2.D MAPS AND CROSS SECTIONS OF USDWs

Submit maps and cross sections indicating the vertical limits of all underground sources of drinking water within the area of review (both vertical and lateral limits for Class I), their position relative to the injection formation and the direction of water movement, where known, in every underground source of drinking water which may be affected by the proposed injection activities.

RESPONSE

The major bedrock aquifers in the Black Hills area include the Deadwood, Madison, Minnelusa, Minnekahta, and Inyan Kara (Carter et al, 2003). These aquifers are regionally extensive in areas surrounding the Black Hills as shown on Figure D-1 (Driscoll et al., 2002). A regional east-west geologic cross section across the Black Hills Uplift is shown on Figure D-2. The location of the cross section A-A' is indicated on Figure D-1. Ground-water flow in the regional aquifer system in the Paleozoic aquifer units (i.e., Deadwood, Madison, Minnelusa, and Minnekahta Formations) is generally interpreted to be radially outward from the outcrops surrounding the Black Hills (Figure D-3). Groundwater recharge from the Black Hills area comingles with groundwater in the Powder River Basin to the west and then migrates northeastward into the Williston Basin where it eventually discharges at lower elevations to the land surface in eastern North Dakota and along the outcrop of the Canadian Shield in Canada.

Only two of these major aquifers, the Madison and Inyan Kara, are considered to be USDWs within the AORs of the Dewey-Burdock Disposal Wells. As discussed below, the Deadwood, Minnelusa, and Minnekahta do not supply water wells in the Dewey-Burdock area and are not considered to be USDWs locally. Further, due to local total dissolved solids (TDS) concentrations in excess of 10,000 mg/l, (shown Table D-1 from the USGS Produced Waters Database [http://energy.cr.usgs.gov/prov/prodwat/data2.htm]), the Minnelusa is not a USDW.

Minor aquifers in the area include the Sundance formation (Driscoll et al., 2002). While some authors differentiate geologically between the Sundance and overlying Unkpapa Formation, they are thought to be hydrogeologically connected and are referred to as the Unkpapa/Sundance in this document. Further, the Unkpapa/Sundance is considered to be the lower-most USDW above the Madison below the Dewey-Burdock Project area.

<u>Deadwood Formation</u>

The Cambrian-age Deadwood Formation consists of massive to thinly-bedded, brown to light-gray sandstone; greenish glauconitic shale; dolomite; and flat-pebble limestone conglomerate. Sandstone with conglomerate occurs locally at the base of the formation. The Deadwood ranges in thickness from 0 to 500 feet (Carter et al., 2003) in the area. Generally, groundwater flow in the Cambrian-Ordovician aquifer system is from the high-altitude recharge areas on the top of the Black Hills radially outward (Figure D-4). Regionally the Deadwood is confined by the Precambrian basement (Williamson and Carter, 2001). It overlies the Precambrian basement and granite wash (where present) and outcrops approximately 20 miles to the northeast of the Dewey-Burdock Project (Figure D-1). As stated previously, the Deadwood is not considered to be a local USDW. Based on available data, there are no known water wells supplied by the Deadwood Formation in the Dewey-Burdock Project area. There are no water quality data available in the area, but it is suspected that water quality declines with depth and distance down-gradient from the recharge at the outcrop. As a result, it is likely that the Deadwood contains dissolved solids in excess of 10,000 mg/l below Sites 1 and 2 and will not meet the USEPA criteria for a USDW. An isopach map of the Deadwood is included as Figure D-5.

Madison Formation

The Mississippian Madison aquifer is contained within the limestones, siltstones, sandstones, and dolomite of the Madison Limestone or Group. Generally, water in the Madison is confined except in outcrop areas and can frequently demonstrate artesian conditions. Groundwater flow in this aquifer system generally is from the recharge areas radially outward from the Black Hills (Figure D-6). Water in the Madison is typically fresh only near the recharge areas, becoming slightly saline to saline as it moves down-gradient (Figure D-7). In the deeper parts of the Williston Basin, the water is a brine with dissolved solids concentrations greater than 300,000 mg/L (Driscoll et al., 2002). Local water quality for the Madison is summarized by analysis of the Edgemont city wells and is presented in Table D-1. Structure contour and isopach maps of the Madison are included as Figures D-8 and D-9, respectively. A potentiometric surface map of the Madison Formation is presented as Figure D-10.

Minnelusa Formation

The Pennsylvanian- and Permian-age Minnelusa Formation consists of yellow to red, cross-stratified sandstone, limestone, dolomite, and shale. The Minnelusa Aquifer occurs primarily in sandstone and anhydrite beds in the upper part of the formation (Williamson and Carter, 2001). Water in this aquifer moves from recharge areas radially outward from the Black Hills and to the northeast to discharge areas in eastern South Dakota (Figure D-6). It is confined above by the Opeche Shale and below by layers of lower permeability in the Minnelusa Formation.

The Minnelusa is referred to as an aquifer but is an oil and gas producer in the Dewey-Burdock area. Table D-2 and Figure D-11 present local water quality data from the USGS Produced Waters Database for the Minnelusa Formation that shows TDS concentrations in excess of 10,000 mg/l in the Dewey-Burdock area. In addition, this formation does not supply water to any local water wells. As such, it is not considered to be a USDW in the Dewey-Burdock area. Structure contour and isopach maps of the Minnelusa are included as Figures D-12 and D-13, respectively. A potentiometric surface map of the Minnelusa Formation is presented as Figure D-14.

It has been postulated that in the vicinity of the Black Hills, there may be communication between the Madison and Minnelusa Formations and even communication from the Minnelusa to the surface via breccia pipes. However, this communication is thought to occur near the outcrop in areas where these formations are near surface. These areas are located well to the north and east of the Project area and up-gradient in the system. Evidence of regional isolation is the contrast between water quality in the Madison and Minnelusa. There is no evidence to suggest that there is communication between these formations locally.

Minnekahta Formation

The Permian-age Minnekahta Limestone is a thin to medium-bedded, fine-grained, purple to gray laminated limestone, which ranges in thickness from 25 to 65 feet (Driscoll et al., 2002). The Minnekahta is considered a major aquifer in parts of the Black Hills area but does not supply any known water wells locally.

Unkpapa/Sundance Formation

The Sundance Formation consists of greenish-gray shale with thin limestone lenses; glauconitic sandstone, with red sandstone near the middle of the formation. The Sundance ranges from 250 to 450 feet thick (Carter et al., 2003). The Unkpapa Sandstone is a massive fine-grained sandstone, 0 to 225 feet thick (Carter et al., 2003). A potentiometric surface map of the Unkpapa is presented as figure D-14a. The Unkpapa/Sundance is considered a minor aquifer in the area. Local water quality data from wells located within the Dewey-Burdock Project are presented in Table D-3.

<u>Inyan Kara Group</u>

Several sandstone units compose the lower Cretaceous aquifer, which is known as the Inyan Kara aquifer in South Dakota. These units are the Lakota and Fall River Formations and the Lakota is divided into the Chilson, Minnewaste, and Fuson Members. Some authors include the Minnewaste Limestone Member regionally, but it is not present below the project area. Generally, water in the Inyan Kara is confined by several thick shale layers of the Graneros Group (including the Skull Creek Shale), except in outcrop areas around structural uplifts, such as the Black Hills Uplift. Regionally, groundwater in the Inyan Kara moves from high-altitude recharge areas to discharge areas in eastern North Dakota and South Dakota. Although the aquifer is wide-spread, it contains little fresh water except in small areas in central and south-central Montana and north and east of the Black Hills uplift. Water in the Inyan Kara is saline in the deeper parts of the Williston and Powder River Basins (Driscoll et al., 2002). Table D-4 presents local water quality data from wells located within the Dewey-Burdock Project. A structure contour map of the Inyan Kara is included as Figure D-15. Isopach maps of each of the units that compose the Inyan Kara are included as Figures D-16, D-17, and D-18. A potentiometric surface map of the Fall River Aquifer is presented as Figure D-19.

Figure D-20 is a cross-section location map that shows A - A' (Figure D-21) and B - B' (Figure D-22) which show the vertical extent of the USDWs across the project area. The lowermost formations (Madison, Englewood, and Deadwood) are not shown due to the lack of deep well logs.

TABLE D-1 Local Water Quality Data - Madison Formation

Summary of Madison well data, Edgemont city water														
		Well ID	BNR/TVA	well 2	well 4	well 5	TVA	well 2	well 4	well 5	Mean	Minimum	Maximum	Std. Dev
		Sample Date	11/6/2002	11/6/2002	11/6/2002	11/6/2002	5/23/2000	5/23/2000	5/23/2000	5/23/2000				
Component		**units**												
Physical properties														
Conductivity	Cond.	umhos/cm	1154	1671	1785	2140	1300	1700	1800	2300	1731.3	1154.0	2300.0	382.1
Hardness			406	503	528	580	410	460	500	560	493.4	406.0	580.0	64.3
pH	pH		7.81	7.7	7.73	7.66	7.15	7.23	7.26	7.37	7.5	7.2	7.8	0.3
TDS	TDS	mg/L	726	1047	1101	1333	690	980	940	1000	977.1	690.0	1333.0	205.0
TSS	TSS	mg/L												
Turbidity	Turbidity	NTU												
Acidity	Acidity													
Alkalinity	CaCO3		188	181	182	180	170	160	160	170	173.9	160.0	188.0	10.5
Carbonate	CO3	mg/L												
Bicarbonate	HCO3	mg/L	229	221	222	220	210	200	200	210	214.0	200.0	229.0	10.7
Chloride	Cl	mg/L	185	255	300	385	150	250	270	360	269.4	150.0	385.0	79.7
Cyanide	CN	mg/L												
Flouride	F	mg/L	0.843	1.1	1.07	1.32	0.9	1.05	1.03	1.2	1.1	0.8	1.3	0.2
Nitrogen, Ammonia	NH3	mg/L												
Nitrogen, Nitrate	NO3	mg/L	0.211	0.086	0.063	<.05	0.15	0.16	0.16	<.1	0.1	0.1	0.2	0.1
Nitrogen, Nitrite	NO2	mg/L					<.01	<.01	<.01	<.01		0.0	0.0	
Sulfate	SO4	mg/L	211	295	309	353	210	300	340	390	301.0	210.0	390.0	64.0
Metals														
Aluminum	Al	mg/L												
Arsenic	As	mg/L	0.006	0.01	0.01	0.008					0.0085	0.0	0.0	0.0019
Calcium	Ca	mg/L	115	150	156	175	100	120	130	140	135.8	100.0	175.0	24.4
Iron	Fe	mg/L	0.05	0.091	<.05	2.53	<0.05	0.09	<.05	2.6	1.1	0.1	2.6	1.4
Magnesium	Mg	mg/L	28.8	31.1	33.7	34.8	30	32	35	36	32.7	28.8	36.0	2.6
Manganese	Mn	mg/L	0.05	0.05	<.05	<.05	<.03	<.03	<.03	0.05	0.05	0.1	0.1	0.00
Mercury	Hg	mg/L												
Lead	Pb	mg/L												
Molybdenum	Mo	mg/L												
Potassium	K	mg/L	10.6	17.3	17.9	23	12	19	20	24	18.0	10.6	24.0	4.7
Selenium	Se	mg/L												
Sodium	Na	mg/L	86.9	161	174	228	88	150	170	200	157.2	86.9	228.0	49.4

Source: Summary of Madison well data, Edgemont city water http://www.sdgs.usd.edu/other/db.html

TABLE D-2 Local Water Quality Data - Minnelusa Formation

API Number	Location					County	Formation Sampled	Sample Method	Test Interval		TDS (mg/L)
	Section	Township	Range	Latitude	Longitude				Top (feet)	Bottom (feet)	
4003305005	34	6S	2E	43.48664	-103.86925	Custer	Minnelusa	DST	1,338	1,375	18,814
4003305010	34	6S	2E	43.48814	-103.86781	Custer	Minnelusa	Production	1,368	1,388	13,512
4003305010	34	6S	2E	43.48814	-103.86781	Custer	Minnelusa	Wellhead	1,356	--	7,740
4003305015	34	6S	2E	43.49021	-103.86926	Custer	Minnelusa	Separator	713	--	7,429
4003305035	30	5S	2E	43.58112	-103.93146	Custer	Minnelusa	Bailer	845	851	4,288
4004705067	15	9S	2E	43.26232	-103.87392	Fall River	Minnelusa	DST	2,692	2,707	24,823
4004705067	15	9S	2E	43.26232	-103.87392	Fall River	Minnelusa	DST	2,692	2,707	24,422
4004705067	15	9S	2E	43.26232	-103.87392	Fall River	Minnelusa	WLT	2,230	2,234	9,803
4004705089	21	7S	1E	43.42595	-103.99711	Fall River	Minnelusa	DST	2,390	2,400	21,391
4004705089	21	7S	1E	43.42595	-103.99711	Fall River	Minnelusa	DST	2,390	2,400	17,279
4004705089	21	7S	1E	43.42595	-103.99711	Fall River	Minnelusa	DST	2,390	2,400	16,652
4004705092	21	7S	2E	43.42964	-103.88318	Fall River	Minnelusa	Unknown	1,415	1,418	10,183
40000185	34	6S	2E	43.48480	-103.86630	Custer	Minnelusa	Separator	713	--	7,427
40000183	34	6S	2E	43.48480	-103.86630	Custer	Minnelusa	Separator	680	--	6,968

Notes:
-- - Data not provided.
Shading indicates duplicate samples.
Source: USGS Produced waters Database; http://energy.cr.usgs.gov/prov/prodwat/data.htm

TABLE D-3 Local Water Quality Data - Unkpapa/Sundance Formation

Well #635				
Analyte	**9/26/07 18:08**	**11/27/07 8:25**	**2/10/08 14:55**	**4/29/08 19:00**
A/C Balance (± 5) (%)	-1.14	-0.831	-0.25	3.52
Alkalinity-Total as CaCO3 (mg/L)	124	118	120	118
Aluminum-Dissolved (mg/L)	<0.1	<0.1	<0.1	<0.1
Ammonia (mg/L)	0.1	0.4	0.5	0.5
Anions (meq/L)	30.4	31.6	33.7	32.8
Antimony-Total (mg/L)			<0.003	<0.003
Arsenic-Dissolved (mg/L)	<0.001	<0.001	<0.001	<0.001
Arsenic-Total (mg/L)			<0.001	0.001
Barium-Dissolved (mg/L)	<0.1	<0.1	<0.1	<0.1
Barium-Total (mg/L)			<0.1	<0.1
Beryllium-Total (mg/L)			<0.001	<0.001
Bicarbonate as HCO3 (mg/L)	151	144	146	144
Boron-Dissolved (mg/L)	0.4	0.4	0.5	0.4
Boron-Total (mg/L)			0.5	0.4
Cadmium-Dissolved (mg/L)	<0.005	<0.005	<0.005	<0.005
Cadmium-Total (mg/L)			<0.005	<0.005
Calcium-Dissolved (mg/L)	110	120	132	136
Carbonate as CO3 (mg/L)	<5	<5	<5	<5
Cations (meq/L)	29.8	31.1	33.5	35.2
Chloride (mg/L)	24	23	26	20
Chromium-Dissolved (mg/L)	<0.05	<0.05	<0.05	<0.05
Chromium-Total (mg/L)			<0.05	<0.05
Conductivity @ 25 C (umhos/cm)	2890	2830	2950	2810
Copper-Dissolved (mg/L)	<0.01	<0.01	<0.01	<0.01
Copper-Total (mg/L)			<0.01	<0.01
Fluoride (mg/L)	0.3	0.3	0.4	0.4
Gross Alpha-Dissolved (pCi/L)	2.5	4.4	14.8	13.2
Gross Beta-Dissolved (pCi/L)	4.3	6.3	10	-8
Gross Gamma-Dissolved (pCi/L)	960	1000	91	
Iron-Dissolved (mg/L)	<0.03	<0.03	<0.03	<0.03
Iron-Total (mg/L)			1.11	1.08
Lead 210-Dissolved (pCi/L)	<1	1.7	<1	
Lead 210-Suspended (pCi/L)	<1	5.1	<1	-9.6
Lead 210-Total (pCi/L)	<1			
Lead-Dissolved (mg/L)	<0.001	0.003	<0.001	<0.001
Lead-Total (mg/L)			<0.001	<0.001
Magnesium-Dissolved (mg/L)	44.3	49	52.3	54.1
Manganese-Dissolved (mg/L)	0.06	0.07	0.06	0.06
Manganese-Total (mg/L)			0.06	0.05
Mercury-Dissolved (mg/L)	<0.001	<0.001	<0.001	<0.001
Mercury-Total (mg/L)	<0.0002	<0.001	<0.001	<0.001
Molybdenum-Dissolved (mg/L)	<0.1	<0.1	<0.1	<0.1
Molybdenum-Total (mg/L)			0.01	<0.1
Nickel-Dissolved (mg/L)	<0.05	<0.05	<0.05	<0.05
Nickel-Total (mg/L)			<0.05	<0.05
Nitrogen, Nitrate as N (mg/L)	<0.1	<0.1	<0.1	<0.05
Nitrogen, Nitrite as N (mg/L)	<0.1	<0.1	<0.1	<0.05
Oxidation-Reduction Potential (mV)		270	129.4	180
pH	7.72	7.64	7.91	8.2
Polonium 210-Dissolved (pCi/L)	<1	1.9	<1	1.1
Polonium 210-Suspended (pCi/L)	<1	<1	<1	
Polonium 210-Total (pCi/L)	<1			
Potassium-Dissolved (mg/L)	7.8	8.3	8.2	7.3
Radium 226-Dissolved (pCi/L)	1.6	0.8	1.3	
Radium 226-Suspended (pCi/L)	0.8	<0.2	0.6	0.3
Radium 226-Total (pCi/L)	2.4			

