FINAL REPORT

TOWN OF PINE BLUFFS
WATER SUPPLY PROJECT
LEVEL II

SUBMITTED TO THE

ROMING WATER DEVELOPMENT COMMISSION

NOVEMBER 7, 1995
FINAL REPORT
FOR
PINE BLUFFS WATER SUPPLY INVESTIGATION
LEVEL II

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I. INTRODUCTION

1.1 Authorization and Purpose

In November of 1994, the Town of Pine Bluffs submitted an application to the Wyoming Water Development Commission (WWDC) to fund a Level II study of the municipal water supply. On June 1, 1995 Lidstone & Anderson, Inc. (LA) entered into a contract with the WWDC to provide professional services related to the Level II Pine Bluffs Water Supply Project. Lidstone & Anderson, Inc. was assisted by their subcontractor, AVI, p.c., throughout the project. The purpose of this project is to (1) investigate declining well production within certain wells, (2) document the hydrogeologic and hydraulic characteristics of the Brule Aquifer for the purposes of wellhead protection and well rehabilitation design, (3) evaluate the need for and develop the conceptual design of an isolated transmission line and water treatment program for the Town’s water supply, and (4) develop methodology for the Town to achieve compliance with Wyoming’s proposed Wellhead Protection Program. In summary, the purpose of the Level II Pine Bluffs Water Supply Study is to collect sufficient field data, including the examination of specific improvements to the current well production system, to outline a course of action for future system improvements.

1.2 Project Location and Summary of Existing Problems

The Town of Pine Bluffs is immediately adjacent to the Wyoming/Nebraska border in southeastern Laramie County, Wyoming (Figure 1.1). Pine Bluffs and its economy are closely tied to agriculture, which comprises most of the land use in the area. The 1990 census population was 1,054 persons. This value represents a slight decrease from 1980’s estimates; however, the Town has shown a slow but a steady increase in population since 1990. Estimates from the State Economic Analysis Division predict a population of 1,350 in the year 2035.

The water source for the community, including agricultural activities, is a shallow aquifer: the Oligocene age Brule Formation. The Brule is an unusual aquifer because it is a siltstone which, by itself, has a very low permeability and will not yield significant quantities of water to wells. However, fractures, fissures, pipes, and tubular openings within the formation provide discontinuous secondary permeability that can yield significant quantities of water. In the Pine Bluffs area, research and televiewing of existing wells using downhole cameras suggest that piping and tubular openings predominate. Piping is the process by which
Figure 1.1. Location Map.
subterranean channels form because of the movement of water in insoluble clastic rocks, under large hydraulic head differences over short distances. The position of pipes may have been controlled by fractures or other planes of weakness formed during the post-depositional period. The implication of these aquifer characteristics is that no certainty of yield can be expected from any given well. Therefore, well completion in the Brule is a "hit or miss" operation. Low yielding wells can be completed immediately adjacent to high yielding wells if pipes and fractures are not encountered.

Six wells, all completed in the Brule, serve as the sole source of municipal water for the Town. The wells are integrated directly into the Town's water distribution system (Figure 1.2), and there is no independent transmission line from the supply wells directly to storage. The distribution system consists of approximately 21,550 lineal feet of 4-inch mains, 12,600 lineal feet of 6-inch mains, 14,400 lineal feet of 8-inch mains, and 5,400 lineal feet of 12-inch mains. Pine Bluffs has two concrete water-storage tanks with a combined capacity of approximately 710,000 gallons. The system is well maintained and functional, yet certain upgrades are required to replace the more antiquated portions of the system. Many old cast-iron mains in the downtown area are in very poor condition and need to be replaced. An insufficient number of gate valves and fire hydrants are present throughout the Town, resulting in an inefficient operating system. The taps and wells are metered, but many meters are old and possibly inaccurate. The Level I investigation found that the metered production of water at the wells did not balance with the quantity of water sold.

Concern has been expressed about the regionally declining water table. Overall, water levels have declined approximately four feet since 1979. The majority of this decline occurred during the 1985 to 1992 time period, which corresponds with a period of severe drought. The decline may be a result of low precipitation coupled with increased irrigation demand during the drought period. The data for 1992 and 1993 show a significant decrease in the rate of decline in response to near-average precipitation. Data from 1995, a high precipitation year, suggest a slight increase in static levels. Seasonal fluctuations in the water table will undoubtedly continue as a function of precipitation and the irrigation demand. The static water levels in the wells now range from 29 feet to 84 feet below the ground surface.

Several institutional constraints will dictate the direction taken regarding any improvements or modifications to the Town's water system. Since the 1960's, experts have recognized that ground water in the Pine Bluffs area is in short supply. In 1977 the State Engineer established a ground water control area and placed a moratorium on additional ground
water development in the area. The area now falls within the Laramie County Control Area, established September 1981.

Additional regulatory constraints that will influence the Town’s options are the 1986 amendments to the Safe Drinking Water Act (SDWA). The amendments include the provision for states to enact regulations requiring development of wellhead protection plans for municipal wells. The Wyoming Wellhead Protection Program is currently being prepared by the Department of Environmental Quality. At this time, participation in the program is assumed to be voluntary, and the incentives to encourage participation may be attractive to the Town. Regardless of the regulatory requirements, the Town is strongly encouraged to develop a Wellhead Protection Plan because of the aquifer’s sensitivity to contamination.

Subsequent to the 1986 amendments to the SDWA, the Groundwater Treatment Rule (GWTR) was passed. It is not yet mandatory. At this time, ground water does not require treatment before use, but disinfection will be required under the GWTR. The Town does not currently treat their municipal supply, and the existing system, which connects the wells directly to the distribution system, makes treatment impractical and costly. In anticipation of the regulatory mandate, the Town of Pine Bluffs is faced with a difficult compliance situation. An isolated transmission line connecting the most productive Town wells directly to storage will be an essential component in any ground water treatment program.

1.3 Previous Investigations

In the Fall of 1994, AVI, p.c. of Cheyenne, Wyoming, in conjunction with Lidstone & Anderson, Inc., completed a Level I investigation. The Level I investigation focused on an evaluation of the existing water supply system and the development of alternatives to mitigate the existing and anticipated water quality and quantity problems.

As part of the Level I investigation, short-term aquifer tests were conducted on several wells to provide data for preliminary estimates of aquifer productivity. Results of these tests showed that production capabilities of the wells were not in balance with their adjudicated water rights. In addition, production capacity had dropped noticeably in two of the wells, when compared to the brief 1977 testing data documented in the Town records.

During the Level I evaluation of the supply system, certain critical issues were identified with respect to the production wells. These include:
1. Emergency power is available at only Well No.3; this well is the lowest capacity well in the system and cannot meet any reasonable portion of the Town’s water needs.

2. As described above, the Town’s adjudicated water rights are poorly matched with well production. The wells that have the highest production capacity have the poorest (lowest adjudication) water rights.

3. Well completion information is poor and contradictory, particularly for the higher producing wells. Foot valves may be absent on most wells.

4. Static water levels in all wells, and certain well yields, have decreased since 1979. Minimum pump maintenance has taken place since 1978, and the operating pump and pump setting may no longer be appropriate for the individual wells.

5. Elevated levels of nitrate were identified in all of the Town’s water wells. No trend (spatial or temporal) in nitrate concentration could be identified with the limited data set available in 1994. Nevertheless, a wellhead protection program may be in order.

1.4 Summary of the Current Project

The issues identified in the Level I investigation served as the basis for the Level II investigation. The objectives of this investigation are to:

- Address the declining production of certain municipal wells and prepare conceptual designs for rehabilitation;
- Document the hydrogeologic characteristics of the Brule Aquifer for the purposes of wellhead protection, evaluation of long-term productivity, and well rehabilitation design;
- Address the need and prepare conceptual designs for an isolated transmission line and water treatment program;
- Develop a methodology for the Town of Pine Bluffs to achieve compliance with the requirements of the proposed Wyoming Wellhead Protection Program.
The specific tasks conducted to address these objectives, along with the results and conclusions of each task, are presented in the subsequent chapters of this report. Briefly, they are:

Chapter 2. Evaluation of Existing Water Supply System

This chapter presents the results of the detailed field investigation into the condition of the existing system. For the reader's convenience the investigation is presented on a well by well basis. Pumps and related equipment were pulled from the producing wells, inspected, repaired as needed, and reinstalled. While the pumps were out of the wells, geophysical and video logs of selected wells were obtained. These logs enabled the project team to view, first hand, the condition of each well and casing, and to make recommendations for possible improvements.

Aquifer tests and analyses were also conducted at two of the wells: Well No. 1 (Municipal Well) and the Ekstrom Well (Well No. 6). The results of these tests are presented as part of the well by well discussion.

Chapter 3. Ground Water Modeling

Recommendations of the Level I investigation included the reallocation of the Town's existing water rights to result in a better balance between the adjudicated rights and the production capabilities of the wells. A ground water model of the well field was developed for existing and future pumping schedules. This chapter describes the modeling effort, its results, and conclusions.

Chapter 4. Conceptual Design and Recommendations

This chapter summarizes conceptual designs for proposed well rehabilitation and transmission line options based on the pump inspection and rehabilitation program. A wellhead protection program is briefly summarized in this chapter; more detailed information is presented in Appendix C.
Chapter 5. Conceptual Design Cost Estimates

This chapter summarizes design and construction costs for the purposes of Level III funding. The data are presented in tabular form, with non-WWDC project components in a separate table.

Chapter 6. Ability to Pay Economic Analysis

This chapter presents an economic analysis of total project costs based on WWDC and Farm Loan Board funding. Final costs are presented as project-related, monthly cost increases to the current users.
II. PUMP INSPECTION AND REHABILITATION

2.1 General

The Town's water supply system consists of six water wells completed in the Brule Formation. The depths of the wells vary from 98 to 128 feet. Table 2.1 presents a summary of the available completion data for each well. During normal operation of the water supply system, the pumping units are operated in pairs. Well No. 2 and Ekxtrom No. 1 operate Monday through Thursday, and Wells No. 1 and No. 5 operate Friday through Sunday. Well No. 4 is used primarily as a backup unit; it is operated manually when demand cannot be met by the pumping scheme described above. Well No. 3 is also operated manually but is rarely used. Pumping is dictated by the water level in the storage tanks at the south end of town. When the water level in the main storage tank reaches a preset level, the two on-line pumps start automatically and continue operating until the water level in the tank reaches the shut-off level. Town maintenance personnel maintain manual override control of all six wells.

Since most of the pumps had not been thoroughly inspected since 1977 and 1978, the Level II investigation included a detailed evaluation of the condition of each well except the rarely used Well No. 3. Sargent Irrigation Co., of Scottsbluff, NE, was contracted to remove the pump and related equipment from each well and thoroughly inspect them for wear or breakage. Table 2.2 summarizes the pump information obtained during this task, including dimensions, capacities, and serial numbers. Since this project was a Level II study, repairs could not be made to the pumps using Water Development Commission funds. However, once the pumps were removed from the wells for inspection, it became cost effective to make simple repairs at this time. Therefore, the Town of Pine Bluffs approved a rehabilitation budget for Sargent to make repairs to the pumps, motors, bearings, shafts, and bushings.

After removal of the pumps, video and geophysical logging were conducted for certain wells. A Laval CAM Model No. 400 Borehole Camera was lowered into the well to record a continuous image of the well annulus or casing on videotape. Information gathered from these videos contributed to the data on Table 2.1. Where appropriate, geophysical logs are included in this report as figures. The video cassettes are on file with the Town of Pine Bluffs and the WWDC.

The inspection program was conducted from the middle of July into early August, which coincides with the annual period of peak water demand. Therefore, the shut down and removal
Table 2.1. Summary of Pine Bluffs Municipal Well Data.

<table>
<thead>
<tr>
<th>Well #</th>
<th>Permit #</th>
<th>Priority Date</th>
<th>Completion Date</th>
<th>Casing (yes/no)</th>
<th>Diameter (inches)</th>
<th>Screen Interval</th>
<th>DTW$^1$ (feet)</th>
<th>DTW$^2$ (feet)</th>
<th>DTW$^3$ (feet)</th>
<th>DTW$^4$ (feet)</th>
<th>Measuring Point Elevation (ft msl)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>P295C</td>
<td>1920</td>
<td>1920</td>
<td>yes</td>
<td>20</td>
<td>open hole$^7$</td>
<td>20$^6$</td>
<td>39.1</td>
<td>40.3</td>
<td>41.1</td>
<td>5045.12</td>
</tr>
<tr>
<td>2$^5$</td>
<td>P124G</td>
<td>1-11-52</td>
<td>9-13-78</td>
<td>no</td>
<td>20</td>
<td>open hole (22' - 122')</td>
<td>39</td>
<td>36.6</td>
<td>44.4</td>
<td>41.7</td>
<td>5033.58</td>
</tr>
<tr>
<td>3</td>
<td>P13171W</td>
<td>12-30-71</td>
<td>1953</td>
<td>yes</td>
<td>18</td>
<td>?</td>
<td>32</td>
<td>84.9</td>
<td>84.2</td>
<td>83.3</td>
<td>5090.74</td>
</tr>
<tr>
<td>4</td>
<td>P13170W</td>
<td>12-30-71</td>
<td>1960</td>
<td>yes</td>
<td>20</td>
<td>open hole (31' - 99')</td>
<td>22</td>
<td>68.9</td>
<td>71.6</td>
<td>68.8</td>
<td>5057.44</td>
</tr>
<tr>
<td>5</td>
<td>P3994W</td>
<td>1-2-70</td>
<td>9-7-73</td>
<td>yes</td>
<td>16</td>
<td>36'-120'</td>
<td>36</td>
<td>33.5</td>
<td>40.0</td>
<td>37.4</td>
<td>5037.05</td>
</tr>
<tr>
<td></td>
<td>EKXTROM</td>
<td>5045.12</td>
<td>NO. 1</td>
<td>P298C</td>
<td>1920</td>
<td>1977</td>
<td>16</td>
<td>24'-97.6'</td>
<td>?</td>
<td>24.9</td>
<td>29.0</td>
</tr>
</tbody>
</table>

Notes

1. Depth to water at time of completion.
2. Depth to water, Summer 1979; Well No. 2 measured Summer 1980; Ekxtrom No. 1 measured Summer 1986.
4. Depth to water, June and July 1995.
5. Well was redrilled and relocated in 1978.
7. Depth to bottom of casing not available.
Table 2.2. Pumping Systems - Pine Bluffs Water Supply.

<table>
<thead>
<tr>
<th>Item</th>
<th>Well No. 1</th>
<th>Well No. 2</th>
<th>Well No. 4</th>
<th>Well No. 5</th>
<th>Well No. 6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Installation Date</td>
<td>1974</td>
<td>1979</td>
<td>1960</td>
<td>1973</td>
<td>1983²</td>
</tr>
<tr>
<td>Make of Motor</td>
<td>General Electric</td>
<td>U.S. Electric</td>
<td>Fairbanks Morse</td>
<td>General Electric</td>
<td>General Electric</td>
</tr>
<tr>
<td>Motor HP</td>
<td>125</td>
<td>40</td>
<td>60</td>
<td>60</td>
<td>75</td>
</tr>
<tr>
<td>Pump Manufacturer</td>
<td>Western Land Roller</td>
<td>Western Land Roller</td>
<td>Fairbanks Morse</td>
<td>Western Land Roller</td>
<td>Fairbanks Morse</td>
</tr>
<tr>
<td>Discharge Outlet</td>
<td>8&quot; Dia.</td>
<td>6&quot; Dia.</td>
<td>8&quot; Dia.</td>
<td>8&quot; Dia.</td>
<td>8&quot; Dia.</td>
</tr>
<tr>
<td>No. of Bowls</td>
<td>5 stages</td>
<td>7 stages</td>
<td>5 stages</td>
<td>6 stages</td>
<td>3 stages</td>
</tr>
<tr>
<td>Impellor Model No.</td>
<td>12B</td>
<td>10 CM</td>
<td>12 MC</td>
<td>10 CH</td>
<td>12M 8.75</td>
</tr>
<tr>
<td>Serial No.</td>
<td>79226</td>
<td>C7911</td>
<td>K2D491</td>
<td>C72775</td>
<td>N3K2815186</td>
</tr>
<tr>
<td>Type of Column</td>
<td>8&quot; Dia. Flange</td>
<td>6&quot; Dia. Flange</td>
<td>8&quot; Dia. Threaded</td>
<td>8&quot; Dia. Flange</td>
<td>8&quot; Dia. Threaded</td>
</tr>
<tr>
<td>Total Column Length</td>
<td>100 ft</td>
<td>110 ft</td>
<td>85 ft</td>
<td>110 ft</td>
<td>70 ft</td>
</tr>
<tr>
<td>Section Lengths</td>
<td>10 @ 10 ft</td>
<td>11 @ 10 ft</td>
<td>7 @ 10 ft, 2 @ 5 ft</td>
<td>11@ 10 ft</td>
<td>7 @ 10 ft</td>
</tr>
<tr>
<td>Intake Length</td>
<td>7.5 ft</td>
<td>4 ft</td>
<td>6 ft</td>
<td>5 ft</td>
<td>8 ft</td>
</tr>
<tr>
<td>Intake Setting³</td>
<td>113 ft</td>
<td>120 ft</td>
<td>90 ft</td>
<td>121 ft</td>
<td>82.3 ft</td>
</tr>
<tr>
<td>Total Depth of Well</td>
<td>116 ft</td>
<td>122 ft</td>
<td>98 ft</td>
<td>128 ft</td>
<td>97.6 ft</td>
</tr>
</tbody>
</table>

Notes

¹Motor replaced August, 1995.
²Pump replaced, 1983.
³Depth below ground surface.
of the pumping units was closely coordinated with the Town to reduce any impact to the quantity of available water.

