Availability of Coal Resources in the Vermejo and Raton formations, Raton coalfield, Raton Basin, northeast New Mexico

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Introduction

New Mexico ranks 11th in the nation in coal production (2004) and the state's coal industry contributes significantly to New Mexico's educational funds through royalties and taxes. Production in the state comes from four operations in the San Juan Basin; two of the mines produce from the Fruitland Formation and two mines produce coal from the Cleary Coal Member of the Menefee Formation. There is no active coal mining in the Raton basin in Northeast New Mexico; however, the area now produces coalbed methane. Cumulative coalbed methane production from 1990 through April 2005 is 58,344,228 mcfs for the New Mexico portion of the Raton Basin. As of April 2005 there are 425 producing wells operated by El Paso Energy.

Recent coal mining activity in the Raton basin centered near the upper reaches of the Vermejo and Canadian rivers and to the southeast in the Crow Canyon area where Pittsburg and Midway operated the Ancho surface mine until 2002. The study area for this project includes four 7.5-minute quadrangles in the Vermejo-Canadian rivers area: the Vermejo Park, Van Bremmer Park, Casa Grande, and Casa Grande SW (Fig. 1). Both Raton and Vermejo Formation underlie most of this 238-sq mi study area. The Vermejo Formation and underlying Trinidad Sandstone crop out in the northeastern corner along The Wall, a structural and topographic feature, and in the Vermejo Park area; the Raton Formation crops out in a northeast–southwest trend through the study area.

Raton, New Mexico is east of the study area on Interstate Highway 25 and the largest urban area in Colfax County. Interstate 25 is the main north-south highway through New Mexico and Colorado. The main north-south line of the Burlington Northern Santa Fe follows the eastern edge of the basin and a spur line up the Vermejo River valley provides access to the coal areas. Railroads played a major role in coal production for the Raton area from the 1890s to the present. Pittsburg and Midway shipped coal to Wisconsin via rail from their Raton basin operations.

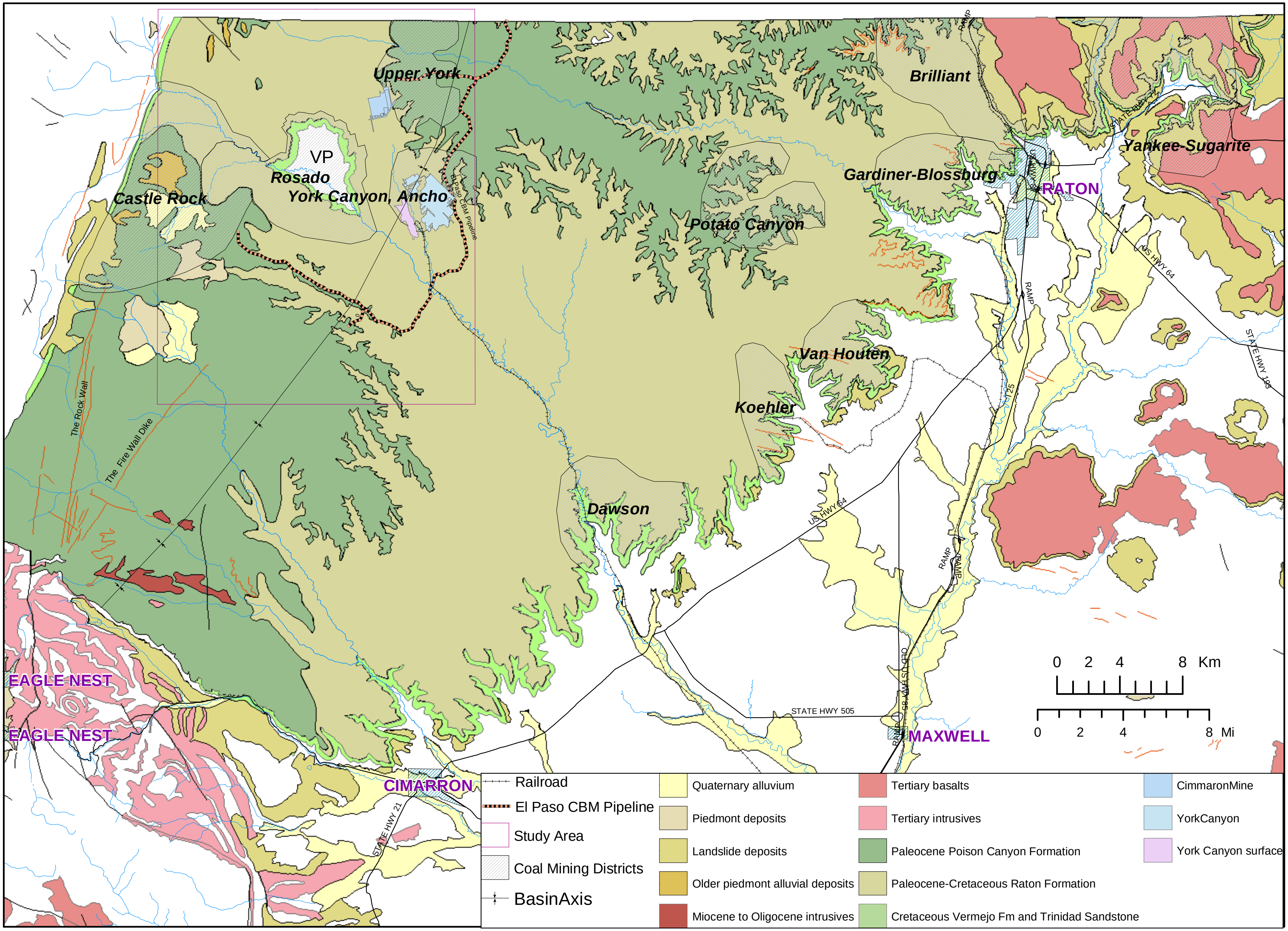

Figure 1.Generalized geologic map of Raton coalfield, New Mexico with mining districts (Pillmore, 1991) and outline of study area. Geology from New Mexico Bureau of Geology, 2003.

Mining History

Coal deposits were recognized the Raton Basin as early as the 1820s. The first phase of coal development began in the 1870s with coal mined for local domestic use. In the 1890s and early 1900s, railroads were built into the area, coal supplied fuel for the steam engines, and coke was transported to southwest copper smelters.

The earliest mines developed near the mouths of major river canyons dissecting the Raton Basin. Early coal camps developed in Dillon Canyon west of the town of Raton at Gardiner and Blossburg mining districts (Fig.1). Mines at the mouth of Dillon Canyon extracted coal from the Cretaceous Vermejo Formation. Some of these early mines near Blossburg reported problems with ventilation, allowing methane to accumulate in the mine resulting in a few explosions and mine closures (Lee, 1924). During the late 1890s, a few mines opened east of Raton on the south slopes of Horse Mesa in Raton Formation. These mines supplied domestic fuel to local residents and were only open a few years.

The early 1900s witnessed significant development of coal in the Raton basin. The Raton Coal and Coke and Dawson Fuel Companies opened several mines. Raton Coal and Coke, owned by the Atchison, Topeka and Santa Fe Railroad (ATS&F) and Maxwell Land Grant Company, operated mines in the Vermejo Formation in the Van Houten area, southwest of the city of Raton at the mouth of Willow Canyon. Lee (1924) reported methane in some of the Van Houten mines. In 1906, the St. Louis and Rocky Mountain Pacific Railway acquired the property and mines owned by Raton Coal and Coke. St. Louis and Rocky Mountain opened other mines at Brilliant in the Raton Formation, farther up Dillon Canyon, and at Koehler near the mouth of Prairie Crow and Ox Canyons, mining Vermejo Formation coals. St. Louis and Rocky Mountain also mined coals in the Raton Formation at Sugarite, east of Raton, in the canyon between Bartlett and Horse mesas. Spurs from the main rail line of then ATS&F gave easy access to the coal produced at these locations.

In 1900, the Dawson Fuel Company developed mines in the Vermejo Formation coals near the mouth of Vermejo Canyon. The coal camp of Dawson is about 25 miles southwest of Raton along the eastern edge of Raton Mesa (Fig. 1). Charles Eddy first opened the Dawson mines to supply fuel to the El Paso and North-eastern Railroad. Phelps Dodge acquired the Dawson coal property and rail line in 1906 and began shipping coke from Dawson to Phelps Dodge copper smelters in Arizona. Phelps Dodge operated the mines under the name Stag Canyon Fuel and continued production at Dawson until 1950. During the life of these mines, Dawson had two serious explosions. In October of 1913, 263 workers were killed in an explosion from an unsupervised shot during a work shift. The shot ignited coal dust causing a massive explosion. Today the Mine Safety Health Administration (MSHA) still lists this as one of the three worst coal mine disasters in U.S. history (U.S. Department of Labor, 2005). The second explosion occurred in February 1923 killing 120 men when an electric spark from an ore car derailment ignited coal dust. Both explosions led to increased safety measures limiting the coal dust in the mine by spraying the walls with a lime mixture and introducing battery-powered ore cars, eliminating power lines. Mine inspector reports and Phelps Dodge records do not indicate gas buildup as a cause for these explosions.

Many of the mines in the Raton coalfield that opened in the early 1900s continued to operate into the 1950s. The declining need for coal by the railroads and oil replacing the need for coke at the copper smelters led to mine closures. From 1888 until 1958, 61.7 million short tons (st) of coal were extracted from the Raton coalfield in New Mexico.

In 1955, Kaiser Steel of Fontana California acquired 530.000 acres from St Louis Rocky Mountain Pacific and took over the underground mine at Koehler. At this time, they also began an extensive exploration program of their acquired acreage. Exploration determined the York Canyon region, west of Casa Grande along the Left Fork of the Vermejo River, had the greatest potential for development of both underground and surface mining. Through exploration, the York Canyon coal in the upper coal zone of the Raton Formation proved to have significant reserves. Underground mining by continuous miners and longwall method began in 1966 east of Road Canyon. By the 1960s, all equipment from the Koehler area and extension of the spur along the Vermejo River to the main line was complete. Surface operations west of Road Canyon began in 1972. In 1983, Kaiser Steel closed their mills in California and the York Canyon mine experienced shutdowns. In 1989 Pittsburg and Midway, a subsidiary of Chevron, acquired Kaiser's coal reserves within 623,000 acres, including the York Canyon (underground) and Cimarron (surface) mines in the York Canyon area. Pittsburg & Midway did extensive renovation of the mine facilities and began an intensive exploration program. In 1993, Pittsburg and Midway (P&M) submitted a mine plan for the Ancho, East Ridge and Road Canyon surface mines in the York Canyon area. P&M marketed the coal for electrical generation, shipping it by rail to a power plant in Wisconsin. The East Ridge, Road Canyon and West York mines closed in December 1994. The underground Cimarron mine closed in September 1995 because of problems with faulting as well as increased methane in the mine that would have required overhauling the ventilation system. Only the Ancho surface mine, permitted in February 1989, continued to operate until the latter part of 2002. Closure came as surface reserves were becoming more difficult to develop and more expensive to mine (EMNRD, 2002). Pittsburg & Midway recently sold there holdings in the Raton Basin to Ted Turner who owns the adjacent Vermejo Park Ranch. Production from 1958 through 2001 was 42.3 million st.

Topographic Influence on Mining

The Raton coalfield is defined as the New Mexico portion of the Raton Basin underlain by Upper Cretaceous and Paleocene coal-bearing sequences in the Vermejo and Raton formations. This field encompasses a highly dissected plateau region, incised by the Canadian and Vermejo rivers and their tributaries. The eastern margin of the plateau rises over 1,000 ft above the surrounding plain and access to the coal-bearing units is through canyons created by the drainage systems. The rugged terrain is more conducive to underground mining, starting at coal outcrops in canyon walls and tunneling inward either in a room and pillar configuration or more recently by longwall mining methods. Surface mining is limited to areas of lesser relief in the upper drainages of the Vermejo and Canadian Rivers.

There is no active coal mining in the Raton coalfield today in part because of the economics. Although rail access is available, the cost of mining coal in the area cannot compete with Wyoming coal selling for $6.74/ton (2003) on the open market. Underground mining has the greatest potential in the Raton coalfield. However, the recovery rate for underground operations is less than surface mining, making this method not as economic. Additionally, the coals in the Vermejo and Raton formations tend to be discontinuous and relatively thin dictating the mining of multiple seams adding to the overall mining costs.

Previous Work

Orestes St. John was one of the earliest geologists to look at the coal resources in the Raton Basin as part of the Hayden survey, later assessing the coal resources for the Maxwell land grant in the 1870s. Willis T. Lee, employed by the U.S. Geological Survey, did extensive geologic work in the basin in the early 1900s. Lee (1917) further defined the Trinidad Sandstone in the Raton Basin from R.C. Hills' description (1899) and defined the Vermejo Formation (1913) for exposures at Vermejo Park. Lee (1917) divided the Raton Formation into the basal conglomerate, lower coal zone, the barren, sandstone-dominated series and the upper coal zone. Knowlton (1917) investigated the fossil flora in the Vermejo and Raton formations, helping to define the age of these formations. Lee (1924) outlined the coal resources of the Raton coalfield in New Mexico and discussed the mining districts of the area. Lee did numerous outcrop measurements throughout the basin for both his 1917 and 1924 publications. Wanek (1963) published a map with text on the coal resources of the southern Raton coalfield, from Koehler south to Cimarron, and west to the edge of the basin.

Pillmore began mapping several quadrangles in the Raton field in the 1960s and published a comprehensive paper (1969) on the coal deposits, drawing on previous work and access to coal data from Kaiser Steel. Pillmore defined areas within the coalfield where significant coal beds or zones occur in the Vermejo and Raton formations. Pillmore and Flores published several papers together, separately, and with other co-authors throughout the 1980s on the sedimentology of the Raton Basin and the location of the Cretaceous/Tertiary boundary within the lower coal zone of the Raton Formation.

In 1993, Scott and Pillmore’s geologic and structure map of the Raton 30’X 60’ quadrangle incorporated much of the geologic mapping and stratigraphic work done in the area from the 1890s forward. The U.S. Geological Survey posthumously open-filed two of the 7.5 min quadrangle maps in digital format that Pillmore mapped in the 1960s. The Van Bremmer Park (Pillmore, 2003a) and Vermejo Park (Pillmore, 2003b) quadrangles are available on the web as pdfs and in GIS format.

Work on the coalbed methane potential of the Raton basin began in earnest in the 1980s. Jay Close (1988) completed his dissertation on the coalbed methane potential of the Raton Basin in Colorado and New Mexico. Close did a detailed study of the depositional environments, cleat orientation and fracture patterns, thermal maturity parameters, and regional thermal history of the Raton Basin. Some of his conclusions on the depositional environments and shoreline orientation of the Vermejo and Raton differ from Flores and Pillmore ideas. Gas Research Institute published a coalbed methane assessment of the Raton Basin in 1992 (Stevens et al, 1992).This report summarizes reservoir characteristics and estimates the coalbed methane resources of the Raton and Vermejo coals. New data from wells drilled in the basin were incorporated into this report along with gas desorption measurements and new vitrinite reflectance data. Flores and Bader (1999) summarized previous studies on the Raton Basin and discussed the past mining and potential of mining and coalbed methane. Specific resource assessment of the basin was not included in this report. Johnson and Finn (2001) evaluated the potential for basin-centered gas in the Raton basin. This report looked at the potential of the sandstones in the Trinidad, Vermejo, and Raton formations. The center of the basin,where vitrinite reflectance is greater than 1.0 percent R_o, has the greatest potential for gas in the interbedded sandstones. However, because of the shallow depths, some of the gas potential may have been lost because of surface water intervention. Hoffman and Brister (2003) summarized the work in the New Mexico portion of the Raton Basin and Brister, Hoffman and Engler (2004) used the coalbed methane and coal mining data for the basin to prepare a Reasonable Foreseeable Development Scenario (RFDS) for the Valle Vidal unit, Carson National Forest.

Geologic Setting

Structure–The Raton field covers 900 mi^2 in northeastern New Mexico and is part of a large asymmetrical, arcuate northeast trending basin formed during the Laramide on the eastern edge of the Rocky Mountains (Baltz, 1965). The Sierra Grande arch and the Apishapa arch bounds the Raton Basin on the east in New Mexico and Colorado, respectively. The southeast boundary of the basin is defined by the Cimarron arch and on the west by the Sangre de Cristo uplift (Fig. 2; Pillmore, 1991). The western flank of the basin is steeply dipping to overturned while the eastern flank dips gently westward. The Vermejo Park dome is a prominent structure northwest of the basin axis with 2500 ft of structural relief across 3.85 mi. Vermejo Park is underlain by a laccolith delineated by drill records (Pillmore, 1976). Several drill holes northeast of Vermejo Park have igneous intrusions within the coal-bearing sequence.

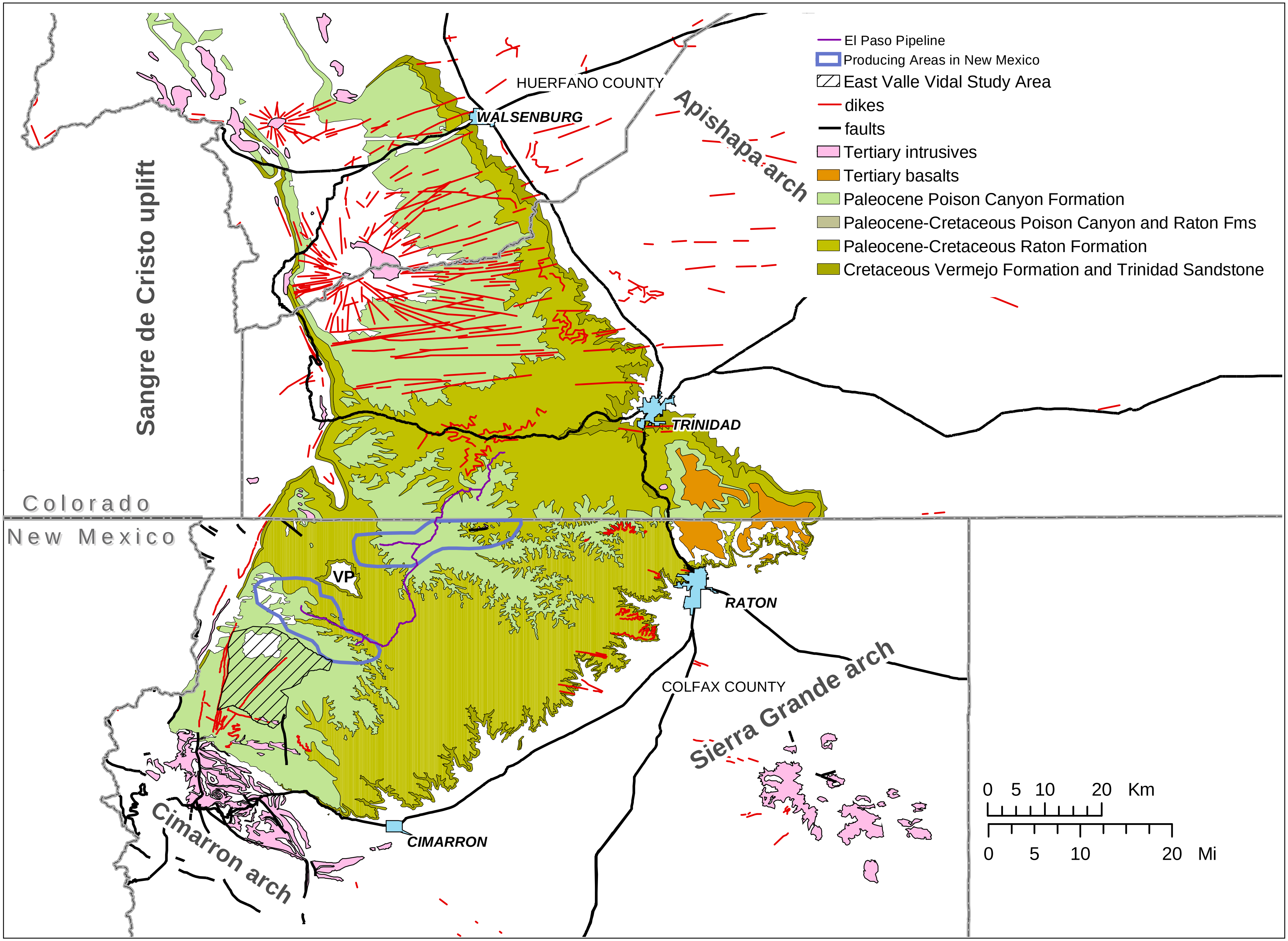

Figure 2. Geologic and structural features of the Raton Basin, Colorado and New Mexico. Geology derived from New Mexico Bureau of Geology and Mineral Resources (2003) and Tweto (1979) .

