3.1 Geology and Mineral Resources

Environmental issues associated with geology and mineral resources include topographic changes to the project area, geologic hazards, and the effects of removal of mineral resources from the project area.

The study area for direct and indirect impacts to geology and minerals encompasses the area within the proposed mine permit boundary. The geology and minerals cumulative effects study area encompasses the proposed permit boundary and other projects within 15 miles of the permit boundary. The 15-mile distance was selected to include other existing and known proposed lignite mines in the area.

3.1.1 Affected Environment

3.1.1.1 Topography and Physiography

The Rusk Permit Area is in the West Gulf Coastal Plain section of the Coastal Plain physiographic province (Fenneman 1928). The underlying geology of the area has created topography that is characterized by alternating long sandy ridges and swales. Elevations in the study area range from approximately 200 to 400 feet above mean sea level (amsl).

3.1.1.2 Regional Geology

Stratigraphy

The Rusk Permit Area is located on the western flank of the Sabine Uplift, a structural feature that dominates northeast Texas and northwest Louisiana (**Figure 3.1-1**). It is a large dome-like structure centered on De Soto Parish, Louisiana, and is approximately 65 miles east to west and 80 miles north to south (Granata 1963). This structure was emergent from pre-Cretaceous through at least the lower Tertiary time periods (Moody 1931). Recurrent movement on the Sabine Uplift influenced the deposition of sediments throughout the Cretaceous period and into the Tertiary period, including the Paleocene-Eocene-age Wilcox Group, the lignite bearing unit in the Rusk Permit Area. During the Tertiary period, subsidence of the Gulf of Mexico Basin and an influx of continental sediment resulted in the deposition of a thick sequence of fluvial-deltaic sediments that began with deposition of the Wilcox Group (Fisher and McGowan 1967). The Wilcox Group was deposited on an erosion surface that marks the top of the Midway Group that is composed of calcareous clay with minor layers of limestone, silt, and clay (Sandeen 1987). The influx of fluvial-deltaic sediment occasionally was interrupted by pulses of transgression of the Gulf of Mexico resulting in deposition of thin marine strata.

Regionally in northeast Texas, the Wilcox Group sediments were deposited in the Mount Pleasant Fluvial System (Fisher and McGowan 1967). This fluvial (relating to rivers or streams) system was fed by major channels from the north and northwest. Where the major channel systems deposited their sediment loads into the Gulf of Mexico, deltaic environments were present. Depositional environments were highly variable and resulted in a complex of meandering and tributary channel sands, marsh-distributary channels, delta front, and pro-delta deposits. Within this complex were marsh and swamp deposits located between the major channel systems (Kaiser et al. 1980). It is believed that lignite was derived from the buildup of peat deposits in the marsh-swamp areas.

The Wilcox Group in the Sabine Uplift area is subdivided into upper and lower units (**Figure 3.1-2**). The Wilcox Group ranges in thickness from approximately 600 to 1,550 feet and consists of thin to massive beds of sand, clay, and lignite (Sandeen 1987). The beds within the Wilcox Group are discontinuous and are difficult to correlate over short distances. However, in Rusk and Panola counties, the lignite seams in the Wilcox Group are the thickest and most consistent of the lignite in the Texas-portion of the Sabine Uplift (Kaiser et al. 1980).

Above the Wilcox Group is the Carrizo Formation (Carrizo Sand) of the Claiborne Group that was deposited in environments similar to the Wilcox Group. The thickness of the Carrizo Formation ranges up to 135 feet and consists of massive sandstone and clay lenses (Sandeen 1987).

Recent alluvial deposits are present in the flood plains of the major streams and rivers of the study area. Alluvium consists of fine-grained sand, silt, clay, and occasional gravel deposits and may be up to 35 feet thick (Sandeen 1987). Older (Pleistocene-age) terrace and alluvial deposits are present along the larger rivers and represent erosional remnants of previously more extensive deposits.

Structure

The geologic formations in the region generally dip to the west and southwest into the East Texas Salt Basin Embayment (Sandeen 1987). On the south side of the uplift, structural dip is to the south, and the formations drop off steeply toward the Gulf of Mexico (**Figure 3.1-1**) (Granata 1963). In addition to the Sabine Uplift, other regional structural features include the Mexia-Talco Fault Zone to the west and northwest of the Sabine Uplift and the Mount Enterprise Fault Zone that parallels the southern boundaries of Rusk and Panola counties. The fault zone is approximately 80 miles long and generally consists of north-dipping faults (Davis et al. 1989). There is evidence that the Mount Enterprise Fault Zone was active during deposition of the Wilcox Group because of stratigraphic changes that occur in the Wilcox from south to north across the fault zone (Murray and Thomas 1945).

3.1.1.3 Rusk Permit Area Geology

The geologic units that outcrop in the Rusk Permit Area consist of the Wilcox Group, Carrizo Formation, and Quaternary-age terrace and fluvial deposits (**Figure 3.1-3**).

