APPENDIX E

SUMMARY OF WATER RESOURCES REPORT

E.1 BACKGROUND

Two formal studies have been completed to assess the feasibility of developing the groundwater system. A Level I Study was completed by PMPC Civil Engineering in March 2003 (PMPC 2003). This study compared the groundwater alternative to updating the existing surface water system. The alternatives were compared based on feasibility and cost. It was determined in this Level I Study that using groundwater would satisfy the immediate and projected needs for the Town and would be economically feasible to construct.

A Level II Study, completed by Hinckley Consulting in June 2007 (Hinckley 2007a), analyzed more completely the feasibility of a groundwater system. Two test wells were drilled for this study (in 2003 and 2005) and it was concluded that there was sufficient water within the North Park Formation to supply the Town. It was also determined that groundwater from the North Park Formation would require less treatment than surface water to meet EPA Drinking Water Standards. Additionally, groundwater quality stays consistent throughout the year whereas surface water quality fluctuates seasonally. The cost for construction of the groundwater system was comparable to upgrading the current system with pre-sedimentation clarifier and membrane filtration. However, the annual operation and maintenance costs and user fees would be lower with the use of groundwater.

E.2 WATER RESOURCES – EXISTING CONDITIONS

E.2.1 NORTH PLATTE RIVER

The North Platte River is a dominant surficial presence in the Saratoga Valley. The river has been incised into the late-Tertiary (Miocene) North Park Formation, which underlies both the alluvial deposits and the surrounding landscape. The North Park Formation, in turn, fills a broad valley eroded into the underlying, much-older bedrock.

E.2.1.1 Drainage Basin Size and Characteristics

Beginning as snowmelt, the North Platte River flows northward from north central Colorado into central Wyoming where it gradually curls to the southeast before joining the South Platte River in Nebraska. From its source at about 11,000 ft above sea level to its confluence with the South Platte River, the North Platte River traverses about 665 miles and drains an area of 34,900 square miles (see **Figure E1**). The North Platte River Basin has its headwaters in northern Colorado, flows through Wyoming, and to Lake McConaughy in Nebraska.

The North Platte River is a tributary to the Platte River system. In 1997, the states of Wyoming, Colorado, and Nebraska along with the U.S. Department of the Interior (USDOI) signed a *Cooperative Agreement for Platte River Research and Other Efforts Relating to Endangered Species Habitats Along the Central Platte River, Nebraska*. The goal of this agreement is to pursue a recovery program to improve and maintain habitat for key threatened and endangered species.

E.2.1.2 Tributaries Close to or Within the Project Area

The proposed well field is located approximately 17,000 ft (3.2 miles) northeast of the North Platte River. Lake Creek, a perennial tributary to the North Platte River, is about 22,000 ft (4.2 miles) to the north of the proposed well field. Other stream reaches within the project area include the upper portions of the South Fork of Lake Creek to the northeast and Cedar Creek to

the southeast; however, neither of these two streams is mapped as perennial based on the 1:100,000 U.S. Geological Survey (USGS) mapping. There are additional intermittent streams mapped in the vicinity of the proposed well field that flow only in response to periodic precipitation or snowmelt events in excess of infiltration capacity.

Figure E-1
North Platte River Basin

E.2.1.3 Flow Statistics

River discharge has changed in volume and character over time with population increases and development along the Platte River system. The average annual flow of the Platte River near Overton, Nebraska, was 2.65 million acre-feet (MAF) per year during the period between 1895 and 1909, and 84 percent of this flow came from the North Platte River (USDOI 2006). During the period 1910 to 1935, the mean annual flow decreased to 2.29 MAF per year. With additional reservoir construction and drought, the mean annual flow decreased to 0.83 MAF per year during the period 1936 to 1969. During the period 1970 to 1998, the mean annual flow of the Platte River near Overton, Nebraska, increased to 1.4 MAF per year.

Peak flows began dropping in 1909 following completion of the first large reservoir on the North Platte River behind Pathfinder Dam. After 1940, after several additional reservoirs were completed, the peak flow on the North Platte River at North Platte, Nebraska, was seldom more than 5,000 cubic feet per second (cfs).

There is a USGS gaging station (#06627000) at Saratoga and another station (#06630000) located further north upstream of the Seminoe Reservoir near Sinclair (see **Figure E-1**). Annual mean discharge for these stations is shown on **Figure E-2** and peak flows are shown on **Figure E-3**. Data from both stations are included because the data at Saratoga ends in 1970, while the data from the Seminoe station extends through 2006. A best-fit line on the plots shows a general decline in both annual mean and peak flows since 1960.

Figure E-2
Annual Mean Discharge at USGS Gaging Stations

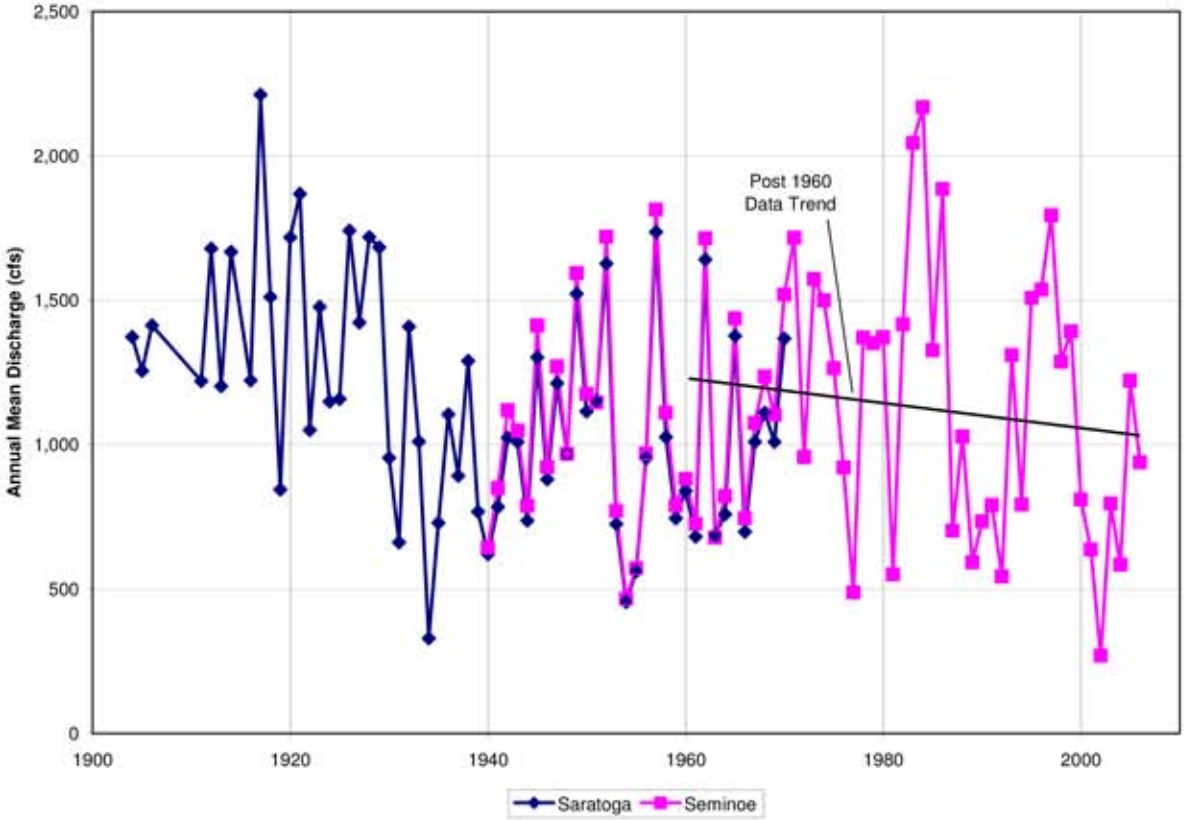
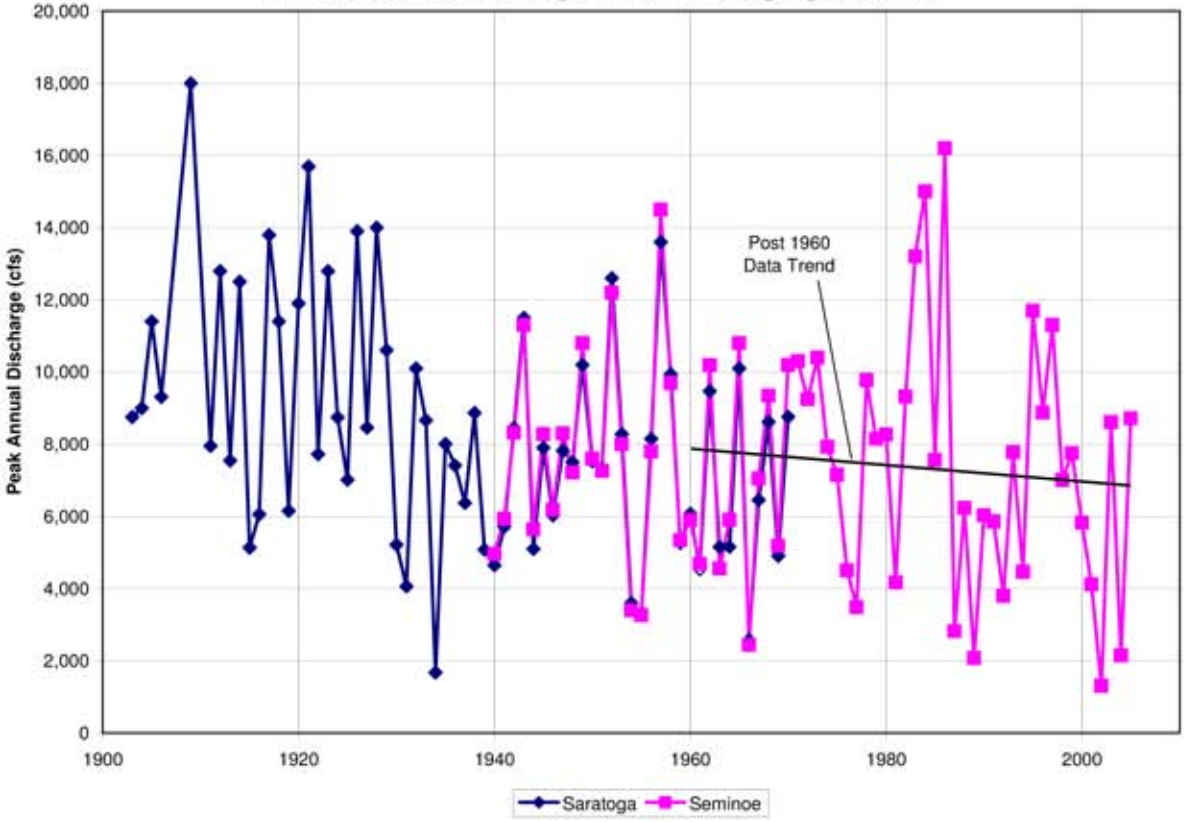


Figure E-3
Annual Peak Discharge at USGS Gaging Stations



E.2.1.4 Water Quality

The North Platte River watershed in the project area is uncontrolled (i.e., no major dams) and includes heavily grazed pastures for livestock and wildlife. The water produced from this watershed has very predictable seasonal variations in water quality characteristics but can also produce dramatic water quality changes that are coincident with localized precipitation events within the drainage basins of the watershed. The water quality is generally considered good.

Spring runoff produces water that is high in turbidity, low in alkalinity, high in levels of color, and high in concentrations of total organic carbon. Color is caused by dissolved natural organic matter that includes humic and fulvic organic material. Residual color in the finished water from the river, along with the taste and musty odor associated with the presence of organic concentrations, is a source of customer complaints at the local water utility (PMPC 2003).

E.2.1.5 WDEQ Classification and Designated Use

Chapter 1 of the Wyoming Water Quality Rules and Regulations establishes classifications for all surface waters of the state. Each classification refers to the uses that are designated for the associated waters and the water quality criteria necessary to assure the attainment of each designated use. "Designated uses" means those uses specified in water quality standards for each water body or segment whether or not they are being attained. Wyoming water quality standards are the rules concerning designated uses and the associated water quality criteria. The Wyoming

water quality standards consist of three parts: 1) surface water classes and associated uses, 2) numeric and narrative water quality criteria, and 3) antidegradation policy.

The North Platte River in the project vicinity is designated as Class 1 Water. The classification covers the main stem of the North Platte River from the mouth of Sage Creek (approximately 15 miles downstream from Saratoga) upstream to the Colorado state line.

Class 1 designations are based on value determinations rather than use support and are protected for all uses in existence at the time or after designation. There are four major classes of surface water in Wyoming with various subcategories within each class. Class 1, Outstanding Waters, are those surface waters in which no further water quality degradation by point source discharges other than from dams will be allowed. Nonpoint sources of pollution shall be controlled through implementation of appropriate BMPs. Pursuant to Section 7 of the regulations, the water quality and physical and biological integrity that existed on the water at the time of designation will be maintained and protected. In designating Class 1 waters, the Environmental Quality Council shall consider water quality, aesthetic, scenic, recreational, ecological, agricultural, botanical, zoological, municipal, industrial, historical, geological, cultural, archaeological, fish and wildlife, the presence of significant quantities of developable water and other values of present and future benefit to the people.

E.2.1.6 303(d) Listings/Impairments

In 1998, the North Platte River was placed on the WDEQ 303(d) list of impaired water bodies. Selenium was listed as the constituent causing the impairment of the river for cold water fisheries, aquatic life, and wildlife beneficial uses. In 2000, tributary streams located within the Kendrick watershed downstream from Saratoga were also placed on the WDEQ 303(d) list, leading to the preparation of the draft Kendrick Watershed Plan.

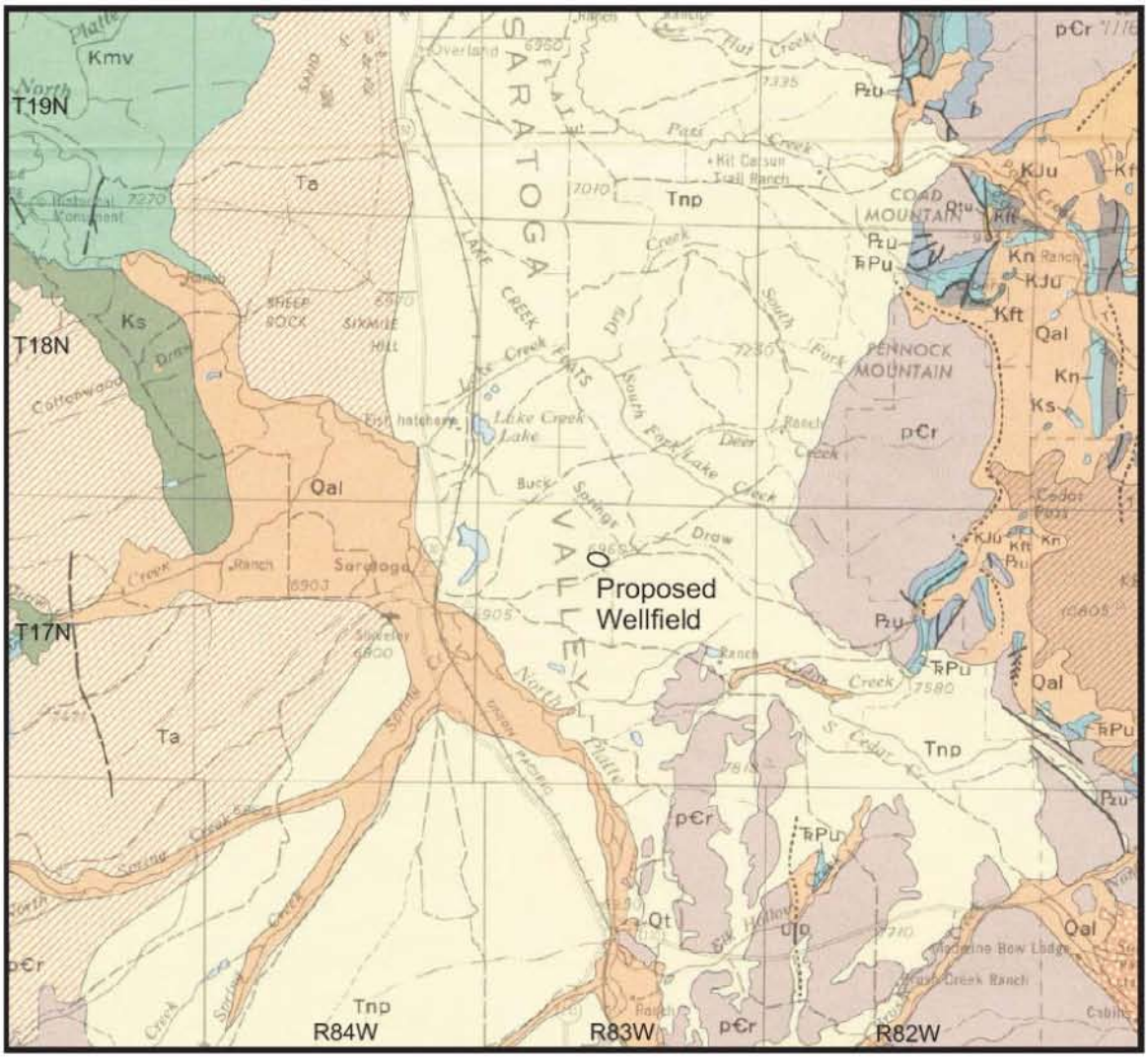
E.2.2 HYDROGEOLOGY

E.2.2.1 Geologic Setting

The area surrounding Saratoga is comprised of three main geologic units (see **Figure E-4)**. The geologic units, from youngest to oldest, are:

Qal - alluvial deposits
Tnp - North Park Formation
Ta - Arikaree Formation (grouped with the North Park Formation for this report)
pCr - Precambrian rocks, “basement,” largely granitic compositions

Figure E-4
Geologic Map of the Project Area



0 3 6 miles

Source: Lowry et al., 1973

The youngest geologic materials in the area are the alluvial sands, silts, and gravels along the North Platte River and its tributaries. Due to the manner in which these materials are deposited, alluvial deposits tend to be relatively coarse-grained and, thus, relatively permeable to the flow of groundwater. Thickness is at a maximum near the original valley center (not necessarily coincident with the present stream channel) and thins to zero at the edges of the deposit.

