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HYDROGEOLOGIC ANALYSIS OF THE A AND B IRRIGATION DISTRICT AREA

Prepared for the

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INTRODUCTION

Water management on the Snake Plain Aquifer by the Idaho Department of Water Resources (IDWR) is dependent in large part on understanding the hydrogeologic characteristics of the aquifer. The purpose of this report is to analyze the hydrogeology of a segment of the aquifer north of Rupert in the south-central portion of the aquifer. The focus of the study is the North Side Pumping Division (A&B Irrigation District), which is a portion of the U.S. Bureau of Reclamation (USBR) Minidoka Project. Irrigation water is supplied to Unit A via a pump in the Snake River. Ground water is the source for irrigation for Unit B. The general location of the production wells is shown on Figure 1.

The objectives of this report are as follows: 1) develop a hydrogeologic conceptual model of in the general vicinity of the A&B Irrigation District with an emphasis on the presence of low hydraulic conductivity sedimentary strata interbedded with the basalt of the aquifer, 2) analyze the significance of hydrogeologic conceptual model with respect to the ability of the A&B Irrigation District wells to obtain water from the aquifer, and 3) evaluate the impacts on A&B Irrigation District production wells from declining ground-water levels in the aquifer. The report is based on a review of published reports, unpublished information from a range of sources and discussions with individuals with knowledge of the area (citations provided in the text). The unpublished information provided by the A&B Irrigation District in December 2007 and posted on the FTP portion of the IDWR website is a particularly important source.

OVERVIEW OF THE AREA

The general description of the Minidoka Project that is presented below was taken from the USBR website (www.usbr.gov/dataweb/html/minidoka.html) on November 14, 2007.

> "Minidoka Project lands extend discontinuously from the town of Ashton, in eastern Idaho along the Snake River, about 300 miles downstream to the town of Bliss in south-central Idaho…. The project works consist of Minidoka Dam and Powerplant and Lake Walcott, Jackson Lake Dam and Jackson Lake, American Falls Dam and Reservoir, Island Park Dam and Reservoir, Grassy Lake Dam and Grassy Lake, two diversion dams, canals, laterals, drains and some 177 water supply wells" (page 1).
>
> "Water is diverted from the north side of Lake Walcott into the North Side Canal, a gravity canal and lateral system serving 72,000 acres of land called the Gravity division, in the vicinity of Rupert, Idaho. The 8-mile main canal has an initial capacity of 1,700 cubic feet per second" (page 2).
>
> The North Side Pumping division consists of some 77,000 acres of irrigable public land that have been withdrawn from entry, of which some 62,000 acres (Unit B) are irrigated by pumping ground water from deep wells, and 15,000 acres (Unit A) by pumping from the Snake River…. Water for Unit A is pumped from the Snake River by a pumping plant located about 8 miles west of Burley. The plant capacity is 270 cubic feet per second and the dynamic head is 168 feet. The pumping plant delivers water to a 4.4-mile long unlined canal that has the

> same capacity. Seven groups of deep wells, totaling 177 wells from 12 to 24 inches in diameter, initially supplied water for Unit B. The average discharge of these wells was about 6.4 cubic feet per second. Currently, 174 wells are being used" (page 4).

A general description of the ground-water supply for the North Side Pumping Division is presented in the Planning Report and Draft Environmental Statement for the North Side Pumping Division Extension (U.S. Bureau of Reclamation, 1986, pages 6-12 to 6-14).

> "The Snake Plain aquifer lies beneath the project area and is one of the largest and most prolific aquifers in the Nation….In the North Side Pumping Division area, the Snake Plain aquifer consists of a thick series of basalt flows in the northern part of the project area (mainly Unit B) and basalt flows interbedded with large amounts of fine-grained lake sediments in the southern part. Deep well water yields range from a high of several thousand gallons per minute in the predominantly basalt aquifer to the north to lows of a few hundred gallons per minute in the less permeable sediment-basalt aquifer to the south. One such area is near Extension Area 4 where several low yields wells are found.
>
> The Geological Survey estimates total storage in the aquifer to be about 250 million acre-feet….In an average year, about 8 million acre-feet of water enter and leave the Snake Plain aquifer. Inflow to the system includes about 3 million acre-feet of natural recharge (precipitation and stream losses) and approximately 5 million acre-feet from irrigation seepage. Outflow or depletion is made up of spring discharge from the aquifer of about 6.6 million acre-feet and pumping depletion of about 1.4 million acre-feet annually. Annual discharge by pumping from the aquifer presently does not begin to approach annual recharge.
>
> Changes in recharge and withdrawal rates within the Snake Plain aquifer affect water levels beneath the North Side Pumping Division. The three major influences which cause water levels to change in the aquifer are (1) climatic trends, (2) irrigation diversions, and (3) ground-water pumping.
>
> The most significant influence which affects the water table is long-term climatic change – prolonged wet or dry cycles…. The second major influence on water table levels is changes in the quantity of irrigation diversions onto the plain…. Beginning in 1961, large quantities of water previously diverted each winter for domestic use and stock watering were greatly reduced or stopped. The reduction in diversions in canals below American Falls during winter amounted to over 100,000 acre-feet annually, most of which would have recharged the aquifer.
>
> The third major influence on aquifer water table levels is withdrawals of ground water for irrigation. Use of ground water from the Snake Plain aquifer has reached major proportions. Based on 1979 estimates, total ground-water pumpage from the aquifer is about 2.3 million acre-feet annually. With about 40 percent of this pumpage percolating downward and returning to the aquifer, net pumpage is estimated to be about 1.4 million acre-feet per year.

