**BEFORE THE PUBLIC UTILITIES COMMISSION**
**OF THE STATE OF SOUTH DAKOTA**

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| IN THE MATTER OF THE PETITION OF TRANSCANADA KEYSTONE PIPELINE, LP FOR ORDER ACCEPTING CERTIFICATION OF PERMIT ISSUED IN DOCKET HP09-001 TO CONSTRUCT THE KEYSTONE XL PIPELINE | ) ) ) ) ) ) ) ) | Docket 14-001<br><br>**TESTIMONY OF DR. ARDEN D. DAVIS, Ph.D., P.E., ON BEHALF OF DAKOTA RURAL ACTION** |

My name is Arden D. Davis, Ph.D., P.E. My address is 1014 Milwaukee Street, Rapid City, South Dakota 57701.

This testimony is submitted regarding Findings of Fact 12(2)-(3), 20, 22, 33-34, 36, 37, 40-41, 43-53, 64, 77, 79, 82, 86, 94-95, 98-99, 101-104, 110, 113, and Amended Conditions: 22, 34-35, 37 of the Amended Final Decision and Order in HP 09-001.

**Professional Qualifications and Background**

I have been involved in the fields of ground water and environmental contamination since 1978. I hold a B.A. degree in Geology from the University of Minnesota, and M.S. and Ph.D. degrees in Geological Engineering from South Dakota School of Mines and Technology. I am a registered professional engineer in South Dakota (no. 4663). Since 1985, I have taught courses in ground water, ground-water contamination, geological engineering, and environmental pollution at South Dakota School of Mines and Technology. I have also presented expert witness testimony in numerous cases, and have assisted the State of South Dakota in ground-water contamination problems, including the Williams Pipe Line / Hayward Elementary School site in Sioux Falls.

**Potential Impact of Keystone XL Pipeline on Water Resources in South Dakota**

A crude-oil or diluted bitumen leak could have devastating effects on ground-water supplies, surface water, and environmental resources in South Dakota. The proposed Keystone XL Pipeline would cross the recharge areas of several shallow aquifers in the western part of the State, including the Ogallala aquifer and Sand Hills type material, especially in Tripp County. Other shallow aquifers that would be crossed by the proposed pipeline route are terrace gravel aquifers, eolian (wind-blown) aquifer materials, alluvial aquifers, and the Fox Hills aquifer.

The proposed pipeline also would have major stream crossings at water courses such as the Little Missouri River, the Grand River and its tributaries, the Moreau River, the Cheyenne River upstream from Oahe Reservoir, the Bad River, and the White River. These drainages have associated alluvial aquifers beneath and adjacent to the rivers, and dissolved hydrocarbon contaminants could be transported downgradient in surface water, in ground water within the aquifers, or both.

The proposed route is shown on Figure 1 (from U.S. Dept. of State, 2014) and would cross the western part of South Dakota in a northwest-to-southeast trend. The South Dakota state geologic map is shown on Figure 2, with the proposed route superimposed.

In Harding County, in the extreme northwestern part of South Dakota, the route would cross the Little Missouri River (Figure 3) and the Grand River (Figure 4). The Hell Creek Formation (shown as $K_h$ on Figure 3 and Figure 4) contains bentonitic shale and is exposed in the river valleys at these crossings. The Little Missouri River flows northward into North Dakota, where it eventually joins the Missouri River. The Grand River flows generally eastward and joins the Missouri River in north-central South Dakota.

In Harding County the proposed route would cross permeable wind-blown deposits, shown as $Q_e$ on Figure 4. These wind-blown deposits of silt and sand recharge from rainfall and snowmelt, and they are capable of supplying water to shallow wells in the area. The proposed route also would cross the Fox Hills aquifer (shown as $K_{fh}$ on Figure 4) in Harding County. This sandstone aquifer is one of the most important ground-water reservoirs in northwestern South Dakota and supplies drinking water to public supplies for the City of Buffalo as well as a standby well for the City of Lemmon.

In Butte County the proposed route would cross the North Fork of the Moreau River (Figure 4), and in Perkins County the route would cross the Moreau River (Figure 4), which flows eastward and joins the Missouri River in north-central South Dakota.

In Meade County the proposed route would cross Cherry Creek and Red Owl Creek, as well as a large expanse of the exposed recharge area of the Fox Hills Formation (see Figure 5). As mentioned above, the Fox Hills aquifer is a major aquifer in northwestern South Dakota.

Near the border of Meade, Haakon, and Pennington counties, the proposed route would cross the Cheyenne River (Figure 6). This part of the Cheyenne River watershed is downstream from the Belle Fourche River, which drains the northern Black Hills, and the main branch of the Cheyenne, which drains the southern and eastern Black Hills. At this site, the Cheyenne River has gathered the surface-water drainage from the entire Black Hills. From here downstream, the Cheyenne River flows into the Oahe Reservoir on the Missouri River. The Pierre Shale (shown as $K_p$), which contains bentonite, is exposed along steep sides of the Cheyenne River valley and is prone to slope failures in western South Dakota. The proposed route also would cross the Bad River near Midland in Haakon County (Figure 7), where Pierre Shale also is exposed along the valley sides.

South of the Cheyenne River in Haakon County, the proposed route would cross permeable Quaternary terrace gravels (shown as $Q_t$ on Figure 6) and wind-blown deposits ($Q_e$ on Figure 6). The terrace gravels are stream-bed deposits of former flood plains. Both the terrace gravels and wind-blown deposits are permeable and are recharged by precipitation. In places they are capable of supplying water to wells, springs, and seeps, as well as providing soil moisture for trees and other vegetation.

In Jones and Lyman counties, the proposed pipeline route would cross permeable wind-blown deposits (shown as $Q_e$ on Figure 8) and also would cross Quaternary terrace deposits north of the White River (shown as $Q_t$ on Figure 8). The terrace deposits in this area have a shallow water table and are recharged by rainfall and snowmelt, which provide water for springs and seeps at the heads of streams that drain southward toward the White River. The shallow water table also supports small lakes, ponds, and wetlands in the area.

The proposed pipeline route would cross the White River at the border of Lyman and Tripp counties (Figure 8). The Pierre Shale is exposed in the White River valley at this location and is a concern because of potential slope failures.

