the West Pit WRSF.

Currently, the West Pit serves as a groundwater sink for the perched aquifer in the volcanic rock (Brown and Caldwell 2010c). Evaporative loss from the pit was estimated at approximately 192,545 cubic feet per year (feet^3/year) (approximately 2.7 gpm) (Brown and Caldwell 2010c). When the pit is backfilled, evaporation from the pit would cease, and groundwater in the perched aquifer would flow through and past the pit, rather than being diverted toward the pit. The estimated flow-through rate for groundwater in the perched aquifer would be approximately 106,000 to 130,000 feet^3/year (Brown and Caldwell 2010c). This would result in an increased flux of groundwater flowing southeastward toward Little Antelope Creek of up to 1.8 gpm.

RIBs Impacts

Continued discharge of water to the RIBs located near the confluence of Little Antelope and Antelope creeks would result in localized mounding in the alluvial material beneath the RIBs. This increase in alluvial water levels would be limited to the immediate area of the RIBs.

Water Quality Impacts

Hollister and Hatter Expansion Area Impacts

The Hollister and the Hatter Expansion areas would fill with groundwater after cessation of mining. It would take approximately 200 years for both areas to completely fill with groundwater and reach steady-state water levels. Water quality in the underground mine water at steady-state is provided in **Table 3.5-4**. Under the total exposed surface area for waste rock backfill and wall rock of 5.411 square meters per liter (m^2/L), the mine water after 200 years is predicted to be alkaline with a pH of 10.2 and would exceed NDEP Profile I reference standards for aluminum, antimony, chromium, selenium, sulfate, thallium, and TDS. Geochemical modeling was also performed for the higher 54.11 m^2 of surface area to account for possible uncertainties in the particle sizes of the backfilled material. The results of this modeling were essentially the same as for the 5.41-m^2 particle size modeling with similar exceedences of the NDEP Profile I standards. Beryllium would exceed the NDEP Profile I standards in the case of the higher surface area of 54.11 m^2, but not in the case of the lower 5.41 m^2 of surface area. Sulfate would be approximately 1,600 mg/L, and the water would be calcium sulfate dominated. The level of sulfate in the mine water would be controlled by the precipitation of gypsum, and precipitation of ferrihydrite (iron oxyhydroxide) would limit the concentration of many metals due to adsorption onto the ferrihdyrite. Calcite precipitation would limit calcium and bicarbonate in the mine water.

Precipitation of silica as chalcedony, fluorite, kaolinite, sepiolite and torbermorite would limit the values of silica, fluoride, aluminum, magnesium, and calcium in the mine water. Barium and arsenic would be controlled by precipitation of a barium arsenate solid, and copper would be controlled by precipitation of tenorite (Enchemica 2010). Although the mine water would exceed NDEP Profile I reference values for some constituents, mainly pH, aluminum, antimony, beryllium, chromium, selenium, sulfate, thallium, and TDS, the mine water would not be accessed by wildlife or humans. Potentially, the mine water would migrate in fractures downgradient (southwest) from the mine workings.

Table 3.5-4 Mine Wall Rock and Waste Rock Surface Area Predicted Aqueous Concentrations