Ground-water pumping is the major aquifer discharge in the North Side Pumping Division area, with over 200,000 acre-feet pumped each year with Unit B of the division. A total of 177 deep wells serve the 62,000 acres irrigated within Unit B. Additional ground-water pumping of an estimated 400,000 acre-feet occurs in the general area adjacent to the division….

Snake Plain aquifer ground-water levels generally peaked in the mid-1950's as a result of a moderately wet sequence of years and maximum amounts of surface-water irrigation diversions onto the Snake River Plain which caused abundant ground-water recharge. Ground-water levels then declined during a period of dry years and increased ground-water pumping. Water levels reached new lows in the mid-1960's.

Levels then rose for about a decade because of above average precipitation. A second general ground-water decline began in the mid-1970's because of significant reductions in surface-water diversions onto the Snake river Plain. The water level decline accelerated because of a series of dry years, and water levels reached record lows in 1982. Increased precipitation beginning in late 1981 has stabilized water levels, and some recovery has occurred. In general, the recovery of ground-water levels has continued through 1985.

Studies show that this pattern of Snake Plain aquifer water level behavior occurred both in areas with major amounts of ground-water pumping and in areas with no pumping. Although large quantities of ground water are pumped from the aquifer, they are relatively minor when compared to total aquifer discharge and recharge quantities….

There has been an estimated net 10- to 15-foot decline in the water table elevation beneath the North Side Pumping Division since the project was constructed. These amounts of ground-water level decline have been of some concern to the local area. They are very minor, however, when compared to many other aquifers used for irrigation, including local aquifers south of the Snake River and in other areas of the Northwest where water level declines have in some cases far exceeded 100 feet.

At this time, the Snake Plain aquifer shows only minor evidence of stress in response to major ground-water withdrawals. There are areas of minor decline (such as beneath the North Side Pumping Division) which in part can be attributed to ground-water pumpage. The reduction in total discharge at Thousand Springs may also in part be attributed to ground-water pumping. However, there are no significant changes in the aquifer which would indicate that the system is being overtaxed."

HYDROGEOLOGIC SETTING

<u>Regional Geologic Setting</u>

The A&B Irrigation District is located in a transition zone where the subsurface consists of mostly basalt to the north and northwest and mostly sediment to the south and southeast. Figure 2a is a geologic map of the area taken from Whitehead (1992). Geologic units shown on the map are described in Figures 2b and 2c. The basalt shown north of the A&B Irrigation District well field is identified as Quaternary basalt (Qb or Qtb). Sediments in the area are mapped as wind blown deposits (Qw) and older alluvium (Qts). The general relationship between basalt and sediment is shown on two figures taken from Whitehead (1992). Figure 3 shows the thickness of Quaternary basalt whereas Figure 4 shows the thickness of sedimentary rocks. The two figures show the transition from a basalt-dominated subsurface in the center of the Snake Plain to a sedimentary-dominated subsurface south of the A&B Irrigation District well field.

Local Geologic Setting

Sterns and others (1938), Nace (1948) and Crosthwaite and Scott (1956) describe the subsurface geology of the general Minidoka Project area. The dominant units are Quaternary basalt and sedimentary units. Nace (1948, p. 13) provides the following description of the sequence of geologic events in the creation of the subsurface sequence.

> "Early in the sequence of events the Sand Springs basalt was extruded from sources between Kiamam and Hazelton … spreading westward and southwestward, spilling into the old Snake River Canyon and partially filling it from the northwest part of T7S R13E for a distance of about 50 miles upstream, to the area south of Hazelton and Eden. Filling of the river channel effectively dammed the Snake River and the impounded waters spread widely over what is now called the Minidoka Project in Cassia and Minidoka Counties. In the Sterns report this body of water is called Lake Burley, and in it the Burley lake beds accumulated to a maximum thickness of 90 to 150 feet. The areal distribution of these beds approximately coincides with the area of the Minidoka Project in Cassia and Minidoka Counties. At the boundaries of the lake the shore phases of the accumulating sediments overlapped or abutted on the surrounding lavas and other rocks. Northward and westward from Burley, Rupert, and Acequia, the Burley lake beds thin and disappear against the basaltic rock masses of the unknown thickness. Probably the older sediments beneath the Burley lake beds behave similarly. The lake remnant was then drained as the Snake River entrenched a new outlet through the basalt barrier on the west. As this entrenchment progressed upstream through the lake beds, the lake floor remained as a slightly elevated terrace adjacent to the river. Quaternary alluvium, loess, and residual soil were deposited as a mantle over the Burley lake beds and surrounding lava flows."

Crosthwaite and Scott (1956, pages 7 and 9) describe the Burley lake beds and Snake River Basalt as follows.

