Importance of pre-mining baseline data for sustainable reclamation efforts, surface coal mines, USA

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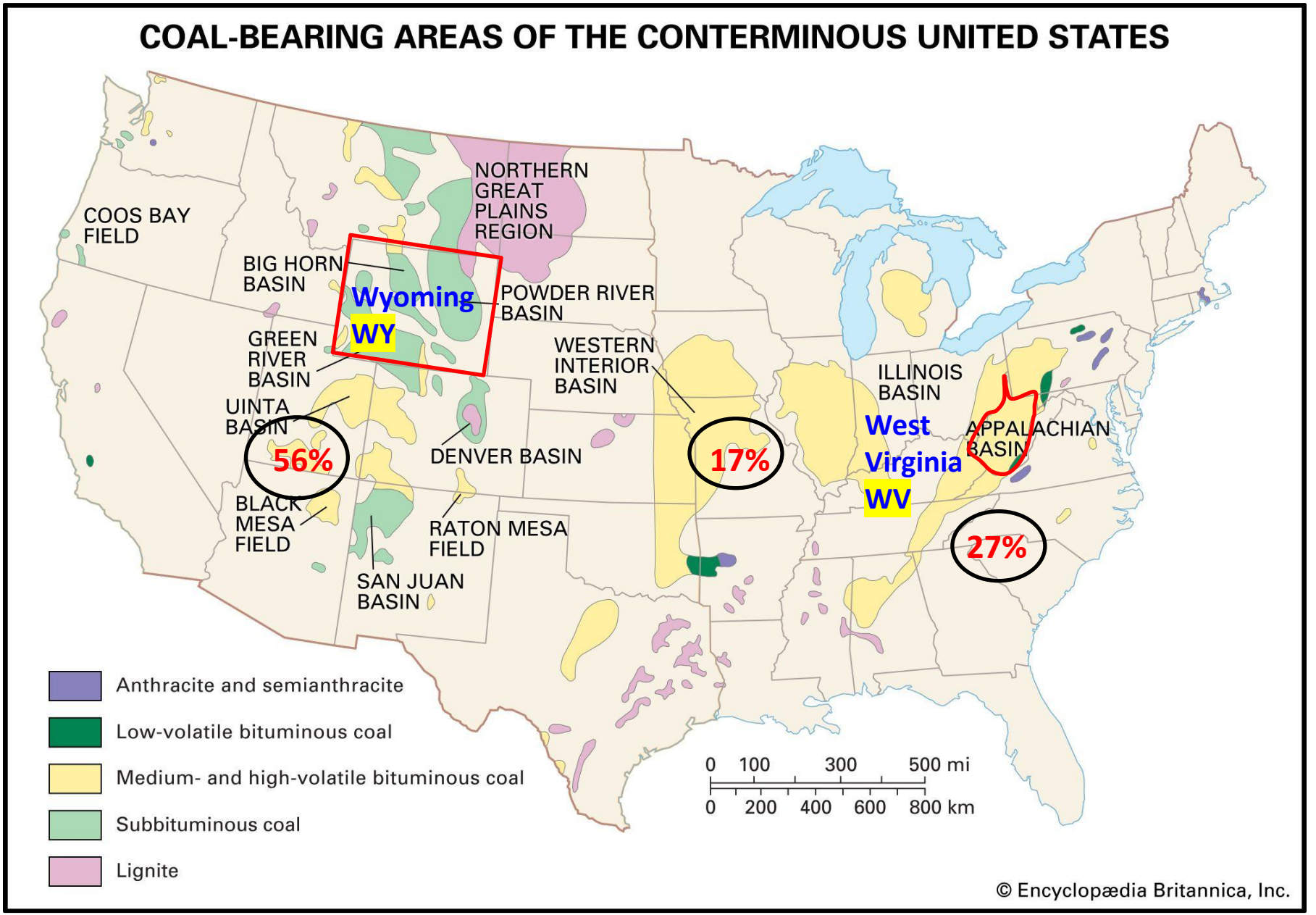
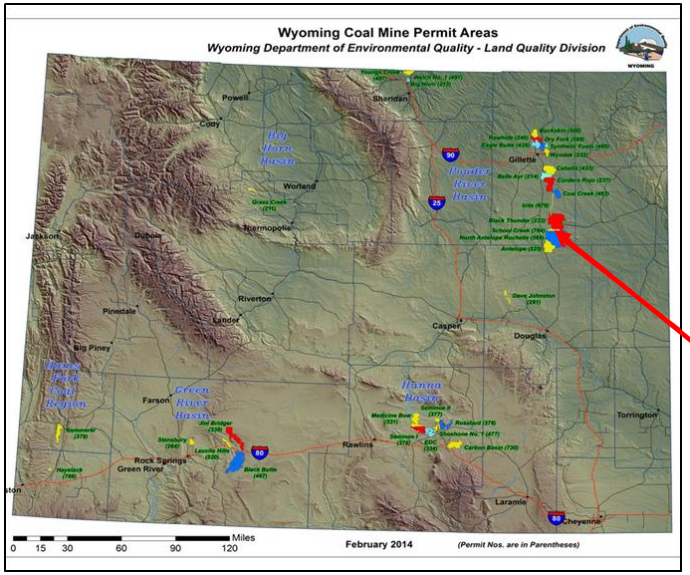
Coal deposits



40 % of US coal production

US Western – Wyoming (WY)



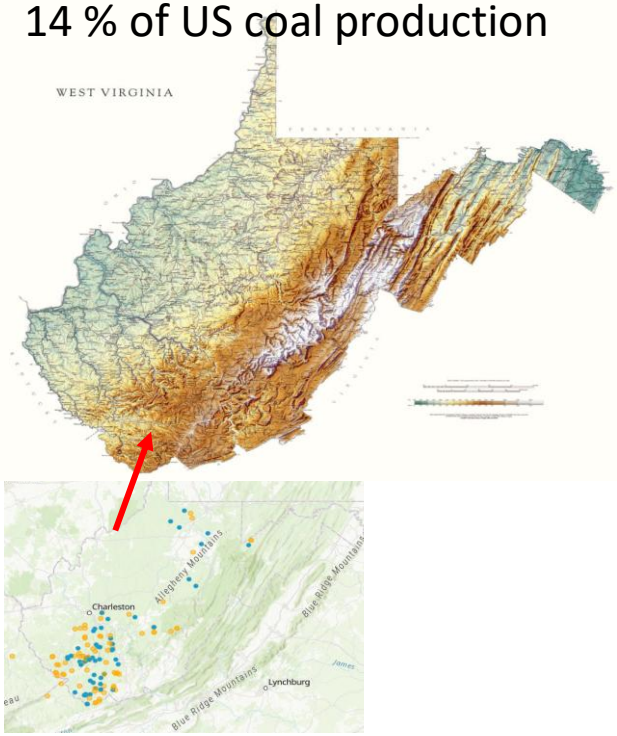
North Antelope Rochelle Mine, NARM

Coal (sub-bituminous) thickness: 15-30 m

Overburden thickness: 30-125 m

Permit surface : 229 km²

14 % of US coal production



US Eastern – West Virginia (WV)

Coal (bituminous) thickness: 1-11 m

Overburden thickness: 50-600 m

Permit surface: 0.4-40 km²

Reclamation goals of active surface coal mines

Reclamation shall restore the land to a condition equal to or greater than the "highest previous use".

The land, after reclamation, must be suitable for the previous use which was of the greatest economic or social values to the community area.

Reclamation goals	What does it mean?
Reclaimed to the planned approved land use	Reclamation is a function of the pre-mine land use.
Post-mining topography - Approximate Original Contour (AOC) (with an exception of mountain top removal)	Mined land restored to a surface shape that closely resembles its pre-mining topography, blending with surroundings.
Hydrologic restoration	Water originating upstream from the mine must be available for a downstream use.
	Stable groundwater level and water chemistry sufficient for the post mine land use.
Preparation for successful revegetation	Salvaging all suitable soil and preparing for seeding.
Revegetation	Diverse, permanent vegetative cover of the same seasonal variety of native plants and capable of self-regeneration. Successful revegetation of planned agriculture crop.
Contemporaneous reclamation	Reclaiming land as it's being mined.

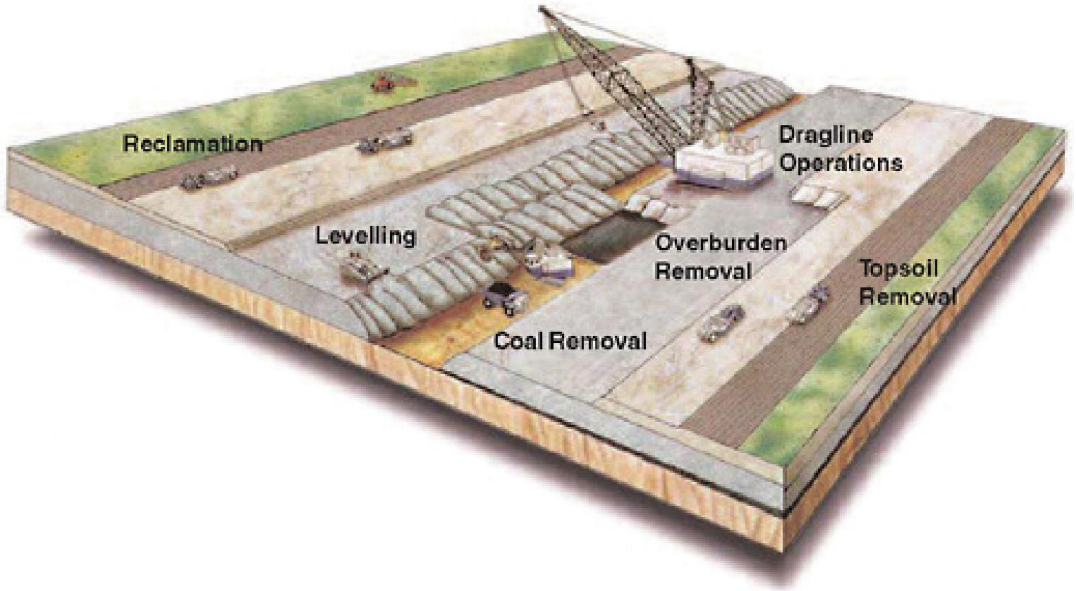
Pre-mining baseline data

NARM Permit:

baseline information	- 69%
mine plans	- 24%
reclamation plans	- 7%

Important baseline data:

- land use
- archeological and paleontological inventories
- climate factors: rainfall
- overburden material: viability, suitability, swell factor
- slope analysis
- hydrology
- topsoil properties
- vegetation inventory analysis
- wildlife survey



