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STRATABOUND GEOTHERMAL RESOURCES IN NORTH DAKOTA AND SOUTH DAKOTA

FINAL REPORT

VOLUME 1 RESOURCE ASSESSMENT

William D. Gosnold, Jr. Professor

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Prepared by
Department of Geology and Geological Engineering
Energy and Environmental Research Center
University of North Dakota
P. O. Box 8213, University Station
Grand Forks, North Dakota 58202

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ABSTRACT

Analysis of all geothermal aquifers in North Dakota and South Dakota indicates an accessible resource base of approximately 21.25 exajoules (10^{18} J = 1 exajoule, 10^{18} J $\sim$ 10^{15} Btu = 1 quad) in North Dakota and approximately 12.25 exajoules in South Dakota. Resource temperatures range from 40°C at depths of about 700 m to 150°C at 4500 m. This resource assessment increases the identified accessible resource base by 31% over the previous assessments of Gosnold (1984, 1987) and by 310% over the earlier assessment of Sorey and others (1983). These results imply that the total stratabound geothermal resource in conduction-dominated systems in the United States is two-to-three times greater than current estimates given by Reed (1983).

The large increase in the identified accessible resource base is primarily due to inclusion of all potential geothermal aquifers in the resource assessment and secondarily due to the expanded data base compiled in this study. These factors were interdependent in that the extensive data base provided the means for inclusion of all potential geothermal aquifers in the analysis. Previous assessments of Gosnold (1984, 1987) and Sorey and others (1983) included only well-known aquifer systems and were limited by the amount of available data.

Analysis of the sources of the geothermal resource indicates that a principal factor is a thick (500–2000 m) insulating layer of shales overlying up to 12 aquifers in the Williston Basin. The thick shale layer has a low thermal conductivity ($1.1 \text{ W m}^{-1} \text{ K}^{-1}$) and produces high geothermal gradients ($dT/dz > 50^\circ\text{C km}^{-1}$) in regions having normal continental heat flow values of about 50–60 mW m⁻². In south-central South Dakota, surface heat flow values of the order of 100–120 mW m⁻² produce geothermal gradients of the order of $100^\circ\text{C km}^{-1}$ and generate high temperatures at relatively shallow depths.

Anomalous heat flow values in south-central South Dakota are caused by heat advection in groundwater flowing eastward in regional aquifers. Heat flow is anomalously high ($Q > 100 \text{ mW m}^{-2}$) in the discharge area for the aquifers in south-central South Dakota and anomalously low (30 mW m^{-2}) in the recharge area near the Black Hills and along the western limb of the Kennedy Basin in western South Dakota. This finding suggests that advection due to confined groundwater flow, where flow is across a basin, may significantly affect subsurface temperatures and create a stratabound geothermal resource where flow ascends along the lower limb of the basin.

Heat flow disturbances due to vertical groundwater flow through fractures in the discharge area of the regional flow system in South Dakota are minor and may be significant only in deeply incised stream valleys. The vertical flow component is largely restricted to the near surface shales and has no influence on the geothermal resource.

Analyses of the thermal regime of the North Dakota portion of the Williston Basin do not show significant heat flow anomalies. Conventional heat flow determinations, that is measured gradients and thermal conductivities, in the Williston Basin show heat flow values ranging from 43 to 68 mW m^{-2} with an average of 55 mW m^{-2} . Comparisons of calculated temperatures and bottom-hole temperatures measured in oil fields over the Nesson anticline and the Billings Nose show temperature differences which suggest that upward groundwater flow in fractures on the westward sides of the structures slightly perturbs the otherwise conductive thermal field. The maximum heat flow disturbance is estimated to be of the order of $10\text{--}20 \text{ mW m}^{-2}$. These thermal anomalies do not significantly alter the accessible geothermal resource base.

Engineering studies show that geothermal space heating using even the lowest temperature geothermal aquifers in North Dakota and South Dakota is

cost-effective at present economic conditions. The Inyan Kara Formation of the Dakota Group (Cretaceous) is the preferred geothermal aquifer in terms of water quality and productivity. Water chemistry in the Inyan Kara formation ranges from 3,000 to more than 20,000 mg L⁻¹. Porosities are normally higher than 20%, and the optimum producing zones are generally thicker than 30 m. The estimated water productivity index of a productive well in the Inyan Kara Formation is 41 bbl/day/psi, which is considered excellent. Deeper formations have warmer waters, but they are less permeable and have poorer water quality than the Inyan Kara.

STRATABOUND GEOTHERMAL RESOURCES IN NORTH DAKOTA AND SOUTH DAKOTA

1.0 INTRODUCTION

Stratabound geothermal resources are hot waters contained in permeable formations in sedimentary basins. More than half of the area of North Dakota and South Dakota is underlain by sedimentary basins (Figure 1); thus there is significant potential for the occurrence of stratabound geothermal resources. The western two-thirds of North Dakota and the northwestern corner of South Dakota are underlain by the Williston Basin, which contains at least 12 aquifers (Table 1), including the Inyan Kara and Newcastle Formations of the Dakota Group (Cretaceous) and extending to the Deadwood Formation (Cambrian). The Kennedy Basin is a small structure which underlies southern South Dakota and includes essentially the same stratigraphy as the Williston Basin.

Previous studies (Sorey et al., 1983; Gosnold, 1984, 1987) identified large quantities of geothermal resources in the well-known aquifers of these basins and promising potential for additional resources in the remaining aquifers. The earlier study (Sorey et al., 1983) included only the Dakota (Cretaceous) and Madison (Mississippian) aquifers. Subsequently, Gosnold (1984, 1987) used additional stratigraphic data to include 4 aquifers in North Dakota and 7 aquifers in South Dakota to significantly increase the identified geothermal resource (Table 2). This study includes compilation of a more extensive data base to facilitate analysis of remaining aquifers and further increase the identified resource base.

Identification and understanding of the origins of geothermal resources are critical for planning utilization of those resources. Thus this study focused on origins as well as identification and quantification of the resources. Gosnold (1984, 1987) attributed the resource to a thick insulating blanket of low-thermal-conductivity shale which produces high temperatures in

Figure 1. Map of study area showing locations of Williston and Kennedy Basins.

TABLE 1
Generalized Stratigraphy of the North Central Great Plains

<u>System</u>	<u>Rock Units</u>	<u>Lithology</u>	<u>Maximum Thickness (meters)</u>
Quaternary	Coleharbor+ unnamed units	Clay, Silt, Sand, Gravel	510
Tertiary	White River	Siltstone, Clay, Sand	75
	Golden Valley	Clay, Siltstone, Lignite	65
	Fort Union	Silt, Clay, Sand	600
Cretaceous	Hell Creek	Sand	200
	Fox Hills	Silt, Shale, Sandstone	120
	Pierre	Shale	700
	Niobrara	Shale	75
	Carlile	Shale	120
	Greenhorn	Shale, Shaley Limestone	45
	Belle Fourche	Shale	105
	Mowry	Shale	55
	Newcastle	Sandstone, Shale	45
	Skull Creek	Shale	40
	Inyan Kara	Sandstone	135
Jurassic	Morrison	Shale, Siltstone	80
	Swift	Shale	150
	Rierdon	Shale	30
	Piper	Limestone, Anhydrite, Shale	190
Triassic	Spearfish	Siltstone, Shale	225
Permian	Minnekahta	Limestone	12
	Opeche	Shale, Dolomitic, Silty	120
	Broom Creek	Sandstone, Dolomite	100
Pennsylvanian	Amsden	Dolomite, Sandstone	135
	Tyler	Shale, Limestone	80
	Otter	Shale	60
Mississippian	Kibbey	Sandstone, Limestone	75
	Madison	Limestone	600
Devonian	Bakken	Shale	35
	Three Forks	Siltstone, Shale	75
	Birdbear	Limestone, Dolomite	40
	Duperow	Limestone, Dolomite	140
	Souris River	Dolomite, Limestone	105
	Dawson Bay	Limestone, Dolomite	55
	Prairie	Evaporites	200
	Winnipegosis	Dolomite, Limestone	120
Silurian	Interlake	Dolomite, Limestone	335
	Stonewall	Dolomite, Limestone	35
Ordovician	Stony Mountain	Dolomite, Limestone	60
	Red River	Limestone, Dolomite	215
	Winnipeg Group	Siltstone, Sandstone, Shale	125
Cambrian	Deadwood	Limestone, Sandstone, Shale	300

Note: Stratigraphy generalized from Blemle and others (1986).

TABLE 2
Results of Previous Research

NORTH DAKOTA			
<u>Formation</u>	<u>Period</u>	<u>Rock Type</u>	<u>Accessible Resource 10¹⁸J</u>
Two aquifers ^a			
Inyan Kara	Cretaceous	Sandstone	628
Madison	Mississippian	Carbonate	5,800
TOTAL			6,428
Four aquifers ^b			
Inyan Kara	Cretaceous	Sandstone	1,100
Madison	Mississippian	Carbonate	6,600
Duperow	Devonian	Carbonate	2,200
Red River	Ordovician	Carbonate	3,600
TOTAL			13,500
SOUTH DAKOTA			
Two aquifers ^a			
Dakota	Cretaceous	Sandstone	1,490
Madison	Mississippian	Carbonate	310
TOTAL			1,800
Seven aquifers ^c			
Dakota Gr.	Cretaceous	Sandstone	805
Minnekahta	Permian	Carbonate	91
Minnelusa	Perm. - Penn.	Carbonate	2,530
Madison	Mississippian	Carbonate	2,826
Winnipeg &			2,787
Red River	Ord.-Sil.-Dev.	Carbonate	2,168
Deadwood	Cambrian	Carbonate	1,043
TOTAL			12,250

^a Sorey et al., 1983

^b Gosnold, 1984

^c Gosnold, 1987

the underlying aquifers. However, previous studies also indicated several anomalous geothermal phenomena which contribute to the total resource base. Heat flow values greater than 100 mW m^{-2} in central South Dakota were reported by Gosnold and Eversoll (1982) and Gosnold (1984). Sass and Galanis (1983) reported a heat flow value of 84 mW m^{-2} in central South Dakota. Heat flow values of the order of 100 mW m^{-2} were reported for the Williston Basin in North Dakota (Majorowicz et al., 1986). Majorowicz and others (1986) also reported differences between heat flow values estimated for Paleozoic and Mesozoic formations in the Canadian portion of the Williston Basin and suggested that groundwater flow is a factor in the thermal regime of the basin.

The anomalous heat flow in South Dakota was hypothesized to result from heat advection by regional groundwater flow (Gosnold, 1987, 1990). However, definitive tests of the hypothesis by heat flow measurements in both recharge and discharge areas were lacking. Further, no analysis of the role of radioactive heat production in the crystalline basement had been made. Thus a specific objective of this study was to investigate possible heat sources for the heat flow anomaly. This objective was pursued by analytical means and by a drilling program designed to test the hypothesis of heat advection in regional aquifers. Investigation of the reported thermal anomalies in the Williston Basin in North Dakota included analysis of thermal conductivities of selected units, analysis of existing heat flow data, collection of new heat flow data, and analysis of the existing bottom-hole temperature data.

Parameters for an economical geothermal resource include adequate temperature, adequate production capacity, and favorable water chemistry. Stratabound geothermal resource temperatures range from low temperature ($T < 90^{\circ}\text{C}$) to intermediate temperature ($90^{\circ}\text{C} < T < 150^{\circ}\text{C}$). Production capacity is a function of the fluid pressure, permeability, and thickness of the aquifer.

Water chemistry is a key factor in engineering design for use and disposal of the geothermal fluids. In most sedimentary basins, the near surface waters tend to have lesser amounts of total dissolved solids, and the deeper waters tend to have larger amounts of total dissolved solids.

Previous statewide assessments of stratabound geothermal resources in conduction-dominated systems have focused on a few, selected aquifer systems with a goal of providing a regional resource assessment. USGS Circular 892 (Reed, 1983) summarized the results of geothermal resource assessments conducted by a number of state geological surveys for the U.S. Department of Energy, and, in part, relied on other published data, necessarily focusing only on the principal aquifers. The analysis described in this report differs significantly because it is the first attempt to analyze all potential geothermal systems within any conduction-dominated region.

The quantity of data compiled in this study is extensive. In particular, the stratigraphic and temperature data bases, if printed, would fill more than 100 pages. Therefore, the stratigraphic and temperature data are presented in summary form as contour maps in the appendices. Computer disks with the data in ASCII format are available on request from the Department of Geology and Geological Engineering at the University of North Dakota.

2.0 GEOTHERMAL SETTING OF THE NORTHERN GREAT PLAINS

2.1 Geology

The study area (Figure 1) includes the Williston and Kennedy Basins. The Williston Basin is a large intracontinental basin which underlies most of North Dakota and northwestern South Dakota, as well as eastern Montana, southern Manitoba, and southeastern Saskatchewan. The Kennedy Basin is a smaller structure which adjoins the Williston Basin in central South Dakota.

Table 1 gives a generalized stratigraphy of the area. At least 12 regional aquifers in the Williston Basin including and underlying the Inyan Kara and Newcastle Formations of the Dakota Group (Cretaceous) contain waters warm enough for development as geothermal resources. Due to shallow depths, any aquifers overlying the Dakota Group generally have temperatures that are too low to constitute a resource. Many of the geothermal aquifers occur throughout the Great Plains, but the formation names may differ across the province.

Downey (1986) provided extensive data and analyses of the subsurface extent and hydrologic characteristics of several Paleozoic and Mesozoic aquifers in the area. Detailed data on depth, thickness, subsurface extent, and permeability of all aquifers for the western half of South Dakota was given by Rahn (1981).

2.2 Subsurface Temperature and Geothermal Studies

Data on subsurface temperatures and geothermal aquifers in the Great Plains have been published primarily in technical reports for the U.S. Department of Energy (Reed, 1983). Primary sources for data are reports for North Dakota (Harris et al., 1982; Gosnold, 1984), Nebraska (Gosnold and Eversoll, 1982), Kansas (Blackwell and Steele, 1987), and South Dakota (Gosnold, 1987). Analyses of these data are found in geothermal literature that are primarily conference proceedings (Gosnold, 1980, 1984, 1987; Gosnold and Eversoll, 1982) and in reports of the U.S. Geological Survey (Sammel, 1979; Sorey et al., 1983).

Geothermal resources in North Dakota and South Dakota were described by Schoon and McGregor (1974), Gries (1977), and Harris and others (1982), and quantitative estimates of the accessible resource base were given by Sorey and others (1983) and Gosnold (1984, 1987). Schoon and McGregor (1974) developed a data base of subsurface temperatures for the Dakota Sandstone (Cretaceous)

and the Madison limestone (Mississippian). Gries (1977) focused on the Madison limestone and on applications of geothermal waters produced from the Madison limestone at three locations in South Dakota. Harris and others (1982) statistically analyzed bottom-hole temperature data and water quality data and produced contour maps of geothermal gradients and water chemistry. Sorey and others (1983) estimated the accessible resource base in North Dakota as 6428×10^{18} J based on the Dakota and Madison aquifers. Gosnold (1984) added the Duperow and Red River aquifers to estimate the accessible resource base in North Dakota at $13,500 \times 10^{18}$ J. Estimates for South Dakota were 1800×10^{18} J based on the Madison and Dakota aquifers (Sorey et al., 1983) and $12,250 \times 10^{18}$ J based on 7 aquifers (Gosnold, 1987).

2.3 Heat Flow

Heat flow studies indicate a stable continental heat flow regime for most of the area with heat flow values of the order of $50\text{--}60 \text{ mW m}^{-2}$ (Combs and Simmons, 1973; Gosnold, 1990). However, heat flow values ranging from 80 to 130 mW m^{-2} extend over a large region in South Dakota and Nebraska (Gosnold and Eversoll, 1982; Sass and Galanis, 1983; Gosnold, 1990).

The thermal regime is conductive except in southern South Dakota where heat advection by regional groundwater flow in dipping aquifers on the flanks of the Kennedy Basin has a significant impact. Commonly, groundwater disturbances to heat flow are termed convective regimes. However, the high heat flow region is caused by groundwater flow within confined aquifers; thus the term advection is preferred to convection. Advection implies horizontal movement of a mass of fluid, whereas convection implies circulation.

Throughout the conductive regime, subsurface temperatures are determined by basement heat flow and the thermal conductivities of the stratigraphic units. Formations within the two intracontinental basins are continuous over most of the region and are generally uniform in lithology. Consequently,

thermal conductivity may be inferred from stratigraphy throughout the area, and a one-dimensional thermal profile, or thermostratigraphy (Figure 2), is readily determined where basement heat flow is known.

High temperature gradients characterize the Pierre, Carlile, Graneros, and Belle Fourche formations (Cretaceous), all of which are shales having low ($1.1 - 1.2 \text{ W m}^{-1} \text{ K}^{-1}$) thermal conductivities. Low temperature gradients characterize the Paleozoic carbonates that underlie most of the region. High and low temperature gradients also occur where upward or downward flowing groundwater advectively disturbs the conductive gradient. Although heat advection can significantly alter the thermal profile of a basin, the degree of thermal disturbance can be determined and included in calculations of subsurface temperatures.

3.0 ORIGINS OF GEOTHERMAL ANOMALIES IN SOUTH DAKOTA

Available data indicate that a substantial part of the geothermal anomaly in South Dakota arises from groundwater flow in the sedimentary units. To investigate this geothermal anomaly, we developed tests of two hypotheses: 1) vertical flow in fractures causes local heat flow anomalies, and 2) advection in confined aquifers affects the heat flow regime of the entire region.

Understanding the hydrogeology of the region is fundamental to this analysis. Critical data and analyses by Downey (1986), Rahn (1981), and Bredehoeft and others (1983) provide a framework for understanding the groundwater flow systems. Bredehoeft and others (1983) and Neuzil and others (1984) suggest that upward groundwater flow through fractures in the Cretaceous shales in South Dakota occurs at vertical velocities of the order of $10^{-11} \text{ m s}^{-1}$. Downey (1986) determined that regional groundwater flow is eastward and northeastward at velocities ranging from about 10^{-8} m s^{-1} to 10^{-7} m s^{-1} .

Figure 2. Thermostratigraphy of eastern edge of Kennedy Basin.

s^{-1} in the Paleozoic and Mesozoic aquifers over most of the northern Great Plains.

We examined both fracture leakage and regional advection by first considering the existing data on groundwater flow and then by acquiring and analyzing relevant thermal data.

3.1 Fracture Leakage

The occurrence and magnitude of flow from the Dakota aquifer to the surface through fractures in the overlying confining layers was deduced during an extensive study by Bredehoeft and others (1983). The vertical component of flow velocities computed by Bredehoeft and others (1983) is of the order of $3 \times 10^{-11} \text{ m s}^{-1}$ for upward flow near the Missouri and James Rivers and for downward flow in the northeastern corner of South Dakota (Figure 3). The region of upflow coincides with the heat flow anomaly along the Missouri, White, Bad, Belle Fourche, and James Rivers, but it does not extend into the high heat flow area west of the Keya Paha River on both sides of the South Dakota-Nebraska border.

The data of Bredehoeft and others (1983) show that the highest velocity, upward flow occurs predominantly in the broad stream valleys (see Figure 3). Neuzil and Pollock (1983) theorized that flow should be focused in the deeply eroded stream valleys as a consequence of unloading due to stream erosion. Unloading causes a reduction in pore-fluid pressure which serves to increase the hydraulic gradient between the deep aquifers and the surface in the unloaded zone. Consequently, any heat flow anomalies associated with fracture leakage should appear in the stream valleys. We tested this hypothesis of heat advection by fracture leakage in stream valleys both analytically and empirically.

Figure 3. Contour map of vertical groundwater velocity modified from Bredehoeft and others (1983). Heat flow values known at the start of this study are located by filled circles.

3.1.1 Analytical Test

An analytical relationship between heat flow, water velocity, and distance of flow for a vertical one-dimensional system is given in the following equation:

$$\ln \frac{Q_2}{Q_1} = \frac{VD\sigma C_p}{K} \quad [\text{Eq. 1}]$$

Q_1 is heat flow at the base of the zone of flow, Q_2 is heat flow at the top, V is Darcy velocity in m s^{-1} , D is the length of the zone in meters, σ is density of the fluid in kg m^{-3} , C_p is heat capacity of the fluid in W s kg^{-1} , and K is thermal conductivity in $\text{W m}^{-1} \text{K}^{-1}$.

This model can be applied to the high heat flow areas west of the Missouri River where vertical velocity of groundwater, depth to the Dakota aquifer, and surface heat flow either are known or have been calculated. Q_1 can be estimated from the tectonic setting and other heat flow values in the region as about 60 mW m^{-2} . Figure 4 graphically illustrates the relationship between surface heat flow and fluid velocity for 500 and 1000 meters of vertical flow. The threshold velocity for a significant heat flow disturbance is about $10^{-10} \text{ m s}^{-1}$ at these depths; thus flow at Bredehoeft and others (1983) maximum flow velocity ($\sim 3 \times 10^{-11} \text{ m s}^{-1}$) would increase surface heat flow by only 5 percent. An interesting implication of this test is that if an observed heat flow disturbance cannot be accounted for other than by vertical fracture leakage, vertical flow velocities would be 1 to 2 orders of magnitude higher than suggested by Bredehoeft and others (1983).

3.1.2 Empirical Test

Heat flow anomalies caused by vertical groundwater flow may be determined empirically by examining temperature gradient curves. Equation 1 predicts that heat flow should vary as a function of the vertical length of

Figure 4. Relationship between one-dimensional fluid flow and heat flow with parameters for fluid velocity, thermal conductivity, and depth to source selected for the Kennedy Basin.

groundwater flow. Thus, for constant conductivity and groundwater flow velocity, the magnitude of the heat flow anomaly should vary systematically in a drill hole. This variation would be apparent in the temperature-depth plots where upward flow would cause temperature gradients to decrease with increasing depth, and vice versa.

As a specific test of this concept, four heat flow holes were drilled in a line across the deeply incised White River Valley west of Chamberlain, South Dakota (see Figures 5 and 6). The heat flow profile crosses a region where

Figure 5. Temperature vs. depth plots for six holes drilled across the White River Valley west of Chamberlain, South Dakota.

Figure 6. Gradient vs. depth plots for six holes drilled across the White River Valley.

Bredehoeft and others (1983) reported upward vertical flow at a rate approaching 10^{-10} m s⁻¹. The holes were drilled in the Pierre Shale, which is assumed to have essentially the same thermal conductivity everywhere. Thus the temperature gradient profiles should provide clear indications of any hydrologic disturbances to heat flow.

The temperature vs. depth (T-D) profiles (Figure 5) show convex upward curvature below the top of the Niobrara Formation that is conceptually consistent with upward fracture leakage at rates of the order of 10^{-8} m s⁻¹ or advection by confined flow in the updip direction (east) within the Niobrara Formation. This velocity is 2 orders of magnitude greater than that calculated for fracture leakage, but is of the correct magnitude for the vertical component due to updip flow in the confined aquifers.

Interestingly, T-D profiles within and south of the White River Valley show a concave upward curvature from the surface down to the top of the Niobrara, but profiles north of the White River do not show this curvature. Curvature in the temperature-depth profiles can be emphasized in gradient vs. depth profiles (Figure 6) which are, formally, vertical-first-derivatives of the temperature profiles. In agreement with the concept discussed above, the form of the curves in Figure 6 suggests downward groundwater flow above the Niobrara formation and upward groundwater flow below the Niobrara.

Analytical models combining steady-state heat flow with a groundwater flow system cannot reproduce the observed curves. Alternatively, models using transient solutions in which downward flow began only within the past 1000 years reproduce the curves fairly well. Because groundwater flow is of key interest in this study, it would be easy to accept this latter interpretation as the best alternative without further deliberation. Yet, at least two other alternative interpretations of the curves are possible. A recent warming of the ground surface due to climate change or a systematic variation in thermal

conductivity could account for the curvature. These latter two alternatives imply that similar curvature should appear in all profiles, but it does not. Thus the favored interpretation is downward flow from the surface to the Niobrara formation beginning about 1000 years ago. This finding is interesting from the hydrological perspective, although it has little impact on the geothermal resource assessment.

The heat flow profile across the White River Valley suggests that fracture leakage from the Dakota aquifer through the upper Cretaceous shales affects heat flow only slightly at the surface and only within the confines of stream valleys. Consequently, there is no significant alteration of the subsurface temperatures by fracture leakage, and the magnitude of the geothermal resource is essentially unaffected at that locality.

3.2 Confined Groundwater Flow

Because of the low velocities involved in fracture leakage, it is more likely that heat advection by groundwater is largely due to confined groundwater flow in regional aquifers. At least three aquifers, the Dakota (Cretaceous), the Madison (Mississippian), and the Minnelusa (Pennsylvanian), have structural and hydrologic properties congruous with this hypothesis. All three aquifers recharge in the Black Hills and transmit groundwater in confined updip flow into the area of the positive heat flow anomaly. We also tested this hypothesis analytically and empirically.

3.2.1 Analytical Tests

3.2.1.1 Numerical Model

A finite-difference numerical analysis of a two-aquifer groundwater flow system was used to model a heat flow profile from the Black Hills to a point east of the Missouri River (Figure 7). Thermal parameters for the model include a basal heat flow of 60 mW m^{-2} and thermal conductivities appropriate

Figure 7. Finite difference grid for modeling advection across the Kennedy Basin.

for the lithostratigraphy. Water flow velocities of approximately 2×10^{-7} to $1.9 \times 10^{-8} \text{ m s}^{-1}$ (Downey, 1986) were used for confined flow in the Madison and Dakota aquifer. Velocities of the order of $6\text{--}7 \times 10^{-8} \text{ m s}^{-1}$ could account for anomalous surface heat flow values of the order of 80 to 100 mW m^{-2} . These values would generate the observed regional anomaly, but would not generate the localized, high values of the order of 130 mW m^{-2} that are inferred from the geothermal gradient data of Schoon and McGregor (1974). Heat flow values of this magnitude were inferred only in the region just west of the Missouri River which includes the area where the heat flow profile was drilled. This region is a discharge area for the Dakota aquifer, and it is plausible that upward flow through fractures could be significantly greater than for the rest of the region. Thus a plausible explanation for the localized anomalies is upward fracture leakage at velocities of the order of 10^{-9} m s^{-1} .

3.2.1.2 Energy Balance

A second analytical test was an energy balance calculation for the advective system. An important aspect of the advection model is that the high heat flow due to upward water movement must be balanced by low heat flow due to downward water movement. Conceptually, low heat flow should occur in the recharge area in and around the Black Hills. The concept is empirically supported by heat flow values of about 20 mW m^{-2} (see Figure 3) reported for two localities in the Black Hills (Sass et al., 1971). The anomalous heat flow component for these two low values is estimated to be about -70 mW m^{-2} by subtracting the low values from the high values.

Absolute determination of the quantity of anomalous energy flux in the area would require tens of thousands of heat flow holes; however, a reasonable estimate can be calculated from the product of the average heat flow and the area of the anomaly. The positive anomaly of about 40 mW m^{-2} extends over an area of $40,000 \text{ km}^2$ and is of the order of 1.6 GW . The negative anomaly of about -70 mW m^{-2} extends over the crystalline outcrops and aquifer outcrops around the eastern side of the Black Hills. A lesser negative anomaly of about -60 mW m^{-2} is computed for the descending limb of the of the groundwater flow systems in the Kennedy Basin. The recharge area for the aquifers varies in character in that most of the recharge comes from streams that cross outcrops of the aquifers, and lesser amounts of recharge come from precipitation (Downey, 1986). The area of groundwater recharge in the crystalline rocks is also difficult to estimate. However, for recharge from the aquifer outcrops and from the crystalline rocks, a total recharge area of only about 8600 km^2 and a negative heat flow component of 70 mW m^{-2} would generate an anomalous energy flux of about -0.6 GW . The area of downdip flow east of the Black Hills is calculated from the finite difference model to

generate an anomalous heat flow of -1.0 GW. Thus the energy flux is balanced with about -1.6 GW in the recharge area and +1.6 GW in the discharge area.

3.2.2 Empirical Test

An empirical test of heat advection in groundwater was obtained by analyzing heat flow along an east-west profile across the anomaly. The general concept of the advection model is that gravity-driven groundwater flow in the Dakota and Madison aquifers causes low heat flow on the descending limb and high heat flow on the ascending limb of the Kennedy Basin (Figure 8). Figure 8 is based on Figure 9, which is a geothermal gradient map of South Dakota modified from Schoon and McGregor (1974). High heat flow over the ascending limb of the system was known from heat flow data (Gosnold and Eversoll, 1982) and temperature gradient measurements (Schoon and McGregor, 1974). However, critical data were missing in the area of the descending limb and to the east of the discharge area.

Locations of potential areas for acquisition of new heat flow and temperature gradient data were selected using two criteria. First, the sites were selected to supply critical heat flow data. Second, a general guideline was to select sites in the Pierre Shale and to avoid sites in Tertiary sands and silts. The rationale for this guideline is that the thermal conductivity of the Pierre Shale may be estimated with acceptable reliability as about $1.1 \text{ W m}^{-1} \text{ K}^{-1} \pm 0.1 \text{ W m}^{-1} \text{ K}^{-1}$ (Gosnold, 1990). Thus a temperature gradient measurement in the Pierre Shale provides a reliable value for calculating heat flow. Conversely, thermal conductivities of Tertiary silts and sands may vary by as much as $1.0 \text{ W m}^{-1} \text{ K}^{-1}$ in a single well (see, for example, Gosnold and Eversoll, 1982). This variability in thermal conductivity and the corresponding temperature gradient measurements makes such measurements unreliable for achieving the objective.

Figure 8. Cross section from Black Hills to eastern South Dakota. Thin line without symbols shows top of the Dakota (Cretaceous). Thick line without symbols shows top of Madison (Mississippian). Line with open circles shows potentiometric surface of Madison. Line with closed circles shows potentiometric surface of Dakota. Line with open triangles shows geothermal gradient data from Schoon and McGregor (1974).

Figure 9. Geothermal gradient map of South Dakota modified from Schoon and McGregor (1974). Original units of °F per 100 ft were retained to preserve the original contour lines.

The specific target areas in South Dakota were 1) where no temperature logs were available, specifically in southwestern South Dakota; and 2) where data relevant to the source for the heat flow anomaly in South Dakota could be obtained. Excellent cooperation with the South Dakota State Geological Survey and the South Dakota Water Commission contributed greatly to the study in South Dakota, and 36 new temperature logs were obtained during the survey (see Appendix A). The data relevant to the advection model include seven new heat flow holes, two previously existing holes, and new temperature gradient measurements in 27 existing boreholes. The new data are superimposed on previous data and incorporated into a new heat flow contour map which includes Nebraska, South Dakota, and North Dakota (Figure 10).

These new data provide critical evidence supporting the regional advection model. In particular, the westward decrease in heat flow on the west side of the anomaly and the low heat flow in the area of the Rosebud Indian Reservation support the energy balance calculation which was the critical missing element in the model. If the region to the west had not shown a decrease in heat flow, the advection model would have been disproved, and a heat source in the crust below the thermal anomaly would have been indicated.

The effect of advection on subsurface temperatures is strikingly displayed in Figures 11 and 12, which show, respectively, 3-D surfaces of the structure on top of the Dakota sandstone and the temperature on top of the Dakota sandstone. The figures are oriented so that the vertical section extending from the lower left lies along latitude 43°N. Both surfaces are tilted at 30° toward the bottom of the page so the Williston Basin does not appear as a prominent feature in the structure surface. The peak on the structure surface is the Black Hills uplift. The temperature surface shows the Williston Basin as a prominent high-temperature zone, but most striking is

Figure 10. Heat flow contour map of the northern and central Great Plains exclusive of Colorado, Wyoming, and Montana. Heat flow contours are in mW m^{-2} .

DAKOTA SURFACE

Figure 11. Surface of the Dakota sandstone in South Dakota. The figure is oriented so that the vertical section extending from the lower left lies along latitude 43°N. The surface is tilted at 30° toward the bottom of the page, so the Williston Basin does not appear as a prominent feature in the structure surface. The peak on the structure surface is the Black Hills uplift.

Figure 12. Temperature on top of the Dakota for the area shown in Figure 11.
Orientation is the same as in Figure 11.

the high-temperature region in the south central area. The apparent holes in the temperature surface correspond to small peaks on the eastern end of the structure surface and are exaggerated by the order of magnitude difference in the vertical scales of the figures.

This finding may establish a paradigm for the occurrence of stratabound geothermal resources. Advection due to confined groundwater flow, where flow is across a basin, may significantly affect subsurface temperatures and create a large stratabound geothermal resource on the ascending limb of the basin. Interestingly, this finding has a close parallel with previous work on heat flow anomalies associated with groundwater flow (Swanberg and Morgan, 1979, 1980, 1981). High heat flow areas inferred from analyses of silica in groundwater (Swanberg and Morgan, 1979) coincide with the discharge areas of regional flow systems in the Denver, Williston (Gosnold, 1990), and, now, Kennedy Basins.

4.0 HEAT FLOW ANOMALIES IN THE WILLISTON BASIN

4.1 Conductive Heat Flow

The first heat flow value reported for the Williston Basin was 1.4 HFU (58.6 mW m^{-2}) based on a measured geothermal gradient of 39.8 K km^{-1} and an estimated thermal conductivity of approximately $1.5 \text{ W m}^{-1} \text{ K}^{-1}$ (Blackwell, 1969). Later, Combs and Simmons (1973) measured geothermal gradients of 56 and 55 K km^{-1} in two oil test holes drilled within 50 km of Blackwell's (1969) site, and, using a thermal conductivity value of $1.7 \text{ W m}^{-1} \text{ K}^{-1}$, calculated a heat flow value of 2.2 HFU (92 mW m^{-2}). Subsequently, heat flow values on the order of $70\text{--}90 \text{ mW m}^{-2}$ were determined for 13 sites in western North Dakota (Scattolini, 1977). These data were conventional heat flow determinations using measured geothermal gradients with measured or inferred thermal conductivities.

More recently, Majorowicz and others (1986) combined geothermal gradients calculated from oil field bottom-hole temperatures in the basin with thermal conductivities estimated from lithology to estimate heat flow values. They determined a region of high heat flow with values ranging from 70 mW m^{-2} to greater than 100 mW m^{-2} in southeastern Saskatchewan, southwestern Manitoba, and northwestern North Dakota.