> "The ancient lake in which the Burley lake beds were deposited covered the area of the Gravity Division but apparently did not extend into the Pumping Division. … The Burley lake beds … .consist of about 450 feet of compacted to unconsolidated clay and silt, and small amounts of sand and fine gravel. Several basalt layers are intercalated in the lake beds 150 to 225 feet below the land surface and at the base of the formation. The sand, gravel and basalt are permeable and yield moderate amounts of ground water to domestic, municipal and industrial wells. The clay and silt beds are very low in permeability and are the base on which shallow ground water is perched in overlying alluvium. At

depth these impermeable beds confine artesian water in associated permeable sediments. ”

“The Snake River basalt underlies all of the Minidoka area and most of the Snake River Plain. At most places in the area of proposed ground-water development the basalt is overlain by 2 to 50 feet or more of windblown deposits, but small outcrops are common…. In Minidoka County and most other parts of the Snake River Plain the Snake River basalt is the principal water-bearing formation, and it yields water copiously to wells. Intertongued sedimentary beds are saturated below the water table but yield little or no water to wells…. The Snake River basalt consists of many individual flow sheets, 10 to 75 feet thick, which originated at numerous volcanic vents scattered over the Snake River Plain…. A few sedimentary beds are intercalated in the basalt. The total thickness of the basalt is not known. In southern Minidoka County wells 500 deep end in basalt.”

The U.S. Bureau of Reclamation (1985a, page 19) describes the hydrogeology of the area as follows.

“The aquifer, as previously discussed, is made up of sediment and basalt….The basalt is made up of a series of thin flow sheets, from a few feet to several tens of feet thick. Where the flow sheets are deposited one upon another to form a relatively thick sequence, and where the basalt is highly fractured and/or contains numerous rubble or cinder zones, the water yield is large, up to several thousand gallons per minute. Where the flow sheets are made up of dense, and massive basalt and/or is covered, penetrated, or innerbedded with fine sediment, the water yield is small to moderate. One such area is in the southwest part of Unit B located mostly in T9S/R22E where several low yielding wells are found. Here the aquifer is comprises of basalt innerbedded with substantial amounts of fine sediment. Some of the basalt in the upper part of the aquifer also contains fine sediment that reduces the permeability. The deeper basalt is relatively free of sediment, but must be thick, massive, and dense with a low permeability because water yield remains low despite more than 100 feet of exposed basalt aquifer in some wells.”

Analysis of Well Logs

Records are available for a large number of wells in the general vicinity of the A&B Irrigation District. The two primary sources were used for analyze information on area wells: 1) the website for the IDWR and 2) the FTP posting of A&B Irrigation District information on the website of the IDWR. Idaho well driller reports on the IDWR website are filed by legal description (township, range and section) and include geologic information, well completion information and in some cases well yield information. The IDWR website also includes records of wells provide by the USBR. Information on these wells is similar to that provided on Idaho well driller reports except that well completion information (casing and screened intervals) is often missing but surveyed well information is often available. A legal description is provided in addition to a well number created for project wells. For example, project well 20A922 is located in section 20 of township 9 south and range 22 east. The focus of the well log analysis was on wells constructed as part of the Northside Pumping Division of the Minidoka Project.

The geologic descriptions for the project wells (identified as USBR or A&B Irrigation District) often are more detailed than for the private wells.

Hydrogeologic information on the project wells is summarized in Tables 1 and 2. The table is a compilation of information from the IDWR well log files and the A&B Irrigation District files available on the FTP portion of the IDWR website. An attempt was made to eliminate duplications in listing of project wells. This task was difficult because multiple logs are available for the wells that have been cleaned out or deepened. In some cases, information is given for deepening of a well for which the original log could not be found.

Explanations of the columns on Table 1 are given below.

- The well location is given in terms of township, range and section number. The location within the section is given as quarter section and then quarter-quarter section with the notation of A, B, C and D for the northeast, northwest, southwest and southeast quarters. Thus, well 7S 23E 34DC is located in the southwest quarter of the southeast quarter of section 34 in township 7 south and range 23 east.
- The owner is listed either as the U.S. Bureau of Reclamation (USBR) or the A&B Irrigation District (A&B).
- The next columns provide information on the well depth, land surface elevation and static depth to water at the time the well was drilled. Blanks in the table show that specific information either was not on the log or in some cases was not readable. A number of the wells have been deepened since they were originally drilled. The depth given in Table 1 is the greatest depth based on the source documents. Surveyed land surface elevations are given to tenths or hundredths of a foot on the individual USBR logs. Comparison of the 1950's surveyed elevations with topographic maps and an A&B Irrigation District summary table from the FTP site revealed an approximate 50-foot datum correction was needed. All of the surveyed elevations from the USBR logs were corrected by subtracting 50 feet. Approximate elevations (rounded to nearest foot) were given for a few wells. No elevation information is available for some of the wells.
- The geologic information of most significance is the presence of fine-grained sedimentary interbeds within the Quaternary basalt below the water table. Sedimentary interbeds were so classified if descriptive terms such as clay or clay and sand were provided on the logs. Professional judgment was used to differentiate between weathering along a basalt flow contact zone (sometimes noted as yellow clay and basalt) and the presence of unconsolidated sediments deposited between basalt placement events. Logically, the aquifer is less productive in those areas where fine-grained sediments make up much of the saturated thickness as compared to areas where the interval below the water table almost all Quaternary basalt. The geologic information on Table 1 is presented in terms of the depth intervals of identified sedimentary interbeds penetrated by the well below the water table at the time of well construction. Wells for which no geologic information is given (such as well 7S 23E 34CD) penetrated only basalt below the water level. Some of the wells in the southern portion of the project

area have as many as four sedimentary interbeds identified below the water table at the time of drilling.

