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COAL RESOURCE OCCURRENCE MAPS AND COAL DEVELOPMENT POTENTIAL MAP OF THE SOUTHWEST QUARTER OF THE NAVAJO DAM 15-MINUTE QUADRANGLE, SAN JUAN COUNTY, NEW MEXICO

[Report includes 27 plates]

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SOUTHWEST QUARTER OF THE NAVAJO DAM 15-MINUTE QUADRANGLE

INTRODUCTION

Purpose

This text is to be used in conjunction with the Coal Resource Occurrence (CRO) Maps and Coal Development Potential (CDP) Map of the southwest quarter of the Navajo Dam 15-minute quadrangle, San Juan County, New Mexico. These maps were compiled to provide a systematic coal resource inventory of Federal coal lands in Known Recoverable Resource Areas (KRCRA's) of the western United States. The work was performed under contract with the Conservation Division of the U.S. Geological Survey (Contract No. 14-08-0001-17172).

The resource information gathered in this program is in response to the Federal Coal Leasing Amendments Act of 1976 and is a part of the U.S. Geological Survey's coal program. The information provides basic data on coal resources for land-use planning purposes by the Bureau of Land Management, state and local governments, and the public.

Location

The southwest quarter of the Navajo Dam 15-minute quadrangle is located in northeast San Juan County, New Mexico. The area is approximately 28 miles (45 km) east-northeast of Farmington, New Mexico.

Accessibility

The southwest quarter of the Navajo Dam 15-minute quadrangle is accessible from New Mexico State Routes 511 and 17 which extend across the area. Light-duty roads provide access to remote parts of the quadrangle. The Atchison, Topeka, and Santa Fe Railway operates a route approximately 106 miles (171 km) to the southwest at Gallup, New Mexico.

Physiography

This quadrangle is in the north-central portion of the Central Basin area (Kelley, 1950) of the structural depression known as the San Juan Basin. Elevations range from 5,640 ft (1,719 m) in the San Juan River Valley to 6,578 ft (2,005 m) in the northern part of the area. The San Juan River flows from the east-central part of the quadrangle to the southwest corner. The river is bordered on each side by steep terrace walls. Dissecting the area are several steep-walled tributary canyons of the San Juan River, of which Pump Canyon, Simon Canyon, and Gobernador Canyon are the largest.

Climate

The climate of the San Juan Basin is arid to semi-arid. Annual precipitation is usually less than about 10 inches (25 cm) with slight variations across the basin due to elevational differences. Rainfall is rare in the early summer and winter; most precipitation is received in July and

August as intense afternoon thundershowers. Annual temperatures range from below 0°F (-18°C) to over 100°F (38°C) in the basin. Snowfall may occur from November to April.

Land Status

Approximately 50 percent of the quadrangle is in the northeastern portion of the San Juan Basin Known Recoverable Coal Resource Area. The Federal Government owns the coal rights for approximately 79 percent of the KRCRA land within the quadrangle as shown on Plate 2 of the Coal Resource Occurrence Maps. No Federal coal leases occur in the quadrangle.

GENERAL GEOLOGY

Previous Work

Reeside (1924) mapped the surficial geology on a scale of 1:250,000 as part of a study of the Upper Cretaceous and Tertiary formations of the San Juan Basin. More recently, Fassett and Hinds (1971) made subsurface interpretations of Fruitland Formation coal occurrences as part of a larger San Juan Basin coal study.

Geologic History

The San Juan Basin, an area of classic transgressive and regressive sedimentation, provided the ideal environment for formation of coals during

Late Cretaceous time. At that time a shallow epeiric sea, which trended northwest-southeast, was northeast of the basin. The sea transgressed southwesterly into the basin area and regressed northeasterly numerous times; consequently, sediments from varying environments were deposited across the basin. Noncarbonaceous terrestrial deposition predominated during Paleocene and Eocene time.

Evidence of the final retreat of the Late Cretaceous sea are the nearshore regressive Pictured Cliffs Sandstone and the overlying paludal Fruitland Formation which were deposited in successively higher stratigraphic positions to the northeast. Southwest (shoreward) of the beach deposits, swamps, which were dissected by streams, accumulated organic matter which later became coals of the Fruitland Formation. Deposition of organic material was influenced by the strandline as shown both by the continuity of the coal beds parallel to the north-south strandline and their discontinuity perpendicular to it to the east.

