

3.1 GEOLOGY

3.1.1 Physiography and Surface and Bedrock Geology

3.1.1.1 Environmental Setting

Proposed Project Route

Montana

The proposed route enters Morgan, Montana along Montana's northern border with Saskatchewan and traverses the state along a south-southeasterly corridor that extends to the southeast corner of the state. The route traverses the Great Plains physiographic province (Fenneman 1928) and is characterized by badlands, buttes, mesas, and includes the Black Hills mountain range. The route crosses the Glaciated Missouri Plateau and the Unglaciated Missouri Plateau. The glaciated section to the north is covered in glacial deposits and represents the furthest southern extent of the last ice age. In the vicinity of Circle, Montana, the proposed pipeline enters the Unglaciated Missouri Plateau. Surface elevations average around 3,000 feet above mean sea level (amsl). The route would cross six EPA Level IV Ecoregions, each with a distinct physiography (Omernik 2009). Regional physiographic characteristics are presented in detail within Montana in Table 3.1.1-1.

Surficial geological materials are composed of Quaternary alluvium, colluvium, and glacial till that consist of sand, gravel, and clay. Bedrock consists of Tertiary (Fort Union Formation) and Late Cretaceous-aged rocks (Hell Creek/Fox Hills Formation, Bearpaw Formation/Pierre Shale, Judith River Formation, and Claggett Shale). The Fort Union Formation (approximately 138 miles crossed between MP 105 and MP 286) consists primarily of sandstone, siltstone, mudstone, carbonaceous shale, and lignite. The proposed route crosses the Ludlow, Tongue River, Lebo, and Tullock members of this Formation. The Tongue River and Tullock members also contain thin coal beds. The Hell Creek/Fox Hills Formation (approximately 56 miles crossed between MP 91 and MP 116; and between MP 245 and MP 273) forms badland topography and consists of shale, mudstone, and lenticular coal beds. The Bearpaw/Pierre Shale (approximately 43 miles crossed between MP 31 and MP 90) consists of bentonitic mudstone and shale, the Judith River Formation (approximately 16 miles crossed between MP 1 and MP 45) consists of sandstone, siltstone, mudstone, shale, and coal, while the Claggett Shale (MP 39 to MP 41) consists of shale and siltstone with beds of bentonite. Geology beneath the Steele City Segment is presented in Figure 3.1.1-1.

South Dakota

The proposed route enters South Dakota in the northwestern corner of the state. The route continues in a generally straight fashion in a southeastern direction south of Pierre in the southwest quarter of the state, exiting South Dakota in southeast Tripp County. The proposed route is located in the Unglaciated Missouri Plateau in the Great Plains physiographic province. Surface elevations range from 3,000 feet amsl in northwest South Dakota to 1,800 feet amsl in the White River Valley. The route would cross eight EPA Level IV Ecoregions, each with a distinct physiography (Bryce et al. 1996). Regional physiographic characteristics are presented in detail within South Dakota in Table 3.1.1-2.

Surficial geological materials are composed of Quaternary alluvium, colluvium, alluvial terraces, and aeolian deposits. The majority of bedrock in South Dakota consist of Upper Cretaceous rocks (Hell Creek/Fox Hills Formation, Pierre Shale), while Tertiary-aged (Ogallala Group and Ludlow Member of the Fort Union Formation) are present beneath the southern portion of the proposed route in South

Dakota. The Hell Creek/Fox Hills Formation (MP 285 to MP 418) forms badland topography and consists of shale, mudstone, and lenticular coal beds. The Pierre Shale occurs sporadically through the route in South Dakota and consists of bentonitic mudstone and shale. The Ogallala Group (MP 521 to 593) consists of well to poorly consolidated sandstone and conglomerate with occasional bentonite layers. The Ludlow Member of the Fort Union Formation (approximately 3 miles crossed between MP 283 and 376) consists primarily of sandstone, siltstone, mudstone, carbonaceous shale and lignite. Geology beneath the Steele City Segment is presented in Figure 3.1.1-1.

Several major structural features would be crossed by the proposed pipeline route in South Dakota. The Williston Basin covers northeast Montana, the majority of North Dakota, northwest South Dakota, and extends into Canada (Peterson and MacCary 1987). Regionally, the Williston Basin is a structural basin that contains approximately 15,000 feet of sedimentary bedrock. South of the Williston Basin, the Sioux Arch is a buried ridge that extends east to west from Minnesota through southeast South Dakota (Gries 1996). South of the White River, the proposed route would cross into the Salina Basin, a sedimentary basin that underlies southern South Dakota and the majority of eastern Nebraska.

Nebraska

The proposed route enters Nebraska in northern Keya Paha County and continues in a southeastern direction across the state. The pipeline route in Nebraska joins the Cushing Extension pipeline route in Steele City in southeastern Jefferson County. The majority of the proposed route in Nebraska lies in the High Plains portion of the Great Plains Physiographic Province. In northern Nebraska, the Unglaciated Missouri Plateau underlies the pipeline route, while the southern portion of the route lies in the Plains Border Region. Surface elevations range from 2,200 feet amsl in Northern Nebraska to 1,400 at the Kansas state line. The route would cross nine EPA Level IV Ecoregions, each with a distinct physiographic (Chapman et al. 2001). Regional physiographic characteristics are presented in detail within Nebraska in Table 3.1.1-3.

The majority of the state is covered by Quaternary deposits along with glacial till, loess, and the Sand Hills. Glacial till is present in southeast Nebraska, south of the Loup River to the Kansas state line. Loess is present from the town of Greeley to the Loup River. Between Stuart and Greeley, the proposed route would cross the eastern extent of the Sand Hills. The Sand Hills are composed mainly of well-sorted sands that are present in dunes and sand sheets and are stabilized by existing vegetation.

The underlying bedrock consists of Tertiary-aged Ogallala Group (approximately 135 miles crossed between MP 597 and MP 745) and Cretaceous sedimentary rocks (Pierre Shale, Niobrara Formation, Carlisle Shale, Greenhorn Limestone and Graneros Shale, and Dakota Group). The Niobrara Formation (approximately 28 miles crossed between MP 738 and MP 777), Carlisle Shale (approximately 34 miles crossed between MP 759 and MP 819), and Greenhorn Limestone and Graneros Shale (approximately 14 miles crossed between MP 797 to MP 823) contain varying amounts of limestone which potentially contain karst formations, causing surface subsidence. The Pierre Shale (MP 599 to MP 605 and MP 614 to MP 617) is exposed in Northern Nebraska and is composed of fissile clay shale, claystone, shaly sandstone, and sandy shale. This formation is prone to slumping and is especially weak where layers of volcanic ash are present. The Dakota Group (approximately 33 miles crossed between MP 798 to MP 851) consists of sandstone and shale. Geology beneath the Steele City Segment is presented in Figure 3.1.1-1.

Kansas

In Kansas, two new pump stations would be constructed along the Cushing Extension of the previously permitted Keystone pipeline (ENTRIX 2008). These pump stations (Pump Station 27 and Pump Station

29) are located in Clay and Butler counties at Cushing Extension MP 49.7 and MP 144.6, respectively. These pump stations are located in the Flint Hills Ecoregion and contain outcrops of Permian sedimentary rocks. Elevations in this area range from 1,150 to 1,400 feet amsl. Surficial materials in the vicinity of the Clay County pump station include thick deposits of loess (greater than 30 feet) (Frye and Leonard 1952). In the vicinity of the Butler County pump station, surficial deposits consist of alluvium, colluvium, and cherty gravels in upland areas (KGS 1999). Karst is not present in either of these locations (Davies et al. 1984).

Oklahoma

In Oklahoma, the proposed Gulf Coast Segment pipeline route connects to the southern terminus of the Cushing Extension of the previously permitted Keystone pipeline (ENTRIX 2008). The segment begins at the border between Payne and Lincoln counties and continues in a south-southeastern direction, where the proposed route enters Texas in southeast Bryan County. The proposed pipeline segment in Oklahoma is present in the Central Lowland physiographic province beginning in Cushing to northern Atoka County, where the Gulf Coastal Plains physiographic province begins and continues into Texas. Surface elevations range from 900 feet amsl in central Oklahoma to 450 at the Texas state line. The route would cross six EPA Level IV Ecoregions, each with a distinct physiography (Woods et al. 2005). Regional physiographic characteristics are presented in detail within Oklahoma in Table 3.1.1-4.

Upper Paleozoic (Permian) rock lies beneath the proposed route beginning at Cushing to MP 121. These rocks consist of alternating beds of sandstone, shale, and occasional limestone formed under both marine and non-marine conditions. In southeast Oklahoma, non-marine river and flood plain sands, silts, and clays are present (Johnson 1996). Beneath these surface sediments lie Cretaceous sedimentary rocks. Geology beneath the Gulf Coast Segment is presented in Figure 3.1.1-2.

Texas

The proposed Gulf Coast Segment pipeline route enters Texas in northeast Fannin County and continues in a south to southeast direction. In Liberty County, at the junction with the Houston Lateral, the Gulf Coast Segment continues in an east to southeast direction and terminates in Port Arthur. The Houston Lateral begins in Liberty County and continues in a west to southwest direction, ending in central Harris County. The proposed pipeline route is present in the Gulf Coastal Plains physiological province, which includes the Coastal Prairies, Interior Coastal Plains, and the Blackland Prairies subprovinces. Surface elevations range from 450 feet amsl in northern Texas to near seal level at the conclusion of the proposed pipeline route. The route would cross 11 EPA Level IV Ecoregions, each with a distinct physiography (Griffith et al. 2004). Regional physiographic characteristics are presented in detail within Texas in Table 3.1.1-5 (Gulf Coast Segment) and Table 3.1.1-6 (Houston Lateral).

In northern Texas along the proposed route, the Blackland Prairie is characterized by black, sandy, calcareous soil originating from the underlying glauconitic sands and clays. The topography is undulating with few bedrock outcroppings (Wermund 2008). The Interior Coastal Plains subprovince is characterized by low-relief bands of eroded shale and sandy ridges. Eocene sandstone bedrock is present where exposed by rivers (Spearing 1991). The Coastal Prairies subprovince in southern Texas is underlain by young deltaic sands, silts, and clays that have eroded to a relatively flat landscape and are present as a grassland (Wermund 2008). Geology beneath the Gulf Coast Segment and Houston Lateral is presented in Figure 3.1.1-2.

