

EXAMINATION OF DISSOLVED CONCENTRATIONS OF As, B, Cd, Hg, Se, AND Al IN WATER QUALITY FROM THE BACKFILL AQUIFER, EASTERN POWDER RIVER BASIN, WYOMING, 2005¹

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Abstract. Water quality of the backfill aquifer associated with coal strip mining is a developing area of analysis where data are allowing regulators to move from depending on predictive techniques to reliance on data collected from the backfill aquifer. The chemical concentrations of dissolved arsenic, boron, cadmium, mercury, selenium, and aluminum in the backfill aquifer were examined. The data are from 84 wells located at 11 mines in the eastern Powder River Basin. A total of approximately 2,500 samples have been collected from 1977 to 2005 from monitoring wells in the backfill aquifer. Each chemical constituent is statistically summarized and compared to appropriate water quality standards. Changes in concentration of selected constituents from individual wells with longer periods of record are examined over time.

Analysis indicates that mobilization of dissolved arsenic, cadmium, mercury, selenium and aluminum was not commonly encountered. Nondetection was common in the data set with dissolved arsenic not detected in 90 percent of the samples, dissolved cadmium at 95 percent, dissolved mercury at 98 percent, dissolved selenium at 81 percent and dissolved aluminum at 84 percent. Dissolved boron was detected in 84 percent of the samples, but generally at low concentrations. Dissolved boron had a median concentration of 0.1 mg/L.

Additional Key Words: coal mining, spoils water quality, reclamation, water chemistry, arsenic, boron, cadmium, mercury, selenium, aluminum, aquifer

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Introduction

Description of the Location

Structurally, the Powder River Basin (PRB) is a large north-northwest to south-southeast trending asymmetric syncline in northeastern Wyoming and southeastern Montana (Fig. 1). The basin is approximately 250 miles long by 90 miles wide, and contains as much as 23,000 feet of sediment (Denson et al., 1989). The climate is semiarid with cool, dry winters and warm, dry summers. Windy conditions exist year-round with prevailing winds from the west to northwest at 8 to 10 miles per hour. The basin receives an average of between 13 and 16 inches of precipitation annually, with the majority received between April and September.

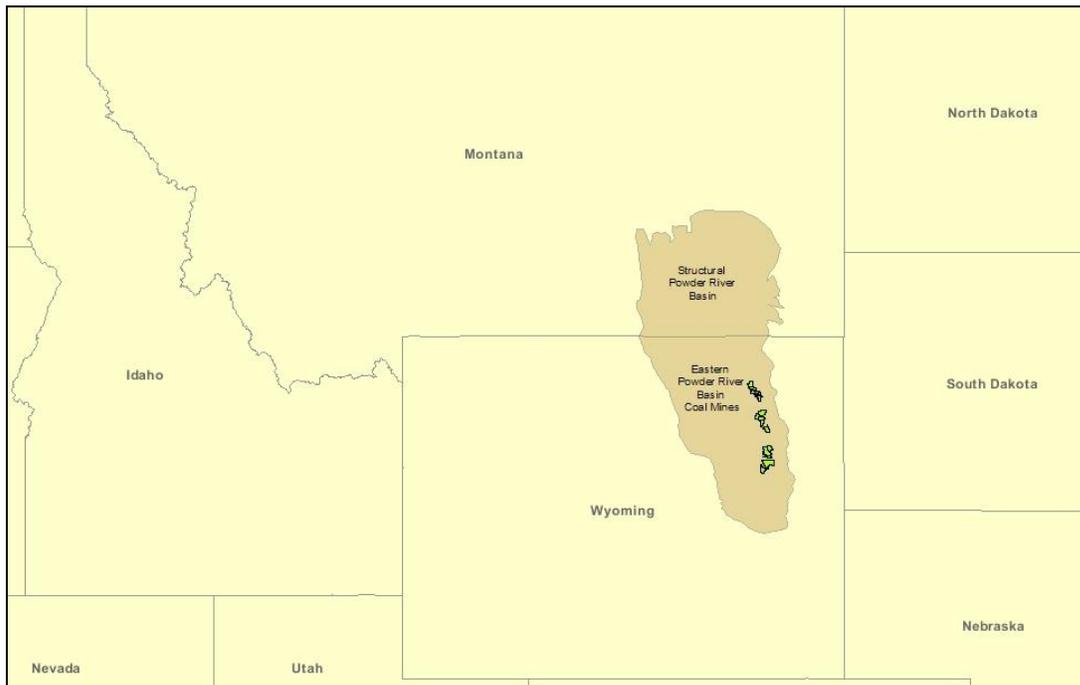


Figure 1. Location of the structural Powder River Basin and the eastern Powder River Basin coal mines, Wyoming, 2005.

The active coal mines are located on the eastern limb of the PRB (Fig. 1). All coal mines in the eastern PRB of Wyoming are open pit surface mines. Depending on the mine operation, truck and shovel, dragline, cast blasting or a combination of these methods are utilized to remove the overburden, mine the coal, and replace the spoil into the pit. Coal production in the eastern PRB is from the Wyodak Anderson coal seam in the Upper Tongue River Member of the Paleocene Fort Union Formation. In this report, the Wyodak Anderson coal is used as an umbrella term to describe all of the mined seams, and individual coal seams are not analyzed. The combined thickness of the coal seams is typically from 50 to 100 feet (Glass, 1980).

Aquifers in the eastern PRB, with the exception of the clinker aquifer and the deeper Tullock aquifer, generally are low yielding and of a quality suitable for livestock use. The Eocene Wasatch Formation is the overburden unit at the coal mines. The Wasatch Formation is often characterized as a leaky aquitard unit with isolated sand lenses that function as local aquifers,

while the Wyodak Anderson coal is generally considered an aquifer. When reclamation of the coal mines is complete, the backfill materials placed in the pit will function as an aquifer matrix. The backfill aquifer will generally need to have water quality suitable for the livestock class of use when the land is reclaimed since livestock grazing will be the predominant post-mining land use. During initial permitting of coal mines in the eastern PRB, no data were available on the post-mining water quality. Therefore, predictions were made based lab tests and geochemical modeling. However, with over 25 years of mining completed, data are available from the backfill aquifers to examine the backfill water quality in the eastern PRB.

Purpose and Scope

The purpose of this paper is to describe selected water quality constituents in the backfill aquifer of the eastern PRB of Wyoming and to compare the concentrations of those constituents to the livestock class of use. The scope is limited to the eastern part of the PRB of Wyoming. By limiting the analysis to this area, comparability is enhanced because the same coal seam is mined and the same overburden unit is placed in the pit throughout the area. Additionally, the mines use similar open pit strip mining techniques.

Methods

The method of analysis was to compile water quality data from the backfill aquifer collected by the coal mining companies in the eastern PRB of Wyoming and reported in their mining annual reports. Results for individual constituents were assembled and analyzed using basic statistical and graphical techniques. The data from all the mines for a selected constituent were examined to characterize the concentrations for each constituent. Those concentrations were compared to the Wyoming Department of Environmental Quality, Water Quality Division (WDEQ/WQD) groundwater use standards. Concentrations at individual wells with longer records and elevated concentration levels were examined in more detail.

Data Source

The source of the data used in this analysis is from self monitoring reports submitted by coal mines in the eastern PRB, Wyoming. As part of the environmental mining permits in Wyoming, coal mine operators are required to monitor aquifers that might be impacted. When strip mining is completed in an area, the mining pit is refilled and the resaturated spoil materials create a backfill aquifer. Coal mines routinely install monitoring wells in this backfill aquifer and collect water quality samples. These data are required to be submitted to the regulatory agency, Wyoming Department of Environmental Quality, Land Quality Division (WDEQ/LQD), as part of their permit monitoring requirements. The data used in this analysis were compiled from those submittals.

Data Limitations

The data were generally collected using a standardized procedure by qualified personnel and reviewed by qualified personnel. Most samples were collected following a WDEQ/LQD hydrology guideline that specifies sampling procedures and methods of analysis. The samples were collected by company personnel or consulting firms, then reported and reviewed by the regulatory agency. It is assumed that the personnel collecting the data were qualified by either education or training, as were the regulatory reviewers. The analysis was usually completed in EPA certified laboratories using either EPA or standard methods.

However, in any dataset that is compiled from numerous sources over a long period of time, there are limitations. Over a period of more than 30 years, detection limits have changed, analysis methods have changed, and sampling procedures have been updated. Numerous personnel were involved with data collection and review. Given these limitations, this paper focuses on median concentrations when applicable and descriptions of the dataset. In addition wells that have a monitoring span of at least ten years and data with higher concentrations are examined individually. By following these two procedures, it is possible to take advantage of the robust nature due to the large number of samples. Since exceedences of groundwater use standards are an important aspect of regulatory evaluations, individual wells with elevated concentrations are examined. These individual concentrations are then compared to the appropriate groundwater use standards.

