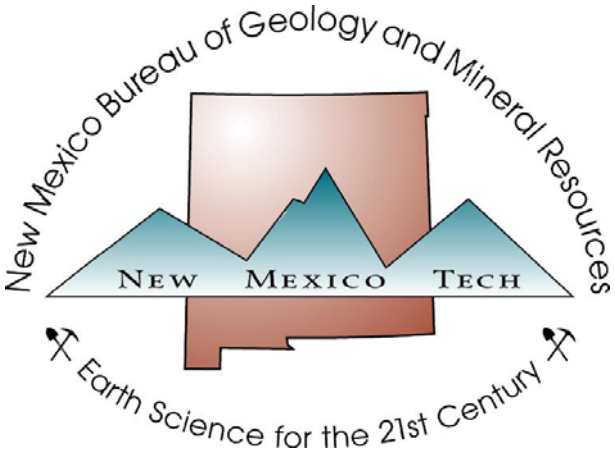

Coal Availability Study—Standing Rock Area, San Juan Basin Northwest New Mexico

BY

Gretchen K. Hoffman and Glen E. Jones

Study funded through US Geological Survey Cooperative Agreement No. 98HQAG2017**-** Availability of Coal Resources Menefee Formation, San Juan Basin, northwest New Mexico April 1, 1998-September 30, 1999

New Mexico Bureau of Geology and Mineral Resources
Division of New Mexico Institute of Mining and Technology
Socorro, NM 87801

Open-file Report 540

July, 2011

Introduction

Coal is an important part of New Mexico's economy and contributes substantially to the state's educational funds through royalties and taxes. New Mexico produced 28.24 million st of coal in 1998, ranking 13th in the nation. Of this total, 11.71 million st (> 41%) is produced from the Lee Ranch and McKinley mines, both extracting coal from the Menefee Formation. Two-thirds of the state's tonnage is delivered to three electrical generating stations in New Mexico. All but a small portion of the remaining production is shipped by rail to generating stations in Arizona. The Lee Ranch and McKinley mines are the only mines in New Mexico with the rail spurs to the main Burlington Northern-Santa Fe line, allowing them to ship coal to Arizona. Lee Ranch delivers coal to nearby Escalante Generating Station at Prewitt, NM. McKinley sends coal to Salt River Project's Coronado generating station and Tucson Electric's Springerville power plant near Springerville, AZ, and to Arizona Public Service Cholla plant, near St. Johns, AZ.*

With the above economic and geologic factors considered, four quadrangles on the southeast edge of the Standing Rock field were chosen for this study (Fig. 1). The four 7.5 minute quadrangles chosen for this study are the Seven Lakes, Kin Nahzin Ruins, Laguna Castillo, and Orphan Annie Rock. This 350-sq mi area along the Menefee outcrop has economic potential because of it proximity to the existing railroad spur and for the quality of the coals. The northern extent of the Lee Ranch coal mine is approximately 10 miles southeast of the study area and the South Hospah lease area (Texas Utilities-Chaco Energy) is within the study area. There is no previous coal production from this area.

*Update 2011: This study was completed in 1999 before McKinley mine closed and Ed Segundo mine, northwest of Lee Ranch opened. El Segundo lease was previously South Hospah mentioned in text and shown on Fig. 1

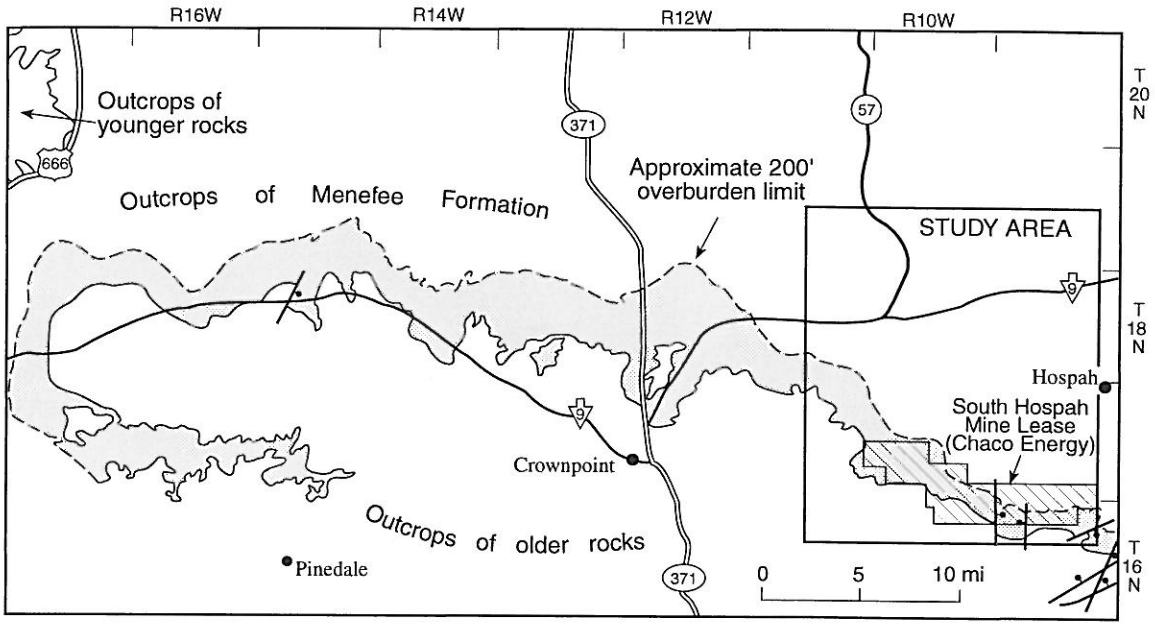

Figure 1. Map of Standing Rock field with Standing Rock study area.

Geologic Setting

Menefee exposures within the Standing Rock field trend, more or less parallel to the Late Cretaceous shoreline (N55ºW). The Standing Rock field is within the Chaco slope and therefore the units dip gently N–NW into the San Juan Basin (SJB). This area is dominated by gently north-dipping beds. Some high-angle faulting was delineated in the southernmost part of the study area during exploration drilling in the South Hospah mine lease as shown on Figure 1.

The southern edge of the Standing Rock field is the contact of the Point Lookout Sandstone and the Cleary Coal Member of the Menefee Formation. This field extends along this contact over portions of T.'s 16-19 N., and R.'s 9-17 W for a distance of approximately 70 miles (Fig. 1). Standing Rock's eastern boundary with the San Mateo field is arbitrarily set at the north-south boundary between R8W and R9W. The northern boundary is the northernmost outcrop of the Cleary Coal Member of the Menefee Formation. The Cleary Coal Member is defined as a coal-bearing sequence and the overlying Allison Member is barren of coal. The western boundary of the Standing Rock field is defined by the pinchout of the Point Lookout Sandstone. This is the southwestern extent of the Point Lookout Sandstone and beyond this northwest-southeast trending line, the Menefee Cleary Coal Member and the Crevasse Canyon Gibson Coal Member are undivided.

Coal Geology

The coals in the Standing Rock field are typically within a shale-dominated sequence, but several are overlain or underlain by siltstone or sandstone. These coals are within the Cleary Member of the Menefee Formation, near the base of this unit. One coal zone, the Green, is directly above or within a few feet of the Point Lookout Sandstone contact. Most of the coals are within 200 ft of the Point Lookout Sandstone (Fig. 2). Six coal zones are recognized in the Cleary coal-bearing

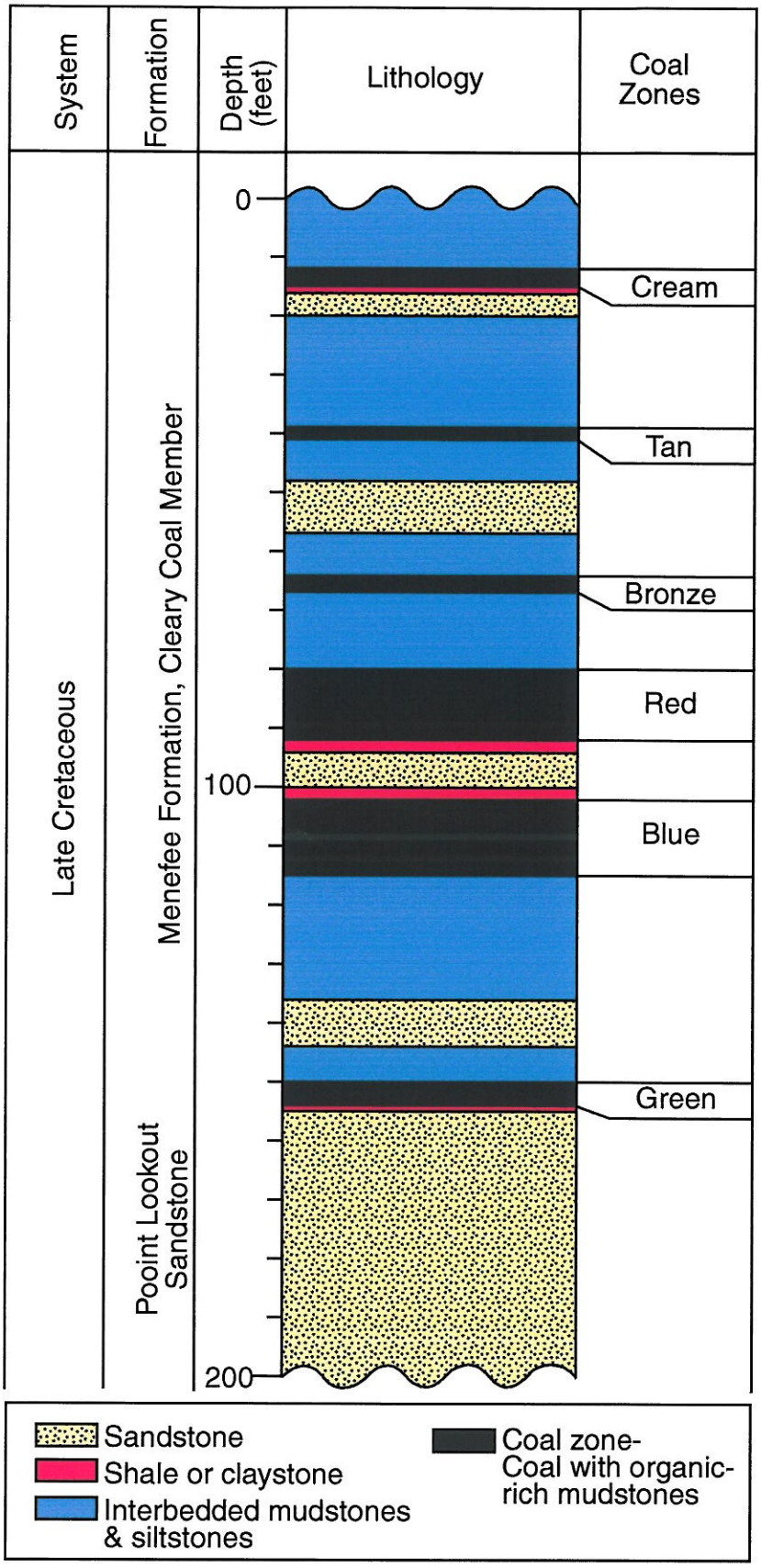

Figure 2. Generalized stratigraphic column of Menefee Formation, Cleary Member in Standing Rock study area.

sequence in the South Hospah mine area (Chaco Energy, 1981). The zones from the base of the Cleary Coal Member upward are the Green, Blue, Red, Tan, Bronze, and Creme zones. The author added a seventh zone, Gold, recognized in this study area.