**TABLE 3.1.1-1
Physiographic Characteristics of Ecoregions Crossed in Montana
by the Proposed Project – Steele City Segment**

MP Range	Physiographic Description	Elevation Range (ft AMSL)	Local Relief (ft)	Surface Geology	Bedrock Geology
Northwestern Glaciated Plains – Cherry Patch Moraines^a					
0 - 8	Glaciated, undulating to strongly sloping topography containing bouldery knolls, gravelly ridges, kettle lakes, and wetlands. Prominent end moraine.	2,300 - 3,600	50 - 375	Quaternary drift.	Cretaceous Claggett Formation, Judith River Formation.
Northwestern Glaciated Plains – Glaciated Northern Grasslands^a					
8 - 90, 109 - 116	Glaciated, dissected, rolling to strongly rolling drift plains.	1,990 - 4,000	50 - 600	Quaternary glacial drift deposits.	Cretaceous Bearpaw Shale, Judith River Formation, Claggett Formation, Hell Creek Formation, Fox Hills Formation, Tongue River Member of Fort Union Formation, and Flaxville Gravels.
Northwestern Great Plains – River Breaks^a					
90 - 104, 192 - 198	Unglaciated, rugged, very highly dissected terrain adjacent to rivers.	1,900 - 3,450	200 - 500	Erodible, clayey soils; gravelly soils on slopes.	Tongue River, Lebo, Slope, and Tullock members of the Tertiary Fort Union Formation, Hell Creek Formation, Fox Hills Sandstone, and Pierre Shale.
Northwestern Great Plains – Central Grassland^a					
104 - 109, 116 - 133, 198 - 282	Unglaciated, dissected rolling plains containing buttes. Areas of gravel, clinker, and salt flats. Streams are intermittent.	2,200 - 5,000	125 - 600	Quaternary terrace deposits and alluvium along channels.	Tertiary Fort Union, Hell Creek Formation, Pierre Shale.
Northwestern Great Plains – Missouri Plateau^a					
133 - 192	Unglaciated rolling hills and gravel covered benches. Some areas are subject to wind erosion.	2,000 - 3,550	50 - 500	Quaternary terrace deposits.	Tongue River and Slope members of the Tertiary Fort Union Formation, Tertiary Flaxville Gravels.
Northwestern Great Plains – Sagebrush Steppe^a					
282 - 282.4	Unglaciated, level to rolling plains. Landscape contains buttes, badlands, scoria mounds and salt pans.	2,300 - 4,200	50 - 600	Quaternary alluvium along channels. Upper Cretaceous sandstone and shale.	Colorado Group, Pierre Shale, Hell Creek Formation, Fox Hills Sandstone, and Fort Union Formation.

^aEPA Level III-IV Ecoregion name.
Source: Omernik 2009.

**TABLE 3.1.1-2
Physiographic Characteristics of Ecoregions Crossed in South Dakota
by the Proposed Project – Steele City Segment**

MP Range	Physiographic Description	Elevation Range (ft AMSL)	Local Relief (ft)	Surface Geology	Bedrock Geology
Northwestern Great Plains – Sagebrush Steppe^a					
282 - 337	Unglaciaded, level to rolling plains. Landscape contains buttes, badlands, scoria mounds and salt pans.	3,000 - 3,475	50 - 350	Quaternary alluvium along channels. Upper Cretaceous sandstone and shale.	Hell Creek Formation and Pierre Shale.
Northwestern Great Plains – Moreau Prairie^a					
337 - 387	Unglaciaded, level to rolling plains. Landscape contains buttes, badlands, and salt pans.	2,100 - 3,200	120 - 250	Upper Cretaceous sandstone and shale.	Hell Creek Formation.
Northwestern Great Plains – Missouri Plateau^a					
387 - 417	Unglaciaded, moderately dissected level to rolling plains. Contains sandstone buttes.	1,750 - 3,300	50 - 500	Tertiary sandstone, shale, and coal.	Ludlow member of Fort Union Formation, Fox Hills Formation.
Northwestern Great Plains – Subhumid Pierre Shale Plains^a					
430 - 478, 487 - 493, 494 - 535, 546 - 570	Unglaciaded, undulating plain. Terrain contains incised, steep-sided stream channels.	1,700 - 2,800	50 - 500	Cretaceous shale.	Pierre Shale.
Northwestern Great Plains – River Breaks^a					
417 - 426, 426 - 431, 478 - 487, 493 - 494, 535 - 546	Unglaciaded, highly dissected hills and uplands. Ecoregion borders major rivers and alluvial plains.	1,300 - 2,700	200 - 500	Cretaceous shale.	Pierre Shale.
Northwestern Great Plains – Keya Paha Tablelands^a					
570 - 575	Unglaciaded, level to rolling sandy plains. Topography is dissected near streams.	2,250 - 3,600	20 - 800	Aeolian and alluvial sand and silt.	Ogallala Formation.
Northwestern Glaciaded Plains – Ponca Plains^a					
575 - 589	Unglaciaded, level to gently rolling plains. Topography formed by stream drainage (preglacial).	1,900 - 2,350	80 - 140	Miocene soft sandstone and cretaceous shale.	Pierre Shale.
Northwestern Glaciaded Plains – Southern River Breaks^a					
589 - 597	Lightly glaciaded dissected hills and canyons. Topography contains slopes of high relief bordering major rivers and alluvial plains.	1,250 - 2,000	250 - 700	Cretaceous shale.	Pierre Shale.

^aEPA Level III-IV Ecoregion name.

Source: Bryce et al. 1996.

**TABLE 3.1.1-3
Physiographic Characteristics of Ecoregions Crossed in Nebraska
by the Proposed Project – Steele City Segment**

MP Range	Physiographic Description	Elevation Range (ft AMSL)	Local Relief (ft)	Surface Geology	Bedrock Geology
Northwestern Glaciated Plains – Southern River Breaks^a					
597 - 600	Dissected hills and canyons. Topography contains slopes of high relief bordering major rivers and alluvial plains.	1,400 - 2,000	250 - 500	Cretaceous shale.	Pierre Shale.
Northwestern Great Plains – Keya Paha Tablelands^a					
600 - 613	Unglaciated, level to rolling sandy plains. Topography is dissected near streams; contains isolated gravelly buttes.	1,900 - 2,400	20 - 400	Aeolian and alluvial sand and silt.	Ogallala Sandstone.
Northwestern Great Plains – Niobrara River Breaks^a					
613 - 617	Unglaciated, dissected canyons. Contains slopes of high relief adjacent to river.	1,700 - 2,700	200 - 600	Sandy residuum.	Miocene soft sandstone over Pierre Shale.
Nebraska Sand Hills – Wet Meadow and Marsh Plain^a					
617 - 664	Flat, sandy plain with numerous marshes and wetlands.	1,900 - 2,400	10 - 50	Aeolian sand dunes and sand sheets, alluvial silt, sand and gravel.	Ogallala Sandstone.
Nebraska Sand Hills – Sand Hills^a					
664 - 709	Sand sheets and extensive fields of sand dunes.	2,200 - 3,900	50 - 400	Aeolian sand dunes and alluvial silt, sand and gravel.	Ogallala Sandstone.
Central Great Plains – Central Nebraska Loess Plains^a					
709 - 739	Rolling dissected plains with deep layer of loess. Contains perennial and intermittent streams.	1,600 - 3,100	50 - 275	Calcareous loess, alluvial sand, gravel, and lacustrine sand and silt.	Ogallala Sandstone.
Central Great Plains – Platte River Valley^a					
739 - 759	Flat, wide alluvial valley. Contains shallow, interlacing streams on a sandy bed.	1,300 - 2,900	2 - 75	Alluvial, sand, silt, clay, and gravel deposits.	Quaternary and Tertiary unconsolidated sand and gravel.
Central Great Plains – Rainwater Basin Plains^a					
759 - 848	Flat to gently rolling loess covered plains. Historical rainwater basins and wetlands.	1,300 - 2,400	5 - 100	Loess and mixed loess and sandy alluvium.	Ogallala Sandstone, Niobrara Formation, and Carlisle Shale.
Central Great Plains – Smoky Hills^a					
848 - 852	Undulating to hilly dissected plain with broad belt of low hills formed by dissection of Cretaceous rock layers.	1,200 - 1,800	100 - 250	Sandstone and shale, loamy colluvium, chalky limestone, and thin loess.	Cretaceous sandstone of Dakota Group.

^aEPA Level III-IV Ecoregion name.

Source: Chapman et al. 2001.

**TABLE 3.1.1-4
Physiographic Characteristics of Ecoregions Crossed in Oklahoma
by the Proposed Project – Gulf Coast Segment**

MP Range	Physiographic Description	Elevation Range (ft AMSL)	Local Relief (ft)	Surface Geology	Bedrock Geology
Central Great Plains – Cross Timbers Transition^a					
0 - 16	Rough Plains that is sometimes broken. Topography contains incised streams.	750 - 1,950	30 - 300	Quaternary alluvium, terrace deposits, and residuum.	Permian and Pennsylvanian sandstone and shale, limestone and mudstone conglomerate.
Cross Timbers – Northern Cross Timbers^a					
16 - 78	Rolling hills, cuestas, ridges, and ledges. Contains shallow streams with sandy substrates and sometimes deep pools, riffles, and bedrock, cobble, or gravel substrates.	600 - 1,300	100 - 350	Uplands contain Quaternary clayey silt to silty clay residuum. Valleys contain Quaternary alluvium. Rock outcrops are common.	Pennsylvanian and Permian sandstone, shale, and limestone.
Arkansas Valley – Lower Canadian Hills^a					
78 - 119	Hill and valley topography in structural Arkoma Basin with scattered ridges and ponds. Streams contain pools and have substrated composed of cobbles, gravel, and sand.	500 - 1,000	50 - 300	Quaternary terrace deposits, alluvium, and sandy to silty clay loam residuum.	Pennsylvanian shale and sandstone.
South Central Plains – Cretaceous Dissected Uplands^a					
119 - 138, 140 - 155	Level to hilly, dissected uplands and low cuestas. Large streams are deep and slow moving and have muddy or sandy bottoms. Smaller streams contain gravel, cobble and boulder substrates.	310 – 700	Less than 50 - 200	Quaternary alluvium in valleys. Uplands contain poorly consolidated, calcareous sands, clays, gravels, and limestone.	Calcareous sands, clays, gravels, and limestone.
Cross Timbers – Eastern Cross Timbers^a					
138 - 140	Rolling hills, cuestas, long narrow ridges with few strongly dissected areas. Stream substrates consist of quartz sand.	640 - 1,100	100 - 200	Uplands are composed of Quaternary sand, gravel, silt, and clay residuum. Valleys consist of Quaternary alluvium.	Cretaceous sand, shale, clay, sandstone, calcareous shale, and limestone.
South Central Plains – Red River Bottomlands^a					
155.3 - 155.7	Broad, level floodplains and low terraces. Topography contains oxbow lakes, meander scars, back swamps, and natural levees.	300 – 530	10 - 50	Holocene alluvium.	Holocene alluvium.

