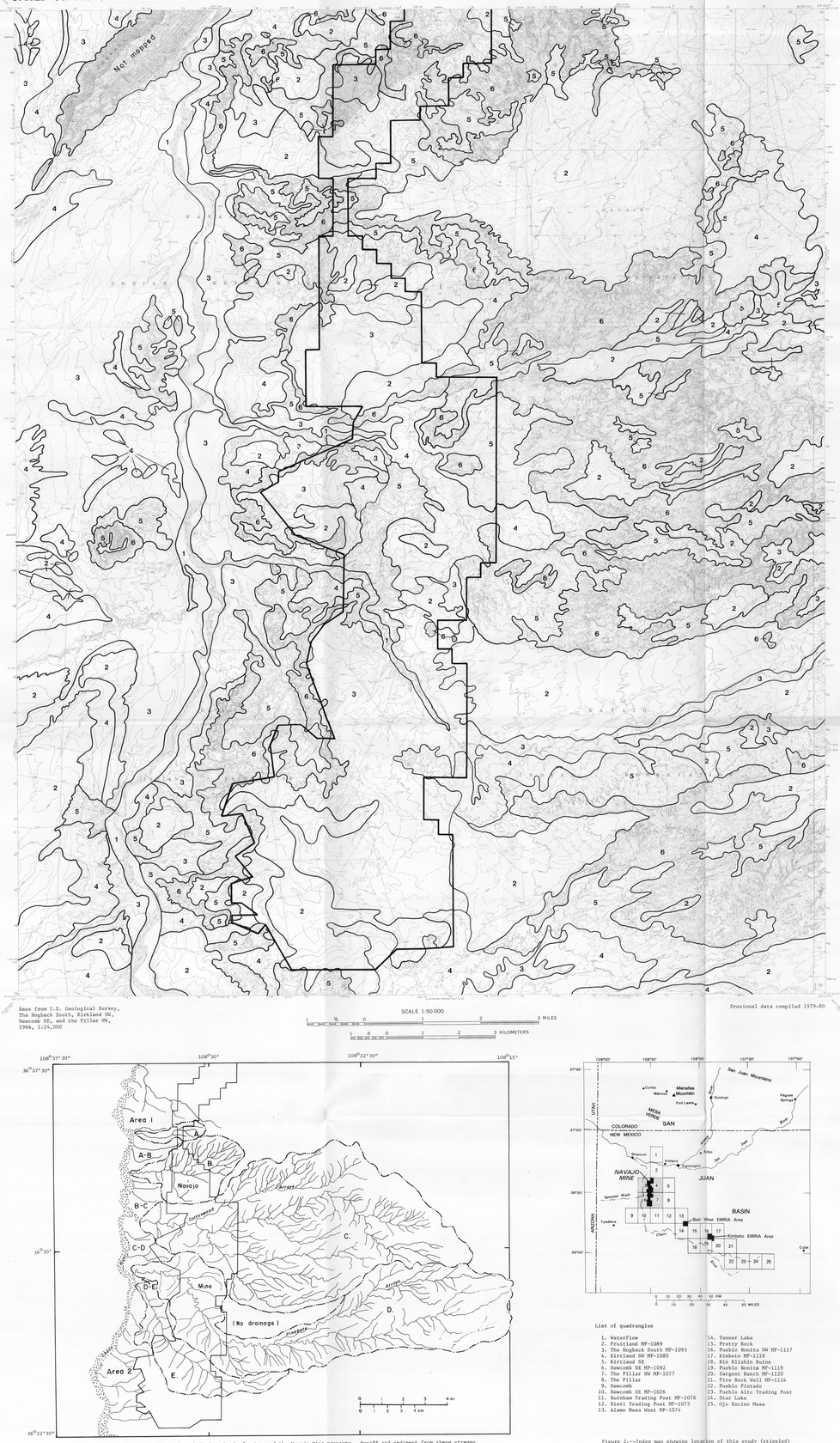
DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY

MISCELLANEOUS FIELD STUDIES
MAP MF-1432



Base from U.S. Geological Survey,
The Bogback South, Kirtland SW,
Newcomb SE, and the Pillar NW,
1966, 1:24,000

Erosional data compiled 1979–80

Figure 1.--Drainage basins A through E, interbasin facets, and the Navajo Mine property. Runoff and sediment from these streams impact the mine. Streams are tributary to the Chaco River (stippled). Areas of soil erosion units (table 2) are based on drainage basins A through E and interbasin facets A-B through D-E.