TABLE D-3 Local Water Quality Data - Unkpapa/Sundance Formation

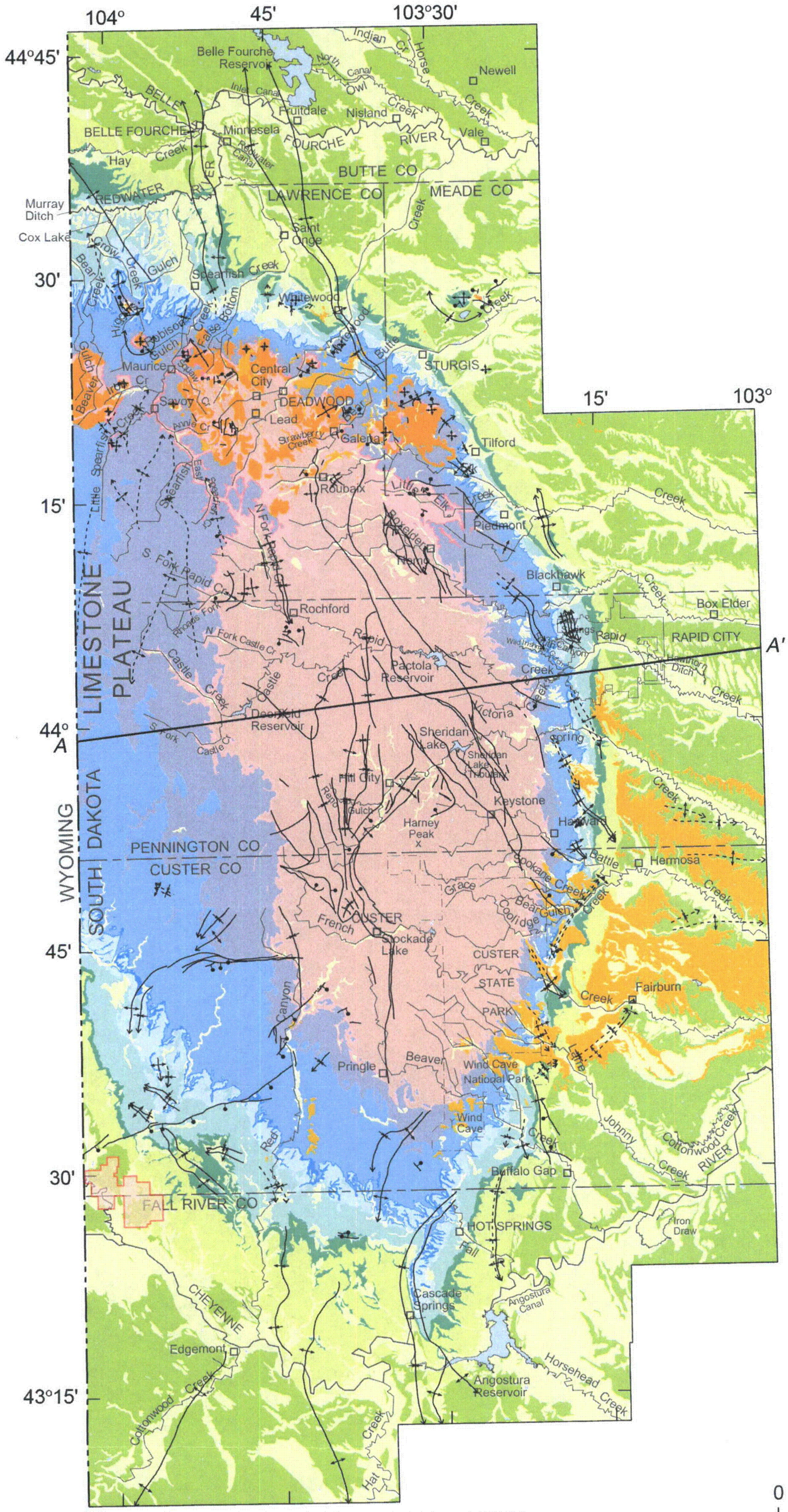
Well #635				
Analyte	**9/26/07 18:08**	**11/27/07 8:25**	**2/10/08 14:55**	**4/29/08 19:00**
Radon 222-Total (pCi/L)		902	806	1070
Selenium-Dissolved (mg/L)	0.001	<0.001	<0.001	<0.001
Selenium-IV-Dissolved (mg/L)		0.001	<0.001	<0.001
Selenium-Total (mg/L)			<0.001	0.001
Selenium-VI-Dissolved (mg/L)		<0.001	<0.001	<0.001
Silica-Dissolved (mg/L)	8.6	9	10	4.9
Silver-Dissolved (mg/L)	<0.005	<0.005	<0.005	<0.005
Silver-Total (mg/L)			<0.005	<0.005
Sodium Adsorption Ratio (SAR) (meq/L)		9.3	9.6	10
Sodium-Dissolved (mg/L)	470	480	515	545
Solids-Total Dissolved Calculated (mg/L)	2040	2120	2270	2280
Solids-Total Dissolved TDS @ 180 C (mg/L)	2200	2300	2300	2200
Strontium-Total (mg.L)			4.2	4.6
Sulfate (mg/L)	1500	1370	1470	1430
TDS Balance (0.80 - 1.20) (dec.%)	1.09	1.08	1.03	0.98
Thallium-Total (mg/L)			<0.001	<0.001
Thorium 230-Dissolved (pCi/L)	<0.2	<0.2	<0.2	0.2
Thorium 230-Suspended (pCi/L)	<0.2	<0.2	<0.2	0.1
Thorium 230-Total (pCi/L)	<0.2			
Thorium 232-Dissolved (pCi/L)	<0.005	<0.005	<0.005	<0.005
Uranium-Dissolved (mg/L)	0.002	0.002	0.0021	0.0017
Uranium-Suspended (mg/L)	<0.0003	<0.0003	<0.0003	<0.0003
Uranium-Total (mg/L)	0.002		0.0021	0.0017
Vanadium-Dissolved (mg/L)	<0.1	<0.1	<0.1	<0.1
Zinc-Dissolved (mg/L)	<0.01	0.02	<0.01	<0.01
Zinc-Total (mg/L)			<0.01	<0.01

Source: Powertech 2008 Class III UIC Permit Application, Appendix F

TABLE D-4 Local Water Quality Data - Inyan Kara Group (Lakota and Fall River Formations)

		Mean			Minimum			Maximum		
	Well	**Powertech**	**TVA**	**RPD**	**Powertech**	**TVA**	**RPD**	**Powertech**	**TVA**	**RPD**
Alkalinity as CaCO3, mg/L	2	181	219	19%	88	200	78%	214	242	12%
	7	171	181	6%	170	171	1%	176	191	8%
	8	166	178	7%	156	166	6%	178	194	9%
	13	159	173	8%	142	160	12%	170	196	14%
	16	153	152	1%	148	144	3%	160	157	2%
	18	179	196	9%	172	180	5%	184	238	26%
	42	178	188	5%	174	179	3%	180	204	13%
	4002	140	158	12%	138	144	4%	144	202	34%
	7002	261	261	0%	250	210	17%	280	300	7%
Conductivity, uS/cm	2	2285	1547	39%	1500	1450	3%	4400	1750	86%
	7	1542	1338	14%	1440	1325	8%	1650	1350	20%
	8	1450	1385	5%	1420	1285	10%	1560	1450	7%
	13	1292	1274	1%	1140	1100	4%	1420	1400	1%
	16	1063	1162	9%	925	1150	22%	1260	1175	7%
	18	1412	1379	2%	1330	1300	2%	1470	1420	3%
	42	1408	1353	4%	1310	1200	9%	1510	1400	8%
	4002	1220	1161	5%	1130	1100	3%	1340	1195	11%
	7002	2328	2339	0%	2200	1925	13%	2480	2500	1%
pH	2	7.91	7.7	3%	7.85	7.16	9%	7.94	8.2	3%
	7	8.11	8.5	5%	8.05	8.3	3%	8.17	8.7	6%
	8	7.95	7.87	1%	7.93	7.59	4%	7.97	8.5	6%
	13	7.9	7.76	2%	7.75	7.48	4%	8.05	8.1	1%
	16	7.46	7.34	2%	7.38	7.31	1%	7.57	7.39	2%
	18	8.08	7.94	2%	8.02	7.69	4%	8.11	8.4	4%
	42	8.02	7.94	1%	7.95	7.67	4%	8.08	8.4	4%
	4002	7.83	7.75	1%	7.65	7.51	2%	8.02	8.5	6%
	7002	7.36	7.44	1%	7.22	7.14	1%	7.56	8	6%
Total Dissolved Solids	2	1750	1043	51%	1100	1004	9%	3600	1113	106%
	7	999	1081	8%	896	1058	17%	1050	1104	5%
	8	1000	965	4%	940	860	9%	1100	1130	3%
	13	878	886	1%	850	792	7%	890	1006	12%
	16	814	846	4%	760	796	5%	940	894	5%
	18	958	909	5%	940	520	58%	990	1118	12%
	42	950	939	1%	930	888	5%	980	1033	5%
	4002	818	773	6%	790	740	7%	850	805	5%
	7002	1875	1843	2%	1800	1690	6%	1900	1970	4%
RPD (Relative Percent Difference) = The absolute difference divided by the average.										

Source: Table 2.7-45: Comparison of Statistics for Selected Constituents between Historic TVA Data and current Powertech Data (2009 Powertech NRC Application)



Base modified from U.S. Geological Survey digital data, 1:100,000
Rapid City, Office of City Engineer map, 1:18,000, 1996
Universal Transverse Mercator projection, zone 13

EXPLANATION

Hydrogeologic Units	Stratigraphic Units	Map Units
Unconsolidated units	QTac	Alluvium and colluvium, undifferentiaed
White River aquifer	Tw	White River Group
Tertiary intrusive units	Tui	Undifferentiated intrusive igneous rocks
Cretaceous-sequence confining unit	Kps	Pierre Shale to Skull Creek Shale, undifferentiated
Inyan Kara aquifer	Kik	Inyan Kara Group
Jurassic-sequence semiconfining unit	Ju	Morrison Formation to Gypsum Spring Formation, undifferentiated
Spearfish confining unit	TRPs	Spearfish Formation
Minnekahta aquifer	Pmk	Minnekahta Limestone
Opeche confining unit	Po	Opeche Shale
Minnelusa aquifer	PIPm	Minnelusa Formation
Madison aquifer	MDme	Madison (Pahasapa) Limestone and Englewood Formation
Ordovician-sequence semiconfining unit	Ou	Whitewood Formation and Winnipeg Formation
Deadwood aquifer	O€d	Deadwood Formation
Precambrian igneous and metamorphic units	p€u	Undifferentiated metamorphic and igneous rocks

A——A' LINE OF GEOLOGIC SECTION

FAULT--Dashed where approximated. Bar and ball on downthrown side.

ANTICLINE--Showing trace of axial plane and direction of plunge. Dashed where approximated.

SYNCLINE--Showing trace of axial plane and direction of plunge. Dashed where approximated.

MONOCLINE--Showing trace of axial plane. Dashed where approximated.

DOME--Symbol size approximately proportional to size of dome. Dome asymmetry indicated by arrow length.

0 10 20 MILES

0 10 20 KILOMETERS

Legend

Dewey-Burdock Permit Boundary

From:
Water-Resources Investigations Report 01-4194
by Joyce E. Williamson and Janet M. Carter, 2001

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Figure D-1
Distribution of Hydrogeologic Units in the Black Hills Area
2010 Dewey-Burdock Class V Permit

Scale: See Bar Scale	Date: March 2010	
2010_DB_Class_Fig_D-01.ai	By: JLM	Checked: HD

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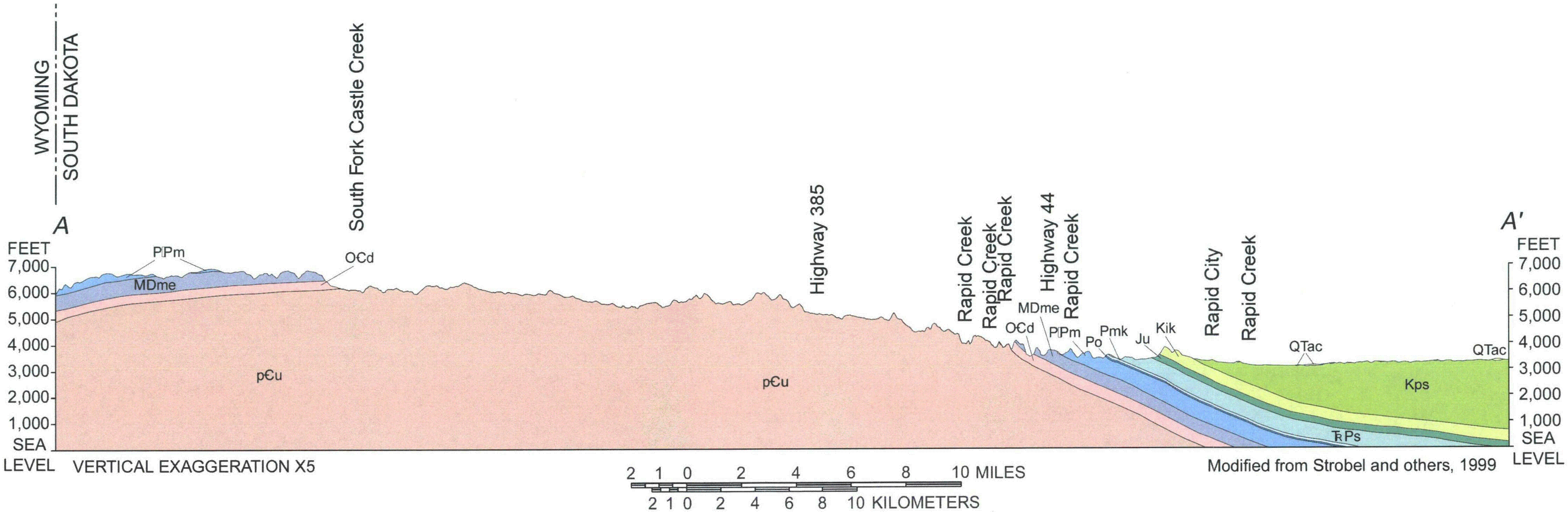

EXPLANATION

Hydrogeologic Units	Stratigraphic Units	Map Units
Unconsolidated units	QTac	Alluvium and colluvium, undifferentiaed
White River aquifer	Tw	White River Group
Tertiary intrusive units	Tui	Undifferentiated intrusive igneous rocks
Cretaceous-sequence confining unit	Kps	Pierre Shale to Skull Creek Shale, undifferentiated
Inyan Kara aquifer	Kik	Inyan Kara Group
Jurassic-sequence semiconfining unit	Ju	Morrison Formation to Gypsum Spring Formation, undifferentiated
Spearfish confining unit	TRPs	Spearfish Formation
Minnekahta aquifer	Pmk	Minnekahta Limestone
Opeche confining unit	Po	Opeche Shale
Minnelusa aquifer	PIPm	Minnelusa Formation
Madison aquifer	MDme	Madison (Pahasapa) Limestone and Englewood Formation
Ordovician-sequence semiconfining unit	Ou	Whitewood Formation and Winnipeg Formation
Deadwood aquifer	OЄd	Deadwood Formation
Precambrian igneous and metamorphic units	pЄu	Undifferentiated metamorphic and igneous rocks

From:
Water-Resources Investigations Report 01-4194
(after Stobel et al., 1999, Modified by Driscoll et al., 2002)

POWERTECH (USA) INC.