Well logs in and immediately around Saratoga indicate no great thickness for the alluvial deposits in this area. Typically, the underlying bedrock, the North Park Formation, is encountered at depths of less than 20 ft. Visher (1952) cites an alluvial thickness of 20 ft at the North Platte River bridge on the north side of Saratoga.

The North Park Formation fills a broad valley eroded into the underlying, much-older bedrock. Crist (1990) indicates a thickness of zero around a small exposure of older bedrock immediately south of the Saratoga Hot Springs, increasing to 650 ft in a local east-west trough 1.5 miles north of Saratoga, with a more general thickening to the northeast beyond Lake Creek. Montagne (1991) presents an alternate interpretation of the subsurface data, with a total North Park thickness of as much as 1,800 ft in a north-south trough a few miles northeast of Saratoga. Visher (1952) concluded the North Park Formation was "about 1,700 ft" thick beneath the Pass Creek Flats area (15 miles north of Saratoga). The divergence of investigators on the basic configuration of the pre-North Park surface reflects the general scarcity of sub-North Park data.

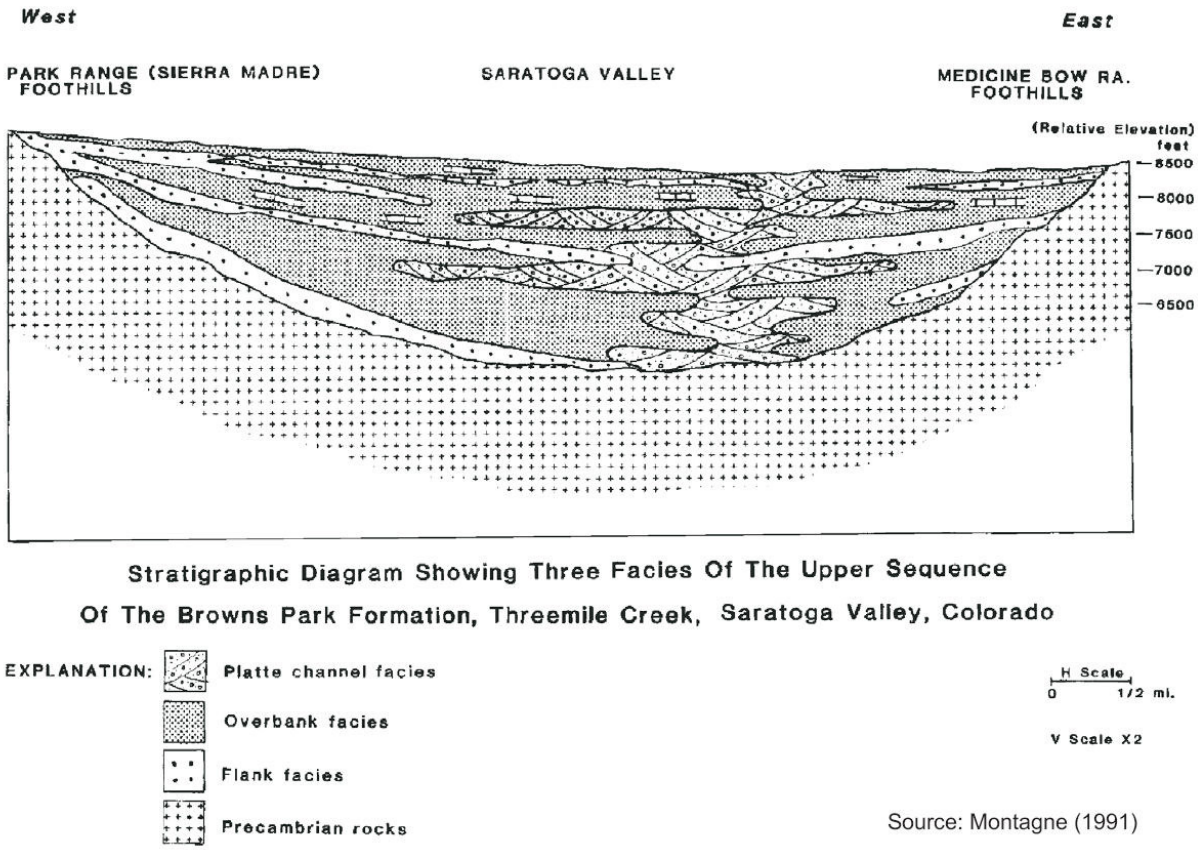
The closest outcrops to Saratoga of the geologic materials beneath the North Park Formation (i.e., North Park Formation thickness thins to zero) are the Precambrian basement rocks 6 miles southeast of Saratoga and the Steele Shale approximately 4 miles northwest of Saratoga.

The North Park Formation in the Saratoga area has been described numerous times including Montagne (1955), Stephens and Bergin (1959), Luft (1985), and Montagne (1991). Montagne (1991) subdivided the formation into three facies: 1) a "channel" facies, in which sandstone and conglomerate units are dominant; 2) a "back-fill" facies, consisting of "fine tuffaceous siltstone and claystone, laminated silty shale, marl, and algal limestone" deposited in backwaters and lakes; and 3) a "flank" facies, representing the colluvial input from the margins of the Saratoga basin. All three facies are commonly interbedded, although the flank facies is relatively rare away from the basin margins.

Figure E-5 is a schematic cross-section of the North Park Formation (called the Browns Park Formation in his work) developed by Montagne (1991) to show the interbedded nature of the various facies. Montagne (1991) describes a pervasive matrix-supported conglomerate at the base of the North Park Formation in the Saratoga area. However, given the complex interlayering of facies within the North Park Formation, it is difficult to predict the subsurface lithology at any specific location.

Lithologic descriptions of drill cuttings for the eight test wells and monitor wells drilled for this project indicate that the bottom of the North Park Formation was never reached when drilling to depths up to 810 ft. Thus, the deeper bedrock directly beneath Saratoga could be any one of many shale, siltstone, sandstone, or limestone formations, or basement granites and related rocks. Shales and siltstones dominate this interval, but several formations have favorable water-bearing qualities where they have been explored elsewhere in the region (e.g., Nugget Sandstone, Casper Formation, and Madison Limestone).

Figure E-5
Geologic Cross-Section with North Park Formation Stratigraphy



Some have suggested that beneath the North Park Formation at Saratoga is likely a northward-dipping section of Paleozoic and Mesozoic-age rocks. Montagne (1991) contends that the North Park Formation rests directly on Precambrian basement rocks east of a northeast-southwest line approximately 3 miles east of Saratoga. In any case, whether or not the Paleozoic and Mesozoic-age rocks are present at Saratoga between the North Park Formation and the Precambrian basement rocks, depth and water-quality considerations likely preclude useful groundwater development from geologic units below the North Park Formation.

The Precambrian rocks beneath Saratoga (and exposed at the surface east, south, and southwest of town) are largely granitic in composition, but include a complex of andesite porphyry, hornblende gneiss, black and green schists, diabase porphyry, pegmatites, slate, vermiculite, and quartzite (Montagne 1955). The Precambrian age rocks are commonly referred to as “basement” and likely represent the lower limit of large-scale groundwater circulation.

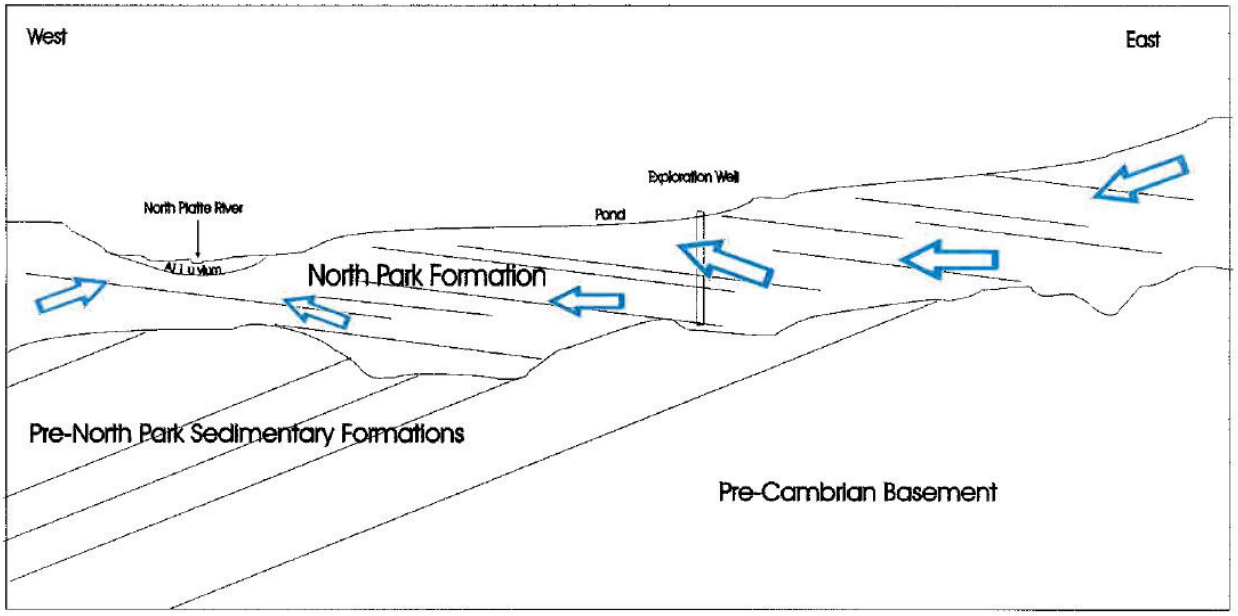
E.2.2.2 Hydrogeologic Boundaries

Hydrogeologic boundaries include physical features that define the spatial extent of aquifers, and also the location and nature of recharge (flow into the aquifer) and discharge (flow out of the aquifer). For the Saratoga Valley, the North Park Formation aquifer is bounded by the Medicine Bow Mountains to the east, the Park Range (Sierra Madre) Mountains to the west, and the

Precambrian basement rock underlying the basin. Water within the basin is constrained by these boundaries.

Groundwater elevation contours from water levels in wells (Crist 1990; Hinckley 2007a and 2007b) show the general flow of groundwater in the North Park Formation to be from the uplands toward the North Platte River, shown in simplified fashion on **Figure E-6**.

Figure E-6
Simplified Groundwater Flow in the North Park Formation



Source: PMPC (2003)

The groundwater system is recharged by water entering the system at the base of the adjacent mountains, through infiltration of precipitation, and from the channel and sub-irrigated areas associated with the various forks of Lake Creek, Buck Springs Draw, and Cedar Creek. Recharge also occurs from scattered tracts of surface irrigated lands north of Cedar Creek.

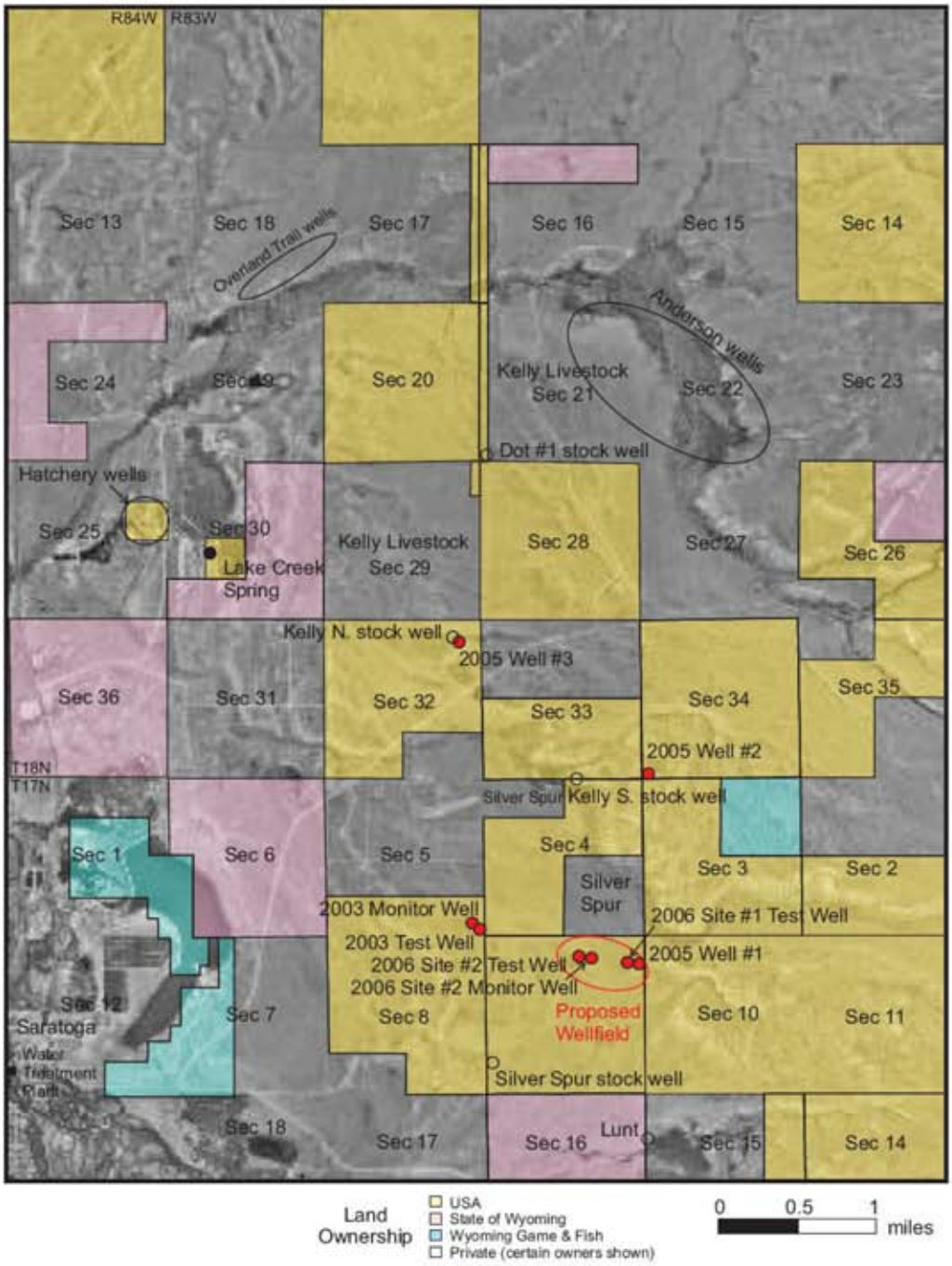
Groundwater flows from the recharge areas to discharge naturally as springs, as evapotranspiration from areas of shallow water table, and as baseflow to the lower reaches of Lake Creek and to the North Platte River. Spring discharge occurs into Lake Creek Lake serving the Saratoga fish hatchery 3 miles north-northeast of town, and is reported to have occurred into Saratoga Lake just east of Saratoga before the supply ditch from the river was constructed. Stagnant ponds south of the county road east of Saratoga may also reflect groundwater outflow to the surface. These various features form a north-to-south-to-southeast band, which has been inferred to represent a lateral change in aquifer permeability where westward flowing groundwater encounters material of lower permeability and is forced to the shallow subsurface (PMPC 2003).

E.2.2.3 Aquifer Characteristics and Hydraulic Properties

Aquifer characteristics can be deduced based upon observations of material encountered during well drilling and installation and also from the yield and drawdown of wells. A number of wells

have been installed in the project area; as of 2003, there were 286 groundwater permits issued by the Wyoming State Engineer's Office (SEO) for the area within 5 miles of Saratoga (PMPC 2003). The large number of wells provides many locations from which the behavior of the aquifer can be observed and predicted. The locations of the key wells in the area that are discussed in this document are shown on **Figure E-7**.

