Manville Well
Level II Study

Executive Summary

December 2014

Submitted to:

Wyoming Water Development Commission
6920 Yellowtail Road
Cheyenne, WY  82002
(Contract No. 05SC0294559)

Level II Study Sponsor:

Town of Manville
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I, Christopher G. Moody, a Wyoming registered Professional Geologist, certify that this Manville Well, Level II Study was prepared by me or under my direct supervision.

Christopher G. Moody

I, Murray T. Schroeder, a Wyoming registered Professional Engineer, certify that this Manville Well, Level II Study was prepared by me or under my direct supervision.

Murray T. Schroeder
EXECUTIVE SUMMARY

ES.1 Statement of the Problem

The Town of Manville (Town) is located at the intersection of Highway 20 and Highway 270 approximately 8.5 miles west of Lusk in Niobrara County, Wyoming (Figure ES-1). The Town obtains drinking water from three wells completed in the Arikaree Formation/Aquifer (Arikaree). The uranium concentration at these wells exceeds the Environmental Protection Agency (EPA) drinking water standard of 0.030 milligrams per liter (mg/L) and the adjusted gross alpha concentration occasionally exceeds the drinking water standard of 15 picoCuries per liter (pCi/L). Manville is currently under two EPA Administrative Orders to comply with uranium and adjusted gross alpha drinking water standards. Two options for water quality compliance are to obtain a new water supply or to treat the current water supply for uranium and gross alpha.

ES.2 Study Objective

The objective of the Manville Well Level II Study is to evaluate the water production and water quality characteristics of the Hartville Formation/Aquifer (Hartville) which occurs at some depth below the Arikaree. The Hartville is part of Wyoming’s Paleozoic aquifer system that often provides water suitable for municipal purposes. A new well completed in the Hartville that complies with EPA primary drinking water standards may provide a cost effective long-term solution to the Town’s water quality compliance problems. The Arikaree was also evaluated because of its historic and regional use as a municipal water supply.

ES.3 Water System Demands

The water system serves a population of approximately 96 people. Currently there are 55 active service taps with 54 of the taps providing water to residences and 1 tap providing water to 3-Sisters Café.

In early 2012, the Town installed individual meters at residential and commercial services and in June 2012 began billing customers monthly according to a tiered water
rate schedule based on actual water use. 2013 represents the first full year of metered
water use subject to the new tiered water use rate schedule. Demand statistics for 2013
indicate that the total annual water demand was reduced by approximately 58 percent;
most likely a direct result of service metering and billing according to use.

2013 water use data were used to define design average day demand and design
maximum day demand values for water supply planning purposes.

- Design Average Day Demand = 33,200 gallons/day (23 gpm)
- Design Maximum Day Demand = 125,400 gallons/day (87 gpm)

ES.4 Current Water Supply

The Town obtains water from three wells – Manville No. 1, Manville No. 2, and
Manville No. 3 – completed in the Arikaree Aquifer. Figure ES-2 shows the location of
these supply wells and Table ES-1 lists construction and hydraulic data for each well.

Manville No. 1 and Manville No. 2 were constructed in 1913 and are enclosed in
the control building at the east end of Town. Despite their age, both wells are in good
condition. Manville No. 1 and No. 2 are high capacity (142 and 247 gpm, respectively)
wells with specific capacity values ranging from 15 to 30 gallons per minute per foot of
drawdown (gpm/ft).

Manville No. 3 is located approximately 230 feet northeast of the control building
and immediately south of the maintenance building. Manville No. 3 is a relatively low
capacity (63 gpm) well with a much lower specific capacity value of 1.3 gpm/ft.

Table ES-2 lists primary water quality data from Manville Nos. 1 - 3. The water
quality is excellent as indicated by total dissolved solids concentrations ranging from 358
to 416 mg/L and compliance with EPA primary and secondary drinking water standards
except uranium.

Uranium concentrations in groundwater from Manville Nos. 1 – 3 have exceeded
the current EPA drinking water standard of 0.030 mg/L since 1989. Uranium
concentrations vary over a fairly narrow range from 0.033 to 0.047 mg/L with an average
concentration of 0.040 mg/L.

Gross alpha concentrations are more variable than uranium concentrations. Pre-
2010 samples have adjusted gross alpha (AGA) values ranging from less than zero to 4.3
pCi/L. However, since 2010, total gross alpha values have increased and AGA values have increased to the point of occasionally exceeding the drinking water standard of 15 pCi/L.

ES.5 Local Hydrostratigraphy

There are numerous regional studies of the geology and hydrogeology that include the Manville area, but detailed and reliable subsurface data in the vicinity of Manville are limited to the Arikaree Formation. Figure ES-3 illustrates that the study area is covered extensively by Tertiary Arikaree Formation sandstone. Paleozoic Hartville Formation carbonates are exposed at the north end of the Hartville Uplift southwest of Manville and exposures of late Paleozoic to early Mesozoic Goose Egg Formation occur near a tributary of the Niobrara River southeast of Manville.

Due to the Arikaree’s good production characteristics and excellent water quality, Manville area water wells are rarely drilled deeper than 200 feet and do not penetrate far into the tan claystone and siltstone of the White River Group which underlies the Arikaree. The White River is not exposed in the study area. Figure ES-4 identifies the sequence, lithology, and anticipated water supply characteristics of rock units that occur at the surface and are anticipated to occur in the subsurface near Manville.

ES.6 Hartville Formation/Aquifer Evaluation

Two test holes were installed to evaluate the Hartville: Test Hole #1 at the Dellview Cemetery located 0.8 miles southeast of the water storage tank and Test Hole #2 at Lee Tschacher’s property located 1.0 miles west of the water tank (Figure ES-2).

