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Conceptual Study of the Hydrology-Based Design of Geomorphic Evapotranspiration Covers for Reclamation of Mine Land

FRED ZHANG[1], NICHOLAS BUGOSH[2], TEKLU TESFA[1], MEGHAN MCDONALD[3], AND JOHN KRETZMANN[3]

[1]Pacific Northwest National Laboratory, Richland, WA;
[2]GeoFlv, Inc., Parma, Ohio
[3]New Mexico Abandoned Mine Land Program, Energy Minerals & Natural Resources Department, Mining & Minerals Division, Santa Fe, NM

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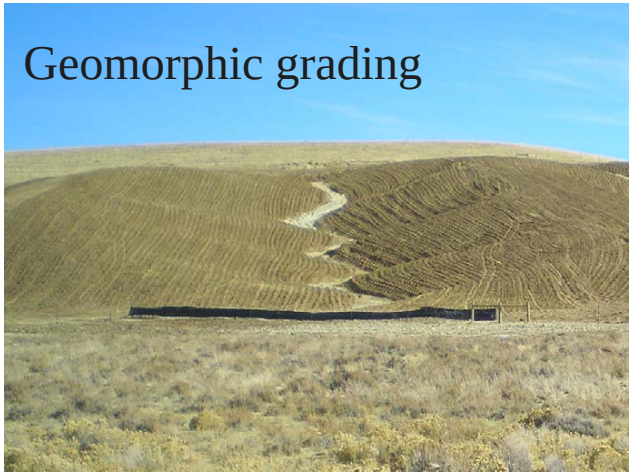
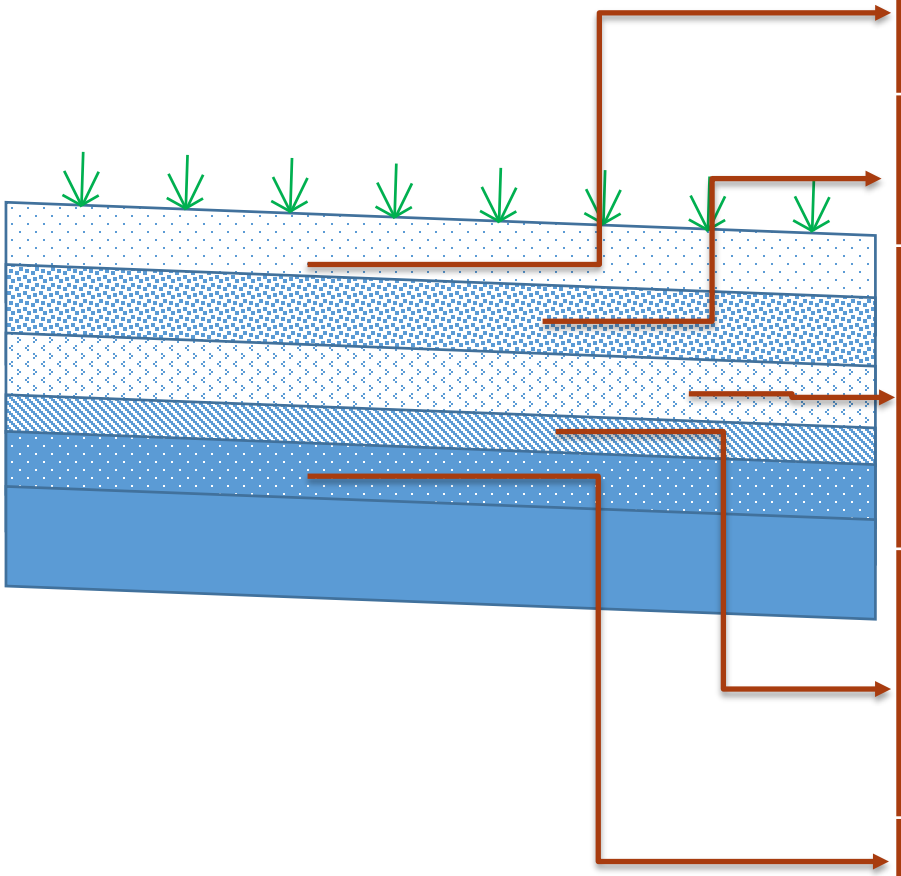
Conventional Reclamation and Geomorphic Grading

- Conventional reclamation
  - Constant-gradient slopes with benches.
  - Combined with elements to redirect and slow runoff
  - Give little consideration for proper hydrologic function for balanced conveyance of water and sediment
- Geomorphic reclamation
  - Provide analogues for post-mining landscapes
  - More functional, cost-effective, long-lasting, and more visually attractive
  - The landform is hydrologically, geomorphologically, and visually compatible with the surrounding area
  - Remain stable for the long term



