ALTERNATIVES ANALYSIS APPROACH TO ABANDONED MINE RECLAMATION DESIGN[1]

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Abstract. The gap between available and required abandoned mine land reclamation funding requires careful and thoughtful design planning to ensure that reclamation goals are identified and met with the least cost alternatives. Traditional abandoned mine land reclamation planning has focused on basic earthmoving methodology without consideration of cost saving from alternative technology or other synergies between land development interests and mine reclamation strategies.

Three case studies are discussed that illustrate the design planning process. Project goals were developed and site constraints are identified. The primary project goal of each site was abatement of highwall hazards, and additional project goals included wildlife habitat, creation of commercially developable post-reclamation property, and minimization of high cost delivery of offsite fill material to achieve stable slopes.

Reclamation alternatives investigated during the design phases included: (1) traditional non-engineered cut and fill; (2) engineered fill techniques with tighter construction specifications and Quality Assurance/Quality Control (QA/QC) requirements; (3) blasting/conventional earthmoving to achieve desired slopes: (4) use of geotextiles, specialized toe buttressing, and landform design to achieve stable slopes and acceptable water conveyance with minimal earthmoving; and (5) site design from a land development perspective. A description of the steps followed during each reclamation design is discussed for each project and include: (1) mapping; (2) review of historical data; (3) review of pre-mining contours and land uses; (4) investigation of soil engineering properties with respect to strength and slope stability; and (5) assessment of suitability of soils for revegetation and erosion control. Cost estimating is discussed for each different reclamation approach, as is the decision making process used prior to selection of remedial alternative or combination of alternatives.

The case studies show that with appropriate planning in the early stages of mine reclamation design, project goals and objectives can be established and met, and significant savings in construction costs can be realized.

Additional Keywords – alternative remediation cost analysis secondary reclamation goals

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Introduction

The gap between available and required abandoned mine land reclamation funding requires careful and thoughtful design planning to ensure that reclamation goals are identified and met with the least cost alternatives. Traditional abandoned mine land reclamation planning has focused on basic earthmoving methodology without consideration of cost saving from alternative technology or other synergies between land development interests and mine reclamation strategies.

This paper discusses the strategies employed during the development of restoration strategies for three surface mine reclamation projects in Pennsylvania. Each project had unique goals and constraints, which influenced the formulation of the reclamation strategies.

Kettle Creek Bio-Capping Project

The Kettle Creek Watershed Association in cooperation with Trout Unlimited initiated a project to bio-cap 57 acres of abandoned mined land in Leidy and Noyes Townships, Clinton County, PA. The objective was to establish a permanent vegetative cover over impacted areas to reduce infiltration, hydraulic loading and metals loading into Two Mile Run, Shintown Run, Kettle Creek, and the Susquehanna River. An organic soil conditioner (from E. H. Hall/Westfield Tanning Company in Westfield, PA) and in place soil fines were combined to produce a viable growth substrate and promote the establishment of vegetative cover. This vegetative cover was expected to improve the physical and chemical properties of the impacted watershed. In addition, an elk food plot seed mix was used to provide an additional food source for the local elk herd.

Design work began on the Kettle Creek Bio-Capping project in 2002. The initial grading plan was developed by the Pennsylvania Department of Environmental Protection, Bureau of Abandoned Mine Reclamation (PADEP, BAMR). Gannett Fleming was retained by the Kettle Creek Watershed Association and Trout Unlimited and tasked with the preparation of plans, specifications and bid documents for the earthmoving, Erosion and Sedimentation (E&S) controls, and the development of a procedure to mix wood waste with the soil conditioner.

The construction project was advertised in June of 2003, and bids received exceeded the project budget due to escalations in fuel and material costs. In an effort to reduce the overall project cost, Gannett Fleming investigated the possibility of altering the grading plan to reduce the total earthwork while still achieving the project goals, which were mainly geared towards decreasing infiltration through mine spoil by promoting positive drainage and providing stable vegetated cover.

In the original construction bid package, the grading plan proposed by BAMR consisted of one fairly uniformly graded mound, and resulted in approximately 340,000 cubic yards (CY) of earthmoving. The revised design decreased the earthmoving by more than 170,000 CY, which brought costs back below the available budget, making it possible to complete the project.

Water quality monitoring was completed by the Kettle Creek Watershed Association after the completion of the reclamation project to develop design data for a passive treatment system immediately down stream of the newly reclaimed surface mine. The results of that monitoring were compared to historical water quality sampling test results in the same area. It was found that the reclamation project was successful in decreasing acidity and aluminum loading by between 30 to 40 percent. As vegetative cover becomes more robust over time, it is expected that those reductions will continue to increase.

