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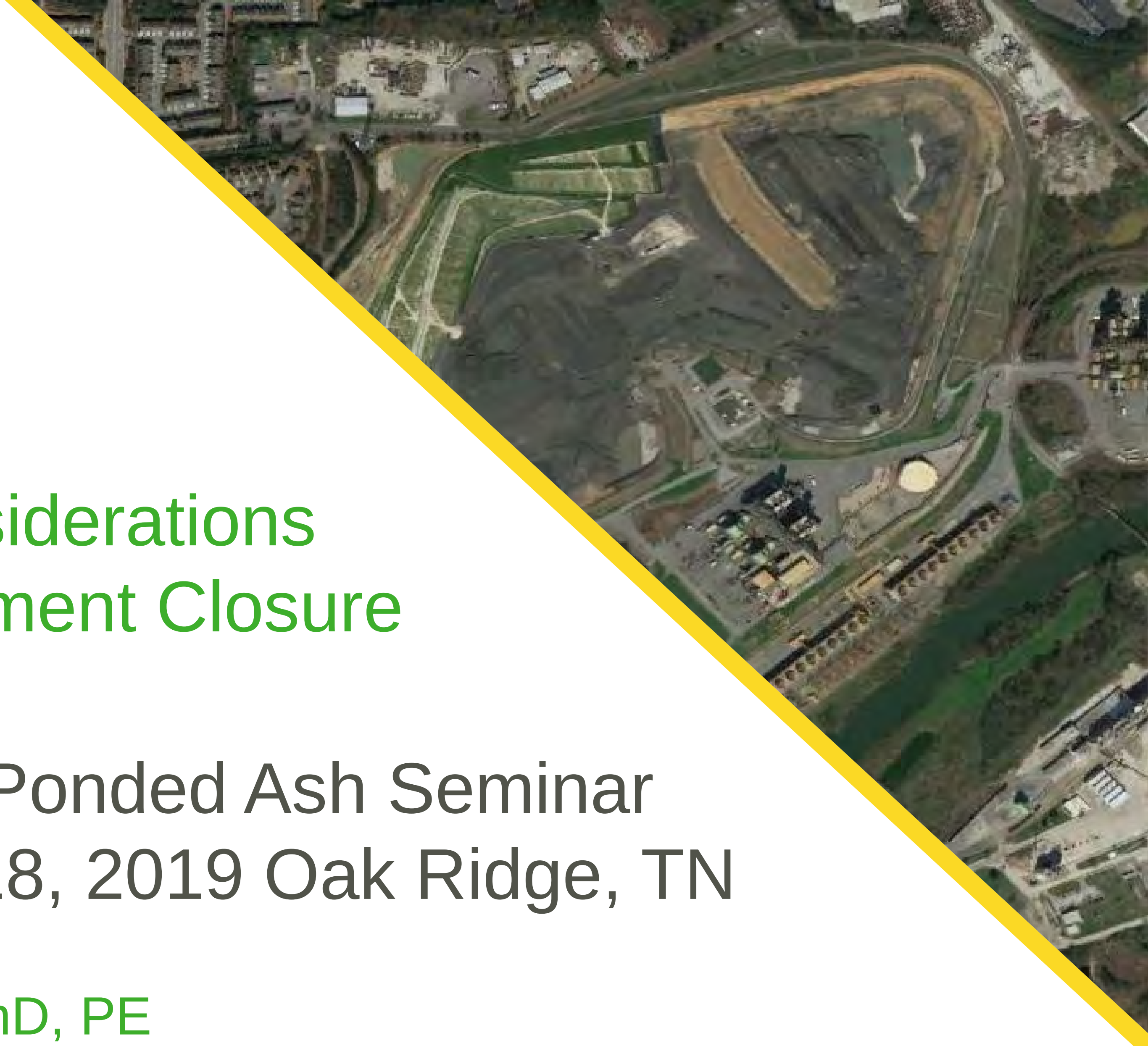

# Design Considerations for Impoundment Closure

## WPCA/TVA Ponded Ash Seminar
## September 18, 2019 Oak Ridge, TN

Greg Hebeler, PhD, PE
Ghebeler@golder.com, 770-492-8252 (Direct)

# AGENDA

**Safety Share**

**Technical Considerations for Closure of CCR Units**

**Importance of Water Management in CCR Projects – Case Studies**

**Hybrid Closure Project Examples**

**Beneficial Use Characterization and Planning**

**Options Assessment & Decision Making Tools**

**Q&A**

# Safety Share

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# Safety Share

## GOLDER SAFETY SHARE – CCR POND ACCESS SAFETY

- Golder Safety Share – CCR Pond Access Safety

Golder takes pride in sharing our approaches and experience in dealing with the unique challenges and safety risks working in and over ash. Our professionals have prepared multiple publications focused on CCR safety aspects.

**CCR Pond Construction Access Evaluation, Monitoring, and Proofing Methods**

World of Coal Ash 2017
May 11, 2017

Gregory Hebeler, PhD, PE
Grant Martin, EIT

**Stability Evaluation and Monitoring During Staged Construction of Fly Ash Closure Projects**

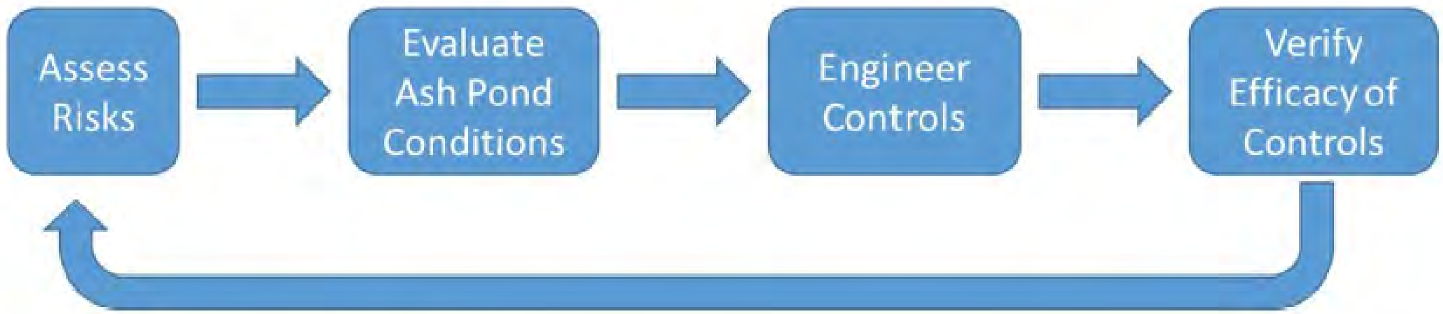
ACAA – World of Coal Ash 2017
10 May, 2017

Gregory Hebeler, PhD, PE
Chris Hardin, PE
Tony Simmonds

UNC CHARLOTTE
Energy Production and Infrastructure Center (EPIC)