Data Distribution

The data are distributed both spatially and temporally. The monitor wells are distributed throughout the reclaimed areas of the eastern PRB (Fig. 2). As mining continues and the amount of reclaimed area increases, the spatial area of the backfill aquifer will increase. As of 2005, most of the backfill areas are not interconnected. Spatial and temporal attributes were analyzed in more detail in (Ogle, 2004).

Monitoring well data spanned the time period from 1977 to 2005. There are 84 monitor wells completed in the backfill aquifer. Forty of the wells have periods of record of from less than 1 year to 10 years while 44 wells have periods of record between 10 and 24 years. The median period of monitoring is seven years. The number of wells with different periods of monitoring records is shown in Fig. 3.

Analysis

The chemical concentrations of dissolved arsenic (As), boron (B), cadmium (Cd), mercury (Hg), selenium (Se), and aluminum (Al) in the backfill aquifer were examined. Approximately 2,500 samples were collected and analyzed between 1977 and 2005 from the backfill aquifer's 84 monitoring wells. Each chemical constituent is statistically summarized and compared to appropriate water quality standards. Concentration changes of selected constituents from individual wells with longer periods of record or with larger concentrations are examined over time. Negative concentrations on graphs indicate a value reported below that detection limit.

Dissolved Arsenic

Groundwater in the western United States has been observed to have elevated concentrations of arsenic when the aquifer matrix is derived from volcanic rock associated with mining districts, or geothermal areas (Fetter, 2001). Elevated As was reported to originate from weathered mining materials containing arsenopyrite in Nova Scotia, Canada (Grantham and Jones, 1977). Anthropogenic sources of As include burning coal, smelting operations, insecticides, remnants of grasshopper bait from the 1930's, and old graveyards where As was used in embalming in the 1880's (Fetter, 2001; Hem, 1989).

Generally, dissolved As was not detected in water samples from the backfill aquifer in the eastern PRB. Dissolved arsenic was not detected in 2,356 samples out of 2,605 samples (Table 1), or in 90 percent of the samples. These concentrations were reported relative to three different detection limits; 0.005 mg/L, 0.002 mg/L, and 0.001 mg/L, depending on the data

source and sample date. Dissolved As concentrations ranged from less than the detection limit of 0.001 mg/L to 0.265 mg/L.

Four of the 2,605 water samples from the backfill aquifer had dissolved As concentrations that exceeded the WDEQ/WQD groundwater use standards. These four samples were collected from three wells. One sample, the largest concentration of 0.265 mg/L, exceeded the arsenic agriculture use standard of 0.1 mg/L, the livestock use standard of 0.2 mg/L, and the domestic use standard of 0.05 mg/L. Three additional samples were at or above the domestic use standard of 0.05 mg/L, but below the agriculture and livestock use standards. Dissolved As concentrations at the three wells with the four concentrations that exceeded the standards are examined individually and graphed as a time series (Figs. 4, 5, and 6).

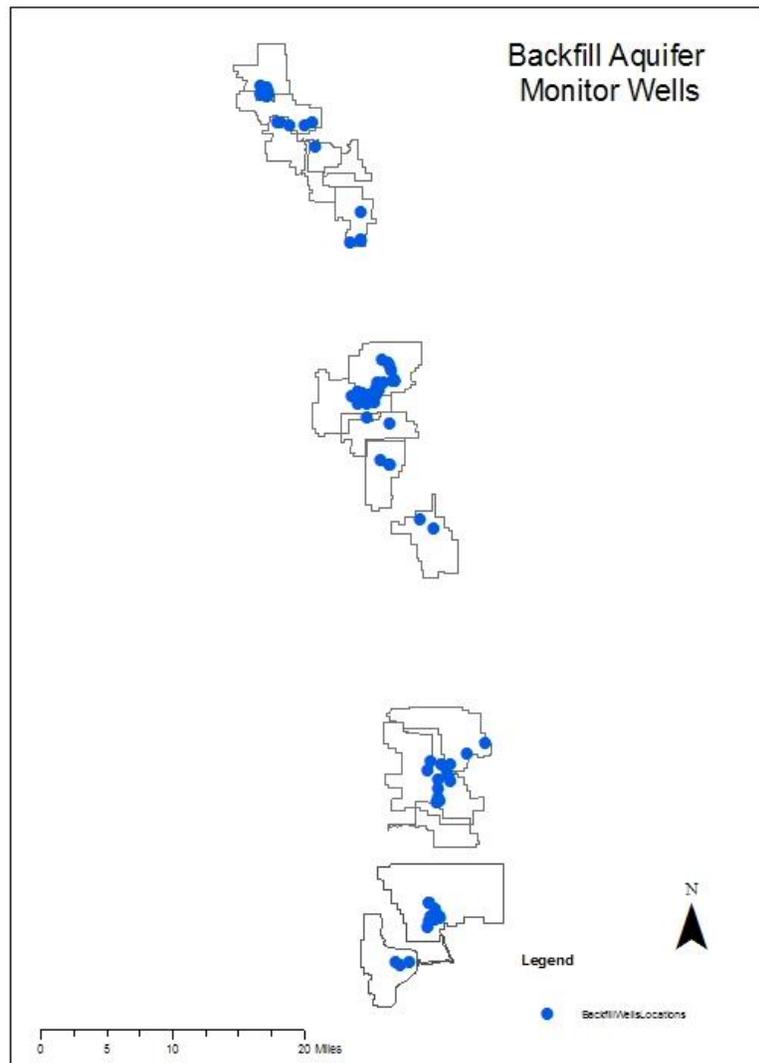


Figure 2. Location of the backfill monitor wells, eastern Powder River Basin, Wyoming, 2005.

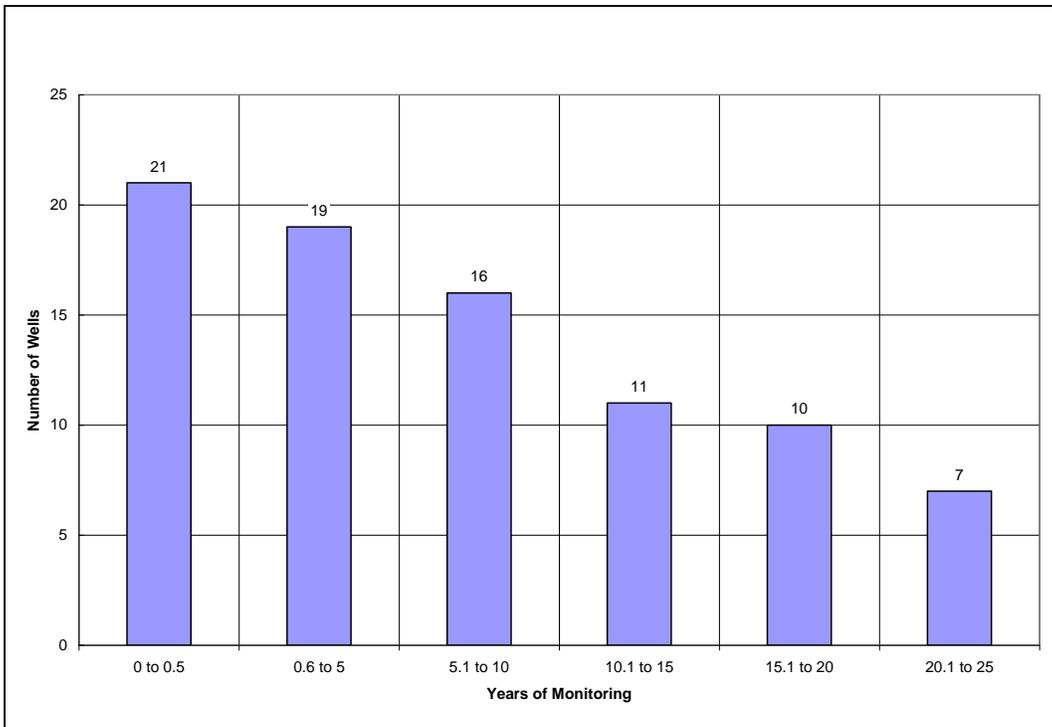


Figure 3. Monitoring period of backfill aquifer wells, eastern Powder River Basin, Wyoming, 2005.