Pre-Post-mining land uses

Wyoming: rangeland (grazing, hunting) – 90%

Western

Eastern

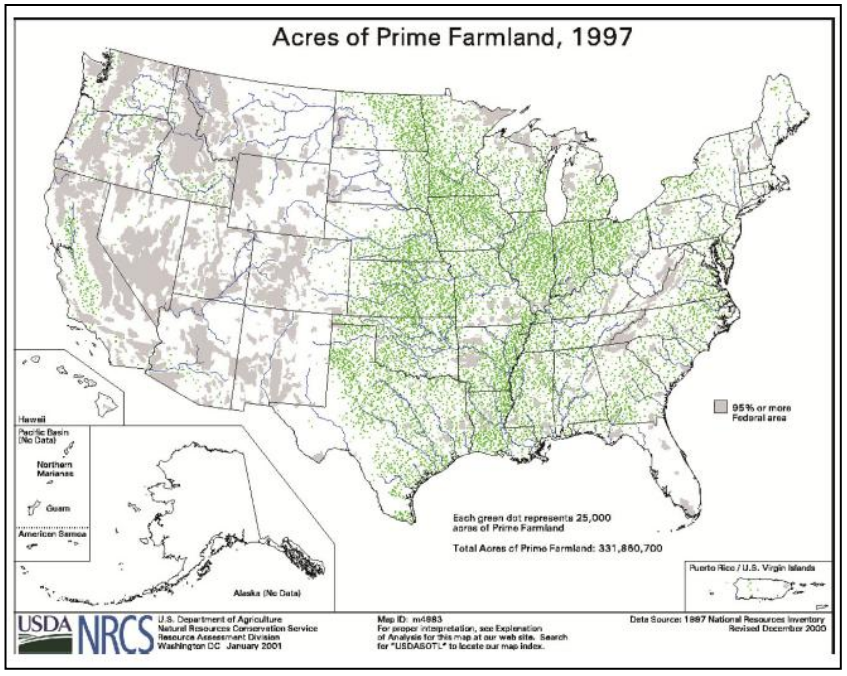
West Virginia: forest – 89%

Special “protected” land uses, USA

Highly sensitive, “special” protected areas requiring permits: wetland, prime farmland, and Alluvial Valley Floor

Wetlands: land area that is saturated with water and with the characteristic vegetation of aquatic plants adapted to the unique hydric soil.

Wetlands must be replaced on a one-to-one area basis



Prime farmland: land with the physical and chemical optimal characteristics for producing high yields of food, feed, forage etc.

- **Requires a plan for:**
  - separation and replacement of soil (separate removal of soil horizons with separate storage piles and application of soil horizons in the correct order),
  - revegetation, information on pre-mining productivity and an approval statement from the local Natural Resources Conservation Service.

Special “protected” land uses, Western US

Under the Surface Mining Control and Reclamation Act of 1977 (SMCRA), the strongest protections for AVFs are restricted to "arid and semiarid areas west of the 100th meridian".

Alluvial Valley Floor (AVF):

- unconsolidated stream-laid deposits holding streams
- critical for agriculture and grazing due to natural flood irrigation or sub-irrigation in Western US
- requires site-specific delineations

- **A mine permit pre-application determination** if mining activities would destroy the agricultural utility of the AVF (significant to a farming operation)
- The mining activity can not materially damage the quantity or quality of water in surface or underground water systems that supply the AVF

Gold Mine Draw, Caballo, WY

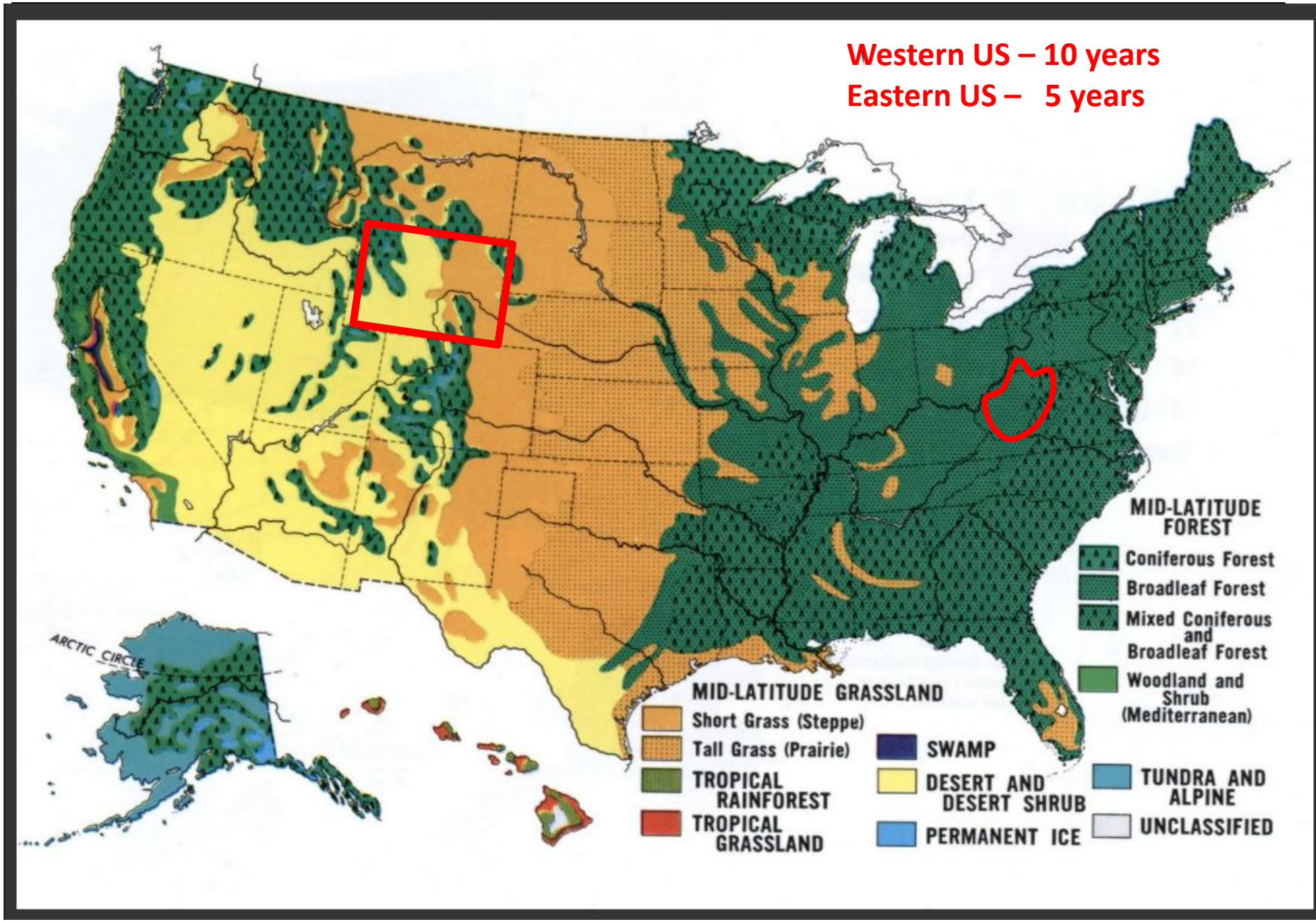
Dry Fork Little Powder AVF, near the Dry Fork, Mine, WY- not significant

Archeological and paleontological investigation

- Surface inventories of historical and pre-contact cultural resources (sites older than 50 years)
- Site evaluation
- Data recovery plans, excavations, and final mitigation reports

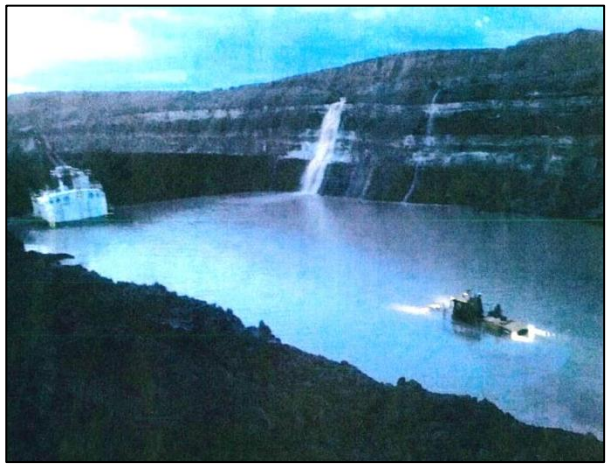
Example of significant findings from multiple time periods from excavations

Climate and types of vegetation



Climatic factors, rainfall

- **Rainfall frequency, intensity, and duration influence the amount of runoff from a given watershed**

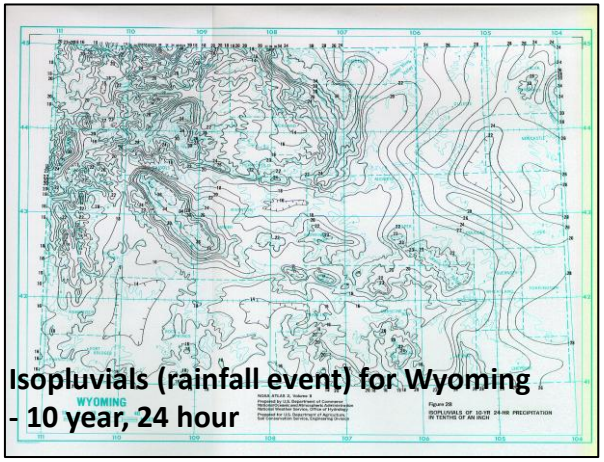


Surface water control - designed to control water flow during and after mining to minimize the effect of mining on surface water quantity and quality (reservoirs and impoundments, diversions)

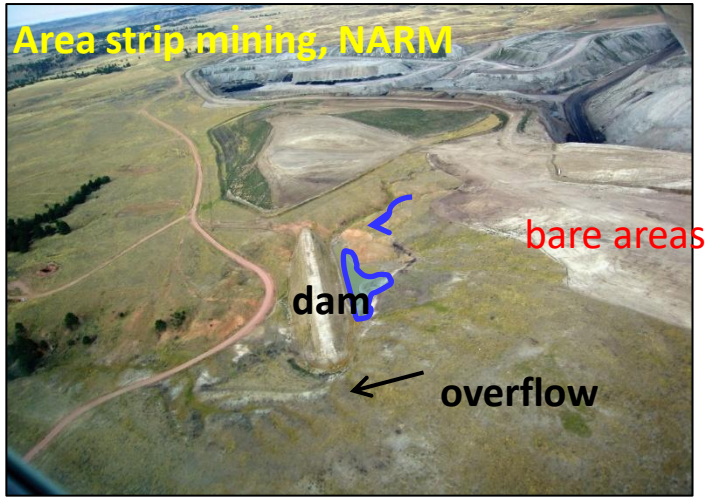
Climatic factor, hydrologic control

Wyoming

All temporary sediment control reservoirs - designed to hold and treat a 10 year 24 hour runoff event or 25 year/24 hour event



Isopluvials (rainfall event) for Wyoming - 10 year, 24 hour



West Virginia

Sediment ponds built for precipitation events (mm)

	Wyoming	West Virginia
Temporary, 25-year 24 hr	28-76	89-140
Flood control, 100-year, 6-hr	38-76	136-151

Stream channels - reconstructed for the 100 year, 6 hour runoff event (depends on the drainage area, type of soil, uses, vegetation, and rainfall).