An additional issue important to the Town water supply is the production capability of the individual wells. Table 2.3 summarizes the adjudicated municipal water rights and the production history of each well. In addition to testing at the time of well completion, “on-line” testing was conducted in 1977 within the supply system. Although accuracy can not be guaranteed, these two periods of testing provide some historical basis for production estimates. In 1994 and 1995, LA conducted aquifer tests at five of the six wells. Well No. 3 was excluded from testing because it could not sustain prolonged discharge. The 1994 testing discussed in the Level I report consisted of short-term step tests. The results of these tests were used to estimate a sustainable yield from the aquifer at each well. Well No. 1 and Ekxtrom No. 1 were selected for more extensive testing during the pump inspection in 1995. An eight-hour step test was followed by an extended constant discharge test at each of the two wells. The tests are described in the following sections, and the results are included on Table 2.3.

2.2 Well Number 1 (Municipal Well)

Well No. 1, also called the Municipal Well, is one of the Town’s oldest wells. It was originally built in 1920 and rehabilitated in 1979. The well has been a dependable producer of water throughout its history. The capacity of the well (approximately 850 gpm) has not changed significantly over time.

2.2.1 Pump Inspection

Maintenance records suggest that the most recent rehabilitation of the well took place in June 1979 when a new set of impellers and bowls were installed. The pump was pulled for inspection on July 24, 1995. A summary of inspection activities follows:

1. A slight amount of play on the shaft for the bowl assembly was observed, suggesting wear of the bearings. Therefore, the bowls were disassembled and inspected, and the bearings were replaced. The impellers were in good condition and not replaced.
Table 2.3. Production History of Pine Bluffs Municipal Wells.

<table>
<thead>
<tr>
<th>Well #</th>
<th>Well Production at Completion UW6 Estimate(^1)</th>
<th>Well Production at Time of Municipal Testing(^2)</th>
<th>Well Production During LA Testing</th>
<th>Adjudicated Water Right</th>
<th>Current Sustainable Yield (gpm)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Year</td>
<td>Discharge (gpm)</td>
<td>Drawdown (feet)</td>
<td>Year</td>
<td>Discharge (gpm)</td>
</tr>
<tr>
<td>1</td>
<td>1947</td>
<td>500</td>
<td>NA</td>
<td>1977</td>
<td>650</td>
</tr>
<tr>
<td>2</td>
<td>1979</td>
<td>430</td>
<td>17</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>3(^5)</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>4</td>
<td>NA</td>
<td>900</td>
<td>57</td>
<td>1977</td>
<td>530</td>
</tr>
<tr>
<td>5</td>
<td>1973(^6)</td>
<td>900</td>
<td>57</td>
<td>1977</td>
<td>425</td>
</tr>
<tr>
<td>EKXTROM NO. 1</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>1995(^3)</td>
<td>975</td>
</tr>
</tbody>
</table>

Totals (excluding Ekxtrom No. 1) | 2,675 | 1,650-2,275 |
Totals (with Ekxtrom No. 1) | 2,706 | 2,650-3,575 |

Actual Production Capacity with Current Adjudication (Adjudication or Production Capacity, Whichever is Less) | 1,081 - 1,256 |

Notes
\(^1\)Estimate based on driller's report on state engineer's completion form. Assumed free orifice flow.
\(^2\)Estimate based on "on-line" testing of well for extended duration.
\(^3\)Estimate based on constant discharge test under free orifice flow.
\(^4\)Estimate based on short-term step test under free orifice flow.
\(^5\)Well data poor. No test was performed because well had minimal production capacity.
\(^6\)Test at time of completion is questionable in accuracy.
\(^7\)Total annual use limited to 49.42 acre-feet to be withdrawn between May 15 and October 15 (153-day average pumping rate of 73 gpm).
2. Three of the column shaft segments were replaced. The shaft sleeve, which is attached to the column shaft, had broken loose. This resulted in the sleeve spinning on the shaft rather than within the rubber spider bushing. As a result, approximately 40% of the shaft had been worn away (Figure 2.1). When this occurs, the resultant vibration typically affects every other shaft segment, eventually causing some kind of failure. The shafts at 20, 40, and 60 feet exhibited significant amounts of wear and were replaced. The remaining shaft segments were tested for "trueness" and found to be within recommended tolerances.

3. The spider bushings showed significant wear and were replaced.

4. When the pump was reinstalled, the ratchet motor drive failed. The manufacturer estimated that replacement parts would take four to six weeks for delivery. Since this was an unacceptable length of time for Well No.1 to remain "off-line," the entire motor was replaced. The manufacturer mistakenly delivered a 125-HP General Electric motor instead of the requested 100-HP motor. Because this was a shipment error, the Town was not required to pay an additional amount for the larger motor, and the 125-HP motor was installed.

5. A large mass of roots was removed from the column (Figure 2.1). Dave Dwinell (Maintenance Supervisor, Town of Pine Bluffs) said that he often caught roots on his measurement probe when checking the water level in the well. These roots are probably not causing a problem with the pump. The elm trees near the well house had recently died, and incursion of new roots into the well annulus should cease.

2.2.2 Borehole Inspection

Well No. 1 has maintained consistent production capability without depletion since its 1979 rehabilitation. Since adequate well completion information is on file with the Wyoming State Engineer, no borehole camera and geophysical logging were conducted at this well.
Wear of Pump No. 1 Shaft.

Roots Removed from Well No. 1.

Figure 2.1 Inspection of Well No. 1
2.2.3 Well Yield and Aquifer Testing

In July 1995, LA performed a two-part aquifer test at the well in conjunction with the pump inspection. Testing consisted of a four-hour step discharge test followed by a 24-hour constant discharge test.

When the existing production pump was taken off site for rehabilitation, a 75-horsepower test pump was installed with the intake set at 105 feet below ground. The discharge line consisted of 20 feet of eight-inch pipe extending to the maintenance shop driveway. Discharged water flowed off the driveway to the municipal storm sewer. The discharge rate was monitored using a totalizing flow meter and regulated by a butterfly valve installed in-line just downstream of the flow meter. The depth to water in the well was measured using an electric well sounder inside of a PVC casing (stilling well) to reduce turbulence and improve reading accuracy.

The step discharge test was conducted to determine the optimum pumping rate for the constant discharge test. The well was pumped at successively higher rates, with each rate maintained until the water table stabilized. At the end of each step, the butterfly valve was opened to permit flow at the next targeted rate. No recovery period was allowed between steps. The test consisted of four steps, each approximately one hour long. Water level readings were made approximately every 30 seconds at the beginning of each step, and the measurement frequency decreased to every five minutes by the end of each step. Figure 2.2 shows the results of the step test as a plot of drawdown versus pumping time. The final step represents the maximum unrestricted flow achievable with the test pump.

The step discharge test also provided data for the calculation of the well’s specific capacity, defined as the discharge produced per unit drawdown. Figure 2.3 shows the average drawdown from each step plotted against the corresponding discharge. From this curve, the specific capacity was calculated at approximately 130 gpm per foot of drawdown.

At the end of the step test, the pump was shut off, and the well was allowed to recover. The constant discharge test was started once the water level had risen to within 90 percent of the initial static water level. Based on the results of the step discharge test, LA targeted a pumping rate of 800 gpm. The test ran for 24 hours. Water level readings were taken every 30 seconds at the start of the test, and by the end of the test the measurement frequency had decreased to every 90 minutes. The long-term average flow rate, calculated by dividing the total discharge by the duration of the test, was 794 gpm.
Figure 2.2. Drawdown in Pumping Well: Step Discharge Test of Well No.1. Pine Bluffs, WY.
Specific Capacity
Well No.1

Figure 2.3. Specific Capacity Diagram for Well No.1.
Pine Bluffs, WY.
Figure 2.4 presents the results of the constant discharge test. After 24 hours of pumping, the total drawdown was approaching ten feet. The data indicate that a steady-state condition had not been achieved. Based on the results of this test, LA calculated an aquifer transmissivity of 77,000 gpd/ft. An observation well was not installed for the test, so a storativity value could not be calculated. Well No. 5, located roughly 1200 feet to the north, was used as an observation well. Pumping of Well No.1 had no discernible impact on this well.

**Yield**

As shown on Table 2.2, the pump intake setting is 113 feet below ground. Immediately prior to aquifer testing, the depth to the static water table was measured at approximately 40 feet. This corresponds to an available saturated thickness of 73 feet.

The calculation of an optimum sustainable yield requires a known transmissivity and storativity. Since LA was unable to calculate a storativity from the aquifer test data, a value of 0.002 was selected from available literature (Crist and Borchert, 1972, and Sibray, 1994). Because water moves through zones of increased secondary permeability, the aquifer behaves like a confined unit even though no overlying confining layer exists. Using the transmissivity calculated from the aquifer test data and assuming that optimum drawdown is 66 percent of the available saturated thickness (in this case 48 feet), LA calculated the optimum sustainable yield for 30 years to be 1300 gpm. Subsequently, LA input this pumping rate into the PLASM model described in detail in Chapter 3. The model employs boundary conditions not included in the assumptions underlying the Theis equations used in the calculation of an optimum sustainable yield (i.e. the model does not assume an aquifer of infinite areal extent). The model, providing recharge from the upgradient portion of the aquifer, predicted a 30-year drawdown less than 48 feet, allowing 1300 gpm to be considered a reasonable estimate of sustainable yield. A critical modeling assumption characterized the regional aquifer system at equilibrium with no new stresses (new wells) added.

There is regional concern for a declining water table in Laramie County, particularly in the vicinity of Pine Bluffs. The decrease in saturated thickness and the lowering of the water table below significant water producing fractures could result in a decline in well production capabilities. Contrary to this theory, however, the data from Well No.1 (Tables 2.1 and 2.3) suggest that the water production capability of this well may have either increased or remained nearly the same over the period of regional water table decline. Nonetheless, and in keeping with the local concern for the Brule Aquifer, a more conservative optimum sustainable safe yield for Well No.1 (700 to 1000 gpm) is recommended (Table 2.3).
Figure 2.4. Drawdown in Pumping Well: Constant Discharge Test of Well No.1. Pine Bluffs, WY.
2.2.4 Conclusion/Recommendations

The production capability of Well No.1 has not declined over the period of record. Although a conservative estimate of optimum sustainable yield suggests that it is an excellent producing well, its adjudicated water right (Table 2.3) is relatively poor. An enlargement application is on file with the State Board of Control; if approved it will balance this condition. Based on the production capability of this well, one can assume that the borehole has maintained its overall integrity. The tree roots found during the borehole investigation do not seem to impact well production. Although not directly part of this investigation, the Town has periodically collected water quality samples from all of their municipal wells. Well No.1 seems to maintain the best water quality and is characterized by the lowest levels of nitrate.

The inspection of the pumping equipment indicated some wear had taken place since the 1979 pump rehabilitation program. All worn components were replaced. The motor failed following pump installation, and a new motor was purchased and installed. The pump impellers and bowls were in good condition, considering their 16 year life. The good condition can be attributed, in large part, to the lack of sand being pumped from the siltstone aquifer. Therefore, it is more likely that equipment would need to be replaced due to factors such as general deterioration, rust, and mechanical failure.

It is recommended that the Town conduct a thorough maintenance inspection for Well No.1 every ten to fifteen years. The pump should be pulled and inspected to determine if any component is in need of replacement. This frequency should be sufficient to monitor normal wear and deterioration of the bowl assembly, shafts and columns, and connections. Power consumption and production rates should continue to be monitored.

2.3 Well Number 2

A new pumping unit was installed at Well No. 2 in 1979. Records from the Town suggest that this pump has historically produced between 400 and 450 gpm. Based on the 1994 tests, the aquifer can produce a sustainable discharge of 600 to 750 gpm. Currently, the well pumps approximately 350 gpm against the system pressure head. The components of the pumping unit include a Western Land Roller Pump with a 40-HP motor (Table 2.2).
2.3.1 Pump Inspection

The pump was pulled on July 19, 1995 for inspection. The equipment was in generally good condition. Specific observations include:

1. There was slight play in the bowl shaft, indicating the bearings for the bowl assembly were in good condition.

2. The impellers and bowls showed no pitting, and no unusual wear was noted. The bolts for bowl assembly, however, were quite corroded and exhibited signs of abrasion. Therefore, the bowl assembly was disassembled and inspected, and the bolts were replaced.

3. The motor headshaft was worn at the packing gland. A new headshaft was installed when the pump was reinstalled.

4. The pump column exhibited deterioration, and all column nuts and bolts were replaced.

5. The pump shaft and spider bushings were in good condition.

2.3.2 Borehole Inspection

A video recording of the subsurface condition of Well No.2 is on file with the WWDC and the Town of Pine Bluffs. Based on the borehole camera evaluation of this well, the surface casing is in good condition and extends from the surface to a depth of 22 feet below the surface. Below the surface casing, the well is an open borehole completed in Brule Formation to a total depth of 122 feet. The well was originally completed in 1978 to a depth of 125 feet, indicating a loss of three feet in 17 years. Current static water level (August 1995) was measured at 41.7 feet.

Unlike most of the higher yielding wells completed in the Brule, Well No.2 does not penetrate any significant lengths of fractures. Intensive fractures were encountered above the static water level between the depths of 22 and 30 feet. Below the water table, minor fracturing was found within the interval from 49 to 58 feet, and extensive fracturing was found from 58 to 65 feet. Below 65 feet, there were very few fractures.
The video shows "skid marks" on the annular wall at several locations. These marks were interpreted as abrasion related to movement of the column flanges and bowls against the uncased annular wall. During the inspection of the pump column, excessive deterioration of the nuts and bolts for the bowl assembly (compared with the other wells) was identified. It is possible that this wear may have resulted from the movement of the column against the relatively narrow annular wall.

Geophysical logging of the well (Figure 2.5) provided information on the borehole diameter (caliper) and the homogeneity of the formation intercepted by this borehole (gamma and resistivity). Below the surface casing, the diameter of the well annulus gradually decreases with depth from 20 inches to 15 inches. A limited loss of annular wall occurs between the water table and the pumping level, specifically the interval from 40 to 56 feet. Comparison of the gamma and the resistivity logs suggests that there are minor sedimentologic variations in the Brule.

2.3.3 Conclusion/Recommendations

Well No. 2 is in good condition, and only minor repairs to the pumping equipment were required. Short-term step testing of this well was conducted in 1994 by Lidstone & Anderson, Inc. (AVI, 1994). Based on this evaluation, the current production capacity may range from 600 to 750 gpm. Based on flow records maintained by the Town, however, the well delivers approximately 350 gpm under existing system conditions. If municipal demand or an alternative operating schedule requires that additional yield must be delivered, the pump should be upgraded and/or changes made to system operation. Currently, Well No. 2 is operated with the Ekxtrom Well, and system pressures created by the Ekxtrom Well pump may dominate or work against the Well No. 2 pump.

This well has typically exhibited the highest nitrate concentrations within the Pine Bluffs municipal well field. Therefore, an enlargement of this water right was not proposed during the Level I study. For the same reason, neither pump replacement nor pump upgrades are proposed as part of the Level II study.

The deterioration of the pump column and bolts for the bowl assembly were identified as a major concern. While maintaining the same pump equipment, the rate of deterioration could be reduced by reentering the hole and reaming the existing annulus. Similarly, smaller pump bowls and pump column could be set into the well; this would result in some loss in production capability. A more cost-effective solution and the Level II recommendation, is to increase the frequency of pump inspection and component replacement to every ten years.
Figure 25.
Geophysical Log of Well No.2.
2.4 Well Number 4

Yield from Well No. 4 has decreased since it was installed in 1960. Records show that this well historically delivered flows of 500 gpm, but at the time of the Level I study, yields were measured at approximately 275 gpm. Because of this, the Town has had to restrict the amount of water that the pump can deliver by placing a regulating valve on the water line. Well No. 4 is operated manually to augment peak demand flows. It is a particularly important well over the long-term since it consistently exhibits low nitrate concentrations compared to the other Pine Bluffs municipal wells.

2.4.1 Pump Inspection

The pump was pulled for inspection on July 17, 1995. The pump is a Fairbanks Morse Pump with a 40-HP motor (Table 2.2). Results of the inspection of the pump and disassembly of the column (Figure 2.6) follow:

1. Play in the bowl shaft indicated potential wear of the bearings, and the bowl assembly was disassembled and thoroughly inspected. The condition of the bowl shaft and bearings did not warrant replacement.

2. The impellers were showing some signs of pitting. Considering the unit has been in use for 35 years, this type of wear was expected. Had this been one of the Town's main production wells, replacement of the impellers or bowl assembly may have been justified. However, because the primary problem associated with this well is not the pump but the aquifer/borehole, these items were not replaced. New bolts were installed when the bowl stages were reassembled.