Table 2 presents information on the sedimentary interbeds in terms of elevation above sea level rather than depth below land surface. Interbed elevation data are presented only for those wells where land-surface elevation data are available and sedimentary interbeds were penetrated below the water level. Information presented in Table 2 allows analysis of the lateral continuity of sedimentary interbeds within the saturated subsurface. The elevations of the bottom of wells are also given in Table 2. Many of the wells do not penetrate interbeds identified using information from deeper wells.

Information from Tables 1 and 2 can be used to document the presence or absence of sedimentary interbeds within the sequence of basalt flows penetrated by the project wells. The following is a description of the subsurface geology in various portions of the project area based on an analysis of data on Tables 1 and 2.

- Neither of the two project wells in section 34 of T7S R23E penetrate sedimentary interbeds to a bottom-hole elevation of about 3,965 feet.
- A number of project wells located in sections 30 to 33 of T7S R24E penetrate a clay interbed that is 6 to 12-feet thick generally in the elevation intervals of 3930 to 3,950 feet in sections 30 and 31 and between 3,970and 4,020 feet in sections 32 and 33. A well in section 32 penetrates about 80 feet into the basalt that underlies the interbed.
- A well in section 27 of T7S R25E penetrates a 28-foot sedimentary interbed in the depth range of 4,055 to 4,083 feet.
- The remaining wells in T7S R24E and T7S R25E do not penetrate an identified sedimentary interbed to the depths drilled.
- One of the six project wells constructed in T8S R21E penetrates a sedimentary interbed greater than six feet in thickness. The bottom 13 feet of a 420-foot well in section 24 was identified as clay (elevation interval of 3,779 to 3,792 feet). No other project wells are in this section. A 587-foot well in section 26 did not penetrate sediments in the same depth interval.
- The majority of the wells in the northern half of T8S R23E do not penetrate a sedimentary interbed to the drilled depths. The bottom elevation of the deepest well is about 3,960 feet.
- Wells in section 23, 24 and 25 of T8S R23E intercept thin (less than 10 feet thick) sedimentary interbed, mostly in the depth range of about 3,990 to 4,020 feet. The deepest well in section 24 penetrates about 77 feet of basalt below the sedimentary interbed.
- Two wells (one in section 27 and one in section 28 of T8S R23E) penetrate a slightly thicker (about 20 feet) interbed in the elevation range of 3,940 to 3,960 feet). The deeper of the two wells penetrates basalt to a depth of about 70 feet below the bottom of the interbed.

- One well in section 34 and four wells in section 35 ofT8S R23E penetrate an interbed. The variation in the thickness (4 to 27 feet) and elevation (4,034 to 4,069 feet) of the unit make it questionable whether there is a single sedimentary layer or several laterally discontinuous layers. One of the wells in section 35 penetrated about 80 feet of basalt below the potential interbed.

- Most of the wells in the northern half of T8S R24E do not penetrate a sedimentary interbed to the drilled depths.

- Two wells in section 20 ofT8S R24E penetrate multiple sedimentary layers below an elevation of about 3,990 feet. About 60 percent of the drilled section below this elevation is composed of sediment with basalt making up the remainder. Two wells are of similar depth are present in section 21 of T8S R24E. One well has two interbeds approximately in the same elevation range as the section 20 wells. The geologic log for the second section 21 well does not show the presence of sedimentary interbeds.

- The project well in section 33 of T8S R24E penetrates a seven-foot thick interbed in the elevation range of 3,966 to 3,973 feet. The well was drilled about five feet into basalt below the interbed.

- Three of the four project wells in section 3 of T8S R25E penetrate two sedimentary interbeds. The higher interbed ranges in thickness from 5 to 8 feet and in elevation from 4,012 to 4,040 feet. The lower interbed ranges in thickness from 3 to 8 feet and in elevation from 3,954 to 3,973 feet. The deepest of the wells penetrates about 40 feet of basalt below the interbed.

- The only two of the remaining project wells in T8S R25E penetrate sedimentary interbeds below the water table. Both of these zones are thin.

- Deeper wells have been drilled in the southwestern portion of the A&B Irrigation District area (T9S R21E). A 700-foot well in section 3 penetrates two sedimentary interbeds below the water table (depth ranges of 447 to 460 feet and 435 to 545 feet – elevation ranges of 3,738 to 3,751 feet and 3,653 to 3,633 feet). About 155 feet of basalt was penetrated below the lower interbed. A 587-foot deep well in section 1 penetrates sediments in the elevation intervals of 3,693 to 3,698 feet and 3,653 to 3,678 feet.

- Wells in sections 9 and 10 of T9S R22E penetrate multiple sedimentary interbeds. About 50 percent of the saturated thickness (water level elevation minus the bottom hole elevation) is composed of sediment in a well in section 9. About 38 percent of the saturated thickness of a well in section 10 is composed of sediment. The depths of these two wells are 415 and 429 feet.

- The 494-foot well in section 11 of T9S R22E penetrated a single interbed about 180 feet thick at the bottom of the well in the elevation range of 3,668 to 3,847 feet. The geologic log shows blue clay for the entire thickness.

- The 700-foot well in section 20 of T9S R22E penetrates a 54-foot thick interbed in the elevation range of 3,783 to 3,837 feet with sand underlain by clay. Thin sedimentary interbeds (<15 feet) were also penetrated both higher and lower in the well.