The Wilcox Group contains the lignite seams that are proposed for surface mining in the study area. The Wilcox Group in the study area consists of sediments from point bars, channels, distributary channels, levees, crevasse splays, and overbank and lignite deposits (Pastor, Behling, and Wheeler, LLC 2009). These deposits consist of medium- to fine-grained sands, clays, carbonaceous clay, and lignite seams. Lignite deposits are thought to have been formed from plant material that accumulated over long periods of time in the relatively quiet, low energy, interchannel areas separating the channel facies of the fluvial systems. See Section 3.1.1.4 for a description of the lignite seams found in the area.

The Carrizo Formation above the uppermost mineable lignite seam is found in two intervals in the study area and consists of a lower unit composed of very fine- to medium-grained quartz sand, and an upper thinner unit of interbedded sand, silt, and clay.

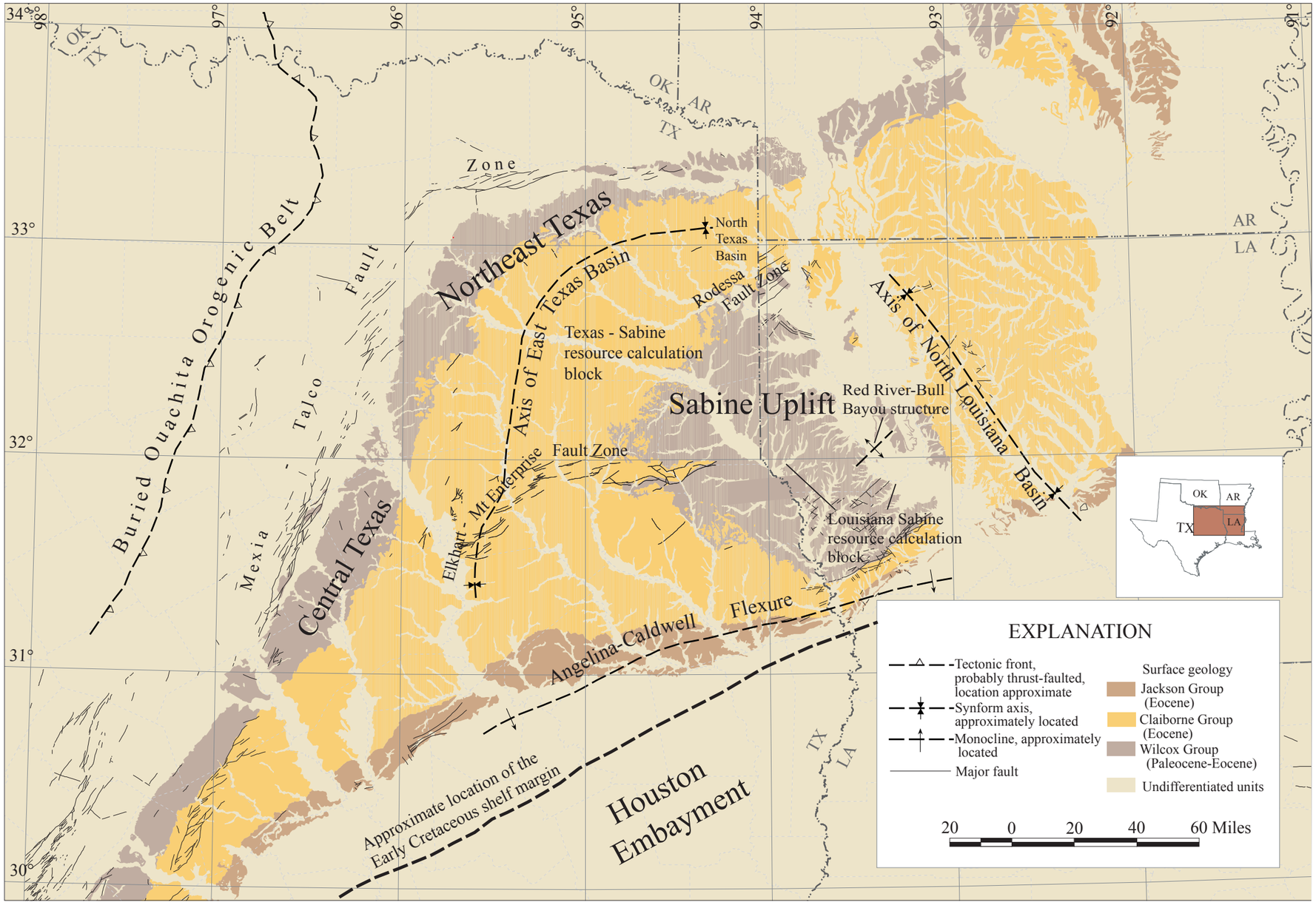
Alluvial and older terrace deposits are present in the northern portions of the study area; they are associated with the Sabine River valley (Pastor, Behling, and Wheeler, LLC 2009).