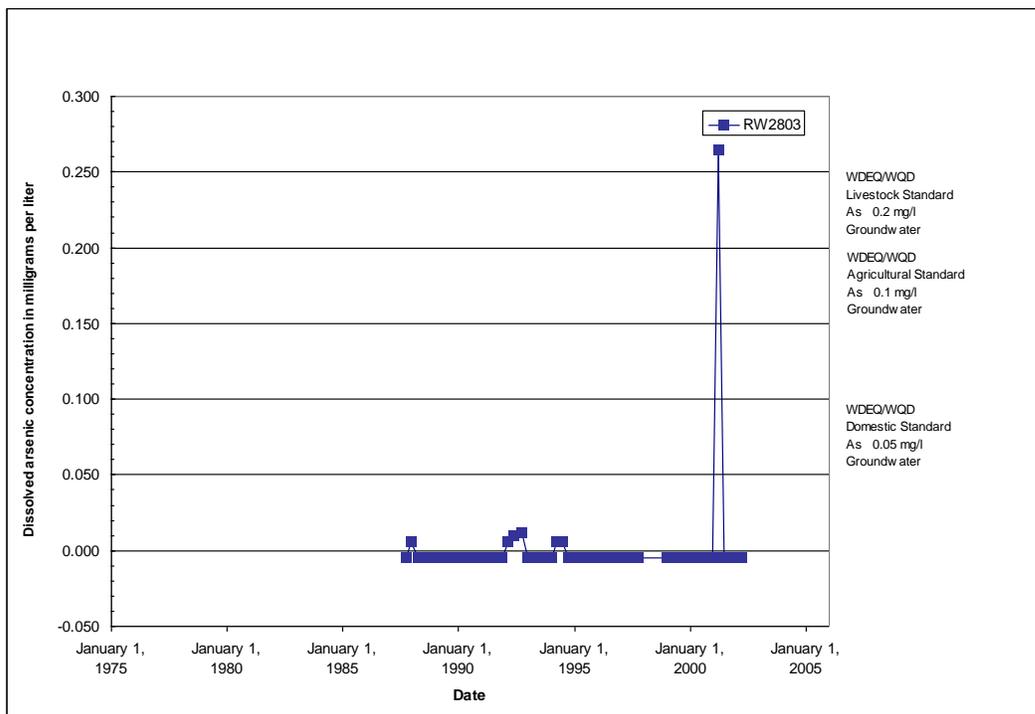


Figure 4. Dissolved arsenic concentration over period of monitoring at backfill aquifer monitor well RW2803, eastern Powder River Basin, 2005, Wyoming.

Table 1. Summary data for selected chemical constituents in the backfill aquifer, eastern Powder River Basin, Wyoming, 2005.

Constituent	Number of samples	Median, (mg/L)	Range		Nondetection	Detection Limits, (mg/L)	Domestic Standard, (mg/L)	Agricultural Standard, (mg/L)	Livestock Standard, (mg/L)	Comments
			Low (mg/L)	High (mg/L)						
Dissolved Arsenic	2,605	NC	<0.001	0.265	90%	0.005 0.002 0.001	0.05	0.1	0.2	High value is likely an error
Dissolved Boron	2,598	0.1	<0.01	0.5	16%	0.1 0.01	0.75	0.75	5.0	Sampling dates of high values correlate between some wells which might reflect sampling error
Dissolved Cadmium	2,504	NC	<0.001	0.264	95%	0.01 0.007 0.005 0.002 0.001	0.005	0.01	0.05	High value is likely an error and 0.075 mg/L may be the actual highest value.
Dissolved Mercury	2,541	NC	<0.001	0.014	98%	0.02 0.01 0.005 0.001	0.002	NS	0.00005	Three wells have one elevated concentration.
Dissolved Selenium	2,606	NC	<0.001	3.388	81%	0.013 0.010 0.005 0.001	0.05	0.02	0.05	Higher values may be associated wells in reclaimed alluvial areas.
Dissolved Aluminum	2,567	NC	<0.1	6.9	84%	1.0 0.1	NS	5.0	5.0	Highest concentration appears to be a natural value.

Note, For calculations of medians, any non-detection value was replaced by one-half of its detection limit.; NC, not calculated. A median was not calculated if more than 50 percent of the samples were nondetections.; NS, no standard; *, All pH values are expressed in standard units.

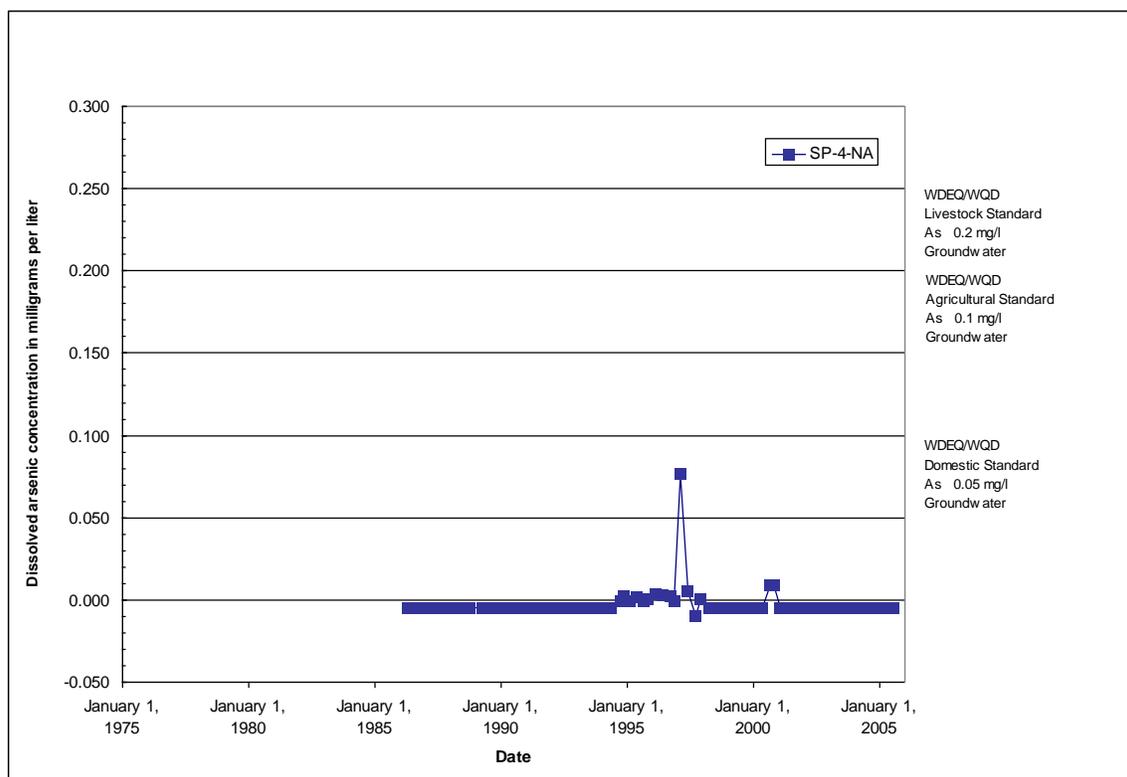


Figure 5. Dissolved arsenic concentration over period of monitoring at backfill aquifer monitor well SP-4-NA, eastern Powder River Basin, 2005, Wyoming.

Based on examination of the 54 samples collected from 1987 to 2002 at well RW2803, the largest concentration of the dissolved As data set, 0.265 mg/L, appears to be an anomaly (Fig. 4). This sample was collected on March 20, 2001. This large value, of 0.265 mg/L, is unusual since the previous 21 samples of dissolved As concentrations were below the detection limit of 0.005 mg/L and the following four samples were also below that detection limit. Dissolved As has been detected only six other times in this well and at much lower concentrations; four times at 0.006 mg/L, and once each at 0.010 mg/L and 0.012 mg/L. For these reasons, it appears that the elevated value is erroneous.

Well SP-4-NA has the next largest concentration of dissolved As at 0.077 mg/L, (Fig. 5). It is a higher concentration than any of the other samples collected at the site. However, unlike well RW2803, the elevated sample at well SP-4-NA was preceded by four nondetections and ten detections of dissolved As and followed by two nondetections and four detections of dissolved As. The elevated value at SP-4-NA is not considered an outlier because of this pattern of both nondetections and detections of dissolved As between September 1994 and March of 1998. All samples collected at well SP-4-NA between January 2001 and July of 2005 are below the detection limit of 0.005 mg/L for dissolved As.

Well EG16-1R(R) has detectable dissolved As in over half the samples but at relatively low concentrations (Fig. 6). Well EG16-1R(R) is below all three standards, but over a 23 year

period, has had a combination of detectable dissolved As values and non detectable values. Dissolved As has been detected in 53 percent of the samples and not detected in the other 47 percent of the samples from well EG16-1R(R).