List of quadrangles

1. Waterflow
2. Fruitland NW--1089
3. The Bogback South NW--1093
4. Kirtland SW MF-1080
5. Kirtland SE
6. Newcomb NE MF-1092
7. The Pillar SW MF-1077
8. The Pillar
9. Newcomb
10. Newcomb SE MF-1026
11. Burnham Trading Post MF-1076
12. Bisti Trading Post MF-1075
13. Alamo Mesa West MF-1074
14. Tanner Lake
15. Pretty Rock
16. Pueblo Bonita SW MF-1117
17. Kimbeto MF-1118
18. Rin Kitahin Ruins
19. Pueblo Bonito MF-1119
20. Sargent Ranch MF-1120
21. Fire Rock Well MF-1124
22. Pueblo Pintado
23. Pueblo Alto Trading Post
24. Star Lake
25. Ojo Encino Mesa

Figure 2.--Index map showing location of this study (stippled) and other adjacent quadrangles along the Fruitland coal belt in the western and southern San Juan Basin, New Mexico

EXPLANATION

Soil erosion unit	Landforms and principle surficial and bedrock units	Slope gradient (degrees) Range	Slope gradient (degrees) Mean	Sediment transport ratio (STR) Range	Sediment transport ratio (STR) Mean	Estimated sediment yield (acre-ft/mi²/yr)
	Low sediment yield					
1	Wide sandy channels and stream terraces that contain Qal and Qnt. Terrace deposits support thin to moderately thick soils.	0.2–.5	0.3	<0.2	0.1	<.01
2	Mesa surfaces and low alluvial plains mantled by sand dunes (Qes) with thin soil.	.6–9.0	3.0	<.1	.05	.01–.02
	Medium sediment yield					
3	Alluvial plains, fans, catchments, and gentle hillslopes with thick soil on Qnt, Qc, Kl, Kf, and Kkf.	1.0–10.0	3.0	.2–.5	.35	.14–.25
4	Alluvial plains dissected fans and steep hillslopes with thin soil on Kl, Kf, Kkf, Kch, and Kpc.	1.0–10.0	3.0	.5–.6	.55	.39–.72
	High sediment yield					
5	Badlands and badland drainage basins with gentle slopes on Kl, Kkf, Kch, and Kpc.	1.0–15.0	5.0	.6–.8	.7	.90–1.54
6	Badland escarpments and badlands with steep slopes on Kf, Kkl, and Kkf	10.0–30.0	17.0	.8–1.0	.9	2.00–3.10

Boundary of planned extension of Navajo Coal Mine

DISCUSSION

This map shows estimated erosion and sediment yields of an area designated for extensive surface mining, in San Juan County, New Mexico. The results of this study are important for the planning of future mining operations and will aid in developing suitable reclamation procedures. In addition, these data will serve as a base line from which a long-term program for determining rates of erosion and deposition could be developed. Such measurements are essential to understanding the impact of surface mining on geomorphic processes affected by extraction of resources from arid lands. The area chosen for the study lies within four 7-1/2-minute quadrangles (The Bogback South, Kirtland SW, Newcomb NE, and The Pillar NW) in the northwest San Juan Basin (figs. 1, 2). The area includes five drainage basins covering approximately 200 mi² (520 km²) that flow west into the Chaco River (fig. 1). Approximately 41 mi² (106 km²) of this area is scheduled for surface mining during the next several years as part of the southern extension of the Navajo Mine. Other factors also contributed to the selection of this area including the availability of the following: (1) detailed information on bedrock and surficial geology, (2) soil maps showing type, distribution, and engineering properties, (3) vegetation maps showing type, distribution, and density, (4) climatic information, and (5) estimates of drainage-basin discharge. In addition, similar studies have been done at two nearby sites which have nearly identical physical characteristics (fig. 2). These two studies, one at Bisti, 28 mi (45 km) to the southeast (U.S. Bureau of Land Management, 1976) and one at Kimbeto, 42 mi (67 km) to the southeast (L. M. Shown, written commun., 1980) have served as effective analog models.

