Landslide Impacts to Infrastructure: State of Practice.

Presented by
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Gannett Fleming, Inc.

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THE PROCESS

- Landslide occurs impacting a roadway
- Initial site visit - immediate actions
- Office investigation
  - Geologic Maps - Landslide Maps
  - Mine Maps - Construction Records
- Site Mapping / Detailed Field Reconnaissance
- Subsurface investigation
- Laboratory Testing
- Design Model – back analysis
- Non-geotechnical constraints
  - Right-of-way - Utilities
  - Environmental - Schedule
  - Other
- Remedial Design

Initial Site Visit

- Limits of movement
- Water presence / patterns
- Proximity to adjacent facilities
- Structure presence or conditions.
- Presence/absence of bedrock

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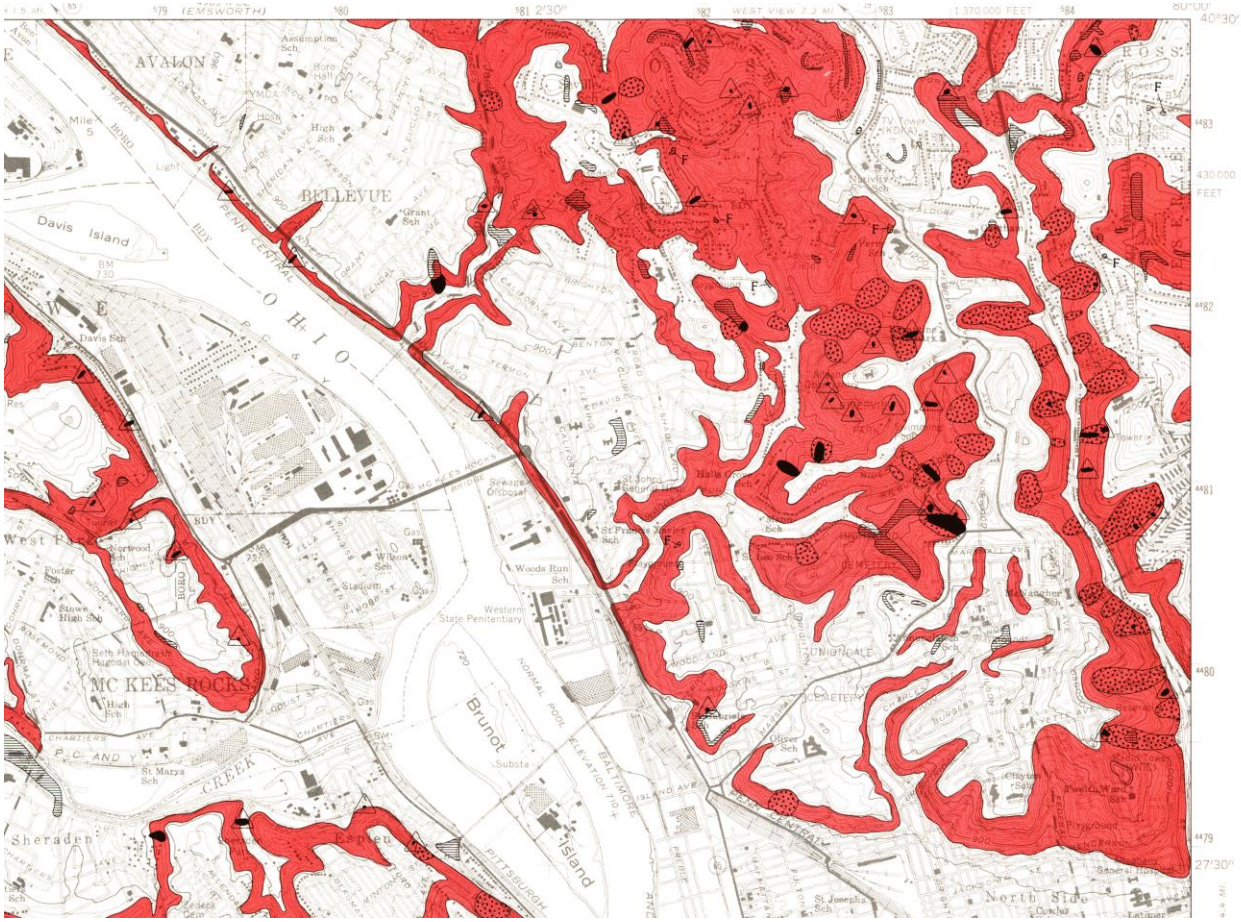
Office Investigation

Landslide Susceptibility Maps – USGS 1977



EXPLANATION

RECENT LANDSLIDES—Predominantly slumps and earthflows (fig. 4 *B, C*) historically recorded or characterized by fresh scars observed in 1974. Small landslides enclosed by triangles

PREHISTORIC LANDSLIDES—Predominantly slumps and earthflows (fig. 4 *B, C*) characterized by uneven, hummocky ground surfaces and slump benches; relatively stable in natural undisturbed state, but can be reactivated by excavation, loading, or changes in ground-water and surface-water conditions. Areas shown probably include some recent undocumented landslides and landslides not recognized during field reconnaissance

SLOPES WITH MODERATE TO SEVERE SUSCEPTIBILITY TO LANDSLIDING—Chiefly areas underlain by thick redbeds and associated rocks of the Glenshaw and Casselman Formations. Red mudstone weathers rapidly on exposure; landsliding and creep (fig. 4*A, E*) often occur in thick reddish clayey soil. Prominent redbeds ("Pittsburgh redbeds") are below the Ames Limestone Member of the Glenshaw, and a lesser known sequence ("Clarksburg redbeds") is above the Ames Limestone Member. Generally cuts and fills in redbeds are not stable