Climatic factors, safety and protection

Metrological stations within the permit boundary measuring:

- Continuous monitoring ambient particulate matter, wind speed, wind directions, temperature, and precipitation

Record of Blasting Operations - North Antelope / Rochelle Mine
339A Antelope Road, Wright, WY 82732 : (307) 464-0054

Shot Details
Operator: NARM MINE — Date: 11/03/2014
Shot Number: 23793 — Location: Railloop West
Material: Overburden — Bench: 3
Time: 1:27 pm — Excavator: 112
Scheduled Shot: Yes / No If no, add reason to comments section

Weather Info
General Cond.: Partly Cloudy — Temp.: 45 F
Wind Speed (mph)/Direction: 17 NE

Seismic Info
Max Lbs per 8 ms: 609 — Holes / 8ms: 1
Nearest Inhabited Structure: Bar Ranch
Distance (Structure to Shot): 24,044.46 Ft. — Direction to Inhabited Structure: 106.24 °
Max Allowable Pounds per 8 ms: 136,957 — Seismograph Required?: Yes (No)
Nearest Engineered Structure: PRB Corp Powerline Reroute
Distance (Structure to Shot): 397.48 Ft. — Direction to Structure: 189.10 °
Max Allowable Pounds per 8 ms: 649 — Seismograph Required?: Yes (No)

Pattern Details
Number of Holes: 97 — Hole Diameter: 10.625 in.
Stem: 50 ft. — Stem Type: DRILL CUTTINGS
Burden: 33 — Spacing: 41
Avg Depth: 62 — Total Loaded Depth: 5,987
BCY: 300,015 — Powder Factor: 0.189
Lbs per Hole: 609 — Initiation Type: Non-Electric

Comments

Accessories

Surface Delays	Manufacturer	MS Delay Time	Number Used	Date Code
	Dyno Nobel	NONEL TD 109MS 60FT	17	22SE14
	Dyno Nobel	NONEL TD 42MS 60FT	52	06OC14
	Dyno Nobel	NONEL TD 42MS 60FT	28	22SE14
Detonating Cord	Manufacturer	Type	Feet Used	Date Code
	Dyno Nobel	PRIMACORD 4Y	8,000	05AU14
Primers	Manufacturer	Type	Number Used	Date Code
	Dyno Nobel	TROJAN NB UNIVERSAL 450G	97	06OC14

Blasting Agents

Blasting Agents	Manufacturer	Type	Lbs Used
	Dyno Nobel	Fuel Oil	2,041
	Dyno Nobel	Ammonium Nitrate	31,981
	Dyno Nobel	ANFO	34,022
	Dyno Nobel	Emulsion	22,682
	Total Weight of Explosives Used (including primers) =		56,801

- PM_{10}- Particulate Matter (PM) of 10 microns or less.
-
- Wyoming standards: sample air quality for 24 hr – 150 ug/m^3

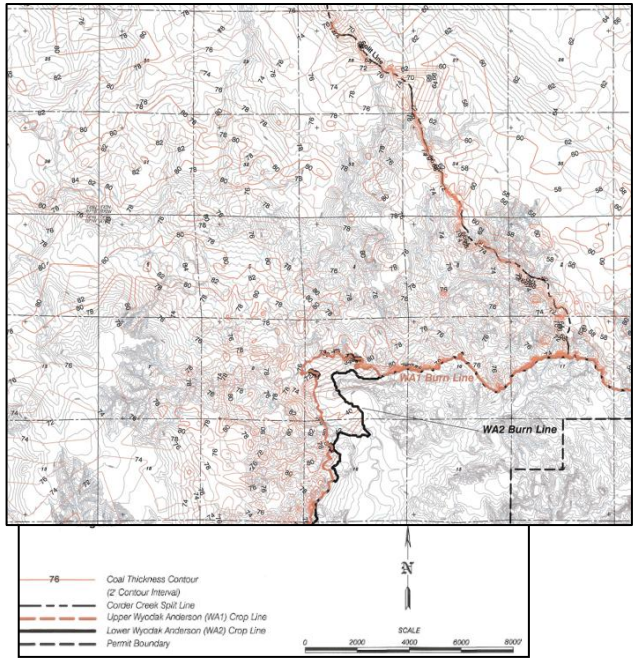
Wind erosion prevention: intensity and direction of wind (air quality)

Photos: Anna Krzyszowska-Waitkus

Overburden material and coal volumes – economic viability

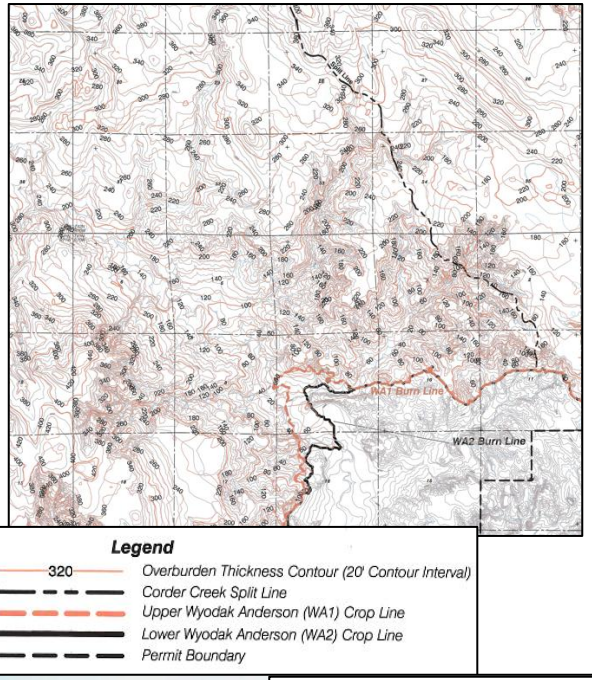
Western US

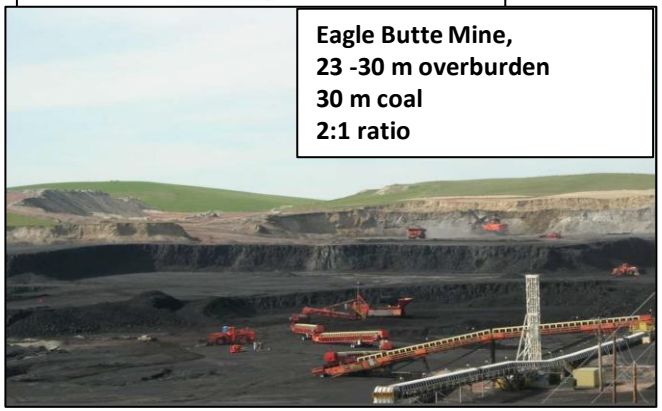
NARM permit map: Coal thickness



North Antelope Rochelle Mine
60 m overburden
20 m coal
3:1 ratio

Overburden thickness





Eagle Butte Mine,
23 -30 m overburden
30 m coal
2:1 ratio

Eastern US

- Successive cuts made until overburden is too thick to economically mine the coal

Effective strip ratio: average in the US -6:1 to 10:1

Post-mining topography – Approximate Original Contour (AOC), USA

The final surface configuration, after backfilling and grading, closely blend with surrounding and pre-mining topography (with an exception of mountain top removal in Eastern USA)

AOC	Baseline knowledge of:
Blend into and complement the drainage pattern of the surrounding terrain.	- pre-mining topography
The amount of backfill material enough to build AOC. No backfill material piles left at the mine	- volumes of overburden material - swell factor
All toxic materials covered or treated	- overburden suitability
Backfilled materials stabilized without erosion	- slope distribution

Pre-mining overburden material suitability

Western and Eastern US

- Ahead of mining - collecting composite samples through a geological strata along e.g.150m profile in WV and WY with one hole per 64 ha in WY (suitability analysis).
- Results - in the permit.
- Sample cuttings collected at intervals of a maximum of 3 meters in specific lifts of 16.5 m to a depth of 148 m (WY).
- Analysis of pH, EC, Sodium Absorption ratio, nitrate, acid base potential, arsenic, organic carbon (WY)

NARM Permit: Overburden suitability

Pre-mining overburden suitability- effect on management practices

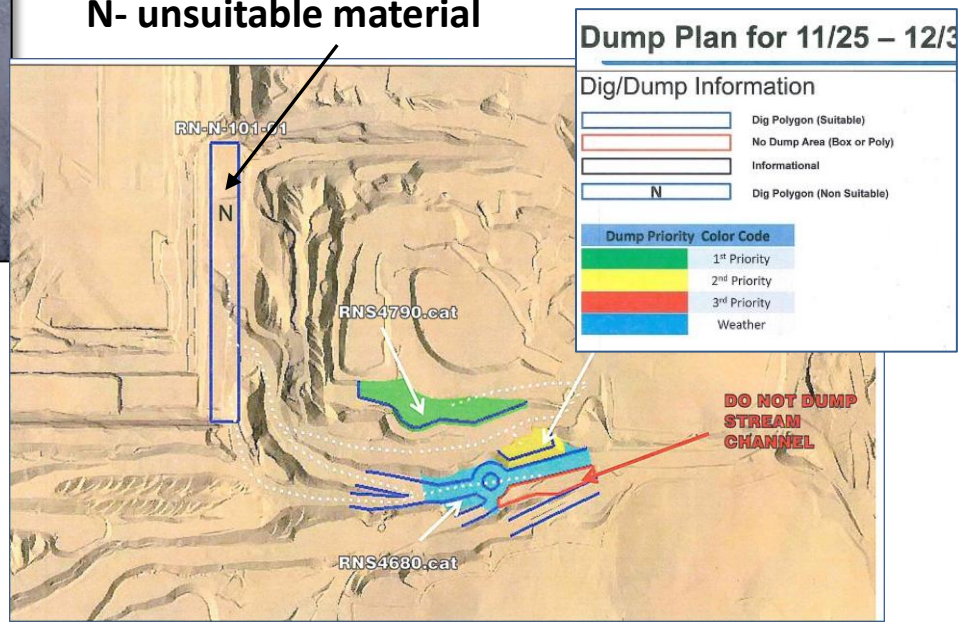
Procedures to mitigate unsuitable material, Western US

- The location of unsuitable material collected from the baseline study - a map uploaded to the GPS in a shovel removing overburden material.