Figures 1-3 show the un-reclaimed surface mine, original reclamation plan, and revised reclamation plans:

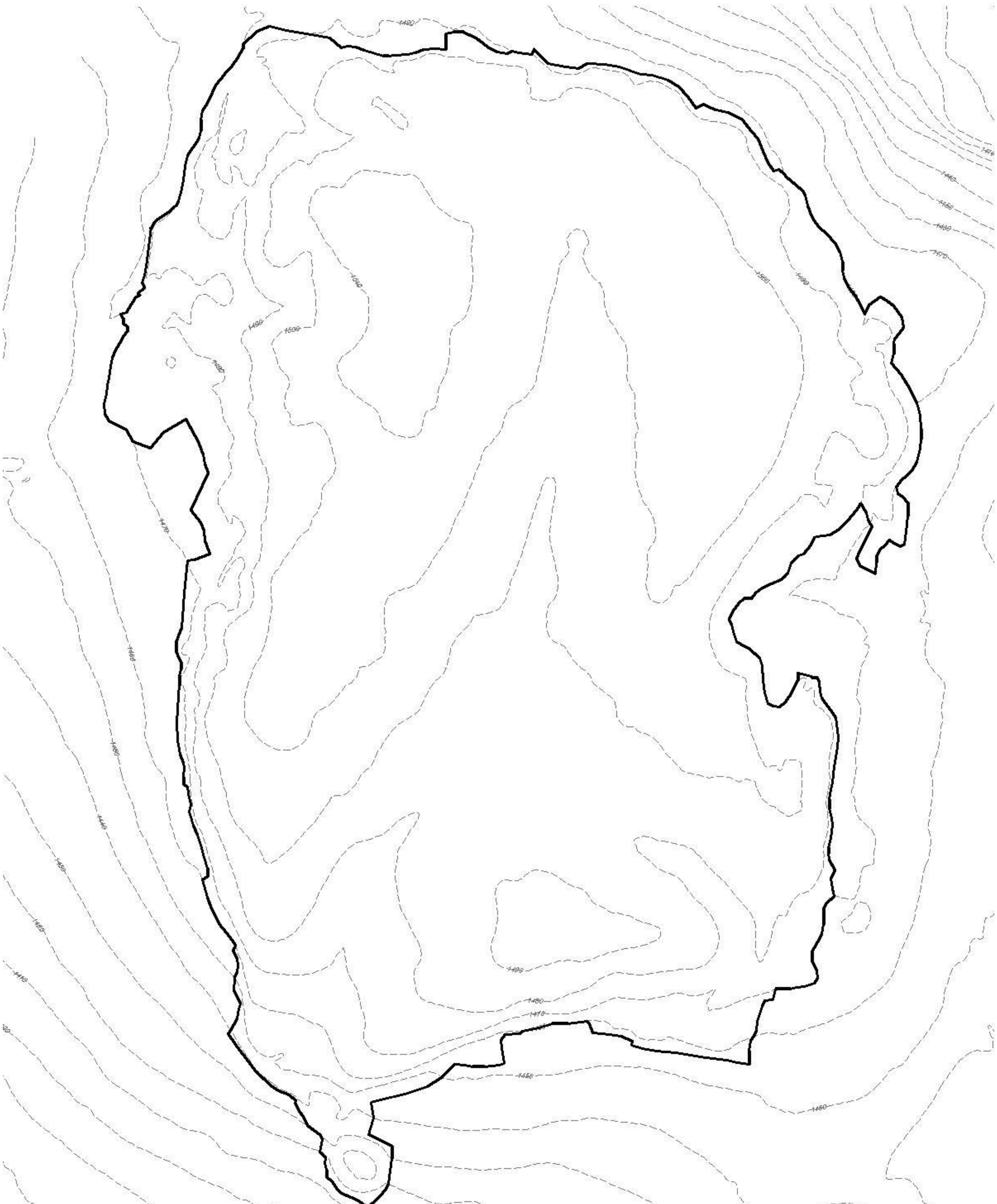

Figure 1 -Unreclaimed Surface Coal Mine

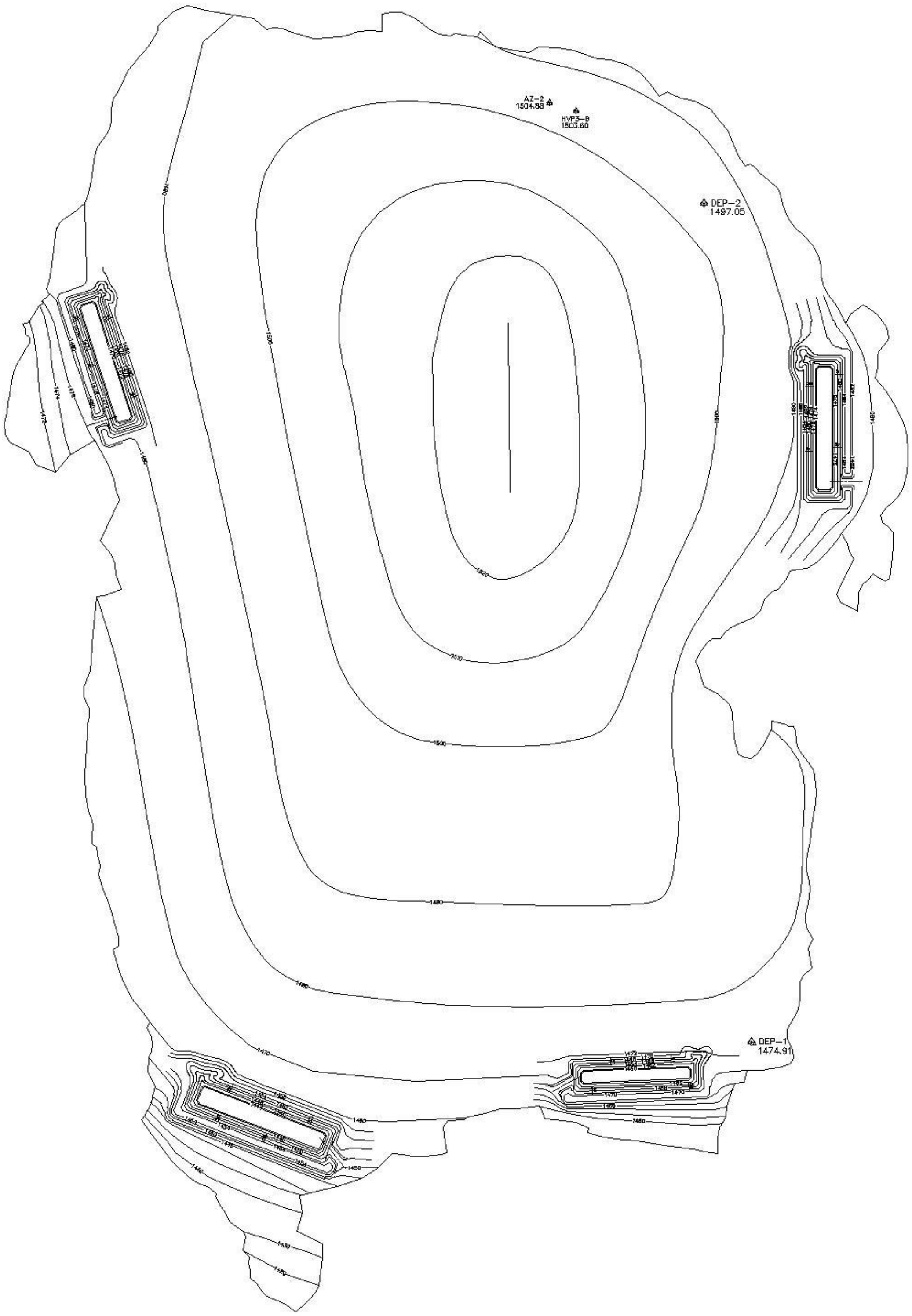

Figure 2 - Original Reclamation Plan

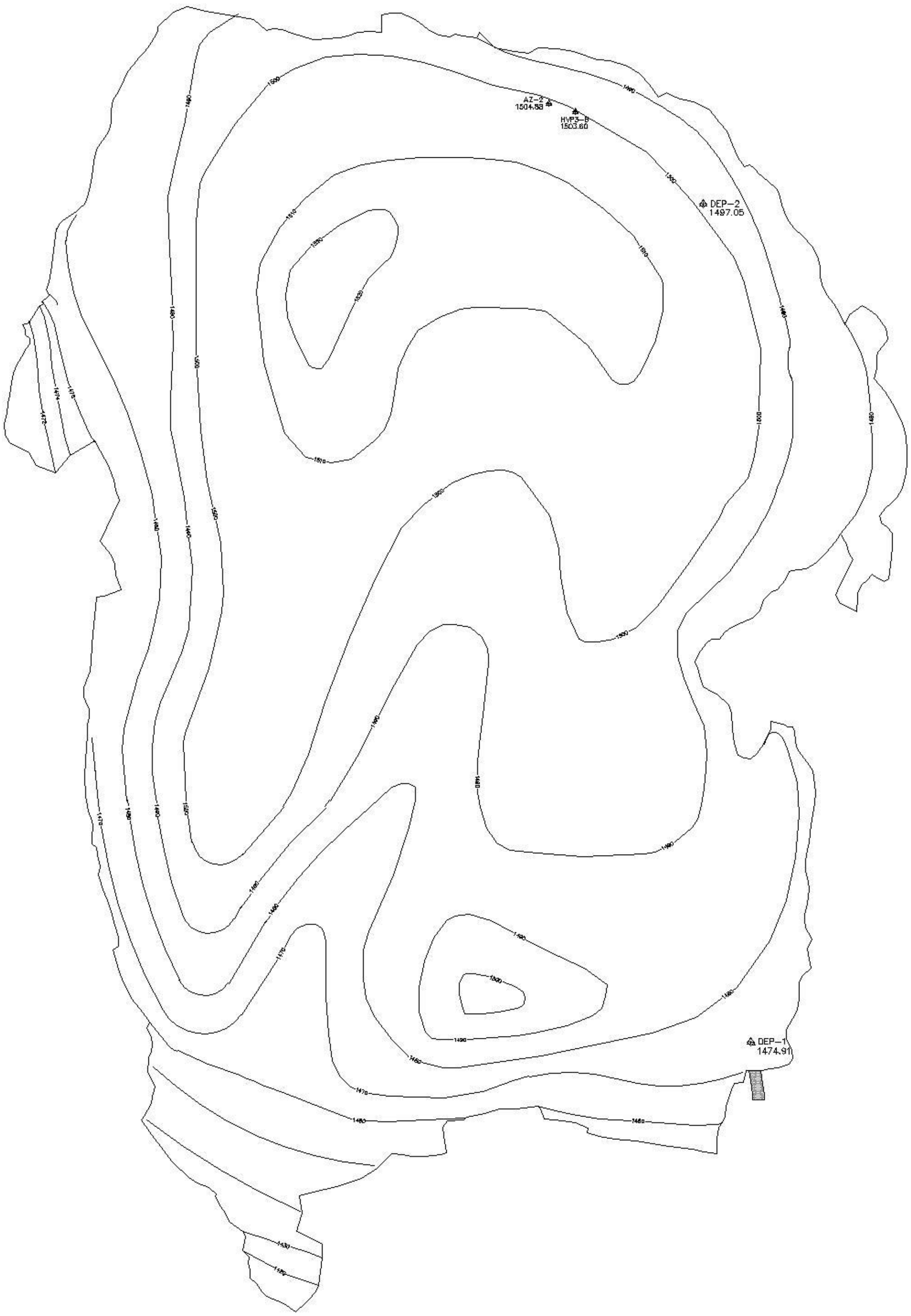

Figure 3 - Revised Reclamation Plan

The factors that increase earthmoving costs include total yardage, the requirement for double handling and/or multiple pieces of equipment and operators, horizontal distance of mass earthmoving, and elevation differences of mass earthmoving. Reclamation of current mining activities in Pennsylvania require the final contours to match the approximate original contours (AOC), which limits the amount of flexibility allowed in the reclamation plan.

If the land owner request that the land be graded for industrial, commercial, residential or public use, reclamation plans can be approved for designs other than AOC, but several conditions must be met. The following conditions are stated in PA Code 25, Section 87.175:

(1) The owner of the surface requests, in writing, that a variance be granted to render the land, after reclamation, suitable for an industrial, commercial, residential or public use, including recreational facilities.

(2) The watershed of the area is improved.

(3) The highwall is completely backfilled with spoil material, in a manner which results in static factor of safety of at least 1.3—using standard geotechnical analyses—after mining and reclamation.

(4) The proposed use, after consultation with the appropriate land use planning agencies, if any, constitutes an equal or better economic or public use.

(5) The proposed use is designed and certified by a qualified registered professional engineer in conformance with professional standards established to assure the stability, drainage and configuration necessary for the intended use of the site.