The brackish-water swamp environment of the Fruitland moved farther to the northeast as the regression continued in that direction. Terrestrial freshwater sediments then covered this quadrangle as indicated by the lacustrine, channel, and floodplain deposits of the Kirtland Shale. This sequence of events is evidenced by both an upward decrease in occurrence and thickness of Fruitland coals and a gradational change to noncarbonaceous deposits of the Kirtland. Continuous deposition during Late Cretaceous time ended with the Kirtland. The sea then retreated beyond the limits of the quadrangle area, and modern basin structure began to develop. An erosional unconformity developed in a relatively short time as part of the Cretaceous Kirtland Shale was removed.

Terrestrial deposition resumed in the Paleocene as represented by the Ojo Alamo Sandstone and the overlying Nacimiento Formation. Alluvial plain and floodplain deposits of the Ojo Alamo were followed by the thick, lithologically varied deposits of the Nacimiento during continuous nonmarine deposition. The Nacimiento was later exposed to erosion.

The Eocene San Jose Formation was subsequently deposited over the Nacimiento erosional surface, reflecting various nonmarine environments which developed across the basin. Deposition and structural deformation of the basin then ceased, and the warped strata of the San Juan Basin have been exposed to the present time.

Stratigraphy

The formations studied in this quadrangle range from Late Cretaceous to Eocene in age. They are, in order from oldest to youngest: the Pictured Cliffs Sandstone, Fruitland Formation, Kirtland Shale, Ojo Alamo Sandstone, Nacimiento Formation, and San Jose Formation. A composite columnar section on CRO Plate 3 illustrates the stratigraphic relationships of these formations and is accompanied by lithologic descriptions of the individual formations.

The Pictured Cliffs Sandstone averages 130 ft (40 m) thick in this area. Because the unit is present throughout most of the San Juan Basin and is easily recognized on geophysical logs, the top was picked as the datum (CRO Plate 3) for Fruitland coal correlations. The formation consists of a cream to light gray, calcareous, slightly micaceous sandstone interbedded with gray shale near the base of the unit. Intertonguing with the overlying

Fruitland Formation occurs throughout the entire basin, and, consequently, minor Fruitland coal beds commonly are present in the upper portion of the Pictured Cliffs.

The major coal-bearing unit in the quadrangle is the Fruitland Formation. Wide variations in reported thickness are common due to an indistinct upper contact with the Kirtland Shale, but the average is about 340 ft (104 m) in this quadrangle. Many authors have utilized various criteria for establishing the upper contact, but, in general, for this study the uppermost coal was chosen (after Fassett and Hinds, 1971). The formation consists primarily of gray to brown, carbonaceous shale with scattered plant fossils, interbedded white to gray sandstone, and lenticular coal beds.

The Upper Cretaceous Kirtland Shale conformably overlies the Fruitland Formation and averages 620 ft (189 m) in thickness in this area. It is predominantly freshwater, gray-green to brown shale and interbedded gray-green siltstone. The formation has previously been divided into several members by various authors; however, for the purposes of this report it was not necessary to distinguish between the individual members.

The Paleocene Ojo Alamo Sandstone unconformably overlies the Kirtland Shale. It is a white to gray, locally conglomeratic sandstone with interbedded gray-green to brown shale which averages 120 ft (37 m) in thickness here.

Approximately 1,200 ft (366 m) of the Paleocene Nacimiento Formation overlie the Ojo Alamo Sandstone. These rocks are exposed in the western and southwestern parts of the quadrangle where they consist of gray-green to brown shale, interbedded tan to gray-green, micaceous siltstone, and interbedded tan to gray, silty sandstone.

The San Jose Formation of Eocene age unconformably overlies the Nacimiento Formation and crops out over most of the quadrangle area. It is predominantly white to gray, locally conglomeratic sandstone, and interbedded gray-green shale and siltstone.

Structure

The axis of the San Juan Basin is about 3 miles (5 km) northeast of the southwest quarter of the Navajo Dam 15-minute quadrangle area and trends in an arcuate pattern across the northern portion of the Central Basin area (Baltz, 1967). Reeside (1924) stated that the rocks in this area are "nearly horizontal."