Many of these coal beds and zones are thin and only the three lowermost zones have any continuity throughout the area. Only these three coal zones are used for resource calculations in this study. The three coal zones are very similar in average coal seam thickness, total coal within a zone, and zone thickness (Fig. 3). There is great variability of seam thickness within a zone over the entire study area. . Total coal isopachs for the Green, Blue and Red zones (Figs. 4, 5, 6) illustrate the variability of thickness in the two most consistent coal zones within the study area. Average zone thickness varies from over 5 ft to 9 ft thick, including interburden. Each zone averages one seam, but the Green zone can have a maximum of five seams, the Blue three seams, and the Red zone a maximum of four seams. Average total thickness of the Cleary Coal Member is 125 ft. There is great variability in this thickness because of the lenticularity of the coals and the coal zones. This lenticularity is illustrated in the cross sections located on Figure 7 along strike (Figs. 8, C-C'; 9, D-D') and downdip (Figs. 10, A-A'; 11, F-F'). Correlation of seams on these cross sections and for resource calculation is by zone rather than by coal bed. Any coal on the cross section does not necessarily represent the same bed on an adjacent section; rather the coals are correlated as being within the same zone.

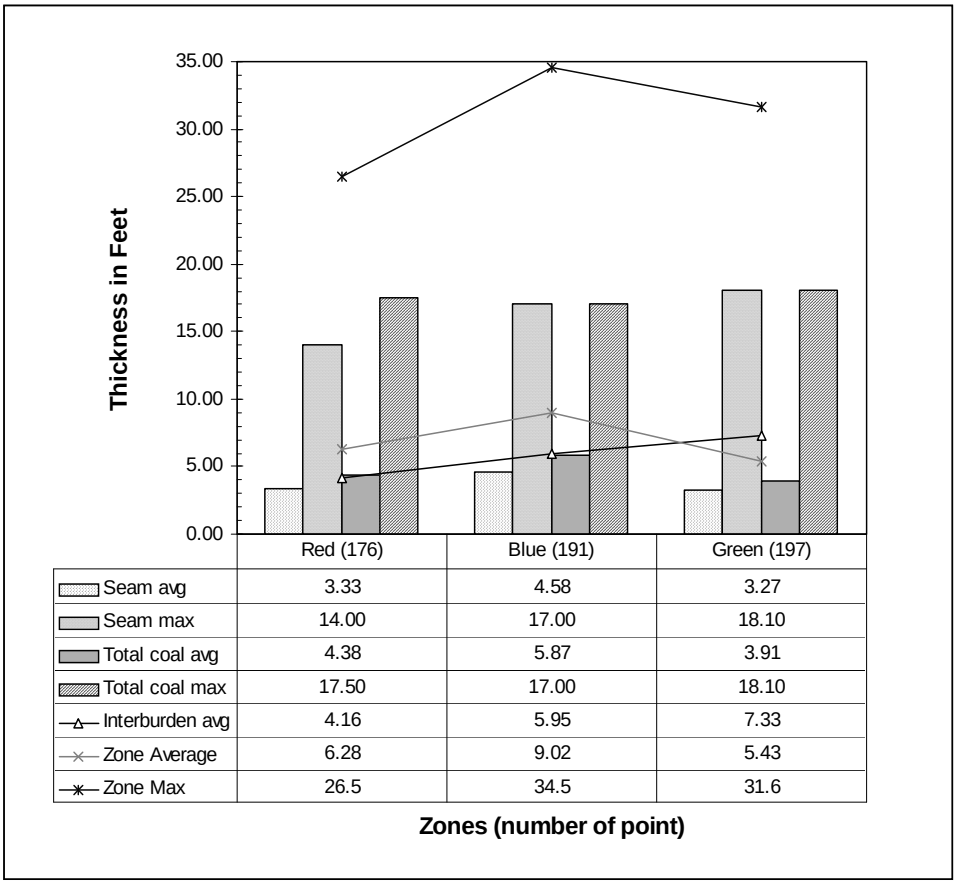

Figure 3. Coal zone thickness and interburden characteristics by zone. Numbers in parenthesis are number of data points.

Coal quality

The apparent rank of Cleary Coal Member coals in the Standing Rock field is subbituminous A (Hoffman, 1996a). Weighted–average analyses on an as–received basis follows:

Standing Rock

	Average	Std Dev.	No. of Samples (Hoffman, 1996a)	Average for Zones (This study)		
				Red (13)	Blue (37)	Green (14)
Moisture (%)	17.03	1.42	27	16.06	16.44	16.74
Ash (%)	13.32	3.35	27	11.37	13.30	13.09
Volatile matter (%)	33.83	1.41	27	34.86	34.55	34.69
Fixed carbon (%)	35.81	2.79	27	37.60	35.74	35.40
Sulfur (%)	1.06	0.38	27	0.79	1.23	1.27
Calorific value (Btu/lb)	9429	552	27	9822	9612	9755
Lbs. of Sulfur/MMBtu	1.09	0.41	30	1.09	1.57	1.31

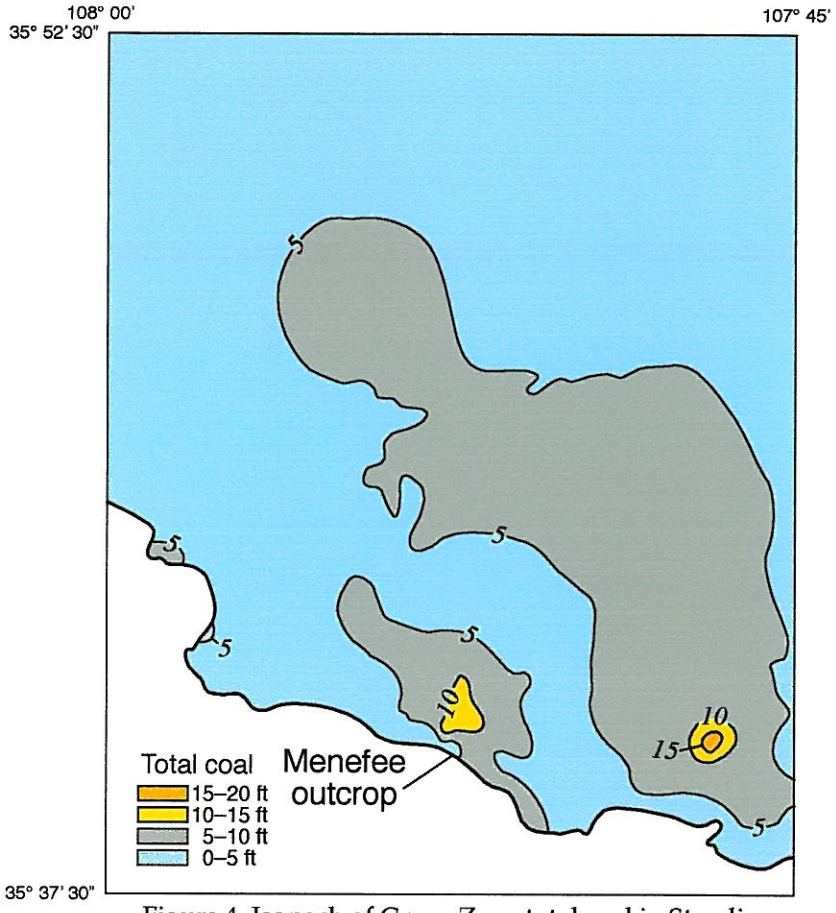

Figure 4. Isopach of Green Zone total coal in Standing Rock study area, northwest New Mexico. Scale 1:250,000. Menefee outcrop from Beaumont, 1998.