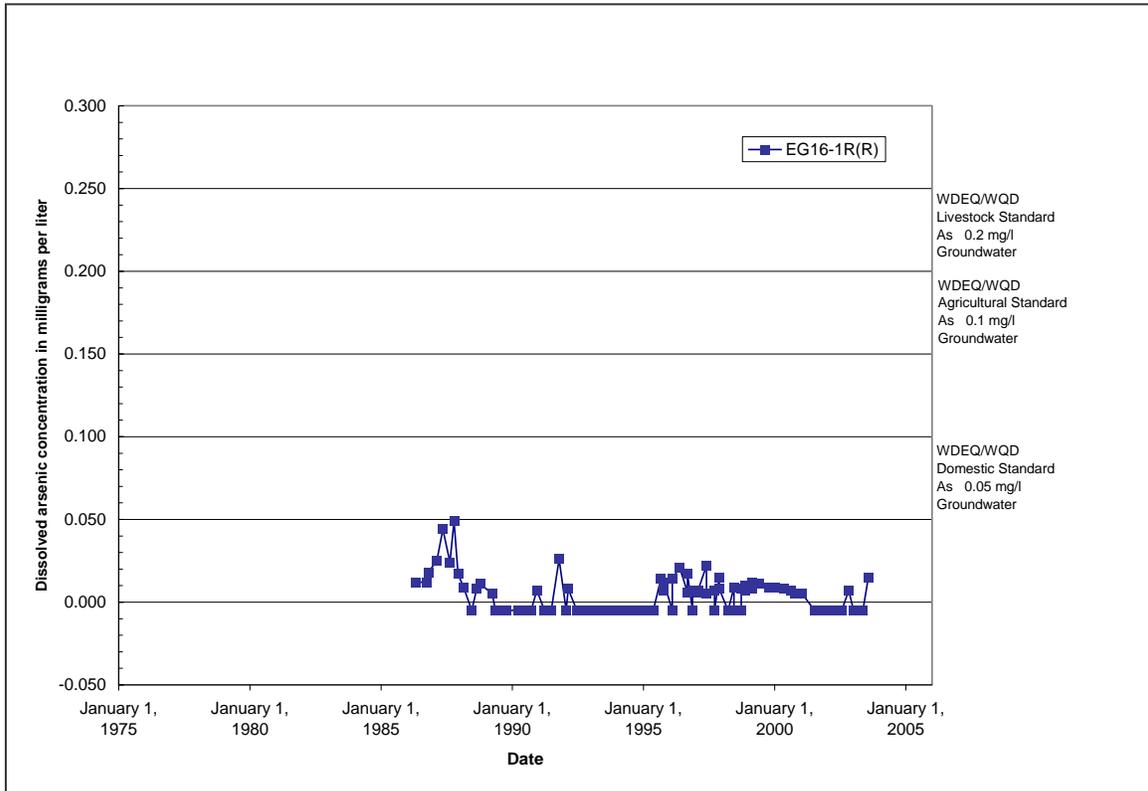


Figure 6. Dissolved arsenic concentration over period of monitoring at backfill aquifer monitor well EG16-1R(R), eastern Powder River Basin, 2005, Wyoming.

Dissolved Boron

Boron is a widely distributed mineral which may be found in evaporate deposits, geothermal waters, and wastewaters. In some closed basins in California, sufficient B has concentrated for it to be mined for B salts. Elevated B concentrations are detected in geothermal waters in New Zealand and Japan. Sewage and industrial wastewaters also can have elevated B concentrations due to cleaning products (Hem, 1989).

Dissolved B was detected at low concentrations in most backfill aquifer water samples. A total of 2,598 water samples from the backfill aquifer were collected and analyzed for dissolved B (Table 1). Nondetect values were reported for 411 samples which represents 16 percent of the dataset. The concentrations were reported at below two different detection limits; 0.01 mg/L, and 0.1 mg/L depending on the data source and the date when the sample was collected.

The median concentration of dissolved B in the 2,598 samples was 0.1 mg/L. The mean was slightly higher at 0.15 mg/L with a standard deviation of 0.22 mg/L. For purposes of statistical calculations, the non detected values were replaced with one-half of the detection limit.

Fifty three dissolved B concentrations exceeded the WDEQ/WQD groundwater use standards. All 53 samples were at or above the domestic and agriculture use standard of 0.75 mg/L. No samples exceeded the livestock standard of 5.0 mg/L. Dissolved B concentrations, at the three wells with a samples that exceeded the domestic and agricultural use standards and that had long periods of monitoring, are examined by plotting the data in a time series (Figs 7, 8, and 9). Well RW3403 has been monitored for 20 years, well RW2902 for 16 years, and well RW2707 for 17 years.

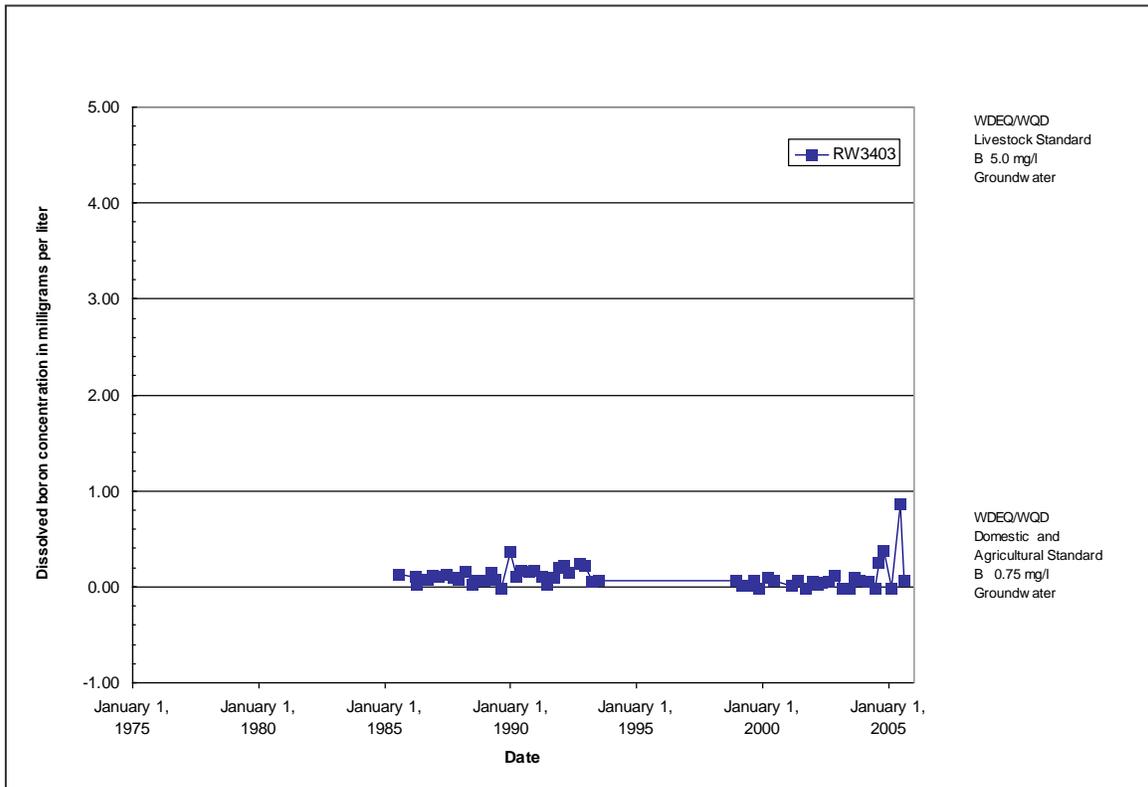


Figure 7. Dissolved boron concentration over period of monitoring at backfill aquifer monitor well RW3403 eastern Powder River Basin, 2005, Wyoming.

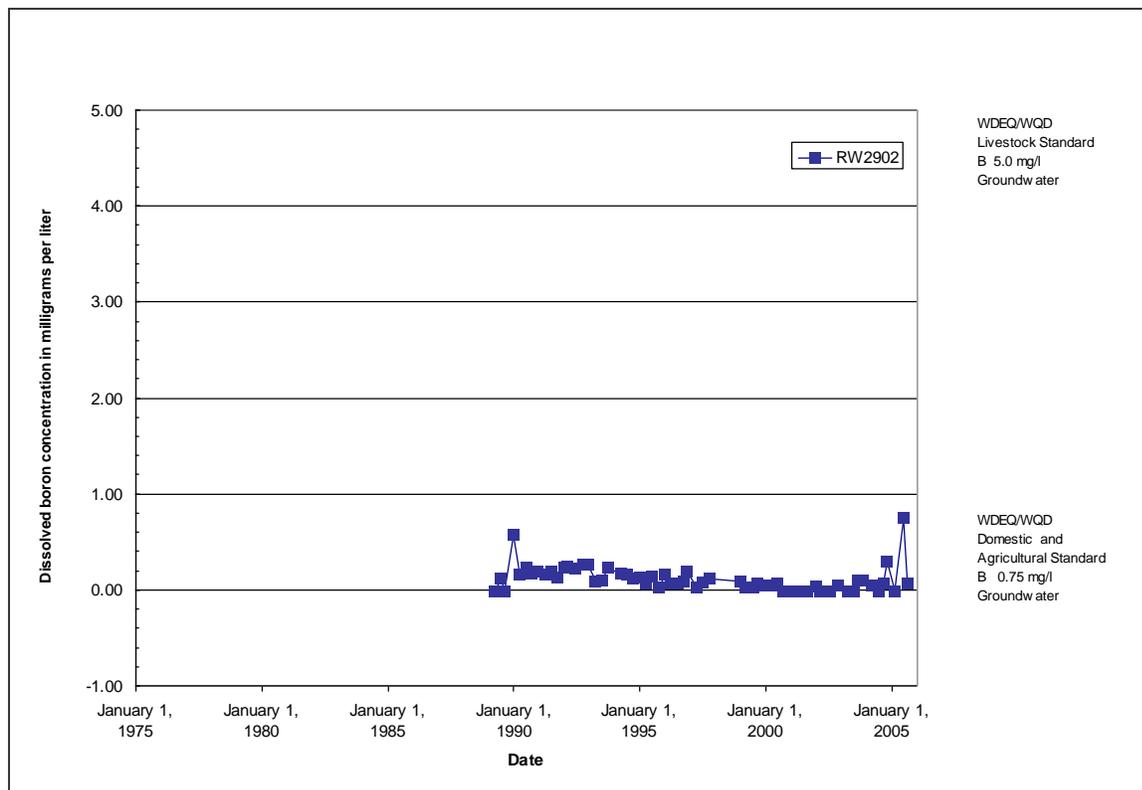


Figure 8. Dissolved boron concentration over period of monitoring at backfill aquifer monitor well RW2902 eastern Powder River Basin, 2005, Wyoming.