Stratigraphy–The following summary is extracted from Hoffman and Brister (2003); see Baltz (1965) for a comprehensive summary of the stratigraphy of the region. The Trinidad Sandstone underlies the coal-bearing sequence in the Raton Basin. As thick as 300 feet, it forms a prominent cliff along the eastern edge of the basin (Fig. 3). The upward-coarsening sandstones show bioturbation and often contain Ophiomorpha casts (Flores, 1987) suggesting a shallow marine to shoreface depositional environment. The lower part of the formation has ripple lamination that grades upwards into planar and trough cross lamination (Flores, 1987) demonstrating an upwards increase in depositional energy and reflecting the overall shallowing/regression of the seaway.

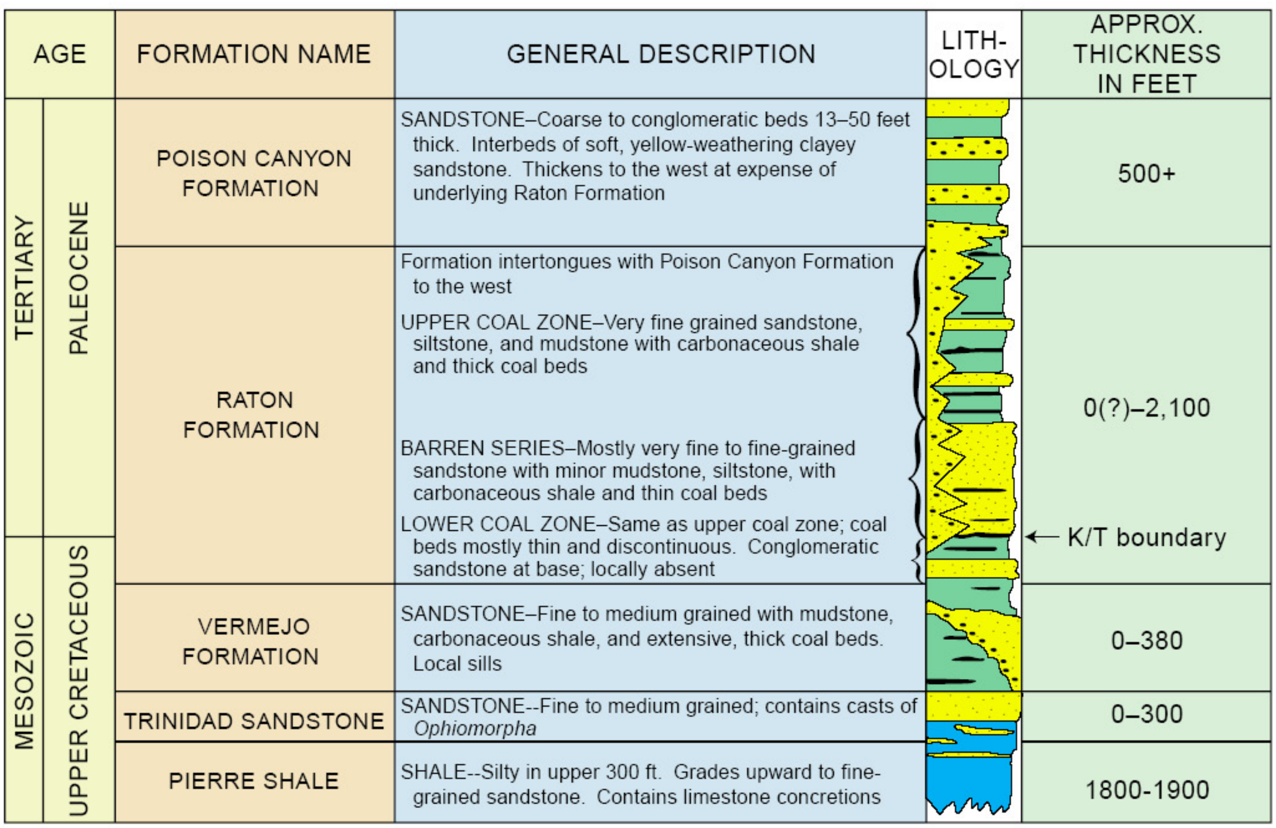

Figure 3. Generalized cross section from Flores and Bader (1999) modified from Pillmore (1969), Pillmore and Flores (1987) and Flores (1987).

Conformably overlying the Trinidad Sandstone is the coal-bearing Vermejo Formation. However, Lee (1917) and Wanek (1963) recognized transgressive tongues of the Trinidad Sandstone extending into the Vermejo Formation along the southern margin of the basin. Both noted the general thinning of the Vermejo Formation to the east. Lee (1913) defined the Vermejo Formation for exposures at Vermejo Park as the "coal measures lying immediately above the Trinidad Sandstone." This sequence of sandstone, siltstone, mudstone, shale, carbonaceous shale, and coal averages about 350-ft thick. The Vermejo Formation represents delta plain deposits landward of the shoreface, delta-front and barrier bar sediments of the Trinidad Sandstone (Flores, 1987; Pillmore and Flores (1987). The thicker coals are commonly concentrated near the base of the Vermejo Formation in proximity to the Trinidad upper shoreface sandstone.

In general, the Raton Formation unconformably overlies the Vermejo Formation. Lee (1917) divided the Raton Formation into the informal basal conglomerate, lower coal zone, a sandstone-dominated barren series (middle barren sequence herein) and an upper coal zone. The Raton Formation basal conglomerate is a 10-30 ft thick pebble conglomerate to granule quartzose sandstone eroded into the Vermejo Formation. Overlying the basal conglomerate, the 100-300 ft lower coal zone consists of sandstone, siltstone, mudstone, carbonaceous shale and thin, discontinuous coal. This sequence represents meandering stream floodplain deposits that grade upward into braided stream deposits of the overlying middle barren sequence (Flores and Pillmore, 1987; Johnson and Finn, 2001) which varies from 165-600 ft thick. The middle barren sequence merges with the Poison Canyon Formation to the west (Pillmore and Flores, 1987). The upper coal zone is a return to finer-grained deposits in an alluvial plain environment (Flores, 1987). Peat swamps developed between the meandering stream channels. Coal beds are lenticular within the upper coal zone, but tend to have greater thickness than those in the lower coal zone of the Raton Formation.

The Raton Formation is overlain and intertongues to the west with the Poison Canyon Formation; the contact can be gradational in parts of the basin. Pillmore mapped this contact as a transitional area probably in part because of the vegetative cover. Detailed studies of the Poison Canyon Formation may be able to better delineate this formation or perhaps recognize it as a transitional sequence of the Raton Formation. The Poison

Canyon Formation consists of course-grained to conglomeratic arkosic sandstones. This unit represents prograding conglomeratic lithofacies derived from the Sangre de Cristo uplift.

Flores (1987) recognized three coarsening-upward megacycles in the Vermejo, Raton, and Poison Canyon Formations. The Vermejo Formation to the basal Raton conglomerate represents the first megacycle; the lower coal zone and middle barren sequence in the Raton the second; and the third megacycle consists of the upper coal zone of the Raton and the Poison Canyon Formation. These megacycles apparently record local Late Cretaceous to Paleocene tectonic pulses affecting the basin and adjacent uplift.

Coal Geology

Both the Vermejo and Raton formations are coal-bearing sequences with multiple coal zones and several very thin seams within these zones. Because of the depositional environments described below, many of these seams are discontinuous and correlation is difficult with the density of data available.

The lower Vermejo Formation is a transitional sequence that contains extensive coal beds, including the Raton coal bed, deposited in back-barrier brackish swamps and lower coastal-plain distributary channels (Fig. 3). Most of the thick, laterally extensive coal beds are back–barrier in origin and are aligned subparallel to the N–NE Late Cretaceous shoreline (Pillmore, 1991). Most of the lower Vermejo coals are within 50 ft of the Trinidad Sandstone contact. Coal in the upper Vermejo Formation accumulated in poorly-drained swamps on the upper coastal plains (Pillmore and Flores, 1987). Coals in this upper Vermejo coal zone can be directly below the basal sandstone of the Raton Formation or can extend to 100 ft below this unit. To the northeast, the Vermejo thins and in places is unconformably overlain by the Raton Formation.

Pillmore and Flores (1987) divided the Raton Formation into three units; the lower coal zone, the barren zone, and the upper coal zone (Fig. 3). The lower coal zone includes all of the Cretaceous age rocks of the formation; the K–T boundary is at the top of this unit. This zone includes basal conglomeratic sandstone that grades upward into overbank floodplain deposits of interbedded mudstone, siltstone, carbonaceous shale and thin coal (Pillmore, 1991). Northeast of the town of Raton, a 6–ft coal bed, the Sugarite bed, is at the top of the lower coal zone. Within the basin, coals within the lower zone can be very discontinuous. Near the top of this bed, in a kaolinitic iridium-enriched parting, the K–T (Paleocene) boundary is recognized (Pillmore and Flores, 1987). The overlying barren series consists of channel sandstones and minor floodplain coal beds. The upper coal zone contains floodplain deposits with several economically significant coal beds of 10 ft or greater in thickness. There are seven coal beds within the upper coal zone in the central and eastern parts of the Raton coalfield that are described in detail by Pillmore (Pillmore, 1976, 1991). The Raton Formation coarsens and interfingers to the west with the wholly continental Poison Canyon Formation (Fig. 3).

For this study, the coal bed/zone nomenclature is from Pillmore (1991) which is widely used by the mines in the area. Three coal bed/zones are recognizable in the upper Raton coal zone. The York Canyon is the uppermost coal within the upper Raton coal sequence, about 1200 -1300 ft above the base of the Raton Formation. The York Canyon is one of the thicker coals recognized in the Raton Formation with an average seam thickness of 4.35 ft and maximum of 11.30 ft (Figs.4, 5). There can be as many as three seams in the York Canyon; however, one seam is the norm. Both the surface and underground mines at the P&M's York Canyon Complex mined the York Canyon coal.

About 300 ft below the York Canyon is the Upper Left Fork and Lower Left Fork coals. Pillmore (1991) recognized these two beds 900- 950 ft above the base of the Raton Formation with 50-60 ft interburden. The average seam thickness within the study area is 4.54 ft and 3.76 ft for the Upper Left Fork and Lower Left Fork, respectively. The average number of seams recognized for both the Upper and Lower Left Fork is one seam with a maximum of three seams for the Upper Left Fork and two for the Lower Left Fork. At a maximum of 15 ft, the Upper Left Fork has the greatest total coal thickness of all the coal zones examined in the study (Fig. 5).

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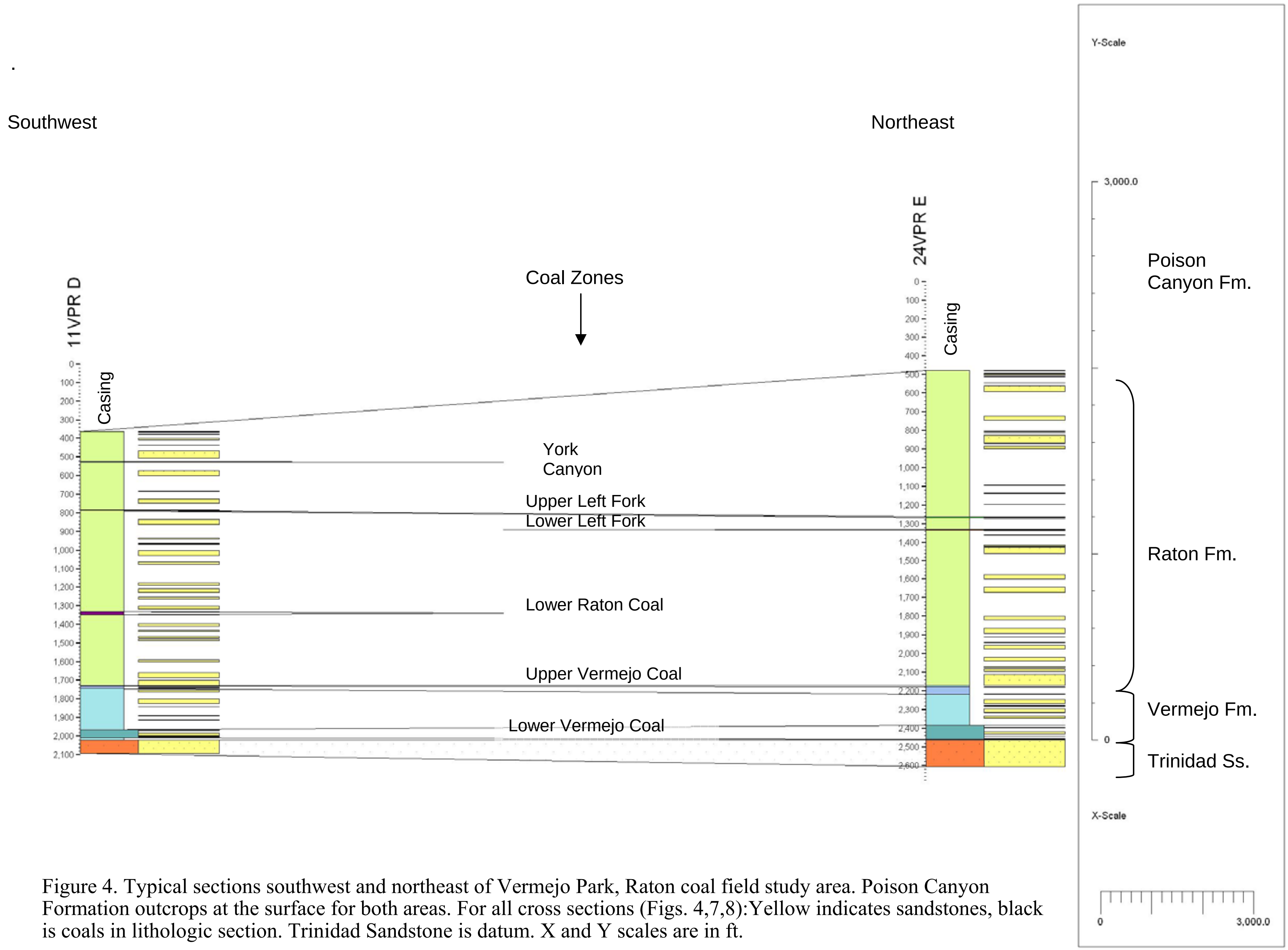
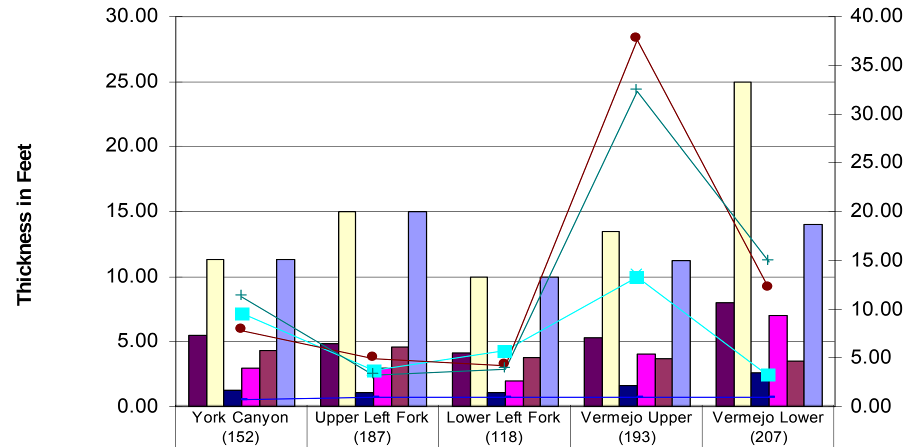


Figure 4. Typical sections southwest and northeast of Vermejo Park, Raton coal field study area. Poison Canyon Formation outcrops at the surface for both areas. For all cross sections (Figs. 4,7,8):Yellow indicates sandstones, black is coals in lithologic section. Trinidad Sandstone is datum. X and Y scales are in ft.



	York Canyon (152)	Upper Left Fork (187)	Lower Left Fork (118)	Vermejo Upper (193)	Vermejo Lower (207)
Total Coal Avg	5.45	4.87	4.11	5.28	7.96
Total Coal Max	11.30	15.00	10.00	13.50	25.00
No. of Seams - Avg	1	1	1	2	3
No. of Seams - Max	3	3	2	4	7
Seam Avg	4.35	4.54	3.76	3.68	3.49
Seam Max	11.30	15.00	10.00	11.20	14.00
Parting Avg	0.75	1.00	1.00	1.00	1.00
Interburden Avg	9.61	3.69	5.77	13.33	3.14
Zone Thickness Avg	7.74	4.95	4.24	37.55	12.10
Zone Thickness Std Dev	11.27	3.19	3.78	32.29	14.86

Coal Zones

Figure 5. Coal thickness and interburden characteristics by zone. Seam refers to individual coal beds; total coal is total coal thickness within a zone. Numbers in parenthesis are number of data points for each zone. Parting Avg., Interburden Avg., Zone Thickness Avg., and Zone Thickness Std. Dev. are plotted on secondary y-axis.

The Vermejo Formation has two recognizable coal zones, the upper Vermejo coal below the basal Raton sandstone and the lower Vermejo coal just above the contact with the Trinidad Sandstone. The upper Vermejo coal zone consists of several seams within 75 ft of the contact with the Raton Formation. Typically, there are two coals within this zone, but there can be as many as four seams. Average seam thickness is 5.28 ft with a maximum of 13.5 ft. The lower Vermejo coal zone is within 50 ft of the contact with the Trinidad Sandstone. This zone has the greatest number of seams on average (3) and a maximum of seven seams. The average seam thickness is 3.49 ft for the lower Vermejo coal zone with a maximum of 14 ft. The lower Vermejo coal zone averages 7.96 for total coal within the zone and 25 ft as a maximum total coal, which is the thickest average and maximum for all the zones examined in this study.

The locations of the two cross sections (Figs.7-8) are on the generalized geologic map of the area (Fig. 6). Figure 7 is sub parallel to dip on the structure at the top of the Trinidad Sandstone, southwest of Vermejo

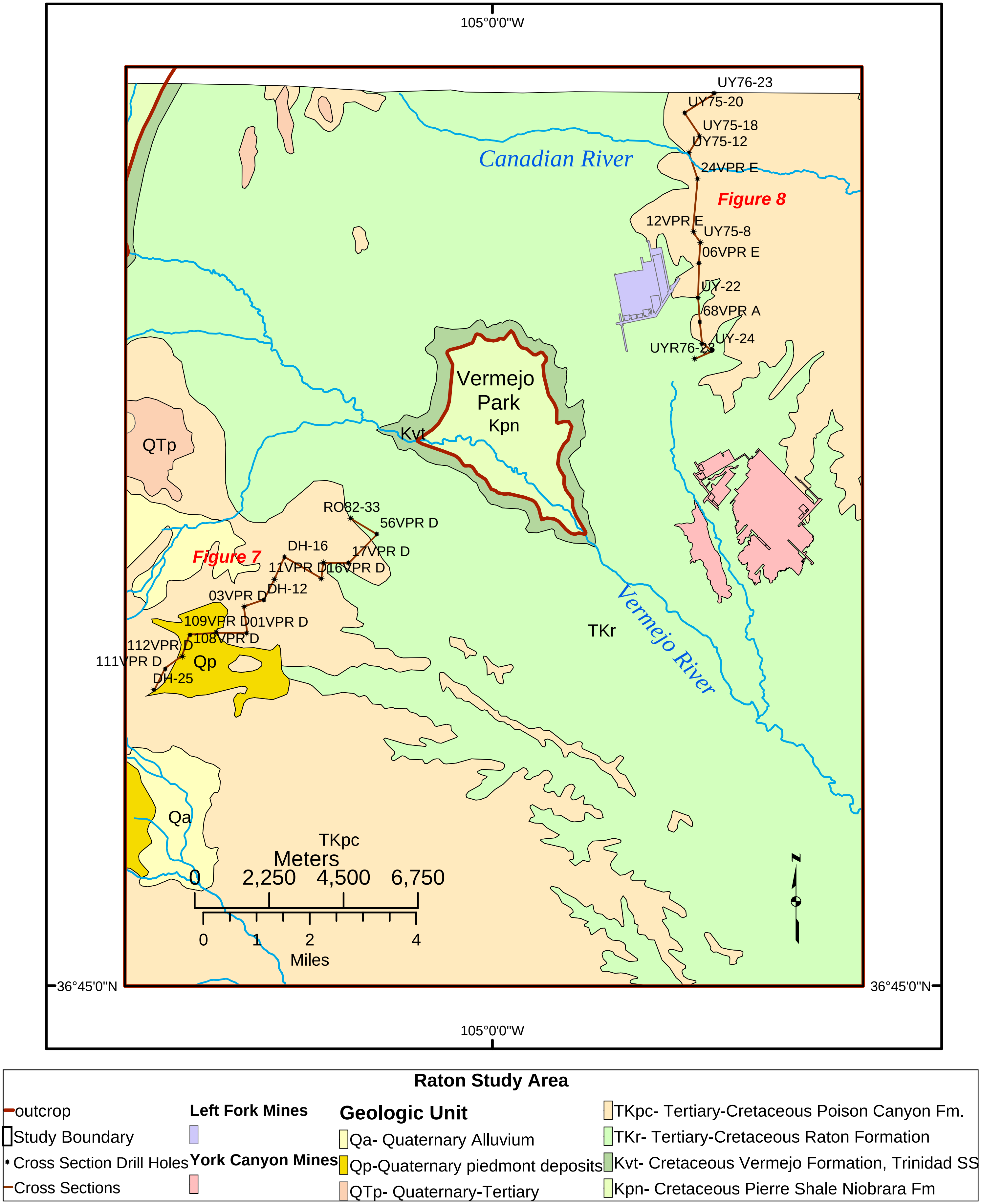


Figure 6. Generalized geologic map of study area, Raton basin, New Mexico 1:150,000 scale. From New Mexico Bureau of Geology, 2003. Cross section lines and drill holes shown for Figures 7 and 8.

