WYOMING STATE GEOLOGICAL SURVEY
Ronald C. Surdam, State Geologist

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1993 – 2006 Coalbed Natural Gas (CBNG) Regional Groundwater Monitoring Report: Powder River Basin, Wyoming

By

Keith E. Clarey, P.G.
Wyoming Water Development Office
Cheyenne, Wyoming

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Abstract
Coalbed natural gas (CBNG) production is an economically viable industry in the Wyoming portion of the Powder River Basin (PRB). CBNG wells are predominantly completed into the coal deposits of the Tongue River Member of the Paleocene Fort Union Formation. CBNG development in the Wyoming PRB is concentrated primarily in Campbell, Johnson, and Sheridan counties.

This report presents and interprets the monitoring well data from the Bureau of Land Management's (BLM's) deep monitoring well network in the Wyoming PRB. These data were collected from a total of 111 monitoring wells from 1993 through 2006. The BLM deep monitoring well network was designed and constructed to evaluate potential leakage between the CBNG water-producing coal deposits and adjacent sandstone beds, and to measure the drawdown in the producing zones. Nests of wells were completed into different water-bearing zones at some locations to evaluate the vertical variation in groundwater elevations.

The extraction of CBNG-produced groundwater from PRB coal deposits has caused widespread public concern about declines in groundwater availability. Between 1987 and 2006, CBNG production in the Wyoming PRB has withdrawn a cumulative total of 4.1 billion barrels (174 billion gallons) of groundwater at total pumping rates up to 77.3 million gallons per day (mgd). Based on the BLM deep monitoring well data, water levels in some of the monitored CBNG wells have declined up to 625 feet within the CBNG production areas of the Wyoming PRB.

Groundwater models and drawdown predictions have been used to forecast the potential hydrogeological impacts of CBNG production in Wyoming. The BLM deep monitoring well data can be used to evaluate impact analysis (Applied Hydrology Associates, Inc., and Greystone Environmental Consultants, Inc. (AHA and GEC), 2002) and provide calibration data for future analysis of CBNG drawdown impacts.

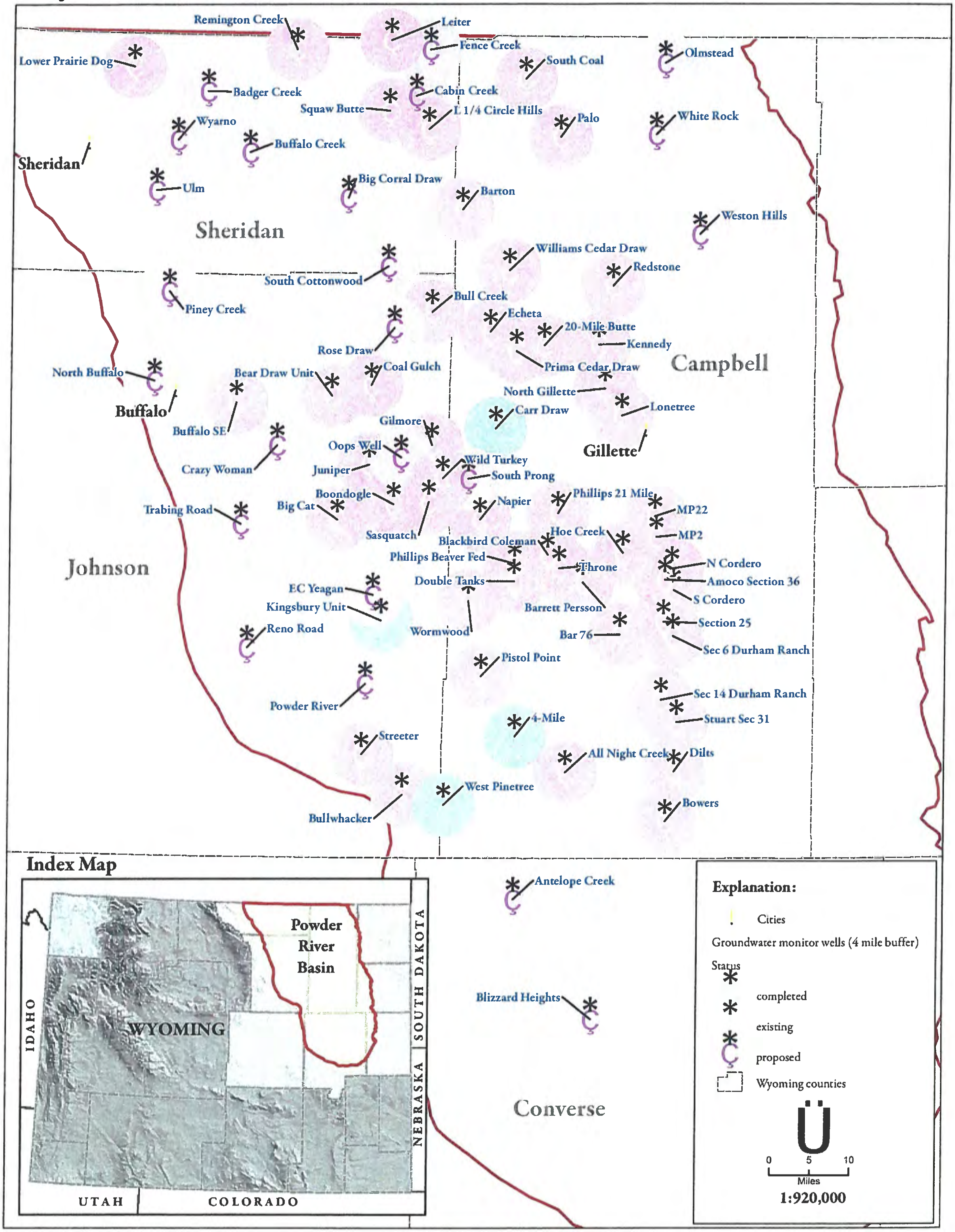
CBNG impacts on groundwater levels in the upper member of the Fort Union Formation are slightly less than the drawdowns that were modeled and predicted for the year 2006 (AHA and GEC, 2002). Also, CBNG impacts on such drawdown in water levels have been measured in some of the overlying sandstone beds of the Wasatch Formation.

Chapter 1
Since the late 1990s, the extensive CBNG development in the PRB has caused public concern about groundwater resources in Wyoming and Montana. To help address this concern, the BLM entered into a cooperative agreement with the Wyoming State Geological Survey (WSGS) to compile and evaluate data collected by the BLM with the overall purpose of assessing impacts of CBNG development on groundwater resources in the PRB of northeastern Wyoming.

This portion of the work is part of an ongoing project in a cooperative effort between various agencies in Montana and Wyoming to conduct groundwater monitoring on a basin-wide scale. The WSGS has compiled and began analysis of the BLM monitoring well data collected from 1993 to 2006, including information on well construction and completion, water levels, and wellhead gas pressure. This WSGS report discusses the drawdown effects of pumping groundwater from various coal zones and compares these effects predicted by previous modeling efforts.

Since 1993, water-level and wellhead gas pressure data have been collected by the BLM from a deep monitoring well network of 111 wells located in the PRB of northeastern Wyoming (**Figure 1**). A summary table of these monitoring well data is included as **Table A-1** in **Appendix A**. These monitoring data are available online at the Wyoming Energy Resources Clearinghouse website: http://www.cbmclearinghouse.info. Additional monitoring wells are located in the adjacent area of the northern PRB in southeastern Montana.

Figure 1


Remington Creek
Leiter
Fence Creek
Lower Prairie Dog
South Coal
Olmstead
Badger Creek
Cabin Creek
Squaw Butte
1 1/4 Circle Hills
Wyarno
Palo
White Rock
Buffalo Creek
Sheridan
Ulm
Big Corral Draw
Barton
Weston Hills
Sheridan
Williams Cedar Draw
Redstone
South Cottonwood
Piney Creek
Bull Creek
Echeta
20-Mile Butte
Kennedy
Rose Draw
Prima Cedar Draw
Campbell
North Buffalo
Bear Draw Unit
Coal Gulch
North Gillette
Buffalo
Lonetree
Carr Draw
Buffalo SE
Gilmore
Gillette
Oops Well
Crazy Woman
Juniper
Wild Turkey
South Prong
Boondoggle
Phillips 21 Mile
Trabing Road
Big Cat
Napier
MP22
Sasquatch
MP2
Blackbird Coleman
Hoe Creek
Johnson
Phillips Beaver Fed
N Cordero
Throne
Double Tanks
Amoco Section 36
EC Yeagan
S Cordero
Kingsbury Unit
Barrett Persson
Section 25
Wormwood
Reno Road
Bar 76
Sec 6 Durham Ranch
Pistol Point
Powder River
Sec 14 Durham Ranch
Stuart Sec 31
4-Mile
Streeter
All Night Creek
Dilts
West Pinetree
Bullwhacker
Bowers
Index Map
Antelope Creek
Powder River Basin
WYOMING
IDAHO
SOUTH DAKOTA
NEBRASKA
UTAH
COLORADO
Blizzard Heights
Converse
Explanation:
Cities
Groundwater monitor wells (4 mile buffer)
Status
completed
existing
proposed
Wyoming counties
0
5
10
Miles
1:920,000

This report summarizes the Wyoming portion of the database (**Figure 1**). The hydrographs and wellhead gas pressure charts for the monitored wells are included in **Appendix A**. Some additional figures and maps including potentiometric surface and drawdown maps are included in **Appendix B**. An evaluation of the collected data for each well or well nest site is discussed in numerical-alphabetical order in **Appendix C**.

The adjacent monitoring well network in the Montana portion of the PRB is being monitored by the Montana Bureau of Mines and Geology (MBMG) for the BLM. The Montana monitoring well network reports include Wheaton and Donato (2004) for the year 2003, Wheaton et al. (2005) for the year 2004, Wheaton et al. (2006) for the year 2005, Wheaton et al. (2007) for the year 2006, and Wheaton et al. (2008) for the year 2007. These Montana PRB monitoring reports are available online at: http://www.blm.gov/mt/st/en/fo/miles_city_field_office/cbng/monitoring.html. All of the data used in the reports is currently available online at: http://mbmggwic.mtech.edu.

Drawdown maps were prepared for the coal deposits in the Fort Union Formation (**Appendix B**). These maps were compared to the predicted drawdowns, and were used to analyze the impacts of CBNG-related groundwater pumping. As shown in **Appendix B**, the 2006 drawdown maps (**B-2**, **B-3**, **B-4**, and **B-5**) were prepared for four combined coal zones based on their stratigraphic positions within the basin.

The cumulative total groundwater production for the CBNG development in the Wyoming PRB was approximately 4.1 billion barrels at the end of December 2006 (Wyoming Oil and Gas Conservation Commission (WOGCC) data accessed online April 1, 2008). This figure includes all of the groundwater produced from federal, state, and fee CBNG development.

By the end of December 2006, there were a total of approximately 24,002 CBNG wells drilled and completed in the Wyoming PRB (WOGCC data accessed online April 1, 2008). This total number of wells included both producing (72 percent) and shut-in (28 percent) CBNG wells. During 2006, CBNG operations in the Wyoming PRB produced an annual total of 377 billion cubic feet (BCF)(one MCF equals one thousand cubic feet of natural gas).

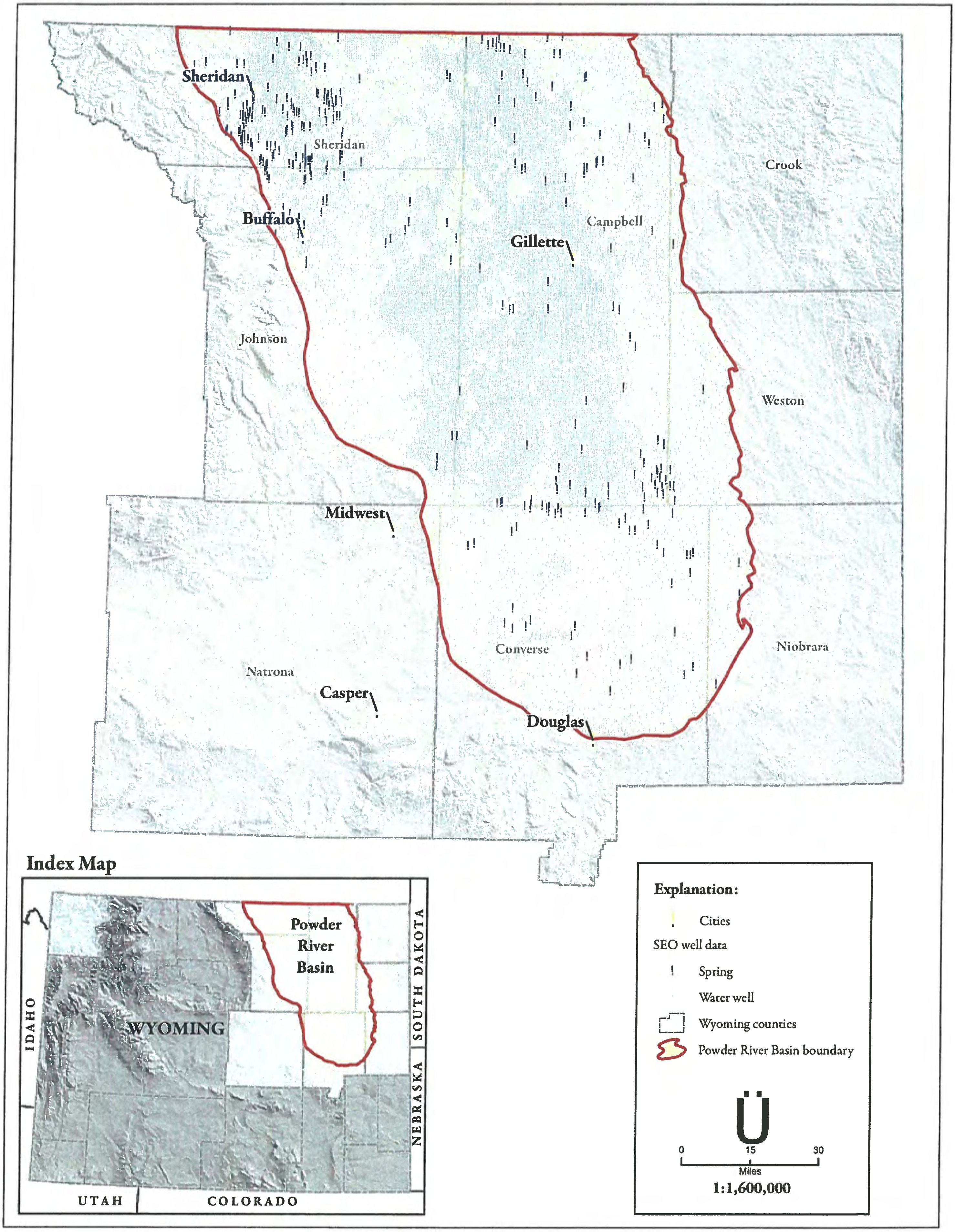
More than 55,000 groundwater permits for wells located in the Wyoming PRB (**Figure 2**) are on file with the Wyoming State Engineer's Office (WSEO) (Clarey and Stafford, 2008). This total permit number includes the basin water wells and also a small number of springs with yields of 25 gallons per minute (gpm) or less that are used for domestic and/or livestock watering. Some of the wells have more than one permit as some actions taken by the WSEO require an additional or replacement permit for the same well. Approximately one-half of these WSEO groundwater permits are issued for CBNG wells in the Wyoming PRB. The year of WSEO permit issuance for CBNG use of groundwater is shown in **Figure B-1** in **Appendix B**, showing the CBNG wells by WSEO permit priority year (1940–2008) across the Wyoming PRB.
Most of the WSEO-permitted water wells in the Wyoming PRB are less than 1,000 feet deep, yield less than 25 gpm, and produce groundwater from either sandstone or coal beds (Clarey and Stafford, 2008). Many of the boreholes of these shallower and older wells in the Wyoming PRB may interconnect multiple water-bearing zones through low-permeability confining beds (aquitards) due to the wells not having adequate annular borehole seals.

Since 1997, hydrologic impacts in the Wyoming PRB from the extensive CBNG development have been regionally confined to some of the Tongue River Member coal deposits of the Fort Union Formation and some of the lower sandstone beds in the overlying Wasatch Formation.

1.1 Purpose and scope

The purpose of this project is to compile, interpret, evaluate, and report the data collected by the BLM deep monitoring well network located in the Wyoming PRB as of the end of 2006. This report is the first in a series, and subsequent work will

Figure 2


Sheridan
Sheridan
Buffalo
Campbell
Gillette
Crook
Johnson
Weston
Midwest
Converse
Niobrara
Natrona
Casper
Douglas
Index Map
Powder River Basin
IDAHO
WYOMING
SOUTH DAKOTA
NEBRASKA
UTAH
COLORADO
Explanation:
Cities
SEO well data
Spring
Water well
Wyoming counties
Powder River Basin boundary
0
15
30
Miles
1:1,600,000

build and expand upon the information provided here, especially with regard to tasks described below that were not completed in this first report. The BLM began collecting the monitoring well data in 1993; additional wells are added annually to the network.

The term *deep wells* refers to those wells installed for the purpose of monitoring impacts associated with the change of water levels in coal deposits during CBNG activities. Other BLM wells monitor shallow groundwater resources that may be potentially impacted by CBNG surface water discharges. Specifically, the purposes of the deep groundwater monitoring program are as follows:

Analyze and interpret data collected from the BLM deep monitoring well network and produce a report of the findings. The groundwater monitoring program was established under the CBNG Environmental Impact Statement (EIS) for the Wyodak coal (BLM, 1999) and was in direct response to issues raised as a result of CBNG development in the PRB.

Monitor and measure leakage between the producing coal zones and adjacent (overlying and underlying) sandstone units, and measure the overall areal extent of drawdown of water levels in the coal producing zones.

Compare the measured versus predicted impacts from the PRB Final EIS (FEIS) associated with water pumpage from the coal zones. This comparison will be further evaluated by the BLM and other federal and state agencies that are cooperative members of the Montana-Wyoming Inter-Agency Task Group. The predicted groundwater impact information is detailed in the December 2002 groundwater modeling technical report prepared by AHA and GEC (2002).

These BLM deep monitoring well data collected over the past 13 years were analyzed to assess the degree to which the BLM's original project objectives have been met. Some specific objectives that were initially developed for the groundwater monitoring program include the following:

Establish baseline conditions for the potentiometric surface using the BLM-collected groundwater-level data in the Wyoming PRB. These data are needed for the future calibration of groundwater modeling efforts.

Quantify drawdown in the coalbed production zone and leakage between the coalbed production zone and overlying/underlying aquifers using the BLM-collected water-level data. These data are critical to an impact analysis of groundwater resources for areas within the PRB.

Measure wellhead total natural gas pressure build-up in production zone monitoring wells using the BLM-collected total natural gas wellhead pressure data. Continuous monitoring data on total wellhead gas pressure for wells completed into production coalbed zones were and are used to estimate in-situ desorption pressure of total natural gas.

Measure potential changes in total natural gas pressure in monitoring well bores completed into production coalbed zones and overlying/underlying lithologies to detect gas migration from the coalbed production zone to adjacent formations. Following future cessation of CBNG production in the PRB, quantify groundwater-level recovery and aquifer recharge rates within the monitoring wells. Little is known about groundwater recharge mechanisms and rates in the Wyoming PRB. The rates of water-level recovery following cessation of CBNG production may be used to estimate recharge rates and the duration of potential impacts. This objective will be analyzed when water-level recharge data become available after CBNG production is complete.

Monitoring of the Wyoming PRB may be separated into two time intervals (1993–2001 and 2002–2006) for the two different BLM PRB Environmental Impact Statements (BLM, 1999 and BLM, 2003) and the December 2002 EIS-associated groundwater technical report (AHA and GEC, 2002).

CBNG activities in the Wyoming PRB from 1993 through 2001 for the CBNG Wyodak coal EIS (2002) were as follows:

As of the end of 2002, there were 14,220 CBNG wells permitted in the Wyoming PRB (WOGCC data accessed online April 1, 2008). Of this total, 10,732 wells were in production and 3,488 were shut-in (WOGCC data accessed online April 1, 2008).

A cumulative total of 532 BCF of CBNG was produced through 2001 (WOGCC data accessed online April 1, 2008).

A cumulative total of 1.2 billion barrels (51 billion gallons) of CBNG water was produced through 2001 (WOGCC data accessed online April 1, 2008).

CBNG activities in the Wyoming PRB from 2002 through 2006 for the PRB Oil and Gas EIS (2002; groundwater report) included the following:

At the end of 2006, there were 24,002 CBNG wells permitted in the Wyoming PRB (WOGCC data accessed online April 1, 2008). Of these, 17,202 were in production and 6,800 wells were shut-in (WOGCC data accessed online April 1, 2008). These data show that approximately 10,000 additional CBNG wells were permitted for construction in the Wyoming PRB from January 2003 through December 2006.

A cumulative total of 2,250 BCF of CBNG was produced through 2006 (WOGCC data accessed online April 1, 2008).

A cumulative total of 4.1 billion barrels (174 billion gallons) of CBNG water was produced through 2006 (WOGCC data accessed online April 1, 2008).

The cumulative effect of pumping groundwater from hundreds or thousands of CBNG wells completed into the same coal deposit in an area is widespread water-level declines in the wells. The resulting decline in water level and corresponding decrease in water pressure within the coal deposit allows the natural gases to desorb from the coal and flow into the CBNG production wells. This is somewhat similar to opening a full soda pop bottle with a resulting decrease in the bottle's confining pressure and the subsequent bubbling (effervescence) of the carbon dioxide degassing from the liquid.

Locally, a monitoring well located in the immediate vicinity of a pumping CBNG production well may lie within the zone of influence (cone of depression) of the pumping well. As a result, a greater drawdown in the monitoring well may be measured than would likely be measured in a monitoring well located farther from any pumping CBNG wells.

In summary, this WSGS report will provide additional public information concerning the water resources within the State of Wyoming. The BLM will benefit from a hydrogeologic analysis and reporting of their collected monitoring well data. Future annual monitoring reports are planned to combine the Wyoming and Montana portions of the PRB into one inter-agency cooperative report produced jointly for the BLM by the WSGS and Montana Bureau of Mines and Geology (MBMG).

1.2 Study area

The BLM deep well monitoring program is concentrated in Campbell, Johnson, and Sheridan counties in the northern portion of the PRB in northeastern Wyoming. As shown in **Figure 1**, the study area covers approximately 12,500 square miles (350 townships), extending from T32N to T58N and from R66W to R86W. The PRB occupies the western part of the Northern Great Plains physiographic province. This project report concerns only the Wyoming portion of the PRB.

1.2.1 Geography

The Powder River structural basin (PRB) is a 24,000-square-mile, north-south basin approximately 120 miles wide and 200 miles long. The PRB is considered a part of the Great Plains. It is bounded by the Big Horn Mountains to the west and the Black Hills to the east. The south end is closed by a combination of the relatively low-lying Casper Arch, the Laramie Range, and the Hartville Uplift. The north end is partially closed by the low Miles City Arch.

The basin is drained almost exclusively by the Powder River, which empties into the Yellowstone River in central Montana. Other drainages include the Tongue, Little Powder, Little Missouri, Belle Fourche, and Cheyenne rivers and their tributaries (**Figure B-2** in **Appendix B**). PRB surface waters flow northward and eastward into the Missouri River system.

The grasslands of the basin consist of gently rolling plains with a few mesas and buttes and are considered part of the Great Plains Province. The annual average precipitation ranges between 10 and 15 inches, humidity is low, summers are warm (70° to 90°F), and winters are cold (20° to -40°F) (Martner, 1986; Ostresh et al., 1990).

Most of the PRB is sparsely populated and rural. The largest communities in the basin are Buffalo, Gillette, Moorcroft, Newcastle, Sheridan, and Wright. Two rail lines transport large quantities of coal to out-of-state power plants. Interstate Highway 90 (I-90) crosses the basin from east to west and Interstate Highway 25 (I-25) crosses the western PRB from the south, intersecting with I-90 near Buffalo. Relatively few federal, state, and county roadways connect the cities, towns, and smaller communities. The major industries in the basin include conventional oil and gas, CBNG, surface coal mining, agriculture (ranching and irrigated farming), and recreation/tourism.

1.2.2 Structural geology

The Powder River structural basin (PRB) is a deep, north-plunging, asymmetric trough or syncline. The structural axis of the basin in Wyoming trends north-northwest to south-southeast. The axis is parallel to and several miles east of the steeply-dipping western margin of the basin, which parallels the steeply dipping, faulted eastern flank of the Bighorn Mountains (Ver Ploeg et al., 2008).

In Montana, the structural axis of the PRB has more of an overall north-south trend. The deepest part of the asymmetric basin is along the axis just east of the Bighorn Mountains. The basin is filled with more than 18,000 feet of Paleozoic, Mesozoic, and Cenozoic age sedimentary formations (Feathers et al., 1981). Geologic cross sections through the northern and central structural basin are presented in McLellan et al. (1990), and PRB coal cross sections are shown in Jones (2008).

On the eastern side of the basin, the formations cropping out at the surface dip gently from one to three degrees westward. Therefore, most of the coal deposits mined in the Wyoming PRB dip gently and are located along the eastern basin margin (Jones, 2008). These coal deposits range from approximately 50 to more than 200 feet thick and constitute the aquifers hosting CBNG development (Jones, 2008). Along the western basin margin and east of the Bighorn Mountains, the formations commonly have eastward dips from 20 to 25 degrees with some dips increasing to vertical or even locally overturned (Ver Ploeg et al., 2008)

Structurally, the PRB is mildly deformed with major reverse and thrust faults present locally along some of the flanks of the surrounding mountain uplifts. Some of these compressional faults have strike-slip components. Locally within the basin, there are normal faults with small displacements (typically less than 150 feet of vertical movement), regional lineaments associated with Precambrian basement motions, and gentle anticlinal and synclinal folds (Clarey and Stafford, 2008; Jones, 2008, Surdam et al., 2008; Ver Ploeg et al., 2008).

1.2.3 Geologic history

The geologic history of the coal-bearing formations in the PRB begins with the draining of the Cretaceous epicontinental seaway that covered large areas of Wyoming during the Early to Late Cretaceous (Ver Ploeg et al., 2008). During the Late Cretaceous, compressional plate tectonics of the Laramide Orogeny slowly elevated the land, draining away the sea and creating the fold-fault mountain uplifts and structural arches that now define the PRB. This mountain-building period continued from the Late Cretaceous to the Early Eocene (Ver Ploeg et al. 2008).

The interior of this newly-formed Laramide intermontane basin was low, flat, and swampy. During the Paleocene and Eocene Epochs, these extensive swamps accumulated the peat deposits that would later form the thick coal deposits so prevalent within the basin (Jones, 2008). The PRB was slowly filled with continental sedimentary deposits, almost to the mountain peaks, and remained relatively full until the Miocene Epoch, when regional erosion began lowering the ground surface down to its present level (Ver Ploeg et al., 2008).

1.2.4 Stratigraphy

A generalized geologic map of the Wyoming PRB and surrounding areas is shown on **Figure 3**. **Figure 4** shows a generalized stratigraphic column for the Wyoming PRB. The following text sections discuss each of the geologic units located above the Lewis/Pierre Shale, which is a thick sequence of marine shale that acts as a regional confining unit (aquitard) beneath the coal deposits (Clarey and Stafford, 2008; Ver Ploeg et al., 2008).

1.2.4.1 Fox Hills Sandstone

The Upper Cretaceous Fox Hills Sandstone is a transitional unit between the older Cretaceous epicontinental sea deposits (Lewis/Pierre marine shale) and the later continental (non-marine) deposits of the uppermost Cretaceous and Tertiary. The Fox Hills was deposited along a retreating, tidally-affected, and wave-dominated shoreline. The formation includes depositional lithofacies from lower shoreface up through tidal flat environments. As a result of minor transgressions and regressions of the retreating Cretaceous seaway, the Fox Hills Sandstone interfingers with the underlying marine Lewis Shale (western basin) and Pierre Shale (eastern basin) (Feathers et al., 1981; Clarey and Stafford, 2008; Ver Ploeg et al., 2008).

1.2.4.2 Lance Formation (Hell Creek Formation)

The Upper Cretaceous Lance Formation is a fluvial and floodplain deposit composed of brown and gray, non-marine, lenticular, fine- to medium-grained sandstone interbedded with sandy siltstone and claystone. Thin, discontinuous coal deposits are locally present. The Lance Formation ranges in thickness from 500 to 1,000 feet in the northern PRB, and from 1,600 to 3,000 feet in the southern basin (Feathers et al., 1981). The Lance Formation is the stratigraphic equivalent of the Upper Cretaceous Hell Creek Formation in Montana.

1.2.4.3 Fort Union Formation

The Paleocene Fort Union Formation consists of a thick, non-marine sequence of fine- to medium-grained lenticular sandstone interbedded with siltstone, shale and coal. The Fort Union has three members: in descending order they are the Tongue River Member, the Lebo Shale Member, and the Tullock Member. In most of the Wyoming PRB, the Fort Union is unconformably overlain by the Eocene Wasatch Formation. The Fort Union Formation lies conformably on the Upper Cretaceous Lance Formation in the east, and unconformably in the west. The Lance-Fort Union contact is the time boundary between the Cretaceous and the Tertiary Periods (designated the Cretaceous/Tertiary or K-T boundary) (Feathers et al., 1981; Ver Ploeg et al., 2008).

The Fort Union Formation ranges in thickness from 1,100 feet to more than 2,500 feet near the western axis of the basin (Feathers et al., 1981). Clinker (scoria or porcellantite) zones of the Tongue River Member along the basin margins are correlated with coal deposits deeper in the basin (Feathers et al., 1981). The depositional environments include fluvial,

Figure 3

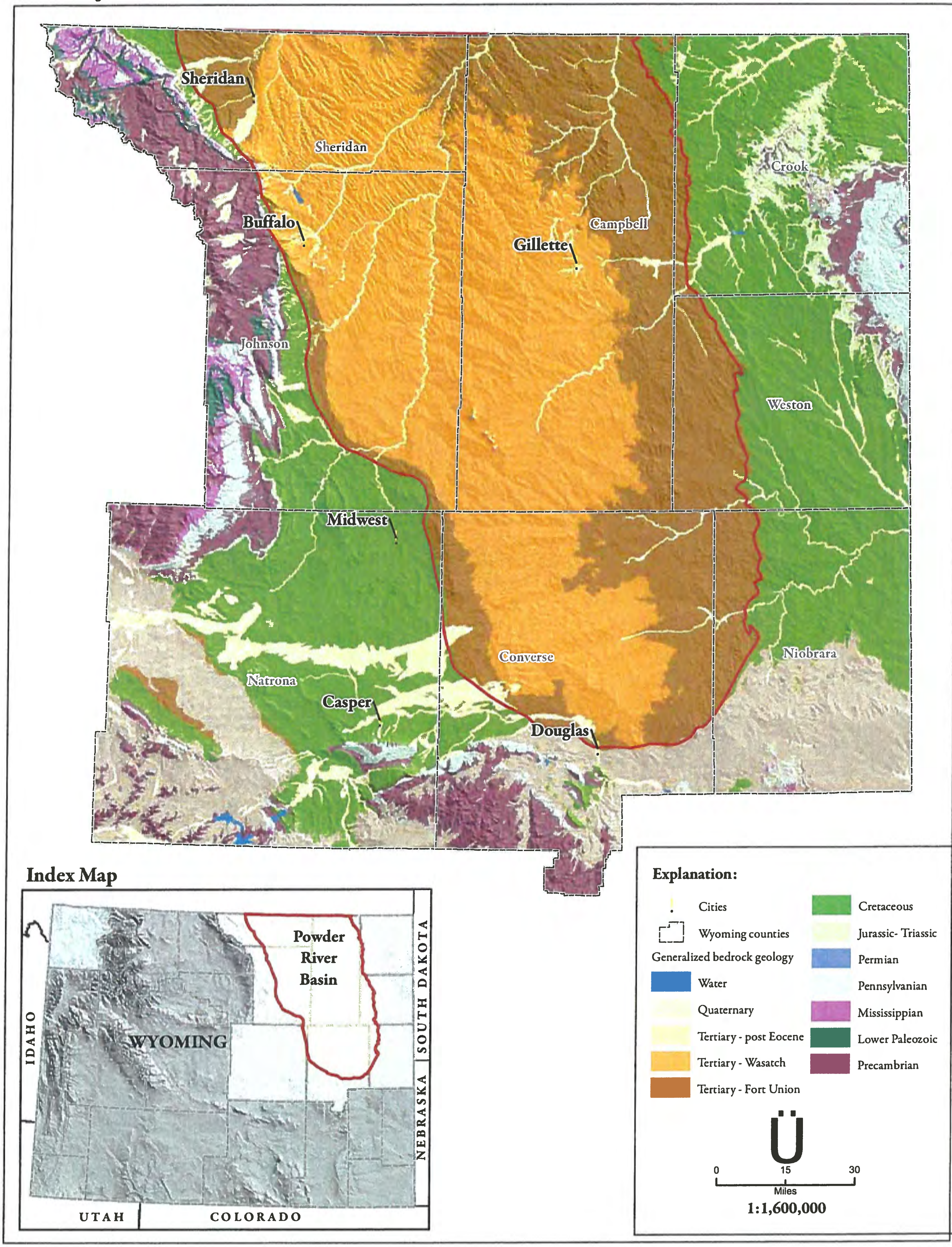

Sheridan
Sheridan
Buffalo
Campbell
Gillette
Crook
Johnson
Weston
Midwest
Converse
Niobrara
Natrona
Casper
Douglas
Index Map
Powder
River
Basin
WYOMING
IDAHO
SOUTH DAKOTA
NEBRASKA
UTAH
COLORADO
Explanation:
Cities
Wyoming counties
Generalized bedrock geology
Water
Quaternary
Tertiary - post Eocene
Tertiary - Wasatch
Tertiary - Fort Union
Cretaceous
Jurassic- Triassic
Permian
Pennsylvanian
Mississippian
Lower Paleozoic
Precambrian
0
15
30
Miles
1:1,600,000

Figure 4

System and Series		Formation		Description	Thickness (Feet)
Quaternary	Holocene and Pleistocene	Surficial deposits		Alluvium, colluvium, landslide, and eolian deposits	300
Tertiary	Pliocene				
	Miocene				
	Oligocene	White River Formation		Volcaniclastic sandstones, siltstones, and conglomerates	200
	Eocene	Wasatch Formation	Moncrief Member	Sandstone, shale, and coals	1000
			Kingsbury Conglomerate Member		
	Paleocene	Fort Union Formation	Tongue River Member	Sandstone, shale, and coals	2900
			Lebo Member		
			Tullock member		
Cretaceous	Upper Cretaceous	Lance Formation		Sandstone, shale, and coals	650 - 3000
		Fox Hills Sandstone		Sandstone and shale	300
		Bearpaw Shale	Pierre Shale / Lewis Shale	Sandstone and shale	175 - 400

Explanation:

Unconformity

Hiatus

floodplain, and wetlands. The wetlands were primarily tree-filled swamps of large areal extent, at times covering most of the basin. These swamps collected the thick organic-rich peat deposits that after burial and thermal alteration became the massive coal deposits of economic importance today. These coal deposits also serve as the primary natural gas reservoirs for recent CBNG activity (Jones, 2008; Surdam et al., 2008).

The Tullock Member is the oldest and lowest of the Tertiary units in the Wyoming PRB, and directly overlies the Upper Cretaceous Lance Formation. The Tullock is composed of brown sandstone interbedded with shale and siltstone beds deposited in a fluvial/floodplain/wetland environment (Zelt et al., 1999). Thin, discontinuous coal deposits are locally present. The Tullock ranges in thickness from 500 feet in the northeastern PRB to 1,440 feet in southeastern basin (Brown, 1993).

The Lebo Shale Member (middle member) ranges from 500 feet thick in the northwestern PRB to 1,700 feet in the southwestern basin (Law, 1976). The Lebo consists of gray shale interbedded with gray siltstone, claystone, and concretionary sandstone deposited primarily in a lacustrine environment. Fluvial, floodplain and wetland depositional environments also contributed sediment to this member (Zelt et al., 1999).

The youngest and uppermost Fort Union member, the Tongue River Member, consists of yellow fine- to medium-grained, massive and crossbedded lenticular sandstone; gray to brown mudstone; carbonaceous shale; and coal deposited in fluvial/flood plain/swamp environments (Zelt et al., 1999). Some coal deposits in the Tongue River Member exceed 200 feet in thickness (Jones, 2008). Most of the Tongue River coal is subbituminous C in rank with as-received heat values between 8,300 to 9,500 British thermal units (BTUs) per pound on a moisture-ash-free basis (Jones, 2008). Some lower rank lignite beds are present around the margins of the PRB (Jones, 2008).

The Tongue River coal deposits are thick, variable, and laterally extensive in the Wyoming PRB. The coal deposits vary unpredictably in three-dimensional geometry and thickness as they thicken, thin, merge, split, abruptly terminate, or transitionally wedge out laterally. The coal deposits are divided into a hierarchy of stratigraphic names that has developed historically.

Since 1907, the nomenclature of the PRB coal deposits has evolved during interactions among local residents, geologists, federal agencies, Wyoming agencies, Montana agencies, coal mine operators, CBNG operators, and conventional oil and gas operators (Jones, 2008). Please note that the interpretation of the named coal monitoring zones in the BLM deep monitoring wells and other wells located within the Wyoming PRB may not match the coal nomenclature system listed below in **Table 1** and modified from Jones (2008).

The stratigraphic column and nomenclature table below were developed in an attempt to clarify these relationships. The coals may directly overlie or be overlain by either sandstone or shale beds, although fine-grained units (shale, mudstone, and claystone) enclose most of the Tongue River Member coal deposits located in the eastern PRB (Jones, 2008). The coal deposits of the Tongue River Member host most of the total recoverable CBNG resources in the Wyoming PRB, which are estimated at 25.2 trillion cubic feet (25,200 BCF) of natural gas (De Bruin et al., 2001).

Currently (2009), fourteen (thirteen active plus one pending mine) large surface coal mines are located along the eastern outcrop of the Tongue River Member. The main coal deposit mined in the eastern PRB is the 50-foot to 100-foot thick Roland-Wyodak Rider-Upper Wyodak-Lower Wyodak located in the upper portion of the Tongue River Member (Jones, 2008). The Eocene Wasatch Formation unconformably overlies this coal deposit (Jones, 2008). A fifteenth surface coal mine in the Tongue River Member was scheduled to begin operating during late 2008 in the Sheridan area of the Wyoming PRB.

The WSGS has recently defined seven major coal zones for the Tongue River Member of the Fort Union Formation within the Wyoming PRB (Jones, 2008). The coal zone definitions are based on basin-wide, geophysical log correlations from 4,185 wells (Jones, 2008). Older coal nomenclature systems for the PRB are described and discussed in Jones (2008). These seven major coal zones in the Tongue River Member are shown, in order from the uppermost stratigraphic position (youngest) to lowermost position (oldest), in **Table 1**.

***Table 1. Stratigraphic column and coal nomenclature table for the Powder River Basin, Wyoming** (modified from Jones, 2008)*

Geologic unit	Member	Coal zone	Order	Coal deposit name
Quaternary unconsolidated deposits (undivided)				
Oligocene White River Formation				
Eocene Wasatch Formation				
		Upper Wasatch	1	***Ulm***
			2	***Buffalo Cameron (Lake De Smet)***
			3	***Murray (Lake De Smet)***
			4	***Ucross (Lake De Smet)***
		Felix	5	***Felix Rider***
			6	***Upper Felix***
			7	***Felix***
		Lower Wasatch	8	***Arvada***
			9	(unnamed coal)
Paleocene Fort Union Formation				
	Tongue River			
		Roland	10	***Upper Roland***
			11	***Roland of Baker***
			12	***Roland of Taff***
		Wyodak Rider	13	***Smith Rider***
			14	***Smith/Big George***
			15	***Lower Smith***
		Upper Wyodak	16	***Anderson Rider***
			17	***Anderson***
			18	***Lower Anderson***
		Lower	19	***Canyon Rider***

		Wyodak		
			20	***Canyon***
		Knobloch	21	***Cook***
			22	***Lower Cook***
		Sawyer	23	***Wall***
			24	***Lower Wall***
			25	***Pawnee***
		Basal Tongue River	26	***Moyer***
	Lebo Shale			
	Tullock			
Upper Cretaceous Lance Formation				
Upper Cretaceous Fox Hills Sandstone				
Upper Cretaceous Lewis Shale (western PRB) & Pierre Shale (eastern PRB)				

1.2.4.4 Wasatch Formation

The Eocene Wasatch Formation was deposited in nearly identical fluvial-floodplain-wetland environments as the underlying Paleocene Fort Union Formation. The contact between the Fort Union and Wasatch formations is gradational in most of the Wyoming PRB and has proven very difficult to distinguish, either in the field or on geophysical well logs. Locally, a stratigraphic marker bed composed of coquina limestone or conglomeratic sandstone may identify the contact between the Fort Union and Wasatch (Hose, 1955). The top and base contacts of the Wasatch Formation are considered unconformable, except in the central PRB, where the Wasatch conformably overlies the Fort Union Formation. Locally, the lowermost Wasatch may be latest Paleocene in age. The Wasatch Formation has been eroded away in most of the Montana PRB.

The Wasatch consists of drab, fine- to coarse-grained, lenticular sandstone interbedded with variegated claystone and shale, and numerous coal deposits. The formation contains coarser-grained sandstone in the southern and southwestern PRB, and conglomeratic sandstone in northwestern PRB. The lower Wasatch also contains numerous coal deposits, including the 250-foot-thick Lake De Smet coal sequence near Buffalo, considered the thickest coal deposit in the United States (Glass and Jones, 1991; 1992). The Wasatch Formation has a total thickness of more than 2,000 feet in the central PRB and 1,500 feet in the northern part. As shown in **Figure 3**, the Wasatch has the greatest areal exposure at the ground surface of any geologic formation in the Wyoming PRB.

1.2.5 Groundwater resources

Groundwater flow occurring within the bedrock formations of the basin is commonly both structurally and stratigraphically controlled, particularly adjacent to the Laramide mountain uplifts. Aquifers are predominantly within interstratified sequences of high- and low-permeability sedimentary beds. Groundwater is present in the open spaces of the formations and flow occurs where there is permeability and sufficient head pressure. The PRB aquifers are commonly heterogeneous and anisotropic in character on both local and regional scales. Many of the Tertiary sandstone aquifers of the Fort Union and

Wasatch are lenticular in nature and were deposited as sandy stream channels.
Locally, groundwater is unconfined (water-table conditions) in shallow outcrop areas of the Wasatch Formation in the central basin and in the shallow outcrop areas of the older (pre-Wasatch) formations along the margins of the basin (Feathers et al., 1981). Groundwater in the unconsolidated Quaternary deposits (e.g., alluvium) is also unconfined. Shallow groundwater flow (less than about 300 to 500 feet below ground surface) is primarily controlled by topography and stream drainage patterns, and is discharged to the streams and rivers. The river drainages affecting the Wyoming PRB are the Little Bighorn, Tongue, Powder, Little Powder, Little Missouri, Belle Fourche, Cheyenne, Niobrara, and North Platte rivers (see **Figure B-2** in **Appendix B**). The surface water resources of the Wyoming PRB are discussed in greater detail in Clarey and Stafford (2008).

Deep regional groundwater in the PRB bedrock formations flows from aquifer recharge areas or outcrops located along the margins of the structural basin towards the structural axis of the basin and down-gradient (downward in elevation) and to the north into the Montana PRB (Davis, 1976; Feathers et al., 1981; Clarey and Stafford, 2008). This overall pattern may be substantially altered on the local scale by factors such as faults, which can function as flow boundaries or conduits for flow; by the heterogeneous character of the sedimentary sequence (lenticular aquifers/confining units (aquitards)); and by anthropogenic factors. Eventual discharge occurs along stream drainages as springs or as subcrop flow into overlying geologic units (Feathers et al., 1981). Subcrop flow from the deep regional bedrock flow discharges into alluvium located along some stream valleys and helps maintain base flow in the reaches where the streams are gaining (Davis, 1976).

1.2.5.1 Fort Union Formation

Aquifers in the Fort Union Formation occur in the multiple stacked beds of sandstone and coal. The Fort Union sandstone beds are lenticular and discontinuous. The thick, main coal deposits act as the regionally extensive aquifers. The low-permeability confining beds (aquitards) interbedded with the coal and sandstone beds consist of claystone, mudstone, and shale. As a result of these interbedded and stacked lithologies, the Fort Union Formation exhibits heterogeneous stratification; anisotropic groundwater flow; and leaky, low-permeability confining strata interbedded between the permeable sandstone and coal deposits (Feathers et al., 1981; Hinaman, 2005).

Locally, the Fort Union coal deposits which directly overlie or underlie adjacent sandstone beds allow some degree of groundwater communication between them. Hinaman (2005) estimated the porosity of the Fort Union (all three members) with the sand beds as 30 percent and the non-sand beds as 35 percent. The hydraulic conductivity of the Tongue River Member coal deposits, as determined by multi-well pumping tests, ranges from 4.6×10^{-7} to 8.6×10^{-4} feet per second (fps), with a median value of 2.3×10^{-5} fps (AHA and GEC, 2002). These reported conductivity values in fps may be converted to feet per day (fpd), with a range from 0.00066 to 1.2 fpd and a median value of 0.033 fpd. The Wyoming Framework Water Plan classifies the Fort Union Formation as a major aquifer in the PRB (WWC Engineering, 2007).

The more permeable Fort Union coal and sandstone beds are interstratified with low-permeability confining units of claystone, mudstone, shale, clayey siltstone, and siltstone beds. The clinker zones are shales and sandstones associated with burnt-out coal deposits located at or near the ground surface in the outcrop area of the Fort Union Formation. The rock adjacent to the burned coal has been baked and fused, often with an increase in groundwater permeability due to melting and heat fracturing (Feathers et al., 1981).

The coal deposits and clinker areas typically exhibit better aquifer properties than the sandstone beds of the Fort Union Formation. Typical aquifer properties of the clinker areas and associated coal deposits include transmissivity of up to 3,000,000 gallons per day per foot of drawdown, and well specific capacity of greater than 2,000 gpm per foot of drawdown (Feathers et al., 1981).

The upper member (Tongue River) and the basal member (Tullock) of the Fort Union are considered confined to semi-confined aquifers in most of the PRB. The middle member (Lebo Shale) is a leaky confining unit composed predominantly of low-permeability mudstone beds (Feathers et al., 1981).

The intensive CBNG development in the Tongue River Member in the PRB from 1997 through 2006 and the associated pumping and extraction of more than 4.1 billion barrels (174 billion gallons) of groundwater through 2006 has caused water-level drawdown in some of these coal deposits. Maximum drawdown from initial groundwater levels measured in BLM deep monitoring wells for the Tongue River coal deposits is up to 625 feet in some areas.

The drawdown in these coal deposits includes ten years of intensive CBNG development from 1997 through 2006, surface coal mine dewatering from 1980 through 2006, pumping of public water-supply wells, pumping of industrial/miscellaneous wells, and pumping of other domestic/irrigation/stock water wells completed into the Tongue River Member. While CBNG development is not the sole cause of groundwater level drawdown, it appears to be the major source of the measured drawdown in the coal deposits of the Tongue River Member in the Wyoming PRB.

Regional geochemical trends across the Fort Union coal deposit waters in the Wyoming PRB include:

An increase in total dissolved solids (TDS) content from approximately 300 to 500 milligrams per liter (mg/l) in the southeastern and eastern basin to between 1,000 and 2,200 mg/l in the western portion of the basin (Clarey and Stafford, 2008). This observed basin-wide increase in TDS of groundwater within the coal aquifers is attributed to increasing concentrations of sodium and bicarbonate due to the geochemical processes of cation exchange and bacterially-mediated sulfate reduction in the Fort Union coal deposits (Bartos and Rice, 2001).

An increase in the sodium adsorption ratio (SAR) from 4–8 (unitless) in the southeastern and eastern PRB to 40–56 in the northwestern and northern portions of the basin (Clarey and Stafford, 2008). This trend has also been attributed to cation exchange and bacterially-mediated sulfate reduction (Bartos and Rice, 2003).

The Fort Union coal deposits produce groundwater that is dominantly sodium/sulfate type in shallow basin areas, and mostly sodium/bicarbonate type in deep basin areas (Clarey and Stafford, 2008). Some groundwater samples collected from Fort Union coal deposits have sodium-calcium-magnesium/bicarbonate signatures.

Davis (1976) described the regional groundwater flow in the Fort Union Formation from an outcrop in the eastern PRB as flowing westward down structural dip toward the structural basin axis and discharging directly to streams in the northwestern part of the Wyoming PRB, helping to maintain the base flow of the Tongue River.

Based on local hydrogeologic data in the Wyoming PRB, Davis and Rechard (1977) and Brown (1980) estimated the average infiltration of water recharge into the Wasatch/Fort Union aquifers of the PRB from precipitation to be approximately 0.15 inches per year.

1.2.5.2 Wasatch Formation

The main water-bearing zones in the Wasatch Formation are the coal and sandstone beds. The rest of the formation consists of low-permeability, interbedded intervals of mixed shale, mudstone, clayey siltstone, and claystone. Some Wasatch wells locally flow water at the ground surface under confined (artesian) pressure. The groundwater produced from the Wasatch coal deposits is dominantly sodium/sulfate type in shallow basin areas and sodium/bicarbonate type in deep basin areas. Groundwater from the Wasatch Formation in its outcrop area (**Figure 3**) is extensively used for both domestic consumption and livestock watering.

The hydraulic conductivity of the sandstone beds of the Wasatch Formation range from 2.3×10^{-7} to 2.3×10^{-4} fps, with a median value of 6.2×10^{-5} fps (AHA and GEC, 2002). These reported conductivity values in fps may be converted to fpd, with a range of 3.3×10^{-4} to 0.33 fpd and a median value of 0.089 fpd. The Wyoming Framework Water Plan (WWC Engineering, 2007) classifies the Wasatch Formation as a major sandstone aquifer within the PRB.

1.3 PRB groundwater monitoring program

Originally, groundwater monitoring in the PRB began as a result of environmental analyses associated with early CBNG projects, including the Marquiss Project, the Lighthouse Project, the Gillette North Project, and the Gillette South Project. A total of 36 groundwater monitoring sites were required by the BLM as part of the approval of these projects between 1993 and 1999 (information provided by the BLM Buffalo Field Office (BFO), 2009).

In October 1999, a regional groundwater monitoring program was established under the Wyodak Coal Bed Methane (CBM) Final Environmental Impact Statement (FEIS) (BLM, 1999). The purpose of the program was to evaluate leakage and communication between the producing coal zone, overlying sandstone units, and underlying sandstone units, and to measure the areal extent of drawdown in the producing zone. These data would be used to verify impact analysis, provide "real-time" impact quantification, and provide baseline data for calibration of subsequent CBNG modeling efforts.

The Wyodak Record of Decision (ROD) stipulated that 140 nests of two or more monitor wells would be drilled over a 10-year period, equaling about two nests per township throughout the projected PRB development area. These well nests were planned to be completed as CBNG development progressed across the basin, and the wells would be stipulated as part of the approval of projects proposed by the various operators.

Additional issues related to CBNG development were later identified during the completion of the Powder River Basin Oil and Gas (PRB O&G) Environmental Impact Statement (EIS) in 2003, and a new groundwater monitoring approach modified the earlier 1999 Wyodak FEIS program. To address water quality issues and infiltration/recharge interactions of produced water on groundwater systems, modifications to the monitoring requirements and approach specified in the 1999 Wyodak FEIS were made. The BLM decided by increasing the installation complexity of each monitoring site and selecting monitoring locations that are representative of major geologic conditions, a fewer number of total well sites would be required. A key to reducing the required number of locations was to complete the wells as far ahead of development as possible.

The BLM developed a reduction from the original 140 proposed well nests of the Wyodak ROD to between 35 and 40 nests of monitoring wells, equaling approximately four townships per well, for CBNG activities in the Wyoming PRB. These 35 to 40 well nests were planned to include additional monitoring zones – including underburden sandstone, multiple coal deposits, and interburden or overburden sandstones – and were all to be completed within two years (by the end of 2005). This would allow for better baseline data collection and provide a better understanding of the CBNG impacts and the dynamics of the groundwater system. In addition to the new well nests, there were seven nests of wells that had been previously stipulated as part of other projects, but are not yet complete (2009).

From 2002 to 2003, the major CBNG operators met with the BLM and the Petroleum Association of Wyoming (PAW) to decide who would be responsible for most of the wells (34 of the proposed 47 sites). It was projected that the remaining 13 monitoring locations would be stipulated as part of the approval of other projects as opportunity and need arose. A cooperative agreement between the BLM and PAW representing Devon Energy, Marathon Oil, Williams Production, and Yates Petroleum was signed May 30, 2003. The 2003 Williams obligations were later divided after 2003 between Williams Production and Western/Lance.