(6) Only the amount of spoil will be placed off the mine bench as is necessary to achieve the planned postmining land use, insure stability of the spoil retained on the bench and meet all other requirements of this chapter. All spoil not retained on the bench shall be placed in accordance with 25 PA Code § § 87.131, 87.141, 87.142, 87.144 and 87.145.

(7) The requirements of § 87.159 (relating to postmining land use) for alternate postmining land use are met.

(8) Land above the highwall is disturbed only to the extent that is necessary to do one of the following:

(i) Blend the solid highwall and the backfilled material.

(ii) Control surface runoff.

(iii) Provide access to the area above the highwall.

(iv) Meet the all other requirements of the regulations.

The watershed shall only be deemed improved if:

(1) There will be a reduction in the amount of total suspended solids or other pollutants discharged to ground or surface waters from the permit area as compared to the discharges prior to mining, so as to improve public or private uses or the ecology of such waters; or there will be reduced flood hazards within the watershed containing the permit area by reduction of the peak flow discharges from precipitation events or thaws.

(2) The total volume of flows from the proposed permit area, during every season of the year, will not vary in a way that adversely affects the ecology of any water or any existing or planned surface water or groundwater.

(c) If a variance is granted under this section, the permit shall be specifically conditioned as containing a variance from approximate original contour.

(d) Any permit incorporating a variance issued under this section shall be reviewed not more than 3 years from the date of issuance of the permit unless the permittee affirmatively demonstrates that the proposed development is proceeding in accordance with the terms of the variance.

In practice, there is generally not much room for reclamation plans outside of AOC for current mining activities, but there can be opportunities on abandoned sites, as evidenced by the Kettle Creek Bio-Capping project. Several options were recommended when beginning the reclamation design:

- Minimize total earthwork
- Minimize requirement for multiple pieces of equipment
- Minimize horizontal and vertical movement of material

- Incorporate multiple drainage paths to de-centralized stormwater management infrastructure and decrease total cost of stormwater Best Management Practices (BMPs).
- Consider designing drainage ditches with flatter slopes to minimize requirements of imported stone for channel protection.
- Maximize use of native vegetation to decrease maintenance costs associated with re-planting or erosion repair that results when vegetation does not succeed.

The Kettle Creek project demonstrated that it is possible to minimize earthmoving costs while still meeting project goals of slope stability and decreased infiltration of surface water to groundwater on acid mine drainage (AMD) producing mine spoil.

Lundberg Reclamation Project

In April 2009, PADEP Bureau of Mining and Reclamation (BMR) issued a request for proposals to develop a reclamation strategy for an abandoned clay mine in Snyder and Washington Townships, Jefferson County, PA. The pre-mining contours of the site were very near 2H:1V in some areas, and a large amount of product were most likely removed during the life of the mining operation, making a traditional 2.75H:1V reclamation project unfeasible without importing fill to the site. Gannett Fleming submitted a proposal to evaluate alternative stabilization methods to reduce the total project costs and provide a technically and economically feasible reclamation solution.

Gannett Fleming initially proposed to evaluate several different stabilization alternatives, including: (1) straight un-engineered backfill; (2) traditional engineered fill with tighter construction specifications; and (3) use of geosynthetics, blasting, and toe-of-slope buttressing. The first techniques investigated were un-engineered fill (2.75H:1V slope), engineered fill for various steeper slopes, and blasting.

Site mapping was obtained, and a project baseline was established. Cross sections were cut from the mapping at 50 foot intervals, and multiple slopes were translated to the sections to determine earthwork quantities for 1.5H:1V, 2H:1V, 2.5H:1V, and 2.75H:1V cross sections. Concurrently, soil samples were taken and sent to a lab for strength testing, the results of which were used in slope stability analyses for different slope configurations.

The results of the preliminary earthwork calculations showed that, as expected, a 2.75H:1V slope was not achievable without costly importation of fill. Steeper slopes were evaluated, and it was determined that a 2H:1V slope was possible with materials available in the project area. Slope stability analyses showed that the 2H:1V slope had a factor of safety of 2.25, which is significantly greater than the minimum of 1.3 accepted by BMR. Slopes steeper than that could be stable from a geotechnical engineering standpoint, but instability of vegetation cover could potentially be a factor beyond the 2H:1V slope range, causing long term maintenance problems.

Blasting was also evaluated, and it was found that blasting could be completed for approximately $1.30/CY of material to be blasted. This is higher than the unit cost for earthmoving of approximately 1.20/CY at the time of the analysis. The blasted material, however, would likely swell by roughly 30%, which would have brought the finished cost of the blasted material to $1.00/CY.