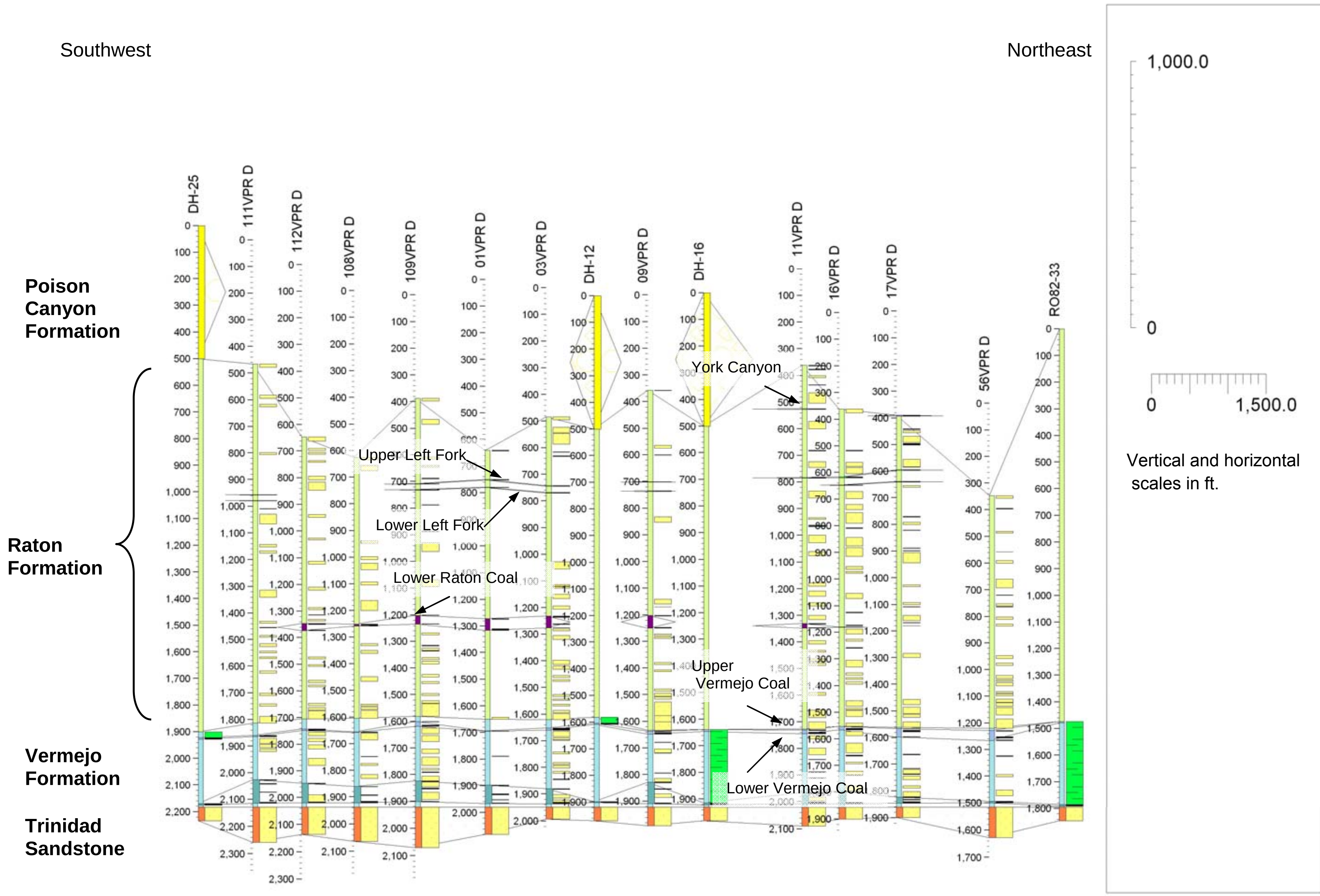


Figure 7. Southwest-Northeast cross section in Raton coalfield study area. See Figure 6 for location

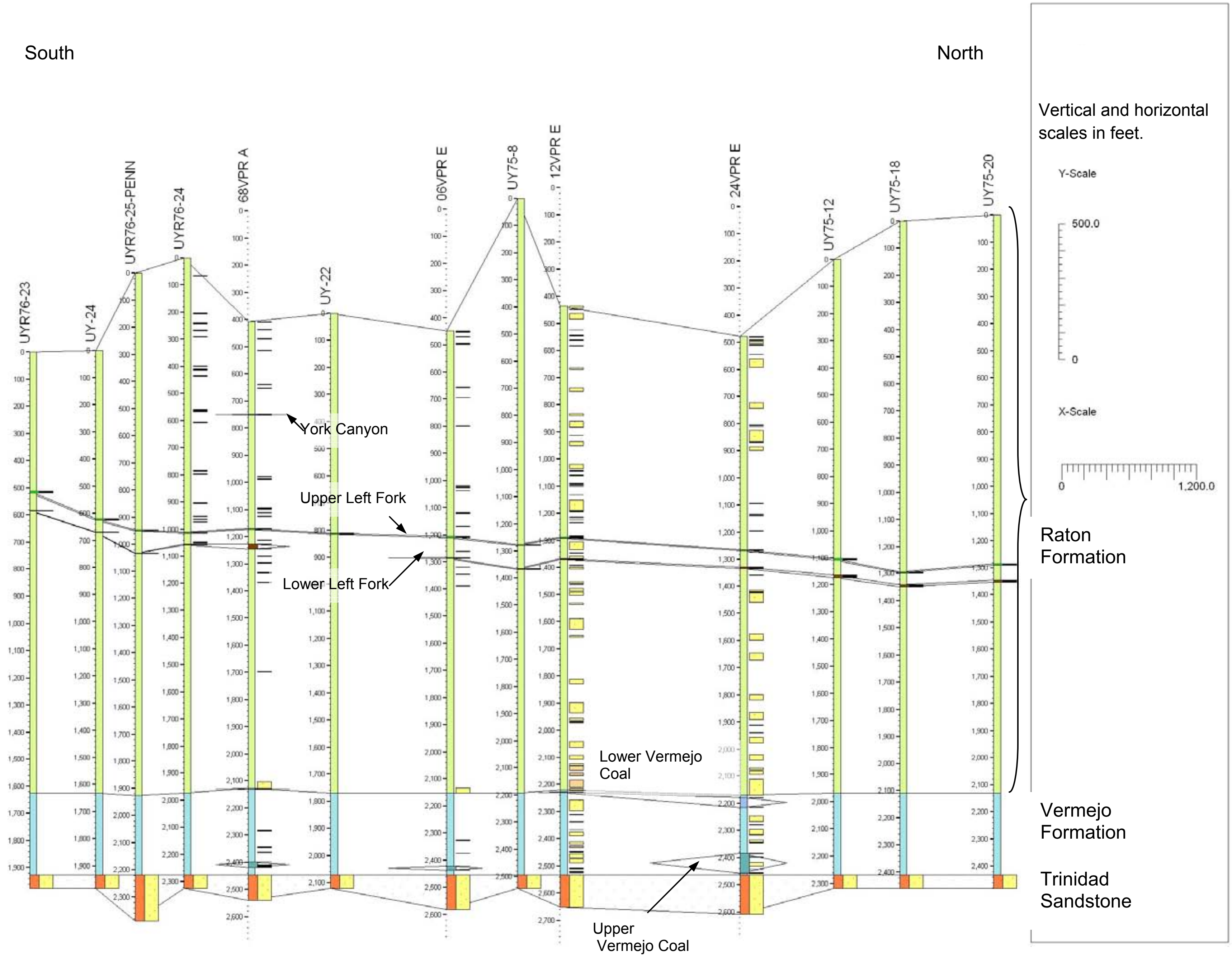


Figure 8. North-South cross section in Raton coalfield study area. See Figure 6 for location

Park and Figure 8 is sub parallel to strike on the top of the Trinidad northeast of Vermejo Park (see Figure 14 for Trinidad sturcture contours). Correlation of the seams on these cross sections and for resource calculations is by zone rather than by individual coal bed. Any coal in one section does not necessarily represent the same bed on an adjacent section; rather the coals are correlated by zone. Both of the cross sections illustrate the lateral lenticularity of these coals, although the Vermejo Formation coals show greater continuity along the southwest- northeast trend in part because most of the data points in this section are deep enough to encounter this unit. The Lower Raton coal zone seen on Figure 7 does not have enough data points for resource calculations. The designation at the top of each section refers to the "Bore" number used in the Microsoft Access® database constructed for this study (See Appendix 1).

The total coal isopachs for all zones (Figs.9-13) illustrate the variability of thickness between and within the zones. York Canyon coals are concentrated between the Vermejo and Canadian rivers (Fig. 9) and the thicker coals are near the Vermejo River in the area of the York Canyon Complex mines. The Upper Left Fork coals (Fig. 10) are concentrated in the northeast part of the study area. These coals were mined at the Cimarron mine along with the Lower Left Fork coals that have a similar distribution pattern (Fig. 11) but are not as thick as the Upper Left Fork Coals. The Upper Vermejo and Lower Vermejo coals are seen in a greater number of the drill holes used in this study. Figure 12 shows a concentration of Upper Vermejo coals south of the Vermejo River in the center of the study area and a general trend of thick coals northwest to southeast (Fig. 12). The Lower Vermejo coals are thickest southwest of the York Canyon mines and the Vermejo River and just south of the Canadian river in the Cimarron mine area.

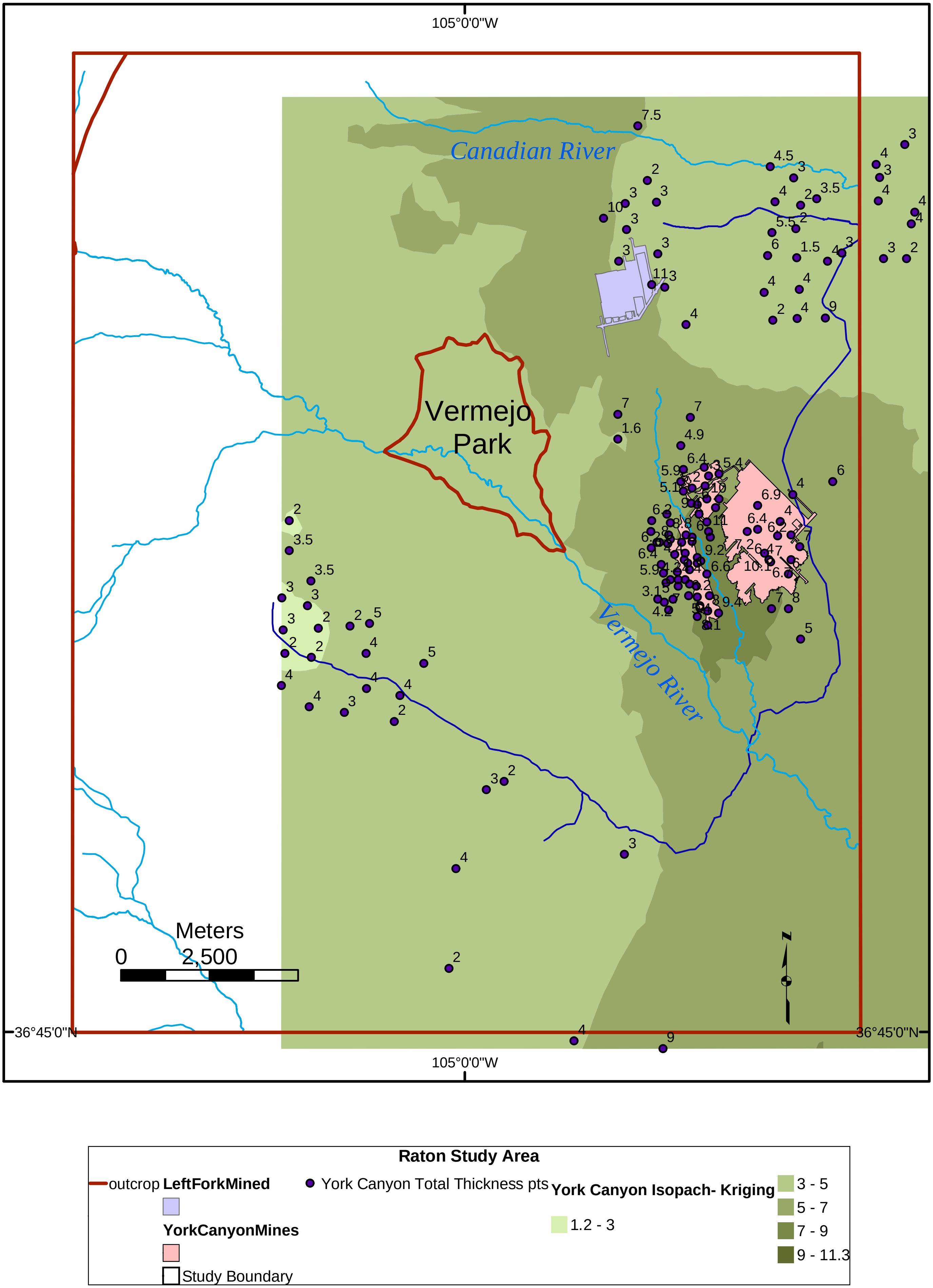


Figure 9. York Canyon coal zone isopach in study area with total thickness data points. Generated by simple kriging method in ArcMap.

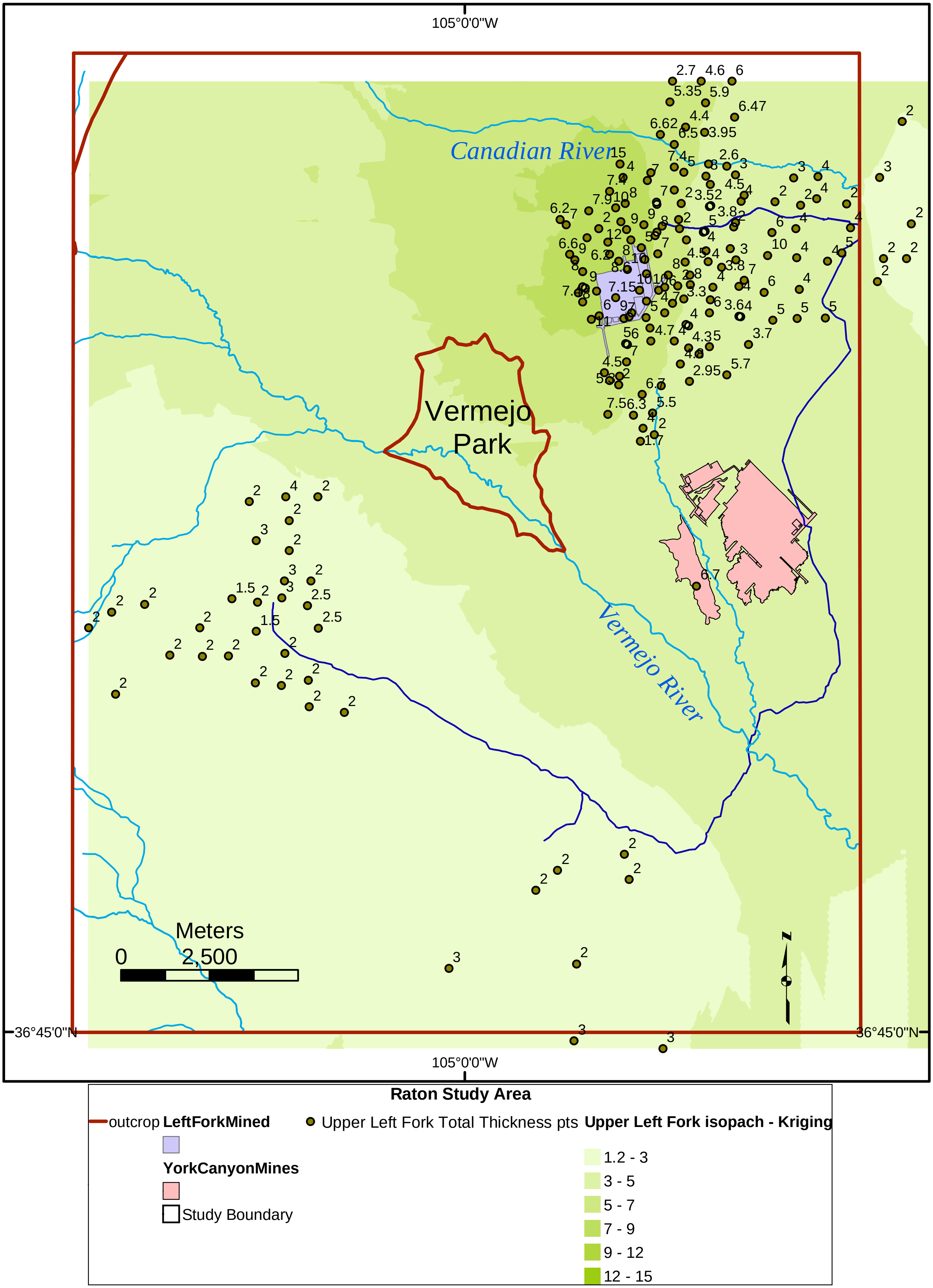


Figure 10. Upper Left Fork coal zone isopach in study area with total thickness data points. Generated by simple kriging method in ArcMap.