Progress in completing the PRB O&G EIS monitoring well program has been slower than projected. Seventeen of the 28 wells have been completed at the time of this report (2009), with one additional well planned for completion in 2009, and a second well being required as a condition of approval for a Plan of Development (POD) being processed in early 2009 by the BLM BFO. Of the 13 well sites that were not obligated to a CBNG operator in the cooperative agreement, none has been stipulated with CBNG operations to date (2009).

Groundwater quality issues that were discussed as part of the BLM-PAW cooperative program will be addressed in future monitoring reports by using available data collected by CBNG operators.

1.4 BLM deep monitoring well network data collection

Installation of monitoring equipment in the BLM deep monitoring well network has been conducted by BLM personnel from the Casper Field Office (CFO) and the BFO. Preliminary locations for the proposed monitoring wells in the Wyoming PRB were identified soon after approval of the 2003 PRB O&G EIS. Final monitoring well locations were selected as the CBNG development progressed into an area or when a preliminary location fell within a proposed federal POD. Monitoring wells have been situated on federally-owned surface land to alleviate the potential for access concerns.

A summary table of BLM deep monitoring well data is included as **Table A-1** in **Appendix A**. Locations of these wells are illustrated on **Figure 1** and the well site names/acronyms are listed in **Table 2**.

Table 2. Existing wells and potential new wells of the BLM deep monitoring well networks by county, Powder River Basin, Wyoming (2009)

County	Well Site Name	Acronym
Campbell County	***4-Mile (new)***	***4MILE (new)***
	20-Mile Butte	20MILE
	Phillips 21-Mile	21MILE
	All Night Creek	ANC
	Amoco Section 36	467236B1
	Bar 76	457301A
	Barrett Persson	PERSSON
	Barton	BARTON
	Blackbird Coleman	BBIRD
	Bowers	BOWERS
	Carr Draw (new)	***CDU (new)***
	Dilts	DILTS
	Double Tank	DTANK
	Echeta	ECHETA
	Hoe Creek	HOE
	Kennedy	KENNEDY
	Huber Lone Tree	HUBERLT
	MP2	MP2

	MP22	MP22
	Napier	NAPIER
	North Cordero	477119C1
	North Gillette	NGILL
	Palo	PALO
	Phillips Beaver Federal	BEAVFED
	Pistol Point	PISTOL
	Prima Cedar Draw	CEDAR
	Redstone	REDSTN
	South Cordero	467106C1
	Sec. 6 Durham Ranch	457106C
	Sec. 14 Durham Ranch	447214A
	Section 25	467225C
	South Coal	SCOAL
	Stuart Sec. 31	447131A
	Barrett Throne	THRONE
	West Pinetree (new)	***WPT (new)***
	Williams Cedar Draw	CEDAR
	Wormwood (new)	***WW (new)***
Converse County	***Duck Creek (new)***	***DUCK (New)***
Johnson County	Bear Draw Unit	BDU
	Big Cat	BIGCAT
	Boondogle (new)	***BOONDOGLE (new)***
	Huber Buffalo SE	BUFFSE
	Bull Creek	BULLCRK
	Bullwacker	BULLWACK
	Coal Gulch Unit	CGU
	Gilmore	GILMORE
	Juniper	JUJNIPER
	Kingsbury Unit (new)	***KDU (new)***
	Sasquatch	SASQUAT
	Streeter	STREETER

	Prima Wild Turkey	WILDTUR
Sheridan County	Lower Quarter (L1/4) Circle Hills	LQC
	Leiter (test well)	LEITER
	Huber Lower Prairie Dog	HUBERPD
	Remington Creek	REMCRK
	Squaw Butte (test well) (new)	***SQUAWB (new)***

Before CBNG water production began in an area, monitoring equipment was installed in most wells to establish baseline (static) water levels in the wells before pumping-induced drawdown began. Sometimes, CBNG wells were installed as part of fee (private minerals) lease and where the fee development preceded the development of federal minerals. Therefore, the decline of groundwater levels may have already begun in an area before baseline water levels (static conditions) were established for the BLM monitoring wells. As a consequence of this staggered timing for some of the fee/federal CBNG development in the basin, many of the BLM deep monitoring wells do not have an accurate baseline groundwater level (static water level).

Most of the BLM deep monitoring wells were installed by the CBNG operator during development of a project area. Monitoring well boreholes are drilled to a depth of 100 feet below the lowest gas production zone. A wire-line gamma-ray log and other geophysical well logs were run in the wells and used by BLM personnel to select potential underburden and overburden sandstone zones for monitoring.

All deep monitoring wells are constructed like CBNG production wells so that the wellhead assembly will withstand high gas pressures. Some of the shallow sandstone wells are constructed for low pressures where hydraulic communication with underlying coal zones is considered unlikely. Most of the BLM wells have a single steel casing installed to the selected monitoring zone. Some wells are dual completions, where a packer connected to the surface with a tubing string was installed to isolate two different monitoring zones within a single well. The tubing is sufficient in inside diameter to allow passage of a water-level probe for manual water-level measurements.

With the exception of some of the older wells installed as part of CBNG exploration activities, most BLM monitoring wells are equipped with continuous-recording equipment. Pressure transducer sensors (installed probes) for recording water level and wellhead gas pressure measurements for each monitoring zone are connected to electronic data-logger equipment that is powered by solar panels connected to 12-volt batteries.

Monitoring of wells is conducted by the BLM BFO, and most wells are visited on a quarterly basis. Water level and wellhead gas pressure are measured manually to verify the electronically recorded data. The manual measurements are recorded in field notebooks at each well house and copies of the field measurements are carried back to the BFO for database entry. These well data are later entered into Microsoft Excel spreadsheets for storage and analysis.

Due to the nature of electronic pressure transducers, the recorded data may drift positively or negatively from the accurate measurement of a parameter. Manual measurements allow for the correction of the electronic data drift between each well station visit (monitoring event) so that data integrity is maintained. Flexible, small-diameter airlines installed in most wells facilitate independent measurement of water levels. These airline measurements allow us to correct electronic water-level measurements, which are affected by positive borehole gas pressure.

Corrected monitoring well data along with graphic presentations of these data are periodically posted on the Wyoming Energy Resources Clearinghouse website and are available online at: http://www.cbmclearinghouse.info/. The BLM updates this database.

Several BLM databases were downloaded and additional electronic data files were received via e-mail, portable memory, and compact disc from the BLM BFO. These well data were compiled by the WSGS to form a summary table of the BLM deep monitoring wells in the Wyoming PRB (see **Table A-1** in **Appendix A**). Permit numbers for the BLM wells in the databases of the WOGCC and the WSEO were identified by the WSGS to the extent practicable and added to the summary table (**Table A-1** in **Appendix A**). Considerable time and effort were spent compiling and cross-checking the BLM deep monitoring well data, WOGCC permit data, and WSEO permit data.

Well location data listed in the permits and databases of various state and federal agencies are of variable quality with discrepancies and typographical errors. Most of the state and federal databases depend on reported well data provided by an applicant/operator. Wyoming state agencies report a well location as quarter-quarter (40 acres), quarter (160 acres), section, township, range, and county. Federal agencies list a well location as township, range, section, quarter (160 acres), and quarter-quarter (40 acres). The state and federal databases completely reverse the quarter-quarter, quarter, section designation for well locations. This reversal has caused some variable degree of inconsistency between the multiple permits and databases for the state and federal agencies.

Chapter 2

In the Wyoming PRB, the Tongue River Member coal deposits of the Fort Union Formation are extensively used for CBNG development. As discussed in the previous chapter, the groundwater present in these Fort Union coal deposits is generally under confined (artesian) pressure in the deeper portions of the basin. These Tongue River coal aquifers are exhibiting water-level drawdowns in the confined pressures of these coal deposit aquifers due to the intensive pumping of groundwater from the CBNG production wells.

The BLM deep monitoring wells constructed into the Fort Union coal deposits are monitored for water level in the well and total gas pressure at the wellhead. Water-level monitoring includes both manual and electronic methods. The water-level data and wellhead gas pressure charts of the BLM deep monitoring well data are included in **Appendix A**. The confined pressure in a coal aquifer is measured by the height (in feet) of the water column in a monitoring well above the top of the coal bed, assuming that the well is only constructed into the target coal bed. A change in the well's water level reflects a change in the confined pressure within the coal aquifer. A decline in water level indicates a decrease in confining pressure.

The actual drawdowns measured in the Fort Union coal monitoring wells were compared with the predicted 2006 drawdowns contained in the groundwater technical report (AHA and GEC, 2002). The 2002 groundwater model predicted that drawdowns would range from 500 to more than 750 feet by the year 2006 (AHA and GEC, 2002). Measured water-level drawdowns in the BLM coal monitoring wells did not exceed 500 feet except in four wells: HOEC (Wyodak coal), BULLWACKC (Big George coal), JUNIPERC (Big George coal), and 457301A1 (Wyodak coal).

2.1 CBNG fields and monitoring wells

The existing BLM deep monitoring well network in the Wyoming PRB includes a total of 48 single and nested monitoring well sites. The nested wells include monitoring wells constructed into different stratigraphic intervals including Fort Union coal deposits, Fort Union sandstone beds, and Wasatch sandstone beds. Monitoring wells were constructed during different years and at various spatial locations proximal to the producing wells, which directly influences the magnitude of the observed drawdowns.

When some of the BLM monitoring wells were constructed, groundwater levels in some areas had already declined as a result of nearby CBNG development. Some of the BLM wells were installed within the zone of influence (cones of depression) caused by pumping an adjacent production well or wells. Therefore, pre-existing drawdowns make it difficult to ascertain the original static water level (baseline level) for some monitoring wells and to determine an accurate drawdown value. An evaluation of the collected data for each well is discussed in numerical-alphabetical order in **Appendix C**.

Through 2006, the existing BLM deep monitoring well network consisted of a total of 111 **wells (see Figure 1 and Table A-1 in** Appendix A). The network consists of 58 Fort Union coal wells, one Fort Union underburden sandstone well, 51 Wasatch sandstone wells, and one Quaternary alluvial sand bed well. The 58 Fort Union coal wells are grouped by coal deposit(s) and summarized below:

6	Anderson coal wells
1	Wyodak-Anderson coal well
16	Big George coal wells
1	Big George-Lower Smith coal well
2	Smith coal wells
19	Wyodak coal wells
4	Canyon coal wells
3	Cook coal wells
1	Cook-Lower Wall-Pawnee coal well
3	Wall coal wells
1	Wall-Pawnee well
1	Pawnee coal well

The 58 BLM coal monitoring wells are listed below in **Table 3** by well acronym, coal deposit(s), county, and year the well was first monitored. These wells are grouped by coal deposits and the well locations are shown on **Figure 1**.

Table 3. Coal monitoring wells for BLM deep monitoring well network, Powder River Basin, Wyoming (1993-2006)

Well acronym	Coal deposit(s)	County	First monitored
20MILEA	Anderson	Campbell	2004
BULLCRKC	Anderson	Johnson	2005
HUBERPDC	Anderson	Sheridan	2000
KENNEDYC	Anderson	Campbell	2000
NGILLAND	Anderson	Campbell	2001
REMCRKANDC	Anderson	Sheridan	2005
HUBERLTC	Wyodak-Anderson	Campbell	2000
21MILEBGC	Big George	Campbell	2001

ANCC	Big George	Campbell	2001
BBIRDBG	Big George	Campbell	2000
BDUC	Big George	Johnson	2006
BEAVFEDBG	Big George	Campbell	2003
BIGCATBG	Big George	Johnson	2003
BULLWACKC	Big George	Johnson	2002
DTANKBG	Big George	Campbell	2002
ECHETA	Big George or "Echeta"	Campbell	1999
GILMORE	Big George	Johnson	1998
JUNIPERC	Big George	Johnson	2001
NAPIERC	Big George	Campbell	2001
PISTOL	Big George	Campbell	1997
SASQUATC	Big George	Johnson	1998
STREETERC	Big George coal #3	Johnson	2004
WILDTURC	Big George	Johnson	2004
CGUBG	Big George-Lower Smith	Johnson	2005
BUFFSEC	Smith	Johnson	2001
CGUS	Smith	Johnson	2005
21MILEWC	Wyodak	Campbell	2001
447131A2	Wyodak	Campbell	1998
447214A1	Wyodak	Campbell	1998
457106C1	Wyodak	Campbell	1997
457301A1	Wyodak	Campbell	1997
467106C1	Wyodak	Campbell	1995
467225C1	Wyodak	Campbell	1996
467236B1	Wyodak	Campbell	1995
477119C1	Wyodak	Campbell	1995
477236B1	Wyodak	Campbell	1995
BBIRDC	Wyodak	Campbell	2000
BOWERSC	Wyodak	Campbell	2002
DILTSC	Wyodak	Campbell	1999
DTANKWY	Wyodak	Campbell	2002
HOEC	Wyodak	Campbell	1998
MP2C	Wyodak	Campbell	1993
MP22C	Wyodak	Campbell	1993
PERSSONC	Wyodak	Campbell	2001
THRONEC	Wyodak	Campbell	2001
NGILLCAN	Canyon	Campbell	2001
PALOC	Canyon	Campbell	2001
REDSTNC	Canyon	Campbell	1988
REMCRKCANC	Canyon	Sheridan	2005
BARTONC	Cook	Campbell	2002

LQCC	Cook	Sheridan	2005
REMCRKCOOKC	Cook	Sheridan	2005
SCOALC	Cook-Lower Wall-Pawnee	Campbell	2001
20MILEW	Wall	Campbell	2004
BARTONW	Wall	Campbell	2002
CEDARC	Wall	Campbell	2004
LQCW	Wall-Pawnee	Sheridan	2005
20MILEP	Pawnee	Campbell	2004

The 53 BLM sandstone and sand monitoring wells are listed below in **Table 4** by well acronym, sandstone/sand, county, and year the well was first monitored. These wells are grouped by together by well nests and the well locations are shown on **Figure 1**.

Table 4. Sandstone and sand monitoring wells for BLM deep monitoring well network, Powder River Basin, Wyoming (1993-2006)

Well acronym	Sandstone or sand	County	First monitored
20MILES	Wasatch sandstone	Campbell	2004
21MILES	Wasatch sandstone	Campbell	2001
447131A1	Wasatch sandstone	Campbell	1998
447131A3	Fort Union underburden sandstone	Campbell	1998
447214A2	Wasatch sandstone	Campbell	1998
457106C2	Wasatch sandstone	Campbell	1997
457301A2	Wasatch sandstone	Campbell	1997
467225C2	Wasatch sandstone	Campbell	1996
ANCS	Wasatch sandstone	Campbell	2001

ANCSS	Wasatch sandstone	Campbell	2002
ANCVSS	Wasatch sandstone	Campbell	2002
ANCVVSS	Wasatch sandstone	Campbell	2002
BBIRDS	Wasatch sandstone	Campbell	2000
BDUS	Wasatch sandstone	Johnson	2006
BEAVFEDS	Wasatch sandstone	Campbell	2003
BIGCATS	Wasatch sandstone	Johnson	2003
BOWERSS	Wasatch sandstone	Campbell	2002
BOWERSSS	Wasatch sandstone	Campbell	2002
BOWERSVSS	Wasatch sandstone	Campbell	2002
BOWERSVVSS	Wasatch sandstone	Campbell	2002
BUFFSES	Wasatch sandstone	Johnson	2001
BUFFSESS	Wasatch sandstone	Johnson	2002
BUFFSEVSS	Wasatch sandstone	Johnson	2002
BUFFSEVVSS	Wasatch sandstone	Johnson	2002
BULLCRKS	Wasatch sandstone	Johnson	2005
BULLCRKSS	Wasatch sandstone	Johnson	2005
BULLWACKS	Wasatch sandstone	Johnson	2002
CEDARS	Wasatch sandstone	Campbell	2004
DILTSS	Wasatch sandstone	Campbell	1999

DRYWILLS	Wasatch sandstone	Campbell	1999
HOES	Wasatch sandstone	Campbell	1998
HUBERLTS	Wasatch sandstone	Campbell	2000
HUBERPDS	Wasatch sandstone	Sheridan	2000
HUBERPDSS	Wasatch sandstone	Sheridan	2002
JUNIPERS	Wasatch sandstone	Johnson	2001
JUNIPERSS	Wasatch sandstone	Johnson	2002
KENNEDYS	Wasatch sandstone	Campbell	2000
LQCS	Wasatch sandstone	Sheridan	2005
MP2S	Wasatch sandstone	Campbell	1993
MP22S	Wasatch sandstone	Campbell	1993
MP22SS	Wasatch sandstone	Campbell	1998
MP22VSS	Wasatch sandstone	Campbell	1998
NAPIERS	Wasatch sandstone	Campbell	2001
NGILLS	Wasatch sandstone	Campbell	2001
PALOS	Wasatch sandstone	Campbell	2001
PERSSONS	Wasatch sandstone	Campbell	2001
REDSTNS	Wasatch sandstone	Campbell	1988

REMCRKS	Quaternary alluvial sand bed	Sheridan	2005
SASQUATS	Wasatch sandstone	Johnson	2001
SCOALS	Wasatch sandstone	Campbell	2001
STREETERS	Wasatch sandstone	Johnson	2004
THRONES	Wasatch sandstone	Campbell	2001
WILDTURS	Wasatch sandstone	Johnson	2004

If CBNG development in a local area proceeds in a timely manner on the normal 80-acre spacing, the monitored wellhead gas pressures will rapidly rise to a pressure peak as natural gases desorb from the coal while water-levels and formation head pressures (confined pressures) decrease in the coal deposit. Over time, the wellhead gas pressures will decline with progressive CBNG production in an area of development in the Wyoming PRB.

2.2 Summary of water-level drawdowns and rises in monitoring wells

2.2.1 Fort Union coal monitoring wells

The largest water-level drawdowns measured (in feet) in the Fort Union coal monitoring wells are largely a function of the length of the monitoring period and the distance from CBNG production wells. The static water level (or baseline level) has not been determined for all of the BLM deep monitoring wells. Some of the initial water levels in the databases and summary tables should be considered as initial water-level measurements and not as static water levels or baseline levels. It is most accurate to consider the initial water-level measurements as initial readings that may include some unknown degree of pre-existing drawdown.

In March 2008 during discussions with BLM BFO staff, it was decided to assume that the last water-level reading recorded for each calendar year (typically December) was the deepest water-level reading of the year for any given well. This reading may or may not be the actual deepest water-level measurement for that monitoring year as some wells show fluctuations in water levels. As shown in **Table 5**, the greatest CBNG development impacts measured in the Fort Union coal wells include:

Table 5. Maximum recorded water-level drawdowns and rises measured the Fort Union Formation coal monitoring wells, Powder River Basin, Wyoming (1993-2006)

Well acronym	Drawdown or rise (feet)	Coal deposit(s)
HOEC	-625.9	Wyodak
BULLWACKC	-592	Big George

JUNIPERC	-583.1	Big George
457301A1	-557.6	Wyodak
BIGCATBG	-486.7	Big George
ANCC	-476.2	Big George
HUBERPDC	-456.2	Anderson
DTANKBG	-420.4	Big George
467225C1	-402.8	Wyodak
21MILEWC	-395.5	Wyodak
NGILLAND	-348.6	Anderson
447131A2	-320.8	Wyodak
447214A1	-311.9	Wyodak
THRONEC	-310.8	Wyodak
SASQUATC	-275.4	Big George
DILTSC	-261.4	Wyodak
WILDTURC	-259.5	Big George
MP22C	-257.2	Wyodak
477236B1	-253.5	Wyodak
BEAVFEDBG	-241.3	Big George
DTANKWY	-240.7	Wyodak
BOWERSC	-234	Wyodak
KENNEDYC	-231.1	Anderson
REDSTNC	-220.7	Canyon
HUBERLTC	-205.7	Wyodak-Anderson
MP2C	-203.8	Wyodak
467106C1	-198.9	Wyodak
CEDARC	-196.6	Wall
21MILEBG	-188.3	Big George
457106C1	-173.2	Wyodak
BARTONC	-154.7	Cook
PERSSONC	-153.8	Wyodak
PALOC	-139.6	Canyon
20MILEW	-130.1	Wall
NAPIERC	-121.5	Big George
REMCRKANDC	-107	Anderson
477119C1	-104.8	Wyodak
REMCRKCOOKC	-98.1	Cook
20MILEA	-98	Anderson
NGILLCAN	-84.5	Canyon
ECHETA	-78.9	Big George or "Echeta"
20MILEP	-76.3	Pawnee
BBIRDC	-69.6	Wyodak
REMCRKCANC	-57.8	Canyon

GILMORE	-36.6	Big George
CGUS	-29.2	Smith
BUFFSEC	-28.8	Smith
SCOALC	-28.3	Cook-Lower Wall-Pawnee
CGUBG	-27.8	Big George-Lower Smith
STREETERC	-20.6	Big George coal #3
BULLCRKC	-17.1	Anderson
BARTONW	-12.6	Wall
BDUC	-10.3	Big George
LQCC	-9.2	Cook
LQCW	0.9	Wall-Pawnee
PISTOL	1.7	Big George
467236B1	(unknown)	Wyodak

One Wyodak coal well (467236B1) did not have water-level data available. As shown in **Table 5**, some coal wells are reported to be completed into two or more coals (e.g., HUBERLTC, Wyodak-Anderson). In **Table 6**, these coal wells are shown under each coal deposit and are listed two or more times. As shown in **Table 6**, the above-listed maximum drawdowns (feet) in **Table 5** may also be regrouped by coal deposit.

Table 6. Maximum water-level drawdowns and rises listed by coal deposit for the Fort Union Formation coal monitoring wells, Powder River Basin, Wyoming (1993-2006)

Well acronym	Drawdown or rise (feet)	Coal deposit(s)
Anderson coal wells (7)		
HUBERPDC	-456.2	Anderson
NGILLAND	-348.6	Anderson
KENNEDYC	-231.1	Anderson
HUBERLTC	-205.7	Wyodak-Anderson
REMCRKANDC	-107	Anderson
20MILEA	-98	Anderson
BULLCRKC	-17.1	Anderson
Big George coal wells (17)		
BULLWACKC	-592	Big George
JUNIPERC	-583.1	Big George
BIGCATBG	-486.7	Big George

ANCC	-476.2	Big George
DTANKBG	-420.4	Big George
SASQUATC	-275.4	Big George
WILDTURC	-259.5	Big George
BEAVFEDBG	-241.3	Big George
21MILEBG	-195.7	Big George
NAPIERC	-121.5	Big George
ECHETA	-78.9	Big George or "Echeta"
BBIRDBG	-38.3	Big George
GILMORE	-36.6	Big George
CGUBG	-27.8	Big George-Lower Smith
STREETERC	-20.6	Big George coal #3
BDUC	-10.3	Big George
PISTOL	1.7	Big George
Smith coal wells (3)		
CGUS	-29.2	Smith
BUFFSEC	-28.8	Smith
CGUBG	-27.8	Big George-Lower Smith
Wyodak coal wells (20)		
HOEC	-625.9	Wyodak
457301A1	-557.6	Wyodak
467225C1	-402.8	Wyodak
21MILEWC	-395.5	Wyodak
447131A2	-320.8	Wyodak
447214A1	-311.9	Wyodak
THRONEC	-310.8	Wyodak
DILTSC	-261.4	Wyodak
MP22C	-257.2	Wyodak
477236B1	-253.5	Wyodak
DTANKWY	-240.7	Wyodak
BOWERSC	-234	Wyodak
HUBERLTC	-205.7	Wyodak-Anderson
MP2C	-203.8	Wyodak
467106C1	-198.9	Wyodak

457106C1	-173.2	Wyodak
PERSSONC	-153.8	Wyodak
477119C1	-104.8	Wyodak
BBIRDC	-69.6	Wyodak
467236B1	(unknown)	Wyodak
Canyon coal wells (4)		
REDSTNC	-220.7	Canyon
PALOC	-139.6	Canyon
NGILLCAN	-84.5	Canyon
REMCRKCANC	-57.8	Canyon
Cook coal wells (4)		
BARTONC	-154.7	Cook
REMCRKCOOKC	-98.1	Cook
SCOALC	-28.3	Cook-Lower Wall-Pawnee
LQCC	-9.2	Cook
Cook-Lower Wall-Pawnee coal well (1)		
SCOALC	-28.3	Cook-Lower Wall-Pawnee
Wall coal wells (5)		
CEDARC	-196.6	Wall
20MILEW	-130.1	Wall
SCOALC	-28.3	Cook-Lower Wall-Pawnee
BARTONW	-12.6	Wall
LQCW	0.9	Wall-Pawnee
Pawnee coal wells (2)		
20MILEP	-76.3	Pawnee
SCOALC	-28.3	Cook-Lower Wall-Pawnee

As shown in **Table 6**, two of the 58 Fort Union coal wells (Big George PISTOL and Wall LQCC) in the BLM deep monitoring well network showed a rise in water level from the initial water level. These two coal monitoring wells may be experiencing early aquifer recovery (or local recharge) as the magnitude of CBNG well pumping has declined in the vicinity. Recovery of water levels may occur as groundwater is redistributed in the coal zone from areas of higher head pressure into the lower pressure zone of influence (cone of depression) in the CBNG-production area.

2.2.2 Wasatch sandstone wells

Twenty-one Wasatch sandstone wells and one Fort Union underburden sandstone well showed the largest measured drawdown (in feet) from initial water level measurements (**Table 7**).

Table 7. Maximum water-level drawdowns measured in the sandstone wells of the Wasatch Formation and Fort Union Formation monitoring wells, Powder River Basin, Wyoming (1993-2006). Note Well 44131A3 is a Fort Union Formation underburden sandstone well.

Sandstone well acronym	Footage separation from coal zone (feet)	2006 Water level change (feet)	Hydrologic connection evaluation
THRONES	56	-268.8	Affected
PERSSONS	36	-252.6	Affected
447131A3	-14 (below coal)	-248.7	Affected
457301A2	47	-218.0	Affected
BULLWACKS	(unknown)	-139.6	Affected
CEDARS	107	-105.4	Affected
SASQUATS	75	-100.3	Affected
447131A1	89	-58.9	Affected
457106C2	43	-57.3	Affected
MP2S	26	-52.9	Affected
MP22S	38	-42.5	Affected
447214A2	26	-21.2	Affected
NAPIERS	63	-20.5	Affected
KENNEDYS	128	-15.6	Affected
JUNIPERS	418	-11.9	Affected
STREETERS	621	-9.1	Slightly affected
BULLCRKS	100	-8.4	Slightly affected
20MILES	357	-7.1	Slightly affected
WILDTURS	187	-7.0	Slightly affected
HUBERLTS	117	-6.0	Slightly affected
NGILLS	214	-5.7	Slightly affected

HUBERPDS	238	-5.5	Slightly affected

The BLM Wasatch sandstone monitoring wells that showed the largest rise in water level (feet) are shown in **Table 8**. These twelve Wasatch sandstone wells may be impacted by surface discharge of CBNG produced water via ponds, reservoirs, and/or surface drainages. The surface water may be infiltrating into the Wasatch and causing some shallow unconfined or confined groundwater levels to rise. Further evaluation of water-level rise in some Wasatch sandstone wells will be conducted in future monitoring reports.

Table 8. Maximum water-level rises measured in the Wasatch Formation sandstone monitoring wells, Powder River Basin, Wyoming (1993-2006)

Well acronym	Footage separation from coal zone (feet)	Water-level rise (feet)
ANCS	124	+26.1
BUFFSESS	993	+11.3
BUFFSES	90	+9.8
BUFFSEVVSS	1458	+3.2
REDSTNS	56	+2.6
BOWERSVVSS	632	+1.1
ANCVVSS	744	+0.6
BOWERSS	117	+0.5
ANCVSS	564	+0.3
21MILES	197	+0.2
BOWERSVSS	362	+0.2
BUFFSEVSS	1358	+0.0

2.3 Summary of wellhead gas pressures in Fort Union coal wells

Wellhead gas pressures for the coal BLM deep monitoring wells are monitored and recorded. The gas is released from the coal as the confined groundwater head pressure decreases in the target coal due to water level declines that occur during pumping of CBNG production wells. The data collected electronically at the monitoring well head are downloaded and entered into databases for each coal well. The graphs of the wellhead gas pressures are shown on the hydrographs for the coal monitoring wells in **Appendix A**. The sandstone wells are not monitored for wellhead gas pressure.

Table 9 shows the BLM coal monitoring wells that recorded the highest maximum wellhead gas pressures (psi).

Table 9. The highest readings of the recorded wellhead gas pressures by well and coal deposit, Powder River Basin, Wyoming (1993-2006)

Well acronym	Wellhead gas pressure (psi)	Coal deposit(s)
BULLWACKC	311.1	Big George
JUNIPERC	221.3	Big George
DILTSC	92.6	Wyodak
457106C1	83.7	Wyodak
WILDTURC	80.9	Big George
HUBERLTC	66.7	Wyodak-Anderson
467225C1	63.8	Wyodak
MP22C	61.2	Wyodak
457301A1	61.0	Wyodak
REMCRKANDC	60.4	Anderson
HOEC	60.4	Wyodak
REDSTNC	58.4	Canyon
PALOC	55.9	Canyon
467106C1	55.3	Wyodak
ANCC	48.5	Big George
HUBERPDC	45.1	Anderson
447131A2	37.9	Wyodak
477236B1	34.1	Wyodak
477119C1	33.8	Wyodak
21MILEWC	28.6	Wall
447214A1	28.1	Wyodak
MP2C	26.8	Wyodak
CGUS	21.9	Smith
20MILEA	19.4	Anderson
21MILEBG	15.3	Big George
ECHETA	14.0	Big George or "Echeta"
SCOALC	12.7	Cook-Lower Wall-Pawnee

Wellhead gas pressures greater than 100 psi may potentially damage the electronic pressure transducer probe installed at the well head of the coal monitoring wells. The pressure transducer probes monitoring the two Big George coal wells (BULLWACKC and JUNIPERC) were damaged by excessive gas pressures (greater than 100 psi).

Some of the coal deposits in some monitored locations showed very little to no build-up of wellhead gas pressures. The coal monitoring wells with the lowest maximum recorded wellhead gas pressures (psi) are shown in **Table 10**.

Table 10. Table of the lowest of the maximum wellhead gas pressure recorded by well and coal deposit, Powder River Basin, Wyoming (1993-2006)

Well acronym	Wellhead gas pressure (psi)	Coal deposit(s)
BULLWACKC	311.1	Big George
JUNIPERC	221.3	Big George
DILTSC	92.6	Wyodak
457106C1	83.7	Wyodak
WILDTURC	80.9	Big George
HUBERLTC	66.7	Wyodak-Anderson
467225C1	63.8	Wyodak
MP22C	61.2	Wyodak
457301A1	61.0	Wyodak
REMCRKANDC	60.4	Anderson
HOEC	60.4	Wyodak
REDSTNC	58.4	Canyon
PALOC	55.9	Canyon
467106C1	55.3	Wyodak
ANCC	48.5	Big George
HUBERPDC	45.1	Anderson
447131A2	37.9	Wyodak
477236B1	34.1	Wyodak
477119C1	33.8	Wyodak
21MILEWC	28.6	Wall
447214A1	28.1	Wyodak
MP2C	26.8	Wyodak
CGUS	21.9	Smith
20MILEA	19.4	Anderson
21MILEBG	15.3	Big George
ECHETA	14.0	Big George or "Echeta"
SCOALC	12.7	Cook-Lower Wall-Pawnee

These coal wells show little evidence of natural gas pressure build-up in these coal deposits and well nests. The wellhead gas pressure data are plotted over time on the BLM coal well charts included in **Appendix A**. A summary discussion of the wellhead gas pressures by coal deposit follows.

Anderson coal wellhead gas pressure

The maximum wellhead gas pressures in four of the seven Anderson coal wells showed a peak in the second quarter of 2002 for HUBERLTC; in the first quarter of 2004 for 20MILEA; in early 2004 for HUBERPDC; and in the third quarter of

2005 for REMCRKANDC (**Appendix A**). The wellhead gas pressure curves for the HUBERLTC and LTREEC wells are excellent examples of the standard CBNG production decline of gas pressure over time since pressure peaked in May 2002 (**Appendix A**). The recorded pressures are very low for the remaining three Anderson coal wells (BULLCRKC, KENNEDYC, and NGILLAND) (**Appendix A**).

Big George coal wellhead gas pressure

The maximum wellhead gas pressures in four of the 17 Big George coal wells showed a peak in the fourth quarter of 2003 for BULLWACKC; in the fourth quarter of 2003 for ANCC; in the fourth quarter of 2004 for JUNIPERC; and in the third quarter of 2006 for WILDTURC (**Appendix A**). The Big George coal wellhead gas pressure curves exhibit the standard CBNG-production decline of gas pressure over time. The recorded pressures are very low for the remaining 13 Big George coal wells (21MILEBGC, BBIRDBG, BDUC, BEAVFEDBG, BIGCATBG, CGUBG, DTANKBG, ECHETA, GILMORE, NAPIERC, PISTOL, SASQUATC, and STREETERC) (**Appendix A**).

Canyon coal wellhead gas pressure

The maximum wellhead gas pressures in two of the four Canyon coal wells showed a peak in the second quarter of 2000 for REDSTNC; in early 2001 for PALOC; and in the third quarter of 2005 for REMCRKANDC (**Appendix A**). The recorded pressures are very low for the remaining two Canyon coal wells (NGILLC and REMCRKCANC) (**Appendix A**).

Cook coal wellhead gas pressure

The maximum wellhead gas pressures in two of the four Cook coal wells showed peaks in the fourth quarters of both 2004 and 2005 for SCOALC; and in early 2006 for LQCC (**Appendix A**). The recorded pressures are very low for the remaining two Cook coal wells (BARTONC and REMCRKCOOKC) (**Appendix A**).

Pawnee coal wellhead gas pressure

The maximum wellhead gas pressures in the two Pawnee coal wells showed a peak in the third quarter of 2006 for 20MILEP; and peaks in the fourth quarters of both 2004 and 2005 for SCOALC (**Appendix A**).

Wall coal wellhead gas pressure

The maximum wellhead gas pressures in two of the five Wall coal wells showed peaks in the fourth quarters of both 2004 and 2005 for SCOALC; and in the third quarter of 2005 for LQCW (**Appendix A**). The recorded pressures are very low for the remaining three Wall coal wells (20MILEW, BARTONW, and CEDARC) (**Appendix A**).

Wyodak coal wellhead gas pressure

As shown in **Appendix A**, the maximum wellhead gas pressures in ten of the 18 Wyodak coal wells showed a peak in the third quarter of 1995 for MP22C; in the second quarter of 1996 for 477119C1; in the fourth quarter of 1996 for MP2C; in the third quarter of 1997 for 477236B1; in the second quarter of 1999 for 467106C1; in the first quarter of 2000 for DILTSC; in the first quarter of 2001 for 467225C1; in the third quarter of 2001 for 447131A2; in the second quarter of 2003 for 457301A1; and in the second quarter of 2004 for 21MILEWC. The Wyodak coal wellhead gas pressure curves show the standard CBNG-production decline of gas pressure over time. The recorded pressures are very low for the remaining eight Wyodak coal wells (447214A1, 457106C1, BBIRDC, BOWERSC, DTANKWY, HOEC, PERSSONC, and THRONEC) (**Appendix A**).

Appendix C includes further detailed discussions of the monitored wellhead gas pressures at individual BLM monitoring wells and well nests.

The two wells with the highest maximum wellhead gas pressures during monitoring (BULLWACKC, 311.1 psi, and JUNIPERC, 221.3 psi); were not pumped as CBNG production wells. These two Big George coal wells were affected by pumping of CBNG wells in the local area (within a 3-mile radius). The drawdowns measured in these wells were the second and third greatest measured drawdowns of 592.0 feet (BULLWACKC) and 583.1 feet (JUNIPERC) for all of the BLM deep monitoring wells.

The greatest maximum drawdown measured in the BLM coal wells are:

#1 HOEC -625.9 feet (Wyodak)
#2 BULLWACKC -592.0 feet (Big George)
#3 JUNIPERC -583.1 feet (Big George)

A maximum drawdown of 139.6 feet was measured in the Wasatch sandstone monitoring well BULLWACKS. This shallower sandstone well constructed above the BULLWACKC coal well is affected by local CBNG activities.

Chapter 3

The predicted groundwater impact information is contained in the 2002 groundwater modeling technical report prepared by AHA and GEC (2002). The 2002 report developed a groundwater model and predicted potential water-level drawdown related to energy development in the upper Fort Union coal deposits and Wasatch sandstone beds of the PRB from the years 2003 to 2030 and water-level recovery from the years 2030 to 2060. The observed drawdowns in the BLM deep monitoring wells were compared with predictions of AHA and GEC (2002) to evaluate how well the model predicted water-level drawdown impacts.

3.1 Comparison of predicted vs. observed drawdowns in Fort Union coal wells

Four maps in the groundwater modeling technical report (Figure 6-2A on p. 6-13; Figure 6-2B on p.6-15; Figure 6-2C on p. 6-17; and Figure 6-2D on p. 6-19 in AHA and GEC, 2002 – see listing below) show predicted water levels for Fort Union coal deposits for the year 2006, which corresponds with this monitoring report and the 2006 monitoring data.

Four upper Fort Union Formation coal zones (Layers 8, 10, 12, and 14) were defined for the groundwater model of AHA and GEC (2002). AHA and GEC (2002) predicted that the maximum drawdowns in the year 2006 for the central portion of the Wyoming PRB would range from 500 feet to greater than 700 feet, as shown on the following listed figures contained in AHA and GEC (2002):

Figure 6-2A Modeled Drawdown Upper Fort Union Coals Layer 8 Year 2006 showing a predicted maximum drawdown of more than 700 feet;

Figure 6-2B Modeled Drawdown Upper Fort Union Coals Layer 10 Year 2006 showing a predicted maximum drawdown of more than 700 feet;

Figure 6-2C Modeled Drawdown Upper Fort Union Coals Layer 12 Year 2006 showing a predicted maximum drawdown of more than 700 feet; and

Figure 6-2D Modeled Drawdown Upper Fort Union Coals Layer 14 Year 2006 showing a predicted maximum drawdown of more than 500 feet.

Unfortunately, AHA and GEC (2002) did not specify which Fort Union coal deposits are contained within each defined layer of the groundwater model. Using geologic information for the Wyoming PRB, the WSGS interpreted which units correlate with each of the model coal layers. According to the WSGS, an approximate correlation between the complex coal nomenclature in the Wyoming PRB and the AHA and GEC (2002) groundwater model layers includes (in descending order from the upper to lower layers):

Layer 8 (Coal Unit 1) is equivalent to the Roland and Wyodak Rider coal zones in the Fort Union containing the Wyodak Rider, Smith Rider, Smith, Big George, Lower Smith coal deposits.

Layer 10 (Coal Unit 2) is equivalent to the Upper Wyodak Coal Zone containing the Anderson Rider, Anderson, and Lower Anderson coal deposits.

Layer 12 (Coal Unit 3) is equivalent to the Lower Wyodak and Knobloch coal zones containing the Canyon Rider, Canyon, Cook, and Lower Cook coal deposits.

Layer 14 (Coal Unit 4) is equivalent to the Sawyer and Basal Tongue River coal zones containing the Wall, Lower Wall, Pawnee, and Moyer coal deposits.

Intervening layers (Layers 9, 11, and 13) and overlying/underlying layers (Layers 7 and 15) represent low-permeability confining zones interbedded between the coal deposit zones of higher permeability (AHA and GEC, 2002). Some recent hydrologic studies indicate that these confining zones in the Tongue River Member may leak at some locations in the Wyoming PRB (Onsager and Cox, 2000; Cox and Onsager, 2002; Mavor et al., 2003; Clarey and Stafford, 2008).

Applying the coal zone correlations, as listed above, to the BLM deep monitoring well data, the WSGS developed the following preliminary correlations:

Layer 8 – As shown in **Figure B-3** in **Appendix B**, the Big George coal showed an actual maximum drawdown of nearly 600 feet by 2006, which is approximately 100 feet less than the predicted maximum of more than 700 feet by the year 2006 in AHA and GEC (2002). The Smith coal wells CGUS and BUFFSEC have each shown only about 29 feet of measured drawdown, which is probably a function of their proximity to actively producing CBNG wells.

Layer 10 – As shown in **Figure B-4** in **Appendix B**, the Anderson coal showed an actual maximum drawdown in excess of 450 feet by 2006, which is approximately 250 feet less than the predicted maximum of more than 700 feet by the year 2006 in AHA and GEC (2002). The Wyodak coal showed an actual maximum drawdown in excess of 625 feet by 2006, which is approximately 75 feet less than the predicted maximum of more than 700 feet by the year 2006 in AHA and GEC (2002).

Layer 12 – As shown in **Figure B-5** in **Appendix B**, the Canyon coal showed an actual maximum drawdown in excess of 220 feet by 2006, which is approximately 480 feet less than the predicted maximum of more than 700 feet by the year 2006 in AHA and GEC (2002). The Cook coal showed an actual maximum drawdown in excess of 150 feet by 2006, which is much less than the predicted maximum of more than 700 feet in AHA and GEC (2002).

Layer 14 – As shown in **Figure B-6** in **Appendix B**, the Wall coal showed an actual maximum drawdown of nearly 200 feet by 2006, which is approximately 300 feet less than the predicted maximum of more than 500 feet by the year 2006 in AHA and GEC (2002). The Cook-Lower Wall-Pawnee coal well SCOALC only showed an actual drawdown of about 8.5 feet, when this well became dry in 2006.

To summarize the comparison between predicted versus actual measured drawdowns from initial levels in the coal wells, all of the Fort Union coal deposits are showing less drawdown than was predicted by the AHA and GEC (2002) groundwater model. The maximum drawdown observed in the Wyodak coal of more than 625 feet is the closest to the predicted 2006 drawdown in the four coal layers defined by AHA and GEC (2002). All of the measured coal drawdowns are less than the drawdowns that were predicted.

However, some of the BLM deep monitoring wells did not have a well established baseline (static water level) for the initial water-level measurement in the coal well. Therefore, the actual drawdown from a static water-level condition for a well may be greater than reported for some of the BLM coal and sandstone wells.

3.2 Comparison of predicted versus measured drawdowns in Wasatch sandstone wells

The observed drawdowns in the Wasatch sandstone wells were also compared with the 2002 model predicted drawdowns (AHA and GEC, 2002) to evaluate the validity of the predicted drawdowns from groundwater modeling. AHA and GEC (2002) defined the Wasatch sandstone zones as Layers 2, 4, and 6, which represent the shallow, intermediate, and deep zones, respectively. Intervening layers (Layers 3 and 5) and underlying Layer 7 represent low-permeability confining zones interbedded between discontinuous sandstone zones of higher permeability (AHA and GEC, 2002). AHA and GEC (2002) did not show drawdown prediction maps of Wasatch water levels except for a few limited areas in the Wyoming PRB.

AHA and GEC (2002) show that by 2006, as much as 50 feet or more of water-level drawdown may occur in deep Wasatch sandstone wells in the Caballo Creek sub-area located near Well MP22S. The predicted drawdown is very close to the actual 42.5 feet of measured drawdown at MP22S in 2006, even though the Wasatch sandstone zones are heterogeneous. However, this similarity in Wasatch drawdown between predicted and actual measured drawdown may be only a coincidence, and may not address the validity of the AHA and GEC (2002) prediction itself because it is only a single data point.

As shown in **Table 11**, any Wasatch or Fort Union underburden sandstone well or Quaternary alluvial sand well with a measured drawdown of 10 feet or greater is considered "affected;" drawdowns between 5 and 10 feet are "slightly affected;" and drawdowns of 5 feet or less are considered "unaffected." Wasatch wells with water level rises are considered "unaffected" by drawdown in the coal zones due to CBNG activities.

Table 11. Summary table of sandstone monitoring wells, footage separation from coal zone, 2006 water-level change, and hydrologic connection evaluation, Powder River Basin, Wyoming (1993-2006). Note: REMCRKS is a Quaternary alluvial sand well, 447131A3 is a Fort Union Formation underburden sandstone well, and the remainder of the wells are Wasatch Formation sandstone wells.

Sandstone well acronym	Footage separation from coal zone (feet)	2006 Water level change (feet)	Hydrologic connection evaluation
20MILES	357	-7.1	Slightly affected
21MILES	197	+0.2	Unaffected
447131A1	89	-58.9	Affected
447131A3	-14 (below coal)	-248.7	Affected
447214A2	26	-21.2	Affected
457106C2	43	-57.3	Affected
457301A2	47	-218.0	Affected
467225C2	250	-1.6	Unaffected

ANCS	124	+26.1	Unaffected
ANCSS	344	-2.7	Unaffected
ANCVSS	564	+0.3	Unaffected
ANCVVSS	744	+0.6	Unaffected
BBIRDS	736	-0.4	Unaffected
BEAVFEDS	561	-4.6	Unaffected
BIGCATS	1082	-0.7	Unaffected
BOWERSS	117	+0.5	Unaffected
BOWERSSS	272	-0.4	Unaffected
BOWERSVSS	362	+0.2	Unaffected
BOWERSVVSS	632	+1.1	Unaffected
BUFFSES	90	+9.8	Unaffected
BUFFSESS	993	+11.3	Unaffected
BUFFSEVSS	1358	+0.0	Unaffected
BUFFSEVVSS	1458	+3.2	Unaffected
BULLCRKS	100	-8.4	Slightly affected
BULLWACKS	100	-139.6	Affected
CEDARS	107	-105.4	Affected
DILTSS	280	-3.2	Unaffected
HOES	620	-0.5	Unaffected
HUBERLTS	117	-6.0	Slightly affected
HUBERPDS	238	-5.5	Slightly affected
HUBERPDSS	368	-0.7	Unaffected
JUNIPERS	418	-11.9	Affected
JUNIPERSS	908	-0.7	Unaffected
KENNEDYS	128	-15.6	Affected
MP2S	26	-52.9	Affected
MP22S	38	-42.5	Affected
MP22SS	253	-1.0	Unaffected
MP22VSS	358	-2.6	Unaffected
NAPIERS	63	-20.5	Affected
NGILLS	214	-5.7	Slightly affected
PALOS	46	-1.4	Unaffected
PERSSONS	36	-252.6	Affected
REDSTNS	56	+2.6	Unaffected
REMCRKS	288	-0.2	Unaffected
SASQUATS	75	-100.3	Affected
SCOALS	207	-0.4	Unaffected
STREETERS	621	-9.1	Slightly affected

THRONES	56	-268.8	Affected
WILDTURS	187	-7.0	Slightly affected

Chapter 4

This report provides the initial organization and compilation of data collected from the BLM deep monitoring well network located in the Wyoming PRB from 1993 through 2006. Future tasks will continue to build upon this initial compilation effort and will expand the data analysis sections.

Ten years (1997–2006) of intensive CBNG development in the Wyoming PRB and the associated pumping and extraction of more than 4.1 billion barrels (174 billion gallons) of groundwater has caused water-level drawdown in the some of the Fort Union coal deposits and associated sandstone beds. The drawdown measured in these coal deposits may be caused by CBNG development, surface coal mine dewatering, pumping of public water-supply wells, pumping of industrial/miscellaneous wells, and pumping of other domestic/irrigation/stock water wells completed into the Tongue River Member. While CBNG development is not the sole cause of groundwater level drawdown, it appears to be the major source of the measured drawdown in the coal deposits of the Tongue River Member in the Wyoming PRB.

Data collected from the BLM deep monitoring well network show groundwater impacts as a result of CBNG development within the Wyoming PRB. The impacts measured through 2006 include a maximum groundwater-level drawdown of up to 625 feet and high wellhead gas pressures (greater than 300 psi) in Fort Union coal monitoring wells, and maximum groundwater-level drawdowns of more than 260 feet in Wasatch sandstone monitoring wells.

All of the monitored Fort Union coal wells show less drawdown than was predicted by the 2002 groundwater model. The maximum drawdown observed in one of the Wyodak coal wells of more than 625 feet is the closest to the predicted 2006 drawdown in the four coal layers defined by the model (AHA and GEC, 2002). However, because of the timing of CBNG development, some Fort Union coal wells did not have an established baseline (static water level) for the initial water-level measurement. Therefore, the actual drawdown from a static water-level condition for a coal well may be greater than measured.

Two of the 58 Fort Union coal monitoring wells showed a rise in water level from the initial water level which may indicate early aquifer recovery (or local recharge), as the magnitude of CBNG well pumping has declined in the vicinity of these two wells.

Twenty-one Wasatch sandstone monitoring wells also showed drawdown, including 14 affected wells and seven slightly affected wells. These 21 sandstone wells are affected by drawdown in groundwater levels in the Wyoming PRB. The remaining 30 Wasatch sandstone wells show no drawdown effects. The one Fort Union underburden sandstone well showed a large drawdown as an affected well. The Quaternary alluvial sand well was unaffected.

Twelve Wasatch sandstone monitoring wells showed water-level rises; these wells may be impacted by surface discharge of CBNG produced water via ponds, reservoirs, and/or surface drainages. The surface water may be infiltrating into the Wasatch and causing some shallow unconfined or confined groundwater levels to rise. Further evaluation of water-level rises measured in some Wasatch sandstone wells will be conducted in future monitoring reports.

4.1 Future monitoring plan

To further assess these groundwater concerns, additional analyses of the well data will be conducted:

Initial data from three additional BLM deep monitoring well nests completed in 2007 and 2008 will be included (South Prong, Kingsbury, 4-Mile, and West Pine Tree).

CBNG water production data will be examined in the vicinity of each of the monitoring wells to relate observed drawdown rates and patterns to water production rates at various distances from the wells.

Relationships between drawdown in coal monitoring wells and drawdown in associated sandstone wells will be further examined.

Additional work toward correcting database errors/discrepancies and also finding and resolving database anomalies will be conducted.

4.2 Existing wells in the BLM deep monitoring well network

At the end of 2006, 111 wells composed the BLM deep monitoring well network in the Wyoming PRB. The network at that time consisted of 58 Fort Union coal wells, one Fort Union underburden sandstone well, 51 Wasatch sandstone wells, and one Quaternary alluvial sand bed well. The coal wells were drilled and completed into ten coal deposits, with some wells completed in more than one coal deposit. The BLM plans to add additional monitoring wells to the BLM network as CBNG development continues in the Wyoming PRB.

4.3 Potential wells for inclusion in the BLM deep monitoring well network

At least one additional well nest, Cottonwood Draw, will be completed and several more wells will be proposed in 2009. Future reports will include data collected from these proposed new wells and others as these data become available. Groundwater data collected from various resources will also be analyzed in an effort to meet the original objectives of this project. A listing of potential wells for future inclusion in the BLM deep monitoring well network in the Wyoming PRB is presented in **Table 12**, and most of these well locations are shown in **Figure 1**.

Table 12. Potential future wells for inclusion into the BLM deep monitoring well network, Powder River Basin, Wyoming (2009)

County	Well name	Status
Campbell County	Olmstead	Proposed
	South Prong	Complete
	Weston Hills	Proposed
	White Rock	Proposed
Converse County	Antelope Creek	Proposed
	Blizzard Hills	Proposed
Johnson County	Crazy Woman	Proposed
	East Yeagan	Proposed
	North Buffalo	Proposed
	Oops Well	Partially complete

	Piney Creek	Proposed
	Powder River	Proposed
	Reno Road	Proposed
	Rose Draw	Partially complete
	Trabing Road	Proposed
Sheridan County	Badger Creek	Proposed
	Big Corral Draw	Proposed
	Buffalo Creek	Proposed
	Cabin Creek	Proposed
	Fence Creek	Proposed
	South Cottonwood	Proposed
	Ulm	Proposed
	Wynaro	Proposed

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Appendix C

Evaluation of the monitoring wells and well nests of the BLM deep monitoring well network, Powder River Basin, Wyoming (1993 – 2006)

This appendix gives a description of each well nest in the BLM deep monitoring well network and a summary of the data that have been collected at each site through 2006. All water levels reported here are depths in feet below the top of the well head. The conversion factor used is 1 psi of water pressure equals 2.31 feet high for a freshwater column.

BLM deep monitoring wells in numerical-alphabetical order, Powder River Basin, Wyoming

As of the end of December 2006, the existing BLM deep monitoring well network consisted of a total of 111 wells and is composed of 58 Fort Union coal wells, one Fort Union underburden sandstone well, 51 Wasatch sandstone wells, and one Quaternary alluvial sand bed well. The 58 Fort Union coal wells are grouped by coal deposit(s) and summarized below:

6	Anderson coal wells
1	Wyodak-Anderson coal well
16	Big George coal wells
1	Big George-Lower Smith coal well
2	Smith coal wells
19	Wyodak coal wells
4	Canyon coal wells
3	Cook coal wells
1	Cook-Lower Wall-Pawnee coal well
3	Wall coal wells
1	Wall-Pawnee well
1	Pawnee coal well

The locations of the existing deep monitoring sites are shown on a location map (Figure 1) for the Buffalo Field Office – BLM deep monitoring well network. The well name(s), site name, and acronym(s) for the BLM wells are listed in Table C-1 below:

Table C-1. BLM deep monitoring well network well names, site names, and acronyms, Powder River Basin, Wyoming (1993 – 2006).

