Applying landforming to reclamation: A case study in Central Appalachia

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April 12, 2017

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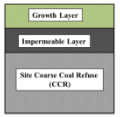
West Virginia University

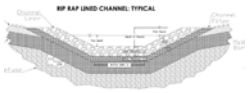
Outline

- Geomorphic reclamation
- Royal Scot reclamation project

Topography



Cap and cover



Drainage

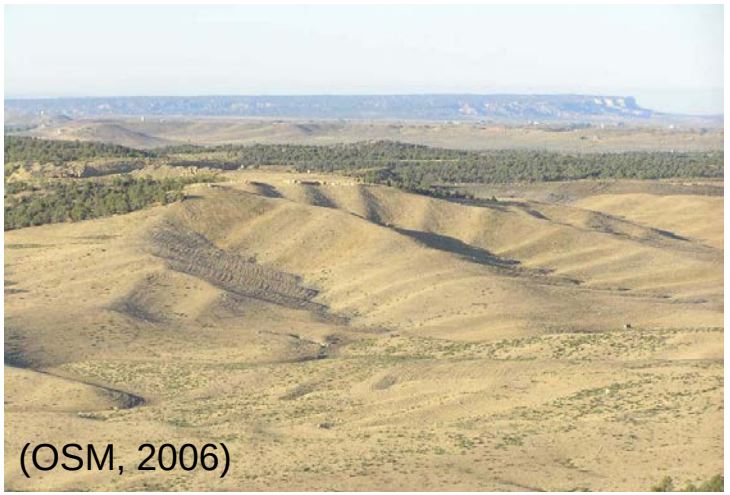
Soil amendment and vegetation

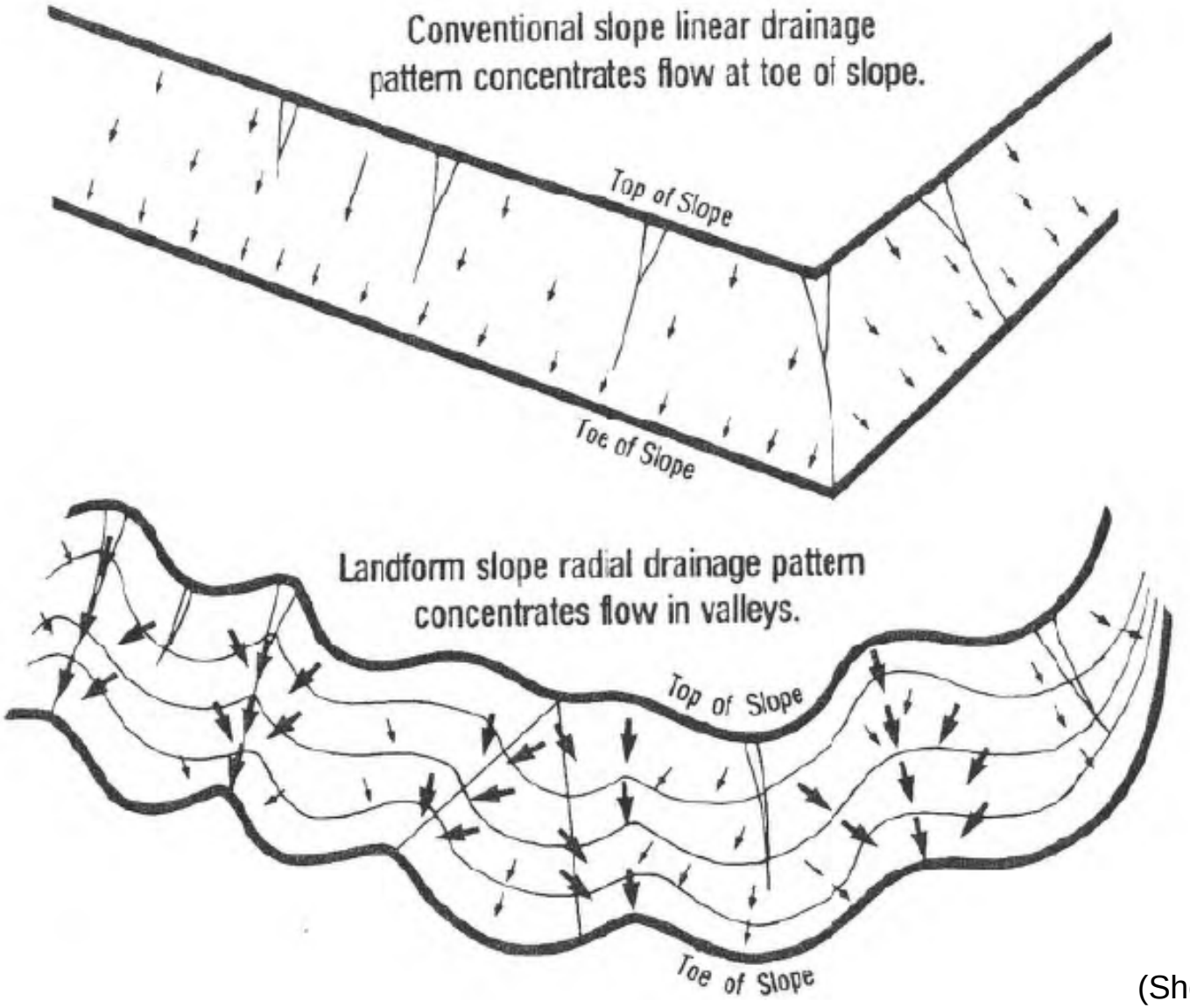
- Conclusions

Geomorphic landform design is a potential approach to reclamation not widely applied east of the Mississippi.

- Simulates undisturbed channel and basin geomorphology
- Applied in Western US and abroad
  - Erosional and geotechnical stability benefits observed


(OSM, 2006)


(OSM, 2006)



(Shor and Gray, 2007)

Challenges in Central Appalachia:

Conventional Landforms

- Continual maintenance
- High flow velocities
- Sediment transport
- Geologically ‘Young’ landforms

Geomorphic Landforms

- High precipitation
- Increased stream impact
- Perceived increase in cost
- Reluctance of industry change

Royal Scot Coarse Coal Refuse Facility:

- Cease and Desist Order: 2001
  - Due to consistent water quality violations
- Groundwater seeps throughout the area
  - Consistent with acid mine drainage
- Water quality is a perpetual problem
  - Highest single cost for an abandoned site in West Virginia

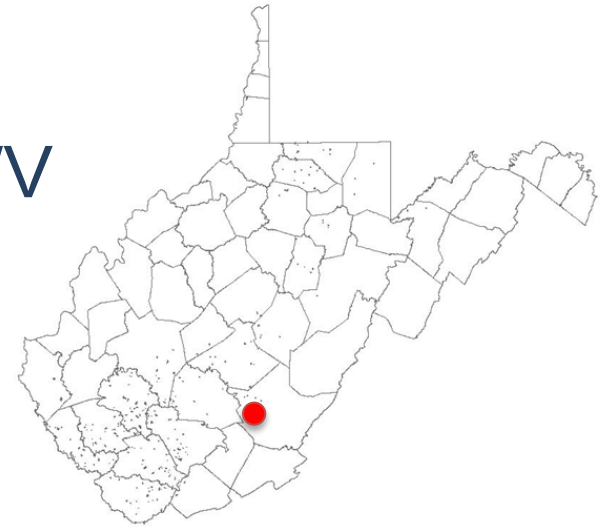
PROJECT GOAL: Minimize perpetual water treatment costs by segregating storm water and groundwater flows

Royal Scot Demonstration Site

- 2015 OSMRE Applied Science Program
- Collaborators:
  - WVU Department of Civil and Environmental Engineering
  - West Virginia Water Research Institute
  - West Virginia Department of Environmental Protection

Royal Scot demonstration site

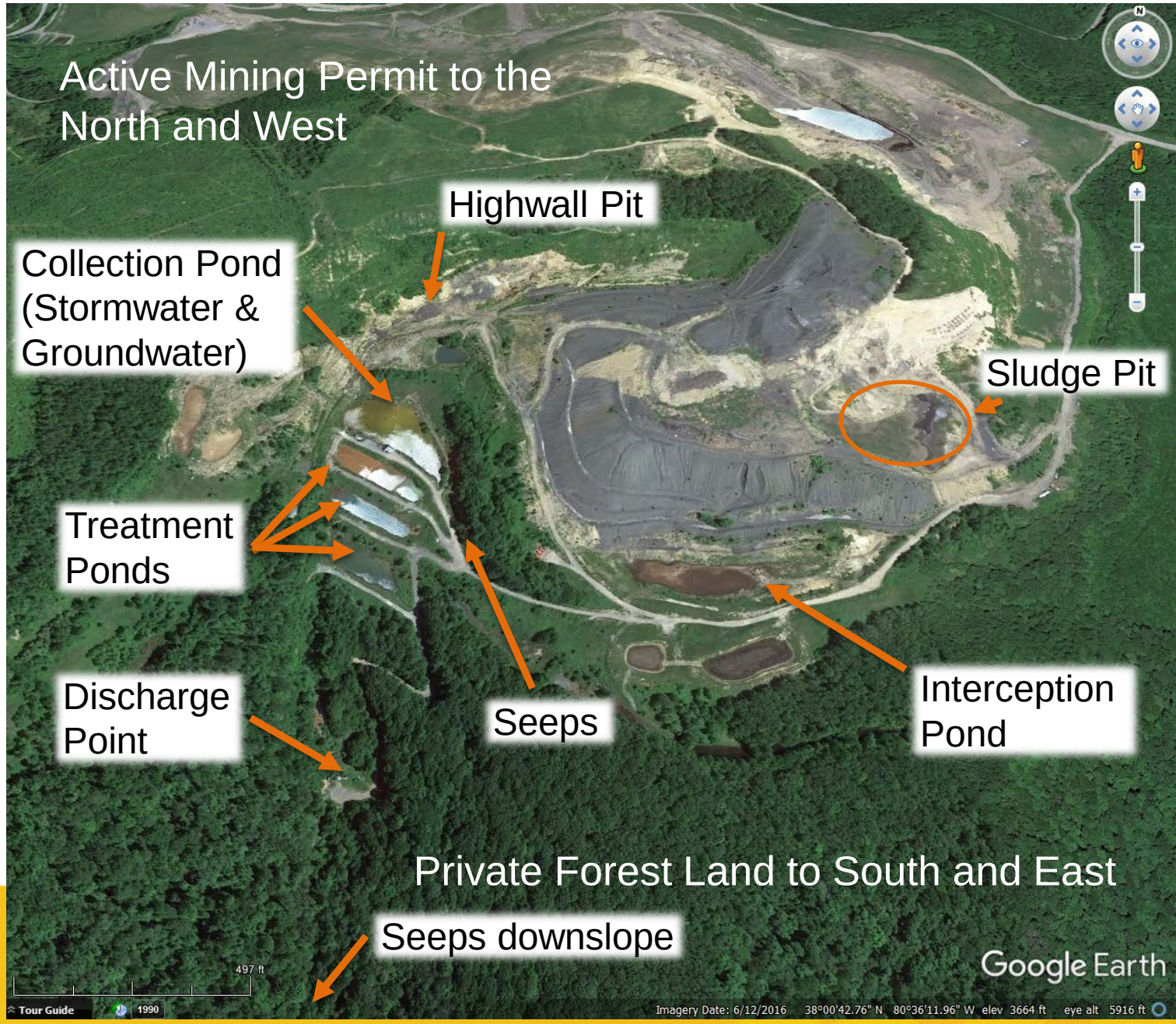
- Located in Greenbrier County, WV
- Coarse coal refuse disposal site
- Abandoned in 2001
- Ridge-top location