3. The spider bushings in the pump column showed a significant amount of deterioration and were replaced with new rubber bushings. In addition, a new ten-foot section of column and shaft was installed in the well to replace a worn five-foot section. This lowered the intake five feet to a total depth of 95 feet. Based on 1994 pump test data, a pump setting at 95 feet is more suitable to the pumping level of the aquifer. The intake screen had also deteriorated and was replaced.
Disassembly and Inspection of Pump Column.

Inspection of Bowl Assembly.

Figure 2.6. Inspection of Pump Components at Well No. 4.
2.4.2 Borehole Inspection

A video recording of the subsurface condition of Well No.4 was made and is on file with the WWDC and the Town. Based on the borehole camera evaluation of this well, the 20-inch diameter welded steel surface casing is in relatively good condition with surficial rust. The casing extends from the surface to a depth of 30.7 feet. Below the surface casing, the well is an open borehole completed in Brule Formation siltstone to a total depth of 99 feet. The original well was completed to a depth of 130 feet in 1960, so there has been a loss of 31 feet in 35 years. Current static water level (August 1995) was measured at 67.4 feet.

The open portion of the borehole penetrates three highly-fractured zones. One fractured zone was found above the water table between the depths of 58 and 67 feet. Below the water table, extensive fracturing was found from 68 to 78 feet. Minor fractures, increasing in frequency with depth, were found between 90 and 95 feet. A large cavity found between the depths of 55 and 75 feet is identified on the caliper log (Figure 2.7). At this location the diameter of the well annulus increases from 18 to 30 inches. The material generated from this cavity roughly accounts for the loss of the lower 30 feet of borehole.

Aside from the caliper log, geophysical logging of the well primarily shows that the intercepted formation is a fairly homogeneous siltstone. Comparison of the gamma log and the resistivity (Figure 2.7) suggests that there are some minor sedimentologic variations in the Brule characteristics.

Water quality testing was conducted in an attempt to evaluate the well's loss of production capacity. The testing program included a 10-hour micro-particulate analysis (MPA) designed to evaluate the concentration of fine to very fine sediment, iron bacteria, and amorphous debris moving through the formation and entering the well. This material could be responsible for "plugging" fractures within the aquifer. In addition to this analysis, a water quality sample was analyzed for major anions/cations and metals. Data from both analyses are included in Appendix A.

The MPA analysis showed that there were no organic contaminants and only rare iron bacteria. The centrifugate collected from this sample averaged 0.1 ml of amorphous debris per 100 gallons of water produced. The amorphous debris was entirely inorganic silica, ranging in diameter from one to 200 μM. These data suggest that there is very limited movement of fine clays and sediment within the aquifer and that it is not likely that fine clays are sealing the
City of Pine Bluffs
Well #4
Lyn Wagner – Sargent Irrigation
July 18, 1995

Figure 2.7. Geophysical Log of Well No. 4.
fractures within the Brule. The water quality chemical analysis characterizes the Brule waters as relatively hard calcium-magnesium bicarbonate waters. The equilibrium chemistry of these waters was modeled using the USGS computer model WATEQ. The results of this analysis suggest that the Brule waters are oversaturated in bicarbonate and that precipitation of carbonate minerals could affect the permeability of the fractures.

2.4.3 Conclusion/Recommendations

The bowls and impellers of Well No. 4 showed the most deterioration of all the pumps inspected. However, the equipment is still in satisfactory condition. Because this well is not used as part of the Town's normal operating sequence, the condition of the equipment is adequate as a "back-up" system.

Historical data suggest that there has been a 35% loss in production since 1977 (Table 2.3). Only one significant fracture zone was identified below the water table. The slight increase in fractures near the bottom of the well, the defined loss of 30 feet of well depth due to collapse of the borehole, and the loss of production suggest that an additional production zone may exist below the 99 foot level. The collapse of the annular wall and the accumulation of debris at the bottom of the well may be limiting production from this lower producing zone.

Well No.4 has an adjudicated water right of 850 gpm and has shown some of the lowest nitrate concentrations within the Pine Bluffs municipal system. In 1977, this well could produce 530 gpm with only 5.5 feet of drawdown (Table 2.3). Production capabilities have decreased below 350 gpm. Because of the value of this well (adjudication and water quality), Lidstone & Anderson, Inc. recommends that the Town rehabilitate this well. Rehabilitation would require reentrance into the Well No. 4 surface casing and reboring the well to 135 feet. To prevent continued loss of the borehole, a liner of a smaller diameter (16 inches) well casing (Schedule 40 steel) and stainless steel screen (minimum .050 slot) should be installed into the borehole. An extremely coarse filter pack should be tremmied into the annular space between the well screen and the wall.

2.5 Well Number 5

Well No. 5 was constructed in 1973 and has also experienced a reduction in yield over time. Records from the Town show that this well has produced sustained flows between 400 and
450 gpm, whereas the existing yield is approximately 150 gpm. Because of this loss of capacity, the Town has had to restrict the amount of water delivered by the pump.

2.5.1 Pump Inspection

The pump was pulled for inspection on July 18, 1995. The pump is a Western Land Roller Pump with a 60-HP motor (Table 2.2), and the general condition of the equipment is good. Specific observations and actions are discussed below:

1. There was only slight play on the bowl shaft, and it is assumed that the bearings for the bowl assembly are in good condition.

2. There was only minor pitting with no unusual wear on the impellers.

3. The pump column, shaft, and spider bushings all appeared to be in good condition.

4. The only items replaced at this well were the packing gland, column nuts, and bolts.

2.5.2 Borehole Inspection

A video recording of the subsurface condition of Well No.5 was made and is on file with the WWDC and the Town of Pine Bluffs. Unlike the previously discussed wells, Well No. 5 is fully cased and screened. Based on the borehole camera evaluation of this well, the 18-inch diameter riveted, galvanized (12 gage) steel surface casing is in acceptable condition. There is a slight "egg shape" stress feature at a depth of 23.9 feet that was not determined to be a problem. The casing extends from the surface to a depth of approximately 35.4 feet. A smaller diameter (16 inches) well screen extends from 35.4 to 112.8 feet below the surface. Blank casing continues from 112.8 to 124.8 feet, and a 5-foot section of screen completes the well to a depth of 128.8 feet. A separation of the well casing was identified at a depth of 55.4 feet. Considering the "clean break" at a casing joint, the casing separation appears to have occurred during the well completion. Because of this rupture and/or in conjunction with the deviation of the original borehole, the casing interval from 55 to 87 feet and 88 to 128 is bowed and poorly aligned. A qualitative evaluation suggests that since the 1973 well completion, the well screen
has lost 25% of its open area to sedimentation and/or accumulation of rust and precipitate. It is also worth noting that some of the information reported on the UW6 form is inaccurate; it indicates a total depth of 120 feet with a single screened interval, from 36 to 120 feet. In addition, the stated drawdown (UW6) during testing exceeded the depth of the pump setting by 19 feet. The current static water level (August 1995) was measured at 38 feet.

A geophysical log was not completed for Well No. 5. In an attempt to evaluate the loss of production, water quality testing of Well No. 5 was conducted. The testing program was similar to that completed for Well No. 4. It included an 10-hour micro-particulate analysis (MPA) designed to evaluate the concentration of fine to very fine sediment, iron bacteria, and amorphous debris moving through the formation and entering the well. In addition to this analysis, a chemical water quality sample was collected and analyzed for major anions/cations and metals. Data from both analyses are included in Appendix A.

The MPA analysis indicated that there were no (or very minor) organic contaminants and only rare iron bacteria. The centrifugate collected from this sample averaged 0.005 ml of amorphous debris per 100 gallons of water produced. This concentration is two orders of magnitude less than that measured in the sample from Well No. 4. Figure 2.8 presents comparative photomicrographs of the two samples. Assuming that the formation yields the same concentration of fine sediment at each well, some type of flow restriction is most likely to account for the difference in the centrifugate concentration between the No. 4 Well (0.1 ml/100 gallons) and the No. 5 Well (0.005 ml/100 gallons). An evaluation of the available well completion data showed that a gravel pack was not installed around the well screen. In Well No. 4, a portion the annular wall failed, and the resultant collapse caused a loss of 30 feet of well. Should a similar event occur in a screened, unpacked well, the siltstone would block the well screen.

Water quality data characterize the Brule waters from Well Nos. 4 and 5 as relatively hard, oversaturated in bicarbonate. Seasonal changes in chemistry or oxidation due to pumping may precipitate carbonate minerals and decrease the permeability of the fractures or, in the case of Well No. 5, the screen. It is possible that significantly more than 25% of the open area of the well screen is lost.
100x Silica, Silt and Sand and Inorganic Precipitate from Well No. 4
(Concentration - 0.1 ml/100 gallons)

100x Amorphous Debris from Well No. 5
(Concentration - 0.005 ml/100 gallons)

Figure 2.8. Photographs of Particulates in Well Nos. 4 and 5 Following 10 Hours of Pumping.
2.5.3 Conclusions/Recommendations

As described in the previous paragraphs, the pumping equipment in Well No. 5 is in good condition, but the well casing and the well screen are in poor condition. Historical data suggest that there has been a 50% loss in production since 1977, when the well could produce 425 gpm with 26 feet of drawdown (Table 2.3). Currently it produces 225 gpm with 72 feet of drawdown. This well was originally installed in 1973 and appears to have been damaged during the original completion. During the 1995 well investigation, a separation of the casing was found at a depth of 55.4 feet, and most of the casing was out of alignment. Although this condition would not necessarily preclude well yield, it does suggest potentially poor well completion. Completion problems such as the failure to place a gravel pack to maintain the annular wall may be associated with this loss of well production. The noted loss of open area in the well screen will also affect well yield.

Because of its relatively low yield, this well is not critical in the Pine Bluffs municipal system. It is, however, strategically located along the proposed transmission line discussed in Chapter 4. Unfortunately, the well is also characterized by higher levels of nitrates and is close to the fertilizer plant; it may be susceptible to contamination.

Because of its good adjudicated water right (750 gpm) and the convenience of its location with respect to the proposed transmission line, Lidstone & Anderson, Inc. recommends that the Town abandon the current damaged well and construct a new, replacement well adjacent to it. Before the actual construction of a replacement for Well No.5, the Town should drill exploratory holes in the general area of the well and investigate subsurface conditions. It is anticipated that the final well completion will be similar to the other town wells, with a total depth of approximately 120 feet deep. Based on the loss of depth that has occurred in other wells, a cased and screened well is recommended. The final completion should include a minimum of 50 feet of coarse (.050 slot) screen, and a very coarse filter pack should be tremmied into the annular space between the well screen and the annular wall. Similarly, a pre-fabricated completion (pre-gravel packed) may be appropriate at the relocated Well No. 5 site.

2.6 Ekstrom No. 1 (Well No. 6)

The Ekstrom No. 1 Well, also called Well No. 6, was originally constructed by hand excavation in approximately 1920. Over the years it has been reconstructed and deepened to its
current depth of 98 feet. In 1983, a new motor and bowl assembly were installed. The components for this pumping unit include a Fairbanks Morse Pump with a 75-HP motor.

2.6.1 Pump Inspection

The pump was pulled for inspection on August 6, 1995. It should be noted that when the pump was removed from the well, the impeller data plate contained different information than the discharge head data plate. Table 2.1 lists the information collected from the impeller data plate. Based on the inspection, the majority of the pumping equipment was in good condition. Specific observations and actions are listed below:

1. The impellers and bowls exhibited few signs of pitting, and no unusual wear was noted. There was very little play in the bowl shaft, suggesting the bearings were in good condition.

2. The spider bushings were inspected, and no abnormal wear or excessive deterioration was noted.

3. The intake screen had deteriorated and was replaced. A new intake pipe was also installed (8-inch diameter, 4.5 feet in length). No other parts were replaced.

2.6.2 Borehole Inspection

A video recording of the subsurface condition of the Ekxtrom No. 1 well was made and is on file with the WWDC and the Town of Pine Bluffs. Based on this borehole camera evaluation, the 16-inch diameter welded steel surface casing is in good condition with normal surficial rust above the water table. Blank casing extends to a depth of 22.7 feet, below which the casing is punch-perforated to the total depth of the well (97.6 feet). The perforated casing was installed in 20 foot lengths with welded joints. Some encrustation was visible below 58 feet, but the surface area loss of the affected screen was minimal. Overall, the well appeared to be in relatively good condition with the majority of the perforations remaining open.
2.6.3 Well Yield and Aquifer Testing

Aquifer testing at Ekxtrom No.1 was conducted in August 1995. LA conducted an eight-hour step discharge test followed by a 48-hour constant discharge test.

Similar to the testing of Well No. 1, the production pump was replaced by a 75-HP test pump. The intake was set approximately 85 feet below ground. Water was pumped through an eight-inch pipe and discharged into a field approximately 250 feet to the north. The discharge rate, regulated by a butterfly valve, was measured by an in-line, totalizing gallon meter. Changes in the water level in the well were monitored both electronically and by hand. Hand measurements were made using an electronic well sounder. The measuring point was the top of a stilling well installed to reduce pumping-related turbulence. An electronic water level record was compiled by a Hermit SE1000B data logger attached to a 250 psi pressure transducer.

An observation well was completed to a depth of 143 feet at a location approximately 80 feet to the east-northeast. Water level changes were monitored in the same manner as in the pumping well. The pressure transducer was connected to the data logger in the well house, and the measuring point for the hand readings was the top of the protective steel casing.

A step discharge test was conducted to determine the optimum pumping rate for the constant discharge test and to provide information on the specific capacity of the well. The well was pumped at successively higher rates, with each rate maintained until the water table stabilized. At the end of each step, the butterfly valve was opened to permit flow at the next targeted rate. No recovery period was allowed between steps. In all, the test consisted of five steps, each approximately two hours long. The data logger made readings on a logarithmic scale. Water level readings were made by hand approximately every 30 seconds at the beginning of each step, and the measurement frequency decreased to every ten minutes by the end of each step. Figure 2.9 displays the results of the step test as a plot of drawdown in the pumping well versus pumping time. The hand measurements are in close agreement with the transducer data. The discharge rate for each step is plotted above the corresponding data. The final step represents the maximum unrestricted flow achievable with the test pump. Pumping during the step test did not produce a measurable impact in the observation well. Figure 2.10 presents a specific capacity curve for the Ekxtrom well.
Figure 2.9. Drawdown in Pumping Well: Step Discharge Test of Ekxtrom No.1 Well.
Pine Bluffs, WY.
Specific Capacity
Ekxtrom No.1 Well

Figure 2.10. Specific Capacity Diagram for Ekxtrom No.1 Well.
Pine Bluffs, WY.
After termination of the step test, the well was allowed to recover overnight. The residual drawdown after recovery was less than one percent of the total drawdown during the step test. LA targeted a pumping rate of 1000 gpm and started what was to be a 48-hour constant discharge test. After approximately seven hours, a power failure at the well house interrupted pumping. The power outage lasted one hour, during which time the well recovered to within four percent of static. LA elected to restart the test without additional recovery time, and pumping followed for an additional 40 hours. Water level measurements were collected on a schedule similar to that used for the step test. By the end of the test, hand measurements were being made every four hours. The restart was treated as a new test for data collection scheduling. The long-term average flow rate for the test was 975 gpm.

Figures 2.11 and 2.12 present the results of the constant discharge test after the restart. Figure 2.11 represents the transducer data for the pumping well, and Figure 2.12 includes the transducer data for the observation well. As with the step test data, the hand measurements are in close agreement with the transducer data. An anomaly is evident in the curve at approximately 120 minutes. While monitoring the flow rate, discharge had apparently increased slightly because of the pump restarting. The high point in the curve represents an aborted effort at reproducing the original discharge rate. Unfortunately, the butterfly valve did not allow enough control to make such a sensitive change, and a minor adjustment resulted in a significant decrease in flow. At the end of the test, drawdown in the pumping well was approaching 10 feet.

Pumping first appears to influence the observation well approximately seven hours into the restarted test. No impact was visible during the eight hours of pumping prior to the power failure. At the end of the test, total drawdown in the observation well was less than one foot, and the data indicate a steady-state condition had not been achieved. The evidence suggests that the observation well was not hydraulically connected to the primary production zone intersected by the pumping well.

LA calculated two separate transmissivity values from the data. The transmissivity of the producing aquifer was calculated at 476,000 gpd/ft. A second transmissivity was derived from the observation data, but the calculation of a corresponding storativity indicated that the value was unreliable. The storativity was greater than one, which suggests that the transmissivity value used in the calculation was several orders of magnitude too large. Since water is primarily produced from fractures within the Brule Aquifer and the average discharge rate during testing was used in the calculation of aquifer parameters, this discharge and the resultant aquifer parameters are not representative of the unfractured aquifer that separates the pumping well from the observation well.
Figure 2.11. Drawdown in Pumping Well: Constant Discharge Test of Ekxtrom No.1 Well
Pine Bluffs, WY
Figure 2.12. Drawdown in Observation Well: Constant Discharge Test of Ekxtrom No. 1 Well. Pine Bluffs, WY.
The static water level immediately prior to testing of the Ekxtrom No. 1 Well was approximately 30 feet below ground. With a pump intake depth of 82.5 feet (Table 2.1), this corresponds to an effective saturated thickness of over 50 feet.