Photos: Anna Krzyszowska Waitkus

- The operator produces a weekly map with the location of unsuitable material.
- The map delineates places where these unsuitable materials will be stored and where can't be stored.

N- unsuitable material



- **Unsuitable material- isolated and buried under nontoxic material and not under a stream channel at the depth of 1.2 m (4 feet) in Western and Eastern US**

Pre-mining overburden material

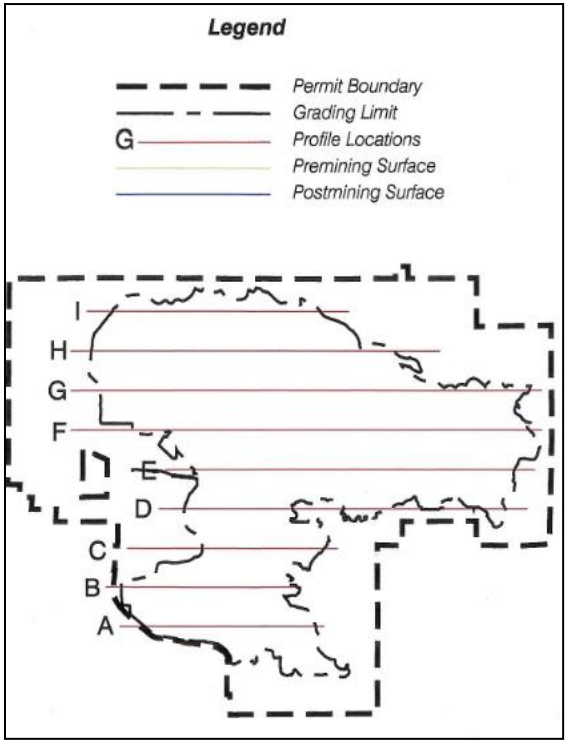
- Overburden volumes

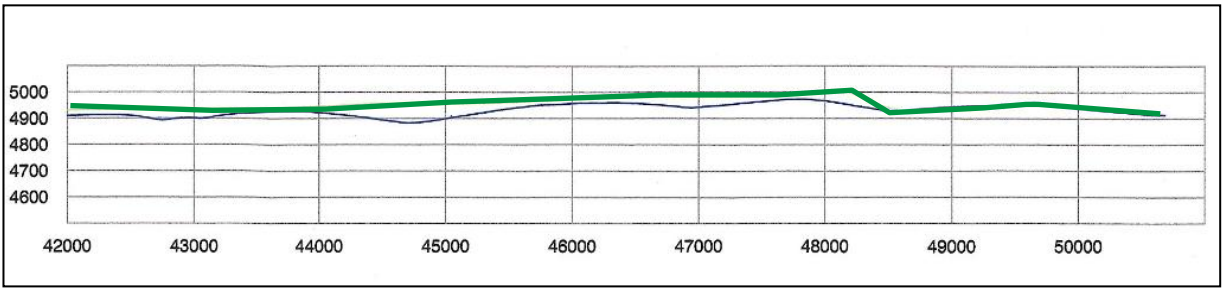
- **Backfill volumes available to fill the void - the volume of the overburden material multiply by a swell factor**

- **Swell factor** - the ratio of the weight or volume of loose excavation material to the weight or volume of the same material in place.

  Swell factor: Western mines: 12%-18%, average 15%
  Eastern mines: 20-30%

- **Analysis of pre-mining surface elevations** to tie into the surrounding



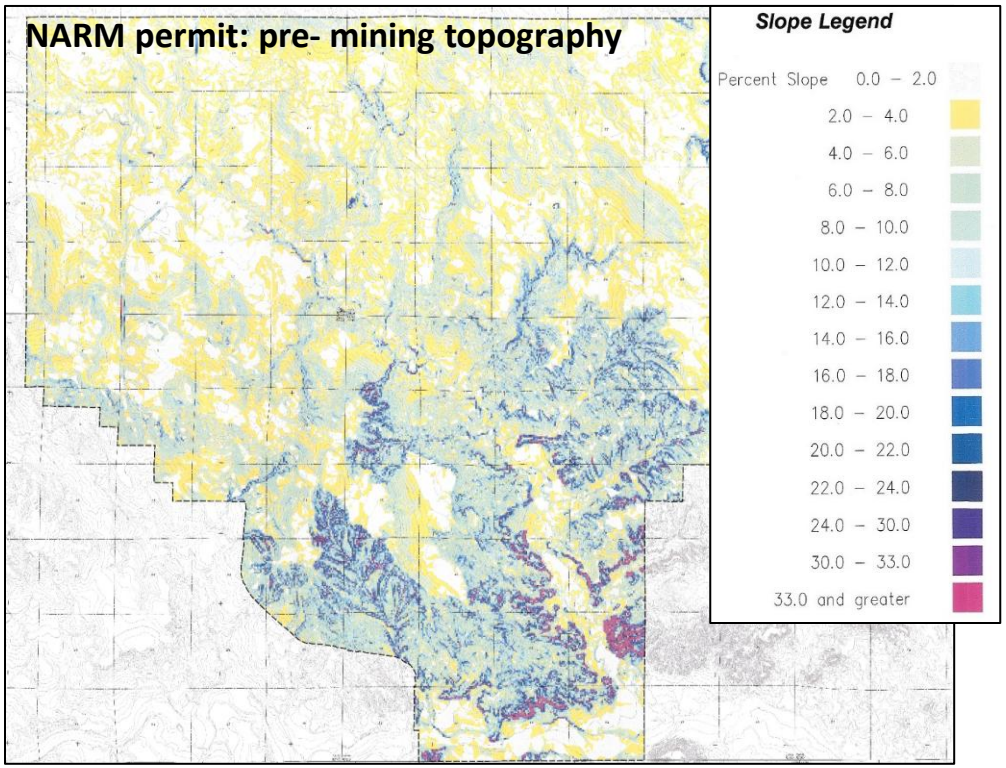


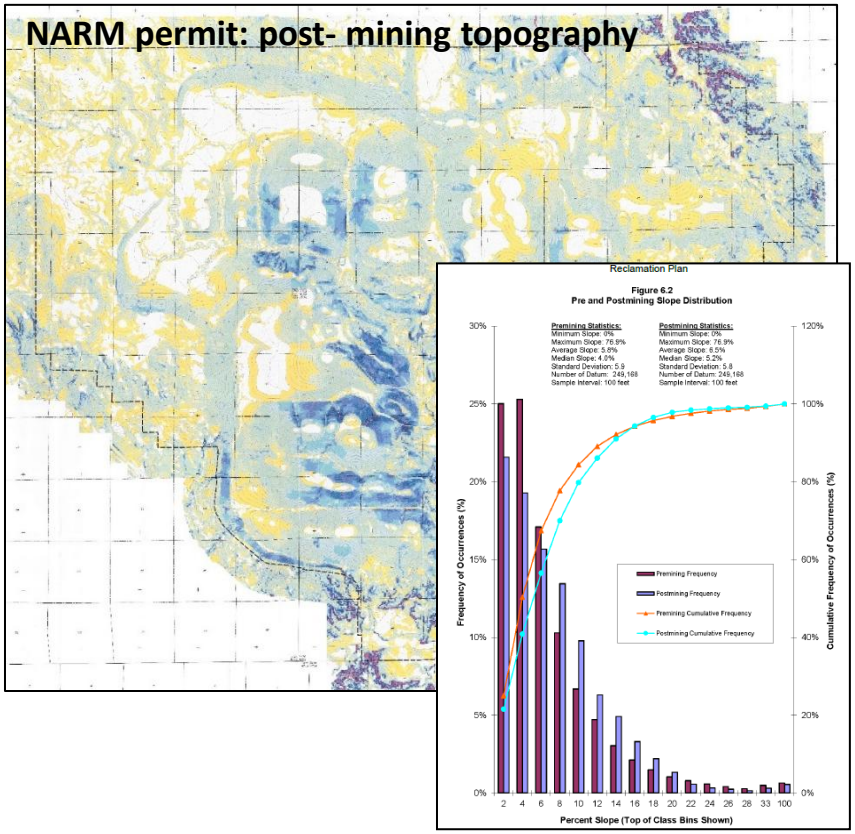
Baseline study - slope assessment method, NARM

- The post-mine slope distribution should approximate the pre-mine slope distribution with the average pre-mine and post-mine slope being nearly identical.

- A square grid pattern (120m between sampling points) overlain on topographic maps for slope determinations (the same sampling points for both pre-mining and post-mining surfaces).

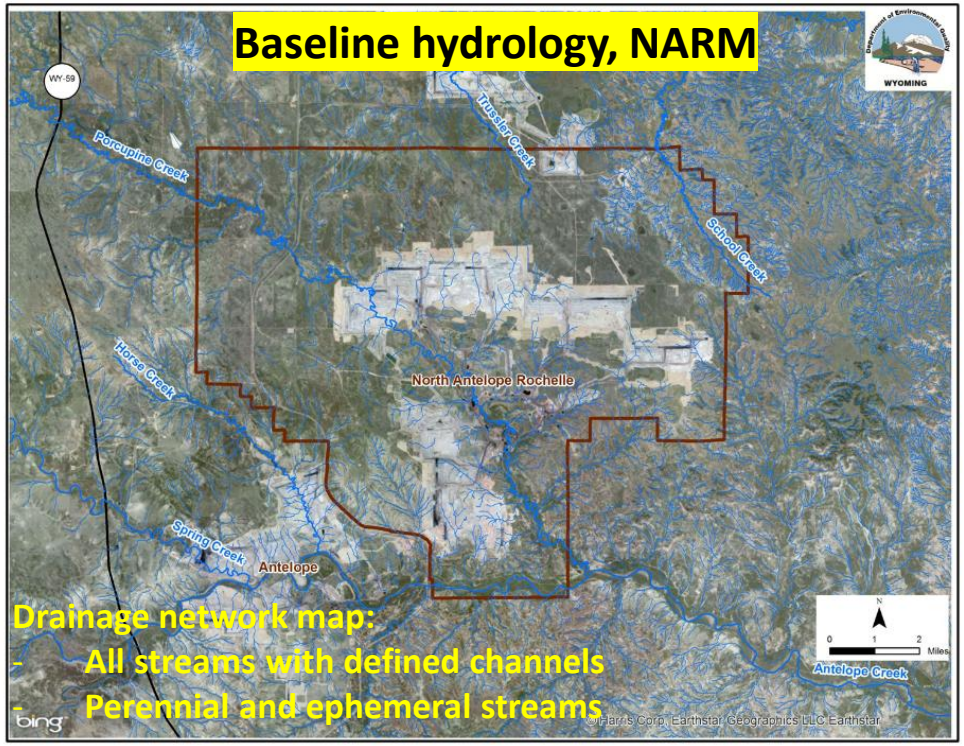
- High-resolution surface models of the pre-and post-mining topographies generated from the high density remote sensing method, LIDAR (Light Detection and Ranging) data.