Although the regional dip of sedimentary units in the study area is to the south, there is no coherent dip in the units in the study area because of differential compaction (Pastor, Behling, and Wheeler, LLC 2009).

3.1.1.4 Mineral Resources

Lignite

The measured near-surface (up to 200 feet) lignite resource in the Wilcox Group in the U.S. Geological Survey (USGS)-defined Sabine-Texas coal resource assessment unit is 1,532 million tons (Mercier and Pierce 2009). The USGS assessment unit generally coincides with the Texas portion of the Sabine Uplift area. The USGS resource estimates do not include lignite in permitted mine areas. Total lignite thickness in the Sabine-Texas assessment unit ranges from less than 5 feet to more than 40 feet.



Source: Warwick et al. 2005.

Rusk Permit Area EIS

Figure 3.1-1

Major Structural Features

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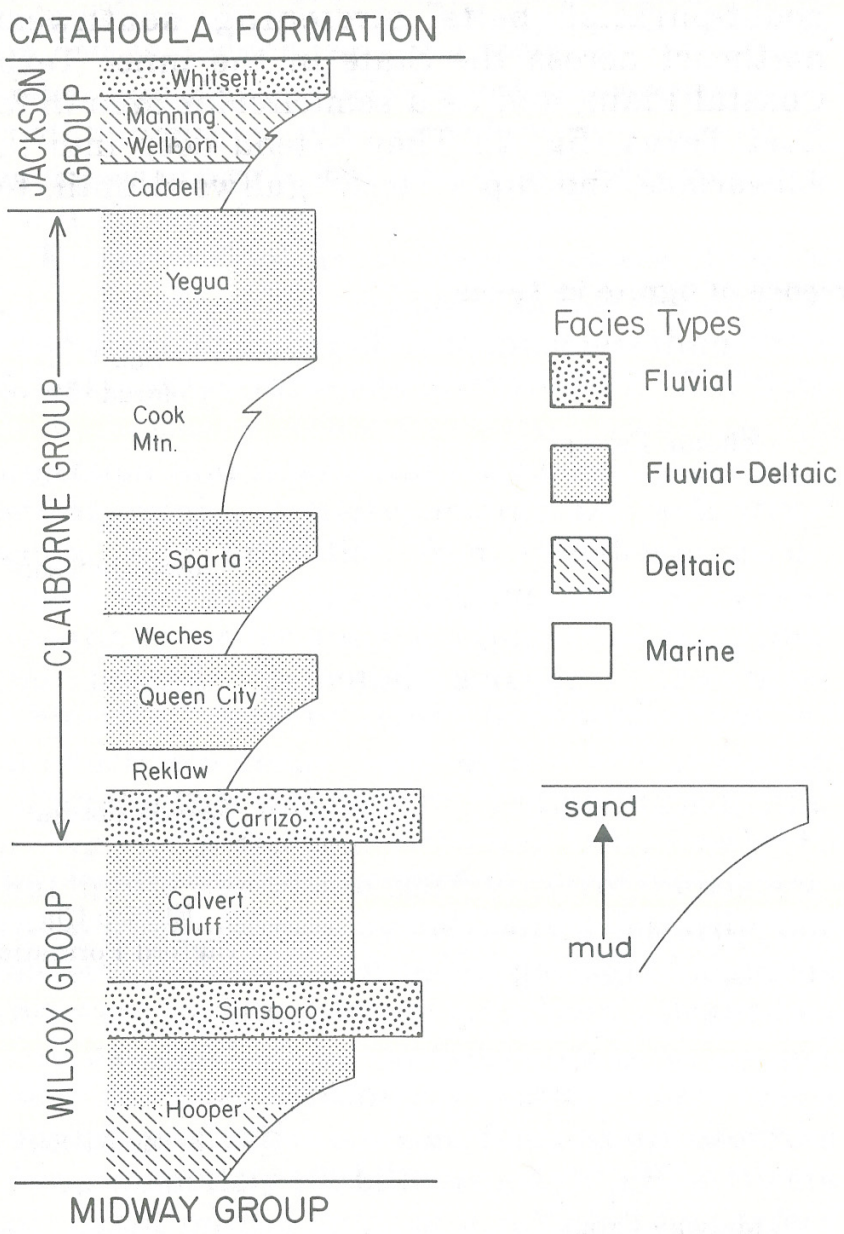

Rusk Permit Area EIS

Figure 3.1-2

General Stratigraphic Column for Rusk Permit Area

Source: Kaiser, Ayers, and LaBrie 1980.