Well name(s)	Site name	Acronym(s)
20-Mile Butte Well	20-Mile Butte	20MILE
Phillips 21-Mile Butte Well	Phillips 21-Mile Butte	21MILE
Stuart Federal #42-31B Well	Stuart Section 31	447131
Durham Ranch Federal #42-14B Well	Durham Ranch Section 14	447214A1
Durham Ranch Federal #23-6B Well	Durham Ranch Section 6	457106C1
Bar 76 LL Federal #1-42-1 Well	Bar 76	457301A1
South Cordero Well	South Cordero	467106C1

Federal #1-14-25 Well	Section 25	467225C1
Durham Ranch State #2-12-36 Well	Amoco Section 36	467236B1
North Cordero Well	North Cordero	477119C1
Amoco WCH 5 Well	Amoco Section 36	477236B1
All Night Creek Well	All Night Creek	ANC
Barton	Barton	BARTON
Blackbird Coleman	Blackbird Coleman	BBIRD
Bear Draw Unit	Bear Draw	BDU
Phillips Beaver Federal	Beaver Federal	BEAVFED
Kennedy Big Cat	Big Cat	BIGCAT
Bowers Oil/Gas Inc. State #4-36 Well	Bowers	BOWERS
Buffalo Southeast	Buffalo Southeast	BUFFSE
Bull Creek	Bull Creek	BULLCRK
Bullwacker	Bullwacker	BULLWACK
Cedar Draw	Cedar Draw	CEDAR
Coal Gulch Unit	Coal Gulch	CGU
BRC Federal #33-1	Dilts	DILTS
Double Tank	Double Tank	DTANK
Dry Willow Wells	Dry Willow	DRYWILL
Echeta Coal Test Well	Echeta	ECHETA
Gilmore Oil & Gas Artesian Unit #1 Well	Gilmore	GILMORE
Hoe Creek	Hoe Creek	HOE
Huber Lone Tree	Lone Tree	HUBERLT
Huber Lower Prairie Dog	Lower Prairie Dog	HUBERPD
Juniper Draw	Juniper	JUNIPER
Kennedy Wells	Kennedy	KENNEDY
L¼ Circle Hills Wells	L Quarter Circle Hills	LQC
Martens & Peck Section 2 Wells	MP2	MP2
Martens & Peck Section 22 Wells	MP22	MP22
Barrett Napier Well	Napier	NAPIER
North Gillette Wells	North Gillette	NGILL

Palo Petroleum Recluse Field Well	Palo	PALO
Barrett Persson Well	Barrett Persson	PERSSON
Shogrin #2 Federal Well	Pistol Point	PISTOL
Redstone Well	Redstone	REDSTN
Nance Petroleum Remington Creek Wells	Remington Creek	REMCRK
Sasquatch Federal #12-2 Well	Sasquatch	SASQUAT
Huber South Coal Well	South Coal	SCOAL
Streeter Road Wells	Streeter	STREETER
Barrett Throne Wells	Throne	THRONE
Prima Wild Turkey Wells	Wild Turkey	WILDTUR

Existing BLM deep monitoring well network (Through Year 2006)
Powder River Basin, Wyoming

20 Mile Butte (20MILE)

The 20-Mile Butte (20MILE) monitoring well nest consists of four wells: One well is constructed into each of the Anderson, Pawnee, and Wall coal beds, and one well is constructed into an overlying Wasatch sandstone bed. Of the three Fort Union coal beds in this well nest, the Anderson is the shallowest coal, the Wall is intermediate in depth between the other two coals, and the Pawnee is the deepest coal. Initial water levels in all three coal zones were similar, even though 600 feet separates the top of the Anderson coal and the bottom of the Pawnee coal bed.

- The Anderson coal well (20MILEA) showed 91.5 feet of drawdown from the initial 2004 water level to 2006. The wellhead gas pressure reached a maximum of 19.4 pounds per square inch (psi) from 2004 to 2006.

- The Pawnee coal well (20MILEP) showed 76.3 feet of drawdown from the initial 2004 water level to 2006. The rate of decline increased in 2006, and future examination of production data may indicate water production proximal to this well. The wellhead gas pressure was a maximum of 19.6 psi from 2004 to 2006.

- The Wall coal well (20MILEW or 20MILEWC) showed 130.1 feet of drawdown from the initial 2004 water level to 2006. Wellhead gas pressure did not rise significantly from 2004 to 2006 and showed a maximum reading of 0.9 psi.

- The overlying Wasatch sandstone well (20MILES), which is constructed into a sandstone bed located 357 feet stratigraphically above the top of the Anderson coal, showed 10.7 feet of drawdown from the initial 2004 water level to 2006. This well is apparently unaffected, or little affected, by drawdown in the underlying Anderson, Pawnee, and Wall coal beds at the 20-Mile Butte well nest. The amount of drawdown measured in this sandstone well may be due to a short, two-year monitoring period.

The 20-Mile Butte Anderson, Pawnee, and Wall coal wells show relatively constant rates of water-level decline over the period from 2004 to 2006. The largest water-level decline is observed in the Wall coal, the second largest is in the Anderson well, and the smallest decline is in the Pawnee coal. The water levels in these three 20-Mile Butte coals are similar at approximately 500 to 650 feet deep but the levels are different enough (a maximum of about 50 to 80 feet difference) to indicate the coals are under relatively confined hydrologic conditions and separated from the each other by intervening low-permeability units. The Wasatch well shows very little water-level decline and is apparently not in hydrologic connection with the underlying coals.

Wellhead gas pressures peaked in the Anderson well at 19.4 psi during the first quarter of 2004 and in the Pawnee coal well at 19.6 psi in the third quarter of 2006. The Wall well has remained relatively stable at nearly zero pressure. The difference in the timing and levels of gas pressures between the coals are additional evidence of hydrologic separation of the coal beds in the 20-Mile well nest.

Phillips 21-Mile Butte (21MILE)

The Phillips 21-Mile Butte monitoring well nest includes three wells: Two wells are constructed into the Big George and Wyodak coals in the Fort Union coal beds, and one well is constructed into an overlying Wasatch sandstone bed. The Big George coal at about 1,280 feet in depth is shallower than the Wyodak coal at about 1,500 feet in depth at this location. The initial water levels in these two coal zones were similar.

- The Big George coal well (21MILEBG) showed 195.7 feet of drawdown in 2006 from the initial water level. The wellhead gas pressure recorded a maximum of 0.9 psi, thus little or no gas pressure build-up at this well site was apparent. The transducer at this well malfunctioned and showed erroneously high pressure readings, but none were encountered at the well head between 2001 and 2006.

- The Wyodak coal well (21MILEWC) showed 394.1 feet of drawdown in 2006 from the initial water level. The wellhead gas pressure was a maximum of 0.9 psi, thus little or no gas pressure build-up in this well was apparent. The transducer at this site malfunctioned and showed erroneously high pressures, but none were encountered at the well head between 2001 and 2006.

- The overlying Wasatch sandstone well (21MILES), which is constructed into a sandstone bed located 197 feet stratigraphically above the top of the Big George coal, showed an increase in water level of 0.2 feet from the initial water level between 2001 and 2006. The water level in this well is relatively stable and is apparently unaffected by drawdown in the underlying Big George and Wyodak coal beds at the Phillips 21 Mile Butte well nest.

The 21-Mile Big George well shows a relatively constant rate of water-level decline over the period from 2001 to 2006. The Wyodak coal shows a rapid water-level decline from 2001 to 2003 and a slower decline rate from 2003 to 2006. The largest water-level decline is seen in the Wyodak well, which has nearly twice the drawdown of the Big George coal. The water levels in these two coals were nearly equal at 600 feet in depth in 2001, but the Wyodak well has declined from near 600 feet to more than 1,000 feet in depth, while the Big George water level is at about 800 feet deep. The difference in water-level depths between the coals and the rapid decline rate in the Wyodak well are evidence that these coals are generally confined and separated from the each other by relatively low-permeability intervening units (confining units or aquitards). The Wasatch sandstone well is also hydraulically separated from the underlying coals.

Stuart Federal #42-31B Wells; Section 31 Wells (447131)

The Stuart Section 31 (447131) monitoring well nest includes three wells: One well is constructed into the Wyodak coal, one well into the Fort Union underburden sandstone located beneath the Wyodak coal, and one well into an overlying Wasatch sandstone bed.

- The Wyodak coal well (447131A2) became dry after more than 320.8 feet of drawdown from an initial water-level measurement of 331.7 feet to 561.9 feet in depth by 2001. High wellhead gas pressures prevented manual measurements for the remainder of the monitoring period, but transducer data shows water levels near the bottom just below 650 feet in depth, therefore the well was mostly dry by the end of 2006. The wellhead gas pressure peaked at a maximum of 37.9 psi from 1998 to 2006.

- The underlying Fort Union underburden sandstone well (447131A3), which is constructed into a sandstone bed located 14 feet stratigraphically beneath the base of the Wyodak coal, showed 248.7 feet of drawdown from the initial water level to 2006. This well is impacted by drawdown in the overlying Wyodak coal bed.

- The overlying Wasatch sandstone well (447131A1), which is constructed into a sandstone bed located 89 feet stratigraphically above the top of the Wyodak coal, showed 58.9 feet of drawdown from the initial water level to 2006. This well is apparently impacted by drawdown in the underlying Wyodak coal bed.

The Wyodak wellhead gas pressure reached at a maximum of almost 38.0 psi and this peak occurred in late June 2001. The water-level in the Wyodak coal well had declined to below about 650 feet deep at the same time, equaling about 320.8 feet of drawdown or about 139 psi of water pressure reduction in the coal bed.

The Fort Union underburden sandstone well showed a relatively steady rate of water-level decline from 336.0 to 580.0 feet in depth over the period from 1998 to 2004, and with drawdown remaining relatively stable at about 580 feet deep since then. The water levels in the Wyodak coal and underburden sandstone well nest are within 75 feet of each other and the drawdown curves have a similar geometry indicating probable hydrologic connection.

The Wasatch sandstone well showed a slow rate of water-level decline from 1997 to January 2002, dropping from 253 to 257 feet deep. Decline rates increased afterward dropping from 257 to 320 feet deep from 2002 to 2006. Since drawdown in the coal well began mid-1997, and the drawdown rate in the Wasatch sandstone well did not sharply rise until 2002, is seems unclear as to which water production is affecting this water-bearing zone. The Wasatch well may be hydraulically connected to the Wyodak coal, but further analysis of water production records of nearby CBNG wells will be necessary before drawing conclusions. A CBNG well was installed in the same quarter-quarter by Lance in 2002 (Stuart Federal #42-31-4471). Rapid drawdown in the Wasatch sandstone corresponds closely with the onset of water production in this nearby CBNG well.

Durham Ranch Federal #42-14B Well; Section 14 Well (447214)

The Durham Ranch Section 14 (447214) monitoring well nest includes two wells: One well is constructed into the Wyodak coal and one well into an overlying Wasatch sandstone bed.

- The Wyodak coal well (447214A1) became dry after 548 feet of drawdown from an initial water level measurement of 268.0 feet deep. The last manual reading of 642.1 feet deep was recorded in 2002 before high wellhead gas pressures prevented further water-level readings. The well was found to be dry in 2004, indicating the water level was below the total well depth of 816 feet. The maximum wellhead gas pressure recorded between 1998 and the end of 2006 was 28.1 psi. Erratic water levels recorded by the transducer generally coincided with the development of high pressure in the coal monitoring zone.

- The overlying Wasatch sandstone well (447214A2), which is constructed into a sandstone bed located 26 feet stratigraphically above the top of the Wyodak coal, showed 21.8 feet of drawdown from the initial water level of 24.6 feet in 1998 to 46.4 feet deep in 2006 for this 690-foot deep well.

The difference in initial water levels between the Wyodak coal and Wasatch sandstone wells in 1998 was about 245 feet with the initial water level for the coal well at about 270 feet deep and the initial sandstone well level at about 25 feet deep. As stated above, water levels in the coal well have dropped dramatically and steadily whereas the sandstone water level has dropped only about 25 feet and in an erratic fashion. These conditions indicate there is little or no hydraulic communication between the sandstone well and the Wyodak coal well.

Durham Ranch Federal #23-6B Well; Section 6 Well (457106)

The Durham Ranch Section 6 (457106) monitoring well nest includes two wells: One well is constructed into the Wyodak coal and one well into an overlying Wasatch sandstone bed.

- The Wyodak coal well (457106C1) became dry with over 199 feet of drawdown from an initial water level of 118.2 feet to 317.5 feet deep by 2003. There is an unresolved data discrepancy for this BLM well with a reported total depth of 363 feet, a water-level reading of over 317 feet deep, and the well is reported as "dry." The wellhead gas pressure peaked at a maximum of 83.7 psi from 1997 to 2005. Erratic water-level readings recorded by the transducer generally coincided with the development of high pressure in the coal monitoring zone, however, water level-trends were still discernable but lacking in accuracy.

- The overlying Wasatch sandstone well (457106C2), which is constructed into a sandstone bed located 43 feet stratigraphically above the top of the Wyodak coal, showed 57.3 feet of drawdown from the initial water level to 2006. This well is affected by drawdown in the underlying Wyodak coal bed.

Wellhead gas pressure peaked in the Wyodak well at 83.7 psi during June 1999 and at about the same time, the coal water level had declined to approximately 131 to 139 feet deep. Both of the coal and sandstone wells experienced drawdown from 1997 to 2006. The similarity of the two initial water level depths in 1997 (96.0 feet for the sandstone versus 119.0 feet for the coal) and the similar geometry of the drawdown curves for the two wells suggests substantial hydraulic communication between the two monitoring zones in this well nest.

Bar 76 LL Federal #1-42-1 Well (457301)

The Bar 76 (457301) monitoring well nest includes two wells: One well is constructed into the Wyodak coal and the other well into an overlying Wasatch sandstone bed.

- The Wyodak coal well (457301A1) recorded 581.2 feet of drawdown between 1998 and 2006 from the initial water level of 161.8 feet. The wellhead gas pressure peaked at a maximum of 61.0 psi during this period.

- The overlying Wasatch sandstone well (457301A2), which is constructed into a sandstone bed located 47 feet stratigraphically above the top of the Wyodak coal, showed 218.4 feet of drawdown by 2006 from the initial water level of 176.0 feet deep in 1997. Water-level readings with the pressure transducer in this well were erratic beginning in 2003, but manual measurements for this well have recorded a smooth water-level drawdown curve.

During June 2003, when the wellhead gas pressure peaked in the Wyodak well at 61.0 psi, the Wyodak water level had declined from approximately 162 feet to 585 feet deep. Both of the wells show drawdown occurring between 1997 and 2006. The closeness of the two initial water level depths in September 1997 (176.0 feet for the sandstone versus 161.8 feet for the coal) and the similar geometry of the drawdown curves for the two wells indicate that some hydraulic connection exists between the two units monitored in the Bar 76 well nest. Both wells show an increased rate of drawdown starting in 2001. It is interesting to note that the initial water levels in 1997 were 14 feet higher in the Wyodak well than in the Wasatch well because most of the other monitoring well nests show Wasatch water levels are commonly higher than the coal water levels. At this Bar 76 (457301) well nest, the initial confining pressure in the Wyodak coal was higher than the initial confining pressure in the overlying Wasatch sandstone well.

South Cordero Well (467106C1)

The South Cordero (467106C1) monitoring well is the only well at this location and it is constructed into the Wyodak coal. There is no Wasatch sandstone monitoring well at this site.

- The Wyodak coal well (467106C1) showed 199.3 feet of drawdown from the initial water level to 2006. The wellhead gas pressure peaked at a maximum of 55.3 psi from 1995 to 2005.

This well is located on the eastern portion of the basin (Figure 1) and was one of the earlier wells added to the BLM deep monitoring well network.

This well had an initial water level of 159.0 feet deep in June 1995. In March 1997, when the wellhead gas pressure peaked at 55.3 psi, the Wyodak water level had declined by only 29 feet to 188.0 feet deep. Since March 1997, both the water level and gas pressure in this well has continued to decline. Wellhead gas pressure readings were trending negative (vacuum condition) at the end of 2006 as a result of blowers being installed on the CBNG production wells in the nearby area that are used to enhance gas recovery. This condition is common to wells located on the eastern margin of the basin in Campbell County.

Federal #1-14-25 Well; Section 25 Wells (467225)

The Section 25 (467225) monitoring well nest includes two wells: One well is constructed into the Wyodak coal and one well into an overlying Wasatch sandstone bed.

- The Wyodak coal well (467225C1) has become dry with over 414 feet of drawdown from an initial water level of 48.3 feet to 463.2 feet in depth by 2004. There is an unresolved data discrepancy for this BLM well with a reported total depth of 525 feet, a water-level reading of over 463 feet deep, and the well is reported as "dry." The wellhead gas pressure peaked at a maximum of 63.8 psi from 1996 to 2006. The transducer readings in this well have been periodically erratic since 2003.

- The overlying Wasatch sandstone well (467225C2), which is constructed into a sandstone bed located 250 feet stratigraphically above the top of the Wyodak coal, showed 1.6 feet of drawdown from the initial water level in 1996 to 2006. This well is apparently not affected by drawdown in the underlying Wyodak coal bed.

When the wellhead gas pressure peaked in the Wyodak well at 63.8 psi in January 2001, the Wyodak water level had declined from approximately 48 feet to 200 feet deep. The Wyodak well shows steady drawdown occurring from 1996 to 2006. The two initial water-level depths in November 1996 (28.1 feet for the sandstone versus 48.3 feet for the coal) and the water-level curves for the two wells show no evidence of hydrologic connection in the Section 25 well nest. It is interesting to note that in 1996, the initial water levels in the two wells were only 20 feet apart. Wellhead gas pressure readings in the coal well were trending negative (vacuum condition) at the end of 2006 as a result of blowers being installed on nearby CBNG production wells to enhance gas production in the area.

Durham Ranch State #2-12-36 Well; Amoco Section 36 Well (467236B1)

Monitored water-level and wellhead gas pressure data are not available for this Wyodak coal well.

North Cordero Well (477119C1)

The North Cordero (477119C1) monitoring well is the only well at this location and it is constructed into the Wyodak coal. There is no Wasatch sandstone monitoring well at this coal well location.

- This Wyodak coal well (477119C1) became dry by 2000 with 53 feet of drawdown from an initial water level of 245.0 feet to 298.0 feet deep. There is an unresolved data discrepancy for this BLM well with a reported total depth of 392 feet, a water-level reading of 298 feet deep, and the well is reported as "dry." The wellhead gas pressure peaked at a maximum of 33.8 psi from 1995 to 2006.

In April 1996, when the wellhead gas pressure peaked in the Wyodak well at almost 34 psi, the Wyodak water level had declined from approximately 245 feet to 291 feet deep (46 feet of drawdown). Since that time, the gas pressure has declined. Wellhead gas pressure readings have been negative (vacuum condition) since late 2001 as a result of blowers being installed on nearby CBNG production wells to enhance gas production in this area.

Amoco Well WCH 5 West Campbell Hydrological Well (477236B1)

The Amoco Section 36 (477236B1) monitoring well is the only well at this location and is constructed into the Wyodak coal bed. There is no Wasatch sandstone monitoring well at this coal well location.

- This Wyodak coal well (477236B1) became dry by 2003 with over 253 feet of drawdown from an initial water level of 241.0 feet to 494.5 feet deep. The wellhead gas pressure peaked at a maximum of 34.1 psi from 1995 to 2006.

When the wellhead gas pressure peaked in October 1997 at slightly over 34 psi, the water level in the well had declined from about 242 to 295 feet deep (53 feet of drawdown). This was at a decline in the formation water head pressure in this well of about 23 psi.

All Night Creek (ANC)

The All Night Creek (ANC) monitoring well nest includes five wells: One well is constructed into the Big George coal and the other four wells are constructed into a series of overlying Wasatch sandstone beds.

- The Big George coal well (ANCC) showed 476.2 feet of drawdown from the initial water level to 2006. The wellhead gas pressure peaked at a maximum of 48.5 psi from 2001 to 2006. This well has one of the greatest drawdowns in water levels measured in the BLM deep monitoring well network.

- The closest overlying Wasatch sandstone well (ANCS), which is constructed into a sandstone bed located 124 feet stratigraphically above the top of the Big George coal, showed a water-level rise of 26.1 feet from the initial water level in 2001 to 2006. This well is apparently not affected by drawdown in the underlying Big George coal bed.

- Another shallow overlying Wasatch sandstone well (ANCSS), which is constructed into a sandstone bed located 344 feet stratigraphically above the top of the Big George coal, showed 2.7 feet of drawdown from the initial water level in 2002 to 2006. This well is also apparently not affected by drawdown in the underlying Big George coal bed.

- Another very shallow overlying Wasatch sandstone well (ANCVSS), which is constructed into a sandstone bed situated 564 feet stratigraphically above the top of the Big George coal, showed a water-level rise of 0.3 feet from the initial water level in 2002 to 2006. This well is also apparently not affected by drawdown in the underlying Big George coal bed.

- Another very very shallow Wasatch sandstone well (ANCVVSS), which is constructed into a sandstone bed located 744 feet stratigraphically above the top of the Big George coal, showed a water-level rise of 0.6 feet from the initial water level in 2002 to 2006. This well is also apparently not affected by drawdown in the underlying Big George coal bed.

During October 2003, when the wellhead gas pressure peaked in the Big George well at over 48 psi, the Big George water level had declined from approximately 440 feet to 846 feet deep (over 400 feet of drawdown). The water-level curves for the four Wasatch sandstone wells showed three wells with water-level rises and one well with less than 3 feet of decline. These data show no evidence of hydrologic connection in the All Night Creek well nest.

Barton Monitoring Wells (BARTON)

The Barton (BARTON) monitoring well nest includes two coal wells: One well is constructed into the shallower Cook coal and the other well into the deeper Wall coal. There is no Wasatch sandstone monitoring well associated with the two Barton coal wells at this location.

- The Cook coal well (BARTONC) showed 154.7 feet of drawdown from the initial water level in 2002 to 2006. The wellhead gas pressure peaked at a maximum of 0.2 psi from 2002 to 2006.

- The Wall coal well (BARTONW) showed 12.6 feet of drawdown from the initial water level in 2002 to 2006. The wellhead gas pressure peaked at a maximum of 1.2 psi from 2002 to 2006.

For the monitoring period from 2002 to 2006, the wellhead gas pressures in both the Cook and Wall wells remained nearly zero. The Cook water level declined from approximately 201 feet to 213 feet deep over the monitoring period from 2002 to 2006. During the same period, the Wall water level showed a larger decline from approximately 366 feet to 506 feet deep (about 140 feet of drawdown). The water-level curves for the two wells show no evidence of hydrologic connection in the Barton well nest.

Blackbird Coleman (BBIRD)

The Blackbird Coleman (BBIRD) monitoring well nest includes three wells: One well is constructed into the shallower Big

George coal, another well into the deeper Wyodak coal, and one well into an overlying Wasatch sandstone bed.

- The Big George coal well (BBIRDBG) showed 38.3 feet of drawdown from the initial water level in 2002 to 2004. The wellhead gas pressure peaked at a maximum of 0.4 psi from 1999 to 2004.

- The Wyodak coal well (BBIRDC) showed 69.6 feet of drawdown from the initial water level in 2000 to 2006. The wellhead gas pressure peaked at a maximum of 0.5 psi from 2000 to 2006.

- The overlying Wasatch sandstone well (BBIRDS), which is constructed into a sandstone bed located 736 feet stratigraphically above the top of the Wyodak coal and 448 feet above the top of the Big George coal, showed 0.39 feet of drawdown from the initial water level in 2000 to 2006. BBIRDS is not affected by the drawdown in the underlying Wyodak and Big George coal beds.

For the monitoring period from 2000 to 2006, the wellhead gas pressures in both the Big George and Wyodak wells remained nearly zero. The Big George water level rose from 489 to 483 feet deep (6 feet) from July 2000 to August 2001. Then the Big George level declined from approximately 483 feet to 527 feet deep over the monitoring period from August 2001 to September 2004 (end of data available). During the same period, the Wyodak water level rose from 371 to 361 feet deep (10 feet) from July 2000 to August 2001, and then declined from approximately 361 feet to 441 feet deep (about 140 feet of drawdown) from August 2001 to 2006.

The plotted Big George and Wyodak water-level curves mirror each other in shape; however, the two levels show a nearly constant separation with the Big George level being over 100 feet deeper than the Wyodak level. The water-level curves for the two coal wells show no evidence of hydrologic connection with the Wasatch sandstone well in the Blackbird Coleman well nest.

Bear Draw Unit (BDU)

The Bear Draw Unit (BDU) monitoring well nest includes two wells: One well is constructed into the Big George coal and the other well into an overlying Wasatch sandstone bed.

- The Big George coal well (BDUC) showed 10.3 feet of drawdown from the initial water level in March 2006 to December 2006. The wellhead gas pressure peaked at a maximum of 0.2 psi in 2006. A depth of 2,204 feet is reported for the top of Big George coal bed in this well.

- The overlying Wasatch sandstone well (BDUS), which is constructed into a sandstone bed located 153 feet stratigraphically above the top of the Big George coal, showed 14.1 feet of drawdown from the initial water level in March 2006 to December 2006. This well is apparently affected by drawdown in the underlying Big George coal bed.

During the period from March 2006 to December 2006, the wellhead gas pressures in the Big George well remained nearly zero. The Big George water level declined from approximately 495 to 505 feet (about 10 feet of drawdown) over the monitoring period from March to December 2006. During the same time, the Wasatch level declined from approximately 500 to 514 feet deep (about 14 feet of drawdown). The water levels measured in both wells were at nearly identical depths. The water-level curves for the two wells show no large drawdowns over the short, ten-month monitoring period. However, the Big George and Wasatch wells are hydrologically connected in the Bear Draw Unit well nest.

Phillips Beaver Federal (BEAVFED)

The Phillips Beaver Federal (BEAVFED) monitoring well nest includes two wells: One well is constructed into the Big George coal and the other into an overlying Wasatch sandstone bed.

- The Big George coal well (BEAVFEDBG or BEAVFEDC) showed 241.3 feet of drawdown from the initial water level in 2003 to 2006. The wellhead gas pressure peaked at a maximum of 4.1 psi from 2003 to 2006.

- The overlying Wasatch sandstone well (BEAVFEDS), which is constructed into a sandstone bed located 561 feet stratigraphically above the top of the Big George coal, showed only 4.6 feet of drawdown from the initial water level from 2003 to 2006. This well is not apparently affected by drawdown in the underlying Big George coal bed.

The wellhead gas pressures were very low in the Big George well and barely exceeded 4 psi only in August 2003 during the time from 2003 to 2006. By 2006, the gas pressure had declined to 1 psi. The Big George water level steadily declined from 331 to 572 feet deep (241 feet of drawdown) during the period 2003 to 2006. The water level in the Wasatch well remained relatively steady about at about 245 feet deep. The Wasatch well shows no clear evidence of hydrologic connection with the underlying Big George coal in the Phillips Beaver Federal well nest.

Big Cat (BIGCAT)

The Big Cat (BIGCAT) monitoring well nest includes two wells: One well is constructed into the Big George coal and one well into a Wasatch sandstone bed.

- The Big George coal well (BIGCATBG or BIGCATC) showed 486.7 feet of drawdown from the initial water level in 2003 to 2006. The wellhead gas pressure peaked at a maximum of 1.0 psi from 2003 to 2006.

- The overlying Wasatch sandstone well (BIGCATS), which is constructed into a sandstone bed located 1,082 feet stratigraphically above the top of the Big George coal bed, showed 0.7 feet of drawdown from the initial water level in 2003 to 2006. BIGCATS is not affected by the nearly 500 feet of drawdown in the underlying Big George coal bed.

The wellhead gas pressure peaked at 1 psi in the coal well during August 2005. The Big George water level remained relatively steady from July 2003 to April 2004. From April 2004 to 2006, the Big George water level showed a relatively rapid drawdown from 243 to 686 feet deep (443 feet of drawdown). The water level in the Wasatch sandstone well remained relatively steady at about 356 feet deep. The Wasatch sandstone well is not hydrologically connected to the underlying Big George coal in the Big Cat well nest.

Bowers Oil/Gas, Inc. (BOG) State #4-36 Well (BOWERS)

The Bowers Oil & Gas, Inc. State #4-36 (BOWERS) monitoring well nest includes five wells: One well is constructed into the Wyodak coal and the other four wells are constructed into a series of overlying Wasatch sandstone beds.

- The Wyodak coal well (BOWERSC) showed 234.1 feet of drawdown from the initial water level in 1998 to 2006. The wellhead gas pressure peaked at a maximum of 1.7 psi from 1998 to 2006.

- The overlying Wasatch sandstone well (BOWERSS), which is constructed into a sandstone bed located 117 feet stratigraphically above the top of the Wyodak coal, showed a water-level rise of 0.5 feet from the initial water level in 2002 to 2006. This well is not apparently affected by drawdown in the underlying Wyodak coal.

- The shallow Wasatch sandstone well (BOWERSSS), which is constructed into a sandstone bed located 272 feet stratigraphically above the top of the Wyodak coal, showed 0.4 feet of drawdown from the initial water level in 2002 to 2006. This well is not affected by drawdown in the underlying Wyodak coal.

- The very shallow Wasatch sandstone well (BOWERSVSS), which is constructed into a sandstone bed located 362 feet stratigraphically above the top of the Wyodak coal, showed a water-level rise of 0.2 feet from the initial water level in 2002 to 2006. This well is not affected by drawdown in the underlying Wyodak coal bed.

- The very shallow Wasatch sandstone well (BOWERSVVSS), which is constructed into a sandstone bed located 632 feet stratigraphically above the top of the Wyodak coal, showed a water-level rise of 1.1 feet from the initial water level in 2002 to 2006. This well is not affected by drawdown in the underlying Wyodak coal bed.

In September 2000, the wellhead gas pressure peaked at 1.7 psi when the water level in the Wyodak well was about 500 feet deep. The Wyodak water level showed steady drawdown from about 420 to 653 feet deep (433 feet of drawdown) over the period from 1998 to 2005. The water levels in the four overlying Wasatch sandstone wells remained relatively steady at about 58 feet (VVSS), 256 feet (VSS), 302 feet (SS), and 332 feet (S) deep. The four Wasatch sandstone wells are not hydrologically connected to the underlying Wyodak coal and the Wasatch wells have different water levels, which indicate that the four sandstone beds are not hydrologically connected to each other.

Buffalo Southeast (BUFFSE)

The Buffalo Southeast (BUFFSE) monitoring well nest includes five wells: One well is constructed into the Smith coal and the other four wells are constructed into a series of overlying Wasatch sandstone beds.

- The Smith coal well (BUFFSEC) showed 28.8 feet of drawdown from the initial water level in 2002 to 2006. The wellhead gas pressure peaked at a maximum of 1.0 psi from 2001 to 2006.

- The overlying Wasatch sandstone well (BUFFSES), which is constructed into a sandstone bed located 90 feet stratigraphically above the top of the Smith coal, showed a water-level rise of 9.8 feet from the initial water level in 2001 to 2006. This well is not affected by drawdown in the underlying Smith coal bed.

- The shallow Wasatch sandstone well (BUFFSESS), which is constructed into a sandstone bed located 993 feet stratigraphically above the top of the Smith coal, showed a water-level rise of 11.3 feet from the initial water level in 2002 to 2006. This well is also not affected by drawdown in the underlying Smith coal bed.

- The very shallow Wasatch sandstone well (BUFFSEVSS), which is constructed into a sandstone bed located 1,358 feet stratigraphically above the top of the Smith coal, showed a water-level rise of 0.03 feet from the initial water level in 2002 to 2006. This well is also not affected by drawdown in the underlying Smith coal bed.

- The very shallow Wasatch sandstone well (BUFFSEVVSS), which is constructed into a sandstone bed located 1,458 feet stratigraphically above the top of the Smith coal, showed 3.2 feet of drawdown from the initial water level in 2002 to 2006. This well is also not affected by drawdown in the underlying Smith coal bed.

In May 2005, the wellhead gas pressure peaked at 1 psi when the water level in the Smith well was about 305 feet deep. The water level in the Smith coal well showed steady drawdown from about 277 to 306 feet deep (28 feet of drawdown) over the period from 2001 to 2006. The water levels in the four overlying Wasatch wells remained relatively stable at about 50 feet (VVSS), 144 feet (VSS), 332 feet (S), and 420 feet (SS) deep. It is interesting to note that the water level (420 feet deep) in the Wasatch shallow sandstone well (BUFFSESS) is generally deeper than the Wasatch sandstone well (BUFFSES) at 332 feet deep. The overlying four Wasatch sandstone wells are not hydrologically connected to the underlying Wyodak coal and the Wasatch wells have four different water levels, which indicate the sandstone beds are not hydrologically connected to each other.

Bull Creek (BULLCRK)

The Bull Creek (BULLCRK) monitoring well nest includes two wells: One well is constructed into the Anderson coal and the other well is constructed into an overlying Wasatch sandstone bed.

- The Anderson coal well (BULLCRKC) showed 17.1 feet of drawdown from the initial water level in 2005 to 2006. The wellhead gas pressure peaked at a maximum of 0.8 psi from 2005 to 2006.

- The overlying Wasatch sandstone well (BULLCRKS), which is constructed into a sandstone bed located 100 feet stratigraphically above the top of the Anderson coal, showed 8.4 feet of drawdown from the initial water level in 2005 to 2006. This well may be affected by drawdown in the underlying Anderson coal bed during the first two years of monitoring (2005 to 2006).

The wellhead gas pressure peaked at 0.8 psi in March 2006 in the Anderson well. The Anderson water level remained steady at about 215.0 feet from November 2005 to February 2006, but the rate of drawdown slightly increased in February 2006. The Wasatch water level declined from 92 to 100 feet over the period from 2005 to 2006. The rate of drawdown increased slightly in the Wasatch well since March 2006. The slightly steeper decline rate of the water level in the Anderson well in February 2006 was followed one month later by a slightly increased rate of drawdown in the Wasatch well.

Bullwacker (BULLWACK)

The Bullwacker (BULLWACK) monitoring well nest includes two wells: One well is constructed into the Big George coal and one well into an overlying Wasatch sandstone bed.

- The Big George coal well (BULLWACKC) showed 592.0 feet of drawdown from the initial water level in 2002 to 2006. The wellhead gas pressure peaked at a maximum of 311.1 psi from 2002 to 2006.

- The overlying Wasatch sandstone well (BULLWACKS), which is constructed into a sandstone bed located 100 feet stratigraphically above the top of the Big George coal, showed 139.6 feet of drawdown from the initial water level to 2006. This well is affected by drawdown in the underlying Big George coal bed.

The extremely high (over 300 psi), wellhead gas pressure in this Big George coal well affected the monitoring of both gas pressures and water levels in this well. The data collection was fragmented because of high-pressure (over-range) damage to the sensors and limited physical access for safely opening the well head during monitoring events. The Big George wellhead gas pressure peaked at about 311 psi in the fourth quarter of 2003. The Wasatch water level showed relatively steady decline from 25 to 165 feet deep (140 feet of drawdown) from 2002 to 2006. The Big George water level showed relatively rapid drawdown from about 93 to 685 feet deep (592 feet of drawdown) during the same period. The Wasatch sandstone well is hydrologically connected to the underlying Big George coal at the Bullwacker well nest.

Cedar Draw (CEDAR)

The Cedar Draw (CEDAR) monitoring well nest includes two wells: One well is constructed into the Wall coal and the other well into an overlying Wasatch sandstone bed.

- The Wall coal well (CEDARC) showed 196.6 feet of drawdown from the initial water level in 2004 to 2006. The wellhead gas pressure peaked at a maximum of 0.2 psi from 2004 to 2006.

- The overlying Wasatch sandstone well (CEDARS), which is constructed into a sandstone bed located 107 feet stratigraphically above the top of the Wall coal, showed 105.4 feet of drawdown from the initial water level in 2004 to 2006. This well has been affected by drawdown in the underlying Wall coal bed.

The wellhead gas pressure in the Wall well peaked at the very low level of 0.2 psi in October 2004 but has remained at nearly zero from 2004 to 2006. The water levels in both the Wall and Wasatch wells declined over the monitoring period from 2004 to 2006. During this period, the Wall water level declined from 228 to 447 feet deep (219 feet of drawdown) and the Wasatch level went down from 229 to 345 feet deep (116 feet of decline). The water levels in the two wells started out at nearly the same level in 2004 and showed a nearly identical drawdown curve from 2004 to 2006. These water-level data indicate the Wall and Wasatch are hydrologically connected at the Cedar Draw well nest.

Coal Gulch Unit Wells (COALGULCH or CGU)

The Coal Gulch (COALGULCH) monitoring well nest includes two coal wells: One well is constructed into the combined Big George-Lower Smith coals and the other well is constructed into the Smith coal. There is no Wasatch sandstone monitoring well associated with these two coal wells at this location.

- The combined Big George-Lower Smith coal well (COALGULCHBG) is completed from 1,637 to 1,670 feet deep (Lower Smith) and from 1,796 to 1,854 feet deep (Big George) and showed 27.8 feet of drawdown from the initial water level in 2005 to 2006. The wellhead gas pressure peaked at a maximum of 2.2 psi from 2005 to 2006.

- The Smith coal well (COALGULCHS) is completed from 1,481 to 1,498 feet deep and showed 29.2 feet of drawdown from the initial water level in 2005 to 2006. The wellhead gas pressure peaked at a maximum of 21.9 psi in October 2005 over the period from 2005 to 2006.

These two coal wells show drawdowns of less than 30 feet each from manual readings over the period from 2005 to 2006. The water levels in these wells are generally very close to the identical depth showing that the two coal wells are hydrologically connected at the Coal Gulch well nest location.

Dilts (DILTS)

The Dilts (DILTS) monitoring well nest includes two wells: One well is constructed into the Wyodak coal and one well into an overlying Wasatch sandstone bed.

- When the Wyodak coal well (DILTSC) became dry by 2000, the drawdown was 45.5 feet from the initial water level of 340.6 feet deep in 1999. The wellhead gas pressure peaked at a maximum of 92.6 psi in February 2000 over the period from 1999 to 2006. The gas pressure in this well has declined since the peak.

- The overlying Wasatch sandstone well (DILTSS), which is constructed into a sandstone bed located 280 feet stratigraphically above the top of the Wyodak coal, showed 3.2 feet of drawdown from the initial water level in 1999 to 2006. This well is not apparently affected by drawdown in the underlying Wyodak coal bed.

When the wellhead gas pressure peaked in February 2000, the water level in the Wyodak well was about 367 feet deep (36 feet of drawdown or 15.6 psi confining pressure decline). The Wyodak well went dry in April 2000 at a water level of 386 feet deep (45.5 feet). The water level in the overlying Wasatch well remained relatively steady at about 120 to 125 feet deep. The Wasatch sandstone well is not hydrologically connected to the underlying Wyodak coal at the Dilts well nest location.

Double Tank (DTANK)

The Double Tank (DTANK) monitoring well nest includes two coal wells: One well is constructed into the Big George coal and the other well is constructed into the Wyodak coal. There is no Wasatch sandstone monitoring well associated with these two coal wells at the Double Tank well nest location.

- The Big George coal well (DTANKBG) showed 420.4 feet of drawdown from the initial water level in 2002 to 2006. The wellhead gas pressure peaked at a maximum of 1.2 psi in February 2003 over the period from 2002 to 2006.

- The Wyodak coal well (DTANKWY) showed 240.7 feet of drawdown from the initial water level in 2002 to 2006. The maximum wellhead gas pressure peaked at 0.5 psi in June 2003 over the period from 2002 to 2006.

The wellhead gas pressures were very low (less than 1.5 psi) in the two coal wells. The Big George water level steadily declined from 295 to 751 feet deep (456 feet of drawdown) from 2002 to May 2004, the level then rose to 679 feet deep by March 2005, and declined again to 715 feet deep by the end of 2006. The water level in the Wyodak well declined rapidly from 149 feet deep in December 2002 to 320 feet deep by March 2003. The Wyodak level steadily declined from 320 feet in March 2003 to 389 feet deep by the end of 2006.

The initial December 2002 to March 2003 water level declines in the two coal wells closely match with the water level in the Big George well remaining about 100 feet deeper than the Wyodak water level. These data indicate that there is some hydrologic connection between the Wyodak and the underlying Big George coal, although there is not a direct correlation between the two wells during the declining water levels after March 2003.

Dry Willow Well (DRYWILLS)

The Dry Willow (DRYWILLS) monitoring well is constructed into a Wasatch sandstone bed. There is no Fort Union coal bed well directly associated with this well at the Dry Willow sandstone well at this location.

- The DRYWILLS Wasatch sandstone well was completed with the main water-bearing zone from 148 to 202 feet deep. The well showed 1.4 feet of drawdown from the initial water level in 1999 to 2006. This well is not apparently affected by any drawdown in the underlying and nearby coal beds.

The water level in this Wasatch sandstone well remained relatively stable with no clear trend from 90 to 95 feet in depth over the period from 1999 to 2006.

Echeta Coal Test Well (ECHETA)

The Echeta Coal Test Well (ECHETA) monitoring well is constructed into the Big George or "Echeta" coal. There is no Wasatch sandstone monitoring well associated directly with the Echeta Coal Test Well.

- The Big George or "Echeta" coal well (ECHETA) showed 78.9 feet of drawdown from the initial water level in 1999 to 2006. During the 1999 to 2006 monitoring period, the wellhead gas pressure peaked at a maximum of 14.0 psi in October 2005 when the water level was at 297 feet deep in the well.

The water level in this Big George or "Echeta" coal well steadily declined from 246 to 325 feet in depth over the period from 1999 to 2006. The maximum wellhead gas pressure peaked at 14.0 psi occurred in October 2005 with the coal water level at 297 feet deep in the well (51 feet of drawdown).

Gilmore Oil & Gas Artesian Unit #1 Well (GILMORE)

The Gilmore Oil & Gas Artesian Unit #1 (GILMORE) monitoring well is constructed into the Big George coal. There is no Wasatch sandstone monitoring well directly associated with the Gilmore coal well.

- The Big George coal well (GILMORE) showed 36.6 feet of drawdown from the initial water level in 1998 to 2006. The wellhead gas pressure peaked at a maximum of 0.3 psi from 1998 to 2006.

The wellhead gas pressure remained at nearly zero from 1998 to 2006. The water level in this Big George well steadily declined from 369 to 410 feet in depth over the period 1998 to 2006.

Hoe Creek (HOE)

The Hoe Creek (HOE) monitoring well nest includes two wells: One well is constructed into the Wyodak coal and one well into an overlying Wasatch sandstone bed.

- The Wyodak coal well (HOEC) showed more than 653 feet of drawdown from the initial water level of 231.25 feet in 1998. The wellhead gas pressure peaked at a maximum of 60.4 psi from 1998 to 2006.

- The overlying Wasatch sandstone well (HOES), which is constructed into a sandstone bed located 620 feet stratigraphically above the top of the Wyodak coal, showed about 0.5 feet of drawdown from the initial water level in 1998 to 2006. This well is not affected by drawdown in the underlying Wyodak coal bed.

The Wyodak wellhead gas pressure peaked in April 2000 and then steadily declined afterwards. The wellhead gas pressure readings were trending negative (vacuum condition) by the end of 2006 as a result of blowers being installed on the nearby CBNG production wells that are used to enhance gas recovery. This condition is common to wells located along the eastern margin of the basin in Campbell County.

The Wasatch water level remained relatively steady at about 100 feet deep over the period 1998 to 2006. The Big George water level remained relatively steady with a slow decline from 225 to 241 feet deep from January 1998 to February 2000. From February 2000 to August 2002, the Big George water level showed a relatively rapid drawdown from 241 to 875 feet deep (634 feet of drawdown). Since August 2002, the Big George water level declined at a slow rate from 875 to 884 feet deep by the end of 2006. The Wasatch sandstone well is not hydrologically connected to the underlying Big George coal at the Hoe Creek well nest location.

Huber Lone Tree Wells (HUBERLT)

The Huber Lone Tree (HUBERLT) monitoring well nest includes two wells: One well is constructed into the Wyodak-Anderson coal and one well into an overlying Wasatch sandstone bed.

- The Wyodak-Anderson coal well (HUBERLTC) became dry by 2005 and the observed drawdown was greater than 198 feet from the initial water level of 453.1 feet in 2000. The wellhead gas pressure peaked at a maximum of 66.7 psi in May 2002 over the period from 2000 to 2006.

- The overlying Wasatch sandstone well (HUBERLTS), which is constructed into a sandstone bed located 117 feet stratigraphically above the top of the Wyodak-Anderson coal, showed 6.0 feet of drawdown from the initial water level in 2000 to 2006. This well is not apparently affected by drawdown in the underlying Wyodak-Anderson coal bed.

The maximum wellhead gas pressure in the coal well peaked in May 2002 and steadily declined as a decay-type curve since then. The Wasatch water level remained relatively steady between 289 and 292 feet deep (6 feet of drawdown) over the period from 2000 to 2006. The Wyodak-Anderson water level declined from about 453 to 651 feet deep from 2002 to 2005. The Wasatch sandstone well is apparently not hydraulically connected to the underlying Wyodak-Anderson coal at this location. The 6 feet of drawdown observed in the Wasatch well may be attributed to natural causes (8 years of regional drought from 1999 to 2007) or alternatively to relatively slow leakage through low-permeability confining units (aquitards) adjacent to this sandstone bed.

Huber Lower Prairie Dog Creek Wells (HUBERPD)

The Huber Lower Prairie Dog Creek (HUBERPD) monitoring well nest includes three wells: One well is constructed into the Anderson coal and the other two wells are constructed into overlying Wasatch sandstone beds.

- The Anderson coal well (HUBERPDC) showed 439.5 feet of drawdown from the initial 2000 water level of 168.4 feet deep to 2006. The wellhead gas pressure peaked at a maximum of 45.1 psi in February 2004 over the period from 2000 to 2006.

- The overlying Wasatch sandstone well (HUBERPDS), which is constructed into a sandstone bed located 238 feet stratigraphically above the top of the Anderson coal bed, showed 5.5 feet of drawdown from the initial water level in 2000 to 2006. This well is apparently not affected by drawdown in the underlying Anderson coal bed during the first seven years of monitoring (2000 to 2006).

- The shallow Wasatch sandstone well (HUBERPDSS), which is constructed into a sandstone bed located 368 feet stratigraphically above the top of the Anderson coal bed, showed 0.71 feet of drawdown from the initial water level in 2002 to 2006. This well is not affected by drawdown in the underlying Anderson coal bed. From the fourth quarter of 2002, the water level in this well generally rose and may be associated with a surface water pond that was constructed nearby to the well and subsequently removed.

The Anderson wellhead gas pressure started to rapidly increase in late May 2003 when the water level in the coal well had declined to 504 feet deep (336 feet of drawdown). The water levels in the Wasatch sandstone well and the shallow Wasatch sandstone well remained steady at about 200 feet deep over the period from 2000 to 2006. Both Wasatch wells have nearly identical water-level depths. The water level in the Anderson coal well steadily declined from 168 to 624 feet deep from 2000 to 2006.

These data show no evidence of hydrologic connection between the Anderson coal and the two Wasatch wells at this location. The 5.5 feet of drawdown observed in the sandstone Wasatch sandstone well (HUBERPDS) may be attributed to natural causes (eight years of regional drought from 1999 to 2007) or alternatively to relatively slow leakage through low-permeability confining units (aquitards) adjacent to this sandstone bed.

Juniper Draw Wells (JUNIPER)

The Juniper Draw (JUNIPER) monitoring well nest includes three wells: One well is constructed into the Big George coal and the other two wells are constructed into overlying Wasatch sandstone beds.

- The Big George coal well (JUNIPERC) showed 583.1 feet of drawdown from the initial water level in 2001 to 2006. The wellhead gas pressure peaked at a maximum of 221.3 psi from 2001 to 2006.

- The overlying Wasatch sandstone well (JUNIPERS), which is constructed into a sandstone bed located 418 feet stratigraphically above the top of the Big George coal, showed 11.9 feet of drawdown from the initial water level in 2001 to 2006. This well may be marginally affected by drawdown in the underlying Big George coal bed during the first six years of monitoring (2001 to 2006).

- The shallow Wasatch sandstone well (JUNIPERSS), which is constructed into a sandstone bed located 908 feet stratigraphically above the top of the Big George coal, showed 0.7 feet of drawdown from the initial water level in 2002 to 2006. This well is not affected by drawdown in the underlying Big George coal bed during the first six years of monitoring (2001 to 2006).

The Big George coal well shows a relatively stable water level with slight decline from first quarter 2001 to the third quarter 2002 of about 15 feet. A very rapid rate of water-level decline level occurred from third quarter 2002 to the end of 2004 and totaled over 530 feet. The water level in the well has continued to decline but at a much slower rate since the beginning of 2005.

The water levels in these two Wasatch sandstone wells have exhibited little decline in water levels from 2001/2002 to 2006. The two sandstone water levels have remained about 90 feet apart with the sandstone well higher in water level than the shallow sandstone well. The JUNIPER Big George water level was initially about 168 to 183 feet deep and above the water levels in both of the Wasatch wells. Since the fourth quarter of 2002, the Big George water level drawdown has remained deeper than the levels in the two Wasatch wells.

The difference in water-level depths between the Big George coal and the two Wasatch wells and the rapid decline rate in the Big George coal without an apparent response in the Wasatch wells provide evidence that these coal and sandstone wells are under relatively confined hydrologic conditions at this location. The Juniper Draw wells are hydrologically separated from the each other by intervening low-permeability confining units (aquitards).

Kennedy Wells (KENNEDY)

The Kennedy (KENNEDY) monitoring well nest includes two wells: One well is constructed into the Anderson coal and the other well into an overlying Wasatch sandstone bed.

- The Anderson coal well (KENNEDYC) showed 231.1 feet of drawdown from the initial water level in 2000 to

2006. The wellhead gas pressure peaked at a maximum of 1.0 psi from 2000 to 2006.

- The overlying Wasatch sandstone well (KENNEDYS), which is constructed into a sandstone bed located 128 feet stratigraphically above the top of the Anderson coal, showed 15.6 feet of drawdown from the initial water level in 2000 to 2006. This well is apparently affected by drawdown in the underlying Anderson coal bed.

The Anderson wellhead gas pressure remained at nearly zero from 2000 to 2006. The water levels in the Wasatch well showed a slow rate of drawdown in water levels from about 271 to 287 feet deep over the period from 2000 to 2006. The water level in the Anderson coal well showed a more rapid decline rate from 406 to 598 feet deep from 2000 to November 2002 and a slower but steady decline from 598 to 636 feet deep from November 2002 to 2006. These data show evidence of some small degree of hydrologic connection between the Anderson and Wasatch wells at this Kennedy well nest.

L¼ Circle Hills Wells (LQC)

The Lower Quarter (Lower ¼) Circle Hills (LQC) monitoring well nest includes three wells: One well is constructed into the shallower Cook coal, another into the deeper Wall coal, and one well into an overlying Wasatch sandstone bed.

- The Cook coal well (LQCC) showed 9.2 feet of drawdown from the initial water level in 2005 to 2006. The wellhead gas pressure peaked at a maximum of 6.4 psi from 2005 to 2006.

- The Wall coal well (LQCC) showed a water-level rise of 0.9 feet from the initial water level in 2005 to 2006. The wellhead gas pressure peaked at a maximum of 9.7 psi from 2005 to 2006.

- The overlying Wasatch sandstone well (LQCS), which is constructed into a sandstone bed located 171 feet stratigraphically above the top of the upper coal bed (Cook), showed a water-level rise of 2.2 feet from the initial water level in 2005 to 2006. This well is not affected by drawdown in the underlying Cook or Wall coal beds.

The Cook wellhead gas pressure reached a maximum of 6.4 psi in May 2006 and the pressure has fluctuated over the period from 2005 to 2006. The Wall wellhead gas pressure showed a broad peak of about 9.7 psi during the time from May to October 2005 and has generally declined since October 2005. The water level in the Wasatch well rose from the initial 41 feet deep in April 2005 to a peak of 23 feet deep in May 2005, which was followed by a rapid decline to 38 feet deep later that month. Since May 2005, the Wasatch level remained between 36 and 39 feet deep. The Cook water level showed fluctuations from 19 to 37 feet deep with peaks and valleys over the period from 2005 to 2006. The Wall water level remained relatively steady at between 14 and 16 feet deep from 2005 to 2006. These data do not show any clear evidence of hydrologic connection between the Cook, Wall, and Wasatch wells at this L¼ Circle Hills well nest.