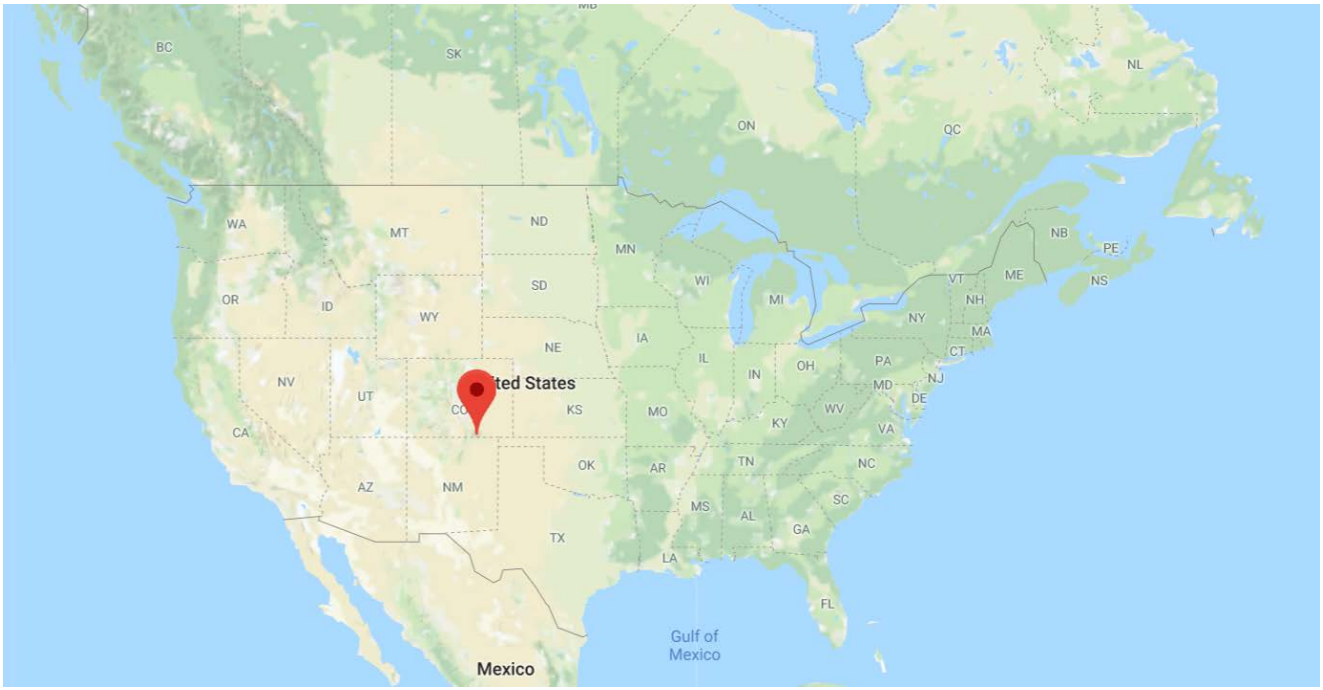
Evapotranspiration Cover



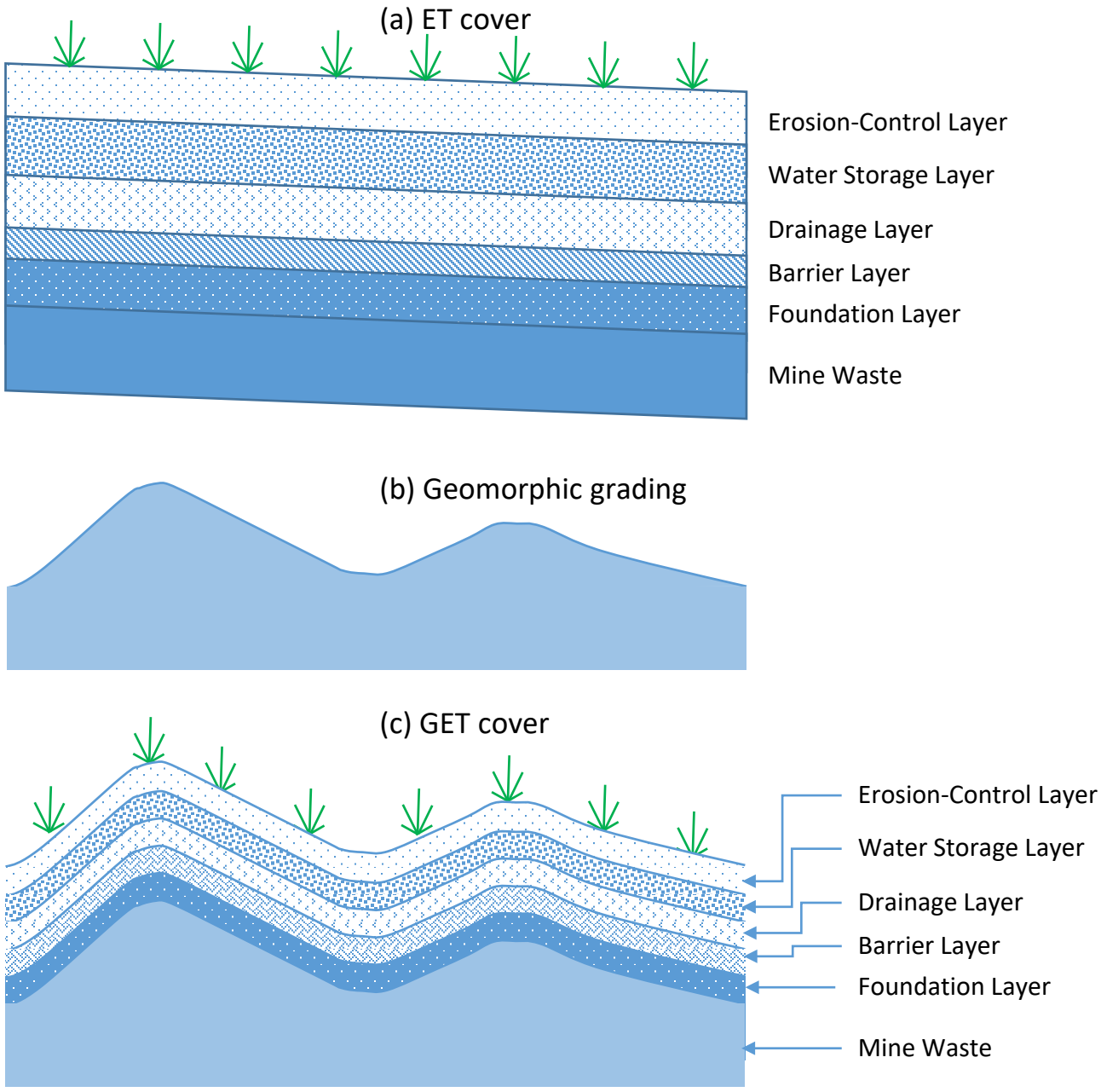
Layer	Primary Function
Erosion-control layer	Resist wind and water erosion
Storage layer	Medium for vegetation growth and stores infiltration water
Drainage layer	Remove excessive water from the storage layer and improve slope stability; deter intrusion of roots, animal burrowing, and/or human digging
Barrier layer	Minimizes percolation of water through the underlying waste; restricts upward movement of any gases or volatile constituents
Foundation layer	Supports upper layers and heavy construction equipment

Objectives

- Introduce the Geomorphic Evapotranspiration (GET) Cover
- Introduce the hydrology-based GET cover design approach
- Demonstrate conceptually the GET cover design at a coal mine site near Raton, NM