This map is designed to be used in four ways: First, the natural or pre-mining sediment yield may be calculated for any area tributary to, within, or downstream from the proposed mining area. Second, water and sediment discharge for runoff events of varying magnitude and frequency may be calculated for different drainage basins. This information can influence the design and placement of water- and sediment-control structures. Third, the approximate location and volume of material suitable for stockpiling for redistribution during reclamation may be estimated. Fourth, variables in the reclamation program such as slope reconstruction, mulching practices, and terracing or contouring techniques can be adjusted by using calculated pre-mining sediment yields. For example, approximately 8.9 mi² (23 km²) of drainage basin C (fig. 1) lie within the mine lease area. In the undisturbed state, this area yields between 12,800 and 20,900 tons of sediment per year (table 1); of the six different soil erosion units exposed in this area, units 2 and 3 cover 2.4 mi² (6.2 km²) and contain top soil suitable for stockpiling. By applying the suggested guidelines for estimating erosion on areas disturbed by surface mining in the Interior Western United States (U.S. Soil Conservation Service, 1977) to the sample area, it is within the capabilities of existing reclamation practices to reduce sediment yields after mining to a point substantially below the pre-mining yield (table 1). The universal soil loss equation factor shown in table 1, indicate that minimum post-mining sediment yield would be reduced by about 45 percent (from about 12,800 tons to 7,100 tons).

Geology

The bedrock geology and coal beds of the Navajo mine area were mapped in 1955 as part of a mineral evaluation program in the western San Juan Basin (Beaumont and O'Sullivan, 1955). The surficial geology was mapped in 1977 to assess the environmental impact of surface mining on the Cretaceous coal-bearing shales of the western and southern San Juan Basin (O'Sullivan and others, 1979a,b; Scott and others, 1979a,b). In general, the bedrock in the area east of the Chaco River is interbedded sandstones and shales of late Cretaceous age that dip uniformly 3° to the east. These rocks are overlain by extensive sheets of Quaternary eolian sand, and are cut by broad channels and embankments filled with Pleistocene and Holocene alluvium. Extensive headward erosion of streams in the shale units has resulted in broad, arcuate belts of badland topography that alternate with shallow basins. Sediments in these basins are too young to have developed soils. Coal deposits of commercial quality and thickness, overlain by less than 200 ft (60 m) of overburden, occur in the Upper Cretaceous Fruitland Formation. The bedrock and surficial units are outlined in the list of lithologic descriptions. More complete descriptions of the bedrock and coal geology are in reports by Bauer and Reeside (1921), Fassett and Hinds (1971), O'Sullivan and others (1972), Reeside (1924), and Shomaker and others (1971). Surficial deposits and Quaternary stratigraphy are discussed by Hack (1942), and Richmond (1965).

Lithologic Components[1] of Soil Erosion Units

Qal — Alluvium (Holocene)--Sand and silt in channels and on flood plains of major drainages

Qla — Landslide deposit (Holocene)[2]--Angular blocks of shale and sandstone from the Cliff House Sandstone (Kch) and Menefee Formation (Kmf) on the southeast face of the Hogback monocline

Qfa — Fan alluvium (Holocene)--[2]Gravelly sand to gravelly silt and clay on terraces

Qc — Sheetwash alluvium (Holocene)[2]--Sand and clayey silt on slopes tributary to flood plains of major drainages

Qnt — Older alluvium (Holocene)--[2]Stratified sand, silt, and gravel filling old drainage networks cut into bedrock and (or) older alluvium; commonly with well-developed soils marked by oxidized and (or) carbonate horizons

Qes — Eolian sand (Holocene and Pleistocene)[2]--Linear dunes and sheet sands composed of medium to coarse sand on flat, upland surfaces and flood plains

Qgs — Gravelly sand (Pleistocene)--Coarse sand and gravels capping older terraces and upland surfaces along ancient drainage networks

Upper Cretaceous[3]