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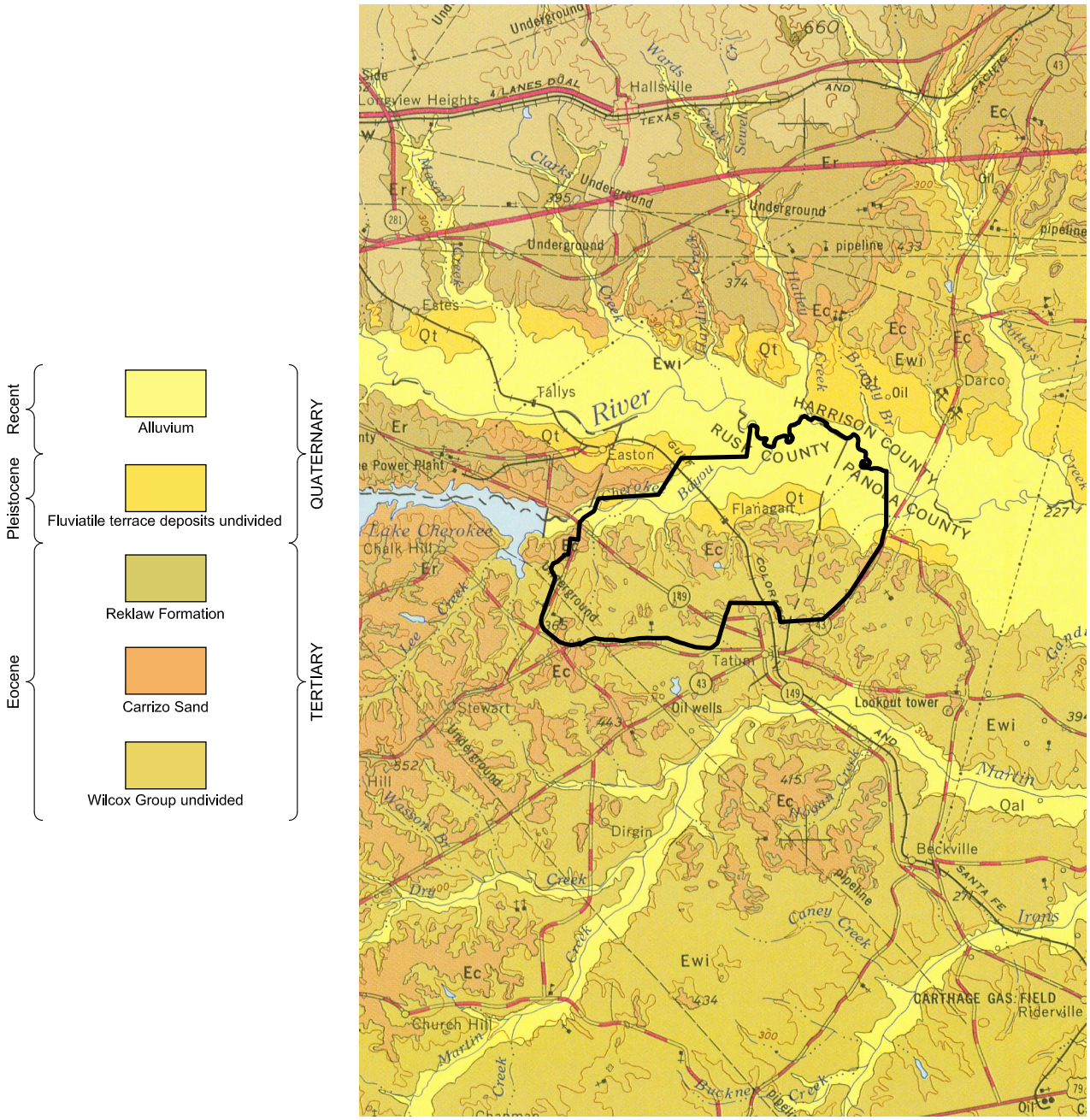

Legend

Approximate Rusk Permit Area Boundary

0 5 Miles

Source: Sabine 2009a.

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Rusk Permit Area EIS

Figure 3.1-3

Surface Geology of the Rusk Permit Area

Historically, lignite has been extensively mined in the region. Just northeast of the study area is the Marshall Permit Area (RCT 2007). At present, there are four permitted lignite mines in the vicinity of the proposed Rusk Permit Area: Martin Lake, Darco, South Hallsville No. 1, and Oak Hill mines (**Figure 2-12**) (RCT 2008). The Darco Mine currently is in final closure, and the last reported production was in 2001 (RCT 2009b). The remaining mines produced a total of 15.5 million tons of lignite in 2007.

In the study area, there are 11 identified lignite seams of which 4 are considered to be major mineable seams (**Figure 3.1-4**) (Pastor, Behling, and Wheeler, LLC 2009). The seams range in thickness from 0.3 to 12 feet. **Table 3.1-1** summarizes the thicknesses of overburden, interburden, and mineable lignite seams in the study area.