LA attempted to calculate the optimum sustainable yield using a storativity of 0.002 and the transmissivity calculated from the pumping well data. However, the pumping rate required to achieve drawdown of 35 feet (66 percent of the saturated thickness) within 30 years was greater than 2500 gpm. Given the conflicting transmissivity values calculated from the pumping well and observation well data, LA then elected to calculate a conservative optimum sustainable yield using a transmissivity of 80,000 gpd/ft, the value derived from the testing of Well No. 1. As discussed in Section 2.2.3, concern over a decline in the water table has led LA to recommend a conservative value for the long-term sustainable yield (1,000-1,300 gpm).

2.6.4 Conclusions/Recommendations

The Ekxtrom pumping equipment has been in place for approximately 13 years. The impeller, bowls, shaft and column are all in good condition. When the pump was installed, it was intended to deliver approximately 1000 gpm to the distribution system. However, it appears the existing pump is slightly undersized to accomplish this. A larger pumping unit, capable of pumping in the range of 1200 gpm, could be installed if water rights modifications are approved. All of the aquifer tests conducted for this well indicate that the optimum sustainable yield for this well is on the order of 1150 gpm.

The primary action to be taken regarding this well is the enlargement of its currently limited adjudicated water right. As discussed in the Level I report, an enlargement of the Ekxtrom Well through a change in place-of-use of the water right from an "undrilled well" (Well No. 6) has been recommended. Physically, the Ekxtrom Well has the potential for long-term service as a primary production well in the system. Current water rights are a limiting factor.
III. GROUND WATER MODELING OF EXISTING MUNICIPAL SYSTEM

3.1 Objective of Ground Water Model

The pump testing performed during 1994 and 1995 provided well-by-well information regarding the aquifer's response to pumping. To evaluate the regional impact of the municipal production system, it is necessary to estimate the cumulative effect of pumping the Town's entire well system at different potential production rates. One must recognize that there are a number of outlying non-municipal and high-production irrigation wells, which have a regional impact on the same aquifer. Inadequate data are available to properly model these wells, and no attempt was made to perform such an analysis. LA used the Prickett Lonnquist Aquifer Simulation Model (PLASM) to estimate the response of the Brule Formation aquifer to pumping of the six Pine Bluffs municipal wells. The objective of the modeling effort was to identify the cone of depression at 20 years into the future, assuming no new stresses beyond those produced by the Town wells will occur. Since the modeled area is a Control District, this assumption appears valid.

3.2 Description of Ground Water Model

PLASM is a 2-dimensional, finite difference, ground water model. The aquifer system is represented by a variably spaced 2-dimensional grid, with 40 columns and 40 rows, oriented north-south and east-west. The entire model grid (Sheet 1) represents an area of 26.5 miles by 26.5 miles, centered approximately on the Town of Pine Bluffs well field. A detailed portion of the grid in the vicinity of the Pine Bluffs municipal well field is shown on Figure 3.1.

Input required for the PLASM model includes values for transmissivity (gpd/ft), storage factor (g/ft), pump rates (gpd), initial and boundary conditions. Transmissivity is a measure of the ease with which water flows through the aquifer formation. The volume of water stored in a given volume of the aquifer material is represented by the dimensionless storage coefficient. The storage coefficient (dimensionless) is converted to the PLASM storage factor (g/ft) for model input. Ground water wells are identified and included in the model by assigning a pump rate (g/d) at the representative model node. For each well, a maximum of twelve changes in pumping rate is allowed in the PLASM model. Initial conditions are specified as starting water levels at each node. The model boundary conditions are classified as either recharge or impermeable boundaries. Unless specified as a recharge boundary in the model, PLASM treats the edges of the model grid as impermeable boundaries. The model results are the water balance and drawdown at each node for each time step of the model.
Figure 3.1
Portion of 2-Dimensional Plasm Model Grid.
3.3 Hydrogeology and Aquifer Properties of the Brule Aquifer

The six municipal ground water wells are completed in the Brule Formation, a fractured siltstone. The unfractured portion of the siltstone aquifer is fairly homogeneous with a relatively low permeability. The fracture system within the formation is very permeable and can transmit large volumes of water to relatively high-production water wells. Being a function of the density and continuity of fractures, and the secondary porosity created by these fractures, water yield to wells and the associated drawdown can be highly variable. The fracture system of the aquifer results in nonhomogeneous, anisotropic conditions; permeability and hydraulic conductivity are highly variable in three directions (x, y, and z). Insufficient information is available to fully characterize the degree of nonhomogeneity or anisotropy on a regional scale.

Transmissivity (the product of hydraulic conductivity and saturated thickness) values were determined by LA based on 1994 and 1995 pump test data as discussed in Chapter 2. The calculated transmissivity value for Well No. 1 was 77,000 gpd/ft. A transmissivity value of 476,000 gpd/ft was determined from Ekxtrom well pump test data.

The relatively high pumping rates sustained by Well No. 1 and the Ekxtrom Well during the constant discharge tests suggest that the wells intercept part of the fracture system of the Brule. The transmissivity values were estimated based on pumping of water from both the fracture system and the parent material. Thus the range of values generated from the pump test evaluations represent effective transmissivities and characterize the overall aquifer hydraulics at the location of the wells.

The volume of water, in gallons, dewatered from the aquifer for each one foot of drawdown is represented in the PLASM model by the storage factor. The storage factor is determined by the equation:

\[ SF = (S) \times (X \times Y) \times (7.481), \]

where

- SF is the PLASM storage factor (g/ft)
- S is the aquifer storage coefficient (dimensionless)
- \((X \times Y)\) is the area of the model grid represented by a node (sf), and
- 7.481 (gal/cf) is a conversion factor.

As discussed in Sections 2.2 and 2.6, insufficient data were available from the pump tests to estimate the aquifer storage coefficient. Therefore, the storage coefficient was determined
from the available literature for the Brule Formation. Crist and Borchert (1972) estimated a $S$ value of $1.0 \times 10^3$ to $3.0 \times 10^3$ for the Brule Formation. Sibray (1994) determined an $S$ value of $3.0 \times 10^3$ based on a 3-dimensional MODFLOW calibration to numerous observation well data. A storage coefficient of $2.0 \times 10^{-3}$ was assumed for the PLASM model.

Recharge by regional ground water flow into the model area was defined based on 1971 isopotentiometric surface mapping by Crist and Borchert (1972). Regional ground water flow is from west to east with an approximate isopotentiometric surface gradient of 30 ft/mile from the western model boundary to approximately 2 miles west of Pine Bluffs. The gradient flattens to approximately 15 ft/mile from 2 miles west of Town to the state line. Isopotentiometric surface mapping was not available east of the state line. In the PLASM model this regional ground water flow was defined as a constant head recharge boundary along the western edge of the grid. Recharge to the aquifer from infiltration of precipitation could not be modeled due to lack of information for calibration as well as the limitations of the PLASM model.

Average annual pumping rates were used in the model to estimate the long-term response of the aquifer to pumping of the municipal wells. Due to a PLASM model limitation on the number of allowable changes in pumping rates for each well, it was impractical to model seasonal variations for the period considered. This model reflects pumping for two 20-year periods, or a total of forty years. During the first 20-year period, modeled wells are pumped at the existing average annual consumptive use rate. A total average annual pumping rate of 253 gpm was calculated from well production records for the six municipal wells during the period from January 1990 to August 1995. This value represents existing conditions. The second 20-year period reflects pumping at the predicted average annual rate. As discussed in the Level I report, the predicted average annual demand in the year 2030 is estimated to be 371 gpm. This value represents future conditions, and the increased demand was distributed proportionately among all six wells. For the future conditions, Well No. 3 is assumed to have been abandoned with the water right transferred to Well No. 1. The model also assumes that the Ekstrom Well can be pumped at the rate required by municipal demand. A summary of existing and predicted average annual pumping rates is shown in Table 3.1.

A final required input to the PLASM model is the initial water surface within the aquifer. The water table was entered into the model as a flat surface. This corresponds to "simplified" aquifer conditions prior to any pumping in the vicinity. Pumping of the municipal wells at the existing rate for 20 years resulted in relatively stable water table levels. These water levels are assumed to represent the water table as it would exist if created by stresses from the municipal wells alone. This provided the initial condition for the twenty-year period of pumping at the predicted demand.
Table 3.1. Summary of Existing and Predicted Average Annual Pumping Rates.

<table>
<thead>
<tr>
<th>Municipal Well No.</th>
<th>PLASM Node (column, row)</th>
<th>Average Annual Pump Rates (gpm)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Existing Demand (1990-95)</td>
</tr>
<tr>
<td>1</td>
<td>19,19</td>
<td>95</td>
</tr>
<tr>
<td>2</td>
<td>23,17</td>
<td>50</td>
</tr>
<tr>
<td>3</td>
<td>19,21</td>
<td>5</td>
</tr>
<tr>
<td>4</td>
<td>23,20</td>
<td>9</td>
</tr>
<tr>
<td>5</td>
<td>19,17</td>
<td>31</td>
</tr>
<tr>
<td>Ekxtrom (Well No.6)</td>
<td>16,17</td>
<td>63</td>
</tr>
</tbody>
</table>
3.4 Calibration

The drawdown data collected during the pump testing of Well No. 1 and the Ekxtrom Well were used individually to calibrate the value of transmissivity in the PLASM model. Calibration runs were conducted using the individual pump rates employed during the tests. The PLASM model output was used to generate drawdown hydrographs for a range of effective transmissivity values. The hydrographs were then compared with the actual pump test drawdown data for the two wells, and a determination of the "best fit" was made. The selected effective transmissivity values were 65,000 and 80,000 gpd/ft for Well No. 1 and the Ekxtrom Well, respectively.

To ensure adequate representation of actual field conditions, the PLASM model was run for 20 years with an effective transmissivity of 80,000 gpd/ft, an assumed storage coefficient of $2.0 \times 10^{-3}$, and pumping rates reflective of the existing average annual rates for each of the six municipal wells (Table 3.1). The predicted 20-year drawdown at the six wells ranged from 3.5 to 4.4 feet, with an average of 3.9 feet. These values were compared to the static water levels measured in 1979 and 1995 for the six municipal wells, which indicated a net drawdown ranging from -1.6 to 5.1 feet with an average of 2.4 feet (Table 2.1). The measured drawdown in the Ekxtrom Well for this period was 5.1 feet, which compares favorably with the predicted drawdown of 3.9 feet. The measured drawdown in Well No. 1 was 2.0 feet, less than the 4.4 feet predicted by the model. The overall agreement of measured and predicted drawdowns supports the selection of an effective transmissivity of 80,000 gpd/ft for the predictive PLASM models. Since the measured drawdown levels include the response to stresses from pumping of irrigation wells, which are not included in the model, the selected hydraulic parameters can be considered conservative estimates.

The ground water level hydrographs maintained by the USGS and Wyoming SE~ near Pine Bluffs were reviewed to identify trends associated with pumping of the municipal wells. A summary of the observation well hydrographs and corresponding periods of record is shown in Table 3.2. The drawdown behavior shown on the hydrographs is influenced primarily by irrigation pumping. The greatest net drawdowns occur as discrete spikes during the summer irrigation months. The ground water levels then recover to a maximum value immediately before the next irrigation season. Municipal water supply demand would be expected to be relatively constant through the year, with increases or declines in the water surface over time related to changes in population and corresponding demand. The population of Pine Bluffs has increased from about 940 in 1970 to 1100 in 1994, or a 17 percent increase in population (AVI, 1994), but the ground water level hydrographs do not suggest regional trends of a continuous
Table 3.2 Summary of USGS and Wyoming SEO Ground-Water Level Monitoring Well Information.

<table>
<thead>
<tr>
<th>Well Number</th>
<th>Well Depth (ft below ground)</th>
<th>Period of Record (year)</th>
<th>Water Levels</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Highest Level (ft)</td>
<td>Lowest Level (ft)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>mo-yr</td>
<td>mo-yr</td>
</tr>
<tr>
<td>13-60-05 ccb01</td>
<td>100</td>
<td>1969-93</td>
<td>34.18</td>
<td>05-84</td>
</tr>
<tr>
<td>13-60-20 bbc01</td>
<td>110</td>
<td>1946, 1970-81</td>
<td>28.67</td>
<td>05-73</td>
</tr>
<tr>
<td>14-60-05 bcb01</td>
<td>98</td>
<td>1957-93</td>
<td>28.96</td>
<td>04-85</td>
</tr>
<tr>
<td>14-60-10 dbb01</td>
<td>80</td>
<td>1973-85</td>
<td>15.56</td>
<td>06-84</td>
</tr>
<tr>
<td>14-60-19 bda02</td>
<td>84</td>
<td>1942, 1971-81</td>
<td>56.97</td>
<td>04-77</td>
</tr>
<tr>
<td>14-61-18 ddd01</td>
<td>90</td>
<td>1977-93</td>
<td>9.08</td>
<td>06-84</td>
</tr>
<tr>
<td>14-61-22 dcc01</td>
<td>--</td>
<td>1975-85</td>
<td>16.10</td>
<td>06-83</td>
</tr>
<tr>
<td>14-61-23 aab01</td>
<td>114</td>
<td>1971-81</td>
<td>52.28</td>
<td>05-74</td>
</tr>
<tr>
<td>14-61-25 ccb01</td>
<td>84</td>
<td>1970-81</td>
<td>40.60</td>
<td>05-74</td>
</tr>
</tbody>
</table>

Source:  

48
or linear decline in the water table. The data suggest that pumping of the municipal well field at its present consumptive use rates has had minimal impact on regional ground water levels. It follows that the drawdowns predicted with the PLASM model for existing consumptive use rates at an effective transmissivity of 80,000 gpd/ft are realistic values.

3.5 Assumptions

As discussed above, a number of assumptions were made for the PLASM model in estimating the response of the Brule Formation aquifer to pumping of the municipal well field. These assumptions include:

- A variably spaced model grid with 40 columns and 40 rows, encompassing an area 26.5 miles by 26.5 miles, was used to represent the Brule Aquifer. The grid was centered on the Town of Pine Bluffs well field.

- Average annual pumping rates were included in the model based on the existing and predicted production from the six municipal wells. Existing production records (1990-95) were used to estimate the existing municipal demand on each well. The total predicted future demand was based on the projected population in the year 2030 at the Town's current per capita usage. The predicted increase in demand was distributed proportionately among the six wells. The predicted demand at Well No. 3 was supplied by Well No. 1 per the proposed transfer of water rights. The Ekxtrom Well was modeled without consideration to water rights limitations.

- Pumping of irrigation wells was not included in the model. This allows an assessment of the response of the aquifer to stresses by the municipal wells only. The restriction on new wells in the Control District would suggest that the regional pumping regime of irrigation wells has remained, and will continue to remain, relatively consistent during the period represented by the PLASM model.

- The water table was assumed to be undisturbed at the commencement of pumping at the existing municipal demand rate. Existing pumping rates were modeled for 20 years to achieve current (1995) conditions. The water table configuration resulting from the existing pumping rate was used as the initial condition for the 20-year future condition model period. Future water table conditions were defined by modeling at the predicted pumping rates, adjusted instantaneously in 1995.
The west-to-east regional ground water flow into the model area is represented in the model as a constant head boundary along the western edge of the model grid. Recharge from precipitation was not included in the model.

Insufficient data were available to quantify the degree or orientation of the Brule anisotropy on a regional scale. An Equivalent Porous Media (EPM) modeling approach was used to address the anisotropic conditions of the aquifer. An effective transmissivity value representing the fractured siltstone formation was estimated based on the results of the pump tests for Well No. 1 and the Ekxtrom Well. The effective transmissivity is an isotropic homogeneous (EMP) representation of the fractured aquifer system. The effective transmissivity value was calibrated to the available data.

The storage coefficient of 2.0x10^-3 used for this model was selected from the available literature.

The selected aquifer hydraulic parameter values were applied to the entire grid.

Additional assumptions associated with the 2-dimensional PLASM model, as discussed in Selected Digital Computer Techniques for Groundwater Resource Evaluation (Prickett and Lonnquist, 1971), apply for this analysis.

3.6 Results

The PLASM model was used to simulate the response of the Brule Formation to pumping of the Pine Bluffs municipal well field. Simulations were run for two 20-year pumping periods, one at existing production rates and one at predicted future production rates. The model simulates pumping of the six municipal wells only; no pumping of irrigation wells was included. This permits an assessment of aquifer response to stresses from the municipal well field alone. The calibration of aquifer transmissivity included a comparison of simulated drawdowns to those actually measured in the municipal wells from 1979 to 1995. The measured drawdowns do include interference from adjacent irrigation wells, so the calibrated aquifer transmissivity results in a conservative assessment of drawdown from pumping of the municipal wells.

Output from the PLASM model includes a tabulation of the cumulative drawdown at each model grid node for each model time step. Two potentiometric surfaces were created from the nodal drawdown values: 1) after 20 years of pumping at the existing average annual production
rate, and 2) after 20 years of pumping at the predicted average annual production rate. The potentiometric surfaces are shown in Figure 3.2. Net drawdown is computed from initial, unstressed conditions.