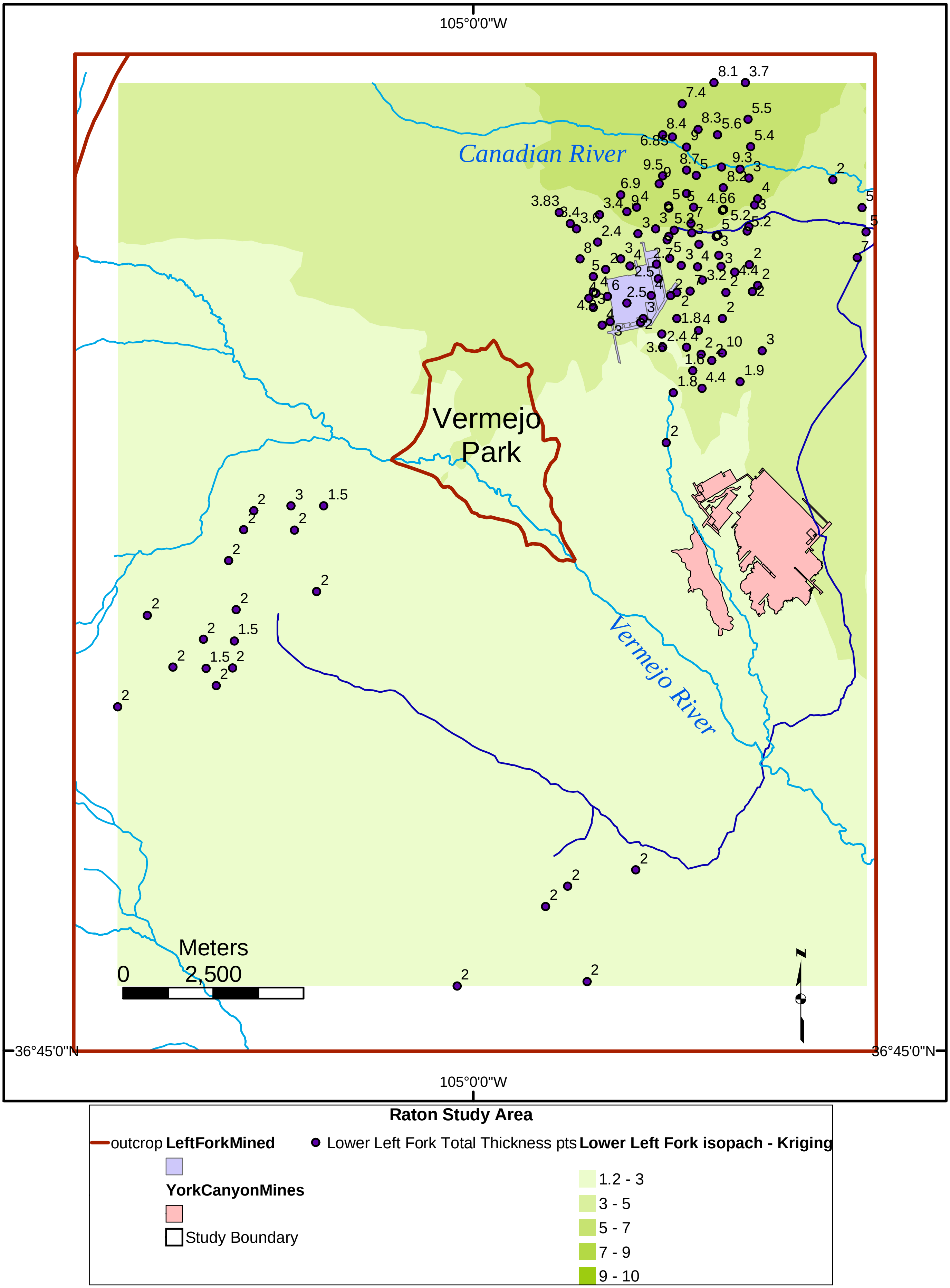


Figure 11. Lower Left Fork coal zone isopach in study area with total thickness data points. Generated by simple kriging method in ArcMap.

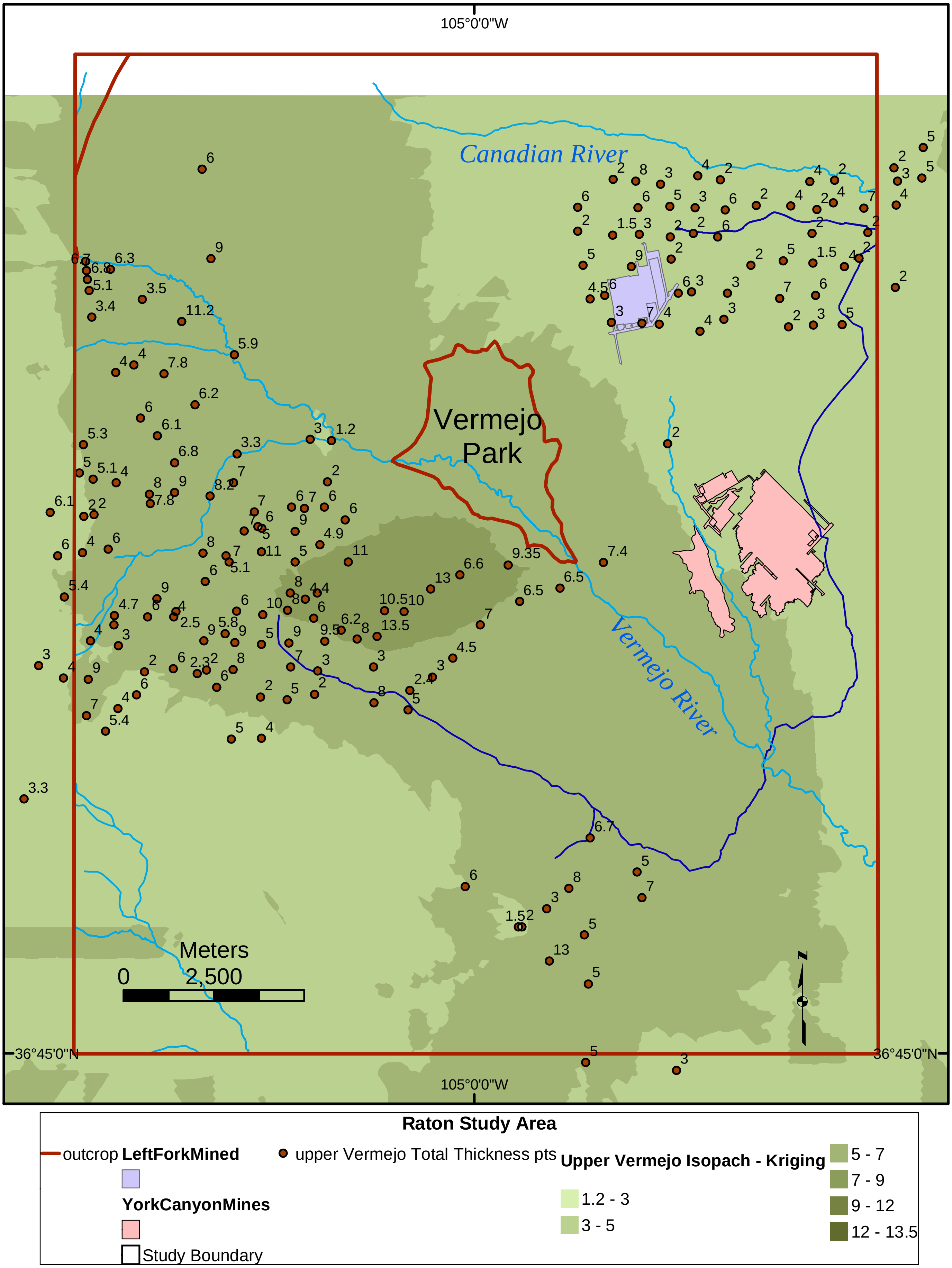


Figure 12. Upper Vermejo coal zone isopach in study area with total thickness data points. Generated by simple kriging method in ArcMap.

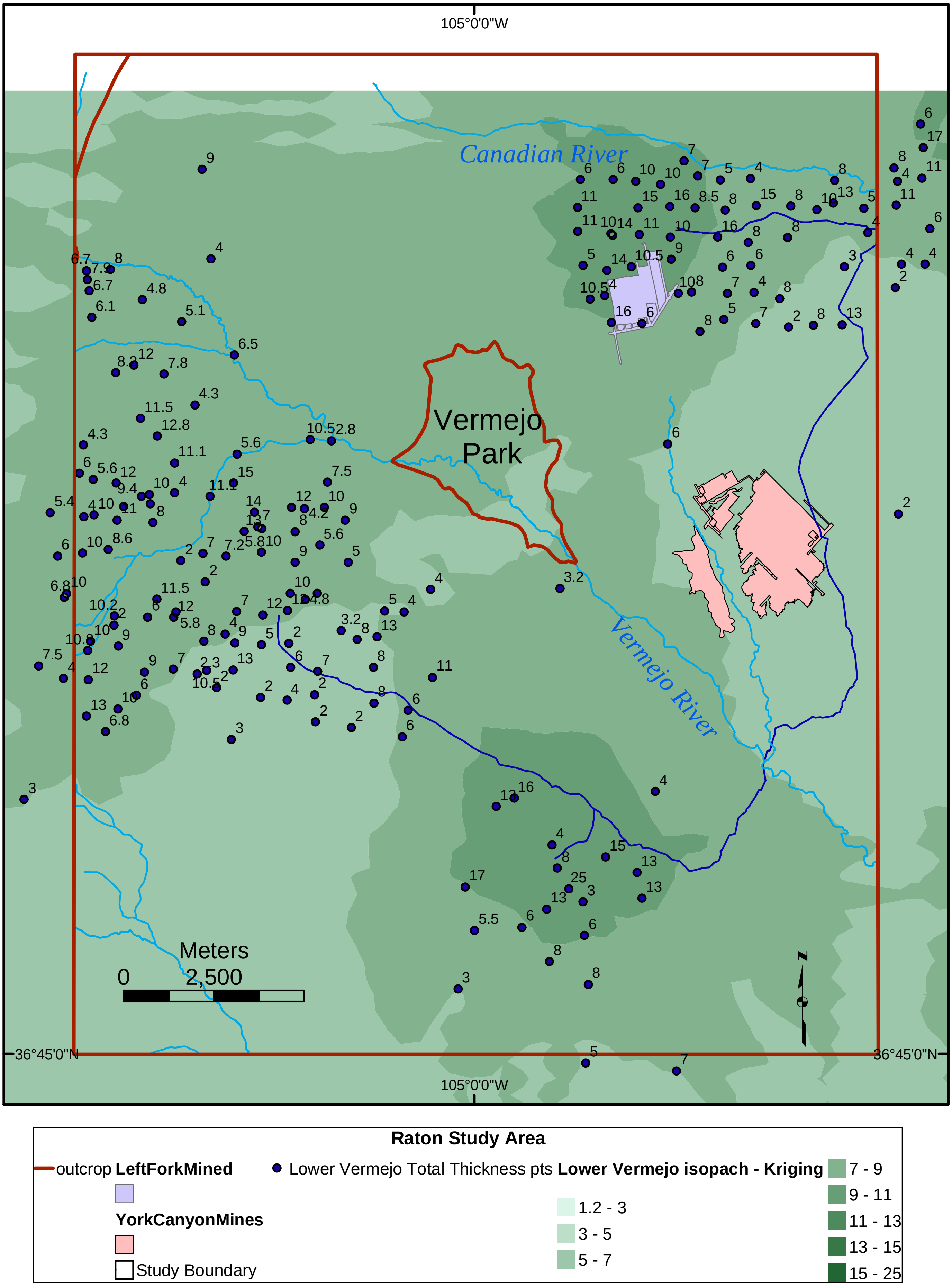


Figure 13. Lower Vermejo coal zone isopach in study area with total thickness data points. Generated by simple kriging method in ArcMap.

Coal Quality

The Vermejo and Raton Formations contain low-sulfur, moderate-ash coals of high-volatile A to B bituminous rank (American Society for Testing and Materials, 1981) . The quality of the coals within the two formations does not vary significantly (Hoffman, 1996a). Most of these coal seams are coking coals and many have been used as metallurgical coals in the past. The averages of the weighted-average as-received analyses for the Raton field are:

Table 1. Weighted averages for the Vermejo and Raton formation coals in the Raton coalfield, New Mexico.

	Vermejo Formation			Raton Formation					
	Average	**Std Dev.**	**No. of Samples**	**Average**	**Std Dev.**	**No. of Samples**	**Average[1]**	**Std Dev.[1]**	**No. of Samples[1]**
Moisture (%)	2.60	0.90	27	4.62	4.72	31	8.42	12.06	18
Ash (%)	14.41	3.55	27	14.35	6.73	35	18.77	10.46	20
Volatile matter (%)	34.72	2.31	27	34.67	3.38	35	33.76	5.14	20
Fixed carbon (%)	48.82	3.19	27	55.71	22.61	22	47.47	7.60	20
Sulfur (%)	0.71	0.11	27	0.54	0.14	36	0.51	0.17	21
Calorific value (Btu/lb)	11807	1747	27	12040	1972	33	12374	2789	18
MMBtu/ton	14029	2058	27	14034	1994	32	14959	3469	17
Lbs of Sulfur/MBtu	0.55	0.12	27	0.47	0.20	33	0.62	0.57	18

[1]Set of analyses is without data from Ellis (1936)

Many of the analyses from Ellis (1936) have very low moisture content making these data suspect. There are very few data points from other sources for the Vermejo Formation coals. About half of the Raton Formation analyses are from mine plans, exploration programs, and recent analyses from the U.S. Geological Survey. The weighted averages of these data are in the second set of columns under the Raton Formation header in the above table.

A detailed examination of the coal quality for each zone is not possible given the limited number of analyses. Many of the Vermejo samples are from the Dawson mines, near the mouth of the Vermejo River Canyon (Fig. 1). The coals mined here were in the lower Vermejo coal zone, often referred to in the literature as the Raton coal in the Vermejo Formation. A few Raton Formation analyses are identifiable by zone and some general differences are noted. The York Canyon coals appear to be higher in calorific value than the Left Fork zones (13499 Btu/lb vs. 11406 Btu/lb; 4 and 6 weighted samples, respectively). The total sulfur content of the Left Fork coals (0.42%) is lower than the York Canyon (0.50%), however, with the difference in Btu value the Lbs sulfur per million Btu (Lbs of Sulfur/MBtu) is the same (0.37) for both zones, which makes these coals within compliance values (< 0.6 lbs Sulfur/MBtu; Energy Information Administration, 1993).

Available Data

The database for the Raton coalfield study area is a subset of the data collected and entered by the New Mexico Bureau of Geology, NMBG&MR into the National Coal Resource Data System (NCRDS). The NMBG&MR has had cooperative grants with the U. S. Geological Survey (USGS) to enter data into the NCRDS for the past 26 years. Much of these data are from coal mine plans submitted to the Mining and Minerals Division, New Mexico Energy, Minerals, and Natural Resources Department. A majority of the drill hole data came from scout card information, PI/Dwights, Drilling Wire drilling progress reports, and information from electric and geophysical logs stored in the NM Bureau of Geology subsurface library. Many of these data points are in a coalbed methane database for previous investigations (Hoffman and Brister, 2003, Brister, Hoffman, and Engler, 2004). After this project began, additional drill holes were entered into the database, particularly oil and gas logs from the subsurface library.

For the four-quadrangle study area, 435 data points were evaluated. The number of drill holes used in this study is greater than previous evaluations because of the greater drilling activity by oil and gas companies for coalbed methane and the proximity of three inactive mines. The data is clustered (see Figs. 9-13) because of the kind of data sources; much of the mine plan data is near the crop line and the oil and gas logs are in the deeper coal areas.

Coal availability studies in New Mexico

Detailed methodology

Correlation of the coal zones was a challenge in this study area, in part because of the discontinuous nature and the available data was either near surface or deep coalbed methane wells. To correlate the formations and coals zones in these two distinct data sets, a datum that could be used for all points was needed. The coalbed methane wells allowed for contact picks between the Raton and Vermejo formations and the Vermejo Formation-Trinidad Sandstone contact. Using the elevation tops of the Trinidad Sandstone from these well points, plotting the remaining data points over a georeferenced image of Scott and Pillmore's (1993) structure contour map, along with the Trinidad structure contour layers from Pillmore (2003a,b) in ArcMap, the Trinidad elevation tops for remaining data could be estimated. The structure contours on top of the Trinidad using the elevations picks from the drill hole data set are seen in Figure 14. These estimated picks along with the coal picks from geophysical logs and mine plan cross sections as well as other formational data were imported into Rockworks 2002 from two Access databases. By making multiple cross sections throughout the study area using the Trinidad as a datum, the Vermejo-Raton contact could be projected from the coalbed methane wells to the mine data and the coal zone picks could be correlated throughout the data set. This dataset was exported from Rockworks to an Access database (RatonAvail.mdb) for the final resource evaluations and analyses.

Coals in the Vermejo and Raton formations are typically bituminous in rank, specifically high volatile A bituminous because of the thermal influence of the Spanish Peaks in Colorado. Bituminous coal resource calculations have a minimum thickness of 14 inches and an average weight per unit volume of 1800 tons/acre ft (Wood, et al, 1983). Although a 10:1 stripping ratio is included in the resource calculations program, it is not practical because of the rugged topography of this area. The following are the resource criteria used in this study:

Thickness (ft)	Depth (ft)	Reliability
1.2–3.5	0–250	Measured (1/4 mi)
3.5–7	250–500	Indicated (1/4–3/4 mi)
7–14	500–1000	Inferred (3/4–3 mi)
>14	>1000	

Reliability categories are limited to measured, indicated and inferred. The hypothetical reliability category in this study area is not practical because of the lenticular nature of these coals and the inferred category is uncertain in this study area.

Line data for the Vermejo Formation was digitized from the New Mexico State Geologic map (1:500,000 scale) for the outcrop mask. Because both the Vermejo Formation and Trinidad Sandstone are thin, they are represented as one unit on the map. To generate grid files in Arc Info® data files with elevations for

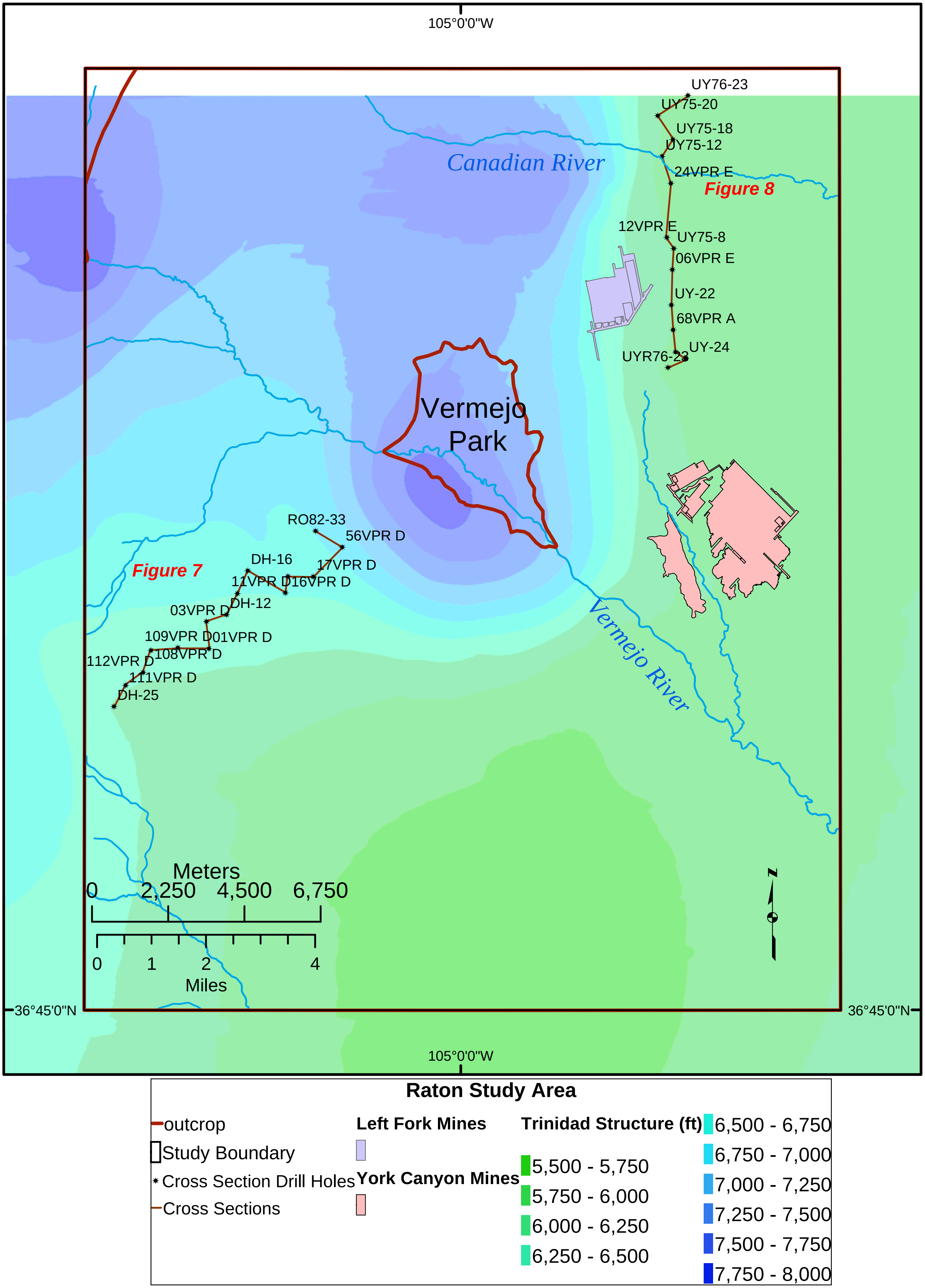


Figure 14. Structure contour on top of Trinidad Sandstone with cross section locations for Figures 7 and 8.

tops of coal zones are overlain with a digital elevation model (DEM) grid from the National Elevation Data set. This combined layer generates the overburden maps for each zone. This overburden layer creates the zero depth line, or crop line for each zone. Figures 15-19 illustrate the resulting overburden maps with the depth categories for the study area quadrangles.