^aEPA Level III-IV Ecoregion name.

Source: Woods et al. 2005.

**TABLE 3.1.1-5
Physiographic Characteristics of Ecoregions Crossed in Texas
by the Proposed Project – Gulf Coast Segment**

MP Range	Physiographic Description	Elevation Range (ft AMSL)	Local Relief (ft)	Surface Geology	Bedrock Geology
South Central Plains – Red River Bottomlands^a					
155.7 - 161	Broad, level floodplains and low terraces. Topography contains oxbow lakes, meander scars, back swamps, and natural levees.	300 - 530	10 - 50	Holocene alluvium.	Holocene alluvium.
South Central Plains – Pleistocene Fluvial Terraces^a					
161 - 163	Broad flats and gently sloping stream terraces.	310 - 400	10 - 50	Terrace deposits.	Terrace deposits.
East Central Texas Plains – Northern Post Oak Savanna^a					
163 - 172, 198 - 202, 203 - 205, 206 - 212, 217 - 227	Level and gently rolling topography.	300 - 800	10 - 50	Fine textured loam soils.	Eocene and Paleocene Formations and Cretaceous Formations in northern extent.
Texas Blackland Prairies – Northern Blackland Prairie^a					
172 - 198	Rolling to nearly level plains.	300 - 800	10 - 50	Fine-textured, dark, calcareous soils.	Interbedded chalks, marls, limestones, and Cretaceous shales.
East Central Texas Plains – Floodplains and Low Terraces^a					
202 - 204, 212 – 214	Wider floodplains of major streams.	300 - 800	10 - 50	Floodplain and low terrace deposits.	Halocene deposits.
East Central Texas Plains – Northern Prairie Outliers^a					
205 - 206, 214 - 217	Land cover is mostly pasture, with some cropland.	300 - 800	10 - 50	Paleocene and Eocene formations south of the Sulfur River.	Cretaceous sediments north of the Sulfur River; Paleocene and Eocene formations south of the Sulfur River.
South Central Plains – Tertiary Uplands^a					
227 - 261, 264 - 333	Rolling topography, gently to moderately sloping.	290 - 390	10 - 50	Tertiary deposits, mainly Eocene sediments.	Tertiary deposits, mainly Eocene sediments.
South Central Plains – Floodplains and Low Terraces^a					
261 - 264, 334 - 337, 348 - 349, 353 - 354, 361 - 362, 365 - 367, 366 - 370	Alluvial floodplains and low terraces.	290 - 390	10 - 50	Clayey and loamy soils.	Halocene deposits.

**TABLE 3.1.1-5
Physiographic Characteristics of Ecoregions Crossed in Texas
by the Proposed Project – Gulf Coast Segment**

MP Range	Physiographic Description	Elevation Range (ft AMSL)	Local Relief (ft)	Surface Geology	Bedrock Geology
South Central Plains – Southern Tertiary Uplands^a					
333 - 334, 337 - 348, 349 - 353, 354 - 361, 362 - 365, 367, 370 - 411	Consists of longleaf pine range north of Flatwoods EcoRegion. Forested topography is hilly and dissected.	290 - 390	10 - 50	Tertiary sediments.	Tertiary sediments.
South Central Plains – Flatwoods^a					
411 - 455, 459 - 460	Topography is flat to gently sloping. Streams are low gradient and sluggish.	290 - 390	10 - 50	Pleistocene sediments.	Pleistocene sediments.
Western Gulf Coastal Plain – Northern Humid Gulf Coastal Prairies^a					
455 - 459, 460 – 483.8	Gently sloping coastal plain.	0 – 400	10 - 50	Fine-textured clay to sandy clay loam soils.	Quaternary deltaic sands, silts, and clays.

^aEPA Level III-IV Ecoregion name.

Source: Griffith et al. 2004.

**TABLE 3.1.1-6
Physiographic Characteristics of Ecoregions Crossed in Texas
by the Proposed Project – Houston Lateral**

Milepost Range	Physiographic Description	Elevation Range (ft AMSL)	Local Relief (ft)	Surface Geology	Bedrock Geology
South Central Plains – Flatwoods^a					
0 -3, 15.9 - 16.4	Topography is flat to gently sloping. Streams are low gradient and sluggish.	290 - 390	10 - 50	Pleistocene sediments.	Pleistocene sediments.
Western Gulf Coastal Plain – Northern Humid Gulf Coastal Prairies^a					
3 - 16, 23 - 49	Gently sloping coastal plain.	0 - 400	10 - 50	Fine-textured clay to sandy clay loam soils.	Quaternary deltaic sands, silts, and clays.
South Central Plains – Floodplains and Low Terraces^a					
16 - 23	Alluvial floodplains and low terraces.	290 - 390	10 - 50	Clayey and loamy soils.	Halocene deposits.

^aEPA Level III-IV Ecoregion name.

Source: Griffith et al. 2004.

3.1.1.2 Potential Impacts and Mitigation

Construction

The proposed Project would not involve substantial long- or short-term, large scale alteration of topography. Most of the proposed route would be within areas where bedrock is buried by unconsolidated sediments consisting of glacial till, alluvium, colluvium, loess and/or aeolian deposits. In these areas, impacts to bedrock would be expected to be minimal, and limited to areas where bedrock is within 8 feet of the surface. Trench excavation would typically be to depths of between seven to eight feet. Potential impacts to surface sediments and topography due to accelerated erosion or soil compaction are described in Section 3.2.

Rock ripping could be necessary where dense material, paralithic bedrock, abrupt textural change, or strongly contrasting textural stratification is present within 8 feet of the ground surface. Over the entire proposed Project route, approximately 166 miles would cross areas identified as potential ripping locations. Table 3.1.1-7 summarizes the approximate locations of expected ripping operations respectively, by state, county, and approximate milepost.

TABLE 3.1.1-7 Potential Ripping Locations for the Proposed Project			
MP Range	State	County	Length (miles)
Steele City Segment			
10.96 - 18.73	Montana	Phillips	1.23 miles
25.82 - 57.59	Montana	Valley	3.31 miles
90.26 - 156.74	Montana	McCone	19.30 miles
156.74 - 197.13	Montana	Dawson	9.45 miles
197.85 - 218.06	Montana	Prairie	6.40 miles
218.54 - 282.67	Montana	Fallon	19.67 miles
282.83 - 354.31	South Dakota	Harding	35.94 miles
355.07 - 358.10	South Dakota	Butte	1.03 miles
358.1 - 373.36	South Dakota	Perkins	13.94 miles
373.36 - 424.61	South Dakota	Meade	30.86 miles
426.26 - 426.28	South Dakota	Pennington	0.02 mile
426.28 - 484.45	South Dakota	Haakon	17.76 miles
485.29 - 523.42	South Dakota	Jones	25.50 mile
530.94 - 536.83	South Dakota	Lyman	2.05 miles
537.56 - 596.84	South Dakota	Tripp	15.26 miles
596.84 - 615.18	Nebraska	Keya Paha	3.36 miles
615.65 - 618.12	Nebraska	Rock	0.35 mile
849.67 - 850.76	Nebraska	Jefferson	0.91 mile
<i>Steele City Segment Subtotal</i>			206.33 miles

**TABLE 3.1.1-7
Potential Ripping Locations for the Proposed Project**

MP Range	State	County	Length (miles)
Gulf Coast Segment	91.4	91.4	<0.1
0.09 - 17.19	Oklahoma	Lincoln	9.83 miles
17.87 - 21.26	Oklahoma	Creek	2.35 miles
23.09 - 38.24	Oklahoma	Okfuskee	10.81 miles
38.79 - 58.99	Oklahoma	Seminole	9.17 miles
58.99 - 86.48	Oklahoma	Hughes	12.05 miles
87.55 - 112.85	Oklahoma	Coal	15.93 miles
113.3 - 133.12	Oklahoma	Atoka	1.81 miles
133.12 - 151.04	Oklahoma	Bryan	1.35 miles
166.28 - 185.78	Texas	Lamar	6.43 miles
192.13 - 201.46	Texas	Delta	0.51 miles
203.42 - 222.58	Texas	Hopkins	11.49 miles
222.67 - 233.15	Texas	Franklin	5.08 miles
233.44 - 252.99	Texas	Wood	3.35 miles
259.9 - 261.53	Texas	Upshur	0.85 mile
263.64 - 293.32	Texas	Smith	8.79 mile
297.33 - 298.7	Texas	Cherokee	0.28 mile
300.93 - 314.56	Texas	Rusk	6.23 miles
314.56 - 334.07	Texas	Nacogdoches	8.77 miles
337.27 - 340.76	Texas	Cherokee	1.19 miles
340.85 - 365.75	Texas	Angelina	13.28 miles
370.51 - 403.97	Texas	Polk	13.21 miles
<i>Gulf Coast Segment Subtotal</i>			142.74 miles
Houston Lateral			
15.2 – 49.21	Texas	Liberty	3.17 miles
51.2 – 52.1	Texas	Chambers	0.29 miles
<i>Houston Lateral Subtotal</i>	-	-	3.46 miles
Proposed Project Total			355.99 miles

Operation

Routine pipeline operation and maintenance activities would not be expected to affect physiography or surface or bedrock geology. Potential impacts to surface sediments and topography due to accelerated erosion or soil compaction are described in Section 3.2.