In Tripp County, near the southeastern end of the proposed pipeline in South Dakota, the route would cross the Ogallala aquifer (shown as $T_o$ on Figure 9). It also would cross wind-blown Sand Hills type material (shown as $Q_e$) above the Ogallala aquifer. According to Martin et al. (2004) the wind-blown material shown as $Q_e$ on the South Dakota state geologic map includes the Sand Hills Formation. The hydrologic situation is similar to the Sand Hills of Nebraska, which form a permeable recharge zone above the Ogallala aquifer and therefore deserve consideration for special protection as a high-consequence area. As noted by Stansbury (2011), areas with shallow ground water that are overlain by permeable soils, such as Sand Hills type material, pose risks of special concern because leaks could go undetected for long periods of time

## Contaminants and Potential Problems

The proposed Keystone XL pipeline would transport crude oil and diluted bitumen. As noted by Stansbury (2011), diluted bitumen is more corrosive than conventional crude oil transported in existing pipelines. Crude oil and diluted bitumen contain hydrocarbons, including benzene, toluene, ethylbenzene, and xylene. Benzene is of particular note because its maximum contaminant level (MCL) in drinking water is 5 parts per billion. Benzene is known to produce leukemia in humans. It has been identified as a human carcinogen by the Occupational Safety and Health Administration and the National Toxicology Program.

Benzene is soluble in water and can be transported downgradient toward receptors such as public water-supply wells, private wells, and springs or seeps. In certain cases, benzene can be transported more than 500 or 1000 feet downgradient in aquifers, according to records of agencies such as the South Dakota Geological Survey, the South Dakota Department of Environment and Natural Resources, and the South Dakota Petroleum Release Compensation Fund. For example, a benzene contaminant plume from a leaking tank at the Williams Pipe Line / Hayward Elementary School site in Sioux Falls, South Dakota, was documented to have traveled about 800 feet downgradient from the tank (Iles et al., 1988). Because of benzene's solubility and its allowable limit of only 5 parts per billion in drinking water, a pipeline leak could contaminate a large volume of surface water or ground water in shallow aquifers of western South Dakota.

Leaks from pipelines have occurred in the past in South Dakota and have threatened ground-water supplies. These include a pipeline spill from Williams Pipe Line Company near water-supply wells for the City of Sioux Falls, and a large spill north of the City of Sioux Falls on glacial till near the Big Sioux aquifer. Reports of these are available in the files of the South Dakota Department of Environment and Natural Resources. A spill of more than 840,000 gallons in 2010 at Marshall, Michigan, caused extensive environmental damage and polluted the Kalamazoo River. The rupture and subsequent investigation resulted in new recommendations for pipeline safety from the National Transportation Safety Board. Two recent pipeline ruptures along the Yellowstone River in Montana were particularly serious and caused serious environmental problems. One, in 2011 near Laurel, Montana, resulted in the discharge of about 63,000 gallons of crude oil. The second, in 2015, released about 30,000 gallons of crude oil and contaminated the public drinking water supply of the City of Glendive, Montana.

A major concern involves the stability of steep slopes where the Pierre Shale or other bentonite-bearing shales are exposed, particularly along the breaks of major rivers, including the Cheyenne River, the White River, the Bad River, the Little Missouri River, the Grand River, and the Moreau River. Expansive clays such as bentonite are a particular concern because they can absorb large amounts of water during wet periods, leading to instability and potential failure. Slope failures are common along these river valleys, and could cause ruptures and serious leaks from the proposed pipeline. Additional safeguards for pipeline integrity should be undertaken in such locations. Leaks in these areas potentially could result in surface-water contamination downstream toward the Missouri River and its reservoirs

A report for TransCanada by DNV Consulting (Appendix A: Frequency-Volume Study of Keystone Pipeline), dated May 1, 2006, indicates on page 19, Table 5-2, that a leak rate of less than 1.5% could go undetected for 90 days for below-ground pipe. Page 20, Figure 5-1, of the same report indicates a leak detection and verification time of 138 min (2.3 hours) for a leak rate of 1.5%. The leak rate for this detection time is approximately 200 barrels per hour (BPH). This potentially could result in a leak of about 19,000 gallons (2.3 hr x 200 barrels/hr x 42 gallons/barrel). It appears, therefore, that larger volumes of oil could leak over a longer time (e.g., 90 days), if the leak rate is less than 1.5%. A leak of 19,000 gallons or greater could contaminate a large volume of ground-water supplies because of the solubility of crude oil components such as benzene and other volatile hydrocarbons.

The Final Supplemental Environmental Impact Statement for the Keystone XL Project (U.S. Department of State, 2014) stated that spill volumes from larger-diameter pipelines tend to be larger than those from smaller-diameter pipelines. It also stated that the primary releases causes, aside from failure of components such as valves, are outside forces and corrosion. In addition, the spill size and impact, for medium to large spills, are more sensitive to response time than for small spills. In other cases, smaller leaks might not be detected (U.S. Department of State, 2014).

The executive summary of the Final Environmental Impact Statement (U.S. Department of State, 2011) stated, "Although the leak detection system would be in place, some leaks might not be detected by the system. For example, a pinhole leak could be undetected for days or a few weeks if the release volume rate were small and in a remote area." The executive summary also stated, "In spite of the safety measures included in the design, construction, and operation of the proposed Project, spills are likely to occur during operation over the lifetime of the proposed Project. Crude oil could be released from the pipeline, pump stations, or valve stations." In addition, the executive summary mentioned 14 spills since 2010 from the existing Keystone pipeline system, including a spill of 21,000 gallons in North Dakota.

Stansbury (2011) stated concerns about questionable assumptions and calculations by TransCanada of expected frequency of spills from the proposed Keystone XL Pipeline. He noted that the pipeline would operate at higher temperatures and pressures than existing pipelines, and that the crude oil that would be transported in the Keystone XL Pipeline will be more corrosive than conventional crude oil. These factors would tend to increase spill frequency. Stansbury (2011) also stated that worst-case spill volumes from the proposed Keystone XL Pipeline are likely to be significantly larger than those estimated by TransCanada.