Kkf — Kirtland Shale

Fármington Sandstone Member--Interbedded sandstone, siltstone, and mudstone

Kkl — Lower shale member--Silty and sandy mudstone

Kf — Fruitland Formation--Intercalated sandstone, siltstone, mudstone, and coal

Kpc — Pictured Cliffs Sandstone--Crossbedded, cliff-forming sandstone underlain by fine-grained sandstone and shale

Kl — Lewis Shale--Gray shale and interbedded thin tan sandstone

Kch — Cliff House Sandstone--Thin- to thick-bedded, lenticular and crossbedded sandstone that intertongues with the overlying Lewis Shale and underlying Menefee Formation

Kmf — Menefee Formation--Interbedded thin sandstone, shale, mudstone, limestone, and coal

Kpl — Point Lookout Sandstone--Crossbedded, massive, medium-grained sandstone interbedded with shale

Km — Mancos Shale--Silty claystone with sandstone lenses and containing limestone concretions

[1]/ From O'Sullivan and others (1979a,b); Scott and others (1979a,b).
[2]/ Units Qla, Qfa, Qc, Qnt, and Qes may be, in part, coeval.
[3]/ The Upper Cretaceous section has an exposed thickness of approximately 4,700 ft (1,430 m) in the vicinity of the Navajo Mine.

Sediment-yield values

The sediment-yield values for the Navajo Mine area are a combination of two factors: (1) sediment production in the source area based on the soil-loss equation, and (2) a sediment-transport ratio (STR) that compensates for in-channel storage of eroded material. The numerical values of sediment yield (table 2) were derived from empirical equations developed for the analog model areas at Bisti (U.S. Bureau of Land Management, 1976) and Kimbeto (L. M. Shown, written commun., 1980) (fig. 2). Field research at these sites was part of the Energy Mineral Rehabilitation Inventory and Analysis (EMRIA) program of the U.S. Geological Survey; a numerical rating method developed by the U.S. Department of Agriculture (U.S. Soil Conservation Service, 1968) which was tested on small drainage basins (Shown, 1970) was used in the current analysis. Nine major factors contribute to the sediment-yield values: surficial geology, soils, climate, runoff, topography, vegetation cover, land use, upland and channel erosion, and sediment transport and storage. The nine factors determined for this area were compared with their counterparts in both the Bisti and Kimbeto analog areas to obtain source-area sediment-production and sediment-transport ratios. The derivative map of erosion potential and sediment sources (this report) represents an integration and compilation of data from 1:24,000-scale topographic, geologic, and soil maps.

Soil erosion units

Six soil erosion units defined on the basis of bedrock and surficial geology, soils, and topography, were mapped in the vicinity of the Navajo Mine. Although the area has over 30 different soil units (U.S. Bureau of Indian Affairs, 1971), six major groupings emerge when the individual units are combined on the basis of thickness, texture, and structure (table 3). As might be expected, major soil groups reflect the physical properties of their parent material and local topography. Soil erosion units, in order of increasing erodability, and their representative soil profiles are as follows (horizon thickness and color measured by Weide, all other information supplied by U.S. Bureau of Indian Affairs, 1971):