It is interesting to note that the shallower Wasatch well has the deepest water level (about between 36 and 39 feet deep) in this well nest compared to the water levels in the Cook well (about between 24 and 26 feet) and the Wall well (about between 14 and 16 feet deep). The deeper Wall coal also has a higher water level in the well by about 10 feet than the shallower Cook coal. These data show that the confining pressures within the coal wells are greater than in the Wasatch well and that there is potential for an upward component of vertical groundwater flow at this site. The difference between these well water levels is relatively small (maximum head of about 25 feet or 11 psi of hydrologic pressure).

Martens & Peck Section 2 Wells (MP2)

The Martens & Peck Section 2 (MP2) monitoring well nest includes two wells: One well is constructed into the Wyodak coal and one well into an overlying Wasatch sandstone bed.

- The Wyodak coal well (MP2C) showed 203.8 feet of drawdown from the initial water level in 1993 to 2006. The wellhead gas pressure peaked at a maximum of 26.8 psi in January 1997 and then declined during the period from 1993 to 2006.

- The overlying Wasatch sandstone well (MP2S), which is constructed into a sandstone bed located 26 feet stratigraphically above the top of the Wyodak coal, showed 52.9 feet of drawdown from the initial water level in 1993 to 2006. This well is apparently affected by drawdown in the underlying Wyodak coal bed.

The Wyodak wellhead gas pressure peaked at in January 1997 when the water level in the well had declined to about 275 feet deep (112 feet of drawdown or 48.5 psi confining pressure decline). The Wasatch water level generally declined at a steady rate from 52 to 105 feet deep from 1993 to 2006. The Wyodak water level declined from 163 feet deep in May 1993 to 405 feet deep in May 2004 and then the level rose from 405 feet to 368 feet deep by the end of 2006. These data indicate that hydrologic connection apparently exists between the Wyodak and Wasatch wells in this Martens & Peck Section 2 well nest location.

Martens & Peck Section 22 Wells (MP22)

The Martens & Peck Section 22 (MP22) monitoring well nest includes four wells: One well is constructed into the Wyodak coal and the other three wells are constructed into a series of overlying Wasatch sandstone beds.

- When the Wyodak coal well (MP22C) became dry by 2000, the drawdown exceeded 246 feet from the initial water level of 173.8 feet in 1993 to 2006. The wellhead gas pressure peaked at a maximum of 61.2 psi from 1993 to 2006.

- An overlying Wasatch sandstone well (MP22S), which is constructed into a sandstone bed located 38 feet stratigraphically above the top of the Wyodak coal, showed 42.5 feet of drawdown from the initial water level in 1993 to 2006. This well is apparently affected by drawdown in the underlying Wyodak coal bed with a water-level decline in this well from 84 to 126 feet in depth.

- The shallow Wasatch sandstone well (MP22SS), which is constructed into a sandstone bed located 253 feet stratigraphically above the top of the Wyodak coal, showed 1.0 feet of drawdown from the initial water level in 1998 to 2006. This well is not apparently affected by drawdown in the underlying Wyodak coal bed.

- The very shallow Wasatch sandstone well (MP22VSS), which is constructed into a sandstone bed located 358 feet stratigraphically above the top of the Wyodak coal, showed 2.6 feet of drawdown from the initial water level in 1998 to 2006. This well is not apparently affected by drawdown in the underlying Wyodak coal bed.

The MP22C Wyodak well shows a relatively constant rate of water-level decline over the period from 1993 to January 2002 from 174 to 490 feet in depth (decline of 316 feet). From January 2002 through 2006, the Wyodak water level has been rising with about 90 feet of rise to 431 feet deep.

The water levels in the three Wasatch wells are shallow (20 feet deep in MP22VSS, 38 feet in MP22SS, and from 84 to 126 feet deep in MP22S) compared to the deeper water level of the Wyodak coal well (174 feet deep initially). These data indicate the Wyodak coal and sand wells at this Martens & Peck Section 22 well nest location are under relatively confined hydrologic conditions and separated from the each other by intervening low-permeability confining units (aquitards). The water level in the MP22S well shows a relatively steady decline and is likely affected by regional CBNG development in the vicinity of this well.

Barrett Napier Wells (NAPIER)

The Barrett Napier (NAPIER) monitoring well nest includes two wells: One well is constructed into the Big George coal and the other well into an overlying Wasatch sandstone bed.

- The Big George coal well (NAPIERC) showed 121.5 feet of drawdown from the initial water level in 2001 to 2006. The wellhead gas pressure peaked at a maximum of 0.2 psi and has fluctuated at nearly zero pressure over the entire period from 2001 to 2006.

- The overlying Wasatch sandstone well (NAPIERS), which is constructed into a sandstone bed located 63 feet stratigraphically above the top of the Big George coal, showed 20.5 feet of drawdown from the initial water level in 2001 to 2006. This well is apparently affected to some degree by drawdown in the underlying Big George coal bed or regional CBNG development in the vicinity of this well.

The Wasatch water level showed a relatively steady drawdown from about 402 to 427 feet deep (25 feet of drawdown) from 2001 to 2006 and then the level rose a few feet during 2006. The Big George water level showed a steady decline from 428 feet to 551 feet deep from 2001 to 2006. However, the coal well did not show a corresponding water-level rise as observed in the overlying sandstone well. These data indicate some degree of hydrologic connection between the Big George and Wasatch wells in this Barrett Napier well nest during the first six years of monitoring (2001 to 2006).

North Gillette Wells (NGILL)

The NGILL monitoring well nest includes three wells: One well is constructed into the shallower Anderson coal, another into the deeper Canyon coal, and one well into an overlying Wasatch sandstone bed.

- The Anderson coal well (NGILLAND) became dry by 2003 and the drawdown exceeded 57 feet from the initial water level of 500.0 feet in December 2001. The wellhead gas pressure peaked at a maximum of 4.6 psi in May 2002 but has remained at nearly zero pressure over the period from 2001 to 2006. There is an unresolved data discrepancy for this BLM well with a reported total depth of 691 feet, a water-level reading of 557 feet deep, and a 2006 water-level reading of 848.6 feet.

- The Canyon coal well (NGILLCAN) showed 84.5 feet of drawdown from the initial water level in 2001 to 2006. The wellhead gas pressure peaked at a maximum of 1.5 psi in July 2003 but has remained at nearly zero pressure over the period from 2001 to 2006.

- The overlying Wasatch sandstone well (NGILLS), which is constructed into a sandstone bed located 214 feet stratigraphically above the top of the shallower Anderson coal, showed 5.7 feet of drawdown from the initial water level in 2001 to 2006. This well is little (if any) affected by drawdown in the underlying Anderson and Canyon coal beds.

The Wasatch water level generally declined from 122 feet to 128 feet deep (6 feet of drawdown) over the period from 2001 to 2006. The Anderson water level showed a maximum fluctuation difference of about between 477 and 575 feet deep (98 feet variation) but rose and declined over the monitoring period from the initial level from 486 to 558 feet deep. The Canyon water level also rose and declined with fluctuations ranging about between 429 and 532 feet deep (103 feet of variation).

From the initial water level, the Canyon level declined from approximately 438 to 532 feet deep over the period from 2001 to 2006. The water level declines measured in the Anderson and Canyon wells are relatively similar and indicate some degree of hydrologic connection between the two coal wells at the North Gillette well nest location. There is little evidence of hydrologic connection with the overlying Wasatch sandstone well.

Palo Petroleum Recluse Field Wells (PALO)

The Palo Petroleum Recluse Field (PALO) monitoring well nest includes two wells: One well is constructed into the Canyon coal and one well into an overlying Wasatch sandstone bed.

- The Canyon coal well (PALOC) showed 139.6 feet of drawdown from the initial water level in 2001 to 2006. The wellhead gas pressure peaked at a maximum of 55.9 psi in March 2001 and then declined over the period from 2001 to 2006.

- The overlying Wasatch sandstone well (PALOS), which is constructed into a sandstone bed located 46 feet stratigraphically above the top of the Canyon coal, showed 1.35 feet of drawdown from the initial water level in 2001 to 2006. This well is apparently not affected by drawdown in the underlying Canyon coal bed.

In March 2001, when the Canyon wellhead gas pressure peaked at nearly 56 psi, the water level in the well had declined from 299 to 307 feet deep (8 feet of drawdown). The Canyon water level showed a general decline from 299 to 438 feet deep (139 feet of drawdown) over the period 2001 to 2006. The Wasatch water level remained relatively stable with very little decline from 246 to 248 feet deep. These data indicate that there is apparently no hydrologic connection between the Canyon coal and Wasatch sandstone wells in this Palo Petroleum Recluse Field well nest.

Barrett Persson Wells (PERSSON)

The Barrett Persson (PERSSON) monitoring well nest includes two wells: One well is constructed into the Wyodak coal and the other into an overlying Wasatch sandstone bed.

- The Wyodak coal well (PERSSONC) showed 153.7 feet of drawdown from the initial water level in 2001 to 2006. The wellhead gas pressure peaked at a maximum of 3.2 psi in February 2005 but has generally been nearly zero pressure over the period from 2001 to 2006.

- The overlying Wasatch sandstone well (PERSSONS), which is constructed into a sandstone bed located 36 feet stratigraphically above the top of the Wyodak coal, showed 252.6 feet of drawdown from the initial water level in 2001 to 2006. This well is affected by drawdown in the underlying Wyodak coal bed.

The Wasatch water level declined from 508 to 760 feet deep over the period from 2001 to 2006. The Wyodak water level showed a steady rate of decline from 826 to 980 feet deep over the same period. The overall difference between the coal and sandstone water levels has decreased from 318 feet in 2001 to 220 feet in 2006 as shown by the slight convergence of the plotted decline curves. These data indicate a general hydrologic connection between the Wyodak coal and Wasatch sandstone wells at this Barrett Persson well nest location.

Shogrin Federal #2 Well (Pistol Point) (PISTOL)

The Shogrin Federal #2 Well (Pistol Point) (PISTOL) monitoring well is constructed into the Big George coal. There is no

Wasatch sandstone monitoring well associated with the Pistol Point coal well.

- The Big George coal well (PISTOL) showed a water-level rise of 1.6 feet from the initial water level in 1997 to 2006. The wellhead gas pressure peaked at a maximum of 0.6 psi in October 2003 over the period from 1997 to 2006.

The Big George wellhead gas pressure remained at nearly zero over the period from 1997 to 2006. The water level in this well showed very little variation. The Big George water level slowly rose 14 feet from 457 to 443 feet deep from February 1997 to January 2002 and then declined 12 feet from 443 to 455 feet deep by 2006. Overall, the water level in this well rose over the monitoring period from 1997 to 2006.

Redstone Wells (REDSTN)

The Redstone (REDSTN) monitoring well nest includes two wells: One well is constructed into the Canyon coal and the other well into an overlying Wasatch sandstone bed.

- The Canyon coal well (REDSTNC) showed 220.7 feet of drawdown from the initial water level in 1998 to 2006. The wellhead gas pressure had a maximum measurement at 58.4 psi in April 2000 and has declined since that time over the monitoring period from 1998 to 2006.

- The overlying Wasatch sandstone well (REDSTNS), which is constructed into a sandstone bed located 56 feet stratigraphically above the top of the Canyon coal bed, showed a water-level rise of 2.6 feet from the initial water level in 1998 to 2006. This well is not affected by drawdown in the underlying Canyon coal bed.

The data for the Canyon wellhead gas pressure are absent before April 2000 and the recorded gas pressure data have some gaps since then. The Wasatch water level remained relatively stable with variation between 20 and 23 feet deep over the period from 1998 to 2006. The Canyon coal water level declined from 33 to 254 feet deep over the same period. These data indicate that there is no apparent hydrologic connection between wells in this Redstone well nest.

Remington Creek – Nance Petroleum Wells (REMCRK)

The Remington Creek – Nance Petroleum (REMCRK) monitoring well nest includes four wells: One well is constructed into the shallower Anderson coal, one into the intermediate Canyon coal, another into the deeper Cook coal, and one well into a shallow Quaternary alluvial sand bed (unconsolidated deposit).

- The Anderson coal well (REMCRKANDC) showed 107.0 feet of drawdown from the initial water level in 2005 to 2006. The wellhead gas pressure peaked at a maximum of 60.4 psi over the period from 2005 to 2006.

- The Canyon coal well (REMCRKCANC) showed 57.8 feet of drawdown from the initial water level in 2005 to 2006. The wellhead gas pressure peaked at a maximum of 0.3 psi over the period from 2005 to 2006.

- The Cook coal well (REMCRKCOOKC) showed 98.1 feet of drawdown from the initial water level in 2005 to 2006. The wellhead gas pressure peaked at a maximum of 0.1 psi over the period from 2005 to 2006.

- The Quaternary alluvial sand well (REMCRKS), which is constructed into an alluvial sand bed located 288 feet stratigraphically above the top of the shallow Anderson coal, showed 0.22 feet of drawdown from the initial water level in

2005 to 2006. This shallow (30.5 feet total depth) alluvial sand well is not apparently affected by drawdown in the underlying Anderson, Canyon, and Cook coal beds.

The Anderson wellhead gas pressure peaked in 60.4 psi in August 2005 and then declined at a steady rate over the period from 2005 to 2006. The water level in the Anderson well had declined to 183 feet deep (23 feet of drawdown) when the gas pressure peaked. The wellhead gas pressures in the other two coal wells remained at nearly zero during the entire monitoring period from 2005 to 2006.

The Quaternary alluvial sand water level remained relatively stable at between 4 and 5 feet over the period from 2005 to 2006. The Anderson water level declined at a steady rate from 160 to 267 feet (107 feet of drawdown) over the period from 2005 to 2006. The water-level decline curves for the Canyon and Cook coals showed steady decline rates and divergence. The water levels in the Canyon and Cook coals started at about the same depth (378 feet) in June 2005. By 2006, the water levels declined to 436 feet deep (58 feet of drawdown) for the Canyon and 476 feet deep (98 feet of drawdown) in the Cook. The Cook water level declined 40 feet deeper than the Canyon level by 2006. The Cook water level declined at a slower rate than the Canyon and Anderson water levels.

These data indicate that there is no evidence of hydrologic connection between the Quaternary alluvial sand well with the three coal wells in this well nest. The steady decline of water levels in all three coal wells indicates a general hydrologic connection between the three coal beds at the Remington Creek well nest location. The nearly identical water level in June 2005 for the Canyon and Cook coals indicates that they are hydrologically connected, but the divergence of 40 feet between the decline curves for these two wells show that this hydrologic connection is limited to some degree.

Sasquatch Federal #12-2 Wells (SASQUAT)

The Sasquatch Federal #12-2 Well (SASQUAT) monitoring well nest includes two wells: One well is constructed into the Big George coal and one well into an overlying Wasatch sandstone bed.

- The Big George coal well (SASQUATC) showed 275.4 feet of drawdown from the initial water level in 1998 to 2006. The wellhead gas pressure peaked at a maximum of 3.1 psi in July 2003 over the period from 1998 to 2006.

- The overlying Wasatch sandstone well (SASQUATS), which is constructed into a sandstone bed located 75 feet stratigraphically above the top of the Big George coal, showed 100.3 feet of drawdown from the initial water level in 2001 to 2006. This well is affected by drawdown in the underlying Big George coal bed.

The Big George wellhead gas pressure showed multiple cycles of highs and lows between about 0 and 3 psi and remained at a relatively low level over the monitoring period from 1998 to 2006. The Wasatch water level declined from 224 to 324 feet deep (about 100 feet of drawdown) over the period from 2002 to 2006. During the period from 1998 to 2006, the Big George water level showed an increasing decline rate from 230 to 524 feet deep (294 feet of maximum drawdown) followed by a slight rise from 524 to 476 feet deep (48 feet of rise) during 2006. These data show hydrologic connection between the Wasatch and Big George wells in this Sasquatch Federal #12-2 Well nest.

Huber South Coal Wells (SCOAL)

The Huber South Coal (SCOAL) monitoring well nest includes two wells: One well is constructed into the combined Cook-Lower Wall-Pawnee coal beds and the other well is constructed into an overlying Wasatch sandstone bed.

- The Cook-Lower Wall-Pawnee coal well (SCOALC) drawdown was more than 8.5 feet from the initial water level of 561.4 feet in 2001 to 2006 and the well became dry in 2006. The wellhead gas pressure peaked at a maximum of 12.7 psi in November 2004 over the period from 2001 to 2006.

- The overlying Wasatch sandstone well (SCOALS), which is constructed into a sandstone bed located 207 feet stratigraphically above the top of the Cook coal, showed 0.4 feet of drawdown from the initial water level in 2001 to 2006. This well is not affected by drawdown in the underlying Cook-Lower Wall-Pawnee coal beds.

When the SCOALC wellhead gas pressure peaked at 12.7 psi in November 2004 and peaked again at 12.3 psi in November 2005, the water level in the coal well was at 561 feet deep (1 foot of rise) in November 2004 and at 565 feet deep (3 feet of drawdown) in November 2005. The Wasatch water level showed a relatively steady level at between 465 and 466 feet deep over the period from 2001 to 2006. The Cook-Lower Wall-Pawnee water level declined from 562 to 589 feet deep (27 feet of drawdown) over the same period. These data show no evidence of hydrologic connection between the Wasatch sandstone and the Cook-Lower Wall-Pawnee coal wells in this Huber South Coal well nest.

Streeter Road Wells (STREETER)

The Streeter Road Well (STREETER) monitoring well nest includes two wells: One well is constructed into the Big George coal and the other well into an overlying Wasatch sandstone bed.

- The Big George #3 coal well (STREETERC) showed 20.6 feet of drawdown from the initial water level in 2004 to 2006. The wellhead gas pressure peaked at a maximum of 0.1 psi in December 2005 over the period from 2004 to 2006.

- The overlying Wasatch sandstone well (STREETERS) showed 9.1 feet of drawdown from the initial water level in 2004 to 2006. This well is constructed into a sandstone bed located 621 feet stratigraphically above the top of the Big George #3 coal bed. This well may be slightly affected by drawdown in the underlying Big George #3 coal bed.

The Big George #3 wellhead gas pressure showed nearly zero pressure over the monitoring period from 2004 to 2006. The Wasatch water level showed a slight decline from 214 to 223 feet deep (9 feet of drawdown) over the period from 2004 to 2006. The Big George #3 coal water level slightly declined from 159 to 180 feet deep (21 feet of drawdown) during the same monitoring period. These data show very little evidence of hydrologic connection between the Wasatch and Big George #3 wells in this Streeter Road Well nest.

Barrett Throne Wells (THRONE)

The Barrett Throne Well (THRONE) monitoring well nest includes two wells: One well is constructed into the Wyodak coal and the other well into an overlying Wasatch sandstone bed.

- The Wyodak coal well (THRONEC) showed 310.8 feet of drawdown from the initial water level in 2001 to 2006. The wellhead gas pressure peaked at a maximum of 1.0 psi in June 2003 over the period from 2001 to 2006.

- The overlying Wasatch sandstone well (THRONES), which is constructed into a sandstone bed located 56 feet stratigraphically above the top of the Wyodak coal, showed 268.8 feet of drawdown from the initial water level in 2001 to 2006. This well is affected by drawdown in the underlying Wyodak coal bed.

The Wyodak wellhead gas pressure remained at nearly zero pressure over the period from 2001 to 2006. The Wasatch water level showed a steady rate of decline from 601 to 870 feet deep (269 feet of drawdown) over the period from 2001 to 2006. The Wyodak water level declined from 816 to 1,126 feet deep (310 feet of drawdown) during the same period. The decline curves of the Wyodak and Wasatch water levels generally parallel each other. These data show evidence of hydrologic connection between the Wasatch and Wyodak wells in this Barrett Throne Well nest.

Prima Wild Turkey Wells (WILDTUR)

The Prima Wild Turkey (WILDTUR) monitoring well nest includes two wells: One well is constructed into the Big George coal and one well into an overlying Wasatch sandstone bed.

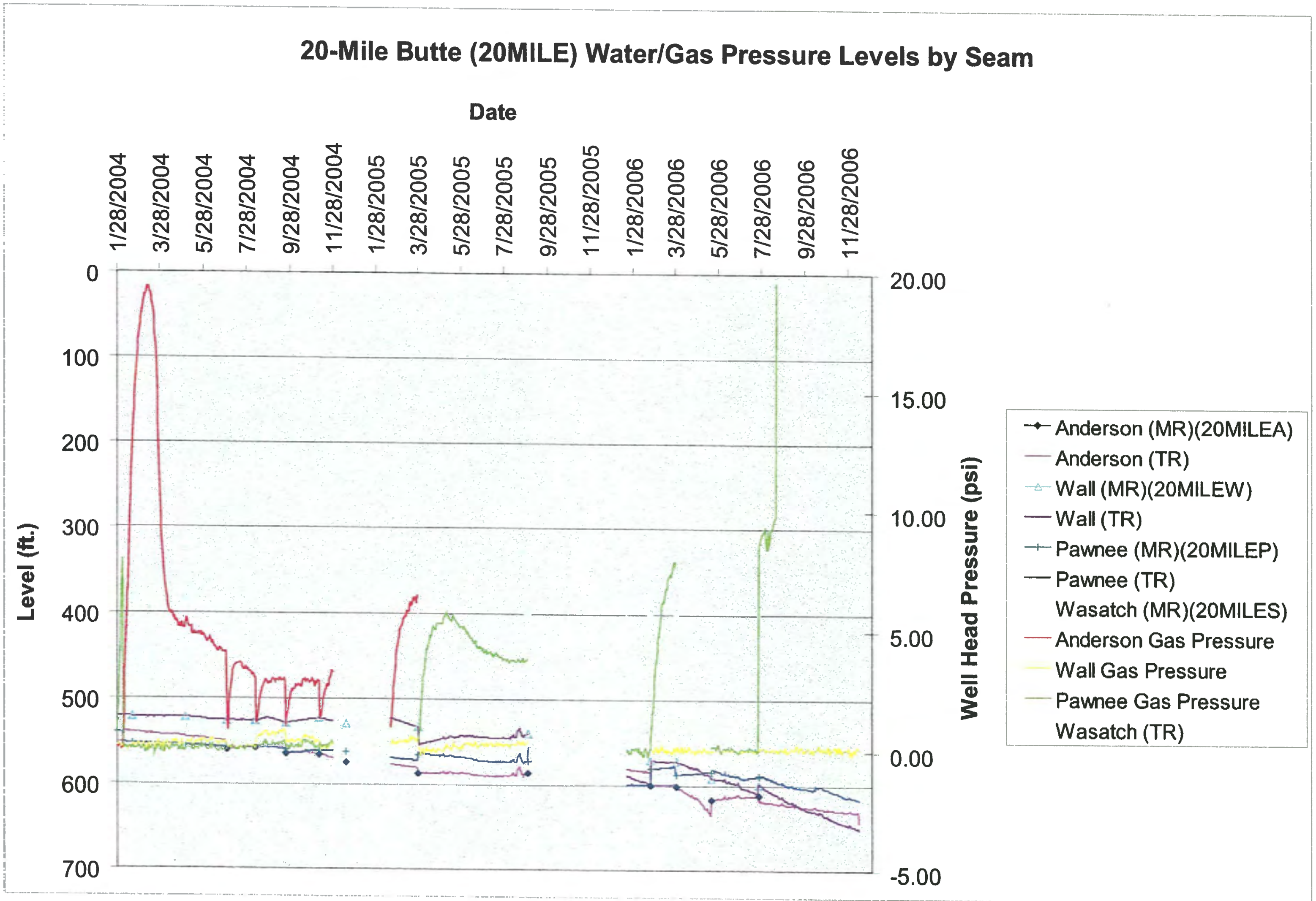
- The Big George coal well (WILDTURC) showed 259.3 feet of drawdown from the initial water level in 2004 to 2006. The wellhead gas pressure peaked at a maximum of 80.9 psi in August 2006 over the period from 2004 to 2006.

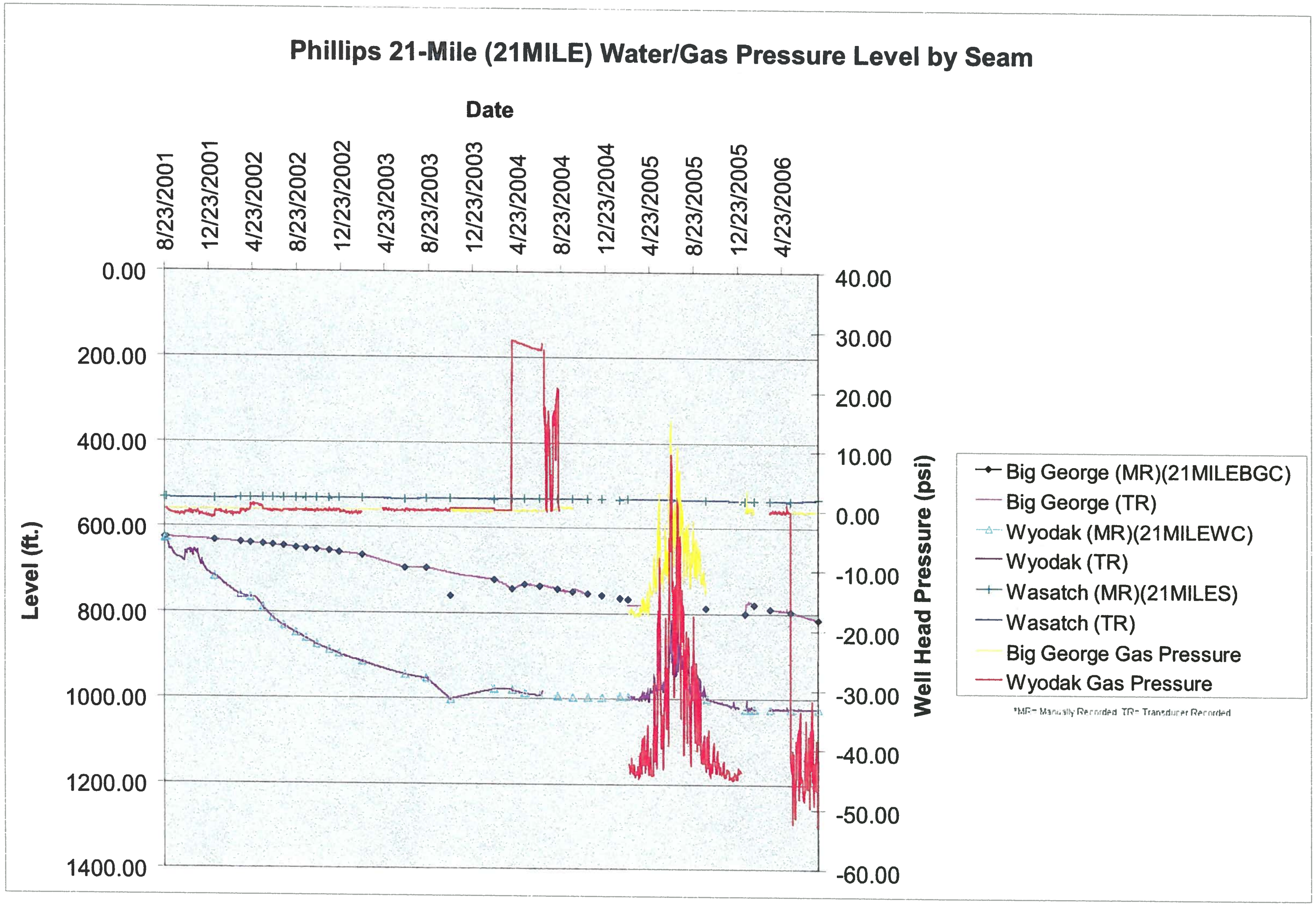
- The overlying Wasatch sandstone well (WILDTURS) showed 7 feet of drawdown from the initial water level in 2004 to 2006. This well is constructed into a sandstone bed located 187 feet stratigraphically above the top of the Big George coal. This well is apparently not affected by drawdown in the underlying Big George coal bed during the first three years of monitoring (2004 to 2006).

When the Big George wellhead gas pressure peaked in August 2006, the water level in the well was at 515 feet deep (247 feet of drawdown), which had risen from a low of 705 feet deep (437 feet of drawdown) in July 2006. After the August 2006 peak, the gas pressure in the coal well started to fall off.

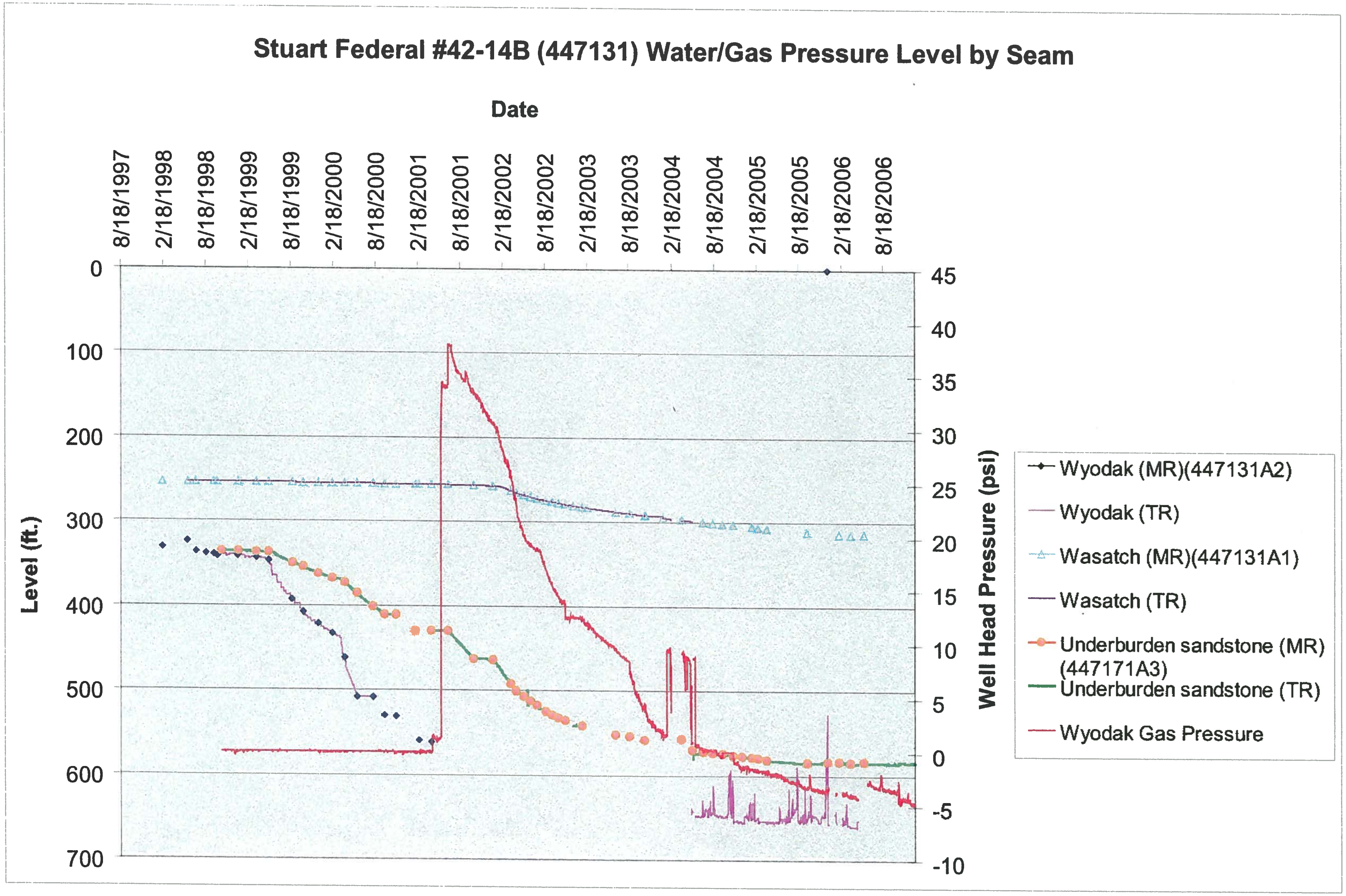
The Wasatch water level showed a relatively small decline from 128 to 135 feet deep (7 feet of drawdown) over the period from 2001 to 2006. The Big George water level declined from 268 to 705 feet deep (437 feet of drawdown) during the same period. The water level decline in the coal well was slow for the first 34 feet of the decline from November 2004 to November 2005, very rapid for the next 388 feet of decline from November 2005 to April 2006, slow for the next 15 feet of decline from April-July 2006, and then rose rapidly (194-foot rise) with the associated gas pressure peak from July-August 2006. Since August 2006, the coal water level has declined slightly. These data show very little evidence of any hydrologic connection between the Wasatch and Big George wells in this well nest.

Appendix A:

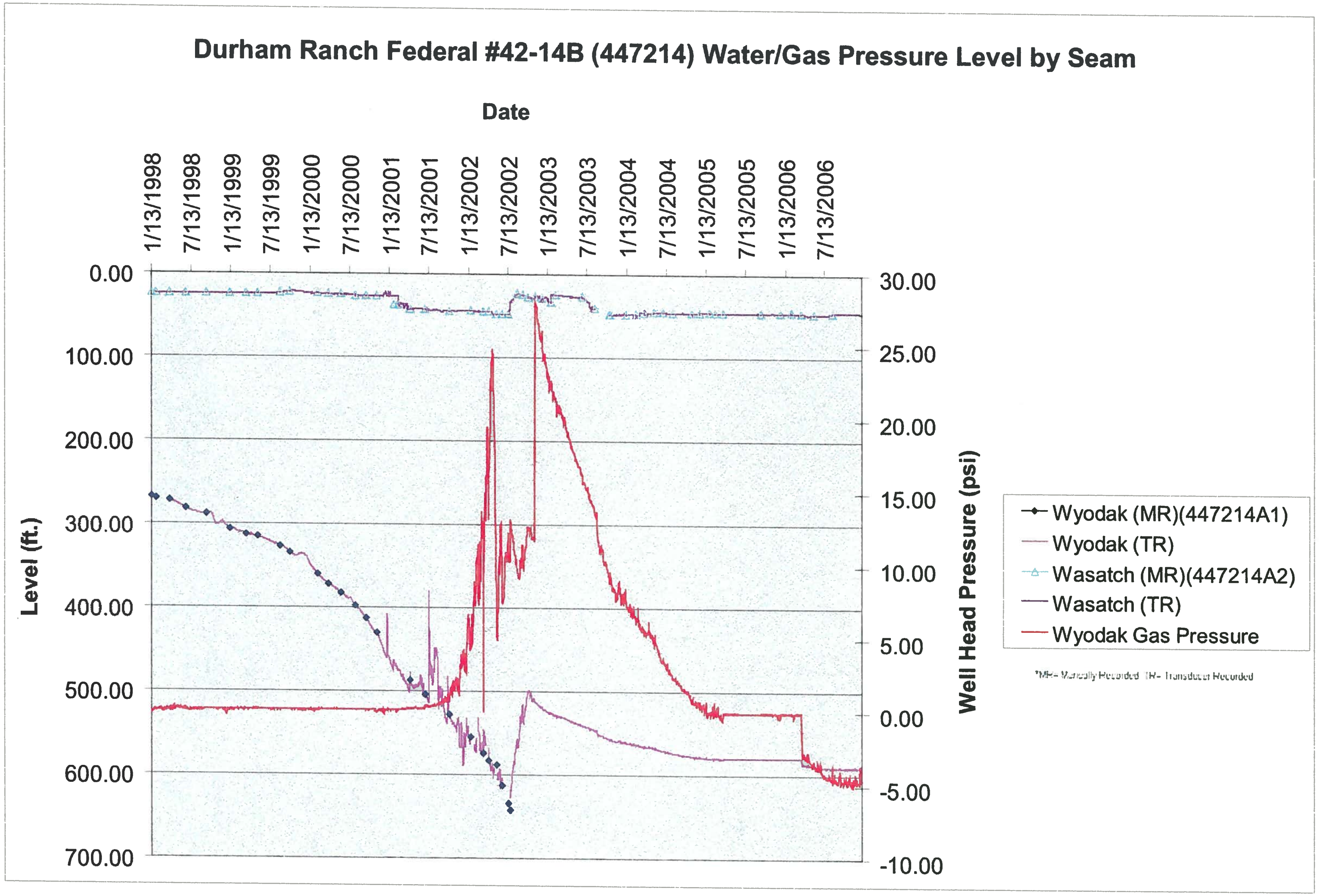

20-Mile Butte (20MILE) Water/Gas Pressure Levels by Seam
Date
1/28/2004
3/28/2004
5/28/2004
7/28/2004
9/28/2004
11/28/2004
1/28/2005
3/28/2005
5/28/2005
7/28/2005
9/28/2005
11/28/2005
1/28/2006
3/28/2006
5/28/2006
7/28/2006
9/28/2006
11/28/2006
Level (ft.)
0
100
200
300
400
500
600
700
Well Head Pressure (psi)
20.00
15.00
10.00
5.00
0.00
-5.00
Anderson (MR)(20MILEA)
Anderson (TR)
Wall (MR)(20MILEW)
Wall (TR)
Pawnee (MR)(20MILEP)
Pawnee (TR)
Wasatch (MR)(20MILES)
Anderson Gas Pressure
Wall Gas Pressure
Pawnee Gas Pressure
Wasatch (TR)



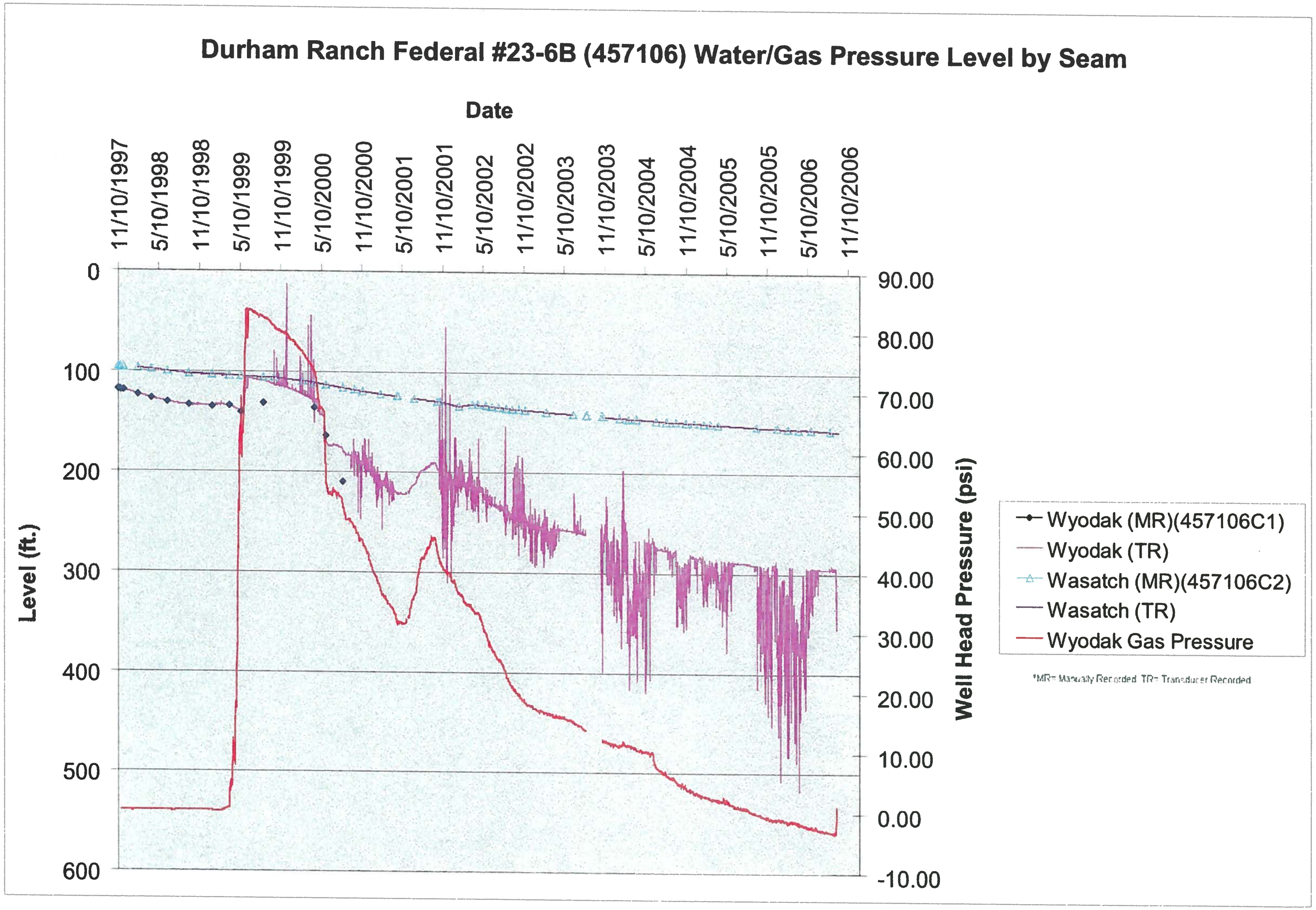
Phillips 21-Mile (21MILE) Water/Gas Pressure Level by Seam
Date
8/23/2001
12/23/2001
4/23/2002
8/23/2002
12/23/2002
4/23/2003
8/23/2003
12/23/2003
4/23/2004
8/23/2004
12/23/2004
4/23/2005
8/23/2005
12/23/2005
4/23/2006
Level (ft.)
0.00
200.00
400.00
600.00
800.00
1000.00
1200.00
1400.00
Well Head Pressure (psi)
40.00
30.00
20.00
10.00
0.00
-10.00
-20.00
-30.00
-40.00
-50.00
-60.00
Big George (MR)(21MILEBGC)
Big George (TR)
Wyodak (MR)(21MILEWC)
Wyodak (TR)
Wasatch (MR)(21MILES)
Wasatch (TR)
Big George Gas Pressure
Wyodak Gas Pressure
*MR= Manually Recorded TR= Transducer Recorded

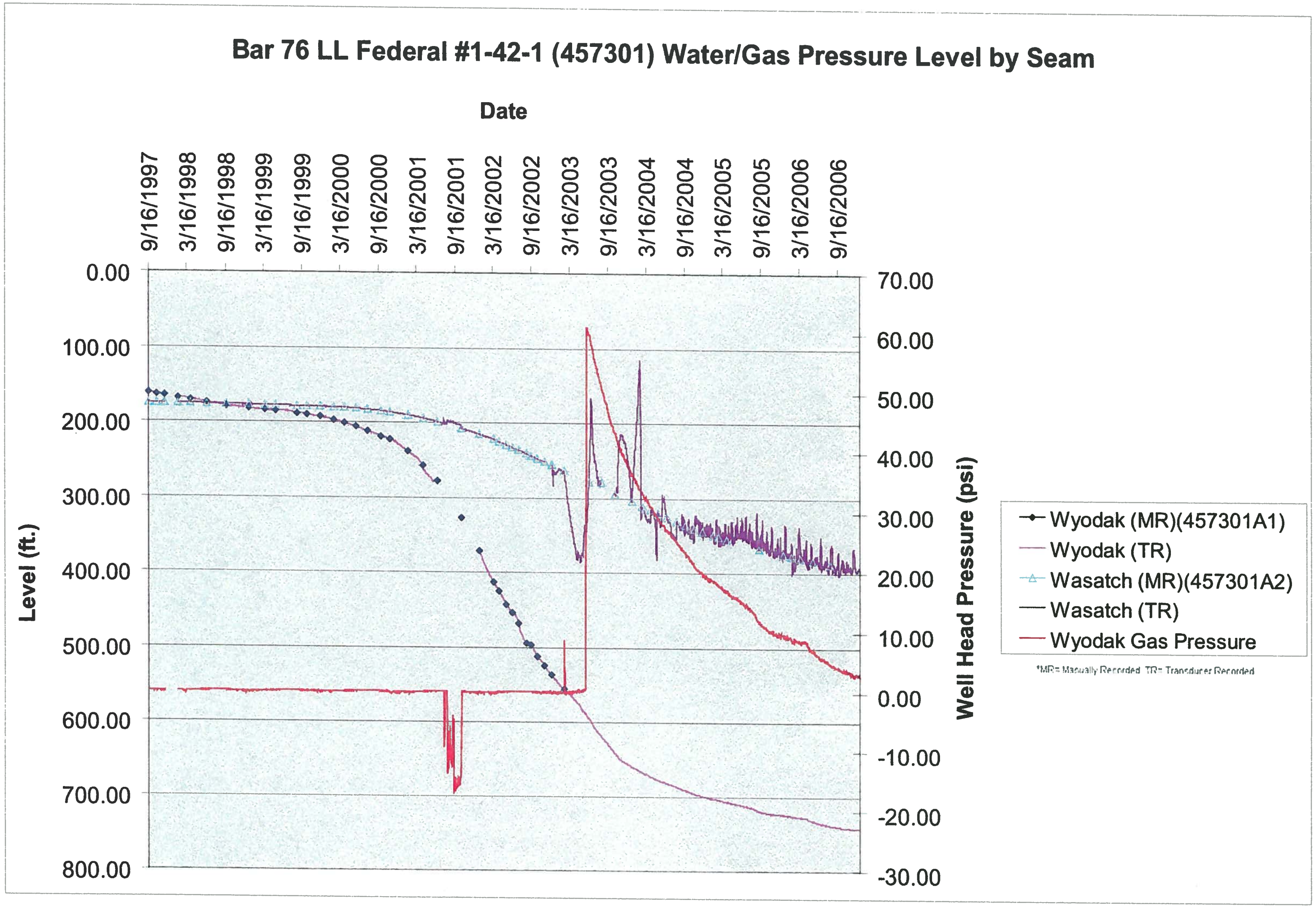


Stuart Federal #42-14B (447131) Water/Gas Pressure Level by Seam
Date
8/18/1997
2/18/1998
8/18/1998
2/18/1999
8/18/1999
2/18/2000
8/18/2000
2/18/2001
8/18/2001
2/18/2002
8/18/2002
2/18/2003
8/18/2003
2/18/2004
8/18/2004
2/18/2005
8/18/2005
2/18/2006
8/18/2006
Level (ft.)
0
100
200
300
400
500
600
700
Well Head Pressure (psi)
45
40
35
30
25
20
15
10
5
0
-5
-10
Wyodak (MR)(447131A2)
Wyodak (TR)
Wasatch (MR)(447131A1)
Wasatch (TR)
Underburden sandstone (MR) (447171A3)
Underburden sandstone (TR)
Wyodak Gas Pressure

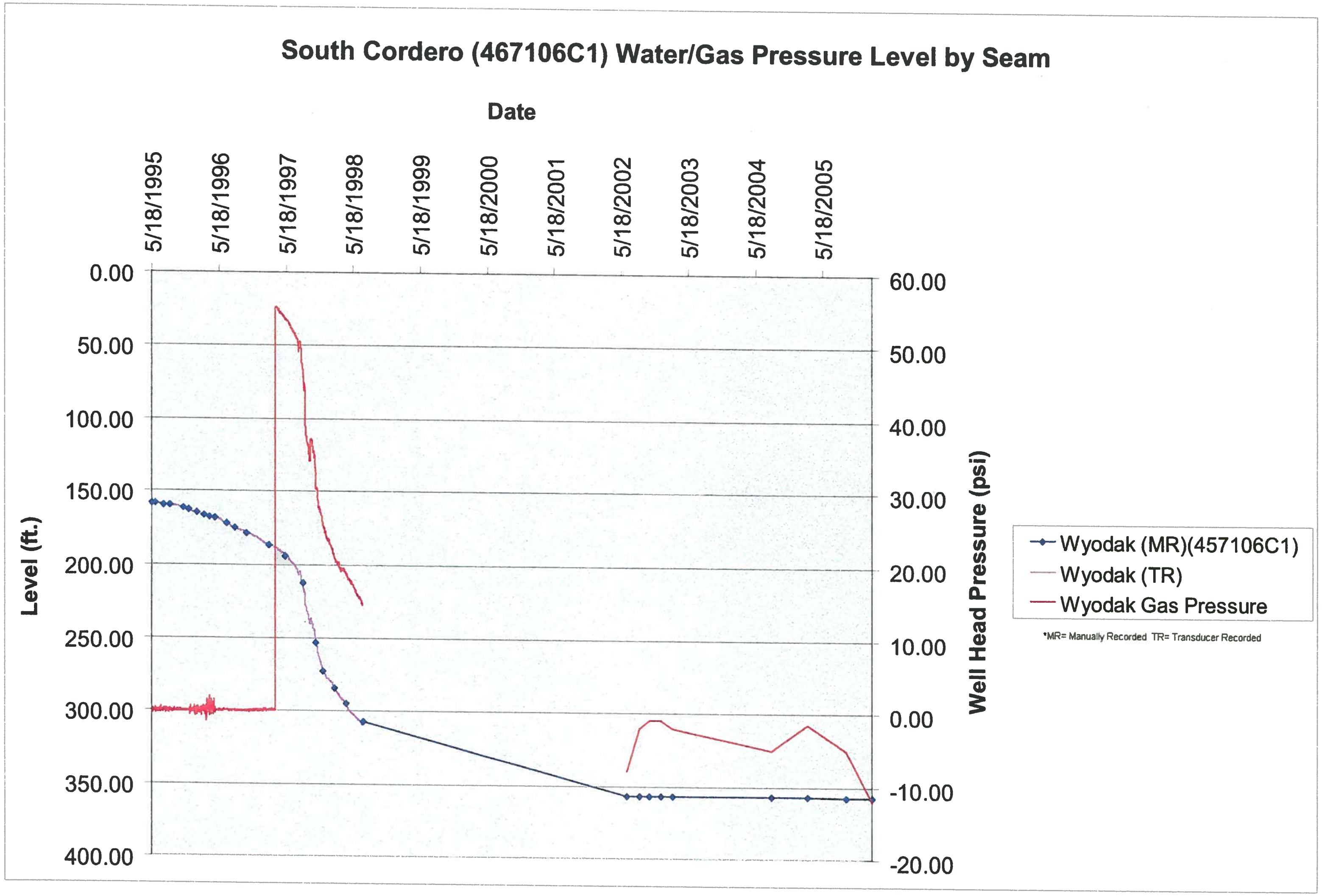


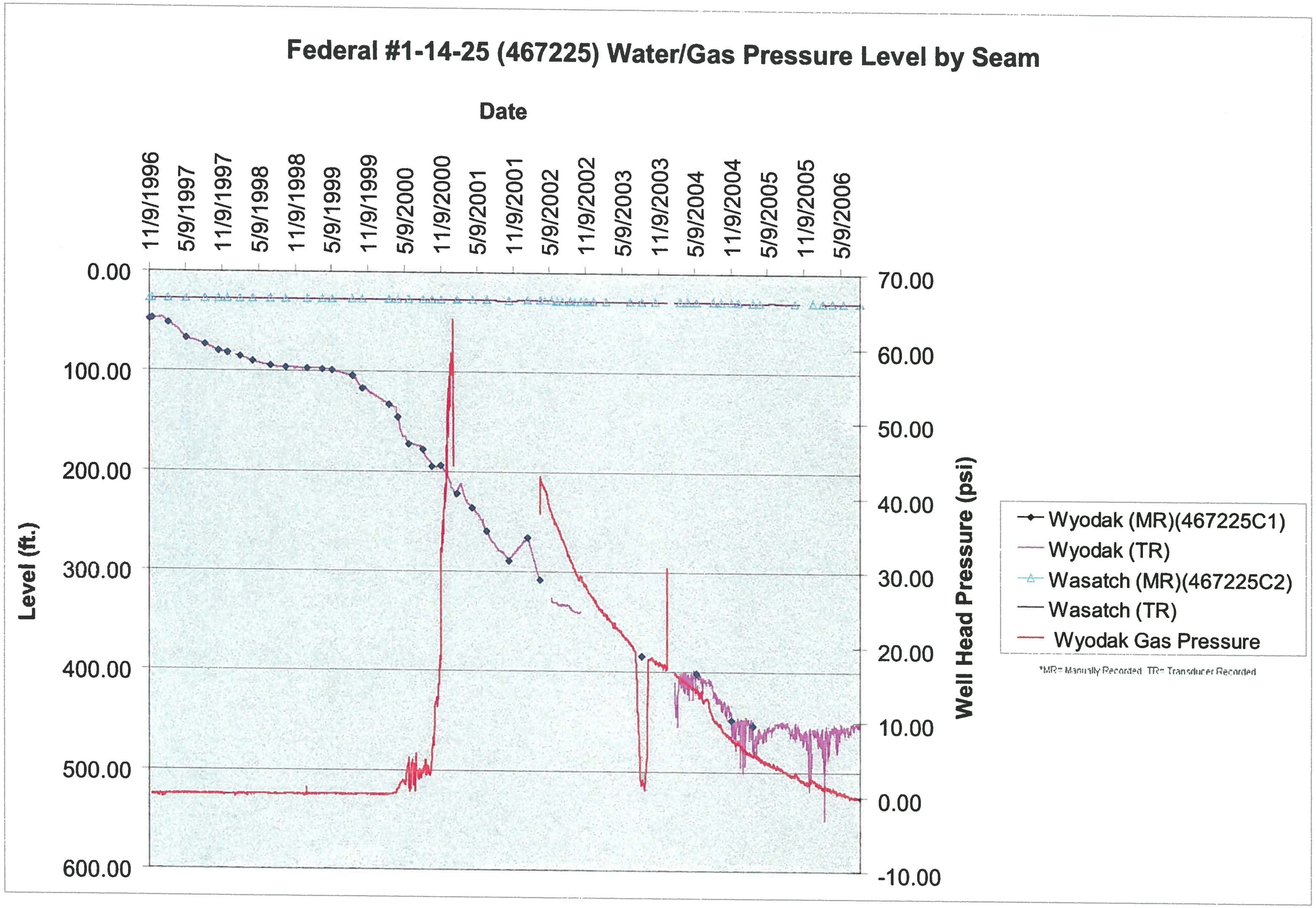
Durham Ranch Federal #42-14B (447214) Water/Gas Pressure Level by Seam
Date
1/13/1998
7/13/1998
1/13/1999
7/13/1999
1/13/2000
7/13/2000
1/13/2001
7/13/2001
1/13/2002
7/13/2002
1/13/2003
7/13/2003
1/13/2004
7/13/2004
1/13/2005
7/13/2005
1/13/2006
7/13/2006
Level (ft.)
0.00
100.00
200.00
300.00
400.00
500.00
600.00
700.00
Well Head Pressure (psi)
30.00
25.00
20.00
15.00
10.00
5.00
0.00
-5.00
-10.00
Wyodak (MR)(447214A1)
Wyodak (TR)
Wasatch (MR)(447214A2)
Wasatch (TR)
Wyodak Gas Pressure