After 20 years of pumping at the existing average annual production rate, the drawdown at the center of the well field (node 20,20) is approximately 3.8 feet. Drawdown at the nearest adjudicated irrigation well (node 19,15) is 3.5 feet. After the subsequent 20-year pumping period, at the predicted average annual production rate, the drawdown increases by 1.7 feet at the center of the well field and 1.6 feet at the irrigation well. This equates to total drawdowns of approximately 5.5 and 5.1 feet, respectively, below the initial flat water table surface.

While average annual production rates were used to estimate the long-term response of the aquifer to pumping, seasonal impacts on the water table were also investigated for existing and predicted rates. Average existing and predicted bi-monthly production rates were determined from available records and input to PLASM for a model period of two years. Input water table conditions were obtained from the PLASM model output for the 20-year simulations. Maximum seasonal fluctuations of 1.1 feet above and 1.3 feet below the average annual drawdown levels were estimated for existing production rates. Maximum seasonal fluctuations of 1.6 feet above and 1.9 feet below the average annual drawdown levels were estimated for predicted rates. Water table hydrographs for the center of the well field are included in the Project Notebook.

Four additional scenarios were modeled to identify water table impacts after long-term pumping at adjudicated pumping rates. A total time period of 40-years was modeled for each scenario. In each case, an initial water table was created by continually pumping the six municipal wells at the present adjudicated rate for 20 years. A subsequent 20-year model period simulates proposed changes to adjudicated pumping rates. The four investigated scenarios include:

1. The adjudicated water right for Well No. 3 is transferred to Well No. 1 as an enlargement. Well No. 3 is then abandoned. Well No.1 is pumped at 750 gmp.

2. The outstanding UW-5 permit (No. 6) is transferred to the Ekxtrom Well as an enlargement, and the Ekxtrom Well is pumped at 1200 gpm.
3. The outstanding UW-5 permit (No. 6) is assumed to be drilled and pumped at its permitted location and rate. 1200 gpm is withdrawn at a new location on the southwest part of town.

4. The conditions of Scenarios 1 and 2 are combined.

Continual pumping of the municipal wells at the adjudicated rates is unrealistic and results in simulated drawdown levels which are an order of magnitude greater than measured values. Future predictions at these modeled rates do not adequately simulate any reasonable rate of growth or water usage. Hydrographs for the four scenarios were created from the PLASM output and are included in the Project Notebook.

3.7 Sensitivity

Aquifer parameters assumed for the PLASM model include a storage coefficient of $2.0 \times 10^{-3}$ and an effective transmissivity equal to 80,000 gpd/ft. The storage coefficient is based on values obtained from the literature, and the transmissivity was determined from pump test data. The sensitivity of the aquifer's response to changes in these parameters was investigated. The municipal well field was pumped at existing and predicted average annual production rates under anisotropic conditions and with a range of storage coefficient values.

Storage coefficient values of $2.0 \times 10^{-2}$, $2.0 \times 10^{-3}$, and $7.0 \times 10^{-4}$ were used for the sensitivity analysis. Table 3.3 summarizes the total drawdowns (below the initial flat water table) associated with each storage coefficient. Drawdowns are shown for the center of the well field (node 20,20) and the nearest irrigation well (node 19,15). Hydrographs of the water level at the center of the well field (node 20,20) indicate that the long-term aquifer response to pumping is not overly dependent on the value of the storage coefficient. The storage coefficient primarily controls the rate at which the water levels approach a steady state condition. The hydrographs are included in the Project Notebook.
Table 3.3. Summary of Sensitivity Analysis of Storage Coefficient.

<table>
<thead>
<tr>
<th>Storage Coefficient</th>
<th>Total Drawdown from Start of Model Period (ft)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>20-year Existing Average Annual Production Rate</td>
</tr>
<tr>
<td></td>
<td>Center of Well Field (Node: 20,20)</td>
</tr>
<tr>
<td>0.02</td>
<td>2.8</td>
</tr>
<tr>
<td>0.002</td>
<td>3.8</td>
</tr>
<tr>
<td>0.0007</td>
<td>3.8</td>
</tr>
</tbody>
</table>

Inadequate data were available to quantify the anisotropy in the fracture system of the Brule Formation. As discussed previously, the aquifer was represented in the model as an equivalent isotropic and homogeneous aquifer with a calibrated effective transmissivity of 80,000 gpd/ft. Transmissivity values of 60,000 gpd/ft and 100,000 gpd/ft were used for the anisotropic sensitivity analysis. These values bracket the effective transmissivity value and fall within the range of transmissivities determined from the available literature and pump test data.

Two conditions of anisotropy were modeled: 1) a north-south orientation for the low transmissivity value and an east-west orientation for the high transmissivity value, and 2) an east-west orientation for the low transmissivity value and a north-south orientation for the high transmissivity value. With regional ground water flow from west to east, these two conditions provide the least and greatest drawdown.

The anisotropic condition with the low transmissivity value oriented north-south resulted in a maximum drawdown at the center of the well field that is less than that achieved under the effective isotropic condition (T=80,000 gpd/ft). Existing pumping rates caused 0.3 feet less drawdown, and predicted rates caused 0.4 feet less drawdown. For the anisotropic condition with the low transmissivity value oriented east-west, the maximum drawdown at the center of the well field is 0.6 feet (existing) and 0.9 feet (predicted) greater than under the effective isotropic condition (T=80,000 gpd/ft). Potentiometric surfaces were developed for the two cases after 20 years of pumping at both existing and predicted rates. Figure 3.3 shows the potentiometric surfaces with the low transmissivity oriented north-south. The potentiometric surfaces with the low transmissivity oriented east-west are shown on Figure 3.4.
3.8 Conclusions

The evaluation of the municipal well field’s impact to the regional aquifer included a review of the historic data and PLASM model simulations of water table response to pumping. Water level drawdowns were simulated for annual and bi-monthly pumping rates. The simulated water table drawdown at the center of the well field (Node 20,20) was 3.8 feet in response to pumping at existing average annual production rates. An additional 1.7 feet of drawdown (5.5 total feet) is anticipated for predicted long-term production rates.

Seasonal changes in production rates were also modeled. At the maximum existing bi-monthly seasonal pumping rate, an additional 1.3 feet of drawdown (5.1 total feet) beyond the average annual value are anticipated. For the maximum predicted bi-monthly rate, an additional drawdown of 1.9 feet (7.4 total feet) is anticipated.

LA also evaluated simulated drawdowns at the nearest adjacent adjudicated irrigation well (Node 19,15). The modeling effort did not assume any pumping at the irrigation well node. Well interference was not directly addressed. For existing production rates (municipal well field only), the simulated drawdown from the theoretical undisturbed water table was 3.5 feet. For predicted production rates, the simulated total drawdown was 5.1 feet. Considering the maximum bi-monthly production rates, the total drawdown increases to 4.6 and 6.8 feet for existing and predicted production rates, respectively. These drawdown levels are fairly small and are not considered to significantly impact the irrigation well.

Based on model simulations and historic pumping and water level records, the municipal well field is believed to be capable of sustaining the existing and predicted production rates, with little additional impact to the Brule Aquifer.
IV. CONCEPTUAL DESIGN AND RECOMMENDATIONS

4.1 General

The purpose of the Level II Pine Bluffs Water Supply Study is to collect sufficient field data and examine existing improvements to the current well production system to outline a course of action for further system improvements. The Level II field effort included: (1) the inspection and rehabilitation of five production well pumps and appurtenances; (2) the borehole and casing inspection of four municipal wells; (3) detailed aquifer testing at two separate locations (Well No.1 and Ekxtrom Well) within the Pine Bluffs Municipal Well Field; and (4) surveying and field evaluation of proposed transmission line alternatives. The following sections discuss conceptual designs for system improvements and wellhead protection guidance based on the information gathered in the field.

4.1 Pumps and Pump Rehabilitation

The pump inspection and rehabilitation program concentrated on Municipal Well Nos. 1, 2, 4, 5 and Ekxtrom. Because of its poor productivity, no effort was expended on Well No. 3. While the pumps were out of each well during the inspection program, LA's site engineer recommended certain improvements (rehabilitation) to individual pumps and pump appurtenances. In lieu of applying for Level III funding, these improvements were made on-site and funded wholly by the Town of Pine Bluffs. Specific improvements made to each well are described in detail in Chapter II of this document and are summarized in the following paragraphs.

The majority of the municipal pumps had not been inspected or rehabilitated since the late 1970's. The Level I effort had identified Well Nos. 1, 2 and Ekxtrom as the principal water production wells within the Town's system. It is anticipated that the pump rehabilitation efforts completed for these wells should suffice until the next inspection. In most cases, the pumps were in relatively good condition, particularly given their continued usage over a 13- to 18-year period. Pump bowls and impellers exhibited limited wear, and in no case were pump bowls or impellers replaced. Slight play in bowl shafts dictated replacement of bearings within the bowl shaft assemblies. The spider bushings, nuts, and bolts in the pump columns typically showed significant wear and were replaced. In each case the intake screen had completely deteriorated and was replaced. Occasionally, the packing gland at the motor head shaft was worn and required replacement. Of all of the wells, the pump, pump motor, and column shafts at Well...
No. 1 exhibited the greatest amount of deterioration. Relative to the other high production/usage wells, the equipment in this well may be the oldest. Although the equipment in Well No. 4 is older, it is operated on a manual basis and only in times of peak demand.

Based on the condition of the pump, motor, and column at Well No. 1, a more frequent inspection and rehabilitation program is recommended. The pumps should be removed and inspected, and worn parts should be replaced every 10 to 15 years. At the time of pump removal, the total depth of the wells should be measured to determine if there has been any "loss of hole." This is especially important for Well Nos. 1, 2, and 4, which are open hole completions.

Well Nos. 4 and 5 are characterized by declining production. The field inspection of the pumping equipment indicated that the loss of production was not directly related to the condition of the pumps or pump appurtenances. The addition of a five foot length of column to the Well No.4 pump was intended to optimize the pump setting and thereby increase the maximum production capability of this well. The pumps installed in both of these wells have production capabilities that greatly exceed the actual well yield. Therefore, in order to prevent immediate drawdown below the pump intake, the Town has used valves to restrict the flow from the wells. Well rehabilitation is recommended to improve aquifer production at both Well Nos. 4 and 5. Following well rehabilitation, new pumps could be sized which optimally match the production capabilities of the aquifer at each well site.

4.2 Well Rehabilitation

Well rehabilitation is applicable to two wells: Well Nos. 4 and 5. Well No. 4 was installed as an "open hole completion" in 1960 and has seen a 35% decline in production since 1977. The primary reason for this loss of production appears to be the loss of 30 feet of production zone at the bottom of the well. Much of the material collapse associated with the loss of "hole" was generated from collapse of the fractured annular wall immediately above and below the water table. To prevent continued loss of this unstable wall and further loss in well production, LA recommends deepening (redrilling) of the well, in place, and completion as a cased and screened well.

Well No. 5 was installed as a "cased and screened" well in 1973 and has seen a 50% decline in production since 1977. The inspection of the well found that the casing was ruptured and that there had been a 25% loss of open area in the screen. Water quality and MPA testing
suggest that the flow of water and very fine grained (300 \( \mu \text{M} \) or less) formation material is being restricted. Well design and construction practices appear to be responsible for the loss of well production. Because of the ruptured condition of the casing, LA recommends abandonment of the existing Well No. 5 and redrilling it at an adjacent location.

Figure 4.1 presents conceptual well completion diagrams for rehabilitation of Well Nos. 4 and 5. Conceptual designs include casing and well screen at both locations. During the Level I effort, concern had been expressed that the only successful wells within the Town’s supply system were open hole completions (Well Nos. 1, 2 and Ekxtrom). The Level II field effort, however, documented that the most productive well in the system, Ekxtrom No.1, is a “cased and screened” well. LA recognizes that the primary reason for well screen and gravel pack in the Brule Formation siltstone is to prevent borehole collapse, rather than to restrict the movement of formation material into the pump bowls. Therefore, LA recommends a relatively large screen slot size (0.050 or larger) and a coarse filter pack (4-8 silica sand or coarser), sized to be compatible with the well screen rather than the formation.

A letter and filing to the Wyoming State Engineer is recommended for both well rehabilitation programs. Board of Control action will be required for the relocation and abandonment of Well No. 5.

4.3 Transmission Line

4.3.1 Introduction

Currently, the Town water system includes water production wells connected directly to the distribution system. The Pine Bluffs Level I Study determined the need for a direct transmission line connecting the Town’s producing wells to the storage tanks. This system would allow the Town to optimize its water storage and water treatment capabilities. With the enforcement of the Ground Water Treatment Rule (GWTR), EPA will require all public water systems to disinfect their water. Without isolating production from distribution via an independent transmission line to storage, the Town would need a chlorine contact chamber, an additional booster pump, and associated chlorination equipment at each well. Such a system could only be implemented at great cost. The proposed transmission line would provide centralized chlorination and eliminate the need for additional pumps and contact chambers. Chapter XII (Water Quality Rules and Regulations) of the current DEQ regulations requires one-half hour chlorine contact time for ground water. The existing storage tanks would provide
Figure 4.1. Completion Diagrams for Wells Nos 4 and 5.
the required contact time. In addition, the proposed transmission line would allow effective
commingling of waters from the various wells. Such commingling would cumulatively reduce
nitrate levels by the process of dilution. In this manner an individual well might exceed EPA
maximum contaminant levels, whereas the municipal system would remain in compliance.

4.3.2 Location

A site reconnaissance was made to find the best alignment for the new transmission line.
This analysis took into account existing utilities, rights-of-way, access, street conditions, etc.
The recommended alignment and required distribution system upgrades are displayed on Figure
4.2. The recommended alignment from the Ekxtrom Well on the northwest end of town
parallels the existing distribution line to Well No. 5. From Well No. 5, the recommended
alignment is as follows: south on Main Street to 2nd Street, east on 2nd Street to Beech, south
on Beech to 9th, west on 9th to Pine Street, south under I-80 through an existing five-foot-
diameter utility conduit, then westerly, parallel to existing water mains, to the water storage
tanks. The best alignment from Well No. 1 is east on 3rd Street to Main Street then north to
2nd Street, where it will tie into the line from the Ekxtrom Well. The best alignment for Well
No. 2 is to proceed westerly along the Highway 30 right-of-way to Beech Street, then south to
a tie-in to the main line at 2nd Street. Well No. 4 would be tied to the main line on Beech
Street by a feeder main running west along 5th or 6th Street.

Required permits and easements include the following:

(1) A highway license to utilize the Highway 30 and I-80 rights-of-way
(2) A construction permit and an additional right-of-way on private property
south of the interstate
(3) A railroad boring permit and special railroad insurance.

4.3.3 Pipe Sizing

Preliminary design configurations show that a 12-inch transmission main beginning just
north of Well No. 5 would operate satisfactorily with existing pumping equipment. A smaller
line may require new well pumps and result in an increase in power requirements. Eight-inch
feeder mains would be used to tie the individual wells to the 12-inch line.
Figure 4.2. Town of Pine Bluffs Water Supply Project
Level II Proposed System Improvements.
4.3.4 Existing System Modeling

The Town's existing water system was modeled using the PipeNet Model for AutoCAD. During normal operation of the water supply system, the pumping units are operated in pairs. The pairs, Well No. 2 with the Ekxtrom Well and Well No. 5 with Well No. 1, were modeled individually through the existing distribution system. The results of the model runs, showing contoured distribution line pressures, are presented on Drawings B.1 and B.2 (Appendix B). Figure B.1 shows the pressures associated with fire flows from Well No. 2 and the Ekxtrom Well, assuming a fire at 3rd and Main. Figure B.2 presents the same situation with flow from Well Nos. 1 and 5. Distribution line sizes are also included on each drawing. In each case, the lowest line pressures are found in the southwest corner of town. Throughout the majority of town, line pressures range from 20 to 45 psi with Well Nos. 1 and 5 on line and 20 to 65 psi with Well No. 2 and the Ekxtrom Well on line.

The existing system leaves a large area of the Town with inadequate water pressures under gravity feed from the tanks. If the backflow preventor on the existing 12-inch distribution line (located at the east end of town) is opened, water pressures rise to adequate levels, except in a small area next to the west interchange during fire flows.

4.3.5 New System Modeling

The Town's water system was also modeled with an isolated transmission main to the Town's two storage tanks. Under this scenario, the water tanks will supply all the water to the Town under gravity feed. Using the existing distribution network, system pressures would drop below 10 psi at a number of locations throughout town. Recommended minimum system pressures are 20 psi during fire flow demand.

4.3.6 Required Distribution System Upgrades

The PipeNet modeling of an isolated transmission line indicates two areas of major concern for the Town's system. The first area of concern is the need for a new supply line from the storage tanks to town. This line should be at least 12 inches in diameter and will need to be connected to the Town's distribution network through the existing 12-inch main under the interstate near Stephens Avenue.
The second area of concern is the approximately 21,500 lineal feet of 4-inch mains in town. These small diameter mains cause a reduction in water pressure at certain locations in town. It is recommended that the Town replace enough 4-inch mains on the southwest and east end of town to keep water pressure above 20 psi during fire flows. The improvements should start with an 8-inch main on 7th Street, between Parson and Elm, and an 8-inch main on 5th, between Maple and Walnut, as shown on Figure 4.2.