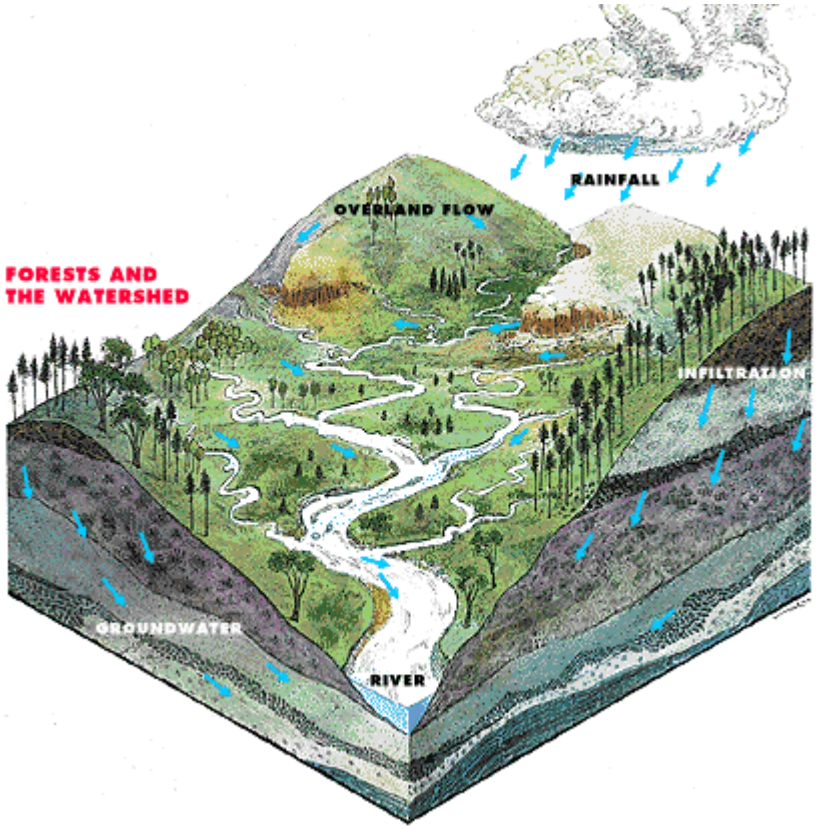


- The Geomorphic Evapotranspiration (GET) Cover



Hydrology-Based GET Cover Design

- **Regulatory requirements** related to
  - groundwater
  - surface water
  - soil and
  - air
- **Cover functional requirements**.
  - Erosion control
  - Medium for vegetation
  - Hydrological control for SW/GW
  - Gas control
- Minimal maintenance
- Land use



Source: http://www.co.greene.pa.us/secured/gc2/images/conserv/what-is-watershed-action.gif

Geomorphic Grading Design

- Using the characteristics of a stable landform of the surrounding area as inputs
- Using the GeoFluv™ fluvial geomorphic landform design method
- The GeoFluv™ method has been incorporated into the Natural Regrade (Carlson Software, Maysville, KY) computer software.
  - Natural Regrade is capable of making and viewing topographic maps and three-dimensional (3-D) images of the landscape design and calculating volumes and cut/fill material balance for designs.
  - It can also be used to evaluate landscape design alternatives that allow the user to select the optimum design for bond alternatives, construction costs, changing mine plans, land use, etc.
- The GeoFluv™ method has been successfully applied in the semi-arid western US and in other climates in the US and internationally.

Geomorphic Grading Design

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- Using Natural Regrade module with GeoFluvTM (patented)

Geomorphic Grading Design

- “The contractor used more material from the borrow for other areas so we ended up with a deficit of material. I had to redesign the highwall reclamation to fit this new condition. Using field data I re-ran the Natural Regrade and was able to generate a new model for the contractor within a matter of hours. This was great!!!!” – Dan Hause, Indiana AML

Geomorphic Grading Design

- ". . .seeded last November, just as winter was starting. . . . vegetation is somewhat sparse . . .only grass and a few legumes . . . stream channels are showing usage, but are not cutting back and are staying in place."

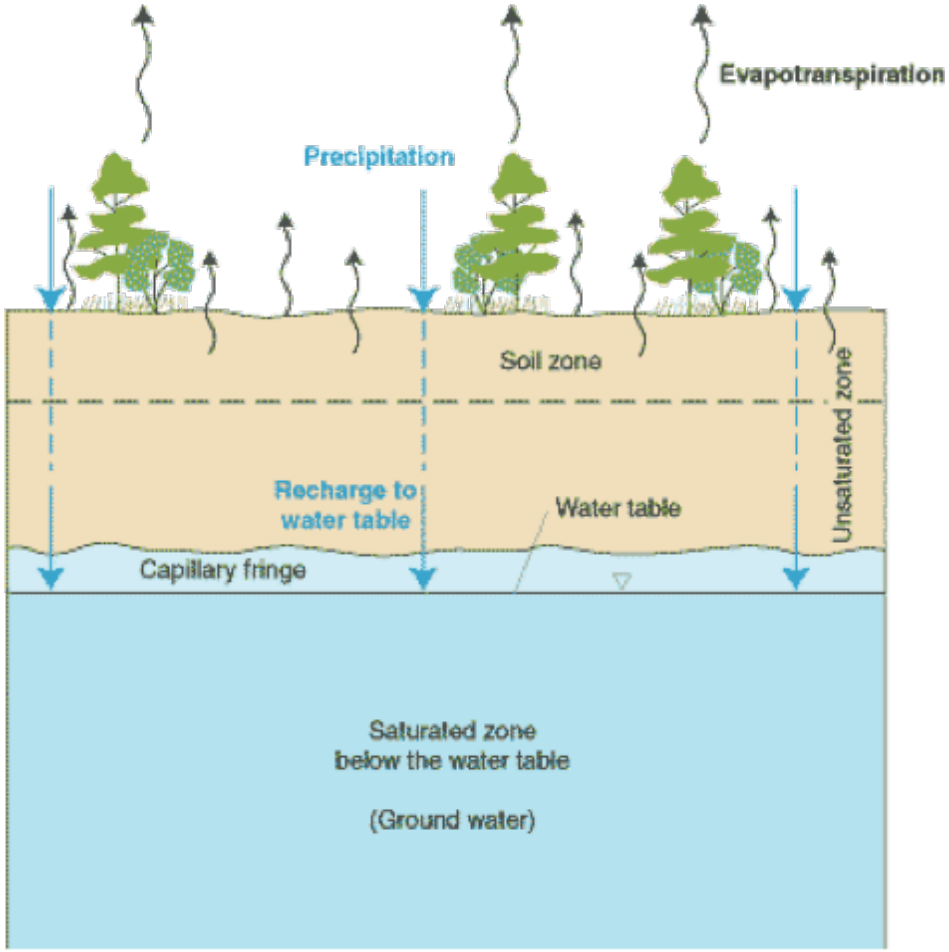
Watershed Hydrology

- Understand how a waste site affects the SW/GW near the waste site.
- Generally, contaminated percolation and/or drainage (D) from the waste flows into and contaminates the SW/GW system.
- Conduct numerical simulation of SW/GW flow at the watershed scale.
- Quantify the SW/GW flow rates, flow directions, and SW/GW interaction
- Provide the initial and boundary conditions for a site-scale simulation