Royal Scot Site

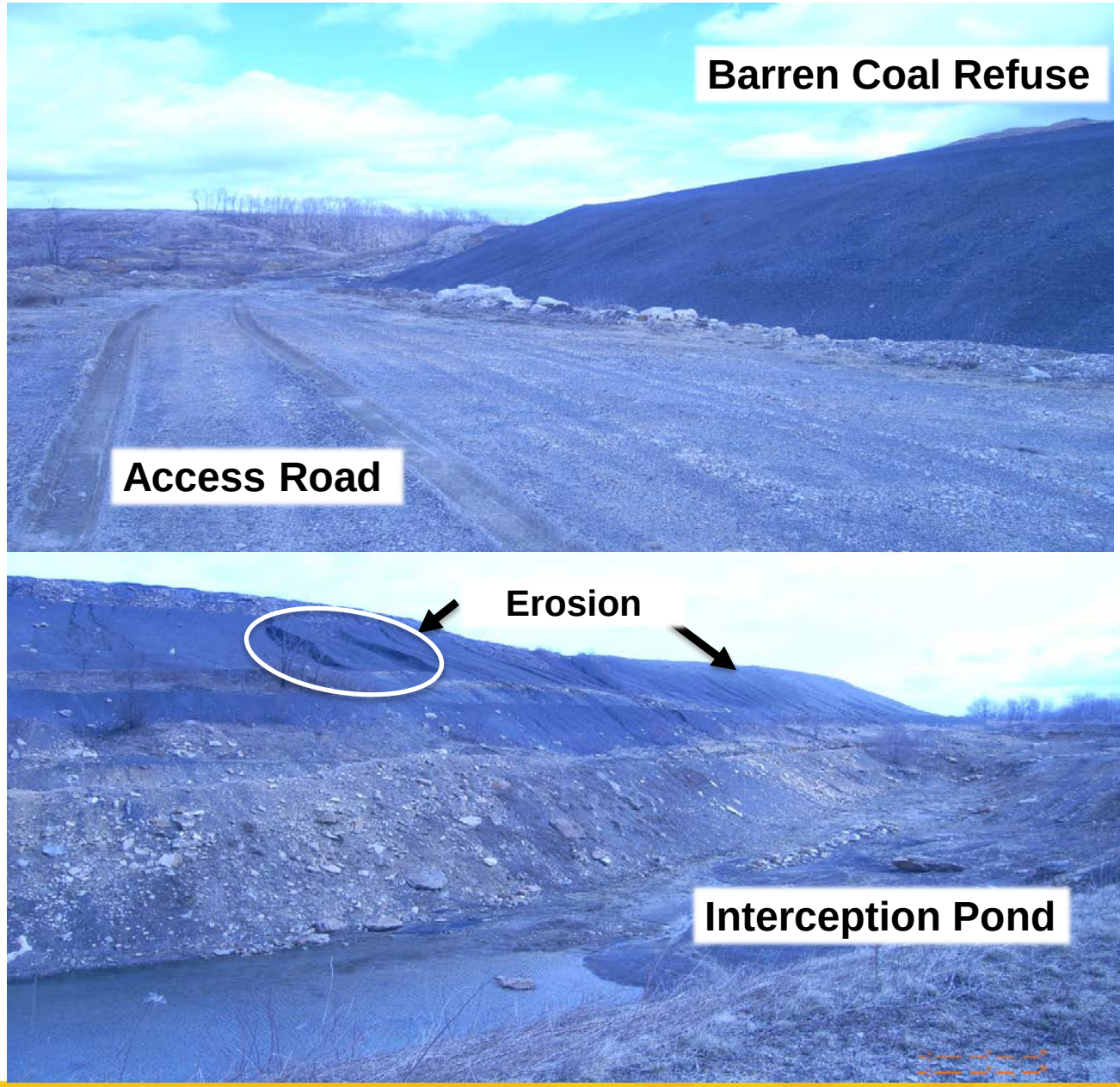
Design Considerations

- Boundaries
- Water quality
- Existing features



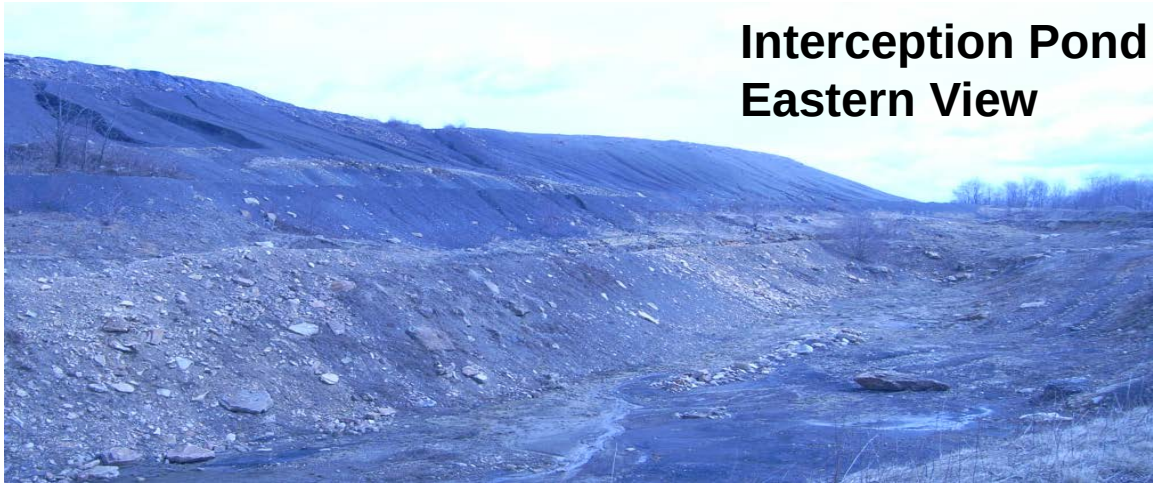
Royal Scot Coarse Coal Refuse Pile:

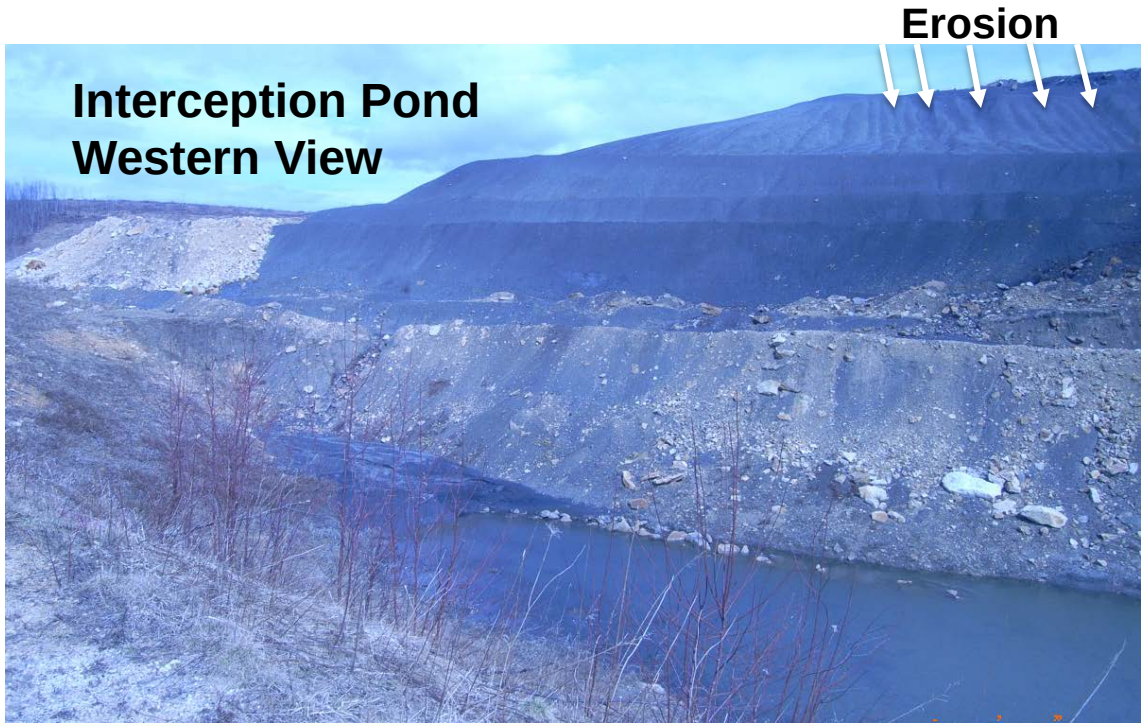
- Negligible vegetation
- Erosion throughout
- Steep slopes
  - + 2:1



Interception Pond:

- Underdrain is plugged
  - No controlled outlet
- Pond invert is on rock
  - Rock mass is heavily jointed
  - Seepage
- Seep response tests conducted by WV DEP
  - Flow paths
  - Response time





Sludge Pit:

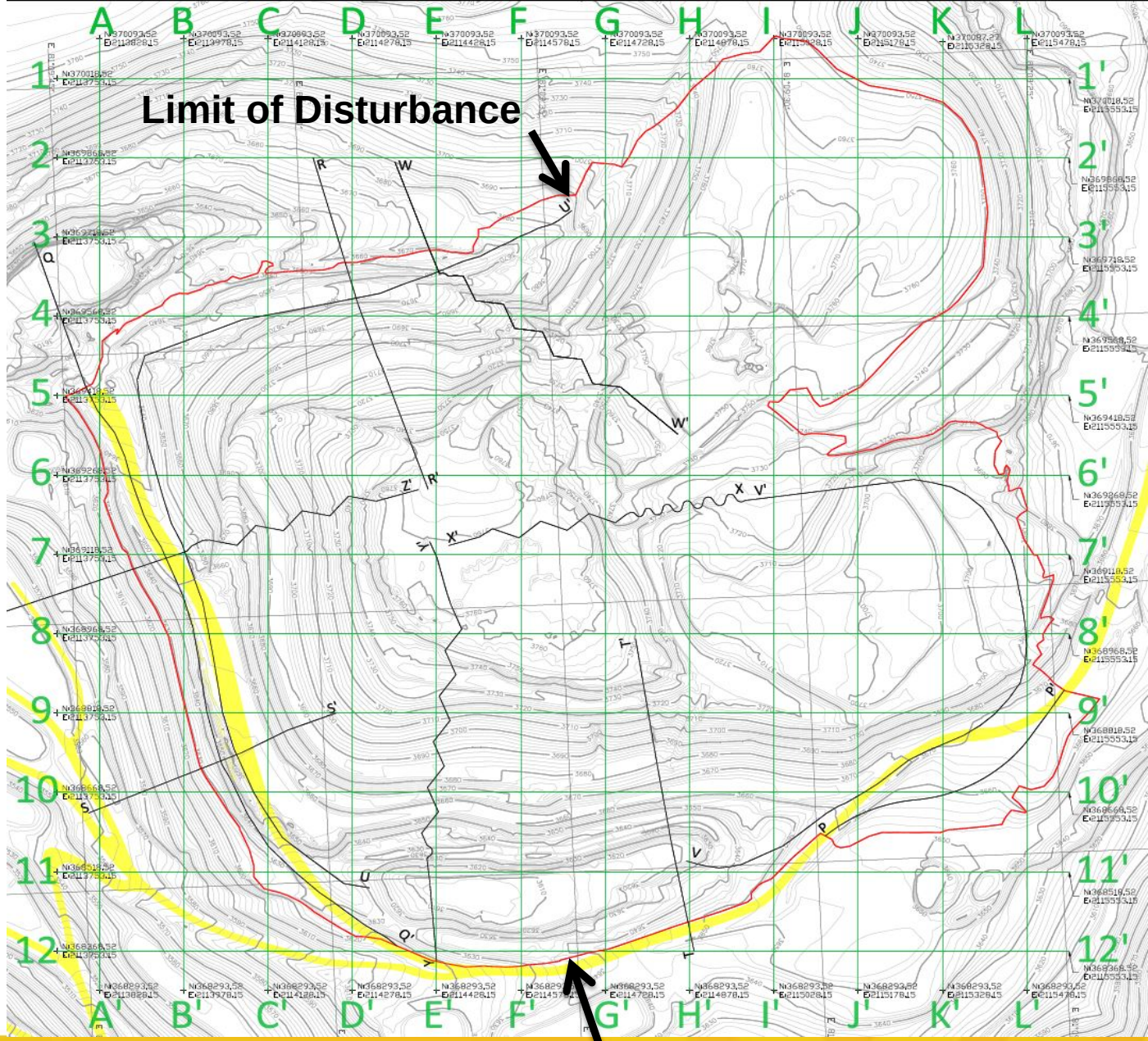
- Disposal of pond sediment
- Air dry sediment in the Sludge Pit
- Sediment contains heavy metals

Adjacent Highwall:

- Active mining permit
- Access must be maintained
- Western limit to the reclamation

Existing Site:

- Advanced erosion
- Barren
- Sludge Pit
- Interception Pond
- Adjacent Permits
- Seeps throughout
- Ongoing water treatment



Royal Scot Reclamation Objective:

Develop a reclamation alternative utilizing geomorphic landform design principles at the Royal Scot Coarse Coal Refuse Facility

1. Reduce stormwater infiltration
2. Segregate stormwater and groundwater flows
3. Minimize construction costs

Basic approach: Regrade site, decrease infiltration, and manage runoff

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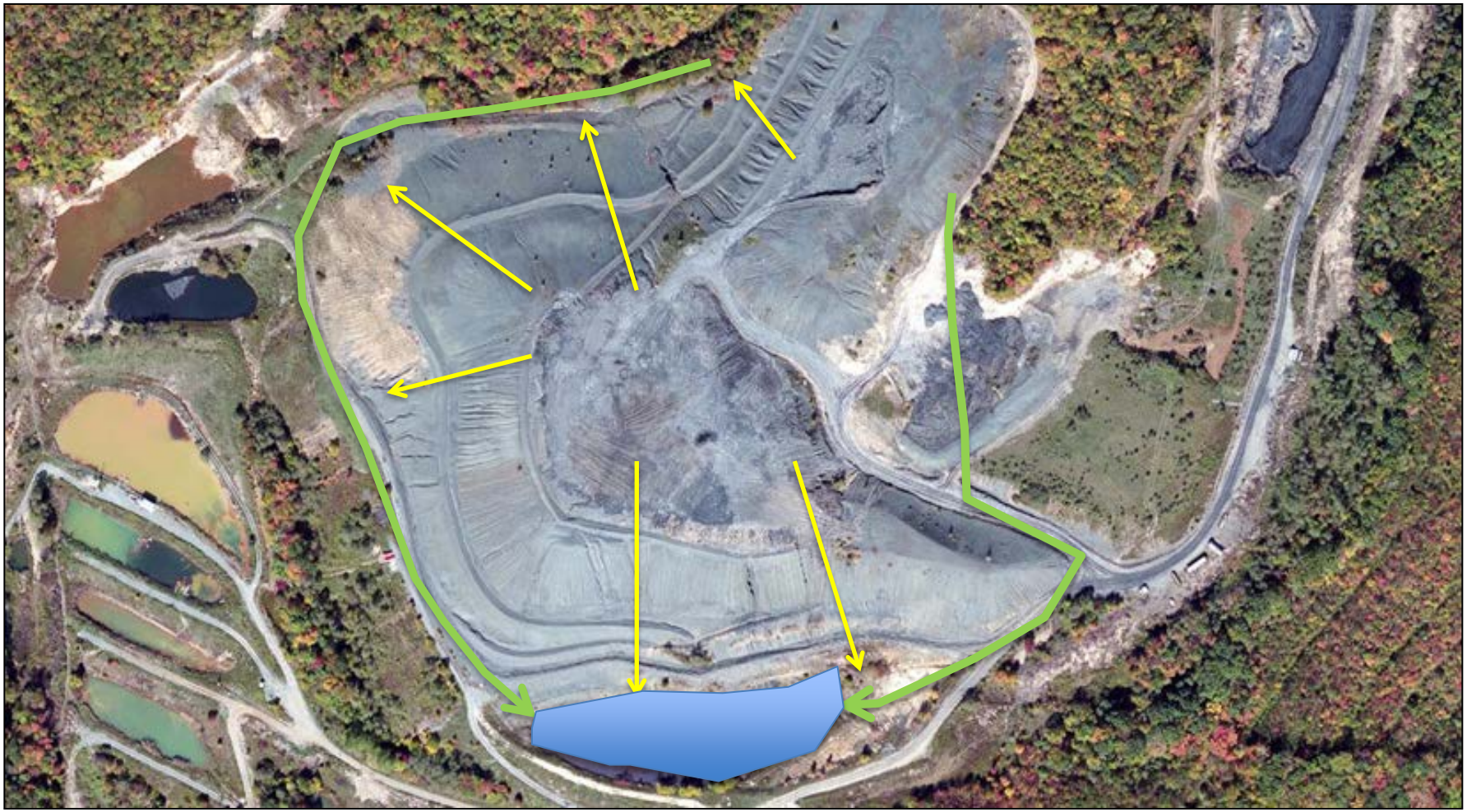

Final design

- Four geomorphic watersheds
- Connected by benched slopes
- Draining to perimeter channel
- Pond sized for 100-yr event