These conventional and estimated heat flow values are twice the typical heat flow value for a stable continental interior (Roy et al., 1968); thus they could have significance for tectonics, kerogen maturation, and geothermal resources. Consequently, analysis of possible origins of the high heat flow is a critical part of this study.

However, not all data from the Williston Basin indicate high heat flow. A number of heat flow determinations by Scattolini (1977) were on the order of $50\text{--}60 \text{ mW m}^{-2}$, and Gosnold (1984) reported heat flow values of 43, 47, 48, and 52 mW m^{-2} in 4 boreholes specially completed for heat flow determination. These latter 4 sites are within about 50 km of the 92 mW m^{-2} sites of Combs and Simmons (1973) and the 58.6-mW m^{-2} site of Blackwell (1969), and they lie within the 100-mW m^{-2} zone projected by Majorowicz and others (1986). Thus, at the beginning of this study, the status of heat flow observations was that recent determinations differed from earlier ones, and conventional heat flow determinations disagreed with estimated values.

Differences in heat flow values at sites relatively close together within a tectonically stable province suggest several possible explanations, including concentrations of radioactive elements in basement rocks, groundwater flow, local tectonics, and inaccurate determination of thermal properties. In fact, the latter explanation has been found to satisfy most of the differences in heat flow values (Gosnold, 1990). The high heat flow values reported by Scattolini (1977) and Combs and Simmons (1973) result from

using thermal conductivity values, for shales, that were about 40% too high (Sass and Galanis, 1983; Blackwell and Steele, 1987; Gosnold, 1990). Gosnold (1990) recalculated 11 heat flow values using thermal conductivities ranging from 1.1 to 1.5 W m⁻¹ K⁻¹ and determined heat flow values ranging from 54 to 68 mW m⁻² with an average of 58 mW m⁻². Thus the high heat flow zone previously reported in the North Dakota portion of the Williston Basin was erroneously determined and does not exist.

The high heat flow zone in the Williston Basin in Canada was suggested to originate from high radioactive heat generation in the Precambrian basement (Majorowicz et al., 1986, 1988). The question of high radioactivity in the basement rocks was untestable in this study due to a lack of samples of basement rocks. However, lateral variation in basement radioactivity over a distance of 10 km could account for the relatively large differences in surface heat flows determined in a sedimentary cover 2-4 km thick. Thus some discussion of this possible source for anomalous heat flow is necessary.

Assuming that mantle heat flow in the Great Plains is about 27 mW m⁻² (Morgan and Gosnold, 1989), the linear relation between heat flow and heat generation (Roy et al., 1968) predicts that about 7.3 μ W m⁻³ would be required to produce heat flow values on the order of 90 mW m⁻² in the province. A critical question is whether this is a reasonable heat production value for the basement in the Williston Basin. Basement rocks underlying areas of supposed high heat flow in the Williston Basin are Precambrian and are part of the Trans-Hudson orogenic belt (Hoffman, 1988). The average heat production in exposed Precambrian granitic rocks in the continental United States is 3.1 μ W m⁻³ (Malan, 1972), which is essentially equivalent to the average for continental crust, i.e., about 3.0 μ W m⁻³ (Wollenberg and Smith, 1987).

The implied heat production value of 7.3 μ W m⁻³ is 2.4 times greater than the average value for the continental crust, but such values are plausible and

are known elsewhere. Values of the order of $4\text{--}5.3 \mu\text{W m}^{-3}$ were reported for some Precambrian batholiths in the Colorado Front Range (Phair and Gottfried, 1964), and values of $6.3 \mu\text{W m}^{-3}$ were found in some Precambrian granites in Australia (Heier and Rhodes, 1966). Anomalous heat production values on the order of 2-10 times the average for the continental crust were reported for samples from 9 Precambrian localities and one Mesozoic locality in the United States (Rosholt, 1983). However, these latter rocks all showed evidence of geochemical redistribution of uranium and thorium; and, in comparison to the plutons from which the samples were taken, the localities are small and may represent only localized concentrations of heat-producing elements.

Discussion can neither prove nor disprove that radioactive heat production is the source for the estimated high heat flow values in the Williston Basin in Canada, but it does establish its plausibility as a source. However, the only measured heat production values (Scattolini, 1977) in the areas where Combs and Simmons (1973) and Scattolini (1977) reported high heat flow are merely average continental values and are consistent with the low heat flow values recalculated by Gosnold (1990). Thus radioactive heat production may be questioned as a source for high heat flow in the basin. This question may be answered only by additional measured heat production values or if the high heat flow values prove to be erroneous.

Indeed, we suggest that the same problem that led to erroneous determinations of heat flow in North Dakota may also account for the estimated heat flow anomalies in Canada. The effective thermal conductivity used for the Mesozoic and Cenozoic rocks (Majorowicz et al., 1986), which are predominantly marine shales, was $2.1 \text{ W m}^{-1} \text{ K}^{-1}$. This value is about twice the value determined for the Pierre Shale (Sass and Galanis, 1983; Gosnold, 1990) and for the Paleozoic marine shales in Kansas (Blackwell and Steele, 1987). Further, the effective conductivity Majorowicz and others (1986) used for

Paleozoic rocks was $3.7 \text{ W m}^{-1} \text{ K}^{-1}$, which is 25 to 50 percent higher than the values used by Gosnold (1990). These differences in thermal conductivities by as much as a factor of 2 account for the high heat flow values and lead to the conclusion that no significant conductive heat flow anomalies exist anywhere in the Williston Basin.

4.2 Advective Heat Flow

Although evidence for a conductive heat flow anomaly in the Williston Basin is doubtful, the question of advective heat transport in parts of the basin appears more solid. Conceptually, it appears plausible and likely that detectable advective heat transport may occur in relation to some of the structures in the basin. Groundwater flow in the extensive regional aquifer system of the basin occurs in both Paleozoic and Mesozoic strata at flow rates ranging from 2 to 10 m y^{-1} (Downey, 1986). As previously demonstrated for South Dakota, such flow velocities in dipping aquifers can cause substantial heat flow anomalies. However, the flanks of the Williston Basin dip very gently, only about 2-3 degrees at most, and confined groundwater flow at such low angles would have a vertical velocity of less than $10^{-10} \text{ m s}^{-1}$, which is an order of magnitude below the detectable threshold for heat advection.

This raises interesting questions because analyses of bottom-hole temperature (BHT) data in the Canadian portion of the Williston Basin (Majorowicz et al., 1986) and in the Prairies Basin in Alberta (Majorowicz et al., 1984) does indeed suggest that regional groundwater flow generates heat flow anomalies in the Basins. Jones and Majorowicz (1985) and Majorowicz and others (1986) suggested that hydrodynamic factors caused differences in heat flow values on the order of 40 mW m^{-2} between the Mesozoic/Cenozoic rocks and Paleozoic rocks of the Williston Basin. Gosnold and Fisher (1986) interpreted BHT data from three different units on the Billings Nose, a small anticlinal

structure in the southwest of the Williston Basin, as indicative of advective heat transport.

The interpretations of Majorowicz and others (1986) and Jones and Majorowicz (1985) are most interesting. In the eastern part of the basin, they find that heat flow in the Paleozoic units is substantially higher than in the Mesozoic units and attribute the difference to confined groundwater flow in the Mesozoic rocks. Curiously, confined flow in the Mesozoic rocks in the eastern part of the basin is updip toward the east (Downey, 1986); thus, if any advection occurs in the Mesozoic units, it should cause a positive heat flow anomaly rather than a negative one. This contradiction between observations and theory suggests that the BHT data may be erroneous or the physical model may be flawed.

A plausible modification of the physical model would be that groundwater recharge into the Mesozoic/Cenozoic units could reduce heat flow in one area and enhance it in another. If this is the case in Saskatchewan and Manitoba, then most heat flow measurements in sedimentary rocks may be called into question on the basis of possible problems caused by groundwater.

The other plausible modification would be to the interpretation of the BHT data. We attempted to do this using BHT data for the Williston Basin in North Dakota to seek similar differences in heat flow between the Paleozoic and Mesozoic-Cenozoic units. We found no differences, and we offer the tentative conclusion that the problem lies in either the BHT data or in interpretation of the data.

We had hoped to test for hydrologic disturbances in the North Dakota portion of the Williston Basin by comparing bottom-hole temperature data from the Madison Formation to calculated temperature profiles over the Nesson Anticline and the Billings Nose. The theoretical application of this test is that measured BHTs should essentially parallel the calculated BHTs in a

conductive thermal realm. Any hydrologic disturbance should appear as a relatively high frequency signal which can be readily identified by taking directional derivatives of the surfaces. We developed computer software to display the temperature data as color contour maps and to take directional derivatives of the surfaces. Unfortunately, none of the BHT data was usable. The data were too disparate to show trends that had any reasonable relationships with groundwater flow, structures, or lithology.

The methodology we developed for analyzing the data has potential if adequate data can be obtained. The procedure requires generation of equivalent size grids of the BHTs and calculated temperatures. The BHT grid is then subtracted from the calculated temperature grid, and horizontal derivatives of the resultant surface are taken in the direction of regional groundwater flow. In theory, downflow areas should have negative anomalies, and upflow areas should have positive anomalies. For the difference surface, where upflow occurs, the calculated temperatures would be lower than the measured temperatures by several degrees and vice versa. Our software uses a 56 color spectrum to display the negative anomalies as cool (gray-to-blue) tones and the positive anomalies as warm (red) tones.

Although low reliability of BHT data precluded a useful basinwide analysis, we applied the method to the area of the Billings Nose, a small anticlinal structure, as a demonstration. Figure 13 shows the BHT surface on the Bakken formation, and Figure 14 shows the calculated temperature surface. The apparent inverse correlation between BHTs and calculated temperatures should indicate heat advection by groundwater flow.

BHTs

Figure 13. Three-dimensional surface of bottom-hole temperatures on top of the Bakken Formation in the western part of the Williston Basin.

Calculated BHTs

Figure 14. Three-dimensional surface of calculated temperatures on top of the Bakken Formation. The differences between the surfaces in Figures 13 and 14 may indicate heat advection by groundwater flow.

5.0 METHOD OF RESOURCE ASSESSMENT

5.1 Methodology

The accessible resource base was calculated using the expression

$$Q_r = \rho_c V (T - 15^\circ) \quad [\text{Eq. 2}]$$

where Q_r is the accessible resource base, ρ_c is the volumetric specific heat of the aquifer, V is the volume of fluid that can be produced, and T is the average temperature of the aquifer (Sorey et al., 1983).

The essential elements of any resource assessment using this method are to identify aquifers and to determine their average temperatures and volumes. Consequently, the stratigraphic and hydrologic data bases compiled by state geological surveys and other research institutions provide two essential components of the resource assessment.

The temperature field of the subsurface is determined using the mean annual surface temperature, the thermal conductivities and thicknesses of strata, and local heat flow which is known from direct temperature measurements in boreholes. Assuming a conductive thermal regime, subsurface temperatures may be determined by Fourier's law of heat conduction:

$$Q = \frac{dT}{dz} K \quad [\text{Eq. 3}]$$

where Q is heat flow in mW m^{-2} , K is thermal conductivity in $\text{W m}^{-1} \text{K}^{-1}$, dT is the increment of temperature change in a vertical length, dz . In a sedimentary basin where the vertical variation in thermal conductivity is controlled by the lithologies of the strata, temperature at any depth, Z , can be calculated by

$$T(z) = T_o \sum_1^n \frac{Z_i Q}{K_i} \quad [\text{Eq. 4}]$$

where T_0 is surface temperature, Q is the conductive heat flow, Z_i is the thickness of the i^{th} stratum, and K_i is the conductivity of the i^{th} stratum. The essential data in the temperature analysis are the heat flow data and the thermal conductivities of all units in the stratigraphic section.

Application of Eq. 3 is shown in Tables 3 and 4, and comparative temperature depth profiles for North Dakota and South Dakota are shown in Figure 15. Table 3 gives subsurface temperatures for the principal stratigraphic formations in the Williston Basin, assuming a constant heat flow value in each vertical section and using the appropriate thermal conductivity for each formation.

TABLE 3
Thermostratigraphy of a Generalized Section of the Williston Basin

	Temperature, °C	Thickness, meters	Depth, meters	Thermal Conductivity, W/mK	Gradient, K/km
	6.3		0.0		
Tertiary	26.8	581.1	581.1	1.7	35.3
Pierre	78.2	1027.3	1608.4	1.2	50.0
Inyan Kara	83.3	135.5	1744.0	1.6	37.5
Jurassic	94.8	344.9	2088.9	1.8	33.3
Spearfish	100.5	293.7	2382.6	3.1	19.4
Otter	103.4	136.4	2518.9	2.8	21.4
Madison	113.9	615.6	3134.5	3.5	17.1
Bakken	117.9	100.0	3234.5	1.5	40.0
Three Forks	119.4	87.6	3322.2	3.5	17.1
Duperow	123.1	213.5	3535.7	3.5	17.1
Dawsonbay	124.5	84.5	3620.1	3.5	17.2
Winnepegosis	125.9	79.6	3699.7	3.5	17.2
Red River	130.8	327.4	4027.1	4.0	15.0
Deadwood	135.7	283.5	4310.6	3.5	17.1

Figure 15. Example of temperature-depth profiles for Williston Basin and Kennedy Basin: a) Williston Basin in northwestern South Dakota; b) geothermal area in Kennedy Basin near Winner, South Dakota; c) Central Williston Basin in North Dakota. The dashed line shows minimum geothermal resource profile; any temperatures to the right of the dashed line qualifies as a potential resource.

Determinations of the thermal conductivities for specific formations were based on interpretations of numerous, measured temperature-depth curves and on thermal-conductivity measurements of core samples of carbonates from the North Dakota Geological Survey's Core and Sample Library. Thermal conductivities given in Tables 3 and 4 are those used in this analyses of subsurface temperatures.

Heat flow data used in calculation of subsurface temperatures include those data summarized by Gosnold (1990) and new data collected in this study. Initially, we planned to drill 10 heat flow holes, five in South Dakota and five in North Dakota. However, through arrangements with the South Dakota Geological Survey, we were able to combine drilling projects and complete 12 new heat flow holes in South Dakota (SD 1-12 in Table 5). Twenty-one new gradient measurements were made in existing observation wells belonging to the South Dakota Water Resources Division. Cooperation with the U.S.G.S. Geohydrology Division in North Dakota provided three holes for heat flow determinations near the Nesson Anticline in North Dakota (Appendix C). Figure 16 shows the locations of the new heat flow sites as well as the locations of existing wells where new gradient measurements were obtained. Table 5 lists the new heat flow data. Appendix B includes gradient measurements in wells that are open at the bottom and are used for water table observations. However, the casings are grouted in all aquifers and near the surface; thus it is unlikely that water flow between aquifers or from the surface causes significant problems with thermal stability.

5.2 Data Format

The stratigraphic data in North Dakota were compiled from well-log files into a series of files corresponding to formation names. Each file contains

TABLE 4
Thermostratigraphy in South Dakota

Williston Basin near Buffalo					
Strat. Horizon	Temperature, °C	Thickness, meters	Depth, meters	Thermal Cond., W m ⁻¹ K ⁻¹	Gradient, °C km ⁻¹
Surface	6.62				
Pierre	20.0	1127.8	139.4	1.1	50.0
Dakota	77.4	42.7	1316.8	1.6	37.5
Jurassic	79.0	228.6	1359.4	1.4	42.9
Spearfish	88.8	167.6	1588.0	1.3	46.2
Minnekahta	96.5	66.4	1775.7	3.0	20.0
Minnelusa	98.6	137.2	1812.1	2.2	27.3
Madison	102.4	390.1	1949.2	3.0	20.0
Ord-Dev	109.1	368.8	2339.4	3.5	17.1
Deadwood	115.4	207.3	2708.2	2.4	25.4

Geothermal Area at Pierre					
Strat. Horizon	Temperature, °C	Thickness, meters	Depth, meters	Thermal Cond., W m ⁻¹ K ⁻¹	Gradient, °C km ⁻¹
Surface	8.4				
Pierre	8.4	543.5	0.0	1.1	66.6
Dakota	44.6	33.3	543.5	1.6	44.8
Jurassic	46.1	12.4	576.8	1.4	55.5
Spearfish	46.6	0.9	589.2	1.3	
Minnekahta	46.6	44.2	590.1	3.0	
Minnelusa	47.7	49.6	634.3	2.2	25.0
Madison	52.9				
Ord-Dev	52.9				
Deadwood	53.8	10.0	683.9	2.4	

Note: Stratigraphic data from selected points were used to generate an evenly spaced grid of points. The gridding process generated a smoothed data set that does not precisely represent the subsurface. Therefore, the depths and temperatures in the table are estimates and should be used with caution.

Figure 16. Heat flow data in North Dakota, South Dakota, and Nebraska gathered during DOE geothermal research work. Holes at the beginning of the study are shown with open circles, and holes during the study are shown with closed triangles.

TABLE 5
New Heat Flow Holes

	<u>Latitude</u>	<u>Longitude</u>	<u>Gradient, °C/km</u>	<u>Depth Interval, m</u>	<u>Thermal Conductivity, w/m/k</u>	<u>Heat Flow, mW m⁻²</u>	<u>Elev., m</u>
SD 1	43° 49.9'	99° 33.9'	53.8	99-181	1.1	59.1	545
SD 2	43° 49.2'	99° 43.1'	90.4	99-179	1.1	99.4	540
SD 3	43° 47.4'	99° 44.6'	96.1	95-175	1.1	105.7	545
SD 4	43° 44.3'	100° 2.6'	108.2	107-179	1.1	119.0	570
SD 5	43° 42.0'	100° 2.3'	82.0	95-175	1.1	90.2	480
SD 6	43° 40.6'	100° 2.6'	89.7	95-175	1.1	98.7	540
SD 7	45° 15.6'	96° 58.2'	40.0	58-270	1.2	48.0	366
SD 8	43° 35.4'	101° 51.6'	51.2	115-260	1.1	56.3	547
SD 9	43° 30.6'	101° 16.8'	95.8	55-185	1.1	105.4	590
SD 10	43° 50.8'	101° 15.5'	65.7	81-181	1.1	72.3	707
SD 11	43° 48.5'	101° 30.0'	51.2	81-181	1.1	55.2	747
SD 12	43° 44.1'	102° 13.7'	32.1	100-181	1.1	35.3	848

3 columns in ASCII format, and each line contains the well coordinates and the elevation of the top in meters. Datum is mean sea level. Stratigraphic tops used for this study were either for formations that were evaluated as potential geothermal aquifers or formations having thermal conductivities that significantly influence the geothermal gradient. The data compilation is extensive and is not included in this report to save space. However, the data are available on floppy disk in ASCII format from the University of North Dakota on request.

5.3 Procedure

Elevations of tops from irregularly spaced data on each formation were used to generate an evenly spaced grid of points (see Appendices D, E, F, and G). A 51 column by 33 row point grid with 10 km spacing on each side was used for North Dakota and a 49 column by 53 row point grid with 6.2 km spacing was used for South Dakota. We used the **GRID** program included in the commercial software package **SURFER**, distributed by Golden Software, Inc., Golden, CO.

The gridding process generated smoothed data sets that do not precisely represent the formation tops; thus there were problems with applying the gridded data. Inspection of the data grids indicates that the process generated inaccurate points near the limits of the data and in areas where data were sparse. In several cases, the procedure created parts of topographic grids near the limits of the data which made stratigraphic units appear reversed. We corrected the topographic grids in cases where stratigraphic positions were reversed by developing software which compared two gridded units point by point and adjusted the selected unit by a selected amount if a reversal or anomalous thinning were detected. This scheme works well in the deeper parts of the basins where formation thicknesses are fairly consistent, but it requires additional software development to apply to areas where formations thin or thicken. Consequently, all calculations near the

limits of the data, that is along the state borders and on the eastern side of the grid, should be used cautiously.

After generation of the evenly spaced topographic grids for each formation, we applied two specially developed computer programs to analyze the data. The first program **RESOURCE** (see Appendix H) calculates the resource within each formation within the grid. The output of program **RESOURCE** includes a screen display and a data file which contains the formation name; the maximum, minimum, and mean temperatures; and the accessible resource base in exajoules. The second program **LOCLTEMP** (see Appendix H) generates a temperature depth profile at a selected site and provides a comparison with a temperature profile that gives the minimum temperature for a geothermal resource. The output of program **LOCLTEMP** includes a screen display, a printer copy, and a data file containing the formation name, depth, calculated temperature, and the minimum temperature for a resource. Temperature depth data for 35 selected towns/cities in the resource area were generated for this report and are included in Appendices I and J.

Analysis of the resource area was done by state rather than as a total area due to constraints imposed by the available data. Although both North Dakota and South Dakota contain essentially the same stratigraphic units, the available data for the two states differ in that more individual units are well-known in North Dakota than in South Dakota. This difference is due to extensive petroleum exploration and data collection in the Williston Basin which lies largely in North Dakota, compared to a relatively minor amount of exploration in South Dakota. Consequently, merger of the two data sets would mean sacrificing detail in North Dakota. Since inclusion of this detail is a primary factor in increasing the total resource base, it would be unwise to do so.

6.0 CONCLUSIONS

The accessible resource base in the two-state study area was calculated to be about 36 exajoules. Twenty-one exajoules of accessible geothermal energy lie within the borders of North Dakota (Table 6) and about 12 exajoules lie within the borders of South Dakota (Table 7). The accessible resource base is generally estimated to be 0.001 times the resource base (Sorey et al., 1983). These figures are larger than the resource estimates reported in previous studies (Table 2) due to the inclusion of all potential aquifers in the resource assessment. This increase of the estimated resource base has broad implications for the stratabound geothermal resource base for the entire U.S., because all previous assessments of stratabound geothermal resources in the U.S. have included only a few of the potential geothermal aquifers.

TABLE 6
Geothermal Resource Base for North Dakota*

Formation	Resource, Exajoules	Avg. Thick., °C	Avg. Temp., °C	Max. Temp., °C
Inyan Kara	0.54	74.6	44.5	85.8
Jurassic	2.06	265.2	47.8	90.5
Spearfish	1.83	251.1	57.7	100.4
Otter	1.87	242.0	62.5	109.0
Madison	3.16	301.4	67.7	111.8
Three forks	0.47	33.0	75.0	125.8
Duperow	1.38	102.2	75.6	127.6
Dawson bay	2.56	232.7	77.3	130.9
Winnepegosis	1.05	96.3	81.3	131.6
Interlake	2.81	184.2	82.3	133.1
Red River	2.11	145.2	85.7	139.0
Deadwood	1.41	100.0	88.2	143.8
TOTAL	21.25			

* Temperatures are given for formation tops. Average thickness values are calculated from top to top. All of the formations named are aquifers which may produce water. Water quality is generally good for the upper Inyan Kara (Cretaceous), but becomes increasingly saline with depth below the Cretaceous.

TABLE 7
Geothermal Resources Base for South Dakota*

<u>Formation</u>	<u>Resource, Exajoules</u>	<u>Avg. Thick., °C</u>	<u>Avg. Temp., °C</u>	<u>Max. Temp., °C</u>
Dakota	0.42	36.5	18.5	73.4
Jurassic	1.22	81.9	42.5	71.5
Spearfish	0.66	43.8	57.7	82.3
Minnekahta	0.52	36.8	46.4	85.4
Minnelusa	2.02	134.1	47.3	86.5
Madison	2.93	153.7	51.0	90.3
Ord-Dev	2.90	140.2	53.7	97.2
Cambrian	1.85	110.0	56.1	104.8
TOTAL	12.52			

* Temperatures are given for formation tops. Average thickness values are calculated from top to top. All of the formations name are aquifers which may product water. Higher temperatures are typical for the Williston Basin in northwestern South Dakota.

The significance of this resource to the region as an energy source for the future and for planning for sustainable development is demonstrated by comparison of the three energy resources in North Dakota (Table 8). Data in Table 8 rank the resources in terms of accessible resource base, lignite ranks first with 118 quads, geothermal second with 21 quads, oil third with 17 quads, and natural gas fourth with 3 quads (Daly, 1990).

TABLE 8
Energy Resources in North Dakota

<u>Resource Type</u>	<u>Accessible Resource Base</u>
Coal-Lignite	~118
Geothermal	~21
Oil	~17
Natural Gas	~3

Surface heat flow values on the order of 100 mWm^{-2} in south central South Dakota and north central Nebraska have an anomalous component of about 40 mW m^{-2} due to advection of heat in flowing groundwater in the sedimentary cover overlying the Precambrian basement. Advection of heat occurs by groundwater flow in regional aquifers and vertical groundwater flow through fractures. The magnitude of anomalous heat flow due to advection in regional aquifers averages about 40 mW m^{-2} , with positive values over the discharge area to the east and negative values over the recharge area to the west. A quantitative energy balance calculation based on observed heat flow and temperature gradients results in 1.6-GW downward advection in the recharge areas in western South Dakota and a 1.6-GW upward advection in the discharge areas in central South Dakota. Over most of the area the magnitude of anomalous heat flow due to fracture leakage is imperceptible, but it may attain a value of about 20 mW m^{-2} where deeply incised stream valleys increase the vertical hydraulic gradient from the confined Dakota aquifer to the surface.

Evidence for advection by upward flow through fractures was found in temperature gradient profiles in a series of heat flow holes drilled across the White River Valley. The profiles show a systematic decrease in temperature gradient with depth near the bottoms of the 200-m drill holes (Figure 7). Analytical modeling of the advective system shows that upward flow from the Dakota aquifer, which is at a depth of about 500 m, at a velocity of about 10^{-9} m s^{-1} could cause the 20-mW m^{-2} heat flow anomaly.

Advective heat transport occurs in groundwater recharge areas within and near the Black Hills and in groundwater discharge areas in south central South Dakota and north central Nebraska. Low temperature gradients of the order of $10\text{-}20 \text{ K km}^{-1}$ occur in northeastern Nebraska, southeastern South Dakota, and around the Black Hills in South Dakota. High temperature gradients of the

order of 100 K km^{-1} occur within a $10,000\text{-km}^2$ area, including parts of southern South Dakota and north central Nebraska.

This finding may establish a paradigm for the occurrence of stratabound geothermal resources. Advection due to confined groundwater flow, where flow is across a basin, may significantly affect subsurface temperatures and create a large stratabound geothermal resource on the ascending limb of the basin.

Analyses of bottom-hole temperatures in the North Dakota portion of the Williston Basin do not show significant heat flow anomalies. However, comparisons of calculated temperatures and measured temperatures over the Nesson Anticline and the Billings Nose indicate temperature disturbances of about 5°C . The nature of the temperature disturbances suggests that upward groundwater flow in fractures on the westward sides of the structures is a plausible mechanism. Regional groundwater flow over structures in the Williston Basin in North Dakota generates local heat flow anomalies on the order of $10\text{-}20 \text{ mW m}^{-2}$. These thermal anomalies do not significantly alter the accessible geothermal resource base.

The large quantity of thermal energy contained in sedimentary rocks is a valuable asset for the region and could be used to attract energy-intensive industry such as food processing and manufacturing. If developed extensively, this resource could provide a new economic base for North Dakota and South Dakota.

Since the findings of this study suggest that the stratabound resource in the United States may be at least double the most recent estimate (Sorey et al., 1983), it is suggested that the methodology used in this study should be applied to all potential resource regions.

7.0 ACKNOWLEDGEMENTS

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APPENDIX A

**TEMPERATURE-DEPTH DATA FOR SOUTH DAKOTA
HEAT FLOW HOLES SD1-SD12**

S087A1

	DEPTH meters	TEMPERATURE deg Celsius	GRADIENT K/km	DEPTH feet	TEMPERATURE deg F.	GRADIENT deg F/100'
1	15.00	11.37	0.00	49.21	52.47	0.00
2	20.00	11.59	44.00	65.62	52.86	2.41
3	25.00	11.78	38.00	82.02	53.20	2.08
4	30.00	12.00	44.00	98.42	53.60	2.41
5	35.00	12.11	22.00	114.83	53.80	1.21
6	40.00	12.33	44.00	131.23	54.19	2.41
7	42.00	12.54	105.00	137.79	54.57	5.76
8	44.00	12.64	50.00	144.36	54.75	2.74
9	46.00	12.74	50.00	150.92	54.93	2.74
10	50.00	12.94	50.00	164.04	55.29	2.74
11	55.00	13.18	48.00	180.44	55.72	2.63
12	57.00	13.29	55.00	187.01	55.92	3.02
13	59.00	13.40	55.00	193.57	56.12	3.02
14	61.00	13.50	50.00	200.13	56.30	2.74
15	63.00	13.65	75.00	206.69	56.57	4.11
16	65.00	13.74	45.00	213.25	56.73	2.41
17	67.00	13.85	55.00	219.81	56.93	3.02
18	69.00	13.98	65.00	226.38	57.16	3.57
19	71.00	14.10	60.00	232.94	57.38	3.29
20	73.00	14.22	60.00	239.50	57.60	3.29
21	75.00	14.35	65.00	246.06	57.83	3.57
22	77.00	14.46	55.00	252.62	58.03	3.02
23	79.00	14.55	45.00	259.18	58.19	2.47
24	81.00	14.66	55.00	265.74	58.39	3.02
25	83.00	14.78	60.00	272.31	58.60	3.29
26	85.00	14.89	55.00	278.87	58.80	3.02
27	87.00	15.00	55.00	285.43	59.00	3.02
28	89.00	15.12	60.00	291.99	59.22	3.29
29	91.00	15.23	55.00	298.55	59.41	3.02
30	93.00	15.35	60.00	305.11	59.63	3.29
31	95.00	15.47	60.00	311.68	59.85	3.02
32	97.00	15.58	55.00	318.24	60.04	3.02
33	99.00	15.70	60.00	324.80	60.26	3.29
34	101.00	15.83	65.00	331.36	60.49	3.57
35	103.00	15.96	65.00	337.92	60.73	3.57
36	105.00	16.08	60.00	344.48	60.94	3.29
37	107.00	16.21	65.00	351.05	61.18	3.57
38	109.00	16.34	65.00	357.61	61.41	3.57
39	111.00	16.47	65.00	364.17	61.63	3.57
40	113.00	16.60	65.00	370.73	61.86	3.57
41	115.00	16.74	70.00	377.29	62.13	3.84
42	117.00	16.88	70.00	383.85	62.38	3.84
43	119.00	17.02	70.00	390.42	62.64	3.84
44	121.00	17.18	80.00	396.98	62.92	4.39
45	123.00	17.33	75.00	403.54	63.19	4.11
46	125.00	17.49	80.00	410.10	63.48	4.39
47	127.00	17.64	75.00	416.66	63.75	4.11
48	129.00	17.82	90.00	423.22	64.08	4.94
49	131.00	17.95	65.00	429.78	64.31	3.57
50	133.00	18.06	55.00	436.35	64.51	3.02

	DEPTH meters	TEMPERATURE deg Celsius	GRADIENT K/km	DEPTH feet	TEMPERATURE deg F.	GRADIENT deg F/100'
51	135.00	18.16	50.00	442.91	64.69	2.74
52	137.00	18.34	50.00	449.47	65.01	4.94
53	141.00	18.42	20.00	462.59	65.16	1.10
54	143.00	18.52	50.00	469.15	65.34	2.74
55	145.00	18.62	50.00	475.72	65.52	2.74
56	147.00	18.72	50.00	482.28	65.70	2.74
57	149.00	18.81	45.00	488.84	65.86	2.47
58	151.00	18.90	45.00	495.40	66.02	2.47
59	153.00	18.98	40.00	501.96	66.16	2.19
60	155.00	19.07	45.00	508.52	66.33	2.47
61	157.00	19.15	40.00	515.09	66.47	2.19
62	159.00	19.23	40.00	521.65	66.61	2.19
63	161.00	19.32	45.00	528.21	66.78	2.47
64	163.00	19.41	45.00	534.77	66.94	2.47
65	165.00	19.49	40.00	541.33	67.08	2.19
66	167.00	19.58	45.00	547.89	67.24	2.47
67	169.00	19.67	45.00	554.46	67.41	2.47
68	171.00	19.76	45.00	561.02	67.57	2.47
69	173.00	19.85	45.00	567.58	67.73	2.47
70	175.00	19.93	40.00	574.14	67.87	2.19
71	177.00	20.02	45.00	580.70	68.04	2.47
72	179.00	20.11	45.00	587.26	68.20	2.47
73	181.00	20.19	40.00	593.82	68.34	2.19
74	183.00	20.28	30.00	600.39	68.45	1.66

SD89A2.DAT

	DEPTH meters	TEMPERATURE deg Celsius	GRADIENT K/km	DEPTH feet	TEMPERATURE deg F.	GRADIENT deg F/100'
1	0.00	0.00	0.00	0.00	0.00	0.00
2	17.00	11.49	675.88	55.77	52.68	94.46
3	18.00	11.50	10.00	59.05	52.70	0.55
4	19.00	11.55	50.00	62.34	52.79	2.74
5	20.00	11.86	310.00	65.62	53.35	17.01
6	21.00	11.89	30.00	68.90	53.40	1.65
7	23.00	11.93	20.00	75.46	53.47	1.10
8	25.00	12.20	135.00	82.02	53.96	7.41
9	27.00	12.44	120.00	88.58	54.39	6.58
10	29.00	12.56	60.00	95.14	54.61	3.29
11	31.00	12.58	10.00	101.70	54.64	0.55
12	33.00	12.70	60.00	108.27	54.86	3.29
13	35.00	12.77	35.00	114.83	54.99	1.92
14	37.00	13.07	150.00	121.39	55.53	8.23
15	39.00	13.23	80.00	127.95	55.81	4.39
16	41.00	13.42	95.00	134.51	56.16	5.21
17	43.00	13.46	20.00	141.07	56.23	1.10
18	45.00	13.68	110.00	147.64	56.62	6.04
19	47.00	13.83	75.00	154.20	56.89	4.11
20	49.00	13.99	80.00	160.76	57.18	4.39
21	51.00	14.14	75.00	167.32	57.45	4.11
22	53.00	14.29	75.00	173.88	57.72	4.11
23	55.00	14.44	75.00	180.44	57.99	4.11
24	57.00	14.58	70.00	187.01	58.24	3.84
25	59.00	14.73	75.00	193.57	58.51	4.11
26	61.00	14.88	75.00	200.13	58.78	4.11
27	63.00	15.03	75.00	206.69	59.05	4.11
28	65.00	15.17	70.00	213.25	59.31	3.84
29	67.00	15.32	75.00	219.81	59.58	4.11
30	69.00	15.47	75.00	226.38	59.85	4.11
31	71.00	15.61	70.00	232.94	60.10	3.84
32	73.00	15.76	75.00	239.50	60.37	4.11
33	75.00	15.91	75.00	246.06	60.64	4.11
34	77.00	16.05	70.00	252.62	60.89	3.84
35	79.00	16.20	75.00	259.18	61.16	4.11
36	81.00	16.35	75.00	265.74	61.43	4.11
37	83.00	16.49	70.00	272.31	61.68	3.84
38	85.00	16.63	70.00	278.87	61.93	3.84
39	87.00	16.78	75.00	285.43	62.20	4.11
40	89.00	16.92	70.00	291.99	62.46	3.84
41	91.00	17.08	80.00	298.55	62.74	4.39
42	93.00	17.22	70.00	305.11	63.00	3.84
43	95.00	17.37	75.00	311.68	63.27	4.11
44	97.00	17.53	80.00	318.24	63.55	4.39
45	99.00	17.69	80.00	324.80	63.84	4.39
46	101.00	17.86	85.00	331.36	64.15	4.66
47	103.00	18.01	75.00	337.92	64.42	4.11
48	105.00	18.15	70.00	344.48	64.67	3.84
49	107.00	18.32	85.00	351.05	64.98	4.66
50	109.00	18.50	90.00	357.61	65.30	4.94