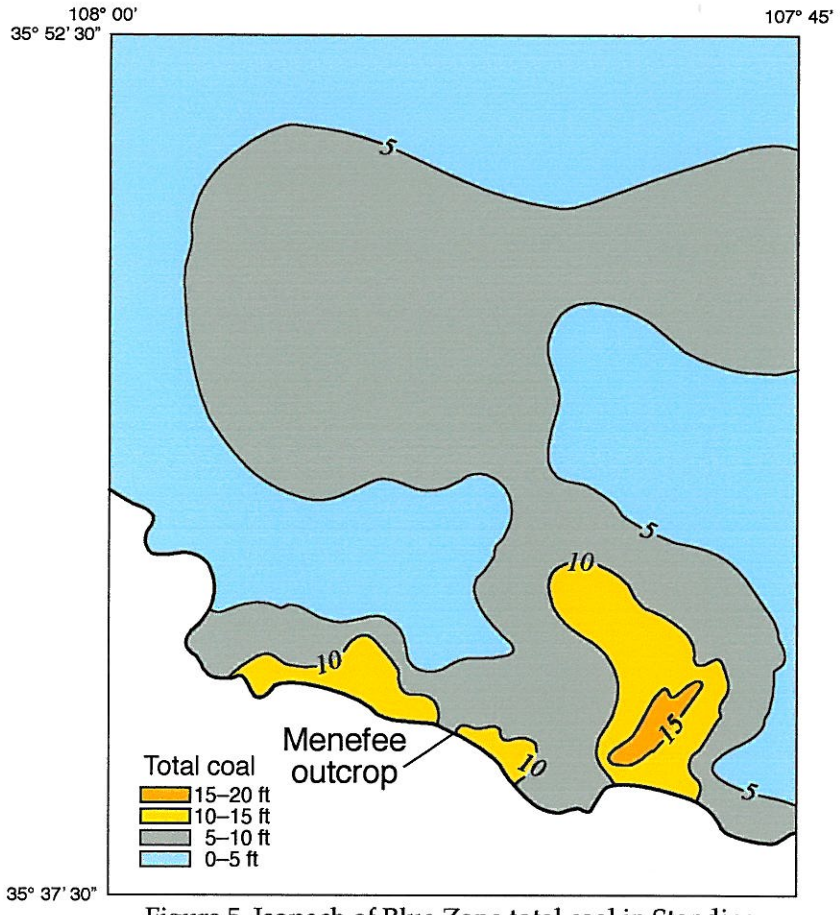

Figure 5. Isopach of Blue Zone total coal in Standing Rock study area, northwest New Mexico. Scale 1:250,000. Menefee outcrop from Beaumont, 1998.

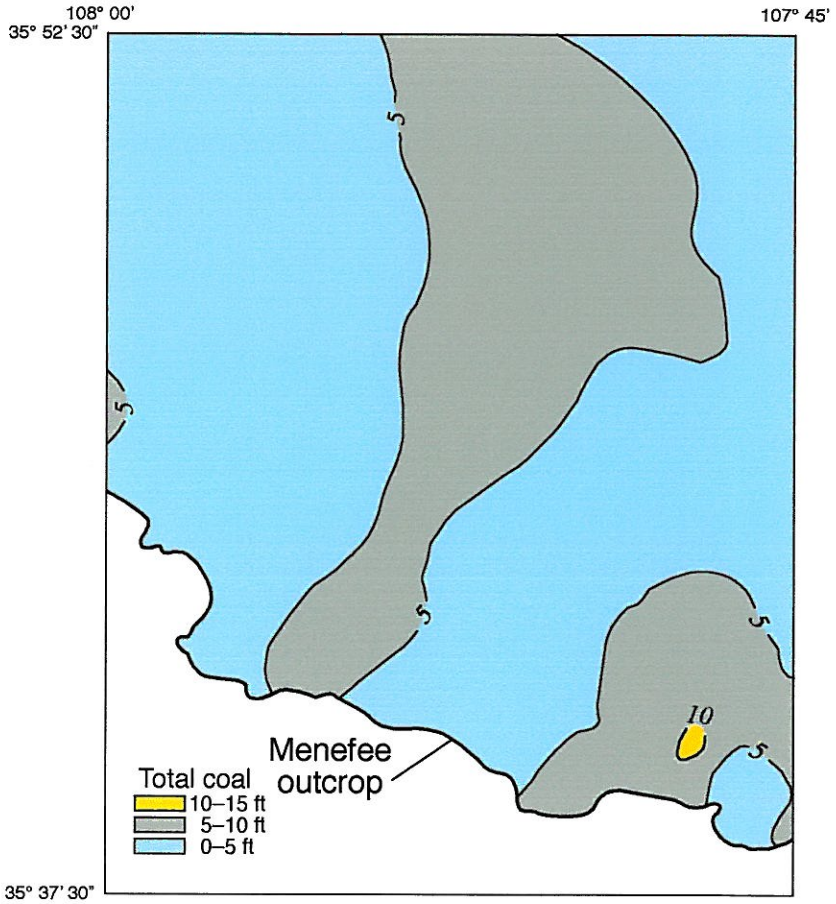

Figure 6. Isopach of Red Zone total coal in Standing Rock study area, northwest New Mexico. Scale 1:250,000. Menefee outcrop from Beaumont, 1998.

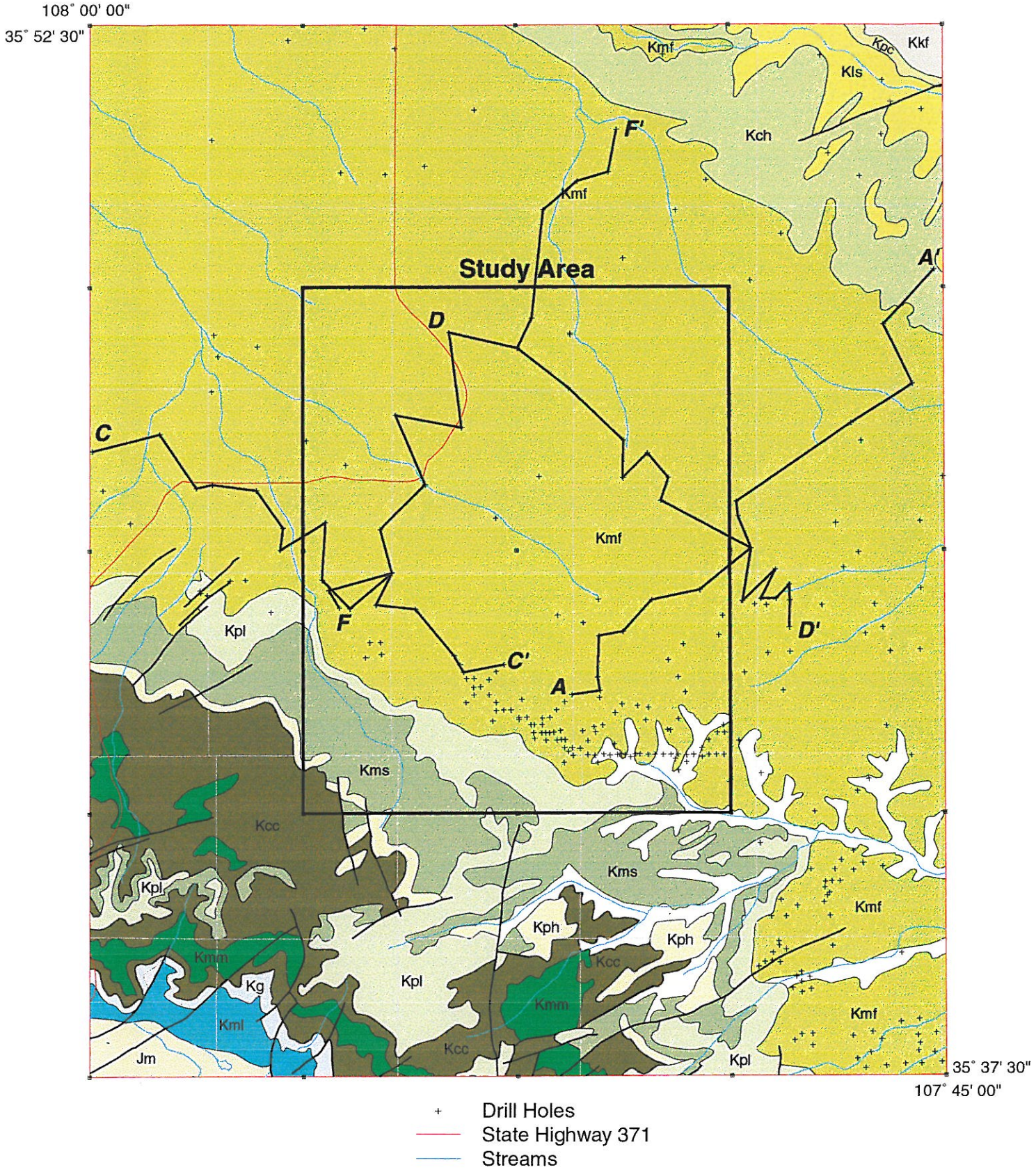

Figure 7. Geologic map of Standing Rock study area with cross section locations. Geology is from Anderson, Jones, and Green, 1997. Note Menefee contact with Point Lookout is different from that used in study for Arc Info files. Kch - Cliff House Sandstone, Kmf - Menefee Formation, Kpl - Point Lookout Sandstone.