Hydrogeologic information on the Hartville from the two test holes is listed below.

- The Hartville Formation underlies the Tertiary cover (i.e., Arikaree and White River Group) in the vicinity of Manville.
- Prior to the deposition of White River sediments, the upper part of the Hartville Formation (i.e., Divisions I/II) was eroded away.
- The Hartville Formation is a diverse, complex, and thick assemblage of limestone, dolomite, siltstone, shale and chert. Test Hole #2 penetrated 690 feet of Hartville Formation.
In the vicinity of Manville, the Hartville is an unconfined aquifer with 390 to 426 feet of unsaturated Hartville Formation situated between the bottom of the White River and the water table surface in the Hartville which occurs at approximately 645 feet below ground surface. The lower 300 feet of the Hartville Formation is saturated.

The head elevation of the Hartville Aquifer at Test Hole #1 and Test Hole #2 is 4624 feet above mean sea level (amsl).

Test Hole #2 encountered a productive water-bearing zone at base of the Hartville/top of the Guernsey at 946 to 950 feet.

Test Hole #1 encountered an open and interconnected fracture zone in the unsaturated part of the Hartville Formation at 461 to 463 feet (Figure ES-5). The fracture zone is laterally extensive and connected to the atmosphere as indicated by the flow of air in and out of the test hole in response to fluctuations in barometric pressure.

Groundwater from the Hartville Aquifer is calcium-bicarbonate type water and is suitable for municipal use. All tested water quality parameters are less than primary and secondary drinking water standards, including uranium and adjusted gross alpha (Table ES-3).

Where saturated, the Hartville is an attractive target for additional groundwater resource evaluation and development. However, the depth-to-water in the Hartville in the vicinity of Manville is likely to be on the order of 645 feet.

The existence of two unconfined aquifers- the Arikaree above and the Hartville below - separated by the low-permeability claystone/siltstone of the White River and up to 426 feet of unsaturated carbonate rock (Figure ES-5) was highly unusual and totally unexpected. The deep depth-to-water of 645 feet, despite proximity to the highland recharge area for the Hartville Aquifer, was also unexpected.

The head elevation of 4624 feet amsl at both test holes provides the opportunity to speculate on hydrogeologic conditions and head controls in the Hartville Aquifer. It is possible that the two test holes are located on the same piezometric contour (i.e., a minimum of three head points are needed to define the hydraulic gradient). The lack of a significant head difference between two test holes separated by 1.6 miles may indicate an aquifer surrounded by no-flow boundaries such that the aquifer does not have a discharge point. Alternatively, structural features and fracture permeability within the lower part of
the Hartville Aquifer may be extensive enough that groundwater can flow to discharge points under very low hydraulic gradients.

Possible regional discharge points are Guernsey and Glendo Reservoirs which are at low elevations for exposures of the Hartville Formation in the Hartville Uplift along the North Platte River. The pool elevations of Glendo and Guernsey reservoirs are 4635 and 4428 feet amsl, respectively. Glendo Reservoir water levels are similar to the Hartville Aquifer head elevation at Manville whereas Guernsey Reservoir water levels are 200 feet lower. Conclusions cannot be drawn from only two test holes regarding regional groundwater flow and the hydrogeology of the Hartville Aquifer; however, it is apparent that very unusual hydrogeologic conditions exist in the Hartville Aquifer in the vicinity of Manville.

ES.7 Arikaree Formation/Aquifer Evaluation

The Arikaree evaluation used data obtained from three wells at the Dellview Cemetery: Test Hole #1, Cemetery Windmill Well, and Test Well #1 (Figure ES-2). Low-volume pumping tests and water samples from Test Hole #1 and the Cemetery Windmill Well indicated the potential for excellent production and acceptable water quality as listed in Table ES-3. Data from these two wells guided the subsequent decision to install a test well in the Arikaree at the Dellview Cemetery.

Test Well #1 is located 29 feet south of Test Hole #1 at the east end of the Dellview Cemetery property. Figure ES-6 illustrates Test Well #1 design and completion. Test Well #1 construction complies with WDEQ/WQD Permit to Construct No. 13-425 which provides authorization to construct the well as a public supply well.

Hydrogeologic information on the Arikaree obtained from Test Well #1 during drilling and pumping tests is listed below.

- The Arikaree Formation is 93 feet thick and the water table of the unconfined aquifer is at 37 feet. Fractured sandstone from 57 to 60 feet appears to be an interval of high permeability and primary water production.

- Test Well #1 was pumped for 7 days at a constant rate of 126 gpm. After 2 days of pumping there was 5.56 feet of drawdown (Figure ES-7). Recycling of pumping test discharge water affected the drawdown response in the well after 2 days of pumping.
The specific capacity of Test Well #1 is 21 gpm per foot of drawdown.

Production capacity from Test Well #1 satisfies design average day demand and design maximum day demand requirements.

Uranium concentrations from Test Well #1 ranged from 0.0112 to 0.0132 mg/L (Table ES-3) which is less than the drinking water standard of 0.030 mg/L.

Adjusted gross alpha concentrations from Test Well #1 ranged from 0.8 to 8.3 pCi/L (Table ES-3) which is less than the drinking water standard of 15 pCi/L.

Water quality from Test Well #1 complies with primary and secondary drinking water standards and is suitable for use by the Town.