# Safety Share

## FRAMEWORK FOR MITIGATION OF RISKS





**CCR Pond Construction Access Evaluation, Monitoring, and Proofing Methods**

World of Coal Ash 2017 - May 11, 2017

Gregory Hebeler, PhD, PE; Grant Martin, EIT

# Technical Considerations for Closure of CCR Units

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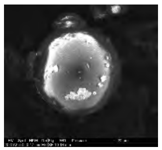
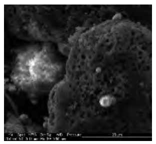
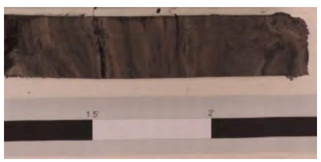
# Technical Considerations for CCR Closures

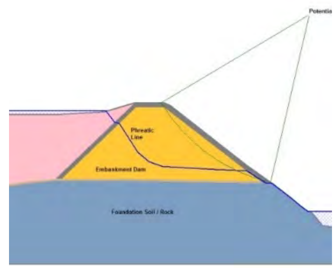
## Material Characterization





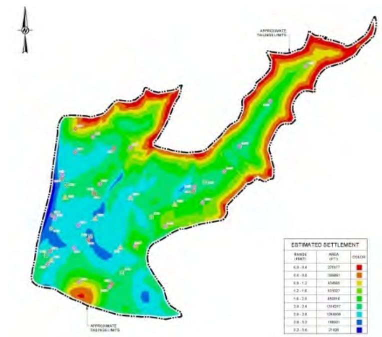


## Stability Evaluations

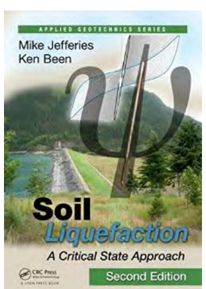



## Stormwater Management

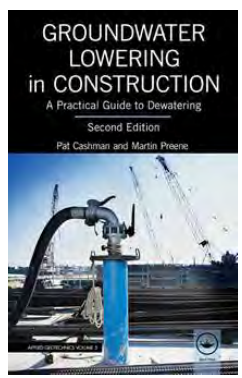
## Settlement & Capping



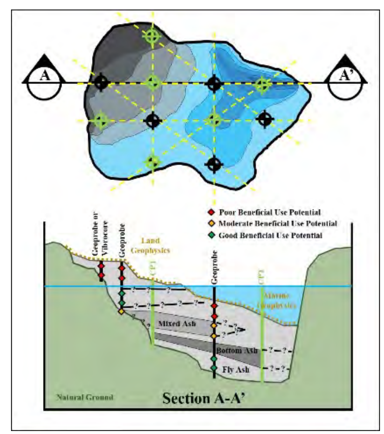

## Liquefaction Potential



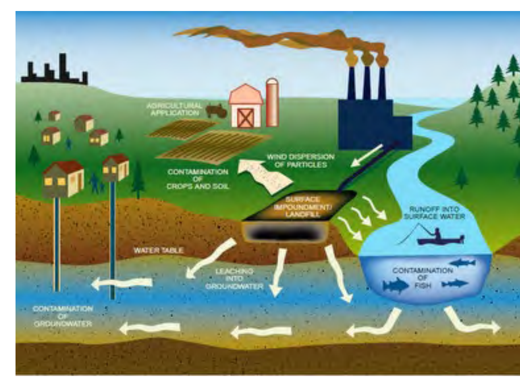

## DeWatering




## Future Harvesting




## Env Protection



# Closure Option Criteria

- Ash Management
  - None
  - Off-Site
  - On-Site
  - Consolidation
  - Total Volume Handled
  - Capacity Flexibility
- Post Closure Site Restoration
  - Stream Restoration & Credits
  - Stormwater Attenuation
- Environmental Factors
  - Long Term GW Levels
  - Buffers to Sensitive Areas
  - GW Quality
  - Risk Factors – Karst, etc.
- Water Management
  - Area of Final Cap
  - Surface water During Construction
  - Surface water Post-Construction
  - Ash Dewatering
  - Treatment & Discharge
- Proven Technology & Constructability / Phasing
- Closure Schedule Duration & Confidence
- Cost
  - CAPEX | OPEX | Long Term Maintenance
- Future Land Use
- Risks
  - Geotechnical | Flood | Environmental
- Acceptance
  - Community | Regulatory

# Design Drivers for CCR Closures

**Water Levels and Control** are **Keys to Design and Performance** of these Systems

**Sluiced and Uncompacted Materials** can show significant strength when dried but **retain risk of return to low strengths and liquefaction / flow susceptibility** if saturated and containment is lost

Obtain **Enough Data** to Evaluate **PFMs,** Potential Critical **Interim Conditions, Future Harvesting** Potential, **Geochemical** Evaluations, etc.

**Economic & Risk Trade offs** Between: Material and Placement Controls & Engineering and Monitoring Controls.

**Public and Regulatory Acceptance and Pressures**

# Engineering Improved Performance in CCR Closures

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# Engineering Improved Performance into CCR Closures

## POTENTIAL ACTIONS

- **Know Your Sites** – Evaluate Data Across Disciplines, Continue to Gather Data During Closures, and Plan Closures with a Holistic Strategy
- **Prioritize Beneficial Use**, Especially in Handled % of CCR Materials
- **Look at Hybrid Closures** – All closures typically require some % of CCR Handling to Achieve Drainage, etc. → Prioritize Removals in Critical / Sensitive Areas
- **Add Passive Engineering Controls** that Achieve Improved GW Levels and Engineering Performance Post-Closure
- **Continually Evaluate Technology, Innovations, and Cross Industry Applications** throughout lifespan of Closure Process
- **Water Management** During and Post Closure is often a Key Driver to Short, Mid and Long Term Performance and Costs.
- **Manage Dust**, Off site **Traffic Loadings**, On-Site **Safety** and **other Risks**

# Engineering Keys During Closure

**Ash Pond Conditions Are Complex and Unique for Each Site**

**Engineering Controls & Hold Points Critical –** Conditions and Ash strengths can change rapidly, recommend engineering guidelines during construction and caution with use of observation method

**CCR Closures are Often Atypical** –More Complex Engineering (Unique design and construction issues wrt deep excavations in and long-term stability of cut slopes in previously ponded ash.)