Upon learning that stable 2H:1V slopes were attainable with on-site material, BMR chose to select that configuration in lieu of other higher risk options, such as steep slopes, geo-grid reinforced slopes, and blasting. In the event that this decision had not been made or that required volumes of backfill material were not present, the costs of steeper slope embankments would have been evaluated against importation of fill and blasting to achieve the recommended alternative. Figures 4 and 5 show the un-reclaimed site and the proposed grading plan:

The analyses carried out during the project illustrate the possibility of cost savings on projects that have adequate material for 2.75H:1V slopes even though it was shown that adequate factors of safety can be reached on steeper slopes. Building upon the lessons learned on the Lundberg and Kettle Creek projects, this approach can be applied to any reclamation project and the costs savings can be significant, compared to the minor additional costs to perform the analyses.

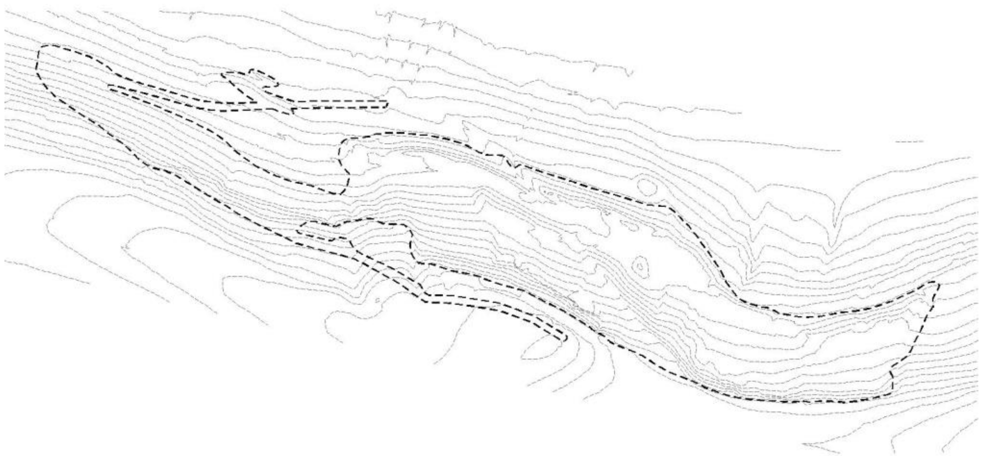

Figure 4 – Unreclaimed Surface Mine

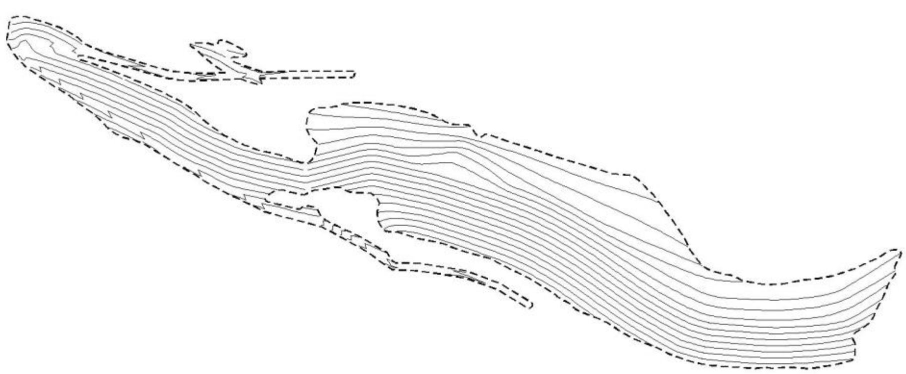

Figure 5 - Reclamation Plan

Lewis Run Reclamation Project

In April 2009, PADEP Bureau of Mining and Reclamation (BMR) issued a request for proposals to develop a reclamation strategy for an abandoned clay mine in Lewis Run Borough, McKean County, PA. The abandoned surface mine left un-reclaimed pits, spoil piles, erosion problems and a severe lack of vegetation. Due to the nature of the mining operation, there was a lack of available fill material in certain areas that prevented the implementation of a standard reclamation approach. Additional site constraints included an active railroad, fiber optic lines, and gas & oil wells and appurtenances. BMR's goals was to develop plans and specifications for the reclamation of the surface mine and adjacent pre-act abandoned surface mine area using a method of slope stabilization that minimized overall construction cost, while maintaining adequate safety factors with respect to slope stability.