Drawing B.3 (Appendix B) depicts the new, upgraded system’s pressure contours with fire flow demand resulting from a fire at 3rd and Main. Throughout the majority of town, the modeled line pressures would range from 20 to 60 psi. With these upgrades in place, there is no significant loss in line pressure from the existing conditions. Because all flow to the distribution system originates at the storage tanks, individual pumping pairs were not modeled separately.

Utilities involved in the additional system upgrades include:

- Town of Pine Bluffs Utilities
- Mountain Bell Fiber Optics
- F.E. Warren Missile Control Cable
- Cheyenne Light, Fuel & Power Gas Mains

4.3.7 Telemetry

The Town is also encouraged to upgrade their operating system through improved telemetry. Today's technology allows a variety of system upgrades which vary in price. With the Town operating four to six wells, two storage tanks, and a booster pump station, the project team recommends a system which allows the operator to monitor and control the production, transmission, and distribution system from one central location.

A system using telephone lines is suggested. Infrared systems were dropped from consideration because of possible interference from morning and evening sun. This system should be capable of monitoring tank levels, turning pumps on and off, monitoring flow, and controlling the booster pump station. The system should also be equipped with alarms. Either a graphic panel or a personal computer could be used to run the system and make necessary adjustments.
4.3.8 Alternatives to the Transmission Line

Alternatives to the isolated transmission line constructed to meet projected EPA chlorination requirements are:

(1) Do nothing and be subject to EPA actions.

(2) Place chlorination facilities at each well. These facilities would include a chlorine contact chamber and adjacent booster pump station. Using the planning parameters outlined in the Level I Study, a minimum of five separate facilities would be required. Such facilities would be located at the Ekxtrom Well and Well Nos. 1, 2, and 4, and 5. Since Well No. 3 is not productive, it would not be treated; it could be isolated from the drinking water supply and used for irrigation of the City Park.

4.4 Wellhead Protection Program

The 1986 Amendments to the Safe Drinking Water Act (SDWA) of 1974 established the Wellhead Protection (WHP) Program. This nationwide program was created to prevent the contamination of ground water resources tapped by public water supply wells. Under the SDWA Amendments (Section 1428), each state is required to develop its own program. These programs are then reviewed by EPA and, following approval, administered by state agencies. In Wyoming, the development and administration of the state’s WHP program are the responsibility of the Department of Environmental Quality, Water Quality Division (WDEQ/WQD). At the time of this report, the WDEQ/WQD was in the process of developing its WHP program. Although, the exact requirements cannot be addressed, EPA has established minimum criteria. The elements required by EPA have been addressed in a draft format by WQD and are discussed in relation to the Town of Pine Bluffs in this report.

The draft guidelines state that participation in Wyoming’s program will be voluntary and at the discretion of the owners of the Public Water System (PWS). If the Town of Pine Bluffs participates, there are several potential economic benefits: 1) elements of the wellhead protection plan can be used to obtain waivers for costly monitoring, 2) the costs associated with treating contaminated water can be avoided, and 3) costs associated with replacement of a contaminated well can be avoided. Due to the reliance of the Town on the aquifer as its sole source of drinking water, participation in the program is highly recommended.
The draft guidelines provide a significant amount of information and guidance, and the Town of Pine Bluffs is strongly urged to obtain a copy of the draft document from the WQD for review. The purpose of this report is neither to recreate nor reiterate the guidelines. Rather, this section of the Level II investigation is intended to interpret the guidelines in view of the Town's specific situation and needs. With these concepts in mind, the specific elements of a WHP plan are addressed.

In order for the State to approve a WHP plan, it must:

1. Specify roles and duties of State agencies, local governments, and public water suppliers, with respect to WHP Programs;
2. Delineate the wellhead protection area (WHPA) for each wellhead;
3. Identify sources of contaminants within each WHPA;
4. Develop management approaches to protect the water supply within each WHPA from such contaminants;
5. Develop contingency plans for each public water supply system to respond to well or well field contamination;
6. Site new wells properly to maximize yields and minimize potential contamination; and
7. Ensure public participation.

An important concept to remember throughout the development of a wellhead protection plan is that of feasibility and implementation. No plan, no matter how well thought out and designed, is of any use if it cannot be carried out. The principal type of contamination to be addressed by the Town of Pine Bluffs is nitrate. Other sources of contamination include underground fuel storage tanks and accidental spills from the railroad and highway transportation corridors. In Pine Bluffs, the Wellhead Protection Area (WHPA) for the six municipal wells is relatively large. It has multiple owners and incorporates many land uses. Moving the wells to a more protected area or purchasing the surrounding land (WHPA) is not feasible. As a result, the Town's ability to control land use and manage ground water quality within the WHPA is limited. Management tools included in typical WHP plans include zoning, operation
and design standards, source prohibitions, public education, monitoring and purchase of property. Some of these techniques are more applicable to the Pine Bluffs situation than others. It will be the responsibility of the Town to determine which of the management tools and strategies they will actually implement. The recommendations included herein have been made with feasibility in mind.

Appendix C provides a detailed discussion of each of the elements required in a WHP plan. Each element is presented with the site-specific requirements of the Town of Pine Bluffs in mind. These recommendations are briefly summarized below:

1. Involvement of the public is strongly encouraged. The effectiveness of any plan will be highly dependent upon cooperation and participation of the public. The Town is encouraged to hold public meetings and solicit ideas and involvement from the start. A Nitrate Awareness Plan should be prepared and distributed for public comment. Such a plan will be pertinent to not only agricultural interests but residential customers.

2. Voluntary Best Management Practices (BMPs) can be created and put in place to reduce the risk of contamination. Examples of BMPs include the placement of anti-backflow valves on chemigation systems to prevent ground water contamination, secondary containment facilities at liquid fertilizer storage facilities, etc. One of the two fertilizer plants in town already has a secondary containment system.

3. A pilot study should be conducted in coordination with the Soil Conservation Service to determine the degree, if any, of nitrate contamination that is associated with current versus historical agricultural activities. The study would involve taking soil samples from various depths within the soil profile to evaluate nitrate migration below the rooting zone. The study can be expanded to include, for example, irrigation practices and application rates, types of crops, amount of fertilization, and soil type.

4. A contingency plan should be prepared in the event that a municipal well becomes contaminated or records unacceptably high levels of nitrate. Such a plan might involve dilution of the specific well’s water with a high volume of water from uncontaminated wells. Such a plan may only be feasible if the Town constructs the recommended isolated transmission line which mixes all well water in the
storage tank before distribution. Emergency mitigation can also be accomplished by shutting off the contaminated well and replacing its yield with another “off-line” well. For this reason rehabilitation of Well No.4 is an attractive option.

The development of a wellhead protection plan is not a trivial exercise. It will require a committed effort by the Town and the public to complete a quality plan. It is not, however, beyond the range of the Town’s capabilities to complete one with the assistance and technical guidance of the WQD and the WWDC. Specific assistance may be required in tasks such as the delineation of the WHPA. The current modeling exercise presented in Chapter III may provide a starting point. Coordination with WQD, WWDC, and the Level III project team may be necessary. These sources will also provide valuable information and guidance in the preparation of the remainder of the plan.

The plan is meant to be used and dynamic. The requirements of the plan allow for considerable flexibility and creativity on the part of the Town of Pine Bluffs in the determination of management strategies and techniques to maintain and protect the quality of the ground water resource. It is intended to be updated as the Town grows and new sources of contamination become present or new data are obtained.

Upon completion, the guidelines currently being developed by WQD will provide specific direction for the accomplishment of each task. At this time, it is recommended that the Town recognize the impending requirements of the WHP plan and begin the planning process. Steps such as the preparation of a Nitrate Awareness Program, delineation of the contributing area, and inventory of potential pollutant sources can begin immediately. Perhaps the most important task that can be commenced at this time is for the Town to lay the groundwork for public involvement. By discussing the future needs through Council meetings, public notices, and press releases, the Town can begin to make the public aware of what will take place in the future.

4.5 Summary

The Level II effort prepared conceptual designs for pump rehabilitation. The majority of this effort resulted in actual rehabilitation, funded by the Town of Pine Bluffs, when the pumps were out of the ground and inspected. No Level III effort will be necessary for pump rehabilitation on Well Nos.1 and 2 and the Ekxtrom Well. Declining well production was identified in two of the Town's municipal wells: Well Nos. 4 and 5. Conceptual designs were prepared for specific well improvements at these two locations; they are presented on Figure

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4.1. Conceptual modeling of the well field production was prepared and is presented in Chapter III of this document. The Brule Aquifer appears to be capable of meeting long-term future production demand from the Town's municipal well field. A proposed transmission line route was identified (Figure 4.2) and subsequently modeled to determine pressure heads and zonation within the distribution network. Because distribution line pressures are dictated by gravity head from the storage tank, improvements to the distribution system and its operation are necessary under this scenario. Required improvements were identified, and selected improvements are shown on Figure 4.2. Finally, a guidance document was prepared for voluntary Well Head Protection. It is presented in Appendix C.
V. CONCEPTUAL DESIGN COST ESTIMATES

Conceptual designs are presented in the previous sections of this report. These designs include the rehabilitation of Well Nos. 4 and 5 and the construction of an isolated 12-inch transmission line with associated distribution system improvements. Chlorination facilities and new well telemetry are presented as part of these designs. Level III assistance in the preparation of a well head protection plan is included under the system design costs. Tables 5.1, 5.2, and 5.3 present the construction costs for various aspects of the Pine Bluffs Water Supply Project. Items may be prioritized following the decision of the State Board of Control. These construction costs are calculated in accordance with guidelines prepared by the WWDC (1995). Non-WWDC costs are assumed to include distribution system upgrades and water treatment.

The following ductile iron pipeline unit costs are used in Tables 5.1 through 5.3:

- 12" Water Main in Existing Streets $36.00 per foot
- 12" Water Main in Vacant Land $32.00 per foot
- 8" Water Main in Existing Streets $29.00 per foot
- 8" Water Main in Vacant Land $25.00 per foot
- Street Patching 6" base, 2" asphalt $8.50 per foot
- Telemetry and Alarm System $4,000.00 per node.

If PVC pipe were used instead of ductile iron, the unit cost would decrease $3.00 per foot for the 8-inch line and $5.00 per foot for the 12-inch line.
Table 5.1. Well Rehabilitation Costs (Materials and Installation) 1996.

<table>
<thead>
<tr>
<th>Item</th>
<th>Unit</th>
<th>Quantity</th>
<th>Unit Price</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Well No.5 Test Hole Construction</td>
<td>EA.</td>
<td>5</td>
<td>$1,560</td>
<td>$7,800</td>
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<tr>
<td>Complete New Well No.5</td>
<td>L.S.</td>
<td>1</td>
<td>$24,500</td>
<td>$24,500</td>
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<tr>
<td>Test New Well No.5</td>
<td>L.S.</td>
<td>1</td>
<td>$10,000</td>
<td>$10,000</td>
</tr>
<tr>
<td>Tear Down and Reconstruct Pump House (Well No.5)</td>
<td>L.S.</td>
<td>1</td>
<td>$10,000</td>
<td>$10,000</td>
</tr>
<tr>
<td>Remove and Reinstall Existing Well No.5 Pump</td>
<td>FT.</td>
<td>220</td>
<td>$5</td>
<td>$1,100</td>
</tr>
<tr>
<td>Telemetry, Plumbing, Appurtenances (Well No.5)</td>
<td>L.S.</td>
<td>1</td>
<td>$4,000</td>
<td>$4,000</td>
</tr>
<tr>
<td>Tear Down and Reconstruct Pump House (Well No.4)</td>
<td>L.S.</td>
<td>1</td>
<td>$15,000</td>
<td>$15,000</td>
</tr>
<tr>
<td>Drill Out Caved Well, Mob/Demob (Well No.4)</td>
<td>L.F.</td>
<td>130</td>
<td>$50</td>
<td>$6,500</td>
</tr>
<tr>
<td>Set Casing/Screen/Develop (Well No.4)</td>
<td>L.F.</td>
<td>130</td>
<td>$100</td>
<td>$13,000</td>
</tr>
<tr>
<td>Pull, Rehab/Reinstall Existing Pump (Well No.4)</td>
<td>L.S.</td>
<td>1</td>
<td>$4,700</td>
<td>$4,700</td>
</tr>
<tr>
<td>Test Rehabilitated Well (Well No.4)</td>
<td>L.S.</td>
<td>1</td>
<td>$10,000</td>
<td>$10,000</td>
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<tr>
<td>Telemetry, Plumbing, Appurtenances (Well No.4)</td>
<td>L.S.</td>
<td>1</td>
<td>$4,000</td>
<td>$4,000</td>
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SUBTOTAL (1) $110,600

ENGINEERING @ 10% OF SUBTOTAL (1) $11,060

SUBTOTAL (2) $121,660

CONTINGENCY @ 15% OF SUBTOTAL (2) $18,249

[I] TOTAL CONSTRUCTION COSTS $139,905

SURVEYING $2,500

WELL HEAD PROTECTION PLAN $5,000

PERMITTING COST $2,500

FINAL PLANS/SPECIFICATIONS $10,000

LEGAL FEES $4,000

[II] TOTAL PROJECT COSTS Well Rehabilitation Only $164,000

[III] TOTAL WWDC PROJECT COSTS With Construction of New Transmission Line (Table 5.2) $1,040,000
Table 5.2. New Transmission Line Estimated Costs (Materials and Installation) 1996.

<table>
<thead>
<tr>
<th>Item</th>
<th>Unit</th>
<th>Quantity</th>
<th>Unit Price</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>12&quot; Main FT.</td>
<td>FT.</td>
<td>6,000</td>
<td>$36</td>
<td>$216,000</td>
</tr>
<tr>
<td>12&quot; Main FT.</td>
<td>FT.</td>
<td>2,000</td>
<td>$32</td>
<td>$64,000</td>
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<tr>
<td>8&quot; Main FT.</td>
<td>FT.</td>
<td>7,100</td>
<td>$25</td>
<td>$177,500</td>
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<tr>
<td>8&quot; Main FT.</td>
<td>FT.</td>
<td>900</td>
<td>$29</td>
<td>$26,100</td>
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<tr>
<td>Telemetry EA.</td>
<td>EA.</td>
<td>8</td>
<td>$4,000</td>
<td>$32,000</td>
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<tr>
<td>Road Patching L.F.</td>
<td>L.F.</td>
<td>7,500</td>
<td>$8.50</td>
<td>$63,750</td>
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<tr>
<td>Misc. Connections &amp; Piping L.S.</td>
<td>L.S.</td>
<td>1</td>
<td>$20,000</td>
<td>$20,000</td>
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<tr>
<td>Railroad Bore L.S.</td>
<td>L.S.</td>
<td>1</td>
<td>$50,000</td>
<td>$50,000</td>
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</table>

**SUBTOTAL (1)** $649,350

**ENGINEERING @ 10% OF SUBTOTAL (1)** $65,000

**SUBTOTAL (2)** $714,000

**CONTINGENCY @ 15% OF SUBTOTAL (2)** $107,000

**[I] TOTAL CONSTRUCTION COSTS** $821,000

**SURVEYING** $15,000

**PERMITTING** $5,000

**EASEMENTS** $5,000

**PREPARATION OF DESIGNS** $30,000

**[II] TOTAL PROJECT COSTS** $876,000
Table 5.3. Non-WWDC Funded Water Distribution and Treatment Construction Costs (Materials and Installation) 1996.

<table>
<thead>
<tr>
<th>Item</th>
<th>Unit</th>
<th>Quantity</th>
<th>Unit Price</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Purchase, Install Chlorination System and Housing Unit</td>
<td>EA.</td>
<td>1</td>
<td>$ 25,000</td>
<td>$ 25,000</td>
</tr>
<tr>
<td>Distribution System Upgrades:</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3,200 L.F. 12&quot; Main</td>
<td>L.S.</td>
<td>1</td>
<td>$ 235,000</td>
<td>$ 235,000</td>
</tr>
<tr>
<td>3,600 L.F. 8&quot; Main</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Appurtenances</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Road Patching</td>
<td>L.F.</td>
<td>6,600</td>
<td>$ 8.50</td>
<td>$ 56,000</td>
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</table>

**SUBTOTAL (1)** $316,000

| ENGINEERING @ 10% SUBTOTAL (1) | $31,600 |

**SUBTOTAL (2)** $347,600

| CONTINGENCY @ 15% OF SUBTOTAL (2) | $52,140 |

**[I] TOTAL NON-WWDC CONSTRUCTION COSTS** $400,000
VI. ECONOMIC ANALYSIS AND ABILITY TO PAY

Tables 6.1 and 6.2 present the ability-to-pay analysis, debt service, and annual O&M costs associated with the proposed new system. WWDC funding is assumed in the form of 50% Grant and 50% Loan at 4% over a 30 year period. Farm Loan Board funding is assumed at the same Grant/Loan ratio with a 7.25% interest rate. Also presented on the tables is an analysis of monthly cost based on 510 current taps.
Table 6.1. Ability to Pay Analysis: Construction Costs, Debt Service and O & M.