Figure D-2
Generalized East-West Geologic Cross Section through Black Hills Uplift (A-A')

2010 Dewey-Burdock Class V Permit

Scale: See Bar Scale	Date: March 2010	
2010_DB_Class_V_Fig_D-2.ai	By: JLM	Checked: HD

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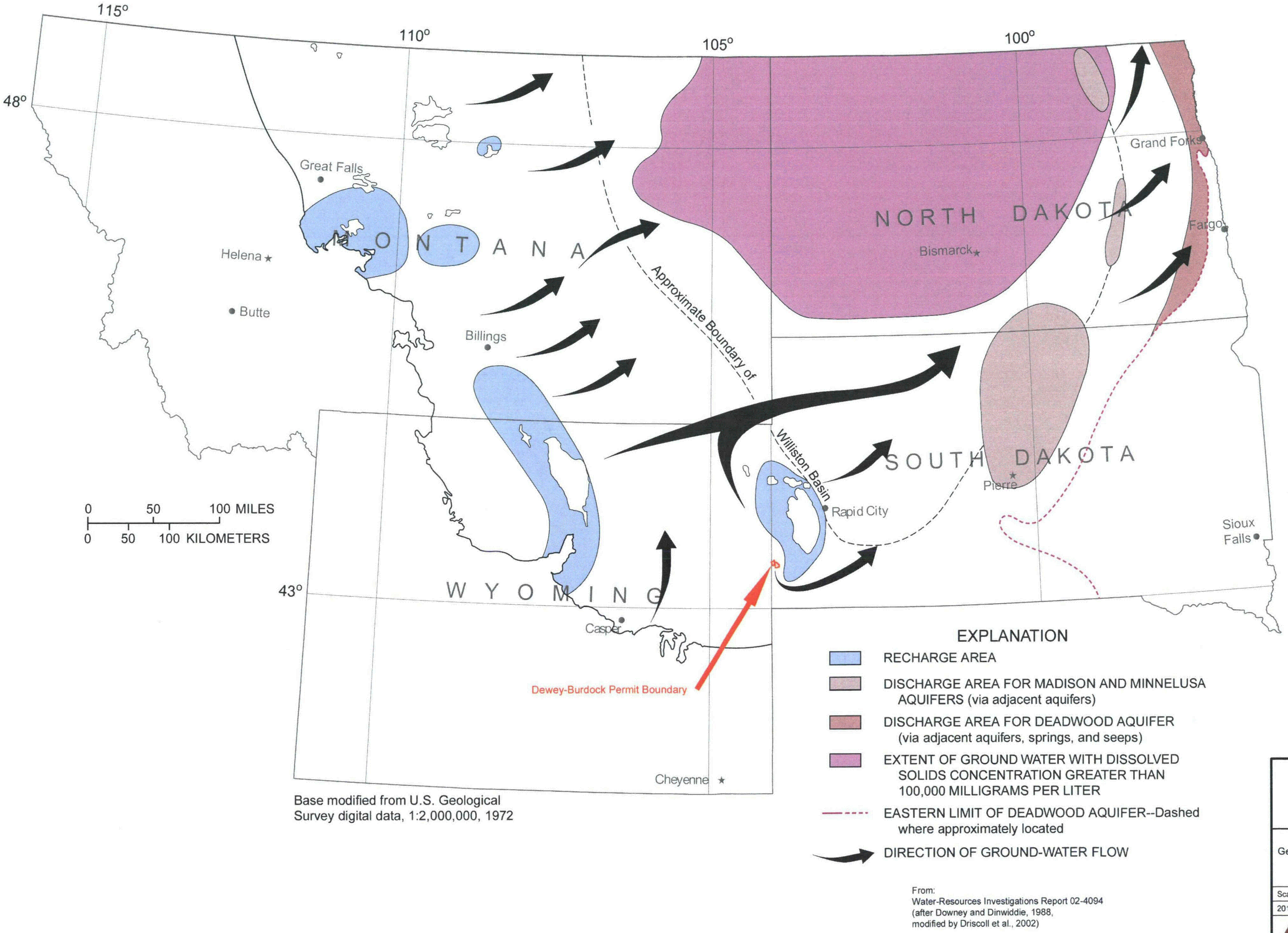

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Figure D-3
General Direction of Groundwater Flow in Regional Aquifer System within Paleozoic Aquifer Units

2010 Dewey-Burdock Class V Permit

Scale: See Bar Scale	Date: March 2010	
2010_DB_Class_V_Fig_D-03.ai	By: JLM	Checked: HD

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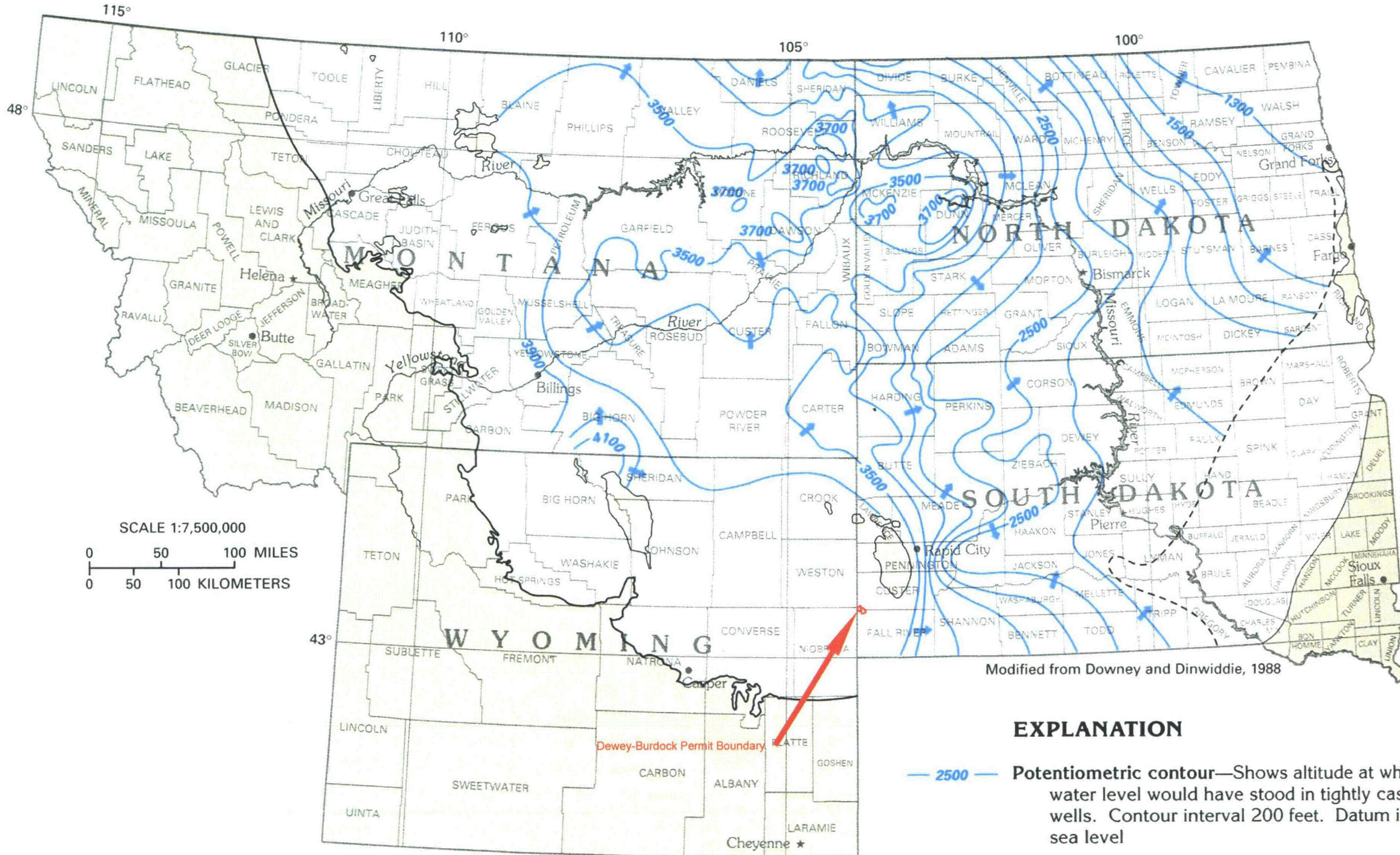

Base modified from U.S. Geological Survey digital data, 1:2,000,000, 1972

EXPLANATION

— 2500 — **Potentiometric contour**—Shows altitude at which water level would have stood in tightly cased wells. Contour interval 200 feet. Datum is sea level

———- - - **Limit of lower Paleozoic aquifers**—Dashed where approximately located

➡ **Direction of ground-water movement**

From:
Ground Water Atlas of the United States, Segment 8 MT, SD, ND & WY, Hydrologic Investigations Atlas 730-I USGS (by Whitehead, 1996)

POWERTECH (USA) INC.

Figure D-4
Regional Groundwater Flow in Lower Paleozoic Aquifer System, Powder River and Williston Basins
2010 Dewey-Burdock Class V Permit

Scale: See Bar Scale	Date: March 2010
2010_DB_Class_V_Fig_D-04.ai	By: JLM / Checked: HD

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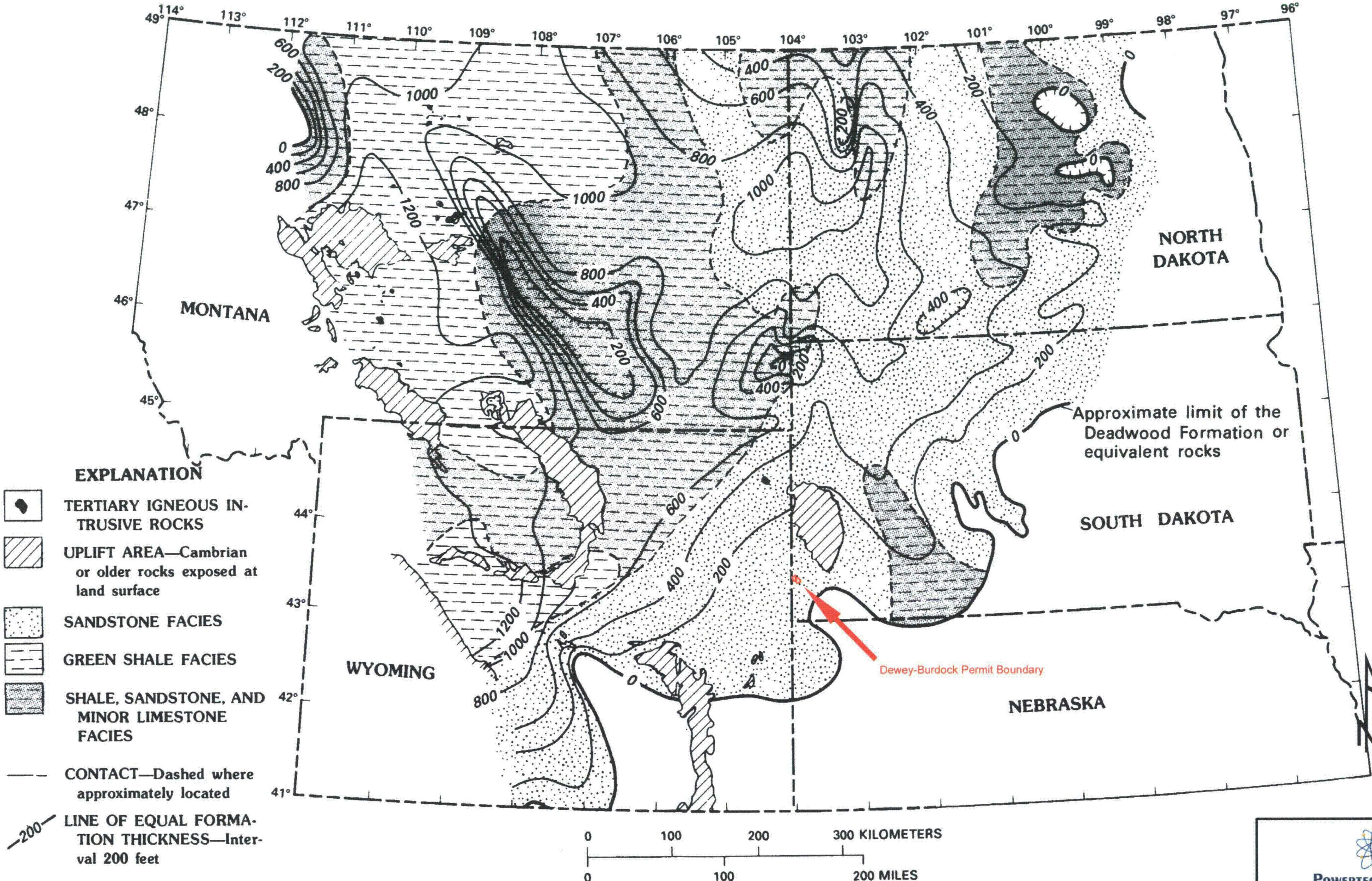

From:
Geological Survey Professional Paper 1273-A
Peterson, 1984

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Figure D-5
Isopach Map,
Deadwood Formation
2010 Dewey-Burdock Class V Permit

Scale: See Bar Scale	Date: March 2010
2010_DB_Class_V_Fig_D-05.ai	By: JLM / Checked: HD

