2009
Tongue River Hydrology Report
Tongue River Information Program

Prepared for:

Montana Board of Oil & Gas Conservation

Montana Department of Natural Resources and Conservation

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EXECUTIVE SUMMARY
Tongue River Hydrology Report
Tongue River Information Program
September 2009

The Tongue River valley of Wyoming and Montana has over 67,000 acres of irrigated land which has supported cattle ranching and farming operations for more than 100 years. The Tongue River runs through the coal-rich Powder River geologic basin which has experienced growth in coal bed natural gas development since 1999, along with surface coal mining since the early 1970's. The Tongue River Information Program (TRIP) has been funded by the Montana Board of Oil and Gas Conservation since 2006 in response to concerns by irrigators, environmental regulators and policy makers that the discharge of produced water from coal bed natural gas (CBNG) production in the upper Tongue River basin may be affecting the water quality of the river and, in turn, soil properties and crop production. TRIP includes an agronomic and soils monitoring program called the Agronomic Monitoring and Protection Program (AMPP), and a hydrologic component, which is summarized in this Tongue River Hydrology Report. All TRIP reports may be accessed on-line at:
http://bogc.dnrc.mt.gov/CoalBedMeth.asp

The findings of the hydrology evaluation begin with the understanding that water supply available to the Tongue River is directly related to the amount of precipitation falling in the upper basin. It is well-documented that water quality indicators, in particular specific conductance (SC) (a measure of total dissolved solids equivalent to temperature corrected electrical conductivity (EC)) and sodium adsorption ratio (SAR), are inversely related to flow; that is, the river typically has higher SC and SAR at lower flows, and vice versa (USGS, 2007). In seven of the past ten years, the average annual flows at the U.S. Geological Survey gauging stations at the State Line and at Miles City have been less than the long term average flow based on 48 and 62 years of measurements respectively. Four of the past ten water years have been among the lowest average flows of record.

Graphical comparisons of SC and SAR versus stream flow indicate comparable readings before and after the onset of CBNG development at all USGS monitoring stations on the Tongue River. An increase of salinity and sodium in the downstream direction is a common occurrence for the Tongue River and other western streams, due to a combination of natural and human-caused factors. The largest salinity increases in the Tongue River typically occur between the USGS stations at Monarch, Wyoming and the State Line, and between the T&Y Diversion and Miles City, based on data from water years 2006 through 2008. CBNG discharges contributed salts and sodium only in the reach above the Tongue River Reservoir in 2008. In a 2007 report (Clark and Mason, 2007), the U.S. Geological Survey, in cooperation with the Wyoming Department of Environmental Quality, evaluated eight sites in the Tongue, Powder, and Belle Fourche River drainage basins, including the USGS stations on the Tongue River at the State Line and Goose Creek below Sheridan, for trends in SC during water years 1991–2005. There were no trends found in SC at the eight sites when values were adjusted for streamflow variability.

The Tongue River basin is home to approximately 25,000 people, 88 percent of whom live in Sheridan County, Wyoming. There are approximately 67,317 irrigated acres in the basin, 75 percent of which are in Wyoming. Water rights filing information demonstrates that claims for water from the basin are far in excess of its historic delivery capability. Approximately 5,700 water wells are drilled in the basin, 60 percent of which are in Wyoming, with the majority being used for domestic and agricultural purposes.

During 2008, approximately 3,358 CBNG wells were operating in the basin, an increase of 5.8 percent over 2007. 73 percent of the wells are in Wyoming. The quantity of CBNG-produced water within the Tongue River basin averaged about 3.33 gallons per minute (gpm) per well during 2008, for an equivalent total average of about 25 cfs, an increase of 4.7 percent over 2007. Approximately 87 percent of this total was discharged to impoundments, beneficially used, or treated prior to discharge, with the remainder discharged to the river untreated via MPDES or WYPDES permits.

There are six permits for discharge of CBNG-produced water to the Tongue River; three are located in Montana and four in Wyoming, however, only two actually discharged in 2008. These permits are authorized for discharge ranging from 1,640 to 2,630 gpm (3.6 – 5.9 cfs) of untreated CBNG water, and 4,438 gpm (9.9 cfs) of treated CBNG water. Actual CBNG discharges have been significantly less than the permitted discharges. The discharge rates and/or water quality authorized by permits are seasonally adjustable in order to meet irrigation water standards set by the State of Montana. During the April-September 2008 irrigation season, total CBNG discharges comprised from 0.2 to 1.6 percent of the flow released from the Tongue River dam, with untreated discharge ranging from 0.1 to 0.8 percent.

The 2008 Montana “303 (d) List” of impaired water bodies indicates that three of the five segments of the Tongue River, and the Tongue River Reservoir in Montana are rated as “Not Supporting” of some beneficial water uses and will require a TMDL The 2008 Wyoming “303 (d) List” indicates that the Tongue River below Goose Creek, much of Big and Little Goose Creeks, all of Prairie Dog Creek, and 14 smaller tributaries are impaired for beneficial uses. The most common causes of impairments are stream flow modification from dams and diversions, irrigated crop production, streambank and riparian zone deterioration, and storm water discharge. Studies to support future TMDLs for the Tongue River in both states are still underway. Point sources of contaminants are well quantified with information from MPDES and WYPDES monitoring and reporting systems. Non-point loads from natural and agricultural sources are relatively unquantified.

This study indicates that the water quality of the Tongue River basin varies directly with the quantity of stream flow, and that salinity and sodium levels since the beginning of coal bed natural gas development in 1999 are comparable to pre-development levels. CBNG discharges are one of a number of point and non-point discharges that affect the water quality of the Tongue River. Continuing concerns over irrigation water supplies and quality indicate that improved accounting of basin-wide point and non-point sources of salinity and sodium loading is warranted.

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Foreword

The Tongue River Hydrology Report is a companion report to the Agricultural Protection and Monitoring Program (AMPP) Report, produced under the auspices of the Tongue River Information Program (TRIP). The Montana Board of Oil and Gas Conservation (MBOGC), a division of the Montana Department of Natural Resources and Conservation, has funded this program since 2006. The AMPP program was originally launched in 2003 by Fidelity Exploration & Production Company, a subsidiary of MDU Resources Group, Inc., in response to concerns by Tongue River irrigators over whether crop yields, soils or water quality were being affected by discharges from the coal bed methane industry. The scientific methodology and implementation of the AMPP was developed by soil scientists, William Schafer and Kevin Harvey of Bozeman, Montana, and agronomist Neal Fehringer of Billings, Montana. These scientists are the principal authors of the companion 2008 AMPP report.

Through its Administrator, Tom Richmond, the MBOGC specified that the TRIP project include a scientific summary of the available hydrology and water quality information on the Tongue River, to place the AMPP findings in context. This report provides that summary. The 2008-2009 TRIP contract was administered by HydroSolutions Inc, a Montana based environmental science and engineering firm. The principal author of this report is Tom Osborne, with technical assistance from other HydroSolutions staff. Review and comments on the report were provided by Shane Bofto of HydroSolutions, and William Schafer of Schafer Limited. Biographical sketches of the authors and reviewers may be found at the end of this report. The interpretations provided herein are solely those of the authors.

2009 Tongue River Hydrology Report

The Tongue River Information Program (TRIP)

The Tongue River is a principal tributary of the Yellowstone River, with its headwaters in the Bighorn Mountains of northern Wyoming, and its confluence with the Yellowstone River in southeastern Montana. The Tongue River valley, which is developed extensively for irrigated agricultural production, flows through the coal-rich Powder River geologic basin. Large scale coal strip mining in the valley has been on-going since the early 1970's and coal bed natural gas (CBNG) development since 1999. The Tongue River Information Program (TRIP) is an outgrowth of the Agronomic Monitoring and Protection Program (AMPP) which preceded it from 2003 to 2006. The AMPP program which was originally privately funded, was developed in response to concerns by Tongue River irrigators that the discharge of produced water from CBNG production in the upper Tongue River basin may be affecting the water quality of the river and, in turn, soil quality and ultimately crop production.

The Montana Board of Oil and Gas Conservation (MBOGC) sponsored this program beginning in 2006 due to its significance to the energy production activities under its jurisdiction, along with the need to protect water resources of the State of Montana. The project includes scientific evaluations in the areas of agronomy, soil science, hydrology and water quality; and public information and education related to project results. This report is a summary of the hydrology of the Tongue River watershed in Montana and Wyoming. It is a companion report to the AMPP report which presents the results of the crops and soils monitoring at the study fields in the Tongue River valley. Project reports and information for previous years may be found at: http://www.tongueriverampp.com/default.aspx. The current reports may be found on the web site for the Montana Board of Oil and Gas Conservation: http://www.bogc.dnrc.mt.gov.

Tongue River Hydrology and Water Quality Trends

The agronomic and soils studies developed by the AMPP portion of TRIP are designed to detect changes in soil salinity, sodium content and crop yields related to changes in irrigation water quality from the Tongue River. The hydrology portion of TRIP is a focused effort to assemble existing sources of flow, salinity and sodicity data on the Tongue River, and to evaluate the temporal and spatial trends along the Tongue River, from Wyoming through Montana. Salinity refers to the dissolved mineral content of the water and sodicity to the dissolved sodium content. This assessment integrates existing sources of stream flow data and of point sources and non-point sources of salinity and sodium loading to the Tongue River.

The specific tasks for the Hydrology Report include the following:

1. Obtain stream flow and water quality monitoring results for all U.S. Geological Survey (USGS) stations and any other publicly-available monitoring on the Tongue River and its tributaries in Wyoming and Montana for the 2008 water year (October 1, 2007 – September 30, 2008);

2. Obtain information from state agencies and irrigation companies regarding rates, volumes and quality of discharges into the Tongue River basin and withdrawals from the basin for industrial and agricultural uses during the previous year, including the quantities of produced water from oil and gas operations in the Tongue River basin to the extent that they are available.

3. Analyze temporal and spatial trends in stream discharge and water quality throughout the Tongue River basin.

4. Prepare a scientifically valid synopsis of the current year's discharge, salinity and sodium characteristics along the river to place the current year's information in the context of the available historical record.

1.0 Trends in Tongue River Flow and Water Quality

1.1 The Tongue River Basin

The Tongue River watershed encompasses approximately 5,399 square miles in the states of Wyoming and Montana (Figure 1). The headwaters originate in north-central Wyoming and flow generally to the northeast into southeastern Montana. Approximately 70 percent of the watershed (3,781 square miles) lies in Montana, while 30 percent (1,618 square miles) lies in Wyoming. Numerous tributaries join the Tongue River as it flows toward the Yellowstone River. Major tributaries include: Goose Creek, Prairie Dog Creek, Hanging Woman Creek, Otter Creek, and Pumpkin Creek. The Tongue River Dam and Reservoir are located approximately 10 miles downstream of the Wyoming-Montana state line. The reservoir has a storage capacity of 79,071 acre-feet.

Three trans-basin water diversions, originally built in the 1880's, transfer water for irrigation from the North Fork and South Fork of Piney Creek into Jenks Creek, a tributary of Prairie Dog Creek. The transfers amount to approximately 60 cubic feet per second (cfs) over an average 153-day irrigation season per year (Entech, 2001). Piney Creek is a tributary of Clear Creek and eventually the Powder River.

1.2 Relation of Streamflow to Precipitation

In the plains regions, with elevations from 3,000 to 6,000 feet above mean sea level, annual average precipitation ranges from 10 to 14 inches, and rainfall is the more dominant form of precipitation (Lindner-Lunsford, et al., 1992). Average monthly precipitation is greatest from April through September, and maximum temperatures occur in July, while minimum values occur in January (MDEQ, 2003). About 75 percent of the year's precipitation falls as rain during the April-September growing season. May and June are usually the wettest months of the year.

Streamflow is driven by precipitation, although the relationship is complex in reality. Variations in the pattern and timing of precipitation over the basin and lag time between snowfall and snowmelt are some of the complicating factors. A general correlation between the 2-year moving average of annual precipitation at the Sheridan Field weather station, and streamflow in the Tongue River at the State Line gauging station is displayed in Figure 2.

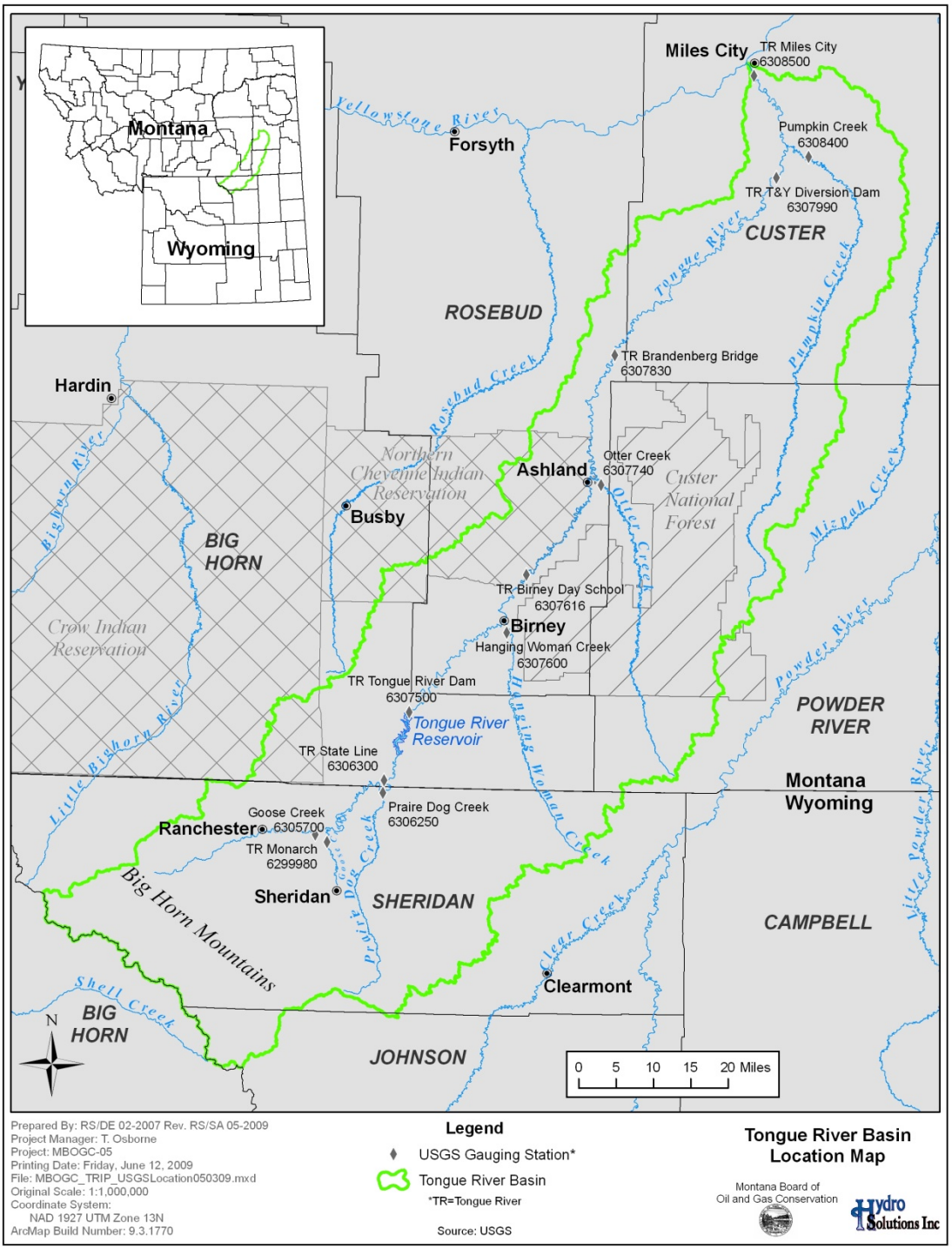

Figure 1. Tongue River Basin Location Map

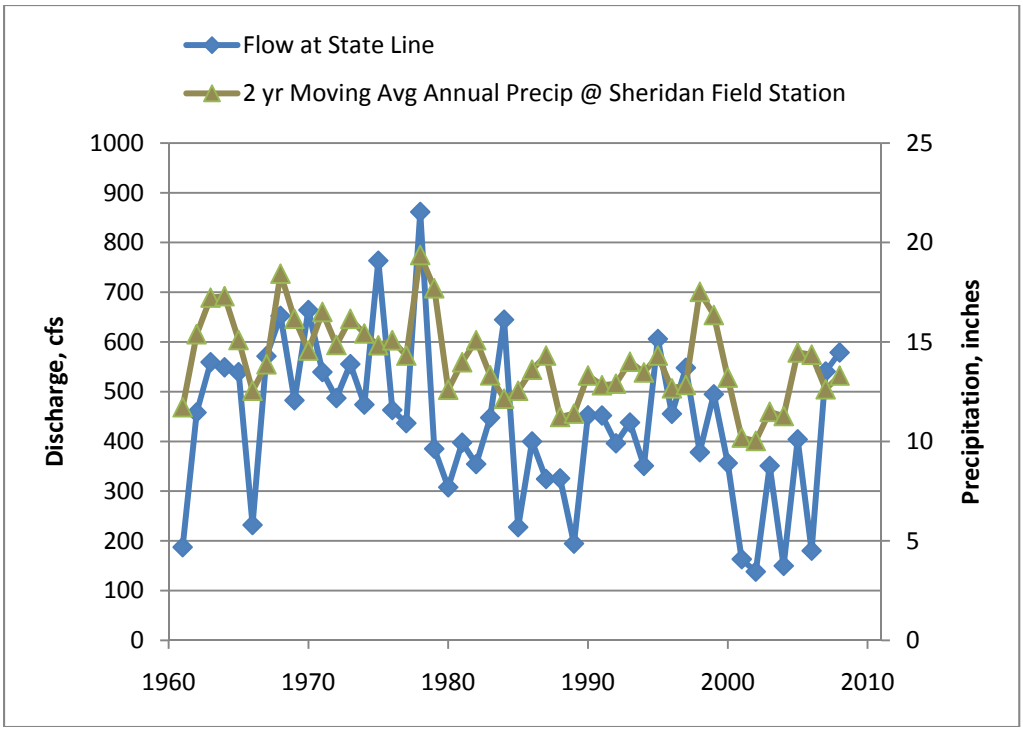

Figure 2. Average Annual Discharge of Tongue River at State Line Gauging Station versus 2-Year Moving Average Annual Precipitation at the Sheridan Field Weather Station (through 2008). (Personal Communications,Jim,WRCC, USGS, 2009; WRCC, 2008)

Correlation of precipitation with river discharge becomes less well defined at gauging stations lower in the basin because of the increase in the variability of the factors mentioned above, and an increasing number of human sources of diversions, discharges and impoundments throughout the basin, particularly the Tongue River Reservoir. The USGS stream gauging stations in the basin are shown on Figure 1.