SLOPES WITH SLIGHT TO MODERATE, LOCALLY SEVERE, SUSCEPTIBILITY TO LANDSLIDING—Chiefly areas underlain by weathered claystone and shale of the Casselman and Pittsburgh Formations on which landsliding is infrequent; soil creep, however, is conspicuous. Overloading caused by improper placement of fills or structures can greatly accelerate slope movement

GROUND WITH HIGHLY VARIABLE SLOPE CONDITIONS—Ground on side with ticks has been disturbed by earth-moving operations related to residential and commercial development and to surface mining of coal. Redbeds are relatively rare. Complex zones of thin to locally thick, stable to unstable soil and weathered rock mantle this area. These conditions combine to prevent consistent classification of slopes on the basis of soil creep. Largely underlain by rocks of the Monongahela and lower part of the Dunkard Groups

STEEP SLOPES MOST SUSCEPTIBLE TO ROCKFALL—Steep, locally vertical, natural and manmade slopes and cliffs 15 ft (4.5 m) to more than 150 ft (45 m) high exposing layers of sandstone, subordinate limestone and flaggy, sandy shale, and interbedded claystone and shale. Sandstone and limestone are often highly fractured and are undercut by relatively rapid weathering of claystone and shale (fig. 4 *D*)

GROUND WITH LITTLE SUSCEPTIBILITY TO LANDSLIDING—Slopes commonly exhibit slight soil creep but are susceptible to significant landsliding only where extensively modified by man (see map area 1.2 mi (2 km) southwest of Brunot Island

MANMADE FILL—Heterogeneous soil and rock material with variable susceptibility to slope failure depending on nature of material, foundation conditions, design, and construction. Fills in redbed areas commonly contain red bedrock and soil which rest on redbeds and, therefore, are less stable than similarly constructed fills in other areas. Fills in older urbanized areas and fills resulting from mining are shown only where associated with significant recent landslides. Many fills are too small to show by pattern and are identified by letter "F"

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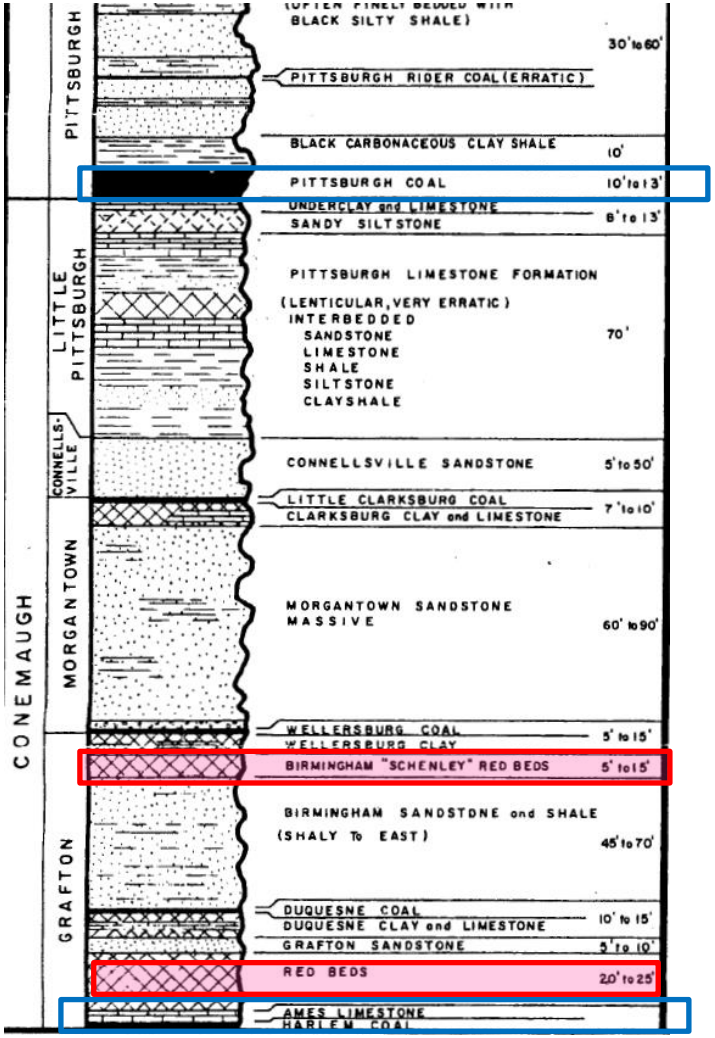
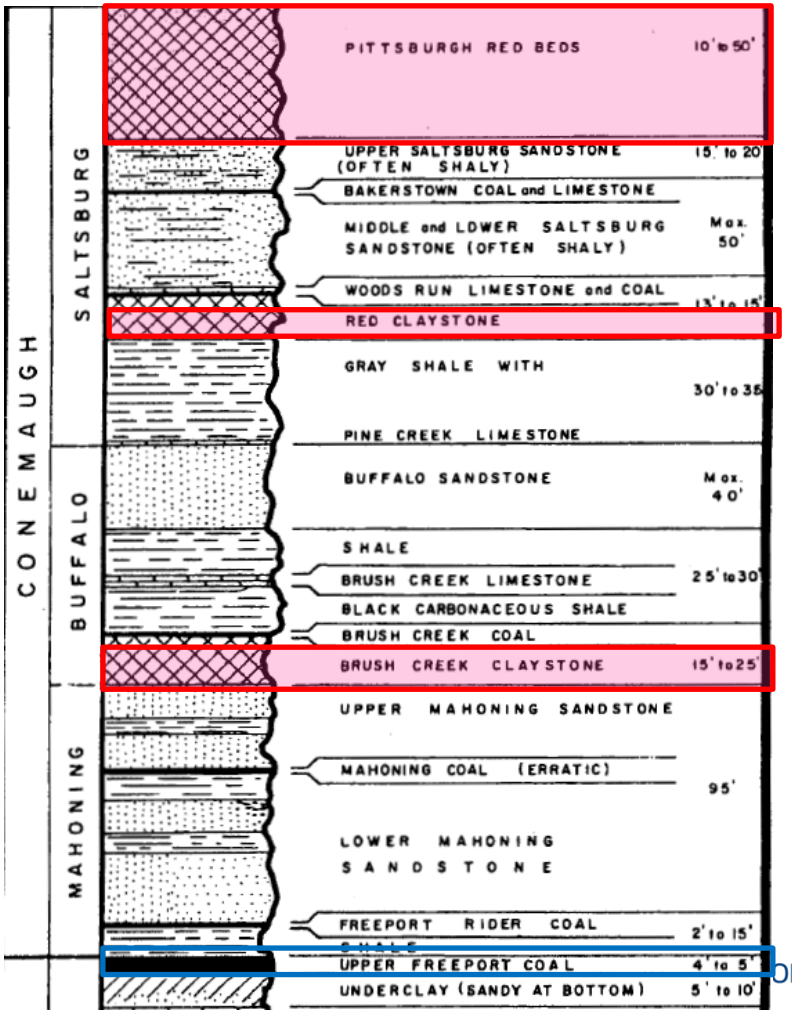
Office Investigation