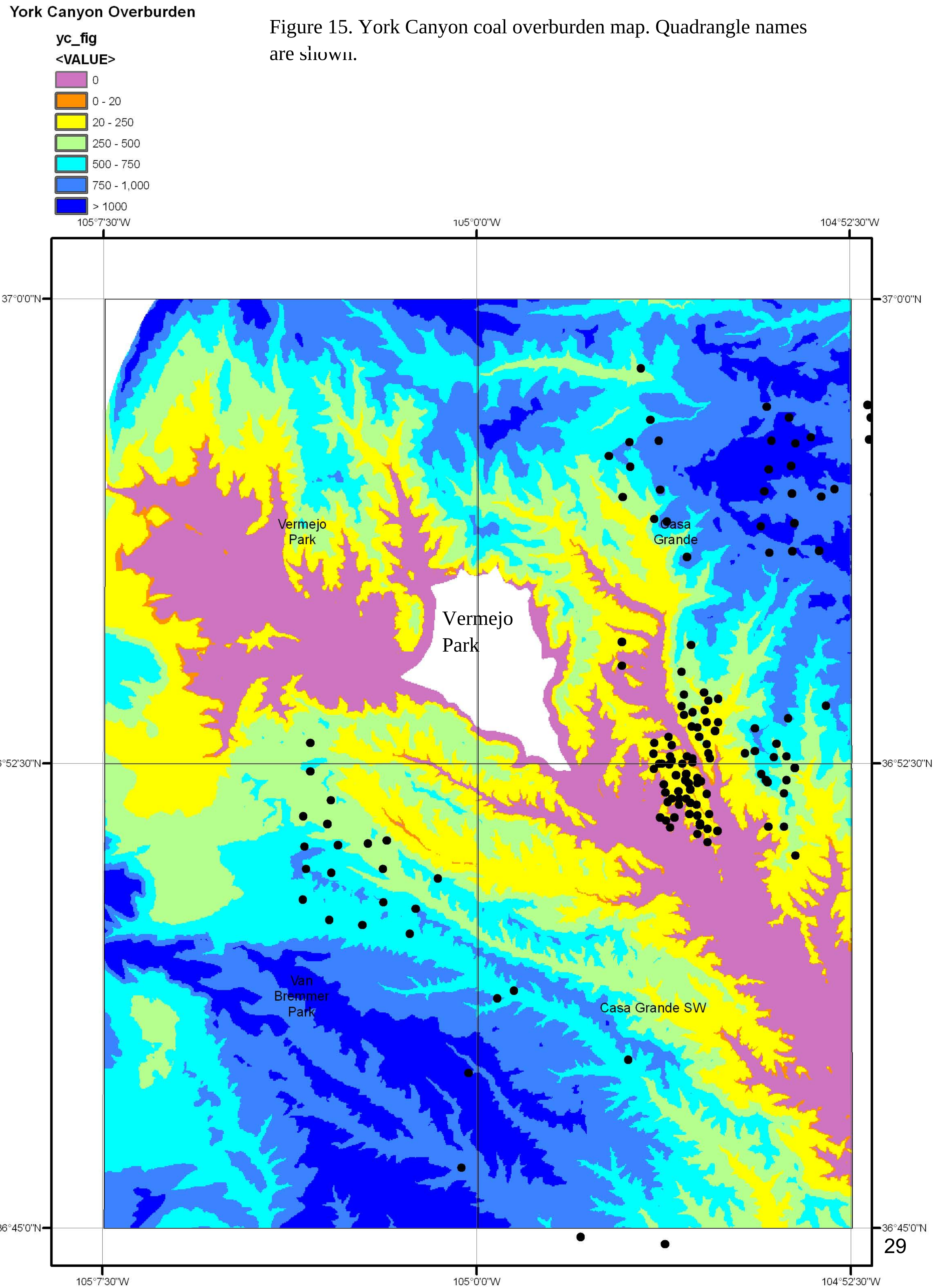
From the original database (Ratonavail.mdb) created for this study, subset files were created for each zone with latitude, longitude, total thickness, and point identification. These files included data from the four-quadrangle study area as well as the surrounding quadrangles. By using data from the surrounding quadrangles, reliability categories that overlap into the study area are included in the resource calculations. From these data, coal thickness grids and polygons files for the reliability categories were produced. The reliability polygons were gridded and each cell (10 m^2) assigned a thickness by applying the thickness grid. By overlaying the overburden layer on the reliability and thickness layers (calculated in m^2 and converted to acres) volumes for each thickness, depth, and reliability category were determined in the four-quadrangle area. Volumes (acre-ft) were multiplied by 1800 tons/acre ft to result in the original resource tonnage for each zone.

The surface mined-out area and the river valleys land-use restrictions were digitized from the 7.5-minute quadrangles TIFF images. Mine maps from mine plans were scanned and georeferenced. From these images, the mined out areas were digitized in ArcMap. Road and river coverages were acquired from the New Mexico Resource Geographic Information System (RGIS) web site. These county coverages were clipped to the study area boundary. Technological restriction masks were applied to the remaining resource layers for each zone. Appropriate buffers, as discussed in the following section, were assigned to the land-use restrictions. These restriction layers were consecutively overlain on the combined overburden, reliability, and thickness layers after the technical and mined out restrictions had been applied to calculate the resource tonnage removed by each restriction.

Overview of restrictions

The following are the restrictions considered for this area. The buffers applied to these restrictions adhere to the New Mexico Coal Surface Mining Regulations 19.8.2.200 NMAC - Rn 19 NMAC 8.2.2.200, 9-

Figure 15. York Canyon coal overburden map. Quadrangle names are shown.



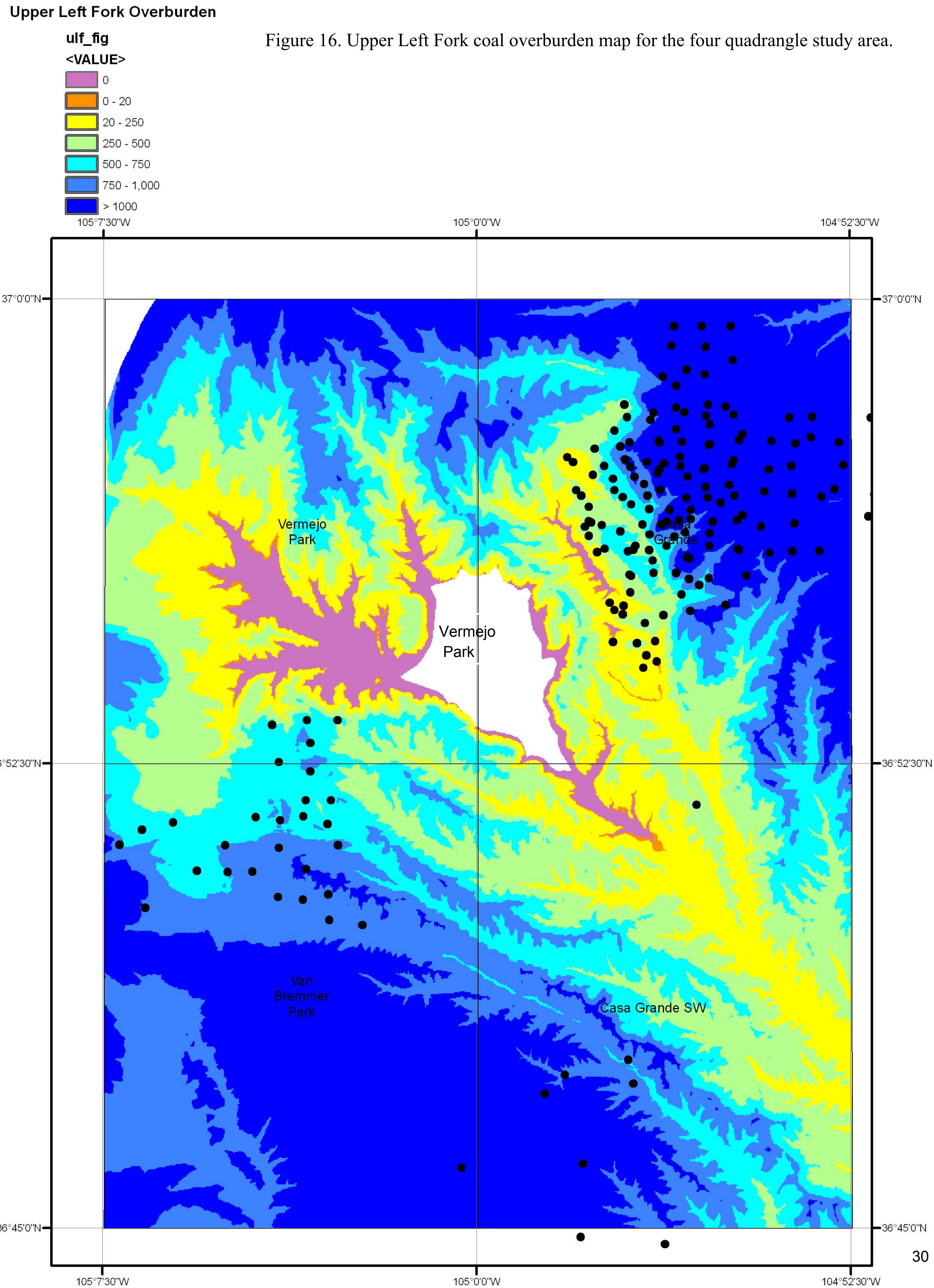
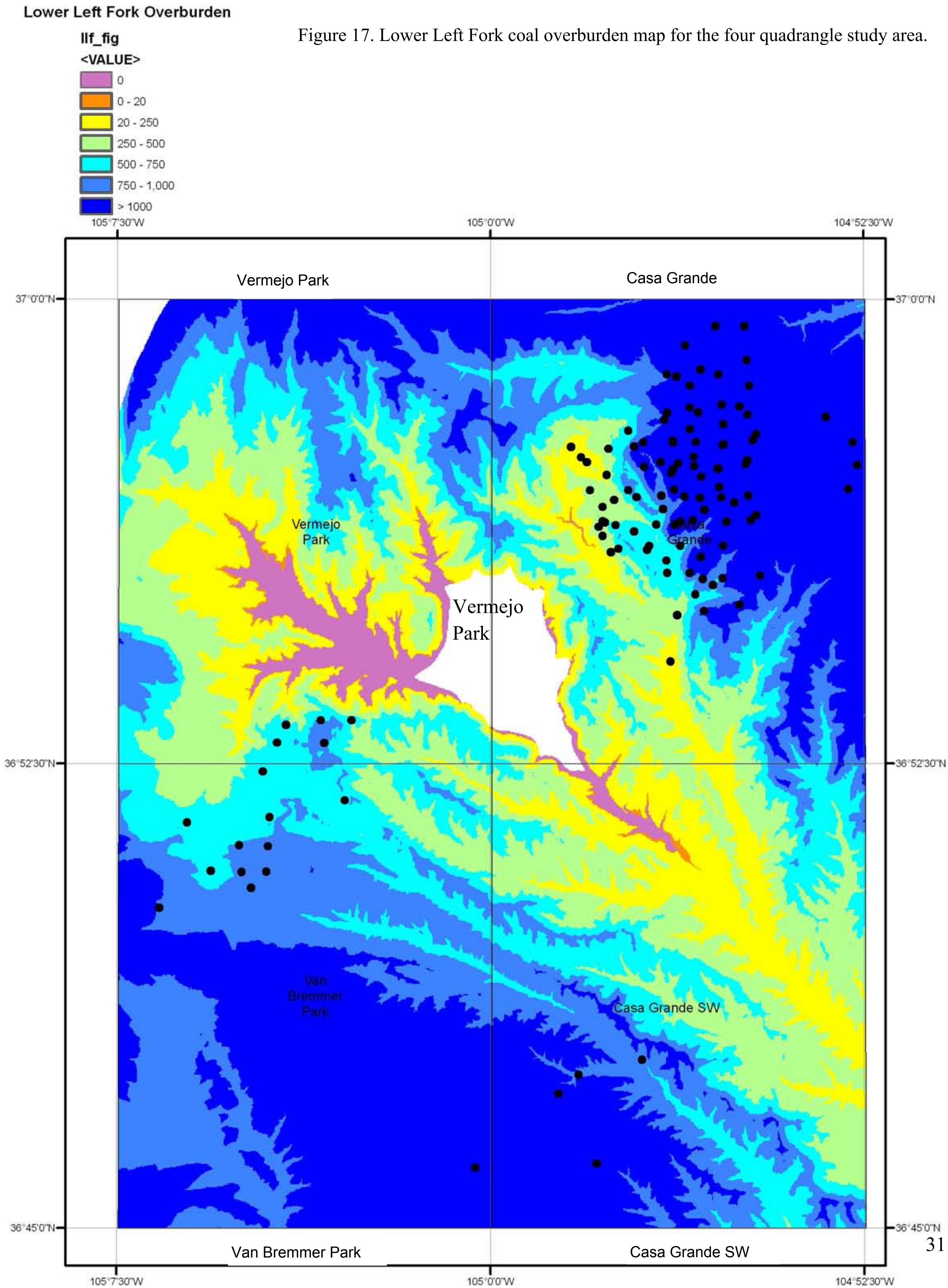


Figure 16. Upper Left Fork coal overburden map for the four quadrangle study area.

Figure 17. Lower Left Fork coal overburden map for the four quadrangle study area.



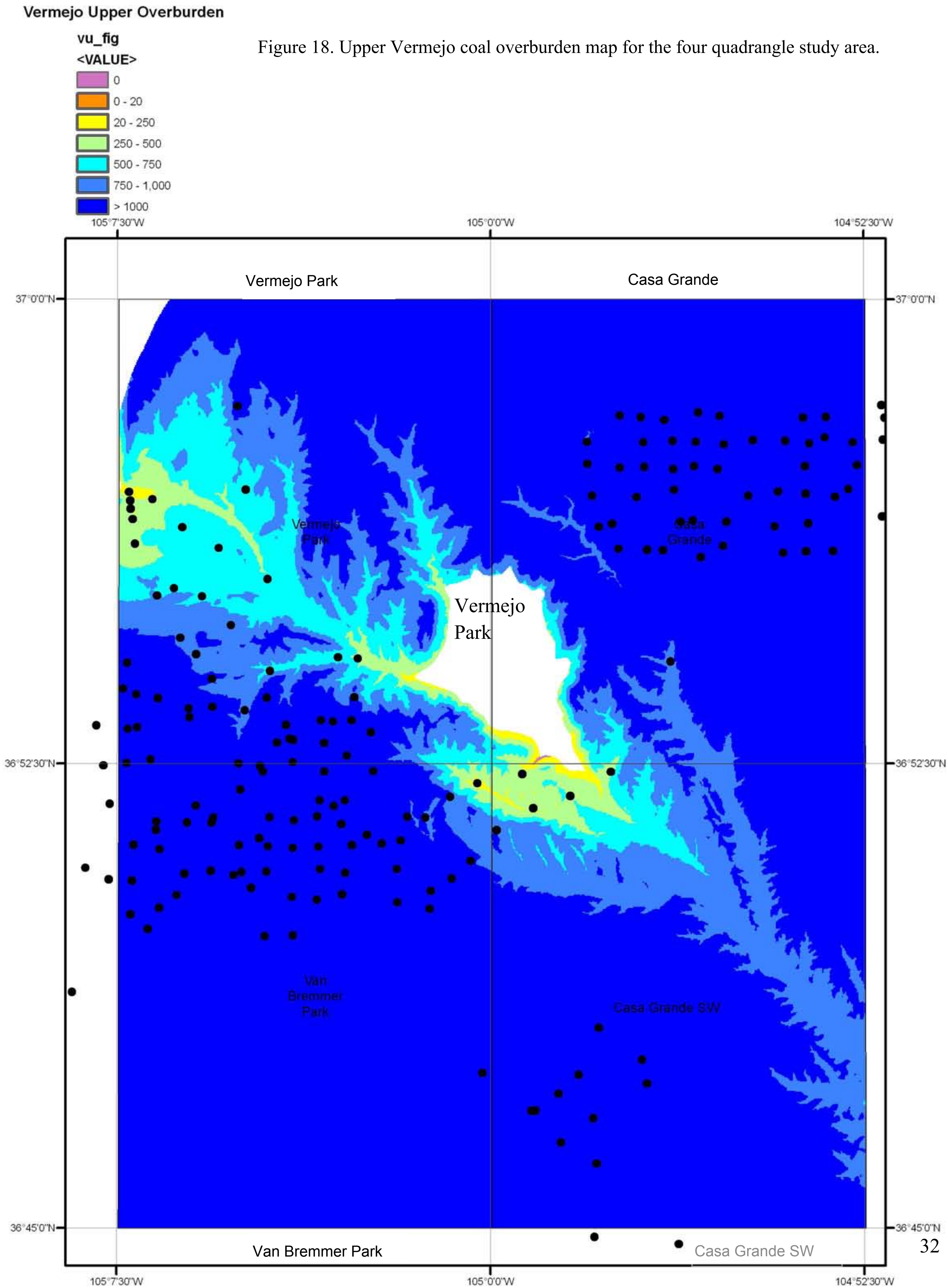
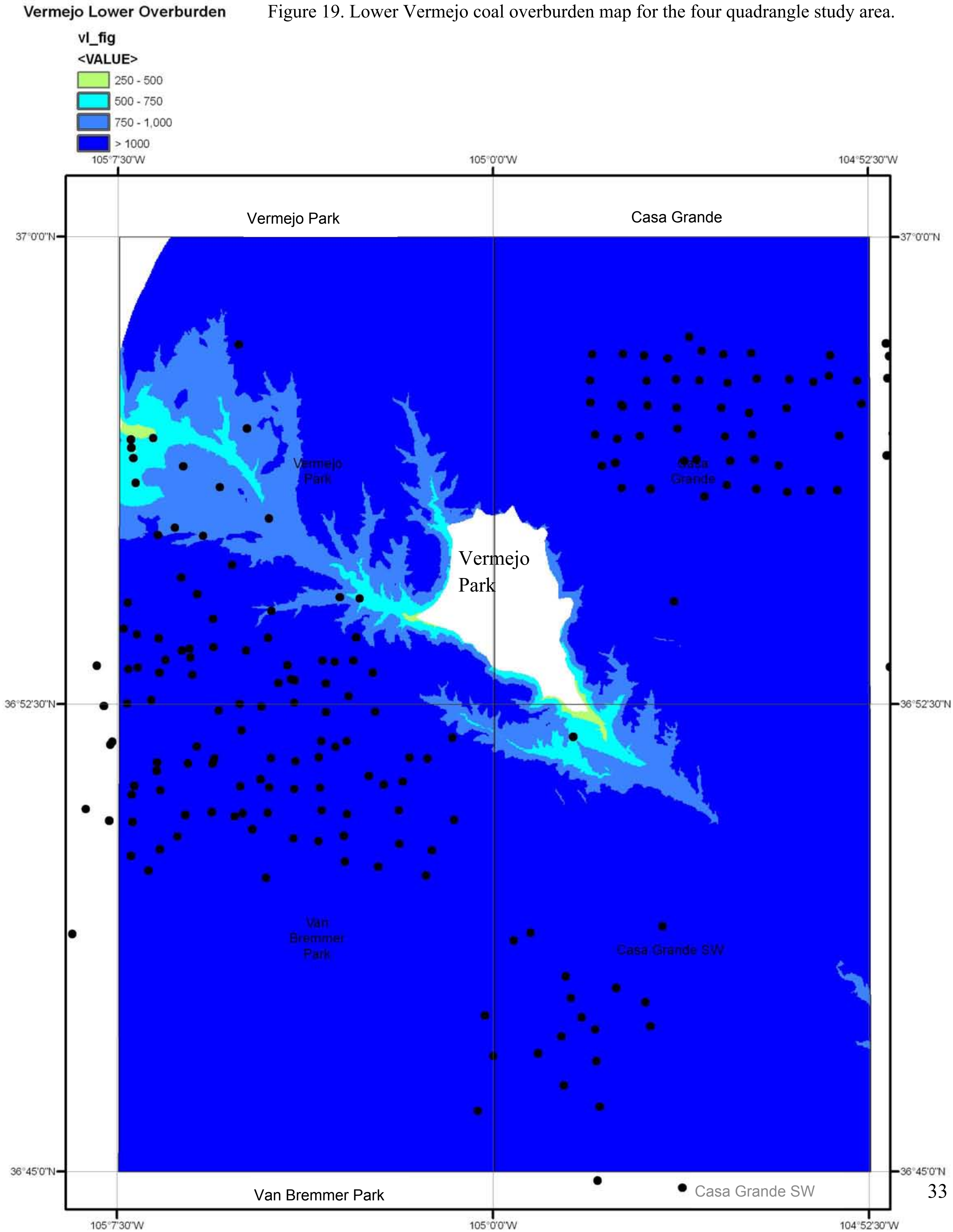


Figure 18. Upper Vermejo coal overburden map for the four quadrangle study area.