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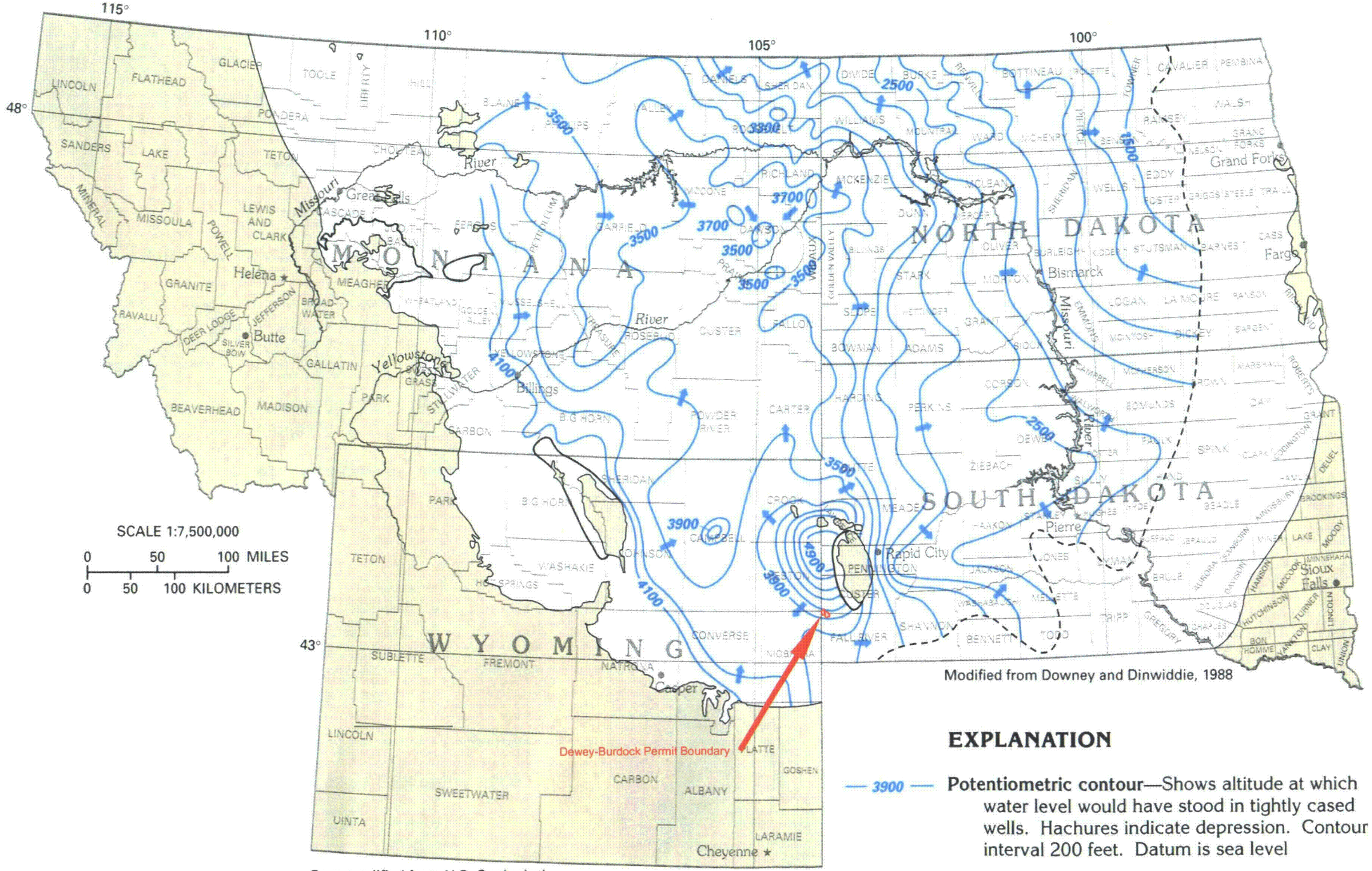

Modified from Downey and Dinwiddie, 1988

Base modified from U.S. Geological Survey digital data, 1:2,000,000, 1972

EXPLANATION

— 3900 — **Potentiometric contour**—Shows altitude at which water level would have stood in tightly cased wells. Hachures indicate depression. Contour interval 200 feet. Datum is sea level

——— - - - **Limit of upper Paleozoic aquifers**—Dashed where approximately located

➡ **Direction of ground-water movement**

From:
Ground Water Atlas of the United States,
Segment 8 MT, SD, ND & WY,
Hydrologic Investigations Atlas 730-I USGS
(by Whitehead, 1996)

POWERTECH (USA) INC.

Figure D-6
Regional Groundwater Flow Pattern in Upper Paleozoic Aquifer System, Powder River and Williston Basins
2010 Dewey-Burdock Class V Permit

Scale: See Bar Scale	Date: March 2010	
2010_DB_Class_V_Fig_D-06.ai	By: JLM	Checked: HD

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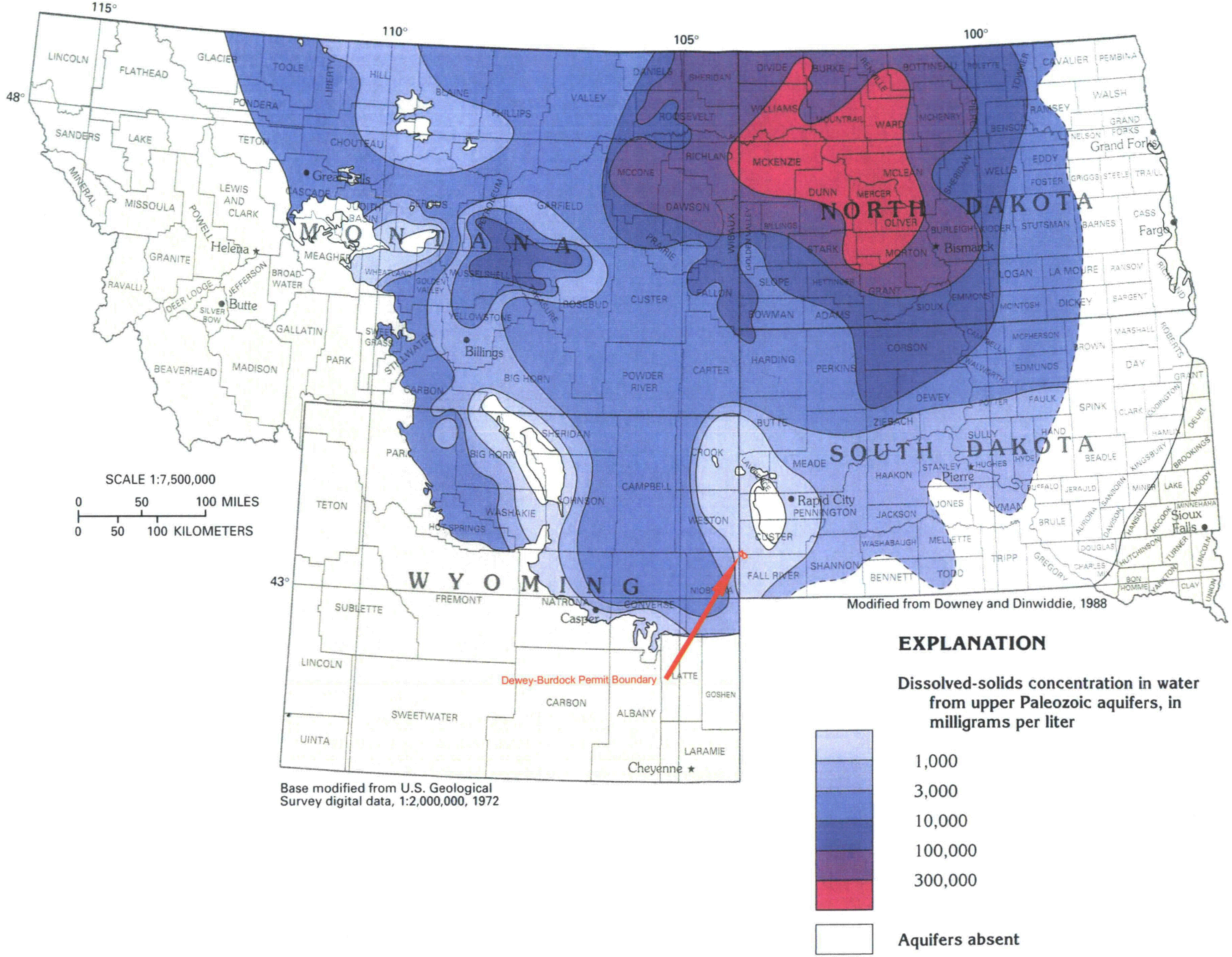

From:
Ground Water Atlas of the United States,
Segment 8 MT, SD, ND & WY,
Hydrologic Investigations Atlas 730-I USGS
(by Whitehead, 1996)

POWERTECH (USA) INC.

Figure D-7
Dissolved Solids Concentrations in Upper Paleozoic Aquifer System, Powder River and Williston Basins

2010 Dewey-Burdock Class V Permit

Scale: See Bar Scale	Date: March 2010	
2010_DB_Class_V_Fig_D-07.ai	By: JLM	Checked: HD

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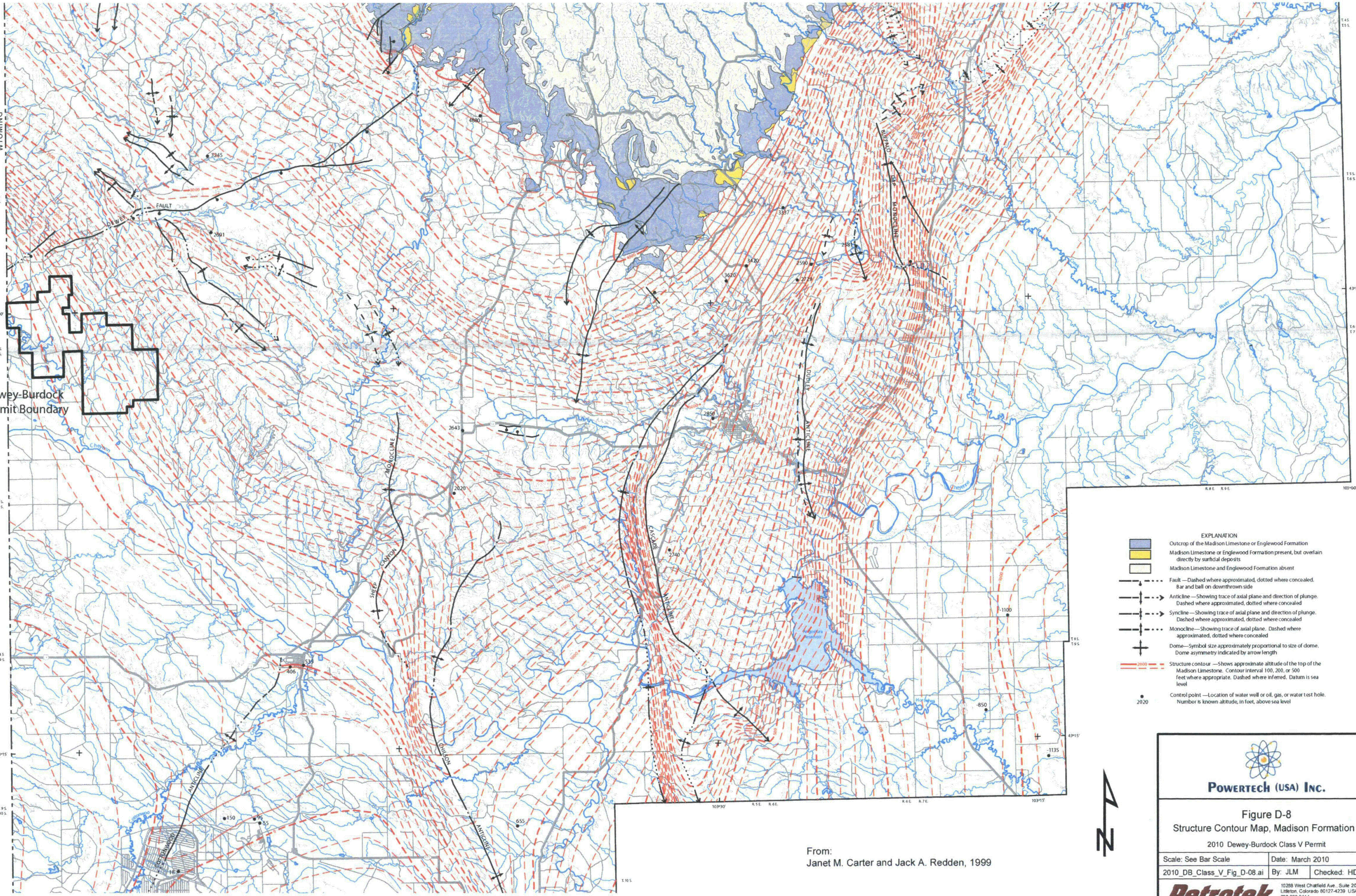

From:
Janet M. Carter and Jack A. Redden, 1999

POWERTECH (USA) INC.

Figure D-8
Structure Contour Map, Madison Formation

2010 Dewey-Burdock Class V Permit

Scale: See Bar Scale	Date: March 2010
2010_DB_Class_V_Fig_D-08.ai	By: JLM — Checked: HD

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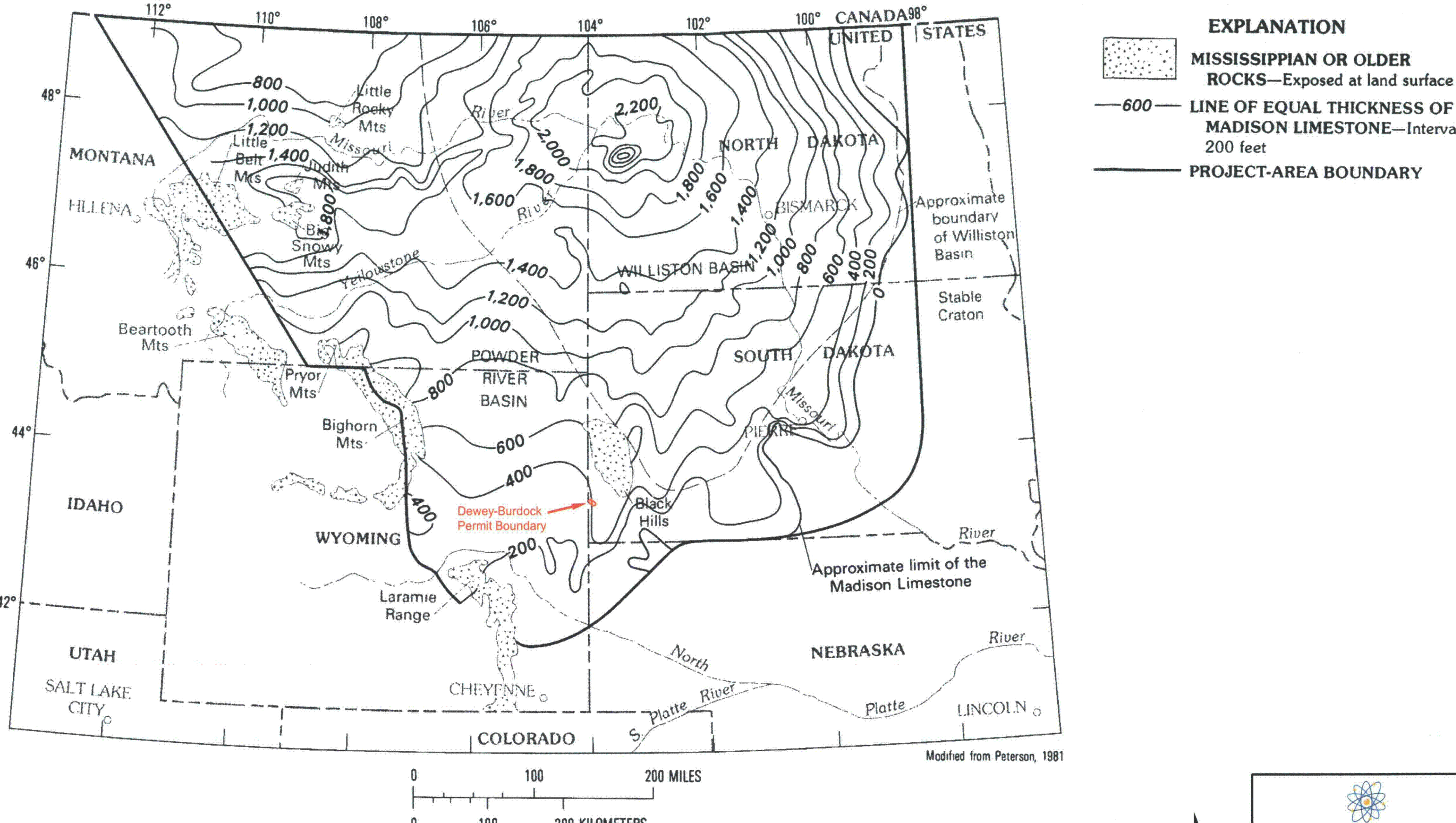