1.3 Long Term Flow Trends, Upper & Lower Basin

The average annual discharges for the Tongue River at Miles City and at the State Line gauging stations are depicted in Figures 3 and 4, respectively. The average annual discharge of the river at these two stations for water years 1961 through 2008 is approximately 404 cfs and 450 cfs, respectively. Two general patterns emerge from the long-term discharge trends: year-to-year variation of 50 to 150 (cfs), superimposed on longer-term swings of a decade or more that show variations of 400 to 600 cfs on an average annual basis. Long-term low flows were realized in the late 1930's, 1956, 1989 and 2002. Long term high flows were seen in 1945, 1971, 1984 and 1997. The 1970's also saw two abnormally large spikes of flow in 1975 and 1978. May 19-20, 1978 saw the largest flood of record, with 17,500 cfs measured at the State Line station and 10,800 cfs measured at the Tongue River Dam station.

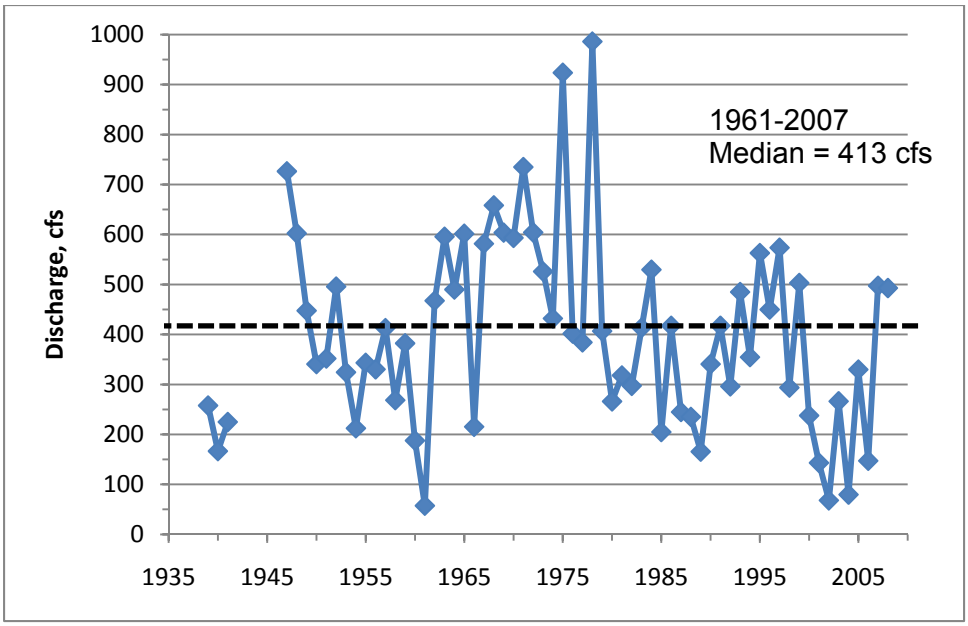

Figure 3. Annual Discharge of the Tongue River at Miles City, MT through 2008

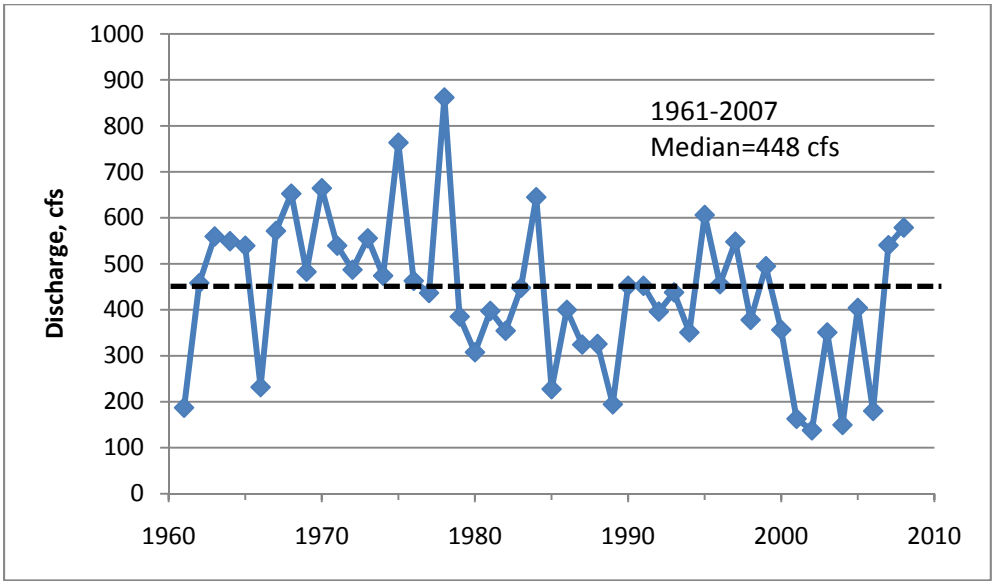

Figure 4. Annual Discharge of the Tongue River at the State Line through 2008

Of the nine water years from 2000 through 2008, only the 2007 and 2008 flows exceeded the respective median annual discharge at the State Line and Miles City gauging stations. The seven straight years of below normal flows from water years 2000 through 2006 is the longest such series in the monitoring records of both these stations. Table 1 summarizes the rank order of annual discharges, from smallest up to the respective median flows over the periods of records for the two stations.

Table 1. Annual Average Low Flows for the Tongue River in Ascending Rank Order

Tongue River at State Line Median Annual Flow = 449.85 cfs (1961-2008)		Tongue River at Miles City Median Annual Flow = 404.2 cfs (1961-2008)	
Year by Rank	Annual Discharge cfs	Year by Rank	Annual Discharge cfs
2002	137.9	1961	57.2
2004	149.6	2002	67.9
2001	163.0	2004	79.5
2006	180.0	2001	143.0
1961	187.2	2006	147.1
1989	194.4	1989	165.5
1985	227.5	1940	166.5
1966	231.8	1960	187.6
1980	307.7	1985	204.7
1987	324.3	1954	212.2
1988	325.6	1966	215.2
1994	350.8	1941	224.8
2003	350.8	1988	235.1
1982	354.4	2000	237.7
2000	356.3	1987	244.8
1998	378.0	1939	257.7
1979	385.2	1980	266.0
1992	396.1	2003	266.2
1981	397.5	1958	268.5
1986	399.8	1998	293.5
2005	404.0	1992	296.1
1977	436.6	1982	297.2

Table 1. (Continued) Annual Average Low Flows for the Tongue River in Ascending Rank Order

Tongue River at State Line Median Annual Flow = 449.85 cfs (1961-2008)		Tongue River at Miles City Median Annual Flow = 404.2 cfs (1961-2008)	
Year by Rank	Annual Discharge cfs	Year by Rank	Annual Discharge cfs
1993	437.9	1981	318.0
1983	447.7	1953	324.3
		2005	329.7
		1956	330.2
		1990	340.6
		1950	340.7
		1955	343.2
		1951	351.8
		1994	354.6
		1959	382.2
		1977	384.1
		1976	401.7
		1979	406.7
		1957	412.8
		1983	413.4

Source: USGS, 2009.

A comparison of average annual discharge of the Tongue River at gauging stations between the State Line and Miles City indicates that in some years there are net increases in flow, while in others there are net decreases. Evaporation from the river and wet areas, riparian zone transpiration, and crop irrigation tend to deplete stream flow except in years where surface runoff and groundwater contributions are sufficient to offset these losses. A summary of average annual discharges at the USGS gauging stations at State Line, Tongue River Dam and Miles City from water years 1961 to 2008 is provided in Table 2. Gray-shaded entries designate values which are less than that of the nearest upstream gauging station, indicating times that net decreases in average flow occurred between the stations.

Table 2. Trends in Down River Average Annual Discharge of the Tongue River Water Years 1961-2008

Water Year	State Line cfs	TR Dam cfs	Miles City cfs
1961	187	154	57
1962	458	487	468
1963	559	582	596
1964	549	565	490
1965	539	542	602
1966	232	270	215
1967	571	567	582
1968	653	628	658
1969	483	512	604
1970	664	662	593
1971	540	554	735
1972	487	485	604
1973	556	565	526
1974	474	485	432
1975	764	782	924
1976	463	415	402
1977	437	437	384
1978	862	853	986
1979	385	377	407
1980	308	319	266
1981	398	374	318
1982	354	326	297
1983	448	446	413
1984	645	611	530
1985	228	250	205
1986	400	406	417
1987	324	296	245
1988	326	340	235
1989	194	206	166
1990	452	426	341
1991	452	422	417
1992	396	374	296
1993	438	446	485
1994	351	348	355
1995	606	638	563
1996	456	481	450
1997	548	572	574

Water Year	State Line cfs	TR Dam cfs	Miles City cfs
1998	378	388	294
1999	495	468	503
2000	356	350	238
2001	163	174	143
2002	138	133	68
2003	351	309	266
2004	150	162	80
2005	404	366	330
2006	180	176	147
2007	541	526	497
2008	579	578	493
Averages	436	434	415
No. of Years with Gain		23	16
No. of Years with Loss		25	32
Total No. of Years		48	48

Note: Gray shading indicates stations having net stream flow loss with respect to the up-stream gauging station. Source: USGS, 2009

The data for the Tongue River Dam station indicates that over the 48 years of record, 23 years show gains and 25 years show losses compared to the State Line station, with an average loss of 2 cfs. The Miles City gauging station had 16 years of relative stream flow gains, with 32 years of losses when compared to the gauging station at Tongue River Dam, with an average loss of 19 cfs.

1.4 Relation of Flow to Quality

Many authoritative sources have established that the water quality of the Tongue River and that of many streams in the region are directly related to the quantity of flow. A 2007 report by the U.S. Geological Survey in cooperation with the Wyoming Department of Environmental Quality (Clark and Mason, 2007) studied the trends in water quality at 22 sampling sites in the Tongue, Powder, Cheyenne and Belle Fourche River systems in Wyoming. They specifically examined the relation of streamflows with specific conductance (SC) and sodium adsorption ratios (SAR). The following excerpts from their discussion of streamflow and water quality illustrates this concept:

> "Water-quality constituents frequently are correlated with streamflow."

> "Specific conductance and streamflow for water years 2001–05 were negatively correlated at all 22 sampling sites; however, the strengths of the relations were variable. For most streams, the largest specific-conductance values tended to occur during low-flow conditions, when ground water composes a large part of the streamflow. Correspondingly, the smallest values tended to occur during high streamflows associated with precipitation runoff."

> "SAR and streamflow were negatively correlated at 21 of the 22 sites. Similar to specific conductance, the largest SAR values tended to occur during low-flow conditions, when ground water composes a large part of the streamflow."

In their summary, the authors concluded that,

> "An analysis of specific conductance and sodium-adsorption ratios indicated both constituents generally had inverse relations with streamflow; thus, the largest concentrations tended to occur during low flows when ground water composes a large part of the streamflow." *(Clark and Mason, 2007).*

The relationship between salinity and streamflow may be made by comparing the SC of the water with the rate of flow at each Tongue River gauging station when the USGS collects its periodic water quality samples. Figures 5 through 9 provide charts displaying this relationship for the main USGS gauging stations on the Tongue River, from upstream to downstream. Each point represents one concurrent measurement of discharge and water quality. Note that in each chart, solid diamond symbols represent the period of record prior to and through water year 1999, open square symbols represent the period from water years 2000 through 2007, and the triangles are data for water year 2008. The earliest CBNG production in the basin began in 1999 in both Wyoming and Montana. River discharge is portrayed on a logarithmic scale. If there were trends of increasing SC and/or SAR since 2000, the data since 2000 would be evident on these graphs as a shift of those data points above the range of the pre-2000 data, at any given rate of flow. Detailed statistical tests for potential differences were not performed in this study. However, as described at the end of this section, the USGS study (Clark and Mason, 2007) conducted statistical analyses of SC at two Tongue River basin stations.

The charts reveal that SC and SAR for comparable flows at all of the gauging stations remain relatively consistent. The graphs show that since 2000, the majority of the data points are shifted slightly to the left, which is indicative of the lower flows in this period. If the SC and SAR had increased, it would be denoted on the graphs by an upward shift of the data points. The range in distribution of the data points since 2000 is generally within that of the pre- 2000 data points.

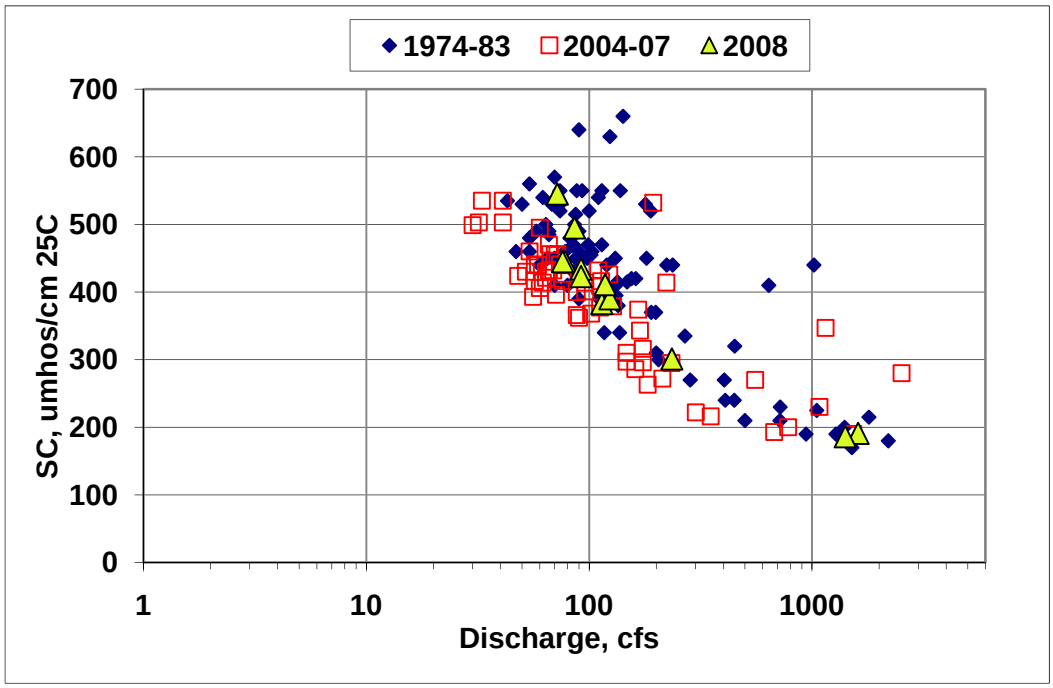

Figure 5. SC versus Discharge for the Tongue River at Monarch, WY

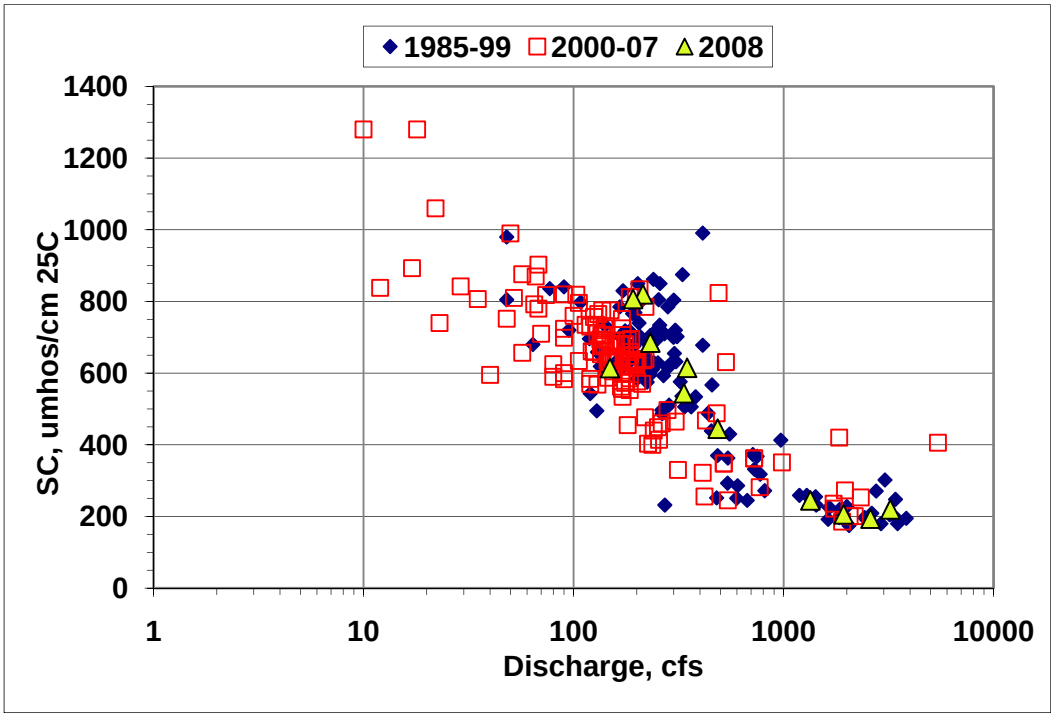

Figure 6. SC versus Discharge for the Tongue River at the State Line.