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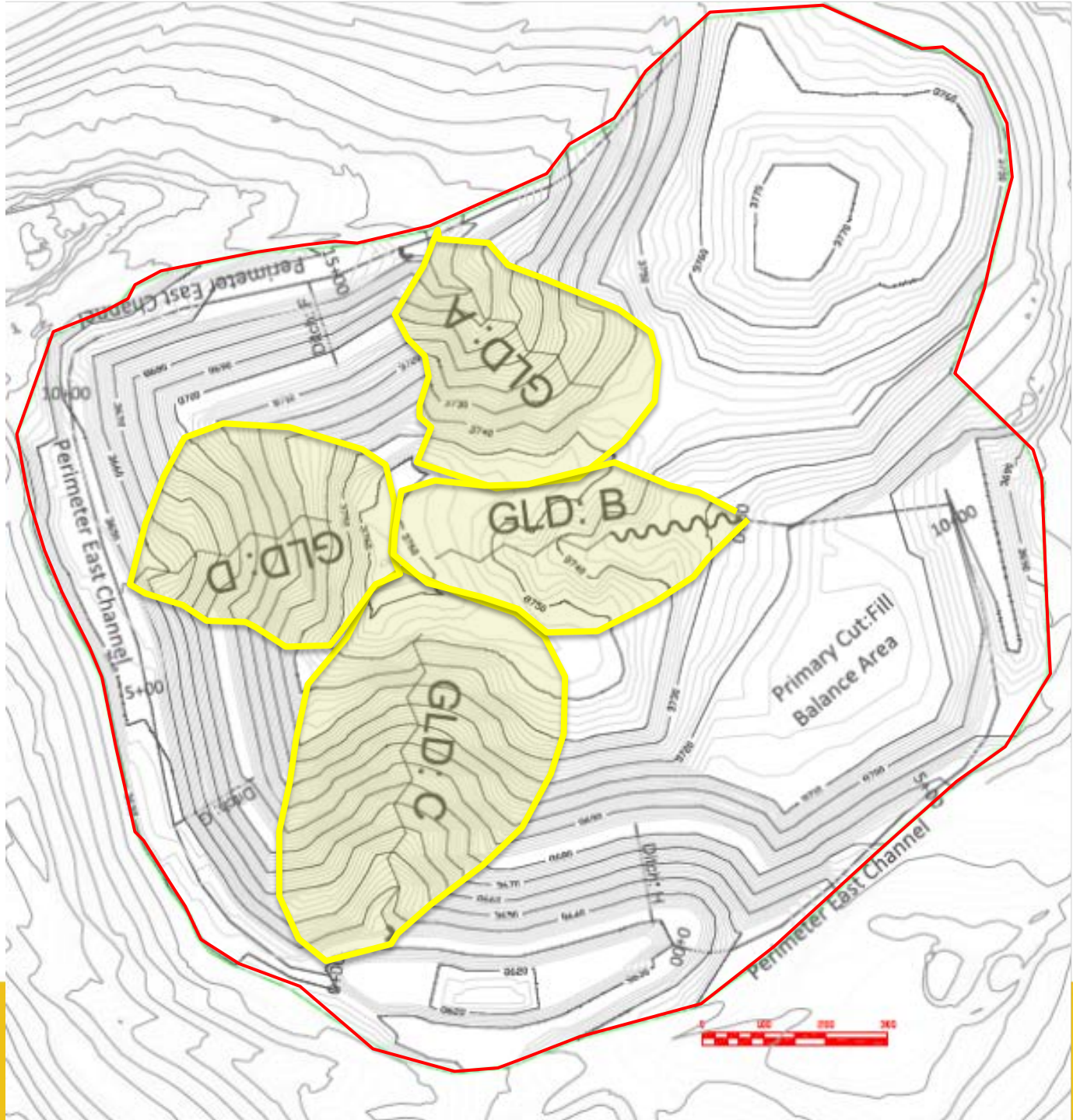

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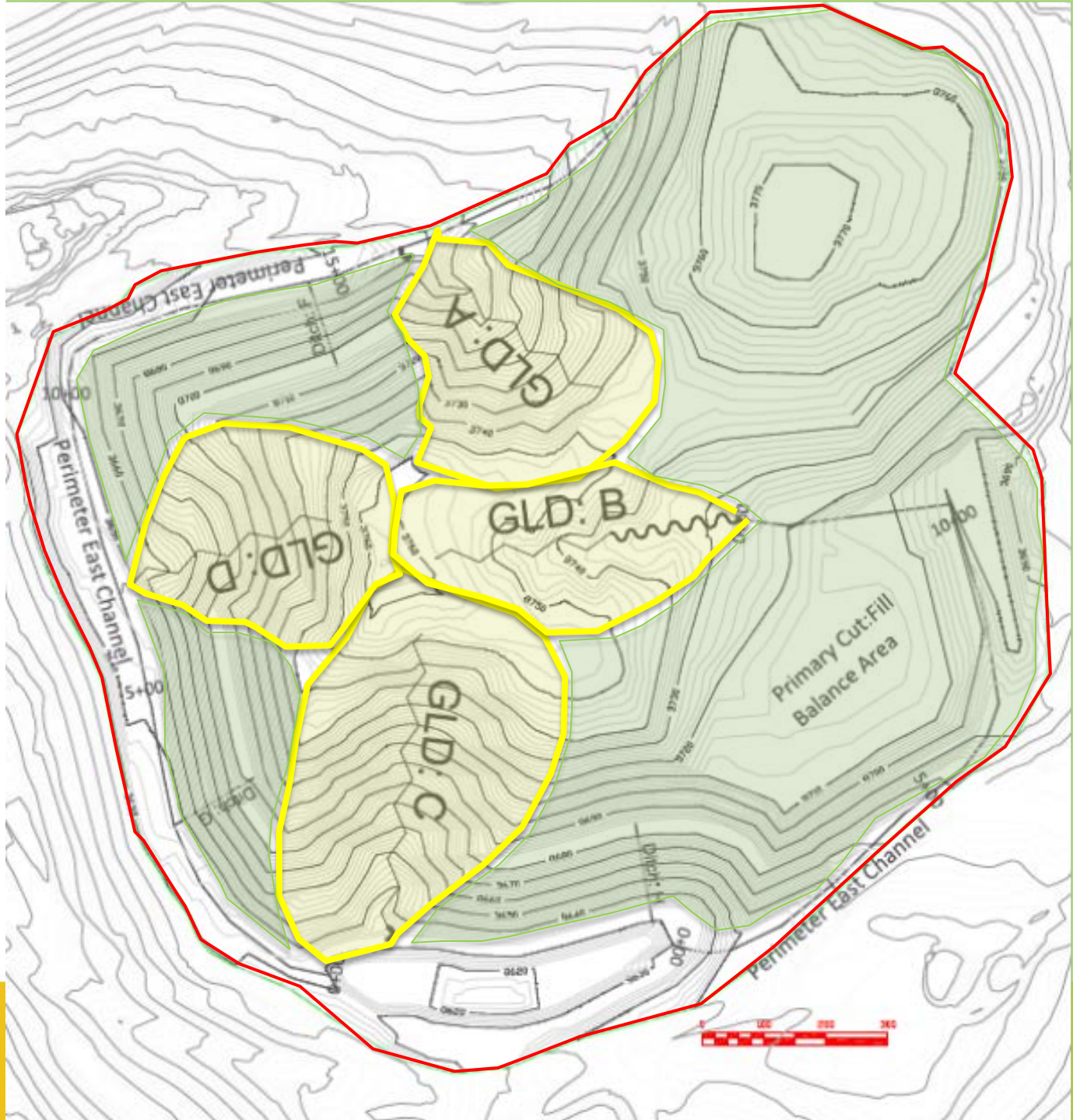

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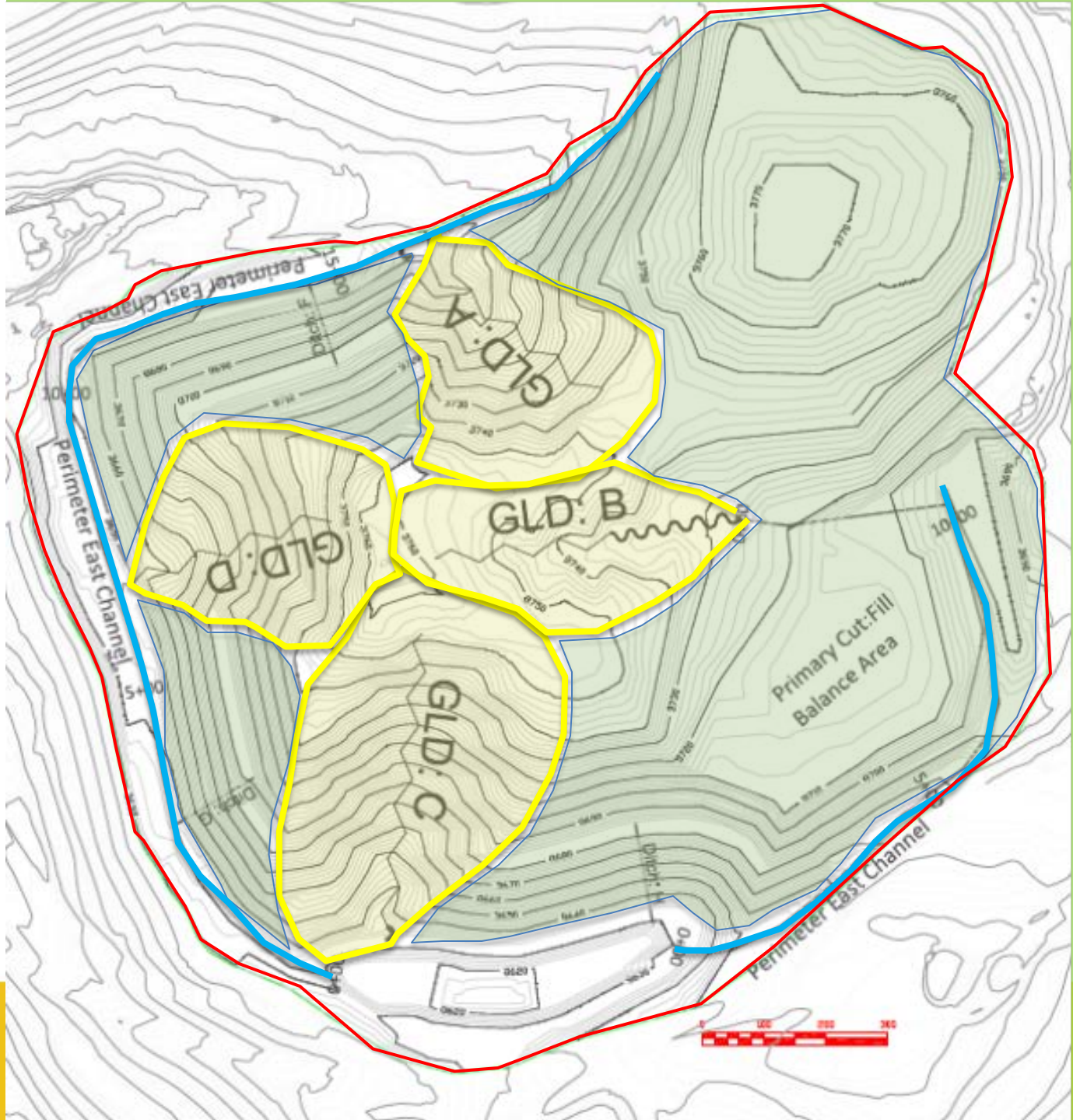