From:
USGS Professional Paper #1402 F

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Figure D-9
Isopach Map, Madison Formation
2010 Dewey-Burdock Class V Permit

Scale: See Bar Scale	Date: March 2010
2010_DB_Class_V_Fig_D-09.ai	By: JLM Checked: HD

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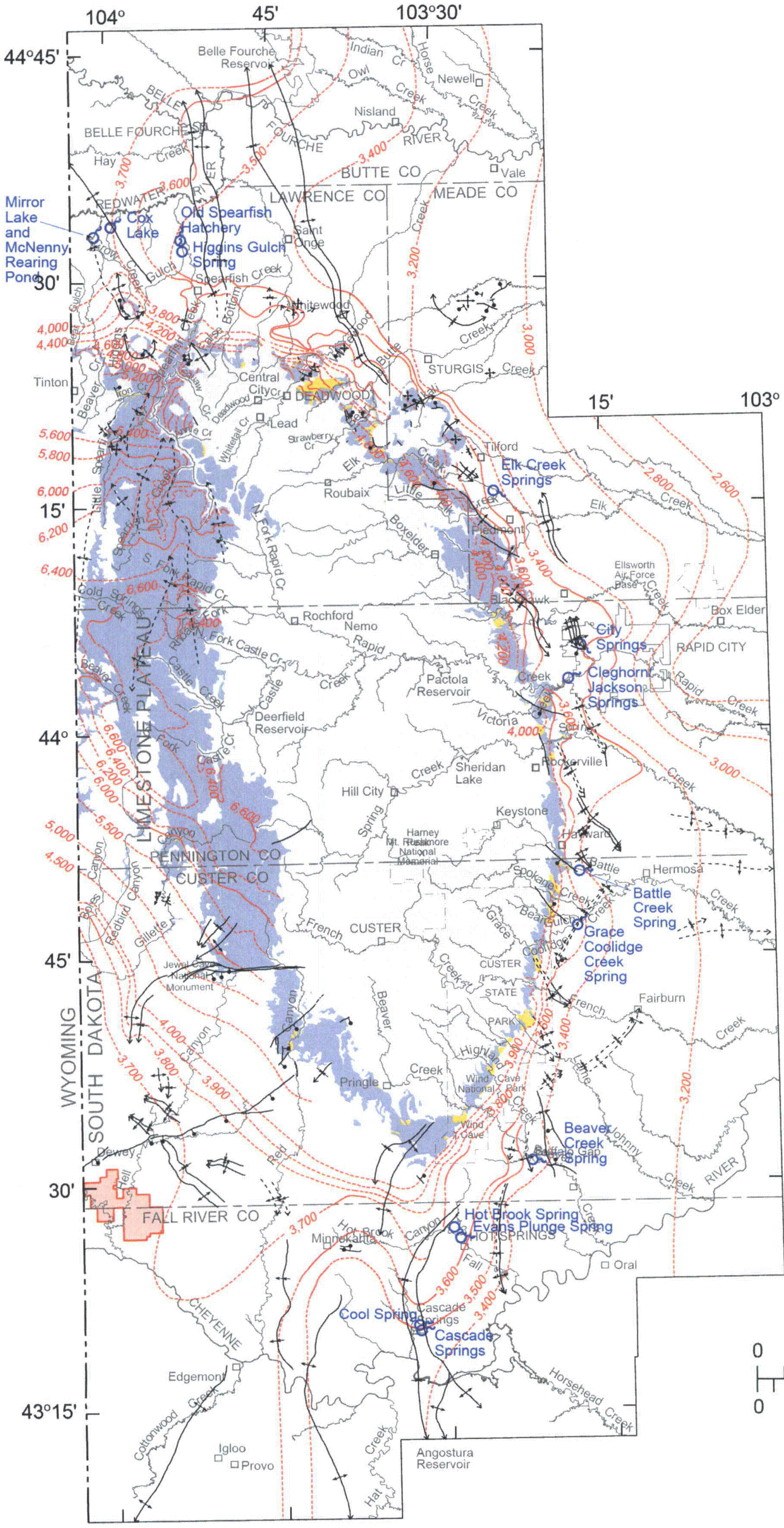

EXPLANATION

OUTCROP OF MADISON LIMESTONE (from Strobel and others, 1999)

MADISON LIMESTONE PRESENT, BUT OVERLAIN BY SURFICIAL DEPOSITS (from Carter and Redden, 1999d)

MADISON LIMESTONE ABSENT (from Carter and Redden, 1999d)

—3,000— POTENTIOMETRIC CONTOUR--Shows altitude at which water would have stood in tightly cased, nonpumping wells (modified from Strobel and others, 2000a). Contour interval 100, 200, or 500 feet, where appropriate. Dashed where inferred. Datum is sea level

FAULT--Dashed where approximated. Bar and ball on downthrown side

ANTICLINE--Showing trace of axial plane and direction of plunge. Dashed where approximated

SYNCLINE--Showing trace of axial plane and direction of plunge. Dashed where approximated

MONOCLINE--Showing trace of axial plane. Dashed where approximated

DOME--Symbol size approximately proportional to size of dome. Dome asymmetry indicated by arrow length

ARTESIAN SPRING

Base modified from U.S. Geological Survey digital data, 1:100,000, 1977, 1979, 1981, 1983, 1985
Rapid City, Office of City Engineer map, 1:18,000, 1996
Universal Transverse Mercator projection, zone 13

N

Legend

Dewey-Burdock Permit Boundary

From:
Water-Resources Investigations Report 02-4094
(modified by Driscoll et al., 2002)

POWERTECH (USA) INC.

Figure D-10
Potentiometrc Surface of the Madison Formation and Locations of Major Artesian Springs
2010 Dewey-Burdock Class V Permit

Scale: See Bar Scale	Date: March 2010	
2010_DB_Class_V_Fig_D-10.ai	By: JLM	Checked: HD

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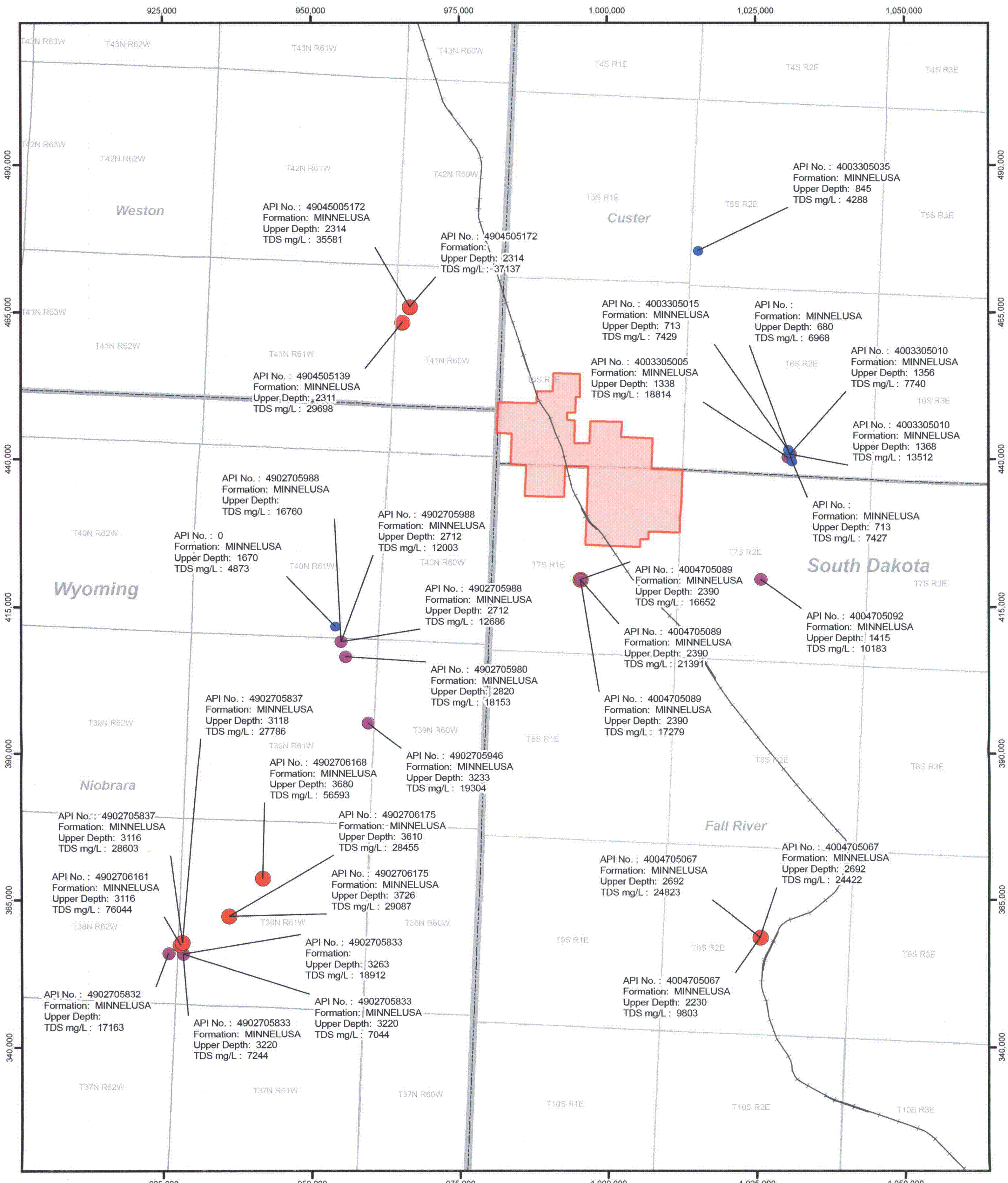

Legend

DeweyBurdockPermitBoundary

SD_DB_MinnelusaFm_TDS

TDS

- 0 - 3,000
- 3,001 - 10,000
- 10,001 - 20,000
- 20,001 - 400,000

WY_DB_MinnelusaFm_TDS

TDS

- 0 - 3,000
- 3,001 - 10,000
- 10,001 - 20,000
- 20,001 - 400,000

N

0 1 2 3 4 Miles

Projection: South Dakota State Plane South, NAD83 (feet)

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Figure D-11
Dewey-Burdock Project Area
TDS Concentrations, Minnelusa Formation

2010 Dewey Burdock Class V Permit

Scale: 1:200,000	Date: March 2010
2010 DB_Class_V_Fig_D-11.mxd	By: JLM	Checked: HD

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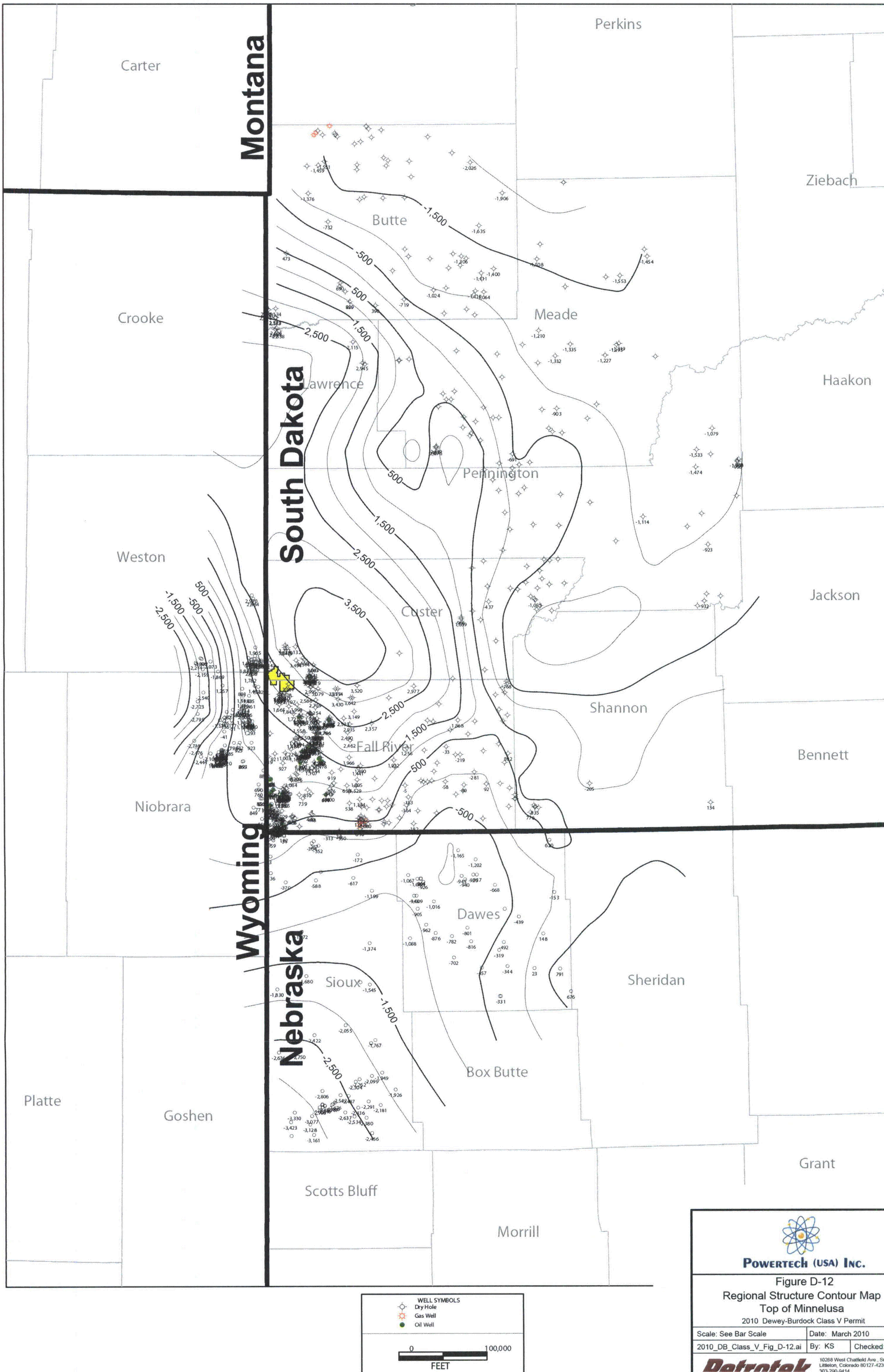

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Figure D-12
Regional Structure Contour Map
Top of Minnelusa
2010 Dewey-Burdock Class V Permit

Scale: See Bar Scale	Date: March 2010	
2010_DB_Class_V_Fig_D-12.ai	By: KS	Checked: HD

