BADGER CANYON GROUNDWATER INVESTIGATION

for the

Kennewick Irrigation District

Kennewick, Washington

CH2M HILL, Northwest Inc.

Yakima, Washington

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BADGER CANYON
GROUNDWATER INVESTIGATION

INTRODUCTION

Property adjacent to Badger Road, approximately 4 miles southwest of Kennewick, Washington, has experienced significant increases in wet areas, springs, and seeps over the past few years (see Figure 1). Les Borms, one owner of the property in the area, has lost farmable acreage because of the expansion of the wetlands. Because of the continued increase in unfarmable area, the Kennewick Irrigation District (KID) hired CH2M HILL to investigate the possible causes. Our objectives were to determine the local groundwater conditions, identify possible mechanisms causing the problem, and propose a physical solution.

Our approach was twofold, first to gain a regional perspective of the hydrogeologic environment and second to investigate the possibility of localized canal leakage acting as a direct source of water to the wet areas on the Borms property.

CONCLUSIONS

1. The wet areas on and adjacent to Mr. Borms' property are the result of rising water tables throughout the valley. Water tables have risen and are continuing to rise at an average rate of 4 to 5 feet per year. The problem is compounded in the vicinity of Mr. Borms' property by a fault which apparently impedes groundwater movement.

2. The rise in water table is caused by infiltration of water imported from outside the basin. Infiltration occurs from excess water applied for irrigation and leakage from the KID canals. We estimate 60 to 70 percent of the water table rise is attributable to canal losses, and 30 to 40 percent is attributable to excess water applied for irrigation.

3. The water table will continue to rise in the valley until the outflow equals the inflow. Increased outflow will naturally occur in the form of surface runoff from springs and seeps, increased evaporation losses from ponds and wet areas, increased consumption by vegetation, and increased groundwater outflow due to a steeper gradient.

4. A water balance can be achieved sooner by decreasing infiltration and increasing basin outflow. Decreasing infiltration can be achieved by improving irrigation

practices and by minimizing canal seepage. Improved outflow can be achieved by subsurface and surface drains or dewatering wells. Under present conditions, an increased outflow of approximately 2,500 to 3,500 acre-feet per year would be necessary to maintain a basin water balance, and therefore stabilize groundwater levels.

5. A combination pipe and ditch system to provide a discharge conduit for collected drainage water could be provided by the district between the county road and the Burlington Northern Railroad track. (Details are appended to this report).

HYDROGEOLOGIC SETTING

Badger Coulee is a narrow valley approximately 13 miles long extending from Kiona to Kennewick. The Coulee averages approximately three-quarters of a mile wide. Valley floor topography ranges from relatively flat to gently rolling hills. Drainage is both east and west, with the drainage divide located near Badger Station. The steep canyon walls are composed of multiple basalt flows dissected by ephemeral streams. Native vegetation is sparse, reflecting the low average annual precipitation (8 to 10 inches).

The thickness of sediments in the Coulee range from a feather edge where the Coulee sediments contact the basalt canyon walls, to a maximum of 300 feet thick (Brown, 1979) at the deeper parts of the basin. Sediments in the valley are generally high-permeability sand and gravels.

GROUNDWATER LEVELS

The unconfined aquifer has experienced a dramatic rise in static water level elevation since 1952. Static water level altitude in a well at Badger Station in 1952 was approximately 415 feet. Subsequent measurements in 1966 and 1975 showed respective elevations of 491 feet and 538 feet, for an average water level rise of 5.3 feet per year (Brown, 1979). In September 1982, a well approximately one-quarter mile north of Badger Station was measured, and the static water level elevation was 562 feet, indicating the water table elevation is continuing to rise.

Data from other areas of the Badger-Coulee indicate the rise in static water level elevation has occurred throughout the valley. In September 1982, CH2M HILL measured 17 wells in the eastern part of the valley which showed an average rate of rise in water table elevation of approximately 4.3 feet per year (see Table 1). Although the period of measurement is not as long, the rate of rise of 4.3 feet per year at the east end of the valley is reasonably consistent with the

5.3 feet per year found at Badger Station. Near Kiona, at the west end of the valley, rising water level elevations have caused increasing spring flows. In September 1982, a spring at approximately 547 feet elevation was observed to be flowing at about 0.4 to 0.6 cfs. According to Mr. Borms, a longtime resident of the Badger Coulee, the spring began as a seep or wet spot about 10 years ago. Since that time, the amount of water flowing from the spring has progressively increased.