Gannett Fleming proposed an approach similar to that executed on the Lundberg project, but additional site constraints complicated the analysis including: the fiber optic lines, gas and oil infrastructure, and an active rail line. In addition, the landowner expressed interest in the development of the site for industrial use because a railroad line was adjacent to the property and the property was in a Keystone Opportunity Zone (KOZ). The KOZ is a powerful incentive to industrial or commercial development through temporary tax reductions. The following Figure 6 shows the site topography and location of gas wells and the active rail line:

As done during the Lundberg project, site mapping was prepared, and cross sections were developed along project baselines. Project planning was delayed due to difficulties in obtaining the locations of oil and gas infrastructure, and is ongoing at the time of the writing of this paper.

The project site has two separate areas to be reclaimed. The northern portion of the site is closer to the rail line, and efforts are being made to grade portions of the northern area such that it can most easily be used for future development, hopefully capitalizing on the adjacent rail line and KOZ status. The southern portion is complicated by oil and gas wells, storage tanks, and underground utility lines. Efforts on the southern side will be focused on attaining adequate factors of safety in the same manner as was done on the Lundberg project.

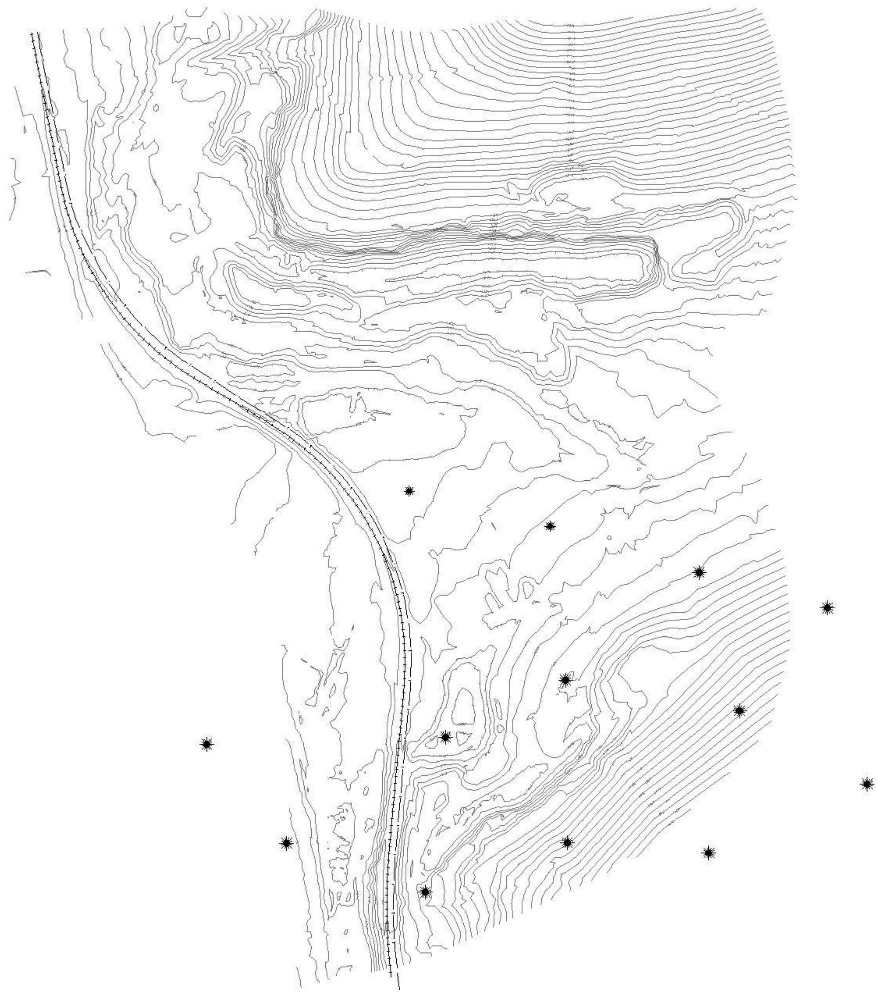

Figure 6 - Lewis Run Project

Conditions on the northern side illustrate opportunities for synergies between mine reclamation and economic development. There are many un-reclaimed mine areas in the United States that can be utilized for future industrial, residential, or commercial development. Re-use of this land eliminates the need to destroy additional green space, while abating the environmental and public safety hazards that currently exist. Had the property on the Lewis Run project been owned by an economic development agency, public dollars for site development could have been leveraged with bond forfeiture dollars to dramatically increase the potential for economic development in the region.