COAL GEOLOGY

Individual coal beds are not continuous across the San Juan Basin because the coal related strata are progressively younger from southwest to northeast; the strata rise in steps due to minor transgressions which occurred during the overall retreat of the sea. However, for the exclusive purpose of reserve and reserve base calculations, the Fruitland coal beds have been correlated and mapped as if each were a single bed, continuous throughout the basin.

A lithologic datum was used for correlation of the coals (CRO Plate 3). The primarily marine sandstone unit (Pictured Cliffs) which underlies the coal-bearing formation (Fruitland) was used as a datum since it represents a more laterally continuous boundary than any of the overlying paludal, fluvial, and lacustrine deposits of the coal-bearing formation. Also, the sandstone unit is generally more easily recognized on geophysical logs. As shown on CRO Plate 3, the top of the Pictured Cliffs Sandstone has been used as a datum for each drill hole and the coals have been plotted in the column and correlated based upon their position relative to the datum.

Six coal beds (Fruitland 1, Fruitland 2, Fruitland 3, Fruitland 4, Fruitland 5, Fruitland 6) and a coal zone (Fruitland) were identified in the subsurface of this quadrangle (CRO Plate 1). The Fruitland 1 (Fr 1) coal bed is defined by the authors as the lowermost coal of the Fruitland Formation; it is generally directly above the Pictured Cliffs Sandstone. The Fruitland 2 (Fr 2) coal bed is above the Fruitland 1 separated by a rock interval of 19 to 45 ft (5.8-13.7 m); the Fruitland 3 (Fr 3) coal bed is above the Fruitland 2 separated by a rock interval of 27 to 50 ft (8.2-15.2 m); the Fruitland 4 (Fr 4) coal bed is above the Fruitland 3 separated by a rock interval of 13 to 44 ft (4.0-13.4 m); the Fruitland 5 (Fr 5) coal bed is above the Fruitland 4 separated by a rock interval of 13 to 32 ft (4.0-9.8 m); the Fruitland 6 (Fr 6) coal bed is stratigraphically above the Fruitland 5, but these two coal beds do not occur together in any drill holes within this quadrangle. Occasionally there is a local (L) coal bed between these coal beds which is noncorrelative and less than reserve base thickness (5 ft [1.5 m]).

The remaining coals in the upper portion of the Fruitland Formation are designated as the Fruitland coal zone (Fr zone). These coals are generally noncorrelative, discontinuous, and less than reserve base thickness (5 ft [1.5 m]) as set by the U.S. Geological Survey; an exception is a 5-ft (1.5-m) coal in drill hole 18. Due to these characteristics, derivative maps were not constructed.

Fruitland Formation coals in the central part of the San Juan Basin are considered high volatile A bituminous in rank. The rank has been determined on a moist, mineral-matter-free basis with calorific values averaging 15,371 Btu's per pound (35,753 kj/kg) (Amer. Soc. for Testing and Materials, 1977). The coal is hard, brittle, and black with a bright luster. The coal readily slakes with exposure to weather; however, it stocks fairly well when protected. The "as received" analyses indicate moisture content of 1.2 to 1.7 percent, ash content ranging from 10.7 to 28.5 percent, sulfur content varying from 0.6 to 2.2 percent, and heating values on the order of 12,073 Btu's per pound (28,082 kj/kg). Analyses of several Fruitland Formation coals are given in Table 1 (Bauer and Reeside, 1921; Dane, 1936; Fassett and Hinds, 1971).

Fruitland 1 Coal Bed

The coal bed has been mapped only in areas of less than 3,000 ft (914 m) of overburden (the study limit). As indicated by the structure contour map (CRO Plate 5) the coal bed dips less than 1° to the northeast. As a result of topography and dip, overburden (CRO Plate 6) varies from less than 2,400 ft (732 m) in the San Juan River Valley in the southwest part of the quadrangle to greater than 3,000 ft (914 m) on the mesas. The isopach map (CRO Plate 4) shows the coal bed is greater than 15 ft (4.6 m) thick in the northwest part of the quadrangle. In general, the coal decreases in thickness in all directions and is absent in the east-central, southwest, and southeast parts of the map.