<table>
<thead>
<tr>
<th>Item</th>
<th>Column 1</th>
<th>Column 2</th>
</tr>
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<tr>
<td></td>
<td>Water Supply Well Rehabilitation Costs (Ref. Table 5.1)</td>
<td>Water Transmission Costs (Ref. Table 5.2)</td>
</tr>
<tr>
<td>Construction Costs</td>
<td>$164,000</td>
<td>$876,000</td>
</tr>
<tr>
<td>50% Loan</td>
<td>$82,000</td>
<td>$438,000</td>
</tr>
<tr>
<td>Repayment Factor: 30 years @ 4%</td>
<td>0.05783</td>
<td>0.05783</td>
</tr>
<tr>
<td>Annual Payment</td>
<td>$4,742</td>
<td>$25,330</td>
</tr>
<tr>
<td>Annual O &amp; M Costs</td>
<td>$0.00</td>
<td>$0.00</td>
</tr>
<tr>
<td><strong>Subtotal (1)</strong></td>
<td>$4,742</td>
<td>$25,330</td>
</tr>
<tr>
<td>Annual Payment Farm Loan Board for Water Distribution and Treatment¹</td>
<td>$0.00</td>
<td>$16,524</td>
</tr>
<tr>
<td><strong>Subtotal (2)</strong></td>
<td>$4,742</td>
<td>$41,854</td>
</tr>
<tr>
<td><strong>Total Annual Costs</strong></td>
<td>$4,742</td>
<td>$41,854</td>
</tr>
<tr>
<td>Project Cost/Tap/Month (Assume 510 Taps)</td>
<td>$0.77</td>
<td>$6.84</td>
</tr>
<tr>
<td><strong>Total Project Annual Cost</strong></td>
<td></td>
<td>$46,596</td>
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<tr>
<td><strong>Total Project Cost/Tap/Month (Assume 510 Taps)</strong></td>
<td></td>
<td>$7.61</td>
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¹ Assumes 50% Grant, 50% Loan @ 7.25% (30 years). See Table 6.2.
Table 6.2. Ability to Pay Analysis: Construction Costs, Debt Service and O & M. Non-WWDC (Farm Loan Board) Funding.

<table>
<thead>
<tr>
<th>Item</th>
<th>Costs</th>
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<tr>
<td>Construction Costs (Table 5.3)</td>
<td>$ 400,000</td>
</tr>
<tr>
<td>50% Loan (30 Years)</td>
<td>$ 200,000</td>
</tr>
<tr>
<td>Repayment Factor of 30 Years @ 7¼%</td>
<td>0.08262</td>
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<td>Annual Payment</td>
<td>$ 16,524</td>
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<tr>
<td>Annual O &amp; M Costs</td>
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<tr>
<td>TOTAL ANNUAL COST</td>
<td>$ 16,524</td>
</tr>
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</table>
VII. REFERENCES


APPENDIX A

WATER QUALITY DATA
AND
MICRO-PARTICULATE ANALYSIS RESULTS
**LABORATORY ANALYSIS REPORT**  
**ENERGY LABORATORIES, INC.**

**Report Date:** 08-28-95  
**Sample Type:** Water  
**Sample I.D.:** PBW4  
**Sample Date:** 08-09-95  
**Sample Number:** 95-48101

<table>
<thead>
<tr>
<th>Major Ions</th>
<th>Units</th>
<th>Results</th>
<th>Detection Limit</th>
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<tbody>
<tr>
<td>Calcium (Ca)</td>
<td>mg/l</td>
<td>88.0</td>
<td>1.0</td>
</tr>
<tr>
<td>Magnesium (Mg)</td>
<td>mg/l</td>
<td>22.1</td>
<td>1.0</td>
</tr>
<tr>
<td>Sodium (Na)</td>
<td>mg/l</td>
<td>37.4</td>
<td>1.0</td>
</tr>
<tr>
<td>Potassium (K)</td>
<td>mg/l</td>
<td>7.2</td>
<td>1.0</td>
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<tr>
<td>Carbonate (CO₃)</td>
<td>mg/l</td>
<td>0</td>
<td>0.10</td>
</tr>
<tr>
<td>Bicarbonate (HCO₃⁻)</td>
<td>mg/l</td>
<td>310</td>
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<tr>
<td>Sulfate (SO₄)</td>
<td>mg/l</td>
<td>67.0</td>
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<tr>
<td>Chloride (Cl)</td>
<td>mg/l</td>
<td>37.4</td>
<td>1.0</td>
</tr>
<tr>
<td>Phosphate (PO₄³⁻)</td>
<td>mg/l</td>
<td>0.08</td>
<td>0.05</td>
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<tr>
<td>Nitrate (NO₃⁻)</td>
<td>mg/l</td>
<td>&lt;</td>
<td>0.10</td>
</tr>
<tr>
<td>Silica (SiO₂)</td>
<td>mg/l</td>
<td>57.3</td>
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</table>

**Non-Metals**

<table>
<thead>
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<th>Parameter</th>
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<th>Results</th>
<th>Detection Limit</th>
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<tbody>
<tr>
<td>Total Dissolved Solids @ 180°C (TDS)</td>
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<td>483</td>
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<td>Conductivity</td>
<td>μmhos/cm</td>
<td>711</td>
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</tr>
<tr>
<td>Alkalinity; measured as CaCO₃</td>
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<td>254</td>
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<tr>
<td>pH</td>
<td>std. units</td>
<td>7.68</td>
<td>0.1</td>
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**Trace Metals**

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<th>Detection Limit</th>
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<tbody>
<tr>
<td>Aluminum (Al)</td>
<td>mg/l</td>
<td>&lt;</td>
<td>0.10</td>
</tr>
<tr>
<td>Arsenic (As)</td>
<td>mg/l</td>
<td>0.005</td>
<td>0.001</td>
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<tr>
<td>Barium (Ba)</td>
<td>mg/l</td>
<td>0.14</td>
<td>0.10</td>
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<tr>
<td>Boron (B)</td>
<td>mg/l</td>
<td>0.10</td>
<td>0.10</td>
</tr>
<tr>
<td>Cadmium (Cd)</td>
<td>mg/l</td>
<td>&lt;</td>
<td>0.01</td>
</tr>
<tr>
<td>Chromium (Cr)</td>
<td>mg/l</td>
<td>&lt;</td>
<td>0.05</td>
</tr>
<tr>
<td>Copper (Cu)</td>
<td>mg/l</td>
<td>0.01</td>
<td>0.01</td>
</tr>
<tr>
<td>Iron (Fe)</td>
<td>mg/l</td>
<td>&lt;</td>
<td>0.05</td>
</tr>
<tr>
<td>Lead (Pb)</td>
<td>mg/l</td>
<td>&lt;</td>
<td>0.05</td>
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<tr>
<td>Manganese (Mn)</td>
<td>mg/l</td>
<td>&lt;</td>
<td>0.01</td>
</tr>
<tr>
<td>Mercury (Hg)</td>
<td>mg/l</td>
<td>&lt;</td>
<td>0.001</td>
</tr>
<tr>
<td>Molybdenum (Mo)</td>
<td>mg/l</td>
<td>&lt;</td>
<td>0.10</td>
</tr>
<tr>
<td>Nickel (Ni)</td>
<td>mg/l</td>
<td>&lt;</td>
<td>0.01</td>
</tr>
<tr>
<td>Selenium (Se)</td>
<td>mg/l</td>
<td>0.006</td>
<td>0.001</td>
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<tr>
<td>Vanadium (V)</td>
<td>mg/l</td>
<td>&lt;</td>
<td>0.10</td>
</tr>
<tr>
<td>Zinc (Zn)</td>
<td>mg/l</td>
<td>0.03</td>
<td>0.01</td>
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</table>

**Radiometric**

<table>
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<th>Acceptance Range</th>
</tr>
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<tbody>
<tr>
<td>Uranium (U⁶⁹⁰⁹³⁶)</td>
<td>mg/l</td>
<td>0.0200</td>
<td>0.0003</td>
</tr>
<tr>
<td>Radium 226 (Ra²²⁶)</td>
<td>pCi/l</td>
<td>0.2</td>
<td>0.2</td>
</tr>
<tr>
<td>Radium Precision ±</td>
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**Quality Assurance Data**

<table>
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<td>Anion</td>
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<tr>
<td>Cation</td>
<td>8.07</td>
</tr>
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<td>1.00 - 5 - +5</td>
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<tr>
<td>Calc TDS</td>
<td>494</td>
</tr>
<tr>
<td>TDS A/C Balance dec. %</td>
<td>0.98 - 0.90 - 1.10</td>
</tr>
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</table>

Report Approved by: R.A. Landy

COMPLETE ENVIRONMENTAL ANALYTICAL SERVICES
**LABORATORY ANALYSIS REPORT**

**Report Date:** 08-28-95  
**Sample Type:** Water  
**Sample I.D.:**  
**Sample Date:** 08-09-95  
**Sample Number:** 95-48102

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<th>Units</th>
<th>Results</th>
<th>Detection Limit</th>
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<tbody>
<tr>
<td>Calcium (Ca)</td>
<td>mg/l</td>
<td>91.0</td>
<td>1.0</td>
</tr>
<tr>
<td>Magnesium (Mg)</td>
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<td>Sodium (Na)</td>
<td>mg/l</td>
<td>30.5</td>
<td>1.0</td>
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<tr>
<td>Potassium (K)</td>
<td>mg/l</td>
<td>7.4</td>
<td>1.0</td>
</tr>
<tr>
<td>Carbonate (CO₃)</td>
<td>mg/l</td>
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<td>0.10</td>
</tr>
<tr>
<td>Bicarbonate (HCO₃⁻)</td>
<td>mg/l</td>
<td>307</td>
<td>0.10</td>
</tr>
<tr>
<td>Sulfate (SO₄²⁻)</td>
<td>mg/l</td>
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<td>1.0</td>
</tr>
<tr>
<td>Chloride (Cl⁻)</td>
<td>mg/l</td>
<td>25.0</td>
<td>1.0</td>
</tr>
<tr>
<td>Ammonium (NH₄⁺)</td>
<td>mg/l</td>
<td>&lt; 0.05</td>
<td>0.05</td>
</tr>
<tr>
<td>Nitrite (NO₂⁻)</td>
<td>mg/l</td>
<td>&lt; 0.10</td>
<td>0.10</td>
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<td>Nitrate (NO₃⁻)</td>
<td>mg/l</td>
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<tr>
<td>Fluoride (F⁻)</td>
<td>mg/l</td>
<td>0.73</td>
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<tr>
<td>Silica (SiO₂⁻)</td>
<td>mg/l</td>
<td>52.2</td>
<td>1.0</td>
</tr>
</tbody>
</table>

**Non-Metals**

| Total Dissolved Solids @ 180°C (TDS) | mg/l | 464 | 1.0 |
| Conductivity | μmhos/cm | 705 | 1.0 |
| Alkalinity measured as CaCO₃ | mg/l | 252 | 1.0 |
| pH | std. units | 7.57 | 0.1 |

**Trace Metals**

| Aluminum (Al) | mg/l | < 0.10 | 0.10 |
| Arsenic (As)  | mg/l | 0.004  | 0.001 |
| Barium (Ba)   | mg/l | 0.24   | 0.10 |
| Boron (B)     | mg/l | 0.10   | 0.10 |
| Cadmium (Cd)  | mg/l | < 0.01 | 0.01 |
| Chromium (Cr) | mg/l | < 0.05 | 0.05 |
| Copper (Cu)   | mg/l | < 0.01 | 0.01 |
| Iron (Fe)     | mg/l | < 0.05 | 0.05 |
| Lead (Pb)     | mg/l | < 0.05 | 0.05 |
| Manganese (Mn)| mg/l | < 0.01 | 0.01 |
| Mercury (Hg)  | mg/l | < 0.001| 0.001|
| Molybdenum (Mo)| mg/l | < 0.10 | 0.10 |
| Nickel (Ni)   | mg/l | < 0.01 | 0.05 |
| Selenium (Se) | mg/l | 0.004  | 0.001|
| Vanadium (V)  | mg/l | < 0.10 | 0.10 |
| Zinc (Zn)     | mg/l | < 0.01 | 0.01 |

**Radiometric**

| Uranium (U³⁺) | mg/l | 0.0170 | 0.0003 |
| Radium 226 (Ra²²⁶) | pCi/l | 0.3 | 0.2 |
| Radium Precision ± | 0.2 |

**Quality Assurance Data**

<table>
<thead>
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<th>Anion</th>
<th>meq</th>
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<td>Cation</td>
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<tr>
<td>WYDEQ A/C Balance</td>
<td>%</td>
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<tr>
<td>TDS A/C Balance</td>
<td>dec. %</td>
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Report Approved by: [Signature]
QUALITY ASSURANCE REPORT - LIDSTONE & ANDERSON

Report Date: 08-30-95
ELI # (s): 95:48101-03

MAJOR IONS:

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<th>%</th>
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NON-METALS:

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<th>%</th>
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TRACE METALS:

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<th>%</th>
<th>%</th>
<th>ANALYST</th>
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Report Approved By: [Signature]

dmc 95:48101-03
ANALYSIS FOR WATERBORNE PARTICULATES

CHDiagnostic and Consulting Service, Inc.
1966 W. 15th St, #4, Loveland, CO 80538
Carrie M. Hancock, President

Customer 91332
Lidstone & Anderson, Inc.
736 Whalers Way, Suite F-200
Fort Collins, CO 80525

Laboratory Information
Hand Delivered; 8/10/95; 0850 Hrs; Polypropylene; Excellent; Results submitted by:

Sample Information:
Pine Bluff Well #4, PBW4F, Source: Drilled well, unchlorinated; 17°C, pH 8.00, ~1.75 gpm
Date/Start: 8/9/95; 0803 Hrs
Date/Stop: 8/9/95; 1811 Hrs
Gallons: 740
Filter Color: Tan
Centrifugate: 0.1 mL/100 gals

Amorphous Debris: All inorganic, silica (1-2 μM), silt (2-50 μM), sand (50-200 μM) & inorganic precipitate (1-50 μM diameter aggregates), 1-200 μM diameter
Other Algae: None Detected (ND)
Diatoms: ND
Plant Debris: ND
Giardia: ND
Coccidia: ND
Rotifers: ND
Nematodes: ND
Pollen: ND
Ameba: ND
Ciliates: ND
Colorless Flagellates: ND
Crustaceans: ND
Insects/Larvae: ND
Other: Rare Iron Bacteria

This sample was analyzed for particulates following the Environmental Protection Agency Consensus Method for Determining Groundwaters Under the Direct Influence of Surface Water Using Microscopic Particulate Analysis (MPA). All limitations stated in the method apply.

Comments: 1.5 gals examined, Photographs taken, Rare iron bacteria found and no other microbiota was detected. MPA Consensus Method was not followed per request by Chris Lidstone.
ANALYSIS FOR WATERBORNE PARTICULATES

CHDiagnostic and Consulting Service, Inc.
1966 W. 15th St, #4, Loveland, CO 80538
Carrie M. Hancock, President Telephone (970) 667-9789

Customer 91332
Lidstone & Anderson, Inc.
736 Whalers Way, Suite F-200
Fort Collins, CO 80525

Laboratory Information
Hand Delivered; 8/10/95; 0850 Hrs;
Polypropylene; Excellent; Results
submitted by: Carrie Hancock

PWSID#

Sample Information: Pine Bluff Well #5, PBW5F, unchlorinated; 12°C, pH 6.6, ~1.6 gpm
Date/Start: 8/9/95; 0825 Hrs Date/Stop: 8/9/95; 1946 Hrs Sampler: JHF/WEF
Gallons: 555 Filter Color: White Centrifugate: 0.005 mL/100 gals

Amorphous Debris: All inorganic, inorganic precipitate (1-250μM diameter), clay, silt & sand sized particles up to 300 μM diameter, could not discern composition

Other Algae: None Detected (ND)
Diatoms: 1 Melosira/28 gals
Plant Debris: ND
Giardia: ND
Coccidia: ND
Rotifers: ND
Nematodes: ND
Pollen: ND
Ameba: ND
Ciliates: ND
Colorless Flagellates: ND
Crustaceans: ND
Insects/Larvae: ND
Other: Rare Iron Bacteria

This sample was analyzed for particulates following the Environmental Protection Agency Consensus Method for Determining Groundwaters Under the Direct Influence of Surface Water Using Microscopic Particulate Analysis (MPA). All limitations stated in the method apply.

Comments: 28 gals. examined, Photographs taken, MPA Consensus Method was not followed per request by Chris Lidstone.
APPENDIX B

SUMMARY RESULTS
OF
PIPENET FLOW MODEL
TOWN OF PINE BLUFFS
EXISTING WATER SYSTEM
WELL 2 AND WELL 6 ON LINE
FIRE AT 3rd AND MAIN

EXISTING SYSTEM
PRESSURE CONTOURS
WITH FIRE FLOWS
TOWN OF PINE BLUFFS
EXISTING WATER SYSTEM
WELL 1 AND WELL 5 ON LINE
FIRE AT 3rd AND MAIN

EXISTING SYSTEM
PRESSURE CONTOURS
WITH FIRE FLOWS
TOWN OF PINE BLUFFS
WITH PROPOSED NEW WATER LINE
AND SYSTEM IMPROVEMENTS
FIRE AT 3rd AND MAIN
APPENDIX C

WELLHEAD PROTECTION PLAN
The 1986 Amendments to the Safe Drinking Water Act (SDWA) of 1974 established the Wellhead Protection (WHP) Program. This nationwide program was created to prevent the contamination of ground water resources tapped by public water supply wells. Under the SDWA Amendments (Section 1428), each State is required to develop its own program. These programs are then reviewed by EPA and, following approval, administered by State agencies. In Wyoming, the development and administration of the state’s WHP program are the responsibility of the Department of Environmental Quality, Water Quality Division (WDEQ/WQD). At the time of this report, the WDEQ/WQD was in the process of developing its WHP program. Therefore, the exact requirements cannot be addressed. However, the EPA has established minimum criteria. The elements required by EPA have been addressed in a draft format by WQD and are discussed in relation to the Town of Pine Bluffs in this report.