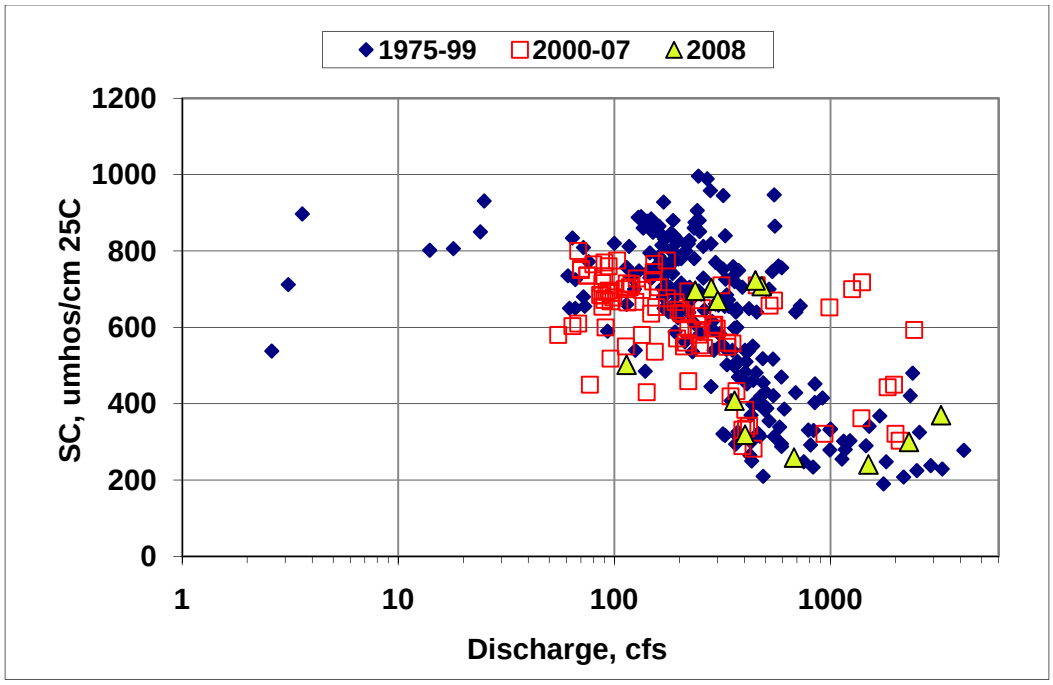

Figure 7. SC versus Discharge for the Tongue River at Tongue River Dam

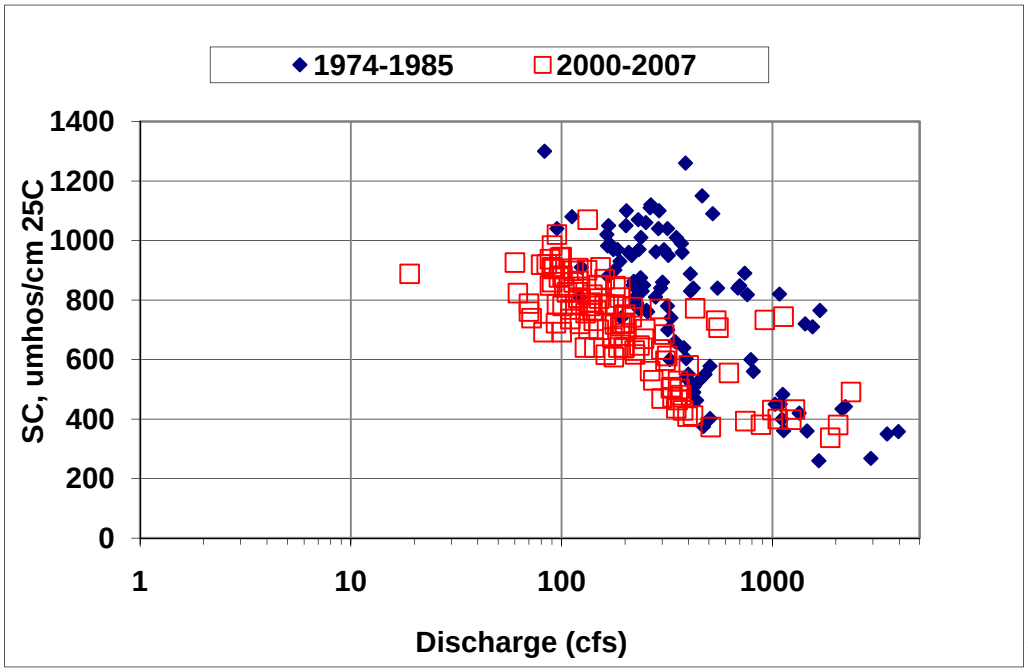

Figure 8. SC versus Discharge for the Tongue River at Brandenberg, MT

Note: SC data were not collected at this station during 2008.

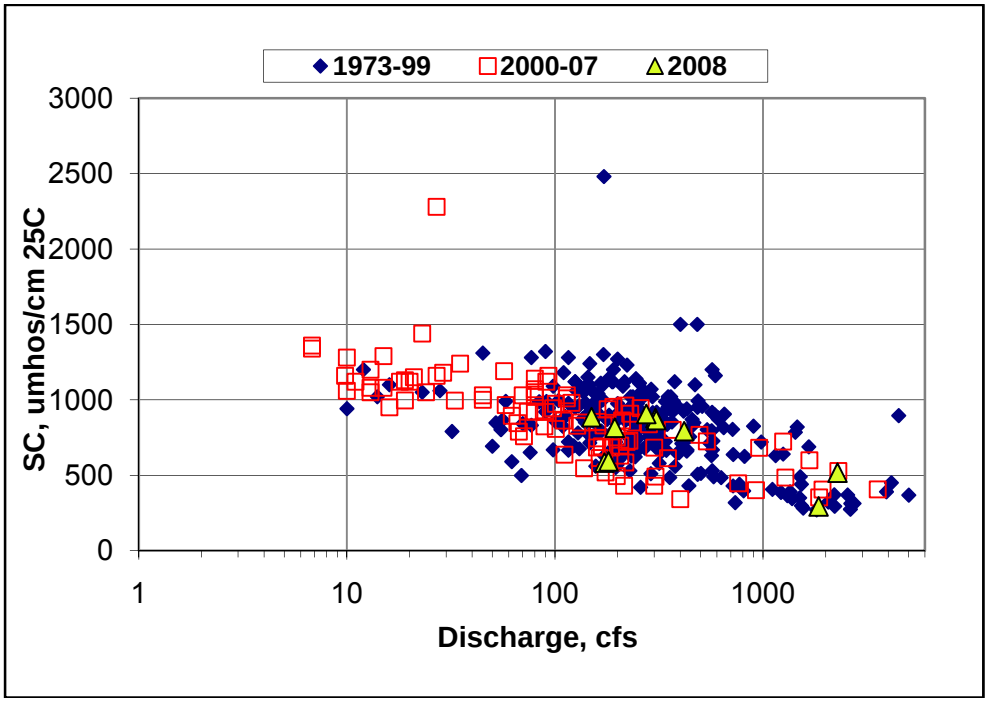

Figure 9. SC versus Discharge for the Tongue River at Miles City, MT

Similar streamflow-water quality relationships can be seen for SAR in the following charts, Figures 10 through 14.

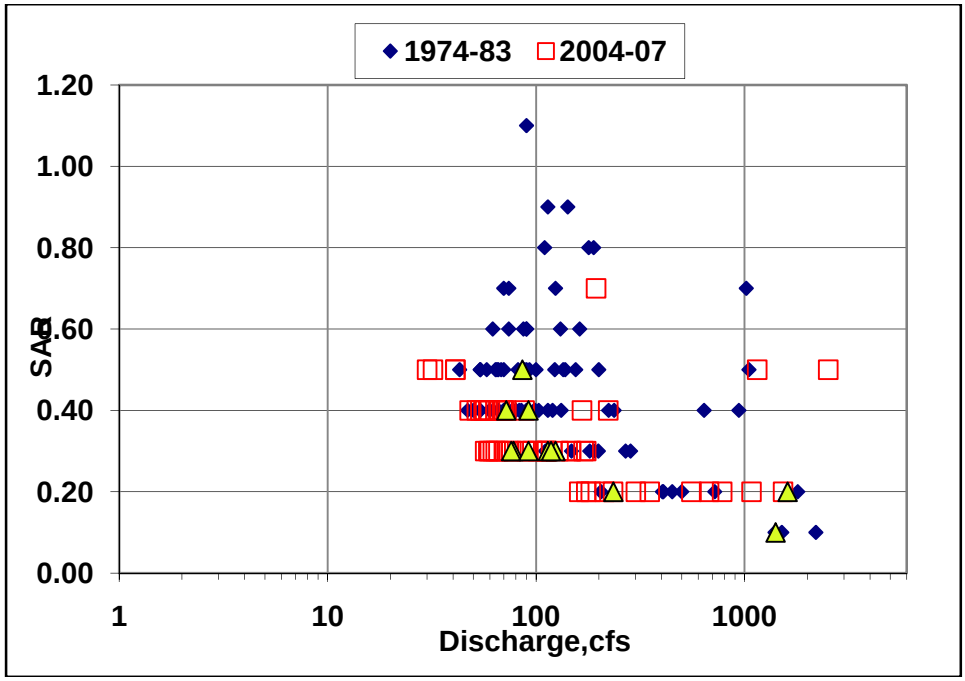

Figure 10. SAR versus Discharge for the Tongue River at Monarch, WY

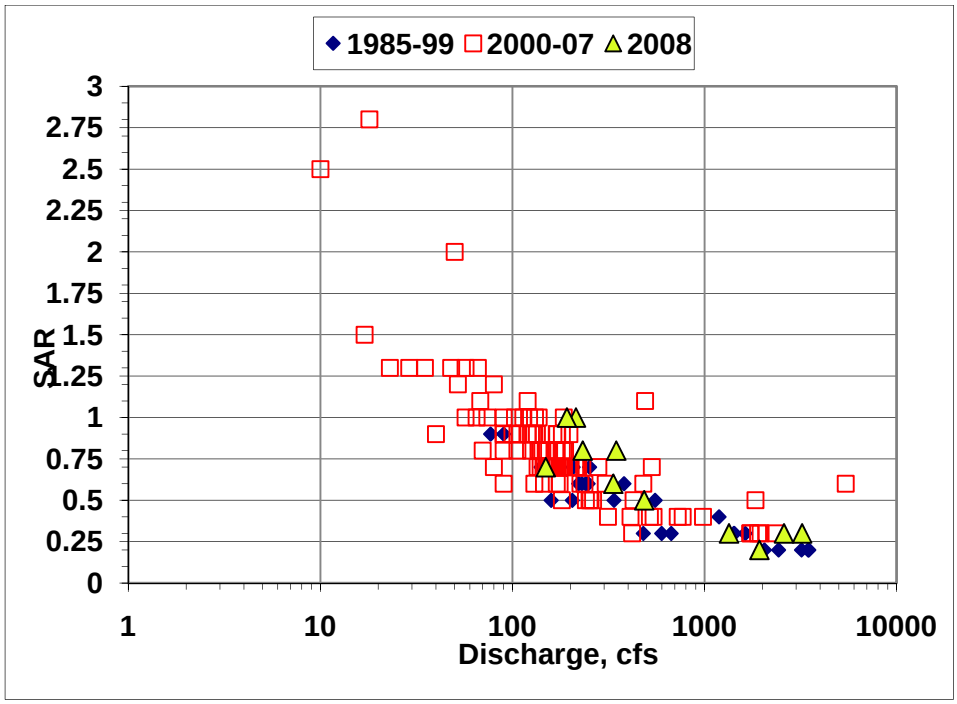

Figure 11. SAR versus Discharge for the Tongue River at the State Line

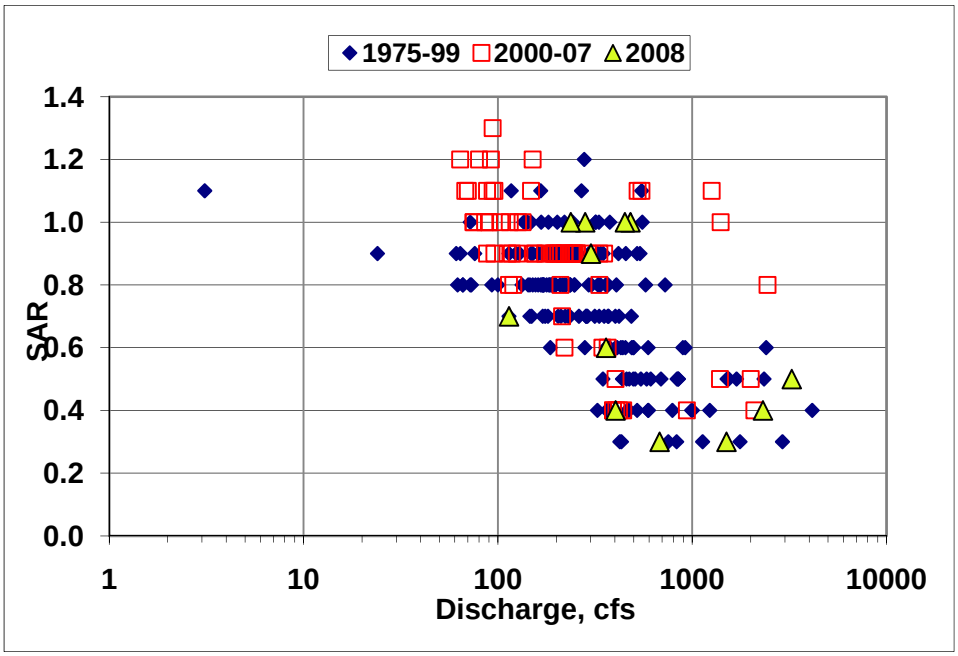

Figure 12. SAR versus Discharge for the Tongue River at Tongue River Dam

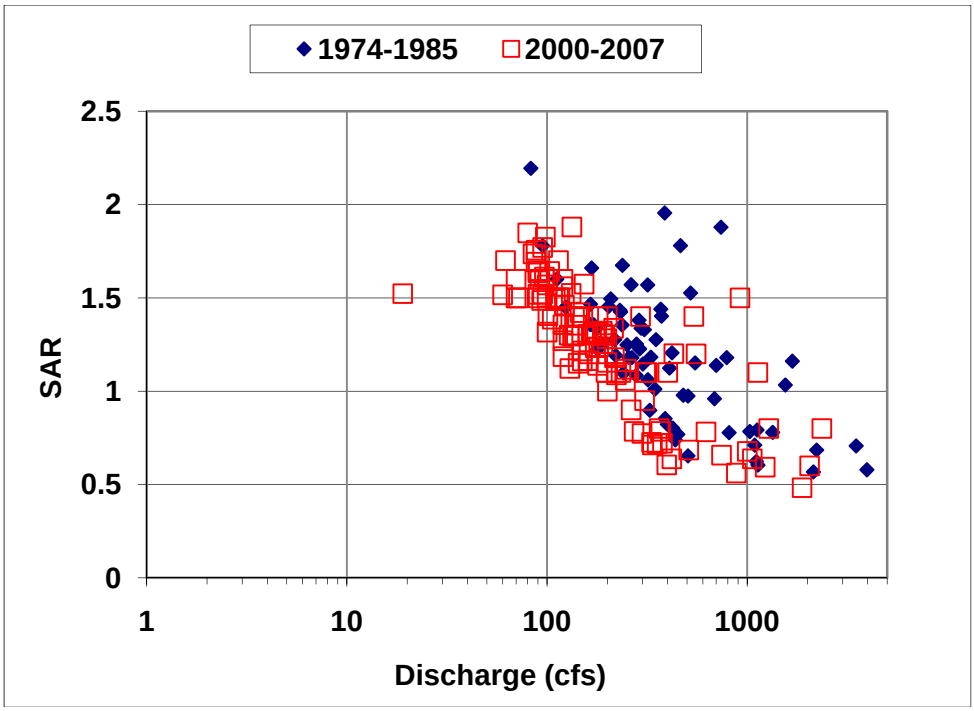

Figure 13. SAR versus Discharge for the Tongue River at Brandenberg, MT
Note: SAR data was not collected at this station in 2008.

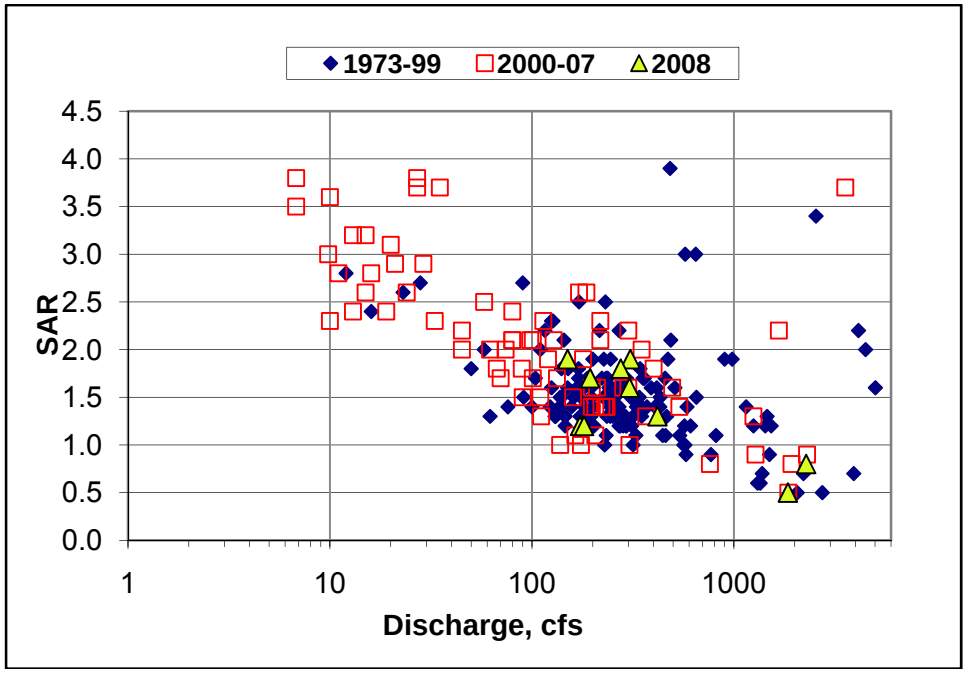

Figure 14. SAR versus Discharge for the Tongue River at Miles City, MT

In a 2007 report (Clark and Mason, 2007), the USGS, in cooperation with the Wyoming Department of Environmental Quality, characterized the water quality at 22 sampling sites in the Tongue, Powder, Cheyenne, and Belle Fourche River drainage basins. Data for general hydrology, field measurements, major-ion chemistry, and

selected trace elements were summarized, and specific conductance and SAR were evaluated for relations with streamflow and seasonal variability. Trend analysis for water years 1991–2005 was conducted for selected sites and constituents to assess change through time. The authors made the following finding in the Abstract of the paper:

> *Eight sites in the Tongue, Powder, and Belle Fourche River drainage basins having sufficient long-term data were evaluated for trends in SC during water years 1991–2005. Trends in SC were found to be not significant (p-values greater than 0.10) at the eight sites when values were flow-adjusted for streamflow variability*.