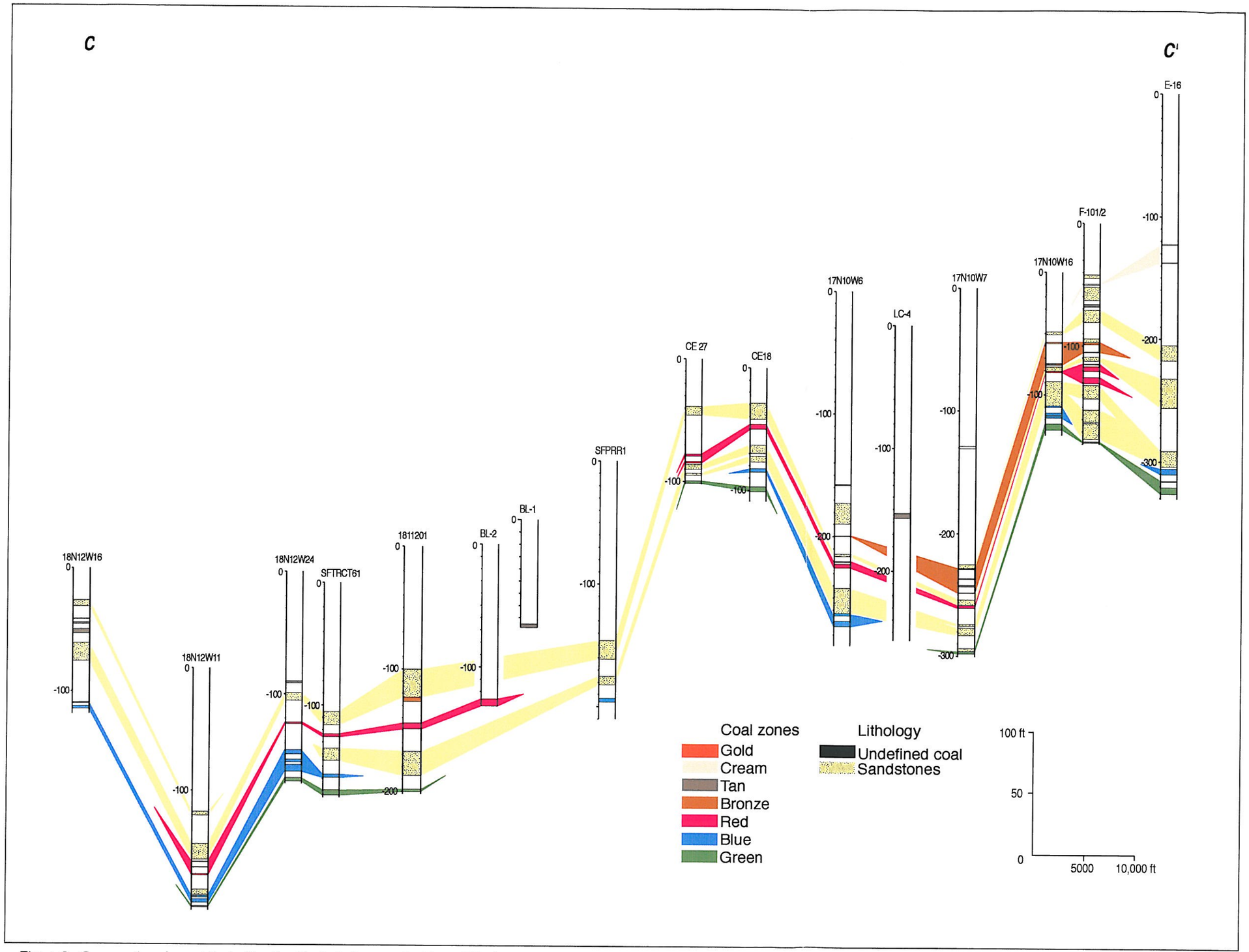

Figure 8. Cross section along strike in Standing Rock study area. See Figure 7 for location.

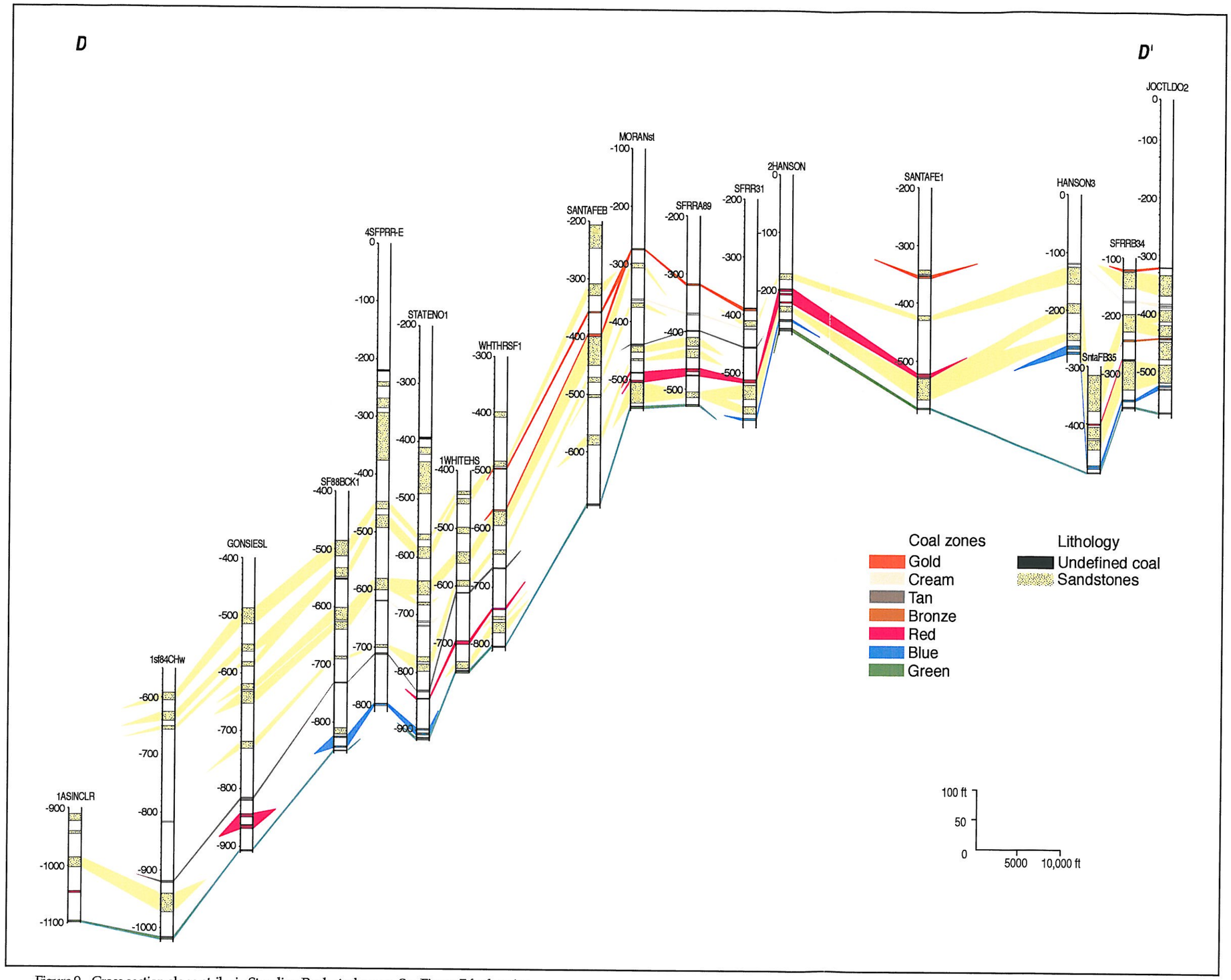

Figure 9. Cross section along strike in Standing Rock study area. See Figure 7 for location.

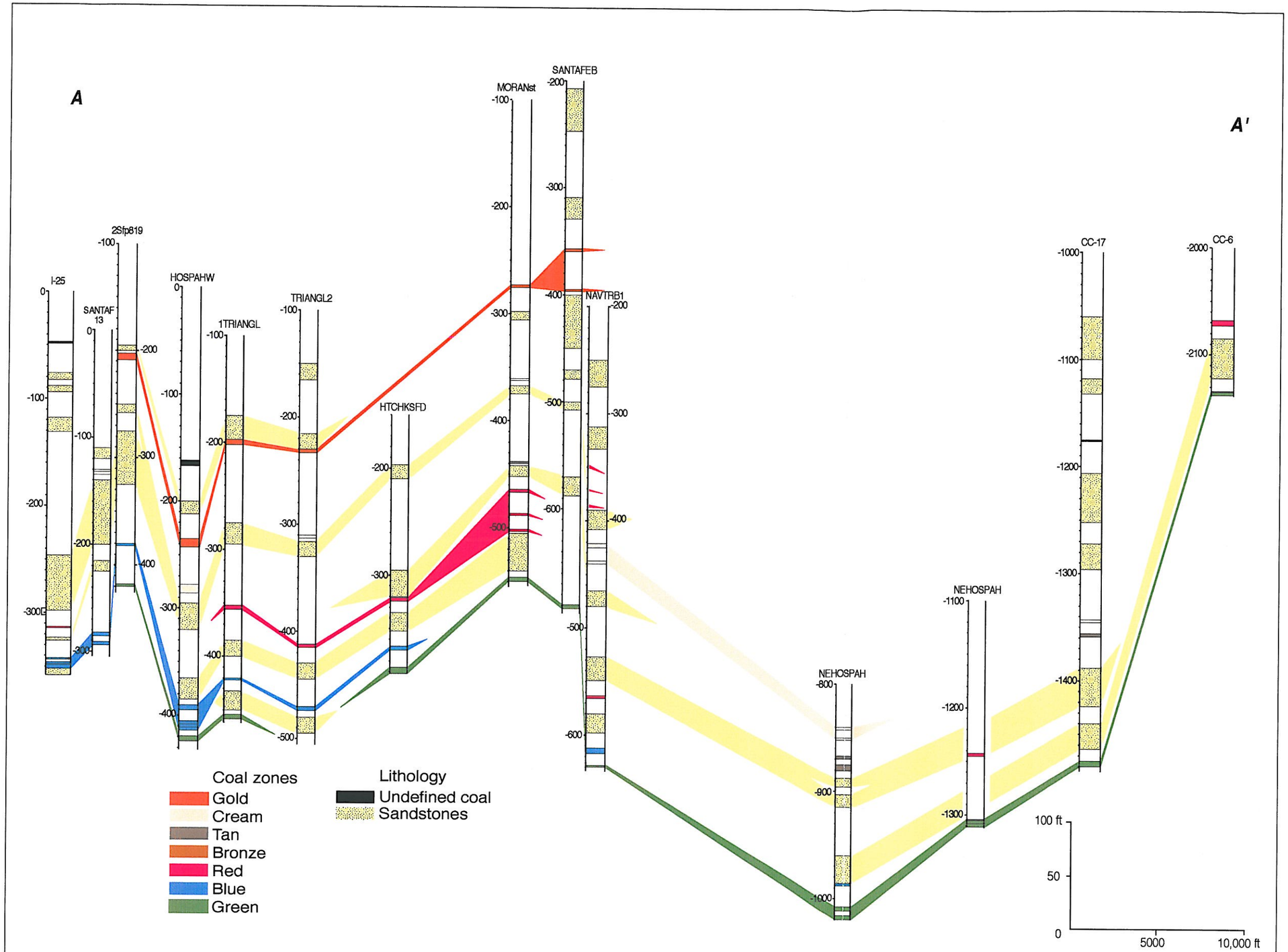

Figure 10. Cross section along dip in Standing Rock study area. See Figure 7 for location.