	DEPTH meters	TEMPERATURE deg Celsius	GRADIENT K/km	DEPTH feet	TEMPERATURE deg F.	GRADIENT deg F/100'
51	111.00	18.67	85.00	364.17	65.61	4.66
52	113.00	18.83	80.00	370.73	65.89	4.39
53	115.00	18.99	80.00	377.29	66.18	4.39
54	117.00	19.15	80.00	383.85	66.47	4.39
55	119.00	19.33	90.00	390.42	66.79	4.94
56	121.00	19.50	85.00	396.98	67.10	4.66
57	123.00	19.69	95.00	403.54	67.44	5.21
58	125.00	19.89	100.00	410.10	67.80	5.49
59	127.00	20.12	115.00	416.66	68.22	6.31
60	129.00	20.36	120.00	423.22	68.65	6.58
61	131.00	20.57	105.00	429.78	69.03	5.76
62	133.00	20.79	110.00	436.35	69.42	6.04
63	135.00	21.02	115.00	442.91	69.84	6.31
64	137.00	21.23	105.00	449.47	70.21	5.76
65	139.00	21.46	115.00	456.03	70.63	6.31
66	141.00	21.68	110.00	462.59	71.02	6.04
67	143.00	21.90	110.00	469.15	71.42	6.04
68	145.00	22.10	100.00	475.72	71.78	5.49
69	147.00	22.31	105.00	482.28	72.16	5.76
70	149.00	22.51	100.00	488.84	72.52	5.49
71	151.00	22.68	85.00	495.40	72.82	4.66
72	152.00	22.86	180.00	498.68	73.15	9.88
73	155.00	23.02	53.33	508.52	73.44	2.93
74	157.00	23.17	75.00	515.09	73.71	4.11
75	159.00	23.31	70.00	521.65	73.96	3.84
76	161.00	23.44	65.00	528.21	74.19	3.57
77	163.00	23.56	60.00	534.77	74.41	3.29
78	165.00	23.69	65.00	541.33	74.64	3.57
79	167.00	23.83	70.00	547.89	74.89	3.84
80	169.00	23.96	65.00	554.46	75.13	3.57
81	171.00	24.09	65.00	561.02	75.36	3.57
82	173.00	24.21	60.00	567.58	75.58	3.29
83	175.00	24.33	60.00	574.14	75.79	3.29
84	177.00	24.43	50.00	580.70	75.97	2.74
85	179.00	24.54	55.00	587.26	76.17	3.02

SD89A3.DAT

	DEPTH meters	TEMPERATURE deg Celsius	GRADIENT K/km	DEPTH feet	TEMPERATURE deg F.	GRADIENT deg F/100'
1	0.00	0.00	0.00	0.00	0.00	0.00
2	4.00	10.76	2690.00	13.12	51.37	391.43
3	4.50	10.53	-460.00	14.76	50.95	-25.24
4	5.00	10.57	80.00	16.40	51.03	4.39
5	5.50	10.57	0.00	18.04	51.03	0.00
6	6.00	10.71	280.00	19.68	51.28	15.36
7	6.50	10.89	360.00	21.33	51.60	19.75
8	7.00	11.07	360.00	22.97	51.93	19.75
9	7.50	11.20	260.00	24.61	52.16	14.26
10	8.00	11.30	200.00	26.25	52.34	10.97
11	8.50	11.37	140.00	27.89	52.47	7.68
12	9.00	11.43	120.00	29.53	52.57	6.58
13	9.50	11.47	80.00	31.17	52.65	4.39
14	10.00	11.51	80.00	32.81	52.72	4.39
15	10.50	11.55	80.00	34.45	52.79	4.39
16	11.00	11.60	100.00	36.09	52.88	5.49
17	11.50	11.68	160.00	37.73	53.02	8.78
18	12.00	11.71	60.00	39.37	53.08	3.29
19	12.50	11.75	80.00	41.01	53.15	4.39
20	13.00	11.82	140.00	42.65	53.28	7.68
21	13.50	11.88	120.00	44.29	53.38	6.58
22	14.00	11.91	60.00	45.93	53.44	3.29
23	14.50	11.94	60.00	47.57	53.49	3.29
24	15.00	12.00	120.00	49.21	53.60	6.58
25	15.50	12.02	40.00	50.85	53.64	2.19
26	16.00	12.04	40.00	52.49	53.67	2.19
27	16.50	12.07	60.00	54.13	53.73	3.29
28	17.00	12.08	20.00	55.77	53.74	1.10
29	17.50	12.11	60.00	57.41	53.80	3.29
30	18.00	12.13	40.00	59.05	53.83	2.19
31	18.50	12.17	80.00	60.69	53.91	4.39
32	19.00	12.22	100.00	62.34	54.00	5.49
33	19.50	12.27	100.00	63.98	54.09	5.49
34	20.00	12.32	100.00	65.62	54.18	5.49
35	20.50	12.38	120.00	67.26	54.28	6.58
36	21.00	12.44	120.00	68.90	54.39	6.58
37	21.50	12.51	140.00	70.54	54.52	7.68
38	22.00	12.58	140.00	72.18	54.64	7.68
39	22.50	12.66	160.00	73.82	54.79	8.78
40	23.00	12.74	160.00	75.46	54.93	8.78
41	23.50	12.82	160.00	77.10	55.08	8.78
42	24.00	12.89	140.00	78.74	55.20	7.68
43	24.50	12.94	100.00	80.38	55.29	5.49
44	25.00	12.98	80.00	82.02	55.36	4.39
45	26.00	13.04	60.00	85.30	55.47	3.29
46	27.00	13.09	50.00	88.58	55.56	2.74
47	28.00	13.14	50.00	91.86	55.65	2.74
48	29.00	13.18	40.00	95.14	55.72	2.19
49	30.00	13.25	70.00	98.42	55.85	3.84
50	31.00	13.33	80.00	101.70	55.99	4.39

	DEPTH meters	TEMPERATURE deg Celsius	GRADIENT K/km	DEPTH feet	TEMPERATURE deg F.	GRADIENT deg F/100'
51	32.00	13.41	80.00	104.99	56.14	4.39
52	33.00	13.50	90.00	108.27	56.30	4.94
53	34.00	13.58	80.00	111.55	56.44	4.39
54	35.00	13.66	80.00	114.83	56.59	4.39
55	37.00	13.83	85.00	121.39	56.89	4.66
56	39.00	14.00	85.00	127.95	57.20	4.66
57	41.00	14.16	80.00	134.51	57.49	4.39
58	43.00	14.32	80.00	141.07	57.78	4.39
59	45.00	14.49	85.00	147.64	58.08	4.66
60	47.00	14.65	80.00	154.20	58.37	4.39
61	49.00	14.80	75.00	160.76	58.64	4.11
62	51.00	14.96	80.00	167.32	58.93	4.39
63	53.00	15.12	80.00	173.88	59.22	4.39
64	55.00	15.28	80.00	180.44	59.50	4.39
65	57.00	15.43	75.00	187.01	59.77	4.11
66	59.00	15.59	80.00	193.57	60.06	4.39
67	61.00	15.75	80.00	200.13	60.35	4.39
68	63.00	15.90	75.00	206.69	60.62	4.11
69	65.00	16.05	75.00	213.25	60.89	4.11
70	67.00	16.20	75.00	219.81	61.16	4.11
71	69.00	16.36	80.00	226.38	61.45	4.39
72	71.00	16.52	80.00	232.94	61.74	4.39
73	73.00	16.67	75.00	239.50	62.01	4.11
74	75.00	16.83	80.00	246.06	62.29	4.39
75	80.00	17.24	82.00	262.46	63.03	4.50
76	85.00	17.64	80.00	278.87	63.75	4.39
77	90.00	18.06	84.00	295.27	64.51	4.61
78	95.00	18.48	84.00	311.68	65.26	4.61
79	100.00	18.90	84.00	328.08	66.02	4.61
80	105.00	19.34	88.00	344.48	66.81	4.83
81	110.00	19.76	84.00	360.89	67.57	4.61
82	115.00	20.16	80.00	377.29	68.29	4.39
83	120.00	20.61	90.00	393.70	69.10	4.94
84	125.00	21.07	92.00	410.10	69.93	5.05
85	130.00	21.53	92.00	426.50	70.75	5.05
86	135.00	21.97	88.00	442.91	71.55	4.83
87	140.00	22.42	90.00	459.31	72.36	4.94
88	145.00	22.89	94.00	475.72	73.20	5.16
89	150.00	23.41	104.00	492.12	74.14	5.71
90	155.00	23.98	114.00	508.52	75.16	6.25
91	160.00	24.60	124.00	524.93	76.28	6.80
92	165.00	25.15	110.00	541.33	77.27	6.04
93	170.00	25.60	90.00	557.74	78.08	4.94
94	175.00	25.97	74.00	574.14	78.75	4.06

SD89A4.DAT

	DEPTH meters	TEMPERATURE deg Celsius	GRADIENT K/km	DEPTH feet	TEMPERATURE deg F.	GRADIENT deg F/100'
1	0.00	0.00	0.00	0.00	0.00	0.00
2	19.00	12.85	676.32	62.34	55.13	88.44
3	21.00	13.11	130.00	68.90	55.60	7.13
4	23.00	13.33	110.00	75.46	55.99	6.04
5	25.00	13.53	100.00	82.02	56.35	5.49
6	27.00	13.75	110.00	88.58	56.75	6.04
7	29.00	13.94	95.00	95.14	57.09	5.21
8	31.00	14.16	110.00	101.70	57.49	6.04
9	33.00	14.35	95.00	108.27	57.83	5.21
10	35.00	14.55	100.00	114.83	58.19	5.49
11	37.00	14.74	95.00	121.39	58.53	5.21
12	39.00	14.93	95.00	127.95	58.87	5.21
13	41.00	15.14	105.00	134.51	59.25	5.76
14	43.00	15.34	100.00	141.07	59.61	5.49
15	45.00	15.54	100.00	147.64	59.97	5.49
16	47.00	15.73	95.00	154.20	60.31	5.21
17	49.00	15.94	105.00	160.76	60.69	5.76
18	51.00	16.13	95.00	167.32	61.03	5.21
19	53.00	16.32	95.00	173.88	61.38	5.21
20	55.00	16.51	95.00	180.44	61.72	5.21
21	57.00	16.70	95.00	187.01	62.06	5.21
22	59.00	16.90	100.00	193.57	62.42	5.49
23	61.00	17.10	100.00	200.13	62.78	5.49
24	63.00	17.29	95.00	206.69	63.12	5.21
25	65.00	17.49	100.00	213.25	63.48	5.49
26	67.00	17.68	95.00	219.81	63.82	5.21
27	69.00	17.89	105.00	226.38	64.20	5.76
28	71.00	18.08	95.00	232.94	64.54	5.21
29	73.00	18.27	95.00	239.50	64.89	5.21
30	75.00	18.47	100.00	246.06	65.25	5.49
31	77.00	18.65	90.00	252.62	65.57	4.94
32	79.00	18.84	95.00	259.18	65.91	5.21
33	81.00	19.03	95.00	265.74	66.25	5.21
34	83.00	19.22	95.00	272.31	66.60	5.21
35	85.00	19.41	95.00	278.87	66.94	5.21
36	87.00	19.61	100.00	285.43	67.30	5.49
37	89.00	19.81	100.00	291.99	67.66	5.49
38	91.00	20.02	105.00	298.55	68.04	5.76
39	93.00	20.23	105.00	305.11	68.41	5.76
40	95.00	20.44	105.00	311.68	68.79	5.76
41	97.00	20.65	105.00	318.24	69.17	5.76
42	99.00	20.85	100.00	324.80	69.53	5.49
43	101.00	21.06	105.00	331.36	69.91	5.76
44	103.00	21.26	100.00	337.92	70.27	5.49
45	105.00	21.46	100.00	344.48	70.63	5.49
46	107.00	21.66	100.00	351.05	70.99	5.49
47	109.00	21.86	100.00	357.61	71.35	5.49
48	111.00	22.06	100.00	364.17	71.71	5.49
49	113.00	22.27	105.00	370.73	72.09	5.76
50	115.00	22.48	105.00	377.29	72.46	5.76

	DEPTH meters	TEMPERATURE deg Celsius	GRADIENT K/km	DEPTH feet	TEMPERATURE deg F.	GRADIENT deg F/100'
51	117.00	22.67	95.00	383.85	72.81	5.21
52	119.00	22.88	105.00	390.42	73.18	5.76
53	121.00	23.09	105.00	396.98	73.56	5.76
54	123.00	23.30	105.00	403.54	73.94	5.76
55	125.00	23.49	95.00	410.10	74.28	5.21
56	127.00	23.69	100.00	416.66	74.64	5.49
57	129.00	23.91	110.00	423.22	75.04	6.04
58	131.00	24.14	115.00	429.78	75.45	6.31
59	133.00	24.36	110.00	436.35	75.85	6.04
60	135.00	24.57	105.00	442.91	76.23	5.76
61	137.00	24.80	115.00	449.47	76.64	6.31
62	139.00	25.01	105.00	456.03	77.02	5.76
63	141.00	25.23	110.00	462.59	77.41	6.04
64	143.00	25.44	105.00	469.15	77.79	5.76
65	145.00	25.64	100.00	475.72	78.15	5.49
66	147.00	25.84	100.00	482.28	78.51	5.49
67	149.00	26.04	100.00	488.84	78.87	5.49
68	151.00	26.25	105.00	495.40	79.25	5.76
69	153.00	26.46	105.00	501.96	79.63	5.76
70	155.00	26.66	100.00	508.52	79.99	5.49
71	157.00	26.87	105.00	515.09	80.37	5.76
72	159.00	27.08	105.00	521.65	80.74	5.76
73	161.00	27.32	120.00	528.21	81.18	6.58
74	163.00	27.55	115.00	534.77	81.59	6.31
75	165.00	27.76	105.00	541.33	81.97	5.76
76	167.00	27.99	115.00	547.89	82.38	6.31
77	169.00	28.23	120.00	554.46	82.81	6.58
78	171.00	28.47	120.00	561.02	83.25	6.58
79	173.00	28.72	125.00	567.58	83.70	6.86
80	175.00	28.97	125.00	574.14	84.15	6.86
81	177.00	29.23	130.00	580.70	84.61	7.13
82	179.00	29.51	140.00	587.26	85.12	7.68

SD89A5.DAT

	DEPTH meters	TEMPERATURE deg Celsius	GRADIENT K/km	DEPTH feet	TEMPERATURE deg F.	GRADIENT deg F/100'
1	0.00	0.00	0.00	0.00	0.00	0.00
2	10.00	12.06	1206.00	32.81	53.71	163.70
3	12.00	12.30	120.00	39.37	54.14	6.58
4	14.00	12.37	35.00	45.93	54.27	1.92
5	16.00	12.58	105.00	52.49	54.64	5.76
6	18.00	12.62	20.00	59.05	54.72	1.10
7	20.00	12.66	20.00	65.62	54.79	1.10
8	22.00	12.97	155.00	72.18	55.35	8.50
9	24.00	13.13	80.00	78.74	55.63	4.39
10	26.00	13.32	95.00	85.30	55.98	5.21
11	28.00	13.52	100.00	91.86	56.34	5.49
12	30.00	13.69	85.00	98.42	56.64	4.66
13	32.00	13.88	95.00	104.99	56.98	5.21
14	34.00	14.07	95.00	111.55	57.33	5.21
15	36.00	14.26	95.00	118.11	57.67	5.21
16	38.00	14.46	100.00	124.67	58.03	5.49
17	40.00	14.68	110.00	131.23	58.42	6.04
18	45.00	15.24	112.00	147.64	59.43	6.14
19	50.00	15.80	112.00	164.04	60.44	6.14
20	55.00	16.37	114.00	180.44	61.47	6.25
21	60.00	16.91	108.00	196.85	62.44	5.93
22	65.00	17.44	106.00	213.25	63.39	5.82
23	70.00	17.99	110.00	229.66	64.38	6.04
24	75.00	18.59	120.00	246.06	65.46	6.58
25	80.00	19.18	118.00	262.46	66.52	6.47
26	85.00	19.83	130.00	278.87	67.69	7.13
27	90.00	20.49	132.00	295.27	68.88	7.24
28	95.00	21.27	156.00	311.68	70.29	8.56
29	100.00	21.95	136.00	328.08	71.51	7.46
30	105.00	22.42	94.00	344.48	72.36	5.16
31	110.00	22.92	100.00	360.89	73.26	5.49
32	115.00	23.43	102.00	377.29	74.17	5.60
33	120.00	23.93	100.00	393.70	75.07	5.49
34	125.00	24.39	92.00	410.10	75.90	5.05
35	130.00	24.81	84.00	426.50	76.66	4.61
36	135.00	25.27	92.00	442.91	77.49	5.05
37	140.00	25.69	84.00	459.31	78.24	4.61
38	145.00	26.08	78.00	475.72	78.94	4.28
39	150.00	26.47	78.00	492.12	79.65	4.28
40	155.00	26.90	86.00	508.52	80.42	4.72
41	160.00	27.22	64.00	524.93	81.00	3.51
42	165.00	27.55	66.00	541.33	81.59	3.62
43	170.00	27.86	62.00	557.74	82.15	3.40
44	175.00	28.18	64.00	574.14	82.72	3.51

SD89A6.DAT

	DEPTH meters	TEMPERATURE deg Celsius	GRADIENT K/km	DEPTH feet	TEMPERATURE deg F.	GRADIENT deg F/100'
1	0.00	0.00	0.00	0.00	0.00	0.00
2	2.00	15.94	7970.00	6.56	60.69	924.96
3	2.50	14.66	-2560.00	8.20	58.39	-140.45
4	3.00	13.51	-2300.00	9.84	56.32	-126.19
5	3.50	12.73	-1560.00	11.48	54.91	-85.59
6	4.00	12.13	-1200.00	13.12	53.83	-65.84
7	4.50	11.77	-720.00	14.76	53.19	-39.50
8	5.00	11.54	-460.00	16.40	52.77	-25.24
9	5.50	11.44	-200.00	18.04	52.59	-10.97
10	6.00	11.41	-60.00	19.68	52.54	-3.29
11	6.50	11.41	0.00	21.33	52.54	0.00
12	7.00	11.45	80.00	22.97	52.61	4.39
13	7.50	11.52	140.00	24.61	52.74	7.68
14	8.00	11.61	180.00	26.25	52.90	9.88
15	8.50	11.70	180.00	27.89	53.06	9.88
16	9.00	11.82	240.00	29.53	53.28	13.17
17	9.50	11.89	140.00	31.17	53.40	7.68
18	10.00	11.93	80.00	32.81	53.47	4.39
19	10.50	11.97	80.00	34.45	53.55	4.39
20	11.00	11.99	40.00	36.09	53.58	2.19
21	11.50	11.97	-40.00	37.73	53.55	-2.19
22	12.00	11.96	-20.00	39.37	53.53	-1.10
23	12.50	11.97	20.00	41.01	53.55	1.10
24	13.00	11.99	40.00	42.65	53.58	2.19
25	13.50	12.04	100.00	44.29	53.67	5.49
26	14.00	12.05	20.00	45.93	53.69	1.10
27	14.50	12.07	40.00	47.57	53.73	2.19
28	15.00	12.10	60.00	49.21	53.78	3.29
29	15.50	12.12	40.00	50.85	53.82	2.19
30	16.00	12.14	40.00	52.49	53.85	2.19
31	16.50	12.16	40.00	54.13	53.89	2.19
32	17.00	12.18	40.00	55.77	53.92	2.19
33	17.50	12.20	40.00	57.41	53.96	2.19
34	18.00	12.23	60.00	59.05	54.01	3.29
35	18.50	12.28	100.00	60.69	54.10	5.49
36	19.00	12.33	100.00	62.34	54.19	5.49
37	19.50	12.44	220.00	63.98	54.39	12.07
38	20.00	12.48	80.00	65.62	54.46	4.39
39	20.50	12.49	20.00	67.26	54.48	1.10
40	21.00	12.52	60.00	68.90	54.54	3.29
41	21.50	12.55	60.00	70.54	54.59	3.29
42	22.00	12.57	40.00	72.18	54.63	2.19
43	22.50	12.59	40.00	73.82	54.66	2.19
44	23.00	12.61	40.00	75.46	54.70	2.19
45	23.50	12.63	40.00	77.10	54.73	2.19
46	24.00	12.65	40.00	78.74	54.77	2.19
47	24.50	12.66	20.00	80.38	54.79	1.10
48	25.00	12.67	20.00	82.02	54.81	1.10
49	25.50	12.69	40.00	83.66	54.84	2.19
50	26.00	12.71	40.00	85.30	54.88	2.19

	DEPTH meters	TEMPERATURE deg Celsius	GRADIENT K/km	DEPTH feet	TEMPERATURE deg F.	GRADIENT deg F/100'
51	26.50	12.73	40.00	86.94	54.91	2.19
52	27.00	12.73	0.00	88.58	54.91	0.00
53	27.50	12.73	0.00	90.22	54.91	0.00
54	28.00	12.93	400.00	91.86	55.27	21.95
55	28.50	12.97	80.00	93.50	55.35	4.39
56	29.00	12.98	20.00	95.14	55.36	1.10
57	29.50	12.99	20.00	96.78	55.38	1.10
58	30.00	12.99	0.00	98.42	55.38	0.00
59	30.50	13.05	120.00	100.06	55.49	6.58
60	31.00	13.14	180.00	101.70	55.65	9.88
61	31.50	13.18	80.00	103.35	55.72	4.39
62	32.00	13.21	60.00	104.99	55.78	3.29
63	32.50	13.25	80.00	106.63	55.85	4.39
64	33.00	13.28	60.00	108.27	55.90	3.29
65	33.50	13.32	80.00	109.91	55.98	4.39
66	34.00	13.36	80.00	111.55	56.05	4.39
67	34.50	13.39	60.00	113.19	56.10	3.29
68	35.00	13.43	80.00	114.83	56.17	4.39
69	40.00	13.78	70.00	131.23	56.80	3.84
70	45.00	14.16	76.00	147.64	57.49	4.17
71	50.00	14.54	76.00	164.04	58.17	4.17
72	55.00	14.93	78.00	180.44	58.87	4.28
73	60.00	15.33	80.00	196.85	59.59	4.39
74	65.00	15.74	82.00	213.25	60.33	4.50
75	70.00	16.15	82.00	229.66	61.07	4.50
76	75.00	16.55	80.00	246.06	61.79	4.39
77	80.00	16.96	82.00	262.46	62.53	4.50
78	85.00	17.36	80.00	278.87	63.25	4.39
79	90.00	17.75	78.00	295.27	63.95	4.28
80	95.00	18.20	90.00	311.68	64.76	4.94
81	100.00	18.67	94.00	328.08	65.61	5.16
82	105.00	19.13	92.00	344.48	66.43	5.05
83	110.00	19.57	88.00	360.89	67.23	4.83
84	115.00	19.99	84.00	377.29	67.98	4.61
85	120.00	20.41	84.00	393.70	68.74	4.61
86	125.00	20.88	94.00	410.10	69.58	5.16
87	130.00	21.35	94.00	426.50	70.43	5.16
88	135.00	21.84	98.00	442.91	71.31	5.38
89	140.00	22.38	108.00	459.31	72.28	5.93
90	145.00	22.97	118.00	475.72	73.35	6.47
91	150.00	23.44	94.00	492.12	74.19	5.16
92	155.00	23.80	72.00	508.52	74.84	3.95
93	160.00	24.18	76.00	524.93	75.52	4.17
94	165.00	24.57	78.00	541.33	76.23	4.28
95	170.00	24.93	72.00	557.74	76.87	3.95
96	175.00	25.29	72.00	574.14	77.52	3.95

SD - 7 Mitchell South Dakota

	DEPTH meters	TEMPERATURE deg Celsius	GRADIENT K/km	DEPTH FEET	TEMPERATURE deg F.	GRADIENT deg F/100 ft
1	20.00	10.07	0.00	65.62	50.13	0.00
2	25.00	10.18	23.00	82.02	50.33	1.26
3	30.00	10.31	24.40	98.42	50.55	1.34
4	35.00	10.37	12.88	114.83	50.67	0.71
5	40.00	10.42	10.24	131.23	50.76	0.56
6	45.00	10.48	11.15	147.64	50.86	0.61
7	50.00	10.55	14.73	164.04	50.99	0.81
8	55.00	10.64	17.90	180.44	51.15	0.98
9	60.00	10.79	29.14	196.85	51.42	1.60
10	65.00	10.94	31.06	213.25	51.70	1.70
11	70.00	11.08	28.45	229.66	51.95	1.56
12	75.00	11.23	29.91	246.06	52.22	1.64
13	80.00	11.40	32.77	262.46	52.52	1.80
14	85.00	11.58	36.56	278.87	52.84	2.01
15	90.00	11.69	22.48	295.27	53.05	1.23
16	95.00	11.77	15.63	311.68	53.19	0.86
17	100.00	11.84	13.35	328.08	53.31	0.73
18	105.00	11.90	12.92	344.48	53.42	0.71
19	110.00	12.05	29.60	360.89	53.69	1.62
20	115.00	12.22	32.98	377.29	53.99	1.81
21	120.00	12.30	17.24	393.70	54.14	0.95
22	125.00	12.34	8.40	410.10	54.22	0.46
23	130.00	12.41	13.09	426.50	54.34	0.72
24	135.00	12.46	9.83	442.91	54.42	0.54
25	140.00	12.53	14.53	459.31	54.56	0.80
26	145.00	12.60	14.56	475.72	54.69	0.80
27	150.00	12.66	10.35	492.12	54.78	0.57
28	155.00	12.70	8.47	508.52	54.86	0.46
29	160.00	12.74	8.01	524.93	54.93	0.44
30	165.00	12.78	9.44	541.33	55.01	0.52
31	170.00	12.83	8.50	557.74	55.09	0.47
32	175.00	12.87	8.52	574.14	55.17	0.47

	DEPTH meters	TEMPERATURE deg Celsius	GRADIENT K/km	DEPTH feet	TEMPERATURE deg F.	GRADIENT deg F/100'
1	24.70	11.44	0.00	81.04	52.59	0.00
2	25.00	11.17	-872.07	82.02	52.11	-47.85
3	30.00	11.18	1.82	98.42	52.13	0.10
4	35.00	11.48	58.72	114.83	52.66	3.22
5	40.00	11.75	54.10	131.23	53.15	2.97
6	45.00	12.02	55.38	147.64	53.64	3.04
7	50.00	12.33	61.38	164.04	54.20	3.37
8	55.00	12.64	62.33	180.44	54.76	3.42
9	60.00	12.93	57.61	196.85	55.28	3.16
10	65.00	13.28	69.53	213.25	55.90	3.81
11	70.00	13.59	61.97	229.66	56.46	3.40
12	75.00	13.88	58.59	246.06	56.99	3.21
13	80.00	14.18	59.06	262.46	57.52	3.24
14	85.00	14.52	69.43	278.87	58.14	3.81
15	90.00	14.87	69.09	295.27	58.77	3.79
16	95.00	15.22	70.78	311.68	59.40	3.88
17	100.00	15.51	58.24	328.08	59.93	3.20
18	105.00	15.78	52.06	344.48	60.40	2.86
19	110.00	16.02	48.33	360.89	60.83	2.65
20	115.00	16.27	50.22	377.29	61.28	2.76
21	120.00	16.52	49.54	393.70	61.73	2.72
22	125.00	16.73	42.00	410.10	62.11	2.30
23	130.00	16.96	47.56	426.50	62.53	2.61
24	135.00	17.19	46.29	442.91	62.95	2.54
25	140.00	17.41	43.93	459.31	63.35	2.41
26	145.00	17.62	40.97	475.72	63.71	2.25
27	150.00	17.79	34.15	492.12	64.02	1.87
28	155.00	17.98	38.70	508.52	64.37	2.12
29	160.00	18.19	42.23	524.93	64.75	2.32
30	165.00	18.40	41.95	541.33	65.13	2.30
31	170.00	18.62	43.34	557.74	65.52	2.38
32	175.00	18.87	49.24	574.14	65.96	2.70
33	180.00	19.14	53.58	590.54	66.44	2.94
34	185.00	19.40	53.45	606.95	66.92	2.93
35	190.00	19.74	68.32	623.35	67.54	3.75
36	195.00	20.05	61.48	639.76	68.09	3.37
37	200.00	20.29	47.39	656.16	68.52	2.60
38	205.00	20.51	44.79	672.56	68.92	2.46
39	210.00	20.74	46.30	688.97	69.34	2.54
40	215.00	20.99	49.65	705.37	69.79	2.72
41	220.00	21.27	56.11	721.78	70.29	3.08
42	225.00	21.54	53.57	738.18	70.77	2.94
43	230.00	21.85	62.07	754.58	71.33	3.41
44	235.00	22.16	60.83	770.99	71.88	3.34
45	240.00	22.48	63.97	787.39	72.46	3.51
46	245.00	22.80	64.65	803.80	73.04	3.55
47	250.00	23.11	61.49	820.20	73.59	3.37
48	255.00	23.38	55.63	836.60	74.09	3.05
49	260.00	23.63	48.29	853.01	74.53	2.65
50	265.00	23.78	31.53	869.41	74.81	1.73
51	270.00	23.87	17.15	885.82	74.96	0.94

	DEPTH meters	TEMPERATURE deg Celsius	GRADIENT K/km	DEPTH feet	TEMPERATURE deg F.	GRADIENT deg F/100'
1	53.00	15.37	0.00	173.88	59.66	0.00
2	55.00	15.46	48.17	180.44	59.84	2.64
3	60.00	15.83	73.00	196.85	60.49	4.01
4	65.00	16.58	149.90	213.25	61.84	8.22
5	70.00	16.94	71.69	229.66	62.49	3.93
6	75.00	17.43	98.21	246.06	63.37	5.39
7	80.00	17.94	102.39	262.46	64.29	5.62
8	85.00	18.38	88.50	278.87	65.09	4.86
9	90.00	18.79	80.73	295.27	65.81	4.43
10	95.00	19.29	101.64	311.68	66.73	5.58
11	100.00	19.74	88.25	328.08	67.52	4.84
12	105.00	20.19	90.09	344.48	68.33	4.94
13	110.00	20.67	96.73	360.89	69.21	5.31
14	115.00	21.18	101.88	377.29	70.12	5.59
15	120.00	21.65	94.99	393.70	70.98	5.21
16	125.00	22.09	87.77	410.10	71.77	4.82
17	130.00	22.58	97.26	426.50	72.64	5.34
18	135.00	23.04	92.44	442.91	73.47	5.07
19	140.00	23.54	100.43	459.31	74.38	5.51
20	145.00	23.97	86.22	475.72	75.15	4.73
21	150.00	24.49	102.33	492.12	76.08	5.61
22	155.00	24.97	95.92	508.52	76.94	5.26
23	160.00	25.45	96.83	524.93	77.81	5.31
24	165.00	25.93	96.36	541.33	78.68	5.29
25	170.00	26.42	98.00	557.74	79.56	5.38
26	175.00	26.98	112.23	574.14	80.57	6.16
27	180.00	27.56	115.25	590.54	81.61	6.32
28	185.00	28.07	102.36	606.95	82.53	5.62
29	190.00	28.55	94.91	623.35	83.38	5.21
30	195.00	28.94	78.38	639.76	84.09	4.30
31	200.00	29.31	75.51	656.16	84.77	4.14
32	205.00	29.67	71.69	672.56	85.41	3.93
33	210.00	30.01	67.72	688.97	86.02	3.72
34	215.00	30.35	68.57	705.37	86.64	3.76
35	220.00	30.72	72.81	721.78	87.29	3.99
36	225.00	31.04	64.42	738.18	87.87	3.53
37	230.00	31.41	72.96	754.58	88.53	4.00
38	235.00	31.77	73.09	770.99	89.19	4.01
39	240.00	32.13	71.43	787.39	89.83	3.92
40	245.00	32.40	53.54	803.80	90.31	2.94
41	250.00	32.72	64.04	820.20	90.89	3.51
42	255.00	33.05	67.59	836.60	91.50	3.71
43	260.00	33.39	66.59	853.01	92.10	3.65
44	265.00	33.76	74.04	869.41	92.76	4.06
45	270.00	34.15	78.92	885.82	93.47	4.33
46	275.00	34.57	84.01	902.22	94.23	4.61
47	280.00	34.97	80.44	918.62	94.95	4.41
48	285.00	35.24	52.65	935.03	95.43	2.89
49	290.00	35.59	71.38	951.43	96.07	3.92
50	295.00	36.02	85.72	967.84	96.84	4.70

Dixon SD - 9						
	DEPTH	TEMPERATURE	GRADIENT	DEPTH	TEMPERATURE	GRADIENT
	meters	deg Celsius	K/km	feet	deg F.	deg F/100'
51	300.00	36.45	85.06	984.24	97.61	4.67
52	305.00	36.76	63.13	1000.64	98.18	3.46
53	310.00	37.11	69.27	1017.05	98.80	3.80
54	315.00	37.48	74.57	1033.45	99.47	4.09
55	320.00	37.87	77.86	1049.86	100.17	4.27
56	325.00	38.30	85.80	1066.26	100.94	4.71