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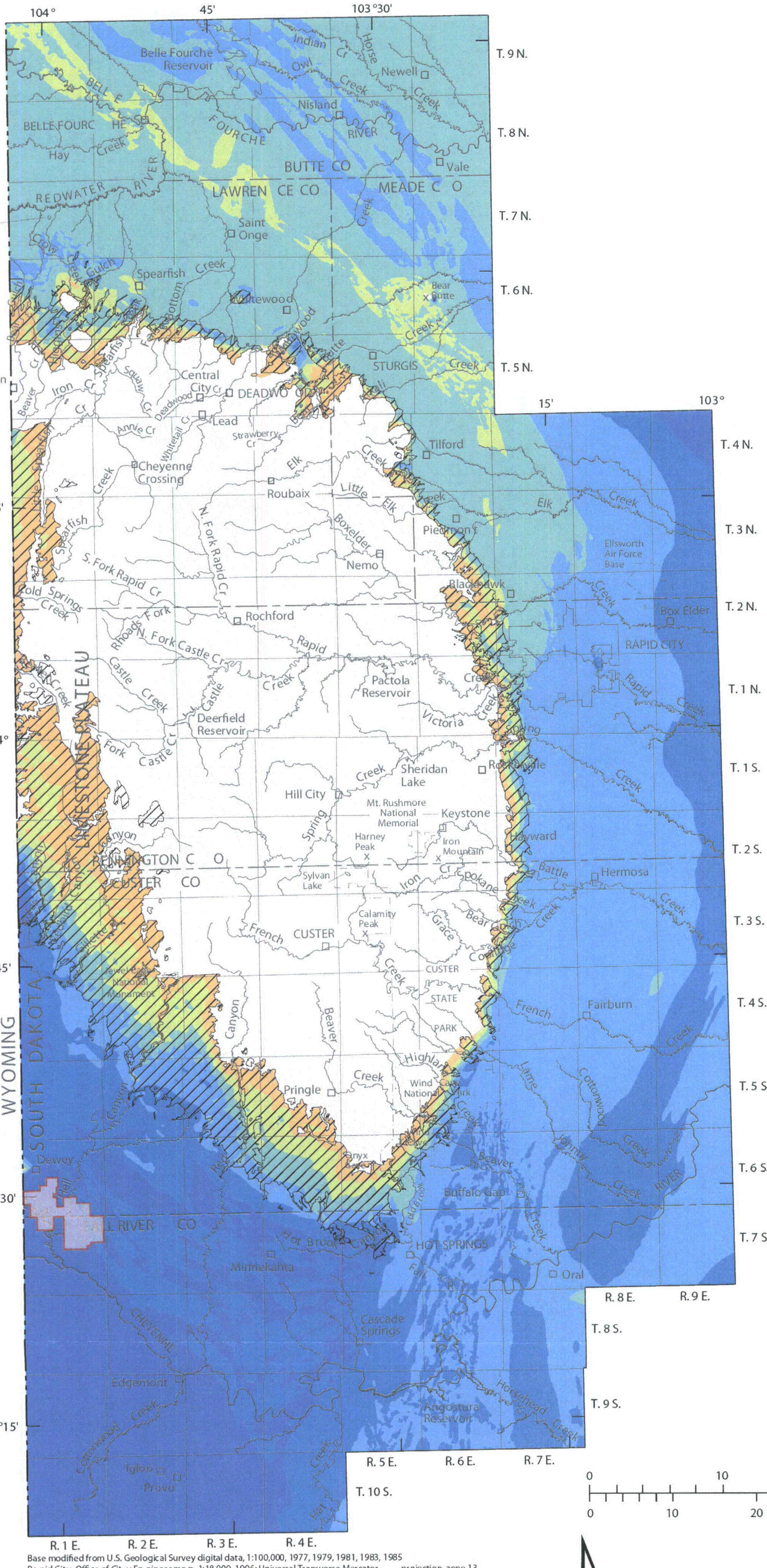

EXPLANATION

OUTCROP OF MINNELUSA FORMATION

MINNELUSA FORMATION ABSENT

THICKNESS OF MINNELUSA FORMATION, IN FEET (from Jarrell, 2000f)

- Less than 200
- 200 to 400
- 400 to 600
- 600 to 800
- 800 to 1,000
- Greater than 1,000
- No data

Base modified from U.S. Geological Survey digital data, 1:100,000, 1977, 1979, 1981, 1983, 1985
Rapid City, Office of City Engineer map, 1:18,000, 1996; Universal Transverse Mercator projection, zone 13

Legend

Dewey-Burdock Permit Boundary

From:
Water-Resources Investigations Report 02-4094
(modified by Driscoll et al., 2002)

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Figure D-13
Isopach Map of the Minnelusa Formation

2010 Dewey-Burdock Class V Permit

Scale: See Bar Scale	Date: March 2010
2010_DB_Class_V_Fig_D-13.ai	By: JLM / Checked: HD

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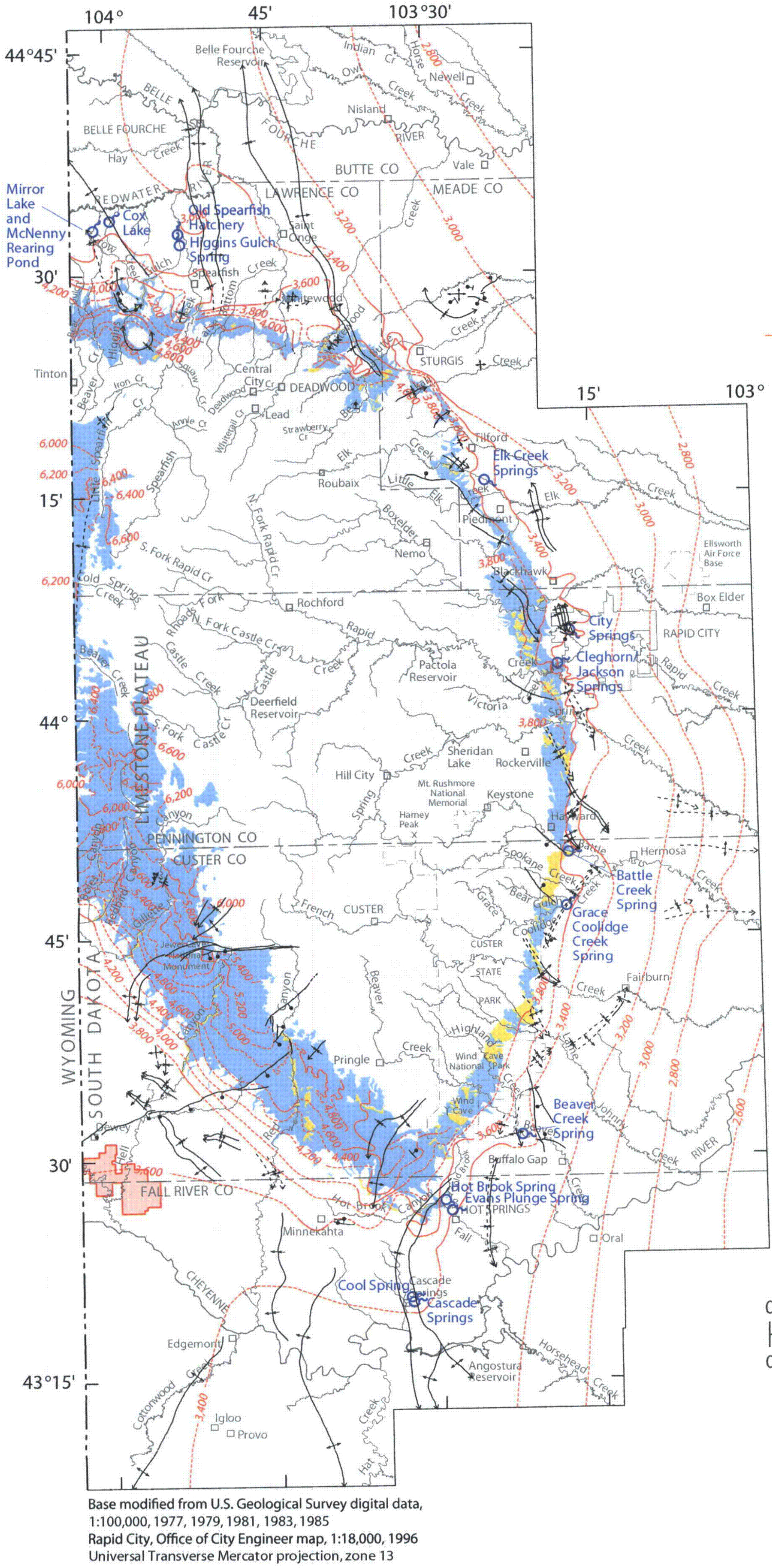

EXPLANATION

OUTCROP OF MINNELUSA FORMATION (modified from Strobel and others, 1999)

MINNELUSA FORMATION PRESENT, BUT OVERLAIN BY SURFICIAL DEPOSITS (from Carter and Redden, 1999c)

MINNELUSA FORMATION ABSENT (from Carter and Redden, 1999c)

3,000 — POTENTIOMETRIC CONTOUR--Shows altitude at which water would have stood in tightly cased, nonpumping wells (modified from Strobel and others, 2000b). Contour interval 200 feet. Dashed where inferred. Datum is sea level

FAULT--Dashed where approximated. Bar and ball on downthrown side

ANTICLINE--Showing trace of axial plane and direction of plunge. Dashed where approximated

SYNCLINE--Showing trace of axial plane and direction of plunge. Dashed where approximated

MONOCLINE--Showing trace of axial plane. Dashed where approximated

DOME--Symbol size approximately proportional to size of dome. Dome asymmetry indicated by arrow length

ARTESIAN SPRING

Base modified from U.S. Geological Survey digital data, 1:100,000, 1977, 1979, 1981, 1983, 1985
Rapid City, Office of City Engineer map, 1:18,000, 1996
Universal Transverse Mercator projection, zone 13

Legend

Dewey-Burdock Permit Boundary

From:
Water-Resources Investigations Report 02-4094
(modified by Driscoll et al., 2002)

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Figure D-14
Potentiometrc Surface of the Minnelusa Formation and Locations of Major Artesian Springs
2010 Dewey-Burdock Class V Permit

Scale: See Bar Scale	Date: March 2010	
2010_DB_Class_V_Fig_D-14.ai	By: JLM	Checked: HD

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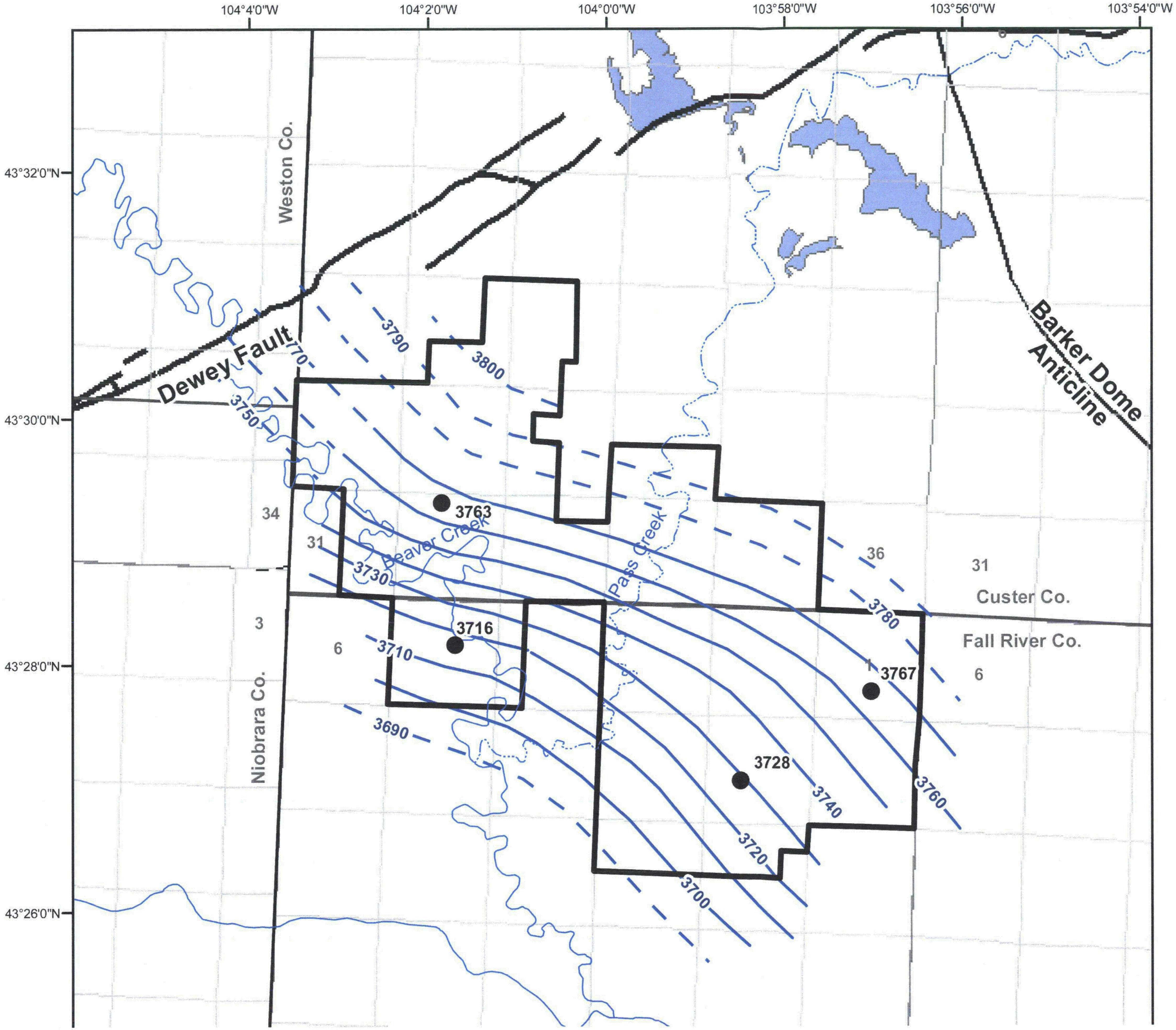

Legend

- Proposed Permit Boundary
- Sundance/Unkpapa Outcrop
- Perrenial Streams
- Ephemeral Streams
- 2008 Potentiometric Surface in Feet
- Unkpapa Water Elevations in Feet

NAD 1983 South Dakota South (ft)

Map Created By: C. Hocking, RESPEC, November 2008

N

0 0.4 0.8 1.2 1.6 Miles

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Figure D-14a
Potentiometric Surface
Unkpapa Aquifer

2010 Dewey-Burdock Class V Permit

Scale: NTS	Date: March 2010	
2010_DB_Class_V_Fig_D-14a.ai	By: JLM	Checked: HD

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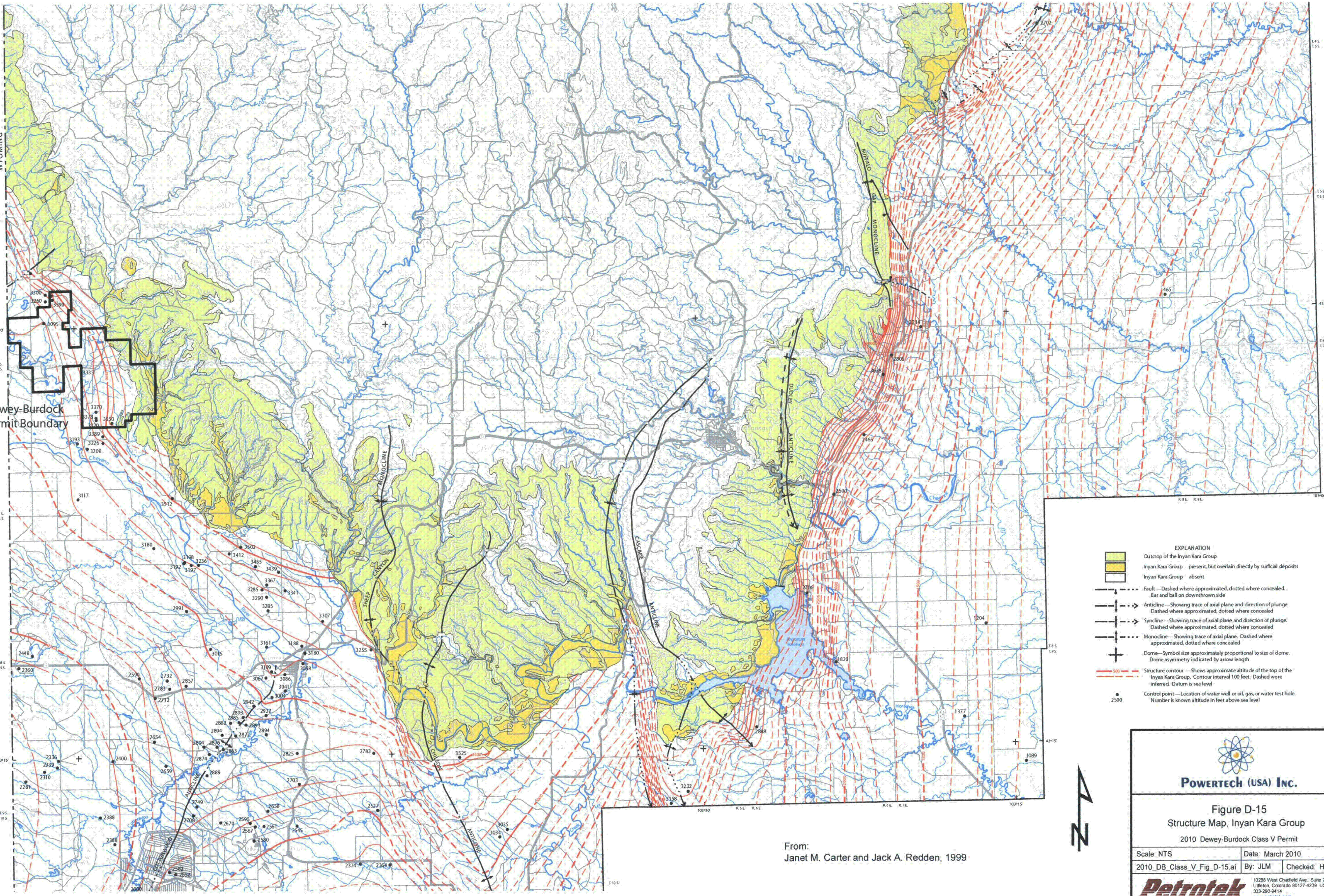