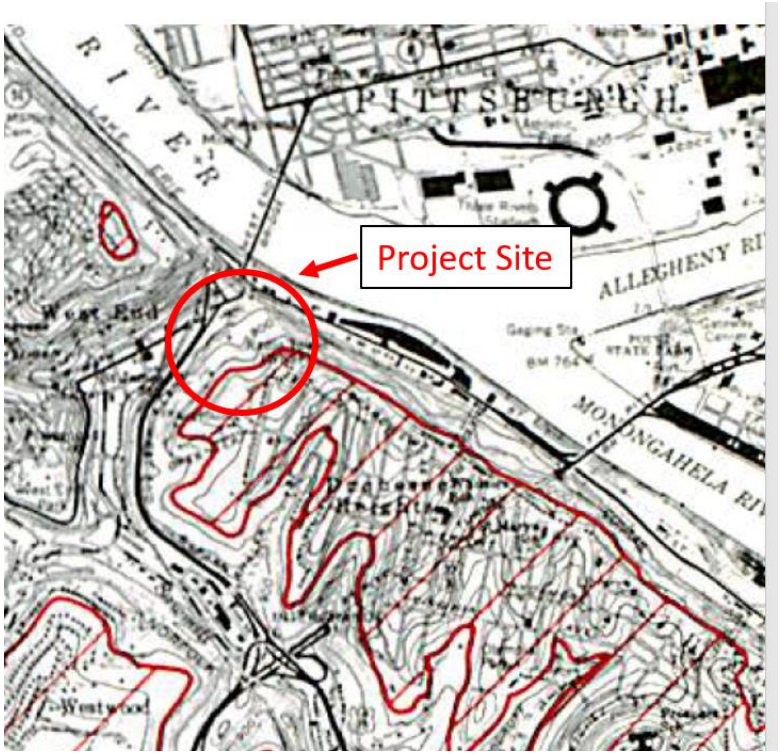
Geologic Section Allegheny County – AC Ackenheil 1968



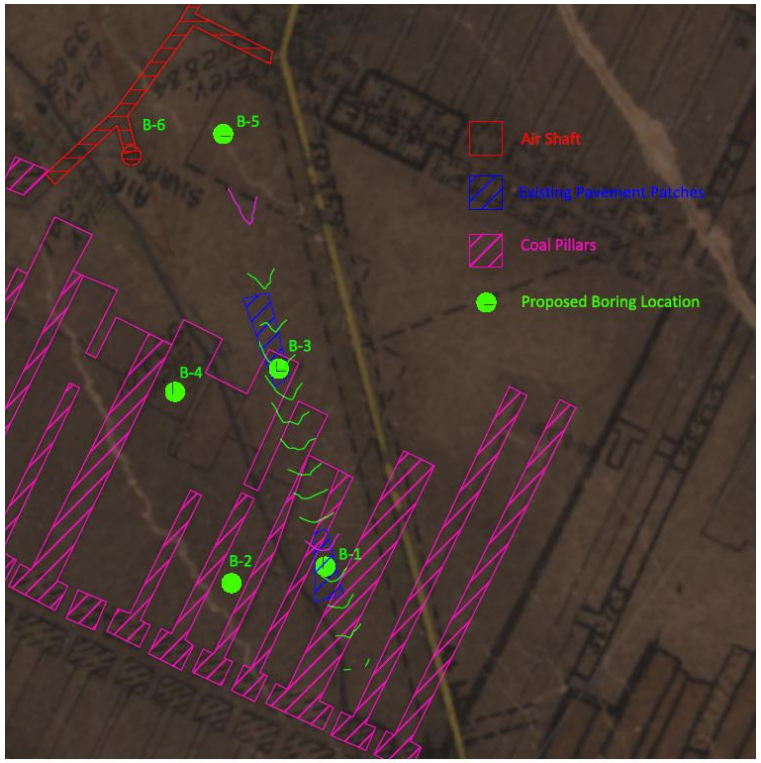


Office Investigation

Mine Maps



USGS Mined Out Areas



DEP detailed mine map overlays

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Bad Actors

Claystones

- Subject to weathering and loss of shear strength when exposed to air, water and repetitive weathering cycles