1. Wide sandy channels of Chaco Wash and Cottonwood and Pinabete Arroyos. Parent material is Holocene alluvium in main stem channels of larger drainage basins. A typical soil profile formed in Quaternary alluvium overlain by unconsolidated sand of the Chaco River channel has the following properties:
   0–14 in. (0–36 cm): Sandy clay loam; pale brown (10YR 6/3) dry, brown (10YR 5/3) moist; platy, blocky and prismatic structure when dry, sticky and plastic when wet; few, very fine pores and roots; strongly calcareous (pH 8.3).
   14–30 in. (36–75 cm): Sandy clay loam; brown (10YR 5/3) dry, dark brown (10YR 4/3) moist; structureless and massive; hard when dry, sticky and plastic when wet; few, very fine pores and roots; strongly calcareous with scattered CaCO₃ nodules (pH 7.9).
   30–42 in. (75–107 cm): Clay; pale brown (10YR 6/3) dry, brown (10YR 5/3) moist; massive to prismatic structure; very hard when dry, very plastic and sticky when wet; few very fine pores and roots; strongly calcareous (pH 7.9).
   42–60 in. (107–152 cm): Clay; brown (10YR 5/3) dry and moist; structureless and massive; very hard when dry, very plastic and sticky when wet; few very small pores and roots; strongly calcareous (pH 7.9).
2. Gently sloping undissected upland surfaces covered with sheet sands and linear dunes and local patches of older sands and cobbles from terrace deposits. Broad alluvial plains covered by sheet sands. A typical soil profile formed in Quaternary eolian sand on Cretaceous Fictured Cliffs Sandstone has the following characteristics:
   0–10 in. (0–25 cm): Sand; pink (7.5YR 7/4) dry, light brown (7.5YR 6/4) moist; structureless single grain when dry, nonplastic and nonsticky when wet; no pores and few very fine roots; slightly calcareous (pH 8.1).
   10–22 in. (25–56 cm): Sandy loam; reddish yellow (7.5YR 7/6) dry, reddish yellow (7.5YR 6/6) moist; very weak prismatic structure when dry, friable, nonplastic and slightly sticky when wet; few, very fine pores and roots; strongly calcareous (pH 8.1).
   22–56 in. (56–142 cm): Sand; pinkish gray (7.5YR 7/2) dry, light brown (7.5YR 6/4) moist; structureless single grain when dry, friable nonplastic and nonsticky when wet; no pores or roots; slightly calcareous (pH 8.3).
3. Alluvial plains, terraces, channel deposits of older alluvium, undissected fans of sheet wash alluvium, and depositional aprons, flats, and dissected fans on Cretaceous shales (Menefee formation, Lewis Shale, Fruitland Formation, and Farmington Sandstone Member of the Kirtland shale) that have soils more than 20 in. (50 cm) thick. A typical soil profile formed on Lewis Shale has the following characteristics:
   0–3 in. (0–7 cm): Very fine sandy loam; light yellowish brown (10YR 6/4) dry, dark yellowish brown (10YR 4/4) moist; weakly platy to granular structure when dry, plastic and sticky when wet; numerous very fine pores and roots; slightly calcareous (pH 8.3).
   3–14 in. (7–35 cm): Fine sandy loam; yellowish (10YR 5/4) dry, dark yellowish brown (10YR 4/4) moist; prismatic and blocky structure when dry, plastic and sticky when wet; abundant small pores and roots; slightly calcareous (pH 8.3).
   14–24 in. (35–61 cm) Very fine sandy loam; yellowish brown (10YR 5/5) dry, yellow brown (10YR 6/6) moist; massive structure, hard when dry, plastic and sticky when wet; few roots, small pores common; strongly calcareous (pH 8.2).
   24–33 in. (61–84 cm) Sandy clay loam; yellowish brown (10YR 5/6) dry, dark yellowish brown (10YR 4/4) moist massive structure, hard when dry, plastic and sticky when wet; no roots, small pores common; strongly calcareous (pH 8.2).
   33 in. (84 cm) Shale bedrock weathered to small, angular, platy chips.
4. Alluvial plains, terraces, older channel deposits, depositional aprons, flats, and dissected fans supporting thin soils. A typical soil profile formed on Lewis Shale has the following characteristics:
   0–3 in. (0–7 cm): Clay loam; light yellowish brown (10YR 7/4) dry, dark yellowish brown (10YR 4/4) moist; prismatic structure; granular when dry, plastic and sticky when wet; no pores and few very small roots; slightly calcareous (pH 8.0).
   3–9 in. (7–23 cm) Clay loam; brown (10YR 5/3) dry, dark yellowish brown (10YR 4/4) moist; weakly platy to blocky structure when dry, plastic and sticky when wet; abundant pores and very small roots; slightly calcareous (pH 8.2).
   9–13 in. (23–33 cm) Clay loam; yellowish brown (10YR 5/4) dry, dark yellowish brown (10YR 4/4) moist; massive structure; hard when dry, plastic and sticky when wet; abundant pores and very small roots; strongly calcareous (pH 7.9).
   13 in. (33 cm) Lewis Shale bedrock weathered to small, angular, platy chips.
5. Badlands and badland catchment basins developed on unweathered Cretaceous shales (Menefee Formation, Lewis Shale, Fruitland Formation, and the lower shale member and Farmington Sandstone Member of the Kirtland Shale) and unweathered sandstones (Point Lookout Sandstone, tongues of the Menefee Formation and Cliff House Sandstone and the Fictured Cliffs Sandstone). Slopes 3°–10°. This unit commonly does not exhibit a soil profile.
6. Badlands and badland escarpments with severe gullying developed on unweathered Cretaceous shales and sandstones having steep slopes (10°–30°). This unit does not commonly exhibit a soil profile.