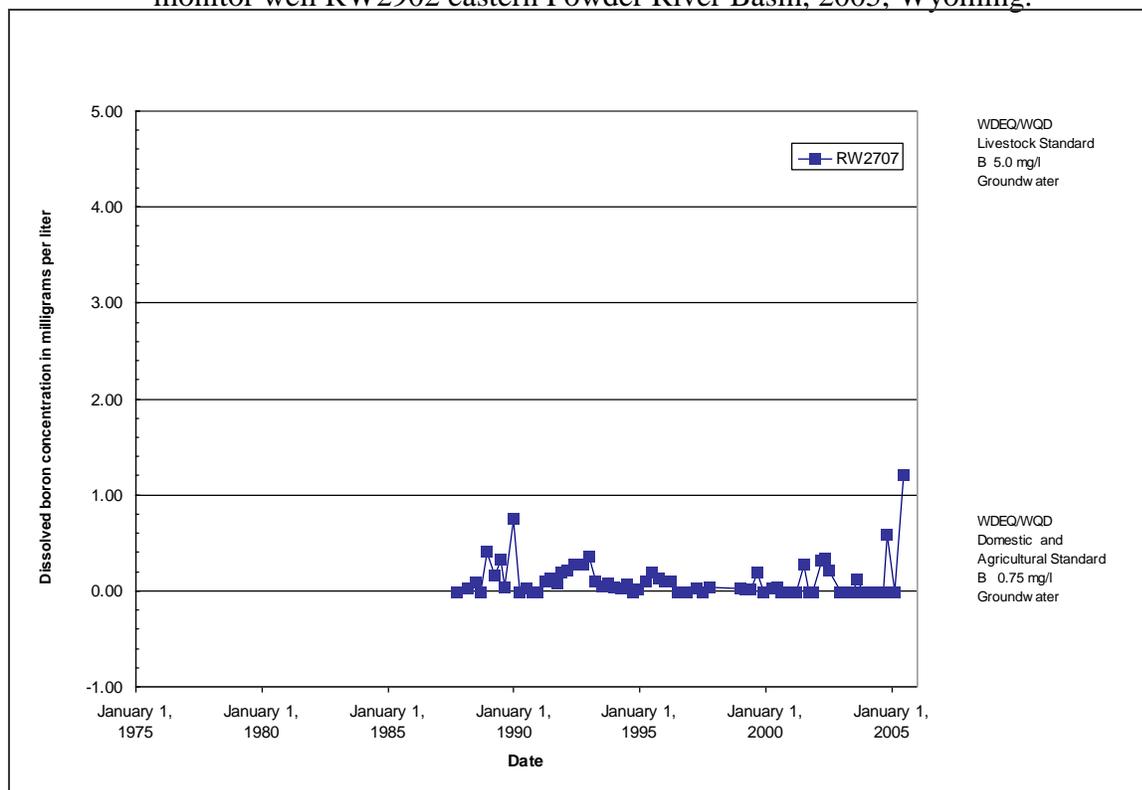


Figure 9. Dissolved boron concentration over period of monitoring at backfill aquifer monitor well RW2707, eastern Powder River Basin, 2005, Wyoming.

An interesting observation is that at all three wells, the highest concentrations occurred in June of 2005 within three days of each other (Table 2). Likewise, the second or third highest concentrations all occurred within close time proximity to each other on either December of 1989 or October of 2004. It is possible that some physical condition caused elevated values at the same time in all three wells. However, the wells are completed at three different depths; well RW3403 at 16 feet, well RW2902 at 200 feet and well RW2707 at 75 feet. Given the variability of the completion depth, it would take an unusual process to affect all three wells. The clustering of these high concentrations around a single sampling period may indicate lab or sampling errors rather than natural elevated concentrations.

Table 2. Comparison of the dissolved boron concentrations and sample date for the three highest concentrations for wells RW3403, RW2902, RW2707, backfill aquifer, eastern Powder River Basin, Wyoming, 2005.

Rank of Concentration for the well	Well	Date of sample	Concentration of Boron (mg/L)	Comment
1 st	RW2707	6/6/05	1.20	highest value for well
1 st	RW3403	6/9/05	0.86	highest value for well
1 st	RW2902	6/9/05	0.75	highest value for well
3 rd	RW2707	10/27/04	0.59	3 rd highest value for well
2 nd	RW3403	10/27/04	0.38	2 nd highest value for well
3 rd	RW2902	10/19/04	0.30	3 rd highest value for well
2 nd	RW2707	12/20/89	0.74	2 nd highest value for well
3 rd	RW3403	12/27/89	0.37	3 rd highest value for well
2 nd	RW2902	12/20/89	0.57	2 nd highest value for well

Dissolved Cadmium.

Common processes that release Cd into the environment are mining and metal processing, combustion of fossil fuel, making and using phosphate fertilizers, or disposing of metal products. Cadmium is also used as a stabilizer in PVC plastics, batteries, and fluorescent tubes. Cadmium occurs naturally in conjunction with Zn, Pb, and Cu mining tailings and becomes soluble when in contact with soft, acidic waters. Cadmium may also be released to drinking water by corrosion of some types of galvanized pipes. In Sweden, naturally elevated levels of Cd were observed in groundwater in contact with shales and slates that contained high concentrations of Cd. Research attributed the elevated concentrations to be the result of the oxidizing of sulphide minerals in those strata where Cd was also present. The solubility of Cd increases with a decline in pH values, thus acidification can lead to increased levels of Cd in groundwater (Swedish Environmental Protection Agency, 2007).

In general, dissolved Cd was not detected in the backfill aquifer samples. Dissolved Cd was sampled and analyzed for in 2,504 samples from the backfill aquifer (Table 1), but was not detected in 2,387 samples or in 95 percent of the samples. Five different detection limits were used over the sampling period; 0.01, 0.007, 0.005, 0.002, and 0.001 mg/L. Dissolved Cd concentrations varied from a low of less than 0.001 mg/L to a high of 0.264 mg/L. The domestic standard of 0.005 mg/L was exceeded in 90 samples and the agricultural standard of 0.01 mg/L

was exceeded in 48 samples. The livestock groundwater use standard of 0.05 mg/L was exceeded twice.

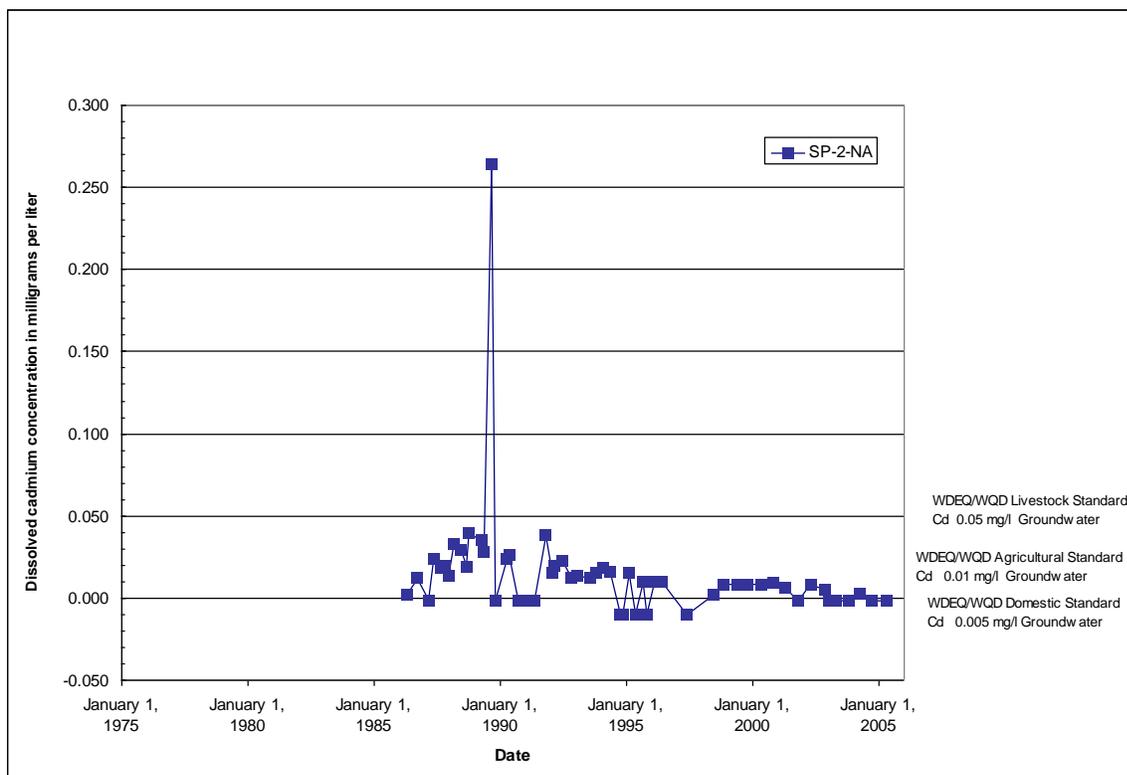


Figure 10. Dissolved cadmium concentration over period of monitoring at backfill aquifer monitor well SP-2-NA, eastern Powder River Basin, 2005, Wyoming.