Thus, the USGS did not find any trend up or down in the SC data from the stations they evaluated. Their analysis included the USGS stations on the Tongue River at the State Line and Goose Creek below Sheridan.

1.5 Seasonal Trends in SC and SAR

The SC and SAR of the Tongue River have natural seasonal variations. These seasonal patterns reflect changes in the flow regime of the river, notably a period of the higher flows in April through June when snowmelt occurs. The average monthly SC of the principal USGS gauging stations along the river is displayed in Figure 15.

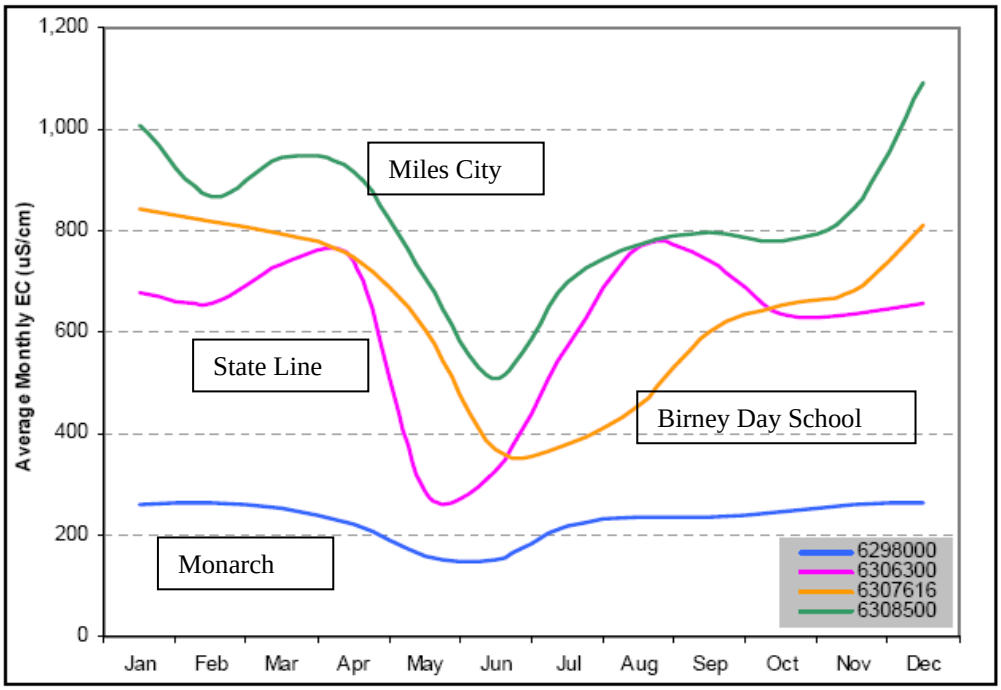

Figure 15. Average Monthly SC at Four Tongue River Stations, 1986-2001
Source: MDEQ, 2003.

The highest SC values at the State Line station are seen in early spring when runoff from low-elevation areas contributes sediment and salts, and in late summer, when high temperatures and lower flows result in concentration of salts from evaporation and transpiration by riparian vegetation. The lowest SC values at all stations are associated with spring snow melt and runoff. The Tongue River reservoir stores some of

the spring runoff and releases it later in the irrigation season, producing a delay in the downstream seasonal low SC compared to above the reservoir. The seasonal trend of SAR generally follows that of SC.

The USGS report by Clark and Mason (2007) also conducted a statistical evaluation of seasonality in SC and SAR. Seasonal variability of these parameters generally was statistically significant for streams that have headwaters in mountainous areas such as the Tongue River and Goose Creek. Seasonal variability in SC generally was not significant for streams that have headwaters in the plains; however, seasonal variability generally was observed for sodium-adsorption ratios at these sites.

1.6 Down-River Trends in SC and SAR

The Tongue River picks up salinity and sodium in its downstream travel, a trend that is common to many western streams. Figures 16 and 17 illustrate the trends in average annual salinity and SAR for the Tongue River from Monarch, Wyoming to Miles City, Montana. Data from a new station established just above the T&Y irrigation diversion dam is included for years 2006-2008. Collection of water quality data at the USGS Station at Brandenburg was discontinued by the USGS after September 2007 (USGS, 2009).

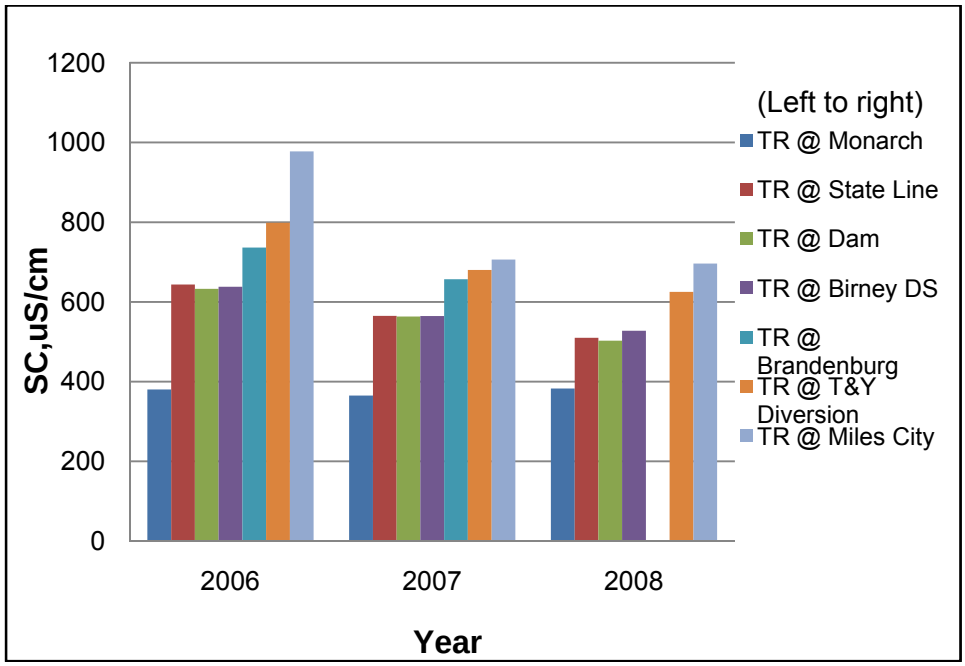

Figure 16. Down-River Trends in Average SC for the 2006-2008 Water Years
Source: Bobst, 2007 and USGS, 2009.

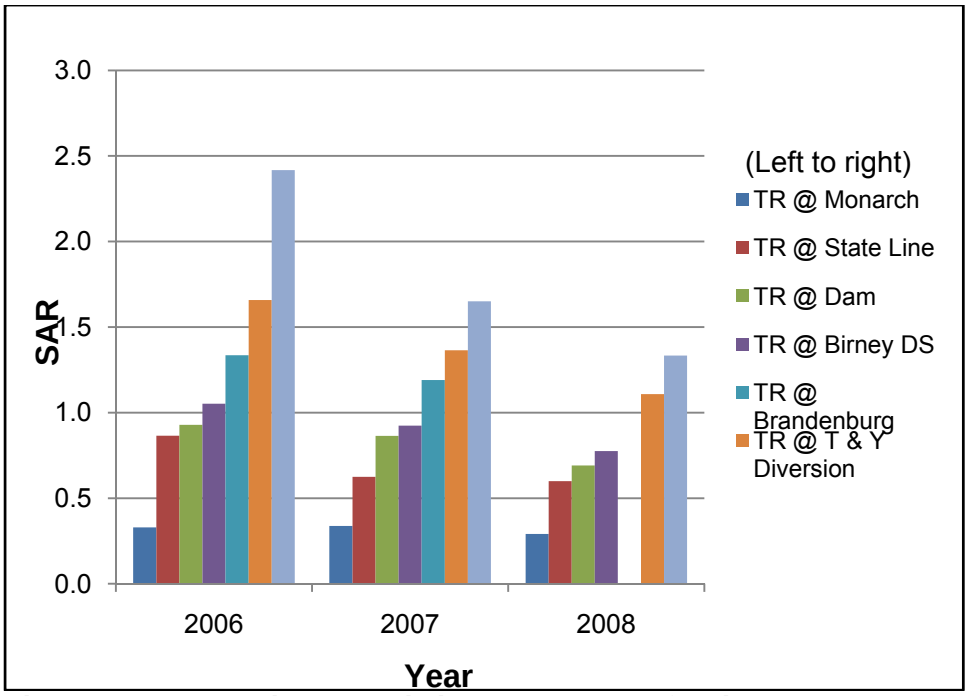

Figure 17. Down-River Trends in Average SAR for the 2006-2008 Water Years
Source: Bobst, 2007 and USGS, 2009.

The average SC and SAR generally declined over these three water years, likely due in large degree to trends in discharge, as discussed above. The average discharge was much greater in 2007 than 2006, and in 2008 was slightly greater than 2007 at all stations except Miles City. The largest increases in SC and SAR usually occur between Monarch and State Line, and between the T&Y Diversion and Miles City. The Brandenburg station was discontinued in Water Year 2008, thus changing the sequence of data available to compare. Between Monarch and the State Line stations, the Tongue River enters the plains region where natural salts from the Wasatch and Fort Union formations are more abundant. Salinity is contributed by Goose Creek which drains the City of Sheridan and the surrounding suburban area; and Prairie Dog Creek, which has naturally higher EC and SAR, but also drains an area of CBNG development along with irrigation diversions and return flows.

Between Brandenburg and Miles City, the surficial geology of the basin transitions from the Tongue River member of the Fort Union formation to the Lebo Shale and the Tullock members, which contain more natural salinity and sodium. Pumpkin Creek contributes salinity and sodium via surface and sub-surface flow, with most measurements exceeding the applicable Montana EC and SAR standards (Bobst, 2007). In addition, irrigation diversions decrease the dilution capacity of the river and irrigation return flows, which follow surface and subsurface pathways, contain higher salinity and sodium concentrations than the river. During low flow periods, the water quality that is monitored at the Miles City station is more representative of irrigation return flows and groundwater base flow than of typical Tongue River flow, because most of the water in the Tongue is diverted for irrigation during low flows (Bobst, 2006). It is notable that while there are general down-river increases in salinity and SAR, the Tongue River meets Montana irrigation season EC and SAR standards everywhere except during some periods at the Miles City gauging station. The EC and SAR standards were met at

the Miles City station throughout Water Year 2008 based on the daily data as well as the periodic water quality sampling conducted by the USGS.

The major tributary streams to the Tongue River other than Goose Creek usually have higher SC and SAR than the Tongue River at their respective confluences. Average annual SC and SAR values for the principal tributaries over the water years 2006-2008 are provided in Figures 18 and 19.

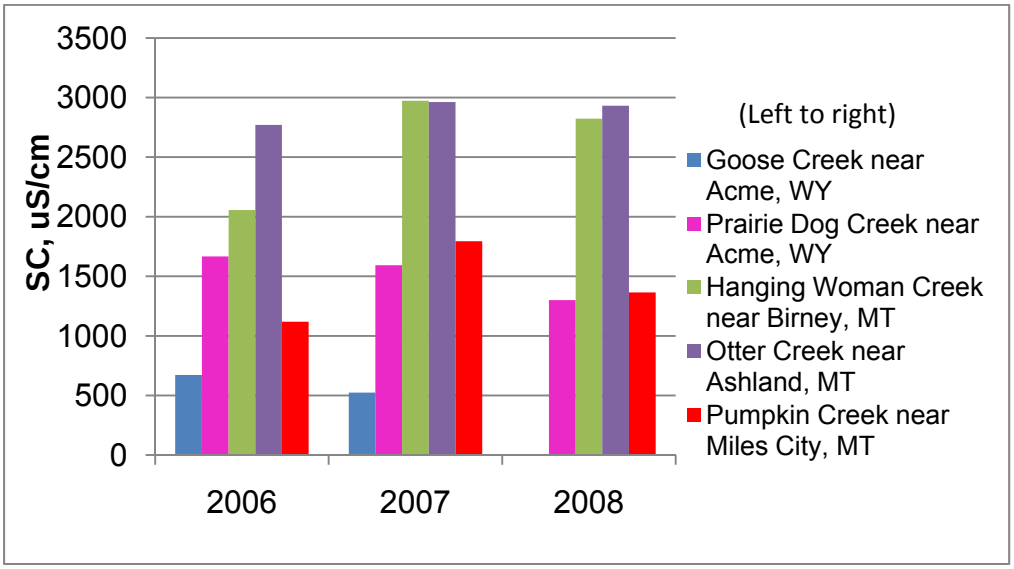

Figure 18. Average SC for Tongue River Tributaries, Water Years 2006-2008
Source: Bobst, 2007 and USGS, 2009.

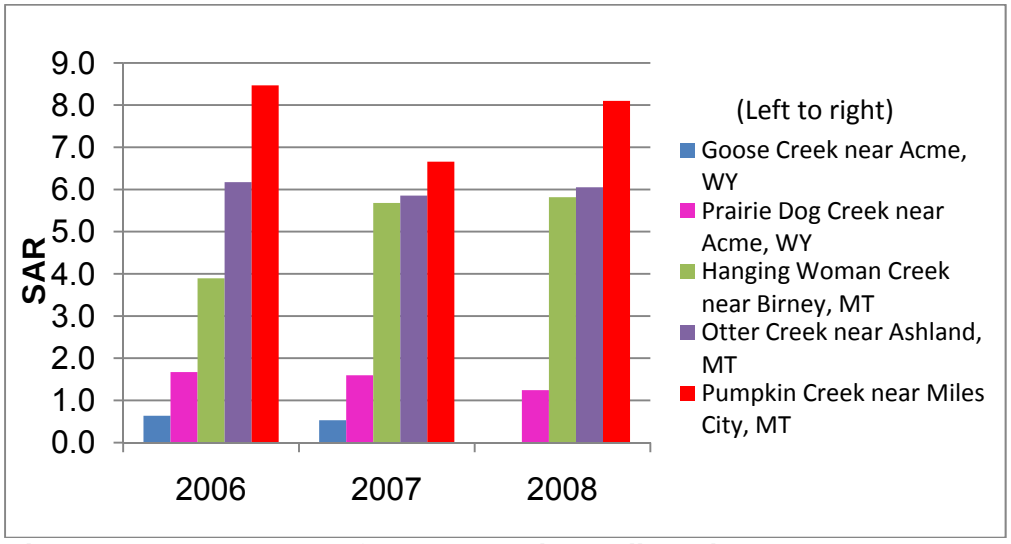

Figure 19. Average SAR for Tongue River Tributaries, Water Years 2006-2008
Source: Bobst, 2007 and USGS, 2009.

In his report on surface water quality in the Tongue River basin, Bobst (2007) found that the water quality at tributary stations typically exceeded the MDEQ surface water standards for SC and SAR, and that elevated SC and SAR occurred even in

watersheds where little or no CBNG development has occurred. The average SC and SAR in water year 2008 remained similar to the previous year with a few exceptions. It should be noted that the sampling frequency declined in water year 2008, with these tributary stations having each only from one to seven samples collected. The Goose Creek station was sampled only once in 2008, and thus omitted from the charts. These stations were generally sampled from 11 to 12 times in water years 2006 and 2007. Sampling frequency and timing can be a significant factor affecting interpretation of trends.

2.0 Trends in Water Use, Montana and Wyoming

2.1 Population

The total population for the watershed is not directly available but may be inferred from the 2000 U.S. Census data (MDEQ, 2003). A population analysis performed for the Tongue River Total Maximum Daily Load (TMDL) Status Report (MDEQ, 2003) found that approximately 25,000 people reside within the Tongue River watershed. The watershed urban and nonurban population totals by county are given in Table 3. The Wyoming portion of the Tongue River watershed is home to 22,460 people, which represents 88.3 percent of the total watershed population. The Montana portion of the watershed contains 2,974 persons, or 11.7 percent of the total.

Cities and towns account for 18,158 people (71.4 percent), while 7,275 people (28.6 percent) reside in nonurban areas (Table 3). Sheridan County, Wyoming has the largest total population in the watershed with 22,408 people (88.1 percent of the watershed total population), and it also has the largest urban population of 17,518 (68.9 percent of the entire urban population) within the watershed. The second largest total county population is found in Custer County, Montana, with 943 people (3.7 percent of the total watershed population). The Montana counties of Custer, Big Horn, and Rosebud contain 2,532 people, or roughly 85 percent of Montana's share of the total watershed population (11.9 percent). The largest community in the Montana portion of the watershed is the town of Ashland with a population of 385.

Table 3. Population Distribution within the Tongue River Basin

County	Total Watershed Population	Percent of Total Population	Nonurban Population	Percent Nonurban	Urban Population	Percent Urban
Sheridan, WY	22,408	88.1	4,890	19.2	17,518	68.9
Custer, MT	943	3.7	903	3.5	40	0.2
Big Horn, MT	841	3.3	806	3.2	35	0.1
Rosebud, MT	748	2.9	223	0.9	525	2.1
Powder River, MT	442	1.7	402	1.6	40	0.2
Johnson, WY	52	0.2	52	0.2	0	0.0
Total	25,434	100.0	7,276	28.6	18,158	71.5

Source: U.S. 2000 Census and GIS analysis. Adapted from MDEQ, 2003.