Sediment-transport ratio

Sediment transport ratio (STR) is a qualitative value representing the amount of sediment carried completely through a channel reach. Numerically it is:

$$\text{STR} = \frac{\text{Quantity of sediment leaving a reach}}{\text{Quantity of sediment entering a reach}}$$

In the Piceance Creek Basin, Colorado, Prickel and others (1975, p. 19) developed numerical values for the STR based on the amount of erosion in main channels and their tributaries as follows:

STR	Channel condition
1.0	Both main and tributary channels are raw gullies
0.75	50 percent of tributary channels are raw gullies
0.50	Only main channels are raw gullies
0.3–0.5	All channels are discontinuous gullies
0.0–0.4	No channels gullied plus evidence of deposition

In the Bisti West EMRIA analog area (U.S. Bureau of Land Management, 1976), the STR values, channel conditions, topographic and geologic settings are as follows:

STR	Channel condition, topographic, and geologic setting
0.9	Raw gullies on steep slopes of Cretaceous shale
0.85	Raw gullies interspersed with healed reaches on gentle slopes of Cretaceous shale
0.7	Interspersed raw and healed gullies and healed channel segments on shallow basins in Cretaceous shale

Sediment-transport ratio values for the Navajo mine area are shown in the explanation to the map.

Impact of large runoff events

Sediment-yield equations commonly contain a parameter dealing with "average annual" stream discharge. It is useful, however, to develop numerical approximations of stream discharge accompanying large, infrequent storms. Following the technique developed by Scott (1971) for small drainage basins in northwestern New Mexico, the discharge resulting from large magnitude storms occurring at intervals (t) of 2, 5, 10, 25, and 50 years was estimated using equation (1) below. These values of discharge (table 4) were then applied to the five drainage basins that intersect the southern part of the Navajo mine (fig. 1).

$$Q_t = aA^b\,Sa^c\,Sa^d\,Pa^e\,I^f\,T^g \qquad (1)$$

where: Q = discharge
t = recurrence interval of a high magnitude storm measured in years (also defined as a probability function)
a = regression constant
A = drainage basin area
Sa = mean basin altitude
St = area of surface water storage within the basin
Pa = average summer precipitation
I = maximum rainfall (inches) for a 24-hour period over a 2-year interval
T = mean minimum January temperature
b,c,d,e,f,g, = regression exponents derived from stepwise multiple regression

Although the discharge values listed in table 4 are only approximate, they represent the best estimates currently available for drainage basins tributary to the Chaco River.

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Table 1.--Estimated erosion, under post-mining conditions in the Navajo Mine lease area of drainage basin C

Soil erosion unit[1]	Universal soil loss equation factors[2] R	K	LS	C	P	Estimated soil loss Area (acres)	Total[3]	Area (acres)	Total[3]
						(Ton/acre/year)		(Ton/acre/year)	
1	15	0.07	0.8	0.45	1	0.38	38	14.4	
2	15	.07	.8	.18	1	.15	344	81.6	
3	15	.17	1.0	.18	.5	.23	966	222.2	
4	15	.24	1.0	.18	.5	.32	1323	487.4	
5	15	.28	4.9	.18	.6	2.06	1229	2531.7	
6	15	.26	6.3	.18	.6	2.65	1414	3747.1	
Total									7084.4

[1]/ Described in text under soil erosion units.
[2]/ The universal soil loss equation (U.S. Soil Conservation Service, 1977) employs five factors to estimate erosion: R, rainfall (from U.S. Soil Conservation Service, 1977, fig. 1); K, average grain size from mechanical analysis data (table 3); LS, slope angle/slope length assumes reconstruction of pre-mining topography; C, a mulch cover factor, assumes 1 ton of straw mulch per acre; and P, a contour-bench-spacing factor assumes post-mining contouring on slopes of 2–12 percent.
[3]/ Tons per acre per year rounded to two decimal places.
Total yield (tons per year) for each soil erosion unit.