- A 1,000-foot well in section 22 of T9S R22E penetrates a 199-foot thick interbed in the elevation range of 3,703 to 3,902 feet and a 55-foot interbed in the elevation range of 3,521 to 3,576 feet with several additional thin sedimentary units.
- Several wells in section 33 of T9S R22E show sediments in the general elevation interval of about 3,870 to 3,920 feet.
- A 340-foot well in section 3 of T9S R23E penetrated three interbeds greater than 20-feet thick (elevation ranges of 3,974 to 4,002 feet, 3875 to 3897 feet and 3,843 to 3865 feet). About 45 percent of the geologic section between the elevations of 3,843 to 4,002 feet is composed of sediment.
- The 646-foot well in section 2 of T10S R21E has only two thin sedimentary interbeds in the geologic section below the water table (elevation ranges of 3,928 to 3,940 feet and 3,591 to 3,597 feet). The remainder of the material penetrated is basalt.

The geologic data from wells supports the general geologic description presented by Crosthwaite and Scott (1956). The percentage of sedimentary interbeds in the subsurface below the water table increases to the south with thicker and more laterally extensive clay units. The number and thickness of clay units interbedded with the basalt below the water table in the northern portion of the project area are small.

Aquifer Characteristics

The Quaternary basalt near the center of the Snake Plain generally is considered to host a single, unconfined aquifer. Water producing zones within the Quaternary basalt occur at flow contacts which are present at depth intervals of about 15 to 20 feet. The average hydraulic conductivity of the basalt is extremely high. The inter-fingering of Quaternary basalt flows with fine-grained sedimentary in the general vicinity of the A&B Irrigation District creates a subsurface environment composed of multiple aquifers and confining units (aquitards).

The A&B Irrigation District is located the south-central portion of the Snake River Plain aquifer. Contours of Fall 2001 water-level elevation data from Cosgrove and others (2006) for this portion of the aquifer are shown on Figure 5. There is a considerable distance between the 4,050 and 4,100-foot contours on the map in the general vicinity of the A&B Irrigation District, indicating a low hydraulic gradient. Also, the 4,100-foot contour appears to follow along the Snake River in the vicinity of below and midway through Lake Walcott.

Cosgrove and others (2006, pages 14 and 16) describe the general water budget for the Snake Plain aquifer and the corresponding temporal changes in ground-water levels and aquifer discharge.

> "The Snake River Plain aquifer is recharged by irrigation percolation; canal stream and river losses; subsurface flow from tributary valleys; and precipitation directly on the plain. The aquifer discharges to the Snake River, springs along the

> Snake River and to ground-water pumping, primarily for irrigation…Historically, aquifer water levels and corresponding discharges to the Snake River rose significantly at the onset of surface water irrigation… Aquifer water levels peaked around 1950 and have been declining since that time. The declines are attributed to the onset of ground-water irrigation, more efficient surface water irrigation practices such as conversion to sprinkler irrigation and canal lining, and the recent seven years of drought."

Water-level data are available from observation wells operated by the U.S. Geological Survey located across the Snake Plain aquifer. Figure 6 shows the locations of three observation wells located near the A&B Irrigation District. The hydrographs for the three observation wells, presented in Figures 7, 8 and 9, show an overall downward water-level trend with highs and lows reflecting changing climatic conditions. The long-term rate of water-level decline is about 0.5 to 0.6 feet per year.

DESCRIPTION OF PROJECT PRODUCTION WELLS

Production Well Information

The majority of the project production wells were constructed by the USBR in the 1950's with some wells deepened and a few additional wells drilled later with ownership noted as the A&B Irrigation District. The U.S. Bureau of Reclamation (1985, page 28) describes the construction of the wells as follows.

> "Since construction of the pumping division in the 1950's, well construction methods have changed, especially construction specifications written by Reclamation planners. The original 177 project production wells were drilled by drilling contractors using cable drills, and were completed using the usual completion methods at that time. Drilling was continued below the water table until the drill cuttings were "lost", which was apparently an indication of good yield. Construction completion usually consisted of installing surface casing with the balance of the well left "open hole". When caving conditions were encountered during the drilling, a casing liner was installed, generally just through the caving interval. The liner would be perforated when the caving interval was located within the "good" aquifer section of the well. After the well was completed, a pump test was run to determine the yield. If the yield was insufficient, the well would be deepened in hopes of encountering additional water.
>
> These methods were workable, but generally did not allow for much lowering of the pump if the water level declined. The project was begun about the water level peak period and was completed during a water level decline period. More than one-half of the wells had less than 100 feet of saturated well bore; therefore, as the water levels declined, drawdown increased, the thickness of the saturated well bore thinned, and yield decreased. Deepening of many of the wells was undertaken before the project was completed. About one-half of the wells have been deepened to date (1984) and about one-half of the wells still have less than 100 feet of exposed aquifer" (page 28).

The same report provides guidance with respect to how new project wells should be drilled.