Water Quality Constituents	Mine Wall Rock and Waste Rock Surface Area		NDEP Profile I Reference Value
	Expected Average Surface Area ($5.411\ m^2/L$)	Expected Maximum Surface Area ($54.11\ m^2/L$)	
pH (standard units)	**10.24**	**10.32**	6.5 to 8.5
Pe (dimensionless)	10.32	3.04	--
Aluminum (mg/L)	**0.2164**	**0.2641**	0.2
Antimony (mg/L)	**0.02222**	**0.1381**	0.006
Arsenic (mg/L)	5.477×10^{-7}	4.100×10^{-6}	0.01
Barium (mg/L)	0.001997	6.134×10^{-4}	2.0
Beryllium (mg/L)	0.002037	**0.01684**	0.004
Boron (mg/L)	0.34651	2.516	--
Total inorganic carbon (as CO_3^{2-})	1.491	5.111×10^{-9}	--
Cadmium (mg/L)	1.427×10^{-4}	0.001451	0.005
Calcium (mg/L)	638.6	548.8	--
Chloride (mg/L)	30.17	75.12	400
Chromium (mg/L)	**0.2253**	**0.4303**	0.1
Copper (mg/L)	2.685×10^{-4}	2.880×10^{-4}	1
Fluoride (mg/L)	1.964	2.367	4
Iron (mg/L)	4.929×10^{-4}	5.948×10^{-4}	0.6
Lead (mg/L)	9.402×10^{-7}	1.055×10^{-5}	0.015
Magnesium (mg/L)	0.004043	0.003428	150
Manganese (mg/L)	3.004×10^{-8}	6.367×10^{-4}	0.1
Nickel (mg/L)	0.02087	0.05370	0.1
Nitrate as N (mg/L)	1.782	5.241	10
Potassium (mg/L)	43.48	414.1	--
Selenium (mg/L)	**0.3231**	**0.08062**	0.05
Silica (mg/L)	68.80	80.27	--
Sodium (mg/L)	56.83	298.2	--
Sulfate (mg/L)	**1,602**	**2,277**	500
Thallium (mg/L)	**0.03141**	**0.3158**	0.002
Zinc (mg/L)	1.935×10^{-5}	0.05634	5
Total Dissolved Solids (mg/L)	**2,473**	**3,736**	1,000
Ionic Strength (moles/L)	0.04528	0.06398	--

All units mg/L unless otherwise noted.

-- indicates no NDEP Profile I standard.

Bold = NDEP profile/reference value exceedences.

Source: Enchemica 2010.

Dilution of such constituents is expected to occur as native groundwater replaces the mine volume. Downgradient attenuation of water quality constituents is expected to occur due to dilution, hydrodynamic dispersion, and chemical processes (Brown and Caldwell 2012).

Because estimates of total exposed surface area require assumptions, there is a level of uncertainty associated with any estimate of exposed reactive surface area. To evaluate the possible maximum range of concentrations of constituents in the mine water, predictions of mine water chemistry also were run using an estimated exposed surface area of 54.11 m^2/L, which is 10 times that used in the base case predictions. These results also are given in **Table 3.5-4**. The main differences are a lower oxidation level (pe value of 3.04 vs 10.3), higher antimony, higher beryllium, higher boron, higher chloride and fluoride, higher chromium, much higher potassium and sodium, and considerably higher sulfate and TDS. Exceedences of the NDEP Profile I reference standards are the same as in the base case, with the addition of beryllium. As with the base case, the mine water would not be accessible to humans or wildlife.

Water that fills the post-mining underground workings when groundwater returns to steady state would have a TDS value well above Nevada drinking water standards (**Appendix B, Table B1-1**). The pH would be more alkaline than any Nevada standards, including stock water and wildlife propagation standards, because of the concrete used in the mine backfill. Antimony, thallium, and chromium would exceed drinking water standards, and beryllium would exceed those standards for the expected maximum surface area case. Selenium would exceed Nevada drinking water standards and stock water standards. Sulfate would exceed drinking water standards. The underground post-mining water quality would not meet drinking water standards or stock water standards for some constituents.

When post-mining groundwater levels reach steady-state, in excess of 130 years after cessation of mining, groundwater would then begin to flow through the refilled underground workings and transport the elevated constituents found in the refilled underground workings downgradient to the southwest. Brown and Caldwell (2012) estimated the concentration of key elevated constituents at the southwest project boundary using three-dimensional transport modeling with MODFLOW-SURFACT (Hydrogeologic 1996) and two-dimensional equilibrium reaction path modeling with PHREEQC (Parkhurst and Appelo 1999).