2.2 Principal Water Uses

In the Montana portion of the Tongue River watershed agriculture accounts for 99.6 percent of all water used (Cannon and Johnson, 2004). Of the other 0.4 percent, public water supplies account for 57 percent and self-supplied domestic sources account for the remaining 43 percent. Industrial uses such as thermoelectric power generation and mining were not specified by the USGS report. Water use data for the Montana portion of the Tongue River watershed are provided in Figure 20 and show withdrawals by the category for which they were reported.

The Wyoming water use data was not available specifically for the Tongue River watershed, but was provided for Sheridan County which essentially encompasses the Tongue River basin in Wyoming. Within Sheridan County, irrigation accounts for 97 percent of all water used. Of the other 3 percent, public water supplies account for 84 percent, self-supplied domestic accounts for 9 percent, mining for 5 percent, and industrial uses make up the remaining 2 percent. The Sheridan County data, provided in Figure 21, generally mimic the trends seen in the Montana portion of the Tongue River basin.

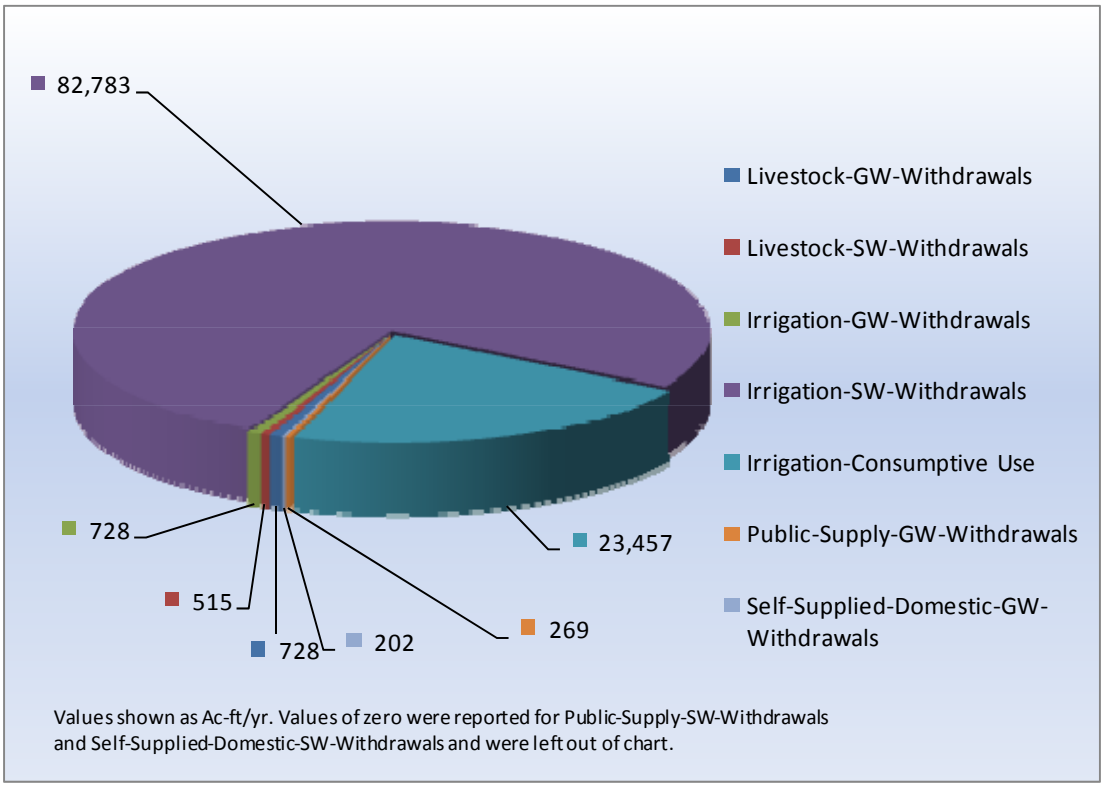

Figure 20. Water Use in Montana portion of the Tongue River Basin
Note: SW-Surface Water; GW-Groundwater
Source: Cannon and Johnson, 2004

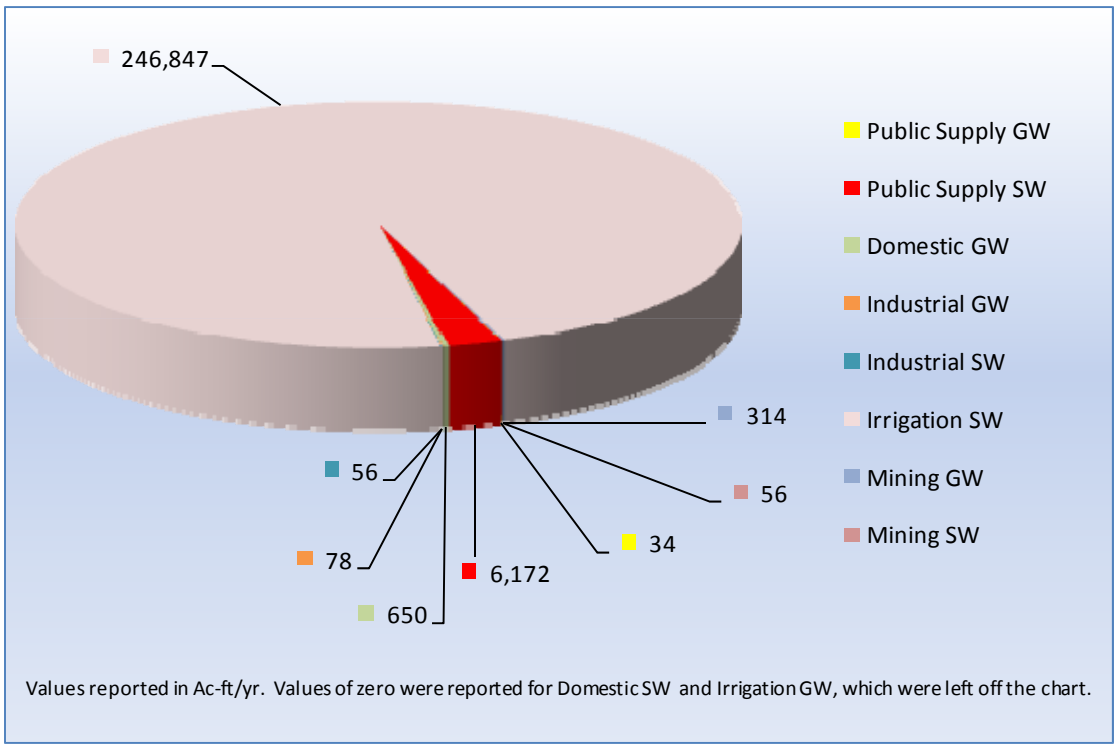

Figure 21. Water Use in Sheridan County, Wyoming
SW-Surface Water; GW- Groundwater
Source: Cannon and Johnson, 2004

This report focused on finding a better estimate of the irrigated area within the Tongue River basin than has been obtainable in previous years. Apparent disparity in estimates from various sources occurs and it is important to note that the time frame, methodology, and resolution of the public data accessed varies among sources and agencies. In addition, estimates of irrigated land fluctuate from year to year as the availability of irrigation water changes.

According to the most recent authoritative source, the 2007 Census of Agriculture (United States Department of Agriculture National Agricultural Statistics Service 2007), irrigated land accounted for 59,570 acres in the Tongue River Basin out of 222,262 acres identified as total cropland, or approximately 27%.

The best visual representation of irrigated lands from the most current land cover datasets publicly available are depicted in Figure 22 (HKM Engineering Inc. 2002; Wildlife Spatial Data Analysis Lab, The University of Montana 1998) found on page 28. The irrigated acreage estimates derived from these datasets include Montana areas identified as irrigated agriculture and Wyoming areas identified as lands with full and/or partial service irrigation. Other land classification categories that indicated lower intensity irrigation or subirrigation were excluded from this analysis. The spatial analysis produced an irrigated acreage estimate of 16,838 acres in Montana and 50,478 acres in Wyoming for a total estimate of 67,317 acres for the Tongue River Basin.

Data referenced in previous TRIP Hydrology reports indicated that the total irrigated acreage in the Tongue River Basin was approximately 100,800 acres (Berkas,

et al. 2006; United States Department of Agriculture Natural Resources Conservation Service 2002).

The Tongue River Dam and Reservoir is located about 10 miles north of the Montana-Wyoming state line. The dam was planned and completed by the Montana Water Conservation Board in 1938. Reservoir storage surface area is about 3200 acres following an enlargement in 1999 that added 20,000 acre-feet to provide for the Northern Cheyenne Tribe's negotiated federal reserved water rights. Current storage capacity is 79,071 acre-feet. The project provides water for the irrigation of 15,000 acres of land between the dam and Miles City. Water use under contract includes 39,300 acre-feet for irrigation and 7,500 acre-feet dedicated for use by the Northern Cheyenne Tribe. Additional water is contracted for the fish hatchery near Miles City and the St. Labre Mission in Ashland. Total contracted water is 40,000 acre-feet. The Tongue River Water Users Association manages the dam.

In early 2002, the Montana DEQ (MDEQ) and the Tongue River Water Users (TRWU) sent surveys to landowners in the watershed to obtain better information on irrigation practices. Some of the key findings of the surveys were summarized by the MDEQ in the TMDL Status Report (MDEQ, 2003). Responding landowners indicated that close to 90 percent irrigate from the Tongue River or its tributaries. Most irrigate less than 50 acres of land but some irrigate as many as 9,400 acres. The average land area that is irrigated is 163 acres. Flood irrigation is the most common form of applying the water, but sprinkler and spreader dikes are also employed. Almost 40 percent of the landowners that responded to the surveys reported that they have experienced crop yield problems due to existing water quality. Slightly more than half of the respondents reported having soil sanitization problems.

The NRCS (Natural Resources Conservation Service) conducted a "rapid aerial assessment" of stream corridor reaches along the Montana portion of the Tongue River in 2001 (USDA, 2001). Approximately 105 river miles were inventoried in Big Horn and Custer Counties. Rosebud County did not participate. The NRCS identified and mapped a total of 263 individual point and linear features. Irrigation pump sites (63 each) were by far the most prevalent type. Most of the pump sites appeared to serve full season irrigation systems.

The NRCS reported two direct diversions located on the Tongue River (USDA, 2002). The Tongue River Diversion Dam is located on the Tongue River near the confluence of Pumpkin Creek and approximately 12 miles upstream of Miles City. It diverts a large portion of the Tongue River during the irrigation season (April to October/November) to the T&Y Ditch, which in turn supplies water to fields throughout the lower Tongue River watershed and irrigated areas in the Yellowstone River basin east of Miles City. Flows in the T&Y Ditch are approximately 200 cfs during the irrigation season when the ditch is full.

On the tributaries, water spreading systems are by far the more common method of water application compared to sprinkler or contour irrigation. In this method, water is periodically diverted or stored in ponds when available from the stream into a feeder canal or directly into a basin contained by earthen dikes. The NRCS report (2002) identified 20 surface irrigation return flows to the Tongue River.

2.3 Water Rights Information

Water rights information is another source of water appropriation and beneficial uses of water in the Tongue River watershed. Water rights information acquired by MDEQ (2003) from the Montana Department of Natural Resources and Conservation (DNRC) shows that there are 5,748,707 acre-feet of water per year in the Montana portion of the Tongue River watershed filed as surface water rights, and 830,244 acre-feet of water per year filed as groundwater rights. These amounts simply reflect the water right claims, which are far in excess of the total available water in the basin. The average annual amount of total water available from the river is approximately 313,260 acre-feet, based on the average annual flow at State Line. As of early 2008, water rights in the Tongue River basin of Montana are in the assessment process by the DNRC (K. Kerbel, DNRC, pers. comm.). Water rights information indicates water is used for irrigation, municipal, stock watering, and domestic uses. As indicated in Table 4, most of the water appropriations (76 percent) are used for irrigation (MDEQ, 2003).

Table 4. Water Uses Designated by Water Rights in Montana Portion of the Tongue River Basin

Water Purpose	Volume (acre-feet/year)	Percentage
Irrigation	4,981,187	75.7%
Municipal	557,562	8.5%
Stock watering	481,647	7.3%
Domestic	401,430	6.1%
Flood control	150,000	2.3%
Other	7,125	0.1%
Total	6,578,951	100%

Source: MDEQ, 2003

2.4 Water Well and Spring Information

Private water wells installed into shallow aquifers of the Tongue River basin are an important source of water for rural households, farms, ranches and livestock. Irrigation from shallow groundwater is typically limited to household lawns and gardens and not agricultural fields, due to relatively low well yields. Most private wells range in depth from several tens to several hundred feet. Wyoming State Engineer's records show that 93 percent of private water wells with reported total depths are 400 feet deep or less. Montana water well records (GWIC, 2009) indicate that 90 percent of private water wells with reported total depths are 400 feet deep or less. Approximately 67 percent of private water wells in Montana and 71 percent in Wyoming are 200 feet deep or less. The principal aquifers providing groundwater to wells include alluvium along stream valleys, along with coals and sandstones of the Fort Union and Wasatch formations.

The number of private water wells registered in public records in the Wyoming and Montana portions of the Tongue River basin are summarized in Table 5, and displayed on Figure 23. For this report, the water well classification for Montana based on records in the Montana Groundwater Information Center (GWIC) database as follows:

- Industrial Well was defined as any well with the following well use attributes from GWIC: Commercial, Industrial, Injection
- Domestic Well was defined as any well with the following well use attributes from GWIC: Domestic;
- Agricultural Well was defined as any well with the following well use attributes from GWIC: Irrigation, Stockwater;
- Wells with any use not mentioned above, or of the following GWIC defined site types were omitted from the calculations for this report: Spring, Coal Bed Methane Well, Petwell.

The water well classification for Wyoming, based on the records at the State Engineer's Office (WSEO, 2009) was defined as follows:

- Industrial Well was defined as any well with the following well use attributes from SEO: Com; Com, Dom; Dew, Mis; Dew,Res,Ind,Mis; Dew,Res,Mis; Dew,Res,Sto,Mis; Dew,Sto,Mis,Res; Ind; Ind,Dom; Ind,Mis; Ind,Mis,Fir; Ind,Mun; Ind,Res; Ind,Sto; Ind.Mis; Min; Rai
- Domestic Well was defined as any well with the following well use attributes from SEO: Dom; Dom, Sto; Dom,Irr; Dom,Irr,Fth; Dom,Mis; Dom,Mis,Res; Dom,Sto; Dom,Sto,Irr; Dom,Sto,Mis; Mun; Mun,Mis;
- Agricultural Well was defined as any well with the following well use attributes from SEO: Irr; Irr,Dom; Irr,Ind,Mis; Irr,Mis; Irr,Mis,Res; Sto; Sto, Mis; Sto,Dom; Sto,Ind; Sto,Ind,Com; Sto,Ind,Dom; Sto,Ind,Irr; Sto,Ind,Mis; Sto,Irr; Sto,Irr,Dom;
- Wells with any use not mentioned above were omitted from the calculations for this report, please note that springs are not differentiated from wells in the current SEO data retrieval system and are therefore not explicitly omitted from the counts provided.

Table 5. Private Water Wells of Record in the Tongue River Basin, 2008

County	Industrial Wells	Domestic Wells	Agricultural Wells	Totals
Big Horn, MT	17	77	138	**232**
Rosebud, MT	1	169	228	**398**
Powder River, MT	1	233	752	**986**
Custer, MT	4	190	468	**662**
Sheridan, WY	3	2567	870	**3440**
Totals	**26**	**3236**	**2456**	**5718**

Sources: Montana Ground Water Information Center (GWIC) and Wyoming State Engineer's Office (SEO) (as defined above).

Coal bed natural gas (CBNG) produced from coal beds of the Fort Union formation in the Tongue River basin in both Wyoming and Montana entails pumping groundwater to reduce water pressure in the coal seams, facilitating release of natural gas. Coal beds are depressurized but are not dewatered. Pumping occurs from coal beds which also may serve as aquifers for private wells. Private water wells within several miles of active CBNG fields which are completed in gas-producing coal beds could experience drawdown of water levels, reduced yield, or gas migration into the well bore. However, most CBNG wells are deeper than private water wells. Wyoming Oil

and Gas Conservation Commission (WOGCC) records (2009) indicate that 91 percent of CBNG wells in the Wyoming portion of the Tongue River basin are deeper than 400 feet. MBOGC (2009) records indicate that 83 percent of CBNG wells in the Montana portion of the basin are greater than 400 feet deep.

Gas producers in Montana are required to offer Water Source Mitigation Agreements to nearby well owners. Wyoming producers are not required to do so, but it is a common practice. Coal beds in the Powder River Basin are generally separated from other aquifers by shale units that act as confining beds or aquitards. Due to these confining shale units, significant water-level drawdown in response to CBNG production is expected to be limited to the coal aquifers and is not expected to migrate vertically to impact overlying or underlying aquifers in most areas (Wheaton et al, 2006).

Springs are also important water sources for livestock and some domestic uses in the Tongue River basin. Original homesteads and ranches were sometimes located near historic springs. Springs typically issue from clinker beds, coal beds and sandstones near their contacts with underlying mudstone or shale units (Donato and Wheaton, 2004). Between 2001 and 2003, the Montana Bureau of Mines and Geology (MBMG) inventoried a total of 279 springs in the Montana portion of the Tongue River and Powder River basins (Donato and Wheaton, 2004). Of these, 164 were found to have a measurable discharge, which ranged from 0.01 gallons per minute (gpm) to 82 gpm. A total of 55 springs were found to have a discharge rate of 1 gpm or greater. The SC of inventoried springs ranged from 123 to 8,540 microSiemens/centimeter (µS/cm) at 25 degrees C. No spring inventory is publicly available in the Wyoming portion of the Tongue River basin.

