Managed Aquifer Recharge in the Treasure Valley: A Component of a Comprehensive Aquifer Management Plan and a Response to Climate Change

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INTRODUCTION

Historically the mountain snow pack upstream of Idaho's Treasure Valley has provided a storage mechanism to retain wintertime precipitation and release it in the spring and summer. In the last century surface-water storage reservoirs were built to provide additional storage, and elaborate canal systems were constructed to deliver water for agriculture, industry and growing cities. Percolation from these canals and from irrigation enhanced existing aquifers, and increasingly these aquifers are also utilized.

In a proactive and forward-looking step, the State of Idaho has embarked on a planning process known as the Comprehensive Aquifer Management Plan (CAMP). One of the anticipated drivers of future needs and supply constraints is climate change, and one anticipated response is to provide additional storage capacity to mitigate the effects of altered patterns of runoff from mountain snow pack. Local aquifers can potentially provide additional storage. Managed aquifer recharge means to intentionally place water in the aquifer at times when supplies exceed current needs, for later withdrawal when supplies are short. It may provide storage at lower cost than building new surface-water structures, protects water from evaporation, and does not carry the threat of catastrophic flood from infrastructure failure.

Aquifer recharge can also mitigate the potential loss of surface storage capacity due to increased flooding risks posed by climate change. With a robust and active aquifer recharge program, carryover water that is at high risk of being spilled for flood-control purposes can be moved to storage in the aquifer and thereby retained in the basin for future use.

This paper provides an initial look at managed recharge, to set the stage and provide context for consideration by participants in the CAMP process. It addresses:

1. Hydrogeology and current aquifer conditions.

2. Potential storage capacity of the Treasure Valley Aquifers available for managed recharge.

3. Location of potential recharge sites.

4. Capacity to deliver water to the recharge sites.

5. Approximate residence time of water stored in the aquifer, before it is depleted by migration to hydraulically-connected surface-water bodies.

METHODS

Hydrogeology was assessed by review of existing data and reports by professional geologists, combined with mapping of stratigraphy from existing well-log data.

Potential Storage Capacity was addressed by Geographic Information Systems (GIS) mapping of the land surface elevation and water-table elevations in the Treasure Valley. Geologic materials deeper than 50 feet below land surface and above the water table were considered as available space which could store water.

Location of Potential Recharge Sites was based on GIS mapping of existing gravel-pit data, along with comparison with aerial images, consultation with local practitioners, and field inspection.

Delivery Capacity was assessed based on information from the Boise Board of Control, along with examination of historical diversion records.

Residence Times were assessed using an adaptation of the Balmer/Glover/Jenkins stream depletion methodology.

HYDROGEOLOGY

General Description

The hydrogeology of the area consists of basalt flows and sedimentary units of the Idaho Group (Ralston and Chapman, 1970). The area of interest (Figure 1; all figures are at the end of the text, preceding the References section) is bisected by a northeast trending zone of complex faulting and is at the edge of the basalt flows that are exposed at the surface southwest of Kuna (Mitchell, 1981). Shallow basalt flows encountered during drilling are generally thicker in the south portion of the study area. Sand, silt, clay, and gravel layers are below the basalt units and form the primary aquifer of the area. The area has undergone significant faulting and both northeast and northwest trending faults are present (Otto and Wylie, 2003). Fault zones impact water temperatures by providing a conduit for geothermal water to flow upward into the overlying cold water aquifer within the Idaho Group (Mitchell, 1981). The diagrams and cross sections do not take into account faulting but rather provide general trends in mega scale hydrostratigraphic units in relation to the water table.

Figure 1 shows a shaded relief map with higher elevations of darker blue tones and lower elevations shown with darker brown tones. Wells used for the geologic model are shown with yellow circles and wells used for water levels with blue circles. The locations of eight geologic cross sections are noted with black lines and letters A through H. For scale the red lines note the Township and Ranges of six square miles. Sections are illustrated in Figure 2 through Figure 5.

Figure 7 shows a solid three-dimensional model with a color air photo draped over the geologic model that has a vertical exaggeration of 50 times the horizontal scale for better viewing. The gray color represents basalt and the orange tones sediments of sand, silt, clay and gravel. The south vertical panel for the basalt is removed to provide a view inside the model. The water table is modeled with a color spectrum for different elevations with the highest elevations shown as red tones and the lowest elevations with purple and dark blue tones. Generally, the water table has a dip from the northeast to the southwest and groundwater flow is interpreted to flow in this same general direction.

The deepest wells are typically about 900 feet below land surface with one exception of an oil and gas exploration well (Figure 6) drilled by Champlin Petroleum Company in 1980 to a depth of 9,022 feet below ground surface (Idaho Geological Survey). The well helps define sediments extending down to about 2,000 feet before the first interbedded basalt is encountered, then more sediments with minor interbeds of basalt on down to 9,022 feet. It is reasonable to assume this general stratigraphy extends below the project area in Figure 1 and the wells used in the geologic model. There is a 'blue' clay commonly described in the well drilling logs from numerous wells and possibly has a more extensive spatial distribution than can be identified from wells, since wells typically don't penetrate deep enough to encounter the clay in the eastern area in Figure 1. This blue clay probably plays a major role in the behavior of the groundwater systems of the area and any aquifer recharge efforts should take this into account. This layer of clay could limit the movement of recharge water into deeper parts of the aquifer unless engineering solutions (discussed later in this report) are pursued.

Figure 8 shows the same geologic model as in Figure 7 but with panel fences and the water table. The view is from above but note how the contact between the base of the basalt and the underlying sediments is undulatory in nature with the water table 'cutting' a more horizontal plane and 'passing' through both sediments and basalt. This relation is important to take into account when interpreting hydrograph trends. Figure 9 shows the same panels as Figure 8 but the view angle is from below the wells and demonstrates how wells are completed in sediments, basalt or a ratio of both. Wells such as the 'Whitehead Construction' well (T2N R2W 22) or other wells in this proximity are pumping water from sediments which tend to have much different hydraulic properties and lower yields than wells completed in basalt 'lows' which typically produce greater yields and different water level patterns. The basalt lows may be due to faulting but the modeled trends support ancient topographic lows, probably old canyons cut into the sediments from streams and rivers that later filled with basalt. This geologic phenomena was identified by Harold Stearns et. al. (1938) in the Glenns Ferry Formation of the Hagerman Valley area. Farmer and Blew (2011) present groundwater flow tracking data that appears to validate Harold Stearns observations.

Landslide Hazard

A geologic hazard that is often overlooked is the possibility of landslides induced by perched aquifers. Landslides are common in this area of the Snake River Canyon and in the Hagerman Valley area. Some landslides in the Hagerman Valley were caused by anthropogenic perched aquifers created by irrigation water from the Bell Rapids Irrigation Project (Farmer, 1999). One landslide destroyed a million dollar pumping station and nearly killed two workers.

The same hydrogeologic conditions are present south of Boise with Figure 10 highlighting one area in the southwest corner of section 30 T2N R3W. This area shows an elevated plateau with irrigation ponds and crops. Perched aquifers are readily present flowing through sediments that can easily fail when saturated. Slope failures in this area and other areas of similar hydrogeology are likely. While the hazard currently exists as a result of irrigation on the bench above the river, managed recharge very near the Snake River in this area could exacerbate the problem. Careful investigation is in order prior to recharge on high-elevation lands near the river.

In this area (T2N and R3W sections 22 and 28) the pattern of geology described above appears to be present, based on data from nearby wells. However if recharge were contemplated in this area a more detailed study would be needed, beyond the scope of this report. Wells in the area near section 28 show little basalt and deep sediments with the 'blue' clay present at depth. The area to the north has a greater thickness of basalt overlying the sediments and probably produces a greater yield. The south area appears to have furrow irrigation which probably recharges the aquifer in the fine grained sediments which explains a high in the water table in this area. An adjacent low in the water table to the north near section 22 has center pivots which have less recharge to the aquifer than furrow irrigation. The important concept to retain is understanding the subsurface geology before interpreting water level trends which may be localized due to a 'pocket' or valley filled with basalt and bounded by fine grain sediment 'ridges' or highs in the contact. These ridges and valleys in the underlying sediments will play a key role in how groundwater levels respond to changes in land use, irrigation practices and aquifer recharge.

<u>Current Recharge Patterns and Water Level Conditions</u>

Primary sources of recharge to the cold water aquifer are irrigation leakage (canal seepage and flood irrigation) and geothermal input from beneath (Otto and Wylie, 2003). Hydrographs for two area wells (02N01W18BBB1 and 02N01W04DDA1) suggest a positive response to development of the canal system in the Treasure Valley in the early 1900's (Figure 11). These hydrographs lend support to the notion that irrigation water is a significant source of aquifer recharge. The first well (02N01W18BBB1) is 300 feet deep and experienced a water level increase of approximately 50 feet between 1917 and 1953. The second well (02N01W04DDA1) is 203 feet deep, and demonstrates a water level increase of approximately 80 feet between 1914 and 1953. Based on these two hydrographs, it appears the response to surface recharge is less significant at depth since the shallower of the two wells showed the greater response.

Ground water flow direction in the study area is generally to the south/southwest towards the Snake River, perpendicular to water-level contours illustrated in Figure 12 and Figure 13. Although gage data is limited, Snake River to the south of the study area is a gaining reach and receives ground water that discharges from this study area (Petrich, 2004; Newton, 1991).

Based on the potentiometric maps of the region (Figures 12 and 13), a significant gradient exists towards the Snake River. Typically steep gradients are caused by either high flows, low hydraulic conductivity, or a combination. Based on indications of low riverbed conductance in the Snake River (Schmidt, 2011), general lack of seeps and springs (other than those induced by irrigation, as discussed above) and the presence of faults (which can limit lateral movement of water), it is possible that flows from the aquifer to the Snake River are somewhat limited.

The hydraulic conductivity of the aquifer varies, depending on the type of aquifer material encountered, with production rates ranging from 11 to over 3,000 gallons per minute (gpm). Transmissivity estimates based upon analysis of specific capacity data from well driller's reports range from approximately 1,000 ft^2/day to 250,000 ft^2/day.

Water levels have been declining since the 1960's with measured declines of approximately 10 to 13 feet during the past 30 years (Figures 14 through 16). The average rate of decline is approximately 0.3 to 0.4 feet per year, indicating the rate of aquifer recharge has been exceeded by rate of withdrawal. Figure 17 shows individual hydrographs for a suite of wells with detailed water level histories.

The cold water aquifer (upper aquifer) has sufficient productivity to develop large capacity irrigation or municipal wells. This statement is based on the fact that many deep wells exist throughout this area that produce cold water. In addition, specific capacity data reviewed from driller's reports indicates high transmissivity values, supporting the conclusion that the aquifer has sufficient productivity for developing deep cold ground water wells.

Although the cold ground water supply is currently sufficient for additional well development in terms of aquifer productivity, the declining water levels indicate the aquifer is currently in an overdraft with respect to the local ground water budget. Future impacts from ground water permit applications and approved but undeveloped ground water permits may increase the rate of water level decline and could cause an increase in water temperature from the geothermal contribution to the aquifer.

The recharge rate to the cold ground water aquifer appears insufficient to sustain additional ground water development without additional water level declines or an increase in recharge. Hydrographs and water level data indicate that the ground water pumping in this area has exceeded the recharge rate, resulting in ground water level declines. The declines indicate a portion of the ground water currently being withdrawn is being removed from storage. The magnitude and timing of the additional water level declines cannot be accurately predicted, but it can be assumed to at least be equal to or more likely exceed the historic water level declines. It is likely that ground water levels will continue to decline, until ground water withdrawals and recharge rates reach an equilibrium. The timing and water level at which this new equilibrium will be met cannot be accurately forecasted at this time.

Interaction Between Cold Water and Geothermal Aquifers

At some point in the future, the depletions and decrease in head may be sufficient to allow the geothermal contribution to impact the cold water supply, resulting in elevated ground water temperatures across the area. The timing and depth at which this may occur cannot be precisely determined due to a lack of data regarding the locations and rates of geothermal input into the cold water aquifer system.

To assess the potential of encountering low temperature geothermal water, a review of driller's reports and records within the IDWR geothermal database was conducted. Between the two data sources, 237 water temperature records were reviewed. Reported temperatures ranged from 50 to 99 degrees, with six wells reporting water temperatures classified as low temperature geothermal (85 degrees or greater).

Figure 18 is a plot of water temperature versus well depth. The relatively low correlation coefficient (R^2) of 0.31 indicates that temperature is not strongly correlated to total well depth. The weakly correlated data suggest a temperature gradient of approximately 17 degrees Fahrenheit for every 200 feet of depth (8.5 °F/100 ft). This gradient is approximately three times higher than the gradient of 29 degrees Fahrenheit for every 1000 feet of depth (2.9 °F/100 ft) reported by Otto, and Wylie (2003) and roughly two times higher than the gradient of 9 degrees Fahrenheit for every 200 feet of depth (4.5 °F/100 ft) reported by Mitchell (1981) for this same aquifer system.

The average temperature gradient for the data on Figure 18 is biased upward by data from several wells that exhibit significantly elevated temperatures. Most notably, the warmest water (99 degrees Fahrenheit) is from a well that is only 553 feet deep. The temperature is considered anomalous because there are 27 wells deeper than 553 feet in which the water temperature is consistently cooler than 99 degrees. This variability required a review of the spatial distribution of elevated water temperatures to determine the potential of applicants to encounter warm water. The relative importance given to these wells in analysis may explain the variation in results among different investigations.

Figure 19 shows wells with elevated (68 degrees or warmer) temperatures in the study area are located throughout the area and do not appear to be completely controlled by structural features. A mapped "zone of complex faulting and northeastern edge of the basalt flows" (Mitchell, 1981) southwest of Kuna appears to correlate with a linear trend of wells with elevated temperatures in that area (Figure 20). In addition to well depth, this zone of faulting appears to be a contributing factor to elevated water temperatures.

Additional unmapped faults may exist in this area that also contribute to the elevated temperatures by providing a conduit of deep geothermal water to enter the cold water aquifer system of the area. It appears that elevated water temperatures within the area of interest can be attributed to a combination of well depth and proximity to conductive fault zones.

The mapped faults to the northwest of the study area have a NW/SE trend. If this trend was extrapolated linearly to the southeast into this area of concern, the extrapolated location of the fault zone would be positioned in the direct vicinity of permit applications associated in the area off of South Cole Road. Therefore, there is the potential for encountering geothermal waters in this area, and any future drilling should be conducted cautiously, so that low temperature geothermal water is not developed. This also suggests a target area for recharge; recharge could maintain the hydrostatic pressure in the upper cold-water aquifer, which may be limiting the upwelling of deeper thermal waters.

Groundwater Supply Considerations

Based on analysis of the hydrographs, water levels have declined across the study area for approximately 50 years. The water level trends suggest that the aquifer has not yet stabilized. The fact that the water levels are declining suggests that the withdrawal rates of ground water have exceeded the rate of natural recharge. Additional withdrawals from the aquifer in this area are expected to result in additional ground water declines. The rate of decline is difficult to predict without a transient numerical groundwater flow model, but it is reasonable to assume that the average rate of decline will equal or exceed the long-term approximate average rate of 0.3 to 0.4 feet per year. Development of a transient version of the Treasure Valley numerical groundwater flow model is underway but it is not scheduled to be available for at least a year.

Based on the relatively high aquifer transmissivity estimates that are derived from specific capacity data submitted on driller's logs, well to well impacts will most likely be minimal. In combination, indications that the aquifer is transmissive and that the rate of withdrawals exceed the rate of recharge make it likely that regional water level declines will continue to be a more significant problem than well to well impacts. If required, the distribution of water level declines that results from pumping (i.e., drawdown) can be calculated on a case by case basis using the semi logarithmic approximation of the Theis (1935) equation. Previous research in this area has predicted drawdown associated with a well pumping 1,550 gpm will result in approximately seven feet of drawdown at a distance of ¼ mile, and less than a foot of drawdown at ¾ mile (Baker, 1993). Wells with water levels at or near the level of the pump intake will either have to have the pumps lowered or be deepened if the water level declines continue into the future.

Summary of Hydrogeology

In summary, it appears that this area of the Treasure Valley is experiencing water level declines associated with withdrawal rates exceeding natural recharge. In addition, the fact that elevated ground water temperatures exist in the area limits the potential of developing the deeper cold water aquifer system. This points to the need to consider either supporting new development with surface-water sources or to provide managed aquifer recharge to offset and mitigate current and new groundwater withdrawals.

RECHARGE POTENTIAL IN THE TREASURE VALLEY

General Considerations and Discussion

Groundwater Flow Principles. In a widespread aquifer with full hydraulic connection, the water-supply benefits of recharge propagate in all hydraulically-connected directions. Counter-intuitively, this is true even when there is flow in the aquifer and an underlying hydraulic gradient (Reilly and others, 1987; Leake, 2011). Consider an aquifer with a hydraulic gradient towards a gaining river, illustrated in Figure 21. Natural and irrigation recharge takes place uniformly across the aquifer and wells pump at various locations. In Figure 22, additional managed recharge has occurred somewhere in the middle of the aquifer and created a mound of stored water. This created mound of water causes three effects:

1. The water-table is flattened up-gradient of the recharge site, slowing flow from the upper regions of the aquifer.
2. The water table is made steeper down-gradient of the recharge site, increasing flow to the river.
3. Water levels are elevated both up-gradient and down-gradient of the recharge site, reducing pumping lift and pumping costs.

The implication of these principles is that recharge can be effective in supporting groundwater pumping whether the recharge occurs up-gradient or down-gradient of the pumping.

Storage of Water in Aquifers. Some aquifers are called confined aquifers. The water is under pressure between nearly impermeable geologic materials above and below. When water is released from the aquifer, the primary mechanism of release is the elasticity of the geologic materials and the water itself. Even when water is released, because the water is confined in a pressurized zone of geologic materials, the physical dimensions of the water body are essentially unchanged.

Other aquifers are called unconfined aquifers. The top of the aquifer is at atmospheric pressure, and the water level moves up and down through the geologic materials as water enters and leaves the aquifer. The Treasure Valley aquifers considered in this report are the upper-most aquifers in the system and are generally unconfined. Water may be delivered to these aquifers by percolation from land surface or recharge basins.

In either case, the depth of water released for a given change in hydrostatic pressure (confined aquifer) or water-table elevation (unconfined aquifer) can be called the storage coefficient. This can be used to quantify the storage capacity of a potential recharge zone. For instance, if the water level were raised ten feet in an area of 1,000 acres, with a storage coefficient of 0.10, 100 acre feet of water would have been placed into storage.

Recharge Management and Preliminary Preferred Location. Recharge will be easiest to manage when the water table is far below land surface. This avoids the hazards of intercepting basements or buried waste, and minimizes the potential of damaging foundations and other structures. As described earlier, Figure 12 shows the general map of depth to water in the Treasure Valley, based upon observations at shallow wells. We recommend that a 50-foot buffer be maintained between land surface and the water surface after recharge, to prevent water from entering basements or damaging infrastructure. This could be refined with site-specific investigation.

Early in the project, IDWR identified a preferred area of potential recharge based on depth to water, location of potential recharge sites, and distance from the Snake River. This area is circled in green in Figure 23. The New York canal is marked in yellow and a gravel-pit GIS data set (IDWR, 2003) is marked in red. IDWR's initial assessment was that "Locations further west have too shallow of depth to water table and further south is too close the Snake River which will short circuit recharge water to the river."