SD - 10 Belvidere South Dakota

	DEPTH meters	TEMPERATURE deg Celsius	GRADIENT K/km	DEPTH feet	TEMPERATURE deg F.	GRADIENT deg F/100'
1	1.00	19.40	0.00	3.28	66.92	0.00
2	2.00	14.24	-5160.00	6.56	57.63	-283.10
3	3.00	12.05	-2190.00	9.84	53.69	-120.15
4	4.00	10.97	-1080.00	13.12	51.75	-59.25
5	5.00	10.74	-230.00	16.40	51.33	-12.62
6	6.00	10.88	140.00	19.68	51.58	7.68
7	7.00	11.13	250.00	22.97	52.03	13.72
8	8.00	11.31	180.00	26.25	52.36	9.88
9	9.00	11.39	80.00	29.53	52.50	4.39
10	10.00	11.39	0.00	32.81	52.50	0.00
11	11.00	11.37	-20.00	36.09	52.47	-1.10
12	12.00	11.39	20.00	39.37	52.50	1.10
13	13.00	11.42	30.00	42.65	52.56	1.65
14	14.00	11.54	120.00	45.93	52.77	6.58
15	15.00	11.56	20.00	49.21	52.81	1.10
16	16.00	11.63	70.00	52.49	52.93	3.84
17	17.00	11.67	40.00	55.77	53.01	2.19
18	18.00	11.70	30.00	59.05	53.06	1.65
19	19.00	11.75	50.00	62.34	53.15	2.74
20	20.00	11.78	30.00	65.62	53.20	1.65
21	21.00	11.83	50.00	68.90	53.29	2.74
22	22.00	11.87	40.00	72.18	53.37	2.19
23	23.00	11.94	70.00	75.46	53.49	3.84
24	24.00	11.99	50.00	78.74	53.58	2.74
25	25.00	12.02	30.00	82.02	53.64	1.65
26	26.00	12.06	40.00	85.30	53.71	2.19
27	27.00	12.10	40.00	88.58	53.78	2.19
28	28.00	12.13	30.00	91.86	53.83	1.65
29	29.00	12.15	20.00	95.14	53.87	1.10
30	30.00	12.35	200.00	98.42	54.23	10.97
31	31.00	12.42	70.00	101.70	54.36	3.84
32	32.00	12.48	60.00	104.99	54.46	3.29
33	33.00	12.54	60.00	108.27	54.57	3.29
34	34.00	12.60	60.00	111.55	54.68	3.29
35	35.00	12.66	60.00	114.83	54.79	3.29
36	36.00	12.71	50.00	118.11	54.88	2.74
37	37.00	12.78	70.00	121.39	55.00	3.84
38	38.00	12.84	60.00	124.67	55.11	3.29
39	39.00	12.90	60.00	127.95	55.22	3.29
40	40.00	12.96	60.00	131.23	55.33	3.29
41	41.00	13.01	50.00	134.51	55.42	2.74
42	42.00	13.08	70.00	137.79	55.54	3.84
43	43.00	13.14	60.00	141.07	55.65	3.29
44	44.00	13.20	60.00	144.36	55.76	3.29
45	45.00	13.27	70.00	147.64	55.89	3.84
46	46.00	13.33	60.00	150.92	55.99	3.29
47	47.00	13.39	60.00	154.20	56.10	3.29
48	48.00	13.45	60.00	157.48	56.21	3.29
49	49.00	13.50	50.00	160.76	56.30	2.74
50	50.00	13.57	70.00	164.04	56.43	3.84

SD - 10 Belvidere South Dakota

	DEPTH meters	TEMPERATURE deg Celsius	GRADIENT K/km	DEPTH feet	TEMPERATURE deg F.	GRADIENT deg F/100'
51	51.00	13.63	60.00	167.32	56.53	3.29
52	52.00	13.69	60.00	170.60	56.64	3.29
53	53.00	13.78	90.00	173.88	56.80	4.94
54	54.00	13.82	40.00	177.16	56.88	2.19
55	55.00	13.88	60.00	180.44	56.98	3.29
56	56.00	13.90	20.00	183.72	57.02	1.10
57	57.00	13.95	50.00	187.01	57.11	2.74
58	58.00	14.05	100.00	190.29	57.29	5.49
59	59.00	14.11	60.00	193.57	57.40	3.29
60	60.00	14.17	60.00	196.85	57.51	3.29
61	61.00	14.23	60.00	200.13	57.61	3.29
62	62.00	14.29	60.00	203.41	57.72	3.29
63	63.00	14.35	60.00	206.69	57.83	3.29
64	64.00	14.42	70.00	209.97	57.96	3.84
65	65.00	14.48	60.00	213.25	58.06	3.29
66	66.00	14.54	60.00	216.53	58.17	3.29
67	67.00	14.60	60.00	219.81	58.28	3.29
68	68.00	14.65	50.00	223.09	58.37	2.74
69	69.00	14.71	60.00	226.38	58.48	3.29
70	70.00	14.76	50.00	229.66	58.57	2.74
71	71.00	14.81	50.00	232.94	58.66	2.74
72	72.00	14.87	60.00	236.22	58.77	3.29
73	73.00	14.93	60.00	239.50	58.87	3.29
74	74.00	14.98	50.00	242.78	58.96	2.74
75	75.00	15.04	60.00	246.06	59.07	3.29
76	76.00	15.09	50.00	249.34	59.16	2.74
77	77.00	15.15	60.00	252.62	59.27	3.29
78	78.00	15.21	60.00	255.90	59.38	3.29
79	79.00	15.27	60.00	259.18	59.49	3.29
80	80.00	15.32	50.00	262.46	59.58	2.74
81	81.00	15.38	60.00	265.74	59.68	3.29
82	82.00	15.44	60.00	269.03	59.79	3.29
83	83.00	15.49	50.00	272.31	59.88	2.74
84	84.00	15.55	60.00	275.59	59.99	3.29
85	85.00	15.61	60.00	278.87	60.10	3.29
86	86.00	15.67	60.00	282.15	60.21	3.29
87	87.00	15.73	60.00	285.43	60.31	3.29
88	88.00	15.79	60.00	288.71	60.42	3.29
89	89.00	15.85	60.00	291.99	60.53	3.29
90	90.00	15.90	50.00	295.27	60.62	2.74
91	91.00	15.95	50.00	298.55	60.71	2.74
92	92.00	16.01	60.00	301.83	60.82	3.29
93	93.00	16.07	60.00	305.11	60.93	3.29
94	94.00	16.13	60.00	308.40	61.03	3.29
95	95.00	16.19	60.00	311.68	61.14	3.29
96	96.00	16.24	50.00	314.96	61.23	2.74
97	97.00	16.30	60.00	318.24	61.34	3.29
98	98.00	16.35	50.00	321.52	61.43	2.74
99	99.00	16.42	70.00	324.80	61.56	3.84
100	100.00	16.48	60.00	328.08	61.66	3.29
101	101.00	16.54	60.00	331.36	61.77	3.29

SD - 10 Belvidere South Dakota

	DEPTH meters	TEMPERATURE deg Celsius	GRADIENT K/km	DEPTH feet	TEMPERATURE deg F.	GRADIENT deg F/100'
102	102.00	16.60	60.00	334.64	61.88	3.29
103	103.00	16.65	50.00	337.92	61.97	2.74
104	104.00	16.73	80.00	341.20	62.11	4.39
105	105.00	16.79	60.00	344.48	62.22	3.29
106	106.00	16.85	60.00	347.76	62.33	3.29
107	107.00	16.92	70.00	351.05	62.46	3.84
108	108.00	16.97	50.00	354.33	62.55	2.74
109	109.00	17.02	50.00	357.61	62.64	2.74
110	110.00	17.10	80.00	360.89	62.78	4.39
111	111.00	17.16	60.00	364.17	62.89	3.29
112	112.00	17.22	60.00	367.45	63.00	3.29
113	113.00	17.28	60.00	370.73	63.10	3.29
114	114.00	17.36	80.00	374.01	63.25	4.39
115	115.00	17.42	60.00	377.29	63.36	3.29
116	116.00	17.48	60.00	380.57	63.46	3.29
117	117.00	17.55	70.00	383.85	63.59	3.84
118	118.00	17.61	60.00	387.13	63.70	3.29
119	119.00	17.68	70.00	390.42	63.82	3.84
120	120.00	17.74	60.00	393.70	63.93	3.29
121	121.00	17.82	80.00	396.98	64.08	4.39
122	122.00	17.89	70.00	400.26	64.20	3.84
123	123.00	17.94	50.00	403.54	64.29	2.74
124	124.00	18.00	60.00	406.82	64.40	3.29
125	125.00	18.06	60.00	410.10	64.51	3.29
126	126.00	18.12	60.00	413.38	64.62	3.29
127	127.00	18.19	70.00	416.66	64.74	3.84
128	128.00	18.25	60.00	419.94	64.85	3.29
129	129.00	18.34	90.00	423.22	65.01	4.94
130	130.00	18.38	40.00	426.50	65.08	2.19
131	131.00	18.47	90.00	429.78	65.25	4.94
132	132.00	18.52	50.00	433.07	65.34	2.74
133	133.00	18.59	70.00	436.35	65.46	3.84
134	134.00	18.67	80.00	439.63	65.61	4.39
135	135.00	18.73	60.00	442.91	65.71	3.29
136	136.00	18.80	70.00	446.19	65.84	3.84
137	137.00	18.86	60.00	449.47	65.95	3.29
138	138.00	18.95	90.00	452.75	66.11	4.94
139	139.00	19.00	50.00	456.03	66.20	2.74
140	140.00	19.07	70.00	459.31	66.33	3.84
141	141.00	19.14	70.00	462.59	66.45	3.84
142	142.00	19.21	70.00	465.87	66.58	3.84
143	143.00	19.27	60.00	469.15	66.69	3.29
144	144.00	19.33	60.00	472.44	66.79	3.29
145	145.00	19.41	80.00	475.72	66.94	4.39
146	146.00	19.47	60.00	479.00	67.05	3.29
147	147.00	19.53	60.00	482.28	67.15	3.29
148	148.00	19.59	60.00	485.56	67.26	3.29
149	149.00	19.68	90.00	488.84	67.42	4.94
150	150.00	19.74	60.00	492.12	67.53	3.29
151	151.00	19.82	80.00	495.40	67.68	4.39
152	152.00	19.88	60.00	498.68	67.78	3.29

SD - 10 Belvidere South Dakota

	DEPTH meters	TEMPERATURE deg Celsius	GRADIENT K/km	DEPTH feet	TEMPERATURE deg F.	GRADIENT deg F/100'
153	153.00	19.95	70.00	501.96	67.91	3.84
154	154.00	20.03	80.00	505.24	68.05	4.39
155	155.00	20.09	60.00	508.52	68.16	3.29
156	156.00	20.09	0.00	511.80	68.16	0.00
157	157.00	20.23	140.00	515.09	68.41	7.68
158	158.00	20.31	80.00	518.37	68.56	4.39
159	159.00	20.39	80.00	521.65	68.70	4.39
160	160.00	20.45	60.00	524.93	68.81	3.29
161	161.00	20.51	60.00	528.21	68.92	3.29
162	162.00	20.60	90.00	531.49	69.08	4.94
163	163.00	20.66	60.00	534.77	69.19	3.29
164	164.00	20.71	50.00	538.05	69.28	2.74
165	165.00	20.80	90.00	541.33	69.44	4.94
166	166.00	20.85	50.00	544.61	69.53	2.74
167	167.00	20.92	70.00	547.89	69.66	3.84
168	168.00	20.99	70.00	551.17	69.78	3.84
169	169.00	21.05	60.00	554.46	69.89	3.29
170	170.00	21.12	70.00	557.74	70.02	3.84
171	171.00	21.19	70.00	561.02	70.14	3.84
172	172.00	21.26	70.00	564.30	70.27	3.84
173	173.00	21.32	60.00	567.58	70.38	3.29
174	174.00	21.39	70.00	570.86	70.50	3.84
175	175.00	21.45	60.00	574.14	70.61	3.29
176	176.00	21.54	90.00	577.42	70.77	4.94
177	177.00	21.59	50.00	580.70	70.86	2.74
178	178.00	21.67	80.00	583.98	71.01	4.39
179	179.00	21.74	70.00	587.26	71.13	3.84
180	180.00	21.82	80.00	590.54	71.28	4.39
181	181.00	21.89	70.00	593.82	71.40	3.84
182	182.00	21.94	50.00	597.11	71.49	2.74
183	183.00	22.03	90.00	600.39	71.65	4.94

SD - 11 Kadoka

	DEPTH meters	TEMPERATURE deg Celsius	GRADIENT K/km	DEPTH feet	TEMPERATURE deg F.	GRADIENT deg F/100'
1	1.00	19.02	0.00	3.28	66.24	0.00
2	2.00	15.73	-3290.00	6.56	60.31	-180.50
3	3.00	13.36	-2370.00	9.84	56.05	-130.03
4	4.00	12.01	-1350.00	13.12	53.62	-74.07
5	5.00	11.33	-680.00	16.40	52.39	-37.31
6	6.00	11.18	-150.00	19.68	52.12	-8.23
7	7.00	11.27	90.00	22.97	52.29	4.94
8	8.00	11.41	140.00	26.25	52.54	7.68
9	9.00	11.52	110.00	29.53	52.74	6.04
10	10.00	11.54	20.00	32.81	52.77	1.10
11	11.00	11.56	20.00	36.09	52.81	1.10
12	12.00	11.57	10.00	39.37	52.83	0.55
13	13.00	11.58	10.00	42.65	52.84	0.55
14	14.00	11.58	0.00	45.93	52.84	0.00
15	15.00	11.58	0.00	49.21	52.84	0.00
16	16.00	11.59	10.00	52.49	52.86	0.55
17	17.00	11.61	20.00	55.77	52.90	1.10
18	18.00	11.63	20.00	59.05	52.93	1.10
19	19.00	11.64	10.00	62.34	52.95	0.55
20	20.00	11.66	20.00	65.62	52.99	1.10
21	21.00	11.68	20.00	68.90	53.02	1.10
22	22.00	11.70	20.00	72.18	53.06	1.10
23	23.00	11.73	30.00	75.46	53.11	1.65
24	24.00	11.75	20.00	78.74	53.15	1.10
25	25.00	11.78	30.00	82.02	53.20	1.65
26	26.00	11.81	30.00	85.30	53.26	1.65
27	27.00	11.84	30.00	88.58	53.31	1.65
28	28.00	11.87	30.00	91.86	53.37	1.65
29	29.00	11.90	30.00	95.14	53.42	1.65
30	30.00	11.93	30.00	98.42	53.47	1.65
31	31.00	11.97	40.00	101.70	53.55	2.19
32	32.00	12.00	30.00	104.99	53.60	1.65
33	33.00	11.98	-20.00	108.27	53.56	-1.10
34	34.00	12.06	80.00	111.55	53.71	4.39
35	35.00	12.10	40.00	114.83	53.78	2.19
36	36.00	12.13	30.00	118.11	53.83	1.65
37	37.00	12.17	40.00	121.39	53.91	2.19
38	38.00	12.21	40.00	124.67	53.98	2.19
39	39.00	12.24	30.00	127.95	54.03	1.65
40	40.00	12.28	40.00	131.23	54.10	2.19
41	41.00	12.32	40.00	134.51	54.18	2.19
42	42.00	12.36	40.00	137.79	54.25	2.19
43	43.00	12.39	30.00	141.07	54.30	1.65
44	44.00	12.44	50.00	144.36	54.39	2.74
45	45.00	12.47	30.00	147.64	54.45	1.65
46	46.00	12.52	50.00	150.92	54.54	2.74
47	47.00	12.56	40.00	154.20	54.61	2.19
48	48.00	12.60	40.00	157.48	54.68	2.19
49	49.00	12.65	50.00	160.76	54.77	2.74
50	50.00	12.68	30.00	164.04	54.82	1.65

SD - 11 Kadoka

	DEPTH meters	TEMPERATURE deg Celsius	GRADIENT K/km	DEPTH feet	TEMPERATURE deg F.	GRADIENT deg F/100'
51	51.00	12.72	40.00	167.32	54.90	2.19
52	52.00	12.77	50.00	170.60	54.99	2.74
53	53.00	12.81	40.00	173.88	55.06	2.19
54	54.00	12.86	50.00	177.16	55.15	2.74
55	55.00	12.91	50.00	180.44	55.24	2.74
56	56.00	12.95	40.00	183.72	55.31	2.19
57	57.00	12.99	40.00	187.01	55.38	2.19
58	58.00	13.04	50.00	190.29	55.47	2.74
59	59.00	13.09	50.00	193.57	55.56	2.74
60	60.00	13.13	40.00	196.85	55.63	2.19
61	61.00	13.18	50.00	200.13	55.72	2.74
62	62.00	13.22	40.00	203.41	55.80	2.19
63	63.00	13.27	50.00	206.69	55.89	2.74
64	64.00	13.32	50.00	209.97	55.98	2.74
65	65.00	13.37	50.00	213.25	56.07	2.74
66	66.00	13.40	30.00	216.53	56.12	1.65
67	67.00	13.46	60.00	219.81	56.23	3.29
68	68.00	13.52	60.00	223.09	56.34	3.29
69	69.00	13.60	80.00	226.38	56.48	4.39
70	70.00	13.63	30.00	229.66	56.53	1.65
71	71.00	13.64	10.00	232.94	56.55	0.55
72	72.00	13.66	20.00	236.22	56.59	1.10
73	73.00	13.73	70.00	239.50	56.71	3.84
74	74.00	13.81	80.00	242.78	56.86	4.39
75	75.00	13.86	50.00	246.06	56.95	2.74
76	76.00	13.91	50.00	249.34	57.04	2.74
77	77.00	13.96	50.00	252.62	57.13	2.74
78	78.00	13.99	30.00	255.90	57.18	1.65
79	79.00	14.05	60.00	259.18	57.29	3.29
80	80.00	14.09	40.00	262.46	57.36	2.19
81	81.00	14.14	50.00	265.74	57.45	2.74
82	82.00	14.19	50.00	269.03	57.54	2.74
83	83.00	14.24	50.00	272.31	57.63	2.74
84	84.00	14.29	50.00	275.59	57.72	2.74
85	85.00	14.34	50.00	278.87	57.81	2.74
86	86.00	14.38	40.00	282.15	57.88	2.19
87	87.00	14.43	50.00	285.43	57.97	2.74
88	88.00	14.48	50.00	288.71	58.06	2.74
89	89.00	14.53	50.00	291.99	58.15	2.74
90	90.00	14.58	50.00	295.27	58.24	2.74
91	91.00	14.63	50.00	298.55	58.33	2.74
92	92.00	14.68	50.00	301.83	58.42	2.74
93	93.00	14.73	50.00	305.11	58.51	2.74
94	94.00	14.77	40.00	308.40	58.59	2.19
95	95.00	14.82	50.00	311.68	58.68	2.74
96	96.00	14.87	50.00	314.96	58.77	2.74
97	97.00	14.92	50.00	318.24	58.86	2.74
98	98.00	14.97	50.00	321.52	58.95	2.74
99	99.00	15.02	50.00	324.80	59.04	2.74
100	100.00	15.07	50.00	328.08	59.13	2.74
101	101.00	15.12	50.00	331.36	59.22	2.74

	DEPTH meters	TEMPERATURE deg Celsius	GRADIENT K/km	DEPTH feet	TEMPERATURE deg F.	GRADIENT deg F/100'
102	102.00	15.17	50.00	334.64	59.31	2.74
103	103.00	15.22	50.00	337.92	59.40	2.74
104	104.00	15.26	40.00	341.20	59.47	2.19
105	105.00	15.31	50.00	344.48	59.56	2.74
106	106.00	15.36	50.00	347.76	59.65	2.74
107	107.00	15.41	50.00	351.05	59.74	2.74
108	108.00	15.45	40.00	354.33	59.81	2.19
109	109.00	15.50	50.00	357.61	59.90	2.74
110	110.00	15.55	50.00	360.89	59.99	2.74
111	111.00	15.60	50.00	364.17	60.08	2.74
112	112.00	15.65	50.00	367.45	60.17	2.74
113	113.00	15.70	50.00	370.73	60.26	2.74
114	114.00	15.75	50.00	374.01	60.35	2.74
115	115.00	15.80	50.00	377.29	60.44	2.74
116	116.00	15.86	60.00	380.57	60.55	3.29
117	117.00	15.90	40.00	383.85	60.62	2.19
118	118.00	15.95	50.00	387.13	60.71	2.74
119	119.00	16.01	60.00	390.42	60.82	3.29
120	120.00	16.05	40.00	393.70	60.89	2.19
121	121.00	16.11	60.00	396.98	61.00	3.29
122	122.00	16.16	50.00	400.26	61.09	2.74
123	123.00	16.21	50.00	403.54	61.18	2.74
124	124.00	16.25	40.00	406.82	61.25	2.19
125	125.00	16.30	50.00	410.10	61.34	2.74
126	126.00	16.35	50.00	413.38	61.43	2.74
127	127.00	16.40	50.00	416.66	61.52	2.74
128	128.00	16.45	50.00	419.94	61.61	2.74
129	129.00	16.50	50.00	423.22	61.70	2.74
130	130.00	16.54	40.00	426.50	61.77	2.19
131	131.00	16.59	50.00	429.78	61.86	2.74
132	132.00	16.64	50.00	433.07	61.95	2.74
133	133.00	16.69	50.00	436.35	62.04	2.74
134	134.00	16.74	50.00	439.63	62.13	2.74
135	135.00	16.79	50.00	442.91	62.22	2.74
136	136.00	16.84	50.00	446.19	62.31	2.74
137	137.00	16.93	90.00	449.47	62.47	4.94
138	138.00	16.96	30.00	452.75	62.53	1.65
139	139.00	16.98	20.00	456.03	62.56	1.10
140	140.00	17.02	40.00	459.31	62.64	2.19
141	141.00	17.08	60.00	462.59	62.74	3.29
142	142.00	17.15	70.00	465.87	62.87	3.84
143	143.00	17.20	50.00	469.15	62.96	2.74
144	144.00	17.25	50.00	472.44	63.05	2.74
145	145.00	17.30	50.00	475.72	63.14	2.74
146	146.00	17.35	50.00	479.00	63.23	2.74
147	147.00	17.41	60.00	482.28	63.34	3.29
148	148.00	17.46	50.00	485.56	63.43	2.74
149	149.00	17.51	50.00	488.84	63.52	2.74
150	150.00	17.56	50.00	492.12	63.61	2.74
151	151.00	17.61	50.00	495.40	63.70	2.74
152	152.00	17.65	40.00	498.68	63.77	2.19

SD - 11 Kadoka

	DEPTH meters	TEMPERATURE deg Celsius	GRADIENT K/km	DEPTH feet	TEMPERATURE deg F.	GRADIENT deg F/100'
153	153.00	17.70	50.00	501.96	63.86	2.74
154	154.00	17.75	50.00	505.24	63.95	2.74
155	155.00	17.80	50.00	508.52	64.04	2.74
156	156.00	17.85	50.00	511.80	64.13	2.74
157	157.00	17.91	60.00	515.09	64.24	3.29
158	158.00	17.95	40.00	518.37	64.31	2.19
159	159.00	18.01	60.00	521.65	64.42	3.29
160	160.00	18.06	50.00	524.93	64.51	2.74
161	161.00	18.11	50.00	528.21	64.60	2.74
162	162.00	18.17	60.00	531.49	64.71	3.29
163	163.00	18.22	50.00	534.77	64.80	2.74
164	164.00	18.28	60.00	538.05	64.90	3.29
165	165.00	18.33	50.00	541.33	64.99	2.74
166	166.00	18.38	50.00	544.61	65.08	2.74
167	167.00	18.43	50.00	547.89	65.17	2.74
168	168.00	18.48	50.00	551.17	65.26	2.74
169	169.00	18.54	60.00	554.46	65.37	3.29
170	170.00	18.59	50.00	557.74	65.46	2.74
171	171.00	18.64	50.00	561.02	65.55	2.74
172	172.00	18.69	50.00	564.30	65.64	2.74
173	173.00	18.75	60.00	567.58	65.75	3.29
174	174.00	18.80	50.00	570.86	65.84	2.74
175	175.00	18.86	60.00	574.14	65.95	3.29
176	176.00	18.91	50.00	577.42	66.04	2.74
177	177.00	18.96	50.00	580.70	66.13	2.74
178	178.00	19.01	50.00	583.98	66.22	2.74
179	179.00	19.06	50.00	587.26	66.31	2.74
180	180.00	19.12	60.00	590.54	66.42	3.29
181	181.00	19.16	40.00	593.82	66.49	2.19
182	182.00	19.21	50.00	597.11	66.58	2.74
183	183.00	19.23	20.00	600.39	66.61	1.10

SD - 12

Wall South Dakota

	DEPTH meters	TEMPERATURE deg Celsius	GRADIENT K/km	DEPTH feet	TEMPERATURE deg F.	GRADIENT deg F/100'
1	1.00	19.61	0.00	3.28	67.30	0.00
2	2.00	15.21	-4400.00	6.56	59.38	-241.40
3	3.00	12.62	-2590.00	9.84	54.72	-142.10
4	4.00	11.17	-1450.00	13.12	52.11	-79.55
5	5.00	10.35	-820.00	16.40	50.63	-44.99
6	6.00	10.14	-210.00	19.68	50.25	-11.52
7	7.00	10.24	100.00	22.97	50.43	5.49
8	8.00	10.36	120.00	26.25	50.65	6.58
9	9.00	10.45	90.00	29.53	50.81	4.94
10	10.00	10.47	20.00	32.81	50.85	1.10
11	11.00	10.45	-20.00	36.09	50.81	-1.10
12	12.00	10.43	-20.00	39.37	50.77	-1.10
13	13.00	10.43	0.00	42.65	50.77	0.00
14	14.00	10.41	-20.00	45.93	50.74	-1.10
15	15.00	10.40	-10.00	49.21	50.72	-0.55
16	16.00	10.39	-10.00	52.49	50.70	-0.55
17	17.00	10.39	0.00	55.77	50.70	0.00
18	18.00	10.39	0.00	59.05	50.70	0.00
19	19.00	10.40	10.00	62.34	50.72	0.55
20	20.00	10.39	-10.00	65.62	50.70	-0.55
21	21.00	10.39	0.00	68.90	50.70	0.00
22	22.00	10.38	-10.00	72.18	50.68	-0.55
23	23.00	10.38	0.00	75.46	50.68	0.00
24	24.00	10.38	0.00	78.74	50.68	0.00
25	25.00	10.39	10.00	82.02	50.70	0.55
26	26.00	10.40	10.00	85.30	50.72	0.55
27	27.00	10.41	10.00	88.58	50.74	0.55
28	28.00	10.42	10.00	91.86	50.76	0.55
29	29.00	10.43	10.00	95.14	50.77	0.55
30	30.00	10.45	20.00	98.42	50.81	1.10
31	31.00	10.46	10.00	101.70	50.83	0.55
32	32.00	10.47	10.00	104.99	50.85	0.55
33	33.00	10.49	20.00	108.27	50.88	1.10
34	34.00	10.50	10.00	111.55	50.90	0.55
35	35.00	10.52	20.00	114.83	50.94	1.10
36	36.00	10.53	10.00	118.11	50.95	0.55
37	37.00	10.55	20.00	121.39	50.99	1.10
38	38.00	10.56	10.00	124.67	51.01	0.55
39	39.00	10.53	20.00	127.95	51.04	1.10
40	40.00	10.60	20.00	131.23	51.08	1.10
41	41.00	10.62	20.00	134.51	51.12	1.10
42	42.00	10.63	10.00	137.79	51.13	0.55
43	43.00	10.65	20.00	141.07	51.17	1.10
44	44.00	10.67	20.00	144.36	51.21	1.10
45	45.00	10.69	20.00	147.64	51.24	1.10
46	46.00	10.71	20.00	150.92	51.28	1.10
47	47.00	10.73	20.00	154.20	51.31	1.10
48	48.00	10.74	10.00	157.48	51.33	0.55
49	49.00	10.76	20.00	160.76	51.37	1.10
50	50.00	10.79	30.00	164.04	51.42	1.65

SD - 12 Well South Dakota

	DEPTH meters	TEMPERATURE deg Celsius	GRADIENT K/km	DEPTH feet	TEMPERATURE deg F.	GRADIENT deg F/100'
51	51.00	10.81	20.00	167.32	51.46	1.10
52	52.00	10.83	20.00	170.60	51.49	1.10
53	53.00	10.85	20.00	173.88	51.53	1.10
54	54.00	10.87	20.00	177.16	51.57	1.10
55	55.00	10.89	20.00	180.44	51.60	1.10
56	56.00	10.91	20.00	183.72	51.64	1.10
57	57.00	10.94	30.00	187.01	51.69	1.65
58	58.00	10.96	20.00	190.29	51.73	1.10
59	59.00	10.98	20.00	193.57	51.76	1.10
60	60.00	11.01	30.00	196.85	51.82	1.65
61	61.00	11.03	20.00	200.13	51.85	1.10
62	62.00	11.05	20.00	203.41	51.89	1.10
63	63.00	11.08	30.00	206.69	51.94	1.65
64	64.00	11.10	20.00	209.97	51.98	1.10
65	65.00	11.13	30.00	213.25	52.03	1.65
66	66.00	11.15	20.00	216.53	52.07	1.10
67	67.00	11.18	30.00	219.81	52.12	1.65
68	68.00	11.20	20.00	223.09	52.16	1.10
69	69.00	11.23	30.00	226.38	52.21	1.65
70	70.00	11.25	20.00	229.66	52.25	1.10
71	71.00	11.28	30.00	232.94	52.30	1.65
72	72.00	11.31	30.00	236.22	52.36	1.65
73	73.00	11.33	20.00	239.50	52.39	1.10
74	74.00	11.36	30.00	242.78	52.45	1.65
75	75.00	11.39	30.00	246.06	52.50	1.65
76	76.00	11.41	20.00	249.34	52.54	1.10
77	77.00	11.44	30.00	252.62	52.59	1.65
78	78.00	11.47	30.00	255.90	52.65	1.65
79	79.00	11.50	30.00	259.18	52.70	1.65
80	80.00	11.53	30.00	262.46	52.75	1.65
81	81.00	11.56	30.00	265.74	52.81	1.65
82	82.00	11.59	30.00	269.03	52.86	1.65
83	83.00	11.61	20.00	272.31	52.90	1.10
84	84.00	11.64	30.00	275.59	52.95	1.65
85	85.00	11.67	30.00	278.87	53.01	1.65
86	86.00	11.70	30.00	282.15	53.06	1.65
87	87.00	11.74	40.00	285.43	53.13	2.19
88	88.00	11.76	20.00	288.71	53.17	1.10
89	89.00	11.79	30.00	291.99	53.22	1.65
90	90.00	11.82	30.00	295.27	53.28	1.65
91	91.00	11.85	30.00	298.55	53.33	1.65
92	92.00	11.88	30.00	301.83	53.38	1.65
93	93.00	11.91	30.00	305.11	53.44	1.65
94	94.00	11.94	30.00	308.40	53.49	1.65
95	95.00	11.97	30.00	311.68	53.55	1.65
96	96.00	12.01	40.00	314.96	53.62	2.19
97	97.00	12.04	30.00	318.24	53.67	1.65
98	98.00	12.07	30.00	321.52	53.73	1.65
99	99.00	12.10	30.00	324.80	53.78	1.65
100	100.00	12.13	30.00	328.08	53.83	1.65
101	101.00	12.16	30.00	331.36	53.89	1.65

SD - 12 Wall South Dakota

	DEPTH meters	TEMPERATURE deg Celsius	GRADIENT K/km	DEPTH feet	TEMPERATURE deg F.	GRADIENT deg F/100'
102	102.00	12.19	30.00	334.64	53.94	1.65
103	103.00	12.22	30.00	337.92	54.00	1.65
104	104.00	12.26	40.00	341.20	54.07	2.19
105	105.00	12.29	30.00	344.48	54.12	1.65
106	106.00	12.32	30.00	347.76	54.18	1.65
107	107.00	12.35	30.00	351.05	54.23	1.65
108	108.00	12.39	40.00	354.33	54.30	2.19
109	109.00	12.42	30.00	357.61	54.36	1.65
110	110.00	12.45	30.00	360.89	54.41	1.65
111	111.00	12.48	30.00	364.17	54.46	1.65
112	112.00	12.52	40.00	367.45	54.54	2.19
113	113.00	12.55	30.00	370.73	54.59	1.65
114	114.00	12.58	30.00	374.01	54.64	1.65
115	115.00	12.61	30.00	377.29	54.70	1.65
116	116.00	12.64	30.00	380.57	54.75	1.65
117	117.00	12.67	30.00	383.85	54.81	1.65
118	118.00	12.70	30.00	387.13	54.86	1.65
119	119.00	12.73	30.00	390.42	54.91	1.65
120	120.00	12.77	40.00	393.70	54.99	2.19
121	121.00	12.80	30.00	396.98	55.04	1.65
122	122.00	12.83	30.00	400.26	55.09	1.65
123	123.00	12.86	30.00	403.54	55.15	1.65
124	124.00	12.90	40.00	406.82	55.22	2.19
125	125.00	12.94	40.00	410.10	55.29	2.19
126	126.00	12.97	30.00	413.38	55.35	1.65
127	127.00	13.00	30.00	416.66	55.40	1.65
128	128.00	13.03	30.00	419.94	55.45	1.65
129	129.00	13.06	30.00	423.22	55.51	1.65
130	130.00	13.09	30.00	426.50	55.56	1.65
131	131.00	13.13	40.00	429.78	55.63	2.19
132	132.00	13.16	30.00	433.07	55.69	1.65
133	133.00	13.19	30.00	436.35	55.74	1.65
134	134.00	13.21	20.00	439.63	55.78	1.10
135	135.00	13.25	40.00	442.91	55.85	2.19
136	136.00	13.28	30.00	446.19	55.90	1.65
137	137.00	13.31	30.00	449.47	55.96	1.65
138	138.00	13.34	30.00	452.75	56.01	1.65
139	139.00	13.37	30.00	456.03	56.07	1.65
140	140.00	13.40	30.00	459.31	56.12	1.65
141	141.00	13.43	30.00	462.59	56.17	1.65
142	142.00	13.46	30.00	465.87	56.23	1.65
143	143.00	13.50	40.00	469.15	56.30	2.19
144	144.00	13.53	30.00	472.44	56.35	1.65
145	145.00	13.56	30.00	475.72	56.41	1.65
146	146.00	13.59	30.00	479.00	56.46	1.65
147	147.00	13.62	30.00	482.28	56.52	1.65
148	148.00	13.65	30.00	485.56	56.57	1.65
149	149.00	13.68	30.00	488.84	56.62	1.65
150	150.00	13.71	30.00	492.12	56.68	1.65
151	151.00	13.75	40.00	495.40	56.75	2.19
152	152.00	13.78	30.00	498.68	56.80	1.65