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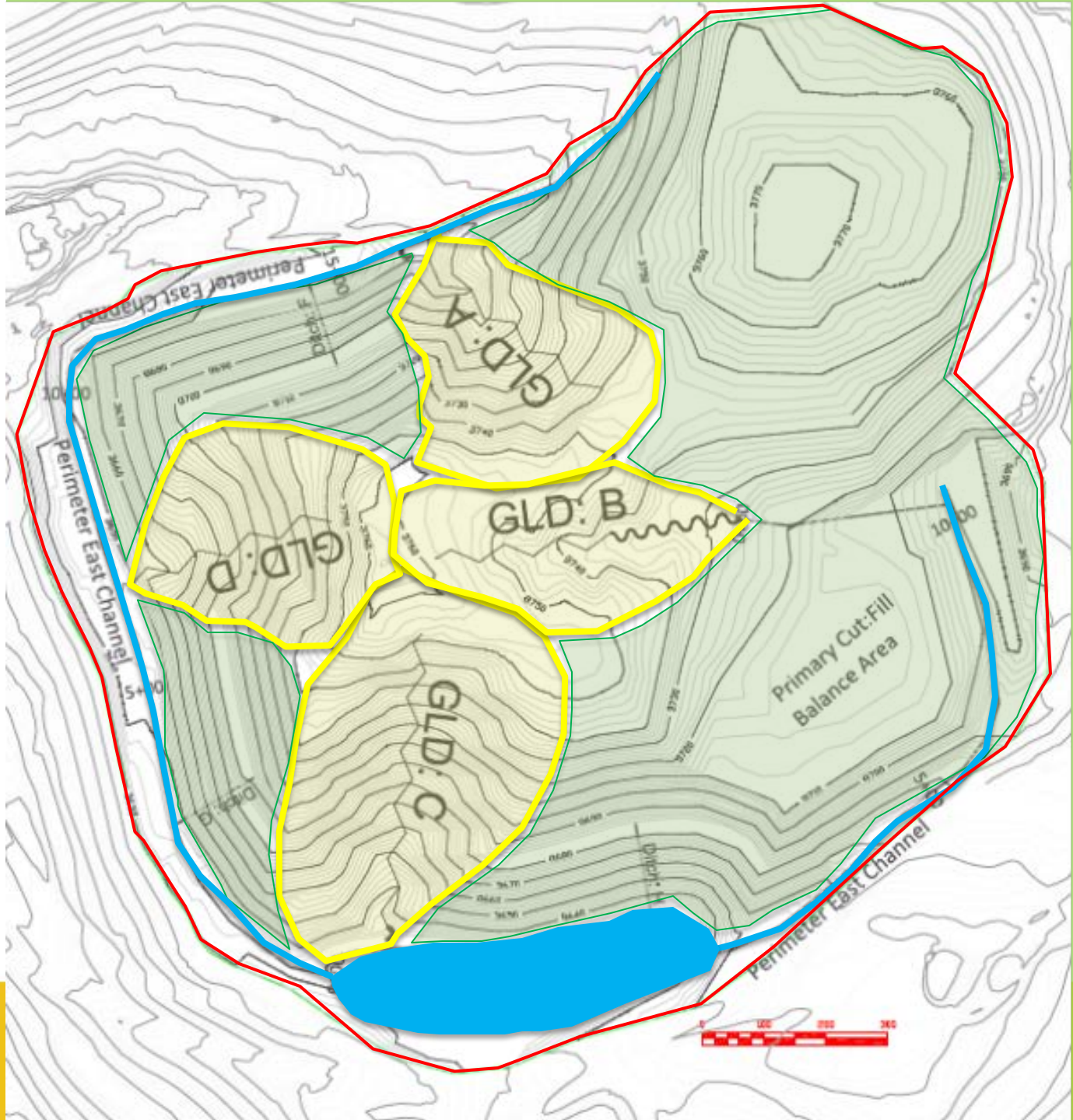
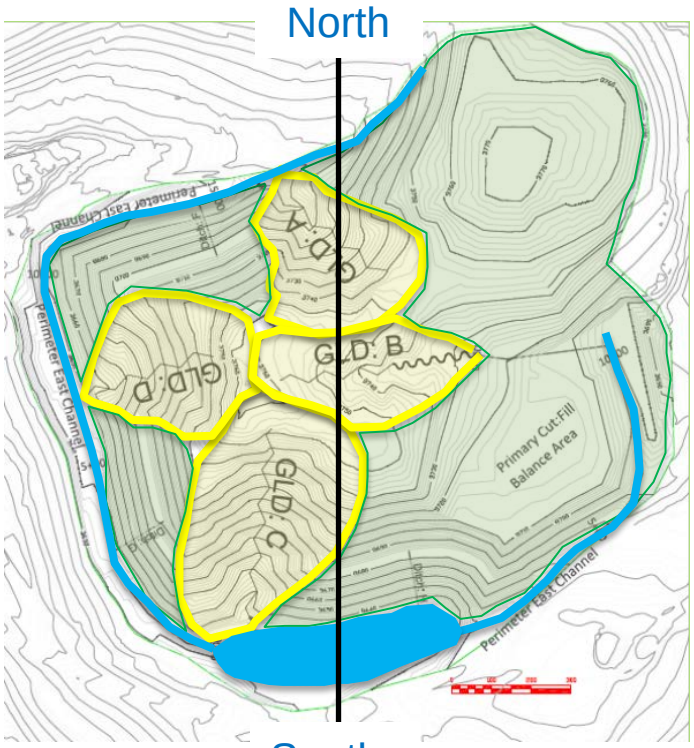
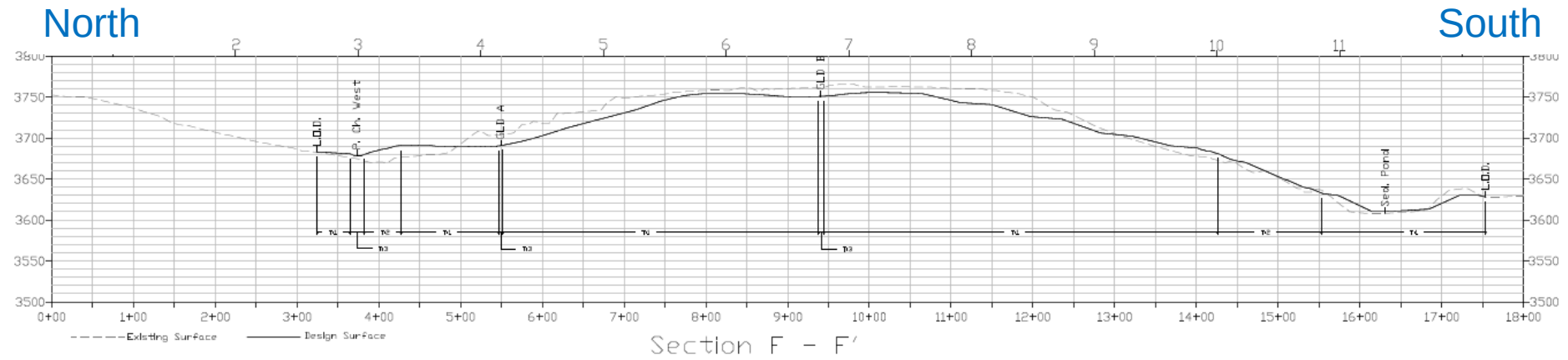
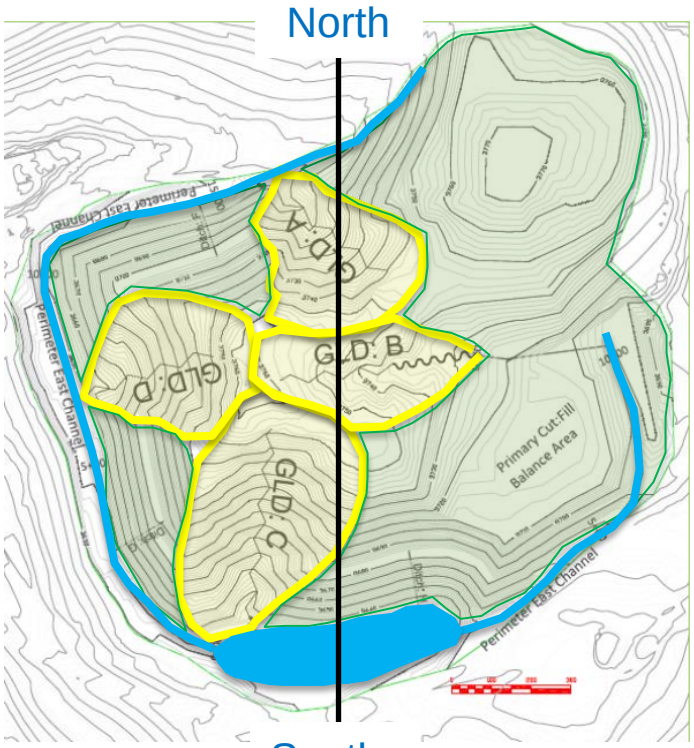


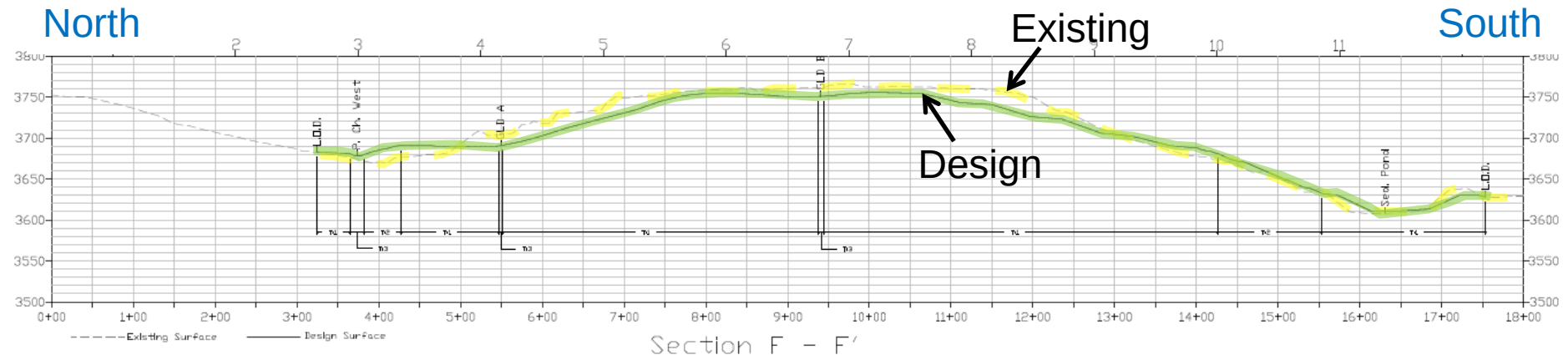
Example longitudinal profile





Example longitudinal profile





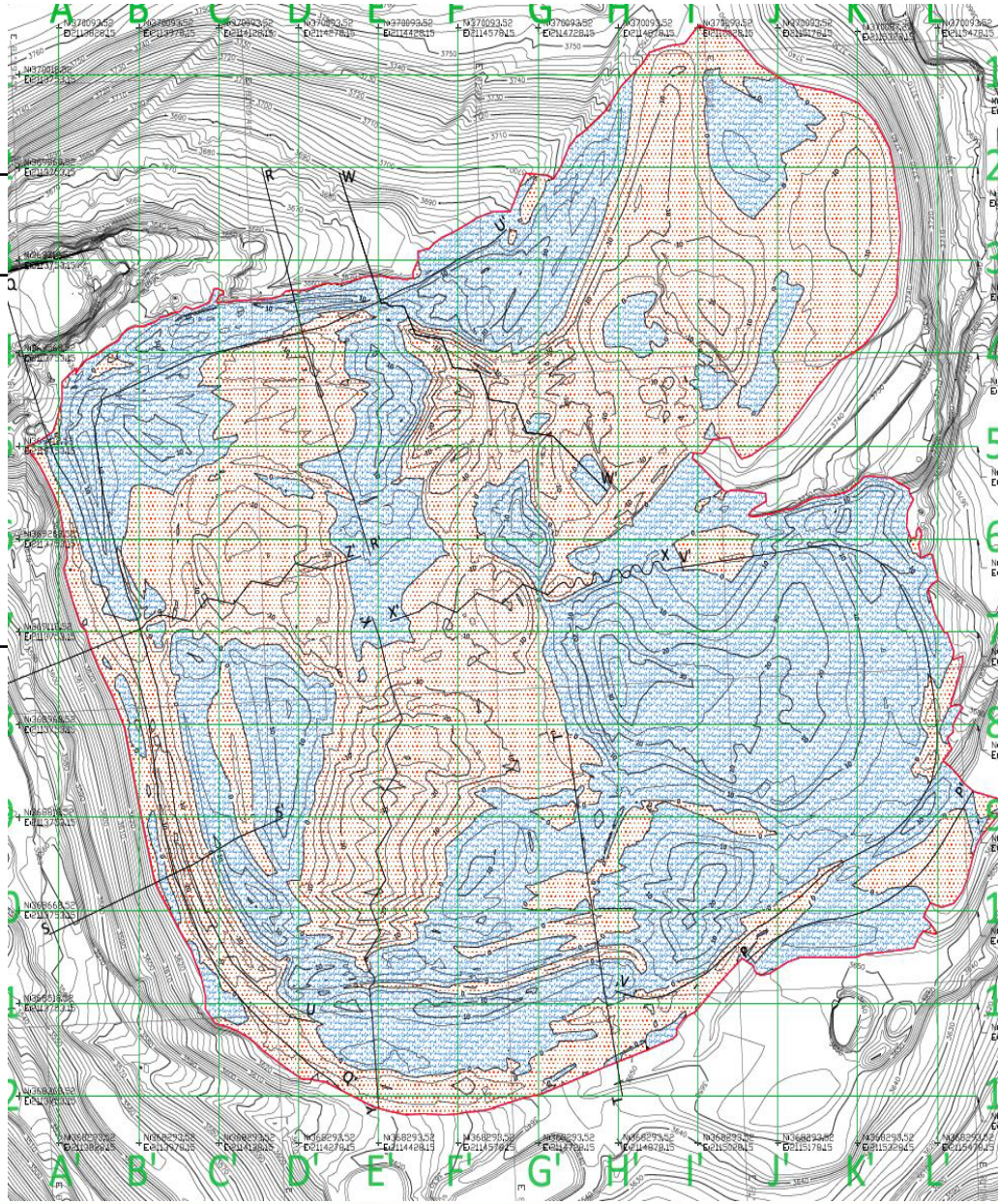
Results: Earthwork Quantities

Description	Unit	Cut	Fill	Total
Area	[acre]	21.6	23.4	47.0
Volume	[yd^3]	267,730	295,839	(28,109)
Avg. Depth	[ft]	7.66	7.84	-
Cut : Fill	[_]	-	-	0.90
Import	[yd^3]	-	-	(28,109)

Note: 1.95 acre at grade

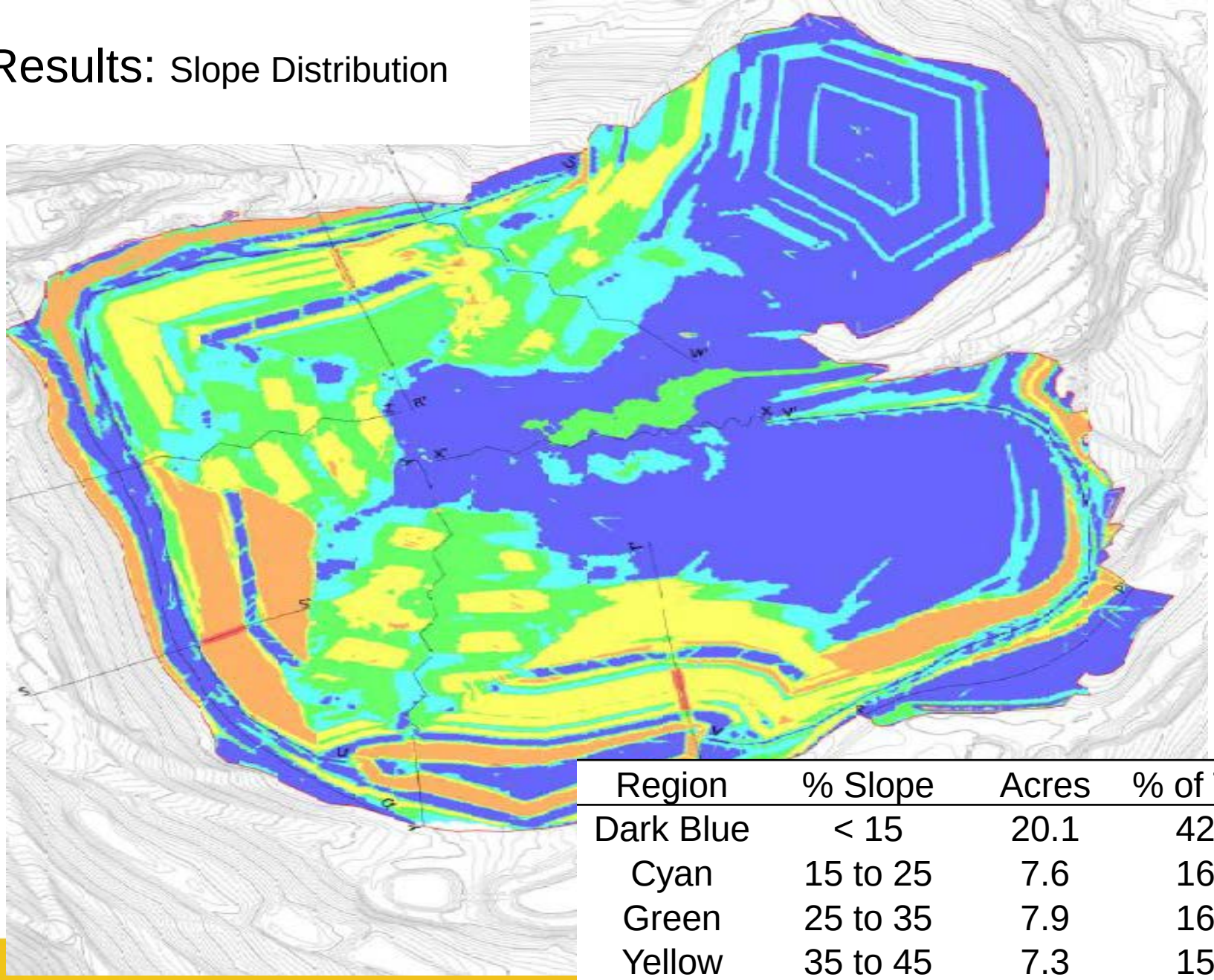
Cut Area

Fill Area



*Contours shown on 5' intervals

Results: Slope Distribution



Region	% Slope	Acres	% of Total
Dark Blue	< 15	20.1	42.9
Cyan	15 to 25	7.6	16.2
Green	25 to 35	7.9	16.8
Yellow	35 to 45	7.3	15.5
Orange	45 to 50	4.0	8.5
Red	> 50	0.1	0.1