> "Well construction should consist of drilling a hole of adequate diameter to the minimal total depth. The total depth can vary somewhat depending upon where the drill site is selected in each tract. The total depth is determined by selecting a depth where the pump can be placed allowing the pumped water level to remain at least 5 feet above the pump bowls after subtracting out drawdown from pumping and natural fluctuations of the water table. Below the pump intake, a pump chamber is drilled about 50 feet into the aquifer. The pump chamber is essentially that portion of the well where the pump is placed and must be deep enough to allow room to lower the pump in case of persistent water level declines…. The portion of the well deeper than 50 feet below the pump intake may be reduced in diameter. The reduction should decrease drilling costs and will not materially reduce the intake potential… Casing must be placed in the upper portions of the well to seal out caving zones in the sediment and prevent aquifer pollution form surface waters. The balance of the well can be left open hole, however, for maximum pump protection, casing should be installed throughout the pump chamber" (U.S. Bureau of Reclamation, 1985, page 32).

Information on the A&B Irrigation District production wells is presented in Table 3. The table was taken from FTP files located on the IDWR website. The columns on Table 3 are described below.

- The first two columns provide the USBR well identification number and the township range number as described previously.
- The well diameter at the deepest point in the third column is assumed to represent casing diameter if casing is present or open-hole diameter is no casing is present.
- The third through sixth columns present information on well productivity at the time of construction. The yield rate in cfs (cubic feet per second) is presented along with drawdown (assumed to be at the end of the test). The specific capacity is the pumping rate divided by drawdown with the units of gpm/ft.
- The seventh column provides ground elevation corrected from the original USBR elevations by 49.7 feet.
- The eighth and ninth columns provide the depth to water at the time of drilling and the ground-water elevation at the time of drilled using the corrected land-surface elevation.
- The tenth and eleventh columns provide the initial well depth and the date the well was drilled.
- The twelfth through seventieth columns present information on depths and years individual wells were deepened. Some of the wells have not been deepened while other wells have been deepened as many as three times.
- The eighteenth column provides the most recent well depth.
- The nineteenth column provides to depth to the top of the pump bowl in 1964.

- The twentieth and twenty-first columns present lowest water-level in 2007 and depth to top of pump bowl in 2007. The lowest water-level is represents pumping conditions for most wells.

- The remaining columns provide information on well history including identification of those wells that have been deepened or replaced.

Information presented in Table 3 is reasonably complete for 178 wells. Limited data are presented for nine additional wells. The analysis presented in this section is limited to the 178 wells for which data are reasonably complete. Summary statistics relative to the production wells when they were first drilled are presented below.

- The production wells are, in general, highly productive. The pumped yields during the tests ranged from 1.5 to 10.5 cfs with an average yield of 5.4 cfs (about 2,400 gpm). The reported specific capacity (discharge divided by drawdown) values ranged from 42 gpm/ft to 20,445 gpm/ft with an average of 1,912 gpm/ft.

- The high yields were achieved with only a small portion of the aquifer penetrated by most of the wells. The difference between the bottom of the well and the depth to water is the saturated thickness of the aquifer penetrated by each well. The saturated thickness values range from 27 feet to 403 feet with an average saturated thickness of 91 feet and a median saturated thickness of 72 feet. These numbers include those wells that have been deepened.

- One hundred and nine of the 178 production wells have been deepened at least one time since they were initially constructed. The average depth increase was 58 feet with 12 wells greater than 100 feet and 2 wells greater than 200 feet. Twenty-two wells were deepened a second time with three wells deepened a third time.

- The difference between the lowest water level in 2007 and the top of the pump bowl provide a measure of the available drawdown for each well. This value ranges from 55.1 feet to minus 6.6 feet. Sixteen of the 131 wells for which data are available had pumping water levels below the top of the pump bowls. An additional 36 wells had pumping water levels within 10 feet of the top of the pump bowls.

<u>Water Production Characteristics</u>

Information on the quantity of water pumped from each production well during the period of 1995 through 2007 was provided by A&B Irrigation District and posted on the FTP portion of the IDWR website. Table 4 includes a small portion of the pumping information as an example of the information provided and the format. Pumped amounts (in acre feet) are given per well for combined two month periods for each year (i.e. April-May of 1995). Totals for each well for each year (April through October) are provided. The information provided does not allow identification of the following: 1) instantaneous pumping rates for each well and any changes in the pumping rate with time; 2) pumping periods (hours per day and/or days per month) and how the pumping patterns have changed with time.

The pumping data were analyzed in several ways. The first approach was to calculate the total amount pumped per year from all of the wells to see if there was a temporal pattern for the time period of 1995 through 2007. The average was about 178,000 acre-feet per year with a low value of about 151,000 acre-feet per year in 2005 and a high value of about 207,000 acre-feet per year in 2000 (Figure 10). No pattern was evident that could be correlated to operational problems associated with water-level decline.

An average withdrawal rate for the 13-year time period was calculated for each well (Table 5). The table also summarizes the years during 1995 through 2007 when each well was pumped. A large percentage of the water withdrawal for the A&B Irrigation District is in townships T8S R23E, T8S R24E and T8S R25E. More than two-thirds of the total pumping for the project is derived from wells in these three townships.

The temporal patterns of pumping from selected individual wells were evaluated to assess whether yields are correlated to declining ground-water levels, particularly wells where pumping water levels are at or below the top of the pump bowls. Figure 10 presents annual pumping amounts from nine wells spread though the project area. Also shown on the legend is the height of the pumping water level above the top of the pump bowls in each well in fall 2007. The temporal pattern of annual pumping amounts from wells where the water level was at or below the top of the pump bowls in 2007 is similar to wells where the pumping water level was considerably higher. This may have been accomplished by pumping the wells at lower discharge rates but for longer periods of time. Information on pumping times for individual wells is not included in the files provided for the IDWR FTP website.