Recharge Locations to Avoid. In addition to controlling recharge to keep groundwater out of basements, waste deposits and infrastructure, recharge sites should be selected to avoid:

1. Close proximity to community drinking water wells.
2. Locations that require high-bank constructed infrastructure above homes or schools.
3. Locations that require high pumping lifts to deliver recharge water. However, the costs of pumping should be evaluated in the context of the costs of other storage options; some moderate-lift pumping may still be rational.

Water Level Changes. Figures 14 through 16 show water level changes between 1996, 2001 and 2008. These indicate areas where existing water use may exceed local supplies, and where managed recharge can be especially beneficial. Existing cones of depression can be back-filled by recharge without raising the water table above historical levels.

Recharge Where Water Levels are Near land Surface. With careful management, Aquifer Recharge can also be used in areas where the water table is near the surface, as practiced in California (Thomas, 2001). The first step is to pump the aquifer to sustain a use for which surface water is not currently available. This creates a cone of depression, making space for recharge of surface water that is delivered later at times of high flow and low water demand.

Other Considerations. Additional considerations for managed recharge are beyond the scope of this report. They include:

Water Storage in Deep Aquifers. Water can also be recharged into deep aquifers, which are often confined. Injection wells are often required and additional technical challenges can arise, including chemical compatibility issues. This practice is often called Aquifer Storage and Recovery (ASR). While it may also be a promising storage technique in the Treasure Valley, it is not considered in this report.

Recharge methods and infrastructure. This project did not thoroughly investigate all the engineering methods and solutions that may be applied in physically performing managed recharge. However, techniques do exist for various physical or geological conditions that might arise. For instance, Figure 24 shows a method that US Bureau of Reclamation and US Geological Survey (Mundorff, circa 1962) have described for overcoming limitations of low-permeability materials that may lie between permeable surface materials that could accept recharge and permeable materials at depth which host a receptive aquifer. As water enters the geologic materials in the upper layer, it is filtered in the same manner that natural recharge from streams and precipitation has always been filtered, and the way the irrigation recharge has been filtered for over 100 years. A cased well is completed through the upper materials, through the confining layer (perhaps the blue clay discussed earlier in this report) and into a lower aquifer, perhaps a cold-water aquifer currently utilized and which it is desirable to protect from upwelling of warm water. The casing is solid near the surface, protecting the aquifer from surface contamination. Deeper in the upper geologic materials, screens or perforations allow water to enter the well casing and flow down into the deeper aquifer. Of course there are additional technical considerations to be analyzed, including chemical compatibility between the recharge waters (as altered by transit through the upper geologic materials) and the waters in the receiving aquifer.

Accounting for Benefits of Recharge. Because recharge provides general benefits to the public at large, recharge can rationally be conducted without any detailed accounting of the fates and benefits of recharged water. Conceptually, the benefits of recharge can also be quantified specifically and applied to offset particular uses of groundwater. Though beyond the scope of this paper, the technological ability to perform this accounting has been demonstrated (Contor, 2009). The method allows quantification of the depletion of stored water, as the recharge mound migrates to hydraulically-connected water bodies.

Water Rights and Water Availability. Any consideration of additional storage by the CAMP process must address availability of water to store, and the associated water-rights issues of authority to place this water into storage. This is true for both surface-water storage and groundwater storage and is beyond the scope of this report.

Land Ownership, Access, Easements, Rights of Way, and Conveyance Agreements. This report does not investigate the ownership of any of the potential sites, nor discuss easements for ditches nor conveyance agreements for water delivery. Nevertheless, these are all essential elements of any recharge program. There is no intent to assume or recommend use of any facility or property for recharge purposes without the full input and participation of the owners and managers of those facilities.

Infrastructure and Management Costs. This report provides the context of potential capacity for storage in the aquifer, but it does not address costs of conveyance, infrastructure, or management. Costs for aquifer recharge should be considered in the context of costs of other storage and supply options.

Aquifer Storage Capacity

Assuming a 50-foot buffer between land surface and the post-recharge water table, the depth of available geologic materials was mapped in GIS. This was multiplied by the storage coefficient 0.10 from the USGS aquifer model of the Treasure Valley (Newton, 1991) and by a storage coefficient of 0.05 from textbook values for typical geologic materials in the Boise Valley (Freeze and Cherry, 1979).[1] Figure 25 shows the average volume of potential storage in each Public Land Survey Township (approximately 36 square miles) using the textbook storage coefficient. The USGS storage coefficient would indicate twice this volume. Across the study area, the text-book coefficient indicates

[1] Note that these values are higher than preliminary values from ongoing modeling efforts (Schmidt, 2010). However the values used here are consistent with pump-test data and are realistic for the expected geologic materials.

approximately 4,000,000 acre feet of potential storage and the USGS coefficient indicates about 8,000,000 acre feet.

Of course this assumes that every available cubic foot of the aquifer would be accessible and useful for storage. Excluding the high-elevation lands on the south and east of the study area leaves approximately 800,000 to 1,600,000 acre feet of capacity, depending on the storage coefficient. If realistically one-fourth of this could be utilized, potentially 200,000 to 400,000 acre feet of storage could be accessed by carefully managed aquifer recharge.

As discussed below, current infrastructure may not be adequate to deliver this volume of water to storage. Costs of needed Infrastructure improvements might be considered in the context of costs for of other storage options.

Additional storage space may be created in the northwest regions of the study area, by first pumping groundwater and then back-filling the created cone of depression with recharge water at a later time (Thomas, 2001). The available storage volume will be the volume pumped, less any flow from the Boise River that is induced by the pumping before the recharge takes effect. Additional considerations for this practice are described in the "Residence Time" discussion, below.

Potential Recharge Sites

A field inspection trip was conducted on November 30, 2010 to field verify the potential sites identified by IDWR staff. A total of 26 sites were visited, mostly in southern Ada County (Figures 26 and 27). Specifics related to each site are presented below. Owners of sites and delivery infrastructure have ***not*** been consulted; obviously this would be an important first step for further consideration. Many of these sites are currently actively mined and therefore are candidates for future recharge development, after extraction of sand and gravel is completed.

<u>Sites 1-5, Southeast Boise</u>. The five sites located around the airport and Gowen Road have high potential for recharge. All of the sites are relatively close to the New York Canal and all are fairly large excavations that could store a significant quantity of water. A recharge site with large storage capacity can be filled rapidly to maximize capture of short-duration runoff at a rate that exceeds the rate of infiltration; stored water can continue to infiltrate after the window of opportunity to divert recharge water has passed. The coarse sands and gravels in the area suggest permeable conditions exist in and around the excavation sites. Details on each of the sites are as follows:

Site 1. Site 1 is the location of an active recycling facility, located in an inactive gravel pit. The New York Canal flows approximately 700 feet to the east of the site.

Site 2. Site 2 contains an active gravel pit and several inactive gravel pits that are currently being operated as a wastewater storage facility. The New York Canal borders this site to the west, approximately 250 feet away.

Site 3. Site 3 is an active quarry, currently operating as a concrete manufacturing plant. The New York Canal borders this facility and is less than 300 feet to the north.

Site 4. Site 4 is a large complex of gravel pits, active and inactive, south of Interstate 84 and east of the Boise Airport. The site is rather extensive in size and depth. The New York Canal flows to the north of the site, approximately 2/3 of a mile away.

Site 5. Site 5 is a gravel pit surrounded by industrial operations of lumber and manufacturing. Access for inspection of this site was limited. The New York Canal flows approximately 0.5 miles to the north of the site.

Sites 6-8, Black's Creek Area. Sites 6, 7, and 8 are near Black's Creek and the Black's Creek Reservoir. Inspection of these sites indicates that permeable conditions exist, however a reliable water source and conveyance mechanism do to not exist. Black's Creek, the nearest surface-water feature of the area, is an intermittent stream and does not flow year-long. The potential to capture spring runoff (in excess of existing reservoir capacity) would be the optimal scenario for sites in this area. Details related to each of the sites visited area as follows:

Site 6. Site 6 is an intermediate sized active gravel pit, located to the south of Interstate 84 near the Black's Creek exit. Black's Creek, an intermittent stream, flows to the south of this site approximately 400 feet away.

Site 7. Site 7 is an Idaho Department of Transportation source material site, and is an active gravel pit. The site is located to the north of Interstate 84, near the Black's Creek exit. Black's Creek flows to the south of the site approximately 2/3 miles away.

Site 8. Site 8 is the location of Black's Creek Reservoir. This reservoir is managed by multiple state and federal agencies to serve as a wildlife refuge. The source of water to the reservoir is Black's Creek.

Sites 9-22. Tenmile Ridge Sites. These sites are existing sand and gravel quarries, most of which are active. The majority of the sites are excavations into the ridgeline, significantly higher in elevation in comparison to existing stream channels. The stream that flows adjacent to these sites is intermittent and does not appear to be a reliable source of water. Sites 21 and 22 are closest in proximity to a potential recharge source, the New York Canal, which flows less than a half mile from these two quarries. Infrastructure and pumping costs are obstacles to the use of sites 9-22, but these should be considered in the light of the costs of other storage and supply options.

Site 23. Site 23 is the Hubbard Reservoir. The reservoir is connected to the New York Canal and is operated for flood control and wildlife habitat. At the time of the field visit, the reservoir was nearly empty, with additional holding capacity available. The footprint of the highwater mark of the reservoir covers approximately 250 acres. The standing water in the reservoir at the time of the field visit suggests that either the parent materials have low permeability or that a seal of low-permeability materials has formed over time. In the latter case, periodic maintenance with mechanical disturbance may be used to increase the infiltration capacity of the site. The reservoir appears to be a good candidate for recharge based on the existing structure, conveyance mechanisms, and source of water.

Sites 24, 25 and 26. Only two of these sites could be field verified. Both have good potential as recharge sites due to the presence of irrigation laterals near each site. However, these sites are located in areas of shallow depth to groundwater. Recharge at these sites may have to be managed under a regime of pumping first and then back-filling the cone of depression.

> Site 24. This site could not be located during the field inspection. It appears that if a potential recharge did exist previously, it has been built on with residential development.
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> Site 25. Site 25 is another Idaho Transportation Department source material site. Currently, several large, active sand and gravel quarries exist. A small irrigation ditch runs along the site, providing a potential conveyance for source water.
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> Site 26. Site 26 is a large sand and gravel quarry located south of Interstate 84, just west of Meridian. The site is extensive and has at least one minor irrigation lateral running adjacent to it which could serve as conveyance for source water.

Eagle Site. In January an additional site was inspected near Eagle (not mapped). This site is where the Farmers Union Canal crosses Dry Creek. The canal appears to be hosted in sandy material and crosses the creek at an elevation that would facilitate infrastructure to deliver Dry Creek water into the canal for direct percolation from the canal bed during the non-irrigation season.

Conveyance Capacity

The most cost-effective means to convey water to recharge sites is to use existing infrastructure to the extent possible. As recharge is contemplated, the Boise Board of Control and local canal managers should be involved early in the planning process. The preliminary evaluation in this report begins to explore the potential capacity of the New York Canal to deliver water to recharge.

In general, existing canals in the New York Canal system operates up to the freeboard limit from April 15 through October 15 (Deveau, 2011). While canals are theoretically available for recharge before and after those dates, icing and maintenance considerations provide some practical limitations to the period during which recharge water might be delivered. However, the historical record shows that some water has been diverted by the New York Canal in each of the twelve months, at some time during the last 20 years. Water users in Eastern Idaho have demonstrated that off-season recharge can occur even in the harsh winters of Fremont County (Taylor and others 2010; Contor and others, 2009).

The necessity to check up canals to maintain head for diversions can create the appearance of no freeboard and no available capacity, even though the canal is delivering less water than it does at other times of the year. Generally, at those times, check structures could be adjusted to allow some delivery to recharge sites without threatening the necessary operational freeboard.

Following work done for the Eastern Snake Plain Aquifer CAMP process (Contor and others, 2008), historical flows in the New York Canal have been analyzed for periods of time when diverted flows are typically less than maximum. Figure 28 shows the historical record of monthly diversion volume. The red line marks 140,000 acre feet per month, suggested as a first estimate of safe monthly diversion volume (in the period 1928-2006, ten percent of monthly deliveries exceeded 158,000 acre feet and the maximum was 187,000).

Figure 29 shows diversions for the last 20 years of canal operation. The wide yellow bars give the average and the whiskers give the maximum and minimum. For instance, the July average diversion was 130,000 acre feet but one year the July volume was almost 150,000 acre feet and it has been as low as 100,000 acre feet.

Using 140,000 acre feet as a safe maximum monthly diversion, the historical potential canal capacity for the period 1990 - 2009 was calculated by subtracting actual volume from the 140,000 maximum during each month of the irrigation season (April - October). For each of the off-season months, the 90th percentile of 1990 - 2009 diversions was used to represent the safe maximum, in an attempt to accommodate maintenance periods and icing conditions. Figure 30 illustrates the calculated monthly average potential capacity as a wide blue bar, with the dark whiskers representing minimum potential capacity during the 1990 - 2009 period.

Caution is needed in interpreting these data; it is quite likely that the years when recharge water might have been most available are years when adequate supplies allowed full canal deliveries and available capacity was at its minimum. During the 20-year period, the minimum potential annual available capacity was 270,000 acre feet and the 25th percentile (which was exceeded 15 years of the 20) was 330,000 acre feet.

This is still less than the potential storage capacity; additional conveyance infrastructure would be required to fully access storage potential in the aquifer. The cost of this infrastructure should be considered in context of infrastructure costs for other storage options, and its necessity should be considered in light of the timing and volume of water available to be stored and the need for additional storage.

This capacity analysis considers only the New York Canal, but water must still be conveyed from the canal to the recharge site. Local lateral capacity and/or new infrastructure should be investigated on an individual basis as potential recharge sites are considered.

Residence Time

In a surface-water reservoir, water remains available for future use, unless it must be spilled for flood-control purposes. Except for usually minor losses to evaporation and seepage, it can be retained in storage until called for. If an aquifer is connected to a surface-water body, however, the recharge mound effectively migrates into the river (via either increased gains to the river, or decreased losses from the river). While this benefits the river, especially in the late summer when cool aquifer water can sustain fisheries, it depletes the stored volume of water. For this report, the time to depletion of 50% of the recharged volume was assessed for seven representative locations in the aquifer, as shown in Figure 31. Point 4 is the location of the Hubbard Reservoir site discussed above.

The residence time depends upon the storage coefficient discussed previously, transmissivity (which is a measure of the ability of water to move through the aquifer) and distance (to the river) squared. Large storage coefficients, large distances and small values of transmissivity all increase the residence time in the aquifer.

The time to depletion can be calculated using a method known as both the Balmer-Glover method and the Jenkins method. It assumes a semi-infinite aquifer in communication with an infinitely long river. In this case, the Boise River has a finite length of connection to the aquifer, and the aquifer is bounded by the Snake River and impermeable hills. For this report, the method was adapted to represent these bounding conditions, as described by Contor (2011).

The adapted methodology was applied using aquifer properties from Newton (1991) and text-book values (Freeze and Cherry, 1979). The aquifer properties acquired from the Newton's investigation were based on model-assigned hydraulic conductivity values and storativity for the upper rock unit (layer 1) with a thickness of 500 feet. These values are displayed in Table 1. The aquifer properties acquired from Freeze and Cherry are values for a low conductivity gravel and/or high conductivity silty sand. These unconsolidated materials seem to best represent the uppermost geologic layer in the Treasure Valley. The storage coefficient of an unconfined aquifer is typically 0.01 to 0.30 (Freeze and Cherry 1979). Based on these given values and values for shallow aquifers in the Treasure Valley provided in recent studies (Thomas and Dion 1974, Newton, 1991), a median value of storage coefficient was chosen from the text. Likewise, the textbook transmissivity values in Table 1 are within the range of Thomas and Dion's investigation of the Treasure Valley.

Based on indications that the Snake River has significantly less communication with the aquifer than does the Boise River (Schmidt, 2010), these calculations were performed with the Snake River as a no-flow boundary. This is reasonable in light of the apparent lack of springs and wetlands on the southern margin of the Treasure Valley. It is also consistent with geologic mapping of faults (which may impede groundwater flow) parallel and just north of the Snake River (Othberg, 1994). Nevertheless, to test this assumption the calculations for Point 5 (near the Snake River) the calculations were repeated with the Snake River as connected.

Table 1 gives the calculated time to 50% depletion for the seven locations in Figure 31, along with the aquifer properties and boundary conditions utilized for each point.

Table 1
Time to 50% Depletion of Recharged Volume,
for Representative Aquifer Locations

Point	Snake Boundary	USGS Data			Textbook Values		
		T (ft^2/day)	S	Time to 50%	T (ft^2/day)	S	Time to 50%
1	No Flow	2,000	0.1	> 5 yr	140,000	0.05	570 d
2	No Flow	8,500	0.1	710 d	140,000	0.05	14 d
3	No Flow	8,500	0.1	88 d	140,000	0.05	4 d
4	No Flow	8,500	0.1	> 5 yr	140,000	0.05	> 5 yr
5	No Flow	8.500	0.1	> 5 yr	140,000	0.05	> 5 yr
5	River	8,500	0.1	> 5 yr	140,000	0.05	3 yr
6	No Flow	19,500	0.1	> 5 yr	140,000	0.05	310 d
7	No Flow	19,500	0.1	> 5 yr	140,000	0.05	780 d

From Table 1 it is apparent that there is significant uncertainty associated with the wide range of possible values for aquifer characteristics.[2] It is also apparent that except for points close to the Boise River, residence times in aquifer storage are long compared to the typical residence times in a surface-water reservoir. Also note that aquifer storage is not subject to spill for flood control requirements.

Comparing Figure 31 (points for depletion-time calculations) with Figure 23 (preliminary map of preferred locations) and Figure 12 (depth to water), it is clear that Points 1, 2 and 6 are in areas where storage will only be possible if space is first created by pumping a cone of depression. If this scheme were employed, the period of time that the cone of depression would remain available for back-filling is the same as the estimated residence time of storage from Table 1. Even with the uncertainty inherent in Table 1, it appears that at Point 1, the aquifer could be pumped to meet summertime needs, and the space created by the cone of depression would still largely be available for back filling by recharge that fall or the following spring. Timing of impacts to surface water would need to be carefully considered; perhaps the recharge would need to take place nearer the river than the pumping that created the space in the aquifer. The accounting methodology mentioned earlier (Contor, 2009) would facilitate this analysis and administration.

Point 3 is included to assess the Eagle/Dry Creek potential recharge location. It

[2] Current IWRRI work (Schmidt, 2010) gives preliminary aquifer characteristics that indicate generally shorter times than in Table 1.

is clear that further investigation into aquifer characteristics is called for. However, if the USGS data are approximately correct, it appears that water recharged in the spring would mostly still be available for use in the drier summertime periods of the same year. This site could be considered to provide about the same timing of storage and release as typical surface-water reservoir operations.

The two different values for Point 5 show that representing the Snake River as connected, rather than as a no-flow boundary, reduces the residence time by about half. Nevertheless, these data indicate that in either case, recharge in the southern-most potential sites could have residence times useful for water management.

The depletion of recharged water in Table 1 is also a potential benefit to the river(s). Even if not recovered by pumping, recharge can benefit surface-water users and fisheries late in the summer as it sustains river gains from the aquifer or reduces river-bed loss in hydraulically-connected reaches of the river. The tools used for the residence-time analysis can also be specifically applied to assess the impact of recharge upon surface-water bodies.

NEXT STEPS

The next logical steps in investigation of storage in the Treasure Valley apply both to surface-water storage and storage in the aquifer:

1. Assess needs for storage, based on projected demands for additional water and current water-supply shortages (if any).
2. Assess availability and timing of water that could be stored. Both physical supply (hydrology) and legal access (water rights) must be considered.
3. Assess the implied per-acre-foot cost of water delivered from storage, including capital costs, operational costs (including water treatment), and expected percentage of fill.
4. Compare this to expected economic demand for stored water.