TABLE 1

Analyses of coal samples from the Fruitland Formation

(Form of analysis: A, as received; B, moisture free; C, moisture and ash free)

U.S. Bureau Mines Lab No.	Well or Other Source	Location			Approx. Depth Interval of Sample (ft.)	Form of Analysis	Proximate, percent					Heating Value (Btu)	Remarks
		Section	T.N.	R.W.			Mois-ture	Volatile matter	Fixed Carbon	Ash	Sulfur		
H-7560	El Paso Nat. Gas S.J.U. 29-6 No. 66	SW¼ 9	29	6	3,575-3,580	A	1.2	27.7	42.6	28.5	0.6	10,780	
						B	---	28.0	43.1	28.9	0.6	10,910	
						C	---	39.4	60.6	----	0.8	15,330	
H-16310	Aztec Oil & Gas Cain No. 16-D	SW¼ 30	29	9	1,985-2,005	A	1.6	41.1	46.6	10.7	0.7	13,310	
						B	---	41.7	47.5	10.8	0.7	13,520	
						C	---	46.8	53.2	----	0.7	15,160	
H-15142	El Paso Nat. Gas S.J.U. 30-6 No. 37	NE¼ 10	30	6	3,100-3,105	A	1.5	24.1	49.4	25.0	0.7	11,310	
						B	---	24.5	50.1	25.4	0.7	11,480	
						C	---	32.8	67.2	----	0.9	15,380	
H-50079	Delhi-Taylor Moore No. 6	NE¼ 5	30	8	2,800-3,028	A	1.7	32.6	41.4	24.3	1.8	11,250	
						B	---	33.2	42.1	24.7	1.8	11,440	
						C	---	44.0	56.0	----	2.4	15,190	
H-35925	El Paso Nat. Gas Turner No. 3	SE¼ 28	30	9	2,385-2,390	A	1.5	39.9	45.5	13.1	2.2	12,960	
						B	---	40.5	46.2	13.3	2.2	13,150	
						C	---	46.7	53.3	----	2.5	15,170	
H-50012	Delhi-Taylor Barrett No. 1	SW¼ 20	31	9	3,230-3,255	A	1.3	33.7	49.2	15.8	0.7	12,830	
						B	---	34.1	49.9	16.0	0.7	13,000	
						C	---	40.6	59.4	----	0.9	15,470	

To convert Btu's/lb to kj/kg, multiply Btu's/lb by 2.326.
To convert feet to meters, multiply feet by 0.3048.

Chemical Analyses of the Fruitland 1 Coal Bed - Analyses of several coals of the Fruitland Formation from this quadrangle and the surrounding area are given in Table 1 (Fassett and Hinds, 1971).

Fruitland 2 Coal Bed

The coal bed has been mapped only in areas of less than 3,000 ft (914 m) of overburden (the study limit). As shown by the structure contour map (CRO Plate 9) the coal bed dips less than 1° to the northeast. Due to the topography and dip, overburden (CRO Plate 10) ranges from less than 2,400 ft (732 m) in the San Juan River Valley in the south and central parts of the map to greater than 3,000 ft (914 m) on the mesas. The isopach map (CRO Plate 8) shows that the coal bed has a thickness of greater than 10 ft (3.0 m) in the southeast part of the quadrangle. It thins to the north and is absent in the north and in the southwest.

Chemical Analyses of the Fruitland 2 Coal Bed - Analyses of several coals of the Fruitland Formation from this quadrangle and the surrounding area are given in Table 1 (Fassett and Hinds, 1971).

Fruitland 3 Coal Bed

The coal bed has been mapped only in areas of less than 3,000 ft (914 m) of overburden (the study limit). As indicated by the structure contour map (CRO Plate 13) the coal bed dips less than 1° to the northeast. As a result of topography and dip, overburden (CRO Plate 14) ranges from less than 2,400 ft (732 m) in the San Juan River Valley in the southwest part of the map to greater than 3,000 ft (914 m) on the mesas. The isopach map (CRO Plate 12) shows the coal bed thickness is greater than 10 ft (3.0 m) in the south and decreases to the north. The coal is absent in portions of the central, southwest, and southeast parts of the map.

Chemical Analyses of the Fruitland 3 Coal Bed - Analyses of several coals of the Fruitland Formation from this quadrangle and the surrounding area are given in Table 1 (Fassett and Hinds, 1971).