3.1.2 Paleontological Resources

Paleontological resources (fossils) are physical remains of floral and faunal species that have mineralized into or left impressions in solid rock. The study of fossils across geological time and the evolutionary relationships between taxonomies are important elements of paleontological science.

3.1.2.1 Environmental Setting

The potential for the disturbance of paleontological resources during proposed pipeline construction was evaluated (Murphey et al. 2010). In Montana, South Dakota, Nebraska, Kansas, Oklahoma, and Texas paleontological research was performed using museum records and current USGS information. In Montana and South Dakota, field surveys were also conducted along the proposed route on federal, state, and privately owned lands where site access was available.

Potential Fossil-Bearing Geologic Formations

The Potential Fossil Yield Classification (PFYC) system is a survey tool for use on BLM managed lands that designates the fossil-bearing potential of geological formations from very low (Class 1) to very high (Class 5) (BLM 1998, 2007, 2008). The PFYC system provides a baseline for predicting, assessing, and mitigating paleontological resources. The PFYC system and other BLM field survey and monitoring procedures were used to help identify important paleontological resources that could be vulnerable to disturbance from construction activities (BLM 1998, 2007, 2008).

Montana geological formations that are designated as PFYC Class 4 or PFYC Class 5 include:

- Ludlow Member of the Fort Union Formation (occurs sporadically between MP 200.9 to MP 282.5) for mammals;
- Tongue River Member of the Fort Union Formation (MP 129.0 to MP 200.9; MP 203.6 to MP 240.7) for plants; mammals, and mollusks;
- Lebo Member of the Fort Union Formation (sporadically between MP 119.7 to MP 129.0) for mammals;
- Tullock Member of the Fort Union Formation (sporadically between MP 105.4 to MP 128.0) for invertebrates and vertebrates;
- Hell Creek Formation (sporadically between MP 91.5 to MP 114.9) for plants, vertebrates, and invertebrates; and
- Judith River Formation (sporadically between MP 1.1 to MP 45.1) for vertebrates.

South Dakota geological formations that are designated as PFYC Class 4 or PFYC Class 5 include:

- Ludlow Member of the Fort Union Formation (MP 282.5 to MP 284.7) for mammals, plants, and invertebrates, and
- Hell Creek Formation (MP 284.7 to MP 387.1) for reptiles (including dinosaurs) and mammals.

Formations in Nebraska that contain fossil potential include:

- Tertiary Ogallala Group (occurs sporadically from MP 595 to MP 744) for horses, rhinoceroses, proboscideans, mammoths, and other ruminants;
- Upper Cretaceous Pierre Shale, Niobrara, Carlisle, Greenhorn Limestone and Graneros Shale Formations (sporadically between MP 595 to MP 823) for ammonites, gastropods, bivalves, mosasaurs, fish, bivalves, sea turtles, and sharks; and
- Lower Cretaceous Dakota Group (occurs sporadically from MP 798 to MP 850) for flowering plants.

In Kansas, where two new pump stations are proposed, Permian sedimentary rocks may contain fossils of shark and invertebrates including corals, brachiopods, ammonoids, and gastropods (KGS 2005). Surficial unconsolidated deposits have the potential to contain large vertebrate fossils such as mammoths, mastodons, camels, and saber-toothed tigers; and invertebrates such as mollusks (Paleontology Portal 2003).

In Oklahoma, Permian rocks in Payne and Lincoln counties may contain invertebrates. Carboniferous rocks in Creek, Okfuskee, Seminole, Hughes, and Coal counties may contain invertebrates, plants, and fish. Cretaceous rocks in Atoka and Bryan counties may contain fish, reptiles (including dinosaur), and invertebrates.

In Texas, Cretaceous rocks in Fannin, Lamar, and Delta counties may contain invertebrate and fish fossils. Tertiary rocks in Hopkins, Franklin, Smith, Rusk, Upshur, Nacogdoches, Cherokee, Wood, Angelina, and Polk counties may contain invertebrates, reptiles, fish, mammals, and plant fossils. Quaternary rocks in Liberty, Jefferson, Chambers, and Harris counties may contain land mammals, birds, and reptiles.

Field Surveys

In Montana and South Dakota, field surveys were conducted along the proposed Project route, potential reroutes, access roads, and at proposed ancillary facility locations to identify the presence of exposed and visible surface fossils and potentially fossiliferous outcrops of bedrock. All exposures of PFYC Class 4 and 5 geologic formations identified on USGS geologic maps were subjected to pedestrian survey. Exposures of PFYC Class 3 geologic formations were spot-checked and PFYC Class 1 and 2 geologic formations were not surveyed. Paleontological resources identified during surveys along the proposed Project corridor were classified as follows:

- Significant Fossil Localities (SFL) are those localities containing specimens that are field identifiable, of outstanding preservation, or otherwise scientifically significant.
- Non-significant Fossil Occurrences (NFO) are those localities that typically consist of highly weathered or unidentifiable bone or tooth fragments, unidentifiable plant fossils, fossils of common occurrence (such as turtle shell), and fragments of silicified wood.

Montana surveys were conducted consistent with existing BLM and State of Montana regulations and MDEQ requirements using BLM guidelines (BLM 2007, 2008). Prior to field surveys background research was completed at the Montana State Historic Preservation Office (SHPO) in order to assist in identifying potential surface exposures of fossiliferous formations. The field methodology consisted of pedestrian surveys of PFYC 4/5 geologic units along the proposed Project ROW on BLM and state land and on private lands where access was granted. PFYC 3 geologic units were spot-checked. In PFYC 1 and 2 areas geologic maps and aerials were used to identify potential fossil bearing rock outcrops.

South Dakota surveys were conducted consistent with South Dakota Public Utilities Commission (SD-PUC) and South Dakota State Land Commission requirements using BLM guidelines (BLM 2007, 2008). Prior to field surveys, background research was completed at the South Dakota Museum of Geology and at the South Dakota School of Mines and Technology in order to determine any surface exposure of potentially fossiliferous formations. The field methodology consisted of pedestrian surveys of PFYC 4/5 geologic units along the proposed Project ROW on BLM and state land and on private lands where access was granted. PFYC 3 geologic units were spot-checked. In PFYC 1 and 2 areas geologic maps and aerials were used to identify potential fossil bearing rock outcrops.

Table 3.1.2-1 identifies field surveys conducted in Montana and South Dakota.

**TABLE 3.1.2-1
Paleontological Surveys and Reports**

Date of Report	Date(s) of Survey	State	Title
October 28, 2008	July 14-22, 2008; August 15-26, 2008	Montana	Paleontological Assessment of BLM Lands along the Steele City Segment of the Keystone XL Project, Montana
May 26, 2009	July 14-22, 2008; August 15-26, 2008	Montana	Paleontological Assessment of BLM Lands along the Steele City Segment of the Keystone XL Project, Montana: Addendum 1
April 23, 2010	July 14-22, 2008; August 15-26, 2008	Montana	Paleontological Assessment of BLM Lands along the Steele City Segment of the Keystone XL Project, Montana: Addendum 2
September 20, 2010	May 17, 2010 – August 27, 2010	Montana	Paleontological Survey Report: BLM Lands along Steele City Segment of the Keystone XL Project, Montana: Addendum 3
September 20, 2010	May 17, 2010 – August 27, 2010	Montana	Paleontological Survey Report: State Lands along Steele City Segment of the Keystone XL Project, Montana
September 20, 2010	May 17, 2010 – August 27, 2010	Montana	Paleontological Survey Report: Private Lands along Steele City Segment of the Keystone XL Project, Montana
April 23, 2010	None given	South Dakota	Paleontological Assessment of BLM Lands along the Steele City Segment of the Keystone XL Project, South Dakota
April 23, 2010	September 9-22, 2009, September 28, 2009 – October 3, 2009	South Dakota	Paleontological Assessment of State Lands along the Steele City Segment of the Keystone XL Project, South Dakota
September 3, 2010	Through June 25, 2010	South Dakota	Paleontological Survey Report: State Lands along Steele City Segment of the Keystone XL Project, South Dakota
September 3, 2010	Through July 10, 2010	South Dakota	Paleontological Survey Report: Private Lands along Steele City Segment of the Keystone XL Project, South Dakota-Volume 1
September 3, 2010	Through July 10, 2010	South Dakota	Paleontological Survey Report: Private Lands along Steele City Segment of the Keystone XL Project, South Dakota-Volume 2

No field surveys were performed in Nebraska, Kansas, Oklahoma, and Texas due to the low potential for paleontological resources.

Field Survey Results

The results of paleontological surveys in Montana identified 27 SFL and 40 NFO sites. The results of paleontological surveys in South Dakota identified four SFL and 21 NFO sites (Table 3.1.2-2).