Table 3.1-1 Overburden, Interburden, and Lignite Thicknesses in the Study Area

Unit	Thickness (feet)
Overburden	20 to 80
L GRN Lignite	1 to 7
Interburden	60 to 80
L TN Lignite	0.4 to 5
Interburden	15 to 30
L BRN Lignite	0.3 to 7
Interburden	15 to 40
L RED Lignite	0.3 to 12
Underburden	Not determined

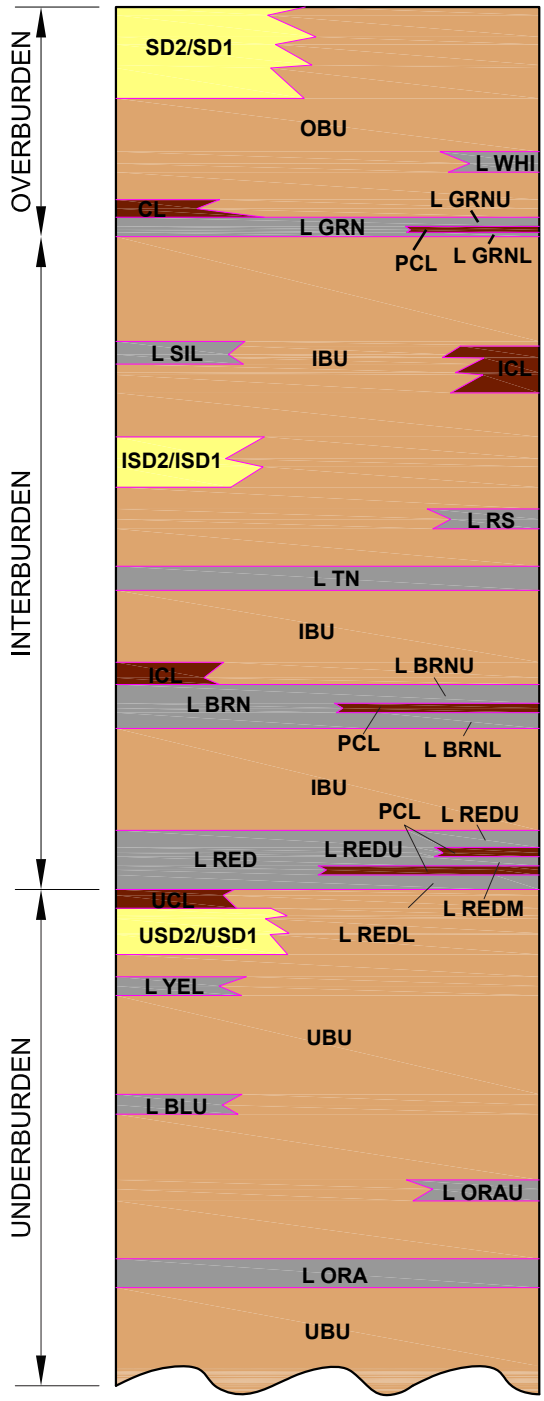
Source: Pastor, Behling, and Wheeler, LLC 2009.

The lignite in the study area generally is consistent with lignite samples analyzed by the USGS (Mercier and Pierce 2009). **Table 3.1-2** summarizes and compares lignite quality analyses from the study area to lignite sampled in the Sabine-Texas coal assessment unit. Most notable is that percent sulfur is lower for the Rusk Permit Area lignite sample than for the lignite from the assessment unit; the heating value expressed in British thermal units per pound (Btu/lb) also was somewhat lower for the lignite from the Rusk Permit Area.

Table 3.1-2 Coal Quality Comparison

Lignite Source	Moisture (percent)	Ash (percent)	Sulfur (percent)	Btu/lb
Study Area Seams	33.4	12.7	0.7	6,508
USGS Sabine-Texas Assessment Unit	33.0	10.0	1.1	6,801

Sources: Mercier and Pierce 2009; Pastor, Behling, and Wheeler, LLC 2009.



Legend

- Sand
- Interbedded Sand, Silt, and Clay
- Clay and Silty Clay
- Lignite

Source: Sabine 2009a.

Rusk Permit Area EIS

Figure 3.1-4

Lignite Seams in Rusk Permit Area

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Oil and Gas

Oil and natural gas are the other principal mineral resources in the study area. Oil was discovered in western Rusk County at the East Texas Field in 1930 (Sandeen 1987). The East Texas Field was the largest oil field discovered in the U.S. until the discovery of the Prudhoe Bay oil field in Alaska in 1967. The East Texas Field produced approximately 5 billion barrels of oil; however, it is near depletion.