Figure E-7
Wells in the Vicinity of Saratoga

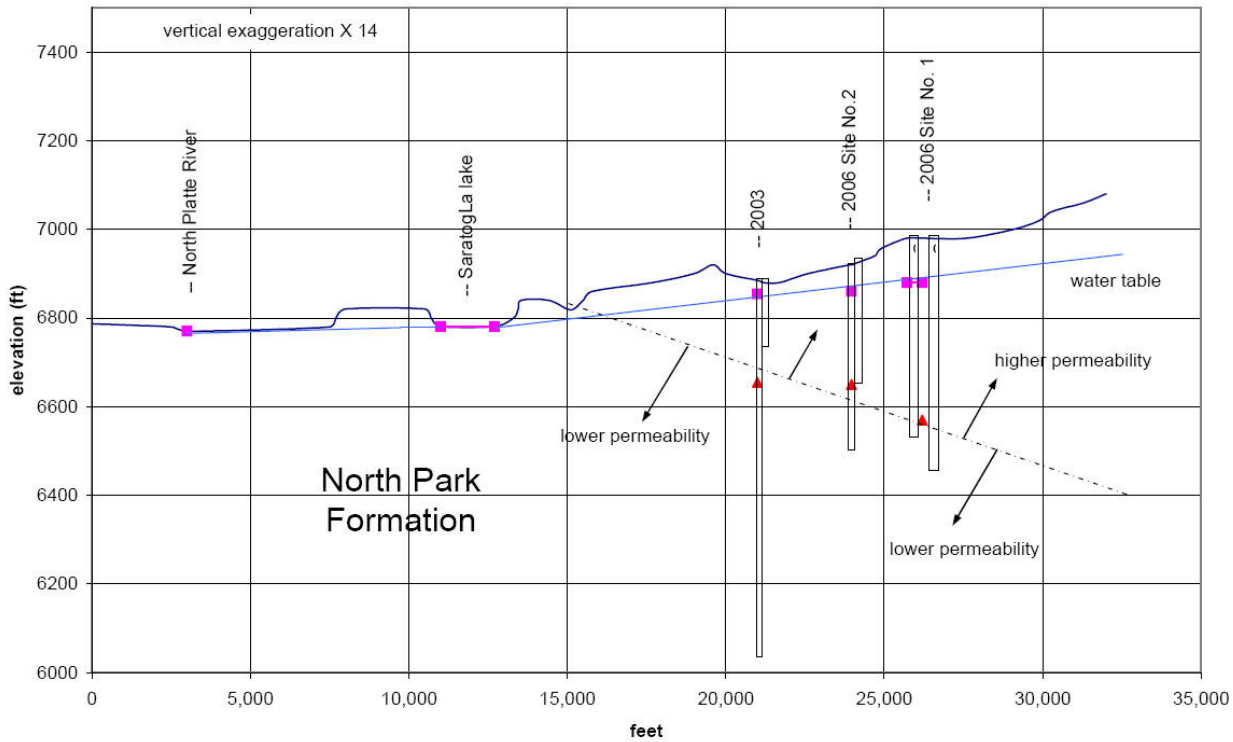


Source: Hinckley (2007a)

Stratigraphy and Permeability

The predominant material in the North Park Formation in the vicinity of the proposed well field is very-fine to fine-grained sandstone, commonly very weakly to weakly-cemented, with thin beds of well-cemented material. The stratigraphy of the North Park Formation can be generally divided into a section containing less fine-grained (higher permeability) material overlying a section containing more fine-grained (lower permeability) material. The rocks dip, or slope, to the east and, therefore, the lower permeability strata are present at depth in the proposed well field area and at the surface around Saratoga Lake. This permeability transition is illustrated on **Figure E-8**.

Figure E-8
Study Area Schematic Cross-Section



Source: Hinckley (2007a)

The shallow, low permeability zone in the Saratoga area is evident from several observations. Well tests at the Saratoga Landfill (Maxim 2000) indicate a lower hydraulic conductivity (0.5 ft/day) than for the 2006 Level II (Hinckley 2007a) test wells (20 ft/day). Around Saratoga Lake, well logs show the dominance of shale, siltstone, and silty sandstone; groundwater quality is poor; and the wells have low specific capacities of less than 0.5 gallon per minute per foot (gpm/ft). In addition, the westward deterioration of groundwater quality is consistent with increasing silt and clay content.

The appearance of springs and potentially groundwater-fed ponds along a roughly north-south line passing through Saratoga Lake and the area of the Saratoga fish hatchery suggests westward-migrating groundwater is forced to the surface by lower-permeability material. The

low escarpment east of Saratoga Lake may reflect the outcrop of this lower unit of the North Park Formation. Exposures on vehicle-worn hills on the northeast side of the lake are of siltstone, shale, and silty sandstones.

In contrast, to the east, the coarsest and cleanest sands encountered over the Level II (Hinckley 2007a) drilling program were in the shallowest portions of the holes. However, the low permeability zone is present at depth, as evidenced by a general pattern of increasing silt and clay content with depth (below approximately 260 ft at the 2003 site, 280 ft at 2005 Site No. 3, 300 ft at 2006 Site No. 2, 400 ft at 2005 Site No. 2, and 410 ft at 2005/2006 Site No. 1). A similar pattern is suggested by the geophysical logs from the Level II (Hinckley 2007a) exploration (i.e., increased natural gamma activity and lower electrical resistivity in the lower portions of the holes), and from the two rehabilitated hatchery wells (higher natural gamma activity below 150 ft and 120 ft in Well Nos. 1 and 2, respectively). In addition, a short, air-lift recovery test of the deep piezometer (506-527 ft) at the 2003 exploration site suggested hydraulic conductivity of less than 0.2 ft/day. This piezometer showed no response to pumping from the overlying strata during the 2003 pumping tests.

Despite this general understanding of the permeability of the North Park Formation, small-scale stratigraphy is sufficiently variable that individual strata cannot be confidently correlated across the study area. While the units depicted schematically on **Figure E-5** have been encountered at various locations, their occurrence at specific locations is difficult to predict. Geophysical logs, which typically provide a clearer understanding of strata, provide few clear stratigraphic correlations even for wells only a few hundred ft apart.

In addition, the generalized higher permeability zone shown on **Figure E-8** appears to contain localized areas where the permeability is quite high. One example of this is the Overland Trail ranch along Lake Creek, where irrigation wells have anomalously high permitted yields of 1,000-1,500 gpm. Lithologic logs identify only “sandstone” from the production zones for these wells, but it is obviously sandstone of much higher permeability than elsewhere in the North Park Formation. Irrigation wells upstream on the Anderson ranch (500-800 gpm) and at the fish hatchery (300-500 gpm) may reflect the margins of an irregular body of highly productive aquifer material. A well less than 1 mile north of the high-capacity Overland Trail wells (groundwater permit P52672W) logged only “clay” over its 242 ft depth. Similarly, a stock well (groundwater permit P29228W, “DOT #1”) ½ mile southwest of the Anderson irrigation wells that was briefly tested for the Level II project produced a specific capacity of only 0.9 gpm/ft and an indicated transmissivity of 1,400 gallons per day per foot (gpd/ft).

A 300 gpm water-supply well just off the southwest corner of the Town of Saratoga (P13764W) shows the potential for high yields from the North Park Formation away from the Lake Creek/fish hatchery area. Although of quality too poor for municipal supply (approximately 2,000 milligrams per liter(mg/l) total dissolved solids [TDS], which is four times the EPA secondary Drinking Water Standard), this well identifies another area of locally high-permeability.

Hydraulic Characteristics and Well Yield

As discussed above, the North Park Formation can be generally divided into a low permeability zone and a high permeability zone. Within each zone, aquifer properties such as permeability (also referred to as hydraulic conductivity) and transmissivity are generally similar. Aquifer parameters can be determined from pumping data and observations and used to anticipate well yields in an area along with potential impacts to the aquifer from pumping.

Low permeability material is more common in the western portion of the study area near Saratoga than in locations further east. Well yields in this zone are typically less than 10 gpm. Hydraulic conductivity beneath the Saratoga Landfill in the low permeability zone is reported to be 0.5 ft/day. Using an aquifer thickness of 300 ft translates to a transmissivity on the order of 1,000 gpd/ft. The low permeability zone in the area of the proposed well field has a hydraulic conductivity of about 0.2 ft/day based on a brief air-lift test of a deep piezometer.

The high permeability zone in the vicinity of the proposed well field for this project and has a hydraulic conductivity of roughly 20 ft/day, with a transmissivity of about 30,000 gpd/ft. However, as drawdown develops, wells pumping on the order of 200 gpm may experience effective transmissivities on the order of 10,000 gpd/ft due to reduced saturated thickness and may be subject to wellbore head losses due to construction effects and completion methods.

Select wells in the relatively high permeability zone of the aquifer in the Lake Creek/fish hatchery area discussed above produce over 500 gpm, with some exceeding 1,000 gpm. The transmissivity in parts of this area is on the order of 400,000 gpd/ft. A second localized area of very high permeability occurs off the southwest corner of the Town of Saratoga where a well produces 300 gpm. While there are likely additional zones of high permeability in the North Park Formation capable of supporting well production in excess of 500 gpm, they are probably rare and their locations cannot be predicted with the current state of knowledge.

Small-scale layering within the aquifer creates low vertical permeabilities and provides for small, but widespread drawdown impacts from pumping. Low vertical permeabilities also inhibit vertical flow through the aquifer toward screened intervals in wells, requiring extensive screens, and, perhaps, allowing of pumping water levels to drop into screened intervals during production peaks to efficiently produce the groundwater available.

E.2.2.4 Groundwater Recharge

Groundwater is present in the Saratoga area due to the infiltration of precipitation, snowmelt, and streamflow. At a regional scale, groundwater moves from recharge areas in the mountains east and west of town, converging on the North Platte River, to which it discharges to maintain the basic balance between groundwater recharge and groundwater discharge.

In the case of the Saratoga area specifically, recharge to groundwater likely occurs over a broad area east of town through the direct infiltration of precipitation (including snowmelt), and infiltration from the channel and subirrigated areas associated with the various forks of Lake Creek, Buck Springs Draw, and Cedar Creek. Additional groundwater recharge also occurs from scattered tracts of surface-irrigated lands north of Cedar Creek (Lenfest 1986).

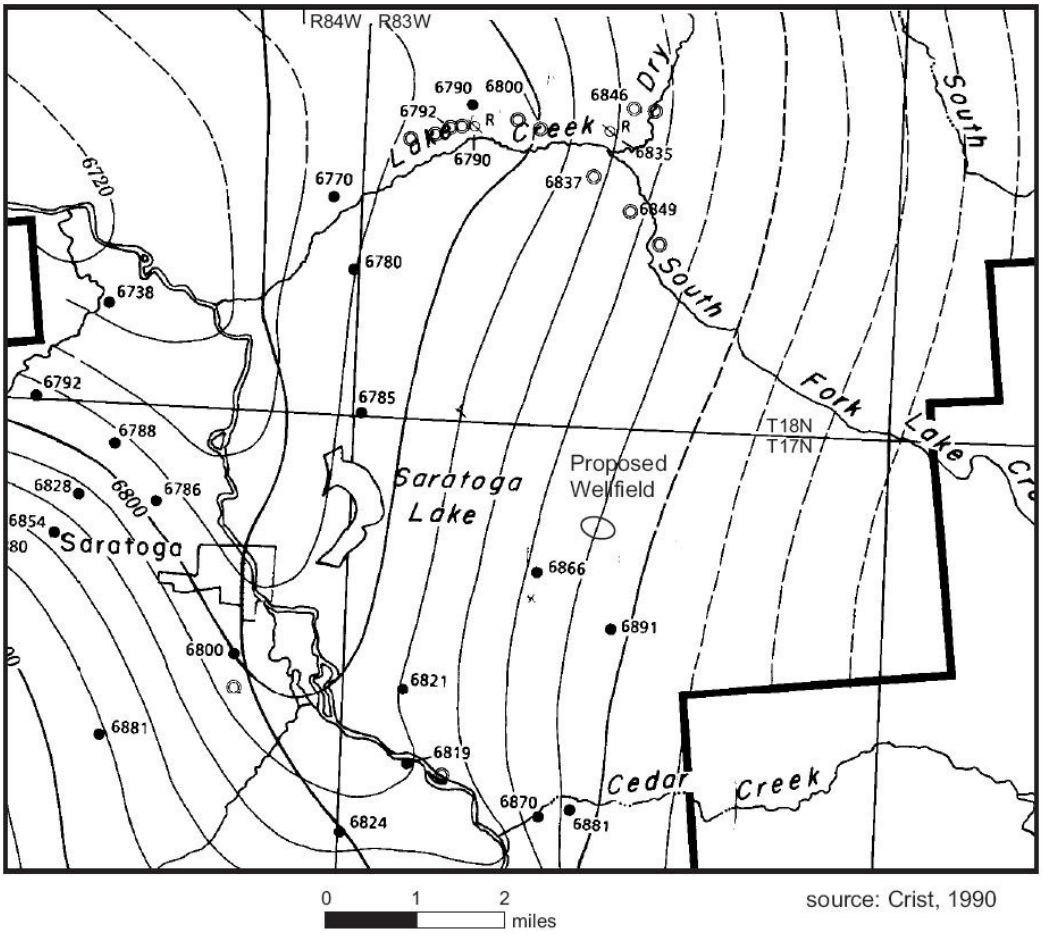
The natural cycle of recharge in this area is dominated by snowmelt and spring rains. This should result in lowest seasonal groundwater levels in late fall and winter, although measurements in the study area indicate the seasonal fluctuation is quite small (See discussion in **Section E.2.2.5**). In areas subject to substantial irrigation pumping, groundwater levels will commonly be lowest during mid-late summer and recover through fall and winter after pumping ceases.

A look at the vertical distribution of aquifer pressure was provided by the dual-completion monitor well completed at the 2003 test site. At this well, two casing strings were installed in the well – one open to a sandstone interval between 500 and 530 ft, and the other open to the main production interval between 60 and 230 ft. These two intervals are separated by approximately 50 ft of mudstone and 200 ft of silty sandstone, the lower permeability of which maintains different groundwater levels above and below. The water level in the lower zone was consistently 20 ft lower than in the upper zone, as measured in October 2003 and July 2005. This identifies a downward gradient at this location, indicating groundwater recharge is dominant. Further west, the opposite is the case. Vertical gradients bring groundwater to the surface to discharge at Lake Creek Spring, Saratoga Lake, and the North Platte River.

E.2.2.5 Groundwater Levels, Potentiometric Surface, and Flow Direction

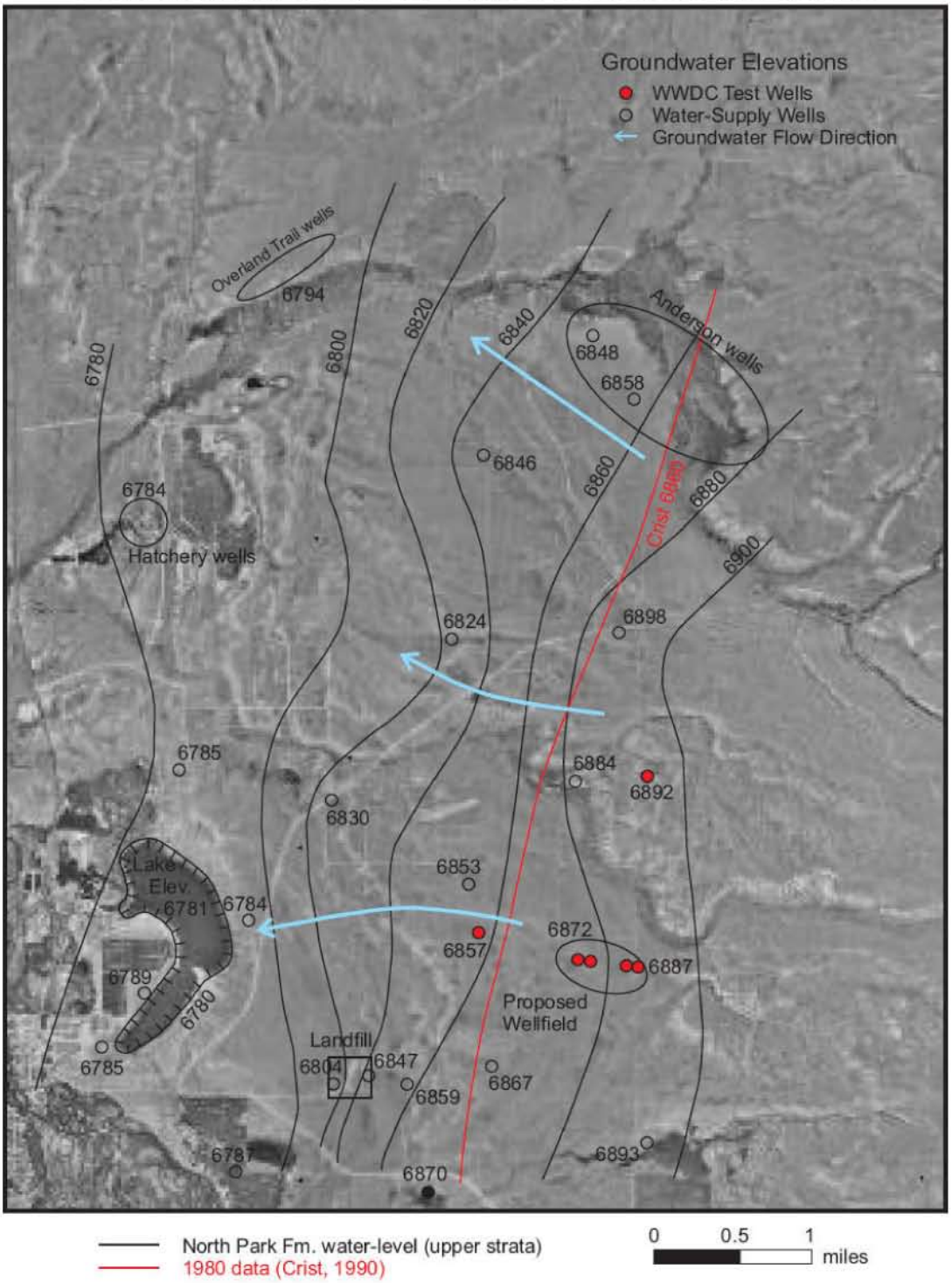
A map of regional groundwater level contours for the North Park Formation from USGS studies is shown on **Figure E-9**. Like surface water, groundwater flows "downhill" (i.e., perpendicular to the contour lines of the figure). Regional groundwater flow is from recharge areas east and west of Saratoga, converging on the North Platte River, which provides the "drain" for both surface water and groundwater. Pumping at the proposed well field east of Saratoga will intercept groundwater that would otherwise, over a long period of time, become part of the river flow.