From:
Janet M. Carter and Jack A. Redden, 1999

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Figure D-15
Structure Map, Inyan Kara Group

2010 Dewey-Burdock Class V Permit

Scale: NTS	Date: March 2010	
2010_DB_Class_V_Fig_D-15.ai	By: JLM	Checked: HD

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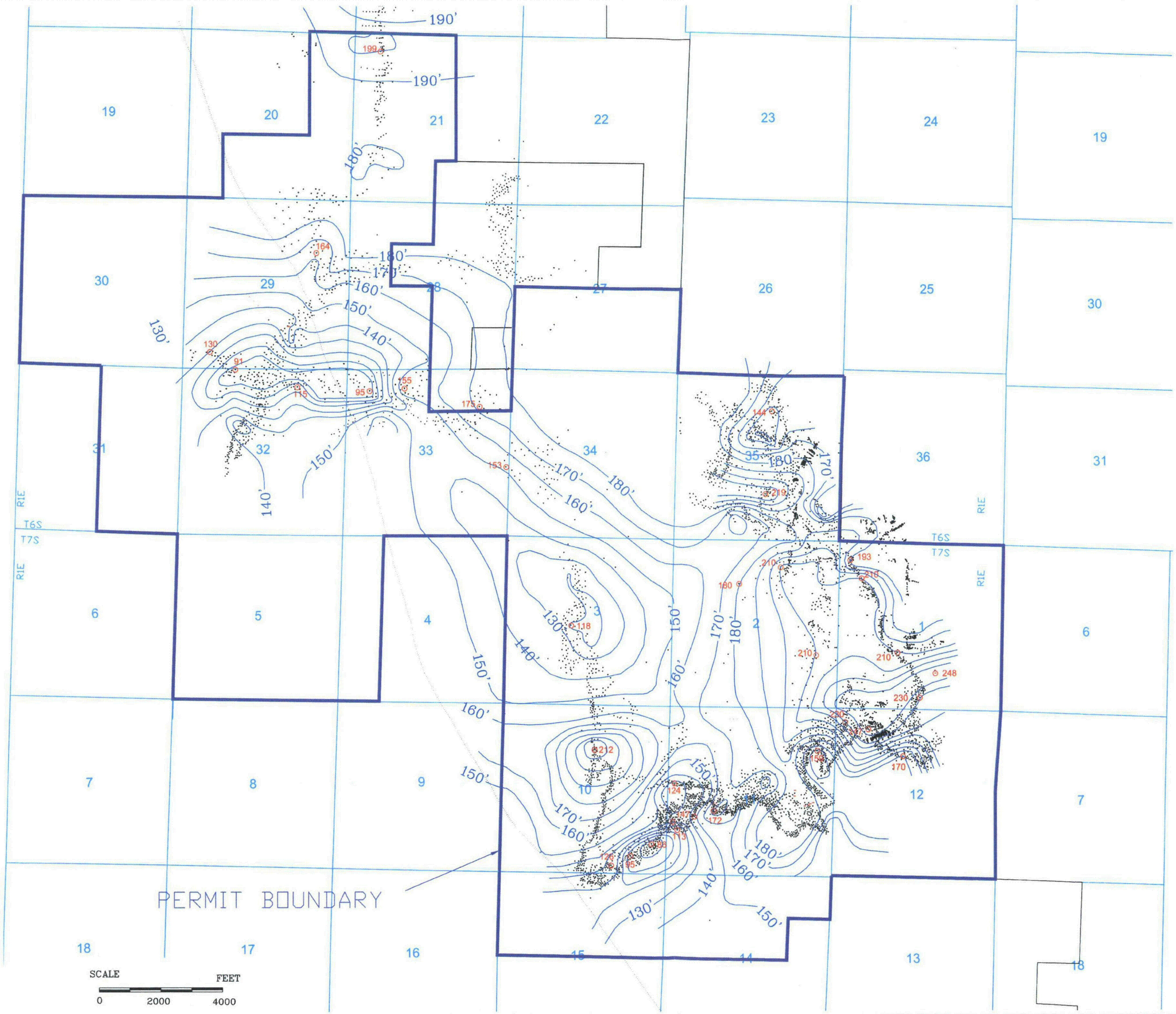

From:
RESPEC Water & Natural Resources, 2008

Powertech (USA) Inc.

Figure D-16
Isopach Map, Chilson Member
of Lakota Formation (Inyan Kara Group)
2010 Dewey-Burdock Class V Permit

Scale: See Bar Scale	Date: March 2010
2010_DB_Class_V_Fig_D-16.ai	By: JLM Checked: HD

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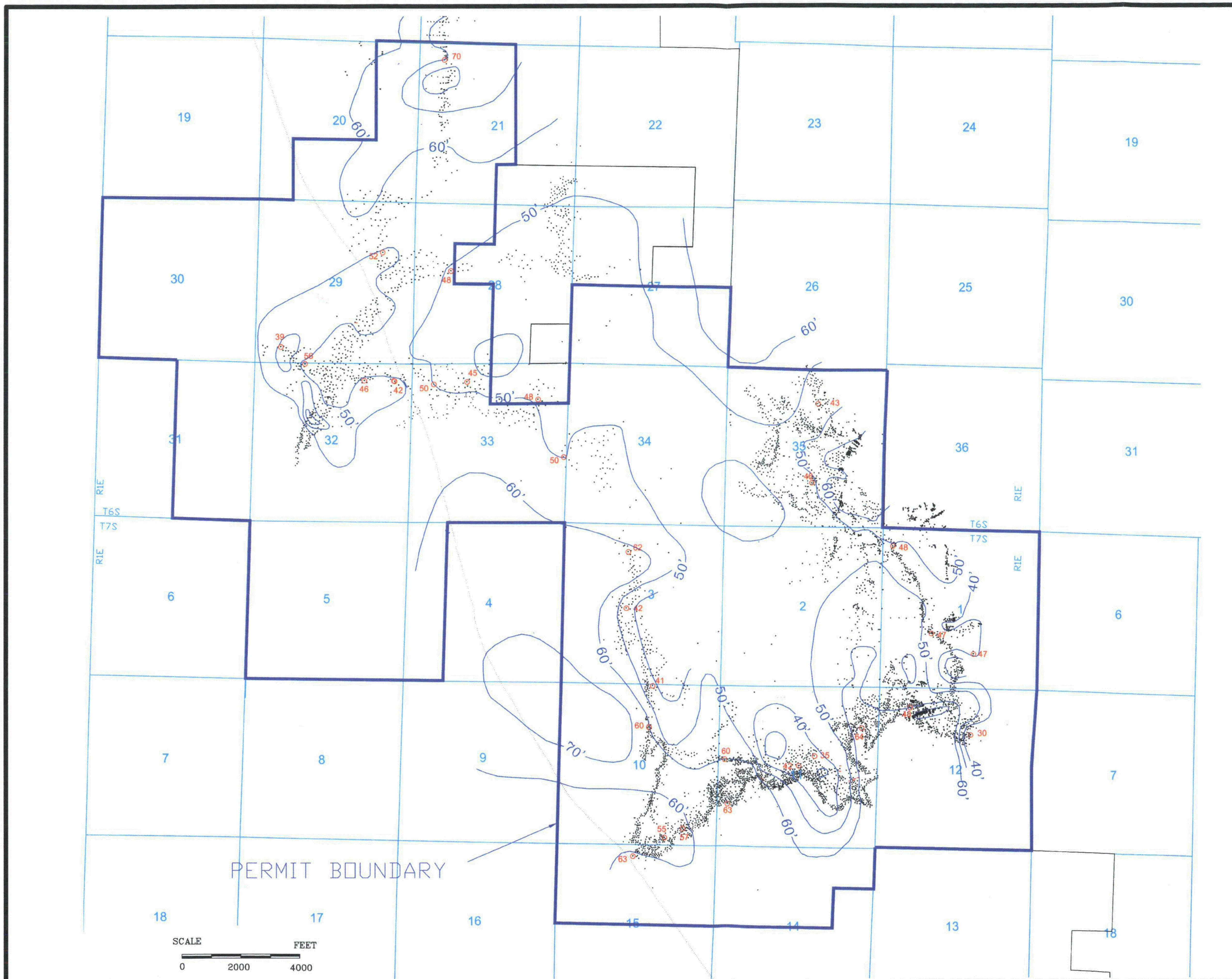

From:
RESPEC Water & Natural Resources, 2008

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Figure D-17
Isopach Map, Fusion Member of Lakota Formation (Inyan Kara Group)
2010 Dewey-Burdock Class V Permit

Scale: See Bar Scale	Date: March 2010	
2010_DB_Class_V_Fig_D-17.ai	By: JLM	Checked: HD

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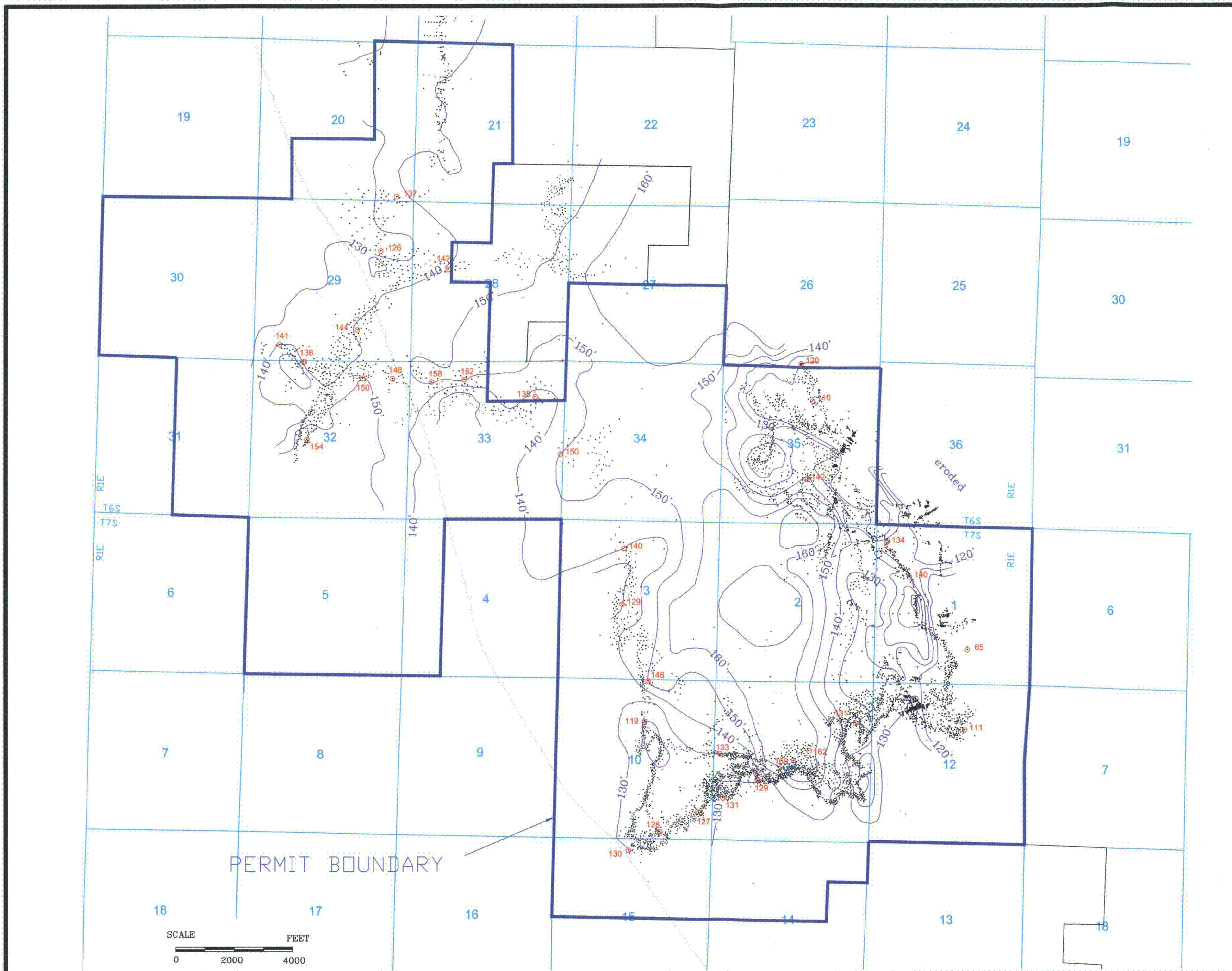

From:
RESPEC Water & Natural Resources, 2008

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Figure D-18
Isopach Map, Fall River Formation
(Inyan Kara Group)
2010 Dewey-Burdock Class V Permit

Scale: See Bar Scale	Date: March 2010	
2010_DB_Class_V_Fig_D-18.ai	By: JLM	Checked: HD

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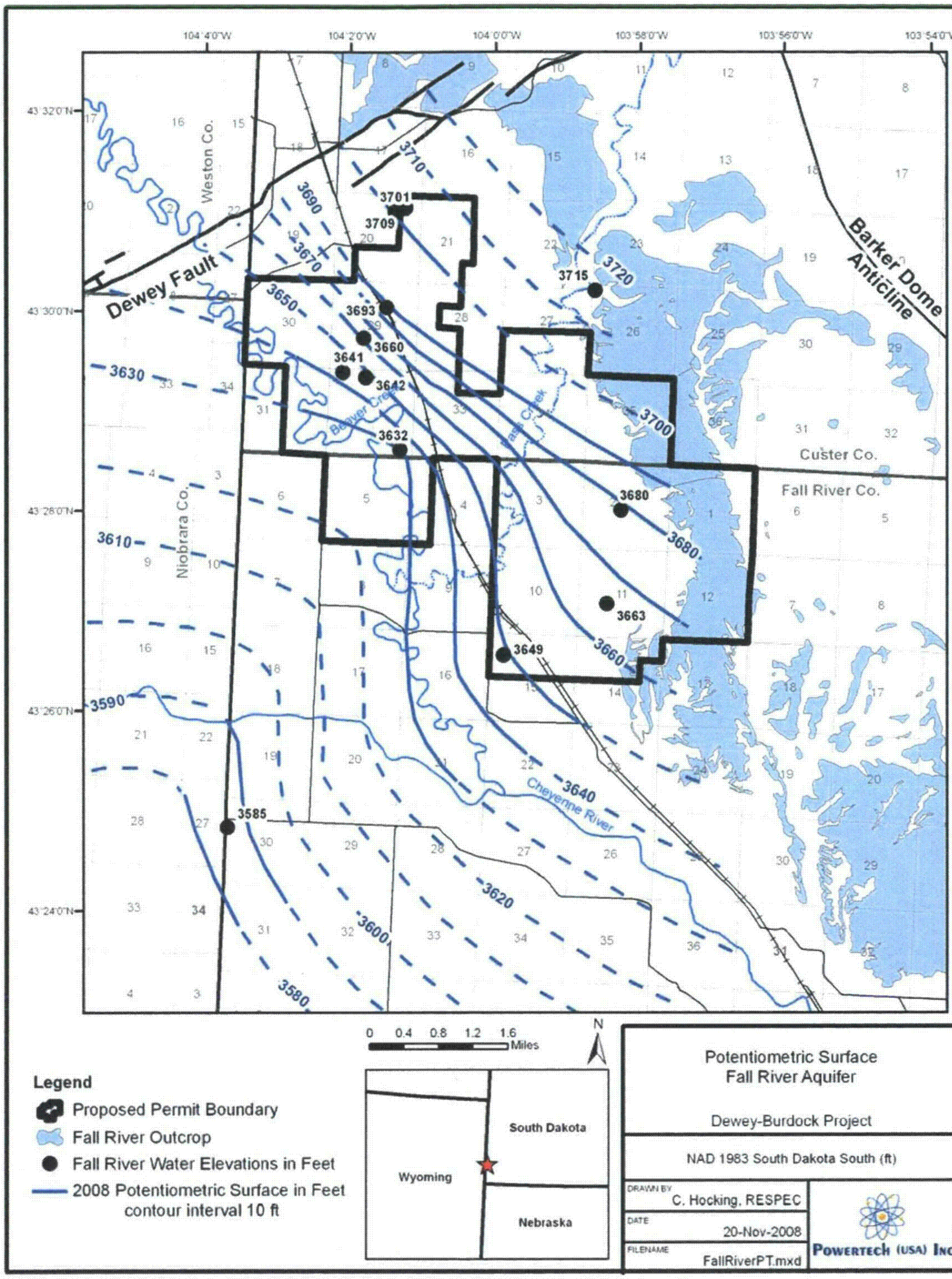

Note: Potentiometric surface based on average water level values at the project site. Contours are dashed where approximate.