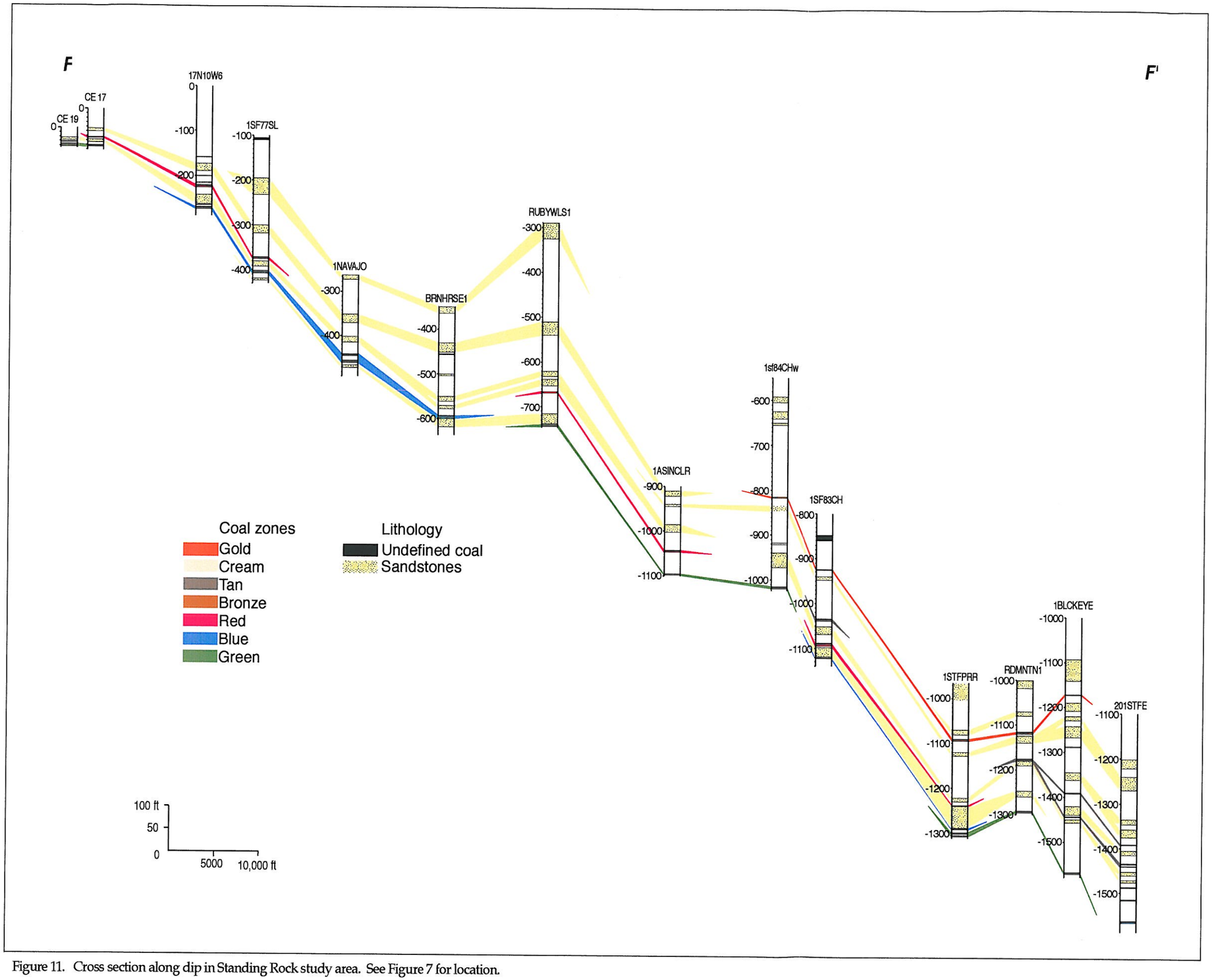

Figure 11. Cross section along dip in Standing Rock study area. See Figure 7 for location.

Weighted averages by zone are shown above and on Figure 12. The sulfur values of the Blue and Green zones are high for the SJB and greater than the weighted average for the entire Standing Rock field. These Menefee coals would not meet the New Source Performance Standards of the Clean Air Act of 1.2 lbs of SO_2 per million Btu (Energy Information Administration, 1993). Both the Green and Blue zones pyritic sulfur content is high, 0.38% of total sulfur for the Green and 0.61% of total sulfur for the Blue zone. Blending is necessary to lower the sulfur content and perhaps washing would help to remove some of the pyritic sulfur, lowering the total sulfur content. Lee Ranch mine blends their product in part because of the variability of the sulfur content.

The Standing Rock study area coals are medium-ash, nonagglomerating, subbituminous coals with weighted zone averages from 11,218 to 11,403 moist, mineral matter-free Btu/lb (MMFBtu/lb). These rank values are higher than Fruitland coals that are mined elsewhere in the SJB and the ash content of these coals is lower than the Fruitland Formation coals. An average of the few oxide analyses available reveal the major constituent of the ash is SiO_2 (52%), followed by AlO_2 (21%), Fe_2O_3 (9%), CaO (5%), and MgO (1.3%). The remaining oxides are individually less than 1%.

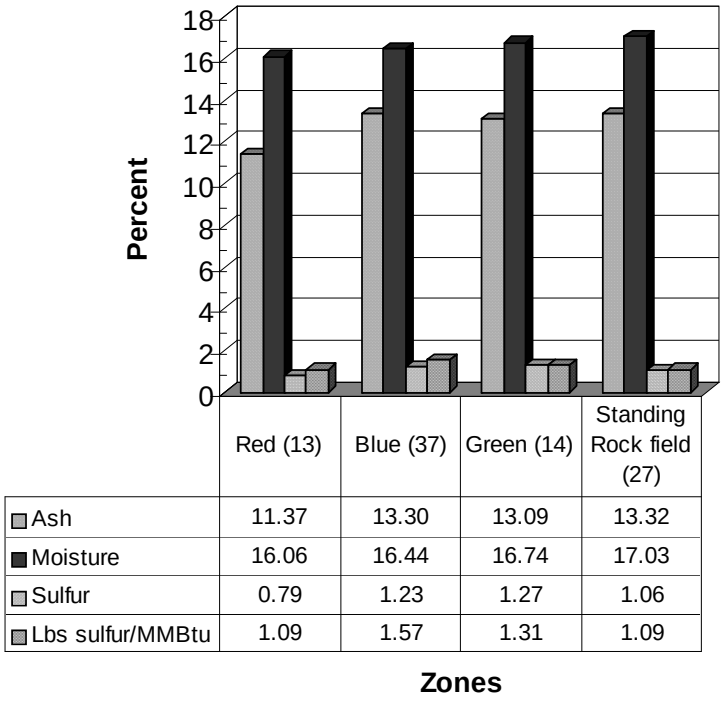

Figure 12. Weighted averages of quality analyses by zone. Numbers in parenthesis are number of data points.

Available data

The database for the Standing Rock study is a subset of the data collected and entered by the New Mexico Bureau of Mines (NMBMMR) into the National Coal Resource Data System (NCRDS). The NMBMMR has had cooperative grants with the U.S. Geological Survey (USGS) to enter data into NCRDS for the past 20 years. Exploration projects in the study area have resulted in a clustered data set (Fig. 7). Drill holes are concentrated in the surface-minable area and less data is available for the deep coal area except where oil and gas logs are available. Other sources of drill hole data are the South Hospah and Lee Ranch mine plans, Coal Resource Occurrence and Coal Development Potential maps (CROCDP), and NMBMMR drilling. After the project began, additional data were entered into the database, in particular oil and gas logs from NMBMMR subsurface library, to help fill in gaps.

A total of 140 data points were evaluated for the four-quadrangle study area (Seven Lakes, Kin Nahzin Ruins, Orphan Annie Rock, and Laguna Castillo). Additionally, 142 data points from the quadrangles surrounding this area were used to calculate resources.

Coal availability studies in New Mexico

Detailed methodology

Cleary Coal Member Menefee coals in the Standing Rock area are subbituminous; therefore, resource calculations are based on a minimum thickness of 2.5 ft and 1770 tons/acre ft. The following parameters, which conform to USGS Circular 891 (Wood et al., 1983), were used to calculate resources for each zone. Total coal (≥2.5 ft) within a zone instead of individual seams is the basis of resource calculations because of the lenticularity of the coals. Coals thinner than 2.5 ft and above or below coals meeting the thickness criteria and separated by a parting less than the thickness of the thinner coal are included in the calculation. The following are the resource criteria used in this study:

Thickness (ft):	**Depth (ft):**	**Reliability**
2.5–5	10:1 stripping ratio	Measured (1/4 mi)
5–10	0–250	Indicated (1/4–3/4 mi)
10–20	250–500	Inferred (3/4–3 mi)
>20	500–1000	
	>1000	

Reliability categories are limited to measured, indicated and inferred. No hypothetical reliability category was used in this study because of the lenticularity of these coal beds.

Line data for the Point Lookout-Menefee contact was digitized from Beaumont (1998). These line data form a boundary mask between areas of coal and no coal. Data files with elevations for tops of coal zones were gridded in Arc Info® and overlain with a grid from the 1:100,000 Chaco Mesa Digital Elevation Model (DEM). From this combined layer, the

overburden maps for each zone were generated. This overburden layer supplied the zero depth line, or crop line, for each zone. The resulting overburden maps for the Green, Blue, and Red zones are illustrated in Figures 13-15. The upper depth limits for the categories are highlighted on these maps.

From the original database created for the study, subset files were produced for each zone with latitude, longitude, total thickness, and point identification. These files included data from quadrangles surrounding the four-quadrangle study area. By using data from surrounding quadrangles, reliability categories that overlap into the study area were included in the resource calculations. The data files were used to produce coal thickness grids and polygon files for the reliability categories. The reliability polygons were gridded and each cell assigned a thickness from the thickness grid. By overlaying the overburden layer onto the reliability layers, the total area (calculated in m^2 and converted to acres) for each thickness, depth, and reliability category were determined for the four-quadrangle area. Volumes (acre-ft) were calculated using the thickness attribute of the cells, and finally multiplied by 1770 tons/acre-ft to result in original resource tonnage for each zone.