Erosion of Pittsburgh Redbeds along existing 3H:1V cut slope along I-79 near Neville Island

Excavation of Schenley Red Beds during landslide remediation

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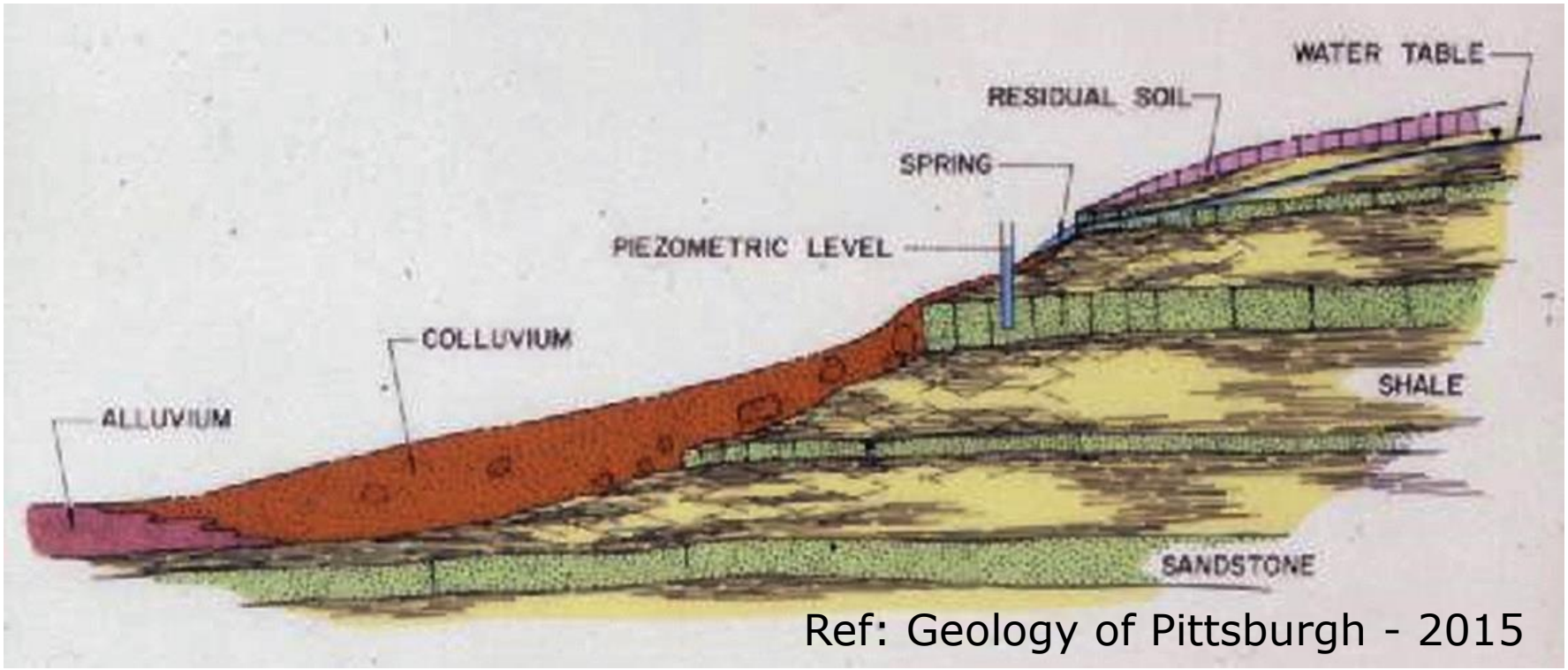
Bad Actors

Colluvial soils

- Soil deposits formed by downslope accumulation of upland parent materials at or near the of toe of slope.
- Low strength properties; subject to continued creep or movement especially when disturbed by cutting, filling, drainage changes, or extreme precipitation events



Ref: Geology of Pittsburgh - 2015

Evaluation

- What are the critical items?
  - Construction Cost
  - Future Maintenance Cost
  - Public Impact (time to repair)
  - 3rd Party Impacts

- What are the feasible solutions
  - Remove and reconstruct
  - Realign
  - Support (Wall)
  - Reinforce (structural elements)
  - Protect (rockfall ditch/fence/drape)
  - Do nothing (close)