GIS tools are available to identify abandoned mine lands and track reclamation progress. One such tool, RAMLIS, was developed by the Eastern Pennsylvania Coalition for Abandoned

Mine Reclamation (EPCAMR). Future modifications of these types of GIS tools could include options to identify mine lands that are near features conducive to economic development, such as population centers, interstate highways, airports, public utilities, railroads, and rivers. Municipalities, local economic development agencies, and even private developers could use these tools to show that an abandoned mine reclamation project in their region could offer potential economic benefits that a competing project with similar environmental and public safety benefits does not offer. Knowing that the expected increase in abandoned mine reclamation funding, while substantial, is not sufficient to complete all projects on the inventory, makes this type of prioritization essential.

Discussions/Conclusions

As illustrated in the discussions of these three case studies above, there are opportunities to substantially decrease construction costs for reclamation projects by using a more efficient, goals based design approach than the traditional unengineered grading approach that has been used in the past. The design approach should consider alternative backfill techniques on a case by case basis to ensure that the least cost alternatives are selected to achieve reclamation goals. As an example of the magnitude of cost savings that can potentially be realized, we consider the backfill volume difference between a reclamation project with a standard 2.75:1 slope and 70-foot highwall as compared to a 2:1 slope with the same height of highwall. The backfill volumes are 250 CY per lineal foot and 181 CY per lineal foot for a 2.75:1 and 2:1 slope, respectively. For a 2000 lineal foot long project, this amounts to a 140,000 cubic yard savings in material. At $1.00 / CY, which is a realistic unit cost for earthmoving at the time of the writing of this paper, this equates to a $140,000 savings on the project, while still meeting the restoration goals, assuming they are centered around abatement of the safety hazard of the highwall, and establishment of permanent vegetative cover for long term erosion control.

In most cases, steeper slopes such as 2:1 or 1.5:1 can be achieved with acceptable factors of safety with respect to slope stability, providing surface and subsurface water is controlled. Surface water control is generally required to minimize surface erosion, and subsurface drainage is necessary to prevent slope stability problems that arise from a buildup of pore water pressure within the constructed embankment. Increases in pore water pressure dramatically reduce the shear strength of soil, resulting in a reduction in slope stability safety factors. Care should also be taken to place fill material in horizontal lifts to prevent potential slip planes, and fill should be compacted with earthmoving equipment to the extent practical to minimize settlement. Settlement is typically not a problem for most mine reclamation projects unless the reclaimed areas are intended for construction of buildings or structures.

Additionally, efforts should be made to capitalize on synergies between funding sources to maximize the total benefit that is realized when mine reclamation projects consider economic development along with abatement of public safety and environmental hazards. Most State and Federal economic funding programs require some form of matching funds. Mine reclamation funding can serve as this match, and effectively double the dollars available for economic development projects. Two examples of federal funding agencies for land development are the Economic Development Administration (EDA) and the Appalachian Regional Commission (ARC).

EDA's Public Works and Economic Development Facilities Program is intended to provide Public Works investments to support the construction or rehabilitation of essential public infrastructure and facilities necessary to generate or retain private sector jobs and investments, attract private sector capital, and promote regional competitiveness, innovation, and entrepreneurship, including investments that expand and upgrade infrastructure to attract new industry, support technology-led development, accelerate new business development, and enhance the ability of regions to capitalize on opportunities presented by free trade. Eligible applicants include Indian Tribes or consortium of Indian Tribes, State, City, or other political subdivision, institution of higher education, and public or private non-profit organization or association acting in cooperation with officials of a political subdivision of a state. This program requires a match of funds that can be provided by the reclamation dollars spent at the state level for Priority 1 and 2 sites. Earthmoving can be completed with reclamation dollars, and infrastructure can be built with EDA funding, resulting in the creation of shovel ready commercial, retail, or industrial sites in areas currently occupied by un-reclaimed surface mines. The key to the success of this type of approach is a high degree of local commitment and strong partnerships with economic development partners.

Examples of projects eligible for ARC grants include industrial site development, business incubators, special technical assistance and training, and expansion of domestic and foreign markets. Like the EDA programs, this grant is also a matching fund program, which can leverage reclamation dollars to secure funding for infrastructure development.

Using a combination of the technical and fiscal strategies described above, we can maximize the mitigation of public safety, environmental, and economic development issues that have arisen out of past mining practices in our region, and build upon the lessons learned to promote successful partnerships for future reclamation efforts.