Figure 19. Lower Vermejo coal overburden map for the four quadrangle study area.



29-2000 (Energy, Minerals, and Natural Resources Department, Mining and Minerals Division, 2000) which follow the Federal regulations. There is no specified buffer for oil and gas wells; a large portion of the data set is from cbm wells and this restriction will be dealt with in a later section of the report.

Restrictions	**Buffer**
Major roads, railroads	100 ft on either side
El Paso Natural Gas Pipeline	50 ft on either side
Vermejo and Canadian Rivers	100 ft
Oil and Gas Wells	no buffer applied

Figure 20 illustrates these restrictions along with the Vermejo/Trinidad out crop for the study area.

Technological restrictions

Technical parameters that influence the resource of this study are:

Coal too close to the surface. Remove coal with less than 20 ft of overburden from the remaining resource estimate. Coal with less than 20 ft of overburden is removed, as it can be weathered and not usable for energy production.

Coal too thin at depth. Coal beds from 1.2 ft to 3.5 ft thick are too thin for mining at depths greater than 250 ft. The original resources include these thin coals in all depth category calculations but they are removed under the technical restrictions.

Land-use restrictions

Restrictions to mining in the project area are dominated by previous mining, the coalbed methane wells and pipeline. Because many of the resource data points are coalbed methane wells, a buffer layer for these wells was not applied to the resource. Instead, a discussion of how coalbed methane wells intersecting with underground coal mining have been treated follows. Figure 20 shows the restrictions and land ownership in the study area.

Raton Coalfield Study Area Resources

Total original resources in the Vermejo Formation upper and lower coal zones are 2.4 billion st in the study area. The majority of these resources are at depths greater than 500 ft and the lower Vermejo coal has the greater resource (1.39 billion st; Tables 2, 3). Total original resources for the Raton Formation coals

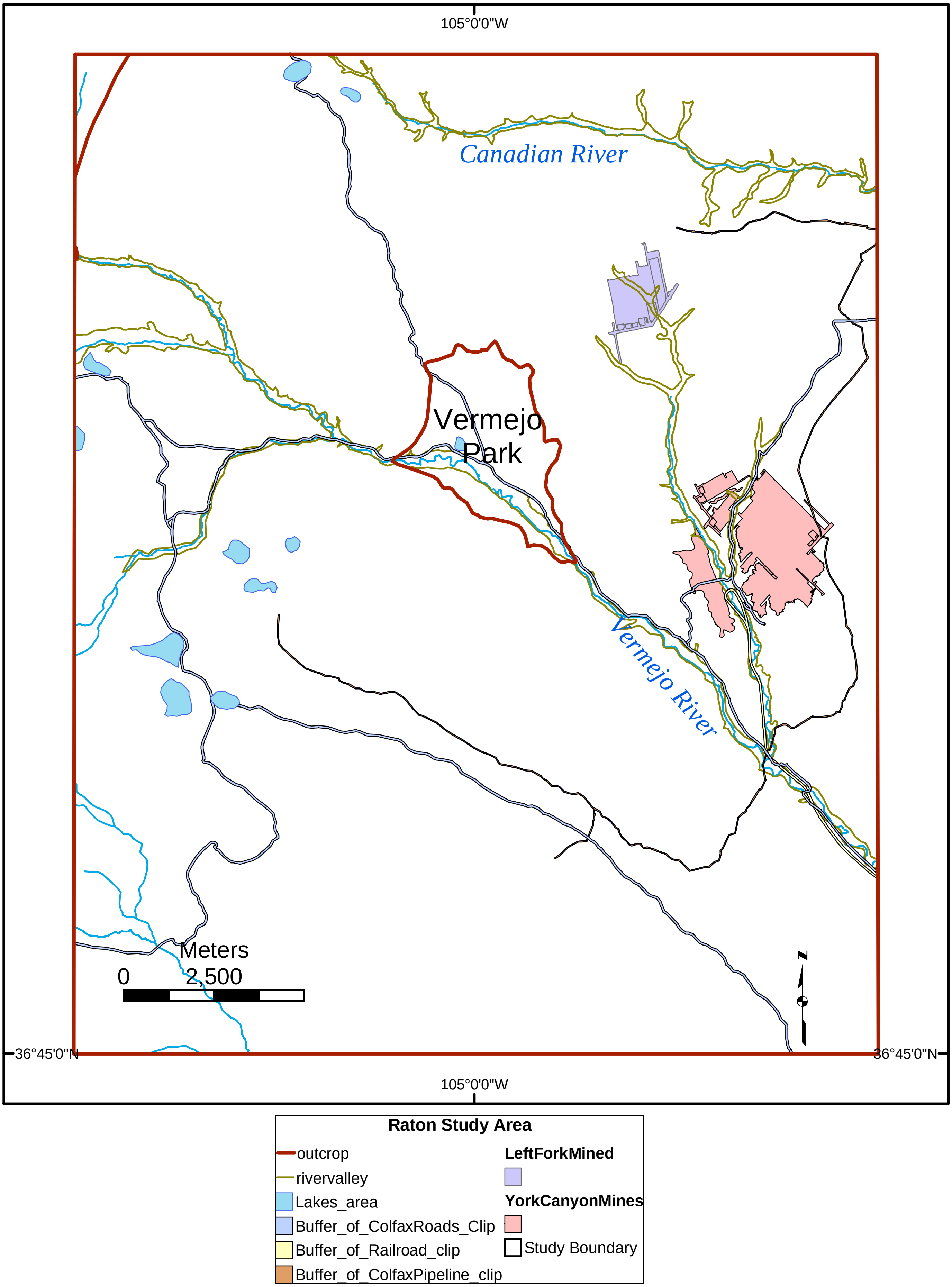


Figure 20. Restrictions applied to original resources in Raton coalfield study area.

Table 2. Summary of surface and underground coal resources and available coal by zone for the Raton coal field study area, New Mexico reported in millions of st.

			Likely Restrictions to mining									
Depth Categories	**Coal Zone**	**Original Resources**	**Technological Restrictions**	**Mined Out**	**Railroad[1]**	**Roads[1]**	**Hydrology: Canadian and Vermejo Rivers, Ponds**	**Pipelines & Powerlines**	**Overlap of Railroad and roads restriction with Hydrology**	**Total Restrictions**	**Available**	**%Available**
Surface (0-250 ft)-Original, (20-250) for remaining	York Canyon	200.64	14.91	14.11	0.01	1.59	4.11	0.43	1.60	33.56	167.08	83%
	Upper Left Fork	117.42	4.48	0.05	1.13	0.35	10.24	0.06	1.49	14.84	102.59	87%
	Lower Left Fork	39.79	1.44	0.00	0.05	1.88	2.13	0.01	1.94	3.57	36.21	91%
	Upper Vermejo Coal	5.52	0.04	0.00	0.00	0.23	0.74	0.00	0.23	0.78	4.74	86%
	Lower Vermejo Coal	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
	Overall	*363*	*21*	*14*	*1*	*4*	*17*	*1*	*5*	*53*	*311*	85%
Underground (250-500 ft)	York Canyon	182.86	45.60	8.46	0.00	0.62	5.76	0.12	0.62	59.93	122.93	67%
	Upper Left Fork	152.64	40.27	2.96	0.00	0.00	2.79	0.45	0.00	46.46	106.17	70%
	Lower Left Fork	73.31	51.41	0.51	0.00	0.62	0.04	0.00	0.62	51.96	21.35	29%
	Upper Vermejo Coal	37.03	3.76	0.00	0.00	0.28	3.51	0.00	0.28	7.27	29.76	80%
	Lower Vermejo Coal	2.02	0.82	0.00	0.00	0.00	0.44	0.00	0.00	1.26	0.75	37%
	Overall	448	142	*12*	*0*	*2*	*13*	*1*	*2*	*167*	*281*	63%
Underground (500 ft->1000 ft)	York Canyon	434.94	93.69	6.77	0.00	2.11	3.48	1.17	2.11	105.11	329.83	76%
	Upper Left Fork	451.08	169.41	4.40	0.00	0.00	8.00	0.99	0.00	182.80	268.28	59%
	Lower Left Fork	350.85	162.81	0.91	0.00	0.87	8.46	0.88	0.87	173.05	177.80	51%
	Upper Vermejo Coal	977.45	105.98	0.00	0.64	10.57	32.25	2.07	11.22	140.29	837.16	86%
	Lower Vermejo Coal	1,388.04	76.01	0.00	0.00	12.69	51.26	5.34	12.69	132.61	1,255.43	90%
	Overall	*3,602*	*608*	*12*	*1*	*26*	*103*	*10*	*27*	*734*	*2,868*	80%

Railroad and Road applied with mined out and technological restrictions - these areas overlap with each other and with river mask..

Table 3. Summary of coal resources and available coal by zone for the Raton coal field study area, New Mexico, reported in millions of st.

		Likely Restrictions to mining									
Coal Zone	**Original Resources**	**Technological Restrictions**	**Mined Out**	**Hydrology**	**Railroads**	**Roads**	**Pipelines & Powerlines**	**Total Restrictions**	**Total Land use restrictions**	**Available Resources**	**%Available**
York Canyon	818.44	154.19	29.33	13.36	0.01	4.32	1.72	198.60	44.41	619.83	76%
Upper Left Fork	721.14	214.15	7.41	21.03	1.14	0.35	1.50	244.10	29.95	477.04	66%
Lower Left Fork	463.94	215.65	1.42	10.62	0.05	3.37	0.89	228.58	12.93	235.36	51%
Total Raton	*2,004*	*584*	*38*	*45*	*1*	*8*	*4*	*671*	*87*	*1,332*	66%
Upper Vermejo Coal	1,020.00	109.78	0.00	36.50	0.64	11.08	2.07	148.34	38.57	871.66	85%
Lower Vermejo Coal	1,390.06	76.83	0.00	51.70	0.00	12.69	5.34	133.88	57.04	1,256.18	90%
Total Vermejo	*2,410*	*187*	*0*	*88*	*1*	*24*	*7*	*282*	*96*	*2,128*	88%
Overall	***4,414***	***771***	***38***	***133***	***2***	***32***	***12***	***954***	***183***	***3,460***	**78%**

evaluated are 2 billion st. York Canyon and Upper Left Fork have significant resources in all of the depth categories; however the Lower Left Fork resources are more concentrated in the greater than 500 ft category. Technological restrictions make up the largest percentage of resource from both Raton (85.5%; Fig. 21) and Vermejo formation (60.9%, Fig. 22) coals. The largest technological restriction percentage is for thin coals at depths greater than 250 ft. Mined out areas remove resources from the York Canyon coal at surface depths and for underground resources from the Upper Left Fork coal zone mainly at underground depths greater than 250 ft. Hydrology, which includes the Vermejo and Canadian rivers and the lakes/ponds in the area, are the next largest restriction to the coal resources. The Vermejo coals show the largest impact from hydrology with the percentage greatest for the lower Vermejo coals (35.3%). Farming does not take place along the river valleys; however, the rail spur and some of the major roads follow these valleys because it is the easiest way to access the region. Figure 20 shows the restrictions with the buffers applied. The following chart (Fig. 23) shows the categorization of resources by coal zone and totals for the Vermejo and Raton formations. The Raton Formation coal zones have the greatest depletion of resources from technological and mining. The available resources for the Raton Formation coal zones are 1.3 billion st; the Vermejo Formation coals have 2.1 billion st of available resources.

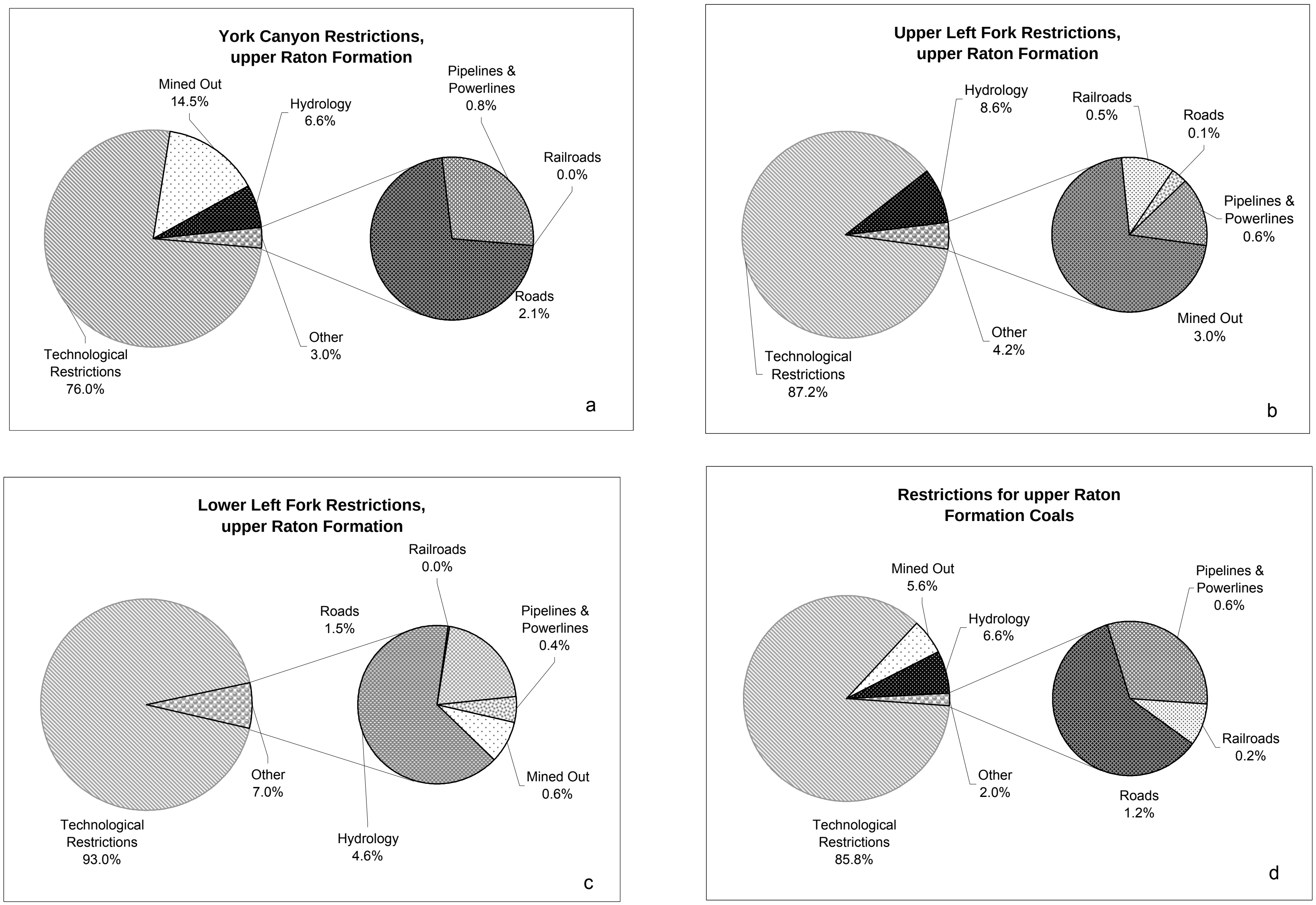


Figure 21a-d. Percentages of resources removed by technologial and land-use restrictions by zone and formation, Raton Formation coals

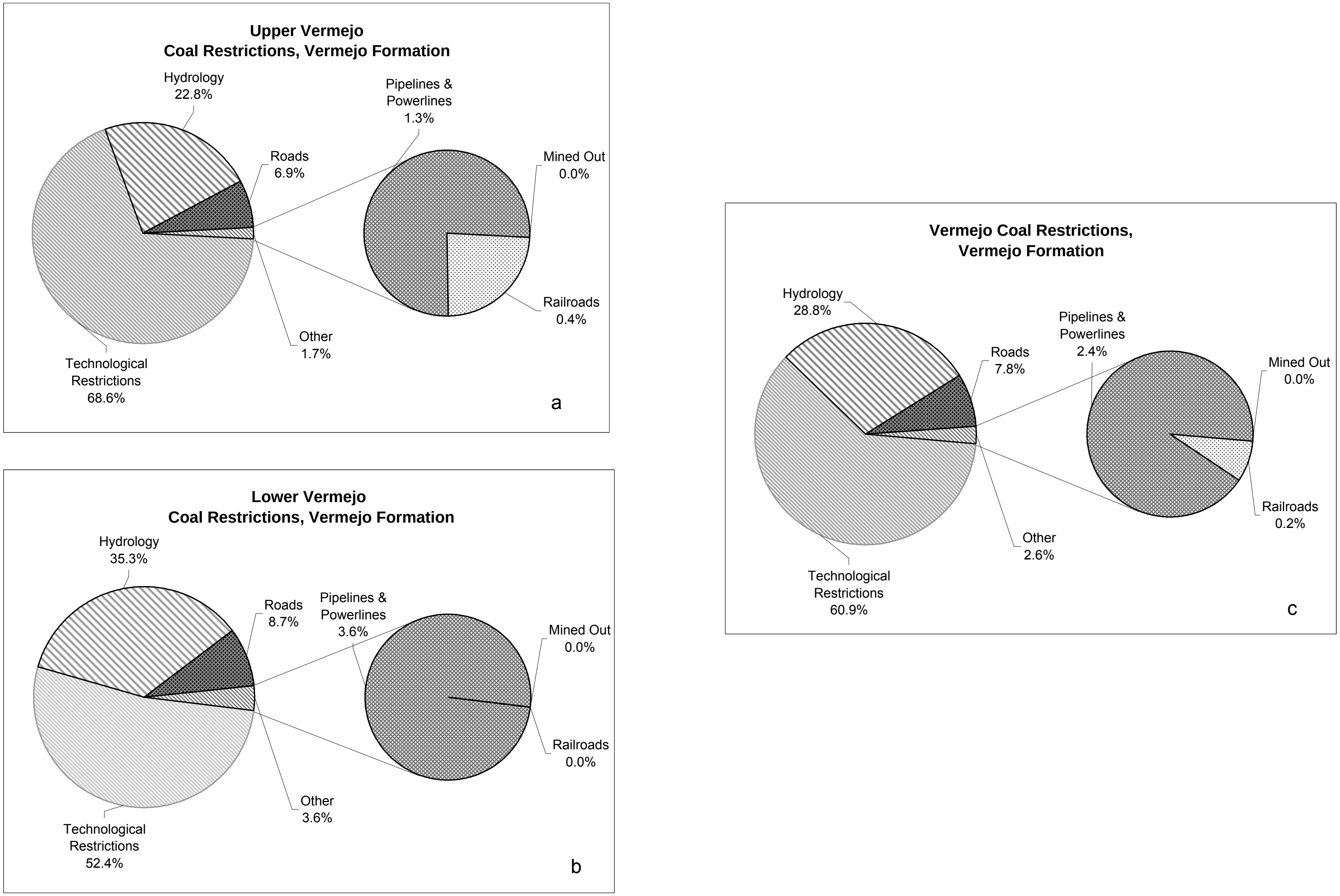


Figure 22a-c.Percentages of resources removed by technologial and land-use restrictions by zone and formation, Vermejo Formation coals.