Required steps specific to managed aquifer recharge are:

1. Contact and coordinate planning with owners and operators of canals and managed recharge sites that are considered for use.
2. Refine understanding of conveyance capacity and timing, and infrastructure or operational changes that might be necessary.
3. Coordinate with Idaho Department of Water Resources and Idaho Department of Environmental Quality to ensure that plans are within

existing water right and water quality guidelines.

4. Refine understanding of aquifer characteristics and expected residence time for promising sites.
5. Consider opportunities to maximize use of water stored in surface reservoirs by moving carryover storage to the aquifer, at times when it is expected that flood-control operations would otherwise cause spill of carryover.

SUMMARY AND CONCLUSIONS

It appears that the Treasure Valley Aquifer has the practical potential to store an additional 200,000 to 400,000 acre feet of water above what occurs naturally and incidentally to other human activities. This can potentially provide a meaningful contribution to water management. Much additional work is needed, but it appears that recharge sites can be identified to accept this water.

Most of the potential exists in the southwest, including the Hubbard Reservoir site. With the California practice of pumping first to create a cone of depression, and then back filling later with recharge water, additional opportunities (beyond 200,000 to 400,000 acre feet) could be accessed in the northwest Treasure Valley.

While uncertainty remains concerning aquifer residence times, it appears that in general recharge water stored in the aquifer is available for periods of months to a few years, except for locations very near the river.

Current infrastructure cannot deliver all the water that potentially could be stored in the aquifer. Managers and operators of canals should be consulted early in the planning process. Construction costs of additional infrastructure should be considered in context of construction and water-treatment costs of other storage alternatives. Tools and methodology exist to quantify the impact that recharge would have upon surface-water bodies, and to facilitate management of recharge and match it to withdrawal activities.

ACKNOWLEDGMENTS

The authors are grateful for the financial support of the US Geological Survey and the Idaho Department of Water Resources. Paul Deveau of the Boise Project Board of Control and R.D. Schmidt of Idaho Water Resources Research Instituted provided valuable input.

FIGURES

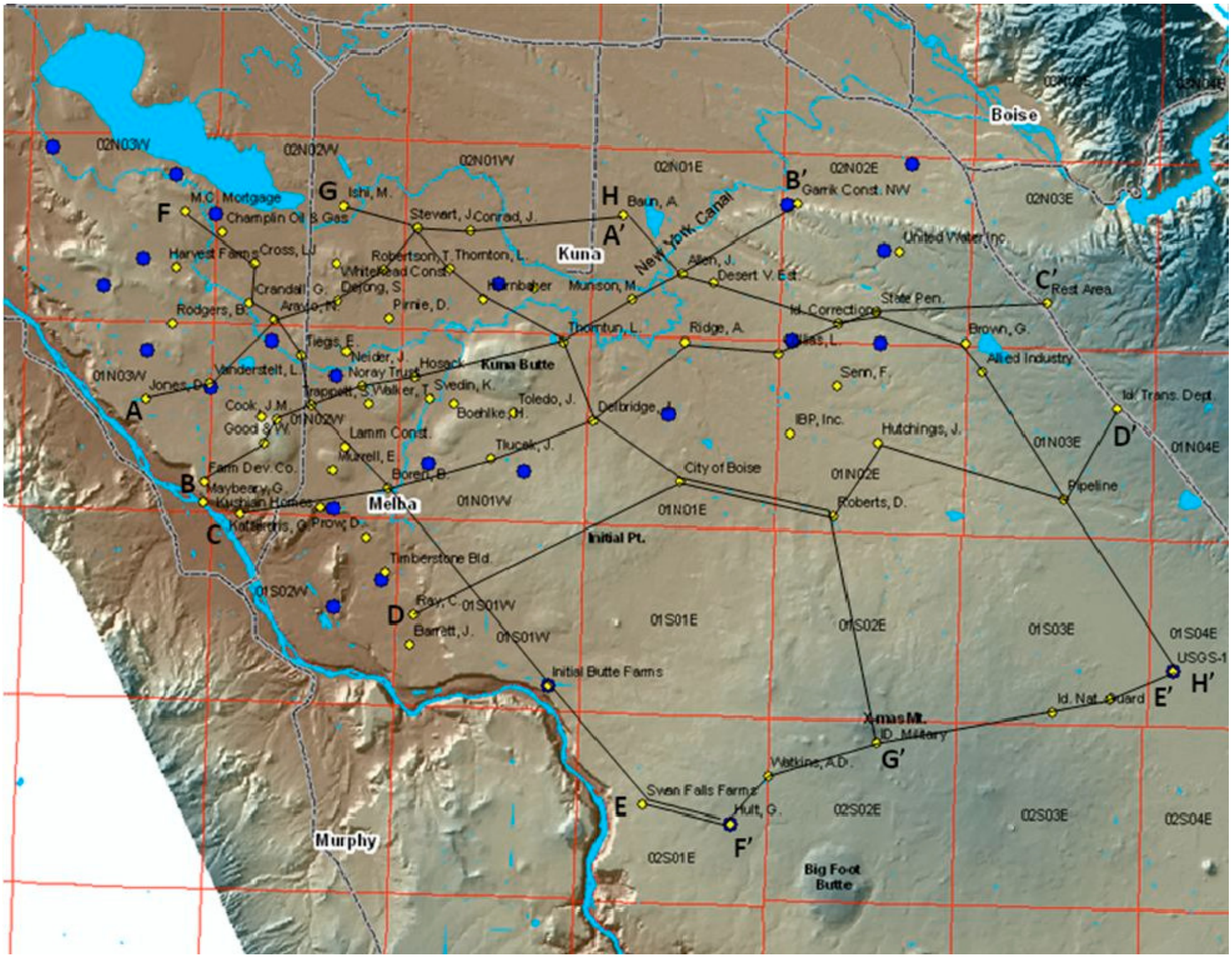

Figure 1. Shaded relief map showing wells used in the geologic 3-D model and cross sections shown as yellow circles and wells used for water levels shown with blue circles. The Township and Range grids are 6 square miles for scale.

Figure 2. Cross sections A-A' and B-B'

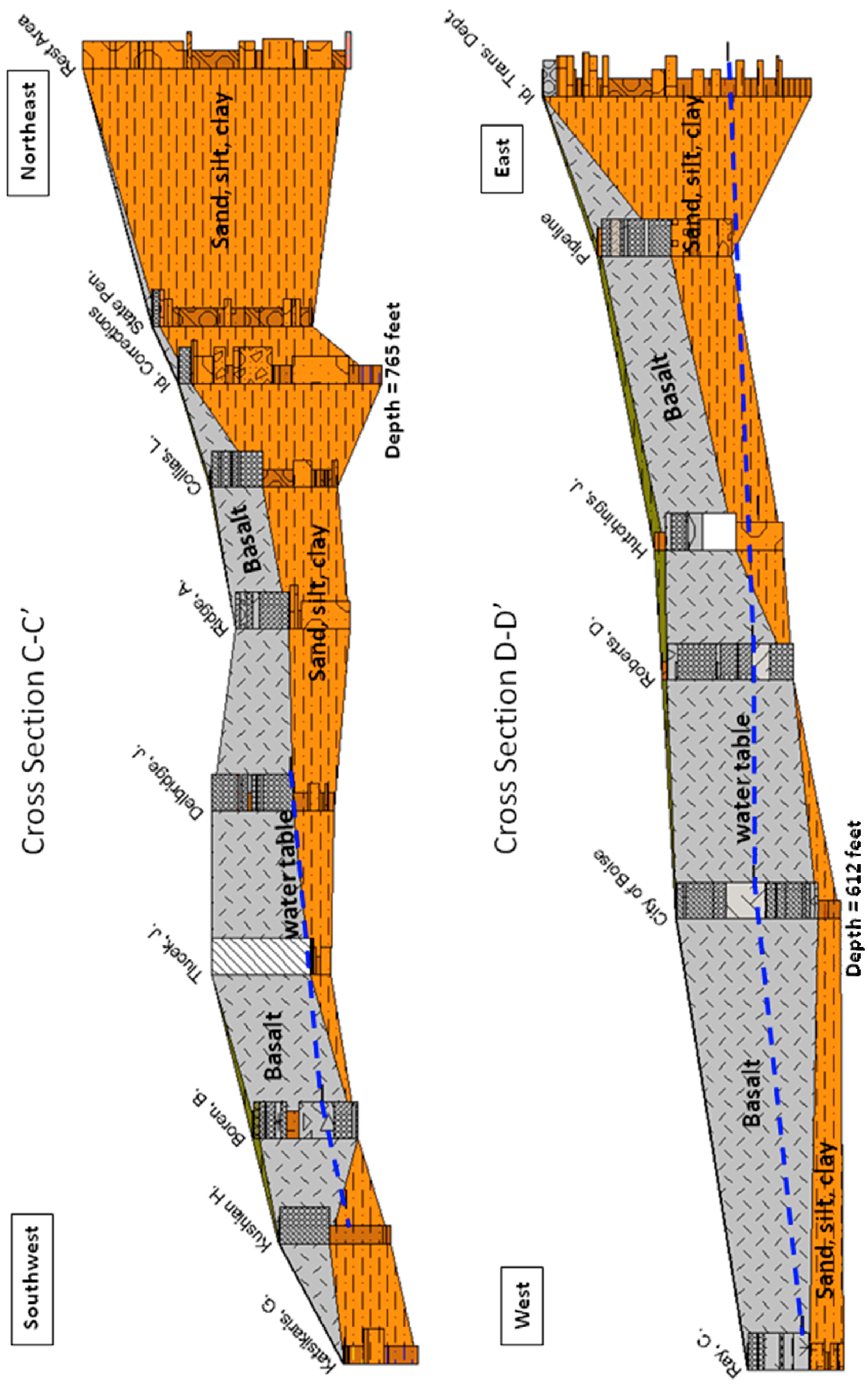

Figure 3. Cross sections C-C' and D-D'

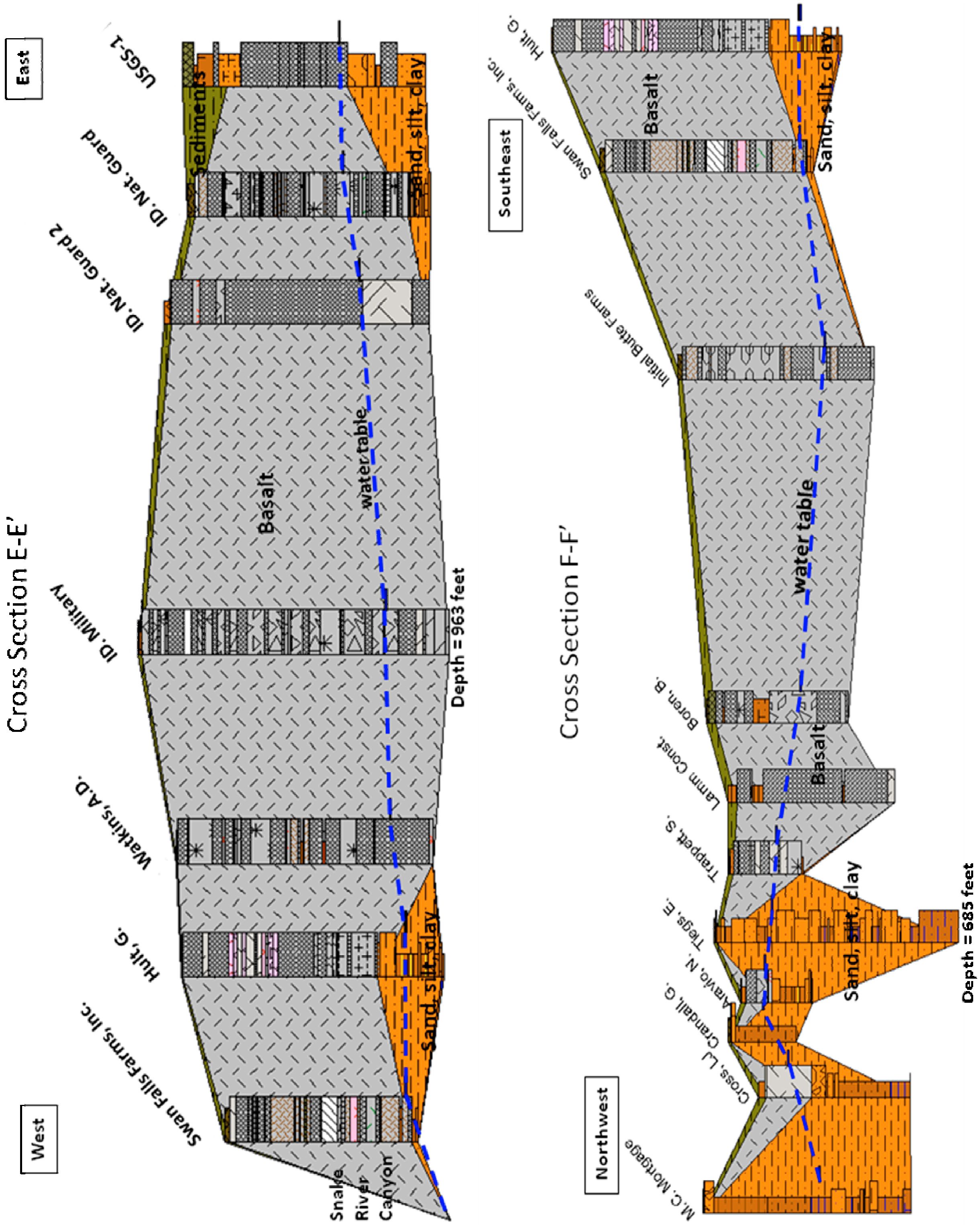

Figure 4. Cross sections E-E' and F-F'

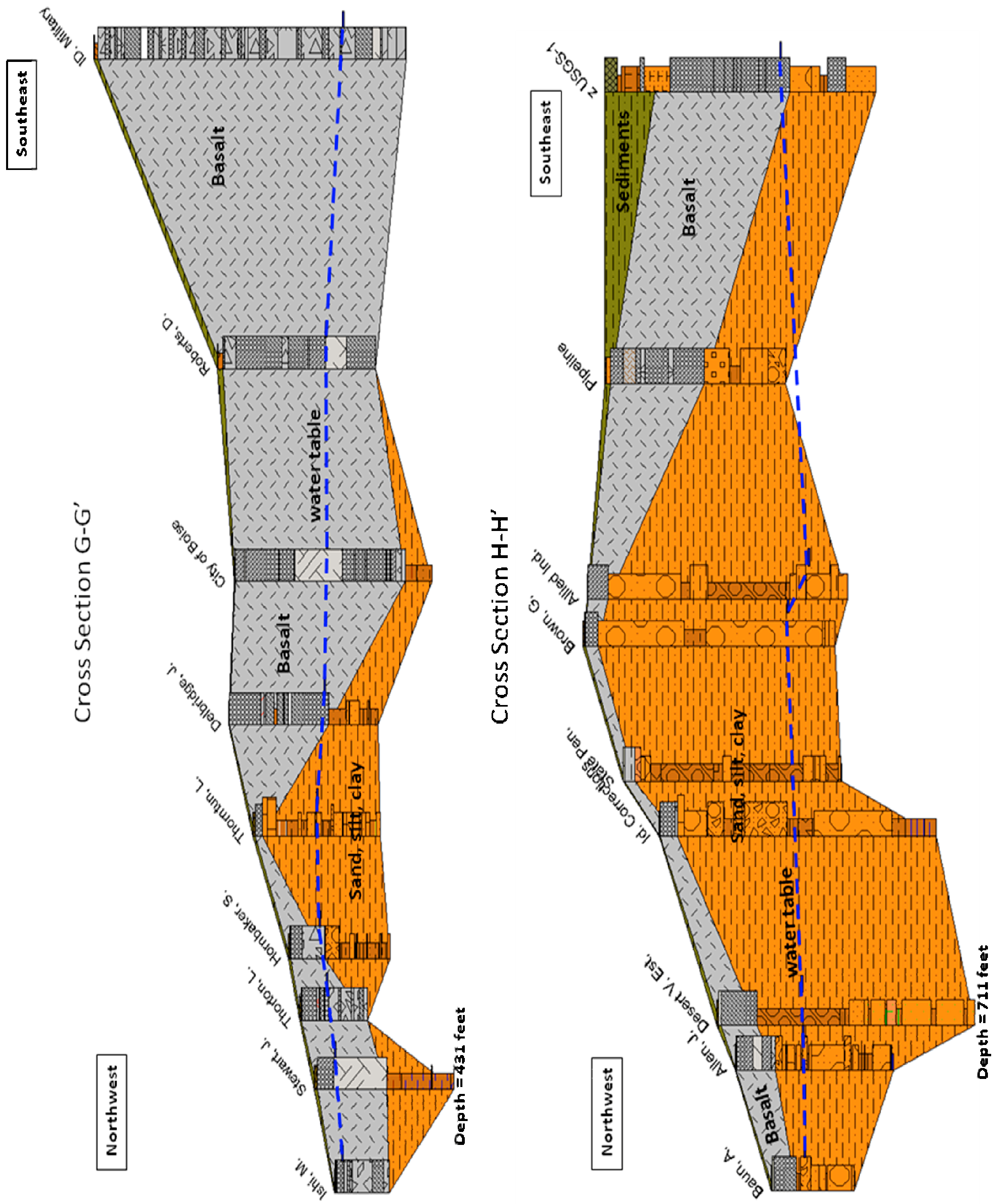

Figure 5. Cross sections G-G' and H-H'