Results: Geomorphic Channels

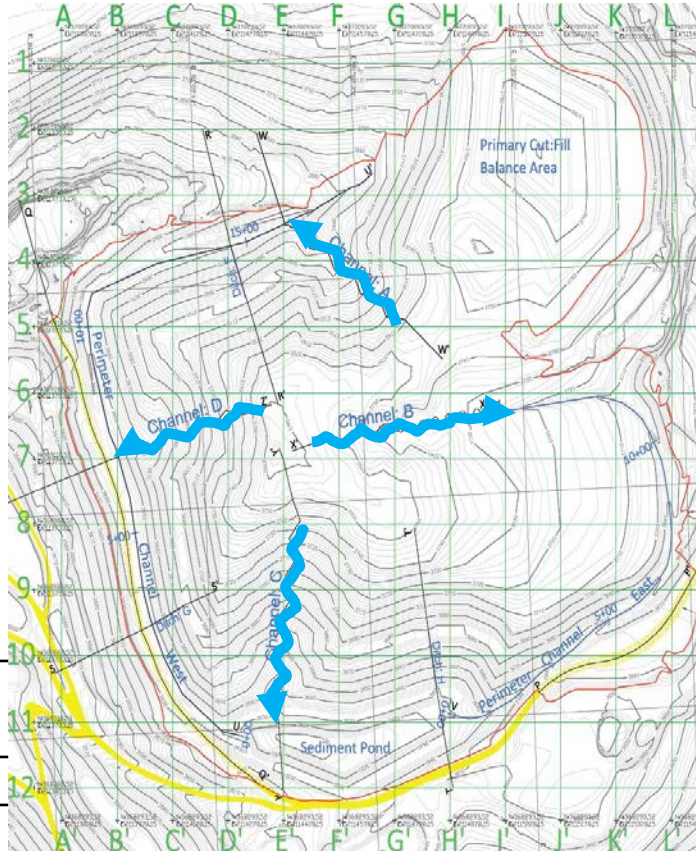
Bed Slope
- Varies

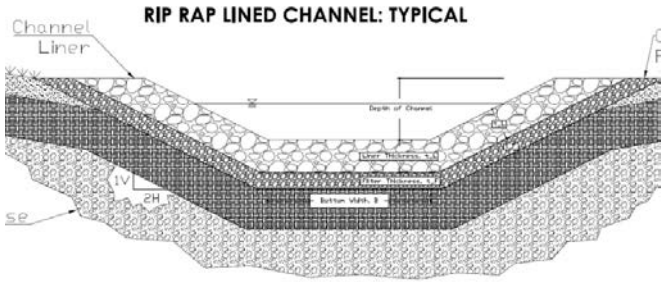
Riprap Liner
- D50: 9.0 to 12.0 inch

Channel Filter
- D50: 3.0 inch

Vegetation Liner
- Type 1 Cap

Flow Reach	Liner	Length	Peak Flow	Bottom Width	Depth	Bed Slope	Bedding D_{50}	Filter D_{50}
[Name]	[Mat'l]	[ft]	[cfs]	[ft]	[ft]	[ft/ft]	[in]	[in]
Channel A – 1	Rip Rap	399	23.4	6.0	0.8	0.12 - 0.20	9.0	3.0
Channel A – 2	Rip Rap	114	5.0	5.0	0.6	0.19	9.0	3.0
Channel B – 1	GRASS	475	19.3	4.5	2.3	0.02 - 0.03	GRASS	
Channel B – 2	Rip Rap	190	11.1	4.0	0.9	0.04 - 0.09	9.0	3.0
Channel B – 3	Rip Rap	67	5.9	3.5	0.7	0.12	9.0	3.0
Channel C – 1	Rip Rap	519	25.9	6.0	0.8	0.12 - 0.24	12.0	3.0
Channel C – 2	Rip Rap	103	3.5	4.0	0.6	0.20	12.0	3.0
Channel D – 1	Rip Rap	313	18.2	5.5	0.8	0.12 - 0.27	12.0	3.0
Channel D – 2	Rip Rap	201	7.0	4.5	0.6	0.26	12.0	3.0

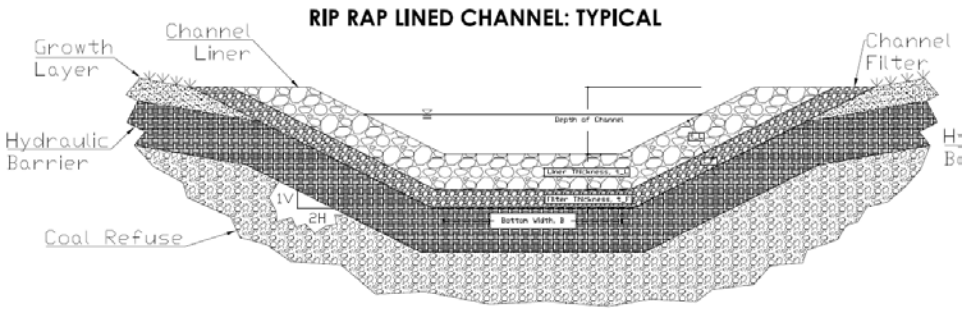




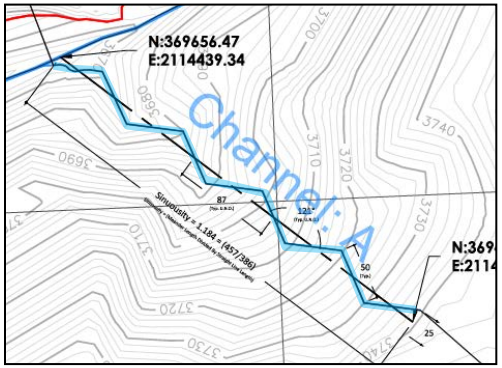
*Channels shown in Blue

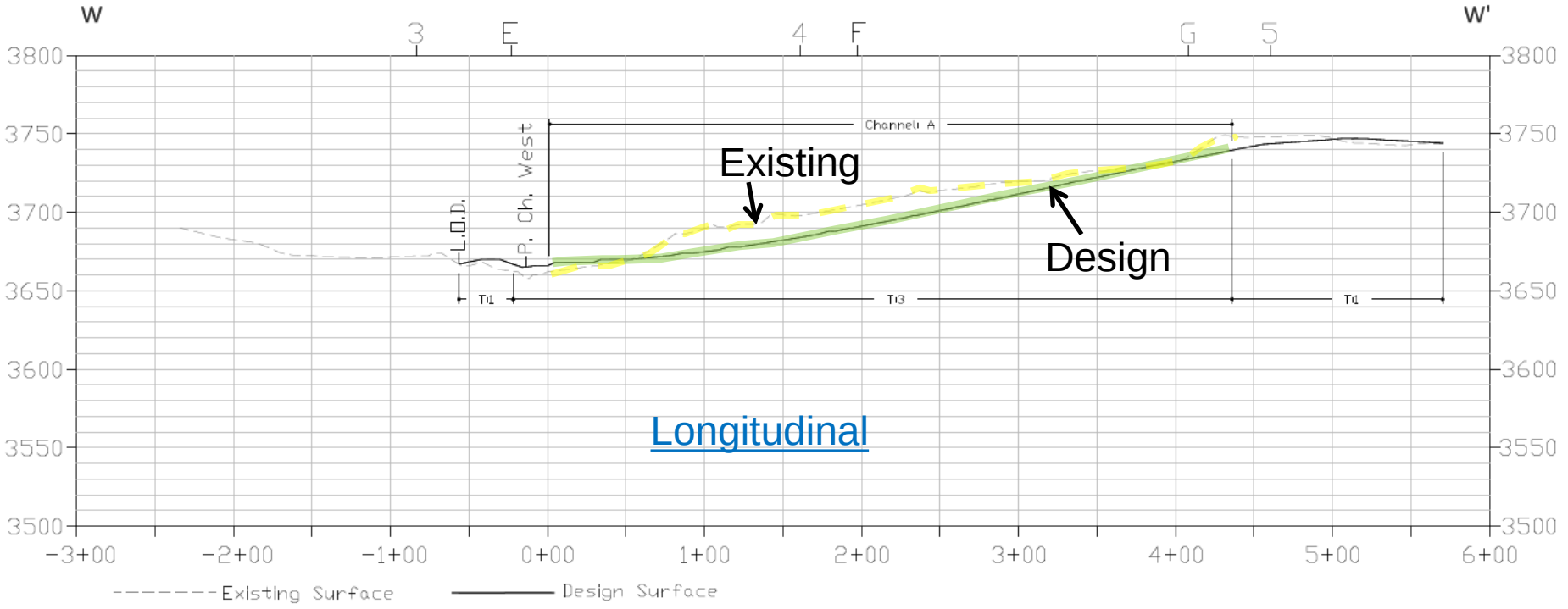
Example geomorphic channel (GLD A)

Cross-section



Plan view





Longitudinal

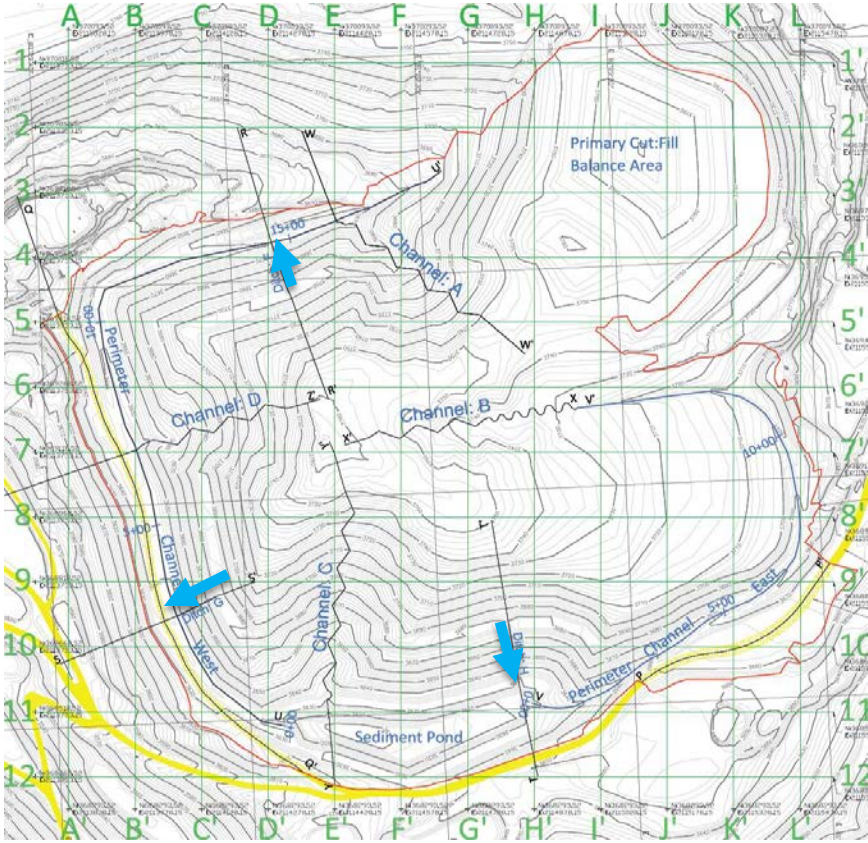
Channel A Profile (Along Flowpath)

Results: Conventional Ditches

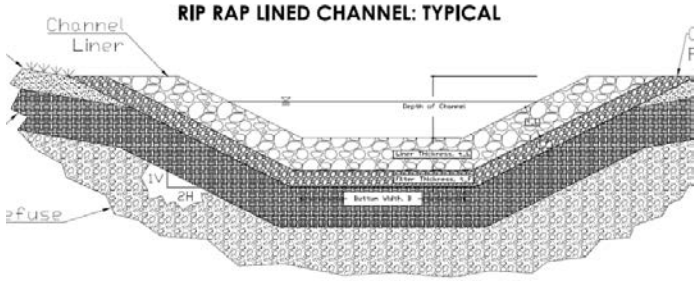
Bed Slope
- 50%

Riprap Liner
- D50: 15.0 to 18.0 inch

Channel Filter
- D50: 3.0 inch



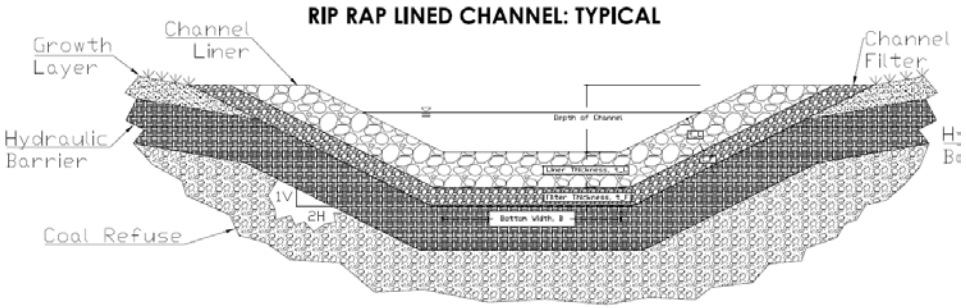
Flow Reach	Liner	Length	Peak Flow	Bottom Width	Channel Depth	Bed Slope	Bedding D_{50}	Filter D_{50}
[Name]	[Material]	[ft]	[cfs]	[ft]	[ft]	[ft/ft]	[in]	[in]
Ditch F	Rip Rap	155	16.9	4.0	1.1	0.50	18.0	3.0
Ditch G	Rip Rap	160	5.9	2.0	1.1	0.50	18.0	3.0
Ditch H	Rip Rap	130	7.8	3.5	1.1	0.50	15.0	3.0