Figure E-9
Regional Groundwater Level Contours for the North Park Formation



Local groundwater level data and approximate contours are shown on **Figure E-10**. The local data is consistent with the regional view shown on **Figure E-9**, depicting an east-to-west flow of groundwater towards the North Platte River. The irregularities in the contours are further indication of the complexity of the permeability distribution of the aquifer. The steepening of the groundwater gradient (i.e., more closely-spaced contours) towards the west side of the figure may reflect the lower permeability zones discussed above.

Figure E-10
Local Groundwater Level Contours for the North Park Formation



As previously discussed, the aquifer is highly stratified, meaning vertical permeability is considerably less than horizontal permeability at most locations, and permeability may vary widely on the scale of individual wells. Most of the data for **Figure E-10** come from wells in the 100-160 ft depth range and, as a result, reflect water levels in the upper layers of the aquifer.

A look at the vertical distribution of aquifer pressure was provided previously in **Section E.2.2.4** and noted by the dual-completion monitor well completed at the 2003 test site. This showed a downward gradient at this location, indicating groundwater recharge is dominant. Further west, the opposite is the case. Vertical gradients bring groundwater to the surface to discharge at Lake Creek Spring, Saratoga Lake, and the North Platte River.

There is little long-term monitoring data on groundwater levels. However, what data are available suggest little change in groundwater levels. On **Figure E-10** the "6860 ft" contour from the more general, and 27-year earlier, study is similar to that of the more recent data (and spot comparisons of specific wells on **Figure E-9** and **Figure E-10** show little change). An earlier study reviewing water levels for the period 1969-1980 (Crist 1990) also found little change in water levels. Finally, comparisons of water levels for individual wells measured over time indicate no area trends of declining groundwater (see **Table E-1**).

Table E-1
Groundwater Measurements at Select Wells

Well	Date	Depth to Water
2003 Monitor Well	10/2003[1]	27
	8/17/2005	26.76
	10/10/2006	27.2
	5/11/2007	26.68
	6/24/2007	26.66
	7/12/2007	27.61
	8/16/2007	26.85
Hatchery Well #5	1/22/1990[1]	23.8
	8/26/1999	24.26
	8/15/2000	26.59
Tuttle 1N	9/19/1979[1]	97
	1999	89
	8/6/2004	91.13
DOT #2	8/28/1984[1]	15
	10/2000	12
	8/16/2005	12
Ravenscroft #2	10/6/1960[1]	40
	1999	23
	8/6/2004	25.02
Lunt	1/3/1978[1]	27
	4/26/2004	31.71
	11/9/2006	31.02
	6/24/2007	32.38
DOT #1	3/18/1975[1]	NR
	5/17/2004	46.15
	6/24/2007	47.75*
	8/16/2007	47.34

Well	Date	Depth to Water
Kelly North Stock Well	12/5/1963[1]	NR
	4/29/2004	58.3
	8/16/2005	58.44
	6/24/2007	59.18*
	8/16/2007	58.87
Kelly South Stock Well	12/10/1963[1]	NR
	4/27/2004	3.13
	11/9/2006	3.94
	4/19/2007	2.90
2006 No.1 Well	10/2006[1]	99.88
	4/19/2007	99.71
	5/11/2007	99.68
	6/24/2007	100.44
	7/12/2007	99.59[2]
	8/16/2007	99.50[2]
2006 No. 2 Well	10/2006[1]	60.05
	4/19/2007	59.47
	5/11/2007	59.68
	6/24/2007	60.45
"Silver Spur"	5/24/1958[1]	52
	9/28/2002	50.02
	11/9/2006	50.37
	4/19/2007	49.64
	5/11/2007	49.64
2005 No. 2 Well	5/11/2007	84.64
Barrailler	8/26/1996[1]	72
	7/2004	64.1

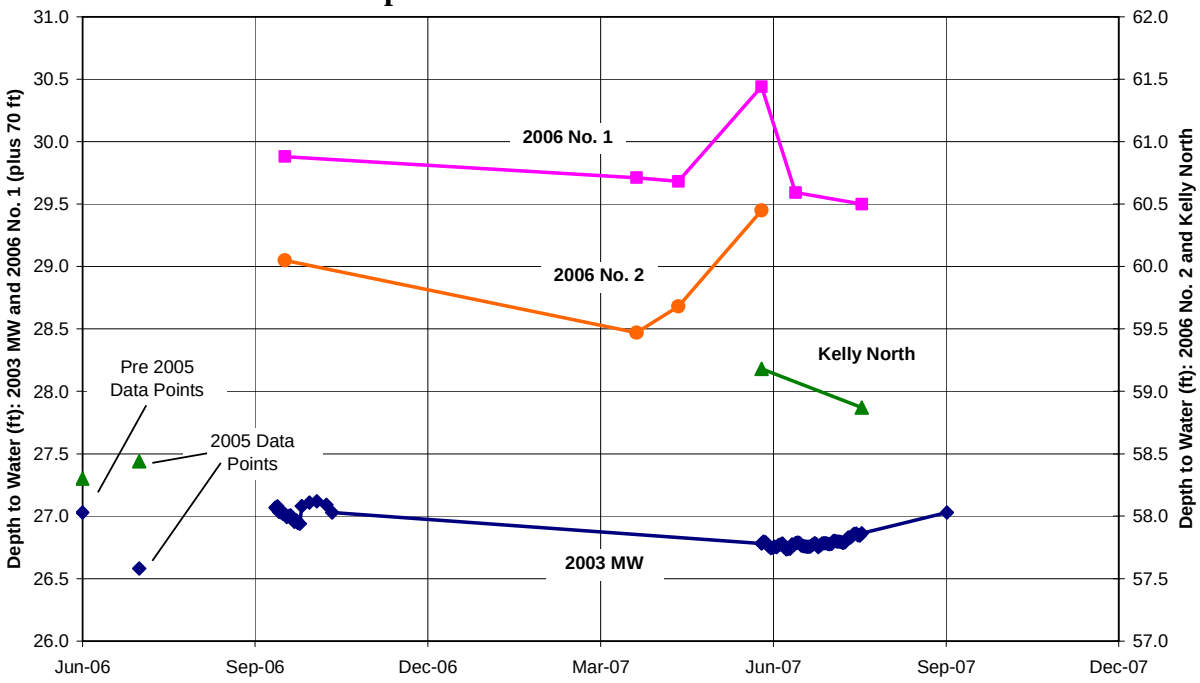
* Recently running
1 Construction date and original depth to water
2 Measurement from 2005 No. 1 Well

The data in **Table E-1** are from Hinckley (2007a), augmented by water-level measurements taken over the course of 2007 (Hinckley 2007b). A plot of the data from select wells is shown in **Table E-1**, which also includes more frequently measured transducer data from the 2003 monitor

well. In addition to the lack of long-term groundwater level declines discussed above, these data indicate little seasonal fluctuation in groundwater levels in the area of the proposed well field or in the larger aquifer. For example, at the 2003 monitor well, the entire variation across the plot is 0.5 ft. This is within the range of water level response in these wells to changes in barometric pressure. To the extent the small variations of the figure are a reflection of seasonal water table, a reasonable interpretation is that spring precipitation and snowmelt increases water levels slightly in early summer, with a combination of natural equilibration and summer pumping decreasing water levels slightly into the fall.

Closest to the area of large, seasonal irrigation drawdown are the "Kelly North" and "DOT #1" wells. In the former, April, June, and October water levels span less than 1 ft. In the latter, June and August 2007 water levels were as much as 1.6 ft lower than a measurement made in May 2004, but the summer measurements include the local drawdown from periodic use of the well. The 2003 monitor well and the "Kelly North" well bracket the area of highest concentration of domestic wells (see **Figure E-7**).

Figure E-11
Depth to Water Data for Select Wells



The data used to develop **Figure E-11** are from monitor wells or low-use wells, provided to reflect general aquifer conditions rather than local drawdown impacts as much as possible. Local areas of drawdown are certain to develop in areas of high discharge (seasonally, in the case of irrigation wells, and permanently, in the case of the fish hatchery supply wells), but significant seasonal effects do not appear to be widespread.

The absence of significant area-wide seasonal water-level fluctuations also validates the timing of pump testing for this project. The 2003 wells were tested in August and October, the 2005 wells in August, and the 2006 wells in October. At the proposed well field, for example,

groundwater levels in October 2006 were nearly identical to those measured in July and August 2007, presumably during the time of peak use by water-supply wells across the larger area.

E.2.2.6 Groundwater Quality

Groundwater quality for the study area was evaluated using published documents and chemical analysis results, a map of TDS that provides an approximation of total mineralization (see **Figure E-12**), and groundwater user interviews (Hinckley 2007a).

Laboratory analyses, included below as **Table E-2**, provide detailed, component-by-component analysis. The locations of the samples in **Table E-2** are shown on **Figure E-12**. Two analyses in **Table E-2** are provided for reference consideration: 1) the current output from the Saratoga Water Treatment Plant (SWTP) (treated North Platte River water; sample "A"); and 2) the flow from the Saratoga Hot Springs (sample "B").

Table E-2
Water Quality Analysis Results

Constituent		Laboratory Analysis									EPA Drinking Water Standards	
	Water Treatment Plant	Saratoga Hot Springs	North Park Formation							alluvium		
	A	B	C	D	E	F	G	H	I	J	Primary	Secondary
Calcium		125	128	54	70	131			110	59		
Magnesium		9.0	15	4.5	12	92			100	12		
Sodium	25	453	28	9.4	9.6	222	130	72	400	59		
Potassium		29	11	6.6	6.9	2.3			17	1.7		
Bicarbonate		77	258	190	212	217			410	267		
Sulfate	37	568	203	16	55	951	340	590	1000	73		250
Chloride		511	35	4.5	13	14			150	16		250
Nitrate	<0.1		0.9	1.4	1.5	1.6		0.2	<.1	1.9	10.0	
Fluoride	0.4	6.5	0.9	0.3	0.6	3.8			1.8	0.6	4.0	2.0
Total Dissolved Solids	(360)	1830	607	242	370	1620	768	1090	1980	384		500
Hardness as CaCo3		349	375	153	224	706	310	520	687	196		
pH			8.1	7.9					7.5			
Arsenic	<.005	0.05	0.01						<.001		.05 (.01)	

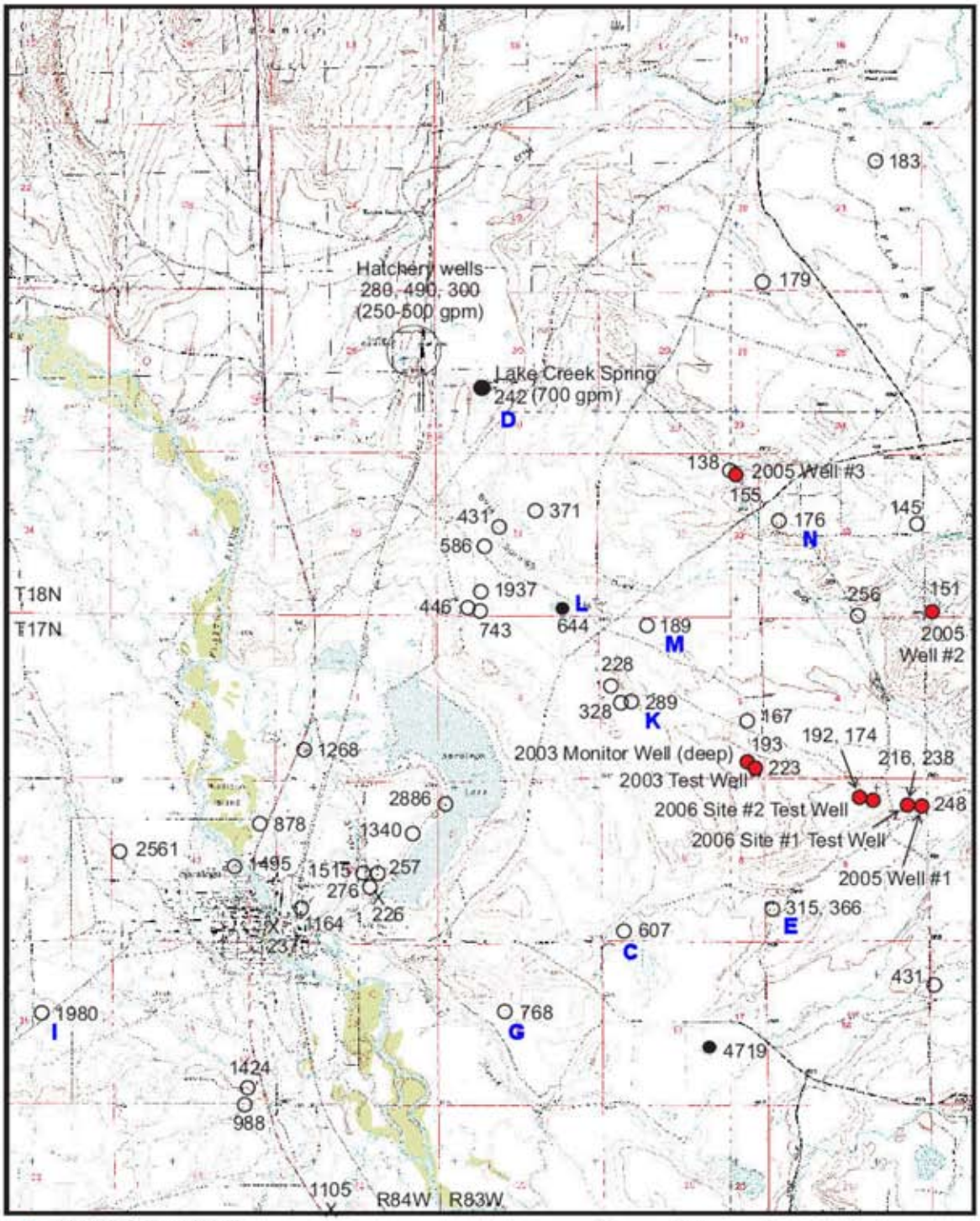
Iron		0.05	0.16	0.06		.012			0.78	0.13		0.3
Constituent	A	B	C	D	E	F	G	H	I	J	Primary	Secondary
Manganese		ND	ND						.092			0.050
Selenium		ND	.047								0.050	
Gross Alpha											15	
conductivity (umhos/cm)	458				484	1990			3000	609		

A - August, 2002 analysis from the Saratoga Water Treatment Plant. (TDS inferred from conductivity.)
B - Breckenridge and Hinckley (1975)
C - composite of 4 samples from Saratoga Landfill monitoring wells (Sec. 8, T17N, R83W; Maxim, 2000)
D - Lake Creek Lake spring (Visher, 1952)
E - Lowry et. al (1973), T17N, R83W, Sec. 9ccb (3 miles east of Saratoga)
F - Lowry et. al (1973), T17N, R84W, Sec. 9bbb (3 miles west of Saratoga)
G - Wyoming State Engineer's Office Permit UW45414, T17N, R83W, Sec. 18bd (1 mi. eastsoutheast of Saratoga)
H - Wyoming State Engineer's Office Permit UW45589, T17N, R83W, Sec. 31dd (4 mi. southsoutheast of Saratoga)
I - 1 mi. southwest of Saratoga (Permit UW13764; sampled for the present study)
J – Lowry et. al (1973), T18N, R84W, Sec. 7dad (North Platte River alluvium 10 miles downstream of Saratoga)

Constituent	**Sample ID (North Park Formation)**					**EPA Drinking Water Standards**
	E	**K**	**L**	**M**	**N**	**Primary**
Uranium (ugm/l)	35.8	14	2.4	4.1	2.3	30
Gross Alpha (pci/l)	8.0	4.3	ND	2.3	1.5	15 (if >5, analyze for $Ra^{226/228}$)
As (ug/l)	4	6	13	6	1	50 – current standard; 10 as of 1/23/06
conductivity (umhos/cm)	563	445	1143	291	223	

Source: PMPC (2003)

Figure E-12
Map of Total Dissolved Solids Values



Source: Hinckley (2007a)

Alluvium

Alluvial groundwater in Saratoga is commonly considered to be of poor quality. Iron staining can be observed on the sides of houses and fences with well-water irrigated lawns. A sulfur smell was reported by several of those interviewed by Hinckley (2007a). A flow of highly-mineralized bedrock groundwater into and through the alluvial deposits to discharge into the river appears to fit the general evidence compiled.