Discharge data for individual wells is included in 2007 Annual Pump Report for the A&B Irrigation District which was posted on the FTP portion of the IDWR website. High and low discharge rates are given for five years (2003-2007) with Idaho miner’s inch as the discharge unit. One Idaho miner’s inch is approximately equal to 9 gpm. The discharge data were compiled and an average discharge rate per well for each township was calculated. These results are presented in Table 6 and plotted on Figures 11A, 11B and 11C. The number of wells per township varies from T8S/R23E with 50 to T10S/R21E with 1 well. The most discernable downward trend in well production is for the three wells in T9SR21E, shown on Figure 11C. The average well yield for most of the townships changed very little over the five-year period.

DISCUSSION OF RESULTS

The historic response within the A&B Irrigation District to water-level declines has been to lower and change pumps within wells and deepen wells as needed. Part of the need for these actions stems from construction of most of the wells in the 1950’s when aquifer water levels were at historic highs. A number of the original production wells were constructed less than 50 feet deeper than the water table at the time of drilling.

Four topics are addressed in the discussion of results: 1) hydrogeologic impacts on well production from continued water-level decline; 2) well operational alternatives to deal with continued water-level decline; 3) hydrogeologic limitations on well deepening; and 4) summary of A and B Irrigation District activities.

Hydrogeologic Impacts on Well Production from Continuing Water-Level Decline

Wells constructed in basalt within the Snake Plain Aquifer obtain water from one or more flow contact zones that are penetrated below the water table. The original USBR well logs do not include identification of water producing zones. The last geologic entry on the depth log for many of the wells includes the notation of "lost cuttings". Other wells were terminated when clay was penetrated. Aquifer tests were run on many of the wells with information shown on the well log. The yield and drawdown numbers given represent the sum of water derived from the unique number of flow contact zones penetrated

Water-level decline does not appreciably decrease the transmissivity of the zone penetrated by a given well until the water level drops below one of the flow contact zones that supply water to the well. The effective transmissivity of the aquifer at that well decreases abruptly at that time. This "stair-step" decrease in transmissivity in a basalt aquifer is much different than occurs in an aquifer where the hydraulic conductivity is uniform over depth (such as a thick sand zone). A step decrease in transmissivity results in greater drawdown and reduced well yield. The impacts associated with decreased transmissivity are unique to each well.

Water-level decline decreases the available drawdown (distance from the static water level to the pump setting) in a well. This is not a critical factor if the available drawdown is 100 feet, the water-level decline is 0.5 feet/year and the drawdown at the design pumping rate is 10 feet. However, this becomes a major problem when the maximum available drawdown (lowest possible pump setting) is 20 feet under the same water level and drawdown conditions. The impacts associated with reduced available drawdown are unique to each well.

Water-level decline causes a decreased pumping rate by increasing the total dynamic head against which the pump operates. The relationship between water-level decline and decreased pumping rate is dependent on the head-discharge rating curve for the given pump installed in the well.

Well Operational Alternatives to Deal with Continued Water-Level Decline

The primary approaches for dealing with continued water-level decline are to lower and change pumps, decrease pumping rates and finally deepen wells. Lowering the pump increases the available drawdown and allows well operation at nearly the design pumping rate. Decreased pumping rates results in less drawdown and allows continued operation of the pump. The pump and motor are changed when the total dynamic head has increased to the extent that the desired pumping rate cannot be achieved or the overall efficiency of the pump has decreased to an unacceptable level.

Wells typically are deepened to increase transmissivity and thus yield and also increase the available drawdown by allowing the pump to be set deeper below land surface. Well deepening can be a relatively simple operation if the well is stable (caving conditions are not encountered) and the strings of casing are not involved. Well deepening may not be possible in some circumstances because of casing configurations, well alignment or penetration of unstable formational material. In this case a replacement well may need to be drilled.

The unique construction of each of the project wells controls the ease and success of lowering pumps and deepening wells. Data on the casing configuration for each project well has not been located; thus, a well by well evaluation of problems associated lowering pumps and deepening wells is not possible. It is likely that decisions made in the construction history of individual project wells make lowering pumps and/or deepening wells not possible.

Depth Limitations to the Aquifer

Successful deepening of wells depends on water producing zones (dominantly flow-contact zones in Quaternary basalt) being present in the aquifer in the depth interval below the bottom of the existing well. The dominant hydrogeologic question is whether water-producing zones in the basalt are present in the depth interval (say 100 feet) below the bottom of each existing wells for which deepening is considered. An associated question pertains to determination of the effective bottom of the aquifer within different parts of the project area.

The first step in the analysis of well deepening potential is to examine the subsurface stratigraphy. Water producing zones are not present in most of the sedimentary interbeds because they are composed dominantly of clay. Thus, the presence of a clay interbed that extends hundreds of feet below the present depth of a well makes the probability of successful well deepening very low. Conversely, the presence of basalt (absence of clay interbeds) in the depth interval below the bottom of a well means that there is a reasonable chance that well deepening can be successful.