Baseline data for hydrologic restoration, Western US

Water originating upstream from the mine must be available for a downstream use all the time.



- **Survey of major drainages within a watershed larger than 20 ha -** reconstructed watersheds will approximate pre-mining conditions.

- **Characteristics of stream channel profiles** that will be reclaimed to maximize stability and blend with the adjacent undisturbed channel profiles.

Drainage basin and stream channel characterization

Pre- and post- mining characteristics data:

- **Watershed area** (topographic drainage basin/drainage divide)
- **Basin relief ratio** (difference in elevation)
- **Valley and channel slopes**
- **Channel sinuosity (**ratio of the length of the curved drainage channel to a straight line)
- **Drainage density**
- **Baseline water quality and quantity on intermittent and perennial streams** (collected monthly)

Table MH5.22. Premining Versus Postmining Watershed Parameters for Major Drainages at the North Antelope Rochelle Mine Campbell County, Wyoming

DRAINAGE BASIN	PREMINING DRAINAGE CHARACTERISTICS		POSTMINING DRAINAGE CHARACTERISTICS		PERCENT CHANGE
	Drainage Area (mi^2)	Maximum Basin Relief (ft)	Drainage Area (mi^2)	Maximum Basin Relief (ft)	For Drainage Area
Beckwith Creek[1]	3.51	281	3.44	240	-2%
School Creek	13.72	325	12.92	325	-6%
Boltz Draw	6.90	212	6.95	177	1%
Peabody Draw	2.39	388	2.44	387	2%
Knapp Draw	3.44	372	3.89	365	13%
Payne Draw	4.80	390	2.63	325	-45%
Corder Creek	4.75	320	4.61	319	-3%
Boss Draw	3.22	310	0.18	266	-94%
Ferret Draw	1.82	185	3.41	296	88%
Rat Draw	2.45	312	0.64	87	-74%
Beaver Draw	0.28	62	1.19	213	325%
Gabe Draw	0.10	183	0.30	270	204%
South Fork Gabe Draw	0.28	243	0.34	286	22%
Anna Draw	0.19	170	0.51	216	170%
Skull Draw	0.53	227	0.97	358	83%
Chyr Draw	2.32	364	8.81	408	280%
Horsey Draw	0.24	190	1.07	228	344%
Mike's Draw	1.42	190	1.38	262	-3%
Roger's Draw	1.49	330	0.77	300	-48%
Katie Draw	0.22	200	0.33	272	50%
Cindy's Draw	0.64	208	1.84	403	188%
Judie's Draw[2]	0.34	210	2.02	392	494%
Belden Draw	0.79	282	1.12	251	42%
Porcupine Creek[1]	94.95	725	96.44	725	2%
Porcupine Ck. (at Antelope Ck.)	117.15	813	117.55	813	0%
Total Internal Playa Drainage Basin (see Mine and Reclamation Plan Table 6.8)	6.73	160	6.86	170	2%

Examples from the mine permit (NARM)

Table **RP-9**
Comparison of Premining and Postmining
Basin Geomorphic Characteristics

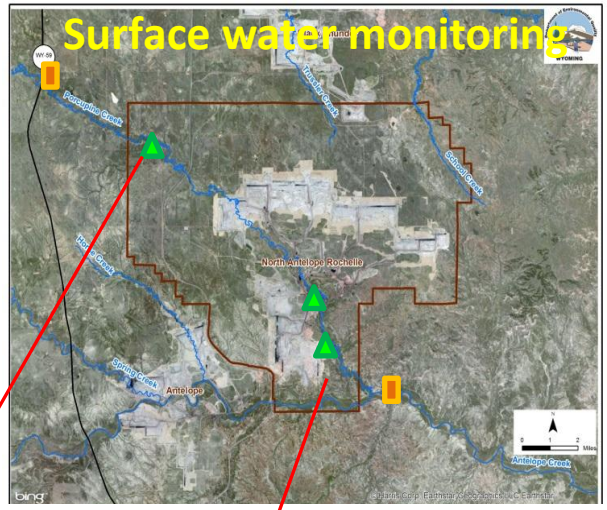
Drainage	Basin Drainage Density (mi/sq mi)		Basin Relief Ratio		Main Channel Sinuosity	
	Premining	Postmining	Premining	Postmining	Premining	Postmining
Tisdale Creek	3.51	**3.22**	0.009	0.009	1.20	1.21
North Tisdale Creek	2.51	**2.09**	0.011	0.011	1.14	1.10
Gold Mine Draw	3.61	**3.22**	0.012	0.012	1.26	1.26

Pre-mining surface water quantity and quality, Western US

- Measurements for a minimum of one year prior to permit application submittal.

- Characterize baseline water quantity (daily, monthly annual flows, peak flows, flow duration curves, hydrographs, etc.) and quality on all major streams in the permit area.

- Estimation of the runoff volume and peak flows of 2-year, 10-year, and 100-year frequencies near the downstream permit boundary for all major streams.



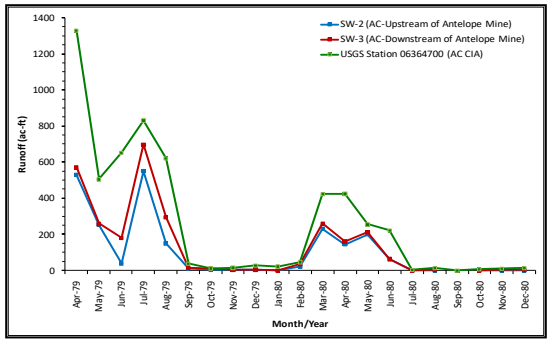


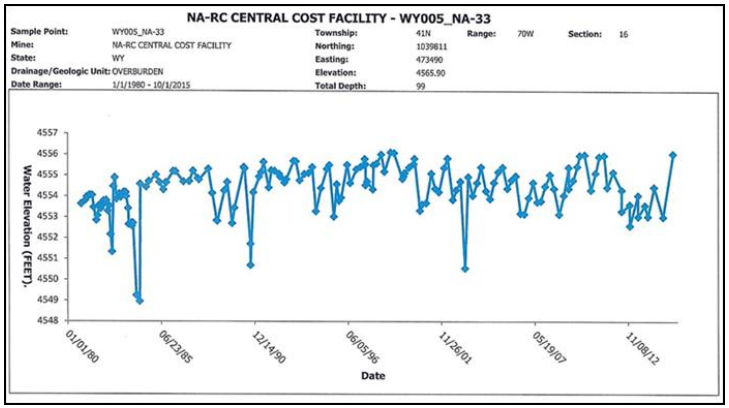
*Table 13. Baseline water quality statistics and number of WDEQ/WQD class of use exceedances for selected constituents on Porcupine Creek at NAR Mine stations GS-1 and GS-5.

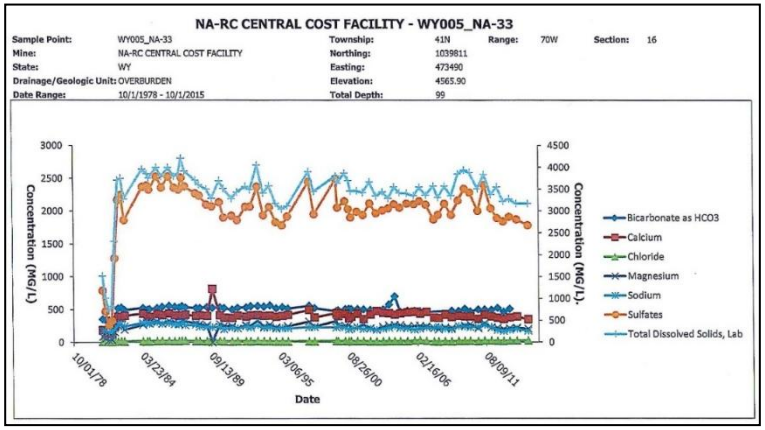
Constituent	Units	Porcupine Creek (upstream) (GS-1) (1980-1984)					Porcupine Creek (downstream) (GS-5) (1980-1984)				
		Number of samples	Min	Max	Median	Number of exceedances	Number of samples	Min	Max	Median	Number of exceedances
Aluminum (dissolved)	mg/L	34	<0.1	1.6	0.06	1	33	<0.1	0.4	88% <0.2	0
Ammonia as N (total)	mg/L	0	-	-	-	NA	0	-	-	-	NA
Arsenic (dissolved)	mg/L	35	<0.001	0.028	86% <0.005	0	34	<0.001	<0.005	91% <0.005	0
Barium (dissolved)	mg/L	35	<0.2	0.5	86% <0.5	NA	33	<0.2	0.4	82% <0.5	NA
Cadmium (dissolved)	mg/L	35	<0.002	0.01	86% <0.002	4	34	<0.002	0.01	94% <0.002	2
Chloride (dissolved)	mg/L	38	3.2	101.0	23.0	NA	39	2.0	66.0	8.0	NA
Chromium (dissolved)	mg/L	32	<0.02	0.14	0.03	0	31	<0.02	0.07	84% <0.06	0
Copper (dissolved)	mg/L	35	<0.01	0.06	0.02	10	34	<0.01	0.07	0.01	6
Dissolved oxygen	mg/L	0	-	-	-	NA	0	-	-	-	NA
Iron (dissolved)	mg/L	36	<0.05	2.2	0.11	1	35	<0.02	0.28	0.03	0
Lead (dissolved)	mg/L	35	<0.02	0.07	86% <0.02	5	34	<0.02	0.04	85% <0.02	5
Manganese (dissolved)	mg/L	35	0.03	10.6	0.7	4	34	<0.02	1.68	0.12	0
Mercury (dissolved)	µg/L	35	<0.01	0.08	89% <1.0	0	34	<0.01	<1.0	100% <1.0	0
Nickel (dissolved)	mg/L	35	<0.01	0.16	80% <0.02	0	34	<0.01	0.03	0.007	0
Nitrite plus nitrate as N (total)	mg/L	22	<0.01	7.62	0.05	NA	23	<0.01	2.16	0.10	NA
pH (field)	S.U.	33	6.3	8.8	7.6	1	33	4.7	8.7	7.7	2
Selenium (dissolved)	mg/L	35	<0.001	0.002	94% <0.005	0	34	<0.001	0.002	94% <0.005	0
Temperature (field)	°C	33	1.8	23.8	13.5	NA	34	0	24.0	11.0	NA
Turbidity	NTU	34	1	1,000	12	NA	33	<5	88	10	NA
Zinc (dissolved)	mg/L	35	<0.01	0.07	0.03	0	34	<0.01	0.10	0.01	0
Boron (dissolved)	mg/L	35	<0.01	0.78	0.16	NA	34	<0.01	0.96	0.33	NA
Fluoride (dissolved)	mg/L	36	0.02	0.55	0.34	NA	35	0.06	1.33	0.59	NA
Sodium (dissolved)	mg/L	38	72	3,100	812	NA	39	8	912	189	NA
Sulfate (dissolved)	mg/L	37	422	8,250	3,400	NA	38	38	3,436	936	NA