Source: https://news.nationalgeographic.com/content/dam/news/photos/000/758/75836.jpg

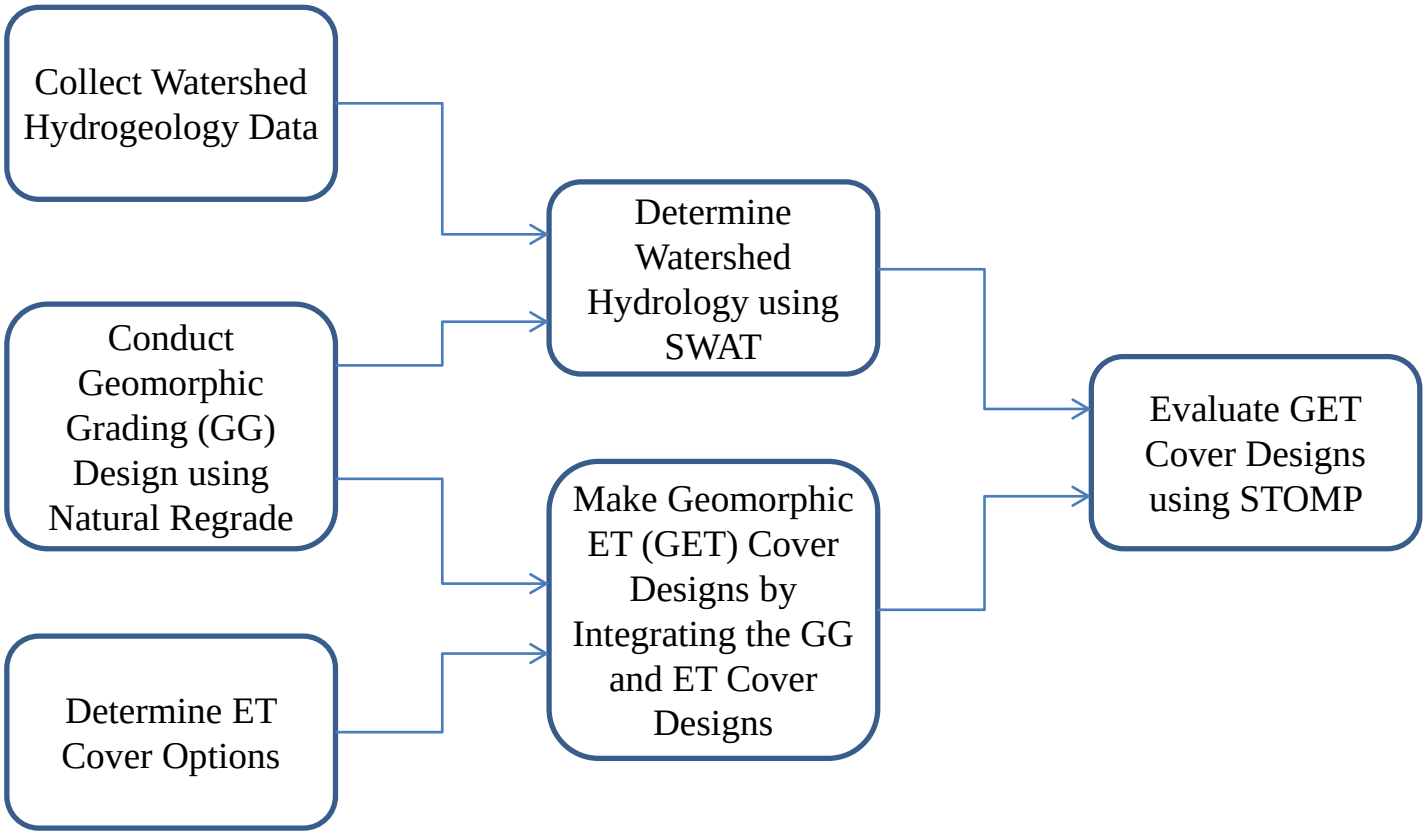
Site-Scale Hydrology

- The design options of the GET cover for a site can be evaluated by numerical simulation
- The simulator should be capable of incorporating transport of water, contaminants in a GET barrier and the underlying waste.
- The watershed simulation results can be used as the boundaries for the site-scale simulation.
- The GG is used as the base for investigating GET cover options.