Remedial Designs

SR2017 Blythedale Road – Remove & Replace + Mine Grouting

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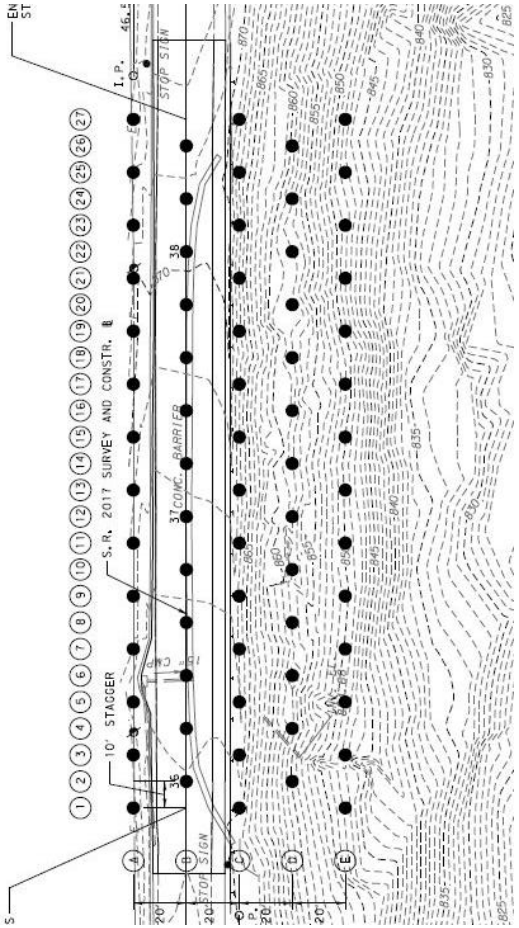
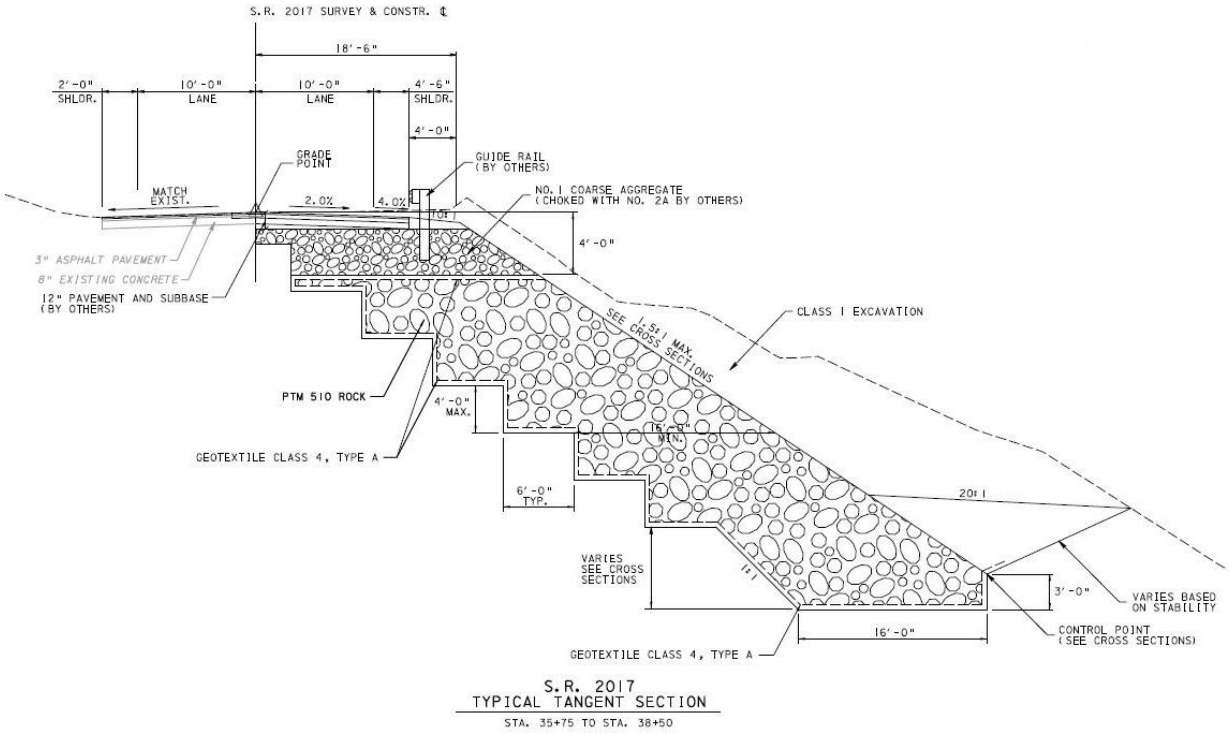
Remedial Designs

SR2017 Blythedale Road – Remove and Replace + Mine Grouting





S.R. 2017
TYPICAL TANGENT SECTION
STA. 35+75 TO STA. 38+50

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SR2017 Blythedale Road – Remove & Replace + Mine Grouting

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Remedial Designs

SR51 – McKees Rocks – Caisson reinforcement

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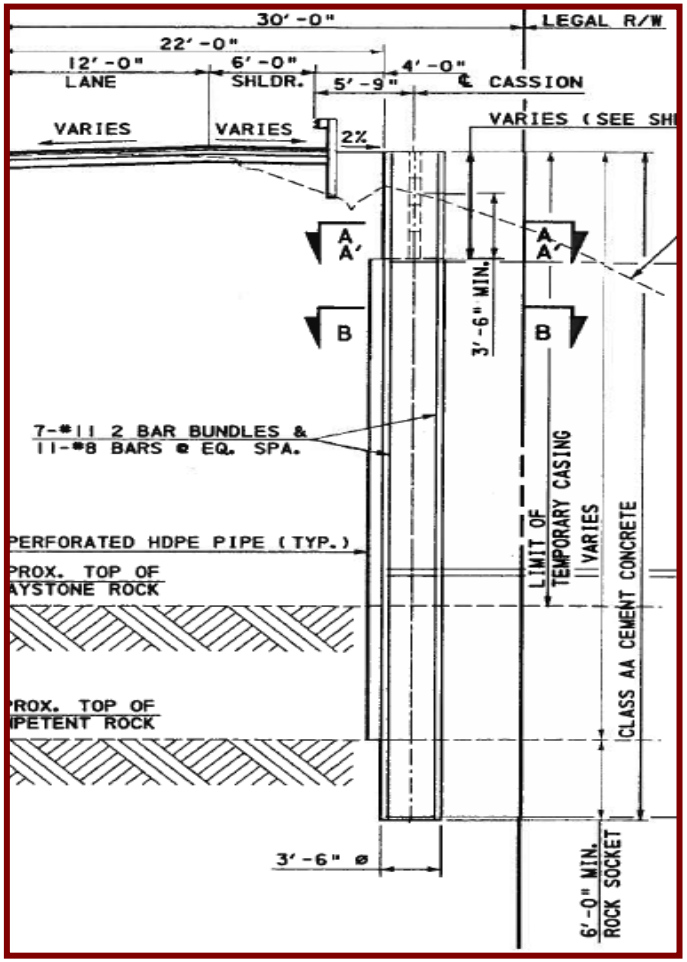
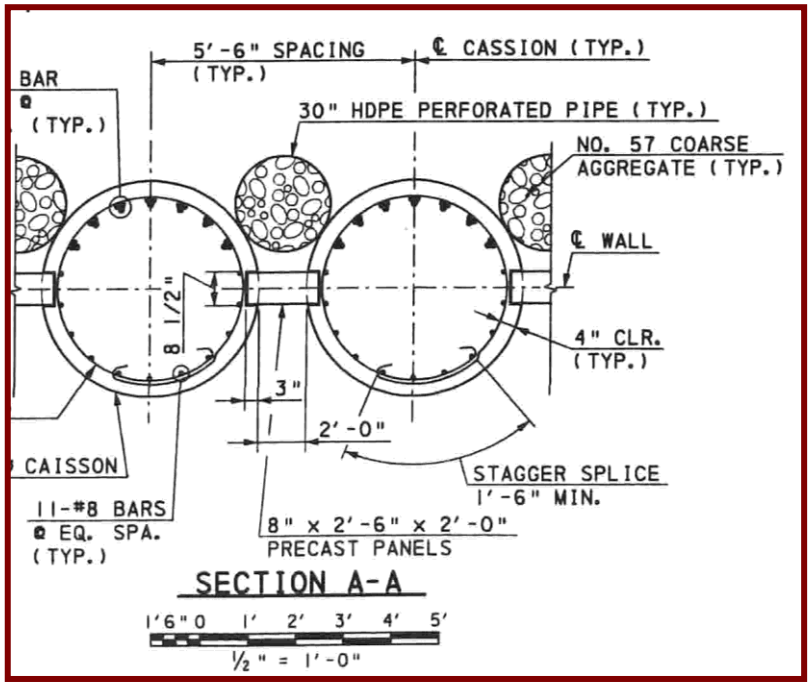
Remedial Designs