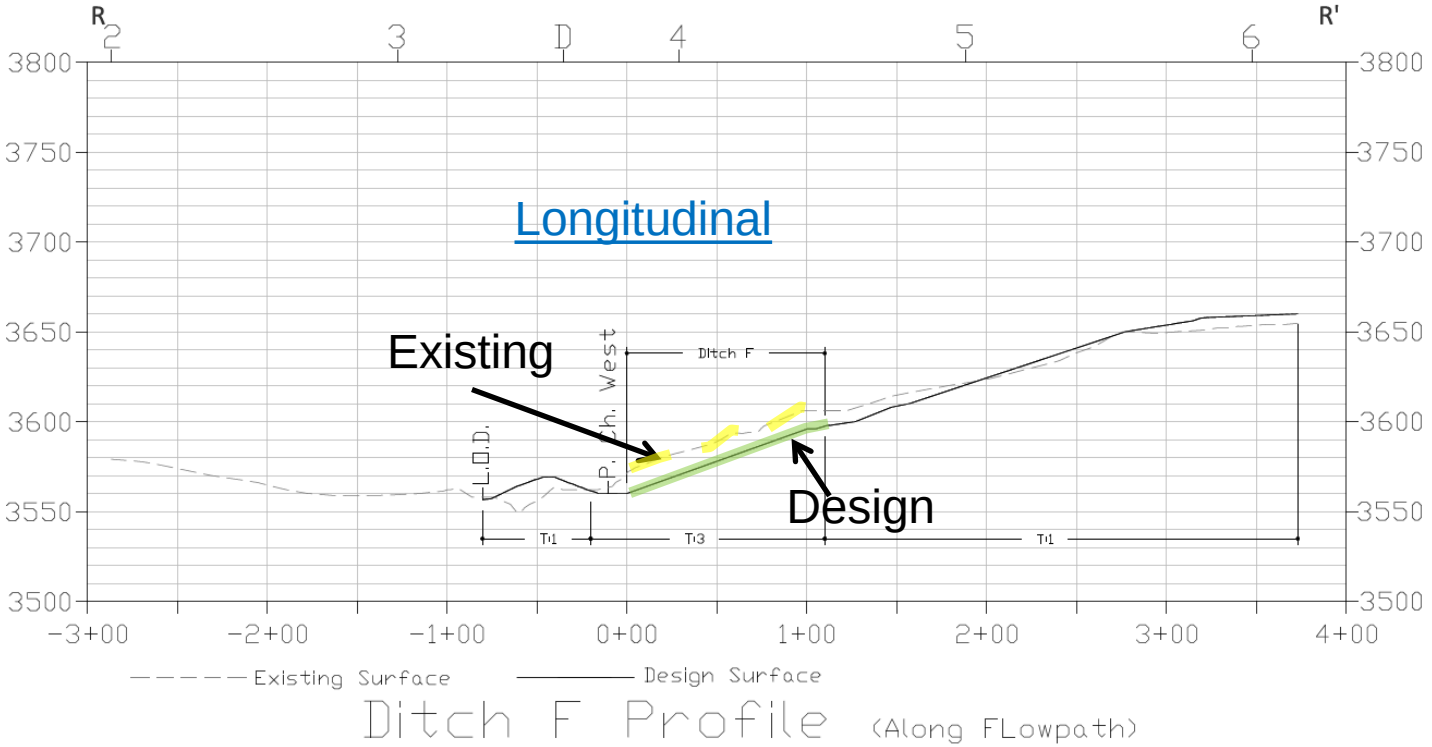
*Channels shown in Blue

Example drainage on benched slope (Ditch F)

Cross-section



Longitudinal

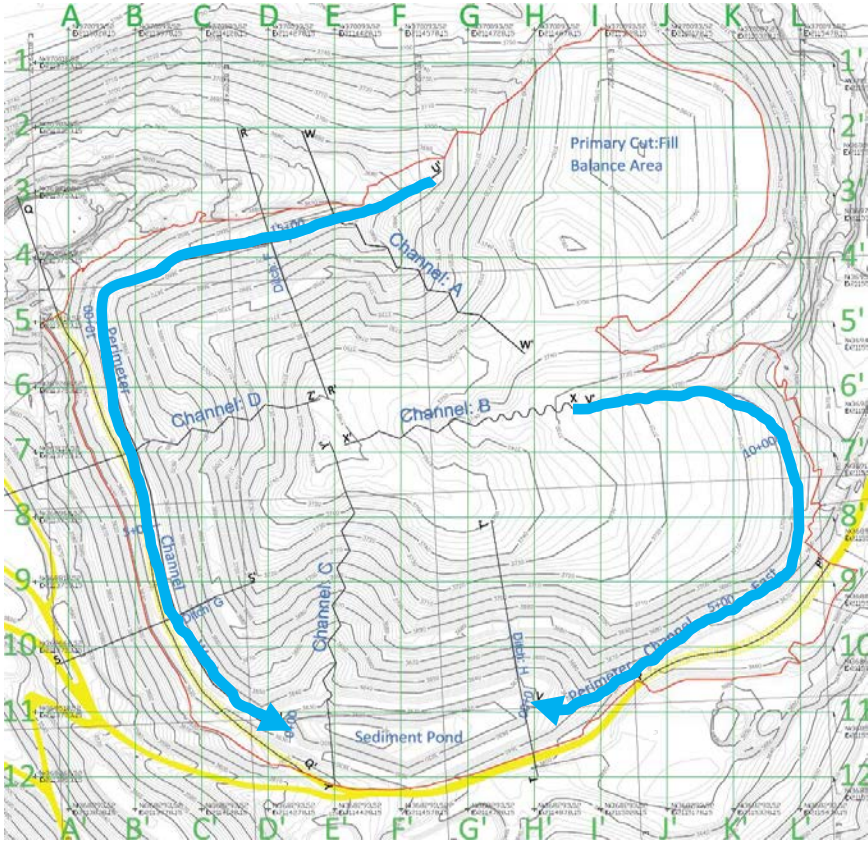


Results: Perimeter Ditches

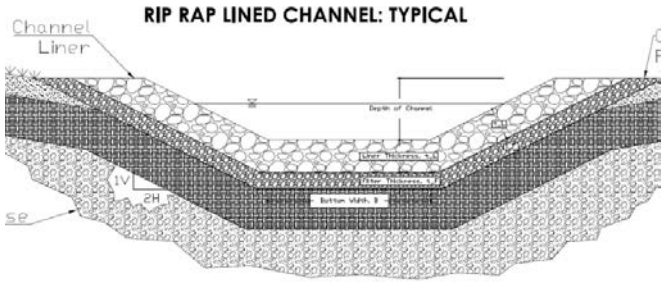
Bed Slope
- 2.0 to 15%

Riprap Liner
- D50: 9.0 to 12.0 inch

Channel Filter
- D50: 3.0 inch



Flow Reach	Liner	Length	Peak Flow	Bottom Width	Channel Depth	Bed Slope	Bedding D_{50}	Filter D_{50}
[Name]*	[Material]	[ft]	[cfs]	[ft]	[ft]	[ft/ft]	[in]	[in]
P. Ch. West - 1	Rip Rap	756	108.8	10.5	1.8	0.02	9.0	3.0
P. Ch. West - 2	Rip Rap	1,514	68.3	7.0	1.8	0.02 - 0.15	9.0	3.0
P. Ch. East - 1	Rip Rap	350	69.6	8.0	1.7	0.10	12.0	3.0
P. Ch. East - 2	Rip Rap	1,142	57.7	8.0	1.7	0.06	9.0	3.0



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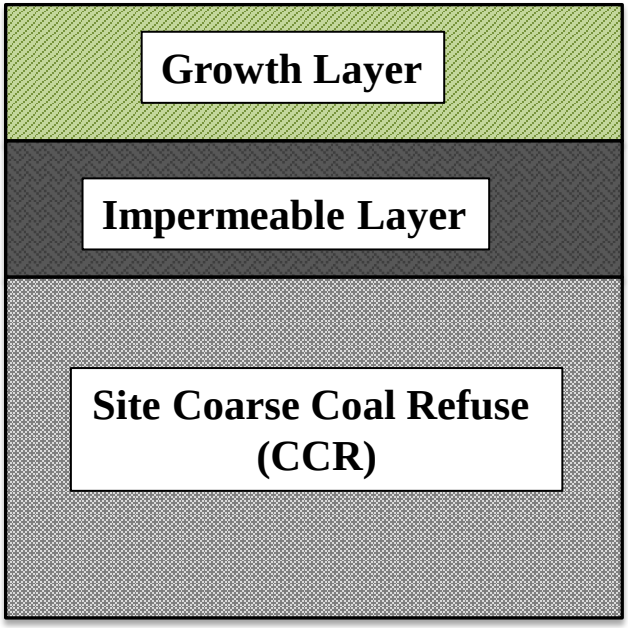
Cap and cover: 2 Layer Design

Growth Layer:
- Mixture of shale and MGro™ in fixed volumetric ratio.
- Initial results from the 60% shale: 40%
- MGro blend have been favorable. (started here)
- 60/40 Mgro Geotechnical properties being defined in laboratory testing
- Proposed thickness = 1 feet

Impermeable Layer
- Intended for seepage infiltration control
- Compacted coarse coal refuse
- Preliminary thickness ranges = 1 – 2 ft

Refuse pile material (Cut / Fill)
- Assess necessary compaction
- Homogeneous
- Source of the acid mine drainage
- Field self weight ranges 80 to 90 pcf.
- Thickness varies 10 ft to 120 ft.

2 Layer Final Cover System

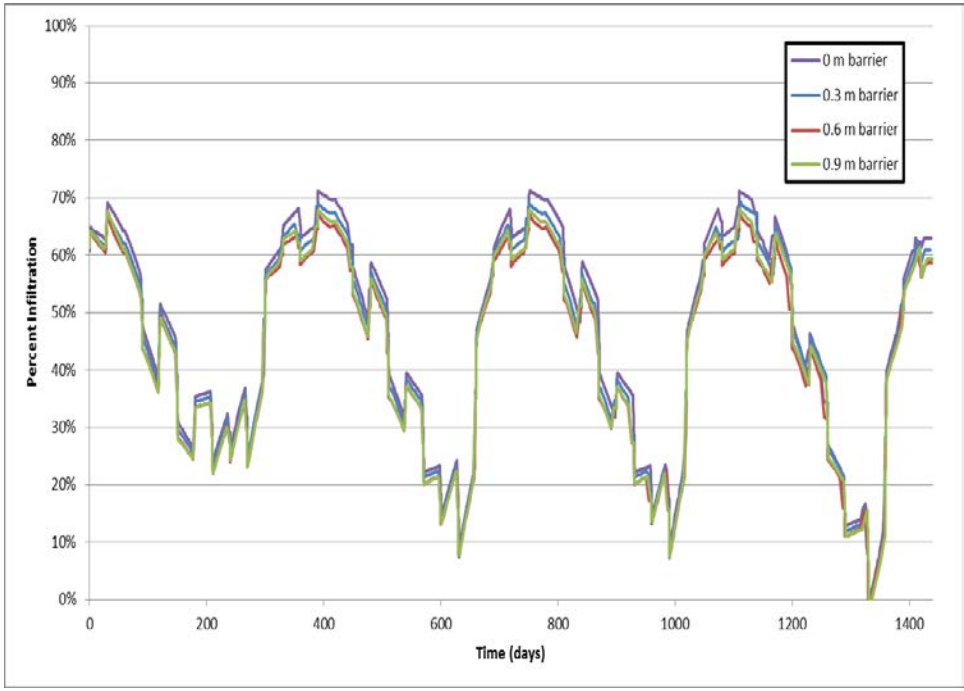


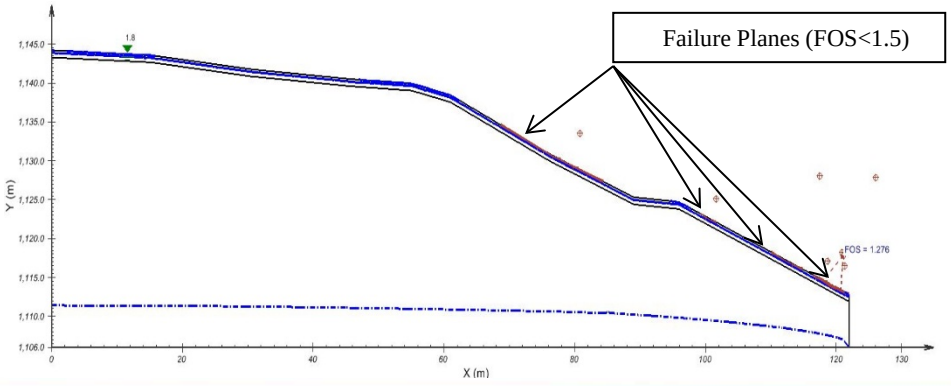
Typical MGro™ sample

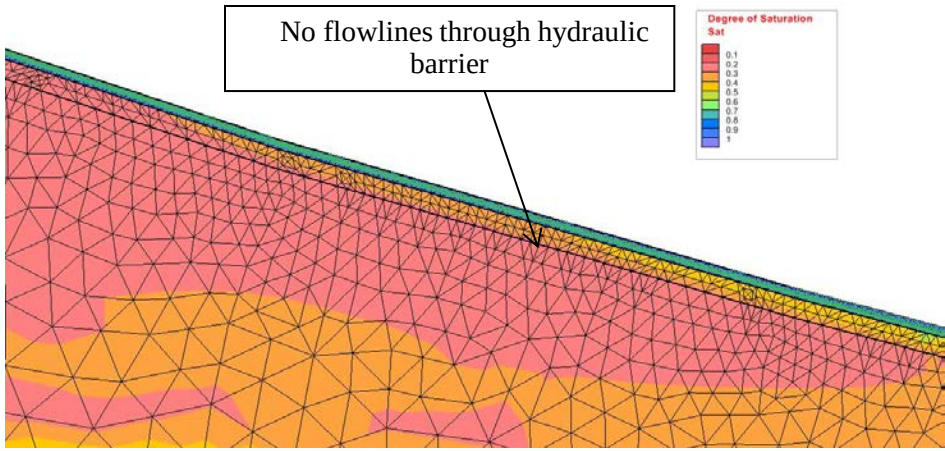
Cap and Cover

Slope Stability and seepage analysis performed by Stevens et al. (2016)