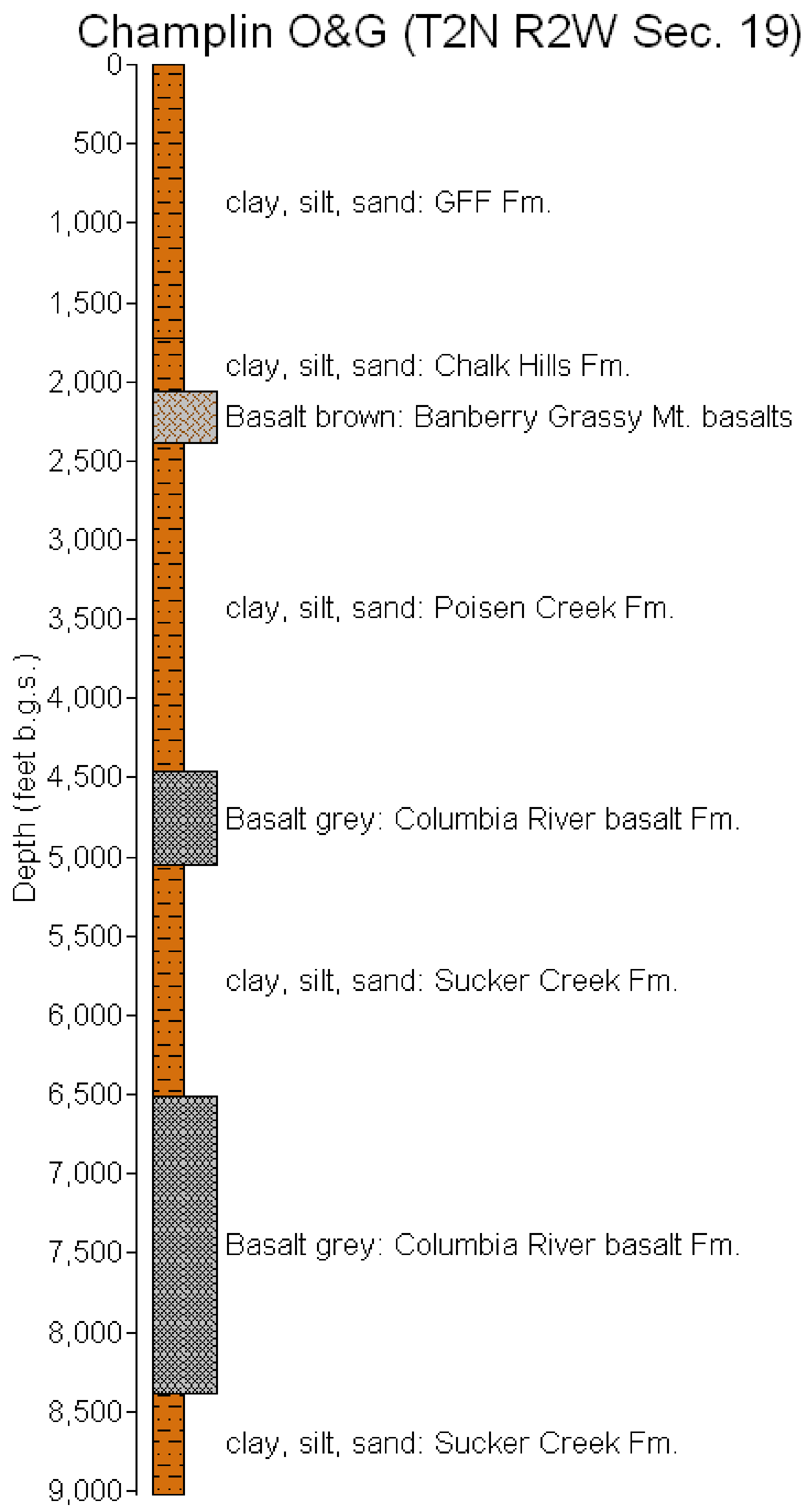

Figure 6. Champlin Oil and Gas well drilling geologic log showing Glenns Ferry Fm. sediments extending down to at least 1,500 feet. These sediments are assumed to extend under the project area cross sections A-H. (source: Idaho Geological Survey)

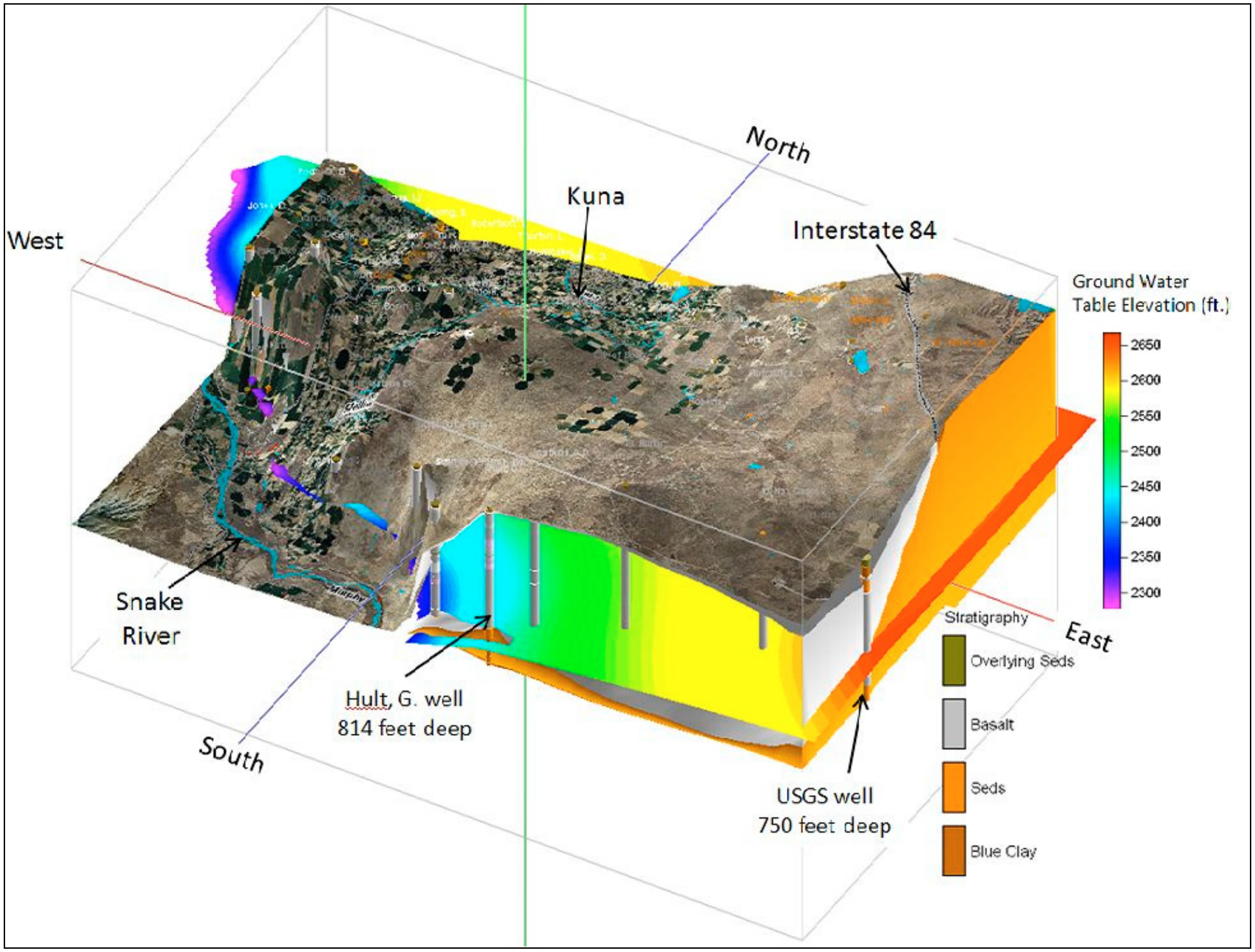

Figure 7. Three-dimensional model of the area in Figure xx showing a color air photo draped over the model surface. The south panel of the basalt is removed to show the interior. High areas of the water table are colored red and low areas of the water table colored blue.

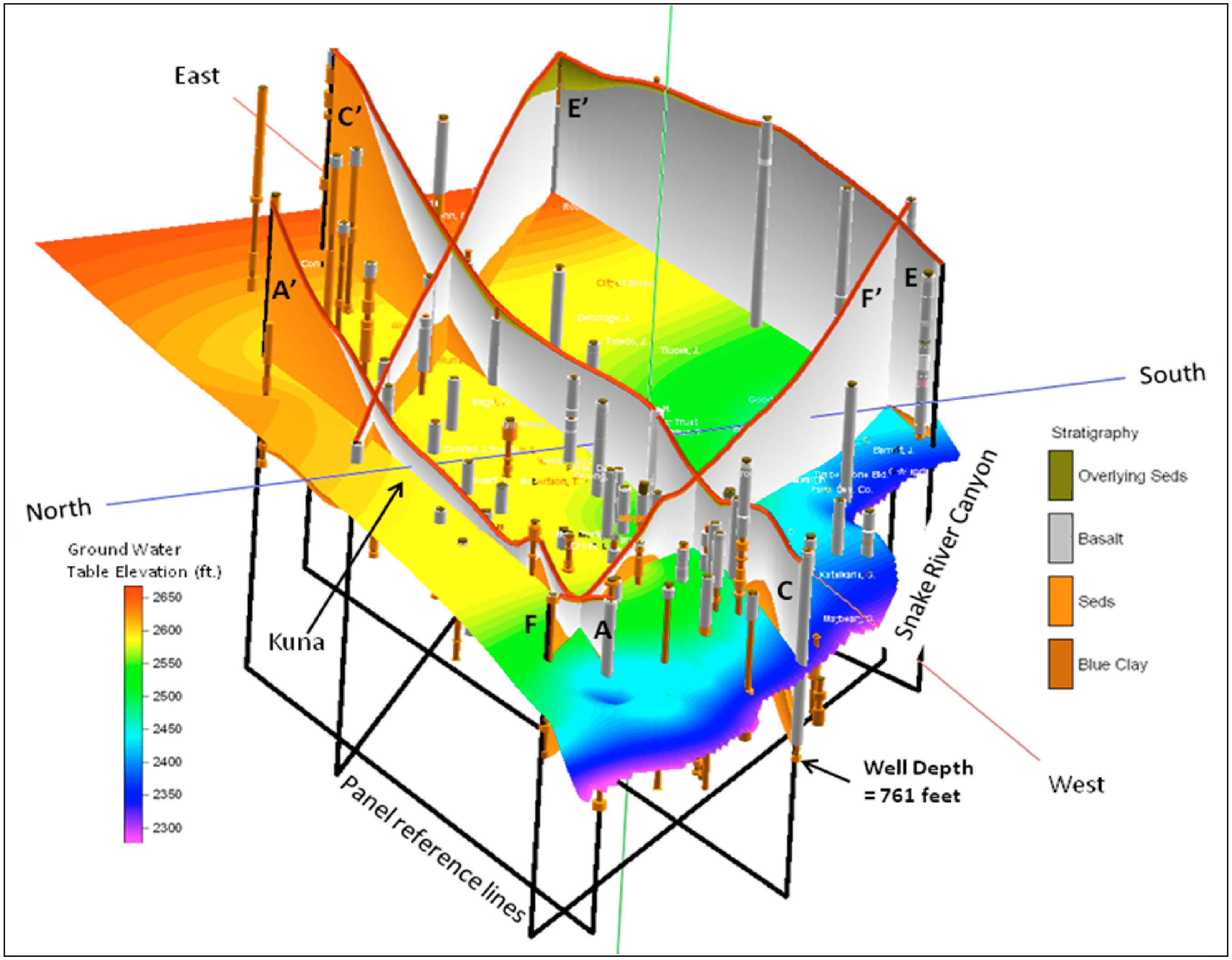

Figure 8. Top view angle fence diagram showing the relation between water table and sediment highs and basalt lows.

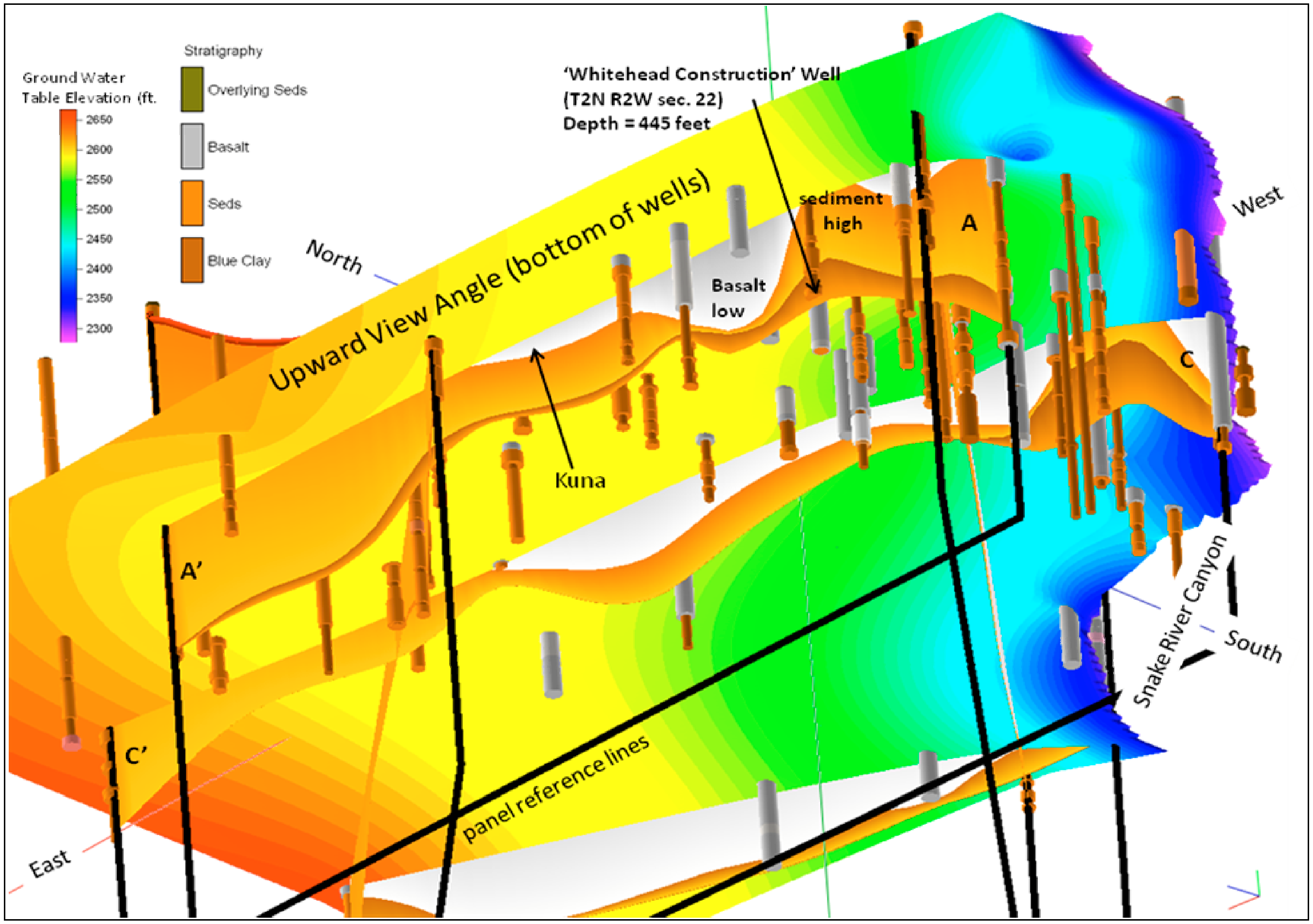

Figure 9. Upward view angle showing the base of wells in relation to the water table and general geology. Note the sediment 'high' at the 'Whitehead' well and adjacent basalt low.

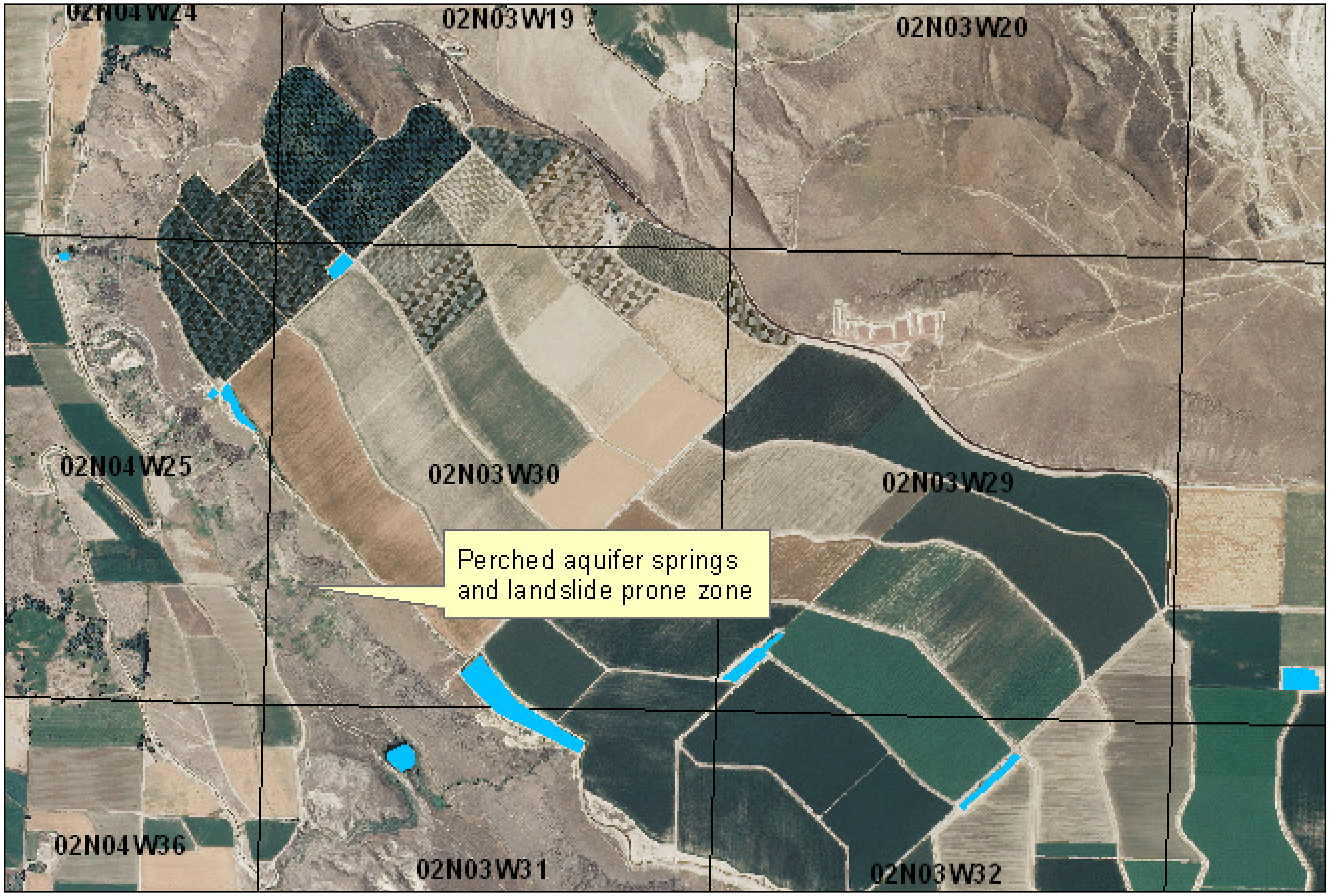

Figure 10. Perched aquifer springs discharging from sediments, probably associated with irrigation above the canyon rim.

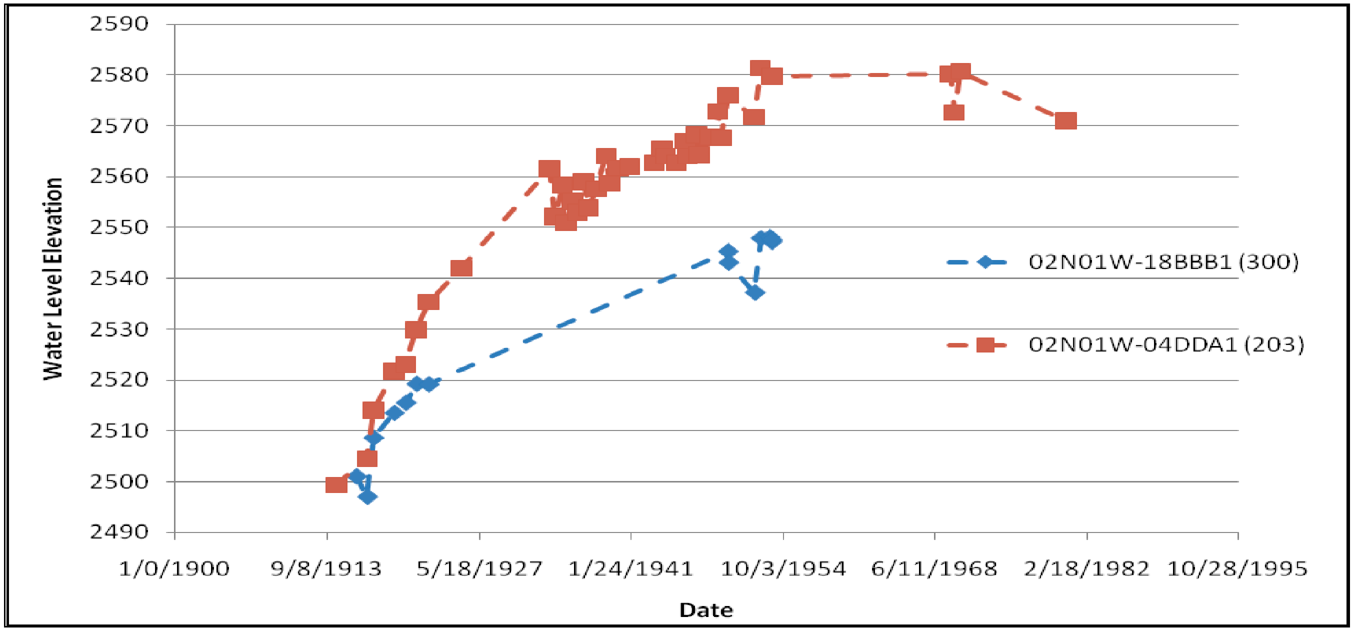

Figure 11. Hydrographs showing water level increases during the period following development of surface water irrigation in the area.