Table 2.--Potential sediment yield from soil erosion units, Navajo mine area
[AF, acre foot; 1 AF=1,233 m³; unit weight estimated at 1,750 tons/AF; See figure 1 for location of drainage areas and drainage basins.]

Geographic subdivision	Soil erosion unit	Area (mi²)	Estimated rate of sediment yield (AF/YR)	Estimated rate of sediment yield of subareas (AF/YR)	Estimated rate of sediment yield of subareas (m³/YR)	Estimated rate of sediment yield of subareas (Tons)
Area 1						
I. [1]/ (5.93 mi²)	2	0.17	<0.1			
	3	1.93	0.97– 3.97			
	6	3.83	7.66– 11.97	8.73–14.84	1076–1904@	15277–25970
II. [2]/ (4.48 mi²)	2	.34	0.01–			
	3	.47	.07– .12			
	5	3.08	2.77– 4.74			
	6	.59	1.19– 1.84	4.04– 6.70	5183–8596	7070–11725
III. [3]/ (7.58 mi²)	2	2.72	.01– .04			
	3	1.70	.17– .30			
	4	1.34	.52– .96			
	5	1.53	1.96– 2.35			
	6	1.29	2.59– 4.01	4.67– 7.66	5992–9828	8172–13405
Total for Area 1 (partial drainage basin; north end of proposed mining area; 17.99 mi²)				17.44–29.20	21939–37464	30519–51100
Drainage basin A						
I. (0.55 mi²)	2	.02	<0.01			
	3	.26	.25– .43			
	6	.25	.50– .78	.76– 1.21	937–1492	1330–2118
II. (0.35 mi²)	2	.11	<0.01			
	3	.10	.09– .15			
	6	.14	.29– .44	.39 .59	481–727	682–1032
III. (0.87 mi²)	3	.03	<0.01			
	5	.38	.34– .59			
	6	.45	.91– 1.41	1.26– 2.00	1554–2466	2205–3500
Total for drainage basin A (1.77 mi²)				2.41– 3.80	2972–4685	217–6650
Interbasin facet A/B	5	.01	.01– .02			
II. (0.03 mi²)	6	.02	.04– .06	.05– .08	62–99	87–140
III. (2.2 mi²)	3	.85	.13– .21			
	4	.01	<0.01			
	5	.66	.59– 1.01			
	6	.68	1.37– 2.12	2.09– 3.35	2577–4131	3657–5862
Total for facet A/B (2.23 mi²)				2.14– 3.43	2639–4230	3744–6002
Drainage basin B	2	.63	<0.01			
I. (3.68 mi²)	3	.52	.07– .13			
	5	.95	.76– 1.31			
	6	.66	.59– 1.01			
	6	.82	1.64– 2.54	2.72– 4.45	3354–5487	4760–7787
II. (3.97 mi²)	3	.55	<0.01			
	3	1.93	.27– .49			
	5	1.21	.43– .87			
	5	.26	.24– .41			
	6	.01	.02– .03	1.01– 1.81	1245–2232	1767–3167
III. (1.80 mi²)	3	.07	<0.01			
	3	.54	.08– .13			
	5	.82	.73– .59			
	5	.56	.23– .39			
	6	.12	.24– .37	.88– 1.49	1085–1837	1540–2607
Total for drainage basin B (9.45 mi²)				4.61– 7.75	5684–9556	8067–13561
Interbasin facet B/C	3	.59	.08– .15			
III. (3.12 mi²)	4	1.31	.51– .94			
	5	.92	.33– .70			
	6	.10	.19– .29			
Total for facet B/C (2.12 mi²)				.90– 1.58	1110–1948	1575–2765
Drainage basin C	2	6.09	.03– .12			
I. (40.03 mi²)	3	.49	.07– .12			
	5	2.51	.96– 1.81			
	5	9.92	8.93– 15.28			
	6	21.09	42.17– 65.36	52.18–82.69	44338–101957	91315–144707
II. (8.93 mi²)	1	.36	<0.01			
	2	.85	<0.01			
	3	1.51	.21– .38			
	4	3.38	.93– 1.72			
	5	3.95	1.73– 2.96			
	6	2.31	4.42– 6.84	7.31–11.92	9013–14697	12792–20860
III. (3.13 mi²)	1	.28	<0.01			
	2	.77	<0.01			
	3	.45	.06– .11			
	4	.68	.26– .49			
	5	.57	.24– .42			
	6	.24	.48– .75	1.06– 1.79	1307–2207	1855–3132
Total for drainage basin C (51.09 mi²)				60.55–96.40	74658–118861	105962–168699