The estimated transport time from the underground workings to the southwest project boundary for the first flush of mine water is about 400 years. At the project boundary (approximately 2 miles southwest of the underground workings), after mixing with background groundwater, geochemical modeling predicts that the plume of first flush mine water would be elevated above NDEP Profile I standards for antimony, iron, sulfate, and thallium (**Appendix B, Table B1-4**). The results of the geochemical modeling (**Appendix B, Table B1-4**) represent the highest predicted constituent concentrations in groundwater at the project boundary, because the calculations were performed using the initial underground workings water composition and only two-dimensional dispersion was considered. Transport modeling was conducted on the four chemical constituents (iron, thallium, sulfate, and antimony) that geochemical modeling predicted to exceed Profile l standards at the project boundary to account for three-dimensional hydrodynamic dispersion. Transport modeling results indicate that at the project boundary at approximately 400 years: 1) iron is predicted to reach a maximum concentration of approximately 0.053 mg/L, which is lower than the 0.60 mg/L Profile l standard; 2) thallium is predicted to reach a maximum concentration of 0.00143 mg/L, which is less than the Profile l standard of 0.002 mg/L; 3) sulfate is predicted to reach a maximum concentration of approximately 101 mg/L, which is less than the Profile 1 standard of 500 mg/L ; and 4) antimony is predicted to reach a maximum concentration of 0.0104 mg/L , which exceeds the Profile l standard of 0.006 mg/L, but background concentrations are 0.010 mg/L and exceed the standard (Brown and Caldwell 2012). Although aluminum, chromium, and selenium concentrations in the underground workings water exceed their NDEP Profile I reference levels, the effects of dilution and moderating pH values during groundwater transport to the project boundary would result in concentrations below the NDEP Profile I reference value. In summary, when

three-dimensional hydrodynamic dispersion is considered in addition to geochemical reactions, only antimony is likely to exceed Profile I standards at the project boundary, but background concentrations of antimony already exceed the Profile I standard. Over time, continued flow of groundwater through the mine workings would result in lower concentrations of constituents being flushed from the mine workings.

West Pit WRSF Impacts

As discussed above under Water Quantity Impacts, the proposed West Pit WRSF would be designed to prevent seepage of effluent to groundwater, and would thus be protective of groundwater quality. No impacts to the perched aquifer groundwater quality are expected from the West Pit WRSF. Because backfilling of the pit would result in an increased flux of the perched aquifer groundwater in the volcanic aquifer toward Little Antelope Creek, the flux of high TDS water with elevated sulfate in the perched aquifer flowing toward Little Antelope Creek would be expected to increase by up to 1.8 gpm. Geochemical analysis using sulfate/chloride ratios (Brown and Caldwell 2010c) suggests that there is not a direct geochemical pathway from the West Pit area to the MA-1 seep in Little Antelope Creek. However, the changes in groundwater flow pathways that may result from the backfilling of the West Pit cannot be anticipated with certainty at this point. Therefore, continued monitoring of the MA-1 seep is recommended.

RIBs Impacts

No groundwater quality impacts are anticipated because current water discharge to RIBs from underground exploration meets water quality permit requirements and would be expected to continue to meet permit requirements under the Proposed Action.

Surface Exploration Impacts

Potential groundwater impacts would include localized aquifer water quality degradation from exploration drilling operations. Impacts would be minimized as all drill holes would be plugged and abandoned according to NAC 534 regulations. Water bearing zones would be sealed to prevent possible contamination between different aquifer zones (i.e., volcanic rock and Vinini Formation) in the drill holes. As a result of these groundwater protection measures, impacts to groundwater resources from surface exploration would be minimal.

3.5.2.4 Mud Springs Road Transmission Line Alternative

Removal of groundwater from mining operations would be the same under this alternative as under the Proposed Action. Therefore, estimated impacts to groundwater quantity and quality would be the same as under the Proposed Action.