The Final Supplemental Environmental Impact Statement (U.S. Department of State, 2014) noted, "For all spills, especially those that reached water resources, the response time between initiation of the spill event and arrival of the response contractors would influence the potential magnitude of impacts to environmental resources." If a pipeline leak goes undetected and a spill of crude oil reaches a major water course such as the Cheyenne River, it could potentially be transported many miles downstream during high-velocity flows at certain times of the year. For example, the Cheyenne River can have a velocity of 7½ to 8 feet per second at times of high discharges (Dawdy, 1961). A river velocity of 8 feet per second is equivalent to about 5½ miles per hour. If a leak is undetected and a spill reaches the river under these conditions, it could potentially be transported about 60 miles downstream in 12 hours. If a leak cannot be controlled or is undetected for 24 hours, it could be transported about 120 miles downstream. This raises concerns about emergency response and mobilization in such a situation. For example, the straight-line distance is about 40 miles from the proposed pipeline route's crossing of the Cheyenne River to the Oahe Reservoir. This is in a remote, sparsely populated area. Assuming a channel sinuosity of about 2 to 2.5 for this reach of the Cheyenne River, the river's actual distance would be about 80 to 100 miles from this crossing to the Missouri River's reservoir. Thus, if a release occurred at this crossing and it could not be controlled or went undetected for 12 to 24 hours, petroleum contaminants could reach the Missouri River, potentially affecting water supplies and surface-water users, and causing environmental damage.

**Summary**

The Keystone XL Pipeline, as currently proposed, would cross shallow aquifers including the Ogallala aquifer, Sand Hills type aquifer material, terrace gravel aquifers, wind-blown aquifer materials, alluvial aquifers along rivers, and the Fox Hills aquifer. Spills in these aquifers could pose serious health risks to ground-water users. The proposed route also would have river crossings at water courses that include the Cheyenne River upstream from Oahe Reservoir, the White River, and the Bad River, and other streams. The sides of these river valleys are vulnerable to large slope failures, especially where bentonite-containing shales are exposed, which potentially could cause pipeline rupture. At these river crossings and downstream, the proposed pipeline poses serious risks and could have devastating effects on surface water and associated environmental resources, potentially affecting water supplies and surface-water users.

**References**

Dawdy, D.R., 1961, Depth-discharge relations of alluvial streams – discontinuous rating curves: U.S. Geological Survey Water-Supply Paper 1498-C.

DNV Consulting, 2006, frequency-volume study of Keystone Pipeline: Report No. 70015849-2 for TransCanada Pipelines.

Iles, D.L., Meyer, M.R., Baron, L.R., and Markley, W.E., 1988, Assessment of hydrogeologic and ground water contamination data in the vicinity of the Hayward Elementary School, West 12th Street, Sioux Falls, South Dakota: Open File Report No. 44-UR, South Dakota Department of Water and Natural Resources.

Martin, J.E., Sawyer, J.F., Fahrenbach, M.D., Tomhave, D.W., and Schulz, L.D., 2004, Geologic map of South Dakota: South Dakota Geological Survey, Vermillion, South Dakota, 1 pl.

U.S. Department of State, 2011, Final environmental impact statement for the Keystone XL Project: United States Department of State, Washington, D.C.

U.S. Department of State, 2014, Final supplemental environmental impact statement, Keystone KL Project: United States Department of State, Washington, D.C.

Stansbury, John, 2011, "Analysis of frequency, magnitude, and consequence of worst-case spills from the proposed Keystone XL Pipeline."

I hereby affirm under penalty of perjury that the above testimony is true and correct.

Arden D. Davis

ARDEN D. DAVIS

April 2, 2015

(date)

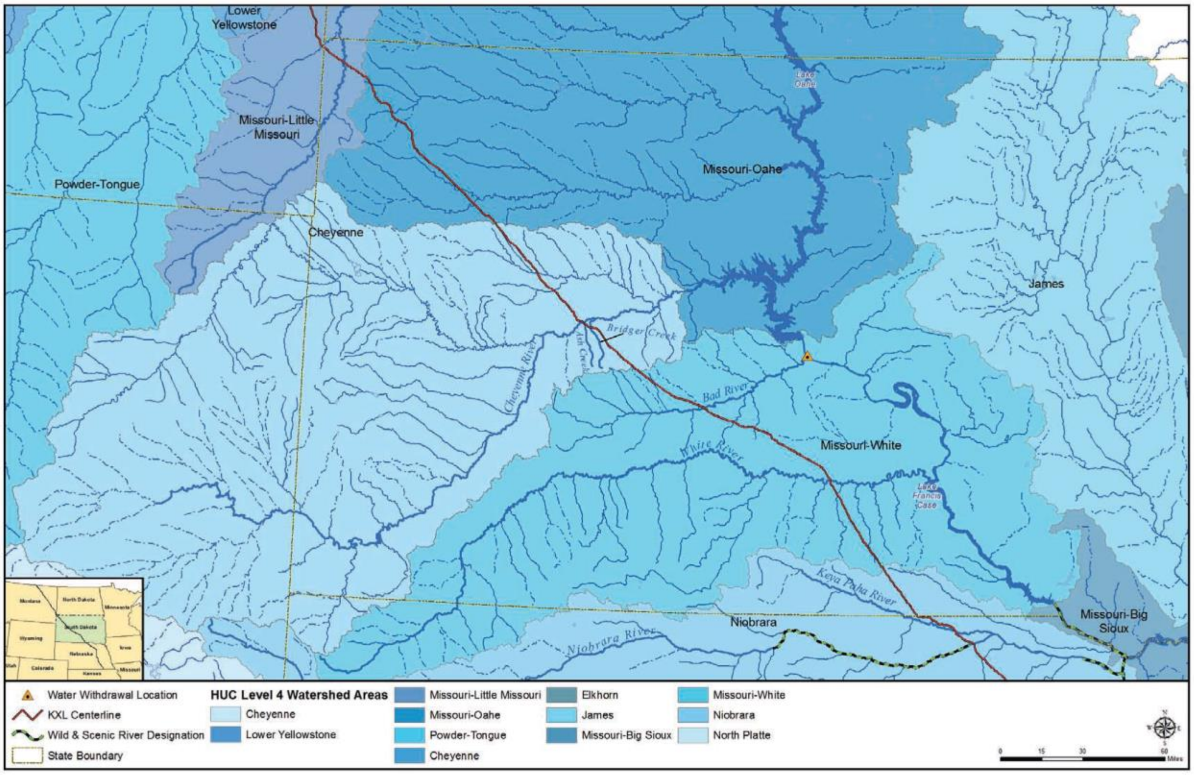


Figure 1. Water crossings of the proposed Keystone XL Pipeline in western South Dakota (from U.S. Dept. of State, 2014, p. 3.3-39.