**TABLE 3.1.2-2
Paleontological Resources Identified Along Proposed Project Corridor in
Montana and South Dakota**

State	Ownership	Parcel	Fossil Type	SFL/NFO	Geology	Recommendation
MT	State	ML-MT-VA-00190	Vertebrate, Invertebrate	SFL	Claggett	Monitor
MT	State	ML-MT-MC-00158	Plant	SFL	Fort Union	Monitor
MT	BLM	ML-MT-MC-00010	Invertebrate	SFL	Bear Paw	Monitor
MT	BLM	PS09-MT-PH10160	Vertebrate	SFL	Judith River	Avoidance
MT	BLM	ML-MT-MC-00010	Invertebrate	SFL	Bearpaw	Spot Check
MT	BLM	ML-MT-MC-00010	Invertebrate	SFL	Bearpaw	Spot Check
MT	BLM	ML-VT-VA-00155	Vertebrate	SFL	Judith River	Monitor
MT	BLM	ML-MT-MC-00010	Invertebrate	SFL	Bearpaw	Spot Check
MT	BLM	ML-MT-MC-00233	Vertebrate	SFL	Hell Creek	Monitor
MT	BLM	ML-MT-MC-00233	Vertebrate	SFL	Hell Creek	Monitor
MT	BLM	ML-MT-MC-00233	Vertebrate	SFL	Hell Creek	Monitor
MT	BLM	ML-MT-MC-00233	Vertebrate	SFL	Hell Creek	Monitor
MT	BLM	ML-MT-MC-00233	Vertebrate	SFL	Hell Creek	Monitor
MT	BLM	ML-MT-MC-00233	Vertebrate	SFL	Hell Creek	Monitor
MT	BLM	ML-MT-MC-00233	Vertebrate	SFL	Hell Creek	Monitor
MT	BLM	ML-MT-MC-00233	Vertebrate	SFL	Hell Creek	Monitor
MT	BLM	ML-MT-MC-00233	Vertebrate	SFL	Hell Creek	Monitor
MT	BLM	ML-MT-MC-00233	Vertebrate	SFL	Hell Creek	Monitor
MT	BLM	ML-MT-MC-00260	Vertebrate	SFL	Fort Union	Monitor
MT	BLM	MI-MT-PR-00140	Vertebrate	SFL	Fort Union	Monitor
MT	Private	ML-MT-MC00100	Vertebrate	SFL	Hell Creek	Avoidance
MT	Private	ML-MT-MC-00100	Vertebrate	SFL	Hell Creek	Surface collect & monitor
MT	Private	ML-MT-MC-00100	Vertebrate	SFL	Hell Creek	Surface collect & monitor
MT	Private	ML-MT-MC-00195	Vertebrate	SFL	Hell Creek	Surface collect & monitor
MT	Private	ML-MT-MC-00400	Plant	SFL	Fort Union	Monitor
MT	Private	ML-MT-FA-00560	Vertebrate	SFL	Fort Union	Surface collect & monitor
MT	Private	MTV16-MT-FA- 00040	Vertebrate	SFL	Hell Creek	Avoidance
MT	BLM	ML-MT-PH_00120	Invertebrate	NFO	Bear Paw	Monitor
MT	BLM	ML-MT-PH-00145	Invertebrate	NFO	Bear Paw	Monitor
MT	BLM	ML-MT-VA-00265	Invertebrate	NFO	Bear Paw	Monitor
MT	BLM	ML-MT-MC-00142	Vertebrate	NFO	Hell Creek	Monitor
MT	BLM	ML-MT-MC-00010	Invertebrate	NFO	Bear Paw	Monitor
MT	BLM	ML-MT-MC-00010	Invertebrate	NFO	Bear Paw	Spot-check
MT	BLM	PS09-MT-PH-10100	Invertebrate	NFO	Claggett	Spot-check

**TABLE 3.1.2-2
Paleontological Resources Identified Along Proposed Project Corridor in
Montana and South Dakota**

State	Ownership	Parcel	Fossil Type	SFL/NFO	Geology	Recommendation
MT	BLM	ML-MT-MC-00010	Vertebrate	NFO	Fort Union	Monitor
MT	BLM	ML-MT-PR-165	Plant	NFO	Bearpaw	Monitor
MT	BLM	ML-MT-PH-00105	Invertebrate	NFO	Bearpaw	Spot -check
MT	BLM	ML-MT-PH-00105	Invertebrate	NFO	Bearpaw	Spot -check
MT	BLM	ML-MT-PH-00105	Invertebrate	NFO	Bearpaw	Spot -check
MT	BLM	ML-MT-VA-00135	Invertebrate	NFO	Bearpaw	Spot -check
MT	BLM	ML-MT-VA-00135	Invertebrate	NFO	Bearpaw	Spot -check
MT	BLM	ML-MT-VA-00155	Invertebrate	NFO	Judith River	Monitor
MT	BLM	ML-MT-VA-00185	Plant	NFO	Judith River	Monitor
MT	BLM	ML-MT-VA-00355	Invertebrate	NFO	Bearpaw	Spot-check
MT	BLM	ML-MT-VA-00355	Invertebrate	NFO	Bearpaw	Spot-check
MT	BLM	ML-MT-VA-00355	Invertebrate	NFO	Bearpaw	Spot-check
MT	BLM	ML-MT-MC00010	Invertebrate	NFO	Bearpaw	Spot-check
MT	BLM	ML-MT-MC00010	Invertebrate	NFO	Bearpaw	Spot-check
MT	BLM	ML-MT-MC00010	Invertebrate	NFO	Bearpaw	Spot-check
MT	BLM	ML-MT-MC00010	Invertebrate	NFO	Bearpaw	Spot-check
MT	BLM	ML-MC-MC-00233	Vertebrate	NFO	Hell Creek	Monitor
MT	BLM	ML-MC-MC-00233	Vertebrate	NFO	Hell Creek	Monitor
MT	BLM	ML-MC-MC-00233	Vertebrate	NFO	Hell Creek	Monitor
MT	BLM	ML-MC-MC-00233	Vertebrate	NFO	Hell Creek	Monitor
MT	BLM	ML-MT-MC-00260	Vertebrate	NFO	Fort Union	Monitor
MT	BLM	ML-MT-MC-00260	Vertebrate, Plant	NFO	Hell Creek	Monitor
MT	Private	MTV1-MT-MC- 00320	Vertebrate	NFO	Judith River	Monitor
MT	Private	MTV1-MT-PH- 00310	Invertebrate	NFO	Claggett	Monitor
MT	Private	ML-MT-VA-00015	Invertebrate	NFO	Judith River	Monitor
MT	Private	ML-MT-MC-00100	Plant	NFO	Hell Creek	Monitor
MT	Private	ML-MT-MC-00109	Vertebrate	NFO	Hell Creek	Monitor
MT	Private	ML-MT-MC-00106	Plant	NFO	Hell Creek	Monitor
MT	Private	ML-MT-MC-00100	Vertebrate	NFO	Hell Creek	Monitor
MT	Private	ML-MT-FA-00040	Plant	NFO	Fort Union	Monitor
MT	Private	ML-MT-FA-00720	Vertebrate	NFO	Hell Creek	Monitor
MT	Private	MI-MT-FA-00730	Vertebrate	NFO	Hell Creek	Monitor
MT	Private	ML-MT-PR-00070	Plant	NFO	Fort Union	Monitor
SD	Private	ML-SD-ME-00150	Vertebrate	SFL	Hell Creek	Surface collect & monitor

**TABLE 3.1.2-2
Paleontological Resources Identified Along Proposed Project Corridor in
Montana and South Dakota**

State	Ownership	Parcel	Fossil Type	SFL/NFO	Geology	Recommendation
SD	Private	CAR-041	Vertebrate	SFL	Hell Creek	Surface Collect & monitor
SD	Private	CAR-041	Vertebrate	SFL	Hell Creek	Surface collect & monitor
SD	Private	ML-SD-PE-00360	Vertebrate	SFL	Hell Creek	Surface collect & monitor
SD	Private	CAR-048A	Vertebrate	NFO	Hell Creek	Monitor
SD	Private	CAR-048A	Vertebrate	NFO	Hell Creek	Monitor
SD	Private	ML-SD-ME-00230	Vertebrate	NFO	Hell Creek	Monitor
SD	Private	CAR-041	Vertebrate	NFO	Hell Creek	Monitor
SD	Private	CAR-041	Plant	NFO	Hell Creek	Monitor
SD	Private	CAR-041	Vertebrate	NFO	Hell Creek	Monitor
SD	Private	ML-SD-HA-01780	Vertebrate	NFO	Hell Creek	Monitor
SD	Private	ML-SD-HA-01780	Vertebrate	NFO	Hell Creek	Monitor
SD	Private	ML-SD-PE-00430	Vertebrate	NFO	Hell Creek	Monitor
SD	Private	ML-SD-PE-00360	Vertebrate, Plant	NFO	Hell Creek	Monitor
SD	Private	ML-SD-HK-11767	Invertebrate	NFO	Pierre Shale	Monitor
SD	Private	ML-SD-JO-10060	Invertebrate	NFO	Pierre Shale	Monitor
SD	Private	ML-SD-TR-11630	Vertebrate, Trace	NFO	Ogallala	Monitor
SD	State	PS-15	Plant	NFO	Fort Union	Monitor
SD	State	ML-SD-HA-13020	Vertebrate	NFO	Hell Creek	Monitor
SD	State	ML-SD-HA-13020	Vertebrate	NFO	Hell Creek	Monitor
SD	State	ML-SD-PE-00410	Vertebrate, Plant	NFO	Hell Creek	Monitor
SD	State	ML-SD-PE-00410	Vertebrate	NFO	Hell Creek	Monitor
SD	State	ML-SD-PE-00330	Vertebrate	NFO	Hell Creek	Monitor
SD	State	ML-SD-PE-00330	Vertebrate	NFO	Hell Creek	Monitor
SD	State	ML-SD-PE-00330	Vertebrate	NFO	Hell Creek	Monitor
SD	State	ML-SD-PE-00330	Vertebrate	NFO	Hell Creek	Monitor
SD	State	ML-SD-HA-02400	Vertebrate	NFO	Hell Creek	Monitor
SD	State	ML-SD-HA-02870	Vertebrate	NFO	Hell Creek	Monitor
SD	State	ML-SD-HA-03310	Vertebrate	NFO	Hell Creek	Monitor
SD	State	PS15-SD-HA-00335	Vertebrate	NFO	Hell Creek	Monitor
SD	State	PS16-SD-HA-10012	Plant	NFO	Hell Creek	Monitor
SD	State	PS16-SD-HA-10012	Vertebrate	NFO	Hell Creek	Monitor
SD	State	PS16-SD-HA-10014	Vertebrate	NFO	Hell Creek	Monitor

3.1.2.2 Potential Impacts

Construction

Potential impacts to paleontological resources during construction include damage to or destruction of fossils due to excavation activities, erosion of fossil beds due to grading, and unauthorized collection of fossils.

Because there is potential for discovery of fossils during trench excavation and pipeline installation activities, a Paleontological Monitoring and Mitigation Plan (PMMP) would be prepared prior to beginning construction on federal and certain state and local government lands. Fossils or other paleontological resources found on private land would only be recovered with approval of the landowner, and therefore, may be unavailable for scientific study. Additionally, prior to initiation of excavation and pipeline installation, appropriate regulatory agencies in each state would be consulted on the requirements for the PMMP for federal, certain state and local government lands. There is currently an effort led by MDEQ and other agencies to develop a Memorandum of Understanding (MOU) in Montana for the identification, evaluation and protection of paleontological resources. This MOU will be completed prior to the FEIS.