SD - 12 Wall South Dakota

	DEPTH meters	TEMPERATURE deg Celsius	GRADIENT K/km	DEPTH feet	TEMPERATURE deg F.	GRADIENT deg F/100'
153	153.00	13.82	40.00	501.96	56.88	2.19
154	154.00	13.85	30.00	505.24	56.93	1.65
155	155.00	13.89	40.00	508.52	57.00	2.19
156	156.00	13.92	30.00	511.80	57.06	1.65
157	157.00	13.95	30.00	515.09	57.11	1.65
158	158.00	13.99	40.00	518.37	57.18	2.19
159	159.00	14.02	30.00	521.65	57.24	1.65
160	160.00	14.05	30.00	524.93	57.29	1.65
161	161.00	14.08	30.00	528.21	57.34	1.65
162	162.00	14.11	30.00	531.49	57.40	1.65
163	163.00	14.15	40.00	534.77	57.47	2.19
164	164.00	14.18	30.00	538.05	57.52	1.65
165	165.00	14.21	30.00	541.33	57.58	1.65
166	166.00	14.24	30.00	544.61	57.63	1.65
167	167.00	14.27	30.00	547.89	57.69	1.65
168	168.00	14.31	40.00	551.17	57.76	2.19
169	169.00	14.34	30.00	554.46	57.81	1.65
170	170.00	14.37	30.00	557.74	57.87	1.65
171	171.00	14.40	30.00	561.02	57.92	1.65
172	172.00	14.44	40.00	564.30	57.99	2.19
173	173.00	14.47	30.00	567.58	58.05	1.65
174	174.00	14.50	30.00	570.86	58.10	1.65
175	175.00	14.54	40.00	574.14	58.17	2.19
176	176.00	14.57	30.00	577.42	58.23	1.65
177	177.00	14.61	40.00	580.70	58.30	2.19
178	178.00	14.64	30.00	583.98	58.35	1.65
179	179.00	14.68	40.00	587.26	58.42	2.19
180	180.00	14.71	30.00	590.54	58.48	1.65
181	181.00	14.74	30.00	593.82	58.53	1.65
182	182.00	14.78	40.00	597.11	58.60	2.19
183	183.00	14.79	10.00	600.39	58.62	0.55

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APPENDIX B

**TEMPERATURE DEPTH DATA AND PLOTS FOR SOUTH DAKOTA
"HOLES OF OPPORTUNITY"**

AU79F

	DEPTH meters	TEMPERATURE deg Celsius	GRADIENT K/km	DEPTH feet	TEMPERATURE deg F.	GRADIENT deg F/100'
1	11.00	10.22	0.00	36.09	50.40	0.00
2	12.00	10.00	-218.87	39.37	50.01	-12.01
3	13.00	10.01	11.01	42.65	50.03	0.60
4	14.00	10.01	-4.39	45.93	50.02	-0.24
5	15.00	10.01	2.20	49.21	50.02	0.12
6	16.00	10.02	8.85	52.49	50.04	0.49
7	17.00	10.03	13.21	55.77	50.06	0.72
8	18.00	10.05	17.64	59.05	50.09	0.97
9	19.00	10.07	17.67	62.34	50.13	0.97
10	20.00	10.09	22.09	65.62	50.16	1.21
11	21.00	10.11	19.90	68.90	50.20	1.09
12	22.00	10.13	22.10	72.18	50.24	1.21
13	23.00	10.16	22.15	75.46	50.28	1.22
14	24.00	10.18	22.13	78.74	50.32	1.21
15	25.00	10.20	19.92	82.02	50.36	1.09
16	26.00	10.22	22.19	85.30	50.40	1.22
17	27.00	10.24	24.35	88.58	50.44	1.34
18	28.00	10.27	22.19	91.86	50.48	1.22
19	29.00	10.30	28.84	95.14	50.53	1.58
20	30.00	10.32	20.02	98.42	50.57	1.10
21	31.00	10.34	24.41	101.70	50.61	1.34
22	32.00	10.36	22.25	104.99	50.65	1.22
23	33.00	10.38	20.02	108.27	50.69	1.10
24	34.00	10.40	20.02	111.55	50.72	1.10
25	35.00	10.42	22.25	114.83	50.76	1.22
26	36.00	10.45	24.50	118.11	50.81	1.34
27	37.00	10.48	26.77	121.39	50.86	1.47
28	38.00	10.50	26.76	124.67	50.90	1.47
29	39.00	10.53	24.57	127.95	50.95	1.35
30	40.00	10.55	24.53	131.23	50.99	1.35
31	41.00	10.58	26.83	134.51	51.04	1.47
32	42.00	10.60	24.56	137.79	51.09	1.35
33	43.00	10.63	26.86	141.07	51.13	1.47
34	44.00	10.66	26.89	144.36	51.18	1.48
35	45.00	10.68	26.88	147.64	51.23	1.47
36	46.00	10.71	26.89	150.92	51.28	1.48
37	47.00	10.74	26.91	154.20	51.33	1.48
38	48.00	10.76	24.69	157.48	51.37	1.35
39	49.00	10.79	24.69	160.76	51.42	1.35
40	50.00	10.81	24.72	164.04	51.46	1.36
41	55.00	10.94	25.66	180.44	51.69	1.41
42	60.00	11.06	24.39	196.85	51.91	1.34
43	65.00	11.17	22.64	213.25	52.11	1.24
44	70.00	11.28	21.81	229.66	52.31	1.20
45	75.00	11.39	21.39	246.06	52.50	1.17
46	80.00	11.48	18.71	262.46	52.67	1.03
47	85.00	11.57	17.85	278.87	52.83	0.98
48	90.00	11.67	20.18	295.27	53.01	1.11
49	95.00	11.77	19.76	311.68	53.19	1.08
50	100.00	11.87	18.43	328.08	53.36	1.01

AU79F

	DEPTH meters	TEMPERATURE deg Celsius	GRADIENT K/km	DEPTH feet	TEMPERATURE deg F.	GRADIENT deg F/100'
51	104.00	11.94	19.62	341.20	53.50	1.08

AU78L

	DEPTH meters	TEMPERATURE deg Celsius	GRADIENT K/km	DEPTH feet	TEMPERATURE deg F.	GRADIENT deg F/100'
1	64.00	10.65	0.00	209.97	51.17	0.00
2	65.00	10.52	-136.41	213.25	50.93	-7.48
3	70.00	10.58	12.96	229.66	51.04	0.71
4	75.00	10.69	21.48	246.06	51.24	1.18
5	80.00	10.76	14.81	262.46	51.37	0.81
6	85.00	10.86	19.32	278.87	51.55	1.06
7	90.00	10.96	19.83	295.27	51.72	1.09
8	95.00	11.06	20.33	311.68	51.91	1.12
9	100.00	11.16	20.37	328.08	52.09	1.12
10	105.00	11.28	24.07	344.48	52.31	1.32
11	110.00	11.37	17.74	360.89	52.47	0.97
12	115.00	11.49	23.74	377.29	52.68	1.30
13	120.00	11.59	21.05	393.70	52.87	1.15
14	125.00	11.71	22.95	410.10	53.08	1.26
15	130.00	11.80	18.86	426.50	53.25	1.03
16	135.00	11.87	12.91	442.91	53.36	0.71
17	140.00	11.97	19.86	459.31	53.54	1.09
18	141.00	11.98	13.86	462.59	53.57	0.76

TD790

	DEPTH meters	TEMPERATURE deg Celsius	GRADIENT K/km	DEPTH feet	TEMPERATURE deg F.	GRADIENT deg F/100'
1	14.00	11.71	0.00	45.93	53.07	0.00
2	15.00	11.68	-25.20	49.21	53.03	-1.38
3	20.00	11.77	17.47	65.62	53.18	0.96
4	25.00	11.75	-2.76	82.02	53.16	-0.15
5	30.00	11.91	30.41	98.42	53.43	1.67
6	31.00	12.44	532.32	101.70	54.39	29.21
7	32.00	13.71	1272.89	104.99	56.68	69.84
8	33.00	15.61	1899.44	108.27	60.10	104.21
9	34.00	16.45	841.28	111.55	61.62	46.16
10	35.00	16.58	125.61	114.83	61.84	6.89
11	36.00	16.67	91.89	118.11	62.01	5.04
12	37.00	16.71	39.46	121.39	62.08	2.17
13	38.00	16.72	10.53	124.67	62.10	0.58
14	39.00	16.78	60.61	127.95	62.21	3.33
15	40.00	16.87	89.75	131.23	62.37	4.92
16	41.00	16.91	39.73	134.51	62.44	2.18
17	42.00	16.94	26.49	137.79	62.49	1.45
18	45.00	17.03	30.05	147.64	62.65	1.65
19	50.00	17.20	34.63	164.04	62.96	1.90
20	55.00	17.32	23.00	180.44	63.17	1.26
21	60.00	17.40	17.17	196.85	63.32	0.94
22	65.00	17.47	13.45	213.25	63.44	0.74
23	70.00	17.60	26.97	229.66	63.69	1.48
24	75.00	17.77	33.04	246.06	63.98	1.81
25	80.00	17.89	25.04	262.46	64.21	1.37
26	85.00	17.94	9.27	278.87	64.29	0.51
27	90.00	18.05	22.43	295.27	64.49	1.23
28	95.00	18.52	94.34	311.68	65.34	5.18
29	98.80	18.79	71.24	324.14	65.83	3.91

BT78C

	DEPTH meters	TEMPERATURE deg Celsius	GRADIENT K/km	DEPTH feet	TEMPERATURE deg F.	GRADIENT deg F/100'
1	12.00	10.28	0.00	39.37	50.51	0.00
2	15.00	10.22	-19.22	49.21	50.40	-1.05
3	20.00	10.44	44.00	65.62	50.80	2.41
4	25.00	10.64	38.86	82.02	51.15	2.13
5	30.00	10.97	66.97	98.42	51.75	3.67
6	35.00	11.30	65.70	114.83	52.34	3.60
7	40.00	11.60	60.27	131.23	52.89	3.31
8	45.00	11.87	52.88	147.64	53.36	2.90
9	50.00	12.18	62.99	164.04	53.93	3.46
10	55.00	12.47	57.40	180.44	54.45	3.15
11	60.00	12.63	32.85	196.85	54.74	1.80
12	65.00	13.09	91.33	213.25	55.56	5.01
13	70.00	13.32	46.80	229.66	55.98	2.57
14	75.00	13.59	52.39	246.06	56.46	2.87
15	80.00	13.86	55.19	262.46	56.95	3.03
16	85.00	14.16	59.51	278.87	57.49	3.27
17	90.00	14.46	60.50	295.27	58.03	3.32
18	95.00	14.78	62.99	311.68	58.60	3.46
19	100.00	15.00	44.98	328.08	59.00	2.47
20	105.00	15.31	61.42	344.48	59.56	3.37
21	110.00	15.61	59.41	360.89	60.09	3.26
22	115.00	15.93	64.03	377.29	60.67	3.51
23	120.00	16.25	64.10	393.70	61.24	3.52
24	121.50	16.38	86.73	398.62	61.48	4.76

BT80D

	DEPTH meters	TEMPERATURE deg Celsius	GRADIENT K/km	DEPTH feet	TEMPERATURE deg F.	GRADIENT deg F/100'
1	11.00	11.43	0.00	36.09	52.58	0.00
2	15.00	11.50	17.70	49.21	52.71	0.97
3	20.00	11.60	18.77	65.62	52.88	1.03
4	25.00	11.74	28.92	82.02	53.14	1.59
5	30.00	11.97	46.12	98.42	53.55	2.53
6	35.00	12.13	31.51	114.83	53.84	1.73
7	40.00	12.25	23.26	131.23	54.05	1.28
8	45.00	12.38	26.12	147.64	54.28	1.43
9	50.00	12.57	38.89	164.04	54.63	2.13
10	50.20	12.58	47.00	164.70	54.65	2.58

PE84B

	DEPTH meters	TEMPERATURE deg Celsius	GRADIENT K/km	DEPTH feet	TEMPERATURE deg F.	GRADIENT deg F/100'
1	28.00	10.59	0.00	91.86	51.06	0.00
2	30.00	10.52	-34.62	98.42	50.93	-1.90
3	35.00	10.53	1.79	114.83	50.95	0.10
4	40.00	10.62	19.22	131.23	51.12	1.05
5	45.00	10.72	19.26	147.64	51.29	1.06
6	50.00	10.80	15.72	164.04	51.44	0.86
7	55.00	10.88	16.64	180.44	51.59	0.91
8	60.00	10.96	15.77	196.85	51.73	0.87
9	65.00	11.01	10.84	213.25	51.83	0.59
10	70.00	11.11	19.44	229.66	52.00	1.07
11	75.00	11.18	14.06	246.06	52.13	0.77
12	80.00	11.26	14.98	262.46	52.26	0.82
13	85.00	11.32	13.64	278.87	52.38	0.75
14	90.00	11.38	10.93	295.27	52.48	0.60
15	95.00	11.45	13.23	311.68	52.60	0.73
16	100.00	11.50	10.05	328.08	52.69	0.55
17	105.00	11.56	13.27	344.48	52.81	0.73
18	110.00	11.64	16.50	360.89	52.96	0.91
19	115.00	11.72	15.61	377.29	53.10	0.86
20	120.00	11.79	12.87	393.70	53.22	0.71
21	125.00	11.86	14.75	410.10	53.35	0.81
22	130.00	11.93	13.39	426.50	53.47	0.73
23	135.00	11.99	11.56	442.91	53.57	0.63
24	140.00	12.03	8.80	459.31	53.65	0.48
25	145.00	12.07	7.87	475.72	53.72	0.43
26	150.00	12.13	11.60	492.12	53.83	0.64
27	155.00	12.20	13.94	508.52	53.95	0.76
28	160.00	12.26	13.04	524.93	54.07	0.72
29	165.00	12.29	5.60	541.33	54.12	0.31
30	170.00	12.34	10.26	557.74	54.21	0.56

AU79H

	DEPTH meters	TEMPERATURE deg Celsius	GRADIENT K/km	DEPTH feet	TEMPERATURE deg F.	GRADIENT deg F/100'
1	19.00	10.13	0.00	62.34	50.24	0.00
2	20.00	10.13	-2.20	65.62	50.23	-0.12
3	25.00	10.20	15.05	82.02	50.37	0.83
4	30.00	10.30	18.18	98.42	50.53	1.00
5	35.00	10.38	17.78	114.83	50.69	0.98
6	40.00	10.47	16.93	131.23	50.84	0.93
7	45.00	10.55	16.96	147.64	51.00	0.93
8	50.00	10.64	17.44	164.04	51.15	0.96
9	55.00	10.73	17.93	180.44	51.32	0.98
10	60.00	10.83	19.31	196.85	51.49	1.06
11	65.00	10.92	18.91	213.25	51.66	1.04
12	70.00	11.03	22.12	229.66	51.86	1.21
13	75.00	11.17	27.15	246.06	52.10	1.49
14	80.00	11.27	19.53	262.46	52.28	1.07
15	85.00	11.38	22.75	278.87	52.48	1.25
16	90.00	11.50	24.65	295.27	52.70	1.35
17	95.00	11.64	27.01	311.68	52.95	1.48
18	100.00	11.78	28.03	328.08	53.20	1.54
19	105.00	11.93	31.37	344.48	53.48	1.72
20	110.00	12.09	30.55	360.89	53.76	1.68
21	115.00	12.25	31.60	377.29	54.04	1.73
22	120.00	12.41	32.20	393.70	54.33	1.77
23	122.00	12.49	40.96	400.26	54.48	2.25

CU83B

	DEPTH meters	TEMPERATURE deg Celsius	GRADIENT K/km	DEPTH feet	TEMPERATURE deg F.	GRADIENT deg F/100'
1	9.00	10.50	0.00	29.53	50.90	0.00
2	10.00	10.67	165.44	32.81	51.20	9.08
3	15.00	10.95	57.08	49.21	51.71	3.13
4	20.00	11.01	12.64	65.62	51.83	0.69

BT79C

	DEPTH meters	TEMPERATURE deg Celsius	GRADIENT K/km	DEPTH feet	TEMPERATURE deg F.	GRADIENT deg F/100'
1	59.00	12.96	0.00	193.57	55.32	0.00
2	60.00	12.77	-189.30	196.85	54.98	-10.39
3	65.00	12.86	17.49	213.25	55.14	0.96
4	70.00	13.04	36.99	229.66	55.47	2.03
5	75.00	13.29	50.09	246.06	55.92	2.75
6	80.00	13.51	43.19	262.46	56.31	2.37
7	85.00	13.72	43.44	278.87	56.70	2.38
8	90.00	13.95	44.67	295.27	57.11	2.45
9	91.50	14.01	40.63	300.19	57.22	2.23

BT77E

	DEPTH meters	TEMPERATURE deg Celsius	GRADIENT K/km	DEPTH feet	TEMPERATURE deg F.	GRADIENT deg F/100'
1	8.00	10.18	0.00	26.25	50.32	0.00
2	10.00	10.29	56.52	32.81	50.53	3.10
3	15.00	10.50	41.85	49.21	50.90	2.30
4	20.00	10.78	54.61	65.62	51.40	3.00
5	25.00	11.03	50.46	82.02	51.85	2.77
6	30.00	11.27	49.40	98.42	52.29	2.71
7	35.00	11.56	57.48	114.83	52.81	3.15
8	40.00	11.80	47.30	131.23	53.24	2.59
9	45.00	12.03	47.11	147.64	53.66	2.58
10	50.00	12.31	55.79	164.04	54.16	3.06
11	55.00	12.63	63.24	180.44	54.73	3.47
12	60.00	13.04	81.81	196.85	55.47	4.49
13	65.00	13.40	73.08	213.25	56.13	4.01
14	70.00	13.69	56.85	229.66	56.64	3.12
15	75.00	14.02	67.04	246.06	57.24	3.68
16	80.00	14.34	62.73	262.46	57.81	3.44
17	85.00	14.67	67.25	278.87	58.41	3.69
18	90.00	15.02	69.38	295.27	59.04	3.81
19	95.00	15.34	63.48	311.68	59.61	3.48
20	100.00	15.65	62.51	328.08	60.17	3.43
21	105.00	15.97	64.63	344.48	60.75	3.55
22	110.00	16.28	61.58	360.89	61.31	3.38
23	115.00	16.62	67.39	377.29	61.91	3.70
24	120.00	16.90	56.40	393.70	62.42	3.09
25	125.00	17.16	52.08	410.10	62.89	2.86
26	130.00	17.40	47.10	426.50	63.31	2.58
27	135.00	17.77	74.54	442.91	63.98	4.09

JA80C

	DEPTH meters	TEMPERATURE deg Celsius	GRADIENT K/km	DEPTH feet	TEMPERATURE deg F.	GRADIENT deg F/100'
1	17.00	12.59	0.00	55.77	54.66	0.00
2	20.00	12.44	-47.68	65.62	54.40	-2.62
3	25.00	12.61	32.84	82.02	54.69	1.80
4	30.00	12.96	69.42	98.42	55.32	3.81
5	35.00	13.22	53.79	114.83	55.80	2.95
6	40.00	13.48	50.32	131.23	56.26	2.76
7	45.00	13.74	53.09	147.64	56.73	2.91
8	50.00	14.01	53.46	164.04	57.22	2.93
9	55.00	14.28	54.84	180.44	57.71	3.01
10	60.00	14.57	56.73	196.85	58.22	3.11
11	65.00	14.84	54.19	213.25	58.71	2.97
12	70.00	15.16	64.15	229.66	59.28	3.52
13	75.00	15.43	54.08	246.06	59.77	2.97
14	80.00	15.76	65.75	262.46	60.36	3.61
15	85.00	16.09	66.89	278.87	60.97	3.67
16	90.00	16.39	60.23	295.27	61.51	3.30
17	95.00	16.57	35.55	311.68	61.83	1.95
18	96.90	16.80	120.43	317.91	62.24	6.61

SN798

	DEPTH meters	TEMPERATURE deg Celsius	GRADIENT K/km	DEPTH feet	TEMPERATURE deg F.	GRADIENT deg F/100'
1	13.00	9.46	0.00	42.65	49.03	0.00
2	15.00	9.38	-40.25	49.21	48.89	-2.21
3	20.00	9.37	-3.05	65.62	48.86	-0.17
4	25.00	9.39	5.22	82.02	48.91	0.29
5	30.00	9.52	25.70	98.42	49.14	1.41
6	35.00	9.52	0.44	114.83	49.14	0.02
7	40.00	9.83	61.71	131.23	49.70	3.39
8	41.00	10.01	176.09	134.51	50.01	9.66
9	42.00	10.10	92.74	137.79	50.18	5.09
10	43.00	10.29	192.69	141.07	50.53	10.57
11	44.00	10.38	82.25	144.36	50.68	4.51
12	45.00	10.52	149.32	147.64	50.94	8.19
13	50.00	11.00	94.73	164.04	51.80	5.20
14	55.00	11.50	99.49	180.44	52.69	5.46
15	60.00	11.96	93.79	196.85	53.54	5.15
16	63.00	12.28	103.69	206.69	54.10	5.69

BT770

	DEPTH meters	TEMPERATURE deg Celsius	GRADIENT K/km	DEPTH feet	TEMPERATURE deg F.	GRADIENT deg F/100'
1	9.00	9.87	0.00	29.53	49.76	0.00
2	10.00	9.67	-201.78	32.81	49.40	-11.07
3	11.00	9.66	-6.53	36.09	49.39	-0.36
4	12.00	9.66	4.36	39.37	49.39	0.24
5	13.00	9.67	10.96	42.65	49.41	0.60
6	14.00	9.69	19.68	45.93	49.45	1.08
7	15.00	9.72	26.28	49.21	49.50	1.44
8	16.00	9.73	6.59	52.49	49.51	0.36
9	17.00	9.72	-4.36	55.77	49.50	-0.24
10	18.00	9.73	8.73	59.05	49.52	0.48
11	19.00	9.75	21.94	62.34	49.55	1.20
12	20.00	9.77	19.71	65.62	49.59	1.08
13	21.00	9.80	26.34	68.90	49.64	1.45
14	22.00	9.83	32.90	72.18	49.70	1.80
15	23.00	9.86	24.20	75.46	49.74	1.33
16	24.00	9.87	17.58	78.74	49.77	0.96
17	25.00	9.90	22.00	82.02	49.81	1.21
18	26.00	9.91	15.41	85.30	49.84	0.85
19	27.00	9.91	2.20	88.58	49.84	0.12
20	28.00	9.91	0.00	91.86	49.84	0.00
21	29.00	9.91	-6.62	95.14	49.83	-0.36
22	30.00	9.92	8.82	98.42	49.85	0.48
23	35.00	10.02	20.26	114.83	50.03	1.11
24	40.00	10.03	3.09	131.23	50.06	0.17
25	45.00	10.09	11.49	147.64	50.16	0.63
26	50.00	10.15	12.82	164.04	50.28	0.70
27	55.00	10.38	45.26	180.44	50.68	2.48
28	60.00	10.62	47.74	196.85	51.11	2.62
29	65.00	11.23	123.05	213.25	52.22	6.75
30	70.00	11.92	137.87	229.66	53.46	7.56
31	75.00	12.54	122.44	246.06	54.56	6.72
32	80.00	13.08	108.20	262.46	55.54	5.94
33	85.00	13.48	81.33	278.87	56.27	4.46
34	90.00	13.81	66.19	295.27	56.87	3.63
35	95.00	14.08	54.06	311.68	57.35	2.97
36	100.00	14.39	61.36	328.08	57.90	3.37
37	105.00	14.81	84.27	344.48	58.66	4.62
38	110.00	15.03	43.52	360.89	59.05	2.39
39	115.00	15.27	47.81	377.29	59.48	2.62
40	116.50	15.37	69.13	382.21	59.67	3.79

BT78E

	DEPTH meters	TEMPERATURE deg Celsius	GRADIENT K/km	DEPTH feet	TEMPERATURE deg F.	GRADIENT deg F/100'
1	25.00	11.87	0.00	82.02	53.37	0.00
2	30.00	12.08	41.64	98.42	53.75	2.28
3	35.00	12.38	58.66	114.83	54.28	3.22
4	40.00	12.61	46.40	131.23	54.69	2.55
5	45.00	12.92	61.83	147.64	55.25	3.39
6	50.00	13.31	78.11	164.04	55.95	4.29
7	55.00	13.55	48.51	180.44	56.39	2.66
8	60.00	13.88	65.33	196.85	56.98	3.58
9	65.00	14.17	58.06	213.25	57.50	3.19
10	70.00	14.42	50.15	229.66	57.95	2.75
11	75.00	14.73	61.42	246.06	58.51	3.37
12	80.00	15.01	56.94	262.46	59.02	3.12
13	85.00	15.28	54.85	278.87	59.51	3.01
14	90.00	15.68	78.25	295.27	60.22	4.29
15	90.40	15.76	210.95	296.58	60.37	11.57

BT77F

	DEPTH meters	TEMPERATURE deg Celsius	GRADIENT K/km	DEPTH feet	TEMPERATURE deg F.	GRADIENT deg F/100'
1	41.00	13.28	0.00	134.51	55.90	0.00
2	45.00	13.38	25.74	147.64	56.08	1.41
3	50.00	13.64	52.95	164.04	56.56	2.90
4	55.00	14.07	84.53	180.44	57.32	4.64
5	60.00	14.26	39.19	196.85	57.67	2.15
6	65.00	14.57	61.66	213.25	58.23	3.38
7	70.00	14.86	58.69	229.66	58.76	3.22
8	75.00	15.18	62.19	246.06	59.32	3.41
9	80.00	15.33	31.81	262.46	59.60	1.75
10	85.00	15.66	65.06	278.87	60.19	3.57
11	90.00	15.89	45.07	295.27	60.59	2.47
12	95.00	16.21	64.03	311.68	61.17	3.51
13	100.00	16.44	46.84	328.08	61.59	2.57
14	105.00	16.74	60.85	344.48	62.14	3.34
15	110.00	17.06	64.06	360.89	62.72	3.51
16	115.00	17.31	49.65	377.29	63.16	2.72
17	120.00	17.56	49.48	393.70	63.61	2.71
18	125.00	17.84	55.83	410.10	64.11	3.06
19	129.00	18.10	66.26	423.22	64.59	3.64

BT80A

	DEPTH meters	TEMPERATURE deg Celsius	GRADIENT K/km	DEPTH feet	TEMPERATURE deg F.	GRADIENT deg F/100'
1	22.00	12.61	0.00	72.18	54.69	0.00
2	25.00	12.52	-30.52	82.02	54.53	-1.67
3	30.00	12.56	9.38	98.42	54.61	0.51
4	35.00	12.71	29.64	114.83	54.88	1.63
5	40.00	12.80	17.93	131.23	55.04	0.98
6	45.00	13.05	50.72	147.64	55.50	2.78
7	50.00	13.31	50.58	164.04	55.95	2.78
8	55.00	13.45	28.30	180.44	56.21	1.55
9	60.00	13.81	71.94	196.85	56.86	3.95
10	61.00	14.06	253.15	200.13	57.31	13.89
11	62.00	14.34	281.98	203.41	57.82	15.47
12	63.00	14.51	167.78	206.69	58.12	9.21
13	64.00	14.71	200.81	209.97	58.48	11.02
14	65.00	14.78	72.20	213.25	58.61	3.96
15	70.00	15.18	78.15	229.66	59.32	4.29
16	75.00	15.82	128.09	246.06	60.47	7.03
17	80.00	16.03	43.74	262.46	60.86	2.40
18	85.00	16.43	79.43	278.87	61.58	4.36
19	90.00	16.79	71.37	295.27	62.22	3.92
20	95.00	17.12	66.27	311.68	62.82	3.64
21	100.00	17.45	66.93	328.08	63.42	3.67
22	105.00	17.81	70.86	344.48	64.06	3.89
23	110.00	18.17	72.18	360.89	64.71	3.96
24	115.00	18.57	80.76	377.29	65.43	4.43
25	120.00	18.91	67.14	393.70	66.04	3.68
26	125.00	19.21	61.02	410.10	66.59	3.35
27	130.00	19.54	64.48	426.50	67.17	3.54
28	135.00	19.85	63.40	442.91	67.74	3.48
29	136.80	19.99	75.78	448.81	67.98	4.16

BT79B

	DEPTH meters	TEMPERATURE deg Celsius	GRADIENT K/km	DEPTH feet	TEMPERATURE deg F.	GRADIENT deg F/100'
1	47.00	13.18	0.00	154.20	55.72	0.00
2	50.00	13.21	10.00	164.04	55.78	0.55
3	55.00	13.28	14.00	180.44	55.90	0.77
4	60.00	13.40	24.00	196.85	56.12	1.32
5	65.00	13.59	38.00	213.25	56.46	2.08
6	70.00	13.73	28.00	229.66	56.71	1.54
7	75.00	14.02	58.00	246.06	57.24	3.18
8	80.00	14.49	94.00	262.46	58.08	5.16
9	85.00	14.81	64.00	278.87	58.66	3.51
10	90.00	15.17	72.00	295.27	59.31	3.95

BT800F

	DEPTH meters	TEMPERATURE deg Celsius	GRADIENT K/km	DEPTH feet	TEMPERATURE deg F.	GRADIENT deg F/100'
1	11.00	10.93	0.00	36.09	51.68	0.00
2	15.00	11.01	17.75	49.21	51.81	0.97
3	20.00	11.10	18.80	65.62	51.98	1.03
4	25.00	11.24	28.80	82.02	52.24	1.58
5	30.00	11.47	46.20	98.42	52.65	2.53
6	35.00	11.63	31.60	114.83	52.94	1.73
7	40.00	11.75	23.20	131.23	53.15	1.27
8	45.00	11.88	26.00	147.64	53.38	1.43
9	50.00	12.07	39.00	164.04	53.73	2.14
10	50.20	12.08	45.00	164.70	53.75	2.47

BT77EF

	DEPTH meters	TEMPERATURE deg Celsius	GRADIENT K/km	DEPTH feet	TEMPERATURE deg F.	GRADIENT deg F/100'
1	8.00	9.68	0.00	26.25	49.42	0.00
2	10.00	9.79	56.50	32.81	49.63	3.10
3	15.00	10.00	41.80	49.21	50.00	2.29
4	20.00	10.27	54.60	65.62	50.49	3.00
5	25.00	10.53	50.60	82.02	50.95	2.78
6	30.00	10.77	49.40	98.42	51.39	2.71
7	35.00	11.06	57.40	114.83	51.91	3.15
8	40.00	11.30	47.40	131.23	52.34	2.60
9	45.00	11.53	47.00	147.64	52.76	2.58
10	50.00	11.81	55.80	164.04	53.26	3.06
11	55.00	12.13	63.20	180.44	53.83	3.47
12	60.00	12.54	81.80	196.85	54.57	4.49
13	65.00	12.90	73.20	213.25	55.23	4.02
14	70.00	13.19	56.80	229.66	55.74	3.12
15	75.00	13.52	67.00	246.06	56.34	3.68
16	80.00	13.84	62.80	262.46	56.91	3.45
17	85.00	14.17	67.20	278.87	57.51	3.69
18	90.00	14.52	69.40	295.27	58.14	3.81
19	95.00	14.84	63.40	311.68	58.71	3.48
20	100.00	15.15	62.60	328.08	59.27	3.43
21	105.00	15.47	64.60	344.48	59.85	3.54
22	110.00	15.78	61.60	360.89	60.41	3.38
23	115.00	16.12	67.40	377.29	61.01	3.70
24	120.00	16.40	56.40	393.70	61.52	3.09
25	125.00	16.66	52.00	410.10	61.99	2.85
26	130.00	16.90	47.20	426.50	62.41	2.59
27	135.00	17.27	74.40	442.91	63.08	4.08

APPENDIX C

TEMPERATURE DEPTH DATA FOR NORTH DAKOTA
"HOLES OF OPPORTUNITY"