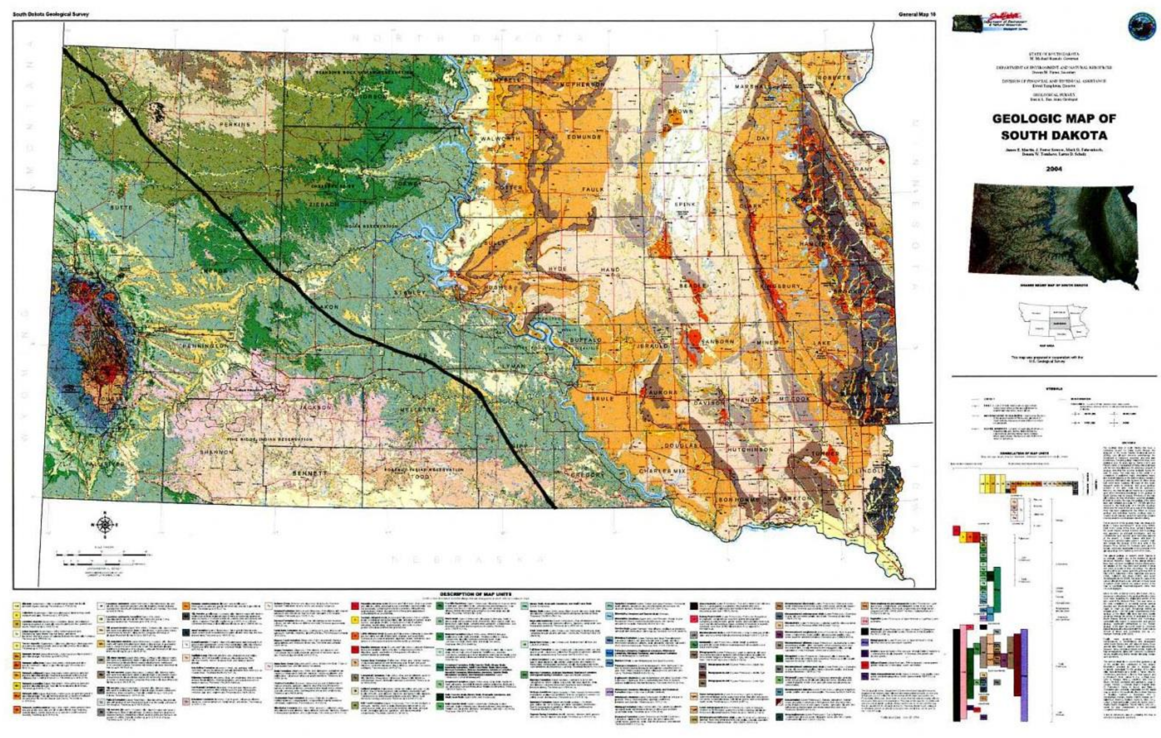


Figure 2. South Dakota geologic map (from Martin et al., 2004) with proposed Keystone XL route superimposed.

South Dakota Geological Survey

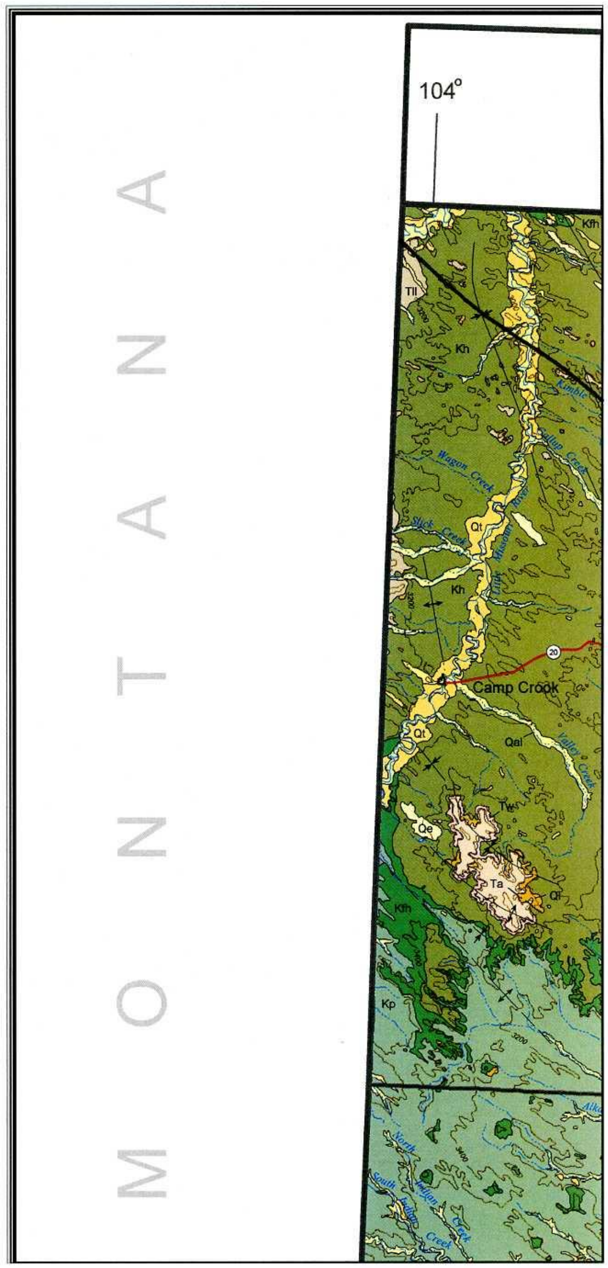


Figure 3. Part of the South Dakota geologic map (from Martin et al., 2004) in the northwestern part of Harding County, with proposed Keystone XL route superimposed.