Testing and analysis of the Arikaree indicate that Test Well #1 is a viable water supply well that can provide adequate water quality and water production for the Town. A well operation strategy can be developed that uses Test Well #1 alone or in combination with Manville Nos. 1-3 that will allow the Town to comply with drinking water standards.

**ES.8 Geophysical Investigation**

Electrical resistivity and seismic reflection surveys were conducted along a north-south transect from the east end of Town, to the Dellview Cemetery, and on to the Manville #2 Landfill and wastewater lagoons. The resistivity and reflection surveys provide a large-scale geologic context for hydrogeologic features observed in the Hartville and Arikaree at Test Hole #1 and Test Well #1 at the cemetery.

The resistivity survey indicates a fault with large vertical displacement in the vicinity of the Dellview Cemetery. Test Hole #1 and Test Well #1 are located directly on or in the fault trace/fault zone. Stratigraphic offset from the fault is up to the south and down to the north. The Arikaree Formation gets progressively thinner south of the cemetery and the Hartville Formation may be within 35 feet of ground surface at the northwest corner of the Manville #2 Landfill.

The resistivity and reflection surveys indicate considerable structural complexity in the subsurface between the cemetery and Town. The geophysical investigation
supports the surface mapping investigation which concluded that the Manville area is a structurally complex region.

The southward thinning and northward thickening of the Arikaree Formation at the cemetery may affect to some degree the long-term drawdown behavior of Test Well #1. The positive or negative effects of aquifer geometry on well performance in the future will depend on the characteristics of fracture networks and hydraulic boundaries and cannot be predicted.

Correlation of resistivity data with drilling data from Test Hole #1 suggests that the Hartville Formation lies directly beneath the Tertiary cover in the area between Manville No. 3 and the cemetery. Numerous stratigraphic offsets observed in the subsurface in this area suggest that the Hartville may be highly fractured. Where saturated, the Hartville may be an attractive target for groundwater development. However, the depth-to-water in the Hartville is likely to be on the order of 650 feet such that well construction and pumping costs will be high.

**ES.9 Water Treatment**

Water treatment to achieve compliance with primary drinking water standards is not required if municipal water is obtained exclusively from Test Well #1. Empirical mixing and dilution calculations show that water from Test Well #1 can be blended with water from Manville Nos. 1-3 in a 2:1 ratio, respectively, and maintain compliance with uranium and gross alpha standards. Viable pumping rates are 120 gpm from Test Well #1 and 60 gpm from Manville No. 3.

**ES.10 Water Supply Improvement Options**

Four options to achieve compliance with drinking water standards were identified and presented to the Town and WWDO for consideration.

- Option #1: Test Well #1 is used as single source of potable water. Manville Nos. 1-3 are available as temporary back-up or emergency supply. This option provides a maximum supply capacity of approximately 120 gpm.
• Option #2: Test Well #1 and Manville No. 3 are pumped simultaneously to produce a blend that complies with drinking water standards. This option provides a maximum supply capacity of 180 gpm.

• Option #3: A Hartville well (currently unavailable) is used as a single source or as one component in a blending scheme.

• Option #4: Point-of-Use/Point-of-Entry water treatment for uranium and gross alpha.

Preliminary cost estimates indicated that Option #1 and Option #2 are the lowest cost options for water customers. The Town selected options involving the use of water from Test Well #1 for further development of conceptual designs and cost estimates for water supply improvements.

ES.11 Conceptual Design of Manville No. 4 (a.k.a., Test Well #1) Connection Project

The conceptual design of connecting Manville No. 4 into the water system involves the installation of 4,700 feet of 6-inch diameter PVC transmission line with a design capacity of 250 gpm (Figure ES-8). The pipeline will bring water from Manville No. 4 located at the Dellview Cemetery to the control building at the east end of Town. Plumbing at the control building will be modified to allow the blending and simultaneous operation of Manville No. 4 at 120 gpm and Manville No. 3 at 60 gpm.

ES.12 Cost Estimate of Water Supply Improvement Project

The estimated cost for the Manville No. 4 connection project is $472,000 (Table ES-4). Purchase of Test Well #1 from the WWDC will cost the Town approximately $7,912. This cost represents 33% of the construction cost of Test Well #1 as incurred during this study. Assuming that the connection project is funded 100% by a WWDC grant/loan or is funded 50% by a WWDC grant/loan and 50% by a WSLIB grant, a monthly fee increase per service connection may range from $16.61 to $9.79, respectively (Table ES-5).
ES.13 Construction Project Financing

In September 2013, the Town submitted a Level III construction project application to the WWDC to fund construction of infrastructure to connect Manville No. 4 into the water system. The 2014 legislature approved funding of $490,000 ($328,300 grant/$161,700 loan) for the Level III project.

In February 2014, the Town submitted an application to the Wyoming State Land and Investment Board (WSLIB) to fund construction of infrastructure to connect Manville No. 4 into the water system. During the June 2014 meeting, the WSLIB approved a $165,700 grant to the Town for water supply improvements.

Grant funding from the WWDC and WSLIB is anticipated to fully cover the cost of water supply infrastructure improvements as identified in this study.

ES.14 Compliance with Administrative Order

On November 13, 2012, the EPA filed Administrative Order Addendum #3 regarding a revised uranium compliance schedule whereby the Town will obtain WWDC Level III construction project funding approval in February 2014, and the Level III construction project will be completed by September 30, 2015. The compliance schedule for gross alpha is assumed to be the same as the compliance schedule for uranium. Execution of the Level III construction project will allow the Town to achieve compliance with uranium and gross alpha drinking water standards.