FORT BERTHOLD NO. 1

	DEPTH meters	TEMPERATURE deg Celsius	GRADIENT K/km	DEPTH feet	TEMPERATURE deg F.	GRADIENT deg F/100'
1	1.00	15.99	0.00	3.28	60.79	0.00
2	2.00	15.23	-767.00	6.56	59.41	-42.08
3	3.00	14.67	-558.00	9.84	58.41	-30.61
4	4.00	14.18	-490.00	13.12	57.52	-26.88
5	5.00	13.53	-650.00	16.40	56.35	-35.66
6	6.00	12.84	-694.00	19.68	55.10	-38.08
7	7.00	12.20	-633.00	22.97	53.97	-34.73
8	8.00	11.68	-519.00	26.25	53.03	-28.47
9	9.00	11.21	-476.00	29.53	52.17	-26.12
10	10.00	10.82	-388.00	32.81	51.48	-21.29
11	11.00	10.52	-305.00	36.09	50.93	-16.73
12	12.00	10.26	-252.00	39.37	50.47	-13.83
13	13.00	10.05	-217.00	42.65	50.08	-11.91
14	14.00	9.78	-263.00	45.93	49.61	-14.43
15	15.00	9.54	-246.00	49.21	49.17	-13.50
16	16.00	9.34	-202.00	52.49	48.80	-11.08
17	17.00	9.17	-166.00	55.77	48.50	-9.11
18	18.00	9.03	-138.00	59.05	48.26	-7.57
19	19.00	8.95	-78.00	62.34	48.12	-4.28
20	20.00	8.91	-43.00	65.62	48.04	-2.36
21	21.00	8.86	-48.00	68.90	47.95	-2.63
22	22.00	8.81	-51.00	72.18	47.86	-2.80
23	23.00	8.75	-60.00	75.46	47.75	-3.29
24	24.00	8.70	-43.00	78.74	47.67	-2.63
25	25.00	8.66	-38.00	82.02	47.60	-2.08
26	26.00	8.62	-45.00	85.30	47.52	-2.47
27	27.00	8.57	-45.00	88.58	47.43	-2.47
28	28.00	8.55	-26.00	91.86	47.39	-1.43
29	29.00	8.53	-17.00	95.14	47.36	-0.93
30	30.00	8.52	-13.00	98.42	47.33	-0.71
31	31.00	8.52	-4.00	101.70	47.33	-0.22
32	32.00	8.50	-11.00	104.99	47.31	-0.60
33	33.00	8.50	-2.00	108.27	47.30	-0.11
34	34.00	8.51	4.00	111.55	47.31	0.22
35	35.00	8.52	9.00	114.83	47.33	0.49
36	36.00	8.52	4.00	118.11	47.33	0.22
37	37.00	8.52	4.00	121.39	47.34	0.22
38	38.00	8.54	13.00	124.67	47.36	0.71
39	39.00	8.55	13.00	127.95	47.39	0.71
40	40.00	8.56	9.00	131.23	47.40	0.49
41	41.00	8.57	10.00	134.51	47.42	0.55
42	42.00	8.58	11.00	137.79	47.44	0.60
43	43.00	8.59	13.00	141.07	47.47	0.71
44	44.00	8.60	8.00	144.36	47.48	0.44
45	45.00	8.62	18.00	147.64	47.51	0.99
46	46.00	8.61	-5.00	150.92	47.50	-0.27
47	47.00	8.64	24.00	154.20	47.55	1.32
48	48.00	8.66	26.00	157.48	47.59	1.43
49	49.00	8.69	30.00	160.76	47.65	1.65
50	50.00	8.72	30.00	164.04	47.70	1.65

FORT BERTHOLD NO. 1

	DEPTH meters	TEMPERATURE deg Celsius	GRADIENT K/km	DEPTH feet	TEMPERATURE deg F.	GRADIENT deg F/100'
51	51.00	8.76	32.00	167.32	47.76	1.76
52	52.00	8.78	28.00	170.60	47.81	1.54
53	53.00	8.80	19.00	173.88	47.84	1.04
54	54.00	8.83	24.00	177.16	47.89	1.32
55	55.00	8.85	21.00	180.44	47.92	1.15
56	56.00	8.88	28.00	183.72	47.97	1.54
57	57.00	8.90	22.00	187.01	48.01	1.21
58	58.00	8.92	24.00	190.29	48.06	1.32
59	59.00	8.95	26.00	193.57	48.10	1.43
60	60.00	8.97	23.00	196.85	48.15	1.26
61	61.00	9.00	26.00	200.13	48.19	1.43
62	62.00	9.02	26.00	203.41	48.24	1.43
63	63.00	9.04	22.00	206.69	48.28	1.21
64	64.00	9.06	21.00	209.97	48.32	1.15
65	65.00	9.09	22.00	213.25	48.36	1.21
66	66.00	9.12	30.00	216.53	48.41	1.65
67	67.00	9.14	20.00	219.81	48.45	1.10
68	68.00	9.16	28.00	223.09	48.50	1.54
69	69.00	9.19	28.00	226.38	48.55	1.54
70	70.00	9.22	31.00	229.66	48.60	1.70
71	71.00	9.25	30.00	232.94	48.66	1.65
72	72.00	9.29	35.00	236.22	48.72	1.92
73	73.00	9.32	32.00	239.50	48.78	1.76
74	74.00	9.35	33.00	242.78	48.84	1.81
75	75.00	9.39	33.00	246.06	48.90	1.81
76	76.00	9.41	24.00	249.34	48.94	1.32
77	77.00	9.44	24.00	252.62	48.98	1.32
78	78.00	9.45	19.00	255.90	49.02	1.04
79	79.00	9.48	22.00	259.18	49.06	1.21
80	80.00	9.50	20.00	262.46	49.09	1.10
81	81.00	9.52	24.00	265.74	49.14	1.32
82	82.00	9.54	20.00	269.03	49.17	1.10
83	83.00	9.56	19.00	272.31	49.21	1.04
84	84.00	9.58	20.00	275.59	49.24	1.10
85	85.00	9.60	22.00	278.87	49.28	1.21
86	86.00	9.62	20.00	282.15	49.32	1.10
87	87.00	9.64	22.00	285.43	49.36	1.21
88	88.00	9.67	24.00	288.71	49.40	1.32
89	89.00	9.69	26.00	291.99	49.45	1.43
90	90.00	9.73	35.00	295.27	49.51	1.92
91	91.00	9.75	22.00	298.55	49.55	1.21
92	92.00	9.78	26.00	301.83	49.60	1.43
93	93.00	9.80	27.00	305.11	49.65	1.48
94	94.00	9.83	26.00	308.40	49.69	1.43
95	95.00	9.85	24.00	311.68	49.74	1.32
96	96.00	9.88	27.00	314.96	49.78	1.48
97	97.00	9.90	24.00	318.24	49.83	1.32
98	98.00	9.93	29.00	321.52	49.88	1.59
99	99.00	9.96	29.00	324.80	49.93	1.59
100	100.00	10.01	44.00	328.08	50.01	2.41
101	105.00	10.22	43.00	344.48	50.40	2.36

FORT BERTHOLD NO. 1

	DEPTH meters	TEMPERATURE deg Celsius	GRADIENT K/km	DEPTH feet	TEMPERATURE deg F.	GRADIENT deg F/100'
102	110.00	10.45	46.80	360.89	50.82	2.57
103	115.00	10.72	53.80	377.29	51.30	2.95
104	120.00	10.88	31.00	393.70	51.58	1.70
105	125.00	11.01	26.80	410.10	51.82	1.47
106	130.00	11.16	29.80	426.50	52.09	1.63
107	135.00	11.37	42.40	442.91	52.47	2.33
108	140.00	11.58	40.80	459.31	52.84	2.24
109	145.00	11.83	51.20	475.72	53.30	2.81
110	150.00	12.03	38.40	492.12	53.65	2.11
111	155.00	12.42	79.40	508.52	54.36	4.36
112	160.00	12.66	46.60	524.93	54.78	2.56
113	165.00	12.80	27.80	541.33	55.03	1.53
114	170.00	12.93	27.60	557.74	55.28	1.51
115	175.00	13.13	38.60	574.14	55.63	2.12
116	180.00	13.35	44.00	590.54	56.02	2.41
117	185.00	13.57	45.00	606.95	56.43	2.47
118	190.00	13.77	39.20	623.35	56.78	2.15
119	195.00	14.08	62.40	639.76	57.34	3.42
120	200.00	14.27	38.40	656.16	57.69	2.11
121	205.00	14.43	31.60	672.56	57.97	1.73
122	210.00	14.65	44.20	688.97	58.37	2.43
123	215.00	14.85	41.00	705.37	58.74	2.25
124	220.00	15.03	34.60	721.78	59.05	1.90
125	225.00	15.23	40.00	738.18	59.41	2.19
126	230.00	15.39	31.40	754.58	59.69	1.72
127	235.00	15.61	45.80	770.99	60.11	2.51
128	240.00	15.90	58.20	787.39	60.63	3.19
129	245.00	16.02	22.60	803.80	60.83	1.24
130	250.00	16.13	22.40	820.20	61.03	1.23
131	255.00	16.28	30.60	836.60	61.31	1.68
132	260.00	16.40	23.60	853.01	61.52	1.29
133	265.00	16.52	23.00	869.41	61.73	1.26
134	270.00	16.64	23.80	885.82	61.94	1.31
135	275.00	16.75	23.20	902.22	62.15	1.27
136	280.00	16.90	30.20	918.62	62.42	1.66
137	285.00	17.27	73.80	935.03	63.09	4.05
138	290.00	17.56	57.60	951.43	63.61	3.16
139	295.00	17.89	66.00	967.84	64.20	3.62
140	300.00	18.07	35.60	984.24	64.52	1.95
141	305.00	18.30	47.40	1000.64	64.95	2.60
142	310.00	18.62	63.60	1017.05	65.52	3.49
143	315.00	18.91	58.40	1033.45	66.05	3.20
144	320.00	19.36	88.80	1049.86	66.84	4.87
145	325.00	19.61	50.40	1066.26	67.30	2.77
146	330.00	19.76	30.80	1082.66	67.58	1.69
147	335.00	19.93	33.60	1099.07	67.88	1.84
148	340.00	20.10	32.80	1115.47	68.17	1.80
149	345.00	20.27	35.80	1131.88	68.49	1.96
150	350.00	20.44	33.20	1148.28	68.79	1.82
151	355.00	20.63	36.80	1164.68	69.13	2.02
152	360.00	20.82	39.40	1181.09	69.48	2.16

FORT BERTHOLD NO. 1

	DEPTH meters	TEMPERATURE deg Celsius	GRADIENT K/km	DEPTH feet	TEMPERATURE deg F.	GRADIENT deg F/100'
153	365.00	20.96	27.80	1197.49	69.73	1.53
154	370.00	21.11	30.80	1213.90	70.01	1.69
155	375.00	21.25	27.20	1230.30	70.25	1.49
156	380.00	21.38	25.00	1246.70	70.48	1.37
157	385.00	21.52	29.40	1263.11	70.74	1.61
158	390.00	21.66	28.20	1279.51	71.00	1.55
159	395.00	21.82	30.40	1295.92	71.27	1.67
160	400.00	21.97	31.60	1312.32	71.55	1.73
161	405.00	22.16	37.60	1328.72	71.89	2.06
162	410.00	22.36	40.20	1345.13	72.25	2.21
163	415.00	22.54	35.40	1361.53	72.57	1.94
164	420.00	22.72	35.00	1377.94	72.89	1.92
165	425.00	22.93	43.00	1394.34	73.27	2.36
166	430.00	23.10	34.20	1410.74	73.58	1.88
167	435.00	23.23	25.80	1427.15	73.81	1.42

FORT BERTHOLD NO. 2

	DEPTH meters	TEMPERATURE deg Celsius	GRADIENT K/km	DEPTH feet	TEMPERATURE deg F.	GRADIENT deg F/100'
1	1.00	7.75	0.00	3.28	45.95	0.00
2	2.00	8.51	761.00	6.56	47.32	41.75
3	3.00	9.06	552.00	9.84	48.31	30.29
4	4.00	9.25	191.00	13.12	48.66	10.48
5	5.00	9.14	-111.00	16.40	48.46	-6.09
6	6.00	8.95	-192.00	19.68	48.11	-10.53
7	7.00	8.76	-187.00	22.97	47.78	-10.26
8	8.00	8.62	-146.00	26.25	47.51	-8.01
9	9.00	8.51	-112.00	29.53	47.31	-6.14
10	10.00	8.42	-85.00	32.81	47.16	-4.66
11	11.00	8.36	-60.00	36.09	47.05	-3.29
12	12.00	8.30	-57.00	39.37	46.95	-3.13
13	13.00	8.23	-73.00	42.65	46.82	-4.01
14	14.00	8.15	-84.00	45.93	46.66	-4.61
15	15.00	8.08	-66.00	49.21	46.55	-3.62
16	16.00	8.04	-45.00	52.49	46.46	-2.47
17	17.00	8.01	-25.00	55.77	46.42	-1.37
18	18.00	8.00	-15.00	59.05	46.39	-0.82
19	19.00	7.99	-10.00	62.34	46.37	-0.55
20	20.00	7.96	-28.00	65.62	46.32	-1.54
21	21.00	7.95	-12.00	68.90	46.30	-0.66
22	22.00	7.94	-7.00	72.18	46.29	-0.38
23	23.00	7.94	-2.00	75.46	46.29	-0.11
24	24.00	7.94	4.00	78.74	46.29	0.22
25	25.00	7.96	15.00	82.02	46.32	0.82
26	26.00	7.98	23.00	85.30	46.36	1.26
27	27.00	8.00	19.00	88.58	46.40	1.04
28	28.00	8.01	13.00	91.86	46.42	0.71
29	29.00	8.03	19.00	95.14	46.45	1.04
30	30.00	8.05	21.00	98.42	46.49	1.15
31	31.00	8.08	26.00	101.70	46.54	1.43
32	32.00	8.10	27.00	104.99	46.59	1.48
33	33.00	8.13	28.00	108.27	46.64	1.54
34	34.00	8.16	25.00	111.55	46.68	1.37
35	35.00	8.19	38.00	114.83	46.75	2.08
36	36.00	8.24	47.00	118.11	46.84	2.58
37	37.00	8.28	41.00	121.39	46.91	2.25
38	38.00	8.33	46.00	124.67	46.99	2.52
39	39.00	8.37	43.00	127.95	47.07	2.36
40	40.00	8.41	43.00	131.23	47.15	2.36
41	41.00	8.45	40.00	134.51	47.22	2.19
42	42.00	8.49	34.00	137.79	47.28	1.87
43	43.00	8.51	22.00	141.07	47.32	1.21
44	44.00	8.56	49.00	144.36	47.41	2.69
45	45.00	8.59	25.00	147.64	47.45	1.37
46	46.00	8.61	30.00	150.92	47.51	1.65
47	47.00	8.64	26.00	154.20	47.55	1.43
48	48.00	8.67	28.00	157.48	47.60	1.54
49	49.00	8.70	30.00	160.76	47.66	1.65
50	50.00	8.73	32.00	164.04	47.72	1.76

FORT BERTHOLD NO. 2

	DEPTH meters	TEMPERATURE deg Celsius	GRADIENT K/km	DEPTH feet	TEMPERATURE deg F.	GRADIENT deg F/100'
51	51.00	8.76	30.00	167.32	47.77	1.65
52	52.00	8.82	56.00	170.60	47.87	3.07
53	53.00	8.90	80.00	173.88	48.01	4.39
54	54.00	8.97	73.00	177.16	48.15	4.01
55	55.00	9.04	67.00	180.44	48.27	3.68
56	56.00	9.12	83.00	183.72	48.42	4.55
57	57.00	9.20	84.00	187.01	48.57	4.61
58	58.00	9.30	91.00	190.29	48.73	4.99
59	59.00	9.35	55.00	193.57	48.83	3.02
60	60.00	9.40	46.00	196.85	48.91	2.52
61	61.00	9.45	50.00	200.13	49.00	2.74
62	62.00	9.50	52.00	203.41	49.10	2.85
63	63.00	9.56	57.00	206.69	49.20	3.13
64	64.00	9.61	57.00	209.97	49.30	3.13
65	65.00	9.67	55.00	213.25	49.40	3.02
66	70.00	9.86	37.80	229.66	49.74	2.07
67	75.00	9.97	23.40	246.06	49.95	1.28
68	80.00	10.10	24.60	262.46	50.17	1.35
69	85.00	10.23	27.60	278.87	50.42	1.51
70	90.00	10.37	28.00	295.27	50.67	1.54
71	95.00	10.63	52.00	311.68	51.14	2.85
72	100.00	10.89	50.80	328.08	51.60	2.79
73	105.00	11.68	158.80	344.48	53.03	8.71
74	110.00	11.88	38.60	360.89	53.38	2.12
75	115.00	12.02	28.40	377.29	53.63	1.56
76	120.00	12.16	28.40	393.70	53.89	1.56
77	125.00	12.32	31.60	410.10	54.17	1.73
78	130.00	12.49	34.80	426.50	54.48	1.91
79	135.00	12.64	29.60	442.91	54.75	1.62
80	140.00	12.80	31.80	459.31	55.04	1.74
81	145.00	12.96	32.60	475.72	55.33	1.79
82	150.00	13.12	32.00	492.12	55.62	1.76
83	155.00	13.27	29.20	508.52	55.88	1.60
84	160.00	13.49	44.40	524.93	56.28	2.44
85	165.00	13.70	42.40	541.33	56.66	2.33
86	170.00	13.86	32.60	557.74	56.96	1.79
87	175.00	14.01	28.80	574.14	57.21	1.58
88	180.00	14.15	28.60	590.54	57.47	1.57
89	185.00	14.30	30.00	606.95	57.74	1.65
90	190.00	14.47	33.00	623.35	58.04	1.81
91	195.00	14.73	51.80	639.76	58.50	2.84
92	200.00	14.88	30.60	656.16	58.78	1.68
93	205.00	15.17	59.20	672.56	59.31	3.25
94	210.00	15.63	91.20	688.97	60.13	5.00
95	215.00	16.20	113.60	705.37	61.16	6.23
96	220.00	16.59	79.40	721.78	61.87	4.36
97	225.00	17.02	84.80	738.18	62.63	4.65
98	230.00	17.25	47.20	754.58	63.06	2.59
99	235.00	17.42	32.20	770.99	63.35	1.77
100	240.00	17.56	28.20	787.39	63.60	1.55
101	245.00	17.67	21.60	803.80	63.80	1.19

FORT BERTHOLD NO. 3

	DEPTH meters	TEMPERATURE deg Celsius	GRADIENT K/km	DEPTH feet	TEMPERATURE deg F.	GRADIENT deg F/100'
1	5.00	8.26	0.00	16.40	46.86	0.00
2	6.00	8.83	577.00	19.68	47.90	31.66
3	7.00	8.94	112.00	22.97	48.10	6.14
4	8.00	8.87	-73.00	26.25	47.97	-4.01
5	9.00	8.82	-52.00	29.53	47.87	-2.85
6	10.00	8.77	-51.00	32.81	47.78	-2.80
7	11.00	8.72	-47.00	36.09	47.70	-2.58
8	12.00	8.70	-22.00	39.37	47.66	-1.21
9	13.00	8.68	-15.00	42.65	47.63	-0.82
10	14.00	8.63	-58.00	45.93	47.53	-3.18
11	15.00	8.62	-4.00	49.21	47.52	-0.22
12	16.00	8.57	-51.00	52.49	47.43	-2.80
13	17.00	8.55	-22.00	55.77	47.39	-1.21
14	18.00	8.55	-2.00	59.05	47.38	-0.11
15	19.00	8.55	0.00	62.34	47.38	0.00
16	20.00	8.54	-6.00	65.62	47.37	-0.33
17	21.00	8.55	10.00	68.90	47.39	0.55
18	22.00	8.57	20.00	72.18	47.43	1.10
19	23.00	8.59	14.00	75.46	47.45	0.77
20	24.00	8.60	11.00	78.74	47.47	0.60
21	25.00	8.60	4.00	82.02	47.48	0.22
22	26.00	8.61	7.00	85.30	47.49	0.38
23	27.00	8.62	15.00	88.58	47.52	0.82
24	28.00	8.62	-2.00	91.86	47.52	-0.11
25	29.00	8.62	4.00	95.14	47.52	0.22
26	30.00	8.63	9.00	98.42	47.54	0.49
27	31.00	8.66	25.00	101.70	47.58	1.37
28	32.00	8.68	26.00	104.99	47.63	1.43
29	33.00	8.74	54.00	108.27	47.73	2.96
30	34.00	8.79	56.00	111.55	47.83	3.07
31	35.00	8.84	47.00	114.83	47.91	2.58
32	36.00	8.89	52.00	118.11	48.01	2.85
33	37.00	8.94	43.00	121.39	48.08	2.36
34	38.00	8.96	28.00	124.67	48.14	1.54
35	39.00	9.00	39.00	127.95	48.21	2.14
36	40.00	9.03	28.00	131.23	48.26	1.54
37	41.00	9.06	28.00	134.51	48.31	1.54
38	42.00	9.09	30.00	137.79	48.36	1.65
39	43.00	9.12	28.00	141.07	48.41	1.54
40	44.00	9.15	29.00	144.36	48.46	1.59
41	45.00	9.17	28.00	147.64	48.51	1.54
42	46.00	9.20	26.00	150.92	48.56	1.43
43	47.00	9.23	28.00	154.20	48.61	1.54
44	48.00	9.25	26.00	157.48	48.66	1.43
45	49.00	9.28	28.00	160.76	48.71	1.54
46	50.00	9.30	22.00	164.04	48.75	1.21
47	51.00	9.33	22.00	167.32	48.79	1.21
48	52.00	9.35	24.00	170.60	48.83	1.32
49	53.00	9.38	28.00	173.88	48.88	1.54
50	54.00	9.40	26.00	177.16	48.93	1.43

FORT BERTHOLD NO. 3

	DEPTH meters	TEMPERATURE deg Celsius	GRADIENT K/km	DEPTH feet	TEMPERATURE deg F.	GRADIENT deg F/100'
51	55.00	9.43	26.00	180.44	48.97	1.43
52	56.00	9.46	29.00	183.72	49.03	1.59
53	57.00	9.48	26.00	187.01	49.07	1.43
54	58.00	9.51	28.00	190.29	49.12	1.54
55	59.00	9.53	16.00	193.57	49.15	0.88
56	60.00	9.62	94.00	196.85	49.32	5.16
57	61.00	9.65	31.00	200.13	49.38	1.70
58	62.00	9.69	37.00	203.41	49.44	2.03
59	63.00	9.77	77.00	206.69	49.58	4.22
60	64.00	9.86	88.00	209.97	49.74	4.83
61	65.00	9.89	35.00	213.25	49.80	1.92
62	66.00	9.92	29.00	216.53	49.86	1.59
63	67.00	9.95	28.00	219.81	49.91	1.54
64	68.00	9.98	27.00	223.09	49.96	1.48
65	69.00	10.00	26.00	226.38	50.00	1.43
66	70.00	10.03	34.00	229.66	50.06	1.87
67	71.00	10.06	26.00	232.94	50.11	1.43
68	72.00	10.09	33.00	236.22	50.17	1.81
69	73.00	10.16	65.00	239.50	50.29	3.57
70	74.00	10.20	46.00	242.78	50.37	2.52
71	75.00	10.26	54.00	246.06	50.47	2.96
72	76.00	10.30	40.00	249.34	50.54	2.19
73	77.00	10.32	26.00	252.62	50.58	1.43
74	78.00	10.36	34.00	255.90	50.65	1.87
75	79.00	10.39	33.00	259.18	50.71	1.81
76	80.00	10.43	38.00	262.46	50.77	2.08
77	81.00	10.48	52.00	265.74	50.87	2.85
78	82.00	10.54	60.00	269.03	50.98	3.29
79	83.00	10.60	58.00	272.31	51.08	3.18
80	84.00	10.63	32.00	275.59	51.14	1.76
81	85.00	10.69	53.00	278.87	51.23	2.91
82	86.00	10.75	63.00	282.15	51.35	3.46
83	87.00	10.79	43.00	285.43	51.42	2.36
84	88.00	10.84	48.00	288.71	51.51	2.63
85	89.00	10.87	29.00	291.99	51.56	1.59
86	90.00	10.90	31.00	295.27	51.62	1.70
87	91.00	10.94	37.00	298.55	51.68	2.03
88	92.00	10.97	38.00	301.83	51.75	2.08
89	93.00	11.01	39.00	305.11	51.82	2.14
90	94.00	11.05	40.00	308.40	51.90	2.19
91	95.00	11.09	41.00	311.68	51.97	2.25
92	96.00	11.14	41.00	314.96	52.04	2.25
93	97.00	11.18	43.00	318.24	52.12	2.36
94	98.00	11.22	39.00	321.52	52.19	2.14
95	99.00	11.27	48.00	324.80	52.28	2.63
96	100.00	11.30	36.00	328.08	52.34	1.98
97	105.00	11.46	32.40	344.48	52.63	1.78
98	110.00	11.59	26.20	360.89	52.87	1.44
99	115.00	11.73	27.20	377.29	53.11	1.49
100	120.00	11.92	37.80	393.70	53.45	2.07
101	125.00	12.15	47.00	410.10	53.88	2.58

FORT BERTHOLD NO. 3

	DEPTH meters	TEMPERATURE deg Celsius	GRADIENT K/km	DEPTH feet	TEMPERATURE deg F.	GRADIENT deg F/100'
102	130.00	12.30	29.40	426.50	54.14	1.61
103	135.00	12.45	30.40	442.91	54.42	1.67
104	140.00	12.61	32.00	459.31	54.70	1.76
105	145.00	12.76	28.80	475.72	54.96	1.58
106	150.00	12.90	27.60	492.12	55.21	1.51
107	155.00	13.10	41.00	508.52	55.58	2.25
108	160.00	13.33	46.80	524.93	56.00	2.57
109	165.00	13.53	39.60	541.33	56.36	2.17
110	170.00	13.93	79.60	557.74	57.07	4.37
111	175.00	14.45	103.80	574.14	58.01	5.69
112	180.00	14.98	105.20	590.54	58.96	5.77
113	185.00	15.22	48.00	606.95	59.39	2.63
114	190.00	15.39	34.00	623.35	59.69	1.87
115	195.00	15.63	49.40	639.76	60.14	2.71
116	200.00	15.86	45.80	656.16	60.55	2.51
117	205.00	16.25	77.20	672.56	61.24	4.24
118	210.00	16.45	41.20	688.97	61.62	2.26
119	215.00	16.64	36.40	705.37	61.94	2.00
120	220.00	16.90	52.40	721.78	62.41	2.87
121	225.00	17.09	39.40	738.18	62.77	2.16
122	230.00	17.24	28.80	754.58	63.03	1.58
123	235.00	17.42	37.20	770.99	63.36	2.04
124	240.00	17.60	36.20	787.39	63.69	1.99
125	245.00	17.79	37.00	803.80	64.02	2.03
126	250.00	17.97	35.60	820.20	64.34	1.95
127	255.00	18.15	36.40	836.60	64.67	2.00
128	260.00	18.36	42.60	853.01	65.05	2.34
129	265.00	18.57	41.60	869.41	65.43	2.28
130	270.00	18.75	35.40	885.82	65.75	1.94
131	275.00	18.92	34.40	902.22	66.06	1.89
132	280.00	19.06	27.20	918.62	66.30	1.49
133	285.00	19.22	31.80	935.03	66.59	1.74
134	290.00	19.38	33.00	951.43	66.88	1.81
135	295.00	19.53	31.00	967.84	67.16	1.70
136	300.00	19.70	32.40	984.24	67.45	1.78
137	305.00	19.87	35.40	1000.64	67.77	1.94
138	310.00	20.06	37.40	1017.05	68.11	2.05
139	315.00	20.29	45.80	1033.45	68.52	2.51
140	320.00	20.51	43.80	1049.86	68.92	2.40
141	325.00	20.69	36.40	1066.26	69.24	2.00
142	330.00	20.88	37.60	1082.66	69.58	2.06
143	335.00	21.13	50.20	1099.07	70.03	2.75
144	340.00	21.32	38.20	1115.47	70.38	2.10
145	345.00	21.53	41.00	1131.88	70.75	2.25
146	350.00	21.75	43.80	1148.28	71.14	2.40
147	355.00	22.18	86.40	1164.68	71.92	4.74
148	360.00	22.51	66.20	1181.09	72.51	3.63
149	365.00	22.65	29.20	1197.49	72.78	1.60
150	370.00	22.88	44.80	1213.90	73.18	2.46
151	375.00	23.09	43.20	1230.30	73.57	2.37
152	380.00	23.27	34.40	1246.70	73.88	1.89

FORT BERTHOLD NO. 3

	DEPTH meters	TEMPERATURE deg Celsius	GRADIENT K/km	DEPTH feet	TEMPERATURE deg F.	GRADIENT deg F/100'
153	385.00	23.47	41.00	1263.11	74.25	2.25
154	390.00	23.72	49.40	1279.51	74.69	2.71
155	395.00	24.01	59.00	1295.92	75.22	3.24
156	400.00	24.24	45.60	1312.32	75.63	2.50
157	405.00	24.52	56.00	1328.72	76.14	3.07
158	410.00	24.72	40.20	1345.13	76.50	2.21
159	415.00	24.90	36.40	1361.53	76.83	2.00
160	420.00	25.06	31.00	1377.94	77.11	1.70
161	425.00	25.24	36.00	1394.34	77.43	1.98
162	430.00	25.40	32.20	1410.74	77.72	1.77
163	435.00	25.56	32.80	1427.15	78.02	1.80

	DEPTH meters	TEMPERATURE deg Celsius	GRADIENT K/km	DEPTH feet	TEMPERATURE deg F.	GRADIENT deg F/100'
1	15.00	11.37	0.00	49.21	52.47	0.00
2	20.00	11.59	44.00	65.62	52.86	2.41
3	25.00	11.78	38.00	82.02	53.20	2.08
4	30.00	12.00	44.00	98.42	53.60	2.41
5	35.00	12.11	22.00	114.83	53.80	1.21
6	40.00	12.33	44.00	131.23	54.19	2.41
7	42.00	12.54	105.00	137.79	54.57	5.76
8	44.00	12.64	50.00	144.36	54.75	2.74
9	46.00	12.74	50.00	150.92	54.93	2.74
10	50.00	12.94	50.00	164.04	55.29	2.74
11	55.00	13.18	48.00	180.44	55.72	2.63
12	57.00	13.29	55.00	187.01	55.92	3.02
13	59.00	13.40	55.00	193.57	56.12	3.02
14	61.00	13.50	50.00	200.13	56.30	2.74
15	63.00	13.65	75.00	206.69	56.57	4.11
16	65.00	13.74	45.00	213.25	56.73	2.47
17	67.00	13.85	55.00	219.81	56.93	3.02
18	69.00	13.98	65.00	226.38	57.16	3.57
19	71.00	14.10	60.00	232.94	57.38	3.29
20	73.00	14.22	60.00	239.50	57.60	3.29
21	75.00	14.35	65.00	246.06	57.83	3.57
22	77.00	14.46	55.00	252.62	58.03	3.02
23	79.00	14.55	45.00	259.18	58.19	2.47
24	81.00	14.66	55.00	265.74	58.39	3.02
25	83.00	14.78	60.00	272.31	58.60	3.29
26	85.00	14.89	55.00	278.87	58.80	3.02
27	87.00	15.00	55.00	285.43	59.00	3.02
28	89.00	15.12	60.00	291.99	59.22	3.29
29	91.00	15.23	55.00	298.55	59.41	3.02
30	93.00	15.35	60.00	305.11	59.63	3.29
31	95.00	15.47	60.00	311.68	59.85	3.29
32	97.00	15.58	55.00	318.24	60.04	3.02
33	99.00	15.70	60.00	324.80	60.26	3.29
34	101.00	15.83	65.00	331.36	60.49	3.57
35	103.00	15.96	65.00	337.92	60.73	3.57
36	105.00	16.08	60.00	344.48	60.94	3.29
37	107.00	16.21	65.00	351.05	61.18	3.57
38	109.00	16.34	65.00	357.61	61.41	3.57
39	111.00	16.47	65.00	364.17	61.65	3.57
40	113.00	16.60	65.00	370.73	61.88	3.57
41	115.00	16.74	70.00	377.29	62.13	3.84
42	117.00	16.88	70.00	383.85	62.38	3.84
43	119.00	17.02	70.00	390.42	62.64	3.84
44	121.00	17.18	80.00	396.98	62.92	4.39
45	123.00	17.33	75.00	403.54	63.19	4.11
46	125.00	17.49	80.00	410.10	63.48	4.39
47	127.00	17.64	75.00	416.66	63.75	4.11
48	129.00	17.82	90.00	423.22	64.08	4.94
49	131.00	17.95	65.00	429.78	64.31	3.57
50	133.00	18.06	55.00	436.35	64.51	3.02

SDDOE1.DAT

	DEPTH meters	TEMPERATURE deg Celsius	GRADIENT K/km	DEPTH feet	TEMPERATURE deg F.	GRADIENT deg F/100'
51	135.00	18.16	50.00	442.91	64.69	2.74
52	137.00	18.25	45.00	449.47	64.85	2.47
53	139.00	18.34	45.00	456.03	65.01	2.47
54	141.00	18.42	40.00	462.59	65.16	2.19
55	143.00	18.52	50.00	469.15	65.34	2.74
56	145.00	18.62	50.00	475.72	65.52	2.74
57	147.00	18.72	50.00	482.28	65.70	2.74
58	149.00	18.81	45.00	488.84	65.86	2.47
59	151.00	18.90	45.00	495.40	66.02	2.47
60	153.00	18.98	40.00	501.96	66.16	2.19
61	155.00	19.07	45.00	508.52	66.33	2.47
62	157.00	19.15	40.00	515.09	66.47	2.19
63	159.00	19.23	40.00	521.65	66.61	2.19
64	161.00	19.32	45.00	528.21	66.78	2.47
65	163.00	19.41	45.00	534.77	66.94	2.47
66	165.00	19.49	40.00	541.33	67.08	2.19
67	167.00	19.58	45.00	547.89	67.24	2.47
68	169.00	19.67	45.00	554.46	67.41	2.47
69	171.00	19.76	45.00	561.02	67.57	2.47
70	173.00	19.85	45.00	567.58	67.73	2.47
71	175.00	19.93	40.00	574.14	67.87	2.19
72	177.00	20.02	45.00	580.70	68.04	2.47
73	179.00	20.11	45.00	587.26	68.20	2.47
74	181.00	20.19	40.00	593.82	68.34	2.19
75	183.00	20.25	30.00	600.39	68.45	1.65

APPENDIX D
STRUCTURE CONTOURS FOR NORTH DAKOTA

PIERRE

INYAN KARA

JURASSIC

SPEARFISH

OTTER

MADISON

BAKKEN

THREE FORKS

DUPEROW

DAWSON BAY

WINNIPEGOSIS

INTERLAKE

RED RIVER

DEADWOOD

APPENDIX E
TEMPERATURE CONTOURS FOR NORTH DAKOTA

INYAN KARA

TEMPERATURE DEG C

JURASSIC

SPEARFISH

TEMPERATURE DEG C

MADISON

TEMPERATURE DEG C

BAKKEN

TEMPERATURE DEG C

THREE FORKS

TEMPERATURE DEG C

INTERLAKE

TEMPERATURE DEG C

RED RIVER

TEMPERATURE DEG C

DEADWOOD

TEMPERATURE DEG C

APPENDIX F
STRUCTURE CONTOURS FOR SOUTH DAKOTA

INYAN KARA (Cretaceous)

Top of Jurassic

MINNEKAHTA (Permian)

MINNELUSA (Permian-Pennsylvanian)

MADISON (Mississippian)

Top of Devonian

DEADWOOD (Cambrian)