Geologic information from drilled wells provides information on the presence or absence of sedimentary interbeds (mostly composed of clay) in the sequence of basalt flows. As described previously in the “Analysis of Wells” portion of this report, sedimentary interbeds below the water table are thin and do not appear to be laterally continuous in the northern portion of the project area. In contrast, clay interbeds below the water table are thicker and are penetrated in more wells in the southern portion of the district. Thick clay units that are probably the Burley Lake Beds are present in the southern portion of the district. The potential for successful well deepening is high in the northern portion of the project and relatively low in the southern portion of the project area.

Knowledge of the subsurface geology is available to a greater depth for the southern portion of the district than the northern portion. The four project production wells that have been drilled to depths greater than 600 feet (656, 700, 700 and 1,000 feet) are all located in the southern portion of the project area (9S/21E, 9S/22E and 10S/21E). The 1,000-foot well in section 22 of T9S R22E penetrates a 199-foot thick interbed in the elevation range of 3,703 to 3,902 feet and a 55-foot interbed in the elevation range of 3,521 to 3,576 feet with several additional thin sedimentary units. Only four project production wells have been drilled deeper than 500 feet (510, 510, 516 and 587 feet) in the three townships that include more than two-thirds of the ground-water production in the northern portion of the project (8S/R23E, 8S/24E and 8S/25E). The deepest of these, a 587-foot well in section 26 of T8S R21E, did not penetrate a sedimentary interbed below the water table.

The second step in the analysis of well deepening potential is to ascertain whether water yielding zones in the basalt become more or less frequent with depth and whether they individually yield more or less water. This type of information is needed but has not been located for either within the A&B Irrigation District files or more generally within the literature dealing with the Snake Plain aquifer. The section of the U.S. Bureau of Reclamation (1985a) quoted previously in this report indicates that the basalt penetrated at depth in the southern portion of the project (T9S R22E) has fewer producing zones than the shallow basalt. This type of information is needed for the northern portion of the project area.

Summary of A&B Irrigation District Activities

Previous sections of the report ("Production Well Information" and "Water Production Information") provide summary comments on actions taken by A&B Irrigation District to respond to declining water levels. More than half of the production wells have been deepened. Summary statistics on changes in pumps and motors are not available from the FTP site. Notations on the records for individual wells show that pumps and motors have been changed at a number of wells. Notations on the district map provided on the FTP site indicate that 7 wells have been abandoned and 5 wells replaced. Water-level and pump setting information indicate that 16 of the 131 wells for which data are available had pumping water levels below the top of the pump bowls in 2007; an additional 36 wells had pumping water levels within 10 feet of the top of the pump bowls.

In contrast with the above information, data presented in the "Water Production Characteristics" section of the report indicate that nearly the same group of wells has been used to supply water for the district for the last 12 years. No decrease in the total amount pumped per year from all of the wells was evident that could be correlated to operational problems associated with water-level decline. The average well yield per township has not varied in the last five years for much of the area.

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

General aquifer conditions such as water-level elevation and the temporal rate of water-level decline are regional in nature within the service area of the A&B Irrigation District and thus are predictable from well to well. However, each existing A&B production well is unique with respect to well construction characteristics and hydrogeologic conditions (such as water producing zones and water yielding characteristics) penetrated by the well. The specific steps necessary to maintain water production in an environment of long-term water-level decline are thus unique to each production well.

In general, the percentage of sedimentary interbeds in the subsurface below the water table is greater in the southern portion of the project area with thicker and more laterally extensive clay units. The number and thickness of clay units interbedded with the basalt below the water table in the northern portion of the project area are small. The hydrogeologic environment generally correlates with the centers of ground-water pumping for the district. The majority of the ground-water production by the A&B

Irrigation District occurs in northern portion of the project area with about two-thirds in townships T8S R23E, T8S R24E and T8S R25E.

The A&B Irrigation District has responded to issues raises by declining ground-water levels by lowering and replacing pumps and deepening selected project wells. Part of the need for these actions stems from construction of most of the wells in the 1950's when aquifer water levels were at historic highs.

The hydrogeologic environment makes the probability of success in well deepening greater in the northern portion of the project area than in the southern portion of the project area. The primary factor is the greater presence of sedimentary (mostly clay) units interbedded with the basalt in the southern portion of the project area.

Detailed information on the depth frequency and water yielding characteristics of water producing zones has not been compiled for A&B Irrigation District production wells. Compilation of this information, if it exists, is needed is help in development of a more quantitative predictive tool for the costs and effectiveness of well deepening efforts in different portions of the project area.

Recommendations

To the extent possible, additional information should be sought from the A&B Irrigation District relative to each of their production wells. The following is a list of the type of information that is needed.

- Information is needed relative to specific water producing zones and estimated yield amounts of these zones for each production well. This information is needed for the original drilled depth and any succeeding well deepening efforts.
- Additional temporal data on pumping rates are needed for each production well. Well-yield information has been provided to date is in the format of acre feet per two-month period from 1995 through 2007 or in the form of high and low pumping rates for the period of 2003 through 2007. This data base does not allow assessment of changed operational practices relative to pumping rate and pumping period from each well.

Construction of one or more test wells would greatly improve knowledge of the yield characteristics of the Snake Plain Aquifer with dept, particularly h in the northern portion of the A&B Irrigation District. This program should include identification of stratigraphic units and determination of yield characteristics of water producing zones.

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