**Water Management & Dewatering Systems** – Water Levels Often Key to Stability, Surface Water Controls Key to Successful Dewatering, Well Designs Can Typically be Aggressive

**Monitoring & Verification of Design Assumptions During Construction** – Water Level Tracking, Assessment of Material Behavior Changes with Dewatering, Loading (Stacking) and Unloading (Excavations) – CPT a quick and effective tool for both

# Importance of Water Management in CCR Projects – Case Studies

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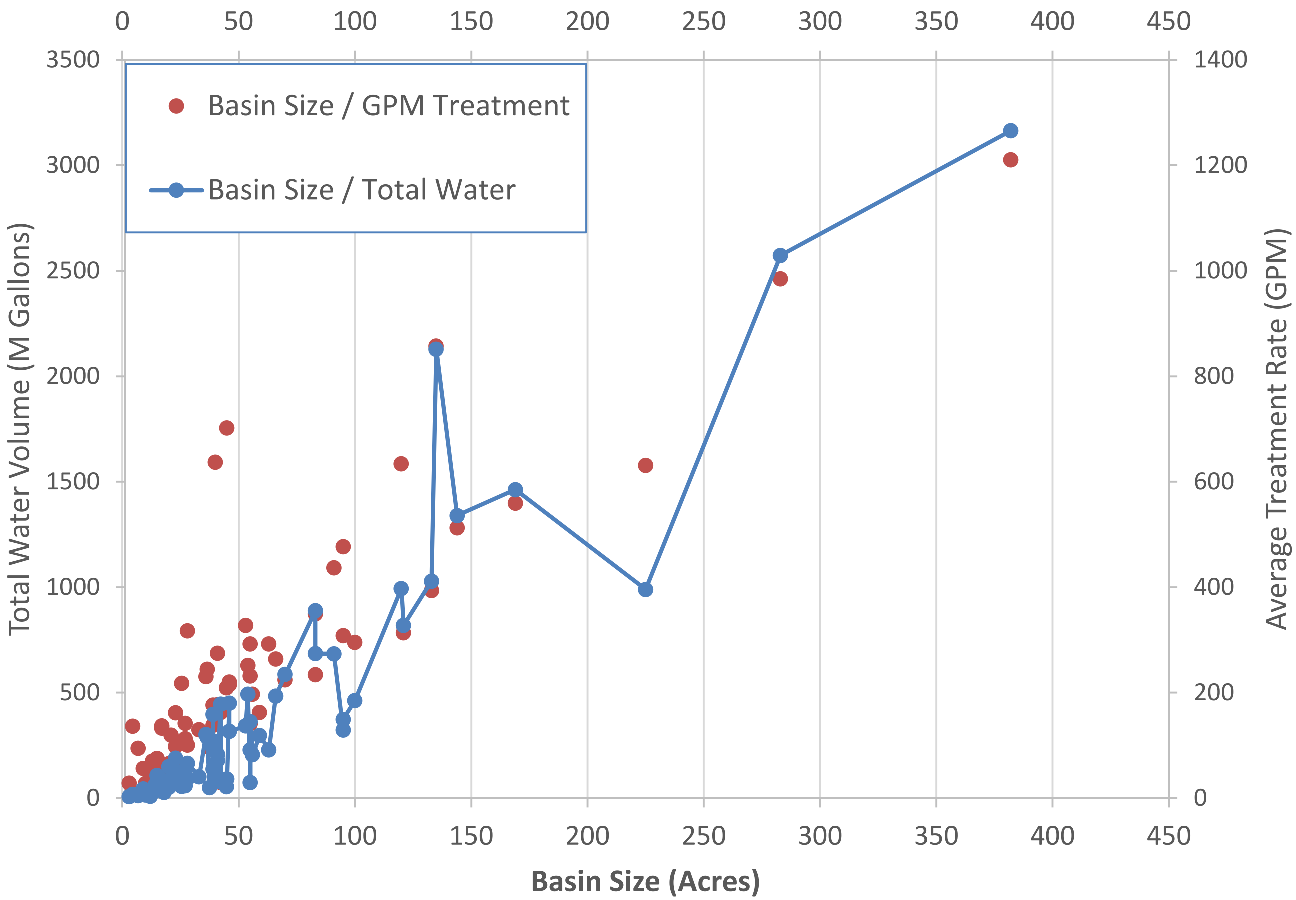
# Volume of Water for Management &Treatment

## Finite Sources:

- Pore Water
- Free Water

## Variable Source - Storm Water

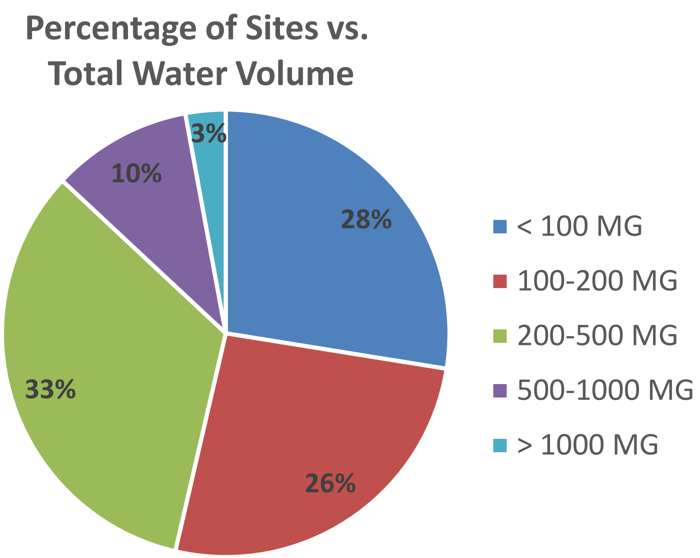
- Diversion Water
- Contact Water
- Closure Timeframe
- Weather dependent

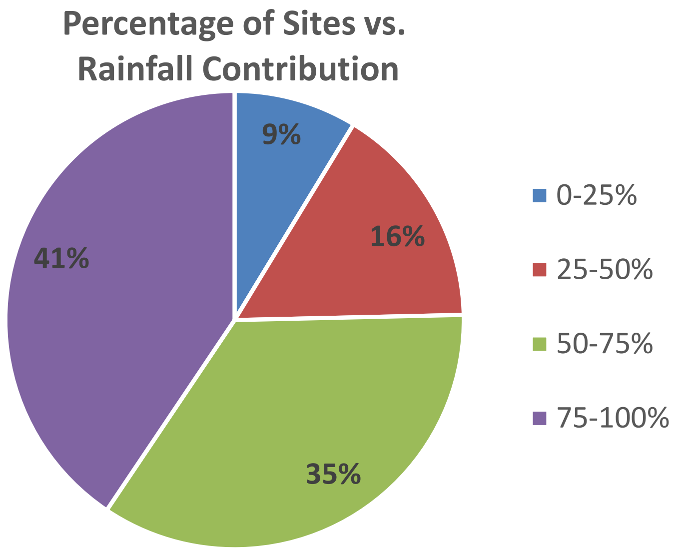



Data Source: Confidential Project Experience with Golder CCR Clients, includes more than 50 CCR basins across US.