3.5.2.5 Mud Springs Waste Rock Storage Facility Alternative

This alternative would allow for the placement of potentially acid-generating waste rock in a new WRSF located along Mud Springs Road east of the historic heap leach facility, as discussed in Chapter 2.0. The Mud Springs WRSF would contain approximately 1.1 million yd^3 of PAG waste rock intermixed with sufficient dolomite to ensure a 3:1 neutralizing capacity to reduce the potential for generation of acidic seepage. To meet the BLM guidance for neutralizing AGP from the 1.1 million cubic yards projected to be contained in the Mud Springs WRSF, an estimated 105 tons of dolomite must be mixed with every 1,000 tons of waste rock (see Section 2.4.4, Waste Rock Management, for how this tonnage rate was calculated). The facility would be lined and have a collection sump to collect any seepage. The site for the proposed facility would require considerable preparation to ensure long-term stability of the facility. Surface water diversion channels would be constructed around the facility. The waste rock would be covered during reclamation with a 36-inch soil and rock cover similar to the existing RCG WRSF and designed to minimize infiltration of precipitation and snowmelt (Section 2.2.10.3, Reclamation of Existing

RCG Waste Rock Storage Facility). Approximately 79,000 yd^3 of material would be imported for construction of the Mud Springs WRSF cover. No surface water or groundwater impacts are expected.

3.5.2.6 Backfill Alternative

Water Quantity Impacts

Under this alternative, RCG would backfill the Hatter production shaft, ramp, or raise (HPS) and the East and West escape raises with waste rock. The shaft and raises would be constructed with concrete liners for stability; over time this concrete can be expected to deteriorate and allow the entrance of groundwater into the shaft and raises. The waste rock backfill would allow passage of groundwater laterally through the shaft and raises due to its blocky, and thus porous, nature. This condition would be expected to enhance groundwater flow laterally through the shaft and raises once the groundwater table has recovered to steady state and pre-mining groundwater flow patterns have been restored. Thus, sections of the shaft and raises that are below the post-mining steady state groundwater level would be expected to experience lateral groundwater flow. A mound of non-PAG rock and soil would cover the backfilled openings to facilitate reclamation and diversion of surface drainage off the mound. The cover would be designed to minimize infiltration of meteoric water.

Water Quality Impacts

Under this alternative, the HPS and the East and West escape raises would be backfilled with PAG waste rock. To offset potential acid generation, the waste rock would be mixed with dolomite such that a minimum neutralizing potential of approximately 3:1 is achieved. The backfilled waste rock likely would release constituents during the oxidation of the PAG waste rock and mobilization of these constituents by groundwater. Some of these constituents may reach levels that exceed Nevada groundwater standards within the shaft or raises. Groundwater flowing laterally through the shaft and raises after a post-mining steady-state condition is reached may transport some constituents beyond the shaft and raises and thus degrade waters of the state for a short distance.