The Town has procured grant/loan funding from the WWDC and WSLIB to connect Manville No. 4 into the water system. The Town is prepared to begin Level III project design and construction in 2015, and is currently on-track to meet the EPA Administrative Order compliance schedules for uranium and gross alpha.

ES.15 Recommendations

Wyoming Groundwater and WWC Engineering provide the following recommendations regarding water supply improvements and planning.

- Purchase Test Well #1 from the WWDC. Submit a new well permit application (UW 5) to the WSEO that designates a proper well name (e.g.,
Manville No. 4), defines area of use, and establishes a water right for miscellaneous use.

- Proceed with the Level III construction project to connect Manville No. 4 into the water system.

- Design Manville No. 4 to pump 120 gpm and provide pipeline infrastructure that can accommodate a second well at the cemetery.

- Blend water from Manville No. 4 and Manville No. 3 to reduce, to the degree possible, the total annual withdrawal of water from the cemetery area. Careful monitoring of water levels and water quality at Manville No. 4 over the course of a few years of operation will provide the data needed to determine if water compliance can be maintained, whether blending is needed in the long-term, and whether wellfield expansion at the cemetery (i.e., a second well in the Arikaree) is possible.

- Design and operate the water system such that water from Manville No. 4 and Manville No. 3 are blended together in a 2:1 ratio to provide water quality compliance and a maximum water production capacity of 180 gpm.

- Discuss with the WDEQ and EPA issues associated with the use of Manville No. 3 as a temporary well in the event that Manville No. 4 is temporarily out of service.

- Enhance control, either by purchase or agreement, of the Dellview Cemetery property as deemed agreeable to the Dellview Cemetery Association.

- Annually update water demand statistics such as average day demand, maximum day demand, and gallons per day per capita to provide a more accurate estimate of trends in water use under the tiered water rate structure.

- Adjudicate the water right associated with Manville No. 4 when well production is demonstrated.

- To avoid the water supply being classified as Groundwater Under the Direct Influence of Surface Water, maintain proper operation of the hypochlorite disinfection system.

- If a bulk load-out facility for non-potable water is desired, contact the Wyoming State Engineer’s Office and the WDEQ Southeast District Engineer to discuss the transfer/change-in-use of Manville No. 1.

- Develop a written operation and maintenance manual so that system operators follow established water sampling procedures and have water system permits and information available for on-site reference and review.
# Table ES-1: Manville Water Supply Well Data. Manville Well, Level II Study

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<td>P594C</td>
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<td>150</td>
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<td>Arikaree</td>
<td>185</td>
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<td>0 to 18</td>
<td>10&quot; Steel</td>
<td>18 to 185</td>
<td>7.5HP Vert. Turbine</td>
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<td>NM</td>
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<td>63</td>
<td>37.5</td>
<td>1.3 @ 64 gpm</td>
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## Table ES-2: Manville Supply Water Quality. Manville Well, Level II Study

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<tr>
<th></th>
<th>Manville No. 1 (East Well)</th>
<th>Manville No. 2 (West Well)</th>
<th>Manville No. 3</th>
<th>EPA MCL</th>
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<td>185</td>
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<td>Location: T, R, Sec, Qtr</td>
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<td>32, 65, 1, NW</td>
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<td>Source Aquifer</td>
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<td>Arickaree</td>
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<td>Calcium, mg/L</td>
<td>69</td>
<td>68</td>
<td>59</td>
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<td>Magnesium, mg/L</td>
<td>19</td>
<td>19</td>
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<td>Sodium, mg/L</td>
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<td>22</td>
<td>23</td>
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<td>Potassium, mg/L</td>
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<td>Bicarbonate, mg/L</td>
<td>287</td>
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<td>Chloride, mg/L</td>
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<td>Conductivity, lab, μmhos/cm</td>
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<td>580</td>
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<td>Total Dissolved Solids @ 180, mg/L</td>
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<td>Total Dissolved Solids, calc. sum, mg/L</td>
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<td>522</td>
<td>493</td>
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<td>Hardness, as CaCO3</td>
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<td>Dissolved Oxygen, field, mg/L</td>
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<td>3.8</td>
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<td>Oxidation Reduction Potential, mV</td>
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<td>Turbidity, NTU</td>
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<td>Uranium, mg/L</td>
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<td><strong>0.035</strong></td>
<td><strong>0.034</strong></td>
<td><strong>0.030</strong></td>
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<td>Gross Alpha, pCi/L</td>
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<td>26.0</td>
<td>22.0</td>
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<td>Adjusted Gross Alpha*</td>
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<td>2.3</td>
<td>&lt; 0</td>
<td>15.0</td>
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<td>Gross Beta, pCi/L</td>
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<td>15.4</td>
<td>11.7</td>
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<td>&lt; 1.0</td>
<td>&lt; 1.0</td>
<td>5.0</td>
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<tr>
<td>Radium 228, pCi/L</td>
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<td>&lt; 1.0</td>
<td>&lt; 1.0</td>
<td>5.0</td>
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<tr>
<td>Radium 226+228, pCi/L</td>
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<td>&lt; 1.0</td>
<td>&lt; 1.0</td>
<td>5.0</td>
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<td>Radon 222, pCi/L</td>
<td>955</td>
<td>835</td>
<td>888</td>
<td></td>
</tr>
<tr>
<td>Total Organic Carbon, mg/L</td>
<td>1.5</td>
<td>1.4</td>
<td>1.0</td>
<td></td>
</tr>
<tr>
<td>A/C Balance, %</td>
<td>-0.6</td>
<td>-0.90</td>
<td>0.64</td>
<td></td>
</tr>
</tbody>
</table>