SR51 – McKees Rocks – Caisson reinforcement





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SR51 – McKees Rocks – Caisson reinforcement

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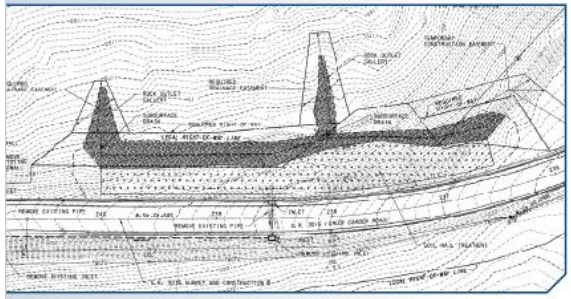
▶ DESIGN/BUILD LANDSLIDE REPAIR? *NAILED IT!*

SR 3016, Green Garden Road Landslide Remediation, Beaver County, Pennsylvania

Stephanie M. Chechak, E.I.T. and Brian F. Heinzl, P.E. – Gannett Fleming, Inc., Pittsburgh, PA

PAST REMEDIATION EFFORTS

- Gabion baskets
- Rock fill
- Patching
- Re-paving
- Re-alignment



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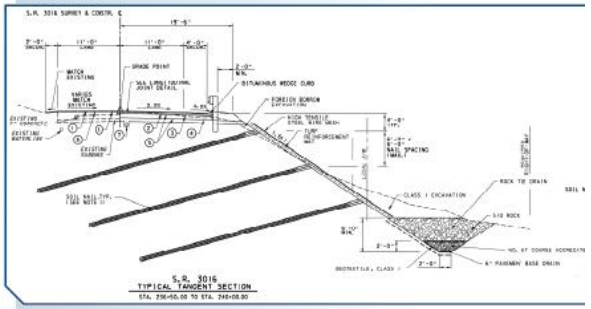
Excellence Delivered ***As Promised***

PROJECT SITE ISSUES

- Persistent groundwater issues
- Complex geology – landslide-prone soils, thick colluvial slopes, and deep residual claystone
- Maintain traffic through construction to avoid a 17-mile detour for emergency vehicles, school buses, and local drivers.
- Public safety under temporary construction conditions – 5,000 vehicles per day.

SOIL NAIL TREATMENT

- Allowed for sufficient temporary stability during construction to maintain traffic through single lane conditions.
- Variable cross section - 3 to 4 rows of soil nails
- Added rock toe for improved stability and long-term drainage of treatment area
- Treatment length – Approximately 350 feet
- Final treatment cost = $ 1,232,000