The study area lies in parts of the Oak Hill and Carthage gas fields. The Oak Hill Field was discovered in 1958; and it is the thirtieth largest gas field in term of reserves in the U.S. and produced 99 billion cubic feet of gas in 2007 (Energy Information Administration 2009). Most of the study area is within the Oak Hill producing area. Eastern portions of the study area abut or overlie portions of the Carthage gas field that was discovered in 1936. Ranked as the twelfth largest in reserves in the U.S., it produced 231.7 billion cubic feet of gas in 2007. Both fields have produced from multiple pay zones; however, the primary producing zones are Jurassic-aged Cotton Valley sandstones (Drake and Pendleton 1984; Farnham 1984). There are records of 400 natural gas and oil wells within the study area (HDR 2009f). The wells generally are widespread across the study area (**Figure 3.1-5**) (RCT 2009a). Also, there are approximately 350 miles of oil and gas pipelines within the study area (HDR 2009f).

At present, the Oak Hill and Carthage fields are in the early development phase of gas production from the Haynesville Shale. The Jurassic-age Haynesville Shale is stratigraphically located below the Cotton Valley sandstones. The Haynesville Shale has become an economically viable gas drilling target because of advances in horizontal drilling and hydro-fracturing technology. In northeast Texas and northwest Louisiana, the estimated technically recoverable resource in the Haynesville is 251 trillion cubic feet of gas. A technically recoverable resource is “the total amount of resource, discovered and undiscovered, that is thought to be recoverable with available technology, regardless of economics” (U.S. Department of Energy 2009). The potential gas resource in the Haynesville Shale that underlies the study area is not known at this time.

Another potential gas resource in the region is the methane gas from the lignite seams (USGS 2007). A recent USGS resource assessment estimated a potential mean of 3.8 trillion cubic feet of gas in the Gulf Coast region. The extent of methane gas in the study area is unknown.

Other Minerals

Sand and gravel is mined in Rusk County; however, it is not a major resource (USGS 2009a). No active sand and gravel operations are present in the study area (National Atlas 2008).

3.1.1.5 Geological Hazards

Seismicity

Northeast Texas is not a seismically active area (USGS 2009b). A search of the USGS earthquake database found two earthquakes events within 60 miles of the study area from 1973 to the present (National Earthquake Information Center 2009). Historically, strong earthquakes have been felt in the area. In 1891, there was a strong earthquake in the vicinity of Rusk, Texas, approximately 60 miles southwest of the study area. Reports indicated that the intensity of the earthquake may have been equivalent to a 5.0 to 5.9 magnitude earthquake (USGS 2009c). This earthquake is thought to have originated from the Mount Enterprise Fault Zone (Davis et al. 1989). There is some evidence of historical movement on the fault zone, which would indicate that it is active (Ferguson 1984). The cause of the movement is not certain; however, it may be related to movement of the Louann Salt that comprises the “basement” of the East Texas Basin. No faults were identified in the study area.

Seismic hazard mapping by the USGS indicates that a strong earthquake in the project vicinity is not likely to produce damaging ground motion. Ground motion in the event of a maximum credible earthquake in the project vicinity is expected to be less than 10 percent of the acceleration of gravity with a 2 percent probability of exceedence in 50 years (Petersen et al. 2008).

Landslides and Subsidence

There are no known potential landslide or subsidence hazards in the study area (National Atlas 2008).

3.1.2 Environmental Consequences

3.1.2.1 Proposed Action

Topography

The topography of the mine areas, which would encompass approximately 10,359 acres of disturbance, would be permanently altered during mining as a result of mine development. This effect would be minimized to the extent possible through implementation of the proposed reclamation plan (see Section 2.5.3, Closure and Reclamation) that is designed to restore mine-related disturbance areas to approximate original topography.

Geology

During operations in the Rusk Permit Area, overburden, interburden, and lignite would be removed from each mine pit, with the overburden and interburden selectively handled and placed as backfill in the previous pit. As a result, the original characteristics of the strata in the mine areas would be permanently affected.