* : Adjusted Gross Alpha = Gross Alpha - Uranium, in consistent units

**Bold** values exceed drinking water standard
Table ES-3: Water Quality Data from Arikaree Wells at the Dellview Cemetery. Manville Well, Level II Study

Uranium MCL = 30 μg/L (equivalent to 0.030 mg/L)  
Adjusted Gross Alpha MCL = 15 pCi/L

| Location | Total Depth, ft. | Aquifer | Calcium | Magnesium | Sodium | Potassium | Bicarbonate | Nitrate + Nitrite, as N | Uranium, μg/L | Gross Alpha, pCi/L | Adj. Gross Alpha, pCi/L | Radium 226, pCi/L | Radium 228+, pCi/L | Radon 222, pCi/L | Conductivity, lab | Conductivity, field | TDS @ 180 | TDS calc | pH, lab | pH, field | Dissolved Oxygen, mg/L | Temperature, degree C | Total Suspended Solids | Total Coliform | Fecal Coliform | Iron Bacteria, CFU/ml | A/C Balance, % | Sample Date |
|----------|-----------------|---------|---------|-----------|--------|-----------|-------------|-------------------------|---------------|----------------------|----------------------|-------------------|-----------------|----------------|----------------|-------------|----------------|----------------|-------------|----------------|------------------|-----------------|----------------|
| Dellview  | 32, 65, 12, NW, NE | 93      | 57      | 13        | 10     | 7         | 228         | 2.2                     | 13.5/17*       | 9.4                 | 0.3                | -0.02             | 0.1             | 420            | 374          | 277             | 405          | 7.78             | 10.2             | 10.9             | NA             | NA            | NA              | -1.33        | 10/25/2013 |
| Cemetery  | Test Hole #1 Air-Lift | 100     | 50      | 12        | 21     | 8         | 244         | 2.1                     | 12.4           | 14.1                | 5.7                | 0.10              | 0.18            | 425            | 373          | 4577            | 416          | 7.84              | 10.7             | 12.6             | NA             | NA            | NA              | -1.37        | 7/29/2013 |
| Windmill  | 32, 65, 12, NW, NE | 104     | NA      | NA        | NA     | NA        | NA          | NA                      | 11.6           | 9.7                 | 1.2                | 0.09              | 0.78            | NA             | NA          | 11.7            | 418          | 390               | 10.3             | 10.5             | < 10           | NA            | NA              | < 1.0        | 10/31/2013 |
| Well      | Test Well #1 | 32, 65, 12, NW, NE | 12.5   | 9.7      | 1.2     | 0.09     | 0.78        | 418                      | 12.0           | 9.7                 | 0.8                | 0.1               | 0.6            | 602            | 378          | 378             | 390          | 7.84              | 10.3             | 10.5             | < 10           | NA            | NA              | -1.37        | 11/6/13 to 11/11/13 |
| Test Hole #1 | 32, 65, 12, NW, NE | 12.8   | 17.1    | 8.3      | 0.1     | 0.6      | 430                  | 12.5           | 13.2                | 8.3                | 0.5               | 0.51           | 571            | 378          | 379             | 402          | 7.78              | 10.5             | 10.7             | < 10           | NA            | NA              | < 1.0        | 11/9/2013 |
| Test Well #1 | 32, 65, 12, NW, NE | 13.0   | 11.3    | 3.2      | 0.14    | 0.82     | 478                   | 11.6           | 13.0                | 15.5               | 0.63              | 0.68          | 433            | 379          | 379             | 392          | 8.01              | 10.3             | 10.5             | < 10           | NA            | NA              | < 1.0        | 11/12/2013 |
| End-Test (168 hrs) | 32, 65, 12, NW, NE | 0.012  | 11.3    | 3.2      | 0.14    | 0.82     | 478                   | 11.6           | 13.0                | 15.5               | 0.63              | 0.68          | 433            | 379          | 379             | 392          | 8.01              | 10.3             | 10.5             | < 10           | NA            | NA              | < 1.0        | 11/13/2013 |
| Dellview  | Test Hole #2 | 32, 65, 12, NW, NE | 1.0    | 1.0      | 0.5     | 0.51     | 1.1                  | 12.5           | 13.0                | 15.5               | 0.63              | 0.68          | 433            | 379          | 379             | 392          | 8.01              | 10.3             | 10.5             | < 10           | NA            | NA              | < 1.0        | 6/27/2013 |
| Cemetery  | Test Hole #1 | 32, 65, 12, NW, NE | 0.67   | 1.0      | 0.5     | 0.51     | 1.1                  | 12.5           | 13.0                | 15.5               | 0.63              | 0.68          | 433            | 379          | 379             | 392          | 8.01              | 10.3             | 10.5             | < 10           | NA            | NA              | < 1.0        | 8/27/2013 |

NA: Not Analyzed
Table ES-4: Cost Estimate of Conceptual Design of Connecting Manville No. 4 Manville Well, Level II Study