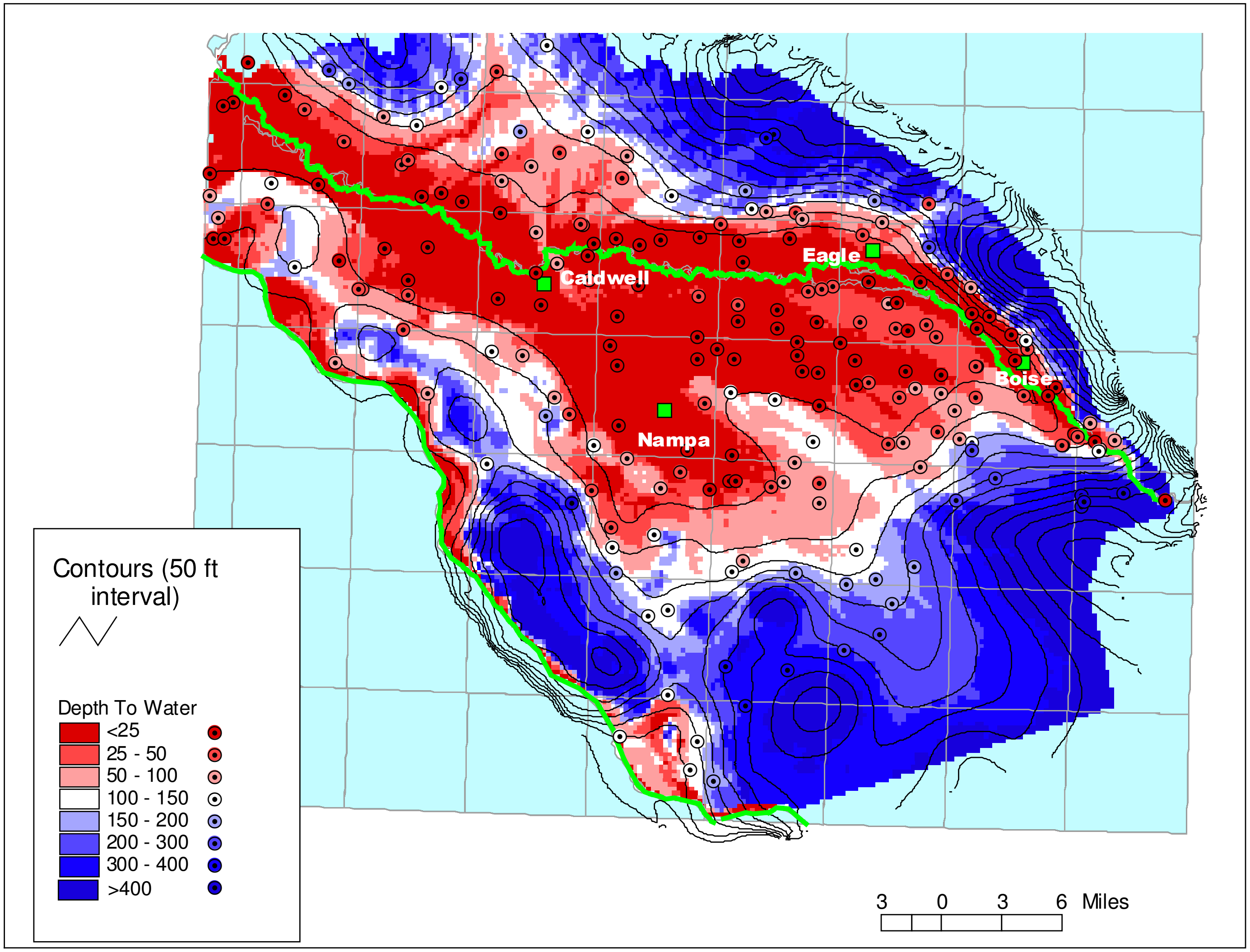

Figure 12. Approximate depth to water. The circles are measurements at individual wells. Note that in some cases the interpolated, smoothed water level surface does not match individual wells. Variations in well completion depth, measurement conditions (such as well pumping) and time of measurements introduce some imprecision. This applies also to the water-level change maps.

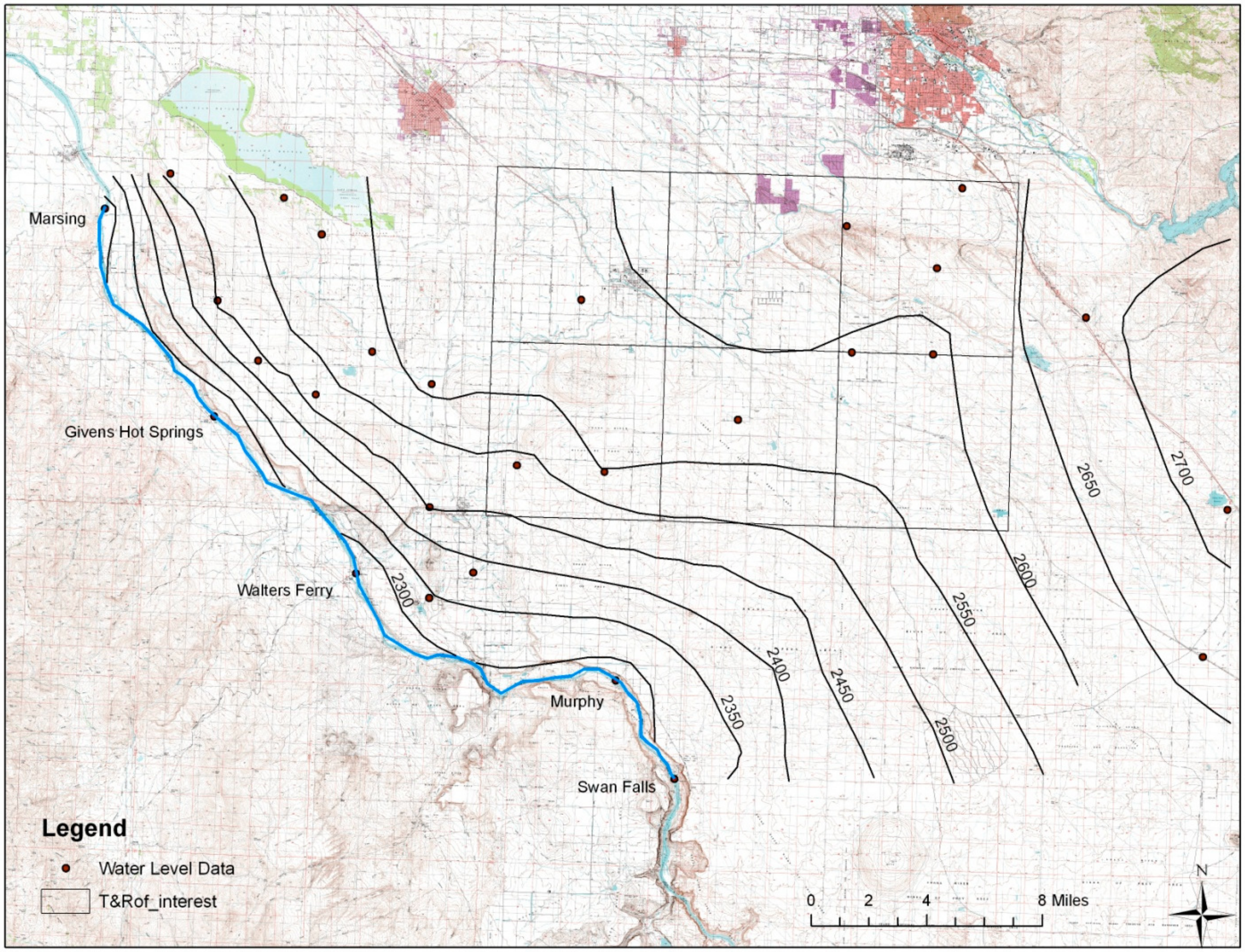

Figure 13. Potentiometric surface map for spring 2009, in the south part of the study area.

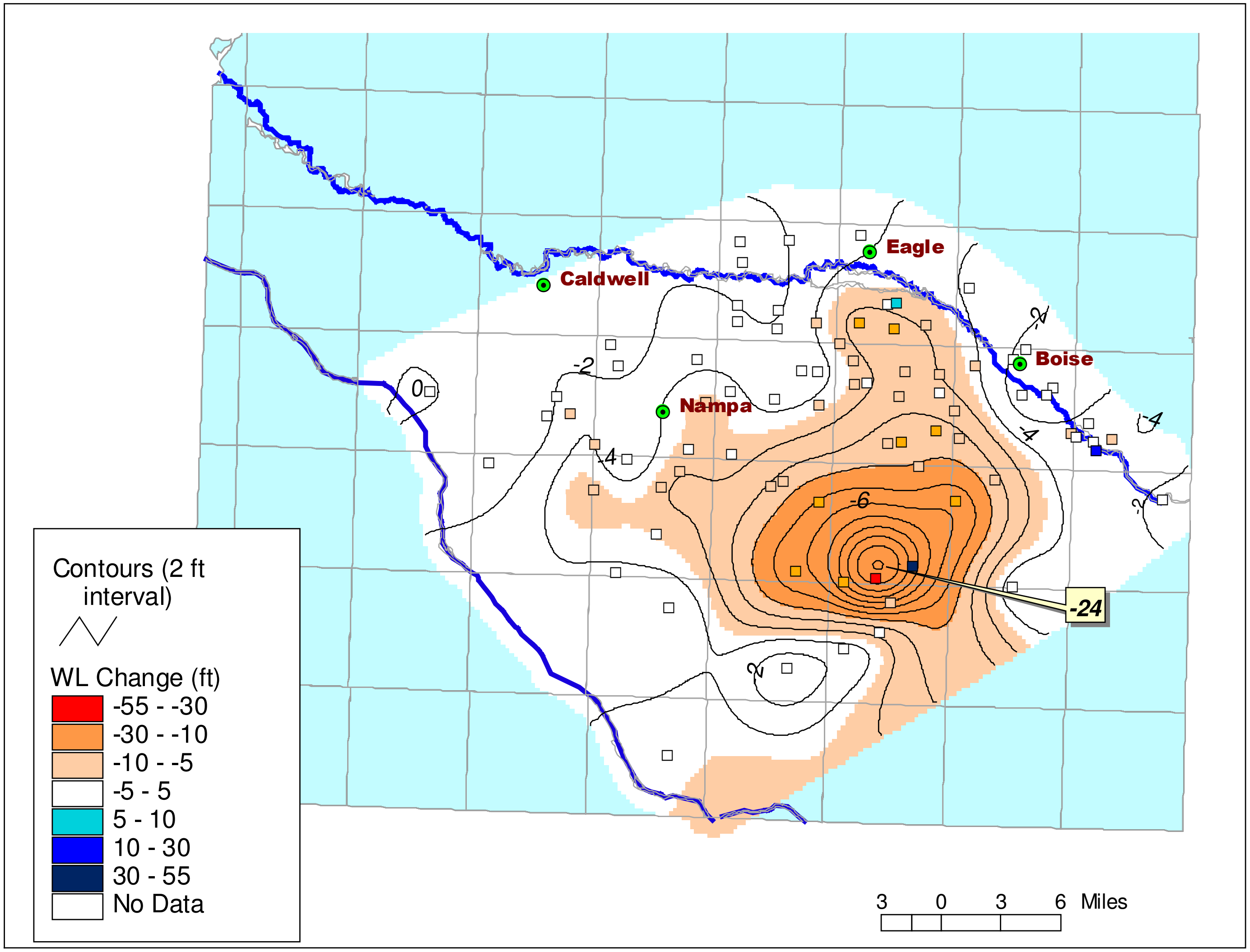

Figure 14. Water level changes fall 1996 to fall 2001. Individual wells are marked with squares, with individual water level changes coded with the same color ramp as the map background. Note that the water level change color map and contours are smoothly interpolated between individual-well results.

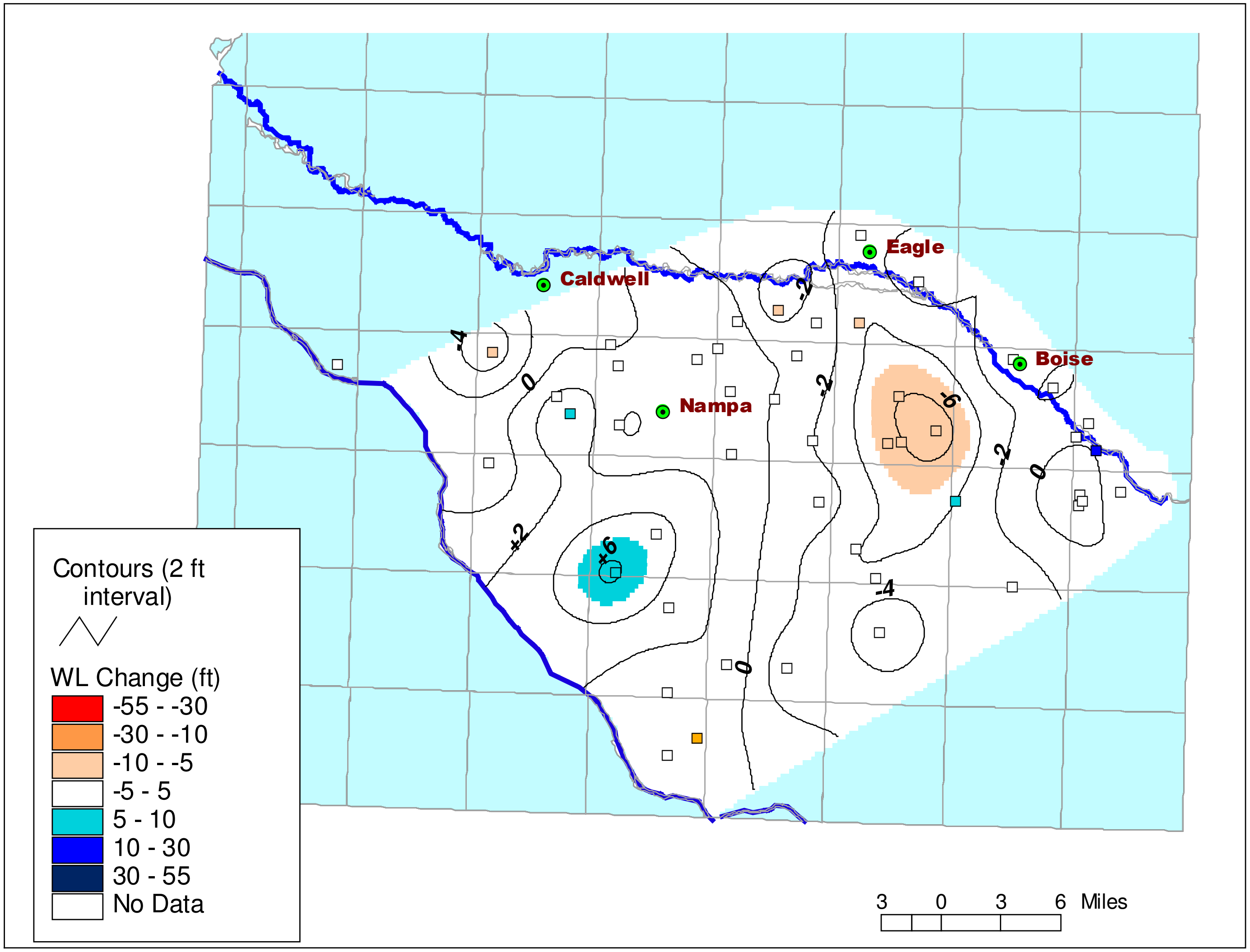

Figure 15. Water level changes fall 2001 through fall 2008.

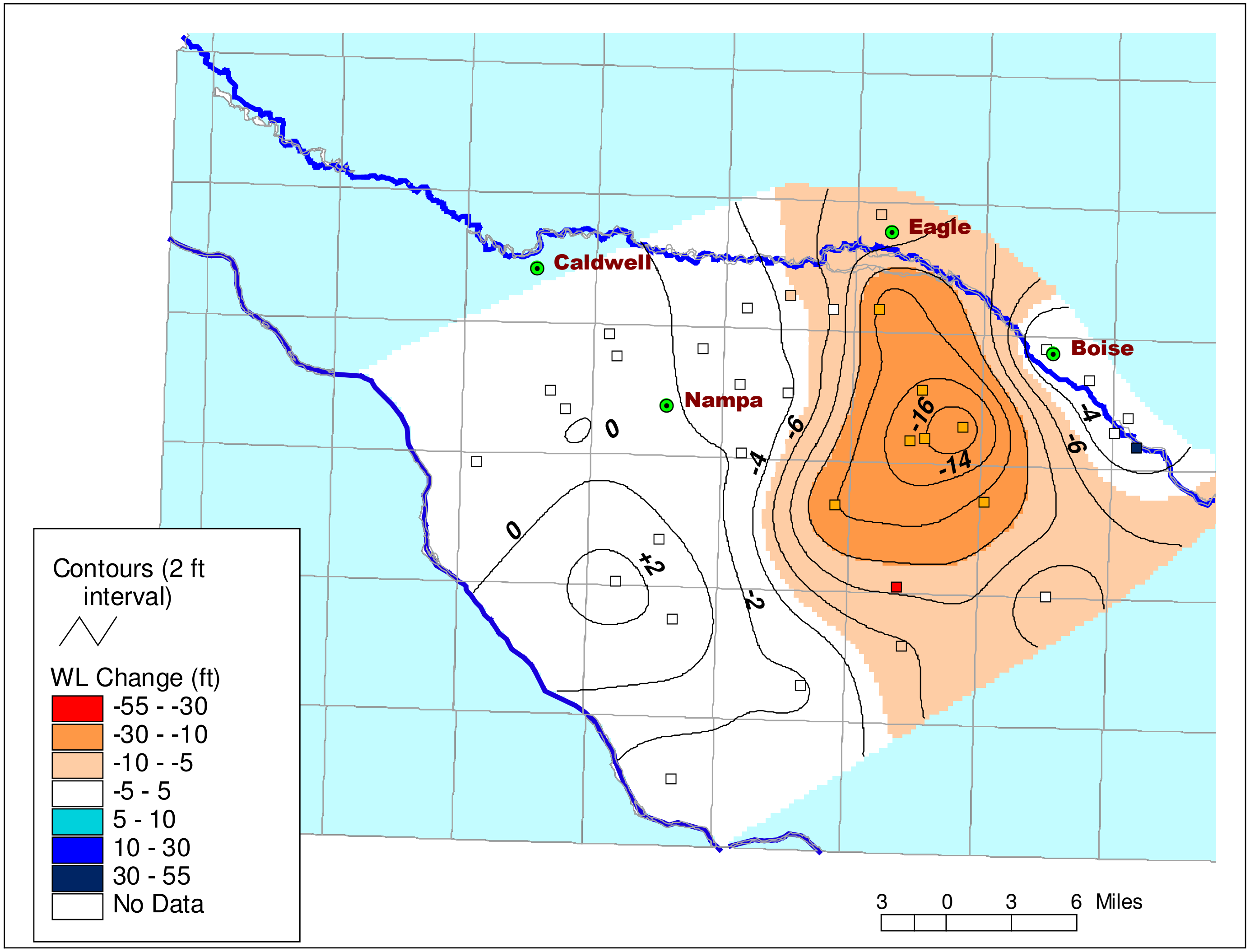

Figure 16. Water level changes fall 1996 through fall 2008.