The change in concentrations of dissolved Cd over time was examined at two wells, SP-2-NA and RW2707 (Figs. 10 and 11). These wells were selected because each had one sample that exceeded the livestock use standard. The one high value (0.264 mg/L) at well SP-2-NA, when it is compared to the other 60 samples from the well, appears to be an erroneous value (Fig. 10). The other elevated value of 0.075 mg/L may reflect a real fluctuation, since other concentrations at well RW2707 ranged from Nondetection to concentrations slightly below 0.05 mg/L. At well RW2707 from 1987 to 1998, dissolved Cd was not detected. However from 1999 until the first part of 2004, dissolved Cd concentrations in well RW2707 fluctuated (Fig. 11). The last six samples at well RW2707 are below the detection limit of 0.002 mg/L.

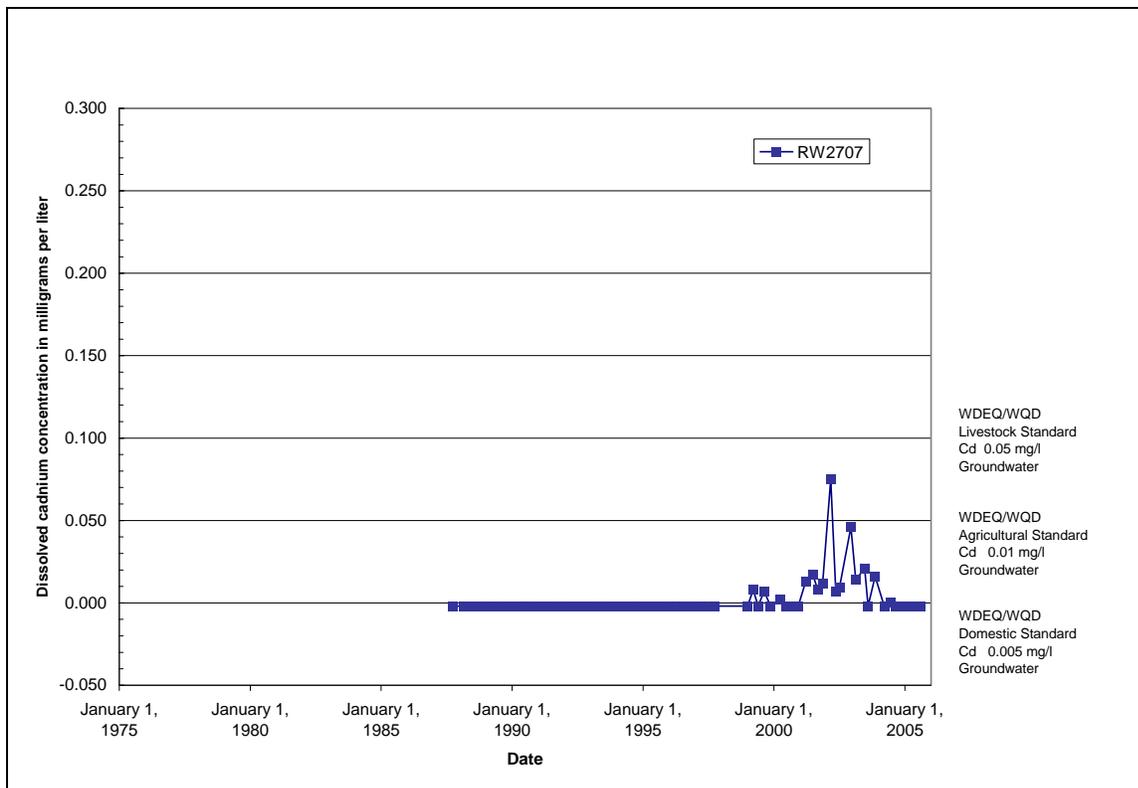


Figure 11. Dissolved cadmium concentration over period of monitoring at backfill aquifer monitor well RW2707, eastern Powder River Basin, 2005, Wyoming.

Dissolved Mercury

Mercury is toxic and can concentrate in the food chain. Generally, inorganic Hg has a low solubility under natural conditions, but methane generating bacteria can convert metallic Hg to organic forms such as methyl mercury, which is soluble in water, and dimethyl mercury, which is volatile (Fetter, 2001). Smelting and fossil-fuel release Hg into the atmosphere and may have raised the general background level of this element over pre-industrial levels (Hem, 1989).

Dissolved Hg was seldom detected in water sample from the backfill aquifer. A total of 2,541 water samples were collected from the backfill aquifer and analyzed for dissolved Hg (Table 1). Nondetection values represented 98 percent of the samples or 2,494 samples. Dissolved Hg was reported at four different detection limits; 0.02 mg/L, 0.01 mg/L, 0.005 mg/L, and 0.001 mg/L depending on the data source and the time when the sample was collected. Concentrations of dissolved Hg ranged from less than the detection limit of 0.001 mg/L to 0.014 mg/L.

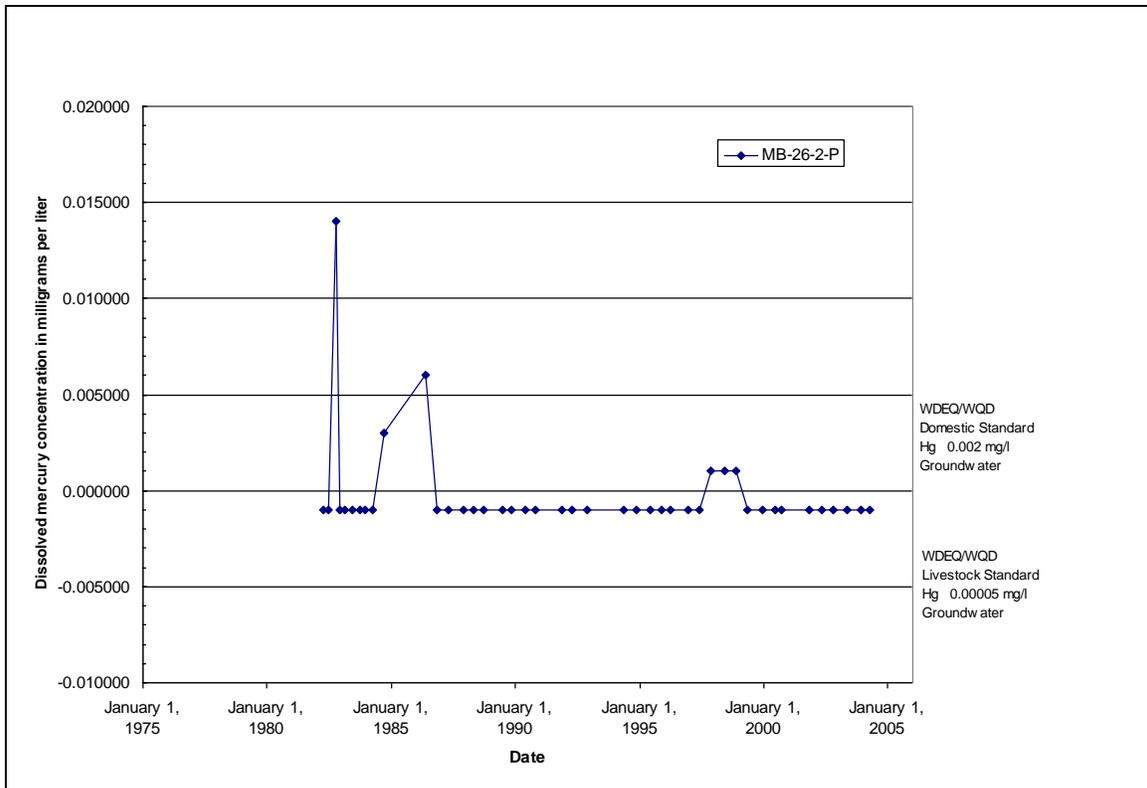


Figure 12. Dissolved mercury concentration over period of monitoring at backfill aquifer monitor well MB-26-2-P, eastern Powder River Basin, 2005, Wyoming.