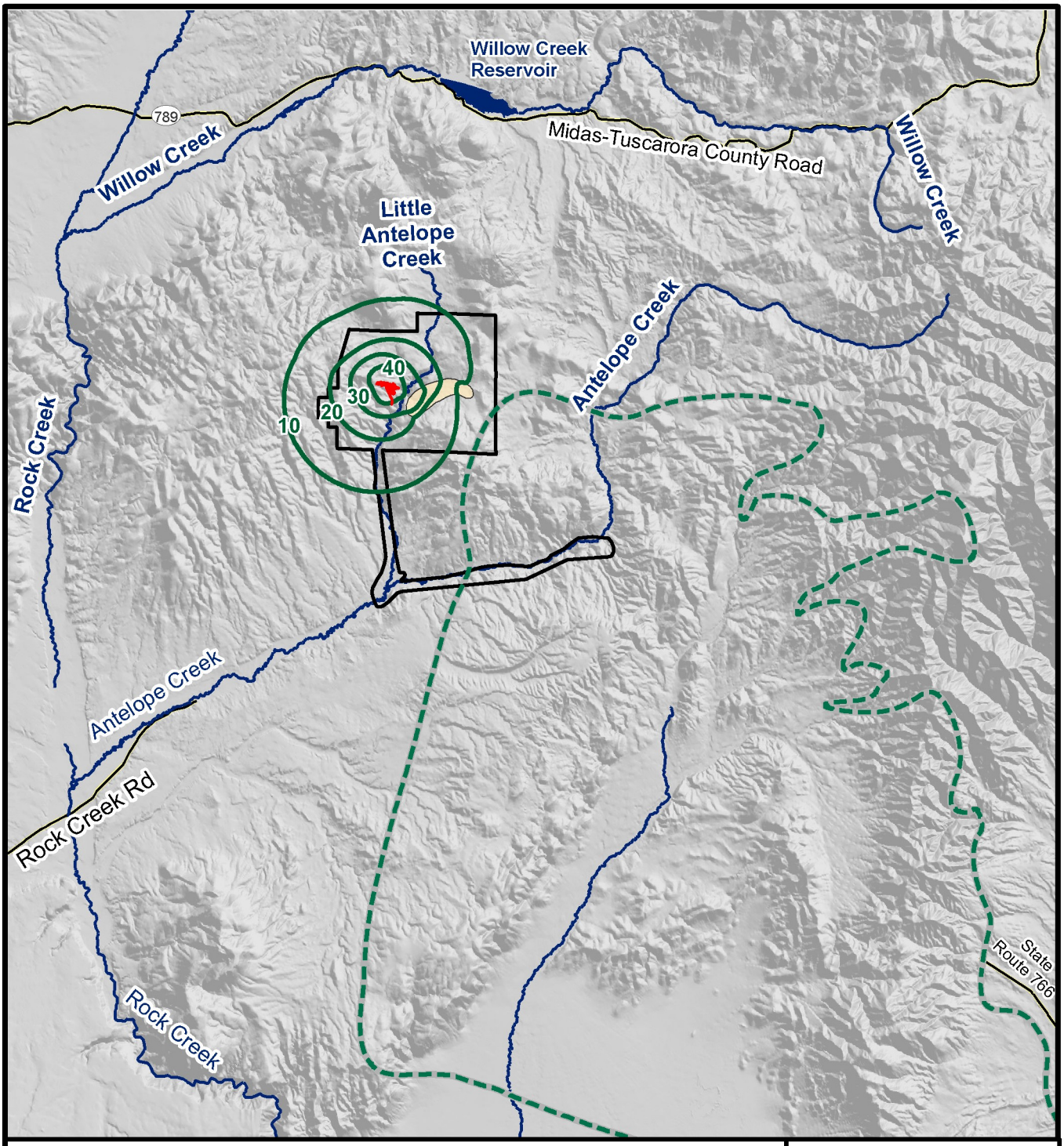
Dilution of such constituents is expected to occur as native groundwater replaces the mine volume. Downgradient attenuation of water quality constituents is expected to occur due to dilution, hydrodynamic dispersion, and chemical processes (Brown and Caldwell 2012).

3.5.2.7 No Action Alternative

Under this alternative, the Hollister Mine would continue to remove groundwater at the 2010 rate of up to 700 gpm. The Hollister underground workings would be backfilled in the same manner as discussed under the Proposed Action. Refilling of the underground workings would begin when operations cease under current authorizations and is predicted to be 99 percent complete within 22 years thereafter (Brown and Caldwell 2010a). The maximum extent of the 10-foot drawdown contour for the No Action Alternative is shown in **Figure 3.5-17**. The maximum drawdown is expected to be reached in approximately 2020-2025. The maximum decline in water levels in the Vinini Formation near the mine workings would be approximately 500 feet. Refilling of the underground workings would be approximately 95 percent complete by 2023 and return to steady state should be reached after 2034. Because the underground workings would be backfilled in a manner similar to that discussed under the Proposed Action, the underground mine water quality after year 2034 should be similar to that discussed for the Proposed Action.