APPENDIX G
TEMPERATURE CONTOURS FOR SOUTH DAKOTA

INYAN KARA (Cretaceous) TEMPERATURES

SPEARFISH (Triassic) TEMPERATURES

MINNEKAHTA (Permian) TEMPERATURES

MINNELUSA (Perm-Penn) TEMPERATURES

MADISON (Mississippian) TEMPERATURES

Top of Devonian

TEMPERATURES

DEADWOOD (Cambrian) TEMPERATURES

APPENDIX H

**COMPUTER PROGRAMS USED IN RESOURCE ANALYSIS OF NORTH DAKOTA
COMPUTER LANGUAGE IS MICROSOFT QUICKBASIC**

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'***** PROGRAM LOCTEMP *****
10 CLS : SCREEN 0: COLOR 11
    DEF SEG = &H40: POKE &H17, (PEEK(&H17) OR &H40):
'CAPS LOCK ON
    DIM NME$(17), PORE(17), DENS(17), Q(31, 51), SURT(31,
51), ELEV(31, 51), DBY(31, 51), WPG(31, 51), INLK(31, 51),
RED(31, 51), DWD(31, 51)
    NME$(1) = "SURT.GRD": NME$(2) = "GROUND.GRD": NME$(3) =
"PIERRE.GRD": NME$(4) = "INYANK.GRD": NME$(5) =
"JURASSIC.GRD": NME$(6) = "SPEARFSH.GRD": NME$(7) =
"OTTER.GRD": NME$(8) = "MADISON.GRD": NME$(9) = "BAKKEN.GRD"
    NME$(10) = "3FORKS.GRD": NME$(11) = "DUPEROW.GRD":
NME$(12) = "DAWSONBY.GRD": NME$(13) = "WNPGOSIS.GRD":
NME$(14) = "INTERLAK.GRD": NME$(15) = "RDRIVER.GRD":
NME$(16) = "DEADWOOD.GRD": NME$(17) = "Q.GRD"
    LOCATE 8, 24: PRINT " PROGRAM LOCAL TEMPERATURE"
    LOCATE 11, 17: PRINT " PROGRAM FOR CALCULATING
TEMPERATURE AT A SITE"
    COLOR 26: LOCATE 15, 27: PRINT "{press any key to begin}"
50  DI$ = INKEY$: IF DI$ = "" THEN 50
    RESS$ = "RESOURCE BASE = ": RESS$ = " JOULES": AVTK$
= " AVG THICKNESS = ": AVTEMP$ = " AVG TEMP = "
    M1 = 6.35: M2 = 3.38: N1 = 506.35: N2 = 333.59: I = 0: N
= 0: CLS : NC = 51: NR = 31: TMAX = 0: TMIN = 100
    ELEK = 1700: PCON = 1200: IKCON = 1600: JCON = 1800:
RESTOT = 0: SPHT = (1 / 2.6) * 1000
    SPFCON = 3100: OTKCON = 2800: MADCON = 3500: BAKCON =
1500: DUPCON = 3500: INLKCON = 4000: REDCON = 3500: DWDCON =
3000
    PORE(1) = 0: PORE(2) = 0: PORE(3) = .05: PORE(4) = .17:
PORE(5) = .1: PORE(6) = .1: PORE(7) = .1: PORE(8) = .11:
PORE(9) = .02: PORE(10) = .2: PORE(11) = .2: PORE(12) = .2:
PORE(13) = .2: PORE(14) = .2
    DENS(1) = 0: DENS(2) = 0: DENS(3) = 2500: DENS(4) = 2700:
DENS(5) = 2500: DENS(6) = 2600: DENS(7) = 2670: DENS(8) =
2750: DENS(9) = 2500: DENS(10) = 2650: DENS(11) = 2750:
DENS(12) = 2700: DENS(13) = 2850: DENS(14) = 2850
    AREA = 1.153684E+08
    OPE$ = "DUPEROW.GRD"
    LF = 1
30 SCREEN 0: LOP = 0: POUT = 0: VARD = 0: EC = 0: COLOR 10:
LOCATE 14, 15: INPUT ; "ENTER CITY OR LOCATION NAME"; OUT$
    COLOR 12: LOCATE 16, 15: INPUT ; "ENTER 1 FOR PRINTER
OUTPUT OR RETURN FOR SCREEN ONLY"; POUT
    COLOR 11: LOCATE 18, 15: INPUT ; "TO ENTER LATITUDE AND
LONGITUDE TYPE 1 ELSE RETURN"; VARD
    IF VARD = 1 THEN GOTO 33 ELSE GOTO 32
32  A$ = " ROW": B$ = " COLUMN": C$ = " COORDINATES ON
THE 33 BY 50 POINT GRID": GOTO 34
33  A$ = " LATITUDE": B$ = " LONGITUDE": C$ = " IN
DECIMAL DEGREES"
34  CLS : SCREEN 12: WIDTH 80, 60: COLOR 10: VIEW PRINT 1
TO 17
    GOSUB 90

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        COLOR 9: LOCATE 10, 8: PRINT "ORIGIN IS LOWER LEFT
CORNER";
        COLOR 15: PRINT " (46 DEG N, 104 DEG W)"
        COLOR 12: LOCATE 6, 8: PRINT "ENTER";
        COLOR 11: PRINT A$;
        COLOR 12: PRINT C$;
25      COLOR 11: INPUT ; LATP:

        IF VARD = 1 THEN GOTO 35 ELSE GOTO 40
35      IF LATP < 46 THEN GOTO 37 ELSE IF LATP > 49 THEN
GOTO 37 ELSE GOTO 28
37      BEEP: LOCATE 6, 13: COLOR 15: PRINT A$;
        COLOR 12: PRINT C$;
        GOTO 25
40      IF LATP < 1 THEN GOTO 37 ELSE IF LATP > 33 THEN GOTO
37 ELSE GOTO 28

28      COLOR 12: LOCATE 8, 8: PRINT "ENTER";
        COLOR 14: PRINT B$;
        COLOR 12: PRINT C$;
        COLOR 14: INPUT ; LONP:

        IF VARD = 1 THEN GOTO 41 ELSE GOTO 43
41      IF LONP < 99 THEN GOTO 42 ELSE IF LONP > 104 THEN
GOTO 42 ELSE GOTO 45
42      BEEP: LOCATE 8, 13: COLOR 15: PRINT A$;
        COLOR 12: PRINT C$;
        GOTO 28
43      IF LONP < 1 THEN GOTO 42 ELSE IF LONP > 50 THEN GOTO
42 ELSE GOTO 45

45      LAT = LATP: LON = LONP
        IF VARD = 1 THEN GOTO 38 ELSE GOTO 36

38      LAT = INT((111.19 * (LAT - 46)) / 10.319):
        IF LAT < 1 THEN LAT = 1
        IF LAT > 33 THEN LAT = 33
        LON = INT((111.19 * (104 - LON)) / 10.204):
        IF LON < 1 THEN LON = 1
        IF LON > 50 THEN LON = 50
36 CLS 2
90      IF LOP > 1 THEN GOTO 91

        FOR I = 0 TO 33
            K = 434 - 9 * I
            IF I MOD 5 = 0 THEN LINE (20, K + 1)-(470, K +
1), 13
            LINE (20, K)-(470, K), 13
        NEXT
        FOR I = 0 TO 50
            K = 20 + 9 * I
            IF I MOD 5 = 0 THEN LINE (K + 1, 138)-(K + 1,
435), 13
            LINE (K, 138)-(K, 435), 13

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NEXT
LOP = 2
GOSUB 1200
CIRCLE (11, 434), 4, 11, , , 2: COLOR 11: LOCATE 17,
1: PRINT "33";
COLOR 14: PRINT " 0"; TAB(57); " 50"
RETURN
91
XX = 437 - 9 * LAT: YY = 18 + 9 * LON: PAINT (YY,
XX), 14, 13
CIRCLE (71, 434), 4, 0, , , 2
.
COLOR 10
FOR I = 1 TO 2
OPEN NME$(I) FOR INPUT AS I
LOCATE I, 1: PRINT "FILE ";
PRINT USING "###"; I;
PRINT , TAB(15); NME$(I); TAB(28); "OPEN"

FOR J = 1 TO 5
INPUT #I, DUM$
NEXT
NEXT
FOR I = 12 TO 17
OPEN NME$(I) FOR INPUT AS I
LOCATE I, 1: PRINT "FILE ";
PRINT USING "###"; I;
IF I = 17 THEN GOTO 187 ELSE GOTO 18
18 PRINT , TAB(15); NME$(I); TAB(28); "OPEN"
187 REM

FOR J = 1 TO 5
INPUT #I, DUM$
NEXT
NEXT

FOR K = 1 TO NR
FOR L = 1 TO 50
11 INPUT #1, SURT(K, L)
12 INPUT #2, ELEV(K, L)
13 INPUT #12, DBY(K, L)
14 INPUT #13, WPG(K, L)
15 INPUT #14, INLK(K, L)
16 INPUT #15, RED(K, L)
17 INPUT #16, DWD(K, L)
INPUT #17, Q(K, L)
NEXT
NEXT
CLOSE
COLOR 12
FOR MM = 1 TO 2
LOCATE MM, 1: PRINT "FILE ";
PRINT USING "###"; MM;
PRINT , TAB(15); NME$(MM); TAB(28); "CLOSED"

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NEXT
FOR MM = 12 TO 16
  LOCATE MM, 1: PRINT "FILE ";
  PRINT USING "###"; MM;
  PRINT , TAB(15); NME$(MM); TAB(28); "CLOSED"

NEXT
COLOR 10
I = 2
150 I = I + 1
  OPEN NME$(I) FOR INPUT AS I
  LOCATE I, 1: PRINT "FILE ";
  PRINT USING "###"; I;
  PRINT , TAB(15); NME$(I); TAB(28); "OPEN"

  IF NME$(I) = OPE$ THEN GOTO 160 ELSE GOTO 150
160 N = I: ' OPEN NME$(N) FOR INPUT AS N
  ' LOCATE I + 1, 20: PRINT "PRESS ANY KEY TO CONTINUE"
170 ' dis$ = INKEY$: IF dis$ = "" THEN GOTO 170
  FOR I = 3 TO N
    FOR J = 1 TO 5
      INPUT #I, DUM$
    NEXT
  NEXT

  COLOR 14
  LOCATE 2, 50: PRINT OUT$:
  LOCATE 4, 45: COLOR 11: PRINT LATP; CHR$(0);
  CHR$(0); CHR$(0); LONP

  TOTEM = 0: SUMTHICK = 0
  FOR I = 1 TO NR
    FOR J = 1 TO NC
      TSUM = 0
      FOR K = 3 TO N
200 INPUT #K, A: IF A = 0 THEN GOTO 200
        SELECT CASE K
          CASE IS = 3: KP = A
          CASE IS = 4: KIK = A
          CASE IS = 5: JURA = A
          CASE IS = 6: SPF = A
          CASE IS = 7: OTK = A
          CASE IS = 8: MAD = A
          CASE IS = 9: BAK = A
          CASE IS = 10: TFKS = A
          CASE IS = 11: DUP = A
        END SELECT
      NEXT
      IF I > LAT AND J > LON THEN GOTO 585
      IF I = LAT AND J = LON THEN GOTO 370 ELSE GOTO
580
370 DPIER = ELEV(I, J) - KP: CLS 2

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      IF KP > KIK THEN GOTO 371 ELSE GOTO 372
371 IF KIK > 0 THEN DINY = ABS(KP - KIK) ELSE DINY = ABS(KIK
    - KP)
      GOTO 373
372   DINY = 0
373 IF KIK > JURA THEN DJURA = ABS(JURA - KIK) ELSE DJURA =
    0
      IF JURA > SPF THEN DSPEAR = ABS(SPF - JURA) ELSE DSPEAR
    = 0
      IF SPF > OTK THEN DOTK = ABS(OTK - SPF) ELSE DOTK = 0
      IF OTK > MAD THEN DMAD = ABS(MAD - OTK) ELSE DMAD = 0
      IF MAD > TFKS THEN DTFKS = ABS(TFKS - MAD) ELSE DTFKS =
    0
      IF TFKS > DUP THEN DDUP = ABS(DUP - TFKS) ELSE DDUP = 0
      IF DUP > DBY(I, J) THEN DDBY = ABS(DBY(I, J) - DUP) ELSE
    DDBY = 0
      IF DBY(I, J) > WPG(I, J) THEN DWPG = ABS(WPG(I, J) -
    DBY(I, J)) ELSE DWPG = 0
      IF WPG(I, J) > INLK(I, J) THEN DINLK = ABS(INLK(I, J) -
    WPG(I, J)) ELSE DINLK = 0
      IF INLK(I, J) > RED(I, J) THEN DRED = ABS(RED(I, J) -
    INLK(I, J)) ELSE DRED = 0
      IF RED(I, J) > DWD(I, J) THEN DDWD = ABS(DWD(I, J) -
    RED(I, J)) ELSE DDWD = 0

460   'BEGIN OUTPUT TO SCREEN AND/OR PRINTER
      PRINT "SURFACE"; TAB(25);
      COLOR 14: PRINT USING "#####.##"; SURT(I, J);
      COLOR 15: PRINT "          HEAT FLOW = ";
    Q(I, J); " mW/m^2"
      TPIERRE = SURT(I, J) + TSUM + Q(I, J) * ((DPIER) /
    ELEK): TSUM = TPIERRE: TRMIN1 = SURT(I, J) + 10 + (DPIER) *
    .025
      COLOR 11: PRINT "PIERRE"; TAB(15);
      COLOR 14: PRINT USING " #####.##"; DPIER;
      IF TSUM > TRMIN1 THEN COLOR 10 ELSE COLOR 12
      PRINT USING " #####.##"; TSUM, TRMIN1

      TINYANK = Q(I, J) * ((DINY) / PCON) + TSUM: TSUM =
    TINYANK: TRMIN2 = SURT(I, J) + 10 + (DPIER + DINY) * .025
      COLOR 11: PRINT "INYAN KARA", TAB(15);
      COLOR 14: PRINT USING " #####.##"; DPIER + DINY;
      IF TSUM > TRMIN2 THEN COLOR 10 ELSE COLOR 12
      PRINT USING " #####.##"; TSUM, TRMIN2

      TJURA = Q(I, J) * ((DJURA) / IKCON) + TSUM: TSUM =
    TJURA: TRMIN3 = SURT(I, J) + 10 + (DPIER + DINY + DJURA) *
    .025
      COLOR 11: PRINT "JURASSIC", TAB(15);
      COLOR 14: PRINT USING " #####.##"; DPIER + DINY +
    DJURA;
      IF TSUM > TRMIN3 THEN COLOR 10 ELSE COLOR 12
      PRINT USING " #####.##"; TSUM, TRMIN3

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    TSPEAR = Q(I, J) * ((DSPEAR) / JCON) + TSUM: TSUM =
    TSPEAR: TRMIN4 = SURT(I, J) + 10 + (DPIER + DINY + DJURA +
    DSPEAR) * .025
        COLOR 11: PRINT "SPEARFISH", TAB(15);
        COLOR 14: PRINT USING " #####.##"; DPIER + DINY +
    DJURA + DSPEAR;
        IF TSUM > TRMIN4 THEN COLOR 10 ELSE COLOR 12
        PRINT USING " #####.##"; TSUM, TRMIN4

    TOTK = Q(I, J) * ((DOTK) / SPFCON) + TSUM: TSUM = TOTK:
    TRMIN5 = SURT(I, J) + 10 + (DPIER + DINY + DJURA + DSPEAR +
    DOTK) * .025
        COLOR 11: PRINT "OTTER"; TAB(15);
        COLOR 14: PRINT USING " #####.##"; DPIER + DINY +
    DJURA + DSPEAR + DOTK;
        IF TSUM > TRMIN5 THEN COLOR 10 ELSE COLOR 12
        PRINT USING " #####.##"; TSUM, TRMIN5

    TMADISON = Q(I, J) * ((DMAD) / OTKCON) + TSUM: TSUM =
    TMADISON: TRMIN6 = SURT(I, J) + 10 + (DPIER + DINY + DJURA +
    DSPEAR + DOTK + DMAD) * .025
        COLOR 11: PRINT "MADISON", TAB(15);
        COLOR 14: PRINT USING " #####.##"; DPIER + DINY +
    DJURA + DSPEAR + DOTK + DMAD;
        IF TSUM > TRMIN6 THEN COLOR 10 ELSE COLOR 12
        PRINT USING " #####.##"; TSUM, TRMIN6

    'TBAKKEN = Q(I,J) * ((DBAK) / MADCON) + TSUM: TSUM =
    TBAKKEN: LPRINT "BAKKEN", TAB(20); ,
    'LPRINT USING " #####.##"; DPIER + DINY + DJURA + DSPEAR
    + DOTK + DMAD + DBAK, TSUM, SURT(I, J) + 10 + (DPIER + DINY
    + DJURA + DSPEAR + DOTK + DMAD + DBAK) * .025

    TTFKS = Q(I, J) * ((DTFKS) / MADCON) + TSUM: TSUM =
    TTFKS: TRMIN7 = SURT(I, J) + 10 + (DPIER + DINY + DJURA +
    DSPEAR + DOTK + DMAD + DBAK + DTFKS) * .025
        COLOR 11: PRINT "THREE FORKS", TAB(15);
        COLOR 14: PRINT USING " #####.##"; DPIER + DINY +
    DJURA + DSPEAR + DOTK + DMAD + DBAK + DTFKS;
        IF TSUM > TRMIN7 THEN COLOR 10 ELSE COLOR 12
        PRINT USING " #####.##"; TSUM, TRMIN7

    TDUPRW = Q(I, J) * ((DDUP) / DUPCON) + TSUM: TSUM =
    TDUPRW: TRMIN8 = SURT(I, J) + 10 + (DPIER + DINY + DJURA +
    DSPEAR + DOTK + DMAD + DBAK + DTFKS + DDUP) * .025
        COLOR 11: PRINT "DUPEROW", TAB(15);
        COLOR 14: PRINT USING " #####.##"; DPIER + DINY +
    DJURA + DSPEAR + DOTK + DMAD + DBAK + DTFKS + DDUP;
        IF TSUM > TRMIN8 THEN COLOR 10 ELSE COLOR 12
        PRINT USING " #####.##"; TSUM, TRMIN8

    TDAWSBY = Q(I, J) * ((DDBY) / DUPCON) + TSUM: TSUM =
    TDAWSBY: TRMIN9 = SURT(I, J) + 10 + (DPIER + DINY + DJURA +
    DSPEAR + DOTK + DMAD + DBAK + DTFKS + DDUP + DDBY) * .025

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COLOR 11: PRINT "DAWSONBY", TAB(15);
COLOR 14: PRINT USING " #####.##"; DPIER + DINY +
DJURA + DSPEAR + DOTK + DMAD + DBAK + DTFKS + DDUP + DDBY;
IF TSUM > TRMIN9 THEN COLOR 10 ELSE COLOR 12
PRINT USING " #####.##"; TSUM, TRMIN9

TWPG = Q(I, J) * ((DWPG) / DUPCON) + TSUM: TSUM = TWPG:
TRMIN10 = SURT(I, J) + 10 + (DPIER + DINY + DJURA + DSPEAR +
DOTK + DMAD + DBAK + DTFKS + DDUP + DDBY + DWPG) * .025
COLOR 11: PRINT "WINNIPEGOSIS", TAB(15);
COLOR 14: PRINT USING " #####.##"; DPIER + DINY +
DJURA + DSPEAR + DOTK + DMAD + DBAK + DTFKS + DDUP + DDBY +
DWPG;
IF TSUM > TRMIN10 THEN COLOR 10 ELSE COLOR 12
PRINT USING " #####.##"; TSUM, TRMIN10

TINLAKE = Q(I, J) * ((DINLK) / DUPCON) + TSUM: TSUM =
TINLAKE: TRMIN11 = SURT(I, J) + 10 + (DPIER + DINY + DJURA +
DSPEAR + DOTK + DMAD + DBAK + DTFKS + DDUP + DDBY + DWPG +
DINLK) * .025
COLOR 11: PRINT "INTERLAKE", TAB(15);
COLOR 14: PRINT USING " #####.##"; DPIER + DINY +
DJURA + DSPEAR + DOTK + DMAD + DBAK + DTFKS + DDUP + DDBY +
DWPG + DINLK;
IF TSUM > TRMIN11 THEN COLOR 10 ELSE COLOR 12
PRINT USING " #####.##"; TSUM, TRMIN11

TRED = Q(I, J) * ((DRED) / INLKCON) + TSUM: TSUM = TRED:
TRMIN12 = SURT(I, J) + 10 + (DPIER + DINY + DJURA + DSPEAR +
DOTK + DMAD + DBAK + DTFKS + DDUP + DDBY + DWPG + DINLK +
DRED) * .025
COLOR 11: PRINT "REDRIVER", TAB(15);
COLOR 14: PRINT USING " #####.##"; DPIER + DINY +
DJURA + DSPEAR + DOTK + DMAD + DBAK + DTFKS + DDUP + DDBY +
DWPG + DINLK + DRED;
IF TSUM > TRMIN12 THEN COLOR 10 ELSE COLOR 12
PRINT USING " #####.##"; TSUM, TRMIN12

TDWD = Q(I, J) * ((DDWD) / REDCON) + TSUM: TSUM = TDWD:
TRMIN13 = SURT(I, J) + 10 + (DPIER + DINY + DJURA + DSPEAR +
DOTK + DMAD + DBAK + DTFKS + DDUP + DDBY + DWPG + DINLK +
DRED + DDWD) * .025
COLOR 11: PRINT "DEADWOOD", TAB(15);
COLOR 14: PRINT USING " #####.##"; DPIER + DINY +
DJURA + DSPEAR + DOTK + DMAD + DBAK + DTFKS + DDUP + DDBY +
DWPG + DINLK + DRED + DDWD;
IF TSUM > TRMIN13 THEN COLOR 10 ELSE COLOR 12
PRINT USING " #####.##"; TSUM, TRMIN13

LOCATE 5, 60: COLOR 11: PRINT OUT$: LOCATE 7, 55:
COLOR 14: PRINT LATP; CHR$(0); CHR$(0); CHR$(0); LONP
COLOR 15: LOCATE 16, 17: PRINT "DEPTH m      TEMP
Min. Res. T": COLOR 11
IF POUT = 1 THEN GOTO 1400 ELSE GOTO 580

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1400 'PRINTER ROUTINE

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        LPRINT : LPRINT : LPRINT
        LPRINT OUT$
        LPRINT LATP, LONP, "HEAT FLOW "; Q(I, J)
        LPRINT
        LPRINT "SURFACE", TAB(38);
        LPRINT USING " #####.###"; SURT(I, J)
        LPRINT "PIERRE", TAB(20); ,
        LPRINT USING " #####.###"; DPIER, TPIERRE, TRMIN1
        LPRINT "INYAN KARA", TAB(20); ,
        LPRINT USING " #####.###"; DPIER + DINY, TINYANK, TRMIN2
        LPRINT "JURASSIC", TAB(20); ,
        LPRINT USING " #####.###"; DPIER + DINY + DJURA, TJURA,
TRMIN3
        LPRINT "SPEARFISH", TAB(20); ,
        LPRINT USING " #####.###"; DPIER + DINY + DJURA + DSPEAR,
TSPEAR, TRMIN4
        LPRINT "OTTER"; TAB(20); ,
        LPRINT USING " #####.###"; DPIER + DINY + DJURA + DSPEAR
+ DOTK, TOTK, TRMIN5
        LPRINT "MADISON", TAB(20); ,
        LPRINT USING " #####.###"; DPIER + DINY + DJURA + DSPEAR
+ DOTK + DMAD, TMADISON, TRMIN6
        LPRINT "THREE FORKS", TAB(20); ,
        LPRINT USING " #####.###"; DPIER + DINY + DJURA + DSPEAR
+ DOTK + DMAD + DBAK + DTFKS, TTFKS, TRMIN7
        LPRINT "DUPEROW", TAB(20); ,
        LPRINT USING " #####.###"; DPIER + DINY + DJURA + DSPEAR
+ DOTK + DMAD + DBAK + DTFKS + DDUP, TDUPRW, TRMIN8
        LPRINT "DAWSONBY", TAB(20); ,
        LPRINT USING " #####.###"; DPIER + DINY + DJURA + DSPEAR
+ DOTK + DMAD + DBAK + DTFKS + DDUP + DDBY, TDAWSBY, TRMIN9
        LPRINT "WINNIPEGOSIS", TAB(20); ,
        LPRINT USING " #####.###"; DPIER + DINY + DJURA + DSPEAR
+ DOTK + DMAD + DBAK + DTFKS + DDUP + DDBY + DWPG, TWPG,
TRMIN10
        LPRINT "INTERLAKE", TAB(20); ,
        LPRINT USING " #####.###"; DPIER + DINY + DJURA + DSPEAR
+ DOTK + DMAD + DBAK + DTFKS + DDUP + DDBY + DWPG + DINLK,
TINLAKE, TRMIN11
        LPRINT "REDRIVER", TAB(20); ,
        LPRINT USING " #####.###"; DPIER + DINY + DJURA + DSPEAR
+ DOTK + DMAD + DBAK + DTFKS + DDUP + DDBY + DWPG + DINLK +
DRED, TRED, TRMIN12
        LPRINT "DEADWOOD", TAB(20); ,
        LPRINT USING " #####.###"; DPIER + DINY + DJURA + DSPEAR
+ DOTK + DMAD + DBAK + DTFKS + DDUP + DDBY + DWPG + DINLK +
DRED + DDWD, TDWD, TRMIN13
        LF = LF + 1
        IF LF > 3 THEN LPRINT CHR$(12)
        IF LF > 3 THEN LF = 0
580     NEXT
        NEXT

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585      ag$ = INKEY$: IF ag$ = "" THEN GOTO 585
      CLS 2: LOCATE 10, 10: INPUT ; "TYPE 1 TO CONTINUE OR
RETURN TO END"; EC
      CLOSE
      IF EC = 1 THEN GOTO 30

      CLOSE
      END

1190 END

1200 OPEN "NODAK.DAT" FOR INPUT AS 18
INPUT #18, Lx, Ly
      INPUT #18, x, y
       $x = 136 + 111.09 / 1.135 * (49 - x): y = 20 + 111.09 /$ 
1.135 * (104 + y)
      PSET (y, x), 10
      WHILE NOT EOF(18)
      INPUT #18, x, y
       $x = 136 + 111.09 / 1.135 * (49 - x): y = 20 + 111.09 /$ 
1.135 * (104 + y)
      LINE -(y, x), 10
WEND
CLOSE 18
RETURN

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***** PROGRAM RESOURCE *****
10 CLS : SCREEN 0: COLOR 11
    DIM NME$(17), PORE(17), DENS(17), Q(33, 50), INLK(33,
50), RED(33, 50), DWD(33, 50)
    DEF SEG = &H40: POKE &H17, (PEEK(&H17) OR &H40): 'CAPS
LOCK ON
    NME$(1) = "SURT.GRD": NME$(2) = "GROUND.GRD": NME$(3) =
"PIERRE.GRD": NME$(4) = "INYANK.GRD": NME$(5) =
"JURASSIC.GRD": NME$(6) = "SPEARFSH.GRD": NME$(7) =
"OTTER.GRD": NME$(8) = "MADISON.GRD"
    NME$(9) = "3FORKS.GRD": NME$(10) = "DUPEROW.GRD":
NME$(11) = "DAWSONBY.GRD": NME$(12) = "WNPBGOSIS.GRD":
NME$(13) = "INTERLAK.GRD": NME$(14) = "RDRIVER.GRD":
NME$(15) = "DEADWOOD.GRD": NME$(16) = "Q.GRD"
    LOCATE 8, 33: PRINT " PROGRAM RESTEMP"
    LOCATE 11, 20: PRINT " PROGRAM FOR CALCULATING GEOTHERMAL
RESOURCES"
    COLOR 28: LOCATE 15, 31: PRINT "{press any key to begin}"
50    DIS$ = INKEY$: IF DIS$ = "" THEN 50
        RESS$ = "R. BASE = ": RESS$ = " J.": AVTK$ = " TCK =
": AVTMP$ = " AVT = "
        M1 = 6.35: M2 = 3.38: N1 = 506.35: N2 = 333.59: SUFAC =
0: I = 0: N = 0: CLS : NC = 50: NR = 33: TMAX = 0: TMIN =
100
        ELEK = 1700: PCON = 1200: IKCON = 1600: JCON = 1800:
RESTOT = 0: SPHT = (1 / 2.6) * 1000
        SPFCON = 3100: OTKCON = 2800: MADCON = 3500: DUPCON =
3500: INLKCON = 4000: REDCON = 3500: DWDCON = 3000
        PORE(1) = 0: PORE(2) = 0: PORE(3) = .05: PORE(4) = .17:
PORE(5) = .1: PORE(6) = .1: PORE(7) = .1: PORE(8) = .11:
PORE(9) = .2: PORE(10) = .2: PORE(11) = .2: PORE(12) = .2:
PORE(13) = .2: PORE(14) = .1
        DENS(1) = 0: DENS(2) = 0: DENS(3) = 2500: DENS(4) = 2700:
DENS(5) = 2500: DENS(6) = 2600: DENS(7) = 2670: DENS(8) =
2750: DENS(9) = 2650: DENS(10) = 2750: DENS(11) = 2700:
DENS(12) = 2850: DENS(13) = 2850: DENS(14) = 2850
        AREA = 1.0165E+08: COLOR 10
        PRINT " 1 = SURFACE      2 = GROUND          3 = PIERRE          4
= INYAN KARA      5 = JURASSIC "
        PRINT " 6 = SPEARFISH  7 = OTTER            8 = MADISON          9
= THREE FORKS 10 = DUPEROW"
        PRINT "11 = DAWSONBAY 12 = WINIPEGOSIS 13 = INTERLAKE 14
= REDRIVER      15 = DEADWOOD"

27 COLOR 14: LOCATE 12, 20: INPUT ; "enter NUMBER OF
FORMATION"; OPE:
    COLOR 12: LOCATE 15, 10: PRINT " (8 characters max.,
extensions will be added)"
30    COLOR 13: LOCATE 14, 20: INPUT ; "enter OUTPUT FILE
NAME"; OUT$
    OPEN OUT$ FOR OUTPUT AS 18
    PRINT #18, "DSAA"
    PRINT #18, NC, NR
    PRINT #18, M1, N1

```

```

PRINT #18, M2, N2
PRINT #18, DUM$, DUM$
CLS : COLOR 10

OPEN NME$(16) FOR INPUT AS 16
LOCATE 12, 10: PRINT "READING HEAT FLOW GRID"

FOR J = 1 TO 5
    INPUT #16, DUM$
NEXT

FOR K = 1 TO 33
    FOR L = 1 TO 50
        INPUT #16, Q(K, L)
    NEXT
NEXT
CLOSE #16

N = OPE:
NN = OPE
IF OPE < 13 THEN GOTO 140 ELSE GOTO 135
135 NN = 13
FOR I = 14 TO 15
    OPEN NME$(I) FOR INPUT AS I
    LOCATE I, 10: PRINT "FILE "; I; NME$(I); " OPEN"

    FOR J = 1 TO 5
        INPUT #I, DUM$
    NEXT
NEXT

FOR K = 1 TO 33
    FOR L = 1 TO 50
12     INPUT #14, RED(K, L): IF RED(K, L) = 0 THEN
GOTO 12
13     INPUT #15, DWD(K, L): IF DWD(K, L) = 0 THEN
GOTO 13

    NEXT
NEXT
CLOSE #14: CLOSE #15
COLOR 12
FOR I = 14 TO 15
    LOCATE I, 10: PRINT "FILE "; I; NME$(I); "
CLOSED"
NEXT
COLOR 10

140     IF N >= 13 THEN NN' = 13 ELSE NN = N + 1
FOR I = 1 TO NN
    OPEN NME$(I) FOR INPUT AS I
    LOCATE I, 10: PRINT "FILE "; I; NME$(I); " OPEN"
NEXT

```

```

FOR I = 1 TO NN
  FOR J = 1 TO 5
    LINE INPUT #I, DUM$
  NEXT
NEXT

TOTEM = 0: SUMTHICK = 0

FOR I = 1 TO NR
  FOR J = 1 TO NC
    TSUM = 0
    IF N >= 13 THEN NN = 13 ELSE NN = N + 1
    FOR K = 1 TO NN
      INPUT #K, A: IF A = 0 THEN GOTO 200
      SELECT CASE K
        CASE IS = 1: SURT = A
        CASE IS = 2: ELEV = A
        CASE IS = 3: KP = A
        CASE IS = 4: KIK = A
        CASE IS = 5: JURA = A
        CASE IS = 6: SPF = A
        CASE IS = 7: OTK = A
        CASE IS = 8: MAD = A
        CASE IS = 9: TFKS = A
        CASE IS = 10: DUP = A
        CASE IS = 11: DBY = A
        CASE IS = 12: WPG = A
        CASE IS = 13: INLK = A
      END SELECT
    NEXT
  200
  370 DPIER = ELEV - KP
    IF KP > KIK THEN DINY = ABS(KIK - KP) ELSE DINY = 0
    TCKNESS = DINY
    IF N = 3 THEN GOTO 460
    IF KIK > JURA THEN DJURA = ABS(JURA - KIK) ELSE
  DJURA = 0
    TCKNESS = DJURA
    IF N = 4 THEN GOTO 460
    IF JURA > SPF THEN DSPEAR = ABS(SPF - JURA) ELSE
  DSPEAR = 0
    TCKNESS = DSPEAR
    IF N = 5 THEN GOTO 460
    IF SPF > OTK THEN DOTK = ABS(OTK - SPF) ELSE DOTK =
  0
    TCKNESS = DOTK
    IF N = 6 THEN GOTO 460
    IF OTK > MAD THEN DMAD = ABS(MAD - OTK) ELSE DMAD =
  0
    TCKNESS = DMAD
    IF N = 7 THEN GOTO 460
    IF MAD > TFKS THEN DTFKS = ABS(TFKS - MAD) ELSE
  DTFKS = 0

```