Table 1
RATE OF RISE IN WATER LEVEL IN WELLS

Well Owner	Water Level Rise (feet)	Time Period (years)	Rate (feet/year)
Snider (ag. well)	17	5	3.4
Borms	66	15	4.4
Henckel	28	7	4.0
Rogers	4	2	2.0
Jensen	16	2	8.0
Fennesy	63	17	3.7
Cable	19	6	3.2
Luginbill	12	3	4.0
Autry	22	6	3.7
Kellog	8	2	4.0
Utley	30	3	10.0
Canyon Village	14	4	3.5
Snider (domestic well)	21	6	3.5
White	16	4	4.0
White	11	3	3.7
		Total	65.1

65.1 divided by 15 =

Average of 4.3 feet/year

OCCURRENCE AND MOVEMENT OF GROUNDWATER

Groundwater in the Badger Coulee occurs within the pore spaces of the sediments beneath the valley floor. Below the water table, the pores are completely filled with water. In the unsaturated zone above the water table, the pore spaces are only partially filled with water, and the direction of groundwater movement is downward. Beneath the water table, groundwater follows the hydraulic gradient from areas of high groundwater elevation to areas of low groundwater elevation.

Groundwater flow in the Badger Coulee is down the hydraulic gradient through the interconnected pore spaces in the sediments. In a porous unconfined aquifer such as in the Badger Coulee sediments, flow is relatively uniform and does not occur in channels, underground streams, or veins.

A groundwater contour map, such as Figure 1, shows the direction of groundwater movement beneath the Badger Coulee. The contours show that groundwater flows northeast out of the east end of the valley and northwest out of the west end of the valley. The diverging direction of flow indicates a groundwater divide occurs somewhere southeast of Badger Station. No wells exist in this area, so data are not sufficient to precisely locate the position of this groundwater divide.