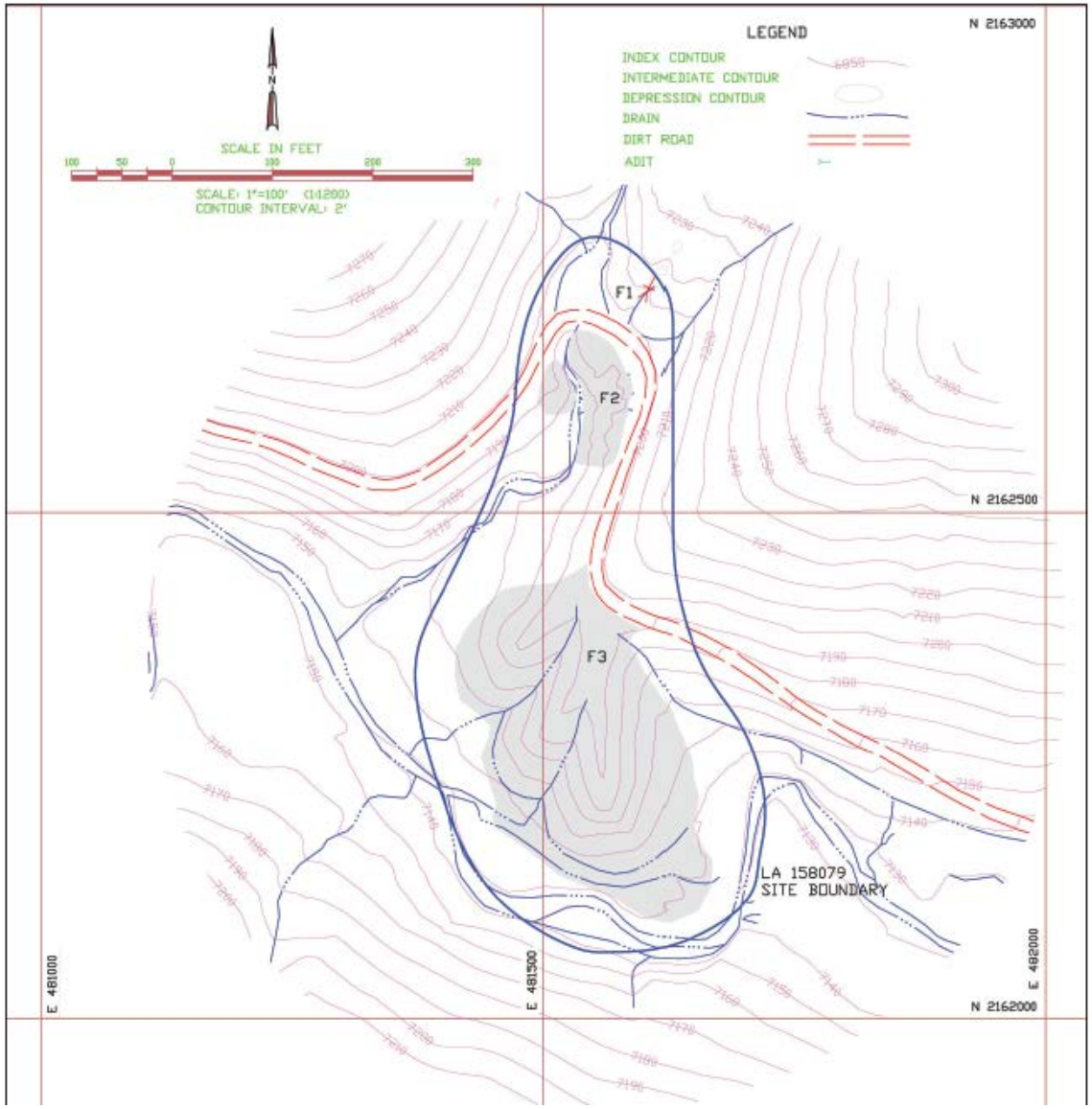
Source: https://www.e-education.psu.edu/earth111/sites/www.e-education.psu.edu.earth111/files/Module6/Earth111Mod6AFig2left.png

Methods and Procedures for a GET Cover Design



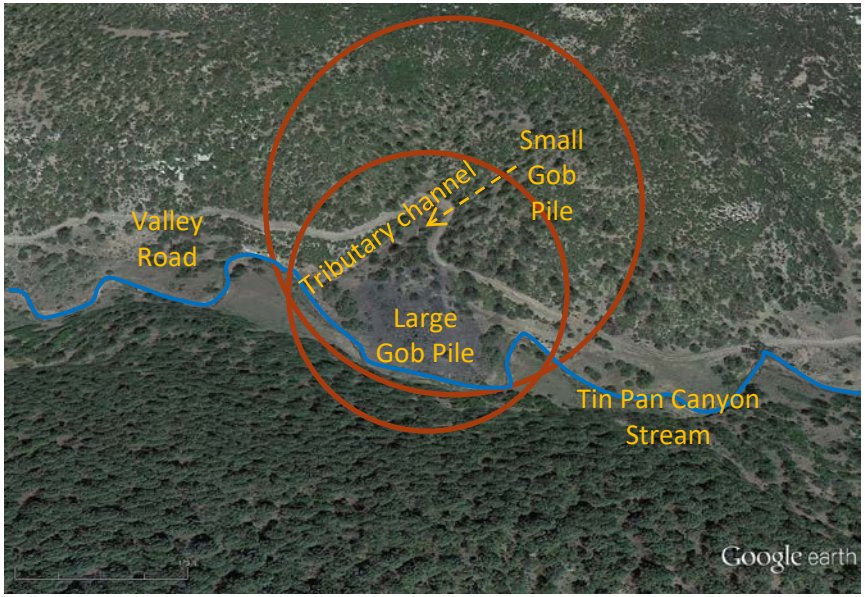
Conceptual Demonstration at the Tin Pan Mine Site

- Tin Pan Canyon coal mine workings consist of one closed adit and two coal gob piles.
- Actual mining of the coal may have started in 1906 and ceased operations before 1949.
- The waste site consists of two gob piles of mine waste
- The Tin Pan Canyon stream flows by the large pile



Site Characteristics

- The waste material was dumped into a narrow valley of ~1 ha
- A pioneered two-track valley road along the Tin Pan valley is still in use
- The watershed area (~32 ha) of the tributary valley above this road has a high runoff coefficient
- There is also the possibility that cultural resources may be present
- There are limited areas for alternate waste disposal
- The GET cover had to be integrated into the design to sequester the designated waste volume.



Site Characteristics

- The stream meandering is controlled by a thick, competent sandstone
- Thin soils over this bedrock combined with short-duration, high-intensity storms
- The tributary channel discharges have eroded a gully along the west valley wall.
- Steep slope that could contribute to rill and gully erosion.