Electrical conductivities were measured in the North Platte River on September 8, 2002. From a value of 358 micromhos per centimeter (µmhos/cm) south of Saratoga, the conductivity increased to 390 µmhos/cm upstream of the hot springs, and was measured between 450 and 476 µmhos/cm at several locations between the hot springs and the north edge of town. It may be assumed that this increase is primarily due to the inflow of groundwater, which is of sufficient volume and salinity to impact the overall mineral content of the river itself. (The North Platte River was at record low flows during the sampling period; a much smaller impact of discharging groundwater would be expected at normal flows.) Electrical conductivities of 1,350 and 2,300 µmhos/cm were measured in shallow wells alongside the North Platte River at the north edge of town, and 1,790 µmhos/cm was measured from a shallow well serving the LP Sawmill on the east side of Saratoga.

Table E-2 includes one laboratory analysis from an alluvial well alongside the North Platte River 10 miles downstream from Saratoga. This sample suggests good water quality, but it was taken in late May 1967, a time when the diluting influence of river flows was likely substantial.

The best groundwater quality available to an alluvial well appears to be that produced by direct river recharge. As bedrock groundwater was developed by the drawdown of an alluvial well, water quality would likely deteriorate substantially. Thus, the value of the alluvial deposits lies in their ability to filter river water (e.g., via a river-bed infiltration gallery, as is presently in use) rather than as a source of abundant, high-quality groundwater themselves.

North Park Formation

North Park Formation groundwater quality has been found to improve systematically as one moves east from Saratoga. Groundwater in the immediate vicinity of Saratoga is commonly in excess of EPA Drinking Water Standards for overall salinity. Across the western one-third of the Mountain View Estates subdivision, around Saratoga Lake, and at the Saratoga Landfill, certain groundwater samples have exceeded standards for sulfate, nitrate, arsenic, and TDS (Hinckley 2007a). One well sample exceeded the primary Drinking Water Standard for uranium.

Data shown in **Table E-2** and on **Figure E-12** indicate a wide range in groundwater quality, from clearly acceptable to clearly unacceptable. Relatively low TDS and good quality is evident for wells to the east where TDS is below 500 mg/l, with most in the 150-300 mg/l range. In contrast, the wells west of Saratoga tend to have higher TDS levels, many of which exceed 1,000 mg/l. Local reports of poor groundwater quality throughout the area west of town are common. The conductivity of 1,700 µmhos/cm measured in Spring Creek at the highway bridge south of Saratoga substantiates the relatively poor quality of groundwater discharging to the surface in

that area. User satisfaction, local concepts of groundwater quality, and measured conductivities east of Saratoga are generally substantially more favorable.

Behind these considerable local variations in groundwater chemistry, the general distribution of mineral concentrations fits the overall groundwater flow directions discussed above, with groundwater quality deteriorating as it flows westward from recharge along the west flank of the Medicine Bow Mountains towards discharge areas along the North Platte River. This characteristic directs groundwater-supply exploration interest in the North Park Formation to the area east and northeast of Saratoga.

Proposed Well Field Water Quality

Table E-3 shows the groundwater quality data for the North Park aquifer at the proposed well field. The EPA primary Drinking Water Standards are based on human health considerations and are mandatory compliance thresholds, whereas the secondary Drinking Water Standards are based on aesthetic considerations and are advisory.

For all constituents analyzed, the groundwater samples from the area of the proposed well field (2005 well #1 and 2006 wells) are all well within EPA Drinking Water Standards. Although the data represents a short period of time, the nature of the aquifer is such that substantial seasonal variation is quite unlikely. A groundwater source will certainly deliver a more consistent water quality than the river.

Serial sampling for select parameters was conducted during the 2006 tests to assess changes in groundwater quality with pumping (i.e., if spatial variations in quality are reflected in well discharge as groundwater is drawn in from the surrounding area). Conductivity and temperature measurements were taken at least twice daily over the course of testing. The total volumes pumped from the test wells at Sites No. 1 and No. 2 were approximately 7 million and 2.3 million gallons, respectively.

Conductivity data from 2006 Test Well No. 1 may suggest a slight decline over the course of pumping (i.e., from an average of 348 to an average of 341 µmhos/cm). Data from 2006 Test Well No. 2 show no systematic change over the pumping period, and little deviation from the 305 µmhos/cm average. Temperature data for both wells were stable over the course of testing, averaging 54.3 and 53.4 °F for Sites No. 1 and No. 2, respectively. The slightly higher salinity and temperature of groundwater from Site No. 1 may be a reflection of the somewhat deeper completion as, all else being equal, deeper groundwater tends to be higher in both of these parameters.

Radioactivity in groundwater is the result of the decay of naturally-occurring minerals, primarily uranium and thorium. There are known low-level deposits of radioactive minerals at various locations around the Saratoga Valley, although none have been identified at sufficient concentrations to merit commercial exploration (Stephens and Bergin 1959). Dissolved uranium concentrations found in waters of interest to the present study include river water (0.005 mg/l), and groundwater at the proposed well field (0.003-0.005 mg/l). The EPA Drinking Water Standard maximum contaminant level for uranium is 0.03 mg/l; therefore, both sources are well below the applicable standard.

Table E-3
Groundwater Analytical Results at the Proposed Well Field

Constituent	Proposed Saratoga Wellfield								EPA Drinking Water Standards	
	Site 1				Site 2					
Collection Date	8/23/05	10/28/06	11/1/06	11/6/06[2]	10/10/06	10/13/06	10/16/06	10/23/06	Primary	Secondary
MICROBIOLOGICAL (CFU/ml and P/A)										
Bacteria, Iron Related			500	1400			500			
Bacteria, Total Coliform			absent	absent				absent		
MAJOR IONS (mg/L)										
Acidity, Total as $CaCO_3$				<1.0				<1.0		
Alkalinity, Total as $CaCO_3$				169				126		
Carbonate as CO_3		<1	<1	<1		<1	<1	<1		
Bicarbonate as HCO_3		192	203	206		174	172	153		
Calcium		55	59	55	39	47	49	37		
Chloride		3	2	4		4	4			250
Fluoride				0.5				0.6	4	2
Magnesium		9.1	9.8	9.2	5.9	6.8	7.1	5.8		
Nitrogen, Nitrate+Nitrite as N				0.6				0.2	10	
Nitrogen, Nitrite as N				<0.10				<0.10	1	
Potassium		5.6	5.7	5.7	5.4	4.9	4.9			
Silica				55				55		
Sodium[3]		7.4	7.3	7.2	7.5	7.6	7.6			
Sulfate		22	22	24		11	12			250
NON-METALS (mg/L)										
Cyanide				<0.005				<0.005	0.2	
PHYSICAL PROPERTIES										
Color (c.u.)				<5.0				<5.0		15
Conductivity (umhos/cm)			357	362			296	255		
Corrosivity (unitless)				-0.053				0.31		non-corrosive
Hardness as $CaCO_3$ (mg/L)				175				117		
Odor (T.O.N.)				NOO				NOO		3
pH (s.u.)			7.79	7.82			7.94	8.02		6.5 - 8.5
Total Dissolved Solids (mg/L)		238	216	238		148	192	174		500
Surfactants, MBAS				<1.0				<1.0		0.5
Turbidity, NTU				<0.10						

METALS - TOTAL (mg/L)										
Aluminum				<0.1				<0.1		0.05 - 0.2
Antimony				<0.001				<0.001	0.006	
Arsenic	0.003	0.003	0.003	0.003	0.002	0.002	0.002	0.002	0.01	
Barium				0.2				0.2	2	
Beryllium				<0.001				<0.001	0.004	
Boron				<0.1				<0.1		
Cadmium				<0.001				<0.001	0.005	
Chromium				<0.05				<0.05	0.1	
Copper				<0.01				<0.01	1.3	1
Iron			<0.03	<0.03			<0.03		0.3	0.3
Lead				<0.001				0.002	0.015	
Manganese				<0.01				<0.01		0.05
Mercury				<0.001				<0.001	0.002	
Nickel				<0.05				<0.05	0.1	
Selenium				0.001				<0.001	0.05	
Silver				<0.01						0.1
Thallium				<0.0004				<0.0004	0.002	
Uranium	0.0059	0.005	0.0051	0.0053	0.0032	0.0046	0.0046		0.03	
Zinc				<0.01				0.02		5
RADIONUCLIDES - TOTAL (pCi/L)										
Gross Alpha	10.8	6.7	8.5	8.1	4.6	7.4	6		15	
Gross Beta			7.9	7.3					50	
Radium 226			<1.0	<1.0			<1.0			
Radium 228			<1.0	<1.0			<1.0			
Radium 226 + Radium 228			<1.0	<1.0			<1.0		5	
Radon 222				423				267		

[1]July 2000 analysis. Conductivity measured in September 2002. (TDS inferred from conductivity.)

[2]Total coliform and iron related bacteria samples collected 11/14/06; all VOCs and SOCs tested resulted in "non-detects."

[3]As of February 2003, "the EPA guidance level for sodium in drinking water is 20 mg/L. This value was developed for those individuals restricted to a total sodium intake of 500 mg/day and should not be extrapolated to the entire population."

Radioactivity from uranium, thorium, and their various daughter products are present in both the river water (gross alpha = 3.8-5.4 pico-Curies per liter [pCi/l]) and the groundwater at the proposed well field (gross alpha = 4.6-6 pCi/l). EPA has set a Drinking Water Standard of 15 pCi/l for gross alpha activity. This measures the composite effect of radioactive disintegrations of a wide variety of elements, some of which are relatively benign and some of which have potentially serious health effects. A specific standard of 5 pCi/l has been set for the combined concentration of the two most radiotoxic naturally-occurring radioactive isotopes in groundwater – Radium^{226} and Radium^{228}. Neither of these isotopes has been detected at a detection limit of 1.0 pCi/l in any of the samples reviewed (Hinckley 2007a).

Radon^{222} is one of the radioactive decay products of Radium^{226} and tends to be highest in groundwater associated with granitic rocks. The USGS (2006) has analyzed seven groundwater samples from the North Park Formation in Carbon County. Three of these were within 10 miles of the present study area; radon concentrations in these samples varied from 590 to 1,290 pCi/l. Although the data are insufficient to map radon concentrations in this aquifer, the higher values in this small dataset are from those locations closest to the outcrops of granitic rocks.

Three radon samples were taken (Hinckley 2007a) for laboratory analysis: Radon^{222} was found at the SWTP at a concentration of 106 pCi/l, and in the groundwater from 2006 Sites No. 1 and No. 2 test wells at 423 and 267 pCi/l, respectively. Informal samples have been taken by PMPC at nine locations in and around Saratoga. Indoor air concentrations of radon varied from 1.2 to 3.3 pCi/l across seven samples. Groundwater samples from a Mountain View Estates well and from a well west of Saratoga produced radon concentrations of 749 pCi/l and 1,162 pCi/l, respectively.

Currently, there is no Drinking Water Standard for Radon^{222}. The EPA "action level" for air concentrations is 4 pCi/l, equivalent to a drinking water concentration of 40,000 pCi/l or more in the absence of any other sources. In 1997, EPA withdrew a 1991 proposal to establish a Drinking Water Standard for radon at 300 pCi/l. EPA went on to propose in 1999 regulating drinking water radon levels to one of two standards: 300 pCi/l in the absence of other programs that address indoor radon levels and 4,000 pCi/l if such programs were being implemented. High-performance aeration (air stripping) was identified by EPA as an effective treatment technology for radon in water.

Thus, the suggestions of the limited data available are that: 1) the concentrations in the 2006 test wells are not anomalously high, and 2) there may be an association between proximity to granitic rocks (present beneath and to the east of the 2006 test wells) and higher radon concentrations. If the latter is correct, the deeper completion and further east location of the test well at 2006 Site No. 1 may partially explain the higher radon concentration encountered there.

E.2.2.7 Landfill Location, Hydrogeology, and Water Quality

The Saratoga Landfill is located roughly 2 miles to the west-southwest of the proposed well field in Section 8, T17N, R83W. **Figure E-10** shows the location of the landfill along with groundwater elevations and flow directions. As with the proposed well field, the general groundwater flow direction at the Saratoga Landfill is to the west.

Detailed evaluations at the Saratoga Landfill found low permeability, silty sandstone, and siltstone at the surface and shallow subsurface. Hydraulic conductivity of 0.5 ft/day was assessed from well tests (Maxim 2000), in contrast with values of 20 ft/day from the 2006 Level II test wells (Hinckley 2007a).

Low permeability material is more common in the western portion of the study area (i.e., in the mile or so east of Saratoga), than at locations further east. For example, extension of the hydraulic conductivity reported for the Saratoga Landfill, 0.5 ft/day, to an aquifer thickness of 300 ft indicates a transmissivity on the order of 1,000 gpd/ft as compared to transmissivities in excess of 20,000 gpd/ft further east.

Groundwater quality data for the area of the Saratoga Landfill from 2000 (Maxim) and 2007 (Hinckley) is summarized in **Table E-4**. The "2000 composite" sample (also shown as sample "C" in **Table E-2**) is from several wells within ¼ mile east and up-gradient of the landfill; UPR-1 is along the east boundary of the landfill and UPR-2 and UPR-3 are the down-gradient monitor wells on the west side of the landfill. Thus, the first two data columns in **Table E-4** likely reflect background water quality at the site, whereas the last two samples reflect the combination of background groundwater and whatever leachate escapes from the landfill. Based on these limited analyses, landfill leachate does not appear to significantly impact native groundwater quality. The analyses for Volatile Organic Compounds (VOC) includes a suite of 48 compounds so, for brevity, only the single detected compound is listed in the table. Similarly, not all of the metals analyses are listed.

For the four samples reported by Maxim (2000) and combined in **Table E-4** as a composite, the only metals for which individual sample concentrations exceeded the detection limits were

arsenic (0.003-0.014 mg/l), barium (0.110-0.150 mg/l), lead (0.002-0.009 mg/l), selenium (0.001-0.169 mg/l), and zinc (0.010-0.060 mg/l). No detectable concentrations were measured for antimony, beryllium, cadmium, chromium, cobalt, copper, nickel, silver, thallium, or vanadium at any of the four wells. In the 2007 (Hinckley) samples, the only metal analyzed was iron, which was below the detection limit in one down-gradient well, and present in the other down-gradient and the up-gradient wells at concentrations of 0.52 and 1.30 mg/l, respectively.

In the four samples from 2000, the only VOC found above the detection limit was chloromethane at a concentration of 1.82 µg/l. This compound was not detected in the 2007 samples, but trichlorofluoromethane was detected in the up-gradient well, UPR-1, at a concentration of 2.1 µg/l.

EPA primary (i.e., health based) Drinking Water Standards were exceeded in this group of samples for arsenic and selenium (one sample) and for arsenic only (one sample). Extensive groundwater-quality sampling from the proposed well field area, up-gradient of the landfill, found no constituents in excess of the primary Drinking Water Standards.

Secondary Drinking Water Standards were exceeded in the landfill area data for TDS and for iron. Secondary standards are non-enforceable guidelines regulating contaminants that may cause cosmetic effects (such as skin or tooth discoloration) or aesthetic effects (such as taste, odor, or color) in drinking water. EPA recommends secondary standards to water systems but does not require systems to comply.

Table E-4
Groundwater Analytical Results at the Saratoga Landfill

Parameter	Units	2000 Composite	6/4/2007 UPR1	6/4/2007 UPR2	6/4/2007 UPR3	EPA Drinking Water Stds Primary	EPA Drinking Water Stds Secondary
Major Ions							
Alkalinity[1]	mg/L	------	214	198	274		
Bicarbonate	mg/L	258	------	------	------		
Calcium	mg/L	128	104	91.2	91.7		
Chloride	mg/L	35	14	24	12		250
Magnesium	mg/L	15	20.9	19.2	16.6		
Nitrogen[2]	mg/L	------	<0.05	<0.05	<0.05		
Nitrate	mg/L	0.9	------	------	------	10.0	
Potassium	mg/L	11	12.7	6.0	4.1		
Sodium	mg/L	28	20.7	29.2	50.8		
Sulfate	mg/L	203	172	148	124		250
Fluoride	mg/L	0.9	------	------	------	4.0	2.0
Non-Metals							
Total Organic Carbon	mg/L	------	1.3	1.4	3.2		
Physical Properties							
Conductivity	µmhos/cm	------	871	781	822		
Hardness as $CaCO_3$	mg/L	------	347	307	297		
Chemical Oxygen Demand	mg/L	------	13.0	11.0	21.0		
pH	s.u.	8.1	7.60	7.19	7.01		6.5-8.5
Total Dissolved Solids	mg/L	**607**	**580**	**498**	**518**		500
Metals-Total							
Arsenic	mg/L	0.01	------	------	------	0.01	
Iron	mg/L	0.16	**1.30**	<0.03	**0.52**		0.3
Manganese	mg/L	ND	------	------	------		0.05
Selenium	mg/L	0.047	------	------	------	0.050	
Volatile Organic Compounds[3]							
Trichlorofluoromethane	µg/L		2.1	<1.0	<1.0		

Bold values exceed listed EPA standards
1 Total as CaCO3
2 Ammonia as N
3 Only detected constituents listed

In the case of TDS, the exceedances are only slightly above the standard. As can be seen in **Table E-2**, this standard has been exceeded in samples from several other wells across the aquifer and at much higher concentrations. TDS for the proposed well field (see **Table E-3**) are below the standard.