3.5.3 Cumulative Impacts

Cumulative impacts for water quantity and quality under the Proposed Action would be the removal of approximately 26,000 acre-feet of groundwater from the Vinini Formation over the mine life, the maximum drawdown of groundwater in the Vinini Formation as shown in **Figure 3.5-18**, and the development of alkaline sulfate mine water after the mine workings refill. The proposed project's water



Legend

- Project Area Boundary
- Maximum Extent of Drawdown (drawdown in feet)
- Maximum Extent of Barrick Cumulative 10-foot Drawdown Contour (Barrick 2007 Model)
- Roads
- Existing Underground Exploration Workings
- Intrusive Area (Model Low K Area)

N

0 2.5 5 Miles

Source: Brown and Caldwell 2010a.

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Figure 3.5-17

No Action Alternative Simulated Maximum Extent of 10-foot Drawdown Contour

quality and quantity impacts would be in addition to mining impacts in the CESA that have resulted in groundwater drawdown in the Paleozoic rocks as well as the formation of mine pit lakes, some of which do not meet Nevada water quality standards.

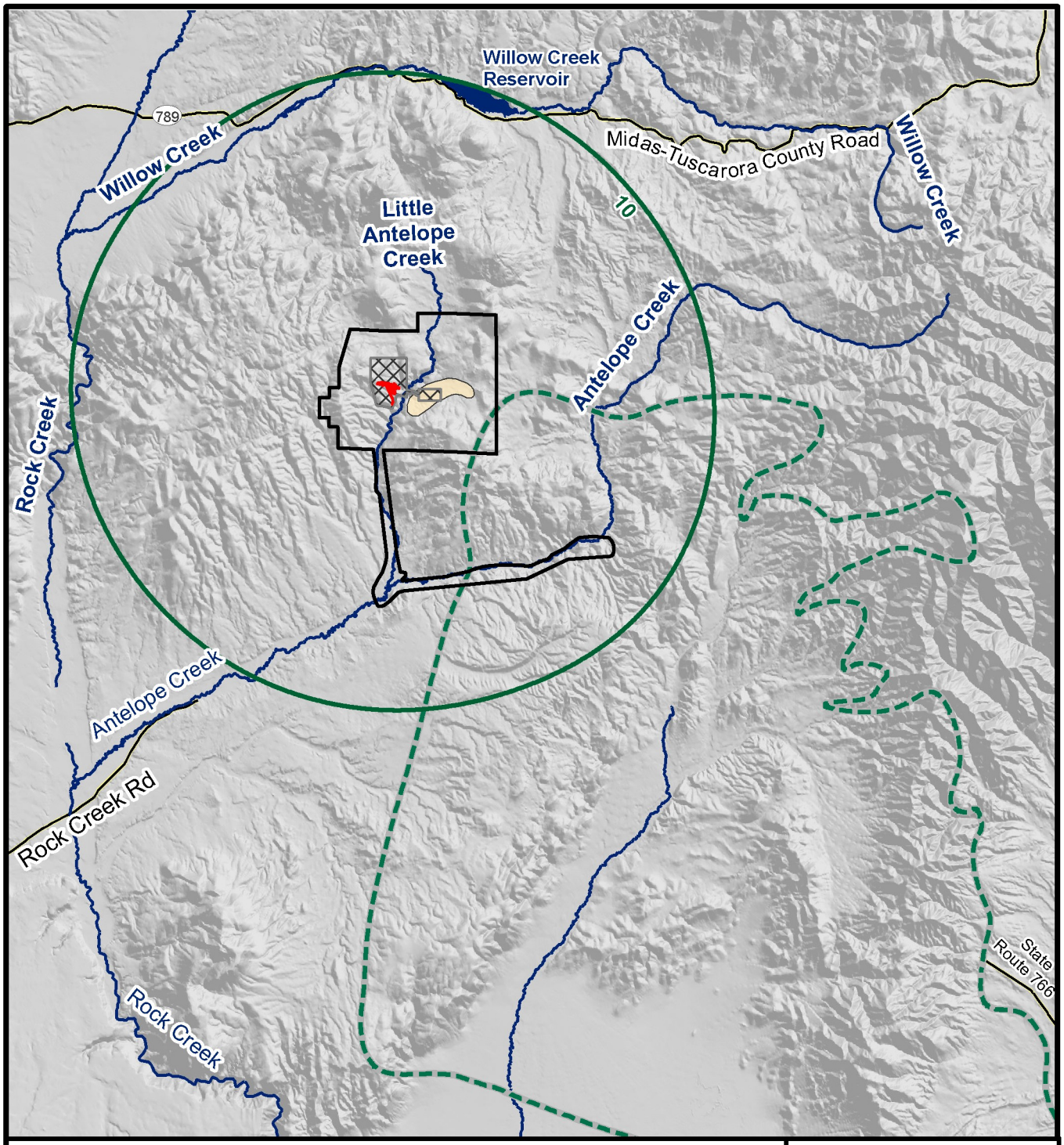
Currently (BLM 2010e), the average pumping rate for major mines in the Carlin Trend near Hollister is approximately 23,000 gpm for Gold Quarry, 18,000 gpm for Leeville, and approximately 18,000 gpm for Betze/Post. Hollister is currently removing about 400 gpm and expects a maximum of approximately 1,100 gpm during expansion of the underground workings. Projected pumping rates for Gold Quarry through 2016 are approximately 17,500 gpm and 24,000 gpm for Leeville. Betze/Post would be decreasing pumping rates from 2010 through 2016. Overall, Hollister contributes very little to the cumulative impact of groundwater removal by mines in the Carlin Trend north of the Humboldt River.