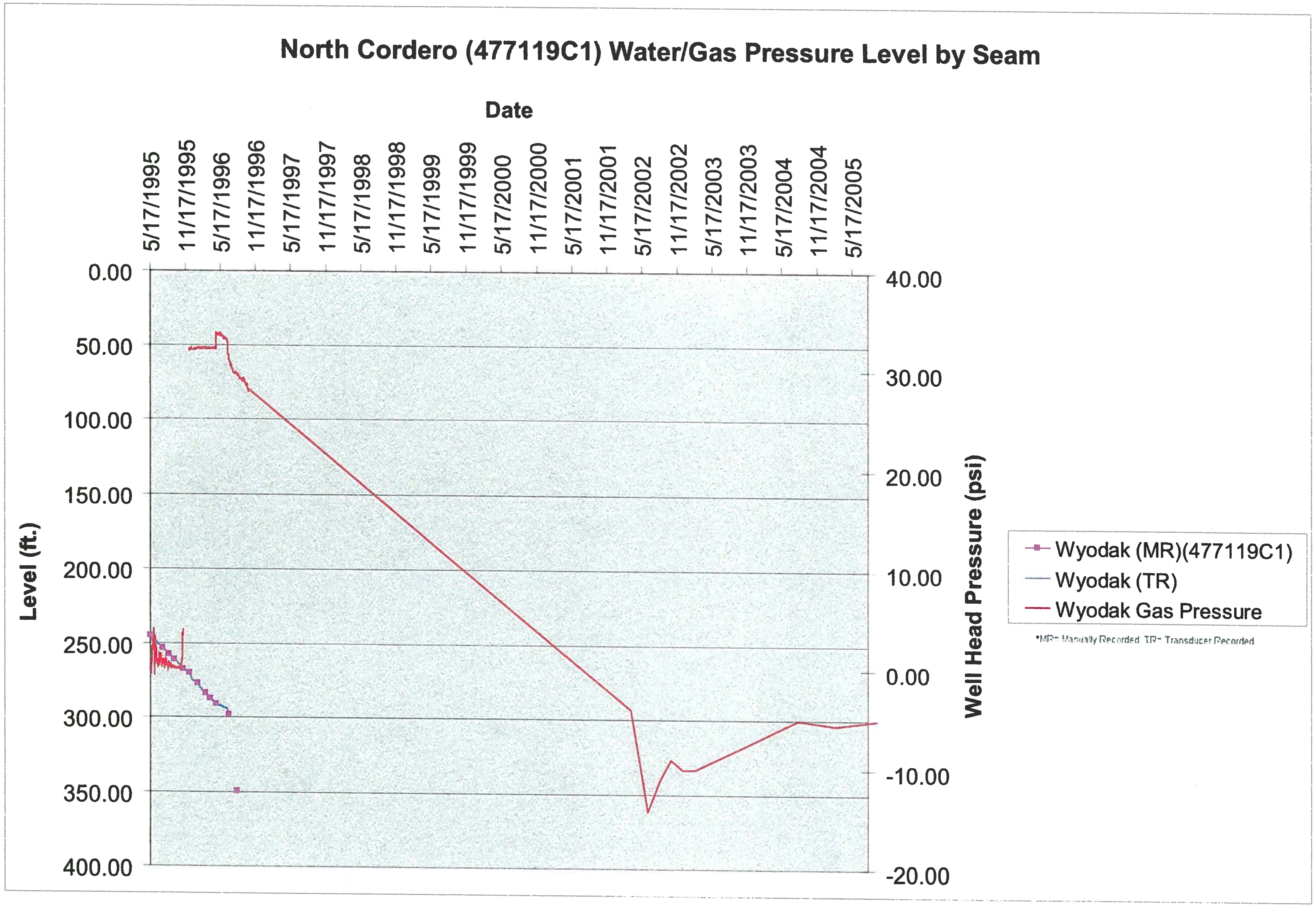

Durham Ranch Federal #23-6B (457106) Water/Gas Pressure Level by Seam
Date
11/10/1997
5/10/1998
11/10/1998
5/10/1999
11/10/1999
5/10/2000
11/10/2000
5/10/2001
11/10/2001
5/10/2002
11/10/2002
5/10/2003
11/10/2003
5/10/2004
11/10/2004
5/10/2005
11/10/2005
5/10/2006
11/10/2006
Level (ft.)
0
100
200
300
400
500
600
Well Head Pressure (psi)
90.00
80.00
70.00
60.00
50.00
40.00
30.00
20.00
10.00
0.00
-10.00
Wyodak (MR)(457106C1)
Wyodak (TR)
Wasatch (MR)(457106C2)
Wasatch (TR)
Wyodak Gas Pressure
*MR= Manually Recorded TR= Transducer Recorded



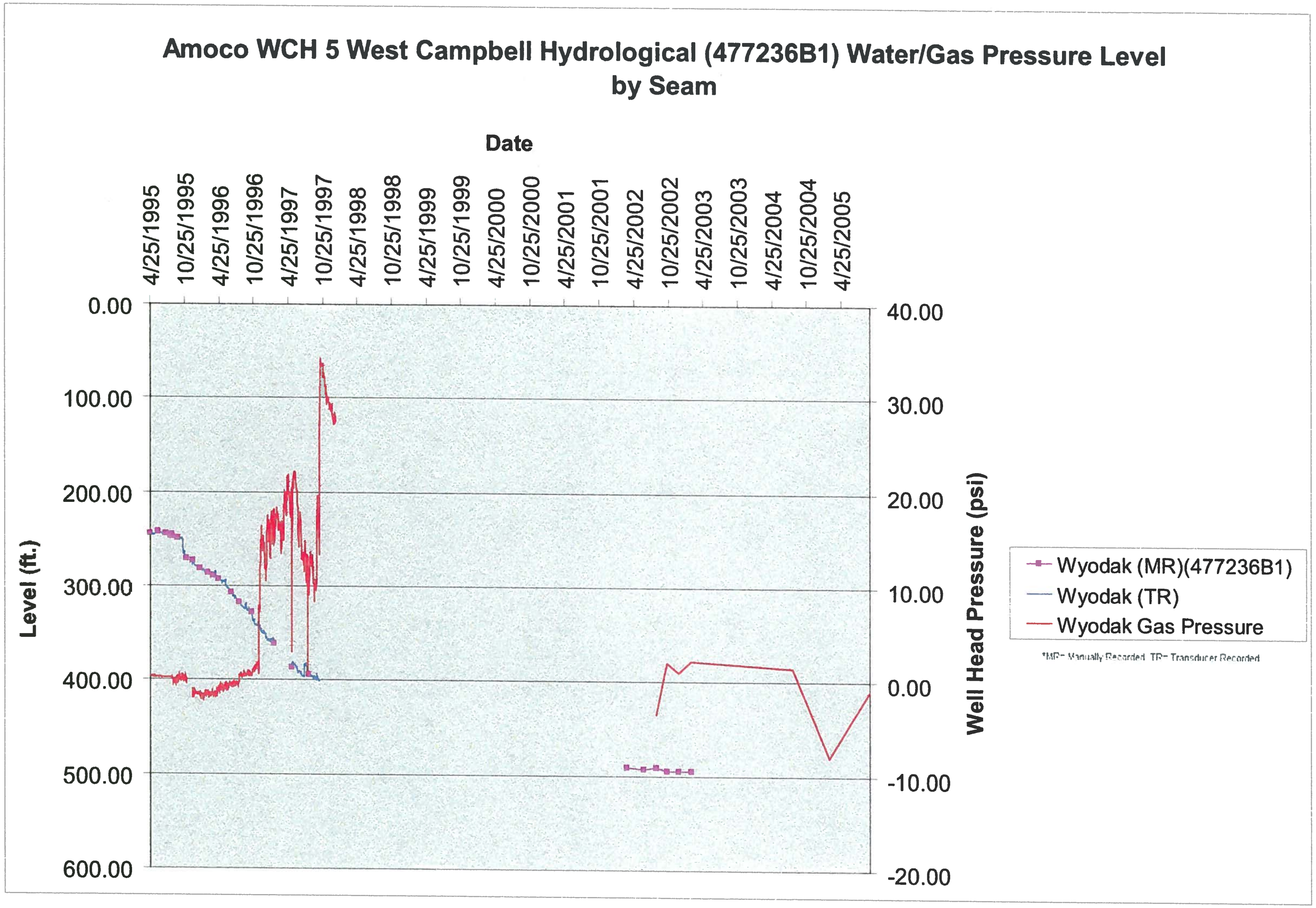
Bar 76 LL Federal #1-42-1 (457301) Water/Gas Pressure Level by Seam
Date
9/16/1997
3/16/1998
9/16/1998
3/16/1999
9/16/1999
3/16/2000
9/16/2000
3/16/2001
9/16/2001
3/16/2002
9/16/2002
3/16/2003
9/16/2003
3/16/2004
9/16/2004
3/16/2005
9/16/2005
3/16/2006
9/16/2006
Level (ft.)
0.00
100.00
200.00
300.00
400.00
500.00
600.00
700.00
800.00
Well Head Pressure (psi)
70.00
60.00
50.00
40.00
30.00
20.00
10.00
0.00
-10.00
-20.00
-30.00
Wyodak (MR)(457301A1)
Wyodak (TR)
Wasatch (MR)(457301A2)
Wasatch (TR)
Wyodak Gas Pressure
*MR= Manually Recorded TR= Transducer Recorded

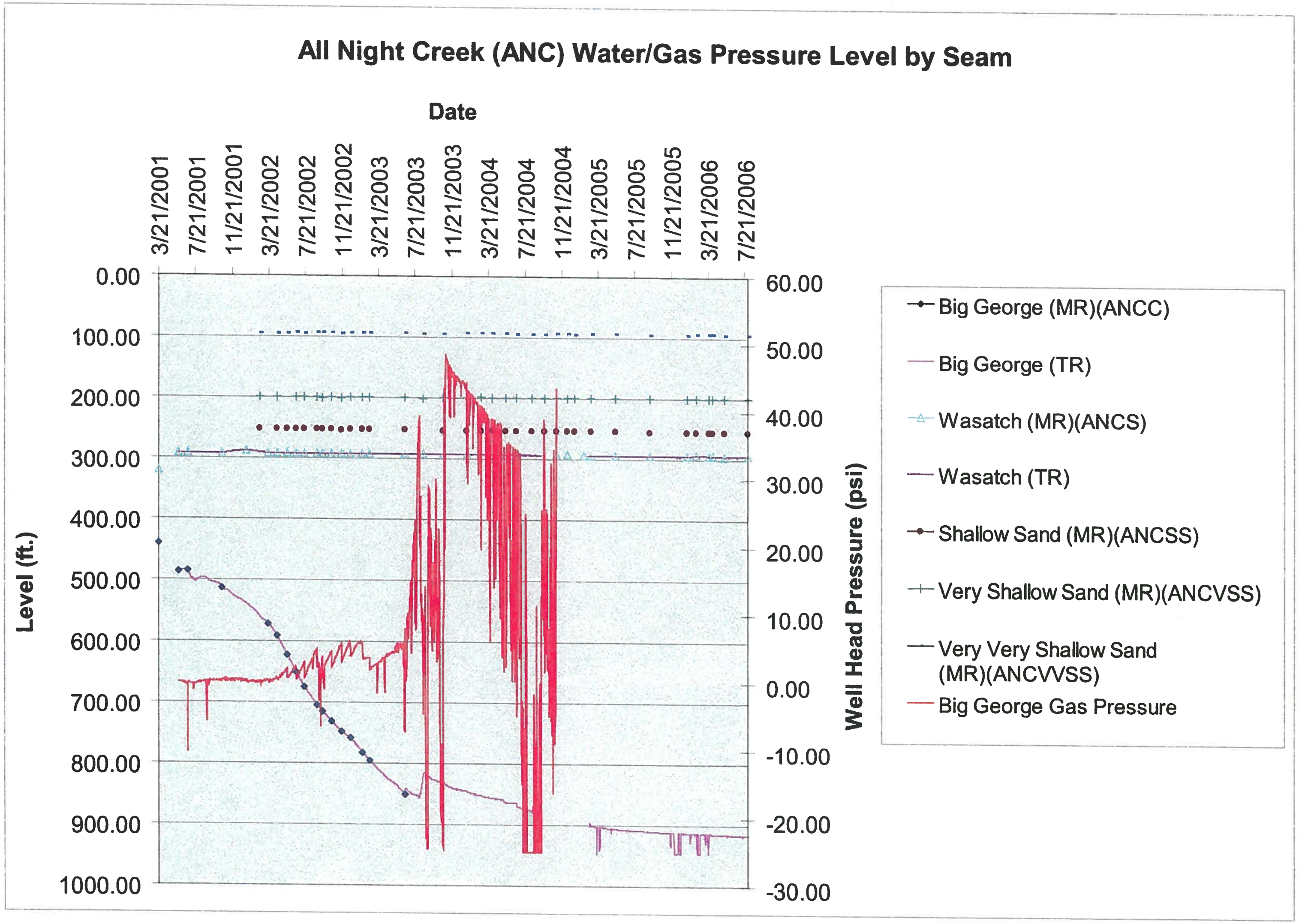

South Cordero (467106C1) Water/Gas Pressure Level by Seam
Date
5/18/1995
5/18/1996
5/18/1997
5/18/1998
5/18/1999
5/18/2000
5/18/2001
5/18/2002
5/18/2003
5/18/2004
5/18/2005
Level (ft.)
0.00
50.00
100.00
150.00
200.00
250.00
300.00
350.00
400.00
Well Head Pressure (psi)
60.00
50.00
40.00
30.00
20.00
10.00
0.00
-10.00
-20.00
Wyodak (MR)(457106C1)
Wyodak (TR)
Wyodak Gas Pressure
*MR= Manually Recorded TR= Transducer Recorded

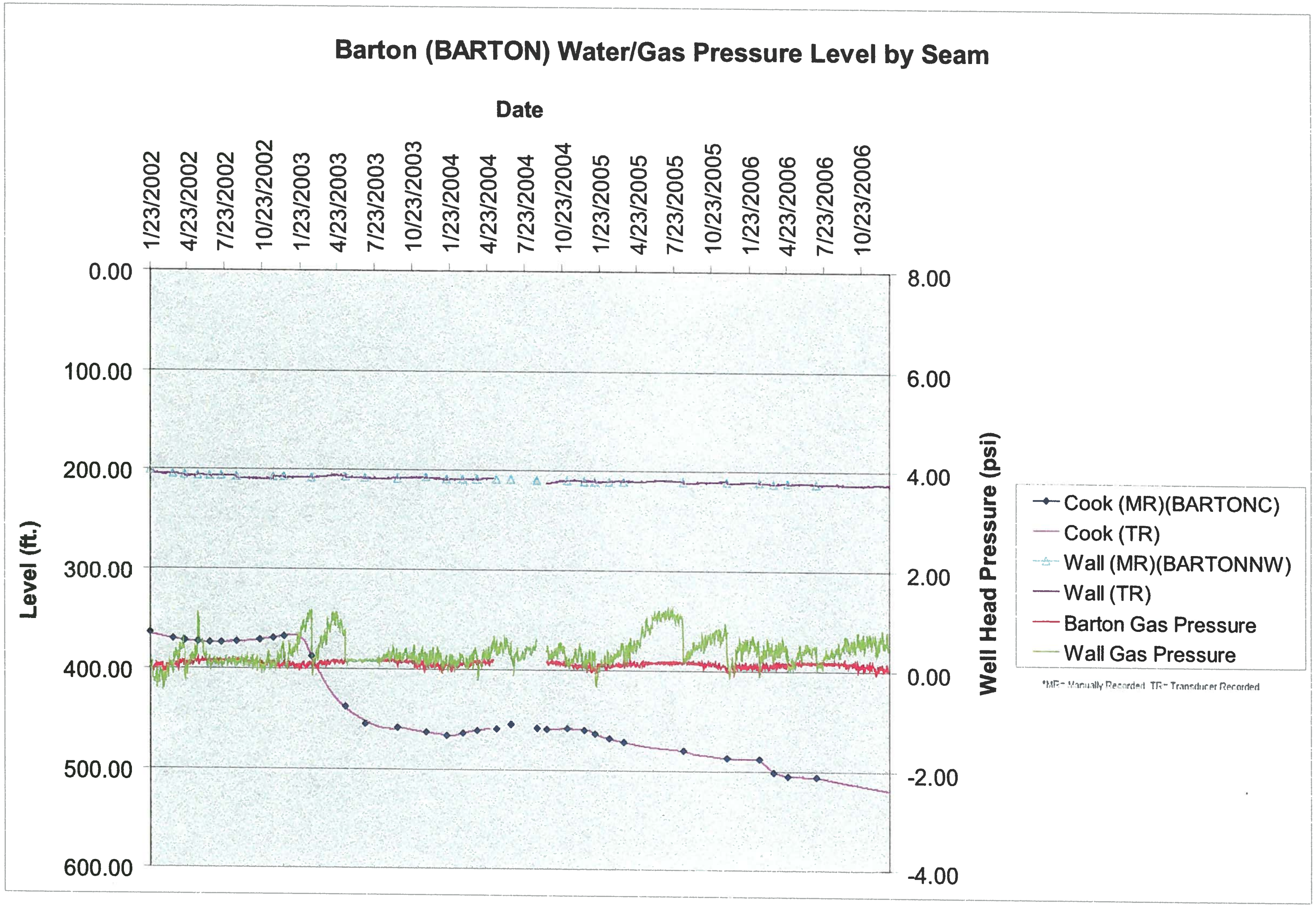

Federal #1-14-25 (467225) Water/Gas Pressure Level by Seam
Date
11/9/1996
5/9/1997
11/9/1997
5/9/1998
11/9/1998
5/9/1999
11/9/1999
5/9/2000
11/9/2000
5/9/2001
11/9/2001
5/9/2002
11/9/2002
5/9/2003
11/9/2003
5/9/2004
11/9/2004
5/9/2005
11/9/2005
5/9/2006
Level (ft.)
0.00
100.00
200.00
300.00
400.00
500.00
600.00
Well Head Pressure (psi)
70.00
60.00
50.00
40.00
30.00
20.00
10.00
0.00
-10.00
Wyodak (MR)(467225C1)
Wyodak (TR)
Wasatch (MR)(467225C2)
Wasatch (TR)
Wyodak Gas Pressure
*MR= Manually Recorded TR= Transducer Recorded



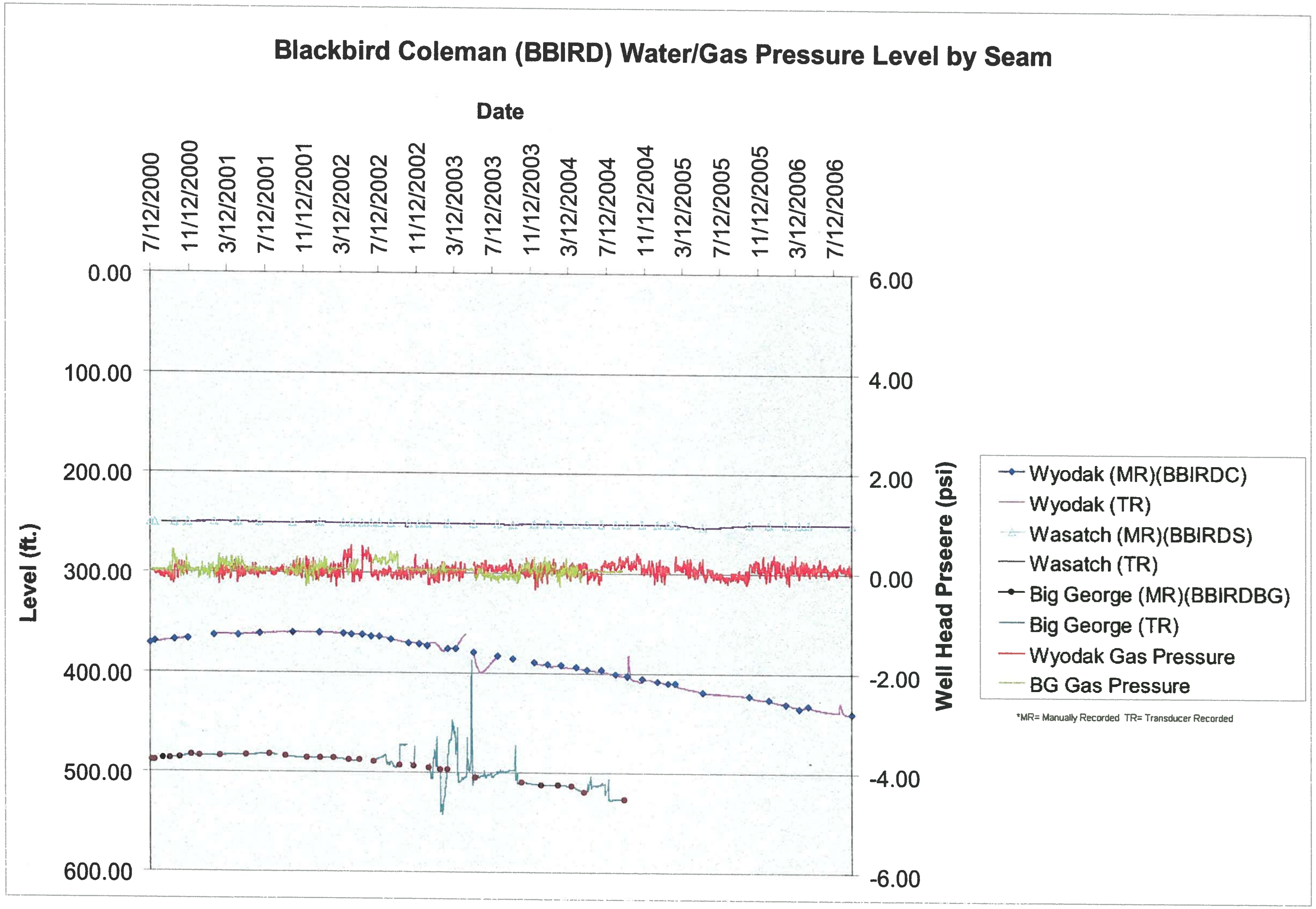
North Cordero (477119C1) Water/Gas Pressure Level by Seam
Date
5/17/1995
11/17/1995
5/17/1996
11/17/1996
5/17/1997
11/17/1997
5/17/1998
11/17/1998
5/17/1999
11/17/1999
5/17/2000
11/17/2000
5/17/2001
11/17/2001
5/17/2002
11/17/2002
5/17/2003
11/17/2003
5/17/2004
11/17/2004
5/17/2005
Level (ft.)
0.00
50.00
100.00
150.00
200.00
250.00
300.00
350.00
400.00
Well Head Pressure (psi)
40.00
30.00
20.00
10.00
0.00
-10.00
-20.00
Wyodak (MR)(477119C1)
Wyodak (TR)
Wyodak Gas Pressure
*MR= Manually Recorded TR= Transducer Recorded

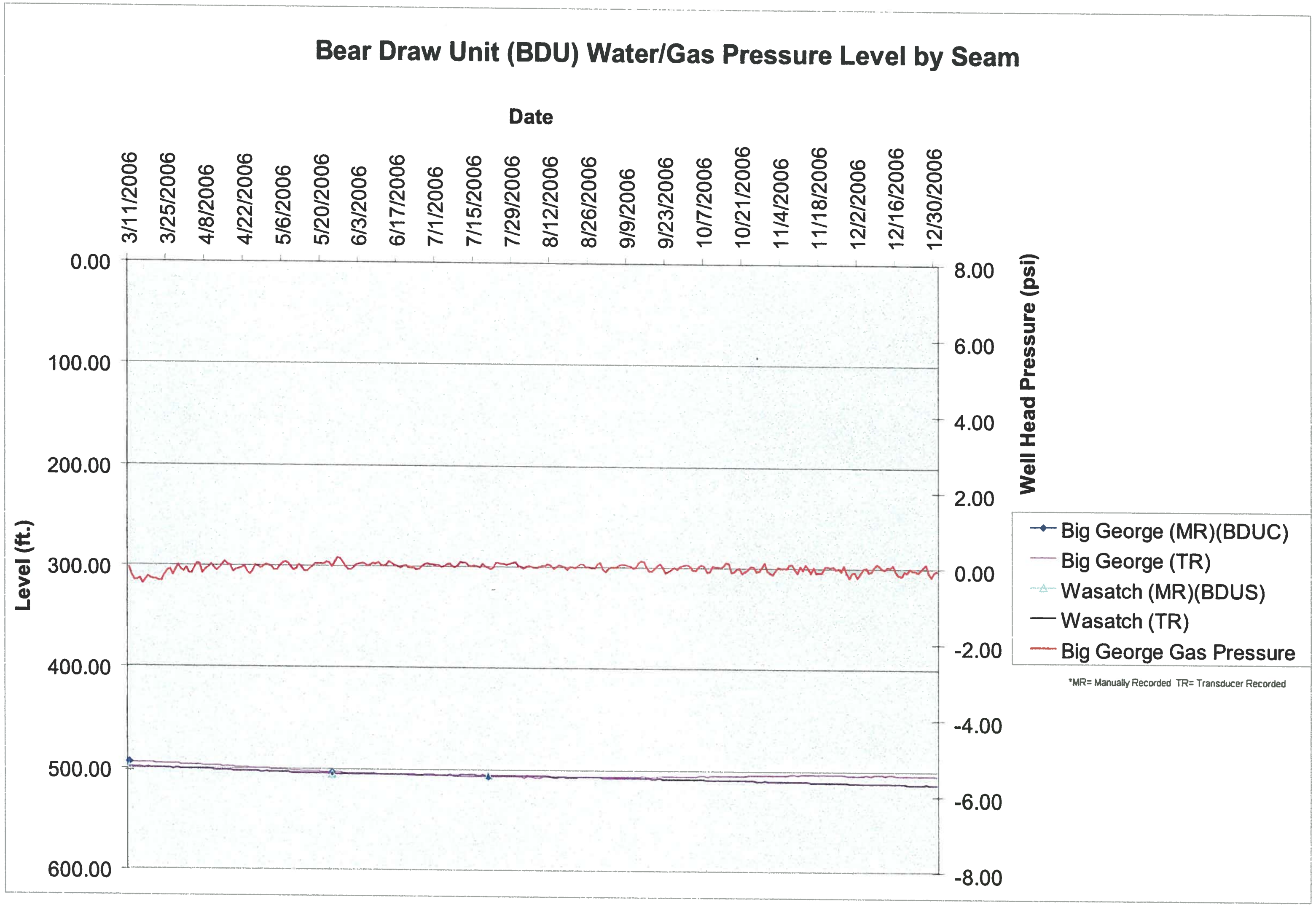

Amoco WCH 5 West Campbell Hydrological (477236B1) Water/Gas Pressure Level
by Seam
Date
4/25/1995
10/25/1995
4/25/1996
10/25/1996
4/25/1997
10/25/1997
4/25/1998
10/25/1998
4/25/1999
10/25/1999
4/25/2000
10/25/2000
4/25/2001
10/25/2001
4/25/2002
10/25/2002
4/25/2003
10/25/2003
4/25/2004
10/25/2004
4/25/2005
Level (ft.)
0.00
100.00
200.00
300.00
400.00
500.00
600.00
Well Head Pressure (psi)
40.00
30.00
20.00
10.00
0.00
-10.00
-20.00
Wyodak (MR)(477236B1)
Wyodak (TR)
Wyodak Gas Pressure
*MR= Manually Recorded, TR= Transducer Recorded

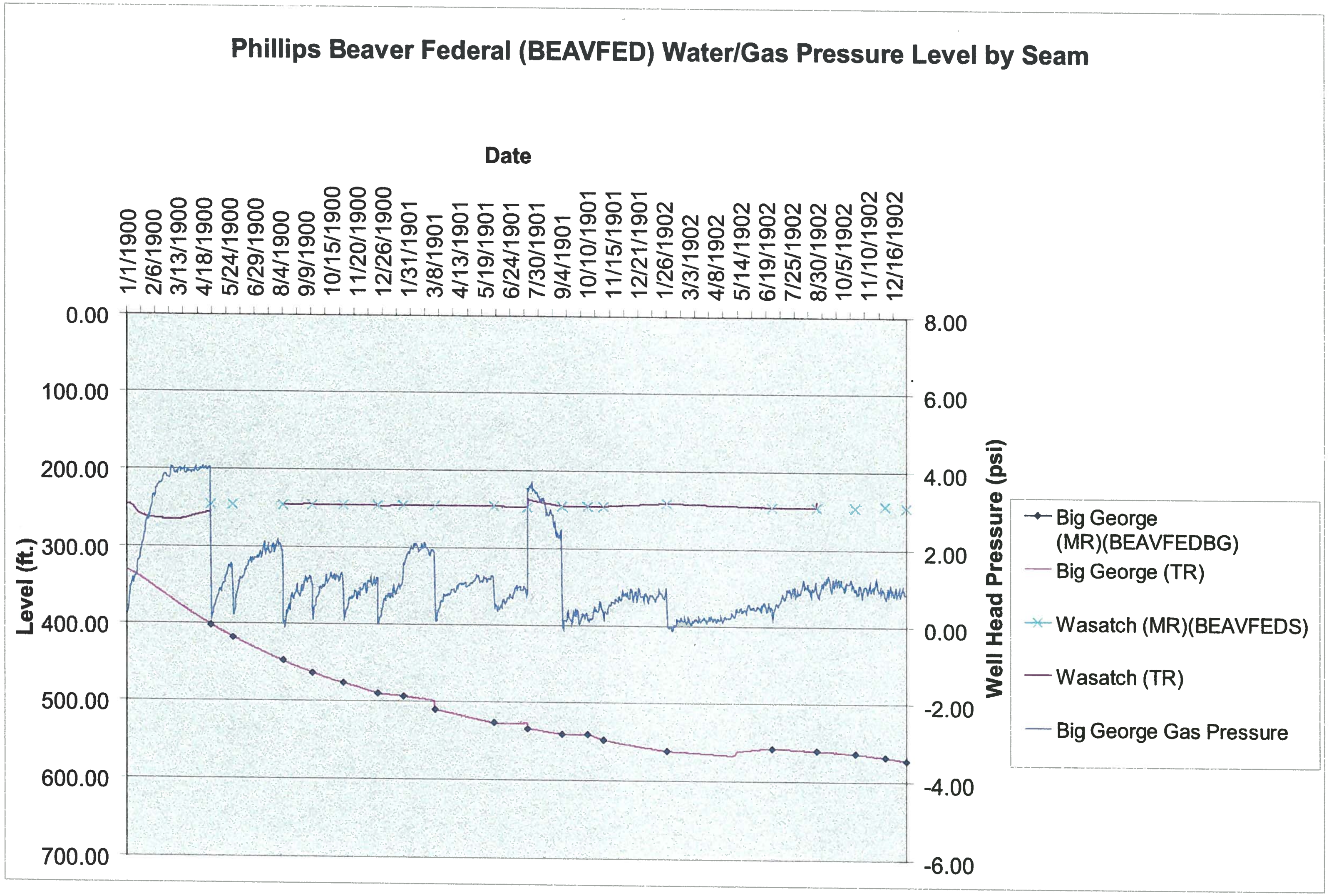

All Night Creek (ANC) Water/Gas Pressure Level by Seam
Date
3/21/2001
7/21/2001
11/21/2001
3/21/2002
7/21/2002
11/21/2002
3/21/2003
7/21/2003
11/21/2003
3/21/2004
7/21/2004
11/21/2004
3/21/2005
7/21/2005
11/21/2005
3/21/2006
7/21/2006
Level (ft.)
0.00
100.00
200.00
300.00
400.00
500.00
600.00
700.00
800.00
900.00
1000.00
Well Head Pressure (psi)
60.00
50.00
40.00
30.00
20.00
10.00
0.00
-10.00
-20.00
-30.00
Big George (MR)(ANCC)
Big George (TR)
Wasatch (MR)(ANCS)
Wasatch (TR)
Shallow Sand (MR)(ANCSS)
Very Shallow Sand (MR)(ANCVSS)
Very Very Shallow Sand (MR)(ANCVVSS)
Big George Gas Pressure

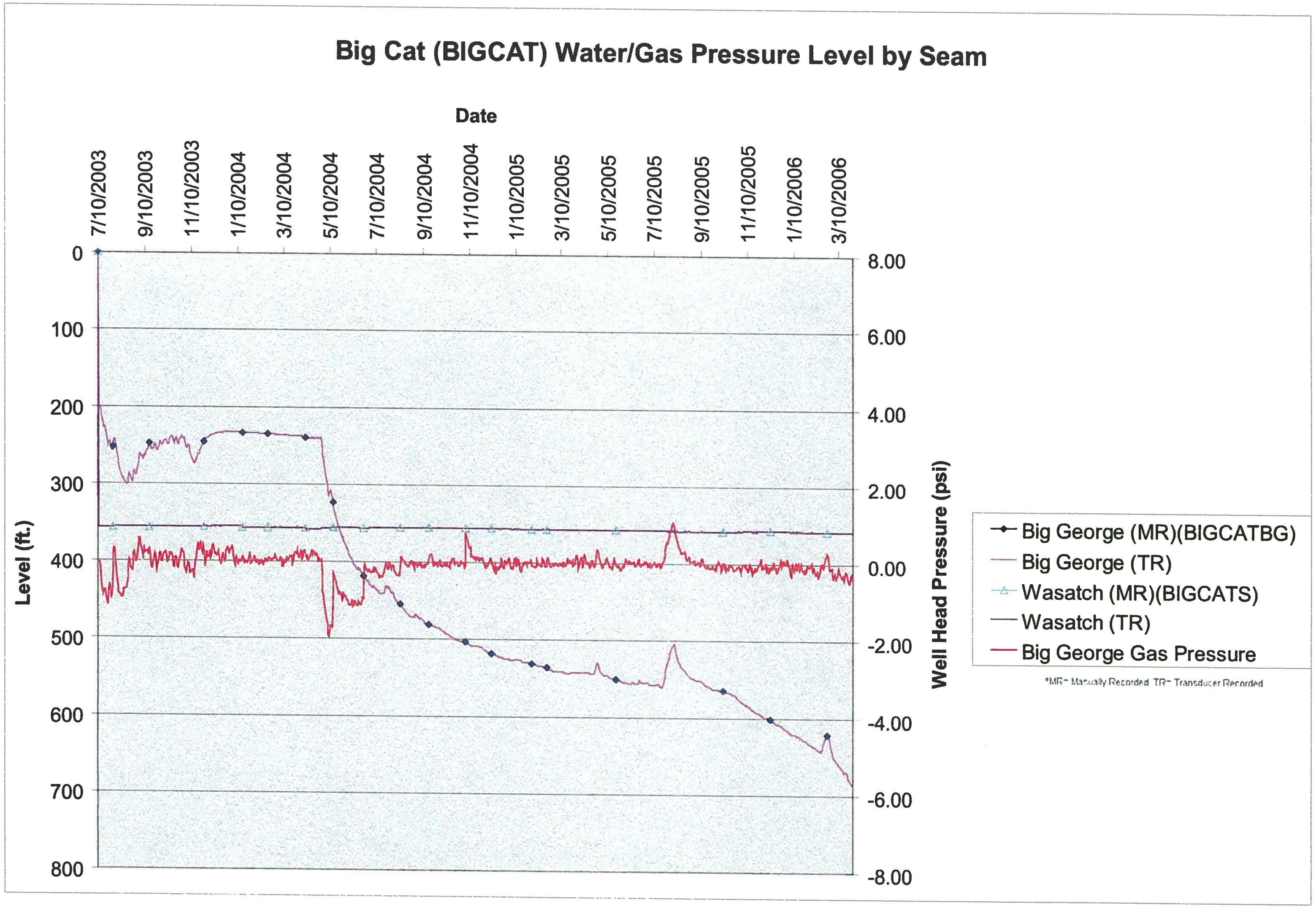


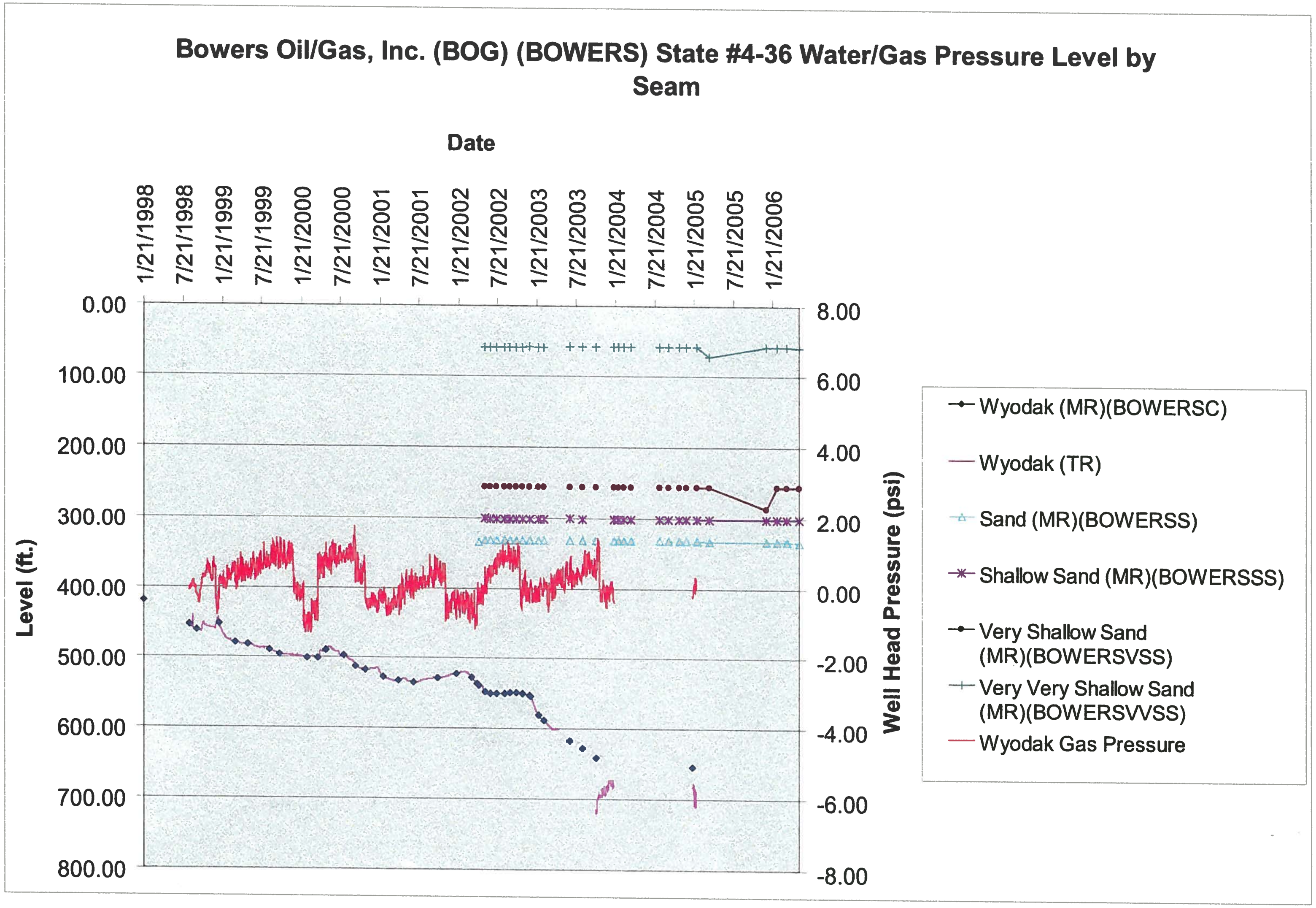
Barton (BARTON) Water/Gas Pressure Level by Seam
Date
1/23/2002
4/23/2002
7/23/2002
10/23/2002
1/23/2003
4/23/2003
7/23/2003
10/23/2003
1/23/2004
4/23/2004
7/23/2004
10/23/2004
1/23/2005
4/23/2005
7/23/2005
10/23/2005
1/23/2006
4/23/2006
7/23/2006
10/23/2006
Level (ft.)
0.00
100.00
200.00
300.00
400.00
500.00
600.00
Well Head Pressure (psi)
8.00
6.00
4.00
2.00
0.00
-2.00
-4.00
Cook (MR)(BARTONC)
Cook (TR)
Wall (MR)(BARTONNW)
Wall (TR)
Barton Gas Pressure
Wall Gas Pressure
*MR= Manually Recorded, TR= Transducer Recorded

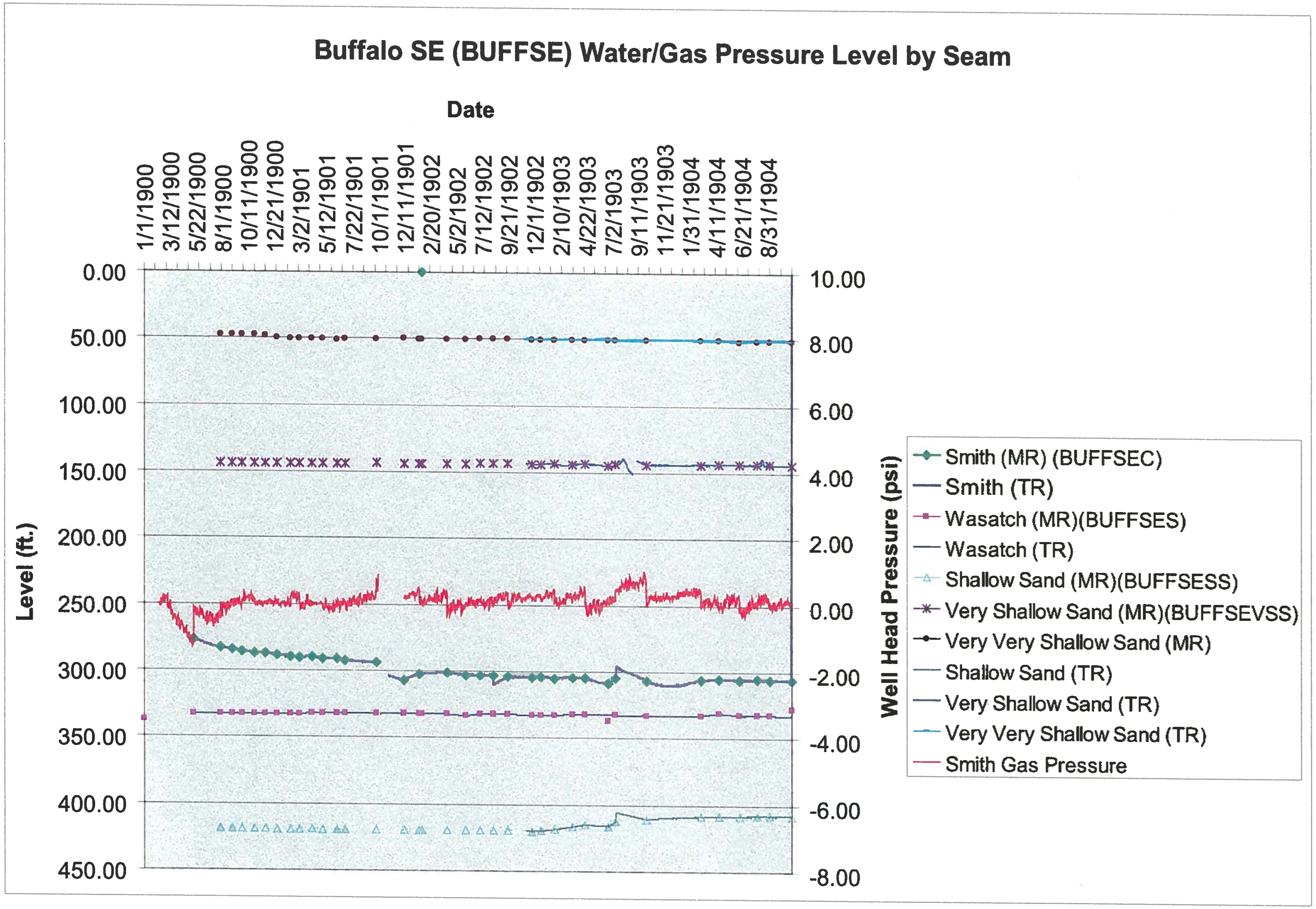

Blackbird Coleman (BBIRD) Water/Gas Pressure Level by Seam
Date
7/12/2000
11/12/2000
3/12/2001
7/12/2001
11/12/2001
3/12/2002
7/12/2002
11/12/2002
3/12/2003
7/12/2003
11/12/2003
3/12/2004
7/12/2004
11/12/2004
3/12/2005
7/12/2005
11/12/2005
3/12/2006
7/12/2006
Level (ft.)
0.00
100.00
200.00
300.00
400.00
500.00
600.00
Well Head Prseere (psi)
6.00
4.00
2.00
0.00
-2.00
-4.00
-6.00
Wyodak (MR)(BBIRDC)
Wyodak (TR)
Wasatch (MR)(BBIRDS)
Wasatch (TR)
Big George (MR)(BBIRDBG)
Big George (TR)
Wyodak Gas Pressure
BG Gas Pressure
*MR= Manually Recorded TR= Transducer Recorded

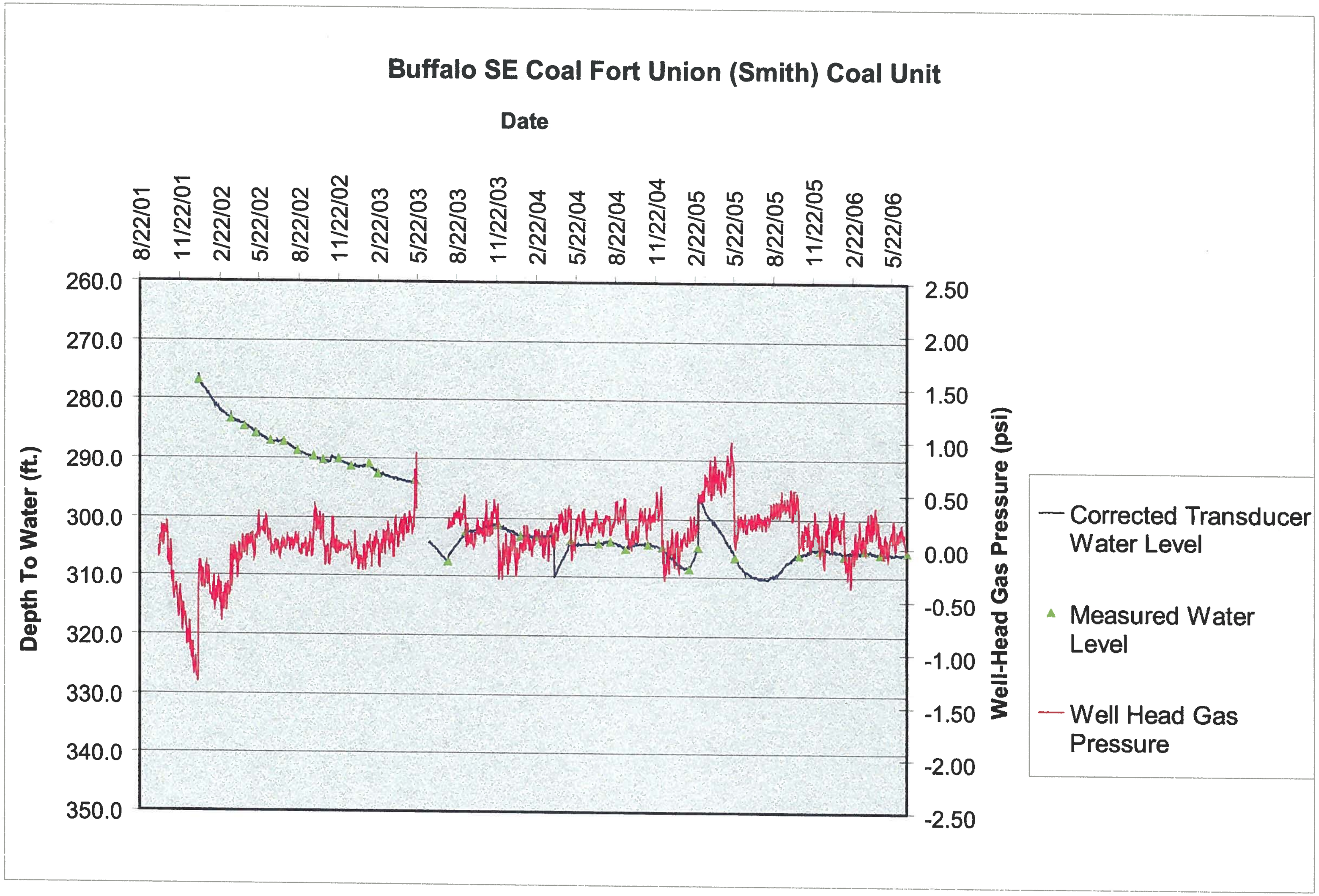

Bear Draw Unit (BDU) Water/Gas Pressure Level by Seam
Date
3/11/2006
3/25/2006
4/8/2006
4/22/2006
5/6/2006
5/20/2006
6/3/2006
6/17/2006
7/1/2006
7/15/2006
7/29/2006
8/12/2006
8/26/2006
9/9/2006
9/23/2006
10/7/2006
10/21/2006
11/4/2006
11/18/2006
12/2/2006
12/16/2006
12/30/2006
Level (ft.)
0.00
100.00
200.00
300.00
400.00
500.00
600.00
Well Head Pressure (psi)
8.00
6.00
4.00
2.00
0.00
-2.00
-4.00
-6.00
-8.00
Big George (MR)(BDUC)
Big George (TR)
Wasatch (MR)(BDUS)
Wasatch (TR)
Big George Gas Pressure
*MR= Manually Recorded TR= Transducer Recorded


Phillips Beaver Federal (BEAVFED) Water/Gas Pressure Level by Seam
Date
1/1/1900
2/6/1900
3/13/1900
4/18/1900
5/24/1900
6/29/1900
8/4/1900
9/9/1900
10/15/1900
11/20/1900
12/26/1900
1/31/1901
3/8/1901
4/13/1901
5/19/1901
6/24/1901
7/30/1901
9/4/1901
10/10/1901
11/15/1901
12/21/1901
1/26/1902
3/3/1902
4/8/1902
5/14/1902
6/19/1902
7/25/1902
8/30/1902
10/5/1902
11/10/1902
12/16/1902
Level (ft.)
0.00
100.00
200.00
300.00
400.00
500.00
600.00
700.00
Well Head Pressure (psi)
8.00
6.00
4.00
2.00
0.00
-2.00
-4.00
-6.00
Big George (MR)(BEAVFEDBG)
Big George (TR)
Wasatch (MR)(BEAVFEDS)
Wasatch (TR)
Big George Gas Pressure