Paleontological resources identified on Federal lands are managed and protected under the Paleontological Resources Preservation Act (PRSA) as part of the Omnibus Public Land Management Act of 2009. This law requires the Secretaries of the Interior and Agriculture to manage and protect paleontological resources on lands under their jurisdiction using scientific principles and expertise. The Act affirms the authority for many of the policies the Federal land managing agencies already have in place such as issuing permits for collecting paleontological resources, curation of paleontological resources, and confidentiality of locality data. The statute also establishes criminal and civil penalties for fossil theft and vandalism on Federal lands.

Operation and Maintenance

Routine pipeline operations and maintenance activities are not expected to affect paleontological resources. However, collection of paleontological resources for scientific or other purposes would not be possible within the permanent ROW during proposed Project operations.

3.1.2.3 Potential Additional Mitigation Measures

The states of Montana and South Dakota have enacted legislation to manage and protect paleontological resources on state-managed lands.

In Montana, a certificate of compliance under MFSA would be obtained from MDEQ prior to construction of the proposed pipeline. A conditional requirement for the issuance of the certificate of compliance relates to the required implementation of mitigation actions when significant paleontological resources are inadvertently discovered during the construction of the proposed pipeline on lands under the jurisdiction of the State of Montana or a federal agency and also on private land. The requirements are set forth in the document entitled *Conditional Requirements for the Treatment of Inadvertently Discovered Significant Paleontological Resources for the Keystone XL Pipeline* (and the proposed PMMP). The requirements are designed to minimize and mitigate the adverse effects of pipeline construction activities on significant paleontological materials. The Montana Antiquities Act, as amended (1995), requires the Department of Natural Resources and Conservation (DNRC) and other state agencies to avoid or mitigate damage to important paleontological resources (when feasible) on state trust lands. The Montana Department of Fish, Wildlife and Parks have written rules for implementing the State Antiquities Act.

The Montana SHPO also issues antiquities permits for the collection of paleontological resources on state owned lands.

South Dakota requires a permit from the South Dakota Public Utilities Commission (SDPUC) as defined in SDCL Chapter 49-41 B to construct the South Dakota portion of the proposed Project. A permit is also required from the South Dakota Commissioner of School and Public Lands to survey, excavate or remove paleontological resources from state land and to determine the repository or curation facility for paleontological collections from state lands. Condition 44 of the proposed Project's permit from SDPUC specifies the need for surveys in accordance with the procedures described for the South Dakota paleontological field surveys and also mandates the following mitigation measures:

- “Following the completion of field surveys, Keystone shall prepare and file with the Commission a paleontological resource mitigation plan. The mitigation plan shall specify monitoring locations, and include BLM permitted monitors and proper employee and contractor training to identify any paleontological resources discovered during construction and the procedures to be followed following such discovery. Paleontological monitoring will take place in areas within the construction ROW that are underlain by rock formations with high sensitivity (PFYC Class 4) and very high sensitivity (PFYC Class 5), and in areas underlain by rock formations with moderate sensitivity (PFYC Class 3) where significant fossils were identified during field surveys.
- If during construction, Keystone or its agents discover what may be a paleontological resource of economic significance, or of scientific significance....Keystone or its contractors or agents shall immediately cease work at that portion of the site and, if on private land, notify the affected landowner(s). Upon such a discovery, Keystone's paleontological monitor will evaluate whether the discovery is of economic significance, or of scientific significance. If an economically or scientifically significant paleontological resource is discovered on state land, Keystone will notify SDSMT and if on federal land, Keystone will notify the BLM or other federal agency. In no case shall Keystone return any excavated fossils to the trench. If a qualified and BLM-permitted paleontologist, in consultation with the landowner, BLM, or SDSMT determines that an economically or scientifically significant paleontological resource is present, Keystone shall develop a plan that is reasonably acceptable to the landowner(s), BLM, or SDSMT, as applicable, to accommodate the salvage or avoidance of the paleontological resource to protect or mitigate damage to the resource. The responsibility for conducting such measures and paying the costs associated with such measures, whether on private, state or federal land, shall be borne by Keystone to the same extent that such responsibility and costs would be required to borne by Keystone on BLM managed lands pursuant to BLM regulations and guidelines, including the BLM Guidelines for Assessment and Mitigation of Potential Impacts to Paleontological Resources, except to the extent factually inappropriate to the situation in the case of private land (e.g. museum curation costs would not be paid by Keystone in situations where possession of the recovered fossil(s) was turned over to the landowner as opposed to curation for the public). If such a plan will require a materially different route than that approved by the Commission, Keystone shall obtain Commission approval for the new route before proceeding with any further construction. Keystone shall, upon discovery and salvage of paleontological resources either during pre-construction surveys or construction and monitoring on private land, return any fossils in its possession to the landowner of record of the land on which the fossil is found. If on state land, the fossils and all associated data and documentation will be transferred to the SDSMT; if on federal land, to the BLM. To the extent that Keystone or its contractors or agents have control over access to such information, Keystone shall, and shall require its contractors and agents to, treat the locations of sensitive and valuable resources as confidential and limit public access to this information.”

To comply with MFSA conditions in Montana and SDPUC conditions in South Dakota, a paleontological monitor would be provided for each construction spread in Montana and South Dakota that includes an area assigned moderate to high fossil-bearing potential (PFYC 3, 4 & 5) and in areas where scientifically significant fossils were identified during surface surveys. The paleontological monitor would satisfy the qualifications established by the BLM for paleontological monitoring on federal lands.

In Nebraska, the State Department of Roads has contracted with the University of Nebraska Museum for a highway salvage paleontologist to identify and collect important paleontological resources that may be impacted by the maintenance and construction of federal highways and roads. While directed to investigate paleontological resources on federally funded road projects, the salvage operations are also conducted on state and county road projects. There are no specific regulations concerning paleontological resources that would apply to the proposed Project.

Kansas and Oklahoma have no state regulations concerning the management and protection of paleontological resources on state lands. In Texas, there are no state regulations concerning the management and protection of paleontological resources on state lands except on lands administered by state forests and state parks.

3.1.3 Mineral and Fossil Fuel Resources

3.1.3.1 Environmental Setting

Montana

In the proposed Project area, oil, natural gas, and coal comprise the major energy resources (Montana Bureau of Mines and Geology 1963). Sand, gravel and bentonite are also mined (Montana Bureau of Mines and Geology/USGS 2004). The proposed route would cross few oil and gas producing areas. There are 9 oil and gas producing wells within one-quarter mile (1,320 feet) of the proposed ROW (Appendix F).

The proposed pipeline route does not cross any coal (lignite) mines. Historically, bentonite has been mined and processed in the area southeast of Glasgow and south of the proposed pipeline route; however, bentonite is not currently being mined and processed in the proposed Project area (Montana Bureau of Mines and Geology/USGS 2004).

Aggregate mining of sand and gravel deposits is also conducted in the region; although the proposed pipeline route would not cross any aggregate mines.

South Dakota

In the proposed Project area, sand, gravel, oil, gas, and coal comprise the major energy resources (South Dakota Geological Survey/USGS 2005). A gravel pit is present approximately 0.5 mile from the proposed route, northeast of MP 552. The proposed pipeline route would traverse the Buffalo Field, an oil and gas producing area in Hardin County. Fifteen oil and gas producing wells are located within one-quarter mile of the proposed ROW (Appendix F).

The proposed pipeline route would not cross any known coal mines. The proposed route would cross approximately 2 miles of coal-bearing formations (Fort Union Formation and Hell Creek Formation), but potential for mining of these formations is low.

Nebraska

There is no known active oil, natural gas, coal, or mineral mining operations along the proposed pipeline route in Nebraska. The main mineral resource in the proposed Project area is aggregate (sand and gravel) used for road and building construction, and concrete. Along the northern portion of the route, sandstone has been quarried for road construction. In southern Nebraska, near the proposed route, shales and clays have been mined for producing bricks. Near Tobias in Salina County, limestone has been mined for agricultural lime.

Kansas

Mineral resources in the area of the proposed two new pump stations include sand, gravel, and crushed stone (USGS 2004); however, construction of the two new pump stations would not affect current mining operations.

Oklahoma

Oil and natural gas represent important natural resources in the area of the proposed pipeline route in Oklahoma. Along the Gulf Coast Segment in Oklahoma there are 700 oil and gas wells within one-quarter mile of the proposed pipeline route (Appendix F). Sand, gravel, and crushed stone are also mined along the proposed route in Okfuskee, Seminole, Hughes, Clay, Coal, Atoka, and Bryan counties (Johnson 1998a, USGS 2004). Coal resources are present in eastern Oklahoma. The proposed ROW would cross areas of documented coal resources in Coal County in southeastern Oklahoma (Johnson 1998b).

Texas

Along the Gulf Coast Segment in Texas, there are 252 oil and gas wells within one-quarter mile of the proposed pipeline route (Appendix F). However, field surveys have not identified any existing or capped wells in the construction ROW. Crushed stone, coal (lignite), clay, iron, peat, and sand are other mineral resources present in the proposed Project area (Garner 2008).

Along the proposed Houston Lateral in Texas, there are 48 oil and gas wells within one-quarter mile of the proposed pipeline route (Appendix F). Clay, sand, and gravel are also present in the proposed Project area (Garner 2008).

3.1.3.2 Potential Impacts

Although the proposed route would not cross any active surface mines or quarries, construction and operation of the proposed Project would limit access to sand, gravel, clay, and stone resources that are within the width of the permanent pipeline ROW. As summarized above, the proposed route would cross deposits of sand, gravel, clay, and stone; however, the acreage of deposits covered by the proposed ROW is minimal when compared to the amounts available for extraction throughout the proposed Project area. As summarized in Section 2.1.2.2, approximately 811,722 cubic yards of gravel and other borrow materials would be utilized for temporary sites such as storage sites, contractor yards, temporary access roads, and to stabilize the land for permanent facilities including pump stations, mainline valves, permanent access roads, and the pipeline trench bottom. Borrow materials would be obtained from an existing, previously permitted commercial source located as close to the pipeline or contractor yard as possible.

The proposed route would cross underlying coal bearing formations in South Dakota and in Coal County, Oklahoma. Although not currently planned, if surface mining was proposed for this area in the future, the pipeline could limit access to these resources.

While there are numerous oil and gas wells within one-quarter mile of the proposed ROW in Oklahoma and Texas, the proposed route would not cross the well-pads of any active oil and gas wells. Accordingly, extraction of oil and gas resources would not be affected by operation of the proposed pipeline.