The MBMG spring inventory suggested that most springs are fed by local groundwater systems, which are unlikely to be hydraulically connected to coal bed aquifers that are targeted for CBNG production. In its Draft Supplemental Environmental Impact Statement (BLM, 2007), the U.S. Bureau of Land Management (BLM) stated that the fact that a coal seam produces CBNG strongly suggests that it is isolated from a surface unit and therefore is unlikely to impact springs.

3.0 Oil and Gas Wells in the Tongue River Basin

The distribution of oil and gas wells in the Tongue River basin is shown on Figure 24. One oil field (Ash Creek) and five gas fields (Castle Rock, Coal Creek, CX, Dietz, and Wildcat Big Horn) lie within the Tongue River basin in Montana. Of these, only the Coal Creek, CX, and Dietz fields have been recently active (MBOGC, 2009). The CX field is a coal bed natural gas (CBNG) producing area in southern Big Horn County that is operated by Fidelity Exploration & Production Company. In 2008, the CX field produced 12,551,068 thousand cubic feet (MCF) of natural gas, and 34,464,334 barrels of water. (MBOGC, 2009). Pinnacle Gas Resources produces the Coal Creek and Dietz fields. The Coal Creek field produced 264,878 MCF of natural gas and 1,976,195 barrels of water, and the Dietz field produced 1,147,587 MCF of gas and 2,800,048 barrels of water (Pers. Comm., J. Halvorson, MBOGC, 2009). One well operated by St. Mary Land & Exploration Company in the Waddle Field located in the upper Hanging Woman basin of Montana, produced 40,507 MCF of gas and 133,529 barrels of water in 2008, Total 2008 CBNG production in Montana (all in the Tongue River basin) was

14,004,175 MCF of gas and 39,374,106 barrels of water from 923 active wells (Pers. Comm., J. Halvorson, MBOGC, 2009).

The history of CBNG well permitting and well completions from the MBOGC is provided in Figure 25. Nearly all of these permits and wells lie in the Tongue River basin. CBNG wells which tap federally owned minerals must be approved by both the MBOGC and the BLM. The permits and wells shown in these maps and figures reflect approvals by MBOGC. Approvals by BLM for many of these wells are pending.

The number of CBNG wells and the average rate of water production per well for the Tongue River basin is shown in Figure 26. The historical trends in production of natural gas, water and well counts for CBNG production in the Montana portion of the Tongue River basin is shown in Table 6.

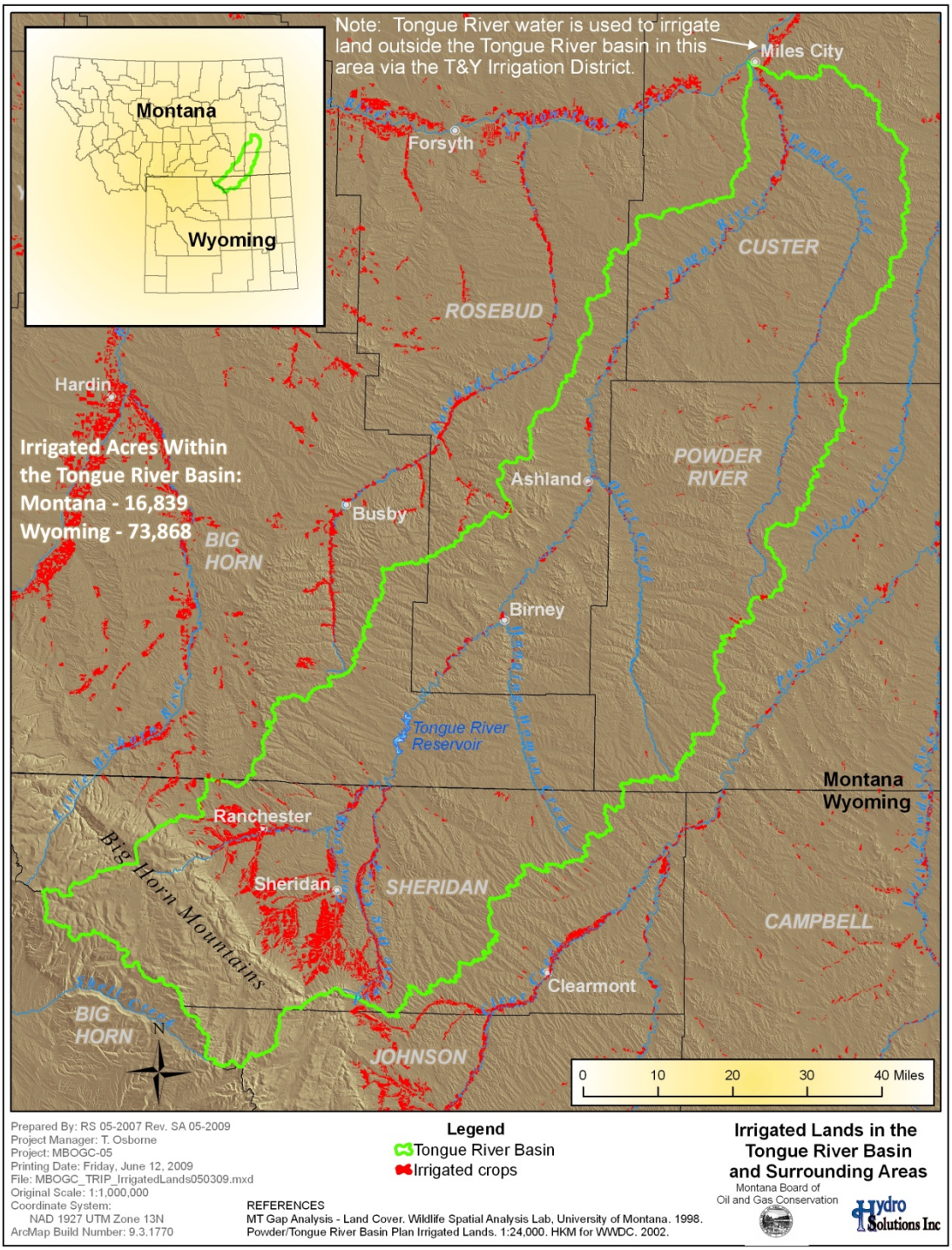

Figure 22. Irrigated Lands in the Tongue River Basin

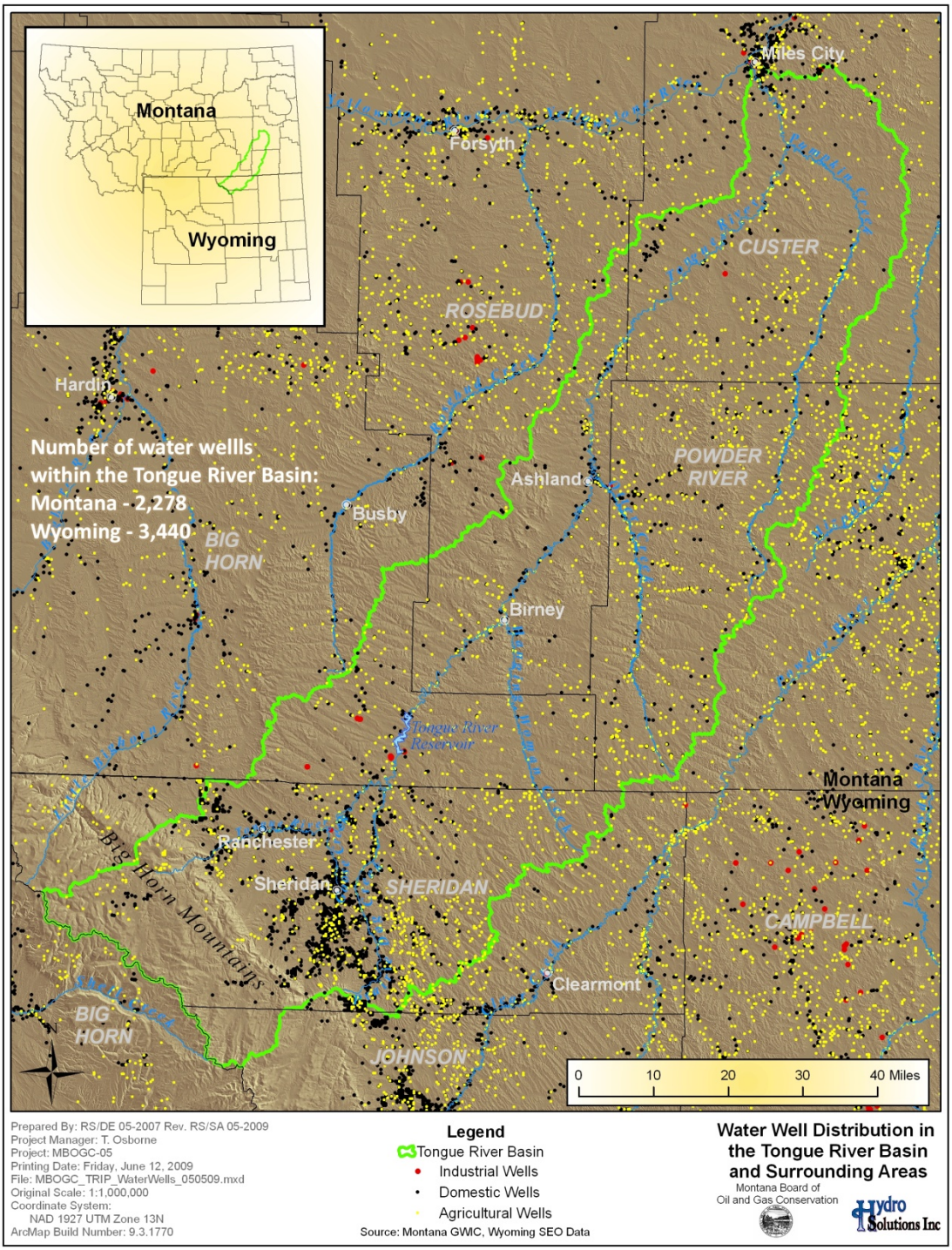

Figure 23. Water Well Distribution in the Tongue River Basin and Surrounding Areas, 2008

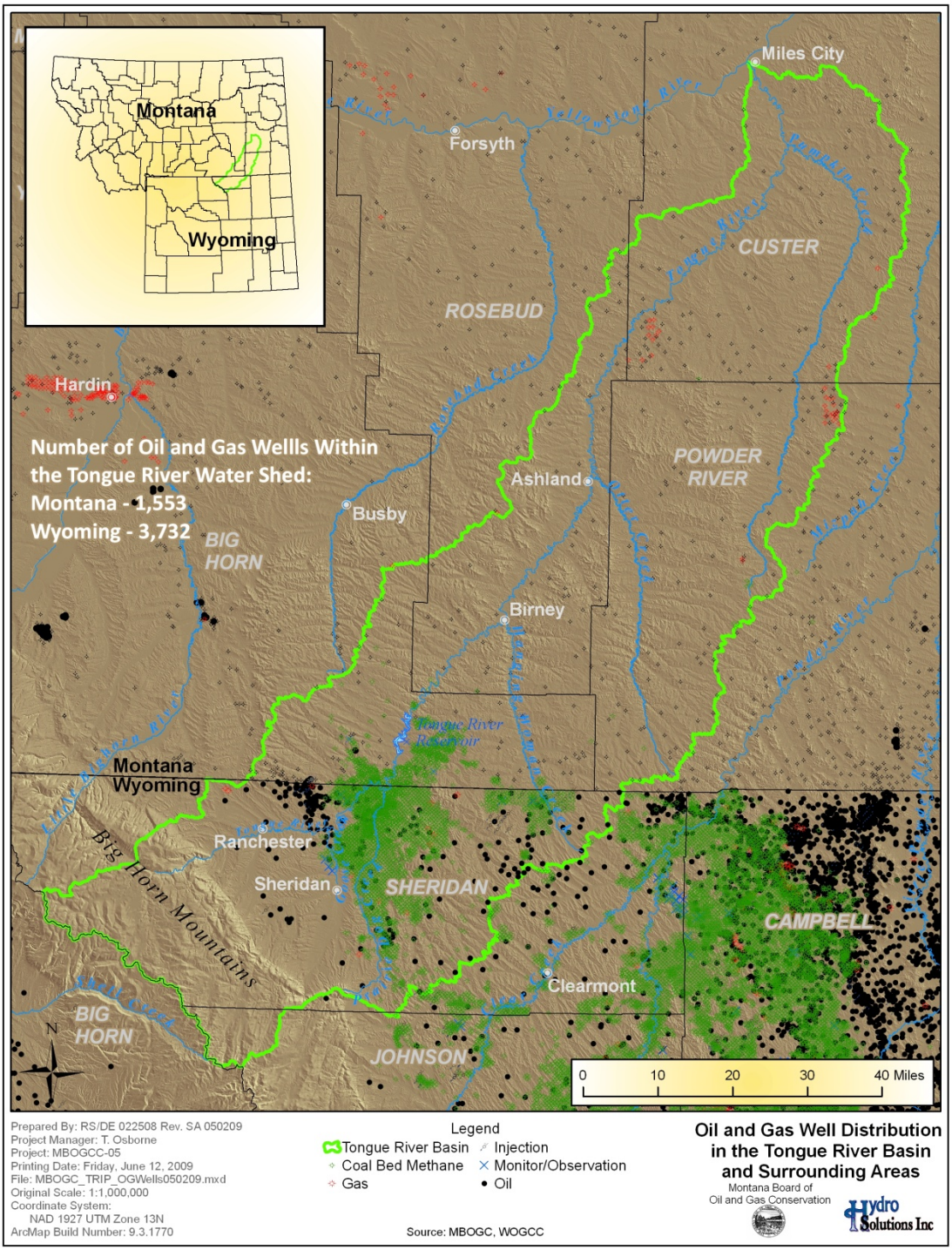

Figure 24. Oil and Gas Well Distribution in the Tongue River Basin and Surrounding Areas, 2008

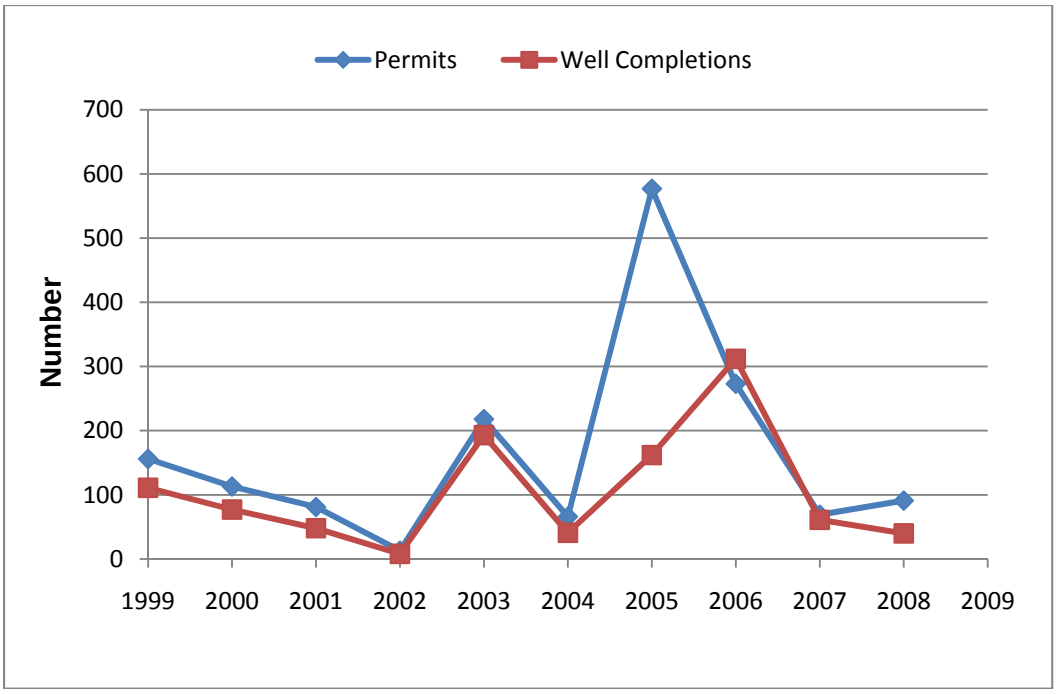

Figure 25. Numbers of CBNG Well Permits and Well Completions in Montana
Source: MBOGC, 2009.

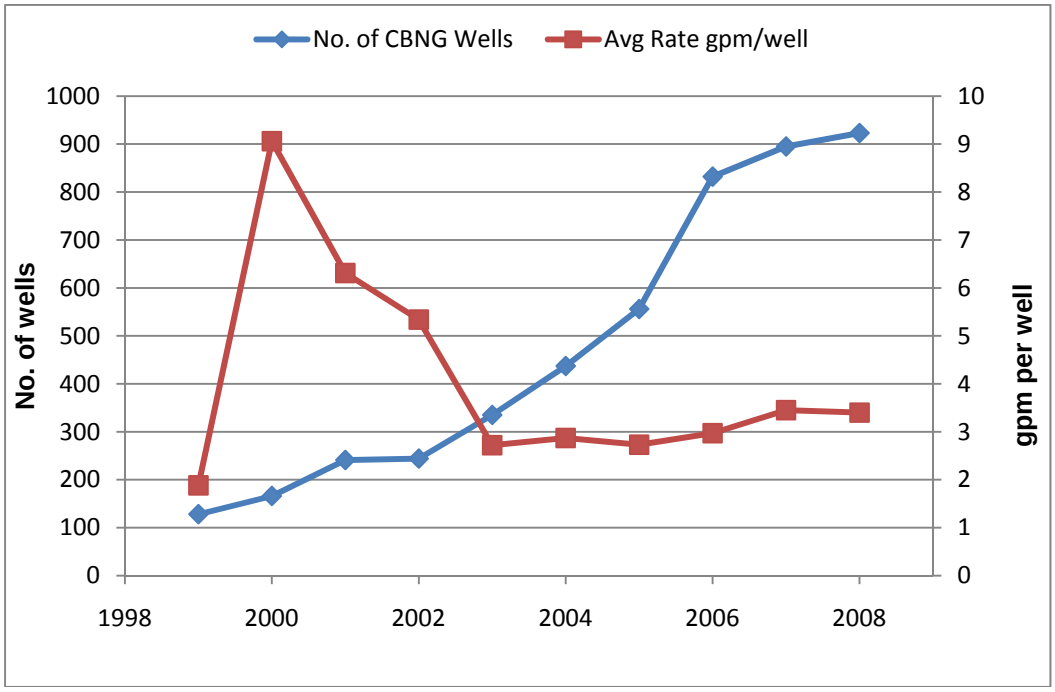

Figure 26. Number of CBNG Wells and Average Rate of Water Production Per Well for the Tongue River Basin, Montana
Source: MBOGC, 2009.