Seven dissolved Hg concentrations exceeded the WDEQ/WQD domestic groundwater use standard of 0.002 mg/L. WDEQ/WQD has not set a Hg groundwater use standard for agriculture. Because of the very low detection limit for livestock standard of 0.00005 mg/L, no meaningful evaluation is possible since the standard is approximately two orders of magnitude smaller than the lowest detection limit in this data set. Dissolved Hg concentrations at the four wells with the higher concentrations that exceeded the domestic standards were examined individually. Well MB-26-2-P has elevated concentrations that occur sporadically with the higher values decreasing with time (Fig. 12). In the time periods between the higher values, the concentrations are below the detection limit for dissolved Hg. Three wells appear to have a single high value that could be either a sampling or analysis error or an unusual hydrologic condition that did not persist. Well RW3403 (Fig. 13) is an example of that pattern of a single elevated concentration.

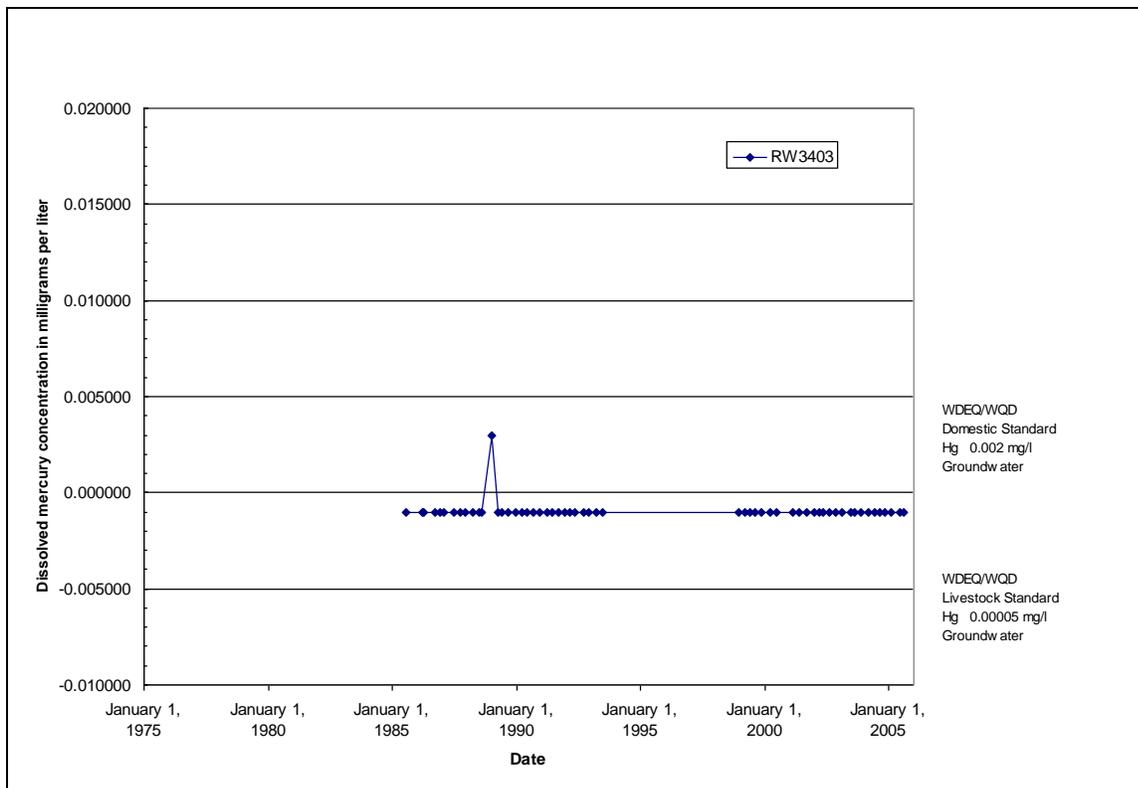


Figure 13. Dissolved mercury concentration over period of monitoring at backfill aquifer monitor well RW3403, eastern Powder River Basin, 2005, Wyoming.

Dissolved Selenium

Selenium is an essential micronutrient for plants and animals but can be toxic in excessive amounts. The chemistry of Se has some similarities to S chemistry, but Se occurs at a much lower concentration in most waters. Selenium often occurs in oxidizing solutions as selenite and selenate, but can readily be reduced to elemental and fairly insoluble Se. Studies have found that Se may become concentrated in waters affected by irrigation drainage. Selenium can be released during coal mining because of the oxidation of Se-bearing pyrite (Dreher and Finkelman, 1992).

A total of 2,606 samples were analyzed for dissolved Se concentration (Table 1). Of that number, 81 percent (or 2,100 samples) were below the detection limits. Five detection limits were present in the dataset; 0.013 mg/L, 0.010 mg/L, 0.005 mg/L, 0.002 mg/L and 0.001 mg/L. The largest dissolved Se concentration was 3.388 mg/L and the lowest value was below the detection limit of 0.001 mg/L. The domestic and livestock groundwater use standard of 0.05 mg/L was exceeded in 126 of the samples from 13 wells. The agriculture groundwater use standard of 0.02 mg/L of dissolved Se was exceeded in 202 of the samples. In many cases there was a single or perhaps two of exceedences per well. Wells with more frequent exceedences are examined individually.

Two wells with occasional elevated concentrations are SP-4-NA and SP-10-NA. Dissolved Se at well SP-4-NA shows two high spikes with a general downward trend (Fig. 14). It is possible that the two high spikes, which are also the two highest values in the 2,606 samples, could be erroneous values. However, the downward trend, a period of Non-detection and a second downward trend appears to represent a real decrease in the dissolved Se values at this

well. The dissolved Se concentration in well SP-10-NA follows a less clear pattern of slightly elevated dissolved selenium in the initial monitoring, which decreased to non-detection levels. The well SP-10-NA experienced a second spike of dissolved Se starting in 2000, followed by a second gradual decrease in concentrations (Fig. 15). Both of these wells are completed in shallow reclaimed alluvial areas. Murphree (2003) and Murphree (2007, in press) discussed the fluctuations of these wells in detail. He noted the effects of wetting and drying cycles and oxidizing and reducing conditions on the changes in concentration.

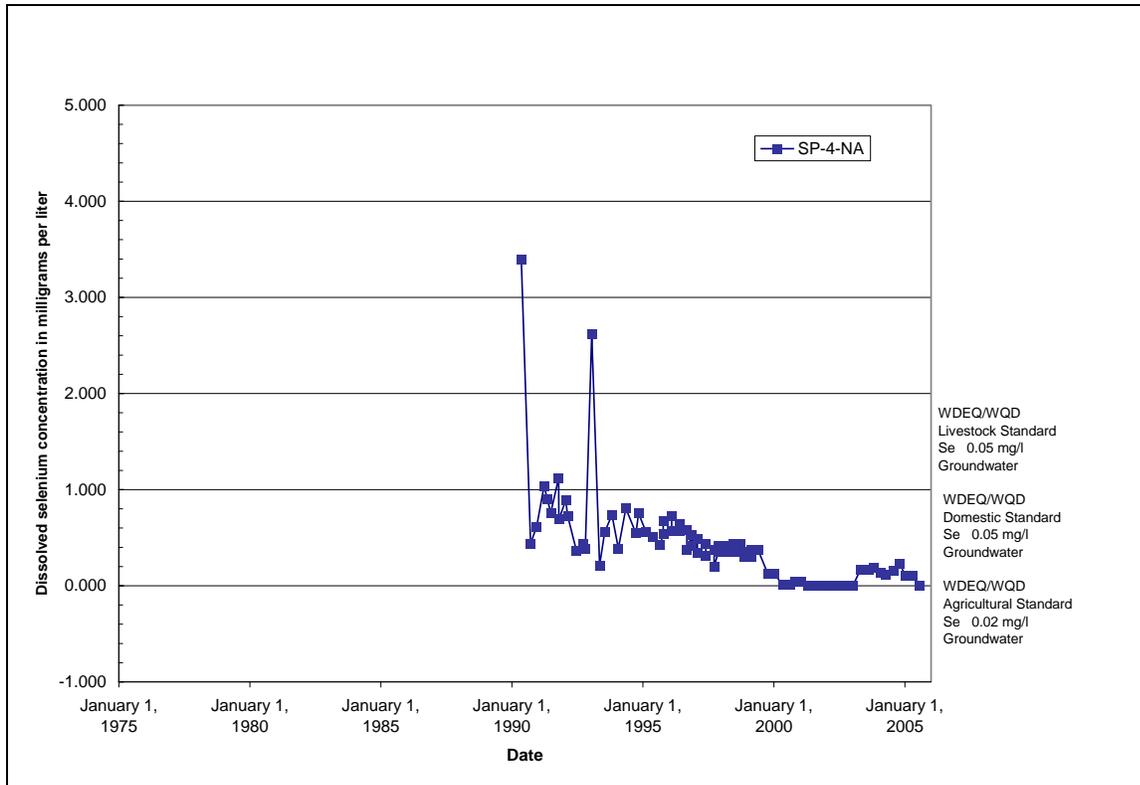


Figure 14. Dissolved selenium concentration over period of monitoring at backfill aquifer monitor well SP-4-NA, eastern Powder River Basin, 2005, Wyoming.