Construction Project Cost Estimator provided by WWC Engineering

<table>
<thead>
<tr>
<th>Item</th>
<th>Unit</th>
<th>Cost/Unit</th>
<th>Quantity</th>
<th>Total Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Mobilization and Bonds (% of Items 2-18)</td>
<td>LS</td>
<td>8%</td>
<td>1</td>
<td>$22,400</td>
</tr>
<tr>
<td>2 Sitework</td>
<td>LS</td>
<td>$5,000</td>
<td>1</td>
<td>$5,000</td>
</tr>
<tr>
<td>3 Structure (Pump House)</td>
<td>LS</td>
<td>$20,000</td>
<td>1</td>
<td>$20,000</td>
</tr>
<tr>
<td>4 Pump, Equipment and Pitless Unit</td>
<td>LS</td>
<td>$12,500</td>
<td>1</td>
<td>$12,500</td>
</tr>
<tr>
<td>5 Interior Pipe, Fittings and Valves</td>
<td>LS</td>
<td>$25,000</td>
<td>1</td>
<td>$25,000</td>
</tr>
<tr>
<td>6 SCADA System</td>
<td>LS</td>
<td>$20,000</td>
<td>1</td>
<td>$20,000</td>
</tr>
<tr>
<td>7 Electrical</td>
<td>LS</td>
<td>$30,000</td>
<td>1</td>
<td>$30,000</td>
</tr>
<tr>
<td>8 Fence</td>
<td>LS</td>
<td>$7,000</td>
<td>1</td>
<td>$7,000</td>
</tr>
<tr>
<td>9 Transmission Line Connection</td>
<td>LS</td>
<td>$3,000</td>
<td>1</td>
<td>$3,000</td>
</tr>
<tr>
<td>10 Transmission Line (Overland)</td>
<td>LF</td>
<td>$25</td>
<td>4500</td>
<td>$112,500</td>
</tr>
<tr>
<td>11 Transmission Line (in Town)</td>
<td>LF</td>
<td>$50</td>
<td>200</td>
<td>$10,000</td>
</tr>
<tr>
<td>12 Transmission Line Fittings and Valves (allowance)</td>
<td>EA</td>
<td>$1,500</td>
<td>10</td>
<td>$15,000</td>
</tr>
<tr>
<td>13 Bore and Case (HWY or RR)</td>
<td>LS</td>
<td>$50,000</td>
<td>0</td>
<td>$0</td>
</tr>
<tr>
<td>14 Power To Site</td>
<td>LS</td>
<td>$20,000</td>
<td>1</td>
<td>$20,000</td>
</tr>
<tr>
<td>15 Unlisted Items (% of Items above, except 1)</td>
<td>LS</td>
<td>5%</td>
<td>1</td>
<td>$14,000</td>
</tr>
</tbody>
</table>

A Construction Cost Subtotal | $316,400 |
B Construction Engineering Costs (10% of A) | $31,640 |
C Subtotal (A+B) | $348,040 |
D Contingency (15% of C) | $52,206 |
E CONSTRUCTION TOTAL COST (C+D) | $400,246 |
F Prepare Final Design and Specs (15% of E) | $60,037 |
G Permitting and Mitigation | $5,000 |
H Legal Fees | $5,000 |
I Acquisition of Access and ROW | $2,000 |

Subtotal (E+F+G+H+I) | $472,283 |
J Construction Project Total Cost | $472,283 |

K Rounded Construction Project Total Cost | $472,000 |

L Additional Non-Construction Costs
   2 Manville No. 4 Well Construction From Level II Study (33% of Level II cost) | $7,912 |
### Table ES-5: Estimated Additional Cost Per Service; Arikaree Well at Dellview Cemetery

**Manville Well, Level II Study**

#### GRANTS AND LOANS

<table>
<thead>
<tr>
<th>Option</th>
<th>Description</th>
<th>Amount</th>
<th>Amount</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>A</strong></td>
<td>Project Cost Estimate</td>
<td>$472,000</td>
<td>$472,000</td>
</tr>
<tr>
<td></td>
<td><strong>1 TOTAL PROJECT VALUE</strong></td>
<td>$472,000</td>
<td>$472,000</td>
</tr>
<tr>
<td><strong>B</strong></td>
<td>GRANTS</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>1 Total of WWDC/SLIB Grant Eligible Items</td>
<td>$472,000</td>
<td>$472,000</td>
</tr>
<tr>
<td></td>
<td>2 WWDC Grant (67% of B1)</td>
<td>$316,240</td>
<td>$316,240</td>
</tr>
<tr>
<td></td>
<td>3 Amount Left to Fund</td>
<td>$155,760</td>
<td>$155,760</td>
</tr>
<tr>
<td></td>
<td>4 WSLIB Mineral Royalties Grant 50% of Amount Left to Fund (Item B3)</td>
<td>$77,880</td>
<td>$77,880</td>
</tr>
<tr>
<td></td>
<td>5 Grant Total (B2+B4)</td>
<td>$394,120</td>
<td>$394,120</td>
</tr>
</tbody>
</table>

#### SPONSOR (Cash)

<table>
<thead>
<tr>
<th>Option</th>
<th>Description</th>
<th>Amount</th>
<th>Amount</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1 From County Capital Facilities Tax (% of A)</td>
<td>0%</td>
<td>0%</td>
</tr>
<tr>
<td></td>
<td>2 Internal District Funding</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

#### LOANS

<table>
<thead>
<tr>
<th>Option</th>
<th>Description</th>
<th>Amount</th>
<th>Amount</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1 WWDC Loan Amount (A4-B5-C1-C2)</td>
<td>$155,760</td>
<td>$77,880</td>
</tr>
<tr>
<td></td>
<td>WWDC Level II Well Construction Loan Amount (Test Well)</td>
<td>$7,912</td>
<td>$7,912</td>
</tr>
<tr>
<td></td>
<td>Total WWDC Loan Amount</td>
<td>$163,672</td>
<td>$85,792</td>
</tr>
<tr>
<td></td>
<td>2 WSLIB Loan Amount (A4-B5-C1-C2)</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