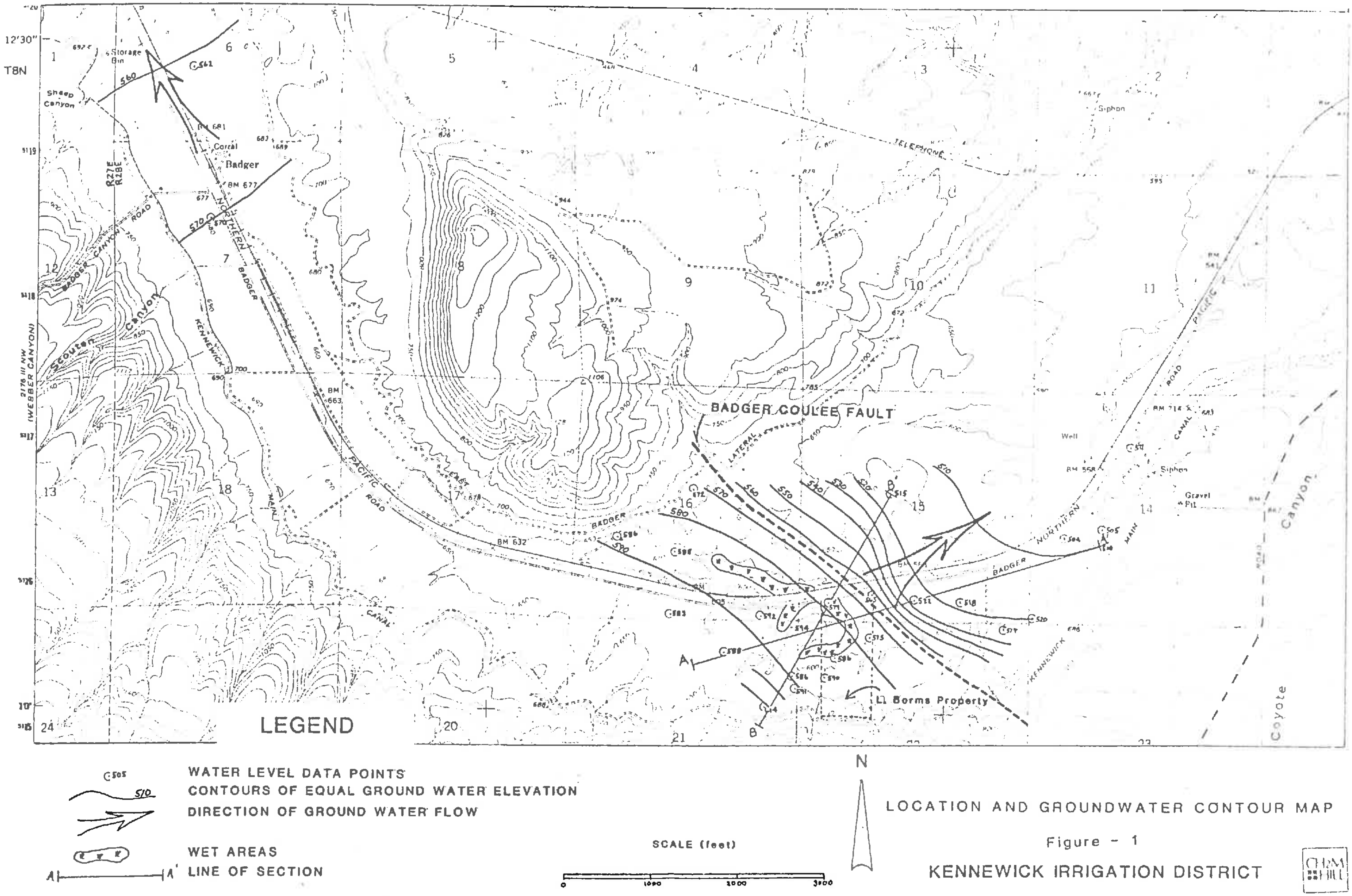
The groundwater contour map also shows groundwater flow at the east end of the valley is strongly influenced by the Badger Coulee Fault. At the fault, the hydraulic gradient dramatically increases (as indicated by the close spacing of the contours). Upgradient and downgradient from the fault, the spacing between contours widens, indicating a relatively flat water table surface. Figures 2 and 3 are sections drawn through the area of the fault and show the relationship of the ground surface, water table elevation, and the fault.

The effect the fault has on groundwater flow is probably a result of one or a combination of the following subsurface conditions (see Figure 4):

- The fault has caused a variation in aquifer thickness due to offset basalt flows.
- The fault has offset sedimentary deposits of differing permeability.
- Movement along the fault zone has caused alteration of the sediments into lower permeability clays.

ANALYSIS OF RISE IN WATER TABLE

The water table is the top of the saturated zone. Below the water table, the pores in the sediments are completely filled with water. Above the water table, in the unsaturated zone, the pores are partially empty. It is important to realize that in the unsaturated zone, the pores are not