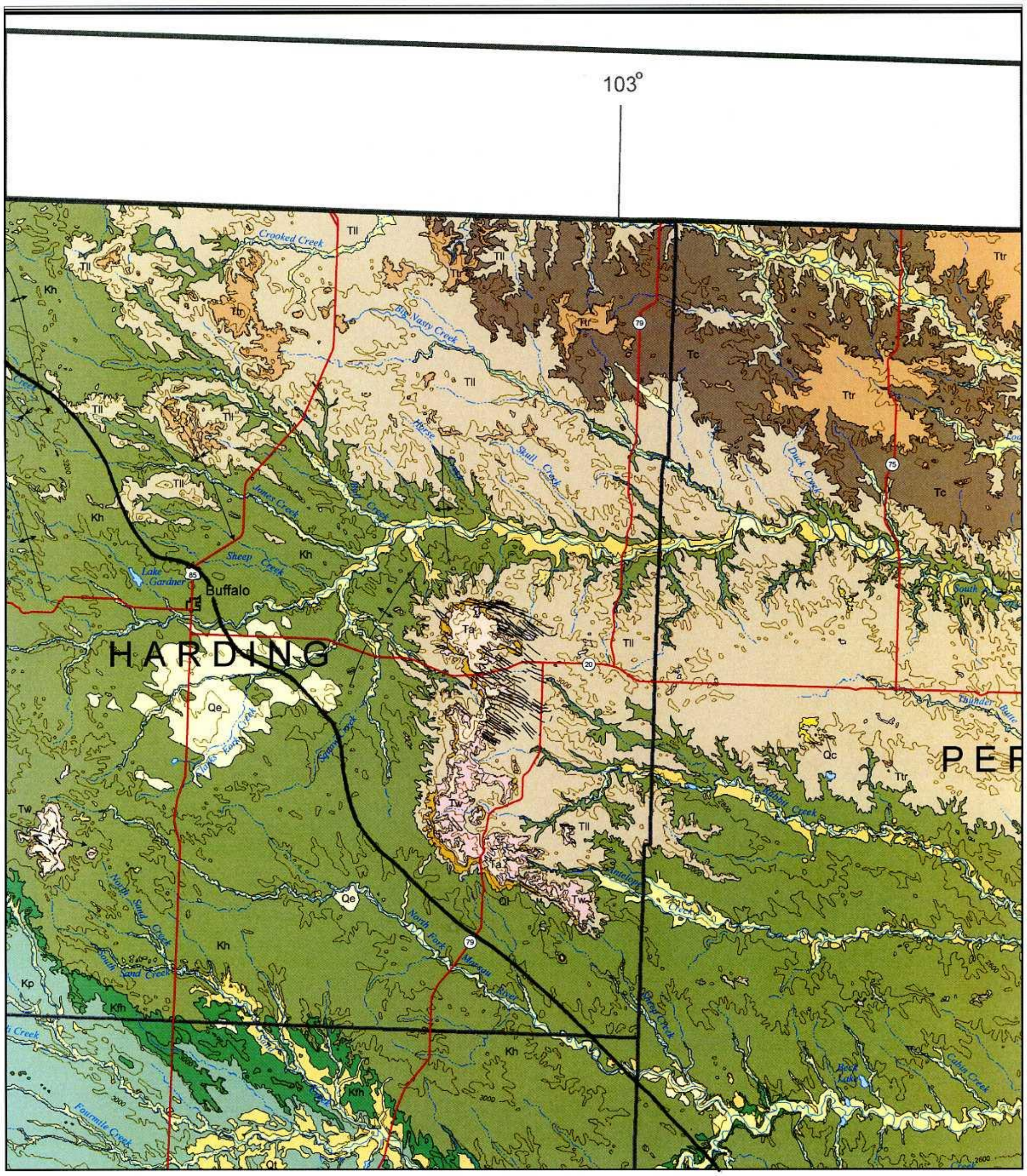


Figure 4. Part of the South Dakota geologic map (from Martin et al., 2004) in Harding and Perkins counties, with proposed Keystone XL route superimposed. The area shown as $Q_e$ south and southeast of Buffalo is mapped as eolian (wind-blown) deposits.