Table 6. Number of CBNG Wells and Water Produced from Montana Portion of the Tongue River Basin

Year	Well Count	Volume	Volume	Avg Rate	Combined Flow Rate
		Bbls	Ac-ft	gpm/well	cfs
1999	128	3,015,039	389	1.88	0.54
2000	166	18,815,397	2,425	9.1	3.4
2001	241	19,017,873	2,451	6.3	3.4
2002	244	16,298,716	2,101	5.3	2.9
2003	335	11,410,961	1,471	2.7	2.0
2004	437	15,679,211	2,021	2.9	2.8
2005	556	18,980,523	2,447	2.7	3.4
2006	832	30,931,774	3,987	3.0	5.5
2007	895	38,654,241	4,983	3.5	6.9
2008	923	39,374,106	5,075	3.4	7.0
Totals		209,162,802	26,961		
Weighted Averages				3.56	3.72

Key: bbl= 42 gallon barrel; ac-ft= acre feet; gpm= gallons per minute; cfs= cubic feet per second. Weighted average rate weighted by well count. Weighted combined flow rate is over 10 years.
Source: (MBOGC, 2009)

Initial water production from CBNG wells in the Wyoming portion of the Tongue River basin began in May 1999, with initial gas production beginning in February 2000. The historic trends in numbers of CBNG well permits and well completions are shown in Figure 27. As of May 2009, approximately 2,435 CBNG wells were in production in the Tongue River basin area of Wyoming (WOGCC, 2009). Trends in numbers of producing CBNG wells and average water rate per well are shown in Figure 28. The WOGCC reports that of the 7,991 CBNG well permits issued over all years, 3,129 wells had been completed and 4,444 had expired, indicating that these wells had not been drilled. The remaining wells had been plugged and abandoned, in a preliminary stage or dormant. The historical trends in production of natural gas, water and well counts for CBNG production in the Wyoming portion of the Tongue River basin are shown in Table 7. The WOGCC on-line database indicates that for 2008, of the 2,463 CBNG wells in the Tongue River basin 785 were shut-in. This is about 32 percent of the total well count. Total 2008 CBNG production in the Wyoming portion of the Tongue River basin was 62,479,384 MCF of gas and 101,759,607 barrels of water from 2,435 active wells (WOGCC, 2009).

The combined history of CBNG well completions in the Tongue River basin is summarized in Figure 29.

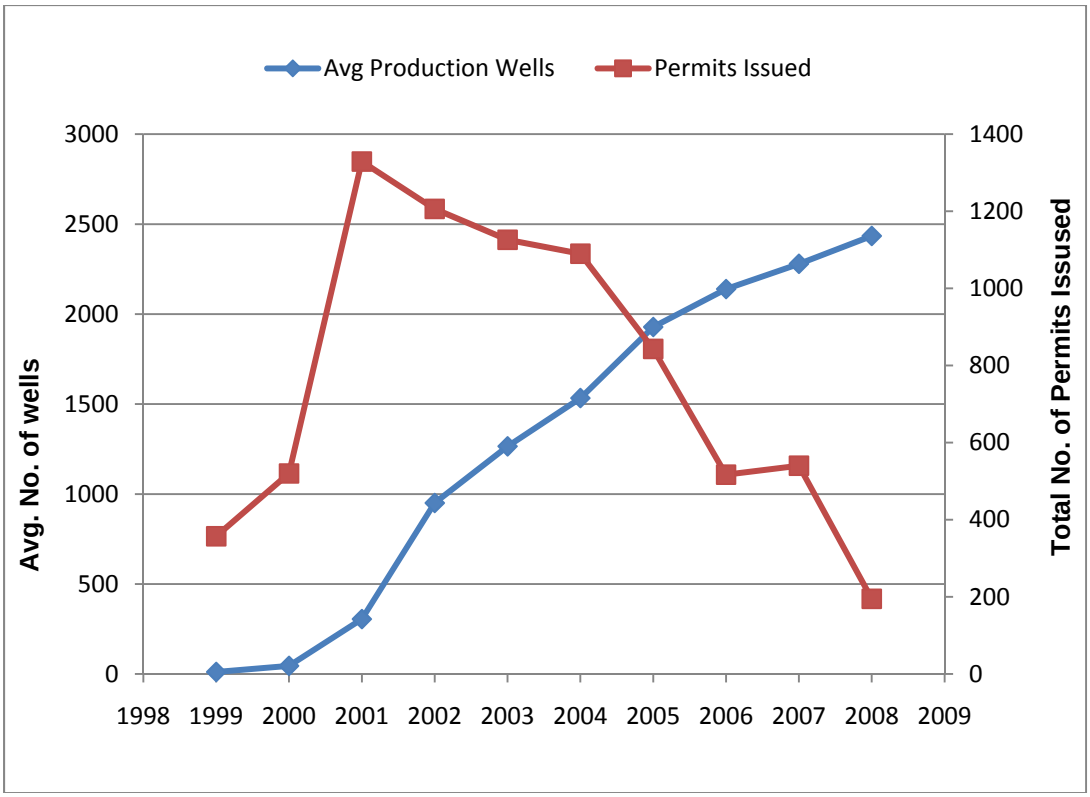

Figure 27. Numbers of CBNG Well Permits Issued and Well Completions in Wyoming (average number of producing wells in each year)
Source: WOGCC, 2009.

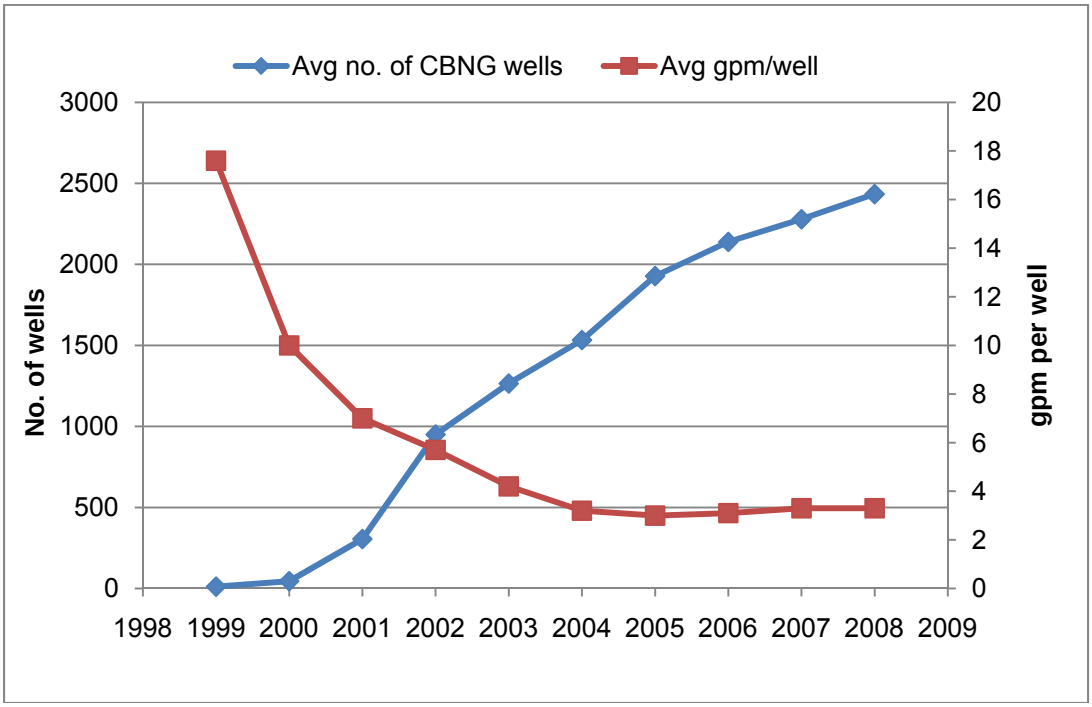

Figure 28. Number of CBNG Wells and Average Rate of Water Production Per Well for the CBNG Wells in Tongue River Basin of Wyoming

Source: WOGCC, 2009

Table 7. Number of Wells and Water Produced from Wyoming Portion of the Tongue River Basin

Year	Well Count	Volume	Volume	Avg Rate	Combined Flow Rate
		Bbls	Ac-ft	gpm/well	cfs
1999	11	2,489,402	321	17.6	0.4
2000	45	5,654,563	729	10.0	1.0
2001	305	26,590,602	3,428	7.0	4.7
2002	950	67,312,635	8,677	5.7	12.0
2003	1,265	66,526,676	8,575	4.2	11.8
2004	1,533	62,094,845	8,004	3.2	11.1
2005	1,928	73,063,264	9,418	3.0	13.0
2006	2,139	83,984,547	10,826	3.1	15.0
2007	2,279	93,212,258	12,015	3.3	16.6
2008	2,435	101,759,607	13,117	3.3	18.1
Totals		582,688,399	75,110		
Weighted Averages				3.61	10.4

Key: bbl= 42 gallon barrel; ac-ft= acre feet; gpm= gallons per minute; cfs= cubic feet per second. Weighted average rate weighted by well count. Weighted combined flow rate is over 10 years.

Source: WOGCC, 2009.

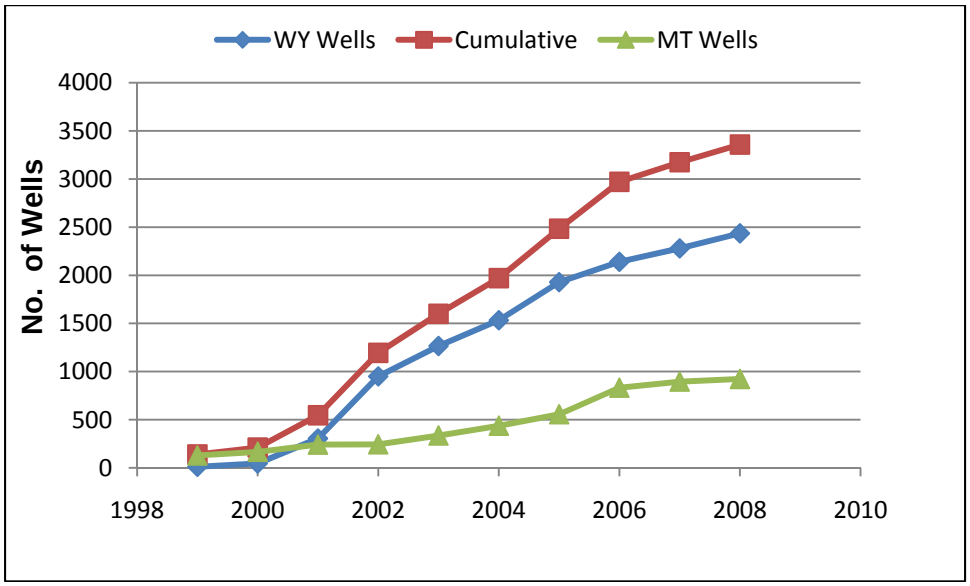

Figure 29. Combined History of CBNG Well Completions in the Tongue River Basin

Sources: MBOGC, 2009; WOGCC, 2009

4.0 Discharges to the Tongue River

Growing public awareness and concern for controlling water pollution led to enactment of the Federal Water Pollution Control Act Amendments of 1972. As amended in 1977, this law became commonly known as the Clean Water Act. The Act established the basic structure for regulating discharges of pollutants into the waters of the United States (USEPA, 2007). It gave EPA the authority to implement pollution control programs such as setting wastewater standards for industry. The Clean Water Act requires that water quality standards be set for all contaminants in surface waters. The Act made it unlawful for any person to discharge any pollutant from a point source into navigable waters, unless a permit was obtained under its provisions. Permits are issued under the "National Pollution Discharge Elimination System" (NPDES). The EPA has delegated the administration of the Clean Water Act of the Tongue River to the States of Montana and Wyoming, both which do so through their respective Departments of Environmental Quality (DEQ).

NPDES permits are only issued for "point sources" of pollution; that is, those with specific outfalls. According to MDEQ, as of 2006 point source pollution in Montana was a source of impairment for 10 percent of Montana's streams and 20 percent of its lakes (MDEQ, 2007), with the remainder of impairments due to non-point sources of pollution. The Non-point Source Pollution Program is designed to encourage voluntary pollution control activities, provide guidance, and match local funding.

4.1 Point Sources

In Montana, permitting is administered by the MDEQ under the Montana Pollutant Discharge Elimination System (MPDES). The average discharge rate per month and total quantity of discharge were obtained from Discharge Monitoring Reports (DMRs) on file at the Montana Department of Environmental Quality. These reports provide average and maximum discharge rates for each month. The average annual rates given in Table 8 are based on the average of all months reported. Available records indicate that 13 MPDES permits exist for direct discharges into the Tongue River, but five actually had reported discharge in 2008. Permits may have multiple outfalls, or discharge locations. Locations of outfalls from available records are mapped in Figure 30.

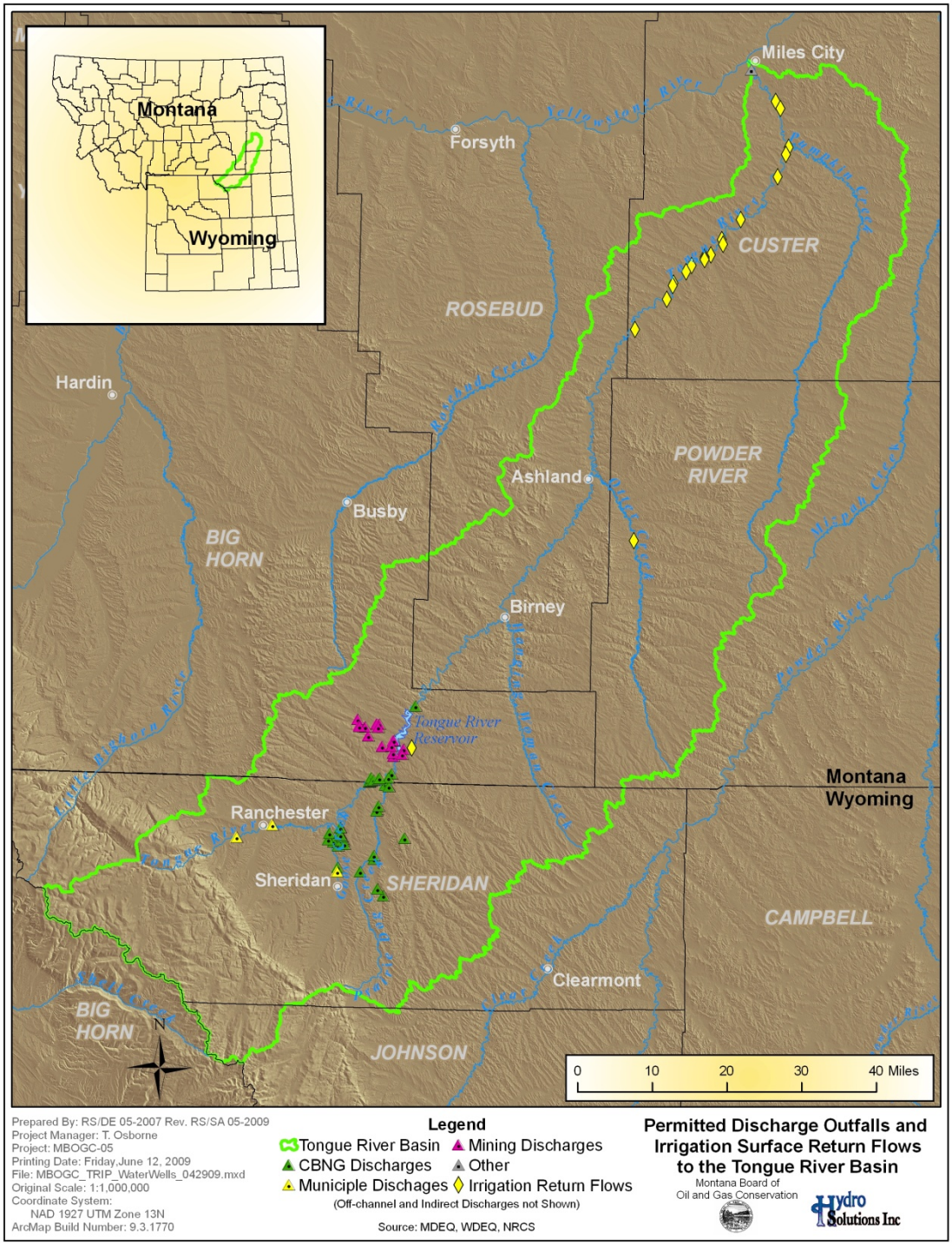

Figure 30. Permitted Discharge Outfalls and Irrigation Surface Return Flows to the Tongue River Basin

Table 8. Summary of MPDES Permits in the Tongue River Basin of Montana

MPDES# No. of Outfalls	Permit Holder	Facility Description	Receiving Water	Permit Status Description	Average 2008 Rate of Discharge cfs
MT0028827 Outfalls: 1	MT DFWP - MILES CITY HATCHERY	Fish Hatchery Effluent	Tongue River	Terminated	2.00
MT0030457 Outfalls: 15	FIDELITY EXPLORATION AND PRODUCTION CO	Coal Bed Methane Produced Water	Tongue River	Effective	3.04
MT0030660 Outfalls: 1	PINNACLE GAS RESOURCES INC	Coal Bed Methane Produced Water (treated)	Tongue River	Effective	No discharge
MT0030724 Outfalls: 1	FIDELITY EXPLORATION AND PRODUCTION CO	Coal Bed Methane Produced Water (treated)	Tongue River	Effective	2.64
MT0000892 Outfalls: 4	DECKER COAL CO (WEST MINE)	Surface Coal Mine Effluent	Tongue River Reservoir	Effective	5.42
MT0024210 Outfalls: 1	DECKER COAL CO (EAST MINE)	Surface Coal Mine Effluent	Tongue River Reservoir	Effective	1.98
MTB001009 Outfalls: 1	MT FISH WILDLIFE AND PARKS		Tongue River Reservoir	Effective	No Discharge
MTB002909 Outfalls: 1	DECKER COAL COMPANY		Tongue River	Effective	No Discharge
MTB005008 Outfalls: 1	DIAMOND CROSS RANCH LLC		Tongue River	Admin Continued	No Discharge
MTG010239 Outfalls: 1	BICE RANCH LLC	CAFO	Tongue River	Pending	No Discharge
MTR101306 Outfalls: 1	PINNACLE GAS RESOURCES	SW construction	Tongue River	Effective	No Discharge
MTR101946 Outfalls: 2	DECKER COAL CO	SW construction	Tongue River	Effective	No Discharge
MTR102830 Outfalls: 1	MT FISH WILDLIFE AND PARKS	SW construction	Tongue River Reservoir	Effective	No Discharge

cfs- cubic feet per second.
Source: Personal Communcation email, Lisa Tucker, MDEQ on 04/23/09.