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Remedial Designs

SR 4063 Structural Elements & Lightweight Backfill

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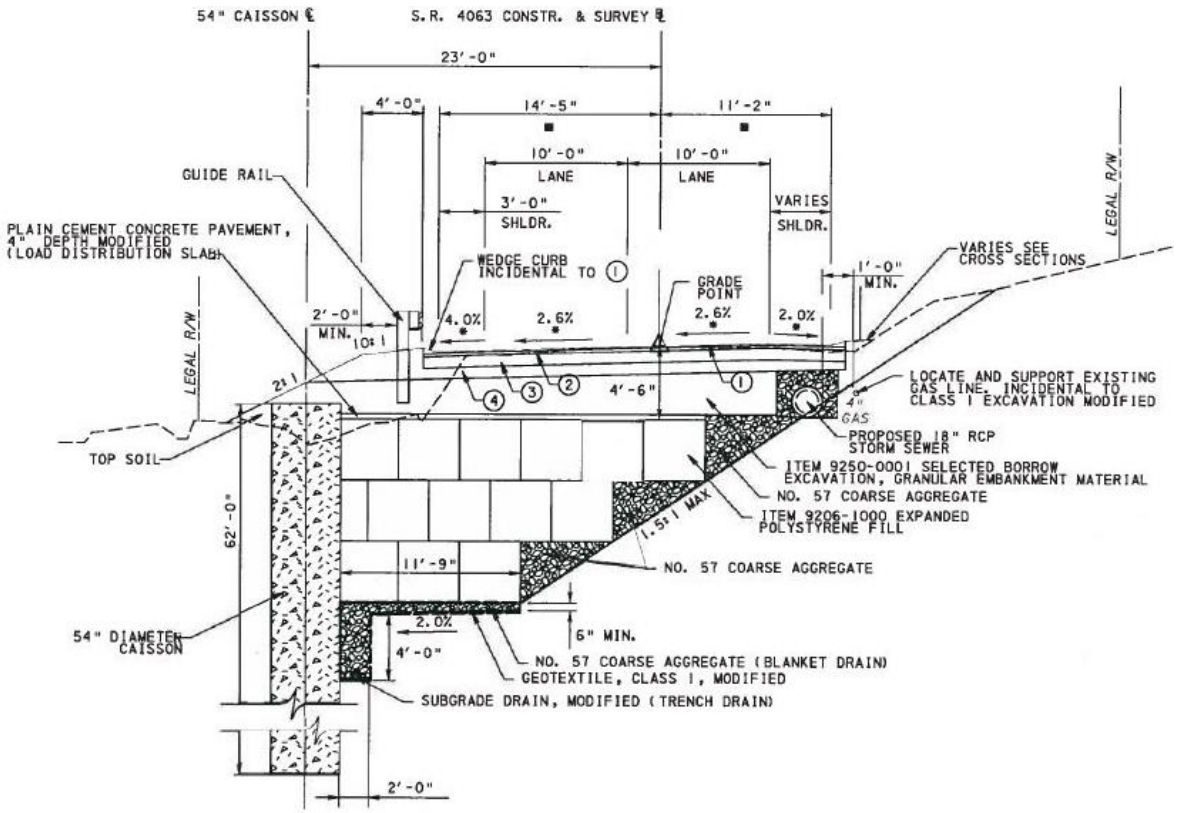
Remedial Designs

SR 4063 Structural Elements & Lightweight Backfill



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Remedial Designs

SR 4063 Structural Elements & Lightweight Backfill

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Remedial Designs

SR 3054 Geogrid Reinforced Slope

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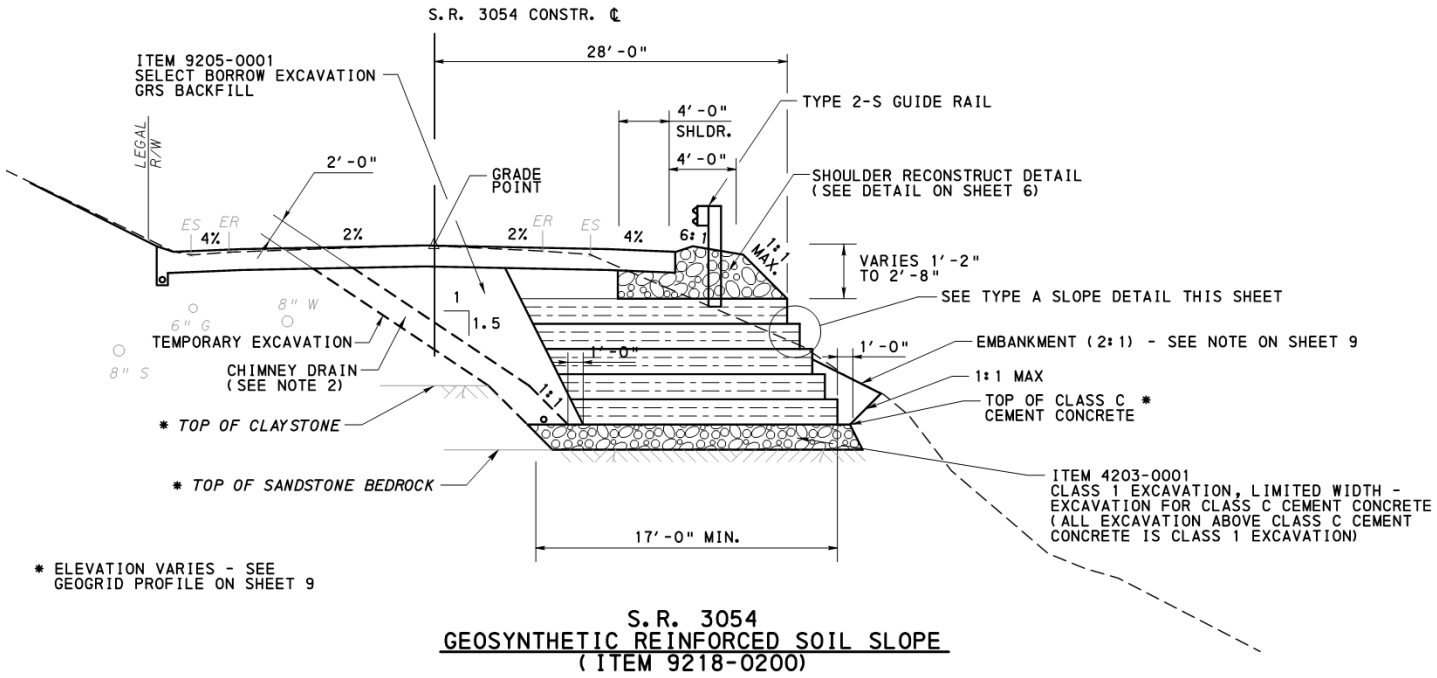
Remedial Designs