The cumulative maximum extent of the 10-foot groundwater drawdown contour from dewatering by Barrick at the Betze Mine (BLM 2008b) is predicted to enter the Hollister project area in approximately 2130 at a time when drawdown in the Vinini Formation due to Hollister groundwater pumping is in the process of recovering. The locations of the predicted Hollister maximum extent of the 10-foot groundwater drawdown contour and the projected Barrick cumulative maximum extent of the 10-foot groundwater drawdown contour are shown in **Figure 3.5-18**. Although **Figure 3.5-18** shows overlap between these two 10-foot drawdown contours in the area between Little Antelope Creek and Antelope Creek, drawdown from Hollister groundwater removal would be limited to the Vinini Formation, and cumulative drawdown from Barrick pumping would be primarily in the carbonate rocks located approximately 6,000 feet below the aquifer in the Vinini Formation. Although, in the Leeville area, drawdown due to mine dewatering and pumping in the carbonate and clastic rocks has resulted in up to 200 feet of drawdown in the overlying siltstone rocks, this drawdown is not expected to affect the Vinini Formation in the Hollister area (Olsen 2011). Thus, there is a low potential for cumulative impact associated with the Vinini Formation where the Hollister maximum extent of the 10-foot drawdown contour and the Barrick cumulative maximum extent of the 10-foot drawdown contour overlap.

The proposed project would result in groundwater quality impacts within the underground workings vicinity with elevated concentrations of aluminum, antimony, chromium, selenium, sulfate, thallium, and TDS with alkaline pH when compared to Nevada Profile I standards after the mine workings refill. In addition, underground workings would be backfilled with cemented rock aggregate causing a neutral or acid-neutralizing effect. These impacts would be in addition to the groundwater quality impacts in the CESA resulting from the development of mine pit lakes (e.g., Betze/Post pit) and saturation of underground mine workings (e.g., Leeville Mine) after cessation of mining. Concentrations of total dissolved solids, sulfate, nitrate, and some metals may be elevated, at least in the short term, for water that comes into contact with mine pit walls and underground workings (BLM 2010d). The Betze/Post pit lake is expected to be a long-term hydraulic sink due to high evaporation rates and relatively low groundwater inflow rates when filled, thereby preventing potential impacts to surrounding groundwater quality (BLM 2008b). For the CESA, inflowing groundwater to pit lakes typically has sufficient alkalinity to maintain neutral pH conditions for the long term (i.e., high buffering capacity). Evaporation from the pit lake surface generally would concentrate levels of total dissolved solids, sulfate, and other major ions in the water. Precipitation of ferric hydroxide in pit lakes, however, acts to continually remove some metals from solution.