- Finite elemental slope stability
- Finite element seepage modelling
  - 3 cap thickness evaluated
- Material property evaluation
  - MGro® and coal refuse



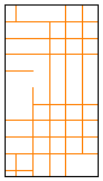




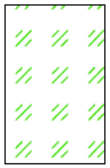
Results: Cap Types

- Minimize infiltration
- Maintain stability
- Establish vegetation
  - MGro® Soil Amendment

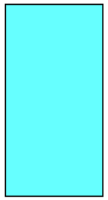
Type 1



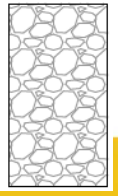
Type 2

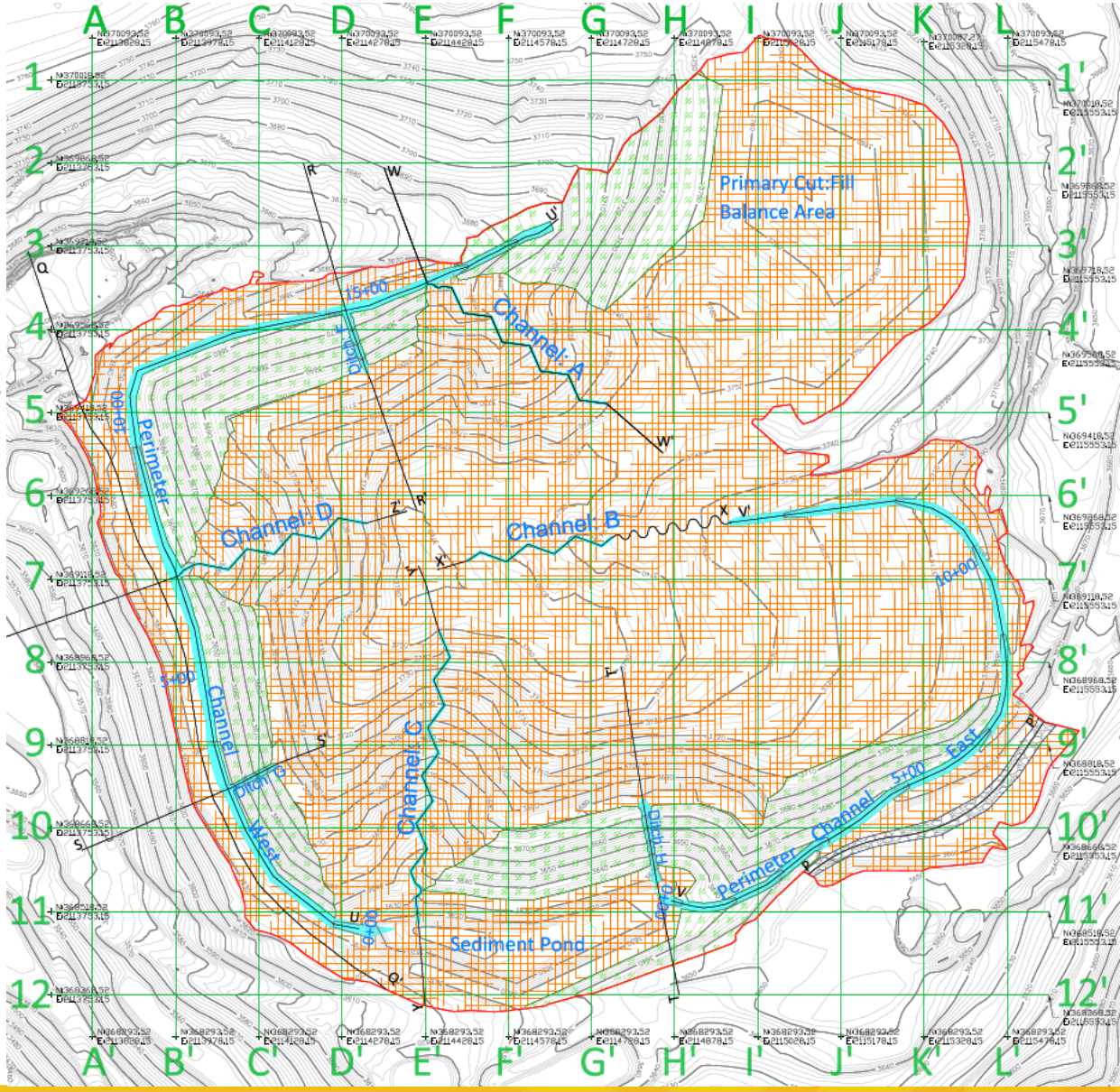


Type 3



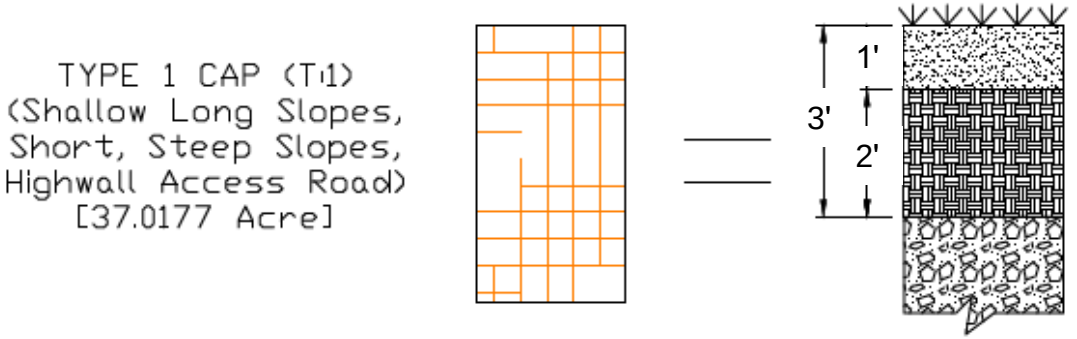
Type 4



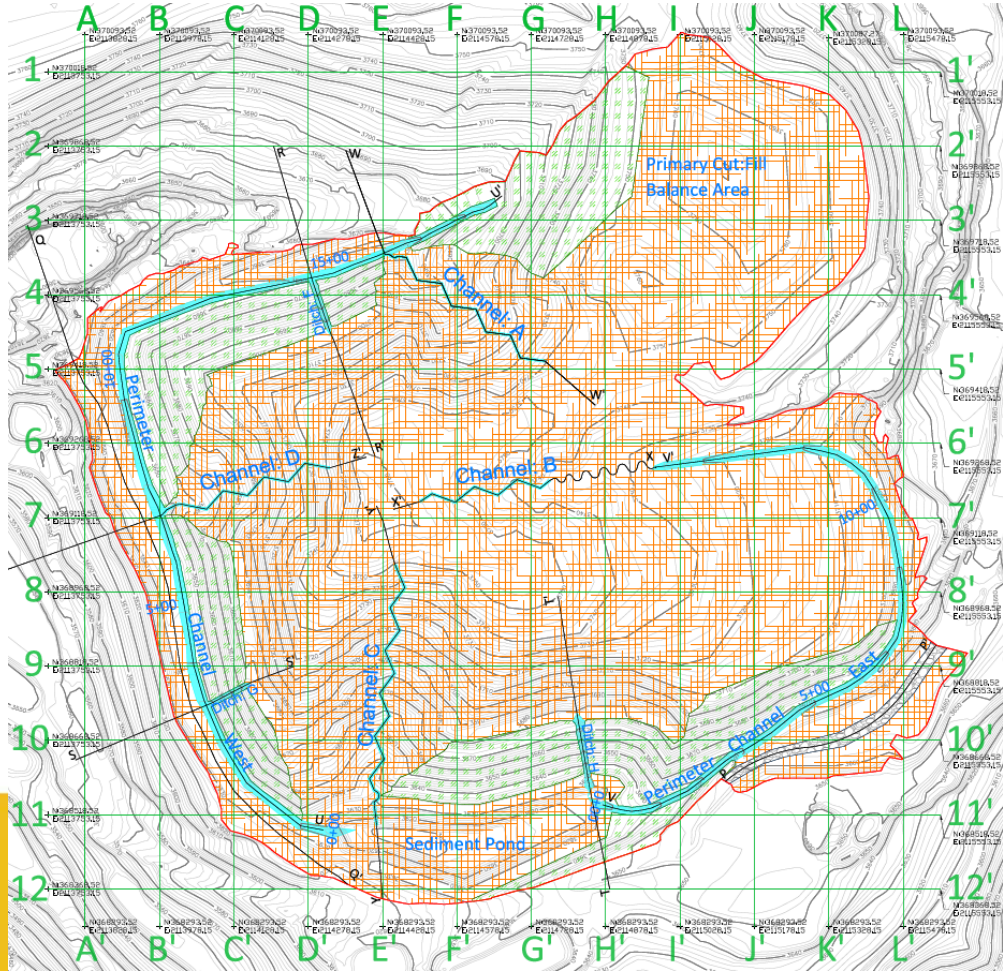


Results: Cap Type 1

(Stevens 2015)

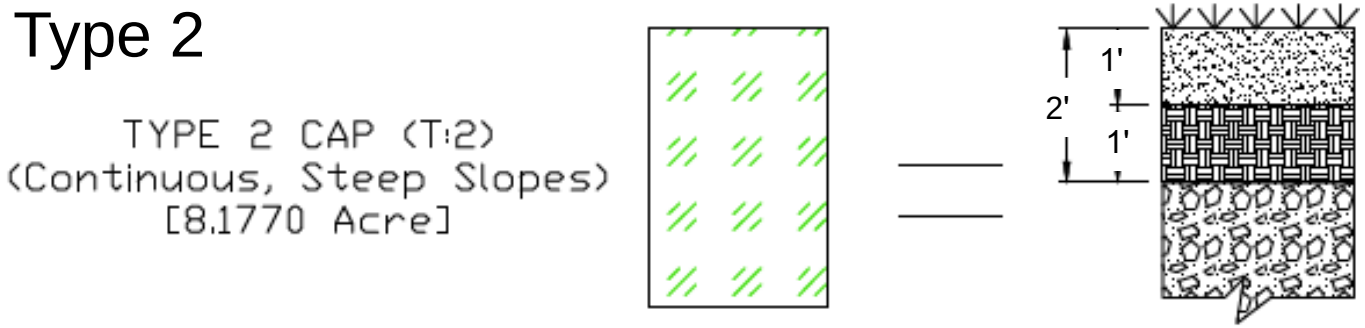


- Growth Zone
  - 60% refuse : 40% MGro®
- Barrier Zone: 2.0’ thickness
  - Minimum infiltration
  - Compacted coal refuse
    - <u>Onsite</u>

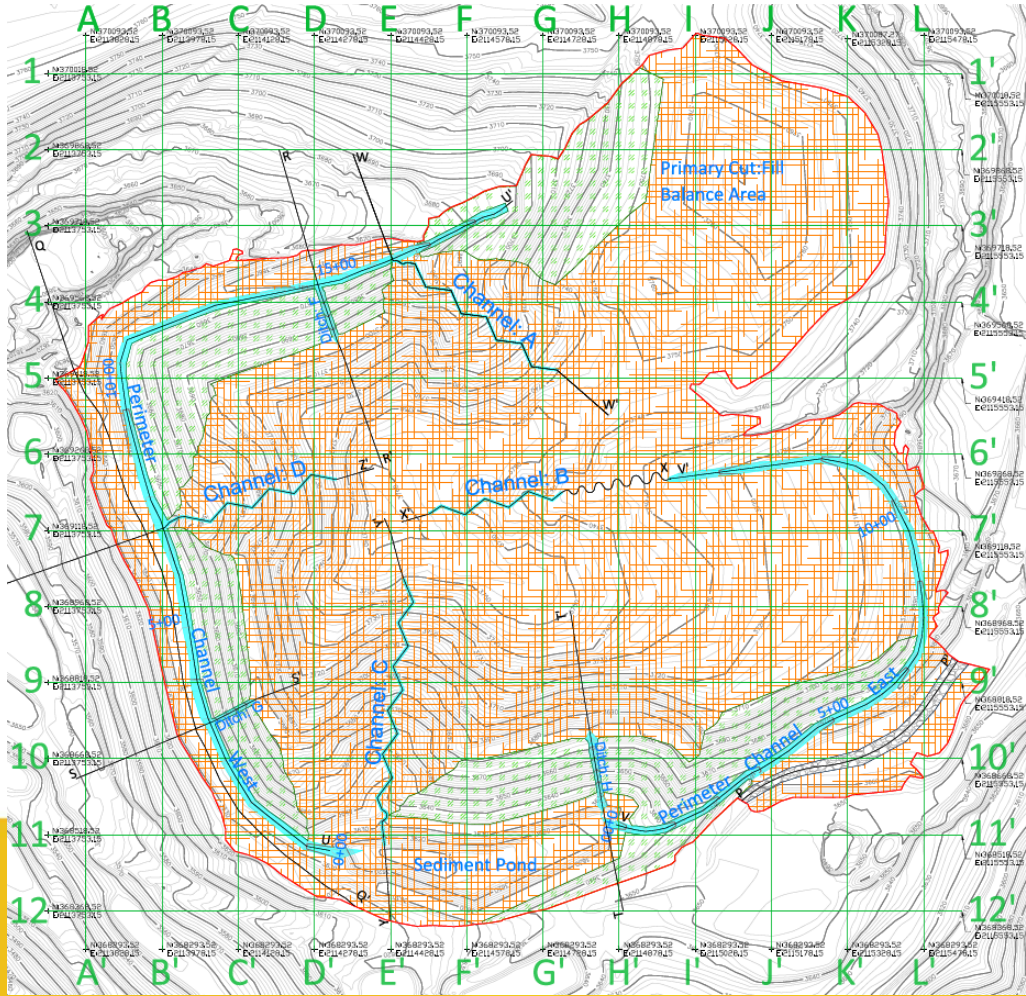


Results: Cap Type 2

(Stevens 2015)