#### USER COSTS

#### ANNUAL LOAN PAYMENTS

<table>
<thead>
<tr>
<th>Option</th>
<th>Description</th>
<th>Amount</th>
<th>Amount</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1 WWDC Loan</td>
<td>$9,465</td>
<td>$4,961</td>
</tr>
<tr>
<td></td>
<td>2 WSLIB Loan (None)</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>3 Existing Debt Obligations</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>TOTAL Annual Loan Payments</td>
<td>$9,465</td>
<td>$4,961</td>
</tr>
</tbody>
</table>

#### RESERVE

<table>
<thead>
<tr>
<th>Option</th>
<th>Description</th>
<th>Amount</th>
<th>Amount</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Set as percentage of loan repayment</td>
<td>0%</td>
<td>0%</td>
</tr>
</tbody>
</table>

#### ADDITIONAL OPERATON AND MAINTENANCE COSTS - Annual

<table>
<thead>
<tr>
<th>Option</th>
<th>Description</th>
<th>Amount</th>
<th>Amount</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>User Fees (Assumes Average Monthly Water Bill)</td>
<td>$1,500</td>
<td>$1,500</td>
</tr>
<tr>
<td></td>
<td>TOTAL ANNUAL COSTS</td>
<td>$10,965</td>
<td>$6,461</td>
</tr>
</tbody>
</table>

#### ESTIMATED INCREASE IN MONTHLY WATER FEE FOR EACH SERVICE TAP

Based on Current Number of Active Taps: 55

<table>
<thead>
<tr>
<th>Option</th>
<th>Description</th>
<th>Amount</th>
<th>Amount</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>10,965</td>
<td>$16.61</td>
<td>$9.79</td>
</tr>
</tbody>
</table>
FIGURE ES-1
STUDY LOCATION MAP
MANVILLE WELL, LEVEL II STUDY
<table>
<thead>
<tr>
<th>PERIOD</th>
<th>FORMATION AND MAXIMUM THICKNESS</th>
<th>LITHOLOGY DESCRIPTION</th>
<th>WATER SUPPLY CHARACTERISTICS</th>
</tr>
</thead>
<tbody>
<tr>
<td>QUATERNARY</td>
<td>ARKARKE FM. 180' IN MANVILLE AREA</td>
<td>LIGHT GRAY TO BUFF TO LIGHT BROWN FINE-GRAINED SANDSTONE, LOOSELY TO MODERATELY CEMENTED, INTERBEDDED COARSE SAND, THIN LIMESTONE, AND CONCRETIONARY SANDSTONE, LENTICULAR CONGLOMERATE AT BASE.</td>
<td>EXCELLENT WATER SUPPLY FOR STOCK, DOMESTIC, MUNICIPAL, AND IRRIGATION PURPOSES. PRIMARY AQUIFER IN THE LUSK AREA. WATER PRODUCED PRIMARILY FROM LOOSE FINE TO COARSE-GRAINED SANDSTONE LAYERS AND LOCAL FRACTURES.</td>
</tr>
<tr>
<td>TERTIARY</td>
<td>WHITE RIVER GROUP 120' IN MANVILLE AREA</td>
<td>PINKISH TAN CLAYSTONE AND SILTSTONE. VANIEGATED CLAYSTONE IN LOWER PART (CHAIDRON FM.), BENTONITE AND TUFFACEOUS. LOCAL CHANNEL DEPOSITS. ARKOSIC CONGLOMERATE AT BASE.</td>
<td>YIELDS SMALL QUANTITIES OF WATER TO STOCK AND DOMESTIC WELLS. CHANNEL DEPOSITS AND FRACTURES MAY YIELD LARGER QUANTITIES</td>
</tr>
<tr>
<td>TRIASSIC TO CRETACEOUS</td>
<td>CHUGWATER FM. TO LANCE FM. 7800'</td>
<td>DIVERSE ASSEMBLAGE OF SEDIMENTARY ROCK: SANDSTONE, SHALE, SILTSTONE, CLAYSTONE, COAL, BENTONITE, GYPSUM, AND CONGLOMERATE.</td>
<td>SHALE DOMINATED FORMATIONS NOT CONSIDERED AQUIFERS. INYAN KARA GROUP SANDSTONES PROVIDE WATER TO TOWN OF LANCE CREEK.</td>
</tr>
<tr>
<td>PERMIAN/TRIASSIC</td>
<td>GOOSE EGG FM. 360'</td>
<td>RED SHALE, SILTSTONE, THIN LIMESTONE, AND GYPSUM BEDS. (COMPRISED OF GYPSUM/RED SHALE SEQUENCE, MINNEKAHA LIMESTONE, AND CRECHE SHALE.)</td>
<td>NOT CONSIDERED AN AQUIFER. WATER QUALITY LIKELY TO BE POOR.</td>
</tr>
<tr>
<td>PENNSYLVANIAN</td>
<td>HAYVILLE FM. 1070'</td>
<td>LIMESTONE AND DOLOMITE WITH INTERBEDDED CHERT, SILTSTONE, SHALE, AND SANDSTONE. ORTHOSANDSTONE AT BASE AND 50-90 FEET OF YELLOW SANDSTONE AT TOP KNOWN AS THE &quot;CONVERSE SAND.&quot;</td>
<td>WHERE PRESENT THE CONVERSE SAND CAN PROVIDE HIGH YIELDS AND GOOD WATER QUALITY. WHERE FRACTURED OR SOLUTION ENHANCED, THE CARBONATES MAY PROVIDE HIGH YIELDS.</td>
</tr>
<tr>
<td>MISSISSIPPIAN AND DEVONIAN</td>
<td>GUERNSEY FM. 220'</td>
<td>LIMESTONE AND DOLOMITE WITH CHERT, THIN ARKOSITE AT BASE.</td>
<td>POTENTIAL AQUIFER WHERE FRACTURED.</td>
</tr>
<tr>
<td>CAMBRIAN</td>
<td>QUARTZITE 50'</td>
<td>DIVERSE ASSEMBLAGE OF CRYSSTALLINE ROCK, GRANITE, GNIESS, SCHIST, MEDISEDMENTS, AND META-VOLCANICS.</td>
<td>POTENTIAL SMALL TO MODERATE YIELDS WHERE FRACTURED.</td>
</tr>
</tbody>
</table>