Geologic Hazards

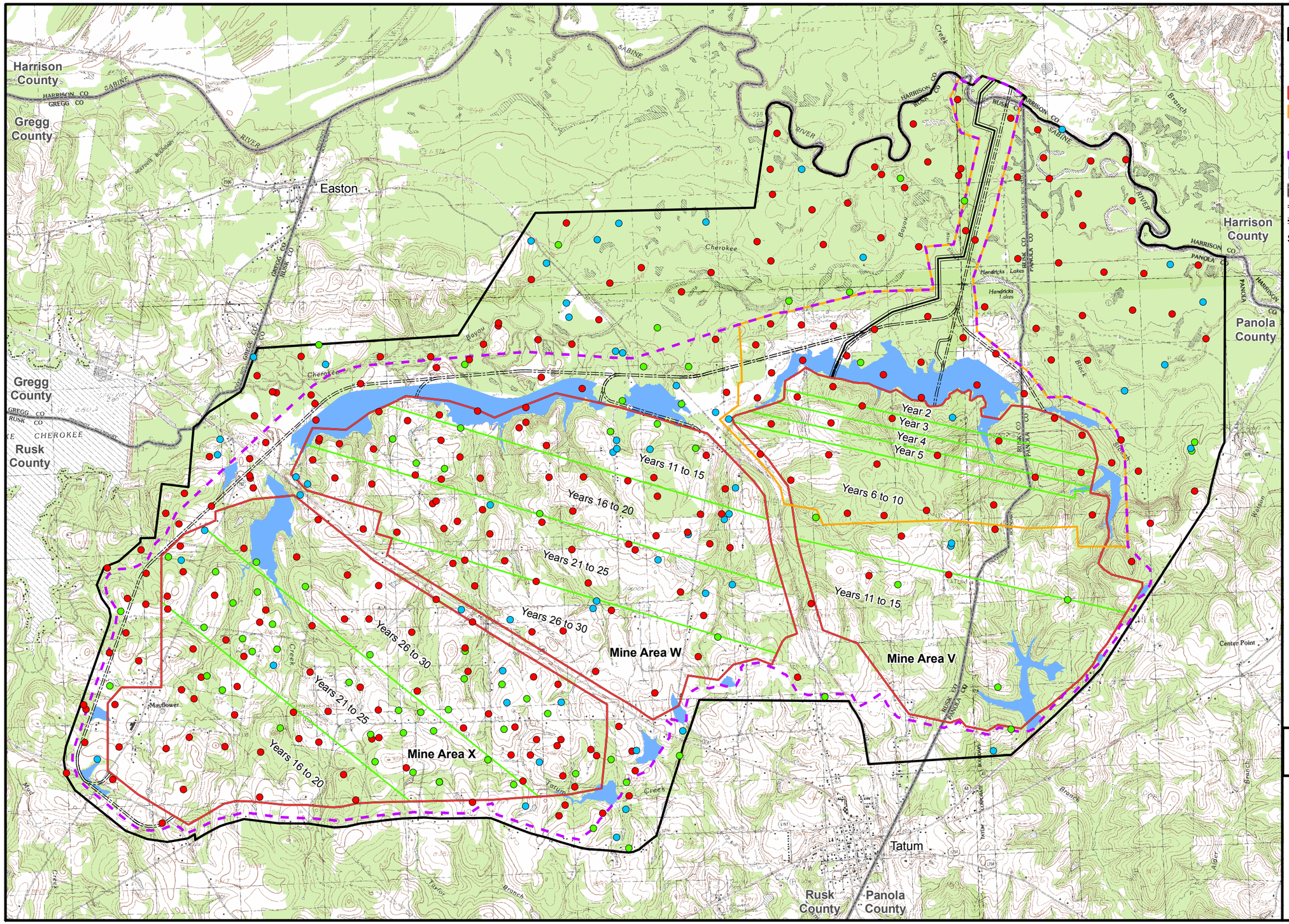
Geologic hazards due to natural conditions are not expected to affect the proposed mining operation. Mining-induced hazards are not anticipated, since properly engineered mine highwalls are expected to be stable. Dewatering is expected to cause negligible (less than 1 inch) of subsidence given the anticipated area of 5-foot groundwater drawdown and the storage coefficient of the aquifer (see **Table 3.2-2** and Section 3.2.3.2, Environmental Consequences, Groundwater).

Mineral Resources

Under the Proposed Action, approximately 138.2 million tons of lignite would be removed from the proposed mine areas. Access to oil and gas resources in the Rusk Permit Area would be restricted during active mining. Currently, there are approximately 200 active oil and gas wells in the proposed life-of-mine disturbance area (see **Figure 3.1-5**). As discussed in Section 2.5, Proposed Action, these wells would be sealed or plugged in accordance with applicable regulations in advance of mining. It is possible that wells could be re-drilled, or new wells drilled, to the Haynesville Shale following the completion of mining. There is no information readily available on the value of oil and gas resources that may be affected by the Proposed Action.

The Oak Hill and Carthage gas fields have been in production for many decades, and many wells in the proposed disturbance area have been abandoned (**Figure 3.1-5**). While there are still a number of active producing wells in the Cotton Valley zone, it is not certain how many wells may be at or near their productive limits. Proposed lignite mining may have an adverse impact on natural gas production from that interval depending on the status of the production life of the individual wells.

The study area is within the emerging Haynesville shale gas play centered on northwest Louisiana and East Texas. The estimated ultimate recovery per Haynesville well ranges from less than 2.0 to over 7.5 billion cubic feet (BCF) of natural gas per well (Berman and Pittnger 2009). Assuming an average estimated ultimate recovery of 4.5 BCF per well, the mine disturbance area could contain a potential resource of 72 BCF gas (assuming a 640-acre well spacing over 10,359 mining-disturbed acres). The estimated ultimate recovery would be dependent on a number of factors, but would be heavily reliant on price. Regardless of the potential size of the resource, coal mining would not result in a permanent loss of the total resource, because the coal would be mined over a long period of time enabling gas to be extracted in areas that would not be affected by mining in the near-term. However, mining has the



Rusk Permit Area EIS

Figure 3.1-5

Oil and Gas Wells

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potential to temporarily preclude access during mining and reclamation. The amount of the resource that temporarily would be unavailable is not quantifiable; however, it is expected to be considerably less than the total potential resource. Although the natural gas resource would not be lost, delayed access would represent a temporary loss of revenue to leaseholders, royalties, property taxes, and severance taxes. As with the amount of resource that would be temporarily unavailable, the temporary monetary loss is not quantifiable.