Cumulative impacts for groundwater quantity and quality under the Mud Springs WRSF Alternative, Mud Springs Road Transmission Line Alternative, and the Backfill Alternative would be the same as described for the Proposed Action.

The No Action Alternative would remove approximately 2,000 acre-feet of groundwater over the life of the exploration project, would have a maximum 10-foot groundwater drawdown contour that would extend approximately 2.0 to 2.5 miles from the mine workings (Brown and Caldwell 2010a), and would have mine water quality similar to that of the Proposed Action once the mine workings fill with water.



Legend

- Project Area Boundary
- Maximum Extent of Drawdown (drawdown in feet)
- Maximum Extent of Cumulative 10-foot Drawdown Contour (Barrick 2007 Model)
- Roads
- Existing Underground Exploration Workings
- Intrusive Area (Model Low Permeability Area)
- Proposed Action Conceptual Underground Workings Areas

Note: Mining activities at the Hatter Expansion area simulated to stop in 2030.
Source: Brown and Caldwell 2010a.

N

0 2.5 5 Miles

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Figure 3.5-18

Proposed Action Maximum Extent of the Hollister 10-foot Drawdown Contour (2070) and the Projected Barrick Cumulative 10-foot Drawdown Contour in 2130

2/29/2012

3.5.4 Potential Monitoring and Mitigation Measures

GW-1

Issue: The Proposed Action may have impacts to groundwater quantity and quality.

A groundwater monitoring program would be established by RCG in consultation with the BLM. This program would be developed to monitor and evaluate the potential impacts of groundwater drawdown on springs, seeps, and surface water. This program would include monitoring of springs and seeps in the fall. This program would include establishing groundwater monitoring via monitoring wells and piezometers in areas around the Hollister Mine in order to develop an understanding of the impact of groundwater drawdown in the Vinini Formation and overlying formations as mining progresses. The geochemical and groundwater flow models would be updated a minimum of every 5 years throughout the life of the project. Potential mitigation for impacts to seeps and springs could include water augmentation (e.g., well, pipeline, or hauling water to replenish seeps and springs).

Monitoring and mitigation measures relative to potential impacts to seeps and springs associated with the Vinini Formation are addressed in Section 3.6.4. Springs in formations directly above the Vinini Formation or associated with the Vinini Formation would be monitored to ensure that drawdown in the Vinini Formation within the maximum extent of the 10-foot groundwater drawdown contour does not affect flow in these springs.

Monitoring/Mitigation Measure: A groundwater monitoring program would be established by RCG in consultation with the BLM to monitor and evaluate the potential effects to groundwater from the proposed project. Piezometers or monitoring wells would be installed, as needed, in areas around the Hollister Site and within the maximum extent of the 10-foot drawdown contour to obtain more information on the groundwater quantity and quality from the proposed project. If necessary, piezometers or monitoring wells would be installed beyond the maximum extent of the 10-foot drawdown contour. This monitoring program would include monitoring seeps and springs on public lands. Monitoring seeps and springs on private lands would require permission from the land owner.

Effectiveness: This measure would ensure early detection and remediation of potential project-related impacts to groundwater quantity and quality in the project area and vicinity. Groundwater data would be used to refine the groundwater model. Monitoring of seeps and springs would provide data regarding possible early detection of potential project-related impacts to seeps and springs. Water augmentation would effectively mitigate any water quality losses.

3.5.5 Residual Impacts

Under the Proposed Action, the long-term residual impacts would be: 1) water in the underground workings that is alkaline and contains elevated sulfate and exceedences of some NDEP Profile I groundwater standards; and 2) the permanent removal of approximately 26,000 acre-feet of groundwater. Replacement of the lost groundwater by natural recharge would be expected to occur within a few hundred to thousand years, assuming no future groundwater withdrawals in the area. These same residual impacts would apply to all alternatives, including the No Action Alternative; the amount of groundwater removal would be considerably less under the No Action Alternative.