LOCATION AND GROUNDWATER CONTOUR MAP

Figure - 1

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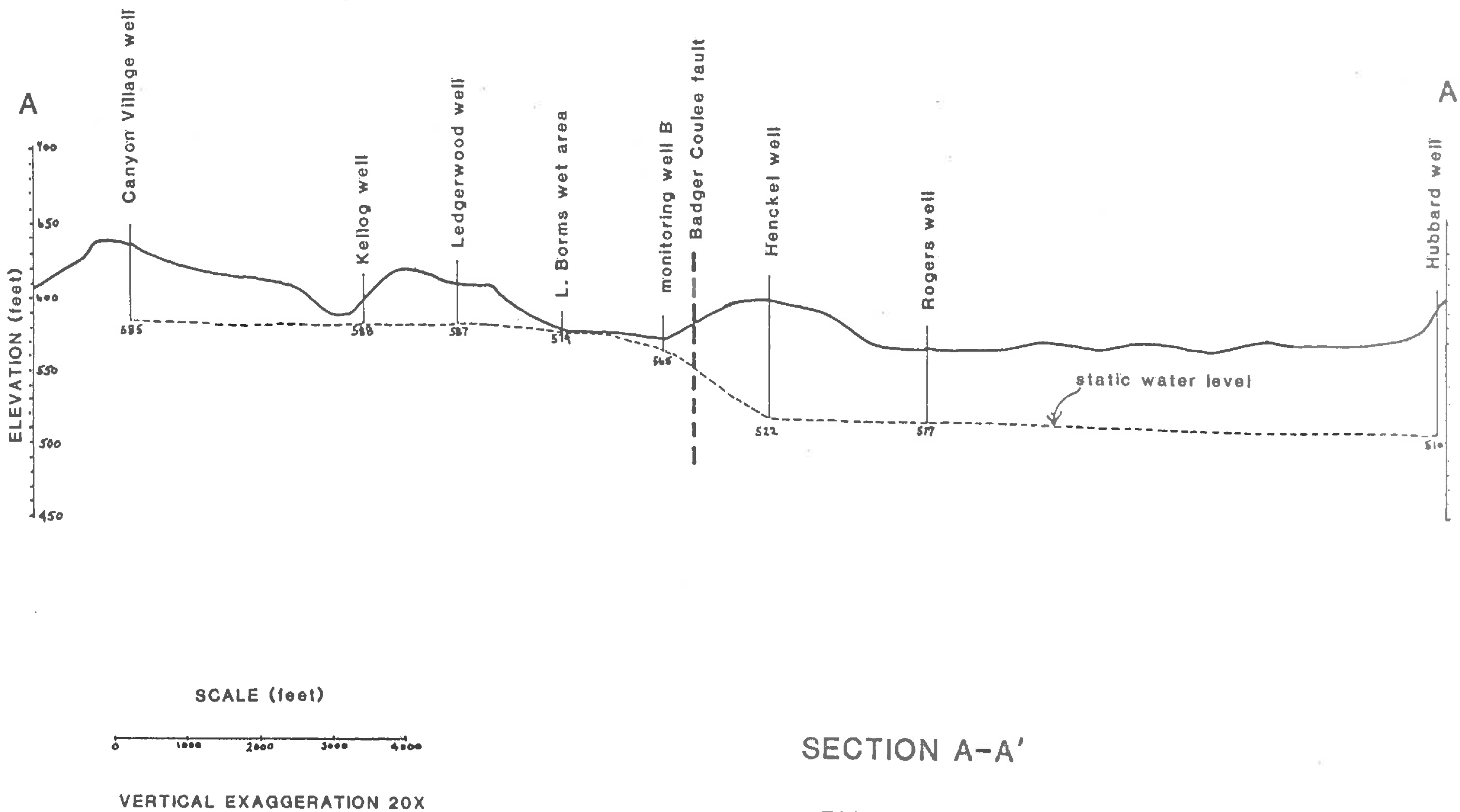

SECTION A–A'