Land-use restrictions were digitized from the 1:100,000 Chaco Mesa topographic quadrangle. No mining has taken place in this area therefore; there was no mined out layer to subtract from the original resource. Technical restriction filters were applied to the remaining resource layers for each zone. Appropriate buffers, as discussed in the following section, were assigned to the digitized land-use restrictions. These restriction layers were consecutively overlain on the combined overburden, reliability, and thickness layers with the mined-out areas and technical restrictions to calculate the resource tonnage removed by each restriction.

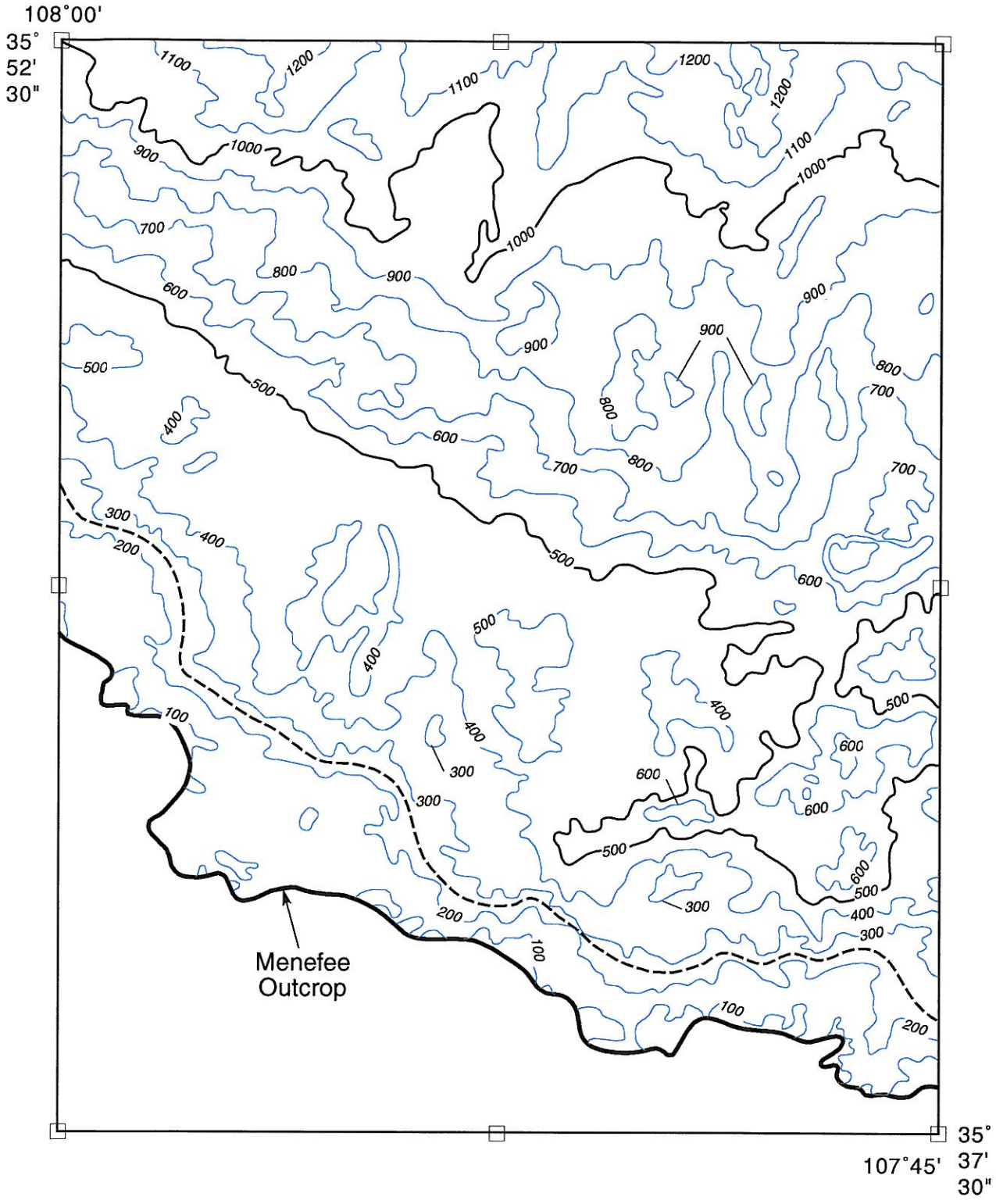

Figure 13. Overburden on top of Green zone, Standing, Rock Study area, northwest New Mexico. Menefee outcrop from Beaumont, 1998. Contour Interval 100 ft. Scale = 1:150,000.

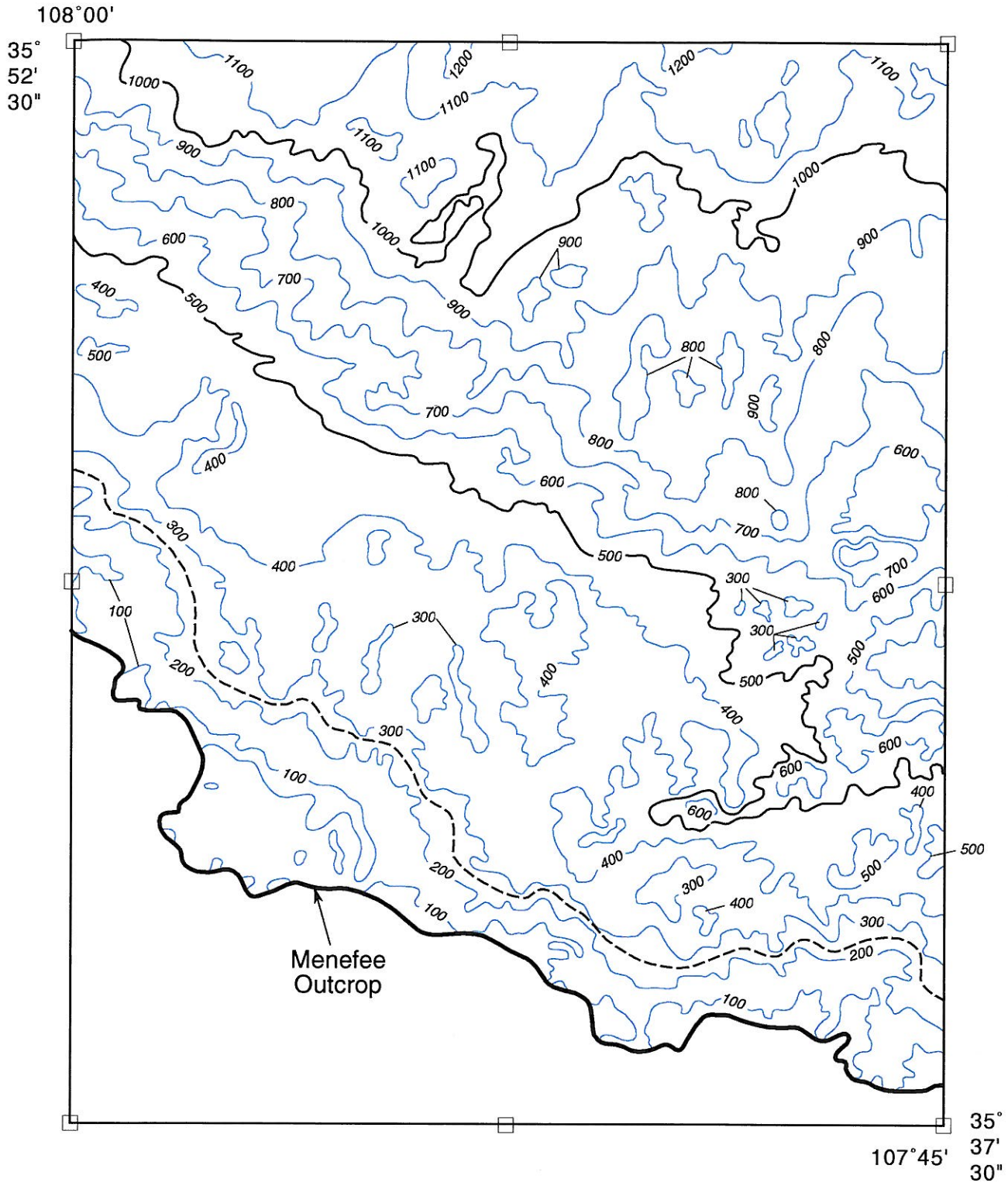

Figure 14. Overburden on top of Blue zone, Standing, Rock Study area, northwest New Mexico. Menefee outcrop from Beaumont, 1998. Contour Interval 100 ft. Scale = 1:150,000.