3.1.4 Geologic Hazards

3.1.4.1 Environmental Setting

At certain locations along the proposed route, seismic hazards, landsliding, subsidence, or flooding would be possible. Since the proposed pipeline ROW would be located in the relatively flat and stable continental interior, the potential for impacts from geologic hazards is lower than for facilities located in active mountain belts or coastal areas.

Seismic Hazards

Seismic hazards include faults, seismicity, and ground motion hazards. Collectively, these three phenomena are associated with seismic hazard risk. Faults are defined as a fracture along which blocks of earth materials on either side of the fault have moved relative to each other. An active fault is one in which movement has demonstrated to have taken place within the last 10,000 years (USGS 2008b). Seismicity refers to the intensity and the geographic and historical distribution of earthquakes. Ground motion hazards are defined as movement of the earth's surface as a result of earthquakes (USGS 2008a). Figure 3.1.4-1 presents the earthquake hazard rank map which shows earthquake hazard risk along the proposed Project route. The map indicates that there is low seismic hazard risk along the entire proposed route.

Minor faults are present in the vicinity of the proposed pipeline route. In Montana, the Brockton-Froid Fault is mapped in the Weldon-Brockton fault zone approximately 50 miles east of the proposed route in Roosevelt County, just north of Culbertson, Montana (Wheeler 1999). Based on exploration and field data, there is no indication that this is an active fault (Wheeler 1999). No other information regarding historic earthquakes in the Weldon-Brockton fault zone was identified.

Historic earthquake activity in the vicinity of the proposed pipeline was reviewed using USGS's National Earthquake Information Center on-line database search. Records were available from 1973 to the present time.

Eastern Montana historically contains little earthquake activity. From 1973 to 2007, 14 earthquakes have been recorded with magnitudes 4.1 or less in the eastern half of Montana (USGS 2008b).

In South Dakota, 30 earthquakes have been recorded since 1973, with magnitudes 4.2 or less (USGS 2008b); however, none of these earthquakes occurred along or adjacent to the proposed route.

In eastern Nebraska, 11 earthquakes have been recorded since 1973, with magnitudes ranging from 2.8 to 4.3 (USGS 2008b). These earthquakes are believed to be associated with either the Humboldt fault zone or deep seated faults in the Salinas Basin. There are no active surficial faults along the proposed route (Crone and Wheeler 2000, USGS 2006).

In Oklahoma, approximately 50 minor earthquakes occur each year. The majority of these earthquakes range in magnitude from 1.8 to 2.5, and would not be expected to damage the buried pipeline. In general, earthquake activity in Oklahoma occurs in south central Oklahoma, south of Oklahoma City, approximately 100 to 200 miles to the west of the pipeline.

In Texas, surface faults have been mapped in the proposed Project area. There is little evidence of ground movement along these faults and as such, they pose very minimal risk to the pipeline (Crone and Wheeler 2000). Epicenter maps show only sparse, low magnitude seismicity (USGS 2008a). Commenters on the draft EIS expressed concern over the potential for seismic or earthquake fault hazards to the proposed Project resulting from the Mount Enterprise Fault Zone. The proposed ROW does cross a portion of the Mount Enterprise Fault Zone. This fault zone is located within the East Texas Salt Basin that is characterized by Mesozoic and Cenozoic sedimentary rocks overlying Jurassic aged Louann Salt deposits. Within the zone, listric normal faults typically dip northward at about 75 degrees from horizontal at the surface and extend into the Louann Salt formation. Fault displacements within this geologic environment are generally thought to be associated with salt deforming plastically at depth and are therefore not likely to be tectonic in origin, and the magnitudes of earthquakes that may be associated with the fault zone would be minor.

A search of the USGS earthquake database found two earthquake events in the vicinity of the Mount Enterprise Fault Zone from 1973 to present. These two events occurred 18 and 35 miles from the proposed Project fault zone crossing and had magnitudes of 3.2 and 3.0 respectively. Earthquakes exhibiting Richter magnitudes less than 4 are considered minor earthquakes and would not threaten the integrity of a buried pipeline. Additionally, the proposed Project corridor does not cross any mapped geologic fault within the Enterprise Fault Zone with documented surface offset.

In addition, approximately 300 surface faults were mapped using Lidar (light distancing and ranging) technology in the Houston area. Movement along these surface faults is not characterized by ground shaking typically associated with earthquakes, but rather, is associated with slow movements of up to 1 inch per year (Khan and Engelkeimer 2008), and these faults are likely associated with salt domes present in this region, where subsidence has been noted to occur. Some of these surface fault movements may also be associated with subsidence due to groundwater and petroleum withdrawal (Kahn and Engelkeimer 2008). The proposed pipeline ROW does not cross any of these Lidar mapped surface faults.

Landslides

Some commenters on the draft EIS have expressed concern related to landslide potential in steep slope areas, particularly “breakaway” landslides. According to the classification of landslide slope movements, the widely accepted terms describing landslides include fall, topple, slide, spread, and flow. These slide classifications can be further modified with the descriptive terms extremely rapid, very rapid, rapid, moderate, slow, very slow, and extremely slow (Turner and Schuster 1996). While the meaning of the term breakaway landslide is not clear, it is assumed that the concern relates to extremely rapid to rapid slides. The potential for these types of landslides is increased in areas that contain steep slopes (>20 percent grade) and may be further influenced by unstable soils or bedrock. Only 4.04 miles of the terrain crossed by the Steele City Segment and 0.70 mile crossed by the Gulf Coast Segment contain steep slopes (>20 percent grade). Most of these steep sections are less than 0.1 mile in length and correspond to stream crossing locations. Landslides may cause increased soil erosion where underlying soils are exposed and may also cause increased input of sediment and/or in-stream turbidity in adjacent water bodies, if present. Landslides typically occur on steep terrain during conditions of partial or total soil saturation, or during seismic-induced ground shaking. Given the low likelihood of significant seismically-induced ground shaking along the proposed pipeline corridor, earthquake induced landslide potential is very minor. Stream erosion, undercutting or undermining topography during the construction

of roads or other structures also can cause instability leading to increased landslide potential. FEMA developed a landscape hazard ranking system (LSHR) that relied on existing data for swelling clays, landslide incidence, landslide susceptibility, and land subsidence. Using these criteria, the LSHR places landscapes into three general risk categories: low hazard, medium hazard, and high hazard. Areas along the proposed Project corridor that are within the FEMA LSHR high general risk category are summarized by state in Table 3.1.4-1 and shown in Figure 3.1.4-2.

In addition to steep terrain, certain formations are susceptible to increased landslide potential due to the makeup of the soil and/or geological materials. Along the Steele City Segment, the Claggett, Bearpaw, Pierre Shale, Fort Union shales, and Hell Creek Formation may contain appreciable amounts of bentonite. Bentonite is soft, plastic, light colored clay that expands when exposed to water and may cause soil and/or geologic formations to become unstable. Cretaceous and Tertiary rocks in the Missouri River Plateau have the potential for slumping due to high clay content. Along the proposed route, potentially unstable soils or geologic formations are present at the Missouri River, Willow Creek, Keya Paha River, and Niobrara River crossings.

In the Gulf Coast Segment, landslide potential is highest where shale formations weather to clayey colluviums and is highest in areas where slopes exceed a 2:1 gradient (Luza & Johnson 2005). The Houston Lateral does not contain any areas of high risk for landslides.

TABLE 3.1.4-1 Mileage within PHMSA High Landslide Hazard Category Along the Proposed Project			
State	Start (MP)	End (MP)	Length (miles)
Steele City Segment			
Montana	0.2	25.5	25.3
Montana	25.5	89.2	63.7
Montana	89.2	102.0	12.8
South Dakota	308.3	313.5	5.2
South Dakota	355.6	358.1	2.5
South Dakota	358.1	370.9	12.8
South Dakota	389.5	425.9	36.4
South Dakota	425.9	426.3	0.4
South Dakota	426.3	426.3	0.0
South Dakota	426.3	485.1	58.8
South Dakota	485.1	525.2	40.1
South Dakota	525.2	537.1	11.9
South Dakota	537.1	571.5	34.4
Nebraska	597.4	608.8	11.4
Nebraska	616.1	622.6	6.5
Nebraska	850.2	851.6	1.4
Steele City Segment Subtotal			323.6
Gulf Coast Segment			
	91.4	91.4	<0.1
Oklahoma	135.5	142.7	7.2
Texas	163.0	168.3	5.3

TABLE 3.1.4-1 Mileage within PHMSA High Landslide Hazard Category Along the Proposed Project			
State	Start (MP)	End (MP)	Length (miles)
Texas	183.1	190.5	7.4
Texas	190.5	190.7	0.2
Texas	190.7	190.8	0.1
Texas	190.8	201.7	10.9
Texas	201.7	204.6	2.9
Texas	261.8	262.0	0.2
Texas	262.1	263.3	1.2
Texas	480.4	482.7	2.3
Texas	482.7	483.8	1.1
Gulf Coast Segment Subtotal			38.8
Houston Lateral			
None	-	-	0
Houston Lateral Subtotal			0
Proposed Project Total			362.4

Source: PHMSA-NPMS <http://www.npms.phmsa.dot.gov/>

Additionally, the Montana Department of Environmental Quality (MDEQ) is concerned about areas where slopes greater than 15 percent occur overlying Cretaceous shales. Table 3.1.4-2 provides a listing of these slopes along the original proposed route in Montana.