```

TCKNESS = DTFKS
IF N = 8 THEN GOTO 460
IF TFKS > DUP THEN DDUP = ABS(DUP - TFKS) ELSE DUP =
0
TCKNESS = DDUP
IF N = 9 THEN GOTO 460
IF DUP > DBY THEN DDBY = ABS(DBY - DUP) ELSE DDBY =
0
TCKNESS = DDBY
IF N = 10 THEN GOTO 460
IF DBY > WPG THEN DWPG = ABS(WPG - DBY) ELSE DWPG =
0
TCKNESS = DWPG
IF N = 11 THEN GOTO 460
IF WPG > INLK THEN DINLK = ABS(INLK - WPG) ELSE
DINLK = 0
TCKNESS = DINLK
IF N = 12 THEN GOTO 460
IF INLK > RED(I, J) THEN DRED = ABS(RED(I, J) -
INLK) ELSE DRED = 0
TCKNESS = DRED
IF N = 13 THEN GOTO 460
IF RED(I, J) > DWD(I, J) THEN DDWD = ABS(DWD(I, J) -
RED(I, J)) ELSE DDWD = 0
TCKNESS = DDWD
IF N = 14 THEN GOTO 460
TCKNESS = 100
460 TPIERRE = SURT + TSUM + Q(I, J) * ((DPIER) / ELEK): TSUM
= TPIERRE
IF N = 3 THEN GOTO 550
TINYANK = Q(I, J) * ((DINY) / PCON) + TSUM: TSUM =
TINYANK
IF N = 4 THEN GOTO 550
TJURA = Q(I, J) * ((DJURA) / IKCON) + TSUM: TSUM = TJURA
IF N = 5 THEN GOTO 550
TSPEAR = Q(I, J) * ((DSPEAR) / JCON) + TSUM: TSUM =
TSPEAR
IF N = 6 THEN GOTO 550
TOTK = Q(I, J) * ((DOTK) / SPFCON) + TSUM: TSUM = TOTK
IF N = 7 THEN GOTO 550
TMADISON = Q(I, J) * ((DMAD) / OTKCON) + TSUM: TSUM =
TMADISON
IF N = 8 THEN GOTO 550
TTFKS = Q(I, J) * ((DTFKS) / MADCON) + TSUM: TSUM =
TTFKS
IF N = 9 THEN GOTO 550
TDUPRW = Q(I, J) * ((DDUP) / DUPCON) + TSUM: TSUM =
TDUPRW
IF N = 10 THEN GOTO 550
TDAWSBY = Q(I, J) * ((DDBY) / DUPCON) + TSUM: TSUM =
TDAWSBY
IF N = 11 THEN GOTO 550
TWPG = Q(I, J) * ((DWPG) / DUPCON) + TSUM: TSUM = TWPG
IF N = 12 THEN GOTO 550

```



```

      TINLAKE = Q(I, J) * ((DINLK) / DUPCON) + TSUM: TSUM =
TINLAKE
      IF N = 13 THEN GOTO 550
      TRED = Q(I, J) * ((DRED) / INLKCON) + TSUM: TSUM = TRED
      IF N = 14 THEN GOTO 550
      TDWD = Q(I, J) * ((DDWD) / REDCON) + TSUM: TSUM = TDWD
550  IF TSUM > TMAX THEN TMAX = TSUM
      IF TSUM < TMIN THEN TMIN = TSUM
      'IF TSUM > 150 THEN PRINT TSUM, I, J
      IF TSUM = 0 THEN GOTO 580
570  PRINT #18, USING "#####.##"; TSUM;
      IF TCKNESS = 0 THEN SUFAC = SUFAC + 1
      IF TSUM < 15 THEN SUFAC = SUFAC + 1
      IF TSUM < 15 THEN GOTO 580
      RESTOT = RESTOT + (TSUM - SURT) * TCKNESS * AREA *
DENS(N - 1) * SPHT
      SUMTHICK = SUMTHICK + TCKNESS: TOTEM = TOTEM + TSUM
580  NEXT
      NEXT
      CLOSE
      LOCATE 22, 10: COLOR 14: PRINT RESTOT, SUMTHICK / (NR *
NC - SUFAC), TOTEM / (NR * NC - SUFAC)
      OPEN OUT$ FOR INPUT AS 1
      OPEN OUT$ + ".IMG" FOR OUTPUT AS 2
      OPEN OUT$ + ".RES" FOR OUTPUT AS 3
      INPUT #1, A$
      PRINT #2, "DSAA"
      INPUT #1, NC, NR
      PRINT #2, NC, NR
      INPUT #1, M1, N1
      PRINT #2, M1, N1
      INPUT #1, M2, N2
      PRINT #2, M2, N2
      INPUT #1, DUM$
      PRINT #2, TMIN, TMAX
      FOR I = 1 TO NR
        FOR J = 1 TO NC
          INPUT #1, T
          IF J < 50 GOTO 590
          PRINT #2, USING "#####.##"; T:

          GOTO 600
590  PRINT #2, USING "#####.##"; T;

600  NEXT
      NEXT
      PRINT #3, OUT$
      PRINT #3, RES$; RESTOT; RESS$; AVTK$; SUMTHICK / (NR
* NC); AVTMP$; TOTEM / (NR * NC)
      CLOSE
      COLOR 11
      END

1190 COLOR 11: END

```

APPENDIX I

**TEMPERATURE-DEPTH PROFILES GENERATED BY PROGRAM LOCTEMP FOR
SELECTED CITIES AND TOWNS IN NORTH DAKOTA**

BEACH	DEPTH	TEMP.	MIN. RES. TEMP.
SURFACE		6.42	
PIERRE	431.83	21.66	27.22
INYAN KARA	1625.03	81.32	57.05
JURASSIC	1743.31	85.76	60.00
SPEARFISH	2030.51	95.33	67.18
OTTER	2441.61	103.29	77.46
MADISON	2569.90	106.04	80.67
BAKKEN	2934.95	112.29	89.79
THREE FORKS	3034.95	116.29	92.29
DUPEROW	3091.14	117.26	93.70
DAWSONBY	3202.87	119.17	96.49
WINNIPEGOSIS	3223.10	119.52	97.00
INTERLAKE	3231.51	119.66	97.21
REDRIVER	3438.69	122.77	102.39
DEADWOOD	3697.49	127.21	108.86

BELFIELD			
SURFACE		6.42	
PIERRE	652.32	29.45	32.73
INYAN KARA	1684.83	81.07	58.54
JURASSIC	1815.24	85.96	61.80
SPEARFISH	2070.63	94.47	68.19
OTTER	2487.30	102.54	78.60
MADISON	2644.64	105.91	82.54
BAKKEN	3039.38	112.68	92.41
THREE FORKS	3139.38	116.68	94.91
DUPEROW	3217.73	118.02	96.87
DAWSONBY	3344.21	120.19	100.03
WINNIPEGOSIS	3443.91	121.90	102.52
INTERLAKE	3501.41	122.88	103.96
REDRIVER	3759.03	126.75	110.40
DEADWOOD	3978.33	130.51	115.88

BEULAH			
SURFACE		6.39	
PIERRE	386.05	20.02	26.05
INYAN KARA	1177.15	59.58	45.82
JURASSIC	1261.13	62.72	47.92
SPEARFISH	1658.08	75.96	57.85
OTTER	1659.61	75.99	57.89
MADISON	2090.85	85.23	68.67
BAKKEN	2143.23	86.12	69.98
THREE FORKS	2243.23	90.12	72.48
DUPEROW	2313.30	91.33	74.23
DAWSONBY	2464.69	93.92	78.01
WINNIPEGOSIS	2937.96	102.03	89.84
INTERLAKE	3001.78	103.13	91.44
REDRIVER	3296.93	107.56	98.82
DEADWOOD	3613.83	112.99	106.74

	DEPTH	TEMP.	MIN. RES. TEMP.
BISMARCK			
SURFACE		6.42	
PIERRE	108.21	10.24	19.13
INYAN KARA	751.43	42.40	35.21
JURASSIC	806.07	44.45	36.58
SPEARFISH	1108.89	54.55	44.15
OTTER	1189.89	56.12	46.17
MADISON	1346.77	59.48	50.09
BAKKEN	1428.92	60.89	52.15
THREE FORKS	1528.92	64.89	54.65
DUPEROW	1556.13	65.35	55.33
DAWSONBY	1648.50	66.94	57.64
WINNIPEGOSIS	1974.53	72.52	65.79
INTERLAKE	1984.91	72.70	66.05
REDRIVER	2096.49	74.38	68.84
DEADWOOD	2237.04	76.79	72.35

BOTTINEAU			
SURFACE		6.25	
PIERRE	126.34	10.71	19.41
INYAN KARA	615.81	35.18	31.64
JURASSIC	663.07	36.95	32.82
SPEARFISH	938.43	46.13	39.71
OTTER	1428.75	55.62	51.97
MADISON	1890.02	65.50	63.50
BAKKEN	2351.28	73.41	75.03
THREE FORKS	2351.28	73.41	75.03
DUPEROW	2351.28	73.41	75.03
DAWSONBY	2351.28	73.41	75.03
WINNIPEGOSIS	2378.09	73.87	75.70
INTERLAKE	2429.22	74.75	76.98
REDRIVER	2575.34	76.94	80.63
DEADWOOD	2596.08	77.30	81.15

CANDO			
SURFACE		6.27	
PIERRE	30.82	7.36	17.04
INYAN KARA	359.71	23.80	25.26
JURASSIC	384.41	24.73	25.88
SPEARFISH	575.27	31.09	30.65
OTTER	1109.36	41.43	44.01
MADISON	1553.19	50.94	55.10
BAKKEN	1997.01	58.55	66.20
THREE FORKS	1997.01	58.55	66.20
DUPEROW	1997.01	58.55	66.20
DAWSONBY	1997.01	58.55	66.20
WINNIPEGOSIS	2273.00	63.28	73.10
INTERLAKE	2286.56	63.51	73.44
REDRIVER	2398.79	65.20	76.24
DEADWOOD	2467.22	66.37	77.95

	DEPTH	TEMP.	MIN. RES. TEMP.
CROSBY			
SURFACE		6.25	
PIERRE	314.05	17.33	24.10
INYAN KARA	1207.80	62.02	46.44
JURASSIC	1317.67	66.14	49.19
SPEARFISH	1653.28	77.33	57.58
OTTER	1796.42	80.10	61.16
MADISON	1797.29	80.12	61.18
BAKKEN	2209.68	87.19	71.49
THREE FORKS	2309.68	91.19	73.99
DUPEROW	2400.69	92.75	76.27
DAWSONBY	2650.99	97.04	82.52
WINNIPEGOSIS	2840.72	100.29	87.27
INTERLAKE	2898.34	101.28	88.71
REDRIVER	3189.50	105.65	95.99
DEADWOOD	3433.38	109.83	102.08

DICKINSON			
SURFACE		6.42	
PIERRE	586.40	27.12	31.08
INYAN KARA	1575.38	76.57	55.81
JURASSIC	1676.63	80.36	58.34
SPEARFISH	2003.74	91.27	66.52
OTTER	2314.35	97.28	74.28
MADISON	2501.25	101.28	78.95
BAKKEN	2872.08	107.64	88.22
THREE FORKS	2972.08	111.64	90.72
DUPEROW	3064.04	113.22	93.02
DAWSONBY	3202.43	115.59	96.48
WINNIPEGOSIS	3304.67	117.34	99.04
INTERLAKE	3359.19	118.28	100.40
REDRIVER	3632.88	122.38	107.24
DEADWOOD	3858.00	126.24	112.87

ELGIN			
SURFACE		6.45	
PIERRE	317.54	17.66	24.39
INYAN KARA	1141.88	58.87	45.00
JURASSIC	1194.31	60.84	46.31
SPEARFISH	1513.32	71.47	54.28
OTTER	1591.77	72.99	56.25
MADISON	1842.87	78.37	62.52
BAKKEN	1994.05	80.97	66.30
THREE FORKS	2094.05	84.97	68.80
DUPEROW	2153.42	85.98	70.29
DAWSONBY	2252.77	87.69	72.77
WINNIPEGOSIS	2516.96	92.22	79.37
INTERLAKE	2521.09	92.29	79.48
REDRIVER	2694.43	94.89	83.81
DEADWOOD	2718.68	95.30	84.42

	DEPTH	TEMP.	MIN. RES. TEMP.
FORT YATES			
SURFACE		6.47	
PIERRE	52.29	8.31	17.78
INYAN KARA	709.76	41.19	34.21
JURASSIC	752.84	42.80	35.29
SPEARFISH	964.44	49.86	40.58
OTTER	1027.72	51.08	42.16
MADISON	1072.20	52.04	43.27
BAKKEN	1073.14	52.05	43.30
THREE FORKS	1173.14	56.05	45.80
DUPEROW	1173.14	56.05	45.80
DAWSONBY	1446.24	60.73	52.63
WINNIPEGOSIS	1479.23	61.30	53.45
INTERLAKE	1542.24	62.38	55.03
REDRIVER	1616.75	63.50	56.89
DEADWOOD	1689.91	64.75	58.72

GARRISON			
SURFACE		6.36	
PIERRE	292.34	16.68	23.67
INYAN KARA	1001.48	52.13	41.40
JURASSIC	1090.54	55.47	43.62
SPEARFISH	1489.40	68.77	53.59
OTTER	1585.51	70.63	56.00
MADISON	1904.52	77.46	63.97
BAKKEN	1978.15	78.73	65.81
THREE FORKS	2078.15	82.73	68.31
DUPEROW	2119.61	83.44	69.35
DAWSONBY	2270.58	86.03	73.12
WINNIPEGOSIS	2686.03	93.15	83.51
INTERLAKE	2772.75	94.63	85.68
REDRIVER	2995.83	97.98	91.25
DEADWOOD	3173.95	101.03	95.71

GLEN ULIN			
SURFACE		6.43	
PIERRE	335.62	18.27	24.82
INYAN KARA	1122.95	57.64	44.50
JURASSIC	1194.21	60.31	46.28
SPEARFISH	1546.35	72.05	55.09
OTTER	1581.78	72.74	55.97
MADISON	1907.83	79.72	64.12
BAKKEN	2013.77	81.54	66.77
THREE FORKS	2113.77	85.54	69.27
DUPEROW	2171.50	86.53	70.71
DAWSONBY	2286.55	88.50	73.59
WINNIPEGOSIS	2617.17	94.17	81.86
INTERLAKE	2635.09	94.48	82.30
REDRIVER	2856.23	97.79	87.83
DEADWOOD	2931.35	99.08	89.71

	DEPTH	TEMP.	MIN. RES. TEMP.
HETTINGER			
SURFACE		6.48	
PIERRE	426.73	21.54	27.15
INYAN KARA	1374.27	68.92	50.84
JURASSIC	1436.79	71.26	52.40
SPEARFISH	1670.30	79.05	58.24
OTTER	1924.66	83.97	64.60
MADISON	2039.10	86.42	67.46
BAKKEN	2280.41	90.56	73.49
THREE FORKS	2380.41	94.56	75.99
DUPEROW	2438.91	95.56	77.45
DAWSONBY	2496.33	96.55	78.89
WINNIPEGOSIS	2601.25	98.35	81.51
INTERLAKE	2619.39	98.66	81.97
REDRIVER	2782.80	101.11	86.05
DEADWOOD	2942.57	103.85	90.05

KENMARE			
SURFACE		6.28	
PIERRE	258.42	15.40	22.74
INYAN KARA	1027.09	53.83	41.95
JURASSIC	1126.10	57.54	44.43
SPEARFISH	1525.56	70.86	54.41
OTTER	1621.91	72.72	56.82
MADISON	1637.64	73.06	57.22
BAKKEN	1811.38	76.04	61.56
THREE FORKS	1911.38	80.04	64.06
DUPEROW	2010.95	81.75	66.55
DAWSONBY	2226.68	85.44	71.94
WINNIPEGOSIS	2628.85	92.34	82.00
INTERLAKE	2696.63	93.50	83.69
REDRIVER	2858.09	95.92	87.73
DEADWOOD	2930.36	97.16	89.53

KILLDEER			
SURFACE		6.38	
PIERRE	463.60	22.74	27.97
INYAN KARA	1636.48	81.38	57.29
JURASSIC	1767.13	86.28	60.56
SPEARFISH	2074.87	96.54	68.25
OTTER	2428.67	103.39	77.09
MADISON	2562.21	106.25	80.43
BAKKEN	3086.20	115.23	93.53
THREE FORKS	3186.20	119.23	96.03
DUPEROW	3259.03	120.48	97.85
DAWSONBY	3429.15	123.40	102.11
WINNIPEGOSIS	3470.39	124.10	103.14
INTERLAKE	3513.48	124.84	104.21
REDRIVER	3772.47	128.73	110.69
DEADWOOD	4043.58	133.38	117.47

	DEPTH	TEMP.	MIN. RES. TEMP.
MARMATH			
SURFACE		6.46	
PIERRE	222.05	14.30	22.01
INYAN KARA	1358.95	71.14	50.43
JURASSIC	1460.89	74.97	52.98
SPEARFISH	1865.60	88.46	63.10
OTTER	2106.38	93.12	69.12
MADISON	2208.59	95.31	71.68
BAKKEN	2564.15	101.40	80.56
THREE FORKS	2664.15	105.40	83.06
DUPEROW	2664.15	105.40	83.06
DAWSONBY	2730.61	106.54	84.73
WINNIPEGOSIS	3010.02	111.33	91.71
INTERLAKE	3303.36	116.36	99.05
REDRIVER	3464.44	118.78	103.07
DEADWOOD	3678.14	122.44	108.41

MCLUSKY			
SURFACE		6.36	
PIERRE	76.52	9.07	18.28
INYAN KARA	637.11	37.10	32.29
JURASSIC	719.57	40.19	34.35
SPEARFISH	1003.67	49.66	41.46
OTTER	1085.78	51.25	43.51
MADISON	1121.74	52.02	44.41
BAKKEN	1157.71	52.63	45.31
THREE FORKS	1171.99	53.21	45.66
DUPEROW	1171.99	53.21	45.66
DAWSONBY	1272.59	54.93	48.18
WINNIPEGOSIS	1685.90	62.01	58.51
INTERLAKE	1702.95	62.31	58.94
REDRIVER	1842.24	64.40	62.42
DEADWOOD	2019.69	67.44	66.86

MINOT			
SURFACE		6.31	
PIERRE	102.26	9.92	18.87
INYAN KARA	738.47	41.73	34.77
JURASSIC	833.59	45.30	37.15
SPEARFISH	1213.72	57.97	46.65
OTTER	1349.52	60.60	50.05
MADISON	1384.46	61.35	50.92
BAKKEN	1458.56	62.62	52.78
THREE FORKS	1558.56	66.62	55.28
DUPEROW	1607.96	67.46	56.51
DAWSONBY	1792.41	70.63	61.12
WINNIPEGOSIS	2189.13	77.43	71.04
INTERLAKE	2262.36	78.68	72.87
REDRIVER	2482.67	81.99	78.38
DEADWOOD	2655.49	84.95	82.70

	DEPTH	TEMP.	MIN. RES. TEMP.
MOHALL			
SURFACE		6.26	
PIERRE	98.38	9.74	18.72
INYAN KARA	702.87	39.96	33.83
JURASSIC	774.42	42.64	35.62
SPEARFISH	1165.50	55.68	45.40
OTTER	1527.68	62.69	54.45
MADISON	1815.51	68.86	61.65
BAKKEN	2103.35	73.79	68.85
THREE FORKS	2103.35	73.79	68.85
DUPEROW	2103.35	73.79	68.85
DAWSONBY	2278.03	76.79	73.21
WINNIPEGOSIS	2599.85	82.30	81.26
INTERLAKE	2691.94	83.88	83.56
REDRIVER	2913.48	87.20	89.10
DEADWOOD	3000.60	88.70	91.28

MOTT			
SURFACE		6.46	
PIERRE	387.00	20.12	26.13
INYAN KARA	1267.06	64.12	48.14
JURASSIC	1345.88	67.08	50.11
SPEARFISH	1665.09	77.72	58.09
OTTER	1768.94	79.73	60.68
MADISON	2035.82	85.45	67.35
BAKKEN	2213.07	88.48	71.79
THREE FORKS	2313.07	92.48	74.29
DUPEROW	2384.60	93.71	76.07
DAWSONBY	2493.73	95.58	78.80
WINNIPEGOSIS	2699.87	99.12	83.96
INTERLAKE	2706.08	99.22	84.11
REDRIVER	2896.09	102.07	88.86
DEADWOOD	2961.43	103.19	90.49

NEWTOWN			
SURFACE		6.33	
PIERRE	474.43	23.08	28.20
INYAN KARA	1387.93	68.75	51.03
JURASSIC	1486.29	72.44	53.49
SPEARFISH	1871.42	85.28	63.12
OTTER	2059.87	88.93	67.83
MADISON	2362.88	95.42	75.41
BAKKEN	2683.58	100.92	83.42
THREE FORKS	2783.58	104.92	85.92
DUPEROW	2885.26	106.66	88.47
DAWSONBY	3090.69	110.18	93.60
WINNIPEGOSIS	3469.56	116.68	103.07
INTERLAKE	3577.56	118.53	105.77
REDRIVER	4029.87	125.31	117.08
DEADWOOD	4097.80	126.48	118.78

	DEPTH	TEMP.	MIN. RES. TEMP.
PARSHALL			
SURFACE		6.33	
PIERRE	417.76	21.08	26.78
INYAN KARA	1271.76	63.78	48.13
JURASSIC	1371.62	67.52	50.62
SPEARFISH	1768.29	80.74	60.54
OTTER	1779.68	80.97	60.83
MADISON	2122.84	88.32	69.40
BAKKEN	2324.41	91.77	74.44
THREE FORKS	2424.41	95.77	76.94
DUPEROW	2520.25	97.42	79.34
DAWSONBY	2713.62	100.73	84.17
WINNIPEGOSIS	3119.18	107.68	94.31
INTERLAKE	3209.47	109.23	96.57
REDRIVER	3582.12	114.82	105.89
DEADWOOD	3671.67	116.36	108.13

RUGBY			
SURFACE		6.29	
PIERRE	4.67	6.45	16.40
INYAN KARA	452.57	28.85	27.60
JURASSIC	465.29	29.32	27.92
SPEARFISH	768.37	39.43	35.49
OTTER	1248.61	48.72	47.50
MADISON	1750.33	59.47	60.04
BAKKEN	2252.05	68.07	72.59
THREE FORKS	2252.05	68.07	72.59
DUPEROW	2252.05	68.07	72.59
DAWSONBY	2252.05	68.07	72.59
WINNIPEGOSIS	2311.05	69.08	74.06
INTERLAKE	2355.35	69.84	75.17
REDRIVER	2510.25	72.17	79.04
DEADWOOD	2605.76	73.80	81.43

TOWNER			
SURFACE		6.30	
PIERRE	56.18	8.28	17.70
INYAN KARA	588.19	34.88	31.00
JURASSIC	652.60	37.30	32.61
SPEARFISH	959.35	47.52	40.28
OTTER	1298.74	54.09	48.77
MADISON	1628.84	61.16	57.02
BAKKEN	1958.95	66.82	65.27
THREE FORKS	1958.95	66.82	65.27
DUPEROW	1958.95	66.82	65.27
DAWSONBY	1958.95	66.82	65.27
WINNIPEGOSIS	2195.64	70.88	71.19
INTERLAKE	2236.42	71.58	72.21
REDRIVER	2398.88	74.02	76.27
DEADWOOD	2562.66	76.82	80.36

	DEPTH	TEMP.	MIN. RES. TEMP.
TIOGA			
SURFACE		6.30	
PIERRE	559.48	26.04	30.28
INYAN KARA	1488.73	72.51	53.52
JURASSIC	1579.42	75.91	55.78
SPEARFISH	1883.80	86.05	63.39
OTTER	2178.76	91.76	70.77
MADISON	2306.68	94.50	73.96
BAKKEN	2901.07	104.69	88.82
THREE FORKS	3001.07	108.69	91.32
DUPEROW	3102.27	110.43	93.85
DAWSONBY	3339.24	114.49	99.78
WINNIPEGOSIS	3415.38	115.80	101.68
INTERLAKE	3499.65	117.24	103.79
REDRIVER	3879.64	122.94	113.29
DEADWOOD	4190.64	128.27	121.06

WATFORD			
SURFACE		6.34	
PIERRE	459.45	22.56	27.83
INYAN KARA	1592.94	79.23	56.17
JURASSIC	1696.76	83.13	58.76
SPEARFISH	2141.84	97.96	69.89
OTTER	2457.12	104.07	77.77
MADISON	2707.66	109.43	84.04
BAKKEN	3246.60	118.67	97.51
THREE FORKS	3346.60	122.67	100.01
DUPEROW	3447.47	124.40	102.53
DAWSONBY	3670.88	128.23	108.12
WINNIPEGOSIS	3839.55	131.12	112.33
INTERLAKE	3938.29	132.82	114.80
REDRIVER	4351.34	139.01	125.13
DEADWOOD	4524.75	141.99	129.46

WILLISTON			
SURFACE		6.32	
PIERRE	581.08	26.82	30.84
INYAN KARA	1608.40	78.19	56.53
JURASSIC	1743.95	83.27	59.91
SPEARFISH	2088.85	94.77	68.54
OTTER	2382.56	100.46	75.88
MADISON	2518.93	103.38	79.29
BAKKEN	3134.54	113.93	94.68
THREE FORKS	3234.54	117.93	97.18
DUPEROW	3322.17	119.43	99.37
DAWSONBY	3535.68	123.09	104.71
WINNIPEGOSIS	3620.14	124.54	106.82
INTERLAKE	3699.72	125.91	108.81
REDRIVER	4027.13	130.82	116.99
DEADWOOD	4310.60	135.68	124.08

APPENDIX J

**TEMPERATURE-DEPTH PROFILES GENERATED BY PROGRAM LOCTEMP FOR
SELECTED CITIES AND TOWNS IN SOUTH DAKOTA**

DEPTH   TEMP.   MIN. RES. TEMP

ARDMORE

SURFACE		7.92	
PIERRE	0.00	7.92	17.92
DAKOTA	227.59	24.99	23.61
JURASSIC	295.13	28.15	25.29
SPEARFISH	554.62	38.96	31.78
MINNEKAHTA	622.40	40.60	33.48
MINNELUSA	709.34	42.93	35.65
MADISON	709.34	53.68	43.54
ORD-DEV	754.07	54.45	44.65
DEADWOOD	761.80	54.58	44.85

BELLE FOURCHE

SURFACE		8.12	
PIERRE	0.00	8.12	18.12
DAKOTA	66.65	12.56	19.79
JURASSIC	132.28	15.44	21.43
SPEARFISH	326.28	22.98	26.28
MINNEKAHTA	589.88	28.93	32.87
MINNELUSA	663.72	30.78	34.71
MADISON	663.72	34.99	38.03
ORD-DEV	885.87	38.80	43.58
DEADWOOD	1061.66	41.81	47.97

BUFFALO

SURFACE		6.62	
PIERRE	0.00	6.62	16.62
DAKOTA	1300.23	71.63	49.12
JURASSIC	1361.52	73.93	50.66
SPEARFISH	1607.25	82.12	56.80
MINNEKAHTA	1727.86	84.45	59.81
MINNELUSA	1774.50	85.45	60.98
MADISON	1774.50	89.69	64.87
ORD-DEV	2148.47	96.10	74.22
DEADWOOD	2245.62	97.77	76.64

CASTLE ROCK

SURFACE		7.77	
PIERRE	0.00	7.77	17.77
DAKOTA	800.36	47.79	37.78
JURASSIC	845.49	49.48	38.91
SPEARFISH	1012.12	55.04	43.07
MINNEKAHTA	1241.14	59.47	48.80
MINNELUSA	1289.28	60.50	50.00
MADISON	1289.28	64.23	53.42
ORD-DEV	1561.52	68.90	60.23
DEADWOOD	1775.35	72.56	65.57

	DEPTH	TEMP.	MIN. RES. TEMP
ELM SPRING			
SURFACE		7.80	
PIERRE	0.00	7.80	17.80
DAKOTA	755.00	58.13	36.67
JURASSIC	768.00	58.70	37.00
SPEARFISH	900.00	63.83	40.30
MINNEKAHTA	977.00	65.57	42.22
MINNELUSA	1030.00	66.90	43.55
MADISON	1030.00	73.98	49.12
ORD-DEV	1218.98	77.22	53.84
DEADWOOD	1328.26	79.10	56.57

FAITH			
SURFACE		7.55	
PIERRE	0.00	7.55	17.56
DAKOTA	1000.11	57.56	42.56
JURASSIC	1020.37	58.32	43.06
SPEARFISH	1173.38	63.42	46.89
MINNEKAHTA	1217.29	64.27	47.99
MINNELUSA	1252.98	65.04	48.88
MADISON	1252.98	71.19	54.52
ORD-DEV	1531.54	75.96	61.48
DEADWOOD	1706.70	78.96	65.86

HAYES			
SURFACE		8.40	
PIERRE	0.00	8.40	18.40
DAKOTA	606.14	48.81	33.55
JURASSIC	629.47	49.83	34.13
SPEARFISH	702.98	52.69	35.97
MINNEKAHTA	729.83	53.29	36.64
MINNELUSA	746.61	53.71	37.06
MADISON	746.61	60.95	42.75
ORD-DEV	872.68	63.11	45.90
DEADWOOD	872.68	63.11	45.90

KADOKA			
SURFACE		8.78	
PIERRE	0.00	8.78	18.78
DAKOTA	740.00	45.78	37.28
JURASSIC	934.00	53.05	42.13
SPEARFISH	934.00	53.05	42.13
MINNEKAHTA	934.00	53.05	42.13
MINNELUSA	964.00	53.69	42.88
MADISON	964.00	60.24	48.88
ORD-DEV	1053.92	61.78	51.12
DEADWOOD	1100.03	62.57	52.28

	DEPTH	TEMP.	MIN. RES. TEMP
LEMMON			
SURFACE		6.10	
PIERRE	0.00	6.10	16.10
DAKOTA	1305.80	71.39	48.75
JURASSIC	1350.02	73.05	49.85
SPEARFISH	1522.82	78.81	54.17
MINNEKAHTA	1595.20	80.21	55.98
MINNELUSA	1641.84	81.21	57.15
MADISON	1641.84	86.36	61.87
ORD-DEV	2035.27	93.11	71.71
DEADWOOD	2500.67	101.09	83.34

LUDLOW			
SURFACE		6.43	
PIERRE	0.00	6.43	16.42
DAKOTA	1296.25	71.24	48.83
JURASSIC	1348.81	73.21	50.15
SPEARFISH	1589.44	81.23	56.16
MINNEKAHTA	1728.27	83.92	59.63
MINNELUSA	1781.85	85.06	60.97
MADISON	1781.85	88.93	64.51
ORD-DEV	2179.42	95.74	74.45
DEADWOOD	2494.72	101.15	82.33

MARTIN			
SURFACE		9.02	
PIERRE	0.00	9.02	19.02
DAKOTA	771.25	66.87	38.31
JURASSIC	819.61	69.13	39.51
SPEARFISH	925.22	73.54	42.15
MINNEKAHTA	949.71	74.13	42.77
MINNELUSA	998.02	75.42	43.97
MADISON	998.02	75.42	43.97
ORD-DEV	1213.83	79.12	49.37
DEADWOOD	1229.92	79.40	49.77

MURDO			
SURFACE		8.81	
PIERRE	0.00	8.81	18.81
DAKOTA	550.60	36.34	32.57
JURASSIC	589.62	37.80	33.55
SPEARFISH	589.62	37.80	33.55
MINNEKAHTA	589.62	37.80	33.55
MINNELUSA	597.30	37.96	33.74
MADISON	597.30	42.71	38.09
ORD-DEV	693.22	44.35	40.49
DEADWOOD	695.16	44.39	40.54

	DEPTH	TEMP.	MIN. RES. TEMP
PIERRE			
SURFACE		8.37	
PIERRE	0.00	8.37	18.37
DAKOTA	543.53	44.61	31.96
JURASSIC	576.80	46.06	32.79
SPEARFISH	589.22	46.55	33.10
MINNEKAHTA	590.05	46.57	33.12
MINNELUSA	634.31	47.67	34.23
MADISON	634.31	52.94	38.37
ORD-DEV	634.31	52.94	38.37
DEADWOOD	683.90	53.79	39.61

PHILIP			
SURFACE		8.62	
PIERRE	0.00	8.62	18.62
DAKOTA	722.85	44.76	36.69
JURASSIC	779.93	46.90	38.12
SPEARFISH	879.54	50.22	40.61
MINNEKAHTA	924.89	51.10	41.74
MINNELUSA	953.34	51.71	42.45
MADISON	953.34	58.16	48.37
ORD-DEV	1087.36	60.46	51.72
DEADWOOD	1149.43	61.52	53.27

PRESHO			
SURFACE		8.88	
PIERRE	0.00	8.88	18.88
DAKOTA	514.90	34.62	31.75
JURASSIC	537.44	35.47	32.31
SPEARFISH	537.44	35.47	32.31
MINNEKAHTA	542.30	35.56	32.44
MINNELUSA	542.30	35.56	32.44
MADISON	542.30	35.56	32.44
ORD-DEV	542.30	35.56	32.44
DEADWOOD	595.38	36.47	33.76

WALL			
SURFACE		8.02	
PIERRE	0.00	8.02	18.02
DAKOTA	827.09	49.37	38.69
JURASSIC	929.87	53.23	41.26
SPEARFISH	1024.87	56.39	43.64
MINNEKAHTA	1083.40	57.53	45.10
MINNELUSA	1136.89	58.67	46.44
MADISON	1136.89	64.92	52.17
ORD-DEV	1288.21	67.52	55.95
DEADWOOD	1372.39	68.96	58.06

	DEPTH	TEMP.	MIN. RES. TEMP
WHITE RIVER			
SURFACE		8.95	
PIERRE	0.00	8.95	18.95
DAKOTA	740.04	64.45	37.45
JURASSIC	740.04	64.45	37.45
SPEARFISH	764.72	65.48	38.06
MINNEKAHTA	765.73	65.50	38.09
MINNELUSA	788.37	66.11	38.66
MADISON	788.37	71.77	42.81
ORD-DEV	788.37	71.77	42.81
DEADWOOD	847.35	72.78	44.28
WINNER			
SURFACE		9.19	
PIERRE	0.00	9.19	19.19
DAKOTA	115.14	17.82	22.07
JURASSIC	527.64	37.16	32.38
SPEARFISH	527.64	37.16	32.38
MINNEKAHTA	599.03	38.89	34.16
MINNELUSA	602.66	38.98	34.25
MADISON	602.66	38.98	34.25
ORD-DEV	602.66	38.98	34.25
DEADWOOD	663.36	40.02	35.77