For iron, two of the three landfill well samples from 2007 exceed the secondary standard. In **Table E-2** only one other well to the southwest of Saratoga exceeds this standard, though not all samples were analyzed for iron. Iron concentrations at the proposed well field are below the standard (see **Table E-3**).

E.2.2.8 Local Springs and Seeps

As discussed above, spring discharges and potentially groundwater-fed ponds appear to form a band of occurrence along a northwest-southeast trend from the large Lake Creek Lake springs serving the Saratoga fish hatchery 3 miles north-northeast of town through Saratoga Lake (which is reported to have been spring-fed before a supply ditch from the river was constructed) and the small stagnant pond southeast of the landfill. This is inferred to represent a lateral change in aquifer permeability (see **Figure E-8**) – westward migrating groundwater encounters lower

permeability material and is forced to the shallow subsurface. Under this model, both the quantity and quality of groundwater should be markedly better to the east of this band.

Breckenridge and Hinckley (1978) suggest that a northeast-southwest trending fault through the site of the Saratoga Hot Springs [as mapped by Montagne (1955)] may control the hot spring location. Montagne (1991) maps several "possible basement fracture system" features in the Saratoga area, including one trending north-northeast by south-southwest 3 to 4 miles east of town. The impact of these conjectured fracture systems on groundwater circulation is unknown; although Montagne (1991) suggests some connection with "the line of springs ... at Saratoga."

E.2.3 WATERS OF THE U.S. AND WETLANDS

The location and classification of potential wetlands within the project area were determined from USFWS National Wetlands Inventory (NWI) data, which classifies wetlands according to the Cowardin System (Cowardin *et al*. 1979), and from site observations. Two types of wetland features are mapped by the NWI within the project area:

- PEMC – Palustrine, emergent, seasonally flooded wetland
- PEMF – Palustrine, emergent, semipermanently flooded wetland

These features were identified during a field visit in October 2007 to be irrigation ditches, which are man-made features that were excavated in upland areas and are not considered jurisdictional waters of the U.S. The ditches originate at a tributary to the North Platte River, where they are regulated by a head gate. Water flows through underground culverts and reappears above ground in the lumber yard at the northeast corner of Pic Pike Road and South State Street. The ditches convey water seasonally to provide irrigation water for several properties. As shown on **Figure E-14**, the ditches support some wetland vegetation such as willows (*Salix* sp.) and cattails (*Typha latifolia*); however, these areas are highly disturbed and also support weed species. Cheatgrass, Canada thistle (*Cirsium arvense*), musk thistle (*Carduus nutans*), and spotted knapweed were observed adjacent to the ditches. No wetlands were observed at the proposed well field and all proposed alignments would cross the two irrigation ditches. The BLM does not have any Proper Functioning Class data for the project area.

Figure E-14
Irrigation Ditch at Lumber Yard

E.3 WATER RESOURCES – GROUNDWATER EFFECTS OF ACTION ALTERNATIVES.

E.3.1 NORTH PLATTE RIVER AND SURFACE WATER DEPLETIONS

E.3.1.1 Proposed Action and Alternative 1 – Pennock Mountain Road Alignment

As discussed in **Chapter 3**, groundwater in the proposed well field area is generally flowing towards and ultimately into the North Platte River. Groundwater intercepted by the proposed well field is water that, ultimately, would proceed to the river under natural groundwater flow. Assuming the consumptive use characteristics of the Saratoga municipal water system would not change under a groundwater supply, the ultimate deficit to the river would be the same whether water was taken directly from the river or taken from the groundwater that would otherwise flow to the river.

Stream depletion is the term that, in this case, refers to the reduction in flow in a stream or river resulting from interception of groundwater that would have flowed into that stream or river. Stream depletion was calculated using computer models that take into account pumping rates, aquifer parameters, and distance from the river. Using aquifer properties of 30,000 gpd/ft for transmissivity and 0.05 for storage coefficient, the cumulative depletion to the North Platte River would be 32 percent of the total volume pumped after 30 years of continuous pumping (Hinckley 2007a). Thus, the 30-year growth scenario pumping rate of 228 gpm per well, or a total of 1,140 gpm, equates to a stream depletion after 30 years of 364.8 gpm (0.9 cfs), or 588.3 acre-feet per year. This is likely an overestimate because the analysis does not take into account the decrease in aquifer transmissivity between the proposed well field and the North Platte River.

In effect, switching from surface water to groundwater would result in an increase in flow of the North Platte River for a considerable time. It would be many decades before each unit of well field production were matched by a unit of stream depletion. In the meantime, normal return

flows through the Saratoga wastewater system would continue, and water would no longer be removed from the river.

E.3.1.2 No Action Alternative

Under the No Action Alternative, groundwater-induced stream depletion will not occur because there will not be any production wells installed and put into service. Impacts to the North Platte River would remain the same as under the current use scenario.

E.3.2 GROUNDWATER

E.3.2.1 Proposed Action and Alternative 1 – Pennock Mountain Road Alignment

The impacts of the Proposed Action on groundwater have been evaluated by using observed pumping data and pumping-tests based on aquifer parameters to project or predict long-term impacts under various pumping scenarios. Groundwater impacts are discussed in terms of drawdown in the aquifer and contingencies associated with the Saratoga Landfill.

Drawdown and Well Interference

Aquifer drawdown projections (Hinckley 2007a and 2007b) were developed based on the Proposed Action. Two demand scenarios were considered: 1) current conditions – population of 1,726, and 2) growth conditions - population of 3,000. The annual average and peak-day water-supply demands are noted below.

Long-term, area-wide impacts, which are transmitted through the entire aquifer, are expected to be a function of average transmissivities on the order of 30,000 gpd/ft and storage coefficients of 0.05. These should be relatively conservative values for the projection of impacts, because they ignore the locally much higher permeabilities of the shallowest portions of the aquifer, the potential for scattered transmissivities of 400,000 gpd/ft in local deposits as encountered along Lake Creek, and the potential for additional gravity drainage over periods of time longer than those tested (i.e., higher effective storage coefficients). Previous investigations of the North Park Formation in this general area concluded transmissivities were in the 30,000-40,000 gpd/ft range (Lowry, et al. 1973). Summary pump test data reported on 26 Statements of Completion (not including the high-production irrigation wells on Lake Creek) were compiled for the Level I report (PMPC 2003), generating an average specific capacity of 11.9 gpm/ft. Application of the rule-of-thumb conversion to transmissivity from Driscoll (1986) suggests an overall transmissivity of approximately 24,000 gpd/ft.

The impacts of pumping on aquifer water levels, discussed below, are considered for the following:

- Drawdown at the individual pumped well;
- Drawdown across the well field;
- Drawdown in other wells;
- Drawdown around the Saratoga Landfill;
- Effect on the fish hatchery spring; and
- Effect on other local springs and seeps.

Drawdown at the Pumping Well

Under the current-conditions scenario, each well of a five-well well field would have to pump continuously at an average rate of 54 gpm to meet the average annual demand. Each well would have to pump an additional 78 gpm to meet the summer peak day demand. In practice, these averages would likely be best achieved through a well rotation approach, each well delivering 150-200 gpm as necessary to meet demands. The pumping water level in the 2006 Site No. 1 test well, under sustained pumping at 200 gpm, is projected to be approximately 160 ft. This will leave the uppermost screened section, 145-160 ft, cascading water into the well. While this is not ideal, it allows the well to take advantage of water available in this important water-bearing zone that would otherwise enter the well only by migrating downward through intervening lower-permeability strata. For the pumping water level to remain above the uppermost screen, a pumping rate of approximately 130 gpm appears to be sustainable. At the 2006 Site No. 2 test well, a similar situation is produced under 170 gpm pumping (i.e., pumping water level is approximately 15 ft below the top of the uppermost screen). For the pumping water level to remain above the uppermost screen, a pumping rate of approximately 130 gpm appears to be sustainable.

Under the growth scenario, the five-well averages are 94 gpm and an additional 134 gpm at peak (for a total production of 228 gpm/well). The 2006 test wells have demonstrated the capacity to produce groundwater at 1.4 to 1.8 times this rate, although efficiency considerations argue against pumping at the maximum rates tested. In practice, the experience of well field operations would be applied to optimizing the growth-scenario distribution of pumping rates.

Drawdown and Interference within the Well Field

Obviously, the wells of a well field will interfere with one another to some extent. The drawdown impacts of a five-well well field were predicted assuming that all wells were pumping. The simulated pumping was run for 30 years with the rate matching the current water demands, which consists of 54 gpm/well base pumping plus an additional 78 gpm/well for three months of each year to represent peak-period pumping.

With the proposed well spacing of approximately 580 ft, a total of 9 to 11 ft of inter-well additional drawdown at the end of 30 years is predicted. In other words, with all five wells pumping, each well would experience the drawdown produced by its own pumping, plus approximately 9 to 11 ft of drawdown created by the other four wells in the well field.

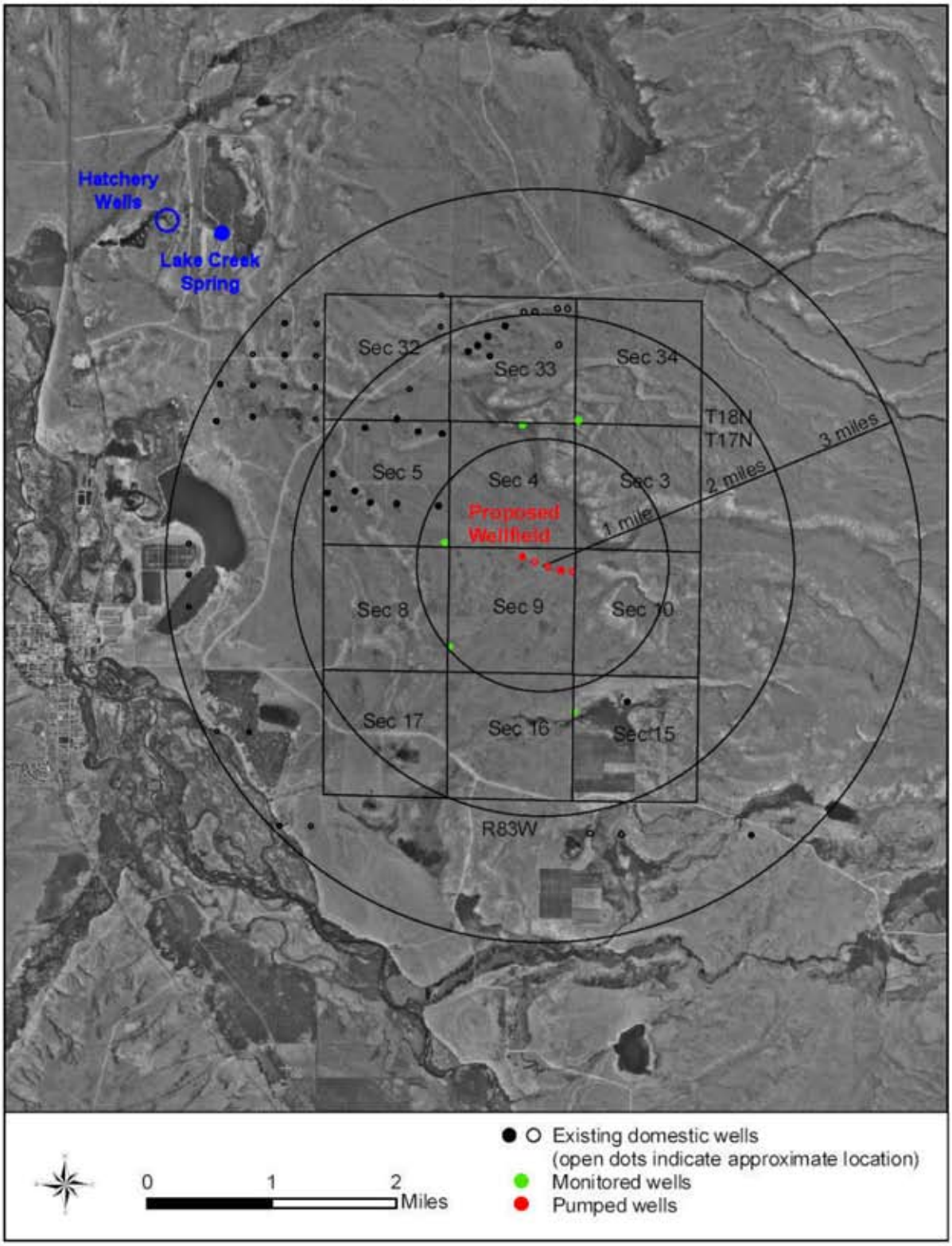
This range in values represents the difference from the end well (least impact from other wells) to the center well (most impact from other wells). The actual impact in practice, of course, will vary somewhat from these theoretical calculations as the variations in well completions and local geologic conditions come into play. Appropriate well field management will evolve as performance data are developed.

Under the growth scenario (population of 3,000), the inter-well drawdown interference increases to 16-19 ft. Spacing the wells further apart would reduce the interference somewhat, but beyond about 580 ft the improvement of reduced interference is small compared to the additional pipeline required and the increase in proximity to neighboring residential wells. For example, spacing the wells at 1,000-ft intervals reduces the calculated 16-19 ft range to 11-14 ft.

Drawdown in Other Wells

Groundwater permits of record for water-supply wells within 3 miles of the proposed well field are shown on **Figure E-18** (closed circles on the diagram indicate actual well location; open circles reflect well locations only to the nearest 1/4 1/4 Section, as listed in the SEO database). The Statement of Completion data filed for these wells are summarized in **Table E-5** (see Hinckley [2007a] for complete listing). These data are as reported in the files of the SEO, which are known to contain scattered location, depth and other transcription and reporting errors. Data known to be in error have been corrected.

Figure E-18
Existing Well Locations



Modified from Hinckley (2007a)