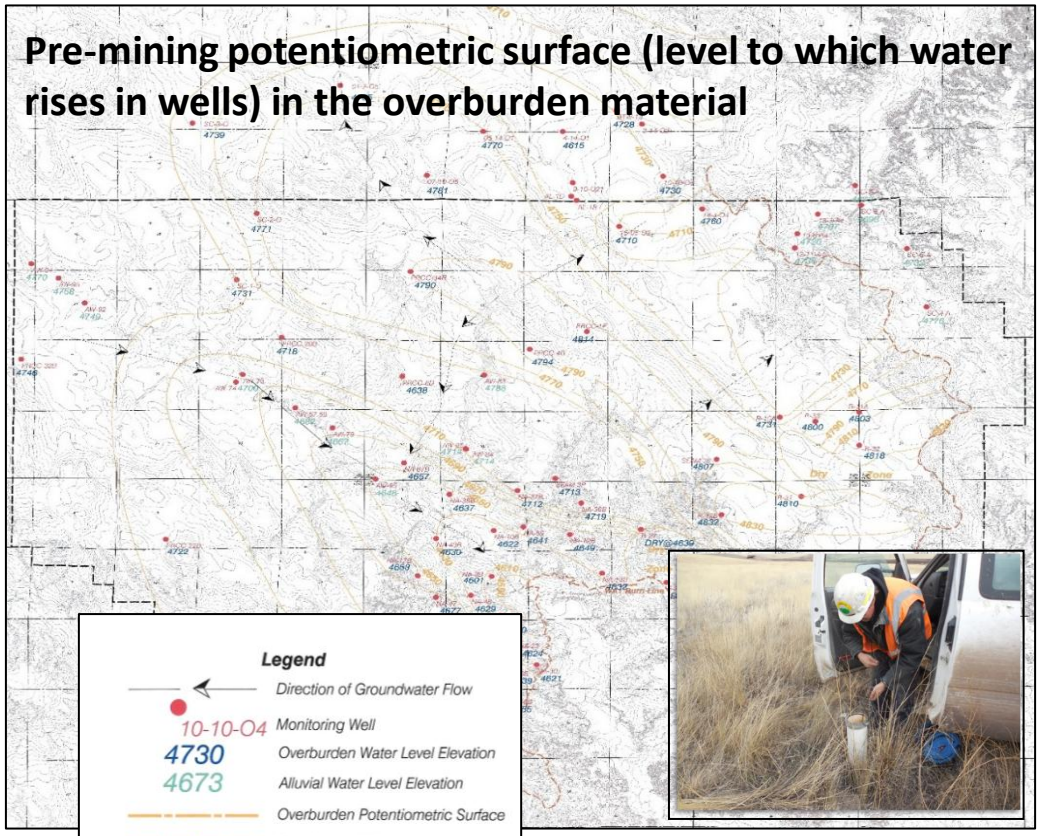
*The state regulators performs Cumulative Hydrologic Impact Assessment (CHIA) of Coal Mining in the Southern Powder River Basin, Wyoming.

Pre-mining groundwater, Western US

- Wells located at or near the permit boundary installed 0.5-2 years before coal removal and in-pit-sumps in groundwater aquifers (e.g. NARM has five aquifers and 67 active wells).
- Estimating dewatering rates and volumes.
- Measuring pre-mining potentiometric water level.
- **Maximum potential drawdowns developed from pre-mine water levels to the bottom of the aquifer.**
- Groundwater analysis (minimum): total dissolved and suspended solids, pH, alkalinity, sulfates, total iron and manganese







Wells located approximately every square mile

Baseline topsoil data

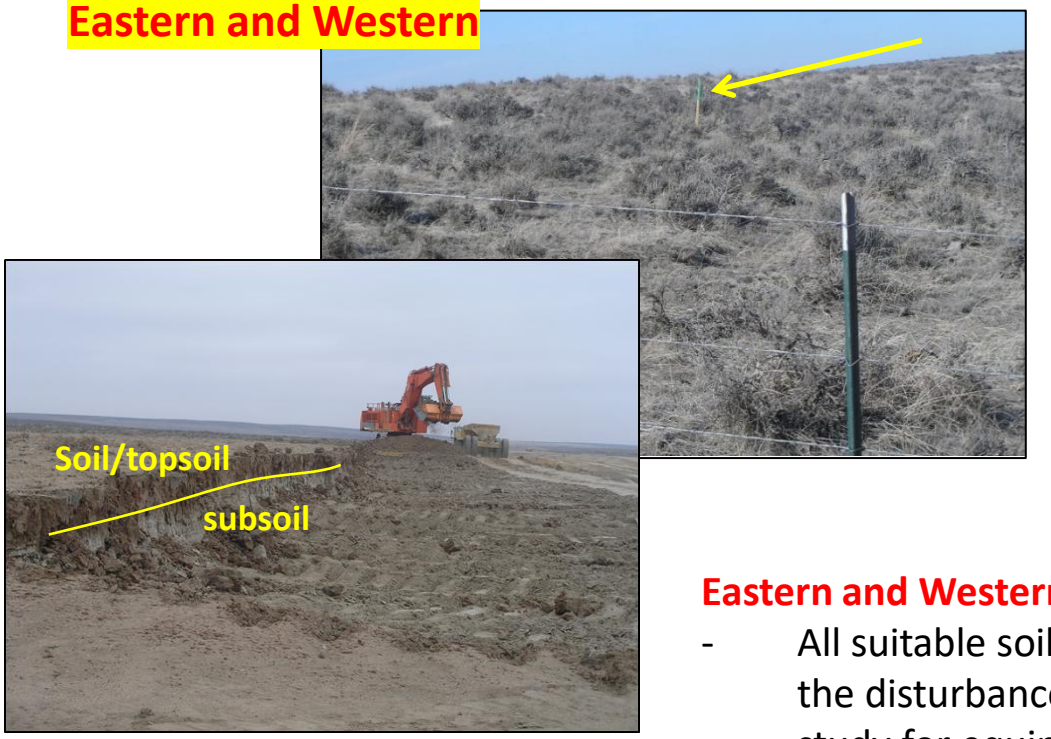
Salvaging all suitable soil

- Soil units identified (physical and chemical characteristics of soil)
- Soil sampling: at least one sample site for each soil series. Soil profiles sampled to a depth of 150 cm or bedrock.
- Soil samples along soil profiles analyzed for soil quality according to the state guidelines (pH, EC, SAR, Selenium, Boron, texture in Wy).
- Each soil mapping unit:
  - the hectares and the average depth of soil removal
  - the volumes of soil to be salvaged

NARM - Porcupine LBA Study		Salvage
Map Symbol	Map Unit Description	Depth (in)
P-Ar	Arvada	18.0
P-Bi	Bidman	28.0
P-Bo	Bowbac	22.0
P-Ca	Cambria	33.0
P-Cl	Clarkelen	4.0
P-D	Disturbed	0.0
P-De	Decolney	12.0
P-Dr	Draknab	15.0
P-Fe	Felix	2.0
P-Fo	Forkwood	24.0
P-Gu	Gullied	0.0
P-Hi	Hiland	30.0
P-Kee	Keeline	17.0
P-Key	Keyner	20.0
P-Ki	Kishona	47.0
P-Re	Renohill	19.0
P-Sa	Savageton	15.0
P-Sh	Shingle	6.0
P-Ta	Taluce	7.0
P-Tul	Tullock	12.0
P-Tur	Turnercrest	10.0
P-Ulm	Ulm	27.0
P-Wa	Wags	4.0

Salvaging suitable topsoil

Eastern and Western



Western only, large mines

Eastern and Western US:

- All suitable soil marked (marker, stakes) in the field ahead of the disturbance by qualified personal during the baseline study for equipment operators.

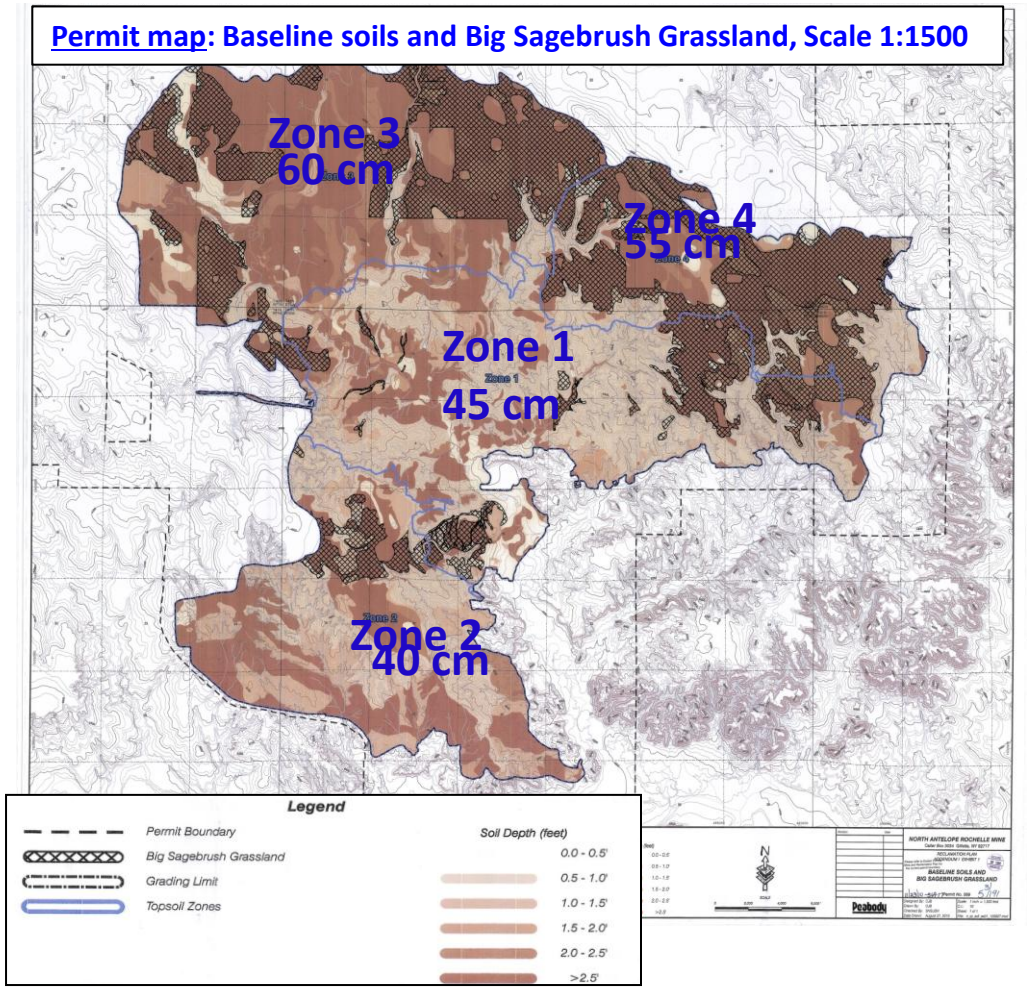
Western US:

- During salvaging: islands of soil (pedestals) temporarily left to verify salvage depths (one per 0.8 ha or on 150 m centers). Each pedestal is labeled with the actual soil removal depth.

- The predicted soil stripping volume calculated from the baseline data overestimates the stripping volumes as compared to the actual volume from soil pedestal data. This information is needed to calculate the correct topsoil depth application.

Baseline topsoil data – soil management for one mine, NARM

- Two maps overlaid: soil depth baseline data and plant communities.
- Measuring topsoil depth in various plant communities to establish the best topsoil thickness for reclamation success of Big Sagebrush communities.
- Found four distinct zones of soil depths in correlation to Big Sagebrush across the mine.

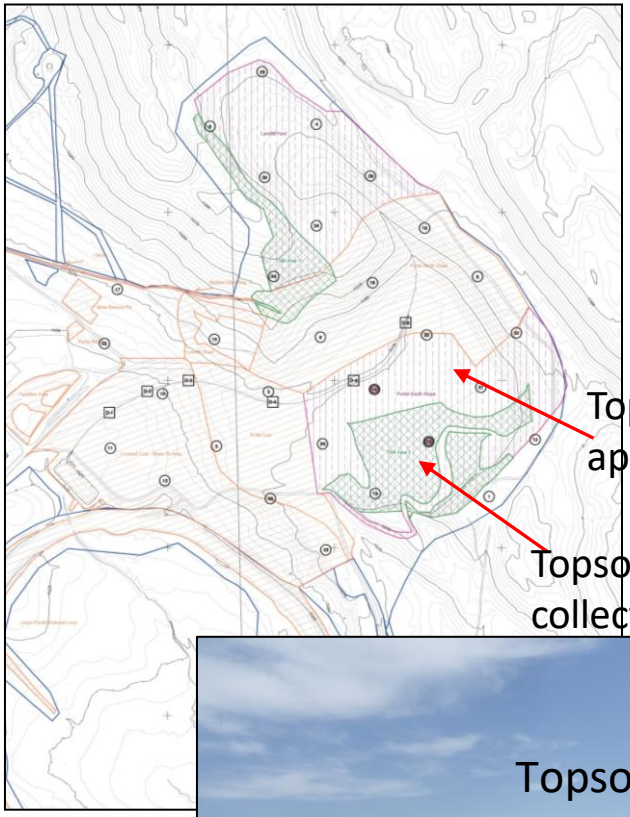


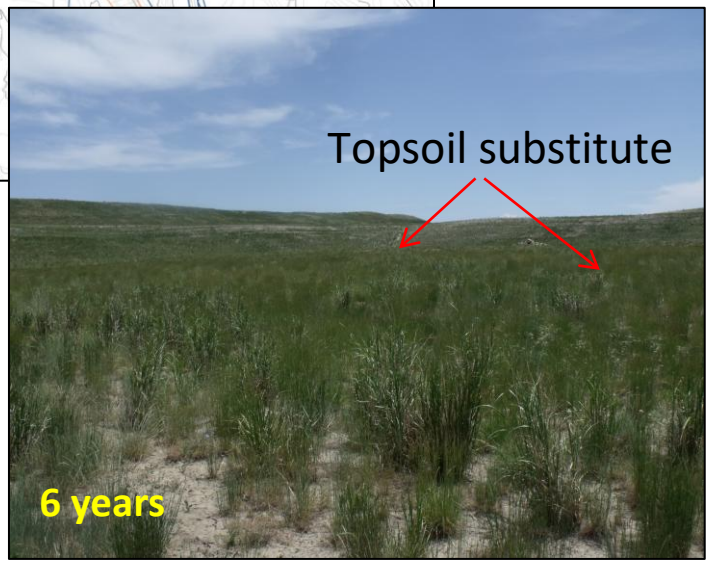
Conclusions:

- Strong relationship between Big Sagebrush and soils deeper than 75 cm.
- Strong relationship between Big Sagebrush and slopes flatter than 8%.
- Aspect of the slope – no relationship
- Sagebrush mosaic seed mixes planted on slopes that are flat <8% on deep soil (75-120 cm) and other seed mixes planted on the “typical” soil (15-75cm) replacement depth areas.

Topsoil substitute suitability

Topsoil substitute, **Wyoming**





Good reclamation results

Weathered brown sandstone in **West Virginia** *

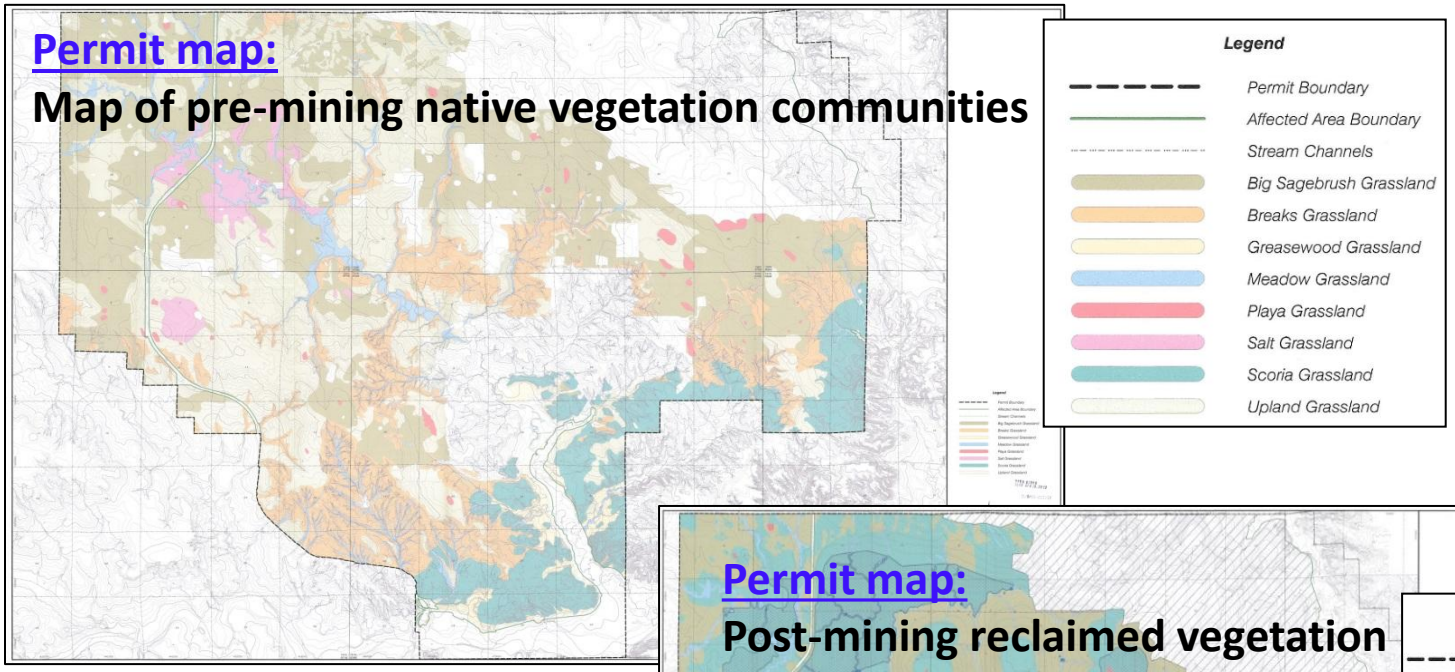
Tree growth and herbaceous plant cover

** Skousen J.et al. 2011 Selecting topsoil substitute for forestry mine soil. Proceedings ASMR, Bismarck.*

Pre- and post - mining plant communities (permit), Western US

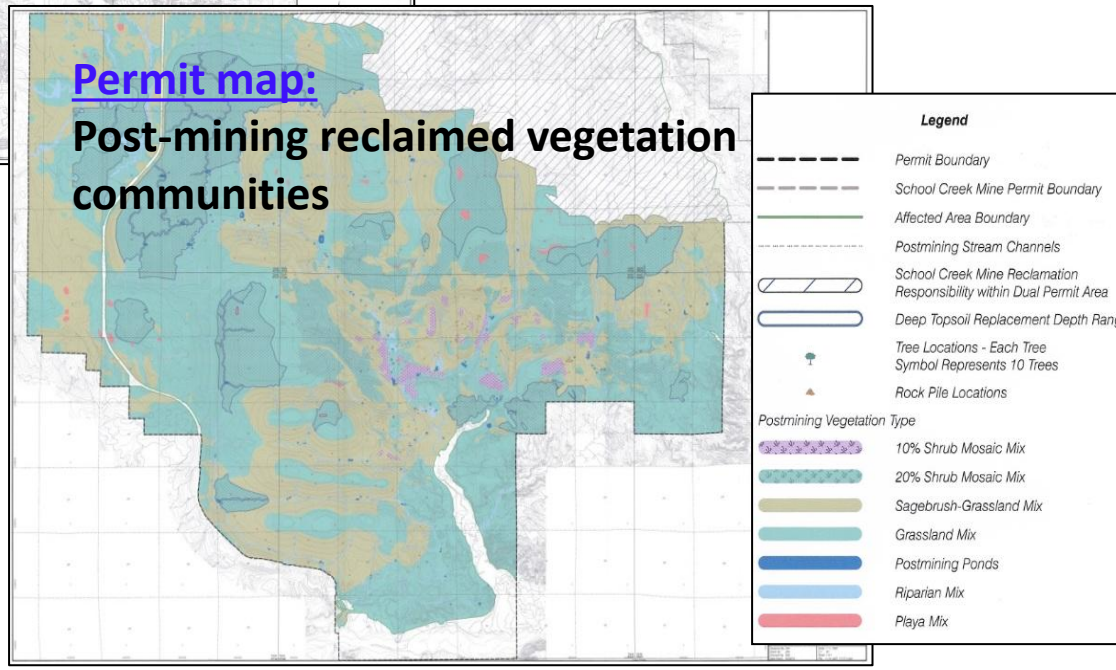
Permit map:

Map of pre-mining native vegetation communities



Permit map:

Post-mining reclaimed vegetation communities



- **Pre-mining plant communities and the post-mine topography – location where to plant specific seed mixes.**
- **Planting native seed mixes corresponding to the pre-mine plant communities.**
- **Seeding rate - post-mining vegetation cover and production should be equal to the pre-mining vegetation cover**

Pre-mining plant communities (permit), Western US

- **Plant species list developed from the pre-mine site evaluation.**

Premining			
Land Use	Plant Community (Vegetation Type)	Affected Area within Permit Area (North Antelope Rochelle Reclamation Liability)	
		Acres	Percent
Grazingland	Big Sagebrush Grassland	13,108.2	28.7%
	Breaks Grassland	8,492.0	18.6%
	Sub-Total	21,600.2	47.3%
Grazingland	Greasewood Grassland	1,116.8	2.4%
Grazingland	Scoria Grassland	4,428.2	9.7%
Grazingland	Upland Grassland	13,936.7	30.5%
Grazingland	Salt Grassland	986.9	2.2%
Disturbed Area	Disturbed Area	305.1	0.7%
Pastureland	Undeveloped Pasture	819.0	1.8%
Hayland	Hayland	6.9	0.0%
	Sub-Total	21,599.6	47.3%
Grazingland	Meadow Grassland	2,136.4	4.7%
	Sub-Total	2,136.4	4.7%
Grazingland	Playa Grassland	292.8	0.6%
	Sub-Total	292.8	0.6%
Stockponds/Reservoirs	Water	45.7	0.1%
	TOTAL	45,674.8	100.0%

Notes:
1. Seed mixtures are discussed in more detail in Section 6.4.5.
2. Locations of each seed mixture, including shrub mosaics, are shown on Exhi
3. Affected and Reclaimed Areas represent lands affected within the NARM per
4. The Fish and Wildlife Habitat 20% Sagebrush Mosaic acres include the minir RPC

		Seed Mixes								
		Postmining Vegetation Type Seed Mixes					Wetland Seed Mixes			
Scientific Name	Common Name	Grassland	Sagebrush Grassland	Riparian	Playa	Sagebrush Mosaic	Wet Meadow	Emergent	Stubble Mulch Cover Crop	Temporary Reclamation
		Pure Live Seed Pounds/Acre								
Cool Season Grasses/Grass-Like										
Achnatherum hymenoides	Indian ricegrass	0.25	0.50							
Carex nebrascensis	Nebraska sedge						1.00			
Eleocharis palustris	Creeping spikerush						1.00	1.00		
Elymus lanceolatus ssp. lanceolatus	Thickspike wheatgrass	0.50	1.00							1.00
Elymus lanceolatus ssp. psammophilus	Streambank wheatgrass	0.50	0.50	1.00			1.50			
Elymus smithii	Western wheatgrass	3.00	1.00	3.00	14.00	1.00	1.50			2.00
Elymus trachycaulus	Slender wheatgrass			2.00	2.00					5.00
Koeleria macrantha	Prairie junegrass	0.50	0.25	0.10		0.10				
Leymus cinereus	Great Basin wildrye		0.10	0.25						
Nassella viridula	Green needlegrass	1.00	1.00	2.00		0.50				4.00
Poa secunda ssp. ampla	Big bluegrass			0.50	0.25					
Poa secunda ssp. canbyi	Canby bluegrass	0.25								
Poa secunda ssp. sandbergii	Sandberg bluegrass	0.75	1.00			0.10	0.50			
Pseudoroegneria spicata	Bluebunch wheatgrass	0.50	0.50							
Scirpus pungens	Three-square bulrush						1.50	4.50		
	Sub-total	7.25	5.85	8.85	16.25	1.70	7.00	5.50		12.00
Warm Season Grasses										
Bouteloua gracilis	Blue grama	1.50	1.00			1.00				
Calamovilfa longifolia	Prairie sandreed	0.25	0.25	0.50						
Distichlis spicata	Inland saltgrass						1.75			
Spartina pectinata	Prairie cordgrass						2.00			
Sporobolus airoides	Alkali sacaton			0.10						
	Sub-total	1.75	1.25	0.60		1.00	3.75			
Forbs										
Achillea millefolium var: occidentalis	Western yarrow	0.05		0.10		0.10				
Astragalus cicer	Cicer milkvetch	0.05								
Dalea purpurea var:purpurea	Purple prairieclover	0.10				0.10				
Hedysarum boreale	Northern sweetvetch	0.75	1.00	1.00						
Linum lewisii	Blue flax	0.10	0.25	0.10		0.10				0.50
Lupinus argenteus	Silverleaf lupine	0.10				0.05				
Medicago sativa	Alfalfa	0.10	0.10			0.10				0.50
		Pure Live Seed Pounds/Acre								
Penstemon strictus	Rocky Mountain penstemon	0.10	0.10	0.25		0.15				
Ratibida columnifera	Prairie coneflower	0.25	0.10	0.10		0.25				
Sphaeralcea coccinea	Scarlet globemallow	0.25	0.10			0.25				
Thermopsis montana	Mountain thermopsis					0.50				
	Sub-total	1.85	1.65	1.55		1.60				1.00
Shrubs/Subshrubs										
Artemesia cana	Silver sagebrush			0.75		0.25				
Artemesia frigida	Fringed sagewort	0.10	0.20	0.10		0.25				
Artemesia tridentata	Big sagebrush	0.50	1.00	0.10		3.00				
Artemisia ludoviciana	Louisiana sagewort			0.10		0.10				
Atriplex canescens	Four-Wing saltbush		0.50							
Atriplex gardneri	Gardner saltbush	0.10				1.00				
Krascheninnikovia lanata	Winterfat		1.00			1.00				
Ericameria nauseosa	Rubber rabbitbrush		2.00			2.00				
Rosa woodsii	Wood's rose			0.50						
Sarcobatus vermiculatus	Black greasewood		0.05							
	Sub-total	0.70	4.75	1.55		7.60				

Monitoring revegetation success

Revegetation success evaluated by comparing data from a reference control area with data from the reclaimed area.

- "Control area" or "Reference area" - established during baseline sampling outside the disturbance.

Quantitative comparisons of:

- Cover (vegetative cover, total ground cover, cover of bare areas)
- Production (total production, specific species production)
- Density and distribution (shrubs, trees)
- Species diversity and species composition similar to pre-mining

Post-mining vegetation cover and production should be equal to the pre-mining vegetation cover

Western

- wildlife/grazing land: shrub density 1 shrub/m^2 recovered on 20% of the land, trees: the same as pre-mining (80% of trees have been in place for 8 years).
- Vegetation evaluated on the year 7^{th} of the 10 years after seeding.

Eastern

- forest/wildlife land: minimum 70% ground cover of legumes and perennial grasses and 1100 trees and/or planted shrubs per ha.
- Vegetation evaluated after 5 growing seasons following seeding, planting, fertilization.

Forestry Reclamation Approach (FRA), Eastern US

(a) Placement of brown topsoil up to 1.5 m in depth

(b) Tree growth after planting on such sites 2 years

(c) Tree growth after planting on such sites 6 years

(d) Tree growth on such sites 15 years

Tree species planted on coal surface mines in eastern USA:

- Baseline survey of tree species
- Selecting tree species depends on site types, landscape position creating tree prescriptions
- Planting crop trees, wildlife trees and N-fixing trees

Method developed by federal US government, state regulatory authorities, and researchers (Appalachian Regional Reforestation Initiative).

Highly productive forestland on reclaimed mine lands

1. Create a suitable rooting medium, thickness more than 1 m (soil, suitable material, organics etc.)
2. Loosely grade the soil (to create a non-compacted medium growth).
3. Plant less competitive ground covers compatible with growing trees (low seeding rates and with relatively low rates of N fertilizer, typically 55–85 kg/ha).
4. Plant two types of trees-early successional species for wildlife and soil stability and commercially valuable crop trees (1250-1700 stems per hectare).
5. Use proper tree planting techniques (at least five species of trees be used, and at least three of the species being higher value hardwoods such as oak, ash, or maple).

All five steps must be accomplished to achieve successful reforestation!

Pre-mining wildlife monitoring (permit), Western US

- Surveys of raptor nests (golden eagle and great horned owl)
- Surveys of active nest and their productivity
- Surveys of migratory bird species of management concern (mountain plovers)
- Observations of any threatened and endangered species on or near the mine permit (e.g. bald eagle, black-footed ferret, and Ute-ladies-tresses)

[NARM Permit map](): Wildlife feature

Why the knowledge of pre-mining baseline data is important?

Baseline data	Reclamation goals	Survey, monitoring of environmental data
Land use	Planned post-mining land uses, determination of the special protected areas (wetlands, primary farm land, alluvial valley floor)	survey of land uses
Cultural resources	Plans to mitigate sites of importance	survey of archeological and paleontological investigation
Geology	Economic viability	ratio of an overburden material to coal seam
Topography	Building post-mining topography to Approximate Original Contour (AOC)	suitability and volumes of overburden material, swell factor, pre-mining slope distribution
Hydrology	Hydrologic restoration: restoring surface water functional drainage system and monitor groundwater quantity and quality supporting post-mining land use	survey of watershed area, basin relief ratio, drainage density, surface and groundwater quality and quantity
Soils	Preparation of successful revegetation: soil replacement to the approved depth	soil survey, thickness of suitable soil
Vegetation	Using pre-mining native species to build post-mining vegetation communities	pre-mining inventory of vegetation communities
Wildlife	Rebuilding land to the pre-mining land use	monitoring indigenous vertebrate species


Questions?
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