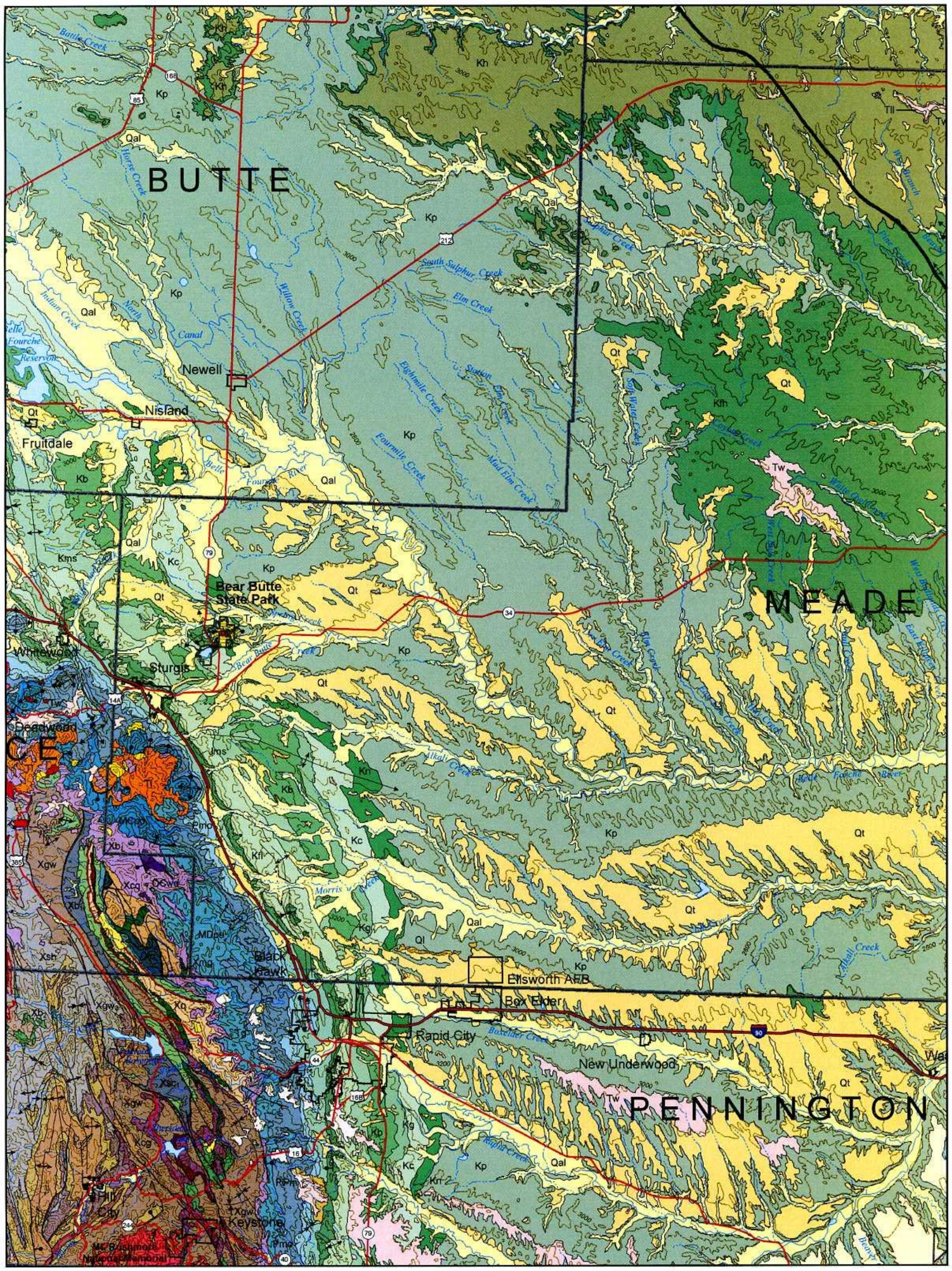


Figure 5. Part of the South Dakota geologic map (from Martin et al., 2004) in Perkins and Meade counties, with proposed Keystone XL route superimposed. The area shown as $K_{fh}$ is mapped as the Fox Hills Formation.

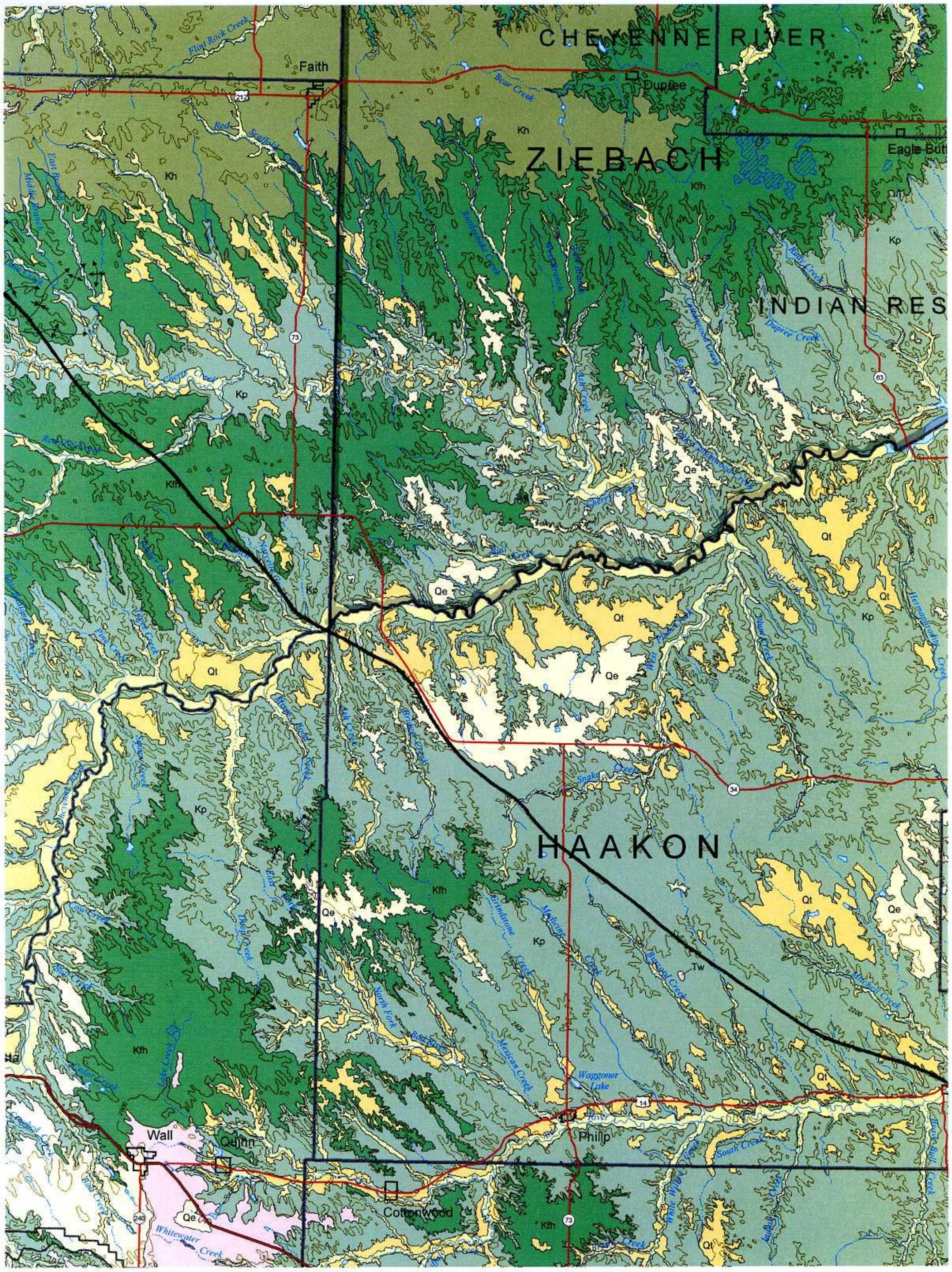


Figure 6. Part of the South Dakota geologic map (from Martin et al., 2004) in Meade and Haakon counties, with proposed Keystone XL route superimposed. The route would cross the Cheyenne River near the border of Meade and Haakon counties. The area mapped as $Q_t$ refers to terrace deposits of streams in former flood plains.