FIGURE ES-4
HYDROSTRATIGRAPHY IN THE MANVILLE/LUSK AREA
MANVILLE WELL, LEVEL II STUDY

TEST HOLE #1 (CEMETERY)

GROUND SURFACE
ELEV. = 5263.6' AMSL

32'

ARIKAREE DEPTH TO WATER = 36.8'
ARIKAREE FORMATION
0-93'
- SANDSTONE
93'
(5171' AMSL)

WHITE RIVER GROUP
93-214'
- CLAYSTONE, SILTSTONE
214'
(5050' AMSL)

RED SHALE MARKER BED
255-268'
275'

OPEN CAVITY AND
FRACTURE NETWORK
311-313'

HARTVILLE FORMATION
DIVISIONS II, III, IV
214-690'
- LIMESTONE/DOLomite, SANDSTONE, Siltstone

EXTENSIVE OPEN CAVITY
AND FRACTURE NETWORK
461-463'

HARTVILLE DEPTH TO WATER = 639.2'
(9/17/14)
WATER LEVEL ELEV. = 4624.4' AMSL
TD = 690'

18' BOREHOLE
0-32'

10 3/4' O.D. STEEL
SURFACE CASING
0-32'

CEMENT ANNULAR SEAL
0-275'

9 7/8' BOREHOLE
32-276'

7' O.D. STEEL CASING; 23 LB/FT
0-275'
CENTRALIZERS: 90', 170', 260'

6 1/4-INCH BOREHOLE
275-690'

LOST CIRCULATION ZONE

UNSATURATED
214-639'

SATURATED
639-690'

LARGE VUG
674-676'

FIGURE ES-5
TEST HOLE #1 COMPLETION DIAGRAM
MANVILLE WELL, LEVEL II STUDY

ALL DEPTHS RELATIVE TO GROUND SURFACE
TEST WELL #1
(MANVILLE NO. 4)

GROUND SURFACE
ELEV. = 5264.08’ AMSL

WELLHEAD
PROTECTION

10 3/4” O.D. STEEL CASING,
32.7 LB/FT, THREADED JOINTS,
+2.0’ TO 50’

15” BOREHOLE
0’ TO 50’

CASING CENTRALIZERS AT:
8’ AND 47’

CEMENT ANNULAR SEAL
0’ TO 50’

DEPTH TO WATER = 36.8’
(09/17/14)
ELEV. 5227.3’ AMSL

ARIKAREE FORMATION
0–93’

93’
(5171’ AMSL)

WHITE RIVER GROUP
(CHADRON FM.)
93–104’

TD = 104’

8.0” PVC LINER, SCH 40,
FLUSH JOINT,
BLANK INTERVALS:
+1.5’ TO 34.7’
93.5’ TO 104’
32–SLOT SCREEN INTERVAL:
34.7’ TO 93.5’

9 7/8” OPEN HOLE
50’ TO 104’

57’ TO 60’: FRACTURED, PRIMARY
WATER PRODUCTION ZONE AS
INDICATED BY CUTTINGS AND
AIR-LIFT PRODUCTION DURING
DRILLING.

FIGURE ES–6
TEST WELL #1
(MANVILLE NO. 4)
COMPLETION DIAGRAM

MANVILLE WELL, LEVEL II STUDY

ALL DEPTHS RELATIVE TO GROUND SURFACE
Figure ES-7: Test Well #1 7-Day Pumping Test, 11/6/13 to 11/13/13
Manville Well, Level II Study

Pumping Rate (Q) = 126 gpm
Pre-Test Depth to Water = 37.95 feet rel. to ground

Transmissivity (T) Calculation
\[ T = \frac{264 \times Q}{\Delta s} \]
\[ = \frac{264 \times 126}{0.5} \]
\[ = 66,530 \text{ gpd/ft} \]
\[ = 8,890 \text{ ft}^2/\text{day} \]

Specific Capacity (7-day) at 126 gpm
\[ SC = \frac{Q}{s} \]
\[ = \frac{126 \text{ gpm}}{5.8 \text{ ft.}} \]
\[ = 21 \text{ gpm/ft of drawdown} \]

\[ \Delta s \text{ over one log cycle} = 0.5 \text{ feet} \]
FIGURE ES-8
PIPELINE ALIGNMENT PLAN AND PROFILE

6" PVC TRANSMISSION MAIN, 250 GPM CAPACITY

EXISTING 50,000 GALLON WATER TANK

STA 42+85 CONNECT TO EXISTING CONTROL BUILDING

DELLVIEW CEMETERY

TEST WELL #1 (MANVILLE NO. 4), WELL, PITLESS

WELL BOTTOM = 160.42

K:\Laramie\WY Ground Water\2011-169 Manville Well\cadd\14_1027_base.dwg, ES-8, 12/1/2014 9:35:25 AM