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

FRED ZHANG¹, NICHOLAS BUGOSH², TEKLU TESFA¹, MEGHAN MCDONALD³, AND JOHN KREITZMANN³

¹Pacific Northwest National Laboratory, Richland, WA;
²GeoFlx, Inc., Parma, Ohio
³New 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**

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

(a) ET cover

(b) Geomorphic grading

(c) 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.
Using Natural Regrade module with GeoFluvTM (patented)

The GeoFluv™ approach asks,

*What would be a stable, natural landform?*

and designs and builds that.
“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
“...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

- Collect Watershed Hydrogeology Data
- Conduct Geomorphic Grading (GG) Design using Natural Regrade
- Determine ET Cover Options
- Determine Watershed Hydrology using SWAT
- Make Geomorphic ET (GET) Cover Designs by Integrating the GG and ET Cover Designs
- Evaluate GET Cover Designs using STOMP
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

<table>
<thead>
<tr>
<th>Physical Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sand</td>
<td>40 %</td>
</tr>
<tr>
<td>Silt</td>
<td>29 %</td>
</tr>
<tr>
<td>Clay</td>
<td>32 %</td>
</tr>
<tr>
<td>Texture</td>
<td>CL</td>
</tr>
<tr>
<td>Saturation</td>
<td>37 %</td>
</tr>
<tr>
<td>Calcium, sat. paste</td>
<td>1 meq/L</td>
</tr>
<tr>
<td>Magnesium, sat. paste</td>
<td>1 meq/L</td>
</tr>
<tr>
<td>Sodium, sat. paste</td>
<td>5 meq/L</td>
</tr>
<tr>
<td>Alkalinity, Total as CaCO$_3$</td>
<td>247 mg/L</td>
</tr>
<tr>
<td>Bicarbonate as HCO$_3$</td>
<td>301 mg/L</td>
</tr>
<tr>
<td>Carbonate as CO$_3$</td>
<td>ND mg/L</td>
</tr>
<tr>
<td>Chloride</td>
<td>5 mg/L</td>
</tr>
<tr>
<td>Sulfate</td>
<td>93 mg/L</td>
</tr>
</tbody>
</table>
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

Existing

GG Alternative #1

Tin Pan Valley

Tin Pan Canyon Stream

GG Alternative #2

Tin Pan Canyon Stream

Tin Pan Valley
Slope Zone Analysis at the Tin Pan Site

Existing

GG Alternative #2
Watershed Hydrology at the Tin Pan Site

- Watershed size: 41.6 km²
- 23 sub-basins
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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