Two CBNG MPDES permits were active in 2008. Fidelity's permit MT0030457, originally issued in 1999, was renewed with modifications on April 1, 2006. It allows for the discharge between 1,600 and 2,500 gpm of untreated water year round with the rate varying by season. The actual average discharge rate under this permit in 2008 was approximately 1,366 gpm for a total volume of 719.8 million gallons (2,209 acre-feet) (MDEQ, 2008). This is nearly identical to that discharged in 2007. Fidelity's permit MT0030724 for treated discharge into the Tongue River also became active April 1,

2006. This permit allows for the discharge of 1,700 gpm year round; however, the quality of the water allowed to be discharged varies by season. The actual average discharge rate in 2008 under this permit was 1,187 gpm for a total volume of 625.5 million gallons (1,920 acre-feet). This is 8.2 percent greater than the amount discharged under this permit in 2007. The treatment system, an ion exchange process known as the Higgins Loop produced by EMIT Technologies, reduces the TDS and sodium content.

Pinnacle Gas Resources permit MT0030660 allows for the discharge of up to 1,122 gpm of treated water year round. There was no discharge under this permit in 2008.

Effluent limits associated with the three CBNG permits restrict discharges as to Electrical Conductivity (EC, synonymous with SC or specific conductance) and SAR based on the season, with allowable instantaneous EC from 1000 to 1500 µS/cm and SAR from 3 to 5. The more restrictive limits are in force during the spring and summer irrigation seasons.

The East and West Decker mines combined to discharge a total average rate of 7.4 cfs to the Tongue River Reservoir. The State of Montana fish hatchery near Miles City discharged an average of 2 cfs, with months of no discharge and others with greater than average.

In Wyoming, permitting is administered by the Wyoming Department of Environmental Quality (WDEQ) under the Wyoming Pollutant Discharge Elimination System (WYPDES). Available records did not allow a categorical breakdown of all WYPDES permits in the Tongue River basin of Wyoming. WDEQ records show there are hundreds of permits; however, many are not active, or not in use. Some of the principal discharge categories include:

- Three municipal wastewater systems with WYPDES discharge permits; Sheridan, Ranchester, and Dayton;
- Three non-community or transient wastewater treatment systems
- Two confined animal feeding operation permits;
- Over one hundred storm water discharge permits;
- One fish hatchery; and
- Hundreds of CBNG-related permits.

Of the CBNG permits, many are not active or in use.

The WDEQ issues WYPDES permits for off-channel impoundments used for CBNG produced water storage, although they do not discharge directly to surface waters. As of March 2009, the WDEQ reported there were 1,999 CBNG impoundments of record throughout the Powder River basin in Wyoming (WDEQ Impoundment Monitoring database, First quarter 2009). WDEQ permitted impoundments numbered 284, with compliance monitoring data submitted, indicating actual use, for 155. A total of 1,472 impoundments were exempt from monitoring due to no groundwater being encountered in the upper 150 to 200 feet, being placed over Class IV groundwater or for other exemptions.

Specific WYPDES permit information was obtained from the WDEQ on the four CBNG direct discharges to the Tongue River, and other permitted direct discharges, as summarized in Table 9.

Table 9. Summary of WYPDES Direct Discharge Permits to the Tongue River in Wyoming

WYPDES# No. of Outfalls	Permit Holder	Facility Description	Receiving Water	Permit Status Description	Average 2008 Rate of Discharge cfs
WY0038571 Outfalls: 1	JM Huber Corporation	Fed. 8-21 & 8-22 Mydland CBM Wells	Tongue River(2) & Beatty Gulch(4)	Permit deactivated as of 02/29/2004, facility never discharged	No Discharge
WY0050571 Outfalls: 1	JM Huber Corporation	Pod B CBM Water Treatment Facility	Tongue River (2AB) via Prairie Dog Crk (2AB) via direct discharge from treatment unit	Did not discharge within first 6 months of 2008	No Discharge
WY0054364 Outfalls: 2	Pennaco Energy, Inc	Adams Ranch CBM Treatment Facility	Tongue River (2AB) via Prairie Dog Crk (2AB) via Wildcat Crk (3B) via direct discharge from treatment facility	Facility did not discharge in 2008	No Discharge
WY0054364 Outfalls: 1	Pennaco Energy, Inc	Adams Ranch CBM Treatment Facility	Tongue River (2AB) via Prairie Dog Crk (2AB) via Wildcat Crk (3B) via direct discharge from treatment facility	Facility did not discharge in 2008	No Discharge
WY0020010 Outfalls: 1	City of Sheridan	Municipal Wastewater Treatment	Goose Creek (2AB), Tongue River Basin	Active	5.103
WY0020931 Outfalls: 3	US Forest Service - Big Horn	Federal Government	North Fork Tongue River (1) via an unnamed ditch (3B), Tongue River Basin	Active	0.061
WY0022161 Outfalls: 3	Town of Ranchester	Municipal Wastewater Treatment	Tongue River (Class 2 water)	Active	0.417
WY0026441 Outfalls: 1	Sheridan Big Horn Mountain KOA	Commercial Wastewater Treatment	Goose Creek (2AB), Tongue River Basin	Active	0.001
WY0020435 Outfalls: 1	Town of Dayton	Municipal Wastewater Treatment	Tongue River (2AB-), Tongue River Basin	Active	0.189

WYPDES# No. of Outfalls	Permit Holder	Facility Description	Receiving Water	Permit Status Description	Average 2008 Rate of Discharge cfs
WY0036251 Outfalls: 1	Powder Horn Ranch, LLC	Commercial Wastewater Treatment	Little Goose Creek (2AB) via Powder Horn Pond #1 (4A), Tongue River Basin	Active	0.082
WY0030481 Outfalls: 1	ConocoPhillips Company	Industrial	Meade Creek (2AB), Tongue River Basin	Active	0.003

Sources: Personal Communications, K. Shreve, WDEQ, 5/1/09; J. Eisenhauer, WDEQ, 8/31/09.

The WDEQ clarified (pers. com., K. Shreve, 2009) that two discharge permits for Fidelity Exploration & Production Company listed in previous versions of Table 9 (HydroSolutions, 2008) were not direct discharges to the Tongue River. The J.M. Huber and Pennaco permits are authorized for 1.33 and 2.27 cfs, respectively, but actually had zero discharge from 2005 through 2008. (pers. com. J. Thomas, WDEQ, 2008, and J. Eisenhaur, 2009). There are additional WYPDES permits for discharge of untreated CBNG water to on-channel impoundments in the Tongue River basin. However, these permits do not allow discharge from the impoundments to the receiving streams except under specified storm events which have been shown to dilute any released CBNG water sufficiently to meet Montana's irrigation water quality standards for the Tongue River.

The monthly totals of all CBNG direct discharges to the Tongue River and tributaries are compared to the monthly flow of the Tongue River below the Tongue River Dam in Figure 31. Both untreated CBNG discharge and treated plus untreated discharges are shown. It can be seen that total CBNG discharges comprised a maximum of 3.7 percent of the river flow in February 2008, and untreated discharge reached a maximum of 2.4 percent in December 2008. During the April-September irrigation season, total CBNG discharges comprised from 0.2 to 1.6 percent of river flow, with untreated discharge ranging from 0.1 to 0.8 percent.

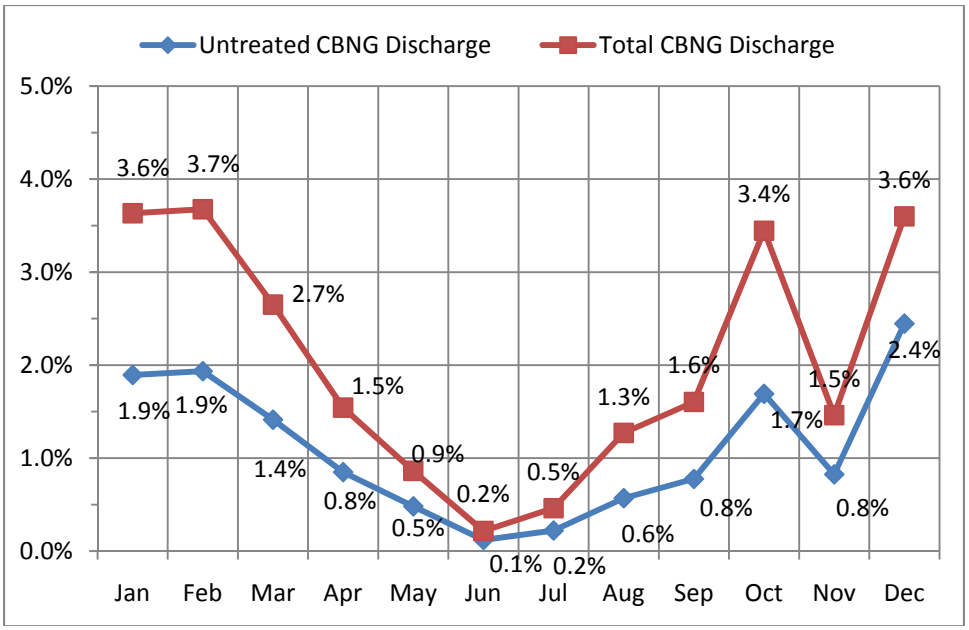

Figure 31. 2008 CBNG Direct Discharges to the Tongue River in Montana and Wyoming as a Percent of Flow in the Tongue River below Tongue River Dam

(Sources: Personal Communcation email, Lisa Tucker, MDEQ on 04/23/09, pers. com., K. Shreve, 2009and USGS, 2009)

The average rate of direct point discharges to the Tongue River in Montana and Wyoming for 2008 can be summarized as follows:

- Total CBNG discharges: 5.69 cfs; (3.04 cfs untreated and 2.64 cfs treated)
- Total of coal mine discharges: 7.4 cfs
- Total of municipal and domestic wastewater: 5.84 cfs
- Fish Hatchery: 2.0 cfs
- Total Other Industrial: 0.003 cfs

4.2 Non-Point Sources

Non-point sources of contaminants are not covered by the NPDES permit system. Potentially significant human and natural causes of non-point sources of contaminants to the Tongue River basin include the following:

- Irrigation return flows: surface and subsurface;
- Sediment, bacteria, nutrients and salinity from agricultural sources;
- Septic system effluent discharge to groundwater in communication with the river;
- Municipal and industrial storm water runoff;
- Natural sources including runoff from wild lands and groundwater discharge;
- Evaporation from the river and Tongue River Reservoir; and
- Salinity concentration via transpiration from riparian vegetation.

Non-point sources have traditionally been addressed, to a limited extent, by a combination of federal, state and local agencies, including the EPA, NRCS, DEQs,

Montana Department of Natural Resources and Conservation, and county Conservation Districts. In September 2000, the Sheridan County Conservation District (SCCD) in cooperation with the NRCS and the Tongue River Watershed Steering Committee (TRWSC) worked with local landowners to publish a local watershed plan for the Upper Tongue River Watershed (SCCD, 2007). After 5 years, all of the action items in the plan were either completed or otherwise addressed by the TRWSC; however, interim monitoring continued to identify unacceptable bacteria levels and excessive sediment in streams. As a result, the TRWSC decided to update the plan and began that process in July 2005. A revised version of the watershed plan was completed in March 2007 (SCCD, 2007).

Non-point source control efforts in the Wyoming portion of the basin undertaken by the SCCD (SCCD, 2005) include:

- Completion of three animal feeding operation improvement projects and three projects in progress;
- Three stream bank/riparian improvement projects with one under construction;
- Two septic system projects with three in progress;
- Educational programs on animal feeding operation;
- Pathogen workshops;
- Development and maintenance of a progress register map;
- A series of educational brochures published and distributed to 1300 residents in the Upper Tongue River Watershed; and
- A video describing a septic system replacement and design considerations.

Other non-point source improvement projects were reported for the Goose Creek watershed (SCCD, 2005). The SCCD report acknowledged that the voluntary nature of the program makes it difficult to determine specifically what types of improvement projects and/or assistance will be requested by landowners.

In Montana, Conservation Districts in Big Horn, Rosebud and Custer Counties undertake educational efforts and sponsor grants to support voluntary reductions of nonpoint source contaminants. In 2004, the Rosebud County Conservation District formally adopted Land Use Ordinance #1 which is intended to regulate management of CBNG produced water and to require additional bonding of CBNG water management facilities (Rosebud CD, 2007).

In its Tongue River TMDL Status Report (MDEQ, 2003), the MDEQ acknowledged that it is difficult to determine the effects of all agricultural sources on the Tongue River because of the large watershed size and multiple contributions from different sources. Agricultural land and rangelands comprise approximately 72 percent of the Tongue River basin (NRCS, 2002). Since irrigation is the largest water use in the Tongue River basin, irrigation return flows are a potential source of contaminants, however little data are available (MDEQ, 2003). The NRCS Phase 1 Rapid Aerial Assessment identified 20 visible irrigation return flows (Figure 30) along the Tongue River in Montana, exclusive of Rosebud County. Most irrigation return flows occur via the subsurface as part of groundwater discharge to streams. No comprehensive inventory or estimate of surface or subsurface irrigation return flows is known to exist in either Montana or Wyoming.

The 2008 Montana "303 (d) List" (web site: http://cwaic.mt.gov/Default.aspx) of impaired water bodies indicates that three of the five segments of the Tongue River, and the Tongue River Reservoir in Montana are rated as "Not Supporting" of some beneficial water uses and will require a TMDL. The two segments not needing TMDLs are from the Tongue River Dam to Prairie Dog Creek (in Montana) and from Prairie Dog Creek to Hanging Woman Creek. The most frequently listed "Probably Sources" of impairment are listed as:

- Impacts from hydrostructure flow regulation/modification
- Irrigated crop production
- Streambank modifications/destabilization, and
- Natural sources.

Most hydrostructures are diversion structures for irrigation. The MDEQ indicates that TMDLs for the Tongue River basin are pending completion of additional studies.

The 2008 Wyoming "303 (d) List" (http://deq.state.wy.us/wqd/watershed/Downloads /305b/2008/2008%20Integrated%20Report.pdf) indicates that the Tongue River below Goose Creek, much of Big and Little Goose Creeks, all of Prairie Dog Creek, and 14 smaller tributaries are impaired for beneficial uses. The most common contaminants were fecal coliform, elevated stream temperatures, storm water discharges and riparian degradation.

Water quality improvement projects in the Tongue River and Goose Creek basins have been implemented by the SSCD including animal feeding operation projects, riparian buffer development, streambank stabilization and grazing management.

Natural processes can increase or decrease salinity, sodium and other contaminants, but the water quality effect of these processes in the Tongue River basin is not well understood. Transpiration of groundwater by riparian vegetation along the Powder River, for example, has been shown through USGS studies to cause an average decrease in flow of approximately 0.3 cfs per river mile from Arvada, Wyoming to Locate, Montana (Lenfest, 1987; Ringen and Daddow, 1990). Evaporation from the Tongue River, and particularly the Tongue River Reservoir, also reduces the volume of water and increases the salinity of the water released. The evaporative loss from the Tongue River Reservoir is equivalent to an average of 9.7 cfs on an annual basis. This is about 2.2 percent of the median discharge of the Tongue River at the State Line gauging station (448 cfs). Since water evaporates leaving the salts, the salinity theoretically increases by an equivalent percent, or about 14 µS/cm, based on a median SC of 640 µS/cm (HydroSolutions, 2008). Such withdrawals from the river remove water, leaving the salts and increasing the salinity of the surface water-groundwater system.

In summary, during 2008, there were a total of three active CBNG point source discharge permits in Montana and Wyoming, two discharging treated water and one untreated water. The known discharges averaged 5.69 cfs, compared to 578 cfs at the Tongue River Dam station. Total known CBNG discharge to the Tongue River in 2008 amounted to from 0.3 to 3.7 percent of the flow released from the Tongue River dam, with untreated discharge ranging from 0.1 to 2.4 percent. Point source discharges from other municipal, mining and industrial facilities in Montana and Wyoming totaled to an

annual average of 15.2 cfs. Non-point source discharges to the Tongue River from urban sources in the Sheridan area, along with agricultural and natural sources in both states may be significant, but are not currently quantified.

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Errata- 2008 Tongue River Hydrology Report

Figures 1, 22, 23, 24, and 30. The line running through Birney is defined as Sub-basin boundary

Figure 2. Decker 1E is not depicted in the data

Table 1. Calculation of median for Miles City is based on years 1961-2008 even though earlier years are listed in the table.

Table 2. Miles City column, year 1990, 341 is a loss and should therefore be shaded. Years of gain should read 14 for Miles city and Years of Loss should read 33. The average for Miles City remains unchanged.

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