Site design criteria

- Road makes a knickpoint subject to erosion

Site Characteristics

- 12.6 hectare run-on watershed
  - thin soils
  - bedrock crops out
  - can generate erosive discharges

Physical and Chemical Properties

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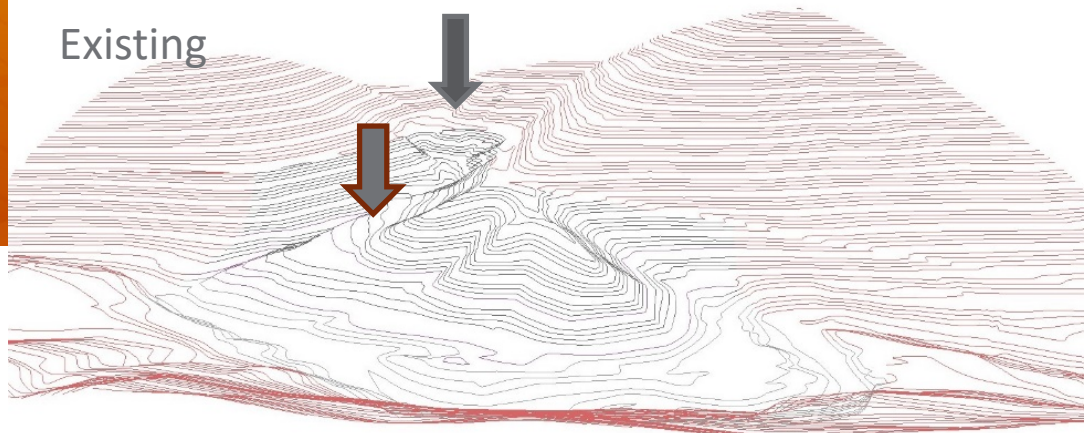
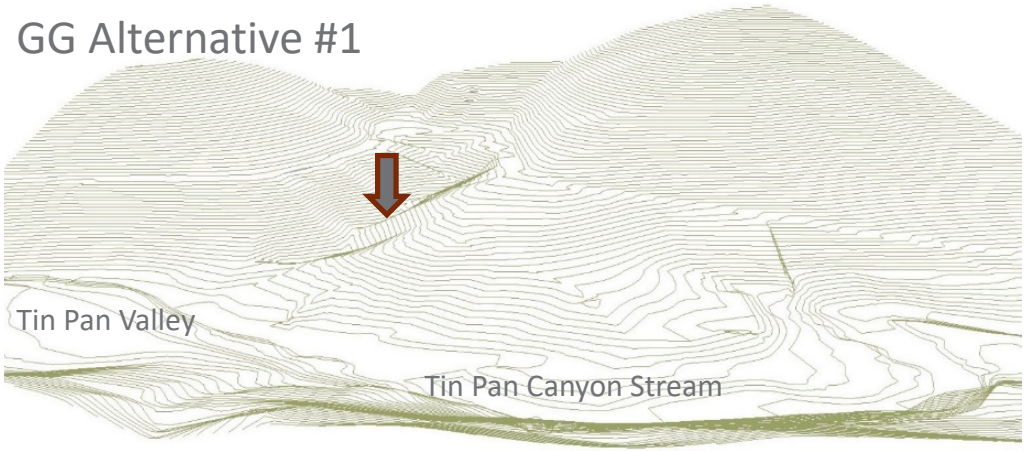
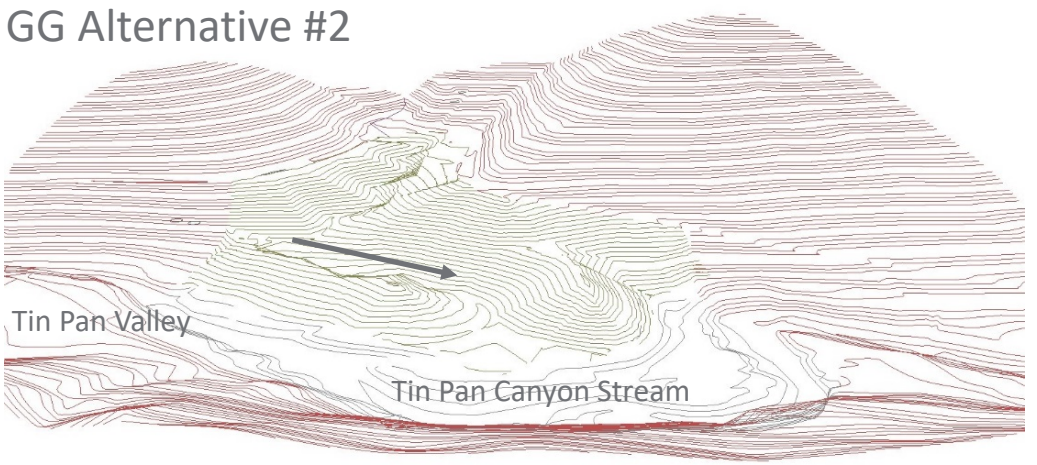
Sand	40	%
Silt	29	%
Clay	32	%
Texture	CL	
SATURATED PASTE EXTRACT		
pH, sat. paste	7	s.u.
Conductivity, sat. paste	1	mmho s/cm
Saturation	37	%
Calcium, sat. paste	1	meq/L
Magnesium, sat. paste	1	meq/L
Sodium, sat. paste	5	meq/L
Alkalinity, Total as $CaCO_3$	247	mg/L
Bicarbonate as HCO_3	301	mg/L
Carbonate as CO_3	ND	mg/L
Chloride	5	mg/L
Sulfate	93	mg/L

Geomorphic Grading at the Tin Pan Site

- Stable reference site
  - drainage density: 83 m/ha; 110 ft/acre)
  - ridge to head of channel distance: 27 m; 90 feet
  - ‘A-channel’ reach length: 15 m/ha; 20 feet/acre
- Two GG design alternatives
  - Alternative #1
  - Alternative #2