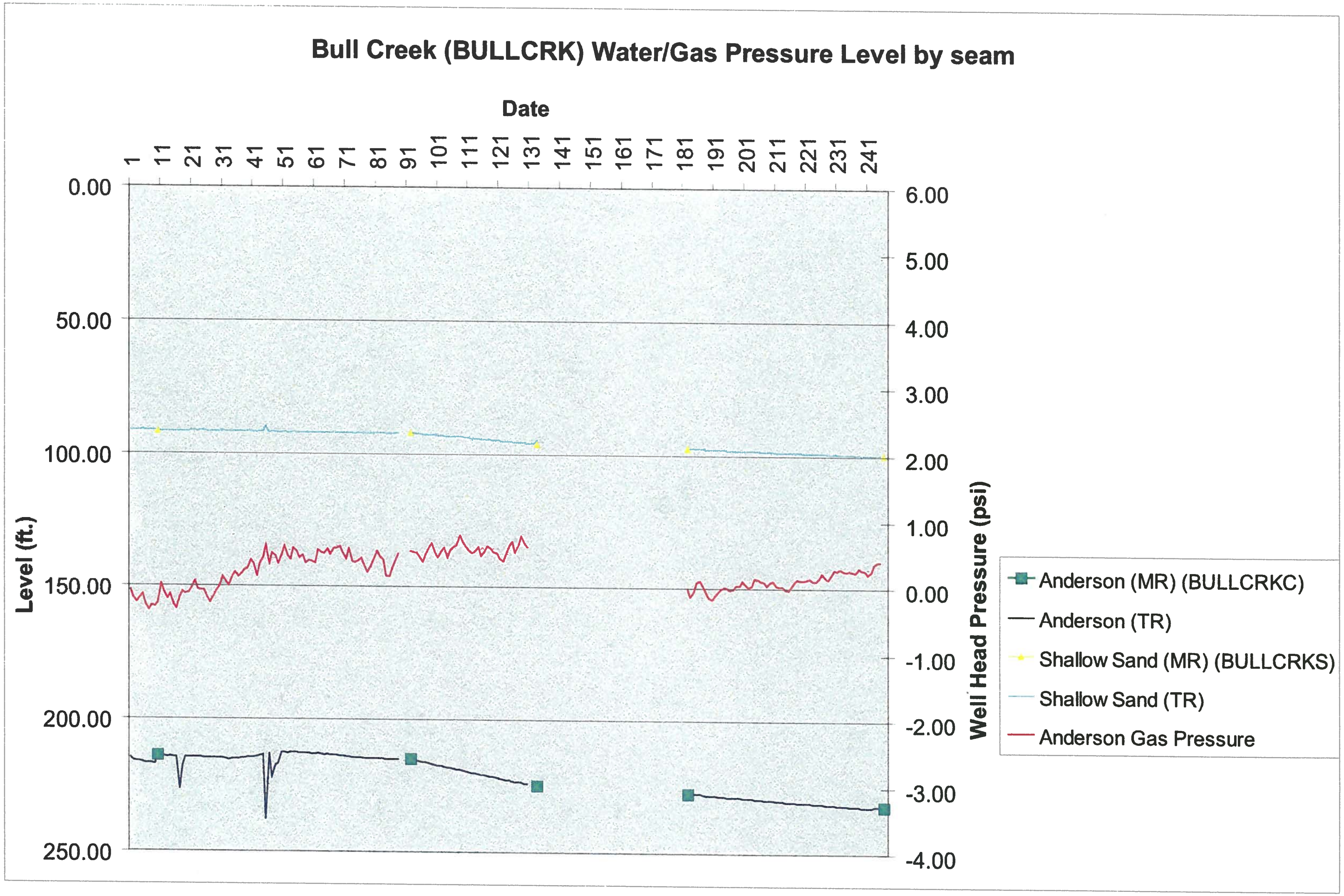

Big Cat (BIGCAT) Water/Gas Pressure Level by Seam
Date
7/10/2003
9/10/2003
11/10/2003
1/10/2004
3/10/2004
5/10/2004
7/10/2004
9/10/2004
11/10/2004
1/10/2005
3/10/2005
5/10/2005
7/10/2005
9/10/2005
11/10/2005
1/10/2006
3/10/2006
Level (ft.)
0
100
200
300
400
500
600
700
800
Well Head Pressure (psi)
8.00
6.00
4.00
2.00
0.00
-2.00
-4.00
-6.00
-8.00
Big George (MR)(BIGCATBG)
Big George (TR)
Wasatch (MR)(BIGCATS)
Wasatch (TR)
Big George Gas Pressure
*MR= Manually Recorded TR= Transducer Recorded


Bowers Oil/Gas, Inc. (BOG) (BOWERS) State #4-36 Water/Gas Pressure Level by Seam
Date
1/21/1998
7/21/1998
1/21/1999
7/21/1999
1/21/2000
7/21/2000
1/21/2001
7/21/2001
1/21/2002
7/21/2002
1/21/2003
7/21/2003
1/21/2004
7/21/2004
1/21/2005
7/21/2005
1/21/2006
Level (ft.)
0.00
100.00
200.00
300.00
400.00
500.00
600.00
700.00
800.00
Well Head Pressure (psi)
8.00
6.00
4.00
2.00
0.00
-2.00
-4.00
-6.00
-8.00
Wyodak (MR)(BOWERSC)
Wyodak (TR)
Sand (MR)(BOWERSS)
Shallow Sand (MR)(BOWERSSS)
Very Shallow Sand (MR)(BOWERSVSS)
Very Very Shallow Sand (MR)(BOWERSVVSS)
Wyodak Gas Pressure

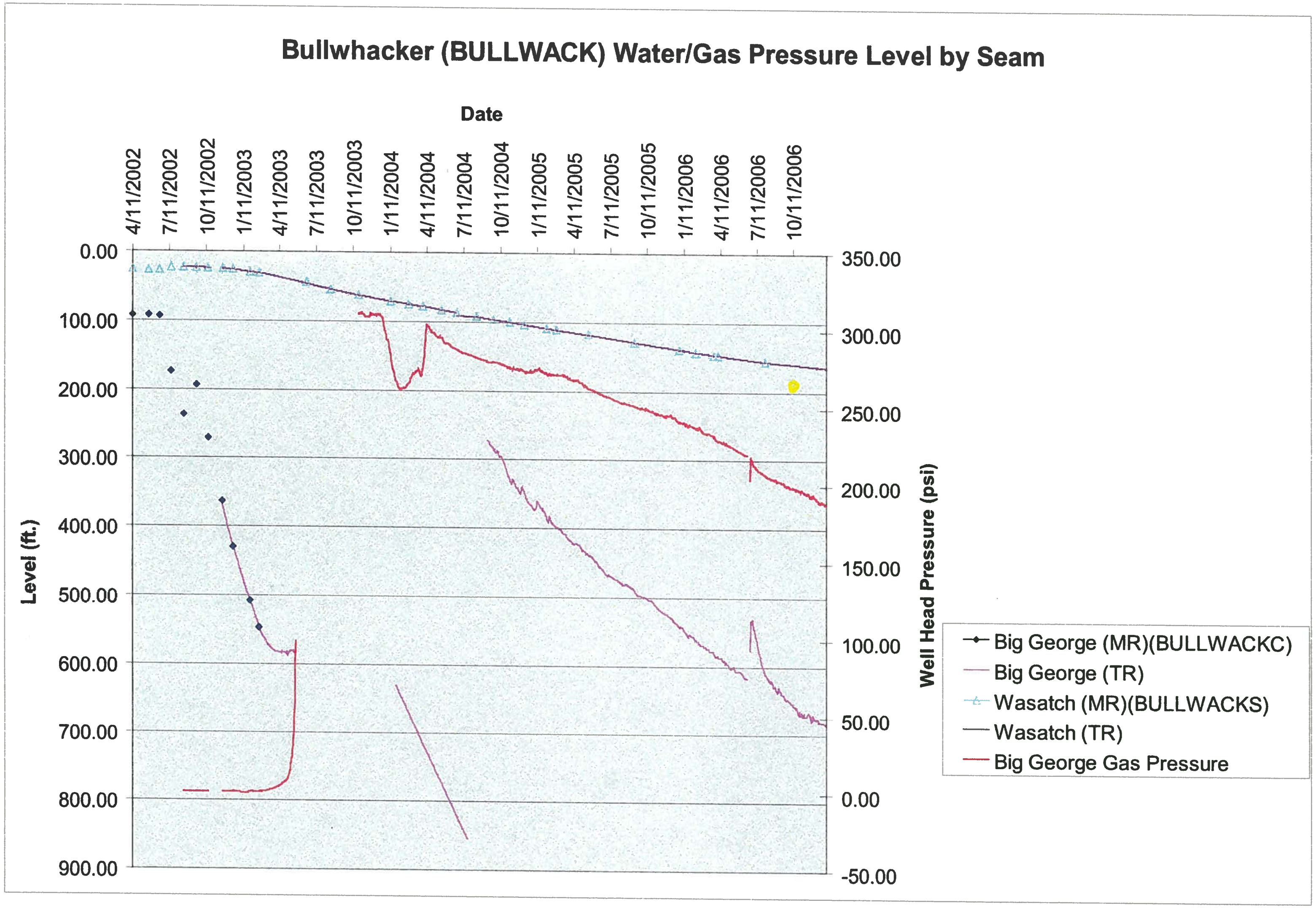

Buffalo SE (BUFFSE) Water/Gas Pressure Level by Seam
Date
1/1/1900
3/12/1900
5/22/1900
8/1/1900
10/11/1900
12/21/1900
3/2/1901
5/12/1901
7/22/1901
10/1/1901
12/11/1901
2/20/1902
5/2/1902
7/12/1902
9/21/1902
12/1/1902
2/10/1903
4/22/1903
7/2/1903
9/11/1903
11/21/1903
1/31/1904
4/11/1904
6/21/1904
8/31/1904
Level (ft.)
0.00
50.00
100.00
150.00
200.00
250.00
300.00
350.00
400.00
450.00
Well Head Pressure (psi)
10.00
8.00
6.00
4.00
2.00
0.00
-2.00
-4.00
-6.00
-8.00
Smith (MR) (BUFFSEC)
Smith (TR)
Wasatch (MR)(BUFFSES)
Wasatch (TR)
Shallow Sand (MR)(BUFFSESS)
Very Shallow Sand (MR)(BUFFSEVSS)
Very Very Shallow Sand (MR)
Shallow Sand (TR)
Very Shallow Sand (TR)
Very Very Shallow Sand (TR)
Smith Gas Pressure



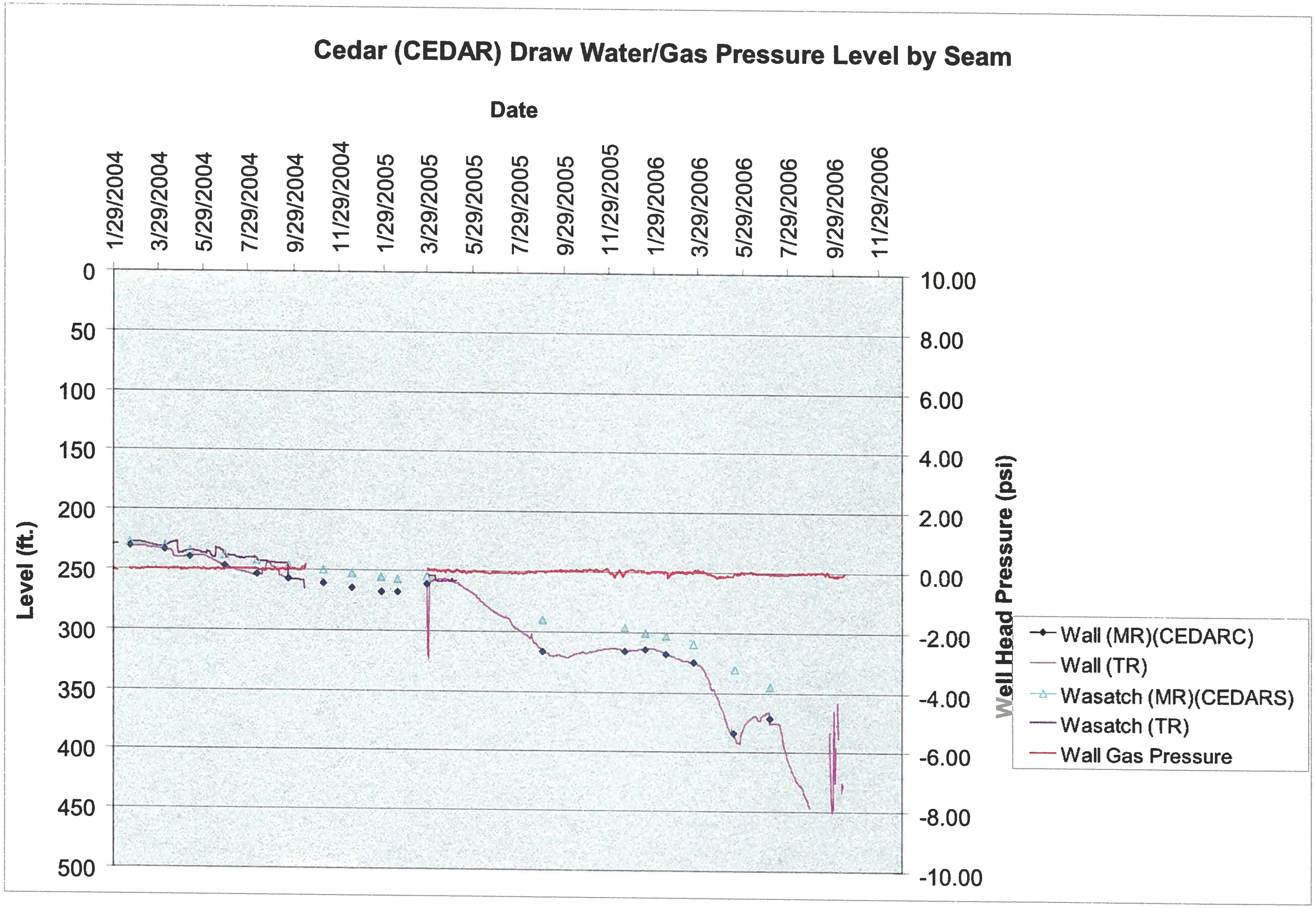
Buffalo SE Coal Fort Union (Smith) Coal Unit
Date
8/22/01
11/22/01
2/22/02
5/22/02
8/22/02
11/22/02
2/22/03
5/22/03
8/22/03
11/22/03
2/22/04
5/22/04
8/22/04
11/22/04
2/22/05
5/22/05
8/22/05
11/22/05
2/22/06
5/22/06
Depth To Water (ft.)
260.0
270.0
280.0
290.0
300.0
310.0
320.0
330.0
340.0
350.0
Well-Head Gas Pressure (psi)
2.50
2.00
1.50
1.00
0.50
0.00
-0.50
-1.00
-1.50
-2.00
-2.50
Corrected Transducer Water Level
Measured Water Level
Well Head Gas Pressure



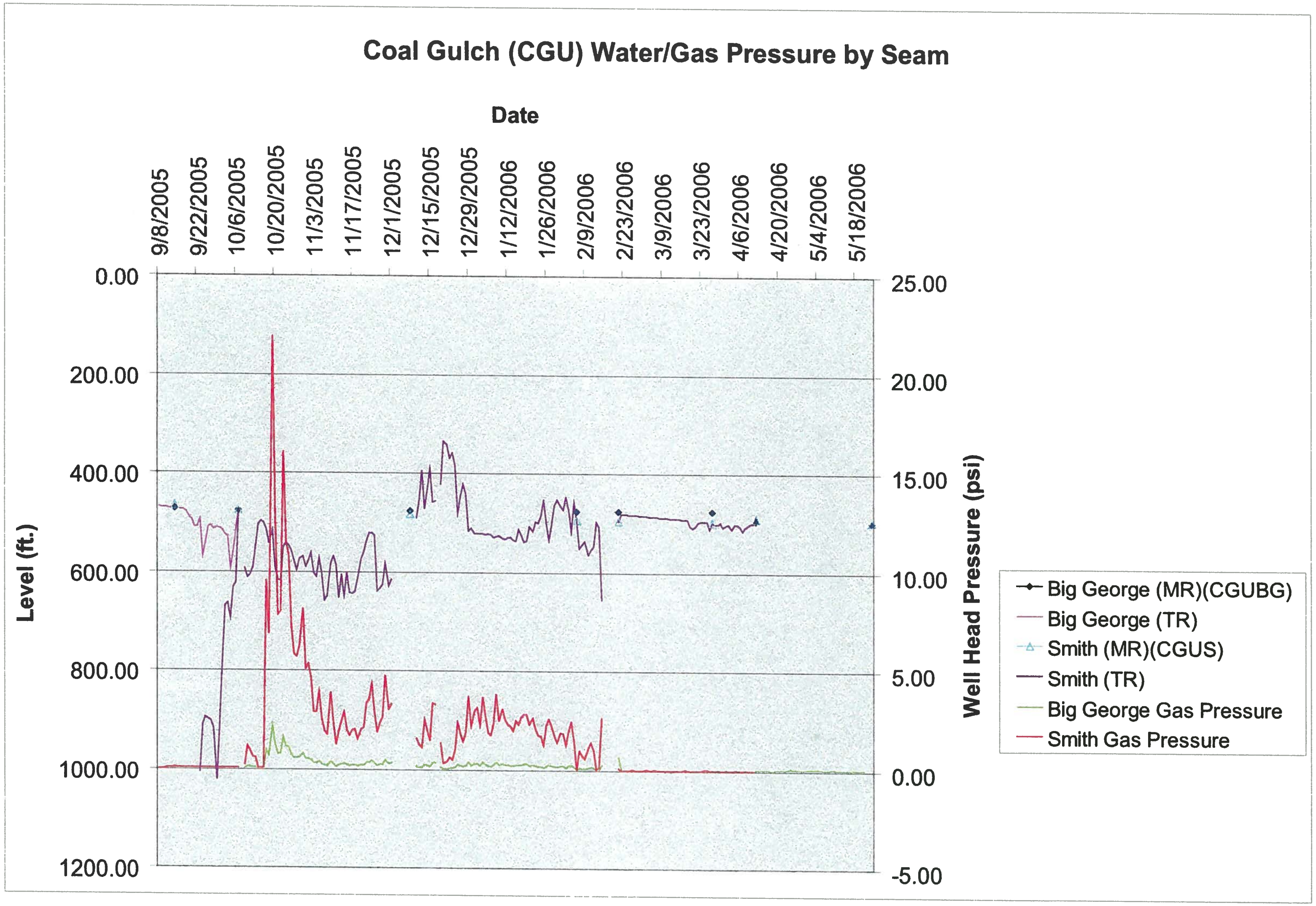
Bull Creek (BULLCRK) Water/Gas Pressure Level by seam
Date
1
11
21
31
41
51
61
71
81
91
101
111
121
131
141
151
161
171
181
191
201
211
221
231
241
Level (ft.)
0.00
50.00
100.00
150.00
200.00
250.00
Well Head Pressure (psi)
6.00
5.00
4.00
3.00
2.00
1.00
0.00
-1.00
-2.00
-3.00
-4.00
Anderson (MR) (BULLCRKC)
Anderson (TR)
Shallow Sand (MR) (BULLCRKS)
Shallow Sand (TR)
Anderson Gas Pressure

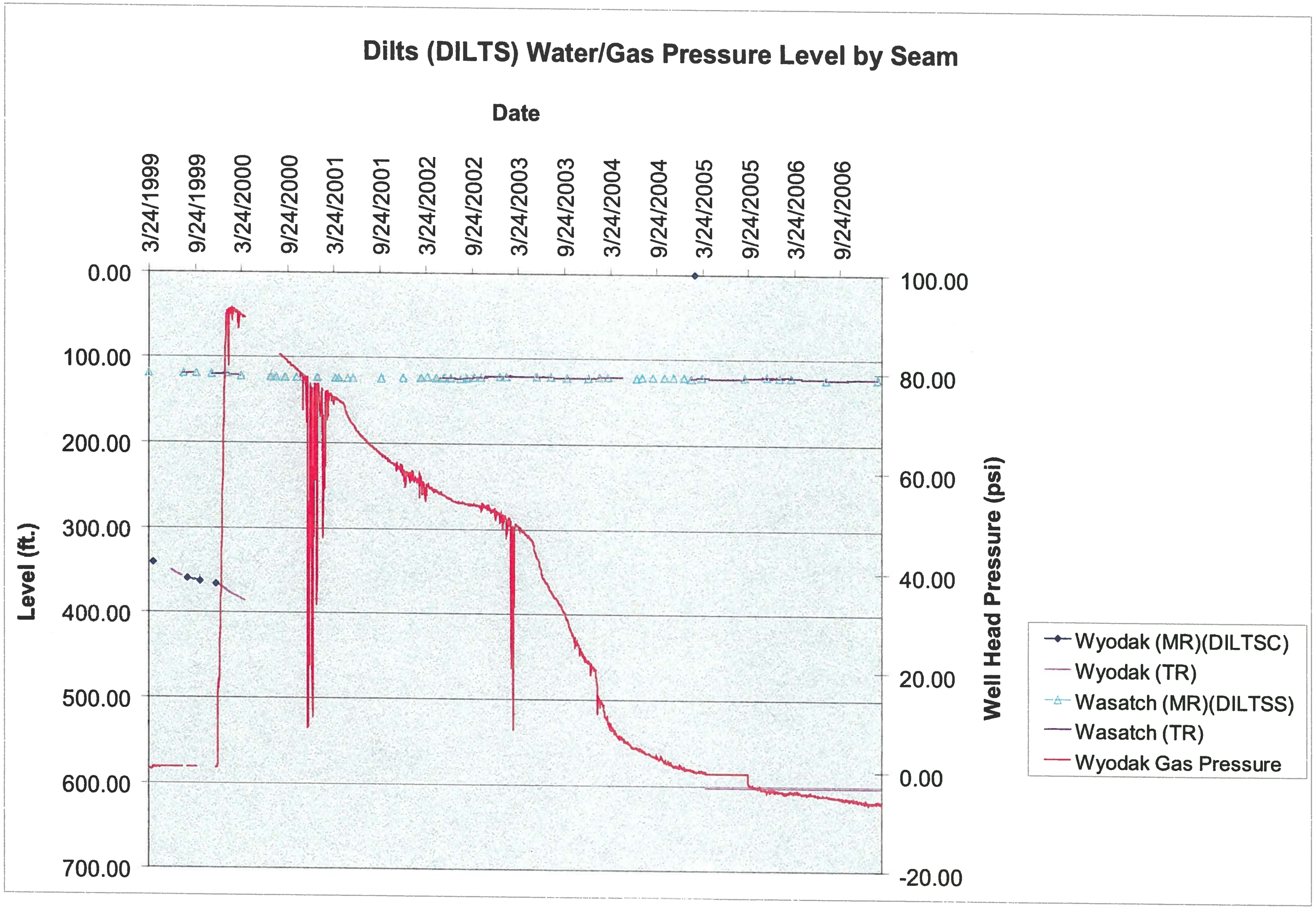


Bullwhacker (BULLWACK) Water/Gas Pressure Level by Seam
Date
4/11/2002
7/11/2002
10/11/2002
1/11/2003
4/11/2003
7/11/2003
10/11/2003
1/11/2004
4/11/2004
7/11/2004
10/11/2004
1/11/2005
4/11/2005
7/11/2005
10/11/2005
1/11/2006
4/11/2006
7/11/2006
10/11/2006
Level (ft.)
0.00
100.00
200.00
300.00
400.00
500.00
600.00
700.00
800.00
900.00
Well Head Pressure (psi)
350.00
300.00
250.00
200.00
150.00
100.00
50.00
0.00
-50.00
Big George (MR)(BULLWACKC)
Big George (TR)
Wasatch (MR)(BULLWACKS)
Wasatch (TR)
Big George Gas Pressure

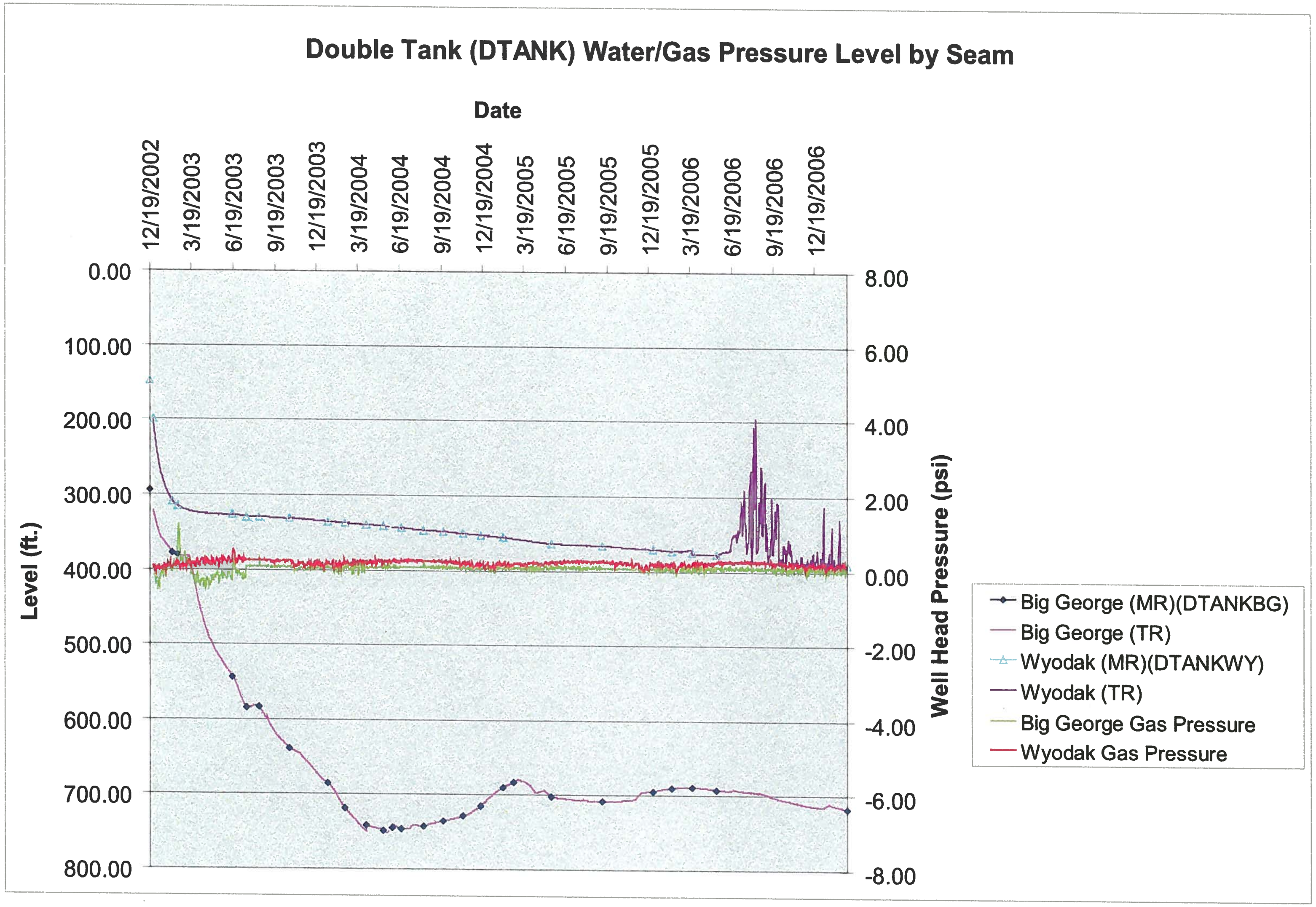


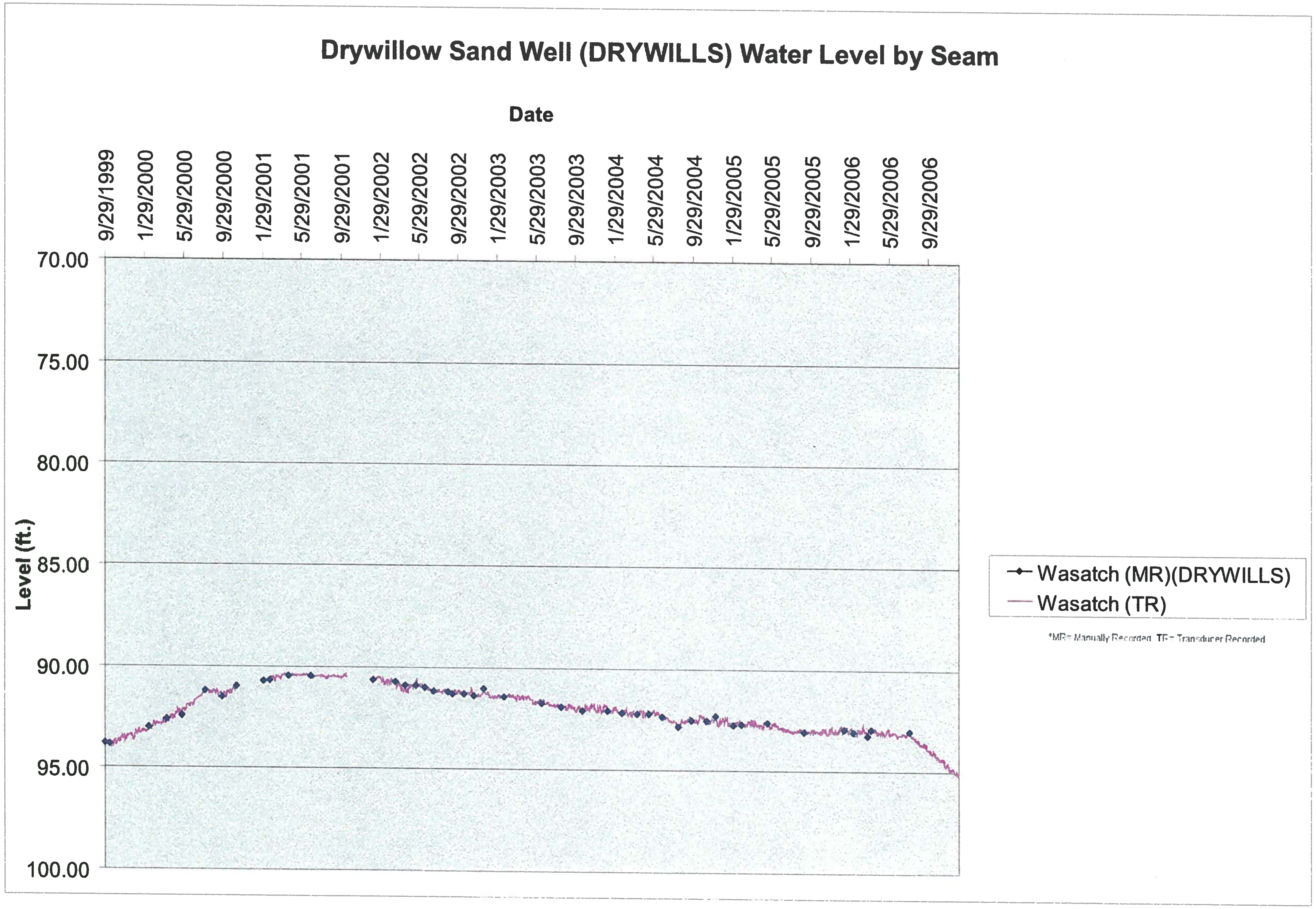
Cedar (CEDAR) Draw Water/Gas Pressure Level by Seam
Date
1/29/2004
3/29/2004
5/29/2004
7/29/2004
9/29/2004
11/29/2004
1/29/2005
3/29/2005
5/29/2005
7/29/2005
9/29/2005
11/29/2005
1/29/2006
3/29/2006
5/29/2006
7/29/2006
9/29/2006
11/29/2006
Level (ft.)
0
50
100
150
200
250
300
350
400
450
500
Well Head Pressure (psi)
10.00
8.00
6.00
4.00
2.00
0.00
-2.00
-4.00
-6.00
-8.00
-10.00
Wall (MR)(CEDARC)
Wall (TR)
Wasatch (MR)(CEDARS)
Wasatch (TR)
Wall Gas Pressure


Coal Gulch (CGU) Water/Gas Pressure by Seam
Date
9/8/2005
9/22/2005
10/6/2005
10/20/2005
11/3/2005
11/17/2005
12/1/2005
12/15/2005
12/29/2005
1/12/2006
1/26/2006
2/9/2006
2/23/2006
3/9/2006
3/23/2006
4/6/2006
4/20/2006
5/4/2006
5/18/2006
Level (ft.)
0.00
200.00
400.00
600.00
800.00
1000.00
1200.00
Well Head Pressure (psi)
25.00
20.00
15.00
10.00
5.00
0.00
-5.00
Big George (MR)(CGUBG)
Big George (TR)
Smith (MR)(CGUS)
Smith (TR)
Big George Gas Pressure
Smith Gas Pressure

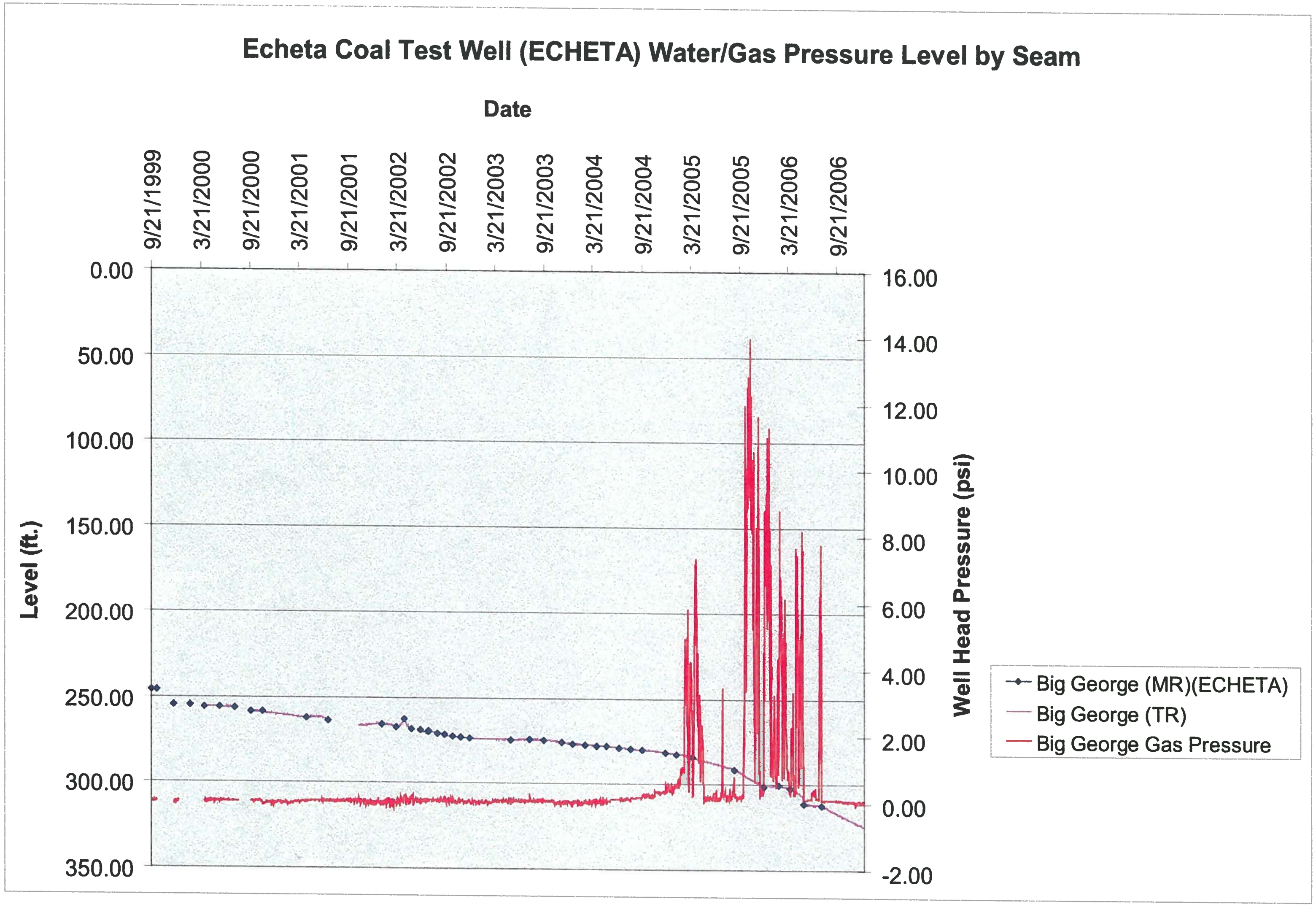


Dilts (DILTS) Water/Gas Pressure Level by Seam
Date
3/24/1999
9/24/1999
3/24/2000
9/24/2000
3/24/2001
9/24/2001
3/24/2002
9/24/2002
3/24/2003
9/24/2003
3/24/2004
9/24/2004
3/24/2005
9/24/2005
3/24/2006
9/24/2006
Level (ft.)
0.00
100.00
200.00
300.00
400.00
500.00
600.00
700.00
Well Head Pressure (psi)
100.00
80.00
60.00
40.00
20.00
0.00
-20.00
Wyodak (MR)(DILTSC)
Wyodak (TR)
Wasatch (MR)(DILTSS)
Wasatch (TR)
Wyodak Gas Pressure

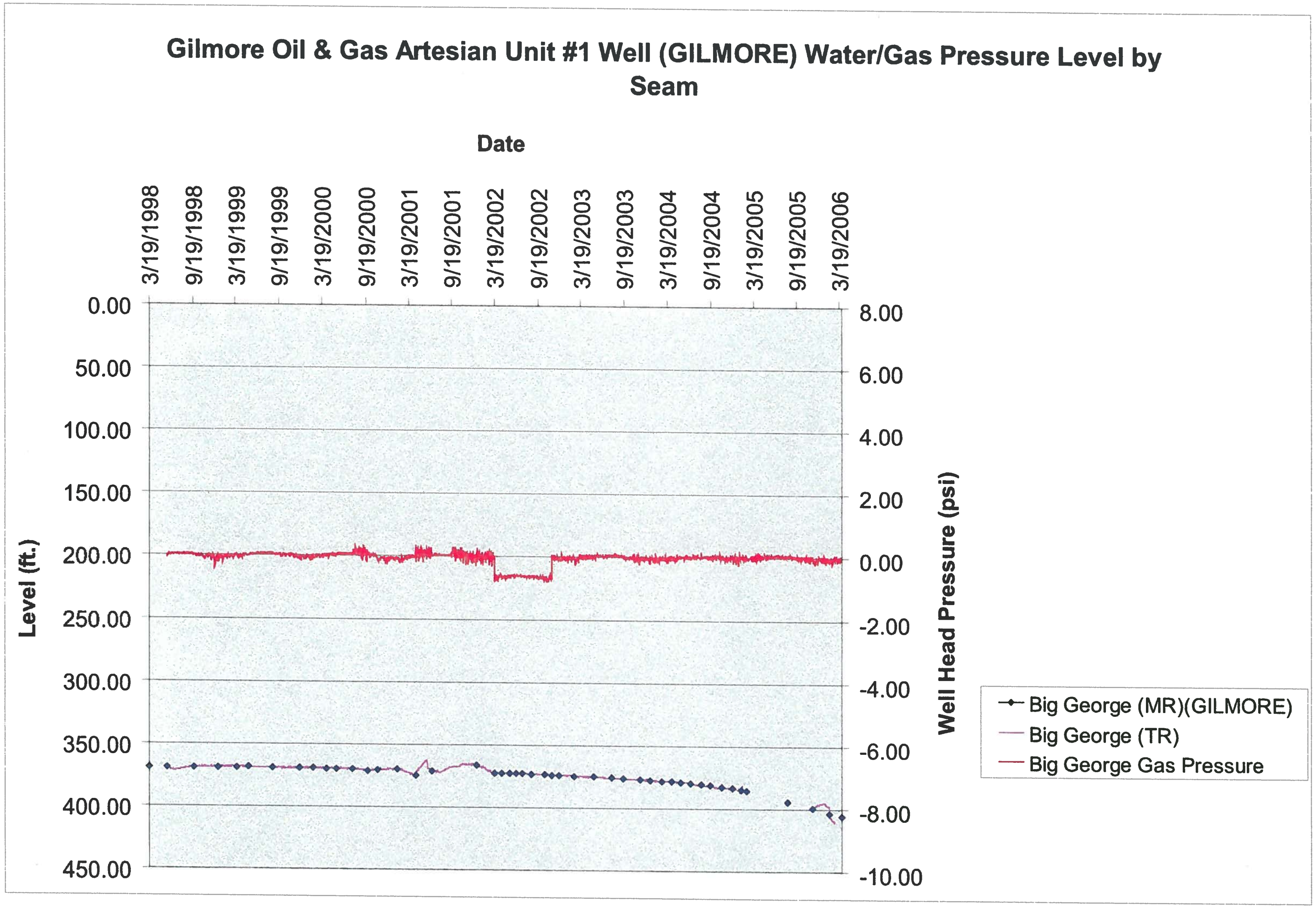

Double Tank (DTANK) Water/Gas Pressure Level by Seam
Date
12/19/2002
3/19/2003
6/19/2003
9/19/2003
12/19/2003
3/19/2004
6/19/2004
9/19/2004
12/19/2004
3/19/2005
6/19/2005
9/19/2005
12/19/2005
3/19/2006
6/19/2006
9/19/2006
12/19/2006
Level (ft.)
0.00
100.00
200.00
300.00
400.00
500.00
600.00
700.00
800.00
Well Head Pressure (psi)
8.00
6.00
4.00
2.00
0.00
-2.00
-4.00
-6.00
-8.00
Big George (MR)(DTANKBG)
Big George (TR)
Wyodak (MR)(DTANKWY)
Wyodak (TR)
Big George Gas Pressure
Wyodak Gas Pressure



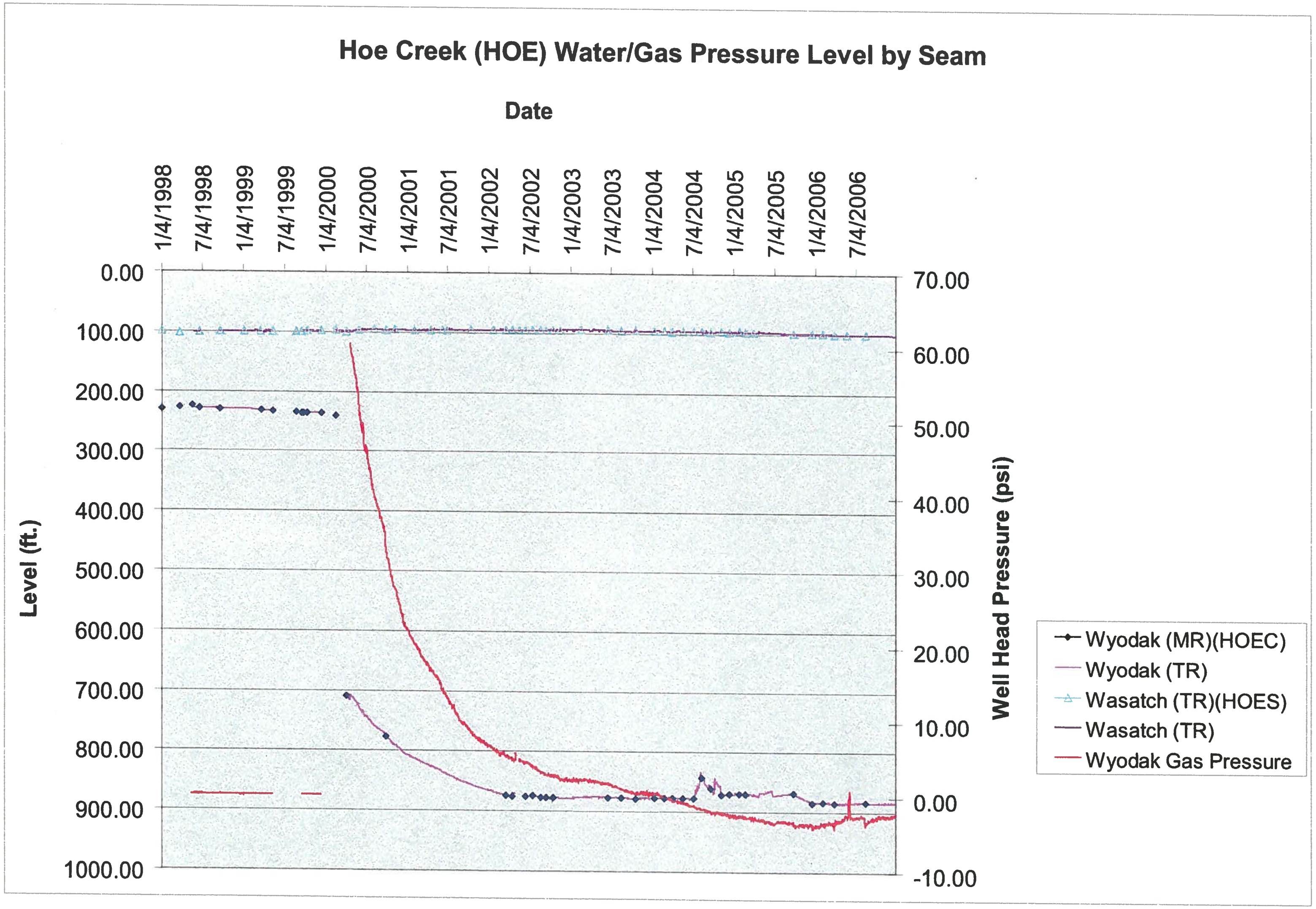
Drywillow Sand Well (DRYWILLS) Water Level by Seam
Date
9/29/1999
1/29/2000
5/29/2000
9/29/2000
1/29/2001
5/29/2001
9/29/2001
1/29/2002
5/29/2002
9/29/2002
1/29/2003
5/29/2003
9/29/2003
1/29/2004
5/29/2004
9/29/2004
1/29/2005
5/29/2005
9/29/2005
1/29/2006
5/29/2006
9/29/2006
Level (ft.)
70.00
75.00
80.00
85.00
90.00
95.00
100.00
Wasatch (MR)(DRYWILLS)
Wasatch (TR)

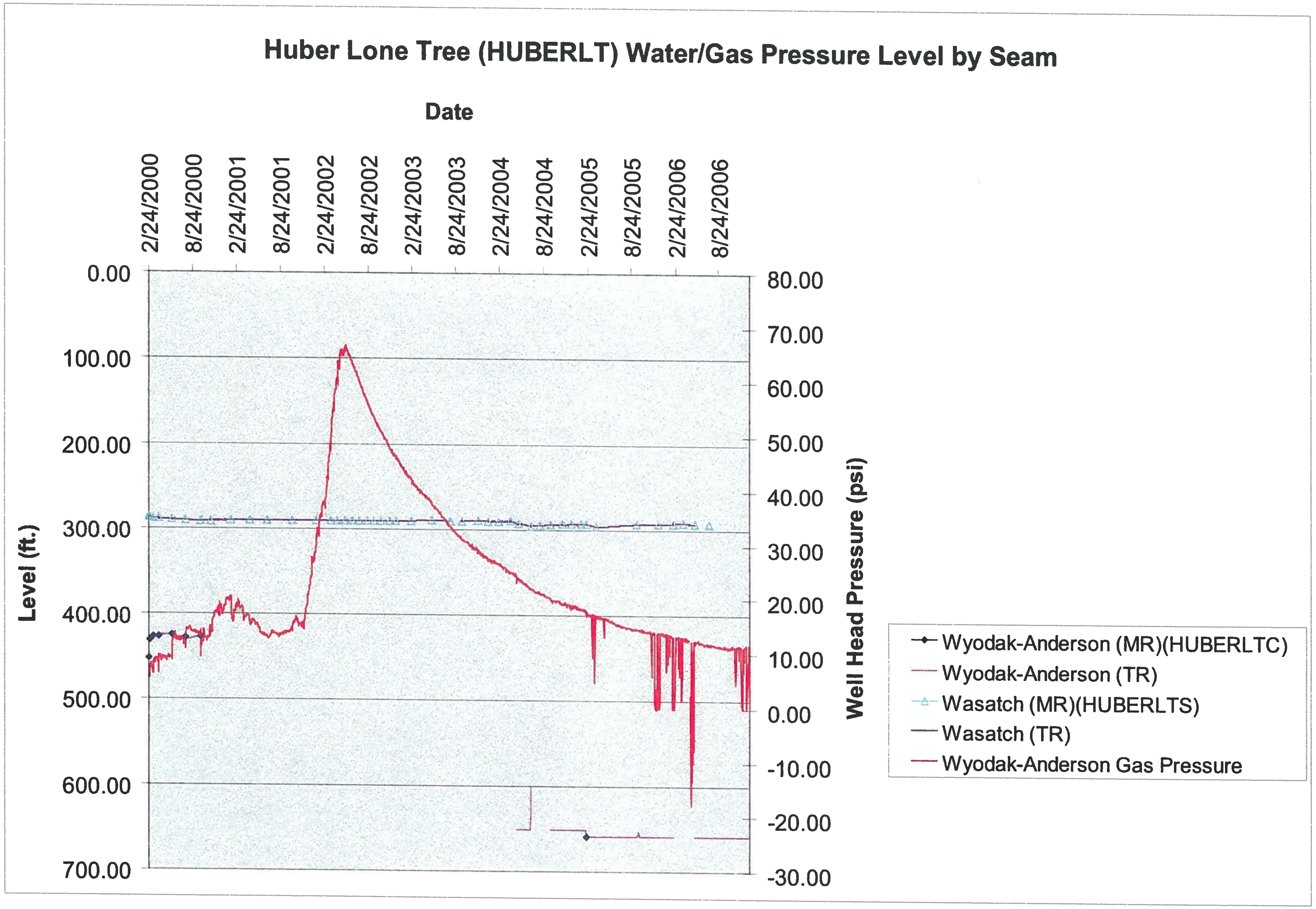


Echeta Coal Test Well (ECHETA) Water/Gas Pressure Level by Seam
Date
9/21/1999
3/21/2000
9/21/2000
3/21/2001
9/21/2001
3/21/2002
9/21/2002
3/21/2003
9/21/2003
3/21/2004
9/21/2004
3/21/2005
9/21/2005
3/21/2006
9/21/2006
Level (ft.)
0.00
50.00
100.00
150.00
200.00
250.00
300.00
350.00
Well Head Pressure (psi)
16.00
14.00
12.00
10.00
8.00
6.00
4.00
2.00
0.00
-2.00
Big George (MR)(ECHETA)
Big George (TR)
Big George Gas Pressure

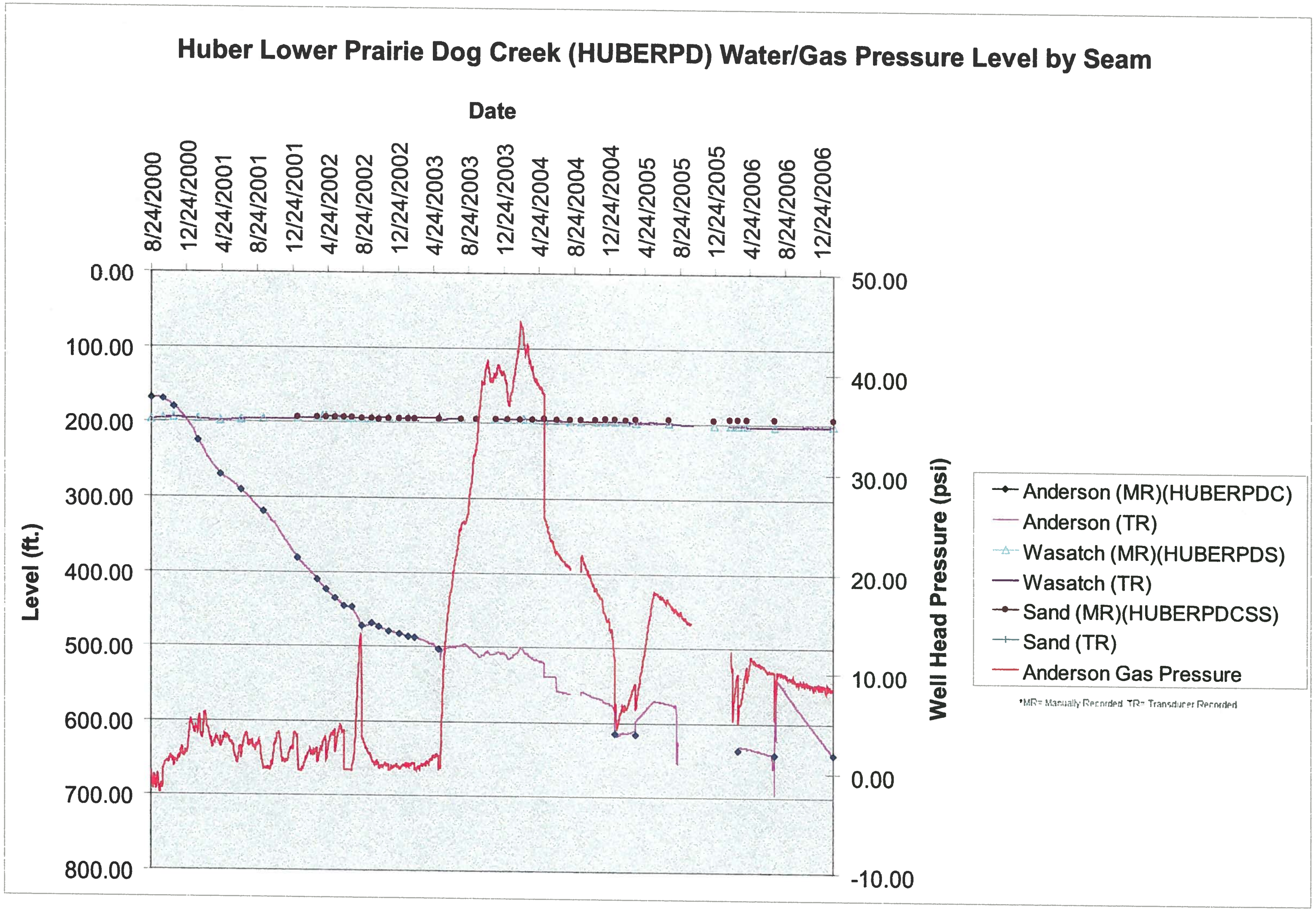


Gilmore Oil & Gas Artesian Unit #1 Well (GILMORE) Water/Gas Pressure Level by Seam
Date
3/19/1998
9/19/1998
3/19/1999
9/19/1999
3/19/2000
9/19/2000
3/19/2001
9/19/2001
3/19/2002
9/19/2002
3/19/2003
9/19/2003
3/19/2004
9/19/2004
3/19/2005
9/19/2005
3/19/2006
Level (ft.)
0.00
50.00
100.00
150.00
200.00
250.00
300.00
350.00
400.00
450.00
Well Head Pressure (psi)
8.00
6.00
4.00
2.00
0.00
-2.00
-4.00
-6.00
-8.00
-10.00
Big George (MR)(GILMORE)
Big George (TR)
Big George Gas Pressure