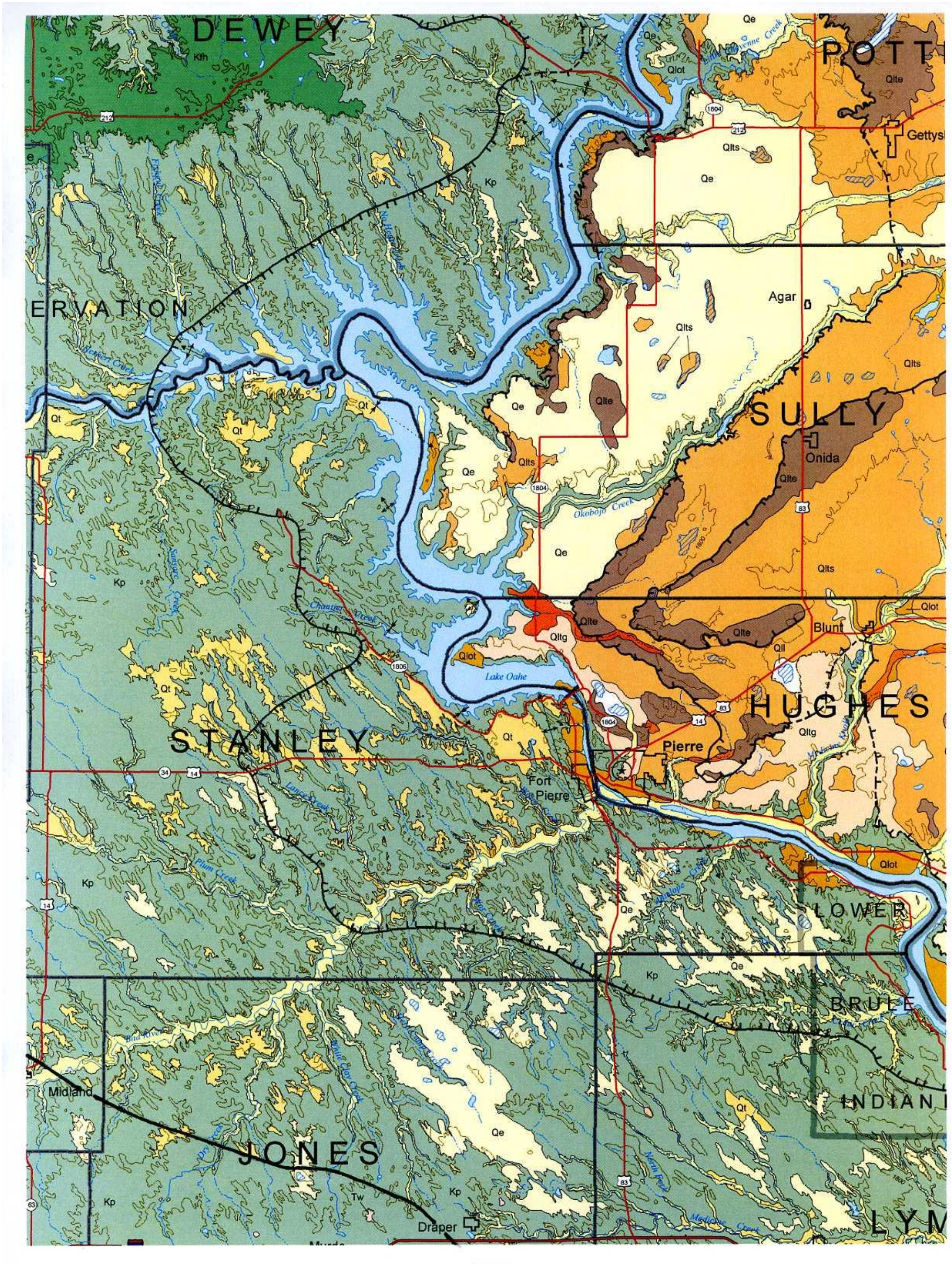


Figure 7. Part of the South Dakota geologic map (from Martin et al., 2004) in Haakon and Jones counties, with proposed Keystone XL route superimposed.