Slope Zone Analysis at the Tin Pan Site

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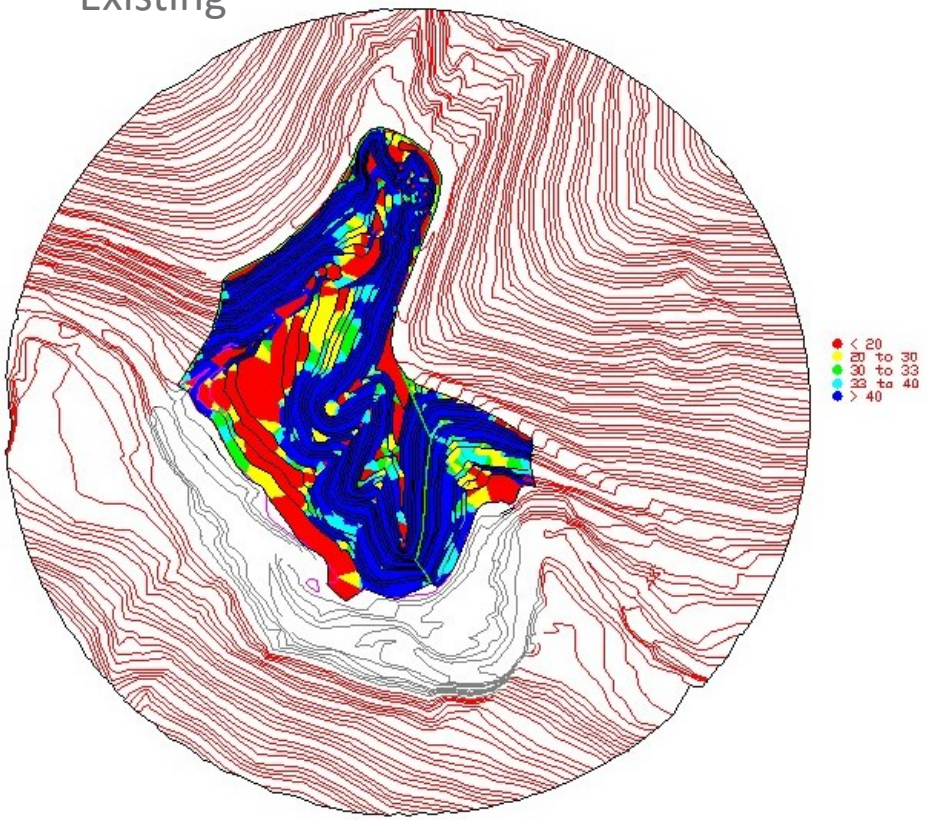
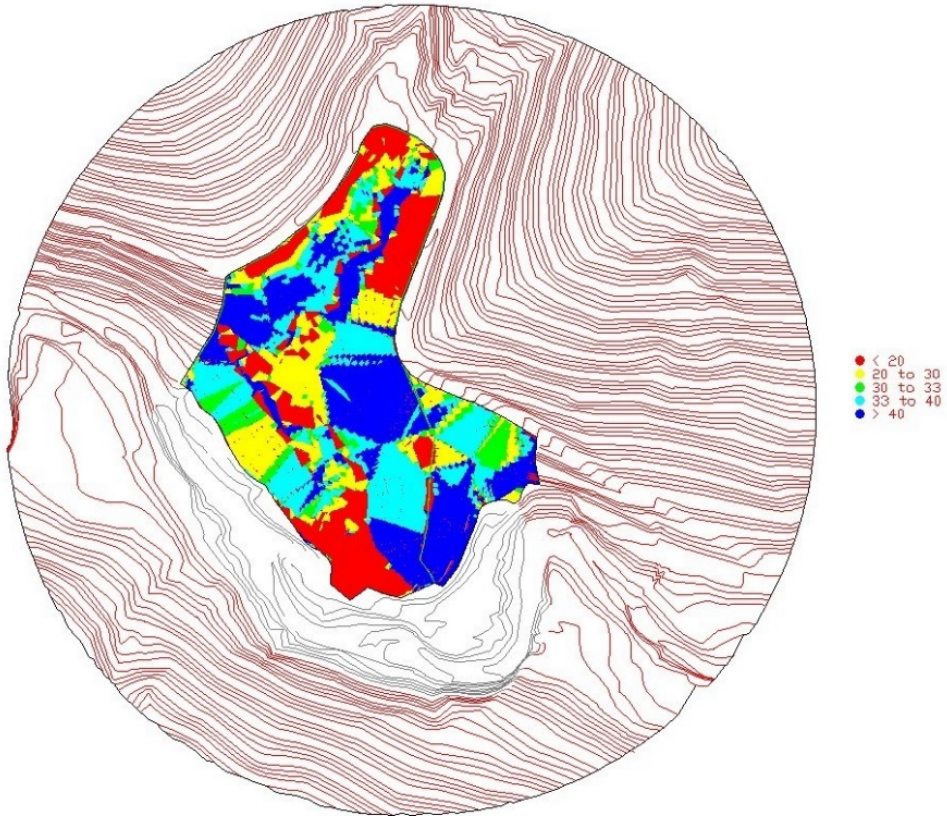
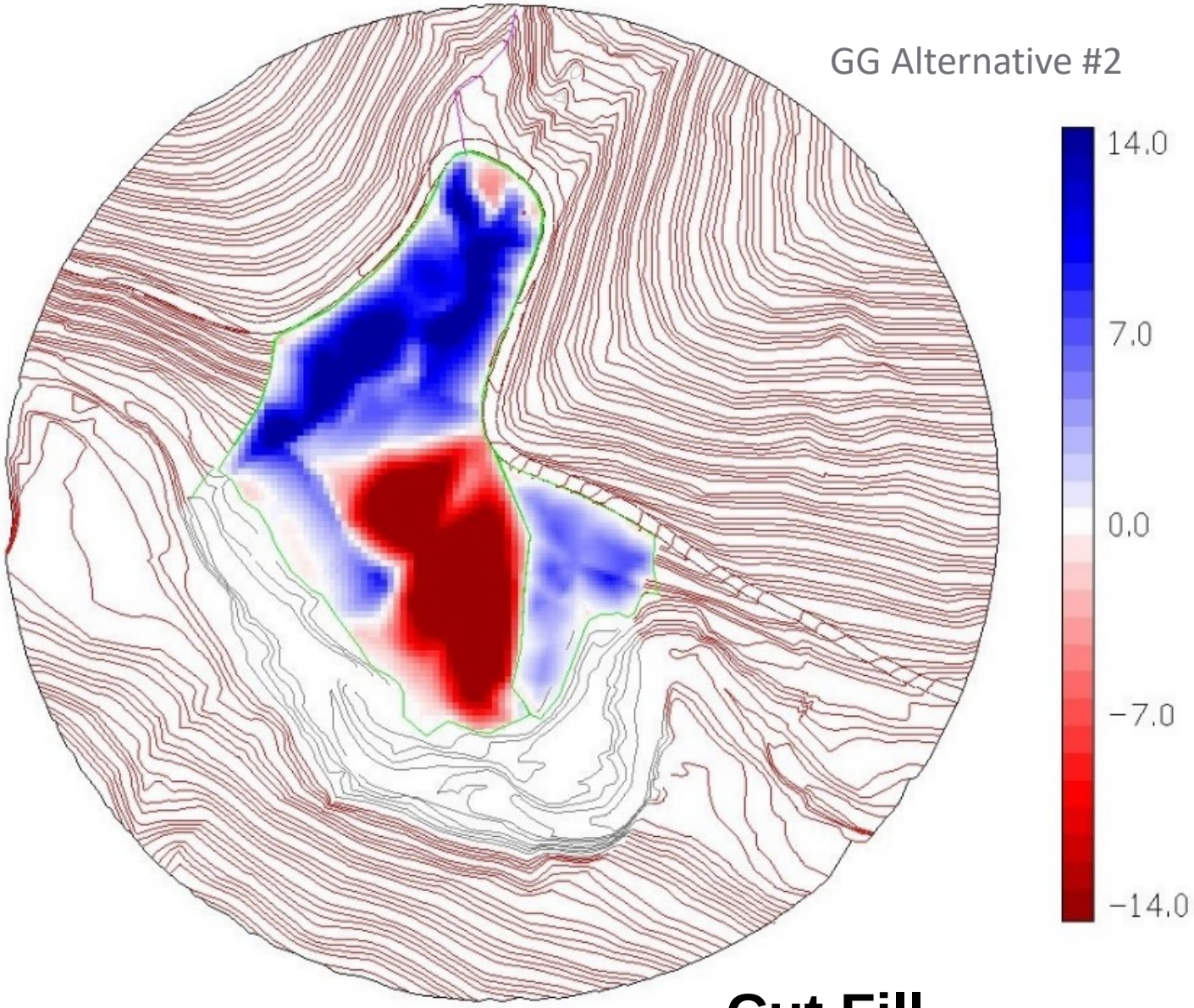
Existing