The draft guidelines state that participation in Wyoming’s program will be voluntary and at the discretion of the owners of the Public Water System (PWS). If the Town of Pine Bluffs participates, there are several potential economic benefits: 1) elements of the wellhead protection plan can be used to obtain waivers for costly monitoring, 2) the costs associated with treating contaminated water can be avoided, and 3) costs associated with replacement of a contaminated well can be avoided. Due to the reliance of the Town on the aquifer as its sole source of drinking water, participation in the program is highly recommended.

The draft guidelines provide a significant amount of information and guidance, and the Town of Pine Bluffs is strongly urged to obtain a copy of the draft document from the WQD for review. The purpose of this report is neither to recreate nor simply reiterate the guidelines. Rather, this section of the Level II investigation is intended to interpret the guidelines in view of the Town’s specific situation and needs. Recommendations are made for the Town in order to provide a tool for use in the development of its plan. With these concepts in mind, the specific elements of a WHP plan are addressed.

In order for the State to approve a WHP plan, it must:

A. Specify roles and duties of State agencies, local governments, and public water suppliers, with respect to WHP Programs;

B. Delineate the wellhead protection area (WHPA) for each wellhead;

C. Identify sources of contaminants within each WHPA;

D. Develop management approaches to protect the water supply within each WHPA from such contaminants;

E. Develop contingency plans for each public water supply system to respond to well or well field contamination;
F. Site new wells properly to maximize yields and minimize potential contamination; and

G. Ensure public participation.

An important concept to remember throughout the development of a wellhead protection plan is that of feasibility and implementation. No plan, regardless of how well thought out and designed, is of any use if it cannot be implemented. In the case of Pine Bluffs, the area contributing to the municipal well field has multiple owners and incorporates a wide variety of land uses. As a result, the Town will be limited with regard to what can actually be done to protect and manage ground water quality. Management tools included in WHP plans include zoning, operating and design standards, source prohibitions, public education, monitoring, and purchase of property. Some of these techniques will obviously be more practical than others. It will be the responsibility of the Town to determine which management tools and strategies will actually be implemented. However, the recommendations included herein have been made with feasibility in mind.

A. Definition of Institutional Roles

Once the decision to participate in the WHP program is made, it will be the Town’s responsibility to complete the various required elements of the plan, submit it to WQD for approval, and, ultimately, implement it. Because the plan will require coordination of several agencies (state and federal) as well as the public, the formation of a committee to oversee the project will be required. The committee should be composed of:

- members of the Town Council;
- the Public Water System Operator;
- representatives of private, commercial and industrial interests;
- residential interest representatives; and
- technical, legal and regulatory advisors.

The development and implementation of a successful WHP plan will require a significant level of public participation. Therefore, the Town is strongly encouraged to solicit participation from the onset of the project and to include the public on the WHP committee. By including the public in the development of the plan, their participation will be maximized. A significant portion of the plan will involve management of nitrates in ground water. Because agriculture, a major source of nitrates, is the economic base of the community, a representative of the agriculture sector should be strongly solicited. In addition, representatives of businesses or industries which could potentially be affected by the plan and its implementation should be selected. For example, coordination with High Plains Co-op should be solicited because their operation poses a potential threat of contamination in the event of a spill or leak at their facility.

A member of the committee should also be a representative from WQD. The draft guidelines stress that WQD will be available for serving on committees and to provide technical and regulatory assistance in plan implementation. Due to the multi-disciplinary nature of a WHP plan, the Town is strongly encouraged to gain the assistance of WQD early in the process. This will serve to not only provide a better plan, but will help to ensure its acceptance by WQD and EPA.
B. Delineation of the Wellhead Protection Area

Subsection 1428 (e) of the Safe Drinking Water Act Amendments of 1986 identify a Wellhead Protection Area (WHPA) as:

"The surface and subsurface area surrounding a well or well field, supplying a public water system, through which contaminants are reasonably likely to move toward and reach such water well or well field."

The guidelines being developed by WQD include detailed instructions to be followed in the delineation of WHPAs. The size and shape of the WHPA is a function of the hydrogeologic characteristics of the aquifer as well as the design and operational characteristics of the Town’s well field. The purpose of the WHPA is to define a specific area in which contaminants can be identified and managed to protect ground water resources.

The accuracy of the defined area is important for several reasons, including the following:

- an accurately defined WHPA will minimize the area requiring pollution control, and
- accurate delineation will be more defensible should the plan be challenged.

The guidelines discuss numerous methods for WHPA delineation. The methodologies range from the simple establishment of a fixed radius about a well to complex hydrogeologic modeling. The size and shape of the WHPA will be a function of the aquifer characteristics including the potentiometric surface and the resultant rates of flow. The draft WQD guidelines propose the establishment of various zones about a well. The concentric zones would have successively reduced pollution control requirements as distance from the well increases.

The first zone (Zone 1) about a well would be an Accident Prevention Zone which is a highly protected area. The objective of the Accident Prevention Zone would be to prevent the direct introduction of contaminants into the wells. Requirements of WQD will likely require a 100-foot radius area for the Town’s wells. Due to the fact that this radius will include various land uses including private residences, coordination with WQD will be required.

Zone 2 is defined as the Attenuation Zone. This zone is established to protect a well from pathogenic microorganisms from a nearby source and to provide emergency response time. Such time will be needed to begin active cleanup and/or implementation of contingency plans in the event of chemical contamination near the well. Because the aquifer used by the Town of Pine Bluffs has conduit flow characteristics, WQD will require a minimum 1000 foot radius about each well to be established as Zone 2.

Zone 3 is defined as the Remedial Action Zone. "The purpose of this zone is to protect the well from chemical contaminants that may migrate to the well and is the area in which protection is provided to a major portion of the recharge area or contribution area for a well." In the case of the Pine Bluff region, this area could become quite extensive due to the nature of the aquifer. The draft guidelines state that Zone 3 in aquifers exhibiting conduit flow traits are
defined by ground water flow boundaries. Using methods involving the time of travel within the aquifer, the radius of this zone could extend several miles.

A WHPA Delineation Report will be required for each well. The Town of Pine Bluffs would, therefore, be required by the regulations to create a total of five reports. Because the zones from the individual wells will undoubtedly coalesce, it is possible that the reporting requirement can be combined. The report will require a summary of geologic data, aquifer data, well data, pump data, and methodologies used in delineation of the WHPAs. The majority of this information has been incorporated elsewhere in this report.

C. Inventory of Sources

An acceptable plan will need to include an inventory of potential contamination sources within the wellhead protection area. Subsection 1428(a)(3) of the SDWA amendments state the programs must as "a minimum . . . identify within each wellhead protection area all potential anthropogenic sources of contaminants which may have any adverse effect on the health of persons." Remediation of a contaminated aquifer, when possible, is a difficult and expensive task. Therefore, the most cost effective approach to controlling ground water quality is the prevention of contamination.

With this objective in mind, the existing and potential sources of contamination need to be inventoried. The inventory must include all activities which pose potential threats to ground water quality. This includes a wide variety of activities and associated materials, for the source need not be actively polluting but must merely pose a threat in the event of an accident, spill or leak. Included in the draft guideline are lists of potential ground water contamination sources. These lists provide a starting point for the Town of Pine Bluffs and are not intended to be fully comprehensive. They merely serve to indicate the variety of potential sources that do exist and the various categories into which they fall.

Once the Town has an understanding of the types and levels of activities which could potentially contaminate the aquifer, it can then develop effective controls and management tools to minimize the potential for contamination. Information included in the inventory should include such data as the location, types and quantities of materials used and stored, the owner/operator of the activity, existence of spill contingency plans, etc. A critical factor to document for each activity is the level of contamination control already in place or planned.

An example of the potential sources within the WHPA is the DRW facility located near Well No 5. This report does not intend to imply that the facility is currently polluting or has a history of doing so. Rather, it is discussed as one example of the more prominent potential sources of local ground water contamination. The materials distributed by this company, a variety of fertilizers and agricultural chemicals, represent a significant potential source of contamination in the event of spills or leaks. These materials are stored and transferred on-site, allowing for the possibility of aquifer contamination in the event of a spill or leak. Several Best Management Practices (BMPs) are utilized by the facility to minimize this risk: chemical storage tanks are situated within concrete secondary containment structures, and chemical transfer occurs within a concrete catchment where spillage is captured within a vault. These types of activities

C - 4
must be included and documented during the inventory phase of the Town's WHP plan development.

Owners of the DRW facility are currently conducting an environmental audit of their property because of the pending sale of the site. The purchaser, High Plains Co-op, operates a similar facility adjacent to the property. This site is also located within the WHPA and represents a potentially greater source of ground water contamination since secondary containment does not exist for the chemical storage tanks. Spills or leaks could therefore pose a significant source of pollution to the Town’s wells. Because nitrates have been identified as a critical parameter of concern, both facilities should be closely inspected.

Agricultural application of fertilizers and chemicals has been identified as an additional potential source of aquifer contamination. In order to determine the effectiveness of fertilizer application methods and the level of contamination attributable to agriculture, if any, a pilot study should be conducted in conjunction with the Soil Conservation Service (SCS). The purpose of the investigation would be to determine whether fertilization is resulting in nitrate migration below the rooting zone such that percolation to the aquifer can occur. The SCS has indicated the need for an investigation of this nature and may be willing to administer and/or provide funding. Such an investigation would involve obtaining samples from discrete depths and analyzing for nitrate levels.

As part of the inventory phase of the project, expanded water quality monitoring should also be implemented. The Town currently monitors water quality at the five water supply wells, which is required by the SDWA. Because of the widespread nature of the detected nitrate concentrations, several outlying wells should be selected for periodic monitoring. At a minimum, three wells located upgradient of the Town's well field should be sampled periodically to monitor nitrate concentrations. A sampling frequency of at least twice per year (spring and fall) is recommended. This sampling would not be expected to place an unrealistic burden upon the Town or its resources. Sampling of three wells could be accomplished within approximately two hours and cost less than $50 in laboratory fees. Data obtained can then be used to determine the quality of water in the upgradient direction and predict potential problems at the Town’s wells.

Additional potential sources of contamination known to exist within the proposed Pine Bluffs WHPA include the following:

**Underground fuel storage tanks**

**Feedlots**

**Highway and Railroad Traffic**

The relative magnitude of the risk associated with each potential source varies. The Town should prioritize the identified sources in terms of the relative contamination potential.

**D. Development of Management Approaches**
Following the delineation of WHPAs for the Town wells and the inventory of potential pollution sources within these areas, the Town will have a tool upon which to develop management strategies. The maps developed during those phases will provide a concise picture of what and where the potential sources of contamination are. Numerous management tools exist that are typically used to control activities which pose a pollution threat to ground water resources. These include but are not limited to:

- Zoning ordinances
- Subdivision Ordinance
- Site Plan Review
- Design Standards
- Operating Standards
- Source Prohibitions
- Purchase of Property
- Public Education
- Ground Water Monitoring
- Household Hazardous Waste Collection
- Water Conservation.

Not all of these tools will be practical or feasible for the Town of Pine Bluffs. As previously discussed, the management approaches actually employed will be limited by several factors. The wells are located within a previously developed community. Therefore, undisturbed buffers do not exist around the wells. It is impractical for the Town to consider purchasing extensive tracts of land outside of the Town limits in order to control development and land use activities. Zoning is possible but would likely be met with resentment and could be unenforceable. Given the size and growth rate of the community, tools such as subdivision ordinances and site plan reviews would be ineffective. Therefore, the most valuable tool available to the Town is education of the public.

Whatever the tools used by the Town, the objective of each should be to control pollution at the source. As previously discussed, it is much more efficient and cost effective to prevent the contamination of ground water than to remediate it. With this concept in mind, the Town should encourage certain minimum management practices upon those using materials which could pollute the aquifer. These practices should include but not be limited to activities such as placement of anti-backflow valves on irrigation/chemigation systems. A single occurrence of siphoning or backflow from a chemigation system could severely degrade the quality of the aquifer. Likewise, secondary containment structures should be required of any liquid storage facility.

Cooperation of the public will determine the success of the WHP plan. The importance of this cannot be overly stressed. Because the public sector conducts the majority of activities which could result in potential contamination of the aquifer, they must be actively involved. The public must be educated about the WHP plan, its goals and objectives, and how they are involved. The public education phase of the WHP plan would, therefore, need to outline not only the regulatory requirements of the plan but also convince the public that a problem exists. For example, nitrate concentrations in the aquifer can only be controlled through public awareness. As previously discussed, a pilot study should be conducted to determine the level
of contamination that can be attributed to existing agricultural activities. This study could serve as a platform for public involvement by soliciting the participation of area farmers. By involving the members of the community in the delineation of the problem, their cooperation would be maximized.

E. Development of Contingency Plans for Each Public Water Supply System for Response to Well or Well Field Contamination

Contingency plans must outline specific actions to be taken in the event of contamination or potential contamination of the water supply. Because of the variety of contamination mechanisms, the contingency plan must be structured to reflect the nature of the pollution source. For example, the accidental spill of hazardous substances resulting from train or highway accidents could result in severe and obvious contamination of the water supply. On the other hand, nitrate concentrations could rise to levels in exceedence of drinking water standards, also causing the need for action. The final guidelines will include specific recommendations for elements of contingency plans, and the creation of a plan cannot be effectively accomplished until the source inventory and WHPA delineation steps have been completed.

Critical elements of a contingency plan will include:

- A notification network including contact names, telephone numbers and addresses (the network should include appropriate members of the WHP committee as well as regulatory agencies involved);
- Control strategies for various types of spills or leaks to physically minimize the amounts reaching the aquifer;
- Well field operation plans to ensure an uninterrupted supply of water, including well usage strategies such as prioritized shut off schemes for any location within the WHPA, and provisions to utilize wells located outside of the Town well field to reverse the hydraulic gradient and prevent contamination of the domestic wells (this concept will require preplanning and agreements with well owners); and
- Spill Prevention Control and Countermeasures (SPCC) plans for activities located within the WHPA, such as site-specific plans for the fertilizer distribution facilities.

F. Siting of New Wells

Siting of new wells in the Pine Bluffs region will require considerations other than simply optimizing water quality. The Town lies within the Laramie County control area, which imposes severe constraints upon the construction of additional wells. Therefore, new wells will require public notice, proof of non-injury to existing users and approval by the Board of Control. Given the demands of the Town in relation to existing water rights and well yields, new water supply wells are not anticipated. However, in the event of contamination of a well, abandonment and relocation may be required. In that event, coordination with the Wyoming State Engineer's office and the Board of Control will be required.
G. Ensuring Public Participation

Public participation in the Town of Pine Bluffs Well Head Protection Program could be deemed the most important aspect governing its ultimate success and has been stressed throughout this section. Strict regulatory control of the wellhead protection area by the Town is not practical. Therefore, voluntary compliance and cooperation with WHP committee recommendations will be essential to the success of the program. In order to facilitate this, recommendations made in the discussions other WHP plan elements should be followed. These recommendations include:

- Soliciting public involvement from the onset of the project
- Conducting public meetings outlining the project, its goals and objectives
- Educating the public of the potential results of aquifer contamination
- Soliciting involvement of farmers in a soil nitrate investigation in conjunction with the SCS
- Including members of the public on the WHP committee
- Inviting the public to determine the best management tools available to control ground water contamination
- Conducting a Nitrate Awareness Program educating the public of the cause for concern, sources and controls.

In summary, the development of a wellhead protection plan is not a trivial exercise. It will require a committed, cooperative effort on the part of the Town and the public in order to complete a quality plan. However, it is not beyond the range of the Town's capabilities to complete one with the assistance and technical guidance of the WQD. Specific assistance may be required in tasks such as the delineation of the WHPAs, and coordination with WQD, WWDC, and hydrogeologists may be necessary. These sources will also provide valuable information and guidance in the preparation of the remainder of the plan.

The plan is meant to be utilized and dynamic. The requirements of the plan allow for considerable flexibility and creativity on the part of the Town of Pine Bluffs in the determination of management strategies and techniques to maintain and protect the quality of the ground water resource. It is intended to be updated as the Town grows and new sources of contamination become present or new data are obtained.

Upon their completion, the guidelines currently being developed by WQD will provide specific guidelines and recommendations for the accomplishment of each task. At this time, it is recommended that the Town begin considering the requirements of the WHP plan in order to start the planning process. The Town can begin the development of its plan without waiting for the final guidelines to be developed. Steps such as the delineation of the contributing area and inventory of potential pollutant sources can begin immediately. Perhaps the most important task that can be undertaken at this time is for the Town to lay the groundwork for public
involvement. By discussing the future needs at Town Council meetings and in public notices and press releases, the Town can begin to make the public aware of what will be taking place in the future.