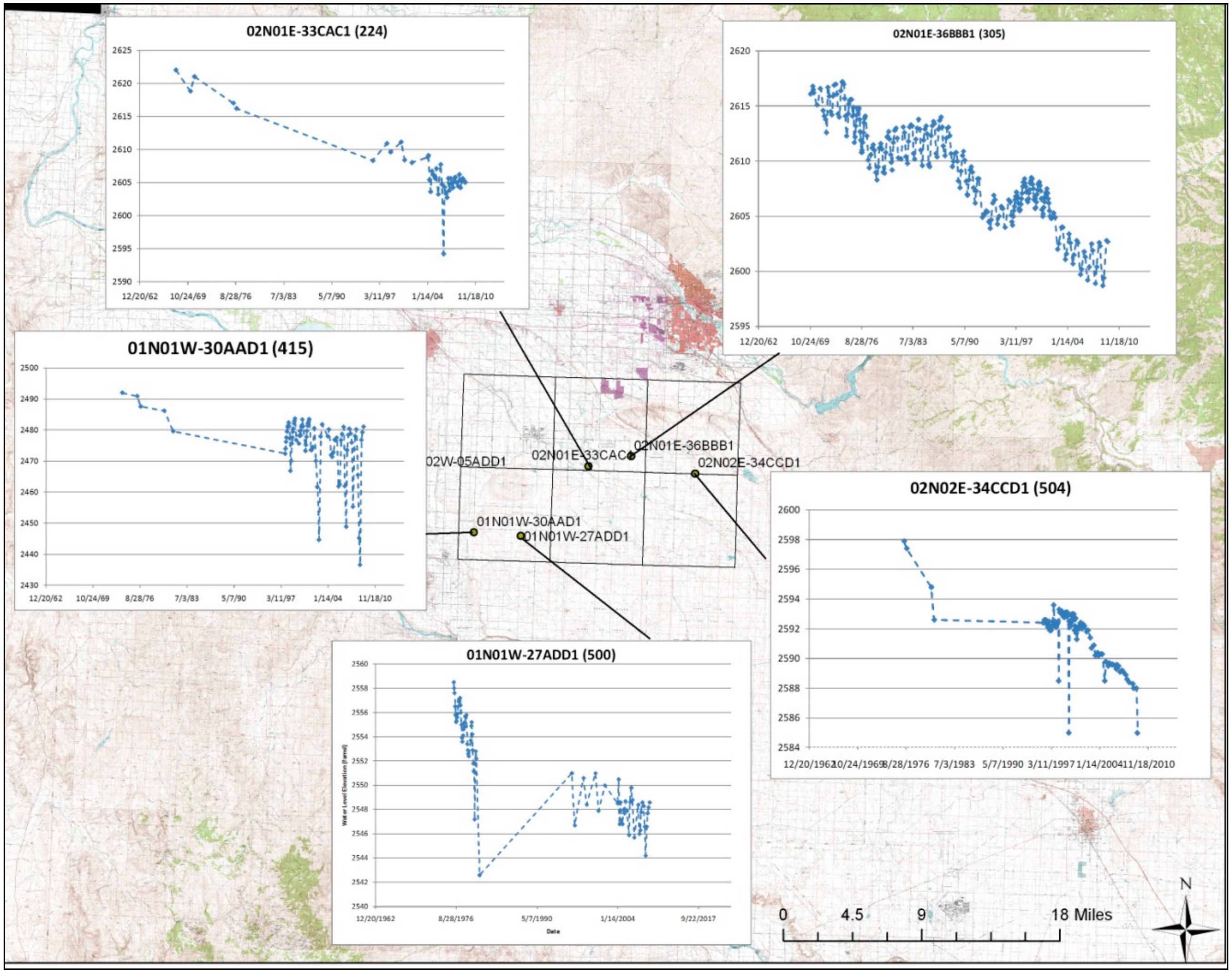

Figure 17. Hydrographs for selected study area wells.

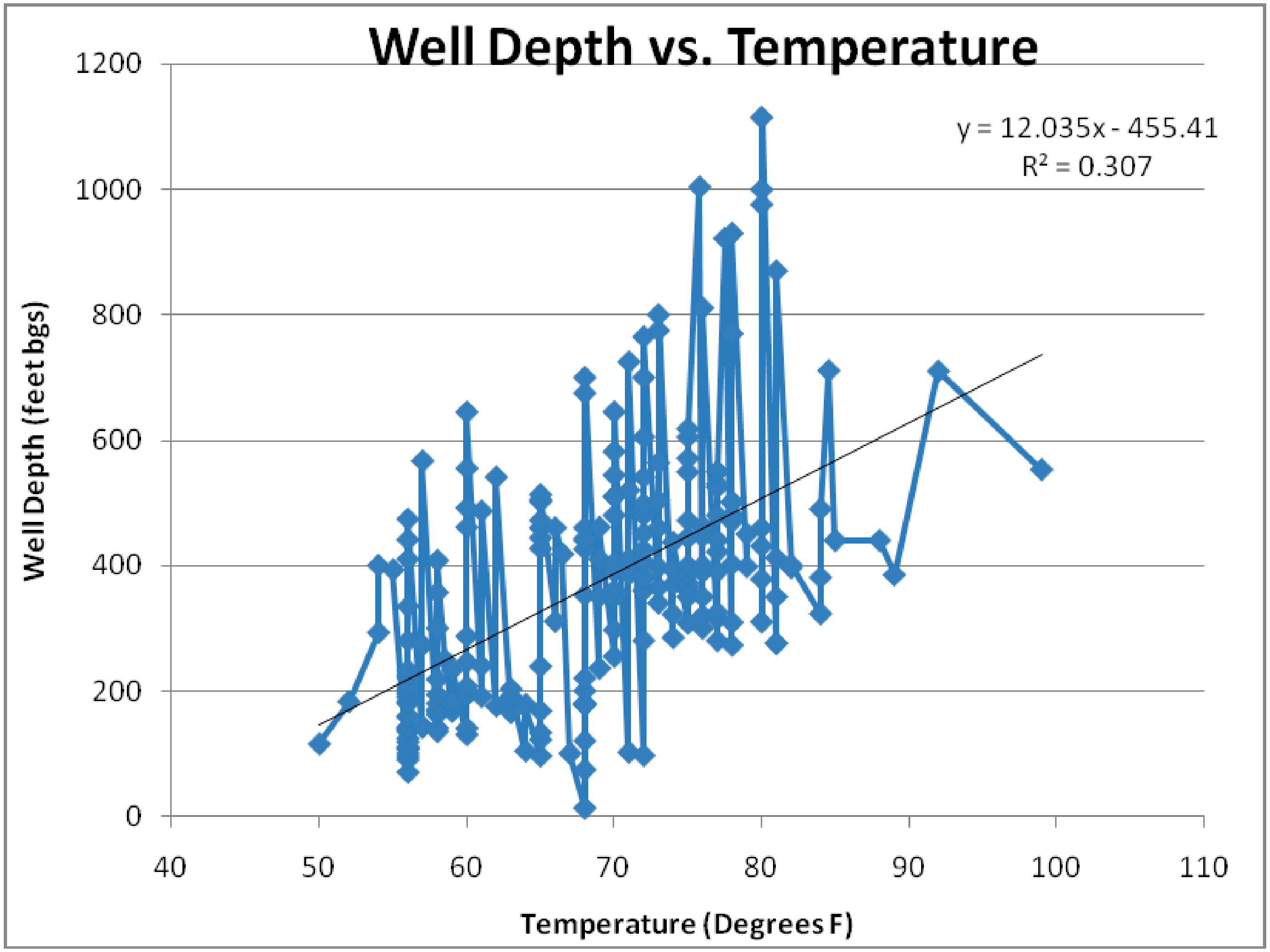

Figure 18. Plot of well depth versus temperature within the study area.

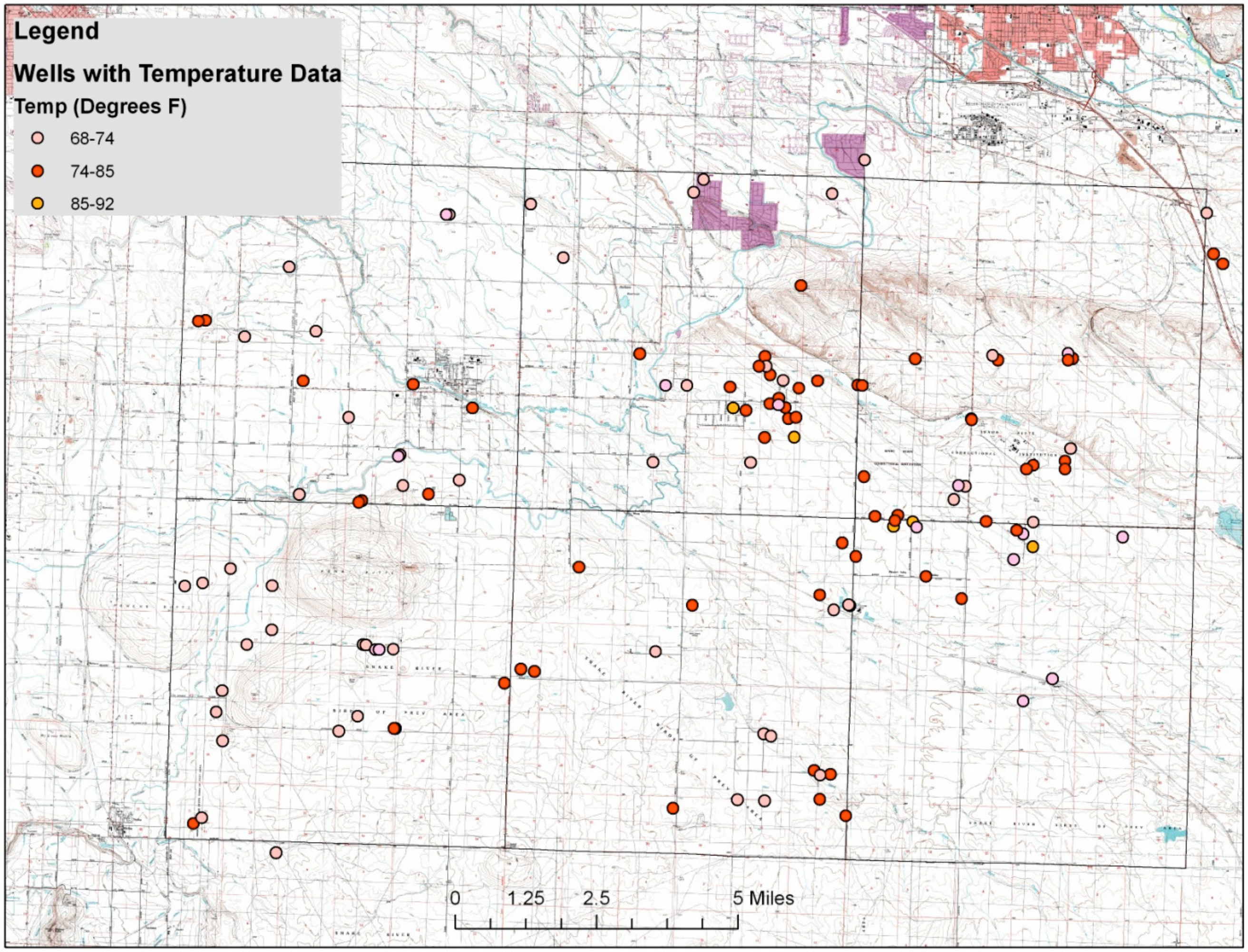

Figure 19. Wells with elevated temperatures (above 68 degrees).

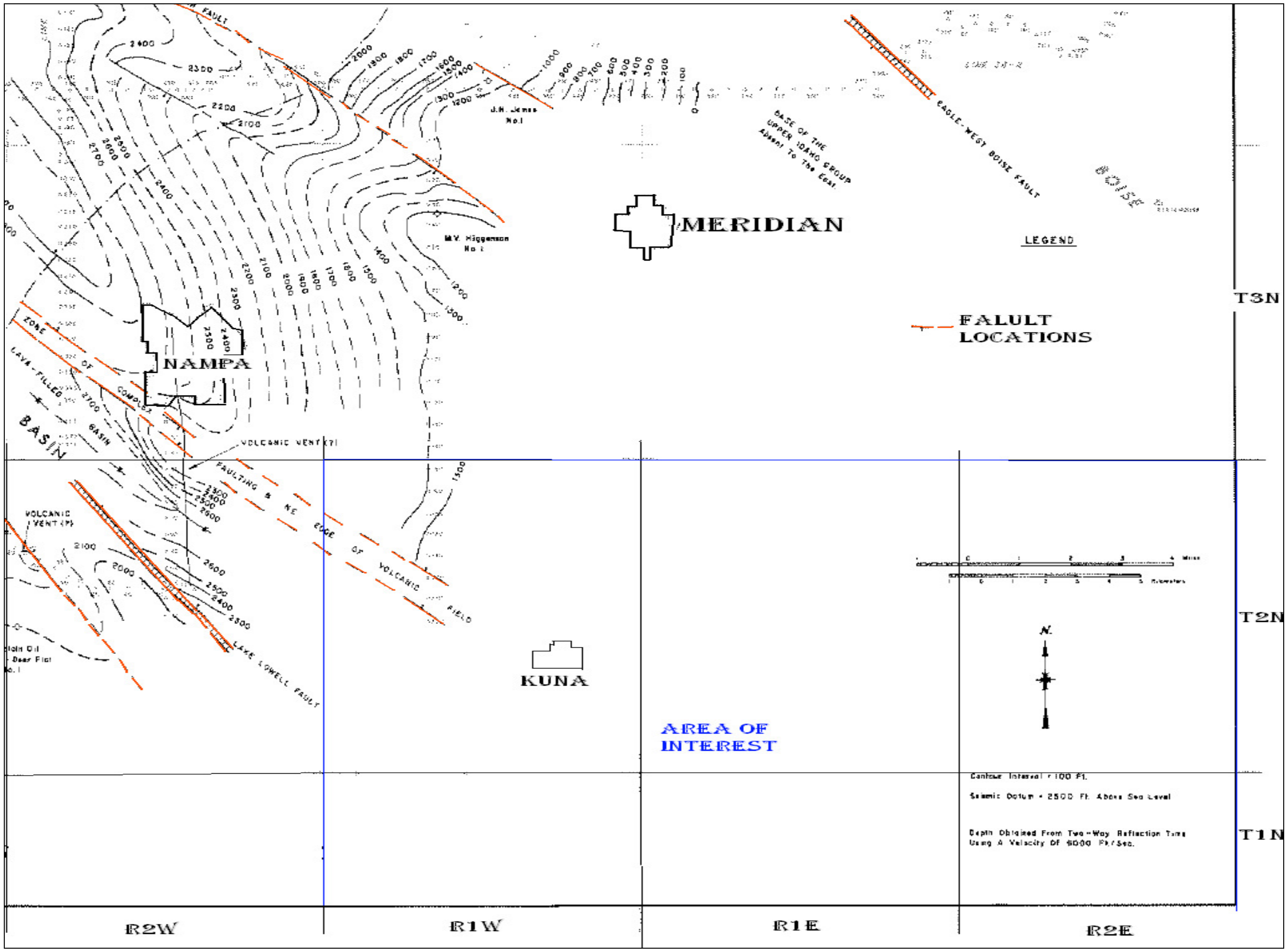

Figure 20. Structural map of the Idaho Group sediments showing the locations of mapped faults in the area (modified from Mitchell, 1981).

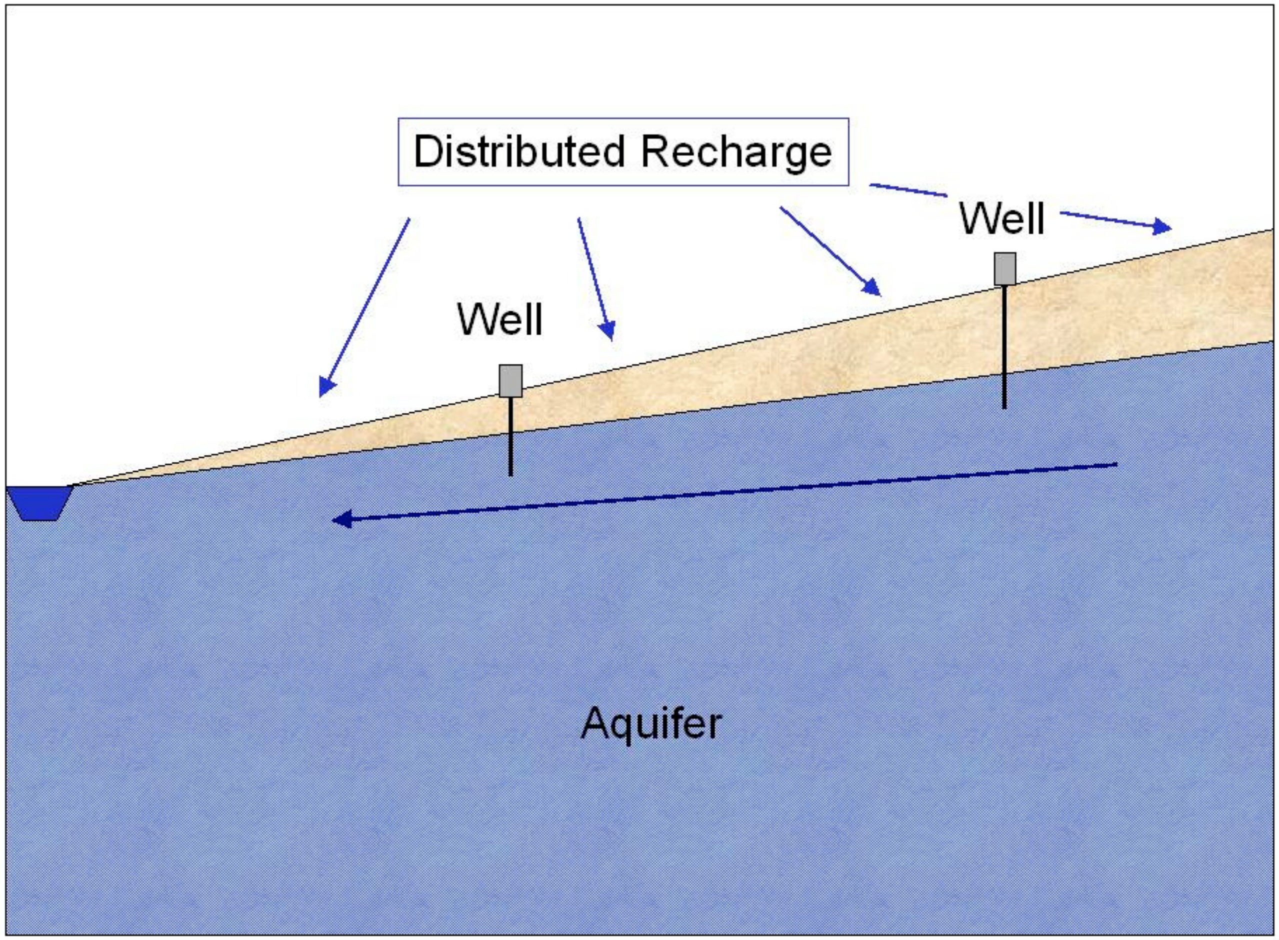

Figure 21. Pre-recharge sketch of water table, wells, and typical spatially-distributed recharge from precipitation and irrigation.