Figure - 2

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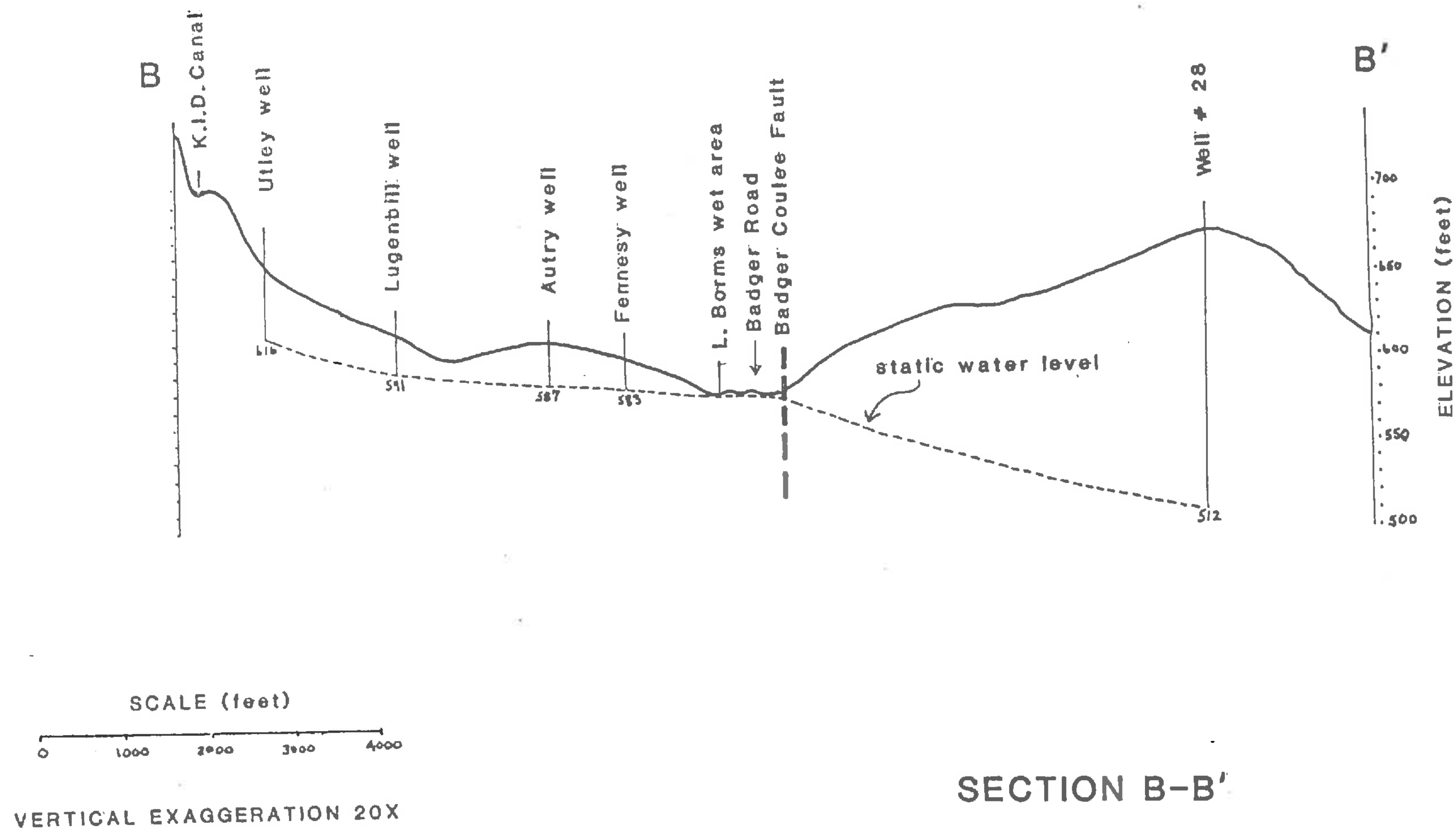

SECTION B–B'

Figure – 3

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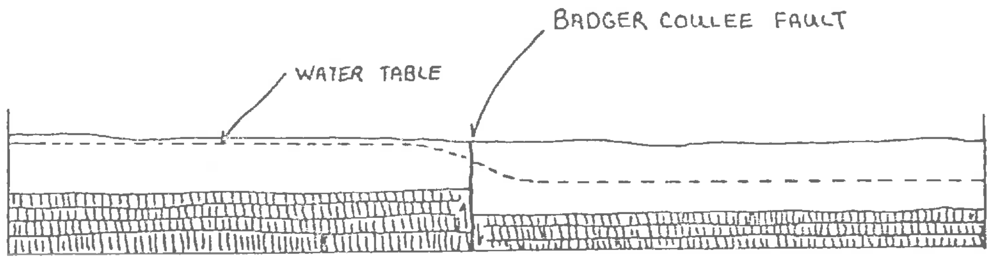
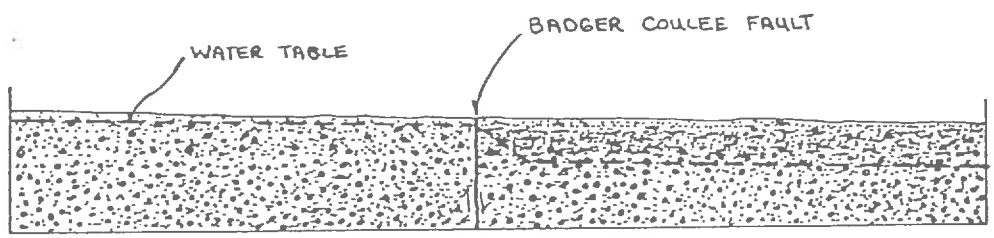