GG Alternative #2



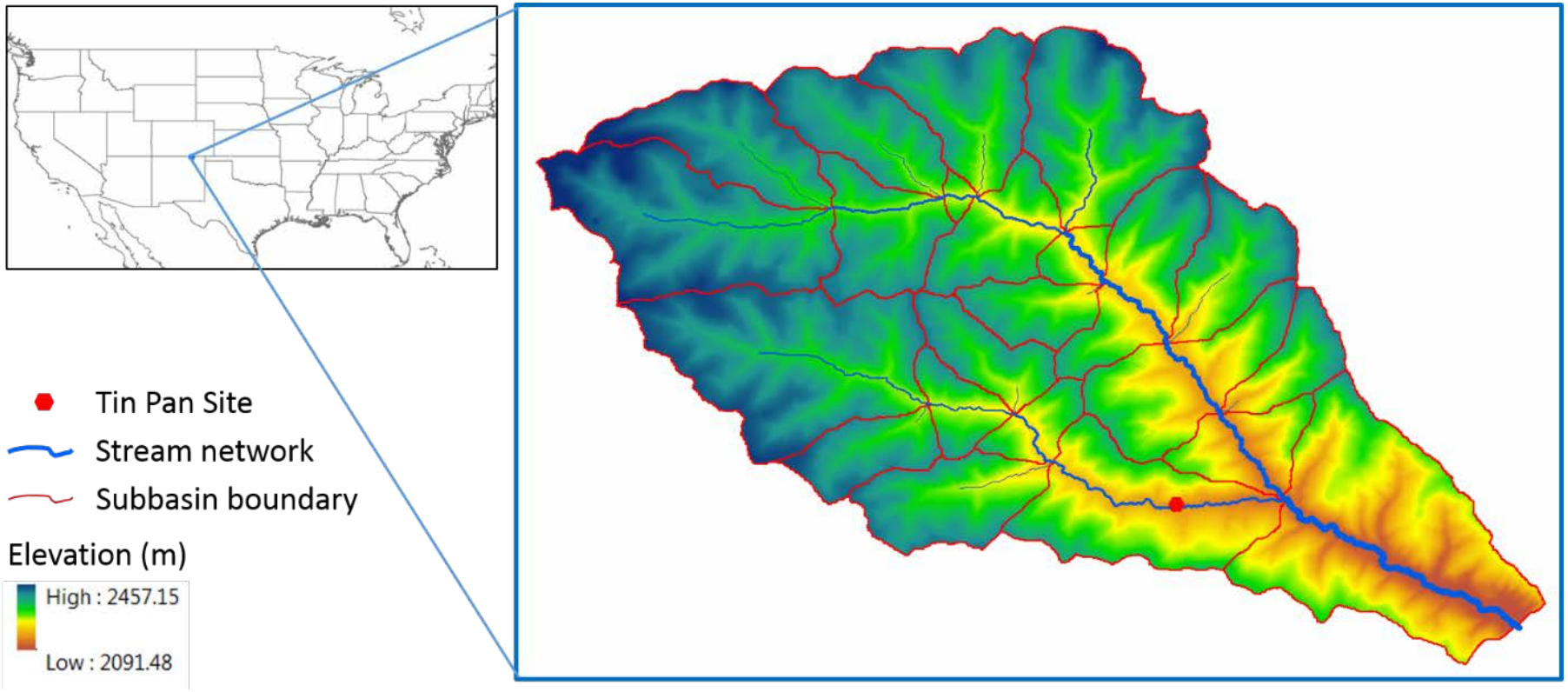
GG Alternative #2



Cut Fill Color Map

Watershed Hydrology at the Tin Pan Site

- Watershed size: 41.6 km^2
- 23 sub-basins



Summary

- Proposed the geomorphic ET (GET) cover to improve the overall performance.
  - The shape of the GET cover can mimic the natural topography of the surrounding area
  - The thickness and layering of the GET cover can be optimized for best vegetation growth and infiltration control.
  - Watershed groundwater flow is considered during GET cover design.
- The GET cover has the benefits of the geomorphic cover: drainage reduction, runoff management, vegetation diversity
- It also has the benefits of ET covers: vegetation growth and sustainability, percolation reduction, protection of surface and groundwater
- A conceptual design study is being carried out based on an actual, typical abandoned mine site near Raton, NM

Acknowledgement

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