Table 3.--Mechanical and engineering properties of erosional and sediment yield units, Navajo Mine area, New Mexico
[S, (surface samples within 18 in, (36 cm) of the ground surface); B, near-surface samples 18–36 in. (36–90 cm) depth
Statistical measures: R, ranges; M, mean; SD, standard deviations. NV, not tested; NO, no data]

Soil erosion unit	Landform and principle bedrock (see lithologic description)	Type and No. of samples tested	Statistical measures	Mechanical properties: Particle size distribution of material less than 4.76mm in diameter (A.S.T.M. classification in percent): Sand (4.76–0.075mm)	Silt (0.075–0.005mm)	Clay (0.005mm)	Organic matter (in percent)	Number of samples tested for engineering properties	Number nonplastic s	Plasticity characteristics: Liquid limit[1]	Plastic limit[2]	Plasticity index[3]	Volume change (swelling pressure) in PSF[4]	Source of data[5] (all samples)
1	Wide sandy channels in Qal, and Qnt; Drainage basin main stems	S 2	R	51–65	27–30	8–19	NT	2	1	22	20	2	0	USGS
		N 2	R	93–95	1–3	4	ND	2	2	ND	ND	ND	0	
2	Mesa surfaces and low alluvial plains with sand dunes (Qes, Qgs)	S 33	R	52–97	1–23	2–17	0.07–1.24							
			M	85	8	7	0.36	3	2	19	18	1	0	USGS
			SD	10.2	5.8	4.6	0.2							(4)
		N 31	R	30–95	1–23	1–47								BIA
			M	76	10	14	NO	1	1	ND	ND	ND	0	(60)
			SD	14.9	6.4	10.7								
3	Alluvial plains, fans, catchments and hillslopes with thick soils (Qnt, Qc, Kl, Kf, Kkf)	S 23	R	17–94	2–52	4–58	0.10–0.53							
			M	64	14	19	0.32	9	4	22–50	18–23	4–27	2050–3500	USGS
			SD	27.2	14.1	15.4	0.13			33–67	26–31	7–36	0	(4)
		N 21	R	8–94	2–45	4–62				25–67	19–25	2–28	1250–3550	BIA
			M	56	17	27	NO	7	1	35.5	21.5	14.0	2050	(28)
			SD	28.6	13.4	17.6				7.4	2.5	8.8	885	
4	Alluvial plains, dissected fans and hillslopes with thin soils (Qes, Kl, Kf, Kkf, Kch, Kpc)		R	35–76	7–31	10–34				20–26	13–16	7–10	500–1075	
		S 5	M	59	19	22	NT	5	3					USGS
			SD	17.0	9.9	8.8								(6)
			R	12–75	7–45	17–43				30–36	16–19	11–20	1175–2500	BIA
		N 5	M	49	26	25	ND	5	3					(2)
			SD	26.3	17.6	10.8								
5	Badlands and badland catchments with gentle slopes (Qes, Kl, Kkf, Kch, Kpc)	N 2	R	7–67	16–25	17–68	NT	2	1	61	29	32	4100	
		N 2	R	2–5	31–42	53–67	ND	2	0	44–59	20–29	24–30	3050–3800	USGS
			M											(4)
6	Badland escarpments and badlands with steep slopes (Qgs, Kf, Kkl, Kkf)		R	13–95	1–33	4–56	0.07–4.53							
		S 7	M	53	19	27	NO	3	3	ND	ND	ND	0	USGS
			SD	29.8	11.9	20.1	2.23							(5)
			R	18–93	3–38	4–44								BIA
		N