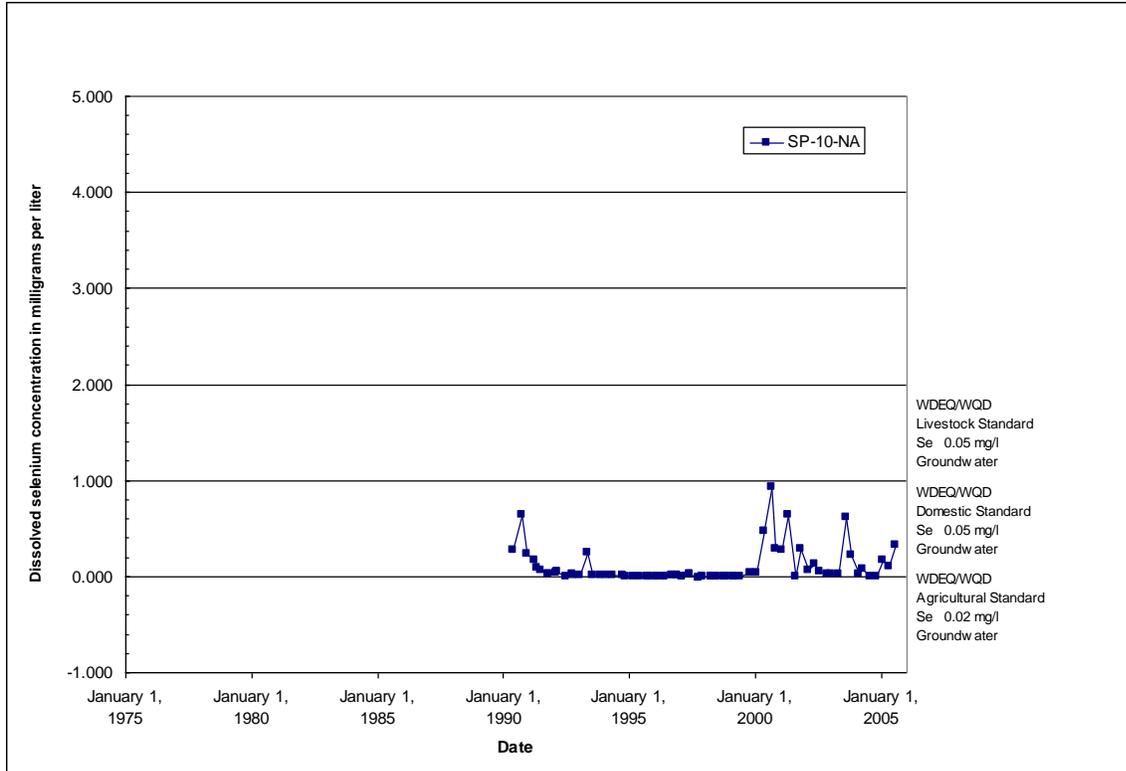


Figure 15. Dissolved selenium concentration over period of monitoring at backfill aquifer monitor well SP-10-NA, eastern Powder River Basin, 2005, Wyoming.

Dissolved Aluminum

Clays are the most common of the sedimentary rocks that may be enriched with Al. Aluminum occurs as a component of rocks such as feldspars, feldspathoids, micas and many of the amphiboles. The pH of the water must be either highly acidic or highly basic to dissolve significant amounts of Al.

A total of 2,567 samples from the backfill aquifer were analyzed for dissolved Al. Values ranged from 6.9 mg/L to below the detection limits of 0.1 mg/L. In 84 percent, 2,152 of the samples from the backfill aquifer, dissolved Al was not detected. Two detection limits were present in the dataset; 1.0 mg/L and 0.1 mg/L. Four samples exceed the agriculture and livestock class of use standard for groundwater of 5.0 mg/L. WDEQ/WQD does not have a domestic use standard for Al. Changes in dissolved Al concentrations over time in a well with higher concentrations are examined in Fig. 16.

Discussion and Conclusions

During initial permitting of coal mines in the eastern PRB, no data were available on the post-mining water quality, and so predictions were made using lab tests and geochemical modeling. However, now with over 25 years of mining completed, data are available from the backfill aquifers to examine the backfill water quality in the eastern PRB. The data are from 84 wells located at 11 mines in the eastern Powder River Basin. A total of approximately 2,500 samples have been collected from 1977 to 2005 from monitoring wells in the backfill aquifer.

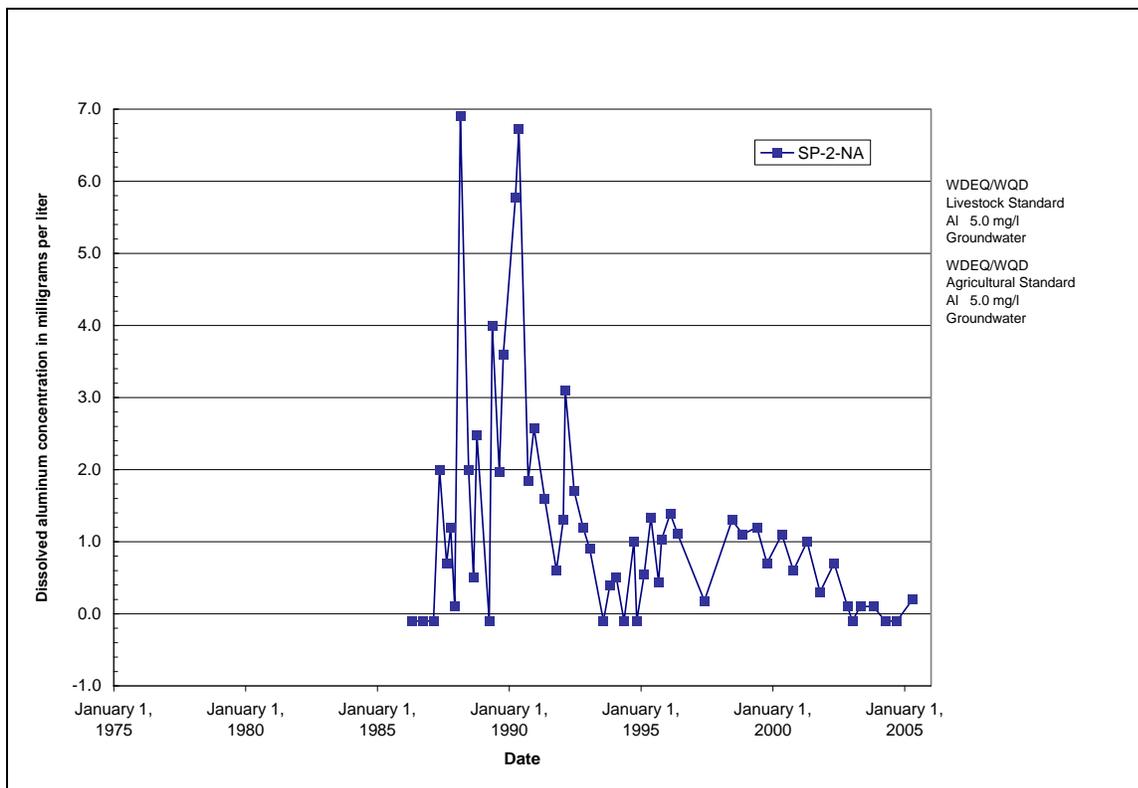


Figure 16. Dissolved aluminum concentration over period of monitoring at backfill aquifer monitor well SP-10-NA, eastern Powder River Basin, 2005, Wyoming.

Mobilization of dissolved As, Cd, Hg, Se and Al does not appear to be a general problem in the backfill aquifer in the eastern Powder River Basin of Wyoming. Dissolved As was not detected in 90 percent of 2,605 samples and dissolved cadmium was not detected in 95 percent of 2,504 samples. Mercury was detected in the least number of samples with nondetection in 98 percent of 2,541 samples. Dissolved Se and Al were detected a little more often, but they still had high nondetection percentages with dissolved Se not detected in 81 percent of 2,606 samples and dissolved Al not detected in 84 percent of 2,567 samples.

For each of these constituents, some higher values were detected. In some cases the elevated values appear to be erroneous results, in other cases the elevated values appear to represent natural concentrations. Some of the elevated concentrations were associated with shallow wells completed in reclaimed alluvial backfill. Each of these constituents had multiple detection limits and no summary statistics were calculated due to the large number of nondetections.

Dissolved B was detected at low concentrations in most of the water samples from the backfill aquifer. Only 16 percent of the samples were reported as nondetection for dissolved boron. The median concentration of dissolved B for 2,598 samples was 0.1 mg/L. Concentrations ranged from less than 0.01 mg/L to 0.5 mg/L. It was observed that the highest concentrations occurred at three wells and there was time proximity of the sampling dates at the three wells and the higher concentrations perhaps indicating a sampling or analysis problem.

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