Table E-5
Study Area Water Well Completion Data and Projected Impact

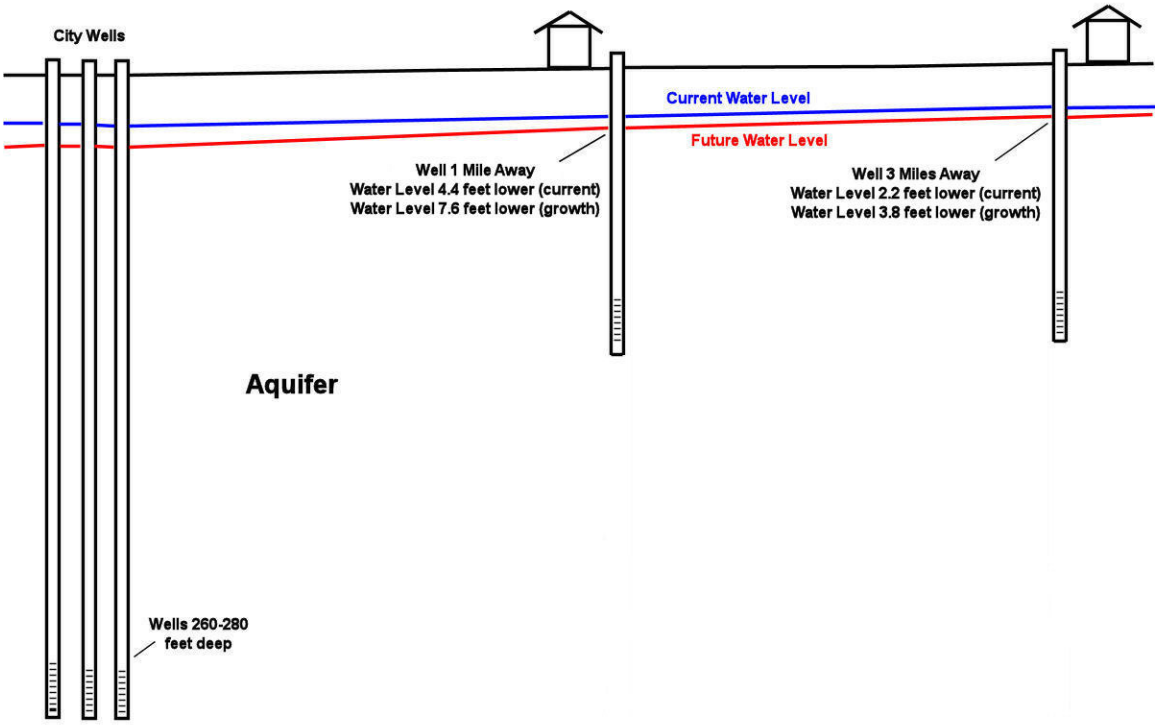
Permit	Priority	Uses	Well Depth (ft)	Static Water Depth (ft)	Main Water Zone Bottom (ft)	Pump Setting (ft)	Distance from Proposed Wellfield (miles)	Projected 30-year drawdown (ft.) under Current Conditions	Projected 30-year drawdown (ft.) under Growth Scenario
P42832W	4/17/1978	DOM	115	72	115		1.00	4.4	7.6
P1151W	5/24/1958	STO	130	52			1.00	4.4	7.6
P17392P	12/10/1963	STO	30				1.14	4.1	7.2
P4442P	12/31/1941	DOM	90	10			1.14	4.1	7.2
P41402W	1/3/1978	STO	62	27	62		1.17	4.1	7.1
P173173W	1/9/2006	MIS	125	80	125		1.19	4.0	7.0
P80212W	7/10/1989	DOM,STO	125	70	85		1.30	3.9	6.7
P105700W	5/15/1997	DOM	126	47	61		1.30	3.9	6.7
P92101W	6/16/1993	DOM,STO	120	70	84	110	1.35	3.8	6.6
P69714W	4/3/1985	DOM,STO	125	35	80		1.35	3.8	6.6
P49158W	7/18/1979	DOM	130	80	130		1.49	3.6	6.2
P61854W	8/30/1982	DOM	130	65	120	85	1.51	3.6	6.2
P73481W	10/16/1986	DOM,STO	120	42	100		1.68	3.3	5.8
P107254W	8/25/1997	DOM	200	80	200		1.73	3.3	5.7
P99631W	7/5/1995	DOM	180	83			1.77	3.2	5.6
P64828W	7/15/1983	DOM,STO	175	105	135		1.84	3.2	5.5
P152153W	6/26/2003	DOM,STO	185	79	134		1.84	3.2	5.5
P98193W	1/19/1995	DOM,STO	160	63	140	105	1.86	3.1	5.4
P58855W	11/6/1981	DOM,STO	205	139	180		1.89	3.1	5.4
P43005W	4/24/1978	DOM,STO	103	31	103		1.93	3.1	5.3
P48132W	5/21/1979	DOM	205	100			1.95	3.0	5.3
P119524W	10/11/1999	DOM,STO	150	37	147		1.96	3.0	5.3
P172412W	12/30/2005	DOM,STO					1.96	3.0	5.3
P126967W	7/26/2000	DOM,STO	162	59	150		2.04	3.0	5.1
P134264W	5/1/2001	DOM	200	80	158		2.04	3.0	5.1
P103894W	9/18/1996	DOM	163	72	135		2.06	2.9	5.1
P103619W	8/26/1996	DOM,STO	183	72	145		2.06	2.9	5.1
P3018P	1/31/1968	DOM	215	60			2.18	2.8	4.9
P37740W	5/5/1977	DOM	220	140	220		2.22	2.8	4.8
P17391P	12/5/1963	STO	105				2.31	2.7	4.7
39/8/10W	5/2/2006	DOM					2.31	2.7	4.7
P20665P	5/1/1959	DOM,STO	100	20			2.42	2.6	4.5
P60845W	5/24/1982	DOM	120	37	110		2.46	2.6	4.5
P115875W	4/29/1999	DOM					2.46	2.6	4.5
P4439P	12/31/1948	DOM	21	11			2.63	2.5	4.3
P4440P	10/31/1959	DOM	80	40			2.63	2.5	4.3
P67493W	6/1/1984	DOM	80	15			2.63	2.5	4.3
P4441P	5/31/1968	STO	85	20			2.63	2.5	4.3
P44939W	9/6/1978	DOM	185	90			2.63	2.5	4.3
P98056W	12/29/1994	DOM	100	44	65		2.69	2.4	4.2
P48568W	6/22/1979	DOM	103	25	103		2.69	2.4	4.2
P48569W	6/22/1979	DOM	123	25	123		2.69	2.4	4.2
P45273W	2/16/1977	DOM	305	100	305		2.69	2.4	4.2

Permit	Priority	Uses	Well Depth (ft)	Static Water Depth (ft)	Main Water Zone Bottom (ft)	Pump Setting (ft)	Distance from Proposed Wellfield (miles)	Projected 30-year drawdown (ft.) under Current Conditions	Growth Scenario
P158705W	5/12/2004	DOM					2.69	2.4	4.2
P45414W	9/12/1978	MIS	350	70			2.70	2.4	4.2
P39498W	8/11/1977	DOM,STO	90	48	90		2.71	2.4	4.2
P1098W	10/28/1962	DOM	120	65			2.75	2.4	4.1
P42760W	4/12/1978	DOM	90	65	80		2.78	2.3	4.1
P39991W	9/16/1977	DOM	100	60	100		2.78	2.3	4.1
P42830W	4/14/1978	DOM	130	70	125		2.78	2.3	4.1
P41095W	12/12/1977	DOM	150	90	150		2.78	2.3	4.1
P10926P	9/30/1959	DOM	51	16			2.84	2.3	4.0
P12833P	12/31/1934	STO	100	60			2.84	2.3	4.0
P78379W	10/28/1988	DOM	222	37	200		2.84	2.3	4.0
P44450W	8/1/1978	MIS	60	18	60		2.86	2.3	4.0
P15522W	9/29/1972	STO	30	3			2.90	2.3	3.9
P4471P	10/13/1925	DOM	45	15			2.90	2.3	3.9
P4472P	7/25/1962	DOM	80	10			2.90	2.3	3.9
P4476P	6/16/1926	DOM	30	8			2.92	2.3	3.9
P92596W	8/5/1993	DOM	110	35	105		2.92	2.3	3.9
P116134W	6/3/1999	DOM,STO	130	71	82		2.92	2.3	3.9
P47565W	4/26/1979	DOM	147	50	147		2.92	2.3	3.9
P47614W	4/25/1979	DOM	104	40	104		2.94	2.2	3.9
P52632W	6/19/1980	DOM	122	56	122		2.94	2.2	3.9
P148213W	11/25/2002	DOM	125	72	81		2.94	2.2	3.9
P159224W	5/21/2004	DOM	130	33	108		2.94	2.2	3.9
P149350W	2/12/2003	DOM	131	78	102		2.94	2.2	3.9
P53218W	8/12/1980	DOM	140	90	140		2.94	2.2	3.9
P45169W	9/8/1978	DOM	164	30	160		2.94	2.2	3.9
P47310W	4/11/1979	DOM	164	30	160		2.94	2.2	3.9
P52376W	6/12/1980	DOM	195	94	182		2.94	2.2	3.9
P108979W	3/3/1998	DOM	222	81	210		2.94	2.2	3.9
P110980W	7/15/1998	DOM	300	60	248		2.94	2.2	3.9
P47566W	4/26/1979	DOM	300	30	300		2.94	2.2	3.9
38/10/92W	7/29/2005	DOM					2.94	2.2	3.9
P165514W	2/11/2005	DOM					2.94	2.2	3.9
P92036W	6/14/1993	DOM	230	37	220		2.95	2.2	3.9
P39305W	6/1/1977	DOM,STO	82	30	82		3.00	2.2	3.8
P49784W	7/9/1979	IRR	82	30	82		3.00	2.2	3.8
P48637W	6/26/1979	DOM	145	60			3.00	2.2	3.8
P74478W	4/24/1987	DOM	160	70			3.00	2.2	3.8
P47311W	4/11/1979	DOM	165	80	165		3.00	2.2	3.8
P150029W	3/25/2003	DOM					3.00	2.2	3.8

The predicted drawdown at each existing well from a hypothetical Saratoga well field under the two demand scenarios, current-conditions and growth, based on 30 years of continuous pumping at the average annual rates is included in **Table E-5**. The predicted drawdown is also illustrated schematically on **Figure E-14**.

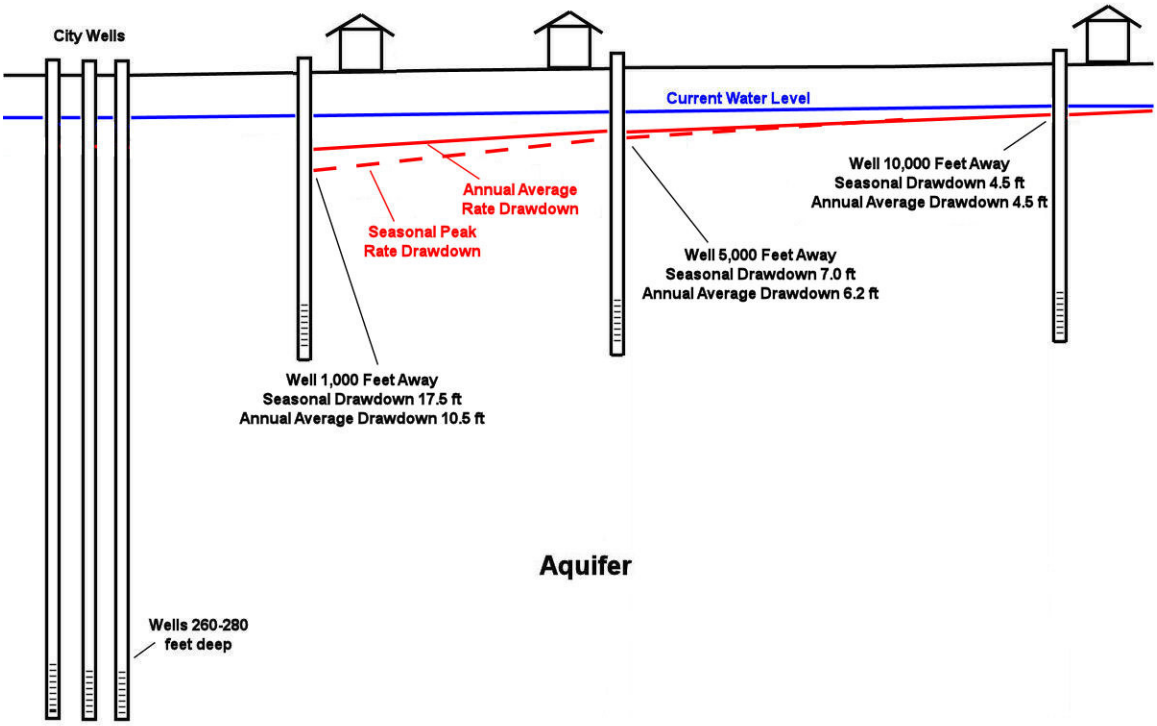
As groundwater is extracted from the proposed well field, the local groundwater level will decline as pumping draws in groundwater from the surrounding aquifer creating a "cone of depression." The greatest drawdown will occur within the well field. Water-level impacts will decrease with distance from the well field because it takes less drawdown to produce the same rate of groundwater flow when spread over an increasing area. Withdrawal of 100 million gallons, for example, would drain a radius of 1,000 ft to a depth of 43 ft (assuming a 10 percent effective porosity), but would drain a 1-mile radius to a depth of only 1.5 ft.

Figure E-14
Schematic of Predicted Drawdown with Distance from the Proposed Well Field



Close to the wells, maximum drawdown would occur under peak-day pumping conditions. Over distance, however, the aquifer will act as a large reservoir, supplying extra water during times of higher pumping, with water levels recovering during times of lower pumping. This is illustrated on **Figure E-15**, which shows the simulated drawdown with distance due to seasonal cyclic pumping at the proposed well field. The simulation used a pumping rate of 468 gpm (average annual rate) with a 60-day peak rate of 1,145 gpm (seasonal rate). At a distance of 1,000 ft from the pumping wells there is roughly a 7-ft difference between the drawdowns due to annual average and seasonal pumping rates. This difference reduces to about 0.8 ft at a distance of 5,000 ft. Beyond approximately 9,000 ft (1.7 miles), the use of annual average pumping rates to predict the long-term drawdown impacts listed in **Table E-5** produces values the same as values predicted based on more detailed tracking of month-by-month pumping cycles.

Figure E-15
Schematic of Predicted Seasonal Drawdown with Distance from the Proposed Well Field



These projections are made based on calculations for an idealized, homogeneous, isotropic aquifer (i.e., the same aquifer properties extending uniformly in all directions), so they reflect the same drawdown at a given distance in any direction. In reality, the aquifer is not so perfect; drawdown impacts would not create perfectly circular patterns; and the approximate estimates could be slightly higher in some cases and slightly lower in others. Beyond 2 or 3 miles the aquifer is known to vary in hydraulic properties (e.g., as the higher permeability strata become thinner to the west and very-high permeability materials are encountered along Lake Creek to the north). These more remote portions of the aquifer have not been studied in detail.

The significance of the listed potential water-level changes is a function of the completion of the affected well. A well drilled to only a short distance beneath the water table is clearly more vulnerable to water-table changes – whether from natural cycles, long-term drought, or nearby well pumping – than one completed substantially deeper than the water table.

Ideally, a water well is drilled deep enough below the water table to accommodate seasonal and long-term fluctuations and the impacts of some level of neighboring development, and the pump is set accordingly. The average depth of the wells listed in **Table E-5 i**s 136 ft. The average depth to the static water level is 53 ft, so these wells have, on average, approximately 83 ft of water available. The average reported "bottom of main water bearing zone" is 133 ft, indicating that few wells include significant depth beyond the zones found to be productive. Thus, the largest predicted drawdown in **Table E-5** (7.6 ft), reflecting 30 years of continuous pumping for a population of 3,000, reduces the average available drawdown in the surrounding wells by 10 percent.

The largest impacts would occur to the nearest wells (i.e., those at the top of **Table E-5**). For example, the closest well (P42832W) is reported to be 115 ft deep, with a static water level of 72 ft. The 30-year, growth-scenario projected impact at the distance of that well is 7.6 ft. This is the area-wide drawdown projected to occur from the well field. As elsewhere in the aquifer, this background impact will be superimposed on the local drawdown, which is different for every well. Based on the specific capacities for other wells nearby, the drawdown in this example well from its own pump could be as much as 14 ft. With the addition of 8 ft of drawdown from the well field, the pumping water level could be as much as 22 ft below the static water level, leaving approximately half of the original, static saturation. The "Kelly S." stock well is the third entry in **Table E-5**. This well was briefly tested in 2004 (Hinckley 2007a). It was found to have a drawdown of 4 ft at the installed-pump discharge rate of 24 gpm. The projected impact (growth scenario) of 7 ft would increase the pumping water level to 11 ft below the static water level, but would still leave 26 ft of water in the well (60 percent of the un-impacted static water level).

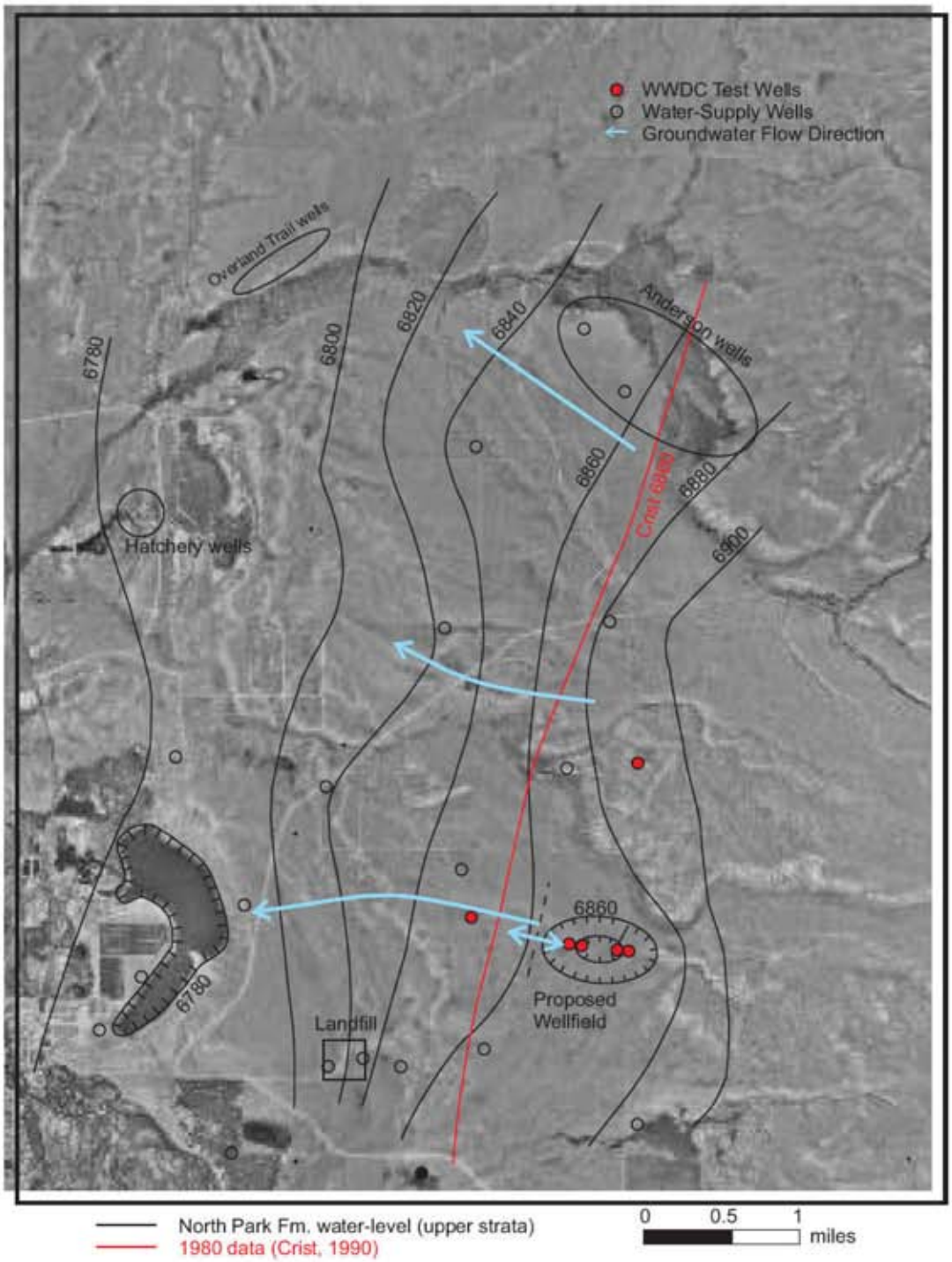
These predicted drawdown values are likely to be conservative, that is, overestimates of the actual impact. Aquifer test data from the 2003 site suggest that transmissivities in the 50,000-100,000 gpd/ft range may better characterize groundwater impacts between wells than the 30,000 gpd/ft value used above. Similarly, the 0.05 value for aquifer storage coefficient is low for an unconfined aquifer, as textbook values for fine sand sediments vary from 0.10 to 0.28 (Fetter 2001). To illustrate how using alternative values would affect the predicted drawdown, the following are calculations of 30-year, growth scenario (468 gpm) drawdown at a distance of 1 mile under ranges of aquifer properties:

Transmissivity (gpd/ft)	**Storage**	**Drawdown (ft)**
15,000	0.05	13
30,000	0.05	8 (as used in impact evaluation)
50,000	0.05	5
100,000	0.05	3
15,000	0.10	10
30,000	0.10	6
50,000	0.10	4
100,000	0.10	3

Drawdown around Landfill

The location of the Saratoga Landfill, roughly 2 miles southwest of the proposed well field, raises the question of how well field pumping may affect groundwater levels and flow directions beneath the landfill. A map showing the predicted 30-year growth scenario groundwater contours is presented as **Figure E-16**.