# Volume of Water for Management & Treatment

- 54% of sites have less than 200 MG total water
- 13% of sites have more than 500 MG total water




**> 50% Rainfall Contribution at 76% of sites**

- Diversion Water – Conveyance/TSS
- Contact Water – Site Specific Storage/Treatment Requirements

Data Source: Confidential Project Experience with Golder CCR Clients, includes more than 50 CCR basins across US.

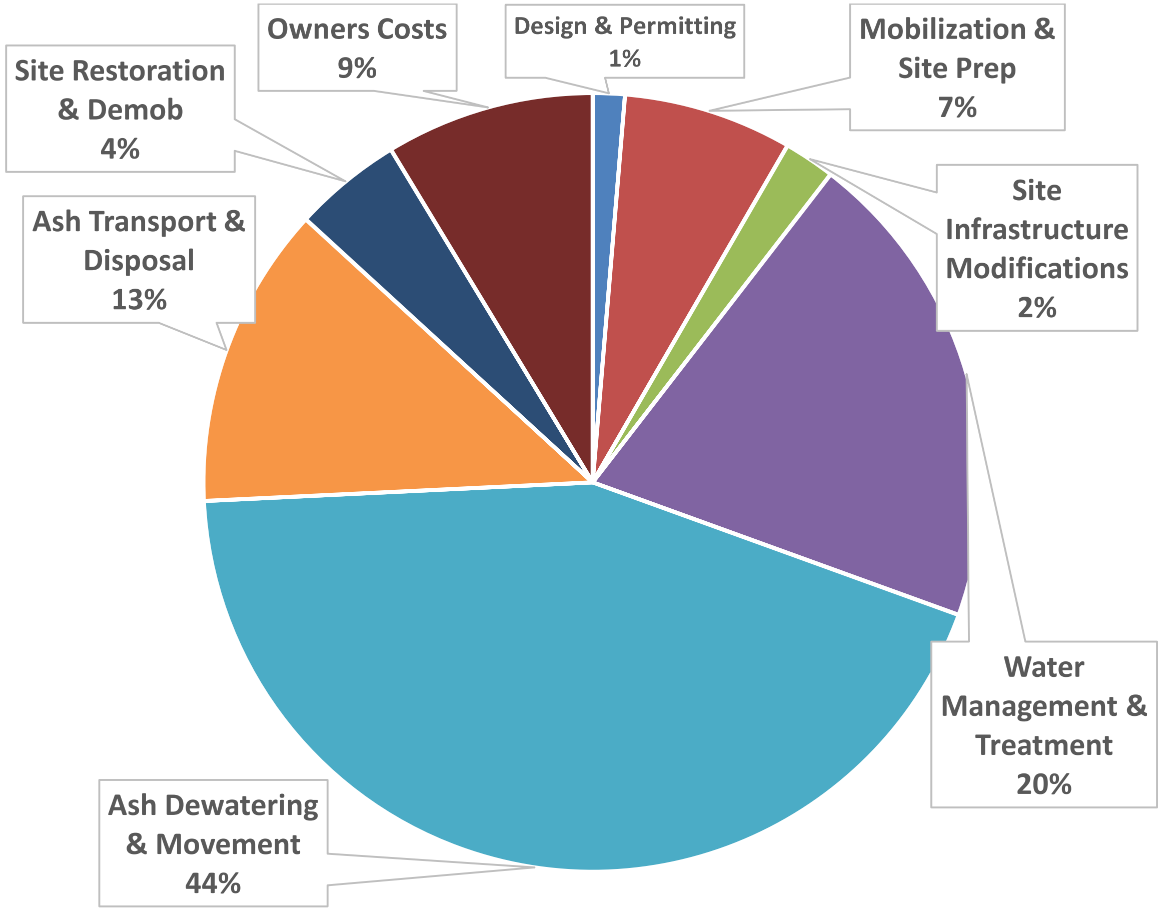
# Relative Basin Closure Cost Impact

## Closure Scenarios

- Clean Close
- Cap In Place
- Combination

## Water Management & Treatment ~ 20%

- Water Storage
- Water Movement
- Water Treatment




Data Source: Confidential Project Experience with Golder CCR Clients, includes closure scenarios for more than 50 CCR basins across US.

# Water Management Case Study

# Use of Temporary Covers – Case Study

**PROJECT BACKGROUND**

North Ash Pond (NAP)

East Ash Pond

Owner : Virginia Electric Power d/b/a Dominion Energy Virginia

Engineer : Golder Associates (Richmond, VA)

Original Scope of Work:

- East Ash Pond - Clean Closure
- North Ash Pond (NAP) - Interim and Final Capping

Motivation: Federal CCR Rule Compliance

CHESAPEAKE CONTAINMENT SYSTEMS, INC.

# Use of Temporary Covers – Case Study

**CHALLENGE**

## Senate Bill 807

Virginia DEQ suspended the issuance of any permit to Virginia Electric Power Company d/b/a Dominion Energy Virginia for any CCR surface impoundment closure within the Chesapeake Bay Watershed.

Consequently… Closure-in-place activities were suspended.

# Use of Temporary Covers – Case Study

CRITICAL SUCCESS FACTORS

Eliminate contact water volume generation.

Prevent increase in pore water phreatic surface elevation.

# Use of Temporary Covers – Case Study

**DESIGN CONSIDERATIONS**

CHESAPEAKE CONTAINMENT SYSTEMS, INC.

- ~68-acres
- Long drainage lengths
- Large volume of storm water
- Installation Phasing
- Wind uplift
- Snow loading
- UV degradation
- Ballast materials damaging underlying rain cover

# Use of Temporary Covers – Case Study

**TEMPORARY COVER**

## Same Closure Benefits as Final Closure

- Eliminate Contact Water
- Reduce Pore Water Generation
- Erosion & Dust Control
- UV Protection
- Improve Stormwater Run-off Water Quality
- Low Maintenance
- Cost-effective

CHESAPEAKE CONTAINMENT SYSTEMS, INC.