No other mineral resources would be affected by the proposed project. Limited studies by the USGS indicate that shallow (less than 150 feet deep) lignite in the Wilcox Group does not represent a commercial resource for coal bed natural gas because of low gas content (Warwich et al. 2000). Therefore, the proposed lignite mining is not expected to have an impact on the coal bed natural gas resource.

3.1.2.2 No Action

Under the No Action Alternative, the proposed Rusk Permit Area would not be developed, and the associated effects to topography, geology, and mineral resources would not occur. Currently authorized operations at the South Marshall Permit Area of the South Hallsville No. 1 Mine and existing mine-related effects to topography, geology, and mineral resources would continue through final reclamation in approximately 2035.

3.1.3 Cumulative Impacts

The past and present actions and RFFAs are identified in Section 2.7 and are shown in **Figure 2-13**. The major past and present actions in the geology and mineral resources cumulative effects study area include four existing lignite mines (inclusive of the existing South Hallsville No. 1 Mine) and two existing power plants and their associated cooling water reservoirs. One RFFA (the proposed Marshall Lignite Mine) also occurs in the geology and minerals cumulative effects study area. These operations have resulted, or would result, in approximately 78,316 total acres of disturbance. Of this total, the approximately 67,697 acres of lignite mining-related disturbance have been, or would be, incrementally reclaimed over the life of these operations. The remaining 10,619 acres of disturbance represent long-term to permanent disturbance areas. The proposed Rusk Permit Area incrementally would increase the cumulative disturbance by approximately 14,392 acres, all of which would be incrementally reclaimed over the life of the mine. As a result, the topography on up to 92,708 acres in the cumulative effects study area permanently would be altered. However, it is assumed this effect would be minimized to the extent possible in areas of mine-related disturbance (approximately 82,089 acres) through permit requirements to restore mine-related disturbance areas to approximate original topography.

Mining of the Rusk Permit Area would have a negligible effect on total Texas lignite production since the mine essentially would replace production from the South Marshall Permit Area of the South Hallsville No. 1 Mine. Currently, the South Hallsville No. 1 Mine produces approximately 4 million tpy. Although the proposed production schedule for the Rusk Permit Area indicates a nominal production of greater than 5 million tpy in years 16 to 30, if current trends are projected over the next few decades, declines in total Texas lignite production would not be offset. Texas lignite production has declined overall from a peak of slightly more than 53 million tpy in 1999 to approximately 39 million tons in 2008 (RCT 2010a). Overall, lignite mining in the cumulative effects study area has resulted, or would result, in the permanent removal of an estimated 614.3 million tons of lignite.

It would be difficult to quantify the cumulative impact on the remaining Cotton Valley Sandstone gas resource and other previously extracted oil and gas resources in the cumulative effects area. However, since these older plays would be nearing depletion, no adverse cumulative impact is anticipated. However, the Haynesville shale play is still emerging. Using the estimated ultimate recovery assumption of 4.5 BCF per Haynesville well and a 640-acre well spacing, the natural gas resource that potentially could be affected by RFFAs would be approximately 16 BCF, a small fraction of the potentially technically recoverable resource of 251 trillion cubic feet in northeast Texas and northwest Louisiana. However,

mining in the cumulative effects study area would take place over a period of years and would not result in permanent loss of the gas resource; rather, it would have the potential to delay access to the resource.

3.1.4 Monitoring and Mitigation Measures

No monitoring or mitigation is being considered for geology or mineral resources. Reclamation procedures, including regrading spoil piles to approximate original contour, would be completed in compliance with RCT requirements.

Since the Haynesville gas wells are being developed using horizontal drilling, it may be possible to overcome access issues during mining in the proposed Rusk Permit Area. The horizontal laterals of Haynesville wells can be up to 4,000 to 4,500 feet in length (Durham 2009). In addition, the Hayneville reservoirs can be more than 10,000 feet below the surface, too deep to interfere with coal mining. The RCT rules require that coal mine applicants identify all active and abandoned oil and gas wells within a proposed mine area; however, there are no requirements regarding compensation for well owners for loss of resource and revenue. Therefore, it is recommended that Sabine contact lease operators and oil and gas mineral owners concerning mine plans and schedules to work agreements of compensation or timing of oil and gas extraction to minimize potential conflicts.

3.1.5 Residual Adverse Effects

There would be no residual adverse effects to geology and mineral resources as a result of the proposed project. Access conflicts to oil and gas resources in the Rusk Permit Area would cease following the completion of mining.