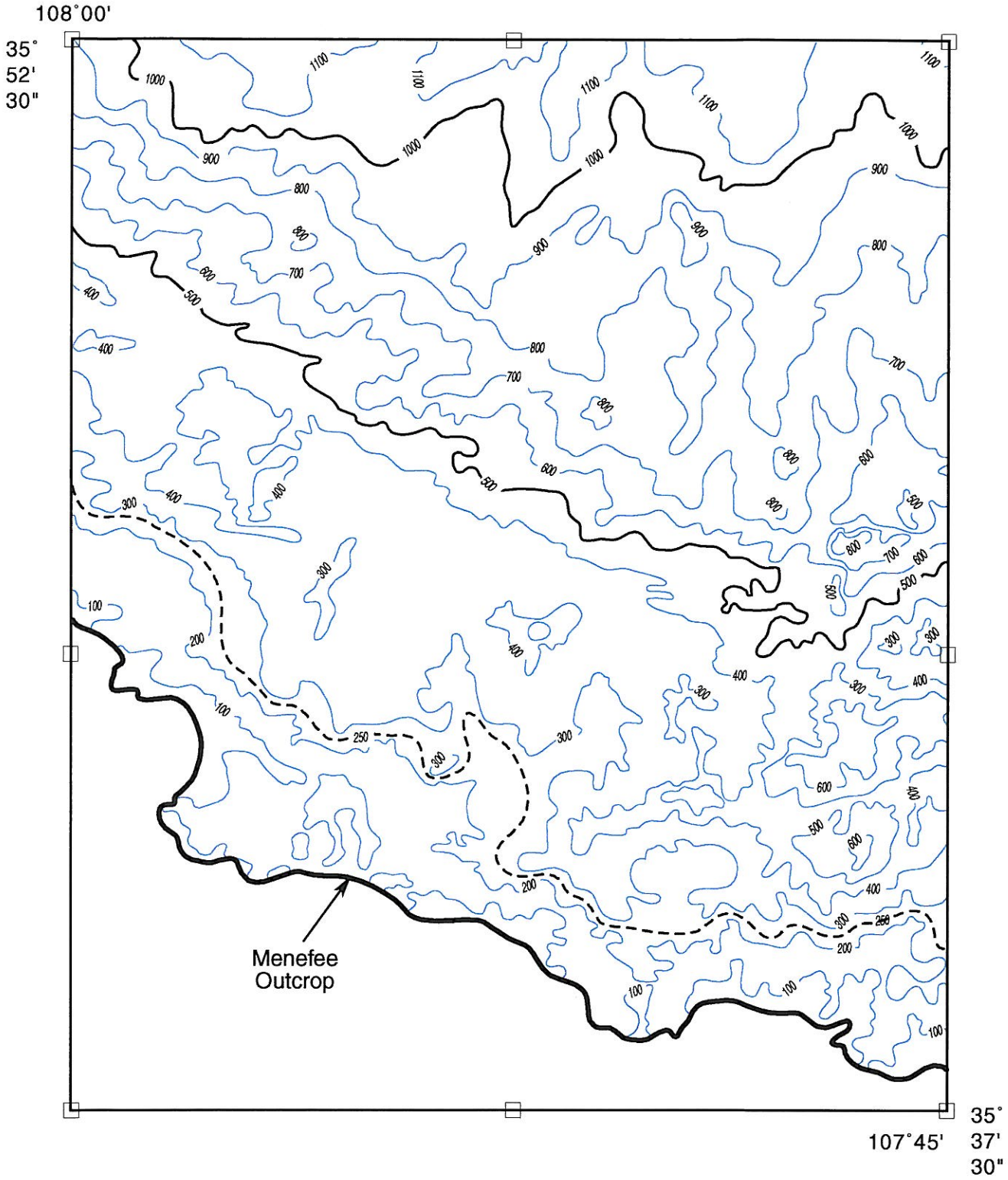

Figure 15. Overburden of Red zone, Standing, Rock Study area, northwest New Mexico. Menefee outcrop from Beaumont, 1998. Contour Interval 100 ft. Scale = 1:150,000.

Overview of restrictions

The following is a list of restrictions that were considered for this area. The buffers applied to these restrictions adhere to the New Mexico Coal Surface Mining Regulations 19 NMAC 8.2, which follow the Federal regulations:

Restrictions	**Buffer**
County roads	100 ft on either side
NM State Highway 57 and Tribal Highway 9	100 ft on either side
Pipelines, powerlines	50 ft on either side
Buildings, public or private	300 ft
Chaco National Monument outlier (1/4 section)	(entire area)
Ponds	100 ft
Railroad spur	100 ft on either side

Figure 16 illustrates these restrictions along with the Menefee outcrop.

Technological restrictions

Technical parameters that influence the resources of this study are:

***Coal too close to the surface*.** Coal with less than 20 ft of overburden is subtracted from the remaining resource estimate. Coal with less than 20 ft of overburden is removed because SJB coal within this interval is generally weathered or sometimes burned and can not be used for energy production. Most operating mines in the SJB use the greater-than-20-ft depth guideline for calculating mine reserves

***Coal too thin at depth*.** Coal beds 2.5 ft to 5 ft thick are not considered minable at depths greater than 250 ft. The original resources are calculated for this depth category but these results are removed under the technical restrictions.

Land-use restrictions

Restrictions to mining in the project area are few, but some are significant. A secondary state road (NM State Highway 57, Tribal Highway 9), pipelines, and powerlines transect the area (Figs. 1, 16). These restrictions were digitized from the 1:100,000 Chaco Mesa topographic quadrangle. The buildings were digitized from the 7.5-min quadrangles and the oil and gas fields were drawn on the Chaco Mesa 1:100,000 quadrangle from oil and gas pool maps available at the NMBM&MR. A railroad spur, built to connect the South Hospah mine to the main line, was plotted on the 1:100,000 Chaco Mesa quadrangle and digitized. The Chaco National Monument outlier was digitized from the 1: 100,000 quadrangle. Although archeological sites are in the study area, they would likely be mitigated, and were not considered.

Standing Rock study area resources

The original resources for the Standing Rock study area are 3.82 billion st (Table 1, 2). There is no mining production in this area to remove from the original resource. The technological restrictions, removing near surface coal (0–20 ft) and thin coal (≥2.5–5 ft) at depths greater than 250 ft removed 1.24 billion st from the total resource, the largest depletion of remaining resources. This restriction withdraws 32.6 % from the remaining available resource, only a minor amount, 8 million st, is from the 10:1 stripping ratio category. Most of the technological restriction applies to thin coals at depths greater than 250 ft.

Restrictions related to pipelines, powerlines, and major roads in the study area remove 21 million st from the remaining available resource. It is unlikely that NM State Highway 57 or Navajo Tribal Highway 9 would be mitigated although some of the county roads might be considered. Figure17a-c illustrates the proportion of coal removed by these restrictions and the

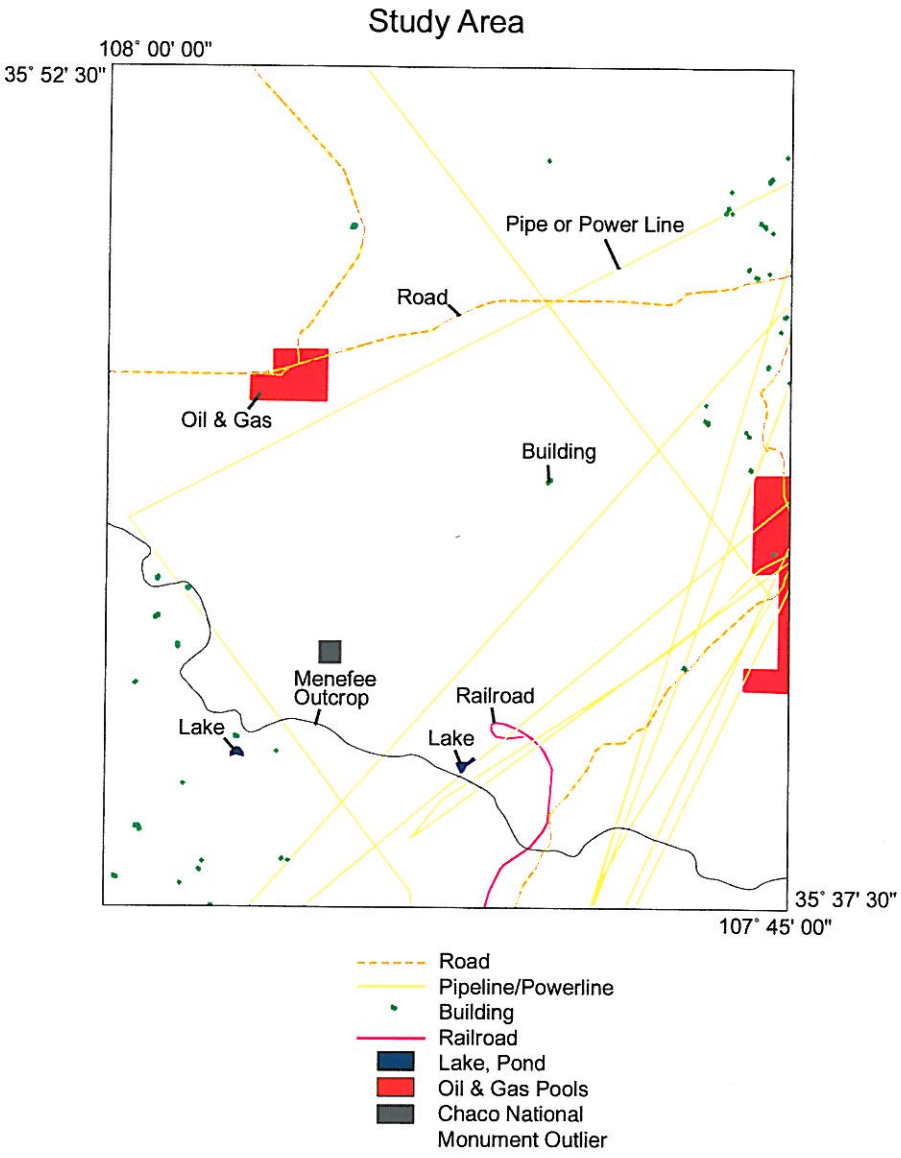

Figure 16. Land-use restrictions in the Standing Rock study area. Scale 1:250,000. Cropline from Beaumont, 1998.

Table 1. Summary of surface and underground coal resources and available coal by zone for the Menefee-Standing Rock area, reported in millions of st.

Depth Categories	Coal Zone	Original Resources	Likely Restrictions to mining								Restrictions that might be mitigated		
			Technological Restrictions	Land-use: Chaco National Monument	Land-use: pipelines, powerlines, roads	Oil And Gas: Seven Lakes and Hospah pools	Railroad: South Hospah and Lee Ranch spurs	Total Restrictions	Available	%Available	Buildings	Ponds	Total Land use restrictions
10:1 Stripping ratio	Red	30	3	2	0	0	0	5	26	84%	0	0	2
	Blue	117	4	0	1	0	0	5	112	96%	0	2	3
	Green	13	1	0	0	0	0	1	12	93%	0	1	1
	Overall	*161*	*8*	*2*	*1*	*0*	*0*	*11*	*150*	*93%*	*0*	*3*	*6*
Surface (0-250 ft)	Red	196	1	3	2	0	1	6	190	97%	0	0	5
	Blue	219	1	1	2	0	1	4	214	98%	0	1	4
	Green	157	0	0	1	0	0	2	155	99%	2	0	3
	Overall	*572*	*3*	*4*	*4*	*0*	*1*	*12*	*560*	*98%*	*2*	*1*	*12*
Underground (>250 ft->1000 ft)	Red	910	391	0	4	3	0	398	512	56%	1	1	9
	Blue	1,332	379	0	10	37	1	427	905	68%	2	3	52
	Green	1,001	469	0	3	17	0	489	512	51%	1	1	22
	Overall	*3,244*	*1,240*	*0*	*17*	*56*	*1*	*1,314*	*1,930*	*59%*	*3*	*5*	*83*

Table 2. Summary of coal resources and available coal by zone for the Menefee - Standing Rock area, reported in millions of st.