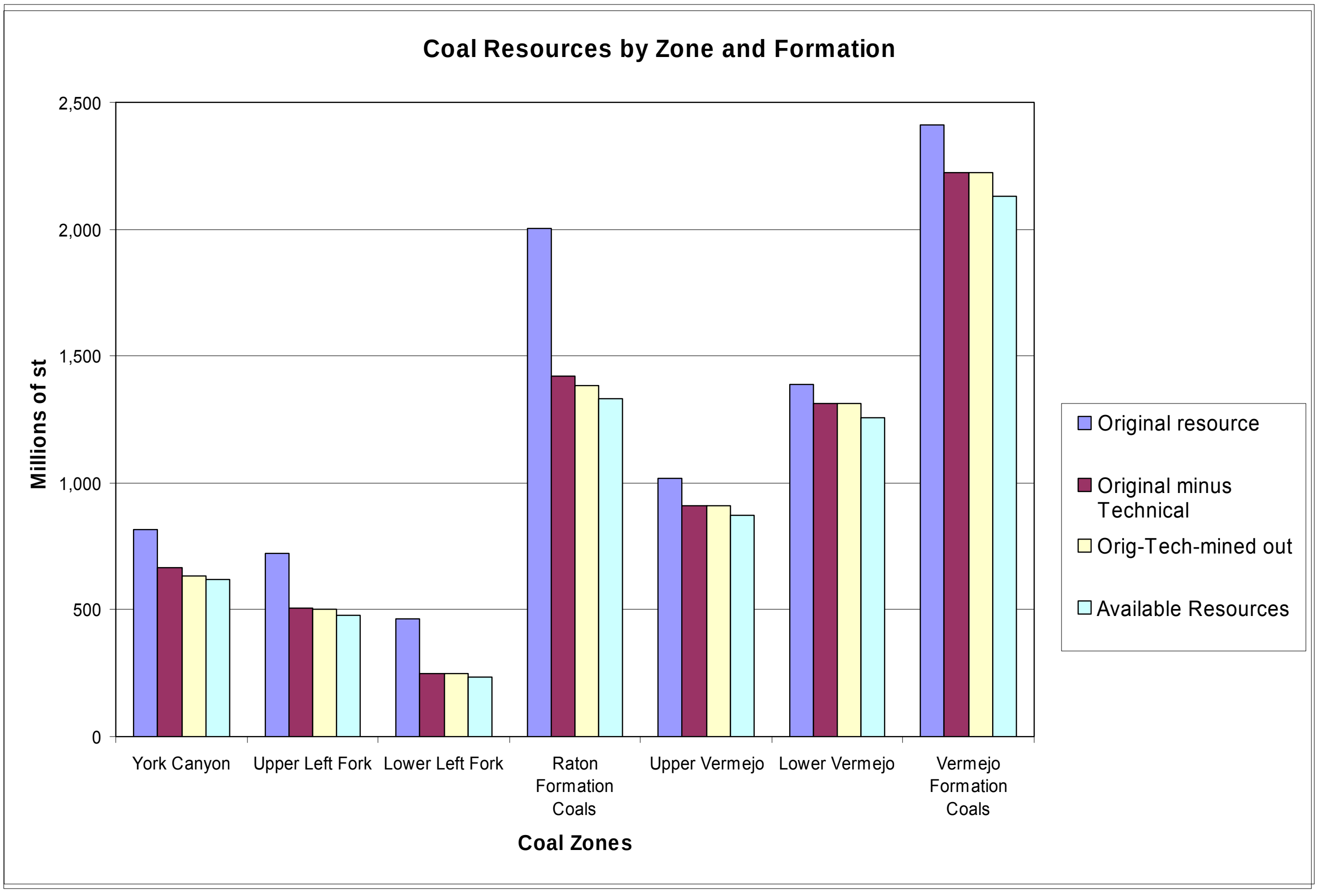


Figure 23. Raton and Vermejo formations coal zone resources, Raton coalfield study area.

Restrictions with potential for mitigation

Mitigation in this area is limited for some of the infrastructure because of the rugged topography; many of the main roads and rail line follow the river valleys. Agreements with the coalbed methane producer would be necessary for any mining to take place. The coalbed methane wells were not buffered as a restriction because they are a major source of data. Figure 24 shows the producing wells as of April 2005 within the study area. Figure 25 shows production for Colfax County, New Mexico through April 2005.Much of the present production is coming from the area south of Vermejo Park, from Vermejo Formaton coals.

Mitigation in an area where there are both coal mining and oil and gas leases is taking place now in the San Juan basin. Recently, the San Juan Mine began underground mining in an area of active wells and coalbed methane leases. BHP Billiton/ San Juan Coal are resolving the issues of mining through this area by working with the oil and gas lessees. If a deep well exists in the path of mining, the operator will pull the hardware and cement the hole. Once the location is mined through, negotiation to redrill and compensation for lost production would be determined. If the area has no wells but has a lease, the mine will capture the

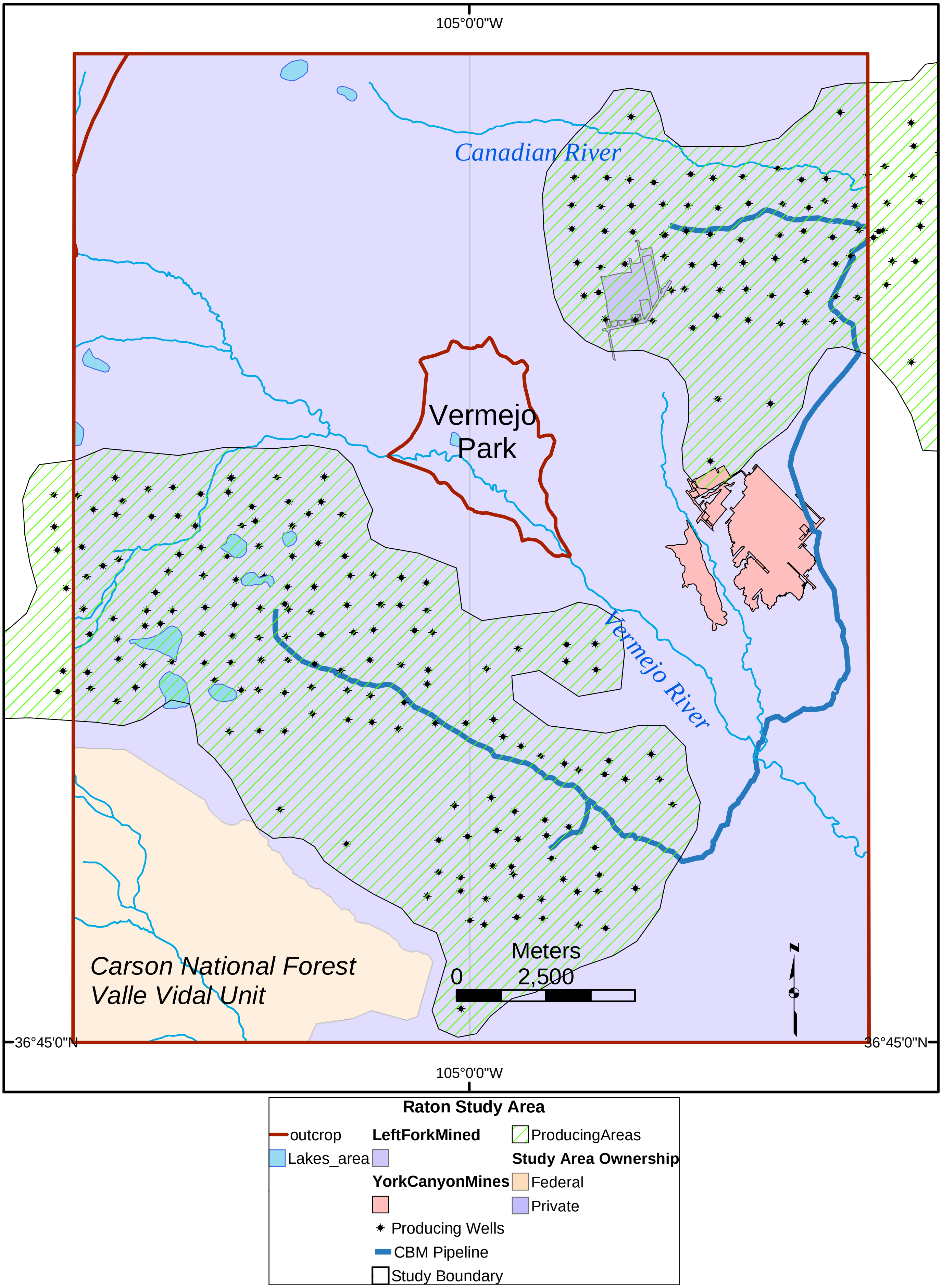


Figure 24. Coalbed methane producing areas as of April 2005 and land ownership in the Raton coalfield study area.

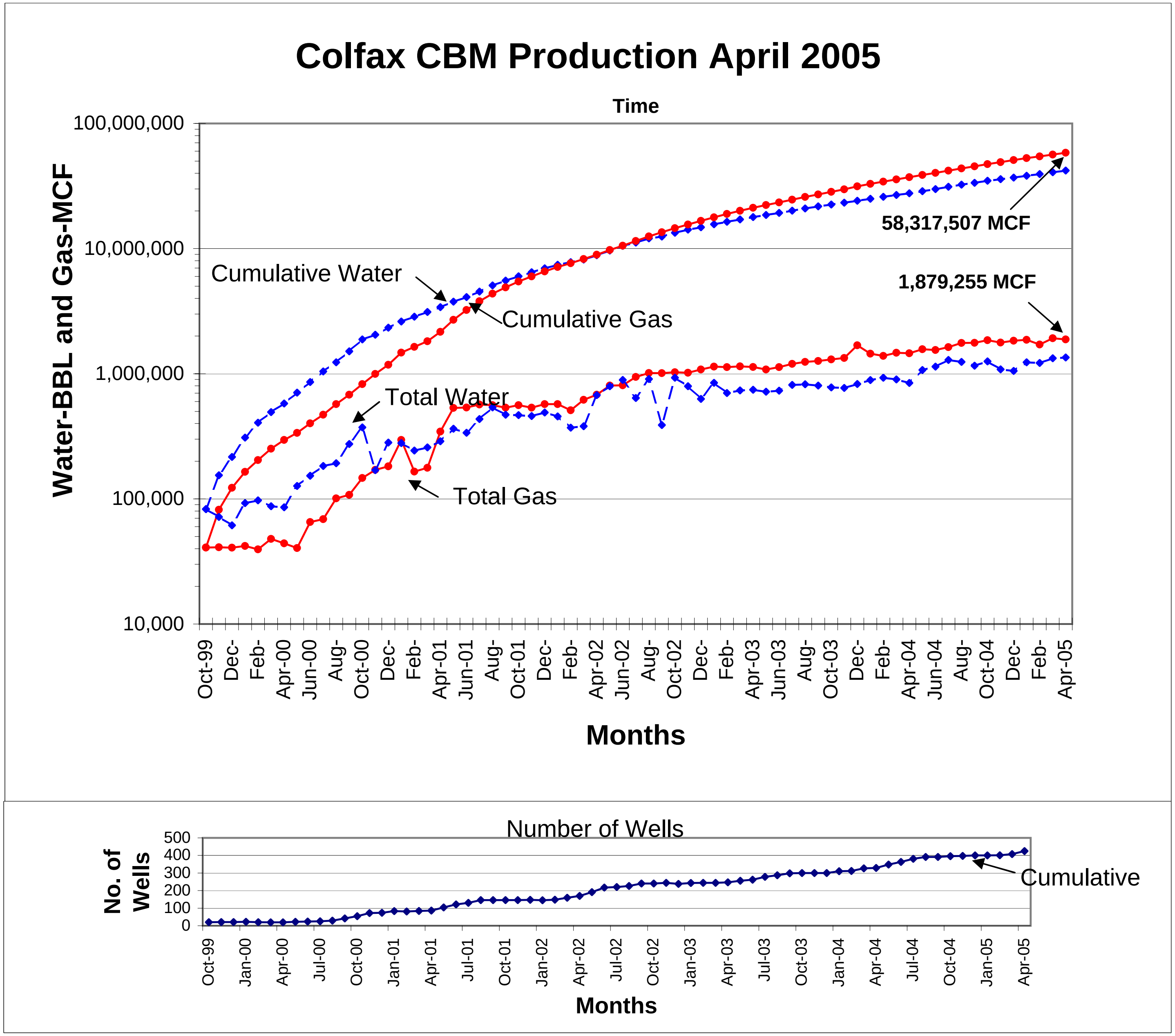


Figure 25. Coalbed methane and water production for Colfax County, New Mexico through April 2005. Data include cumulative production, monthly production and cumulative number of active wells. Data from New Mexico Oil Conservation Division.

coalbed methane and pass it along to the operator. One problem that is occurring is that as an area is mined the coalbed methane becomes diluted over time and cannot be captured. Again, a compensation for lost production has to be determined (Jim Luther, San Juan mine, personal communication, September 2005). This situation takes a great deal of cooperation on both the mine and coalbed methane operators.

Comparison with other resource studies

Pillmore (1991) calculated demonstrated coal resources for coals greater than 2.5 ft thick in defined mining districts. Portions of the Upper York, Castle Rock and all the York Canyon and Rosado districts are within the study area of this project (See Fig.1). Following are the districts and estimated resources from Pillmore (1991):

District	Approximate area (acres)	Coal bed or zone	Average thickness (ft)	Demonstrated resources (million st)
York Canyon	5,500	York Canyon	5.0	6
Upper York	9,375	Upper Left Fork Lower Left Fork	6.0 4.0	94 39
Rosado	9,500	Upper Vermejo coal Lower Vermejo coal	5.5 4.0	102 25
Castle Rock	25,600	Upper Vermejo coal Lower Vermejo coal	5.5 6.0	250 270
Totals				*786*

Demonstrated resources from this study using 3.5 ft or greater coal thickness and depths from >20 ft to >1000 ft:

Coal bed or zone	Average Thickness (total coal in ft)	Demonstrated resources (million st)	Difference in million st (present study – Pillmore)
York Canyon	5.45	210	204
Upper Left Fork	4.87	193	99
Lower Left Fork	4.11	117	78
Upper Vermejo coal	5.28	302	-50
Lower Vermejo coal	7.96	343	48
Total		*1,165*	*379*

The study area covers 238 sq mi or 152,320 acres. Although not all of the area is covered by the spheres of influence constructed by the resource calculations (see Appendix 2), the study area is in general a much larger area than the districts defined by Pillmore. The total demonstrated resources are greater for this study, mainly because of the number of coalbed methane wells that encountered both the Raton and Vermejo Formations. The one exception is the upper Vermejo coal, which has a greater total (352 million st) in the Pillmore study. Probably the difference in estimates is the Castle Rock area extends west of the study area. In addition, there are fewer data points along the western edge of the study area.

Summary

The Vermejo and Raton formations contain low-sulfur, moderate-ash coals of high-volatile A to B bituminous rank. These formations appear to fall within the compliance coal standards of less than 0.6 lbs sulfur/MBtu. More quality analyses are needed be sure of the sulfur quality because many of the analyses were done in the late 1930s–early 1940s and in areas that have been mined out.

Two coal zones are recognized in the Vermejo Formation at the top and base of this unit. Within the Raton Formation, the York Canyon and Upper and Lower Left Fork coals are recognized in the upper Raton coal sequence. Some coals in the lower Raton coal-bearing sequence were picked on logs in the data set, but there are not enough points for resource calculations. The York Canyon and Upper Left Fork coal zones have the thickest average for individual seams and are concentrated in the area between the Vermejo and Canadian rivers. The upper Vermejo and York Canyon coal zones have the greatest total coal averages.

Original resources for the study area are 4.4 billion st with the majority of the resource at depths greater than 1,000 ft. Because many of the data points are from coalbed methane wells that reach depths of 2,000 ft the data is skewed towards deeper resources. In addition, these wells have casing to 300 ft; therefore, many of the upper Raton coals are not recognizable. Mining removes 38 million st and technological restrictions remove 771 million st from the original resource. Technological restrictions are the largest factor in calculating available resources because many of the coals fall within the 1.2-3.5 ft thickness category. Percentages for original resources available after removal of restrictions are York Canyon 76%, Upper Left Fork 66%, Lower Left Fork 51%, upper Vermejo coal 84%, and lower Vermejo coal 89%. Much of the

Vermejo coal resource is very deep (500-1000+ ft) however the upper Vermejo coals have a significant resource in the (29.76 million st) in the 250-500 ft depth category. The Raton coals in this area have the greatest potential for surface and shallow (250-500 ft) underground mining.

Several factors may limit the mining in this area:

- Coalbed methane (cbm) development must be considered because of the overlap of the resources and an agreement with the cbm lessees would be needed.
- Most of the area has private ownership, mainly Vermejo Park Ranch and Carson National Forest (Valle Vidal) with holdings the southeast corner of the study area.
- This is a prime recreational area particularly for hunting and fishing and the Philmont Scout Ranch, south of the study area, uses some of the National Forest Service land near Vermejo Park for scouting activities in the summer months.
- Surface mining is difficult in this rugged topography and much of this resource includes multiple thin coals, which are difficult and perhaps uneconomic to mine by underground methods.

Acknowledgement

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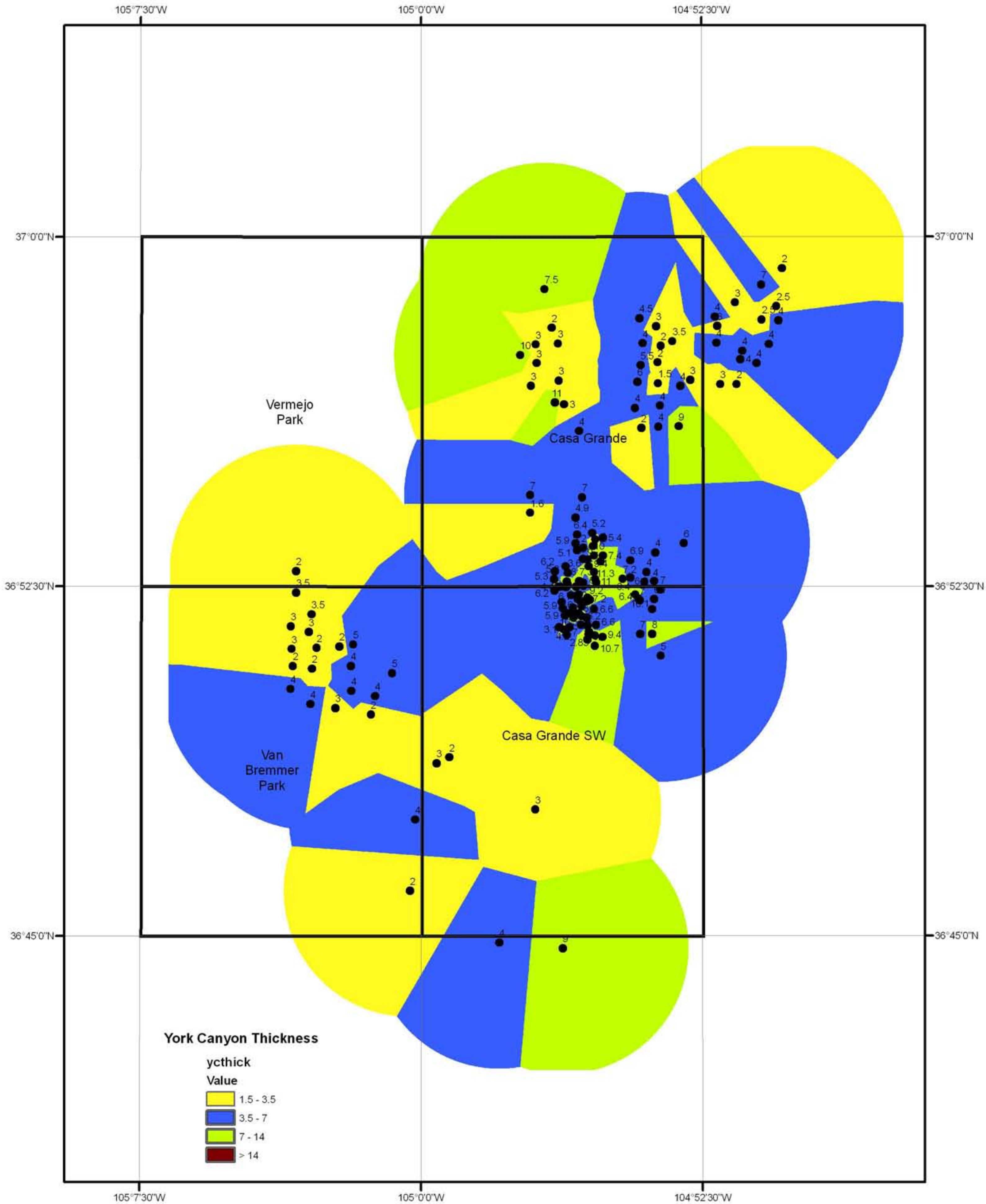
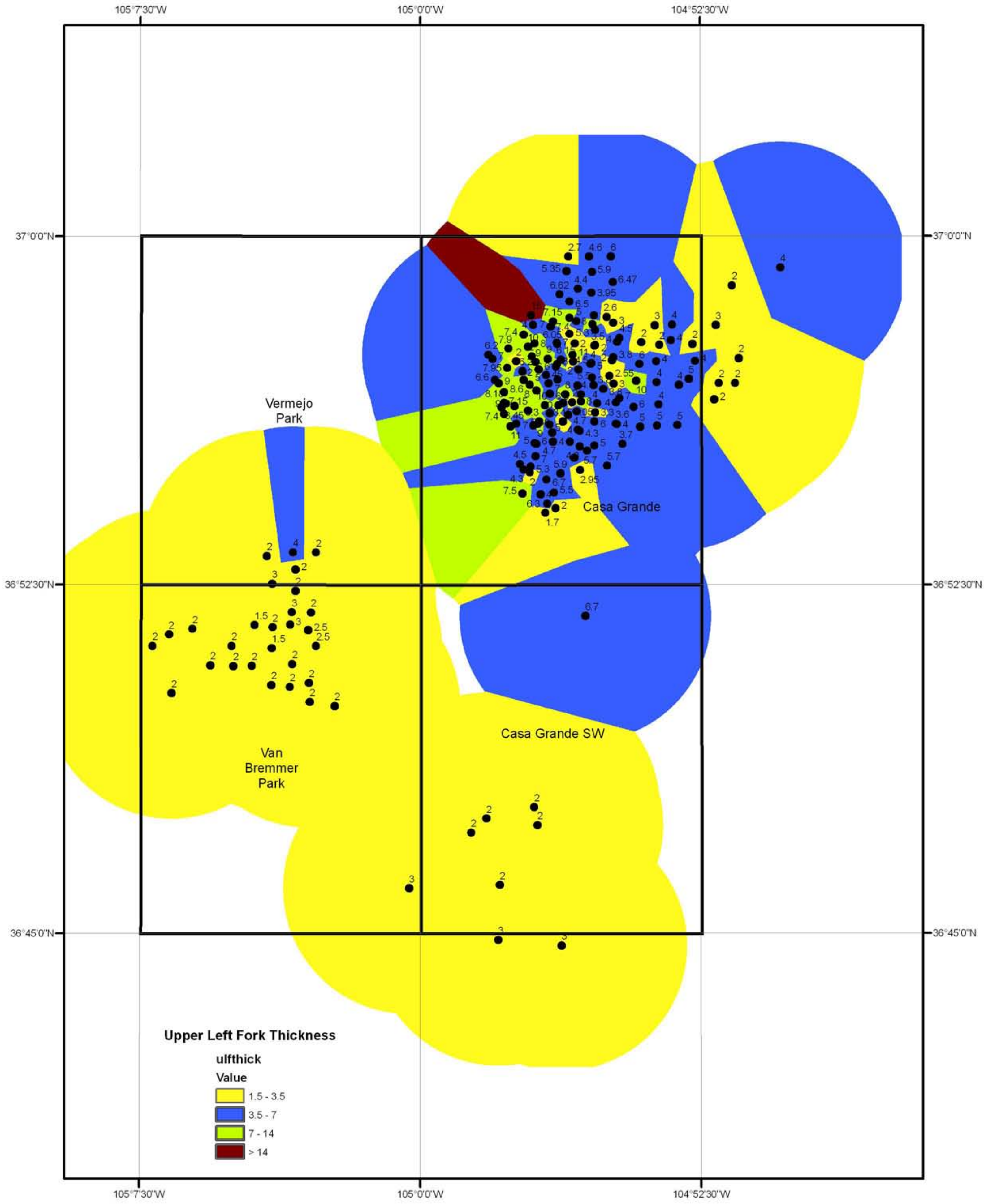
Appendix 1. Cross section drill holes for Raton coalfield study area, New Mexico.