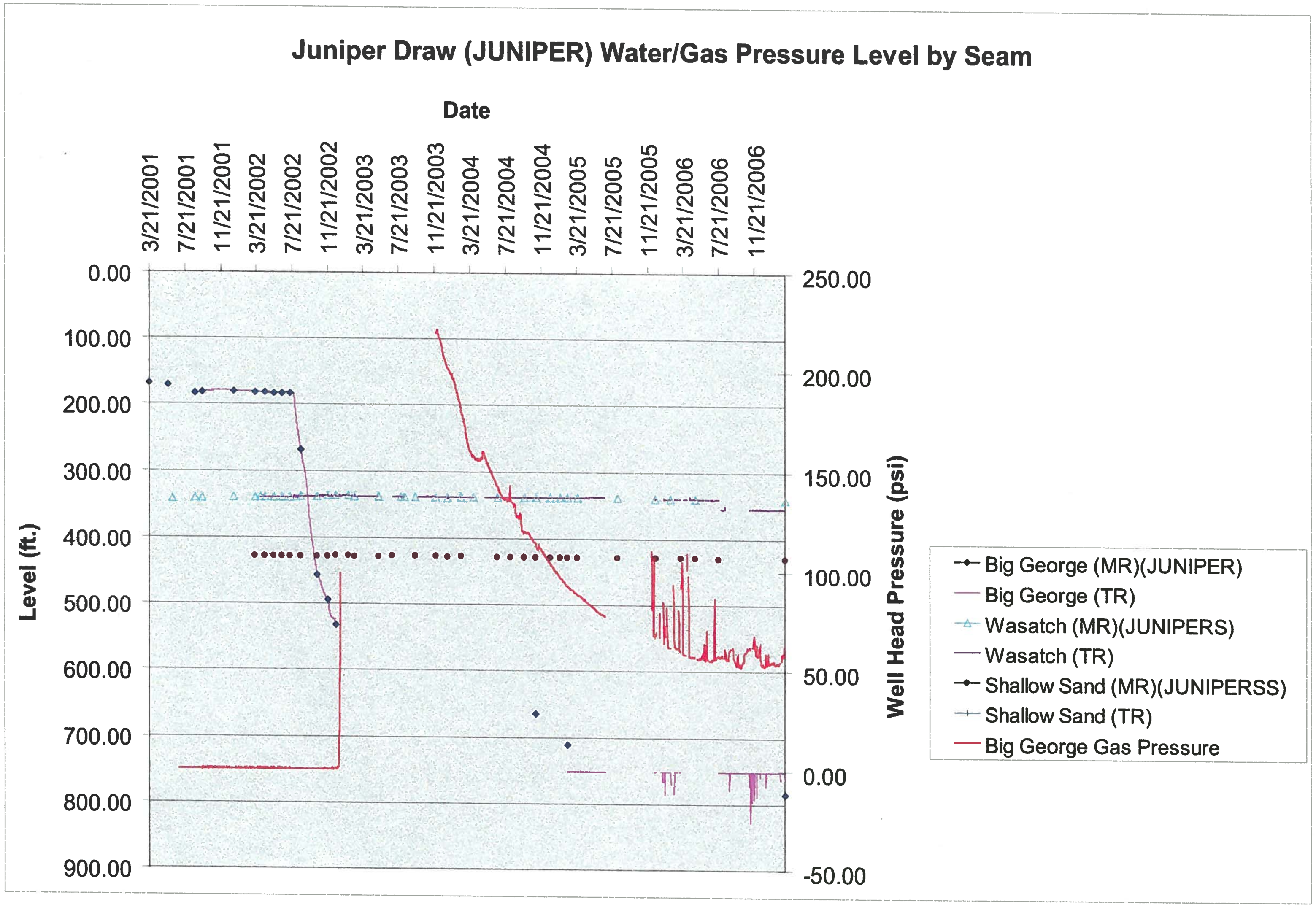

Hoe Creek (HOE) Water/Gas Pressure Level by Seam
Date
1/4/1998
7/4/1998
1/4/1999
7/4/1999
1/4/2000
7/4/2000
1/4/2001
7/4/2001
1/4/2002
7/4/2002
1/4/2003
7/4/2003
1/4/2004
7/4/2004
1/4/2005
7/4/2005
1/4/2006
7/4/2006
Level (ft.)
0.00
100.00
200.00
300.00
400.00
500.00
600.00
700.00
800.00
900.00
1000.00
Well Head Pressure (psi)
70.00
60.00
50.00
40.00
30.00
20.00
10.00
0.00
-10.00
Wyodak (MR)(HOEC)
Wyodak (TR)
Wasatch (TR)(HOES)
Wasatch (TR)
Wyodak Gas Pressure

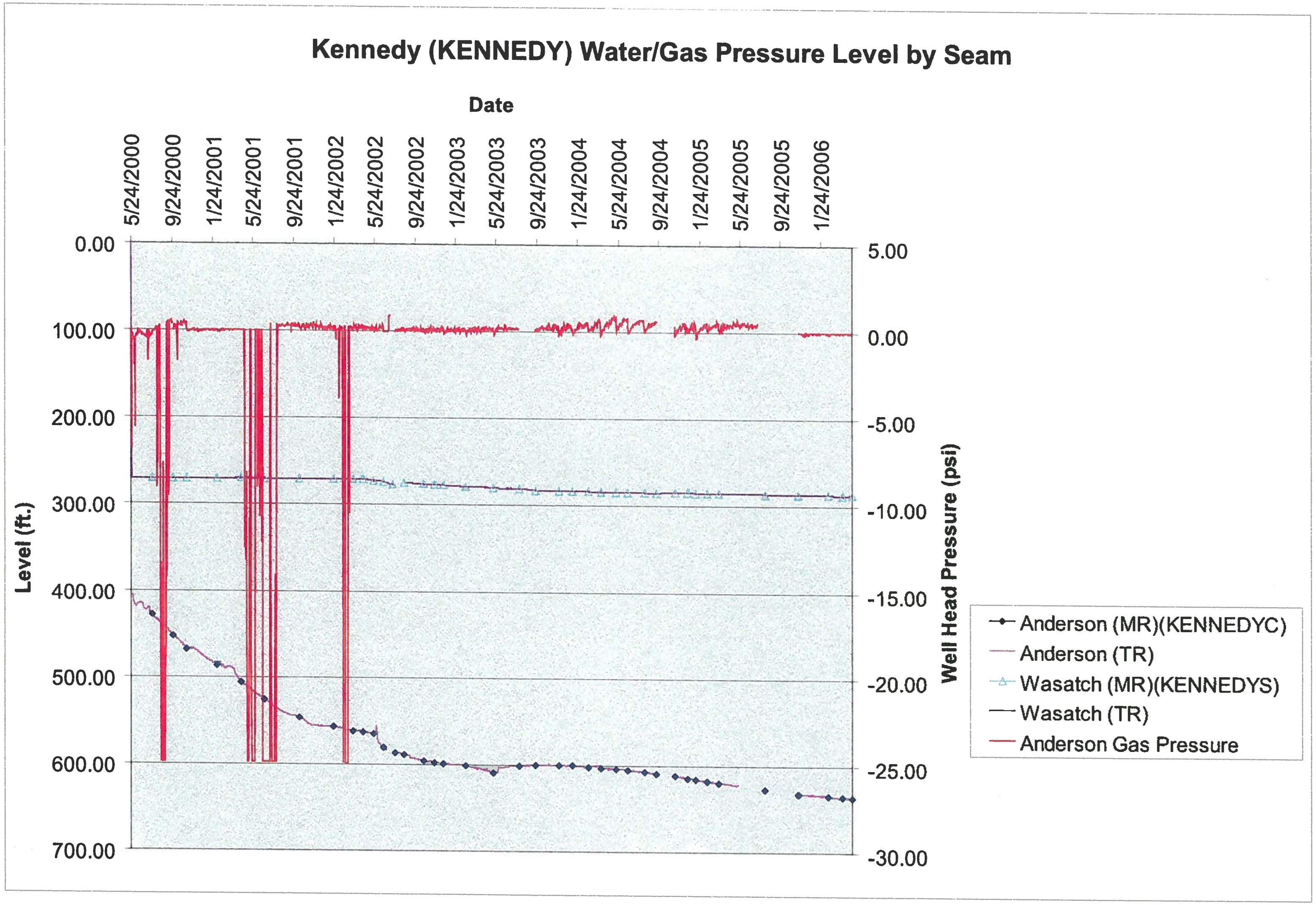


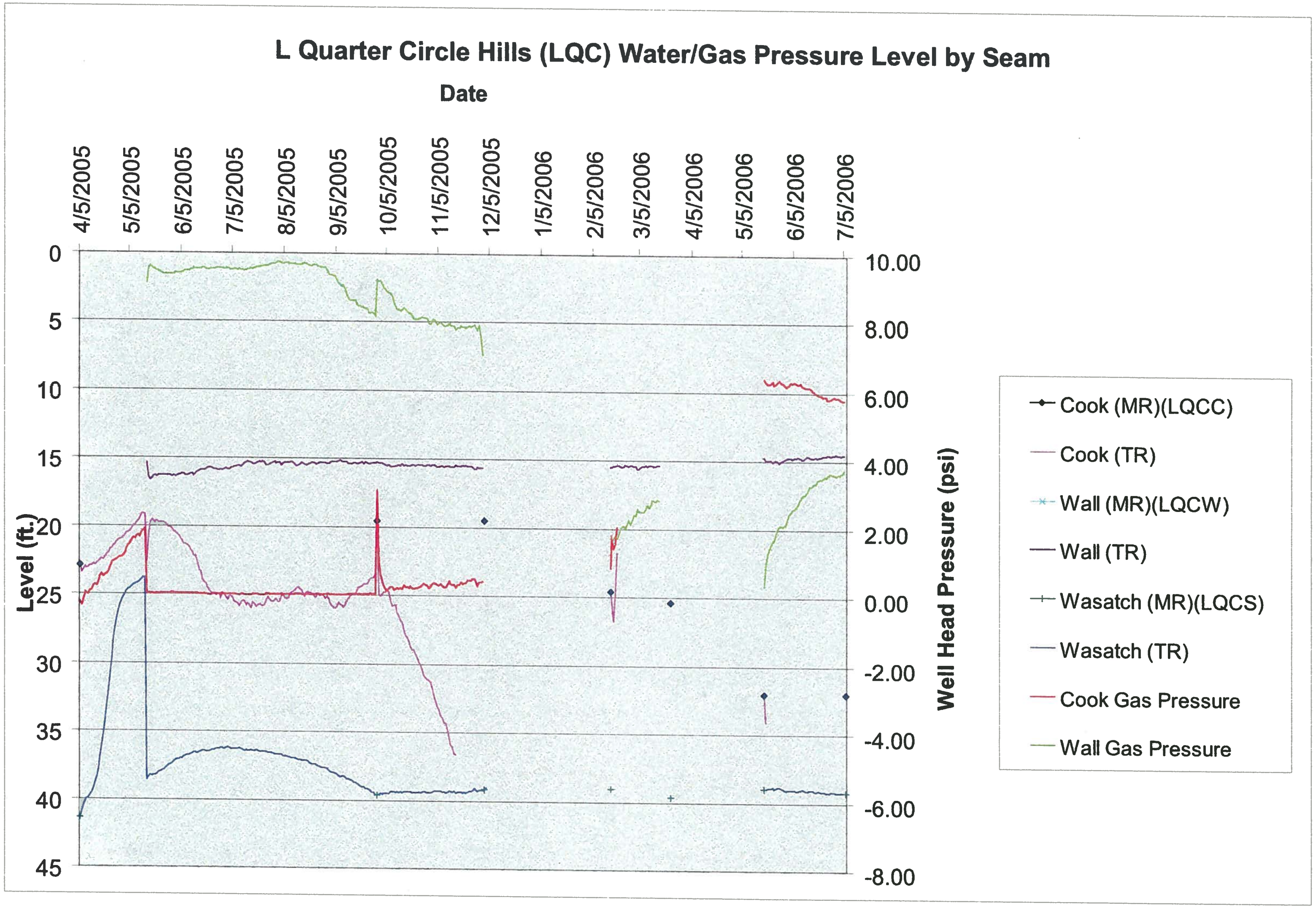
Huber Lone Tree (HUBERLT) Water/Gas Pressure Level by Seam
Date
2/24/2000
8/24/2000
2/24/2001
8/24/2001
2/24/2002
8/24/2002
2/24/2003
8/24/2003
2/24/2004
8/24/2004
2/24/2005
8/24/2005
2/24/2006
8/24/2006
Level (ft.)
0.00
100.00
200.00
300.00
400.00
500.00
600.00
700.00
Well Head Pressure (psi)
80.00
70.00
60.00
50.00
40.00
30.00
20.00
10.00
0.00
-10.00
-20.00
-30.00
Wyodak-Anderson (MR)(HUBERLTC)
Wyodak-Anderson (TR)
Wasatch (MR)(HUBERLTS)
Wasatch (TR)
Wyodak-Anderson Gas Pressure

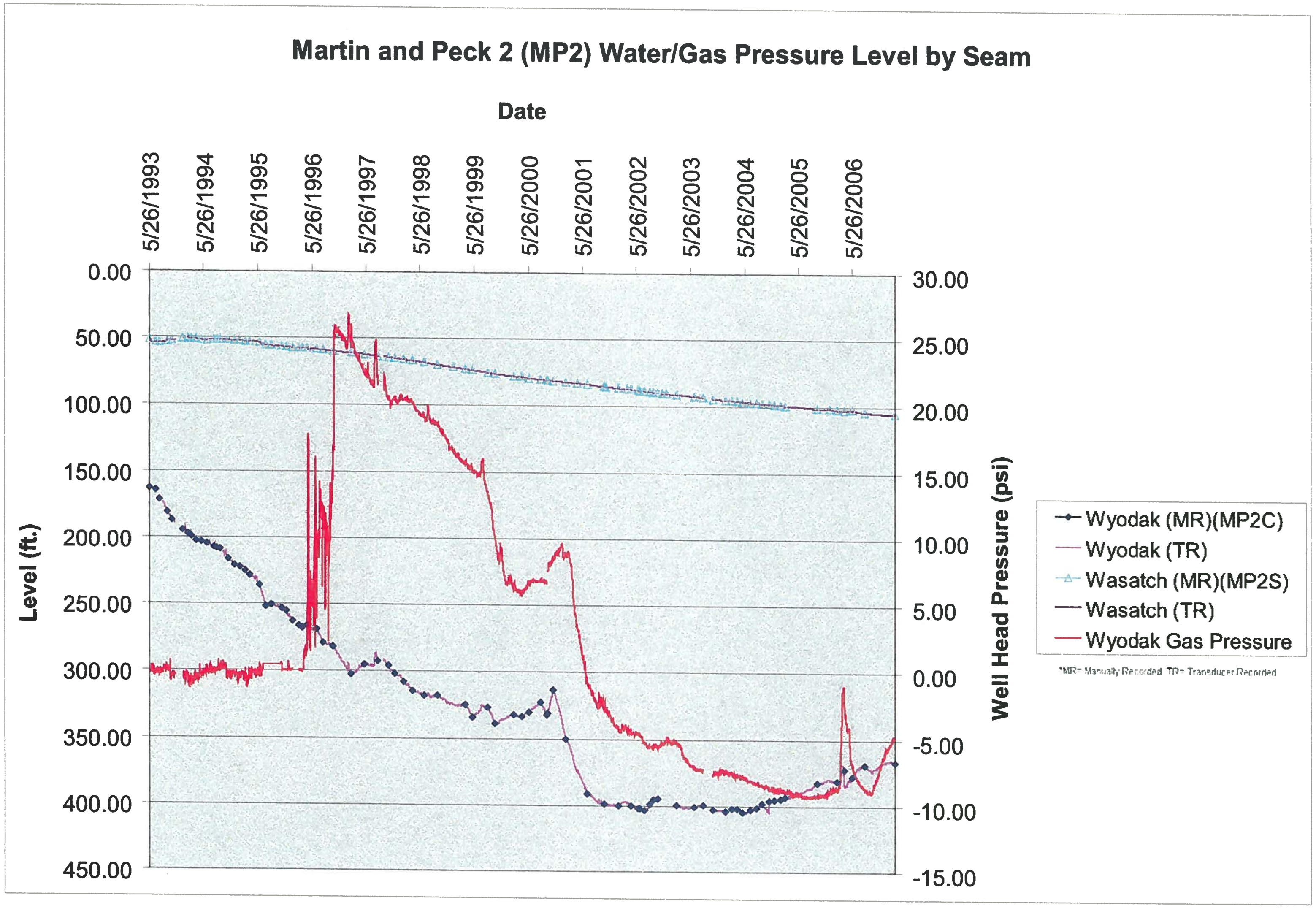


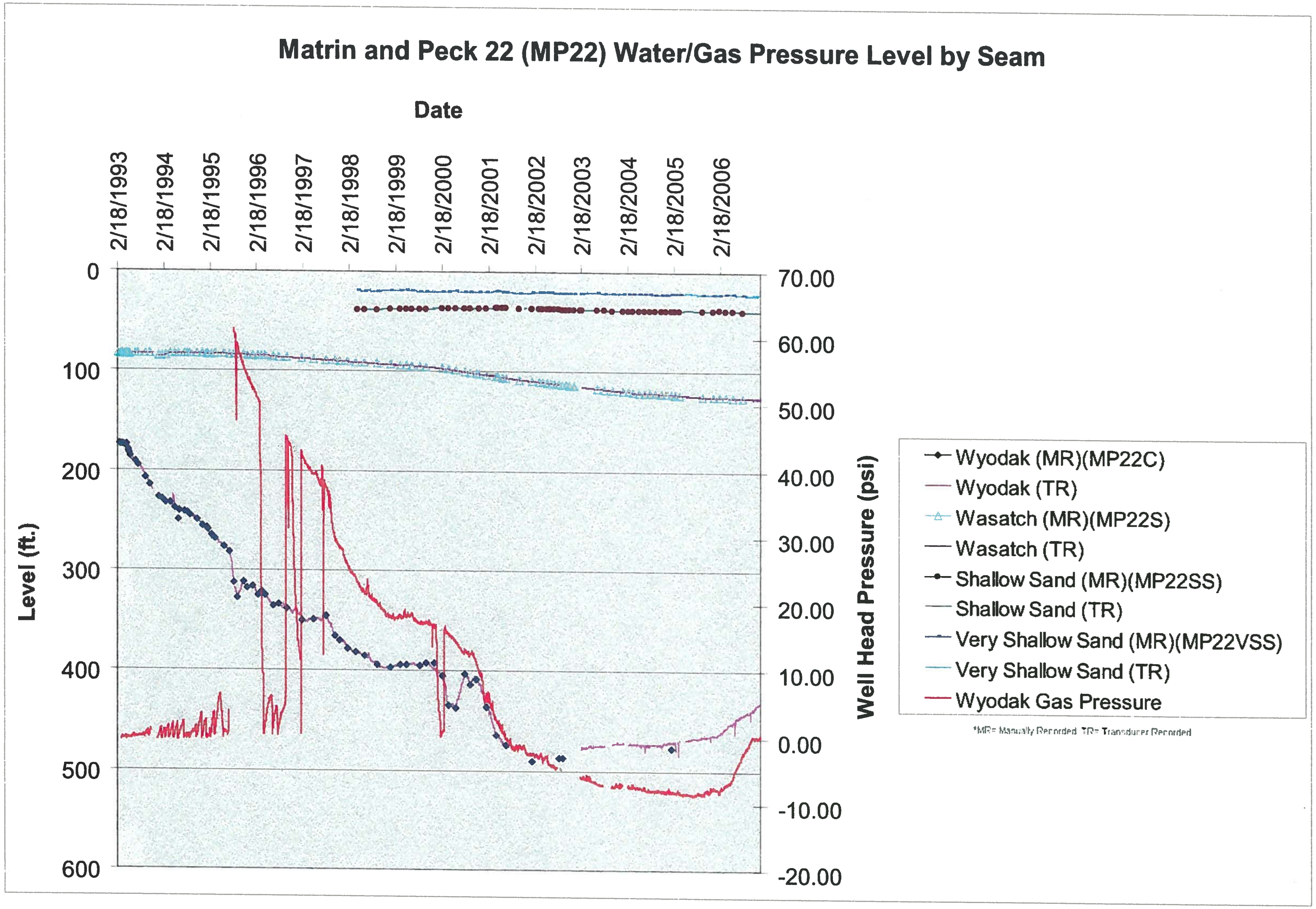
Huber Lower Prairie Dog Creek (HUBERPD) Water/Gas Pressure Level by Seam
Date
8/24/2000
12/24/2000
4/24/2001
8/24/2001
12/24/2001
4/24/2002
8/24/2002
12/24/2002
4/24/2003
8/24/2003
12/24/2003
4/24/2004
8/24/2004
12/24/2004
4/24/2005
8/24/2005
12/24/2005
4/24/2006
8/24/2006
12/24/2006
Level (ft.)
0.00
100.00
200.00
300.00
400.00
500.00
600.00
700.00
800.00
Well Head Pressure (psi)
50.00
40.00
30.00
20.00
10.00
0.00
-10.00
Anderson (MR)(HUBERPDC)
Anderson (TR)
Wasatch (MR)(HUBERPDS)
Wasatch (TR)
Sand (MR)(HUBERPDCSS)
Sand (TR)
Anderson Gas Pressure
*MR= Manually Recorded TR= Transducer Recorded


Juniper Draw (JUNIPER) Water/Gas Pressure Level by Seam
Date
3/21/2001
7/21/2001
11/21/2001
3/21/2002
7/21/2002
11/21/2002
3/21/2003
7/21/2003
11/21/2003
3/21/2004
7/21/2004
11/21/2004
3/21/2005
7/21/2005
11/21/2005
3/21/2006
7/21/2006
11/21/2006
Level (ft.)
0.00
100.00
200.00
300.00
400.00
500.00
600.00
700.00
800.00
900.00
Well Head Pressure (psi)
250.00
200.00
150.00
100.00
50.00
0.00
-50.00
Big George (MR)(JUNIPER)
Big George (TR)
Wasatch (MR)(JUNIPERS)
Wasatch (TR)
Shallow Sand (MR)(JUNIPERSS)
Shallow Sand (TR)
Big George Gas Pressure

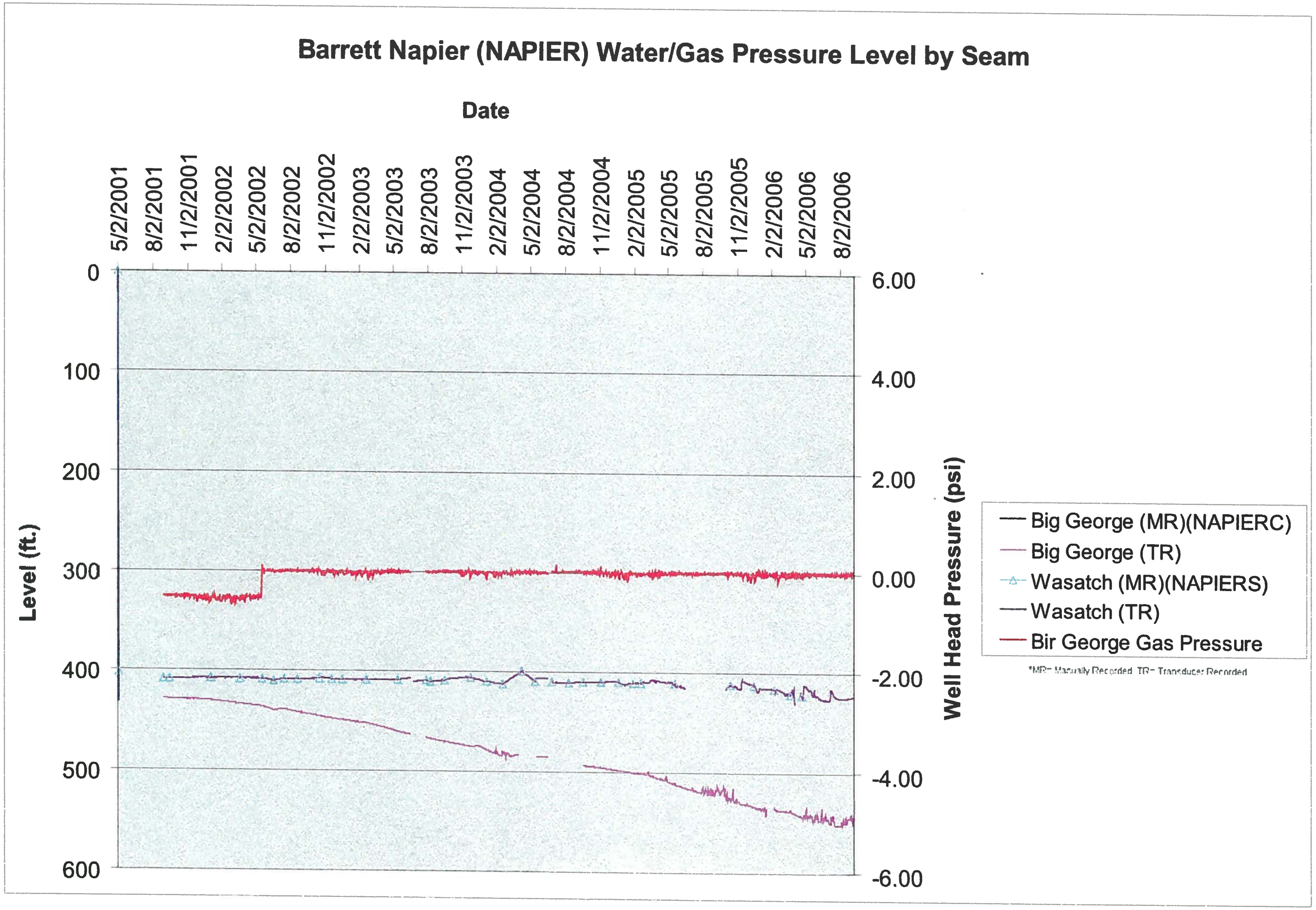

Kennedy (KENNEDY) Water/Gas Pressure Level by Seam
Date
5/24/2000
9/24/2000
1/24/2001
5/24/2001
9/24/2001
1/24/2002
5/24/2002
9/24/2002
1/24/2003
5/24/2003
9/24/2003
1/24/2004
5/24/2004
9/24/2004
1/24/2005
5/24/2005
9/24/2005
1/24/2006
Level (ft.)
0.00
100.00
200.00
300.00
400.00
500.00
600.00
700.00
Well Head Pressure (psi)
5.00
0.00
-5.00
-10.00
-15.00
-20.00
-25.00
-30.00
Anderson (MR)(KENNEDYC)
Anderson (TR)
Wasatch (MR)(KENNEDYS)
Wasatch (TR)
Anderson Gas Pressure


L Quarter Circle Hills (LQC) Water/Gas Pressure Level by Seam
Date
4/5/2005
5/5/2005
6/5/2005
7/5/2005
8/5/2005
9/5/2005
10/5/2005
11/5/2005
12/5/2005
1/5/2006
2/5/2006
3/5/2006
4/5/2006
5/5/2006
6/5/2006
7/5/2006
Level (ft.)
0
5
10
15
20
25
30
35
40
45
Well Head Pressure (psi)
10.00
8.00
6.00
4.00
2.00
0.00
-2.00
-4.00
-6.00
-8.00
Cook (MR)(LQCC)
Cook (TR)
Wall (MR)(LQCW)
Wall (TR)
Wasatch (MR)(LQCS)
Wasatch (TR)
Cook Gas Pressure
Wall Gas Pressure

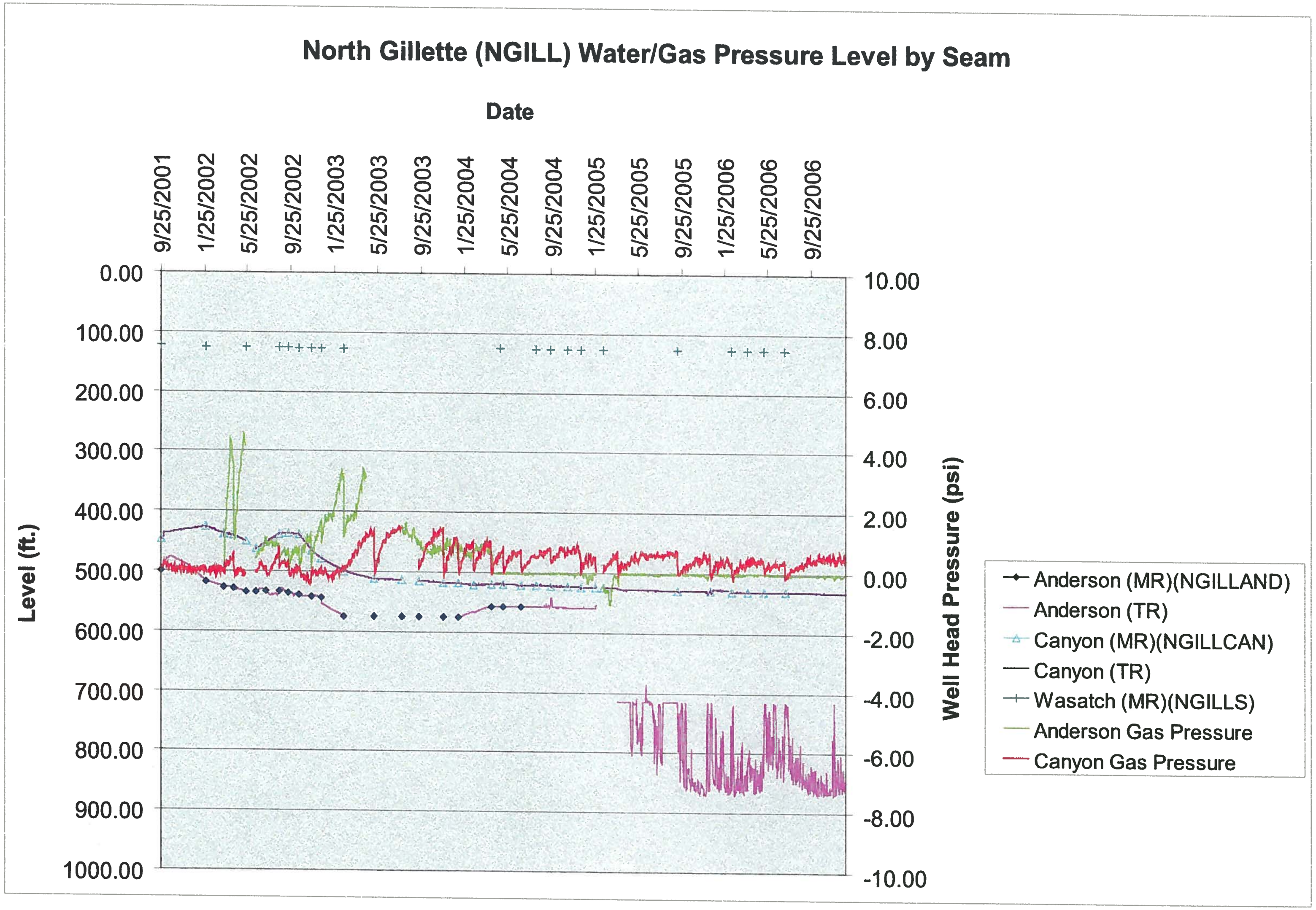

Martin and Peck 2 (MP2) Water/Gas Pressure Level by Seam
Date
5/26/1993
5/26/1994
5/26/1995
5/26/1996
5/26/1997
5/26/1998
5/26/1999
5/26/2000
5/26/2001
5/26/2002
5/26/2003
5/26/2004
5/26/2005
5/26/2006
Level (ft.)
0.00
50.00
100.00
150.00
200.00
250.00
300.00
350.00
400.00
450.00
Well Head Pressure (psi)
30.00
25.00
20.00
15.00
10.00
5.00
0.00
-5.00
-10.00
-15.00
Wyodak (MR)(MP2C)
Wyodak (TR)
Wasatch (MR)(MP2S)
Wasatch (TR)
Wyodak Gas Pressure
*MR= Manually Recorded, TR= Transducer Recorded



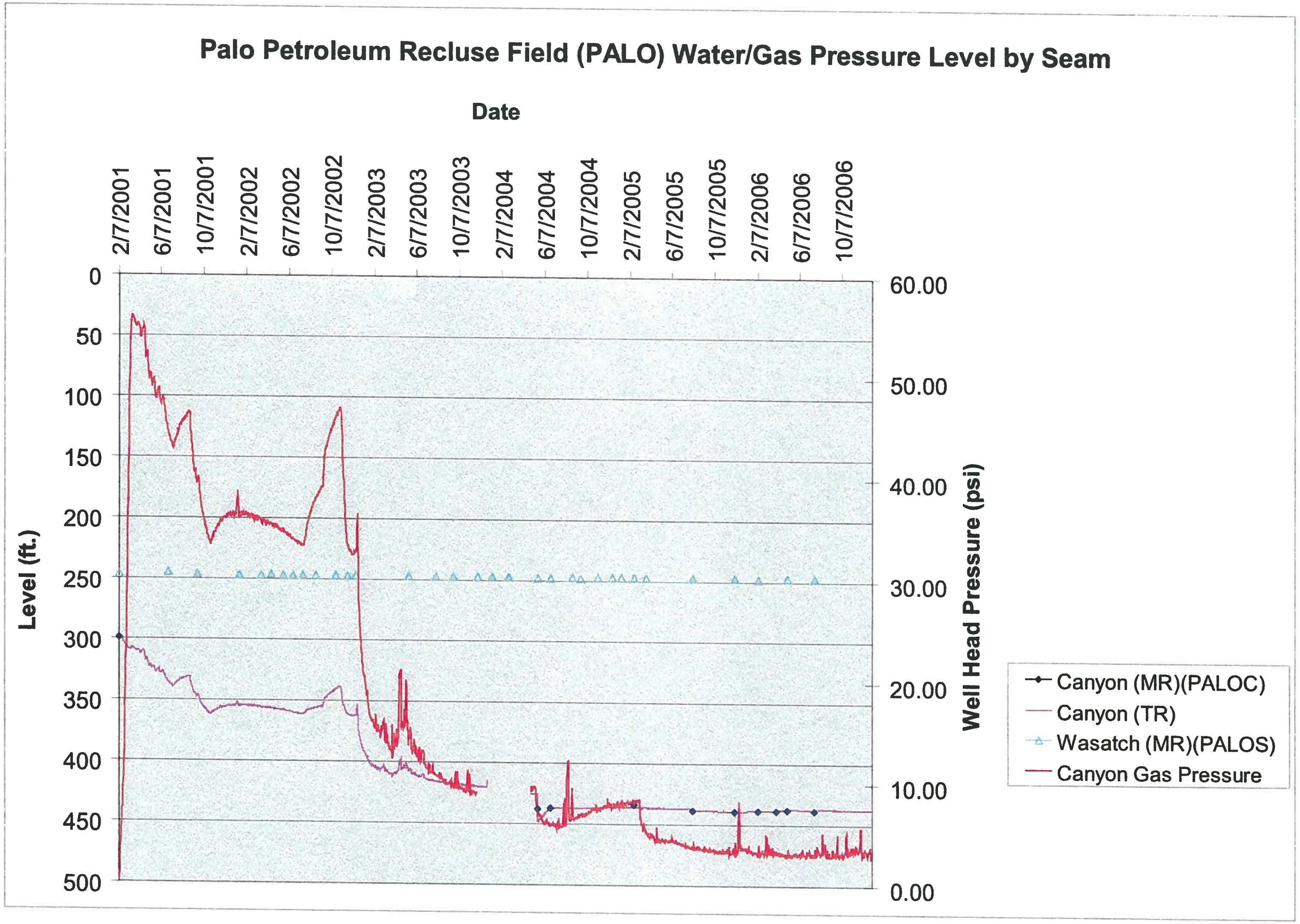
Matrin and Peck 22 (MP22) Water/Gas Pressure Level by Seam
Date
2/18/1993
2/18/1994
2/18/1995
2/18/1996
2/18/1997
2/18/1998
2/18/1999
2/18/2000
2/18/2001
2/18/2002
2/18/2003
2/18/2004
2/18/2005
2/18/2006
Level (ft.)
0
100
200
300
400
500
600
Well Head Pressure (psi)
70.00
60.00
50.00
40.00
30.00
20.00
10.00
0.00
-10.00
-20.00
Wyodak (MR)(MP22C)
Wyodak (TR)
Wasatch (MR)(MP22S)
Wasatch (TR)
Shallow Sand (MR)(MP22SS)
Shallow Sand (TR)
Very Shallow Sand (MR)(MP22VSS)
Very Shallow Sand (TR)
Wyodak Gas Pressure
*MR= Manually Recorded TR= Transducer Recorded



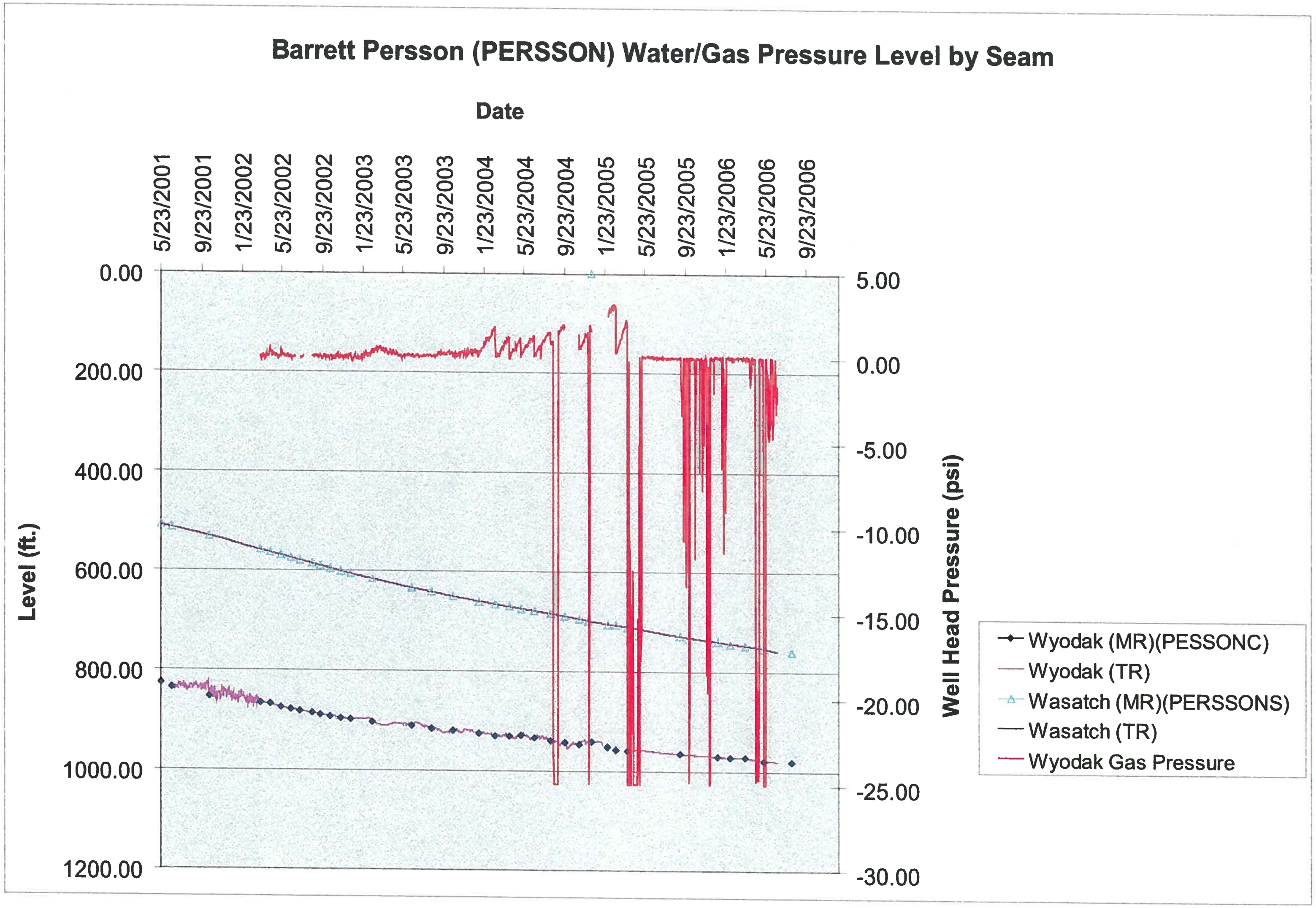
Barrett Napier (NAPIER) Water/Gas Pressure Level by Seam
Date
5/2/2001
8/2/2001
11/2/2001
2/2/2002
5/2/2002
8/2/2002
11/2/2002
2/2/2003
5/2/2003
8/2/2003
11/2/2003
2/2/2004
5/2/2004
8/2/2004
11/2/2004
2/2/2005
5/2/2005
8/2/2005
11/2/2005
2/2/2006
5/2/2006
8/2/2006
Level (ft.)
0
100
200
300
400
500
600
Well Head Pressure (psi)
6.00
4.00
2.00
0.00
-2.00
-4.00
-6.00
Big George (MR)(NAPIERC)
Big George (TR)
Wasatch (MR)(NAPIERS)
Wasatch (TR)
Bir George Gas Pressure

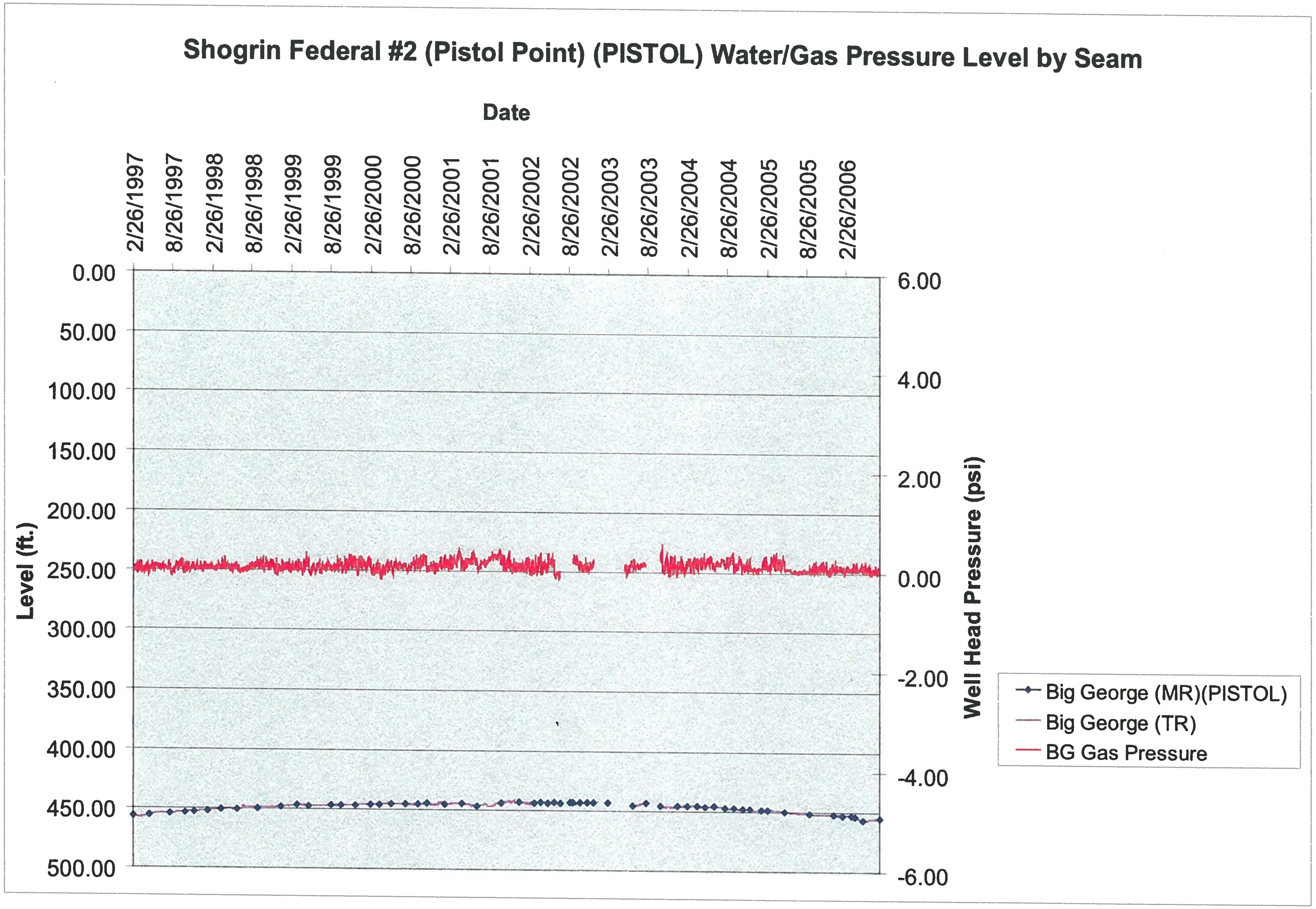


North Gillette (NGILL) Water/Gas Pressure Level by Seam
Date
9/25/2001
1/25/2002
5/25/2002
9/25/2002
1/25/2003
5/25/2003
9/25/2003
1/25/2004
5/25/2004
9/25/2004
1/25/2005
5/25/2005
9/25/2005
1/25/2006
5/25/2006
9/25/2006
Level (ft.)
0.00
100.00
200.00
300.00
400.00
500.00
600.00
700.00
800.00
900.00
1000.00
Well Head Pressure (psi)
10.00
8.00
6.00
4.00
2.00
0.00
-2.00
-4.00
-6.00
-8.00
-10.00
Anderson (MR)(NGILLAND)
Anderson (TR)
Canyon (MR)(NGILLCAN)
Canyon (TR)
Wasatch (MR)(NGILLS)
Anderson Gas Pressure
Canyon Gas Pressure

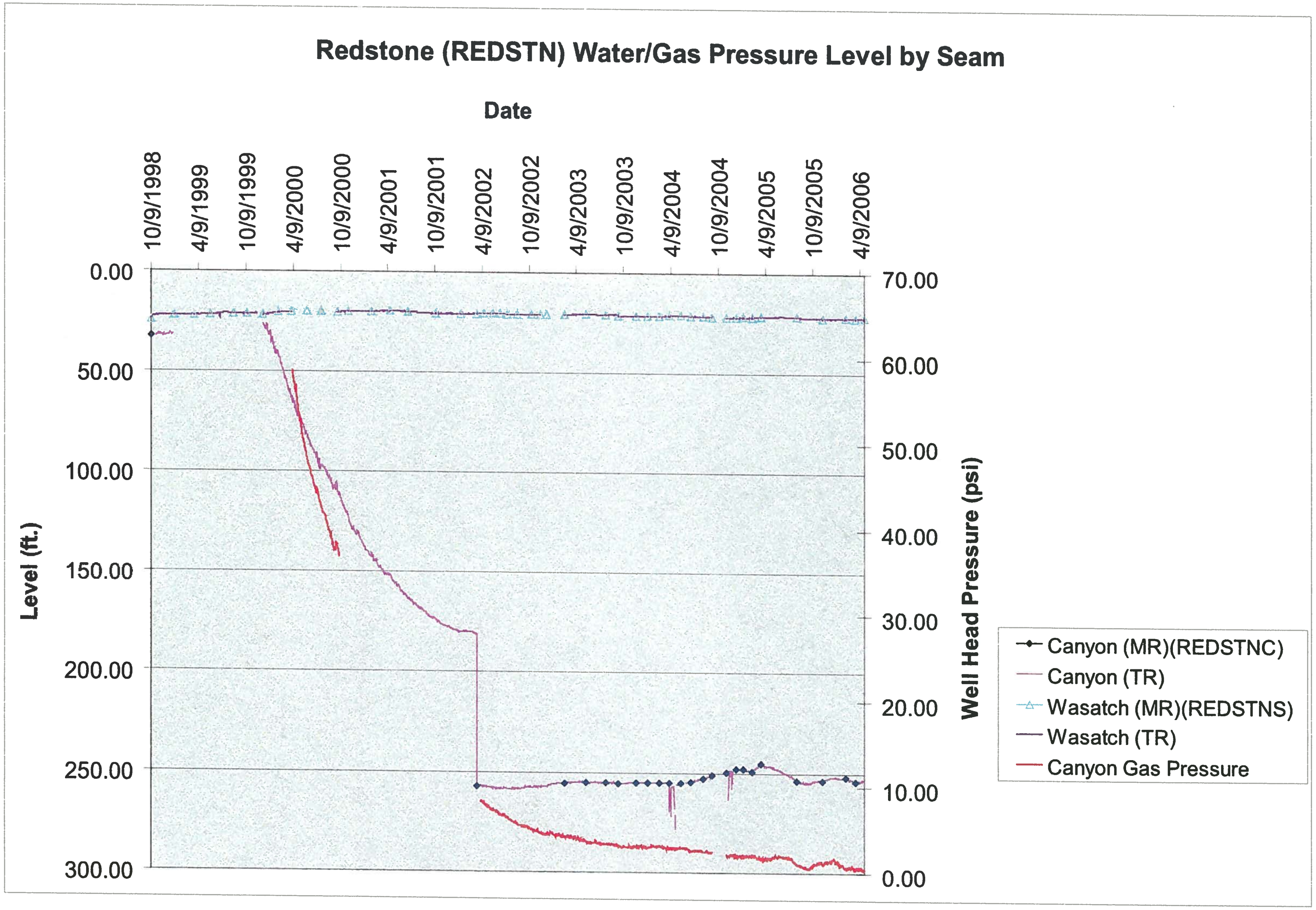


Palo Petroleum Recluse Field (PALO) Water/Gas Pressure Level by Seam
Date
2/7/2001
6/7/2001
10/7/2001
2/7/2002
6/7/2002
10/7/2002
2/7/2003
6/7/2003
10/7/2003
2/7/2004
6/7/2004
10/7/2004
2/7/2005
6/7/2005
10/7/2005
2/7/2006
6/7/2006
10/7/2006
Level (ft.)
0
50
100
150
200
250
300
350
400
450
500
Well Head Pressure (psi)
60.00
50.00
40.00
30.00
20.00
10.00
0.00
Canyon (MR)(PALOC)
Canyon (TR)
Wasatch (MR)(PALOS)
Canyon Gas Pressure