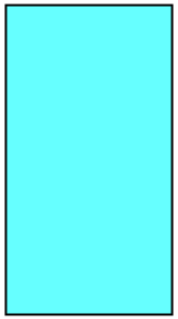


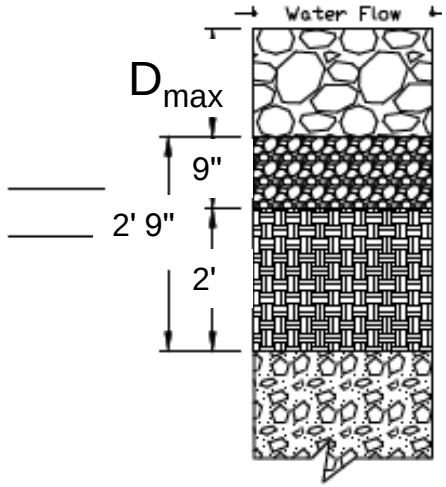
- Growth Zone
  - 60% refuse : 40% MGro®
- Barrier Zone: 1.0’ thickness
  - Slightly increased infiltration
  - Pore pressure reduction
- Compacted coal refuse
  - Onsite
- Located on lower face of conventional profiles



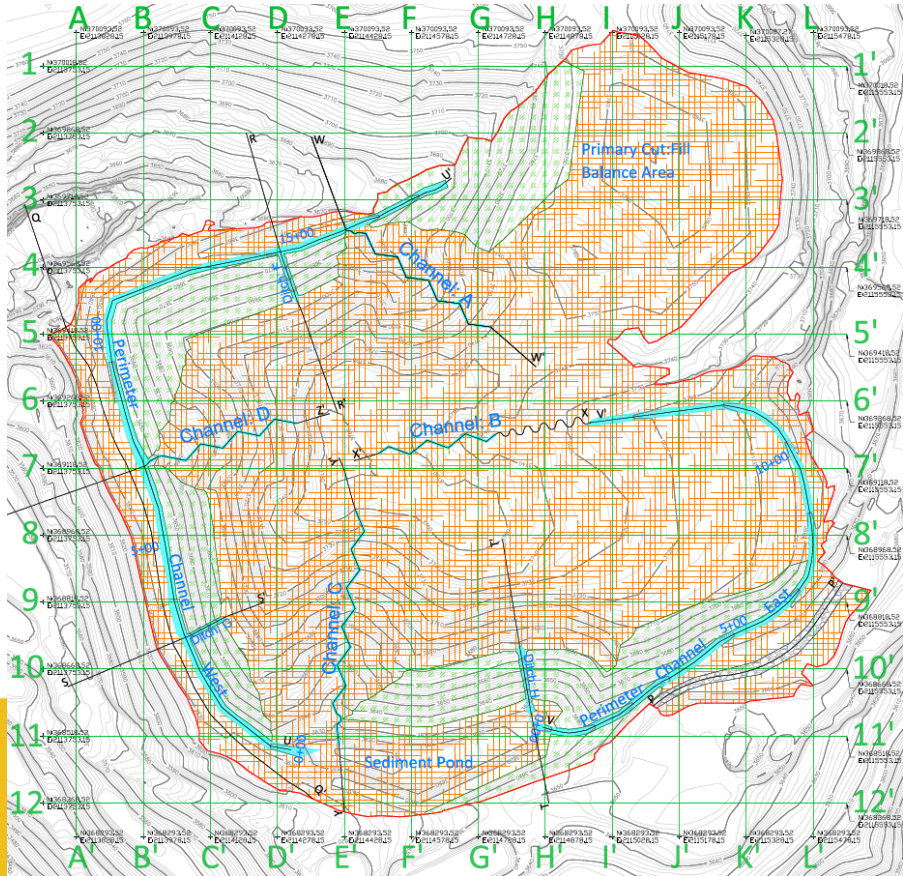
Results: Cap Type 3

Type 3 CAP (T:3)
(Channel Construction)
[1.7284 Acre]



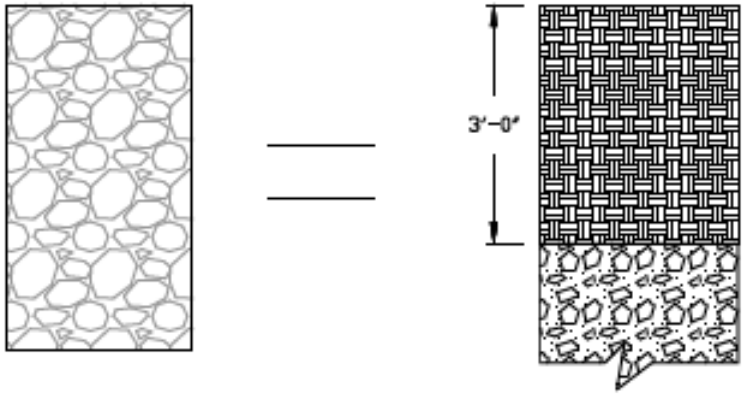


- Channel Bedding
  - Resists flow shear forces
- Channel Filter
  - Inhibits sediment transport of the base material (Refuse)
- Barrier Zone: 2.0’ thickness
  - Compacted coal refuse
    - <u>Onsite</u>

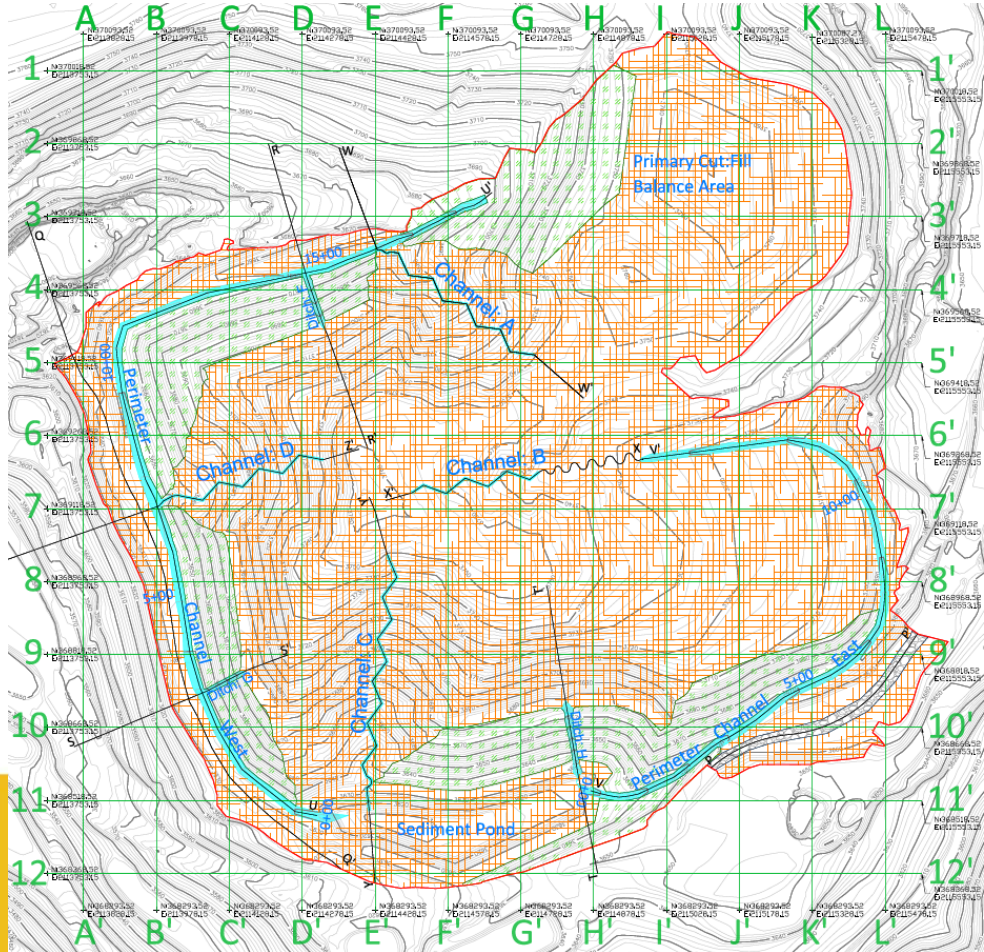


Results: Cap Type 4

TYPE 4 CAP (T:4)
(East Access Road)
[0.0840 Acre]

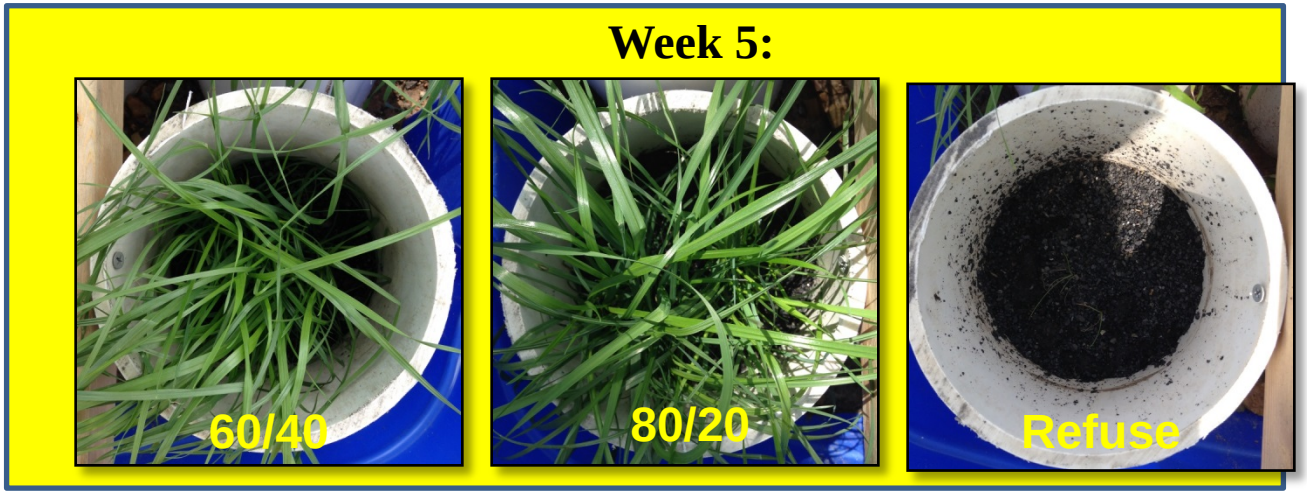


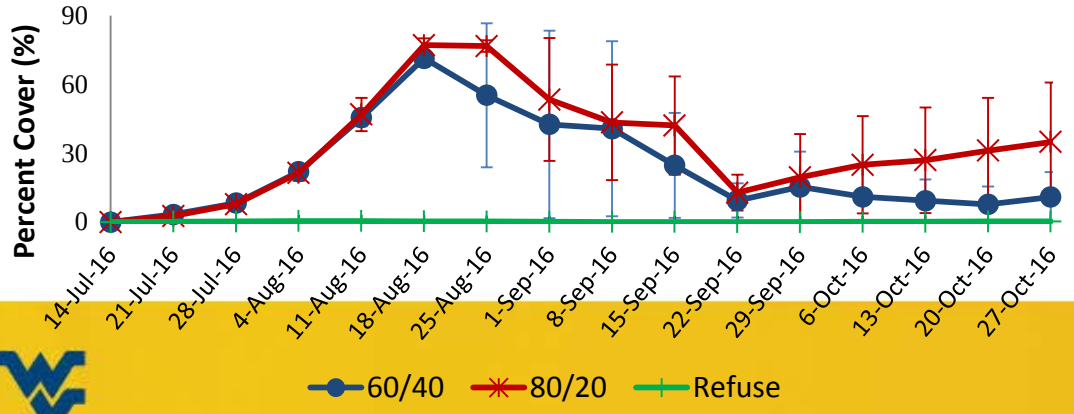
- Barrier Zone: 3.0’ thickness
  - Doubles as road wearing surface
  - Coarse coal refuse
    - Onsite

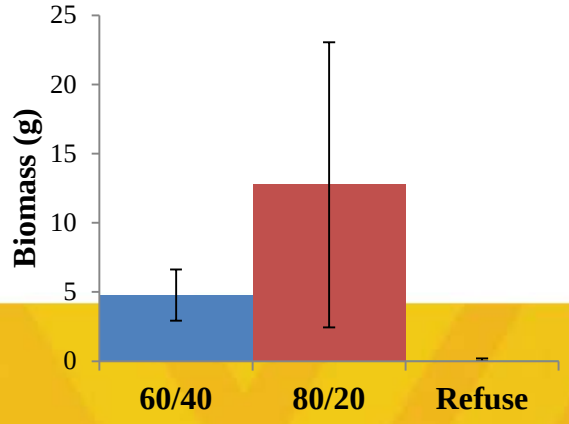


Tested mixtures of short paper fiber (MGro) and Coarse Coal Refuse (CCR)

- 60% MGro 40% CCR
- 80% MGro 20% CCR
- 100% CCR







Conclusion:

- **Sustainable landforms**
  - Four geomorphic watersheds
  - Flow shear force is conservatively designed with “self healing” flexible membrane channel lining
- **Stormwater infiltration reduction**
  - Cap Structure Barrier Zones
  - radial draining, fast but stable channels

Conclusions: Continued

- **Segregate stormwater and groundwater**
  - Sludge Pit was capped and the embankment was not included within any excavation
  - Hydraulic network captures 87% of the rainfall
  - Sediment Pond is filled, allowing an impermeable invert to be constructed
  - Sediment Pond is designed as “dry” and dewaters in 68 hours
- **Minimize construction costs**
  - Earthwork balanced
  - Onsite material used for the Barrier Zone throughout
  - Minimal import for soil amendment
  - Channel liner may be produced onsite

Acknowledgements

- The work described in this publication was supported by Grant/Cooperative Agreement Number S15AC20020 from the Office of Surface Mining. Its contents are solely the responsibility of the authors and do not necessarily represent the official views of the OSM. This work is also in collaboration with the West Virginia Department of Environmental protections. The authors would like to thank Mike Sheehan, Nathan Parks, Dave McCoy, Jason Fox, and Mike Richardson for their continued support.

QUESTIONS?