A. Offset basalt flows causing an increase in aquifer thickness.



B. Changes in permeability across fault zone due to offsetting of sedimentary deposits and alteration of minerals.

Badger Coulee Fault
–Potential Mechanisms of Influence on Ground Water

Figure – 4

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completely dry. Some water always adheres to the mineral grains and is permanently retained. Therefore, the amount of water needed to create a saturated condition (or in other words, cause a rise in water table) is equal to the volume of empty pore space. The volume of empty pore space in the unsaturated zone is equal to the total volume of pore space (porosity) minus the volume of retained water (specific retention). This quantity is called the "specific yield" of the aquifer.

The specific yield of the sediments comprising the aquifer in Badger Coulee has not been measured, but tests in similar unconsolidated sand and gravel aquifers in other areas indicate that a typical specific yield is about 20 percent.

The rise of groundwater levels in the Badger Coulee area has been caused by a surplus of imported water delivered to the area. The quantity of this surplus may be estimated from the following:

$$Q = A \times \Delta S \times Sy$$

Where

Q = Average annual surplus of water

A = Area of interest (limited to 2,500 acres in the east end of the valley)

ΔS = Average annual rise in water table (measured to be 4.3 ft/yr to 5.3 ft/yr)

Sy = Specific yield (assumed equal to 0.20)

Using these values, the average annual surplus of water causing the water table rise is estimated to be 2,100 to 2,700 acre-feet per year. This estimate of the basin water surplus will be compared with an independent estimate based on a water budget.

BASIN WATER BUDGET

The overall basin groundwater budget is expressed by the following:

$$\text{Inflow} - \text{Outflow} = \text{Change in Storage}$$

The change in storage has already been calculated to be 2,100 to 2,700 acre-feet per year. The following sections describe calculations and estimates of the outflow and inflow components of the groundwater budget.

Outflow

The major components of the outflow of groundwater are:

1. Subsurface outflow
2. Direct evapotranspiration of groundwater in wet areas
3. Groundwater discharge to surface streams

Subsurface Outflow

Under present conditions, a significant quantity of groundwater flows out of the basin. The amount of water flowing northeast out of the basin toward Kennewick may be calculated from the following form of Darcy's Law:

$$Q = T\ I\ L$$

Where

Q = Quantity of outflow

T = Transmissivity of aquifer (estimated by Brown, 1979, to be 15,000 gpd/ft

I = Hydraulic gradient (measured on Figure 1 to be about 20 ft/1,850 ft)

L = Width of flow (Coulee width at Badger Coulee Fault is 7,500 ft)

Using these parameters, the subsurface outflow from the basin to the northeast is calculated to be 1,350 acre-feet per year.

Using similar procedures, we have calculated that approximately 200 acre-feet per year flows northwest past Badger Station. Therefore, the total subsurface outflow is about 1,550 acre-feet per year.

Direct Evapotranspiration of Groundwater

Presently, about 50 acres are wet at or near the surface in the study area. Part of the water consumed by evapotranspiration in these wet areas is groundwater. The actual percentage of groundwater consumed by evapotranspiration in these wet areas in unknown. However, for estimation purposes, we can assume that 50 percent of the total consumption is groundwater, the remainder being excess surface water. Using these assumptions and an evapotranspiration rate of 3-1/2 acre-feet per acre, we estimate that about 100 acre-feet per year of groundwater are consumed by evapotranspiration in wet areas.

Groundwater Discharge to Surface Streams

To our knowledge, little if any groundwater discharges to surface streams in the study area. Therefore, this outflow component is zero.

Inflow

The very low amount of rainfall in the area precludes significant amounts of natural recharge. Therefore, virtually all of the groundwater in the basin between Badger Station and the Badger Coulee Fault must be derived from imported water in the Kennewick canals.