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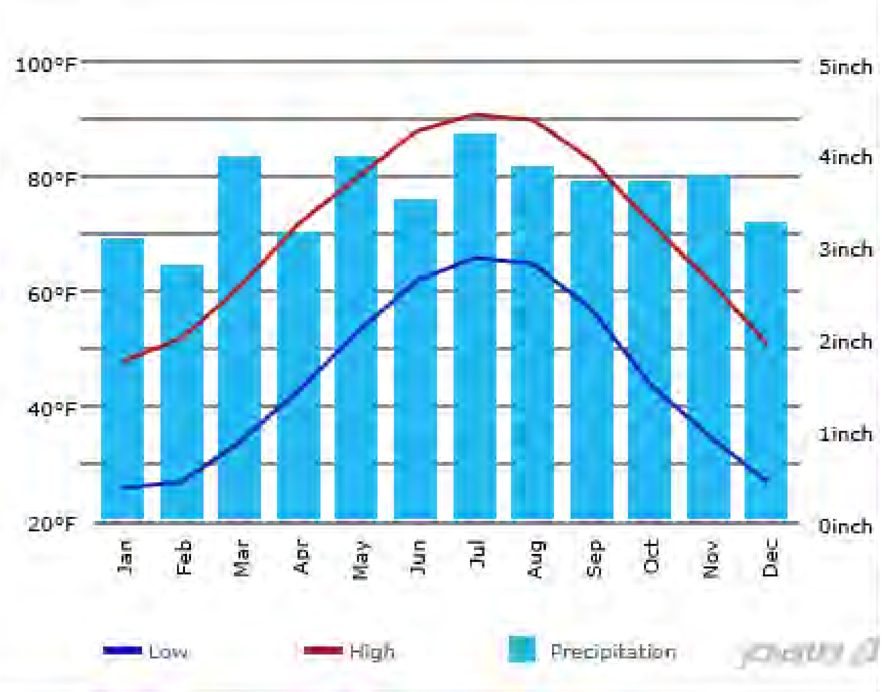
# Use of Temporary Covers – Case Study

TEMPORARY COVERS

- Avg. Annual Rainfall Volume - ~79.3M gal
  - Area - ~68-acres (Lined Area) x 43,560 SF/acre
  - Avg. Annual Rainfall – (43-in/yr)/12-in/ft) = 3.58-ft/yr*
- Average Disposal Cost = $0.10/gallon**
- Annual Estimated Treatment Cost – ~$7.9M/yr. **
  - Avg. Annual Rainfall - ~79.3M gal
  - Avg. Disposal Cost - $0.10/gal**
- Temp Cover System Supply & Install= ~$1.5M**
- Contact water & pore water from the NAP is ~35% of the total water treated by the site.




* Per U.S. Climate data

** Theoretical value for comparison purpose only.

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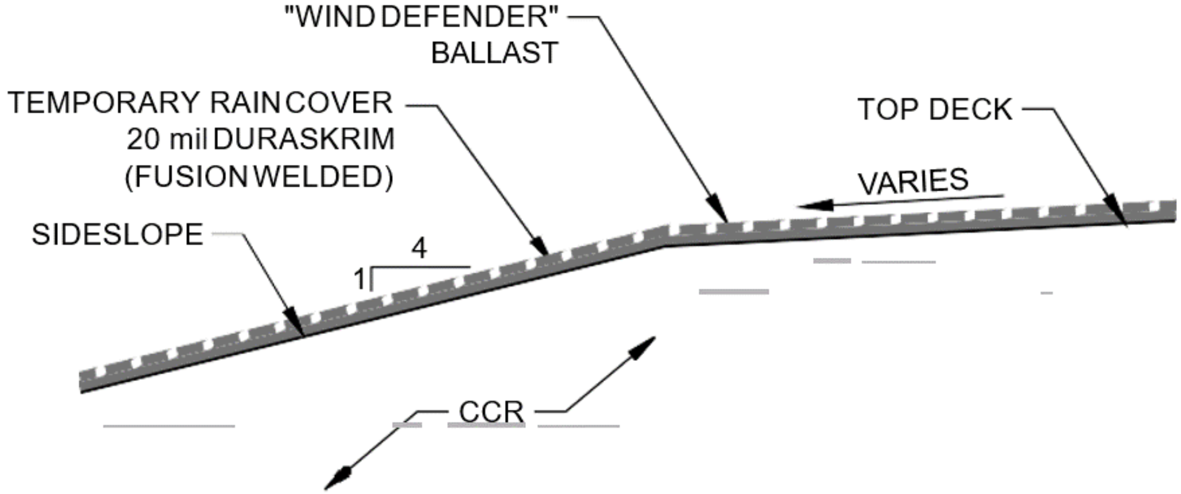
# Use of Temporary Covers – Case Study

SOLUTION

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**RAIN COVER DETAIL**

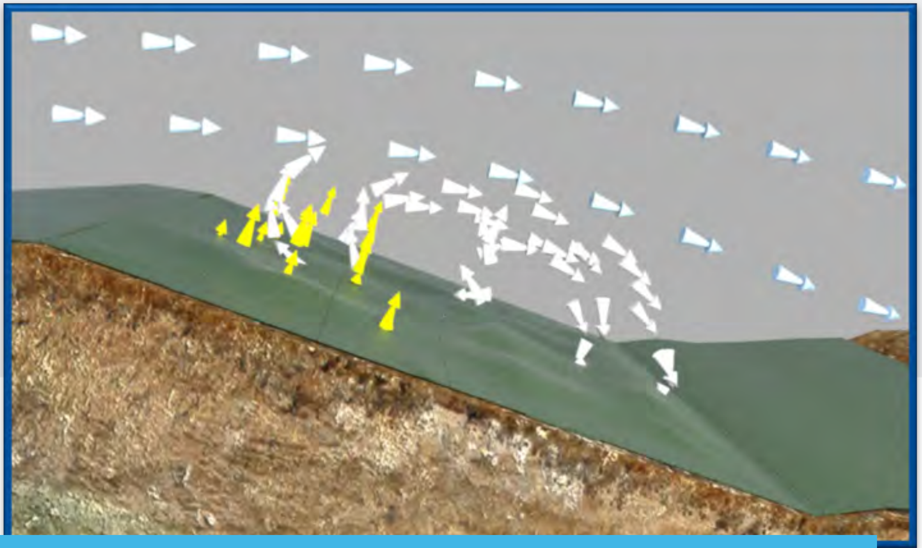
NOT TO SCALE

# Use of Temporary Covers – Wind Defender

**WIND LOADING**

Cross Winds

Wind Uplift or Negative Pressure



**The key performance property of a ballast system is to withstand the wind uplift force through a downward force used to pin or hold down the geomembrane. Wind Defender utilizes aerodynamics to diffuse and cancel out the forces causing wind uplift.**

# Hybrid Closure Examples

# Closure Option Criteria

- Ash Management
  - None
  - Off-Site
  - On-Site
  - Consolidation
  - Total Volume Handled
  - Capacity Flexibility
- Post Closure Site Restoration
  - Stream Restoration & Credits
  - Stormwater Attenuation
- Environmental Factors
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  - Buffers to Sensitive Areas
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- Risks
  - Geotechnical | Flood | Environmental
- Acceptance
  - Community | Regulatory