Fruitland 4 Coal Bed

The coal bed has been mapped only in areas of less than 3,000 ft (914 m) of overburden (the study limit). As indicated by the structure contour map (CRO Plate 17) the coal bed dips less than 1° to the northeast. As a result of topography and dip, overburden (CRO Plate 18) varies from less than 2,300 ft (701 m) in the San Juan River Valley in the southwest part of the quadrangle to greater than 3,000 ft (914 m) on the mesas. The isopach map (CRO Plate 16) shows that the coal bed is greater than 20 ft (6.1 m) thick in a small area in the southern part of the quadrangle. It decreases in thickness from this area, and is absent in portions of the northeast, southeast, and central parts of the quadrangle.

Chemical Analyses of the Fruitland 4 Coal Bed - Analyses of several coals of the Fruitland Formation from this quadrangle and the surrounding area are given in Table 1 (Fassett and Hinds, 1971).

Fruitland 5 Coal Bed

The coal bed has been mapped only in areas of less than 3,000 ft (914 m) of overburden (the study limit). As shown by the structure contour map (CRO Plate 21) the coal bed dips less than 1° to the northeast. As a result of topography and dip, overburden (CRO Plate 22) ranges from less than 2,300 ft (701 m) in parts of the San Juan River Valley to greater than 3,000 ft (914 m) on the mesas. The isopach map (CRO Plate 20) shows that the coal bed thickness is greater than 20 ft (6.1 m) in the southeast and, in general, decreases from this area. This coal bed is absent in portions of the central, southwest, and southeast parts of the quadrangle.

Chemical Analyses of the Fruitland 5 Coal Bed - Analyses of several coals of the Fruitland Formation from this quadrangle and the surrounding area are given in Table 1 (Fassett and Hinds, 1971).

Fruitland 6 Coal Bed

The coal bed has been mapped only in areas of less than 3,000 ft (914 m) of overburden (the study limit). As indicated by the structure contour map (CRO Plate 25) the coal bed dips less than 1° to the northeast. As a result of topography and dip, overburden (CRO Plate 26) varies from less than 2,400 ft (732 m) in the San Juan River Valley to greater than 3,000 ft (914 m) on the mesas. The isopach map (CRO Plate 24) shows the coal bed is greater than 10 ft (3.0 m) thick in the eastern part of the quadrangle. It decreases in thickness from this area and is absent in the central (north to south) and southwest portions of the map.

Chemical Analyses of the Fruitland 6 Coal Bed - Analyses of several coals of the Fruitland Formation from this quadrangle and the surrounding area are given in Table 1 (Fassett and Hinds, 1971).

COAL RESOURCES

Coal resource data from oil and gas wells (El Paso Natural Gas Co., 1978, unpublished data in well log library, Farmington, New Mexico) was used in the construction of isopach and structure contour maps of coals in this quadrangle. All of the coals studied in the southwest quarter of the Navajo Dam 15-minute quadrangle are more than 200 ft (61 m) below the ground surface and, thus, have no outcrop or surface development potential.

The U.S. Geological Survey designated the Fruitland 1, Fruitland 2, Fruitland 3, Fruitland 4, Fruitland 5, and Fruitland 6 coal beds for the determination of coal resources in this quadrangle. Coals of the Fruitland zone were not evaluated because they are discontinuous, noncorrelative, and generally less than the reserve base thickness (5 ft [1.5 m]).

For Reserve Base and Reserve calculations, each coal bed was areally divided into measured, indicated, and inferred resource categories (CRO Plates 7, 11, 15, 19, and 23) according to criteria established in U.S. Geological Survey Bulletin 1450-B. Data for calculation of Reserve Base and Reserves for each category were obtained from the respective coal isopach (CRO Plates 4, 8, 12, 16, 20, and 24) and areal distribution maps (CRO Plates 7, 11, 15, 19, and 23) for each bed. The surface area of each isopached bed was measured by planimeter, in acres, for each category, then multiplied by both the average isopached thickness of the coal bed and 1,800 short tons of coal per acre-foot (13,239 tons/hectare-meter), the conversion factor for bituminous coal. This yields the Reserve Base coal, in short tons, for each coal bed.