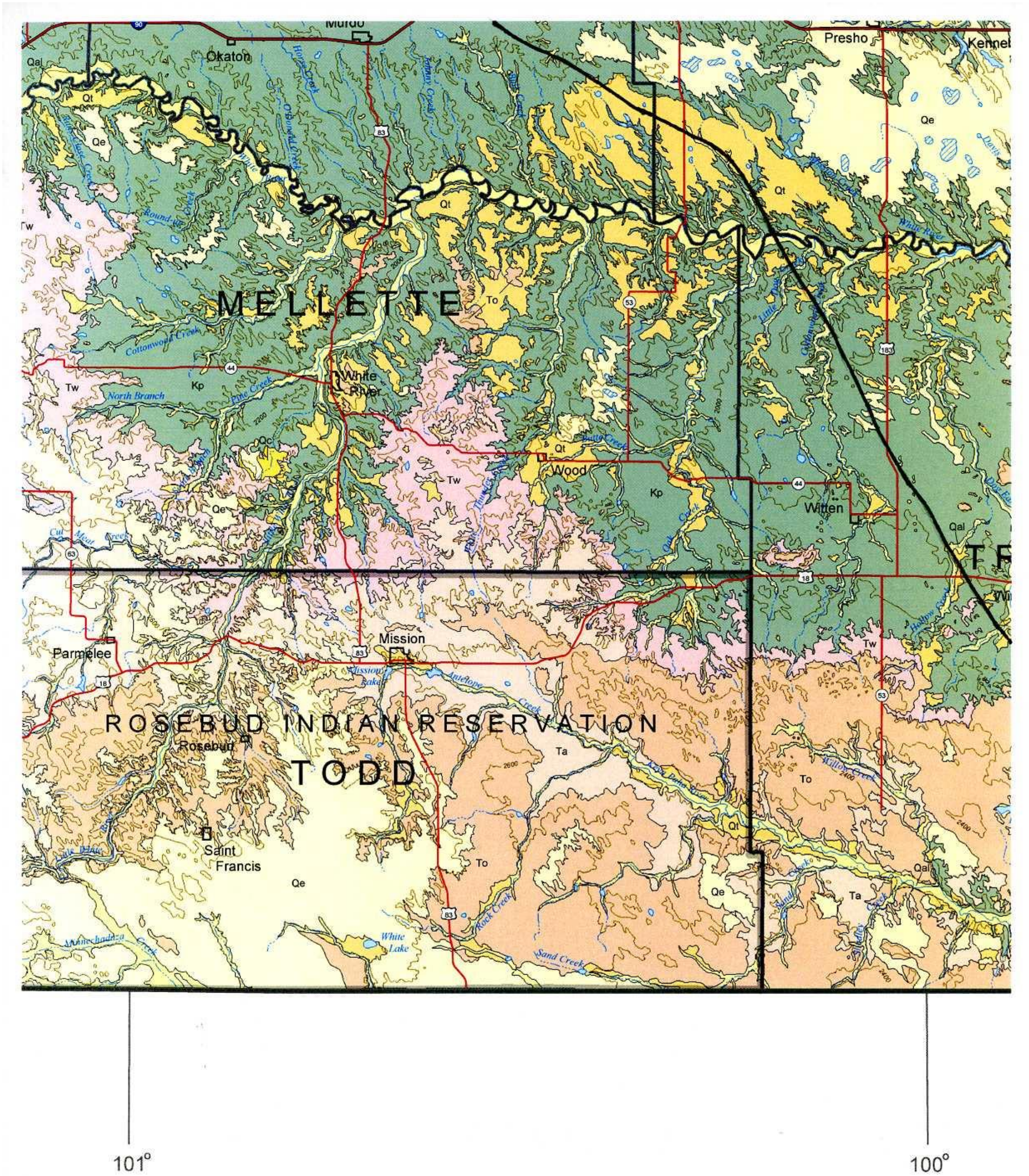


Figure 8. Part of the South Dakota geologic map (from Martin et al., 2004) in Jones, Lyman, and Tripp counties, with proposed Keystone XL route superimposed. The area mapped as $Q_t$ shows terrace deposits of streams in former flood plains.

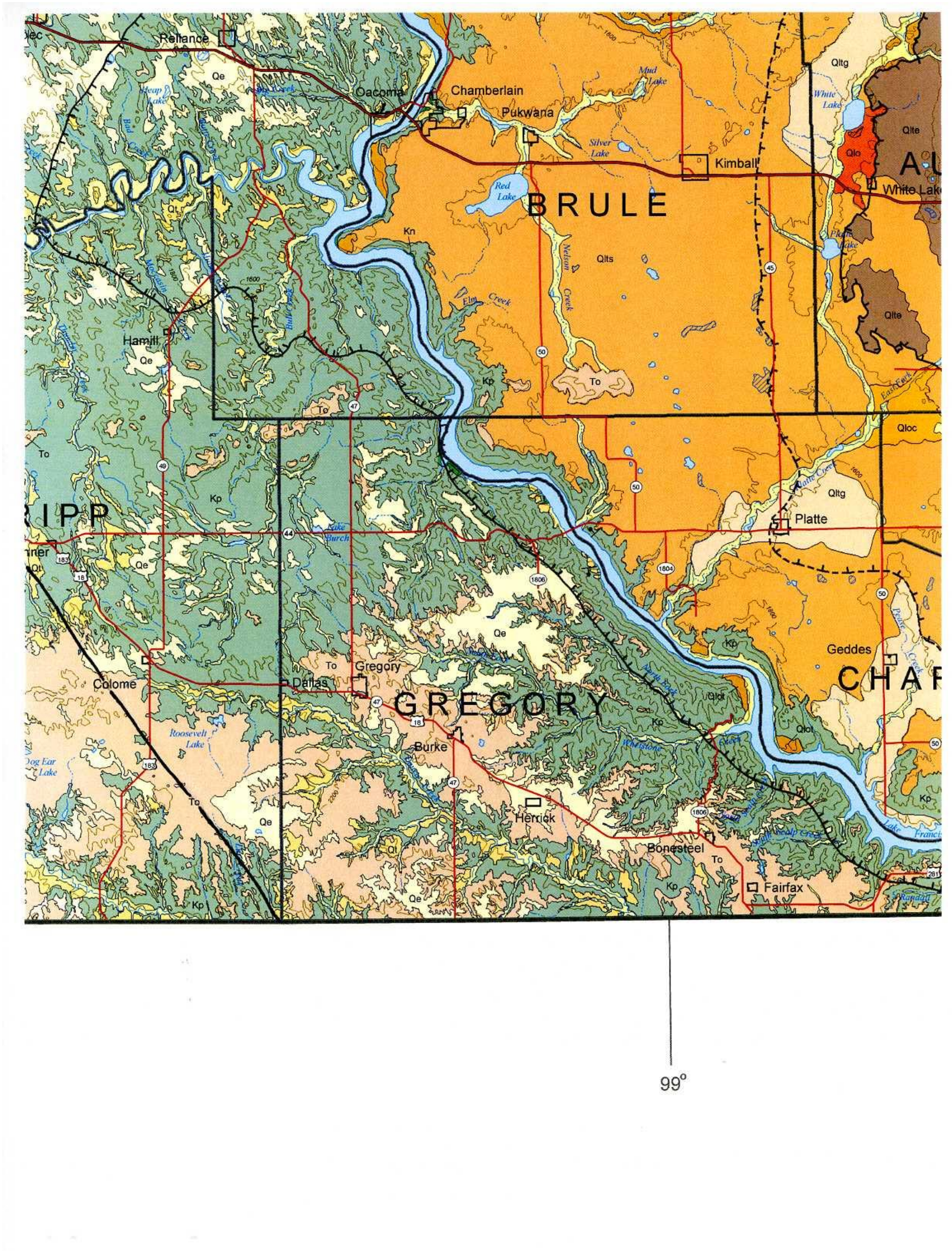


Figure 9. Part of the South Dakota geologic map (from Martin et al., 2004) in Tripp County, with proposed Keystone XL route superimposed. The area mapped as $T_o$ shows the Ogallala aquifer. The areas mapped as $Q_e$ show eolian (wind-blown) deposits, including Sand Hills type material.