# Hybrid Closure Scenarios

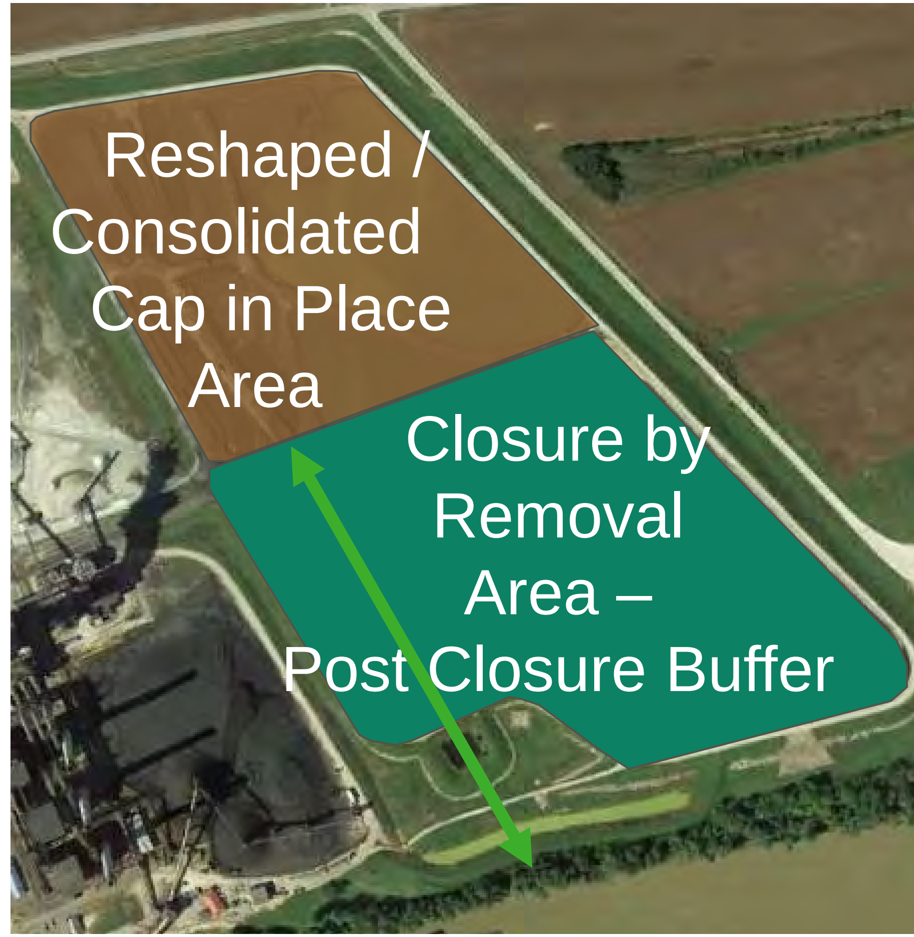
**Combination** of **Impounded** (sluiced) & **Stacked** (dry) CCR

Why Important / Considered

- Can Significantly **Reduce Footprint** for Closure of Existing Impoundments
- Can **Increase Buffer** with Adjacent Sensitive Areas (Rivers / Lakes / Wetlands / Population Centers, etc.)
- Exist to some extent in almost all in-place impoundment closures to provide caps with positive drainage.
- Concepts can be applicable to “dry” Landfills / Stacks if waste becomes saturated.
- Engineering and Construction of Hybrid Closures is **Typically More Complicated**

# Hybrid Closure – Consolidated Close on Site


Option 1




Option 2

# A Few Hybrid Closure Examples

# Closure Plan

Green Contour Areas – Closure by Removal

Purple Contour Areas – Close in Place with ClosureTurf Cover

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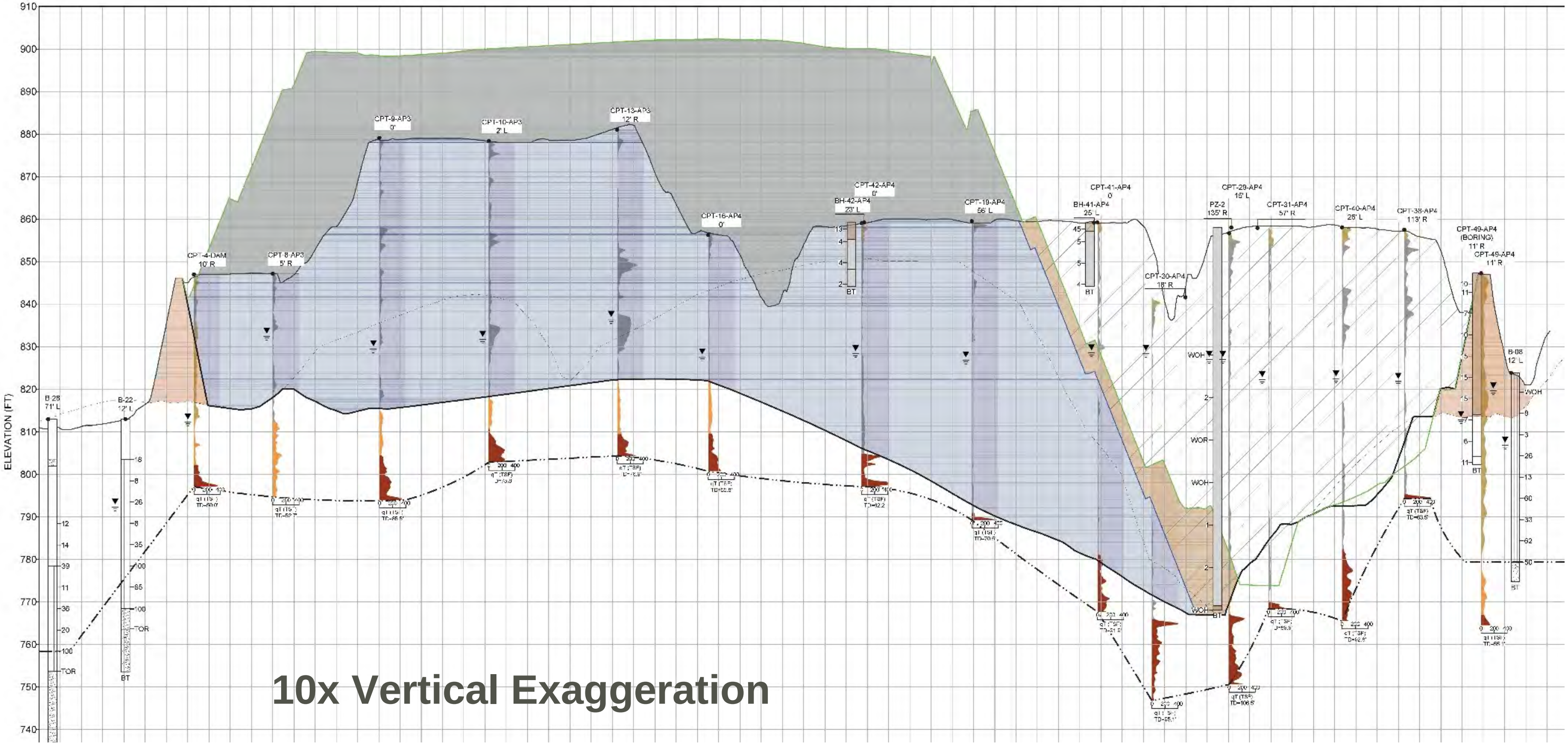
# CCR Closure Example – Hybrid Closure