Figure E-16
Groundwater Level Contours – 30-Year Growth Scenario



Pumping from the well field produces a small, area-wide lowering of groundwater levels, with an oval shaped zone in the immediate vicinity of the well field, shown by hatched contours on **Figure E-16**, where the normal east to west groundwater flow is reversed to flow toward the

wells. To the west of this feature is a “groundwater divide” that marks the location beyond which groundwater no longer flows back toward the well field.

At the landfill, although the predicted groundwater level is lowered due to well field pumping, the direction of flow is not changed. Groundwater continues to flow westward as it currently does, although the gradient is flatter, meaning the speed with which groundwater flows will be lessened.

This analysis indicates that pumping of the proposed well field will not threaten the well field with potential contamination from the landfill. It also suggests that the well field pumping will not alter the groundwater flow paths such that other wells near the landfill could similarly be endangered.

Effect on Saratoga Fish Hatchery Spring

The potential for well field pumping to impact spring flow at the Saratoga fish hatchery has also been evaluated. The SEO is currently finishing investigations generated by a 1999 complaint by the USFWS that nearby high yield irrigation-well production on the Overland Trail Ranch causes decreased flow of the Lake Creek Springs supplying the Saratoga fish hatchery.

The proposed well field, however, is much further away from the hatchery than the irrigation wells (over 4 miles for the proposed well field versus about 1 mile for the irrigation wells) and pumping rates will be substantially lower. Predicted drawdown at the hatchery from pumping of the proposed well field extrapolated from **Table E-5** is less than 2 ft after continuous pumping for 30 years at the higher pumping growth scenario.

This prediction is likely an overestimate because the hatchery lies above an area interpreted to have higher permeability than the surrounding area as implied by several wells with higher than normal yields. The predicted drawdown for the hatchery area is based on uniform aquifer parameters from the well field area, which include a lower permeability than the hatchery area. As a result, the predicted drawdown in the hatchery area is likely greater than would be expected under actual pumping conditions. This is because, as the cone of depression expands into the high permeability area where groundwater can flow faster, that portion of the cone will become flatter (less drawdown). This is illustrated in the discussion above in “Drawdown in Other Wells” where predicted drawdown at 1 mile using different aquifer parameter values results in much less drawdown with a higher transmissivity.

Drawdown at the hatchery from well field pumping is therefore likely to be much less than 2 ft, probably less than 1 ft even under the higher pumping growth scenario. Furthermore, that level of drawdown would only be realized after 30 years. This small of a drawdown is not likely to have much of an impact, if any, upon spring flow.

Effect on Other Local Springs and Seeps

In addition to the springs at Lake Creek that are used for the fish hatchery, springs are reported to have occurred at the site of Saratoga Lake and may help sustain stagnant ponds south and east of the landfill. These occurrences mark a north-to-south-to-southeast trend that is believed to be indicative of a lowering of permeability to the west, which forces groundwater to flow at the

surface. The surrounding area has not been combed for additional springs and seeps, but none are mapped on 1:24,000-scale USGS topographic map quadrangles. Well Field-caused drawdown can be estimated for the occurrences discussed above by comparing these locations with the predicted well field drawdown.

Well Field drawdown along this trend is predicted to range from less than 2 ft at the Saratoga fish hatchery to a maximum of 3 to 4 ft in the area of Saratoga Lake under the higher pumping growth scenario. For the area of shallow ponds southeast of Saratoga, predicted drawdown is less than 2 ft. The potential impact that this level of drawdown would have upon groundwater discharge is difficult to assess but, for the area southeast of Saratoga, the predicted drawdown is small, likely an overestimate, and would take 30 years to be realized.

Cumulative Drawdown

The drawdown predictions presented above provide the best means to evaluate the change in the aquifer and, hence, impact to individual wells that the Proposed Action would cause because it predicts what would change from the current, pre-project conditions.

Another way to look at the impact is to evaluate cumulative drawdown in the aquifer. Cumulative drawdown refers to the total drawdown in the aquifer due to pumping at all of the wells, not just the proposed well field. An evaluation of this nature compares actual or predicted future pumping water levels to those of the original water levels present before any pumping in the area began.

The drawdown values listed in **Table E-5** are the amount of drawdown the proposed pumping would cause to the aquifer, but these values are in addition to the drawdown already present due to the current level of pumping from all existing wells. Because the groundwater contouring shown on **Figure E-10** is from measured water levels in existing wells, it represents the current, cumulative impact of production from all existing wells. With the addition of the anticipated water-level impacts of the Proposed Action, **Figure E-16** represents the cumulative impact of existing wells and the "growth" scenario for the proposed new wells. Translating the groundwater elevations on either **Figure E-10** or **Figure E-16** into cumulative drawdown values relative to pre-development conditions is difficult because pre-development water levels are not available.

Figure E-10 and **Figure E-16** reflect area-wide groundwater levels. As previously discussed, there is little seasonal fluctuation in groundwater levels at the scale of these figures. They reflect the approximate groundwater table throughout the year.

Seasonal variations from the conditions depicted would occur around each individual well in proportion to how much and how often it is pumped. While the cumulative impact of all those individual decisions is reflected in the area groundwater levels on **Figure E-10** and **Figure E-16**, analysis of individual well management and drawdown is beyond the scope of this document. However, it can be reasonably assumed that there is no seasonality to the drawdown from the hatchery, as this is a constant-discharge use. While domestic and stock wells receive heaviest use during the hot summer months, their withdrawals are small and much of the pumped water returns to the aquifer as waste. Seasonal variations in drawdown are confined to the immediate

vicinity of each well. This leaves seasonal impacts from the proposed wells and from the high-capacity irrigation wells to the north of the proposed well field.

Seasonal impacts from the proposed wells were discussed above and illustrated, with the conclusion being that beyond 1 mile there is little to no increased drawdown due to seasonal pumping rate increases.

For the irrigation wells, a similar decline in seasonal influence with distance is expected. Completing an analysis for the irrigation wells requires many assumptions both in terms of the pumping rates and aquifer parameters.

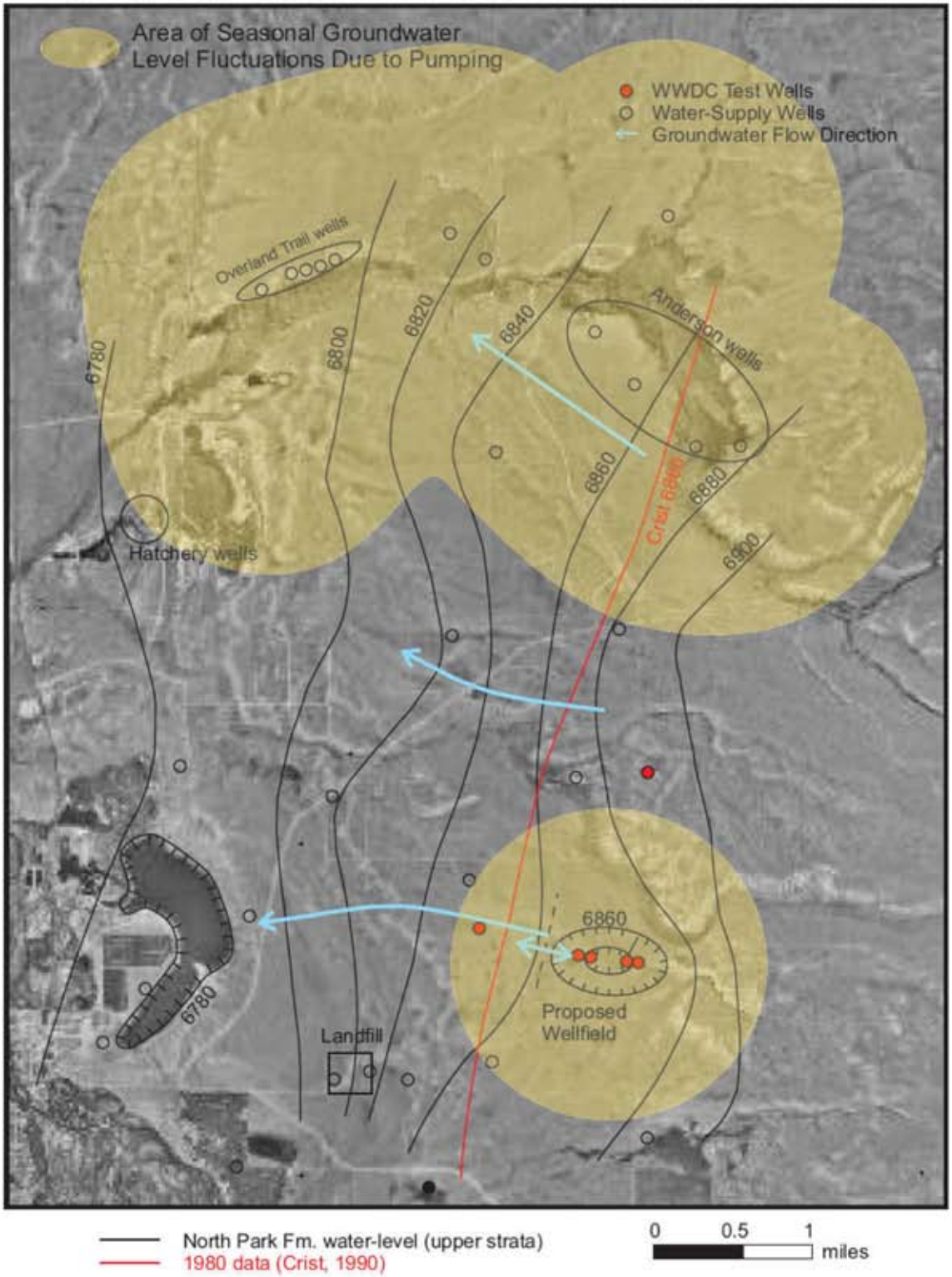
Using the maximum July consumptive irrigation requirement for alfalfa in Saratoga (8.33 inches) (Pochop *et al.* 1992), and applying an irrigation efficiency of 70 percent (for these combined sprinkler and flood systems) across the estimated 1,300 acres of irrigation, indicates a maximum pumping rate of approximately 9,400 gpm. Calculation of an equivalent for the irrigation wells also requires information on aquifer permeability in that area. Application of the transmissivity (30,000 gpd/ft) and storativity (0.05) values determined from pumping tests in the study area for the proposed well field results in a prediction of 0.3 ft of drawdown at a distance of 10,000 ft over a three-month period of such maximal pumping. Application of the transmissivity value of 400,000 gpd/ft determined by the reported performance of several of the irrigation wells results in prediction of 2.8 ft of drawdown. In any case, the seasonal variations in drawdown attenuate with distance.

The potential areas impacted by seasonally maximal pumping is shown on **Figure E-17** as shaded areas. As with the actual drawdown values, the extent of this area around the irrigation wells is not well defined. Data from the “DOT #1" and “Kelly North” wells suggest little seasonal fluctuation at these points. The data points on **Figure E-17** that are within the Anderson Ranch irrigation-wells area were measured following a long period of no use, so are not subject to seasonal irrigation pumping influence.

In summary, regarding seasonal pumping impacts, the primary source of local, seasonal water level fluctuations in the larger study area is the irrigation pumping from high-capacity wells along Lake Creek. Were the proposed well field constructed and pumped to meet “growth” scenario water demands, it would add approximately 10 percent to total annual aquifer withdrawals, and would also produce seasonal fluctuations in groundwater levels. However, it is clear that the distance between these two sources is sufficient to preclude a cumulative effect on the seasonal fluctuations in groundwater levels (i.e., “maximum-rate” impacts are the same as average-rate impacts). Calculations based on aquifer properties demonstrate that well field induced fluctuations in groundwater levels will have attenuated far short of the area impacted by irrigation wells (see **Figure E-17**). Direct measurements (see **Table E-1**) demonstrate that irrigation-well induced fluctuations in groundwater levels have attenuated far short of the area impacted by the proposed well field. Thus, addition of the modeled impacts of annual average pumping rates (see **Table E-5**) to the cumulative effect of existing groundwater development produces a valid representation of the “with-project” groundwater levels. In the areas of existing well development, local, seasonal water-level variations from the **Figure E-17** averages in

response to nearby pumping will continue as at present, unaltered by the operation of the proposed well field.

Figure E-17
30-Year Growth Scenario with Areas of Potential Seasonal Fluctuations



The cumulative drawdown evaluation assumes that the continued pumping of existing wells into the future will not create significant additional drawdown. It was shown that cumulative drawdown at the study-area scale appears to be changing very little or not at all under current conditions of development. These data are insufficient to address conditions at the local scale (e.g., in the immediate vicinity of specific high-yield wells). For example, complaints of seasonal groundwater-level fluctuations in the vicinity of the Saratoga fish hatchery are currently being investigated by the SEO. That this is a local, rather than regional-scale, issue, however, is indicated by the reports of hatchery personnel that spring flows rebound following seasonal cessation of irrigation pumping and by the absence of seasonal fluctuations in water levels in the proposed well field area to the south (discussed above).

An evaluation of the future cumulative effects of new wells beyond those proposed by this project or by increased production from existing wells is complicated by the fact that anticipating major changes from existing pumping is speculative at best and the location and use of potential future wells is even more so. The impact of expanded aquifer use for Saratoga is included in the **Figure E-16** impact projections under the "growth" scenario. Additional regional drawdown caused by future domestic wells will likely be minimal because yields are low and a large amount of the pumped water is returned to the aquifer via septic system discharge. Irrigation pumping is unlikely to increase substantially over present levels because all irrigation wells in the area have recently been adjudicated and future expansions of irrigated acreage are subject to inter-state Decree limitations. Future expansion of the hatchery pumping (by adding new wells or increasing the capacity of existing wells) is possible, but hatchery personnel report that they intend only to replace spring flow deficits rather than expanding net aquifer withdrawals.

Landfill Contamination Contingencies

The predicted drawdown impact of the Proposed Action beneath the Saratoga Landfill was summarized in the discussion above in "Drawdown Around Landfill." Drawdown predictions indicate that while groundwater levels would be lowered beneath the landfill, the groundwater flow direction will not change; it will remain westward, away from the well field and toward the North Platte River.

The landfill is sufficiently down-gradient from the proposed well field that, even assuming a large margin of error on the predicted drawdown impacts, it is difficult to imagine how the well field could be endangered by the landfill. As a result, contingencies in case of contamination from the landfill are not warranted.

E.3.2.2 No Action Alternative

Under the No Action Alternative there would not be any impact to groundwater associated with the Saratoga water supply. Drinking water would continue to be derived from the North Platte River and there would not be any groundwater extraction to replace that source. The current use (and expanded use under a growth scenario) of North Platte River does not impact groundwater. However, as noted in the "Cumulative Drawdown" discussion, some additional drawdown in the aquifer could result from the future installation of new wells beyond those proposed by this project or by increased production from existing wells.