SR 3054 Geogrid Reinforced Slope



S.R. 3054
GEOSYNTHETIC REINFORCED SOIL SLOPE
(ITEM 9218-0200)

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Remedial Designs

SR 3054 Geogrid Reinforced Slope

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Remedial Designs

SR 3054 Geogrid Reinforced Slope

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SR 4070 – Wildwood Rd. GRS & Rock Embankment

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Remedial Designs

SR 2001Retaining Wall

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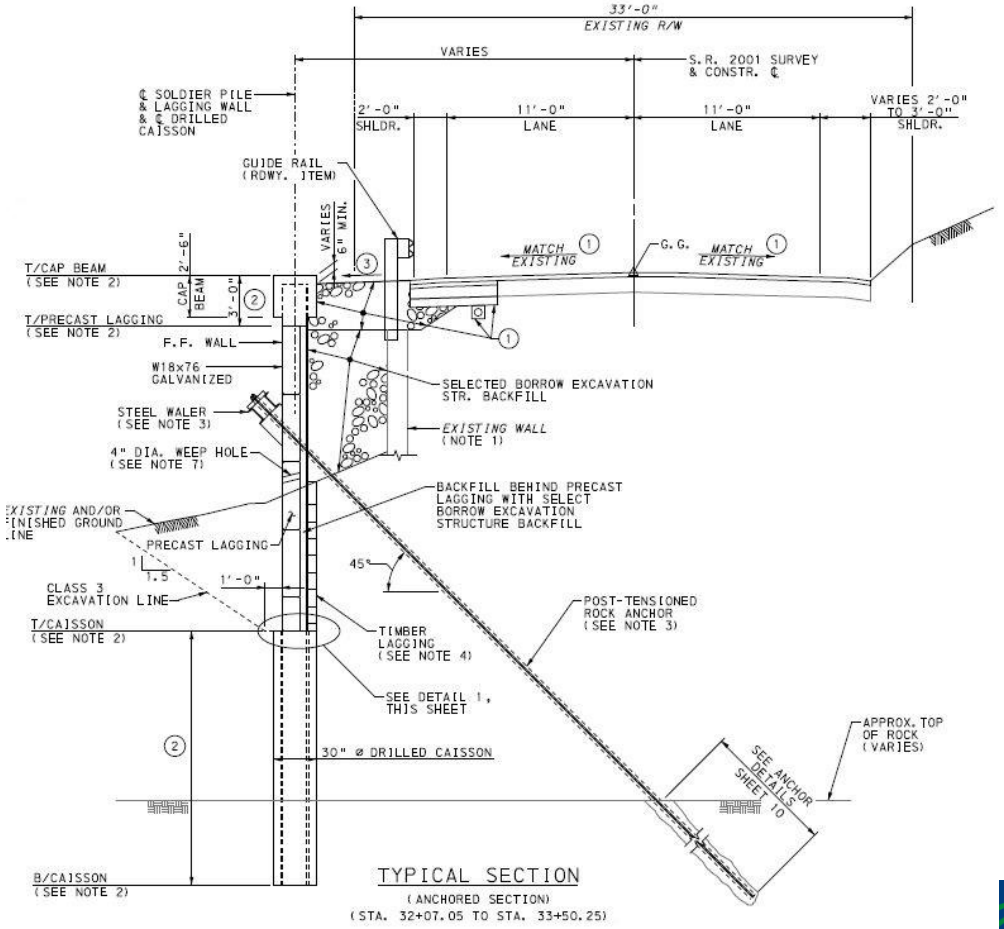
Remedial Designs

SR 2001Retaining Wall



TYPICAL SECTION
(ANCHORED SECTION)
(STA. 32+07.05 TO STA. 33+50.25)

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Remedial Designs

SR 2001Retaining Wall

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REMEDIATION COSTS

Repair Type	Project	ECMS	Year	Bid Price	Length	# Lanes	Cost/LF/Lane
ROCK BUTTRESS	SR 151 BO5	93060	2012	$ 1,232,000.00	775	3	$ 529.89
GEOGRID REINFORCED SLOPE	SR3054 A07	107313	2016	$ 608,085.00	450	2	$ 675.65
SOIL NAILS	SR3016 B09	28996	2012	$ 1,232,000.00	770	2	$ 800.00
CAISSONS / ROCK EMBANKMENT	SR2065 A07	92532	2012	$ 968,726.00	525	2	$ 922.60
ROCK BUTTRESS	SR 2086 A03	87381	2010	$ 343,000.00	185	2	$ 927.03
CAISSONS/MINE GROUTING	SR3028 SLD	80799	2008	$ 828,112.00	425	2	$ 974.25
SOIL NAILS	SR2018 A04	102690	2014	$ 985,450.00	500	2	$ 985.45
ROCK/SOIL NAILS/GRS	SR4070 A18	105384	2016	$ 2,607,655.00	1170	2	$ 1,114.38
ANCHORED WALL	SR2001 A18	109324	2017	$ 1,793,000.00	585	2	$ 1,532.48
CAISSONS	SR51 A64	28491	2006	$ 2,193,924.00	655	2	$ 1,674.75
ROCK BUTTRESS/MINE GROUTING	SR2017 A07	N/A	2013	$ 1,102,150.00	300	2	$ 1,836.92
CAISSONS / GEOFOAM	SR4063 A05	92828	2011	$ 2,483,491.00	550	2	$ 2,257.72
ANCHORED WALL/ ROCK EMB	SR30 A36	82557	2018	$ 6,543,210.00	500	4	$ 3,271.61

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Thank You

OTHER OPTIONS NOT PRESENTED:

- Deep soil mixing
- Pipe dowels (articulated micropiles)
- Jet grouting
- Stone Columns

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