In order to calculate Reserves, a recovery factor of 50 percent was applied to the Reserve Base tonnages for underground coal. However, in areas of underground coal exceeding 12 ft (3.7 m) in thickness, the Reserves (mineable coal) were calculated on the basis of a maximum coal bed thickness of 12 ft (3.7 m), which represents the maximum economically mineable thickness for a single coal bed in this area by current underground mining technology.

Reserve Base and Reserve values for measured, indicated, and inferred categories of coal for the Fruitland 1, Fruitland 2 and Fruitland 6, Fruitland 3, Fruitland 4, and Fruitland 5 beds are shown on CRO Plates 7, 11, 15, 19, and 23, respectively, and are rounded to the nearest hundredth of a million short tons. The total coal Reserve Base, by section, is shown on CRO Plate 2 and totals approximately 290 million short tons (263 million metric tons).

The coal development potential for each bed was calculated in a manner similar to the Reserve Base, from planimetered measurements, in acres, for areas of high, moderate, and low potential for subsurface mining methods. The southwest quarter of the Navajo Dam 15-minute quadrangle has development potential for subsurface mining methods only (CDP Plate 27).

COAL DEVELOPMENT POTENTIAL

Coal beds of 5 ft (1.5 m) or more in thickness which are overlain by 200 to 3,000 ft (61-914 m) of overburden are considered to have potential for underground mining and are designated as having high, moderate, or low development potential according to the overburden thickness: 200 to 1,000 ft (61-305 m), high; 1,000 to 2,000 ft (305-610 m), moderate; and 2,000 to 3,000 ft (610-914 m), low. Table 2 summarizes the coal development potential, in short tons, for underground coal of the Fruitland 1, Fruitland 2, Fruitland 3, Fruitland 4, Fruitland 5, and Fruitland 6 coal beds.

Development Potential for Surface Mining Methods

All coals studied in the southwest quarter of the Navajo Dam 15-minute quadrangle occur more than 200 ft (61 m) below the ground surface and, thus, they have no coal development potential for surface mining methods.

Development Potential for Subsurface Mining Methods

Underground coal of the Fruitland 1, Fruitland 2, Fruitland 3, Fruitland 4, Fruitland 5, and Fruitland 6 beds has low development potential in most of the southern half of the quadrangle encompassed by the KRCRA (CDP Plate 27). The coal resource areas outlined on the respective areal distribution maps (CRO Plates 7, 11, 15, 19, and 23) for each coal bed are areas of low development potential. Coal bed thicknesses in these areas include: 5 to 11 ft (1.5-3.4 m), Fruitland 1 (CRO Plate 4); 5 to 6 ft (1.5-1.8 m), Fruitland 2 (CRO Plate 8); 5 to 15 ft (1.5-3.0 m), Fruitland 3 and Fruitland 6 (CRO Plates 12 and 24); 5 to 21 ft (1.5-6.4 m), Fruitland 4 (CRO Plate 16); and 5 to 19 ft (1.5-5.8 m), Fruitland 5 (CRO Plate 20). The overburden is approximately 2,400 to 3,000 ft (732-914 m) thick for each coal bed in their

TABLE 2

COAL RESOURCE DATA FOR UNDERGROUND MINING METHODS FOR FEDERAL COAL LANDS (in short tons) IN THE SOUTHWEST QUARTER OF THE NAVAJO DAM 15-MINUTE QUADRANGLE, SAN JUAN COUNTY, NEW MEXICO

(To convert short tons to metric tons, multiply by 0.9072)

Coal Bed	High Development Potential	Moderate Development Potential	Low Development Potential	Total
Fruitland 6	—	—	2,300,000	2,300,000
Fruitland 5	—	—	77,170,000	77,170,000
Fruitland 4	—	—	108,290,000	108,290,000
Fruitland 3	—	—	24,210,000	24,210,000
Fruitland 2	—	—	6,470,000	6,470,000
Fruitland 1	--	--	71,080,000	71,080,000
TOTAL	—	—	289,520,000	289,520,000

respective low development potential area (CRO Plates 7, 11, 15, 19, 23, and 26).

Approximately one-quarter of the Federal land within the KRCRA has unknown development potential and includes areas where the individual coal beds are less than 5 ft (1.5 m) thick and areas outside the 3,000-foot (914-m) overburden study limits of each coal bed. Unpatterned areas shown on CDP Plate 27 are outside the KRCRA and are not included in the resource evaluation.

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