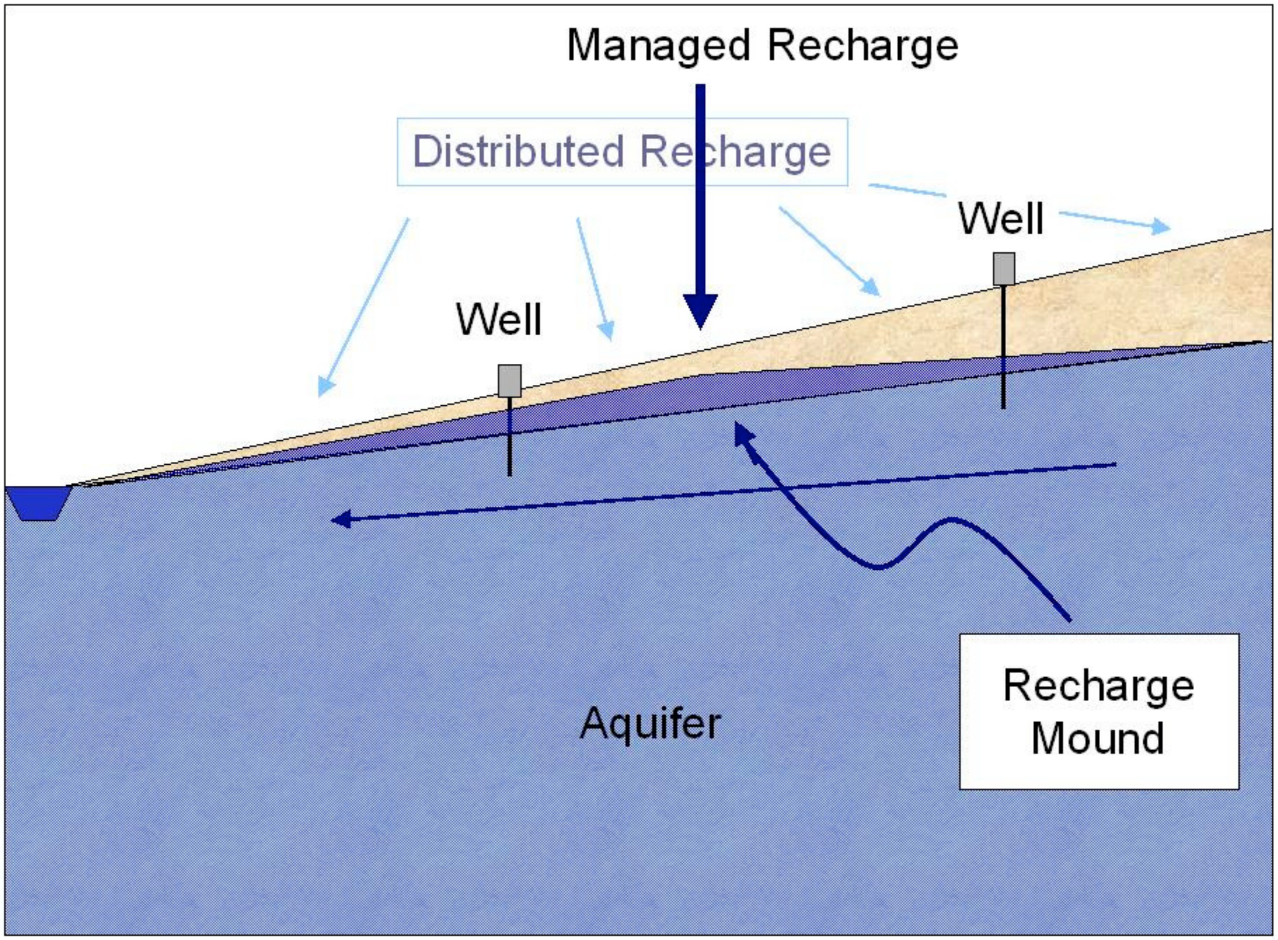

Figure 22. Alteration of water table following a managed-recharge event, benefiting both up-gradient and down-gradient locations.

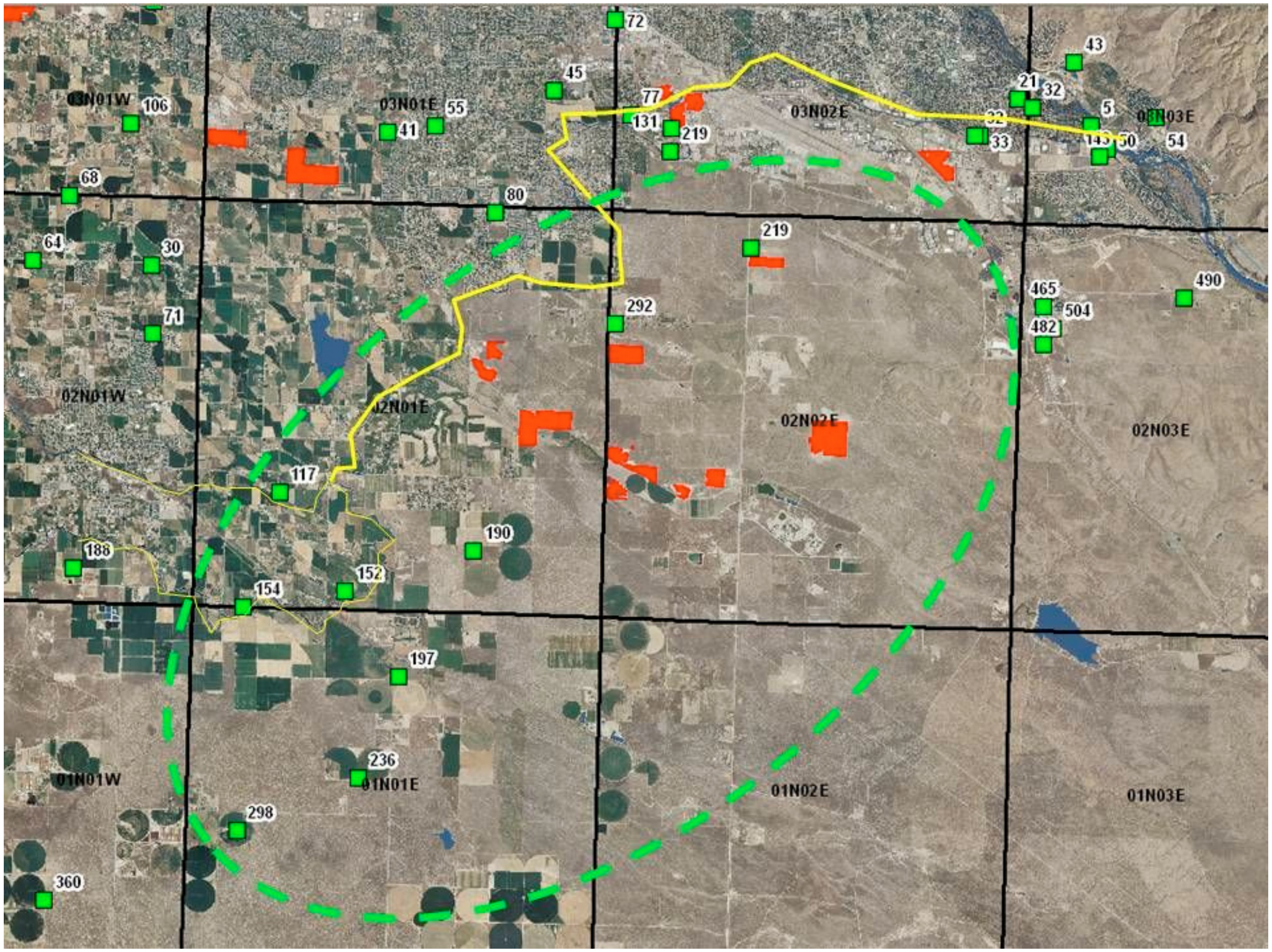

Figure 23. Preliminary map. The preliminary preferred focus area for recharge is circled in green.
Red features are gravel pits and the blue features are existing water bodies.

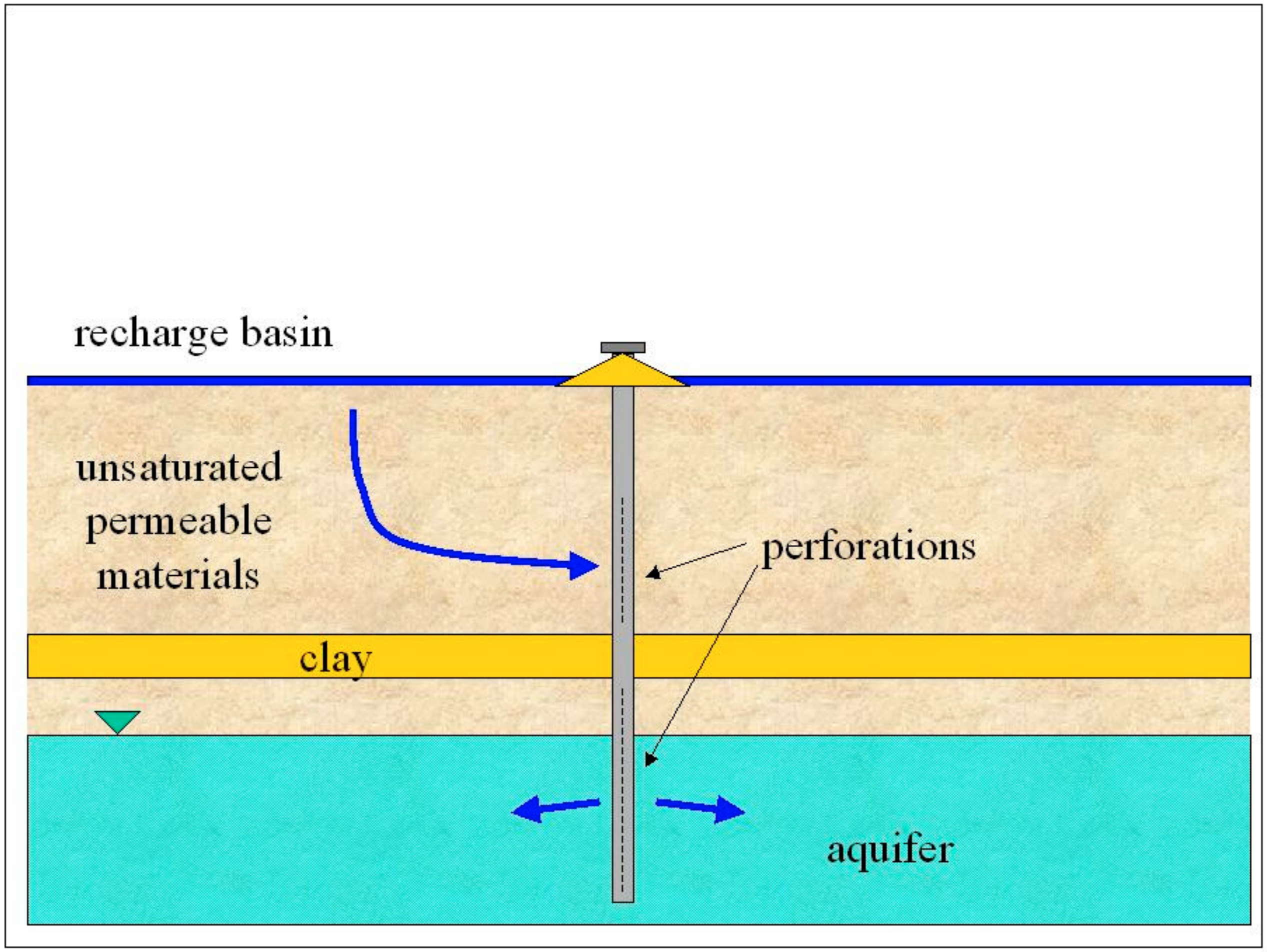

Figure 24. Potential engineering solution to impermeable materials between a recharge zone and the receiving aquifer (after Mundorff, circa 1962)

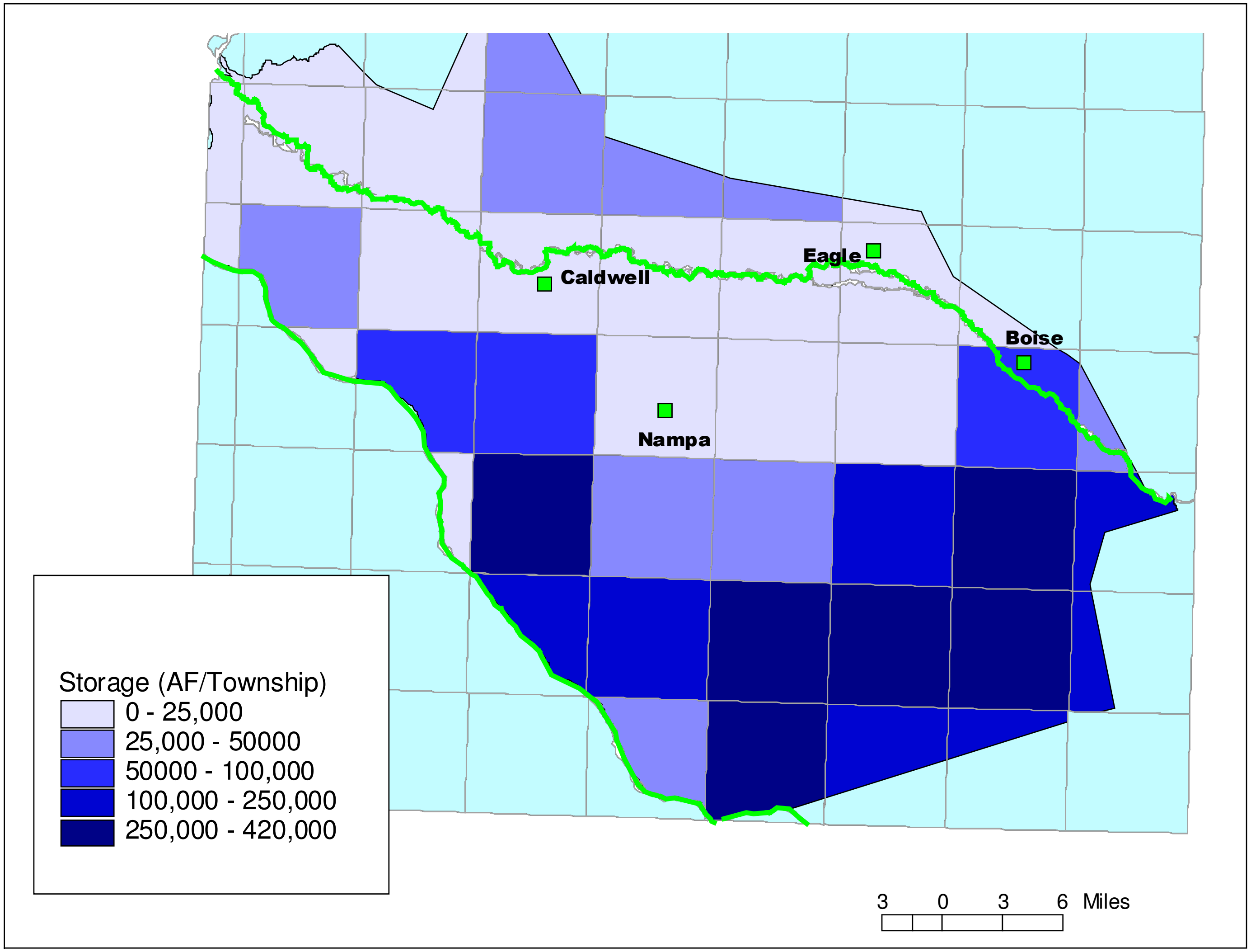

Figure 25. Potential maximum storage volume. This is the volume represented by unsaturated materials between the water table and a buffer 50 feet below land surface. A storage coefficient of 0.05 was used for this map; with a coefficient of 0.10, the capacity would be twice these values.

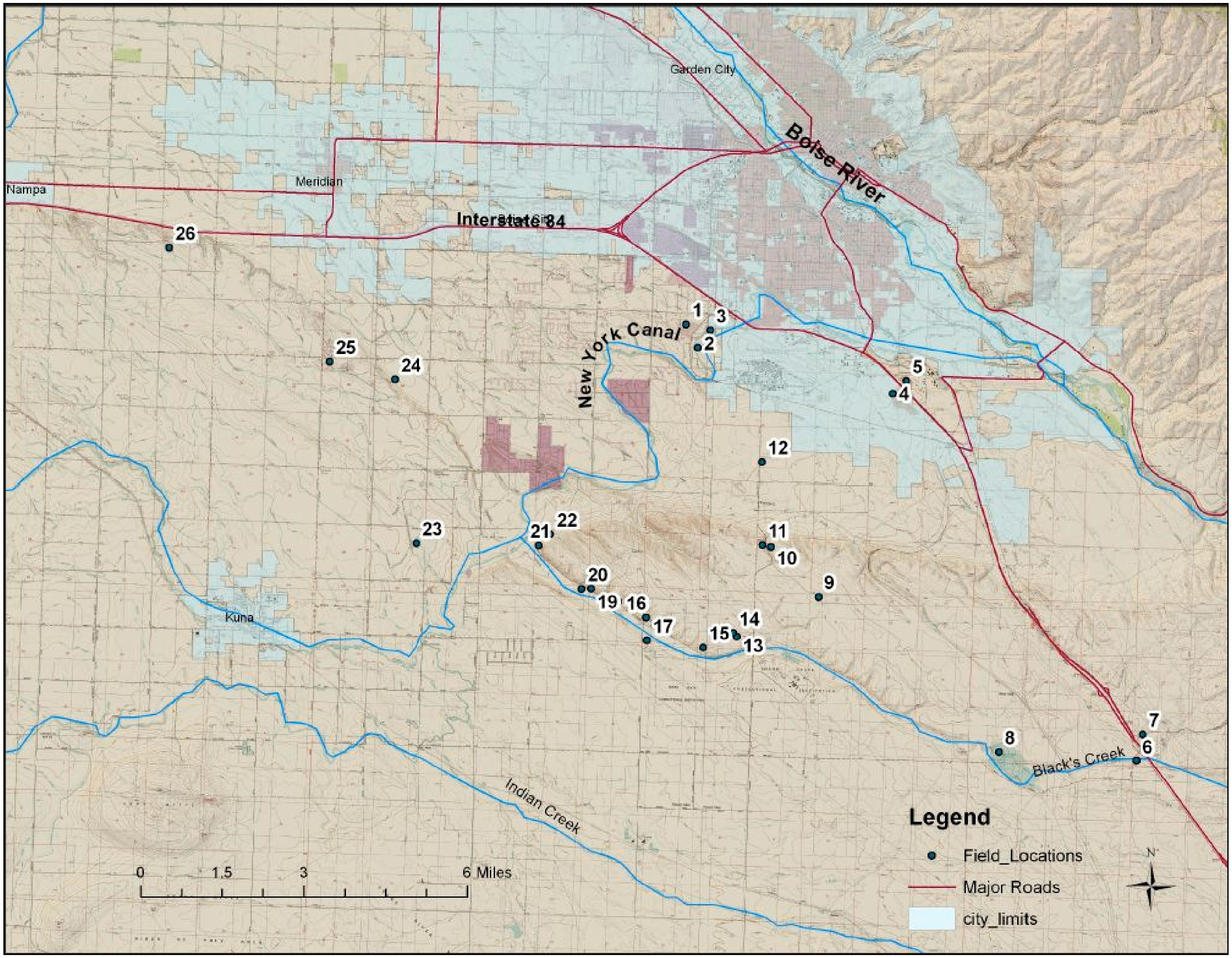

Figure 26. Sites inspected November 30, 2010.