TABLE 3.1.4-2 Areas in Montana with >15% Slopes Underlain by Cretaceous Shale Geology			
County	Start (MP)	End (MP)	Length (miles)
Phillips	13.8	13.8	< 0.1
Phillips	16.3	16.6	0.3
Phillips	21.2	21.2	< 0.1
Phillips	25.2	25.4	0.2
Valley	26.1	26.1	< 0.1
Valley	33.9	34.0	0.1
Valley	36.2	36.2	< 0.1
Valley	38.7	38.8	0.1
Valley	38.9	39.0	0.1
Valley	39.5	39.6	0.1
Valley	40.1	40.2	0.1
Valley	41.0	41.1	0.1
Valley	41.5	41.6	0.1
Valley	43.1	43.1	<0.1
Valley	46.8	46.8	<0.1

**TABLE 3.1.4-2
Areas in Montana with >15% Slopes Underlain by Cretaceous Shale Geology**

County	Start (MP)	End (MP)	Length (miles)
Valley	48.2	48.3	0.1
Valley	48.4	48.5	0.1
Valley	51.3	51.3	<0.1
Valley	53.1	53.2	0.1
Valley	53.7	53.7	<0.1
Valley	55.0	55.1	0.1
Valley	55.1	55.2	0.1
Valley	66.8	66.8	<0.1
Valley	77.8	77.8	<0.1
Valley	78.1	78.1	<0.1
Valley	82.2	82.2	<0.1
McCone	91.4	91.4	<0.1
McCone	91.4	91.6	0.2
McCone	91.6	91.6	<0.1
McCone	91.8	91.9	0.1
McCone	92.0	92.0	<0.1
McCone	93.4	93.4	<0.1
McCone	93.5	93.5	<0.1
McCone	93.7	93.7	<0.1
McCone	93.8	93.8	<0.1
McCone	94.4	94.7	0.3
McCone	94.8	94.8	<0.1
McCone	94.9	94.9	<0.1
McCone	95.0	95.1	0.1
McCone	95.2	95.2	<0.1
McCone	95.3	95.5	0.2
McCone	95.9	95.9	<0.1
McCone	96.6	96.7	0.1
McCone	96.8	96.9	0.1
McCone	97.0	97.1	0.1
McCone	98.6	98.7	0.1
McCone	99.0	99.0	<0.1
McCone	99.5	99.5	<0.1
McCone	100.9	100.9	<0.1
McCone	101.0	101.0	<0.1
McCone	101.6	101.6	<0.1
McCone	102.1	102.2	0.1

TABLE 3.1.4-2 Areas in Montana with >15% Slopes Underlain by Cretaceous Shale Geology			
County	Start (MP)	End (MP)	Length (miles)
Fallon	254.3	254.3	<0.1
Fallon	262.5	262.5	<0.1
Fallon	269.2	269.2	<0.1
Fallon	269.2	269.3	0.1
Fallon	269.3	269.3	<0.1
Fallon	270.5	270.5	<0.1
Fallon	270.9	270.9	<0.1
Fallon	271.9	272.0	0.1

Subsidence

Subsidence hazards along the proposed pipeline route would most likely be associated with the presence of karst features, such as sinkholes and fissures. National karst maps were reviewed to determine areas of potential karst terrain (i.e., areas where limestone bedrock is near the surface) along the proposed pipeline route (US National Atlas 2009). These areas are summarized in Table 3.1.4-3.

TABLE 3.1.4-3 Karst Areas Crossed by the Proposed Project			
Location	Start (MP)	End (MP)	Length (miles)
Steele City Segment^a			
Nance County, NE	741.8	742.8	1.0
Merrick County, NE	742.8	752.4	9.6
Hamilton County, NE	759.3	764.9	5.7
York County, NE	764.9	778.0	13.0
<i>Steele City Segment Subtotal</i>			<i>29.4</i>
Gulf Coast Segment^b			
Atoka County, OK	125.7	133.1	7.4
Bryan County, OK	133.1	134.8	1.7
Lamar County, TX	178.5	185.7	7.2
Delta County, TX	191.7	196.0	4.4
<i>Gulf Coast Segment Subtotal</i>			<i>20.7</i>
Proposed Project Total			50.1

^a Type: Fissures, tubes and caves generally less than 1,000 feet (300 meters) long; 50 feet (15 meters) or less vertical extent; in gently dipping to flat-lying beds of carbonate rock beneath an overburden of noncarbonate material 10 to 200 feet (3 to 60 meters) thick.

^b Type: Fissures, tubes, and caves generally less than 1,000 feet (300 meters) long, 50 feet (15 meters) or less vertical extent, in gently dipping to flat-lying beds of carbonate rock.

Source: US National Atlas.

In Nebraska, potential karst features are present in the Niobrara Formation; however, these potential hazards are considered minimal since approximately 50 feet of sediment typically covers this formation. In southeastern Oklahoma and Texas, the proposed route crosses potential karst features present in flat-lying carbonate rock.

Floods

In general, seasonal flooding hazards occur in areas where the proposed pipeline would cross active stream and river channels, or in areas where the proposed pipeline could be subject to flash flooding in these channels or intermittent drainages. As with landslide risks FEMA has categorized the general flood hazard of landscapes across the U.S. The mileage along the proposed pipeline by state that falls within the FEMA high flooding risk category is as follows: Montana 20 miles; South Dakota 25 miles; Nebraska 14 miles; Oklahoma 51 miles; and Texas 88 miles (see Figure 3.1.4-3). Flooding could cause lateral and vertical scour that could expose and potentially damage the proposed pipeline. Proposed Project design criteria indicate that the proposed pipeline would be buried below the calculated scour depth at active stream crossings. Additionally, at 34 major river crossings, the HDD method would be employed to install the proposed pipeline. At other river and stream crossings, the proposed pipeline would be buried under at least 5 feet of cover for at least 15 feet on either side of the bank-full width. For additional information on stream crossings, see Section 3.3.

3.1.4.2 Potential Impacts

Seismic

Based on the evaluation of potential seismic hazards along the proposed ROW, the risk of pipeline rupture from earthquake ground motion would be considered to be minimal. The proposed route would not cross any known active faults and is located outside of known zones of high seismic hazard.

The pipeline would be constructed to be able to withstand probable seismic events within the seismic risk zones crossed by the proposed pipeline. The pipeline would be constructed in accordance with USDOT regulations 49 CFR Part 195, Transportation of Hazardous Liquids by Pipeline, and all other applicable federal and state regulations. These regulations are designed to prevent crude oil pipeline accidents and to ensure adequate protection for the public.

In accordance with federal regulations (49 CFR 195), internal inspection of the proposed pipeline would occur if an earthquake, landslide, or soil liquefaction event were suspected of causing abnormal pipeline movement or rupture. If damage to the pipeline was evident, the pipeline would be inspected and repaired as necessary.

Landslides

Pipeline routing was conducted to avoid to the degree practicable areas with high landslide potential, particularly areas with slopes greater than 15 to 20 percent with potentially unstable soil or rock conditions (see Tables 3.1.4-2 and 3.1.4-3). However, not all potentially unstable slopes could be practicably avoided. As a result, during construction activities, vegetation clearing and alteration of surface-drainage patterns could increase landslide risk. Implementation of temporary erosion control structures would reduce the likelihood of construction-triggered landslides. Potential erosion control measures would include trench breakers, slope breakers or water bars, erosion control matting and mulching. In addition, areas disturbed by construction along the pipeline ROW would be revegetated consistent with the CMR Plan (Appendix B) and special landowner or land manager requirements.

Revegetation would also help reduce the risk of landslides during the operational phase of the proposed Project. The proposed pipeline would be designed and constructed in accordance with 49 CFR, Parts 192 and 193. These specifications require that pipeline facilities are designed and constructed in a manner to provide adequate protection from washouts, floods, unstable soils, landslides, or other hazards that may cause the pipeline facilities to move or sustain abnormal loads. Proposed pipeline installation techniques, especially padding and use of rock-free backfill, are designed to effectively insulate the pipeline from minor earth movements.

To reduce landslide risk, erosion and sediment control and reclamation procedures would be employed as described in Section 4.11 of its CMR Plan (Appendix B). These procedures are expected to limit the potential for erosion, and maintain slope stability after the construction phase. Additionally, the potential for landslide activity would be monitored during pipeline operation through aerial and ground patrols and through landowner awareness programs designed to encourage reporting from local landowners. TransCanada's Integrated Public Awareness (IPA) plan would be implemented. This plan is consistent with the recommendations of API RP-1162 (Public Awareness Programs for Pipeline Operators). The plan includes the distribution of educational materials to inform landowners of potential threats and information on how to identify threats to the pipeline including the potential for landslides. Landowners would be provided a toll-free telephone number to report potential threats to the integrity of the pipeline and other emergencies.

Subsidence

There is a risk of subsidence where the proposed route crosses karst formations in Nebraska, Oklahoma, and Texas. Table 3.1.4-3 shows the locations by milepost where karst may be present. Site-specific studies would be conducted as necessary to characterize the karst features, if encountered, and would evaluate and modify construction techniques as necessary in these areas. The overall risk to the pipeline from karst-related subsidence is expected to be minimal.

Floods

There is a risk of pipeline exposure due to lateral or vertical scour at water crossings and during floods. An assessment of potential environmental impacts and protection measures related to proposed pipeline stream crossing procedures can be found in Section 3.3 and for Montana in Appendix I.

3.1.5 Connected Actions

3.1.5.1 Big Bend to Witten 230-kV Transmission Line

The construction and operation of electrical distribution lines and substations associated with the proposed pump stations, and the Big Bend to Witten 230-kV electrical transmission line would have negligible effects on geological resources.

3.1.5.2 Cushing Marketlink and Bakken Marketlink Projects

Construction and operation of the Bakken Marketlink Project would include metering systems, three new storage tanks near Baker, Montana, and two new storage tanks within the boundaries of the proposed Cushing tank farm. Keystone reported that the property proposed for the Bakken Marketlink facilities near Pump Station 14 is currently used as pastureland and hayfields and that a survey of the property indicated that there were no waterbodies or wetlands on the property. DOS reviewed aerial photographs of the area and confirmed the current use of the land and that there are no waterbodies associated with the site. A site inspection by the DOS third-party contractor confirmed these findings. As a result, the

potential impacts associated with expansion of the pump station site to include the Bakken Marketlink facilities would likely be similar to those described above for the proposed Project pump station and pipeline ROW in that area.

The Cushing Marketlink project would be located within the boundaries of the proposed Cushing tank farm of the Keystone XL Project and would include metering systems and two storage tanks (see Figure 3.1.1-2). As a result, the geologic impacts of construction and operation of the Cushing Marketlink Project would be the same as potential impacts associated with construction and operation of the proposed Cushing tank farm described in this section.

Currently there is insufficient information to complete an environmental review of the Marketlink projects. The permit applications for these projects would be reviewed and acted on by other agencies. Those agencies would conduct more detailed environmental review of the Marketlink projects. Potential geologic impacts would be evaluated during the environmental reviews for these projects and potential geologic impacts would be evaluated and avoided, minimized, or mitigated in accordance with applicable regulations.

3.1.6 References

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