Imported water can reach the Badger Coulee aquifer by three possible mechanisms:

1. Deep percolation of applied irrigation water
2. Seepage from irrigation storage ponds
3. Direct leakage from canals

Deep Percolation of Applied Irrigation Water

Not all of the water applied for irrigation is consumed by crops. Some applied water runs off, and some percolates below the root zone to become groundwater recharge. Discussion with local agricultural experts and our experience indicate that the deep percolation is typically about 1 acre-foot per acre per year. Therefore, approximately 1,500 acre-feet per year is added to the groundwater in the 1,500 irrigated acres between Badger Station and the Badger Coulee Fault.

Seepage From Irrigation Storage Ponds

Several irrigation storage ponds exist within the study area, with a combined area of 2.1 acres. Using an estimated seepage rate of 0.5 feet per day (similar to that used for the canal seepage estimates), approximately 200 acre-feet per year percolate to the groundwater from these ponds.

Direct Leakage From Canals

The quantity of water seeping from the Kennewick main canal and the Badger East lateral is a function of the wetted area of canal bottom and the average seepage rate. We estimate 30 acres of canal surface lie within the study area. We did not measure the average rate of seepage from the canals. However, the U.S. Bureau of Reclamation conducted infiltration tests during 1954-1955 on a 225-foot-long test section of canal, which indicated that the expected rate of canal seepage is 0.5 foot per day. Based on this average seepage rate, which would occur for about 180 days per year, the calculated canal seepage is about 2,800 acre-feet per year. Approximately 80 percent of the total would be from the Kennewick main canal, and 20 percent from Badger East lateral.

Recently, KID performed a seepage test of the Kennewick Main Canal between the Chandler Siphon and Ammon Pump. In this test, it was determined that 19 cfs were lost along this reach, which has about 18 miles of unlined canal. If it is assumed that the 5.75-mile reach between Badger Station and the Badger Coulee Fault is typical of the unlined portion of this reach, then about 6.1 cfs would leak from the canal. Over the 180-day irrigation season, about 2,200 acre-feet would be lost. This seepage estimate is reasonably consistent with the U.S. Bureau of Reclamation infiltration testing results.

Summary of Water Budget

Table 2 summarizes the water budget for the area between Badger Station and the Badger Coulee Fault.

The two independent estimates of the basin water surplus are very close, supporting their accuracy. The fact that the water budget estimate is higher suggests that other components of groundwater outflow that were not considered may be significant. These could include recharge to the deeper basalt aquifers and pumpage for domestic and agricultural use in the basin.

POSSIBLE REMEDIAL ACTIONS

The problem of rising water tables in the area can only be solved or minimized by reducing the amount of surplus groundwater in the basin. We have investigated several engineering solutions to the problem: canal lining, subsurface drains, and dewatering wells. These are discussed in more detail below. In addition to those discussed below, it is obvious that minimizing leakage from irrigation storage ponds will assist the problem. However, the water budget shows that these ponds contribute to only a small fraction of the problem so that lining these ponds will not be a full solution to the problem.

Canal Lining

Canal seepage losses could be dramatically reduced by lining the canals with low permeability materials. Lining the canals (Kennewick main and Badger east) between Badger Station and the Badger Coulee Fault would probably cost in

Table 2
WATER BUDGET SUMMARY
AREA BETWEEN BADGER STATION AND BADGER COULEE FAULT

Component	Acre-Feet per Year
Inflow	
Deep percolation of applied irrigation water	1,500
Seepage from irrigation storage ponds	200
Direct leakage from Badger East Lateral	500
Direct leakage from Kennewick Main Canal	2,300
Total Inflow	4,500
Outflow	
Subsurface outflow to the northeast	1,350
Subsurface outflow to the northwest	200
Direct evapotranspiration of groundwater in wet areas	150
Groundwater discharge to surface streams	-0-
Total Outflow	1,700
Change in Storage	
o Estimate 1--based on rise of groundwater table	2,100 - 2,700
o Estimate 2--by water budget (inflow-outflow)	2,800

the range of $3,000,000 to $4,000,000, based on an estimated cost

Subsurface Drains

A drainage system could lower and maintain the water table at a minimum of 6 feet below the ground surface. This would be accomplished by installing corrugated drain tubing at a depth of 8 feet at intervals of 120 to 150 feet over approximately 75 acres. To provide some means of discharge for a subsurface drain system would require the construction of a discharge conduit about 4,000 feet long or a sump pump that would discharge the collected drain water into an existing surface drain.