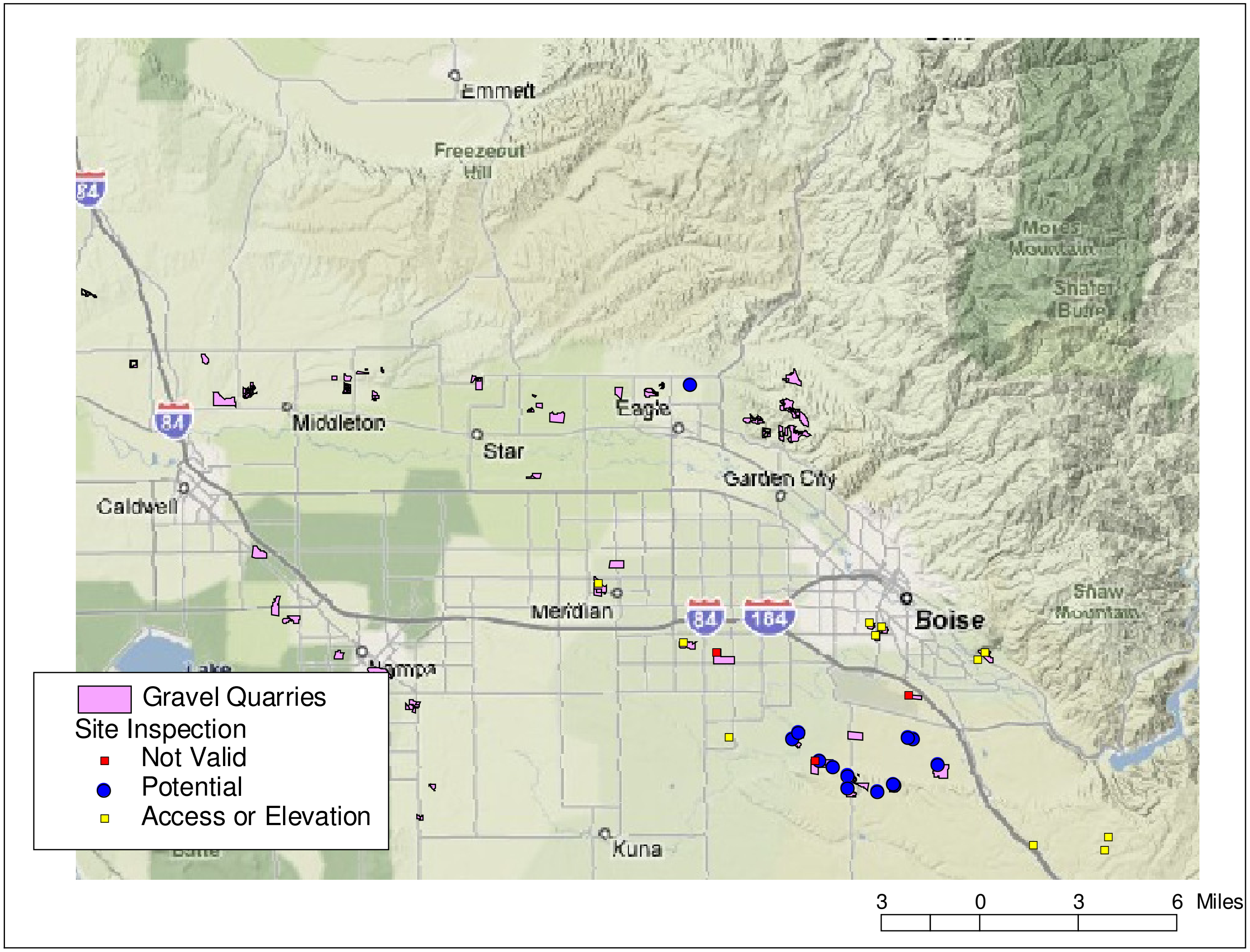

Figure 27. Summary of inspection results. "Not Valid" sites are locations where no gravel pit or potential recharge facility was found. "Potential" sites appear to be physically appropriate for recharge and are reasonably near delivery infrastructure. Sites marked "Access or Elevation" are sites where delivery of water might be difficult due to lack of infrastructure or high pumping lift. Site and facility owners have not been consulted.

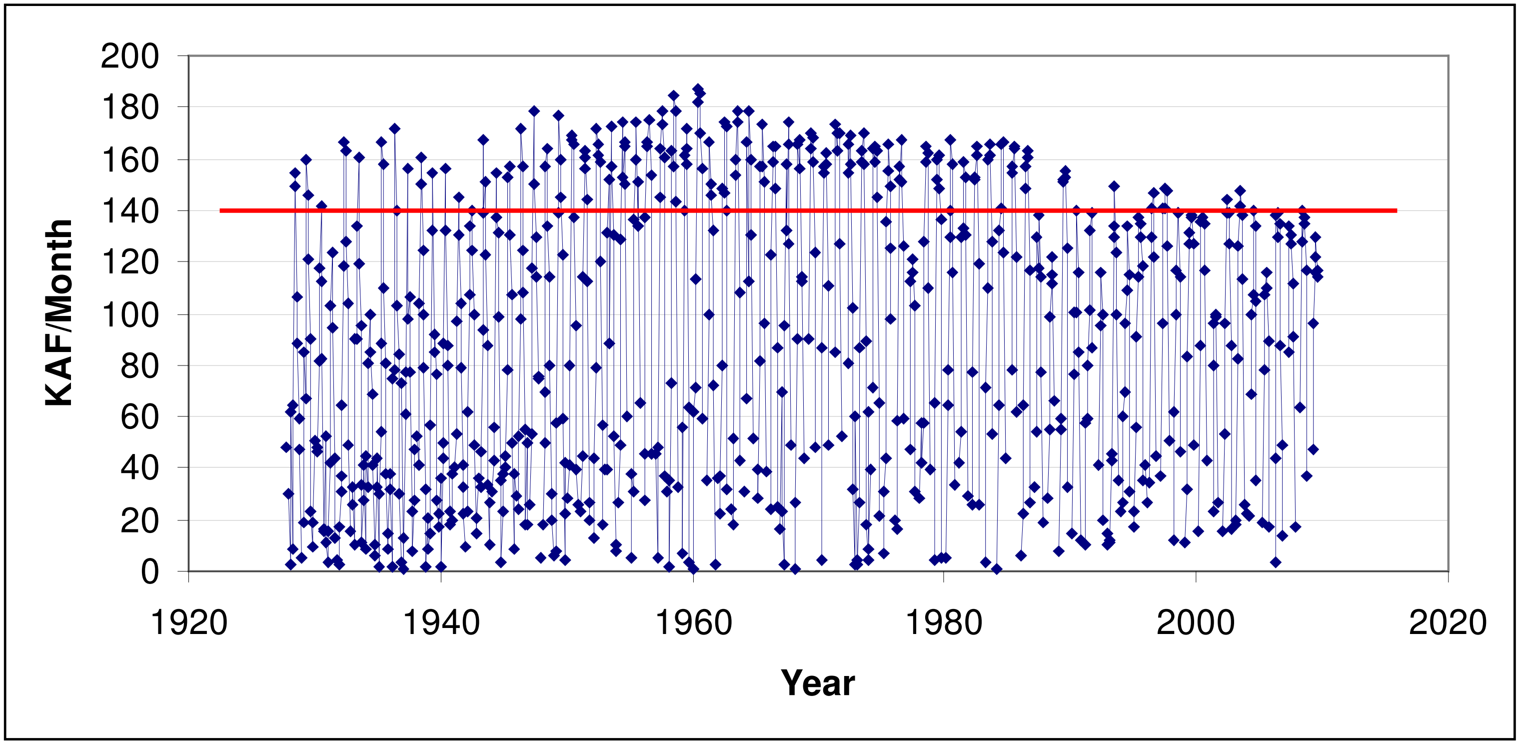

Figure 28. History of monthly diversions of the New York Canal.

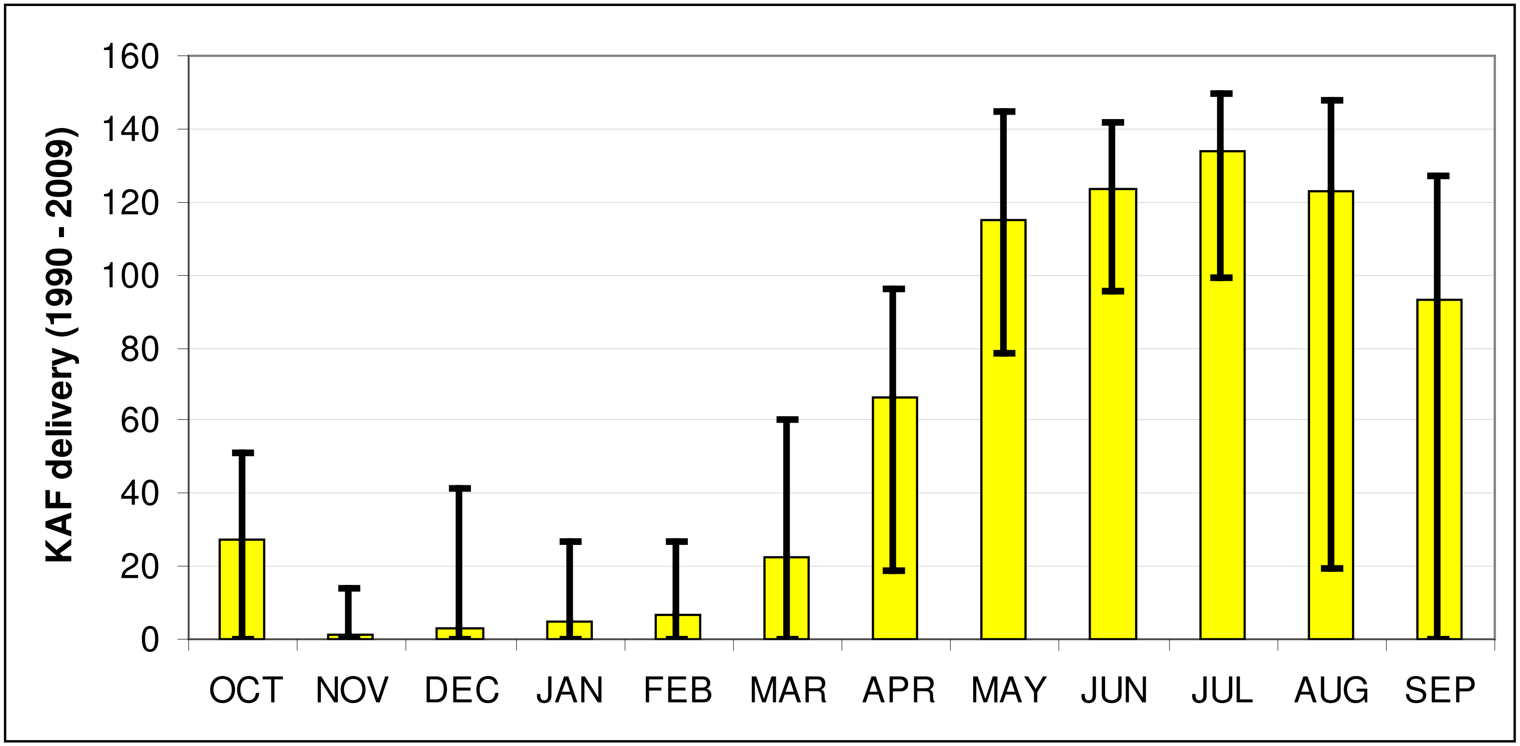

Figure 29. Monthly average, maximum and minimum diversions 1990 - 2009.

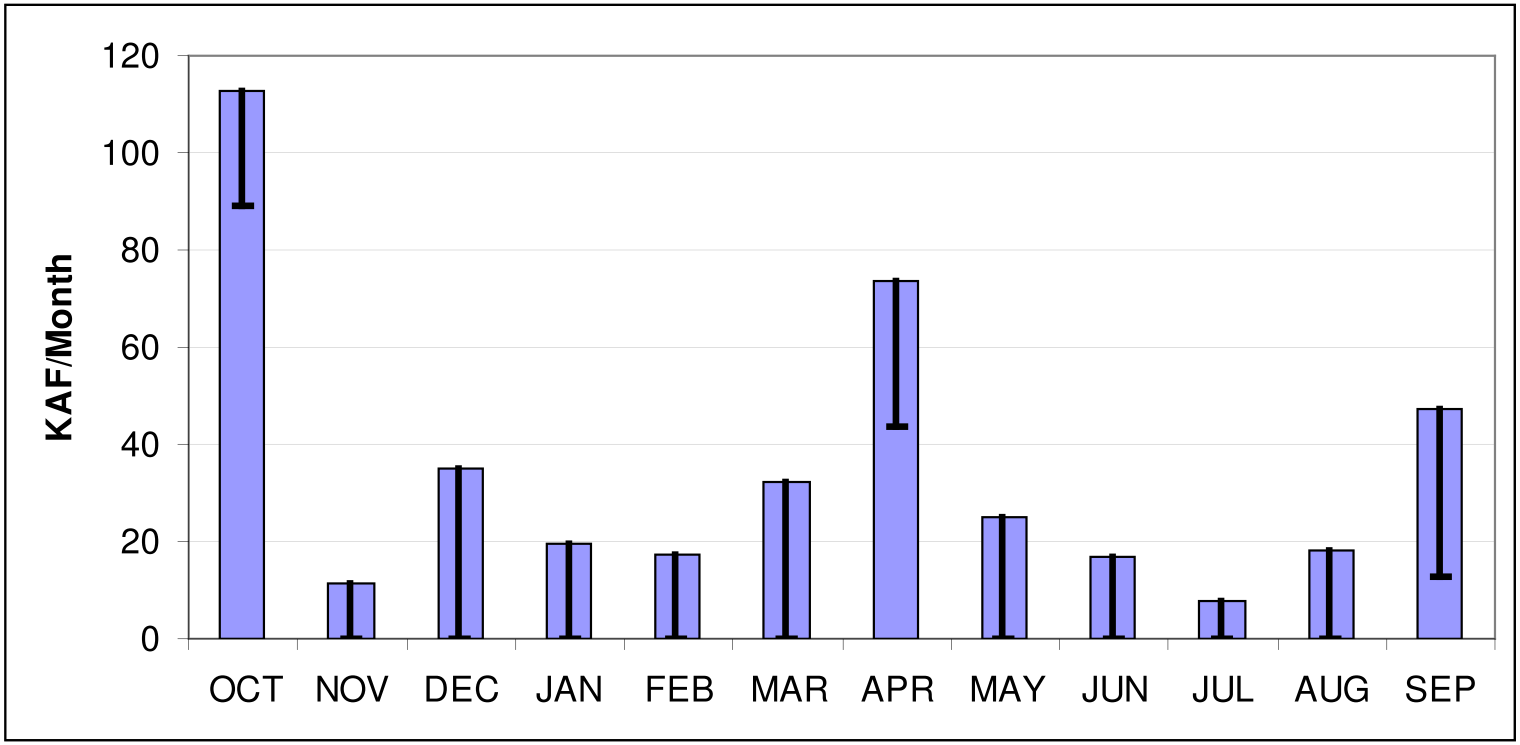

Figure 30. Average and minimum potential additional capacity above historical diversions
for the period 1990 - 2009.

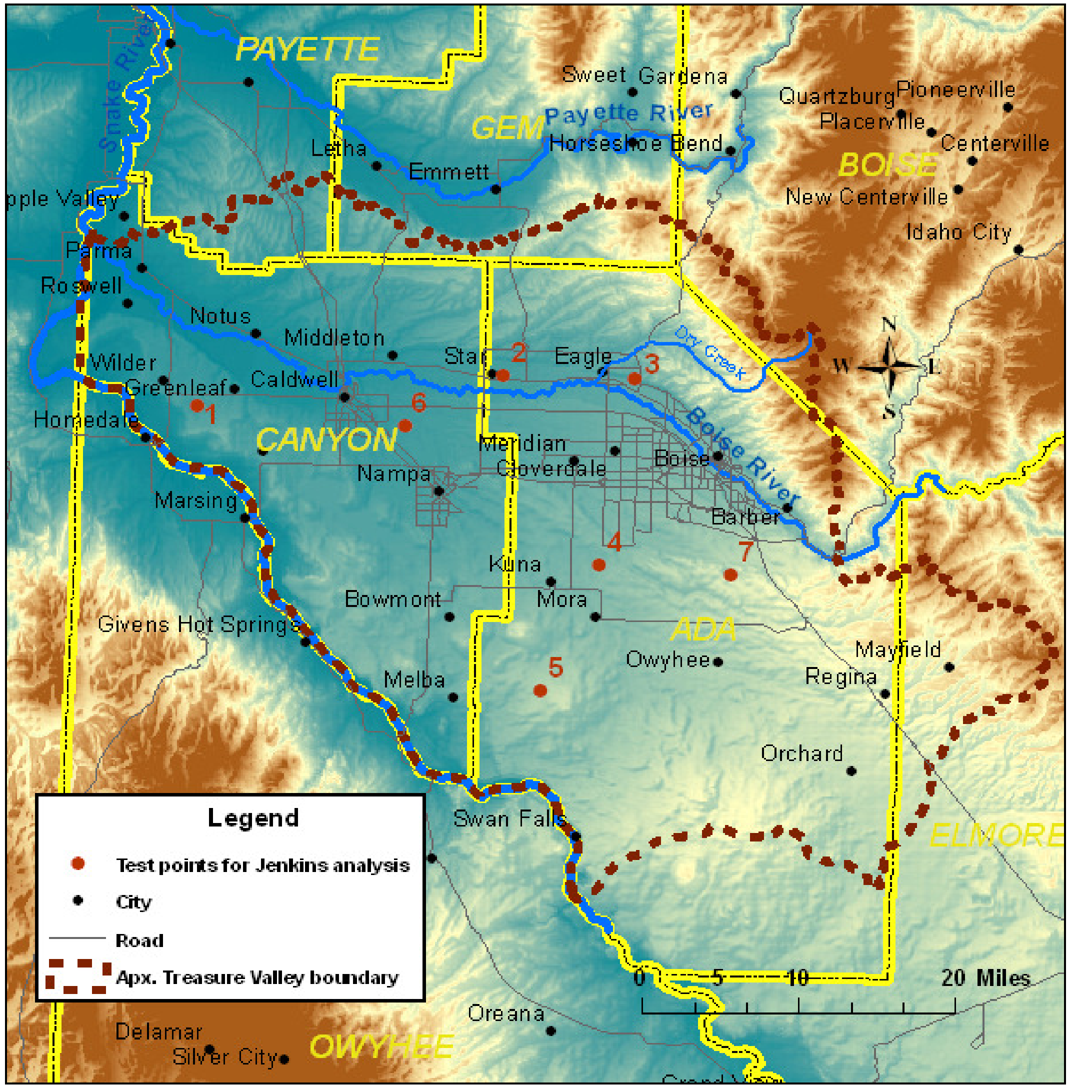

Figure 31. Locations of points for Residence calculations.

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