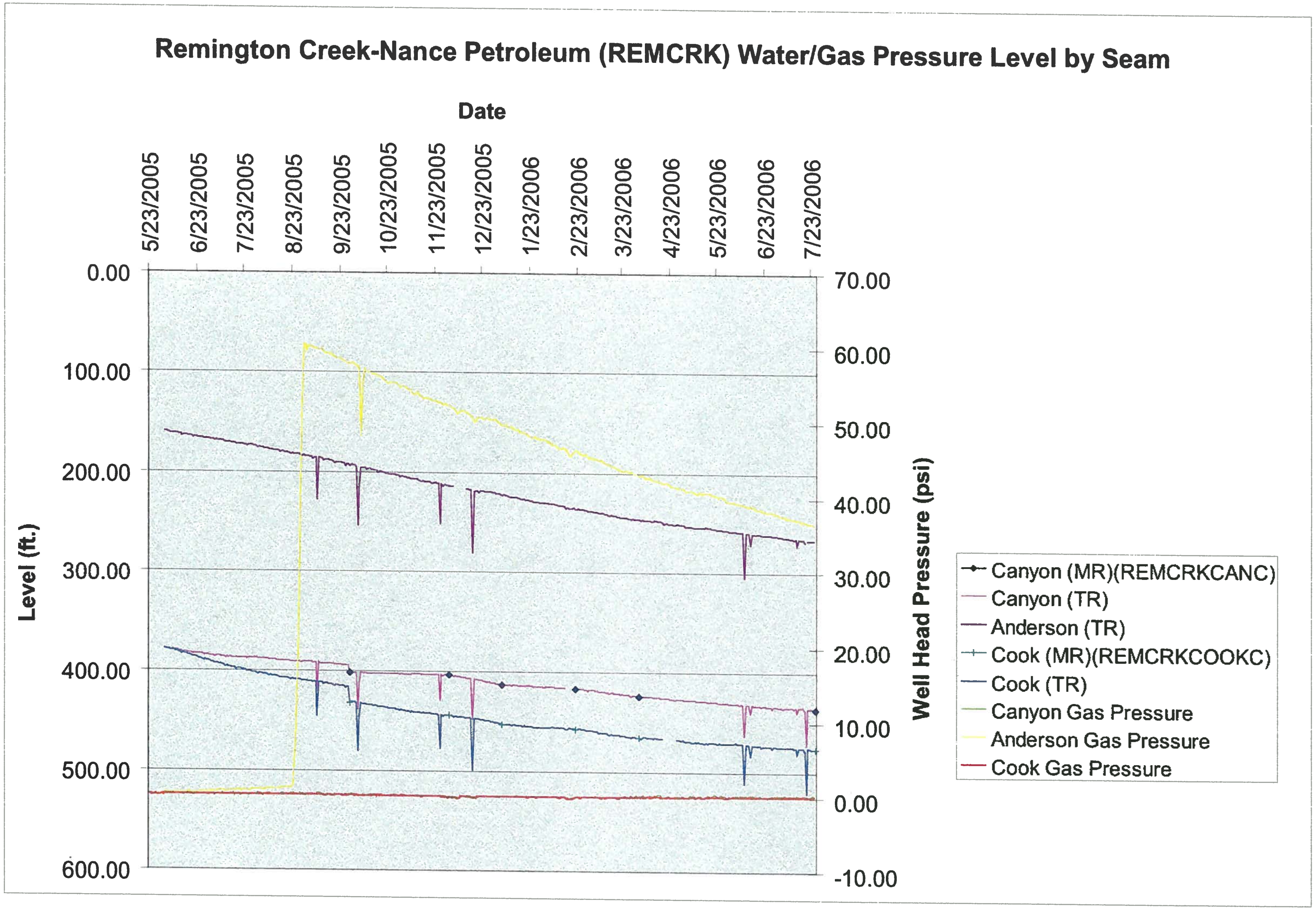

Barrett Persson (PERSSON) Water/Gas Pressure Level by Seam
Date
5/23/2001
9/23/2001
1/23/2002
5/23/2002
9/23/2002
1/23/2003
5/23/2003
9/23/2003
1/23/2004
5/23/2004
9/23/2004
1/23/2005
5/23/2005
9/23/2005
1/23/2006
5/23/2006
9/23/2006
Level (ft.)
0.00
200.00
400.00
600.00
800.00
1000.00
1200.00
Well Head Pressure (psi)
5.00
0.00
-5.00
-10.00
-15.00
-20.00
-25.00
-30.00
Wyodak (MR)(PESSONC)
Wyodak (TR)
Wasatch (MR)(PERSSONS)
Wasatch (TR)
Wyodak Gas Pressure



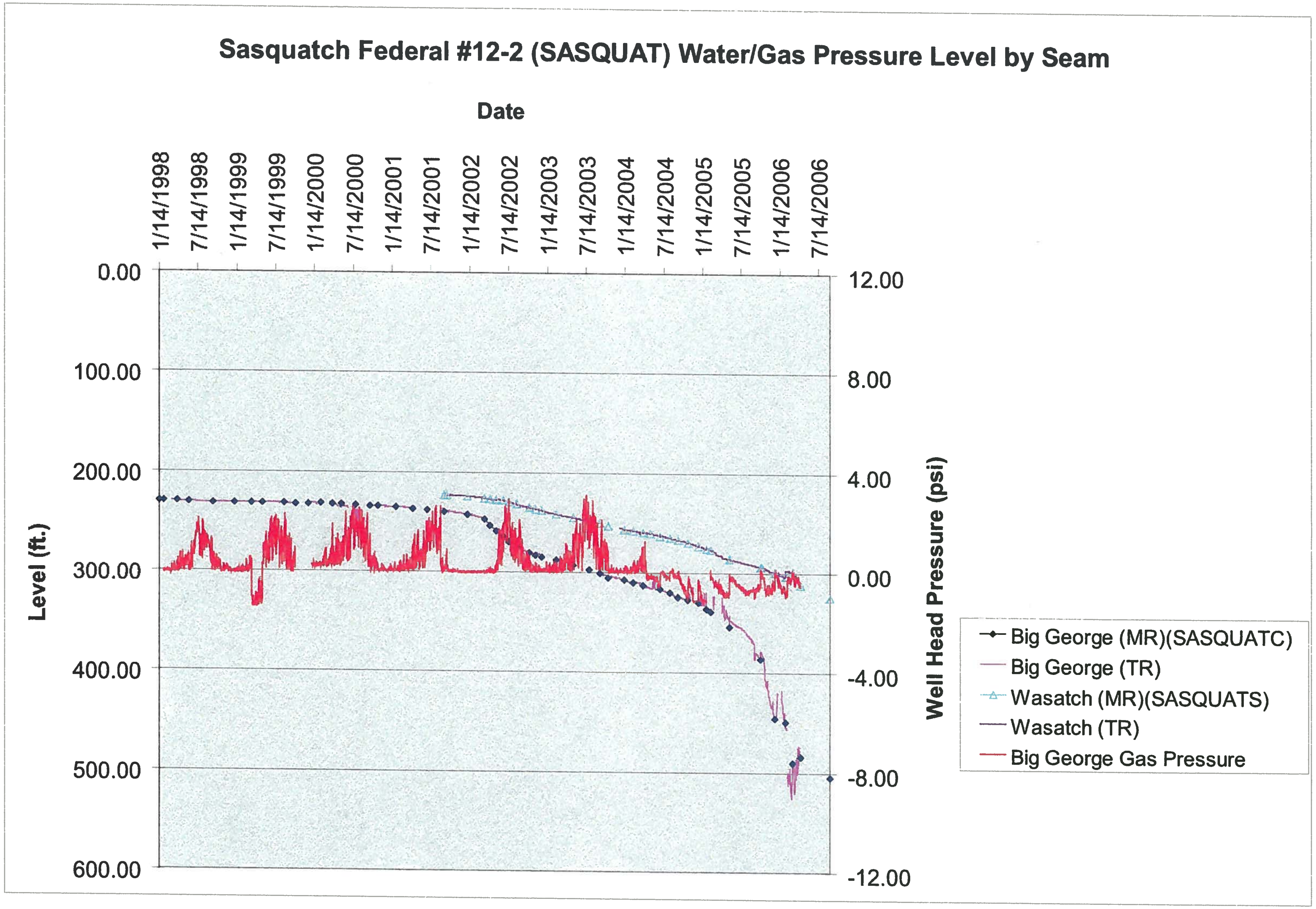
Shogrin Federal #2 (Pistol Point) (PISTOL) Water/Gas Pressure Level by Seam
Date
2/26/1997
8/26/1997
2/26/1998
8/26/1998
2/26/1999
8/26/1999
2/26/2000
8/26/2000
2/26/2001
8/26/2001
2/26/2002
8/26/2002
2/26/2003
8/26/2003
2/26/2004
8/26/2004
2/26/2005
8/26/2005
2/26/2006
Level (ft.)
0.00
50.00
100.00
150.00
200.00
250.00
300.00
350.00
400.00
450.00
500.00
Well Head Pressure (psi)
6.00
4.00
2.00
0.00
-2.00
-4.00
-6.00
Big George (MR)(PISTOL)
Big George (TR)
BG Gas Pressure

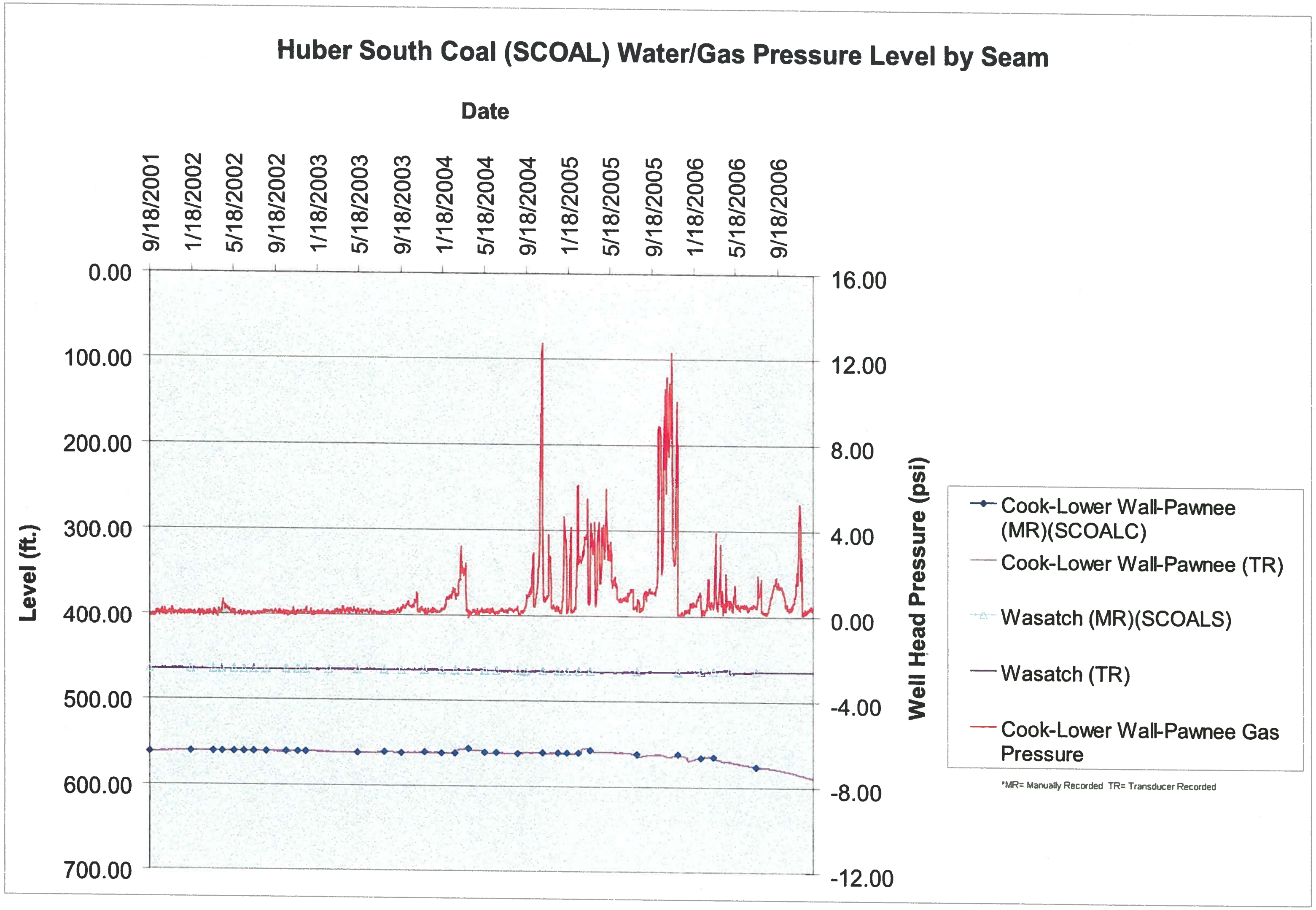


Redstone (REDSTN) Water/Gas Pressure Level by Seam
Date
10/9/1998
4/9/1999
10/9/1999
4/9/2000
10/9/2000
4/9/2001
10/9/2001
4/9/2002
10/9/2002
4/9/2003
10/9/2003
4/9/2004
10/9/2004
4/9/2005
10/9/2005
4/9/2006
Level (ft.)
0.00
50.00
100.00
150.00
200.00
250.00
300.00
Well Head Pressure (psi)
70.00
60.00
50.00
40.00
30.00
20.00
10.00
0.00
Canyon (MR)(REDSTNC)
Canyon (TR)
Wasatch (MR)(REDSTNS)
Wasatch (TR)
Canyon Gas Pressure

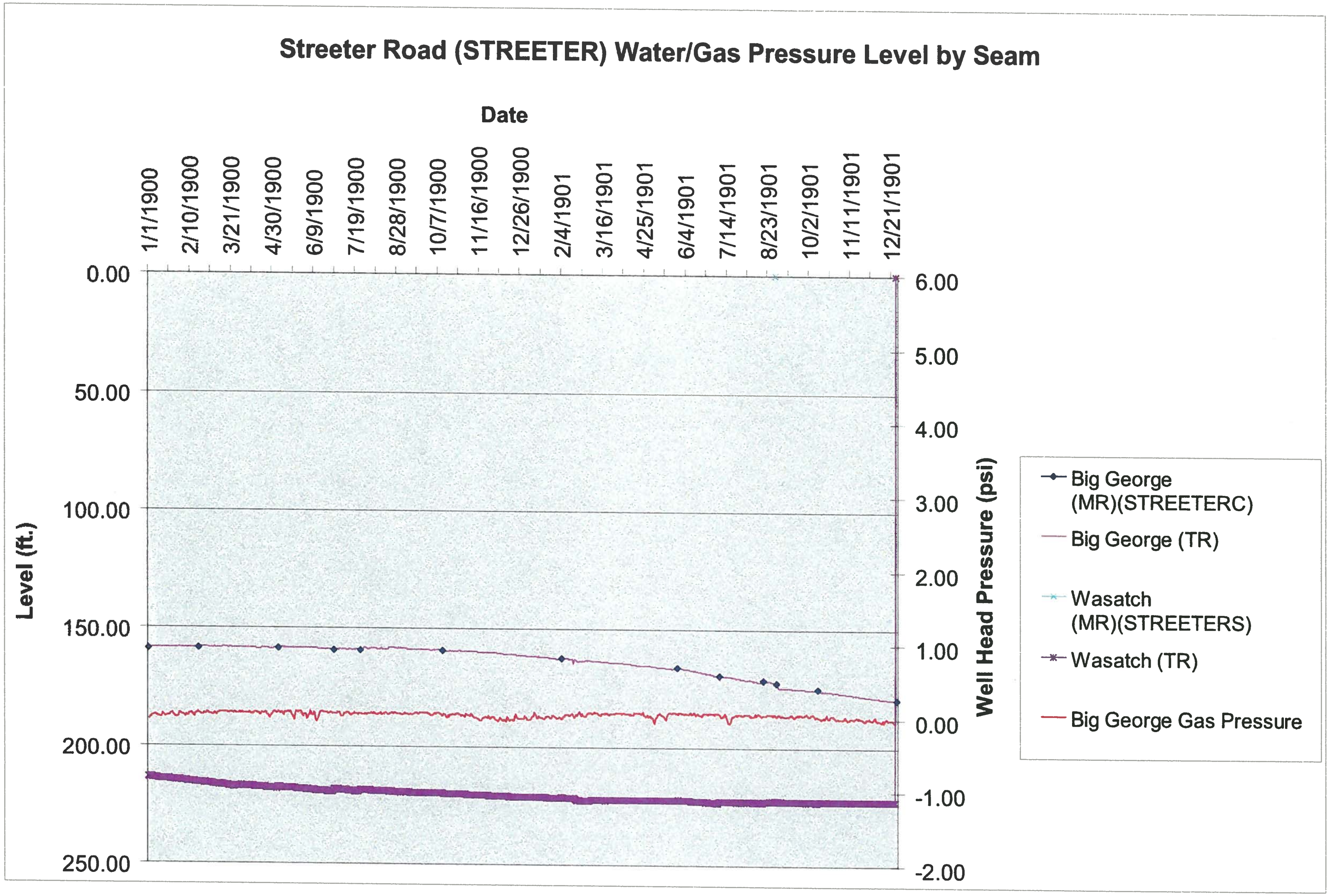


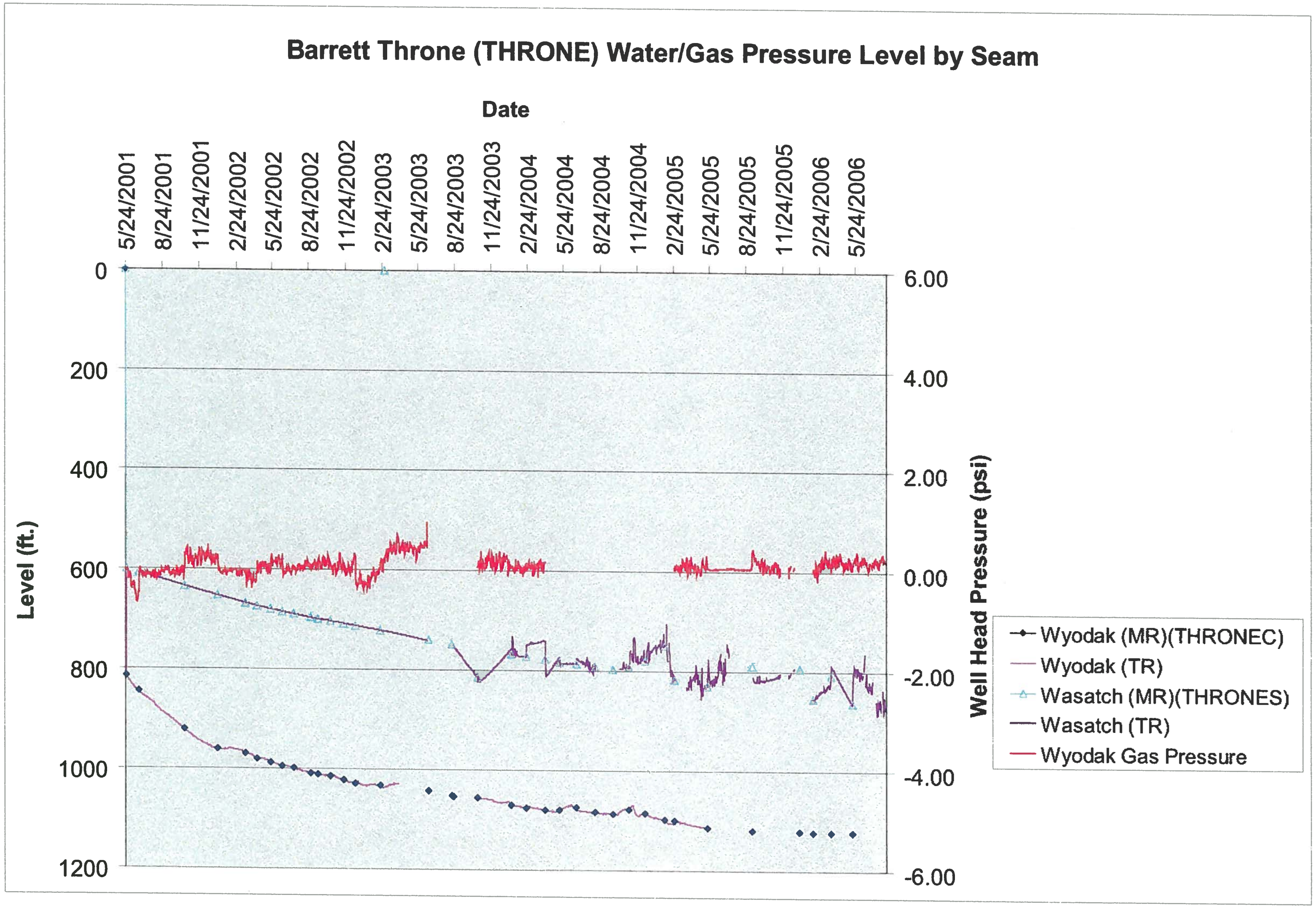
Remington Creek-Nance Petroleum (REMCRK) Water/Gas Pressure Level by Seam
Date
5/23/2005
6/23/2005
7/23/2005
8/23/2005
9/23/2005
10/23/2005
11/23/2005
12/23/2005
1/23/2006
2/23/2006
3/23/2006
4/23/2006
5/23/2006
6/23/2006
7/23/2006
Level (ft.)
0.00
100.00
200.00
300.00
400.00
500.00
600.00
Well Head Pressure (psi)
70.00
60.00
50.00
40.00
30.00
20.00
10.00
0.00
-10.00
Canyon (MR)(REMCRKCANC)
Canyon (TR)
Anderson (TR)
Cook (MR)(REMCRKCOOKC)
Cook (TR)
Canyon Gas Pressure
Anderson Gas Pressure
Cook Gas Pressure

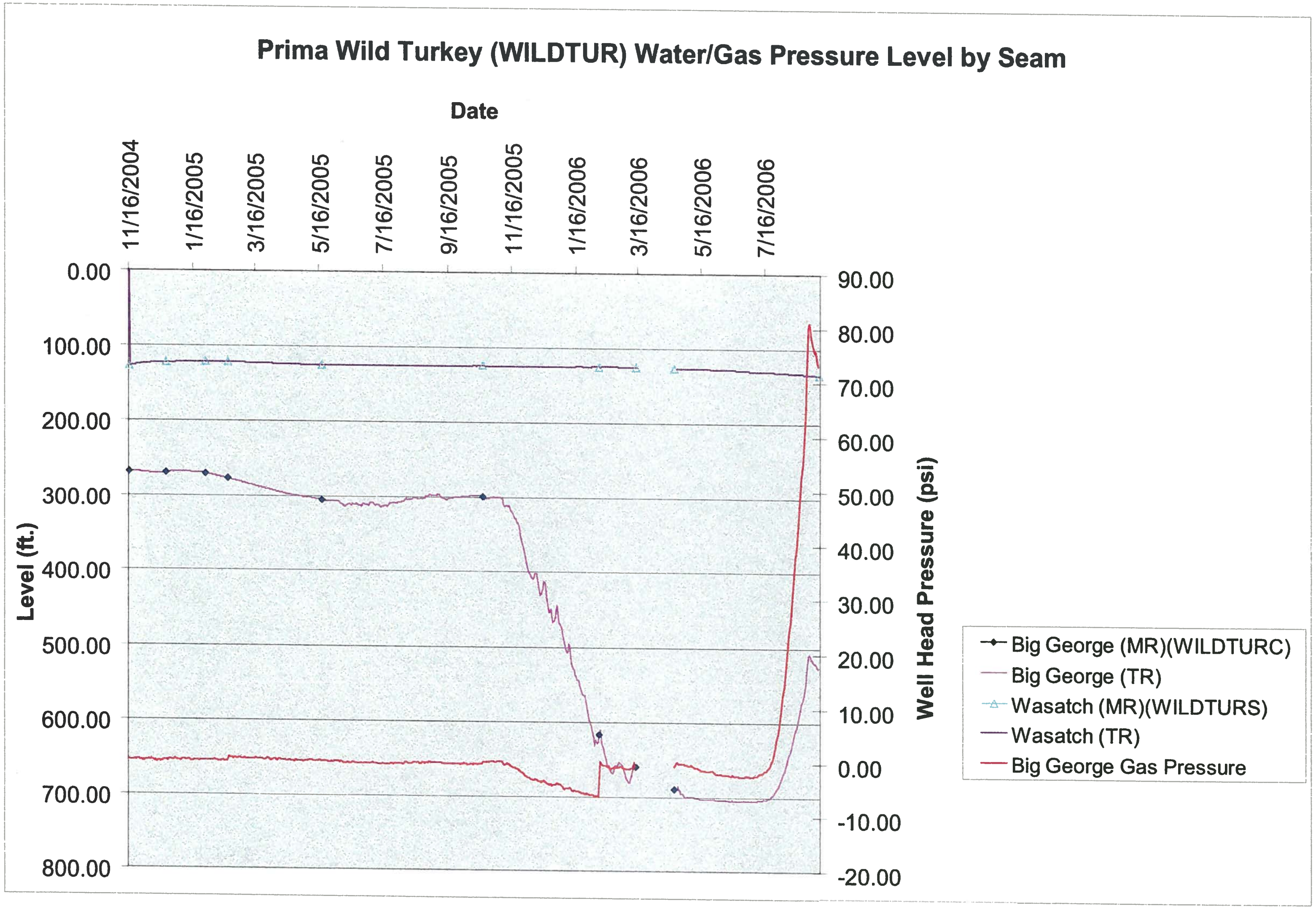

Sasquatch Federal #12-2 (SASQUAT) Water/Gas Pressure Level by Seam
Date
1/14/1998
7/14/1998
1/14/1999
7/14/1999
1/14/2000
7/14/2000
1/14/2001
7/14/2001
1/14/2002
7/14/2002
1/14/2003
7/14/2003
1/14/2004
7/14/2004
1/14/2005
7/14/2005
1/14/2006
7/14/2006
Level (ft.)
0.00
100.00
200.00
300.00
400.00
500.00
600.00
Well Head Pressure (psi)
12.00
8.00
4.00
0.00
-4.00
-8.00
-12.00
Big George (MR)(SASQUATC)
Big George (TR)
Wasatch (MR)(SASQUATS)
Wasatch (TR)
Big George Gas Pressure



Huber South Coal (SCOAL) Water/Gas Pressure Level by Seam
Date
9/18/2001
1/18/2002
5/18/2002
9/18/2002
1/18/2003
5/18/2003
9/18/2003
1/18/2004
5/18/2004
9/18/2004
1/18/2005
5/18/2005
9/18/2005
1/18/2006
5/18/2006
9/18/2006
Level (ft.)
0.00
100.00
200.00
300.00
400.00
500.00
600.00
700.00
Well Head Pressure (psi)
16.00
12.00
8.00
4.00
0.00
-4.00
-8.00
-12.00
Cook-Lower Wall-Pawnee (MR)(SCOALC)
Cook-Lower Wall-Pawnee (TR)
Wasatch (MR)(SCOALS)
Wasatch (TR)
Cook-Lower Wall-Pawnee Gas Pressure
*MR= Manually Recorded TR= Transducer Recorded

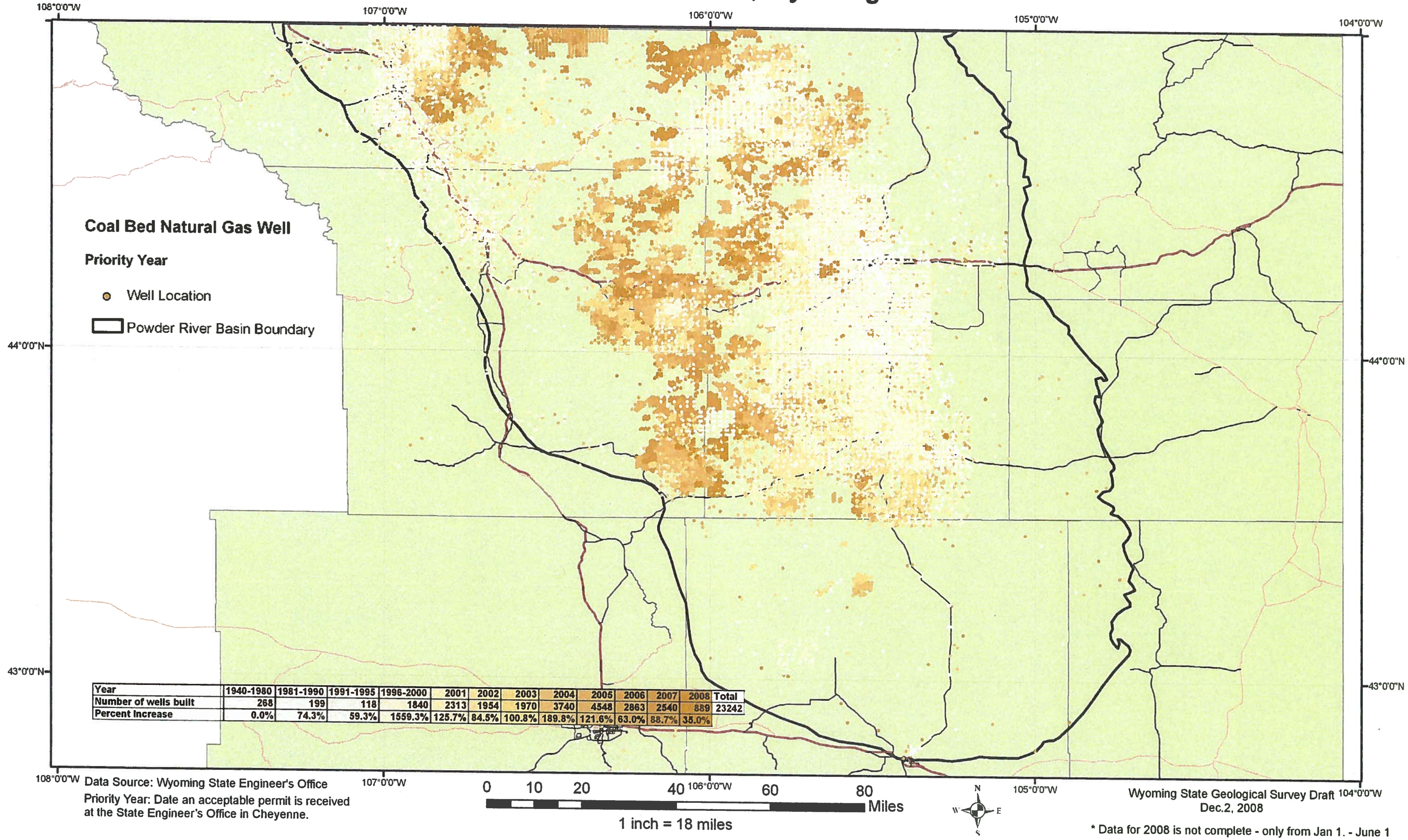

Streeter Road (STREETER) Water/Gas Pressure Level by Seam
Date
1/1/1900
2/10/1900
3/21/1900
4/30/1900
6/9/1900
7/19/1900
8/28/1900
10/7/1900
11/16/1900
12/26/1900
2/4/1901
3/16/1901
4/25/1901
6/4/1901
7/14/1901
8/23/1901
10/2/1901
11/11/1901
12/21/1901
Level (ft.)
0.00
50.00
100.00
150.00
200.00
250.00
Well Head Pressure (psi)
6.00
5.00
4.00
3.00
2.00
1.00
0.00
-1.00
-2.00
Big George (MR)(STREETERC)
Big George (TR)
Wasatch (MR)(STREETERS)
Wasatch (TR)
Big George Gas Pressure


Barrett Throne (THRONE) Water/Gas Pressure Level by Seam
Date
5/24/2001
8/24/2001
11/24/2001
2/24/2002
5/24/2002
8/24/2002
11/24/2002
2/24/2003
5/24/2003
8/24/2003
11/24/2003
2/24/2004
5/24/2004
8/24/2004
11/24/2004
2/24/2005
5/24/2005
8/24/2005
11/24/2005
2/24/2006
5/24/2006
Level (ft.)
0
200
400
600
800
1000
1200
Well Head Pressure (psi)
6.00
4.00
2.00
0.00
-2.00
-4.00
-6.00
Wyodak (MR)(THRONEC)
Wyodak (TR)
Wasatch (MR)(THRONES)
Wasatch (TR)
Wyodak Gas Pressure



Prima Wild Turkey (WILDTUR) Water/Gas Pressure Level by Seam
Date
11/16/2004
1/16/2005
3/16/2005
5/16/2005
7/16/2005
9/16/2005
11/16/2005
1/16/2006
3/16/2006
5/16/2006
7/16/2006
Level (ft.)
0.00
100.00
200.00
300.00
400.00
500.00
600.00
700.00
800.00
Well Head Pressure (psi)
90.00
80.00
70.00
60.00
50.00
40.00
30.00
20.00
10.00
0.00
-10.00
-20.00
Big George (MR)(WILDTURC)
Big George (TR)
Wasatch (MR)(WILDTURS)
Wasatch (TR)
Big George Gas Pressure

Appendix B: Figure B-1. CBNG Wells by WSEO Permit Priority Year (1940-2008*) Powder River Basin, Wyoming



Year	1940-1980	1981-1990	1991-1995	1996-2000	2001	2002	2003	2004	2005	2006	2007	2008	Total
Number of wells built	268	199	118	1840	2313	1954	1970	3740	4548	2863	2540	889	23242
Percent Increase	0.0%	74.3%	59.3%	1559.3%	125.7%	84.5%	100.8%	189.8%	121.6%	63.0%	88.7%	35.0%	

Figure B-2. Major Drainages, Powder River Basin, Wyoming

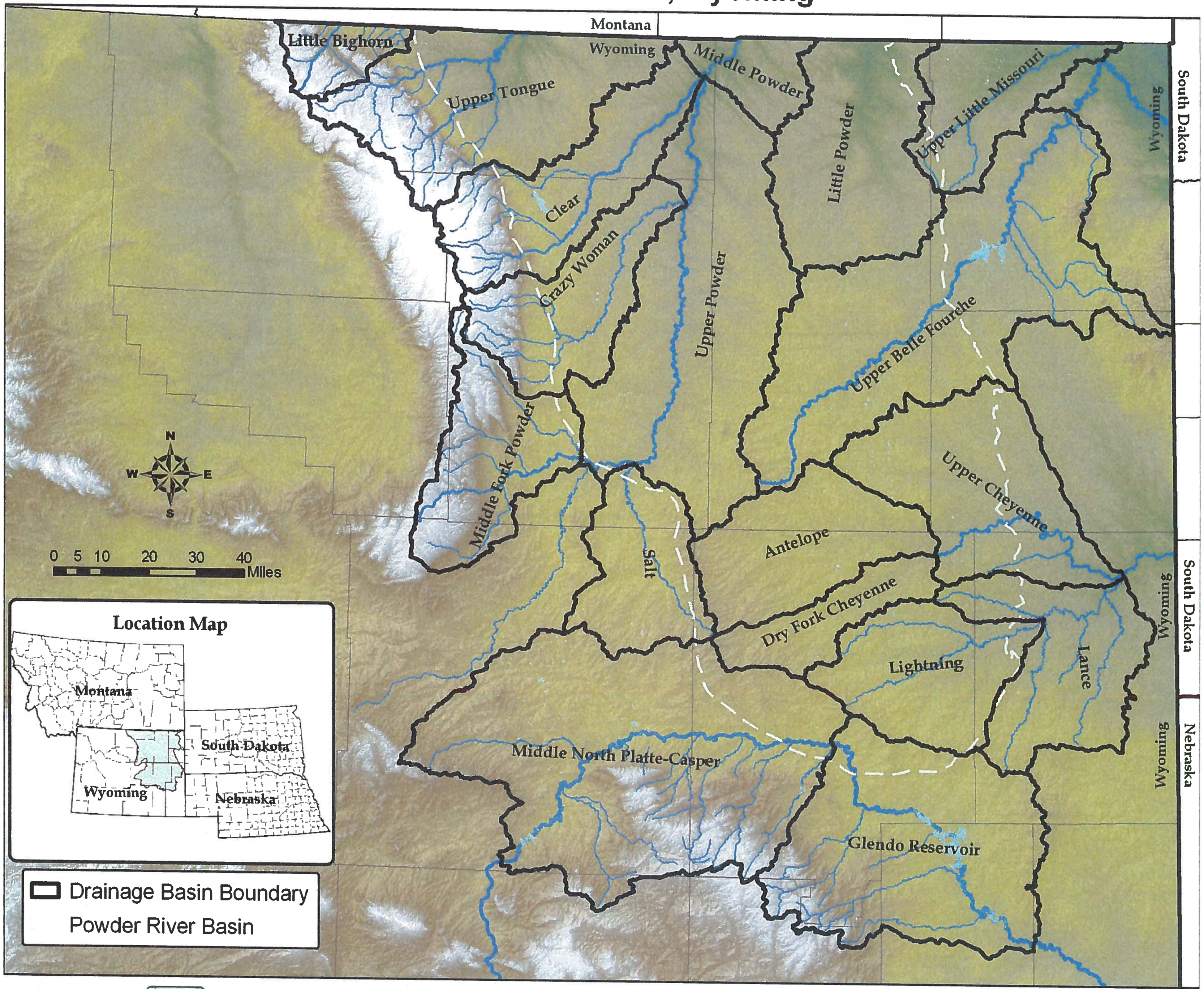
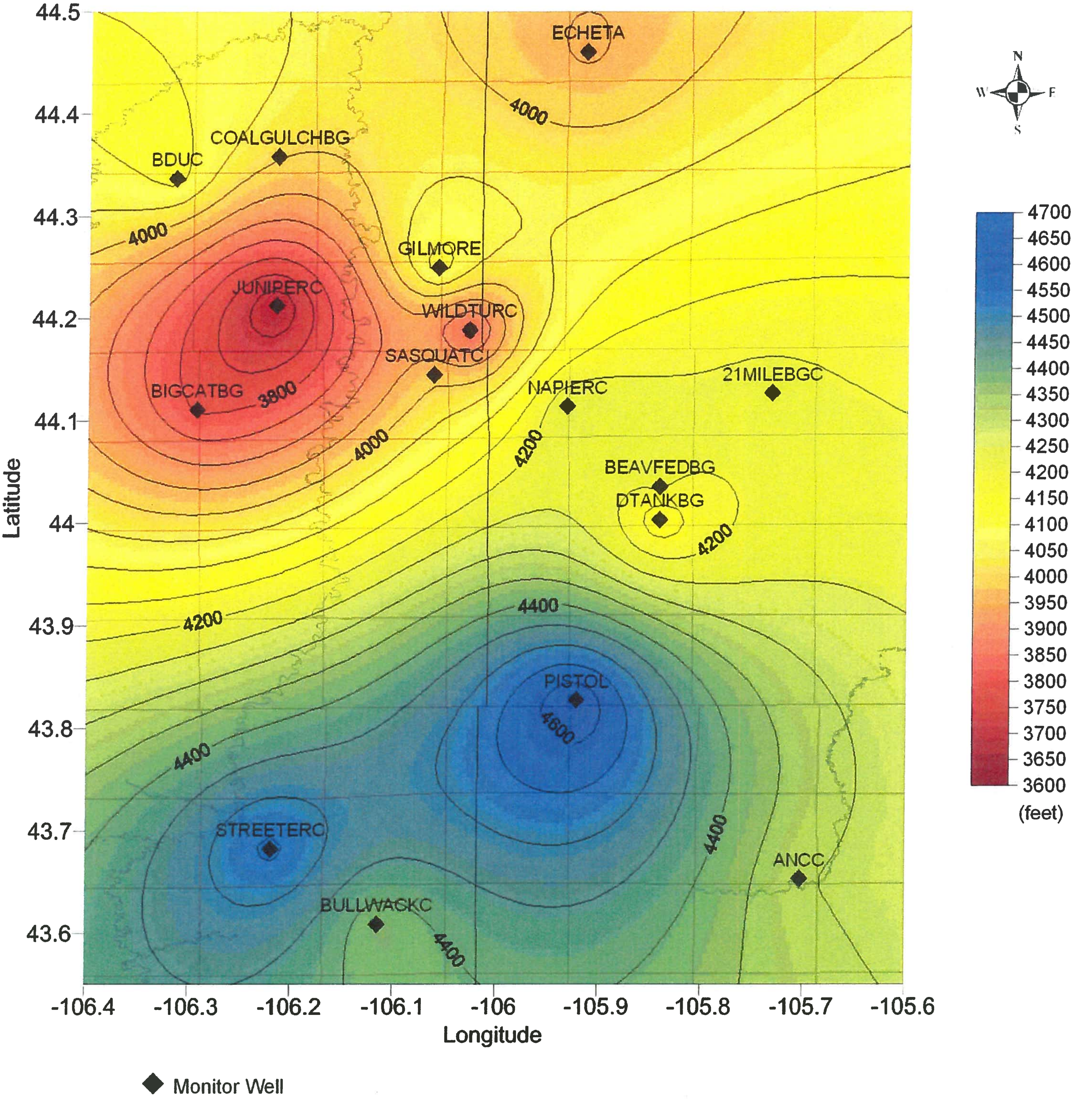


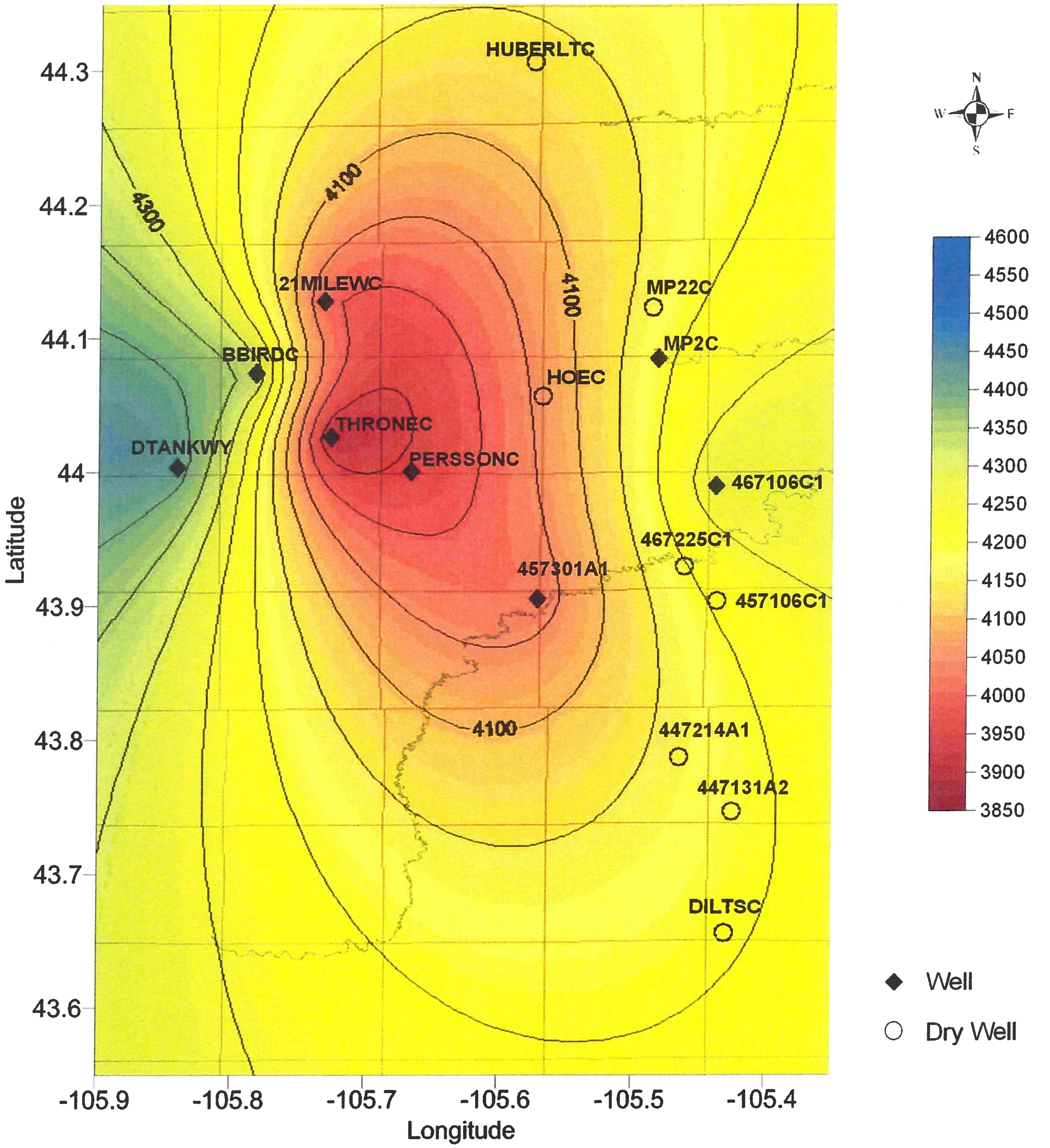
Figure B-3. Big George/Smith Coal: Maximum drawdown for 2006 Powder River Basin, Wyoming



Wyoming State Geological Survey Draft
March 31, 2008

Based on the last recorded/measured levels of the year.
Shows only the BLM wells that we have data for in this year.
All measurements are feet above mean sea level.
Datum: Nad83

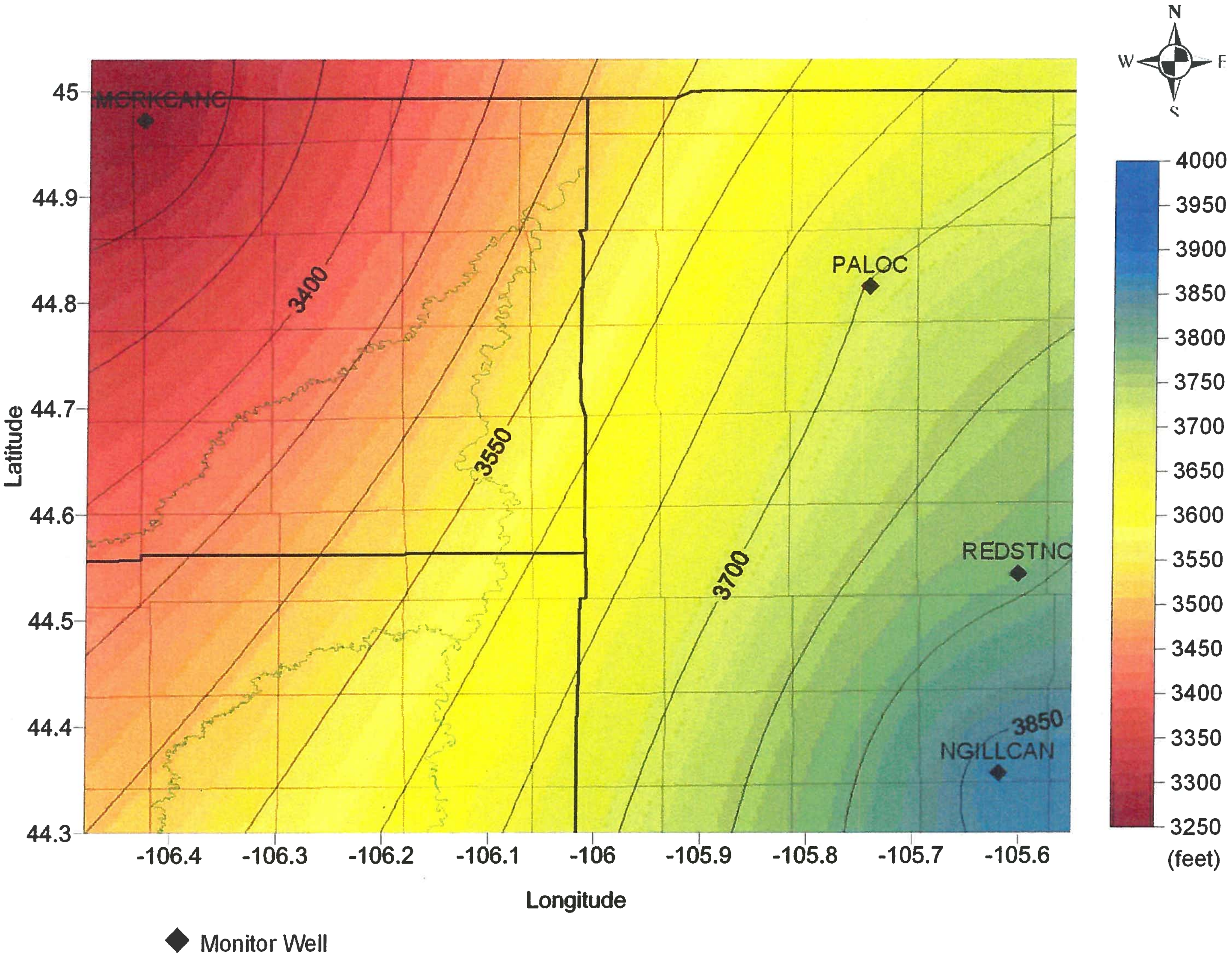
Figure B-4. Wyodak/Anderson coal: Maximum drawdown for 2006 Powder River Basin, Wyoming



Based on the last recorded / measured water levels of the year.
Shows only the BLM wells that we have data for in this year.
Dry Well values were not used in making the interpolation.
All measurements are feet above mean sea level.
Datum: Nad83

Wyoming State Geological Survey Draft
April 18, 2008

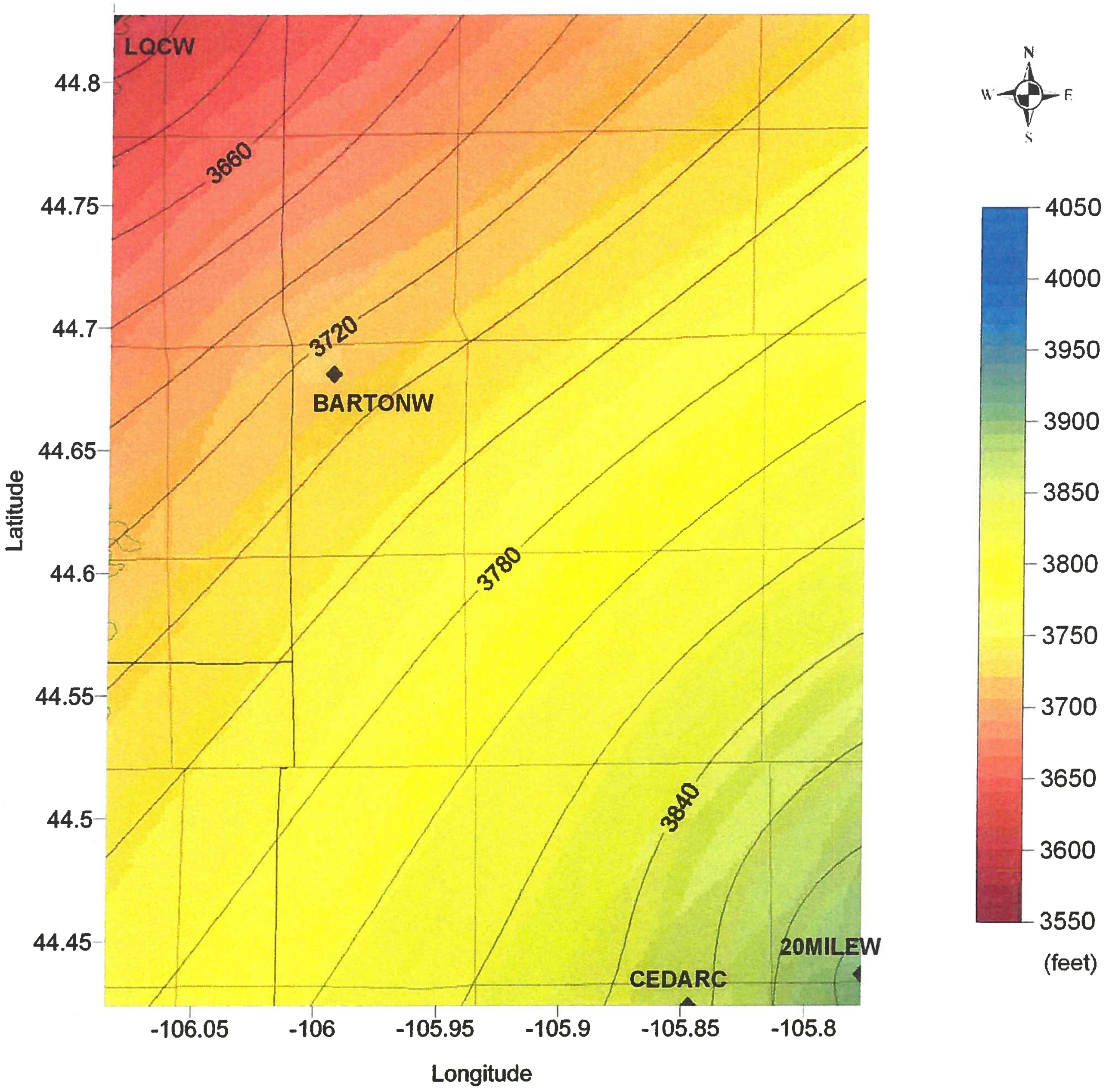
Figure B-5. Canyon/Cook coal: Maximum drawdown for 2006 Powder River Basin, Wyoming



Wyoming State Geologic Survey Draft
May 1, 2008

Based on the last recorded/measured levels of the year.
Shows only the BLM wells that we have data for in this yea
All measurements are feet above mean sea level.
Datum: Nad83

Figure B-6. Wall/Pawnee coal: Maximum drawdown for 2006 Powder River Basin, Wyoming



Note: Well SCOALC is not in display due to its location is not in display parameters.
Well is dry for this year.

◆ Monitor Well

Wyoming Geologic Survey Draft
May 6, 2008

Based on the last recorded/measured levels of the year.
Shows only the BLM wells that we have data for in this year.
All measurements are feet above mean sea level.
Datum: Nad83