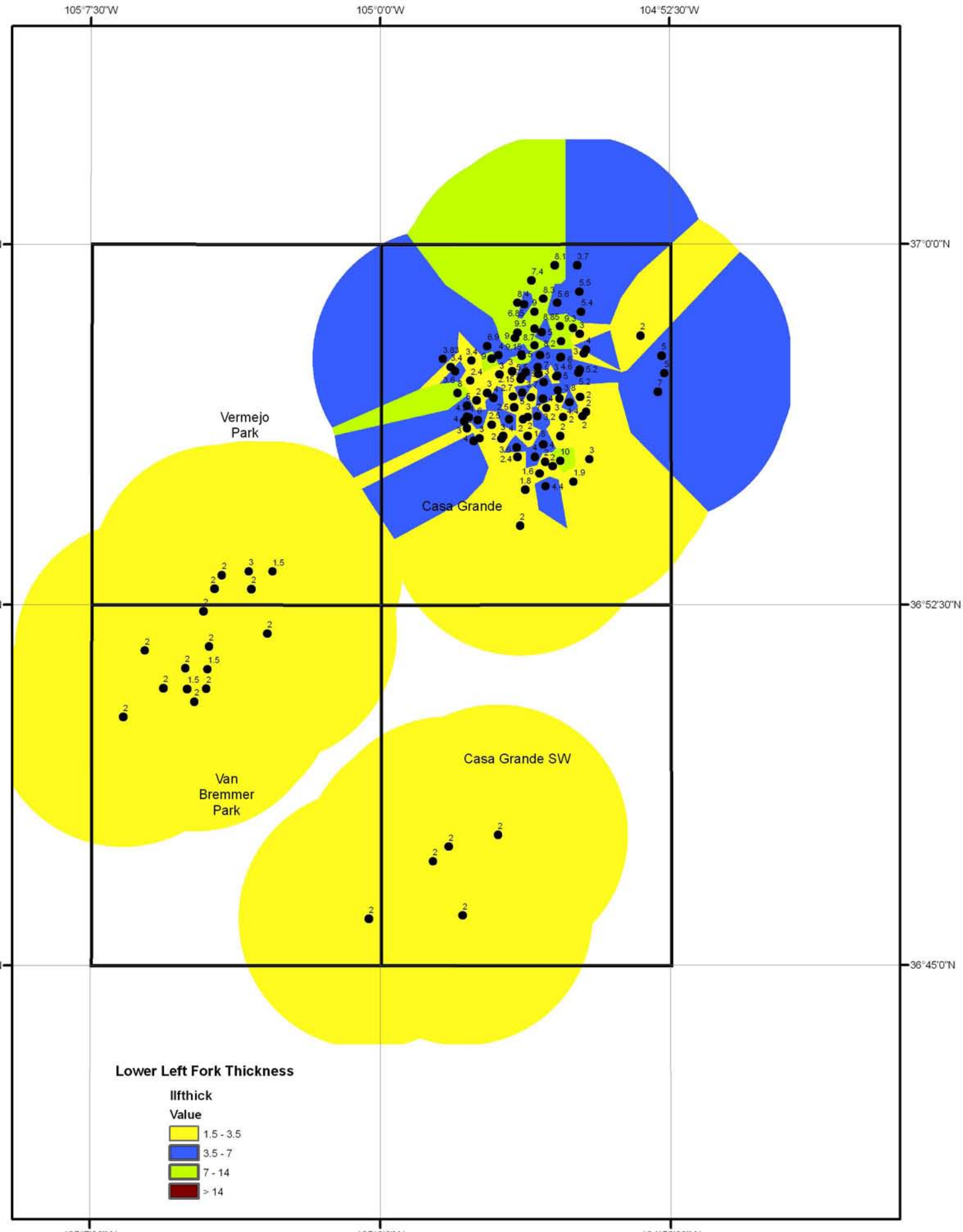
Bore	Longitude	Latitude	Quadrangle	Source	Township	Range	Section	Elevation	TD	LogNumber	Spud Date
DH-25	-105.115	36.83056	Van Bremmer Park	PENNZOIL/KAISER STEEL	30N	17E	14	8383.9	2233		
111VPR D	-105.111	36.83622	Van Bremmer Park	El Paso Energy Raton	30N	17E	14	8388	2365	42294	03-Mar-03
112VPR D	-105.105	36.83962	Van Bremmer Park	El Paso Energy Raton	30N	17E	14	8297	2300	42293	15-Feb-03
108VPR D	-105.103	36.84548	Van Bremmer Park	El Paso Energy Raton	30N	17E	11	8277	2180	42297	09-Mar-03
109VPR D	-105.094	36.8462	Van Bremmer Park	El Paso Energy Raton	30N	17E	12	8263	2180	42296	10-Mar-03
03VPR D	-105.084	36.85315	Van Bremmer Park	EL PASO ENERGY RATON LLC	30.0N	17E	12	8373	2030	40020	01-Apr-00
01VPR D	-105.083	36.84594	Van Bremmer Park	EL PASO ENERGY RATON LLC	30.0N	17E	12	8297	2080	43729	04-Apr-00
DH-12	-105.078	36.855	Van Bremmer Park	PENNZOIL/KAISER STEEL	30N	17E	7	8344.2	1969		
09VPR D	-105.074	36.86063	Van Bremmer Park	EL PASO ENERGY RATON LLC	30.0N	18E	6	8427	1990	40021	10-Mar-00
DH-16	-105.071	36.86667	Van Bremmer Park	PENNZOIL/KAISER STEEL	30N	18E	6	8509.9	1980		
11VPR D	-105.058	36.86084	Van Bremmer Park	EL PASO ENERGY RATON LLC	30.0N	18E	5	8566	2100	40515	05-Apr-00
16VPR D	-105.057	36.86519	Van Bremmer Park	EL PASO ENERGY RATON LLC	30.0N	18E	5	8451	1940	40516	03-Apr-00
17VPR D	-105.049	36.86515	Van Bremmer Park	EL PASO ENERGY RATON LLC	30.0N	18E	5	8481	1936	40027	27-Mar-00
RO82-33	-105.048	36.87722	Vermejo Park	PENNZOIL/KAISER STEEL	31N	18E	32	8555	1845		
56VPR D	-105.039	36.87299	Van Bremmer Park	EL PASO ENERGY RATON LLC	31.0N	18E	33	8358	1710	40546	22-Feb-01
UY75-20	-104.935	36.9875	Casa Grande	PENNZOIL/KAISER STEEL			0	8431	2481		
UY75-12	-104.933	36.97667	Casa Grande	PENNZOIL/KAISER STEEL			0	8267.5	2318		
12VPR E	-104.932	36.95512	Casa Grande	EL PASO ENERGY RATON LLC	31.0N	19E	4	8518	2785	40845	
UYR76-23	-104.931	36.92056	Casa Grande	PENNZOIL/KAISER STEEL			0	7826	1976		
24VPR E	-104.93	36.96954	Casa Grande	EL PASO ENERGY RATON LLC	19E	32.0N	33	8404.8	2695	40870	
UY-22	-104.93	36.93722	Casa Grande	PENNZOIL/KAISER STEEL			0	8070.5	2120		
06VPR E	-104.93	36.94655	Casa Grande	EL PASO ENERGY RATON LLC	31.0N	19E	4	8449	2680	40843	18-Feb-02
UY75-18	-104.93	36.98111	Casa Grande	PENNZOIL/KAISER STEEL	32N	19E	29	8384	2459		
68VPR A	-104.93	36.93062	Casa Grande	EL PASO ENERGY RATON LLC	31.0N	19E	9	8431	2685	40854	25-Feb-02
UY75-8	-104.929	36.95222	Casa Grande	PENNZOIL/KAISER STEEL			0	8492.5	2543		
UYR76-25-PENN	-104.929	36.92472	Casa Grande	PENNZOIL/KAISER STEEL			0	8228	2388		
UY-24	-104.926	36.92306	Casa Grande	PENNZOIL/KAISER STEEL			0	7927.5	1982		
UY76-23	-104.925	36.99278	Casa Grande	PENNZOIL/KAISER STEEL			0	8655	2805		

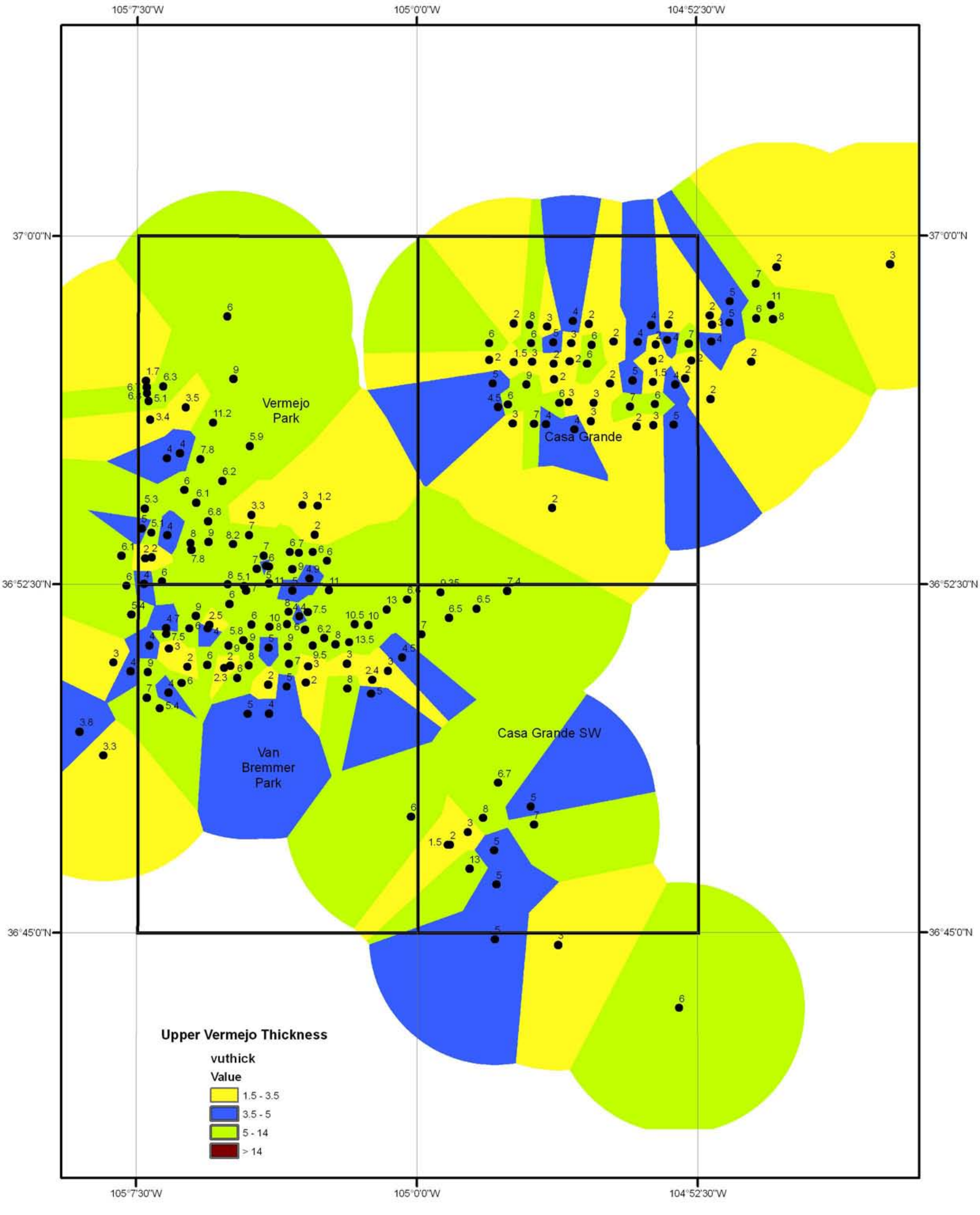
Appendix 2. Areas of influence for coal zones.Based on thickness categories

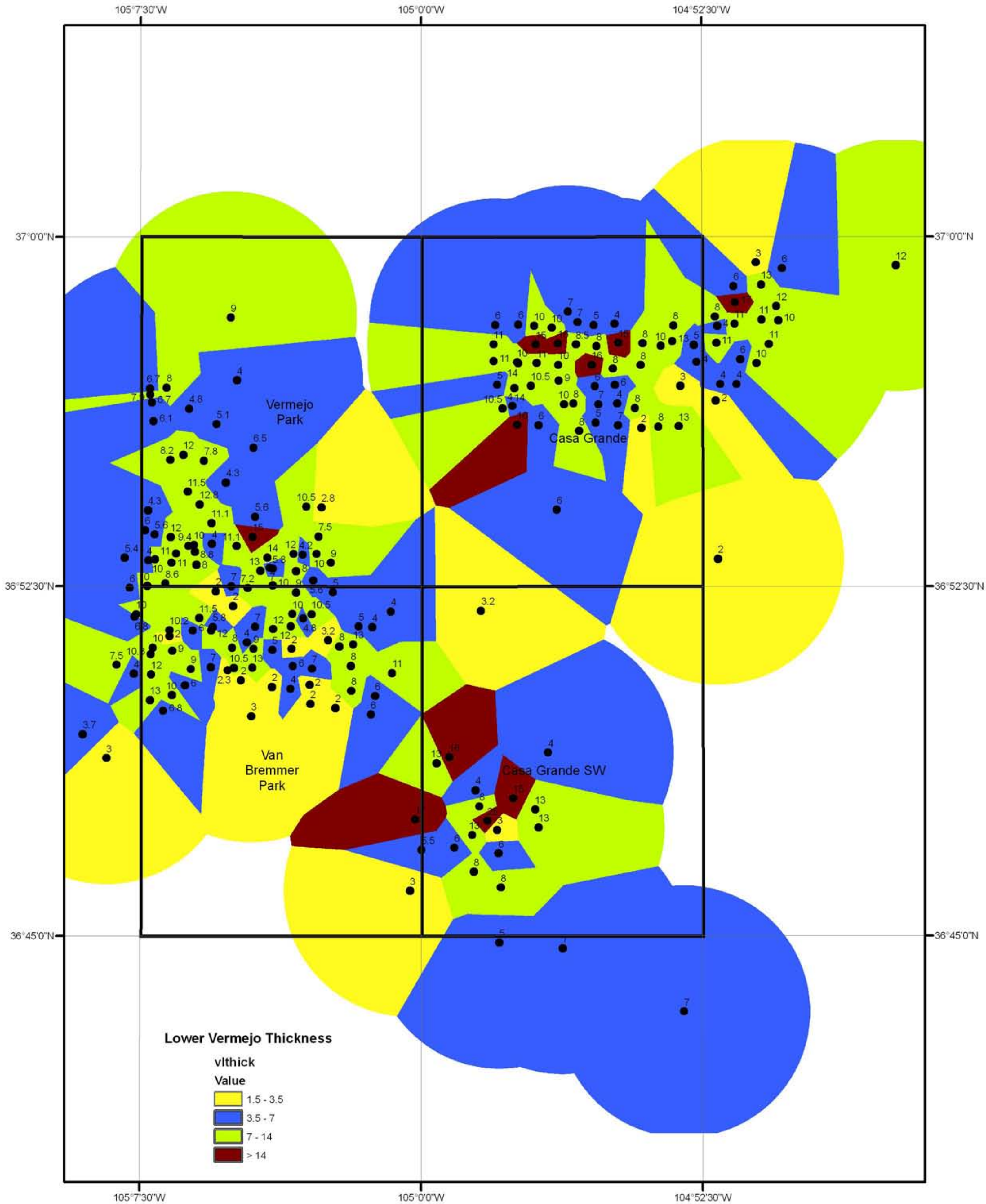




105°7'30"W
105°0'0"W
104°52'30"W
37°0'0"N
36°52'30"N
36°45'0"N
Vermejo Park
Casa Grande
Casa Grande SW
Van Bremmer Park
Upper Left Fork Thickness
ulfthick
Value
1.5 - 3.5
3.5 - 7
7 - 14
> 14


105°7'30"W
105°0'0"W
104°52'30"W
37°0'0"N
36°52'30"N
36°45'0"N
Vermejo Park
Casa Grande
Van Bremmer Park
Casa Grande SW
Lower Left Fork Thickness
llfthick
Value
1.5 - 3.5
3.5 - 7
7 - 14
> 14


105°7'30"W
105°0'0"W
104°52'30"W
37°0'0"N
36°52'30"N
36°45'0"N
Vermejo Park
Casa Grande
Casa Grande SW
Van Bremmer Park
Upper Vermejo Thickness
vuthick
Value
1.5 - 3.5
3.5 - 5
5 - 14
> 14


105°7'30"W
105°0'0"W
104°52'30"W
37°0'0"N
36°52'30"N
36°45'0"N
Vermejo Park
Casa Grande
Van Bremmer Park
Casa Grande SW
Lower Vermejo Thickness
vlthick
Value
1.5 - 3.5
3.5 - 7
7 - 14
> 14