Site Conditions Control Design Decision - Slope Stability, Dewatering & Water Management, Control Design & Construction – Integrate active dewatering and monitoring during and after construction with a Soil Buttress & Underdrain



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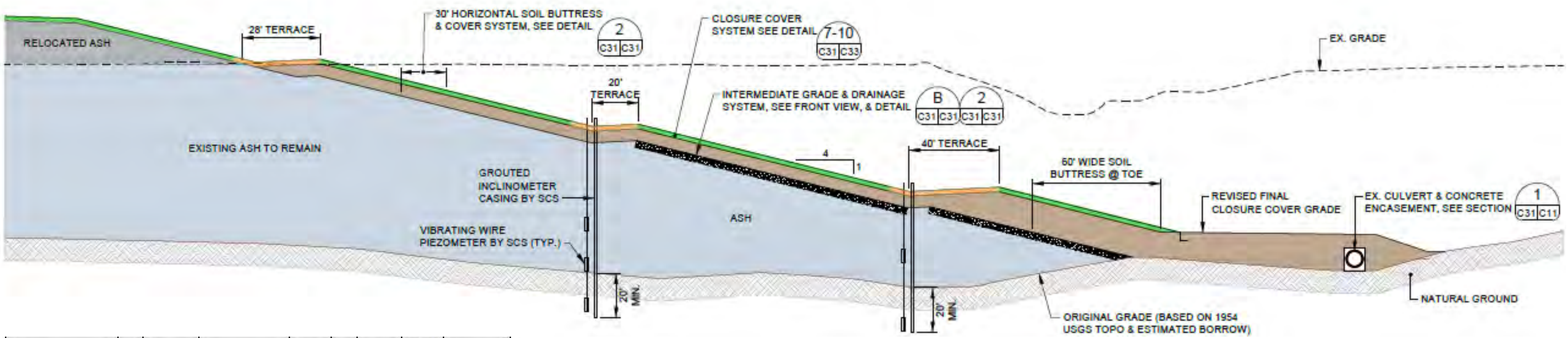
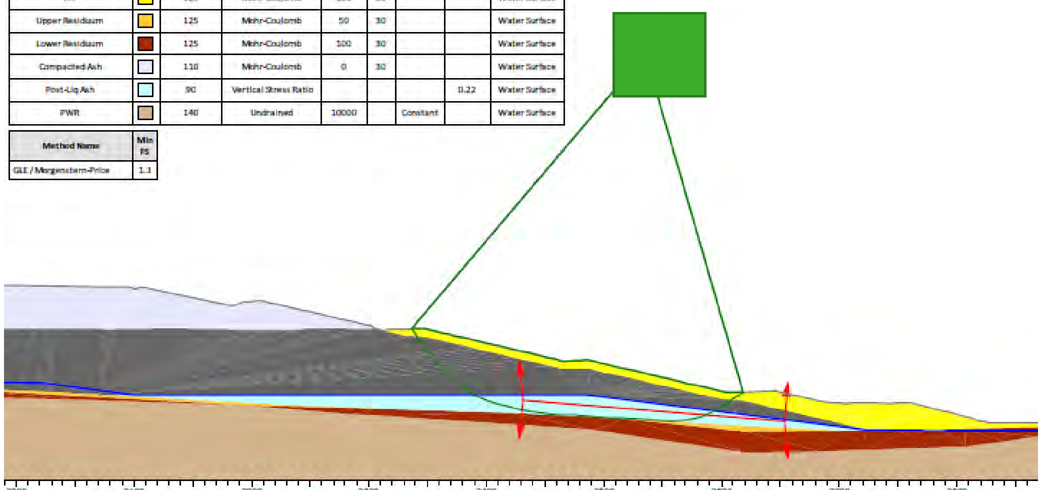
# CCR Closure Example – Hybrid Closure – Slope Stability Drivers w/ Deep Cut Slopes




| Material Name | Color | Unit Weight (lbs/ft3) | Strength Type | Cohesion (psf) | Phi (deg) | Cohesion Type | Vertical Strength Ratio | Water Surface |
|---|---|---|---|---|---|---|---|---|
| Stacked / Compacted CCR | | 110 | Mohr-Coulomb | 0 | 30 | | | Water Surface |
| Saturated Sluiced Ash | | 90 | Mohr-Coulomb | 0 | 24 | | | Water Surface |
| Fill | | 125 | Mohr-Coulomb | 100 | 30 | | | Water Surface |
| Upper Residuum | | 125 | Mohr-Coulomb | 50 | 30 | | | Water Surface |
| Lower Residuum | | 125 | Mohr-Coulomb | 100 | 30 | | | Water Surface |
| Compacted Ash | | 110 | Mohr-Coulomb | 0 | 30 | | | Water Surface |
| Post-Liq Ash | | 90 | Vertical Stress Ratio | | | | 0.22 | Water Surface |
| PWR | | 140 | Undrained | 10000 | | Constant | | Water Surface |

| Method Name | Min FS |
|---|---|
| GLE / Morgenstern-Price | 1.3 |




<u>Dewatering & Slope Stability Control Design</u> – Integrate active dewatering and monitoring during and after construction with a Soil Buttress & Underdrain



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# Stability and Site Controls

Stability of an ash basin during construction is dependent on a variety of factors:

- Presence or absence of water – surface or decant water, and interstitial or porewater.
- Surcharge load of the material -- type of material and thickness.
- Capillary action of the porewater in work areas
- The geometry and slope angle of the cut or fill slope and the staging methods for construction.
- The undrained shear strength of the coal ash.
- Changing conditions in subsurface drainage and improved conditions from dewatering.
- Vibrations and/or the repetitive motion of construction equipment and field personnel
- Variation in material properties and interaction of dissimilar materials such as fly ash, bottom ash, FGD gypsum/fly ash mixtures.
- Unique or challenging construction activities that cause changes that are unforeseen or unexpected.
- Liquid level and percent saturation of the ash materials.
- Climatic factors – precipitation and run-off.