Source:
2009 NRC Application
Powertech (USA) Inc.
Figure 2.7-14
RESPEC Data

POWERTECH (USA) INC.

Figure D-19
Potentiometric Surface Inyan Kara Group
(aka Fall River Aquifer)

2010 Dewey-Burdock Class V Permit

Scale: See Bar Scale	Date: March 2010	
2010_DB_Class_V_Fig_D-19.ai	By: JLM	Checked: HD

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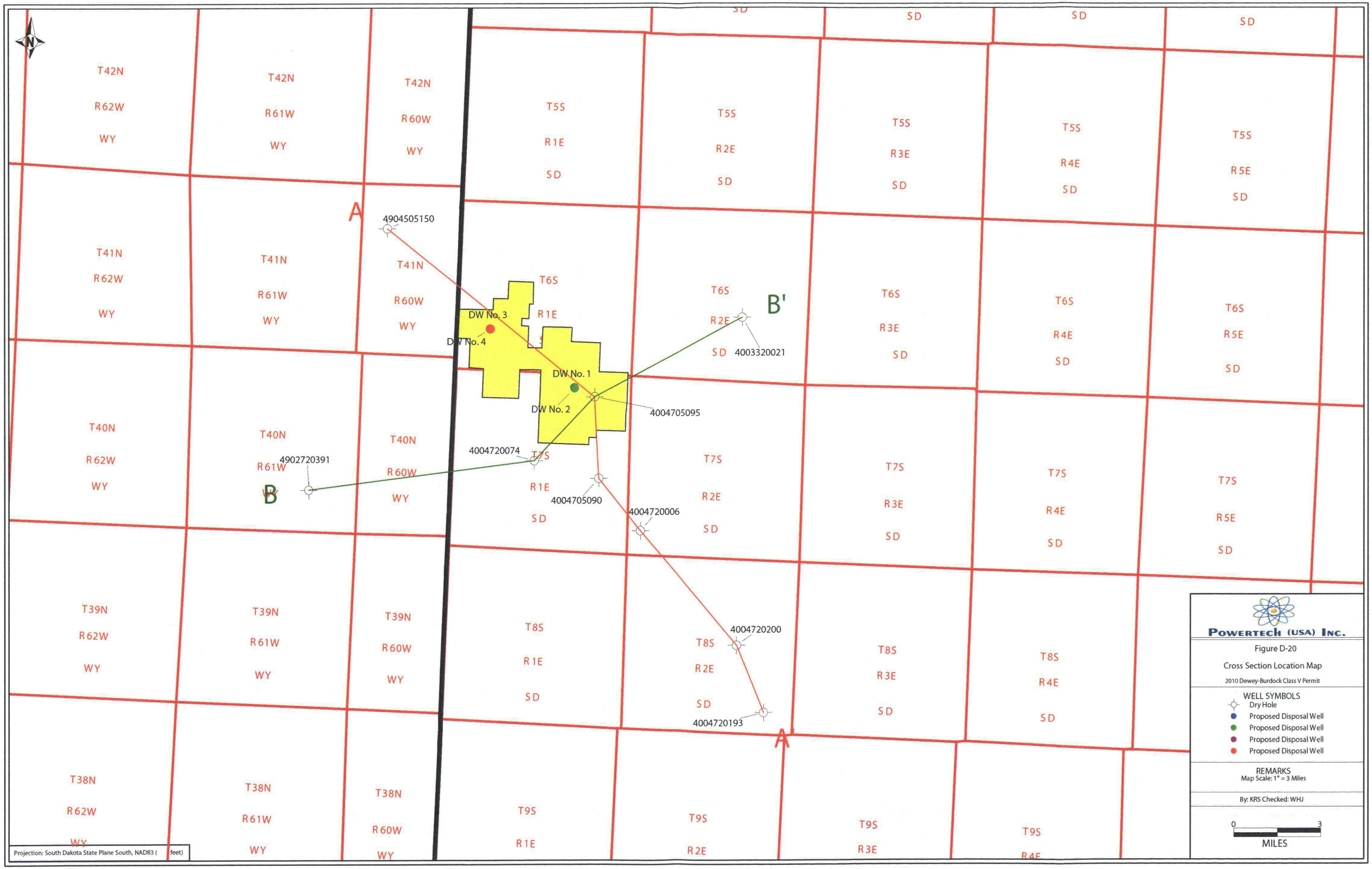

N
T42N R62W WY
T42N R61W WY
T42N R60W WY
T5S R1E SD
T5S R2E SD
T5S R3E SD
T5S R4E SD
T5S R5E SD
T41N R62W WY
T41N R61W WY
T41N R60W WY
T6S R1E SD
T6S R2E SD
T6S R3E SD
T6S R4E SD
T6S R5E SD
T40N R62W WY
T40N R61W WY
T40N R60W WY
T7S R1E SD
T7S R2E SD
T7S R3E SD
T7S R4E SD
T7S R5E SD
T39N R62W WY
T39N R61W WY
T39N R60W WY
T8S R1E SD
T8S R2E SD
T8S R3E SD
T8S R4E SD
T38N R62W WY
T38N R61W WY
T38N R60W WY
T9S R1E
T9S R2E
T9S R3E
T9S
A
A
B
B'
4904505150
DW No. 3
DW No. 4
DW No. 1
DW No. 2
4003320021
4004705095
4004720074
4902720391
4004705090
4004720006
4004720200
4004720193
Projection: South Dakota State Plane South, NAD83 (feet)
Powertech (USA) Inc.
Figure D-20
Cross Section Location Map
2010 Dewey-Burdock Class V Permit
WELL SYMBOLS
Dry Hole
Proposed Disposal Well
Proposed Disposal Well
Proposed Disposal Well
Proposed Disposal Well
REMARKS
Map Scale: 1" = 3 Miles
By: KRS Checked: WHJ
0
3
MILES

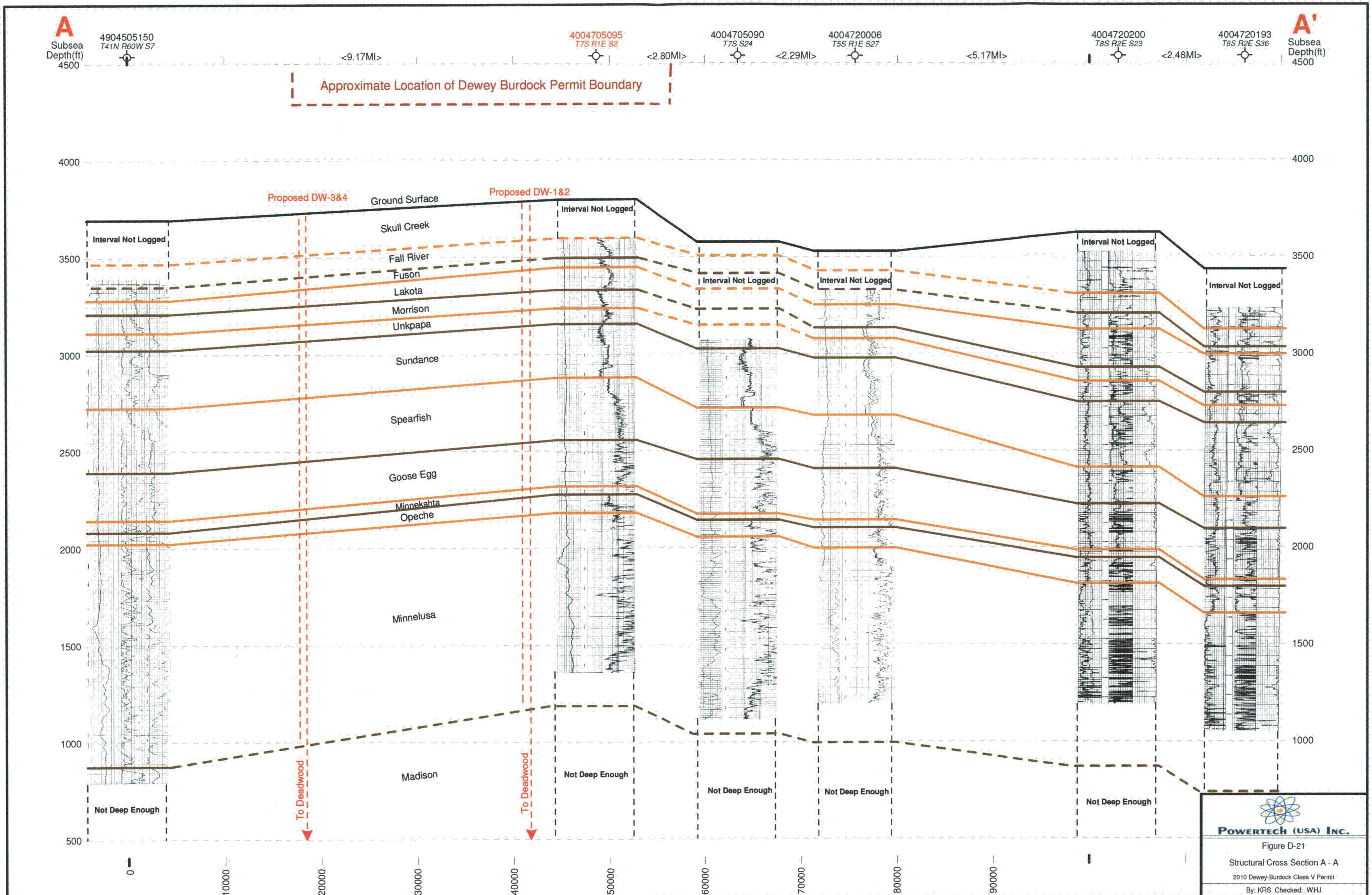

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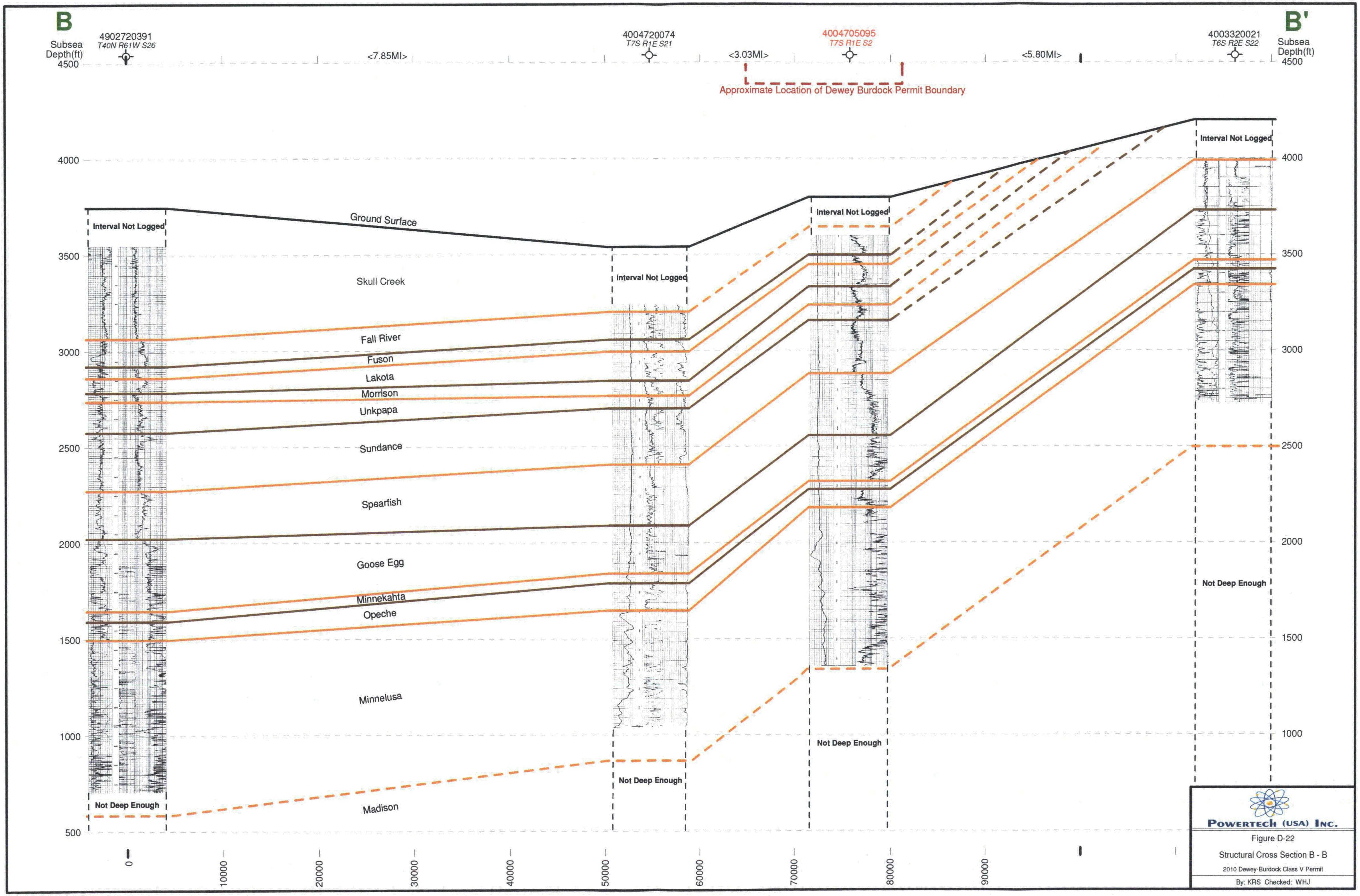
Figure D-21

Structural Cross Section A - A

2010 Dewey-Burdock Class V Permit

By: KRS Checked: WHJ



Powertech (USA) Inc.

Figure D-22

Structural Cross Section B - B

2010 Dewey-Burdock Class V Permit

By: KRS Checked: WHJ