A subsurface drainage system is estimated to cost between $80,000 and $100,000 to install. Annual operation and maintenance costs for this system would be minor. This estimate does not include any charges for drainage design or construction of a discharge pipeline and ditch or sump pump.

Dewatering Wells

The goal of a dewatering system is to stabilize the water table far enough below ground surface so agricultural use of the land is not impaired. In utilizing wells for dewatering, two factors must be considered. First, in order to stabilize the water table, the system must discharge the calculated surplus of 2,800 acre-feet per year outside the basin. Secondly, the system must be designed to drop groundwater levels to the desired elevation without causing excess drawdown at any particular location.

Based on the preceding conditions, a dewatering system in the study area would necessitate 8 to 10 wells, approximately 250 feet apart, with a continuous discharge capacity of 200 gallons per minute (gpm) per well. The 1,600 to 2,000 gpm would discharge the necessary surplus water to stabilize basin inflow with outflow, and the spacing of the 8 to 10 200-gpm wells would produce the desired drawdown without excessively lowering the water table at any one location.

A dewatering system utilizing wells would probably cost between $50,000 and $100,000 to install, including well construction and pumps. Power costs would range between $7,000 and $9,000 per year at current prices. These estimates do not include charges for well field design, construction of a discharge pipeline and ditch, or maintenance.

The use of dewatering wells to stabilize groundwater levels could be made more cost-effective if some or all of the pumped water were used to replace diversions from the canals.

Discharge Pipeline and Ditch

Before either the subsurface drains or dewatering wells can be constructed some means of discharging the collected drainage water is needed. The surface drainage way for the area is located on the north side of Badger Canyon Road between the road and the Burlington Northern Railroad tracks. To determine the existing profile of the drainage channel a survey crew from KID surveyed the invert of the channel in mid-December 1982. The survey began at the concrete culverts under the railroad in Section 14 and ran for about 7,000 feet to the west boundary of Section 15.

Using the survey of the drainage channel profile and other information developed in this report it was determined that a combination pipeline and ditch could be constructed to create an outlet for surface water and drain water collected by subsurface drains. The first 1,900 feet of pipeline would be 12-inch diameter perforated drain pipe at a 0.45 percent slope with a carrying capacity of about 2.5 cfs. The next 2,050 feet of pipeline would be a 21-mile drain at a 0.12 percent slope with a carrying capacity of about 5.0 cfs. This discharge pipeline would have sufficient capacity to carry the flows necessary for balancing the basin outflow with the inflow.

Attached to this report are two sheets of drawings with sufficient detail for the construction of a discharge pipeline and ditch. The drawings are adequate for construction by KID forces but are not suitable for competitive bidding by contractors. The proposed facilities include a surface inlet structure, 1,900 feet of 12-inch diameter pipe, a manhole with a 12-inch diameter stub for future connection to a subsurface drain, 2,050 feet of 21-inch diameter pipe and 2,950 feet of open ditch. The stub for connection to a future subsurface drainage system is located 8 to 9 feet below the ground surface to allow for a direct gravity flow connection to a subsurface drainage system. The upper 2,900 feet of the pipeline is perforated drain pipe which will act as a subsurface drain as well a carrier pipe.

RECOMMENDATIONS

Unless action is taken to limit the net groundwater surplus, groundwater levels will continue to rise at the rate of 4 to 5 feet per year. As a result, an area of 22 acres is now affected by high water tables and the area affected will continue to increase.

From the above discussion, it can be seen that subsurface drainage is the most economically feasible solution. Therefore, we recommend that the discharge pipeline and ditch be constructed by KID forces. The new pipeline will reduce the amount of standing water within the drainage channel and will provide an outlet for a subsurface drainage system.

REFERENCE

Brown, Randall E., September 1979. A review of Water-Well Data from the Unconfined Aquifer in the Eastern and Southern Parts of the Pasco Basin. Prepared for the United States Department of Energy, Document No. RHO-BWI-C-56, p. 13.

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