Coal Zone	Original Resources	Likely Restrictions to mining								Restrictions that might be mitigated		
		Technological Restrictions	Land-use: Chaco National Monument	Land-use: pipelines, powerlines, roads	Oil And Gas: Seven Lakes and Hospah pools	Railroad: South Hospah and Lee Ranch spurs	Total Restrictions	Available	%Available	Buildings	Ponds	Total Land use restrictions
Red	1,106	392	3	5	3	1	404	702	64%	1	2	14
Blue	1,551	380	1	11	37	2	431	1,119	72%	2	3	56
Green	1,158	469	0	5	17	1	491	667	58%	2	2	26
Overall	*3,815*	*1,242*	*4*	*21*	*56*	*3*	*1,326*	*2,489*	*65%*	*5*	*7*	*95*

remaining available resource for each of the zones. Figure 18, Tables 1 and 2 demonstrate how the restrictions influence the available coal resources in each zone. Overall, the original resources in the Green zone are depleted the most by these restrictions.

The Seven Lakes and Hospah oil and gas pools have little effect on surface minable coal, but would impact underground mining, removing 56 million st from the resource. The railroad spur removes 2 million st from the original resource and none of this restricted resource is within the 10:1 stripping ratio category.

Restrictions with potential for mitigation

The restrictions applied to the remaining resource with potential for mitigation are buildings, and ponds. Buildings remove 5 million st from the remaining resource. If mining were to take place these buildings, which are mostly Native American hogans, would be moved and the owners compensated. The small ponds called Laguna Castillo and Orphan Annie Tank remove 6 million st of coal resource. There are minor washes in the study that are not Alluvial Valley Floors and lack flow except during rainy seasons, consequently mining would not be restricted in the wash areas.

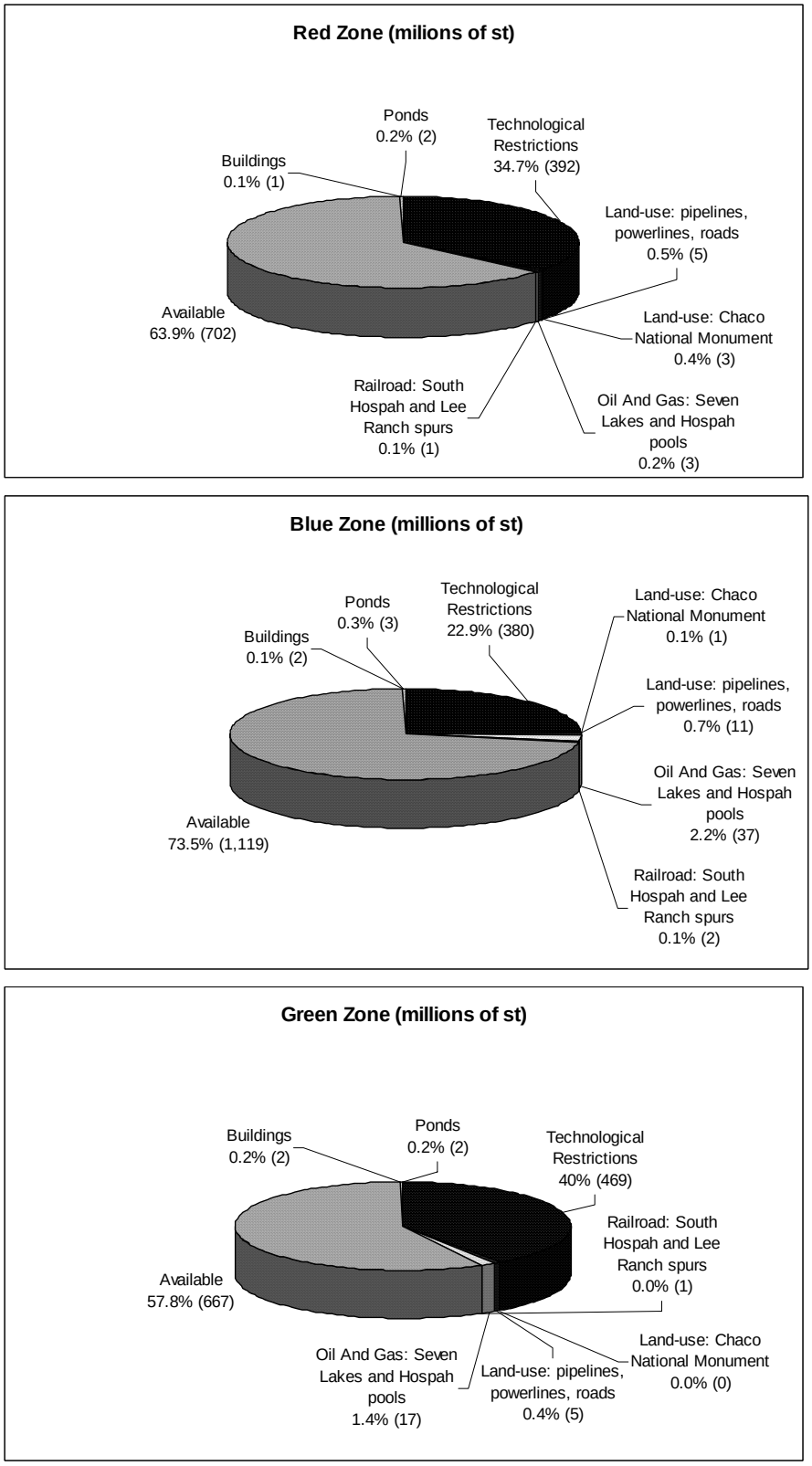

Figure 17a-c. Original zone resources removed by land-use and technical restrictions and remaining available resources.

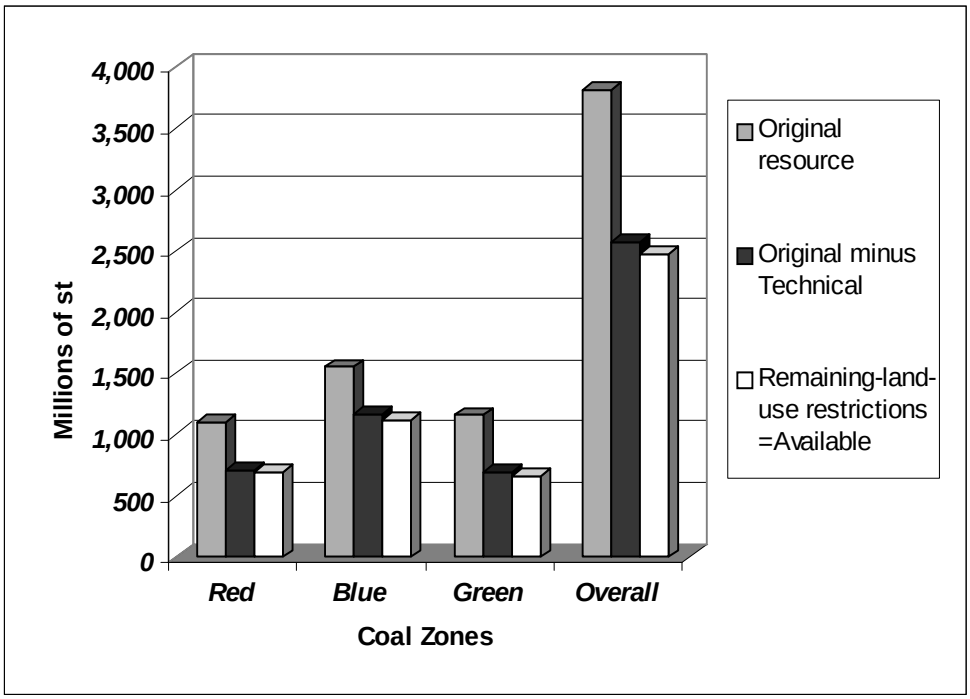

Figure 18. Standing Rock area coal resources by zone.

Comparison with other resource studies

The DOE Demonstrated Reserve Base study (Hoffman, 1996b) estimate of 0.84 billion st for the entire Standing Rock field is difficult to compare to the 2.5 billion st available resource for the four-quadrangle study area. The DRB did not include calculations for inferred reliability and for depths greater than 1000 ft. The inferred category increases the available resource by 1.70 billion st and 0.31 billion st of coal are added for depths greater than 1000 ft for the study area. Removing these two categories leaves 0.49 billion st of available resources, about 58% of the DRB estimate for the entire Standing Rock field, although the study area is about ¼ the total area of this field. New point source data was added during this study, which increased the accuracy of the resource estimate and filled in areas of no data

Summary

The Cleary Coal Member of the Menefee Formation in the Standing Rock study area contains moderate-ash, moderate-sulfur, Subbituminous A-rank coals. This resource does not meet compliance coal standards of less than 0.6 lbs sulfur/MMBtu, but with blending or washing these coals potentially could meet this guideline. Within the Cleary Coal Member, three of the seven coal zones recognized were evaluated for original and available resources in the study area. These zones, Green, Red, and Blue contain relatively thin, variable coal seams with average seam thickness of 3-4 ft.

Using Arc Info® facilitates calculating resources for areas with many restrictions and allows for faster recalculation of resources with new data. Original resources for this study area are 3.8 billion st and are greater than previous studies because the inferred category and depths greater than 1000 ft are included. Another factor influencing the resource total is the acquisition of data during the study. Technical restrictions removed about 1.2 billion st from the original resource, which is the largest restriction on the resource. The available resource is 2.5 billion st for the Standing Rock study area. A percentage breakdown by zone of this total is 27% in the Green, 45% in the Blue, and 28% in the Red. Of this available resource, 0.15 billion st is within the 10:1 stripping ratio category (Table 1). The Blue zone contains 75% (0.11 billion st) of the strippable (10:1) resource.

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