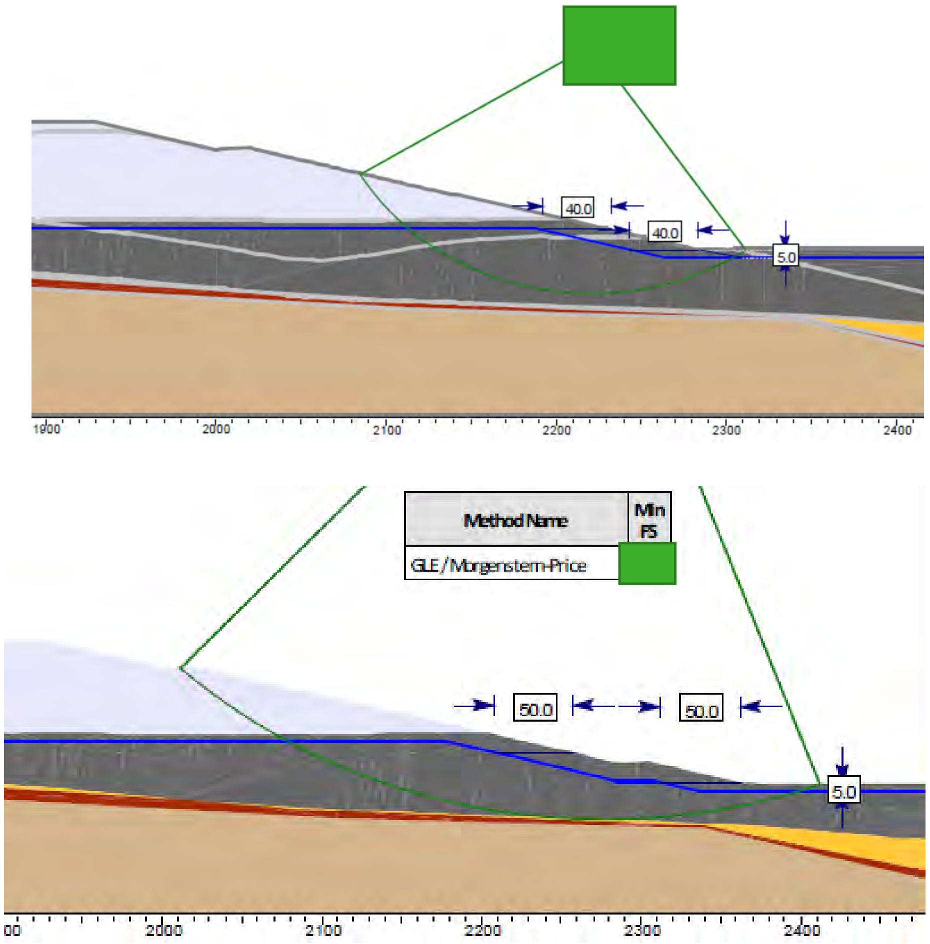
# Stability & Access During Closure Excavations

**Evaluate Stability Over Course of Construction Excavation Stages**

**Automated Instrumentation and Monitoring Put Under Contractor Control with Weekly Update Meetings.**

**Set Intermediate Check Points**:

- Dewatering Performance Criteria set for each bench excavated
- Piezometer and Inclinometer Instrumentation
- Incremental CPT During Construction to Evaluate Pre-Construction Assumptions & Strength Gains from Dewatering

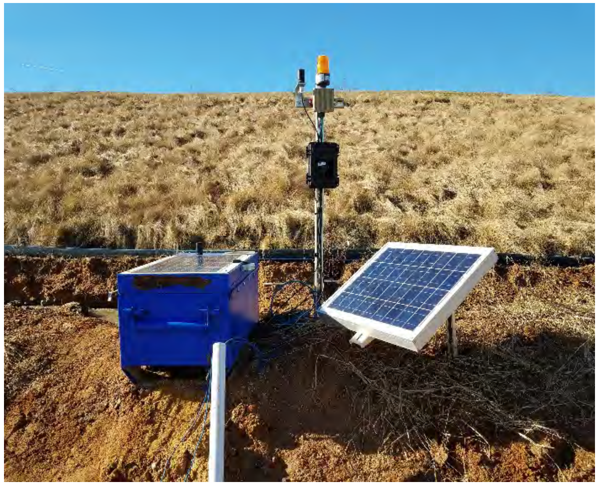


# Verification of Site Controls

Trust, but Verify is an essential principle and practice for safe construction and geotechnical characterization of ponded ash materials.

Field experience indicates that changing conditions on ash basins can change quickly and unexpectedly.

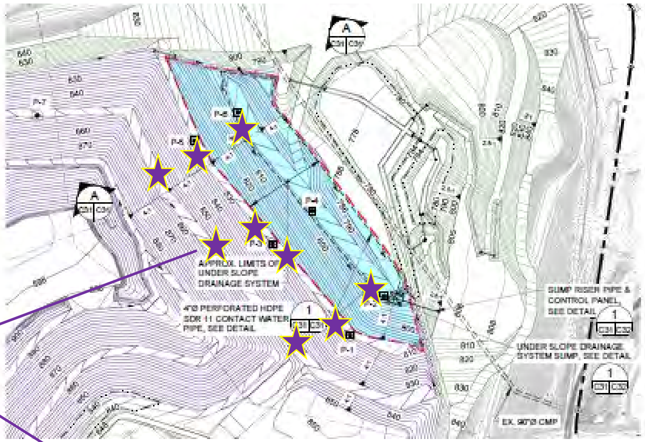
Most challenging ash basin sites are including "real time" monitoring and verification of porewater pressure as an essential part of the stability and safety monitoring program.

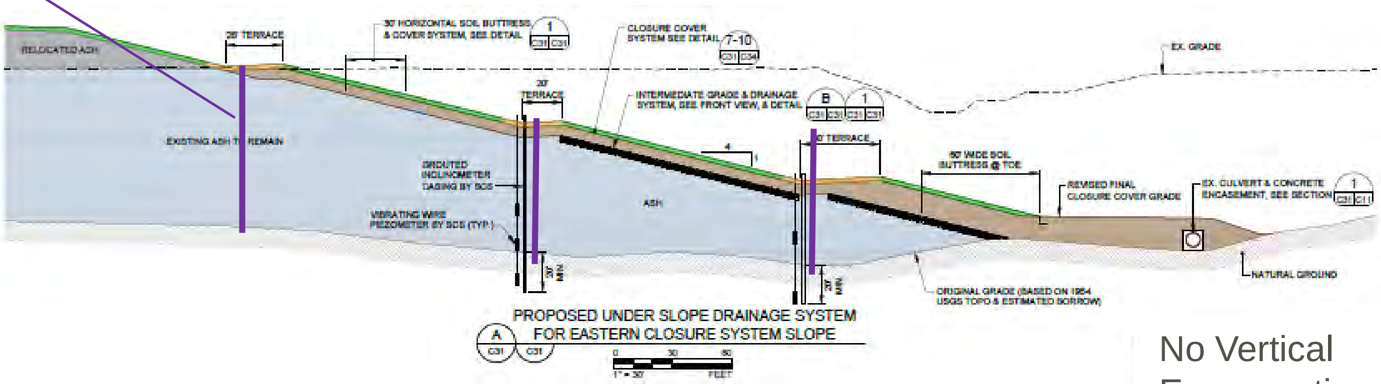


**Solar Powered "Real-time" Porewater Pressure Monitoring**

# Incremental Investigations for Verification

★ CPT Sounding Locations






No Vertical Exaggeration



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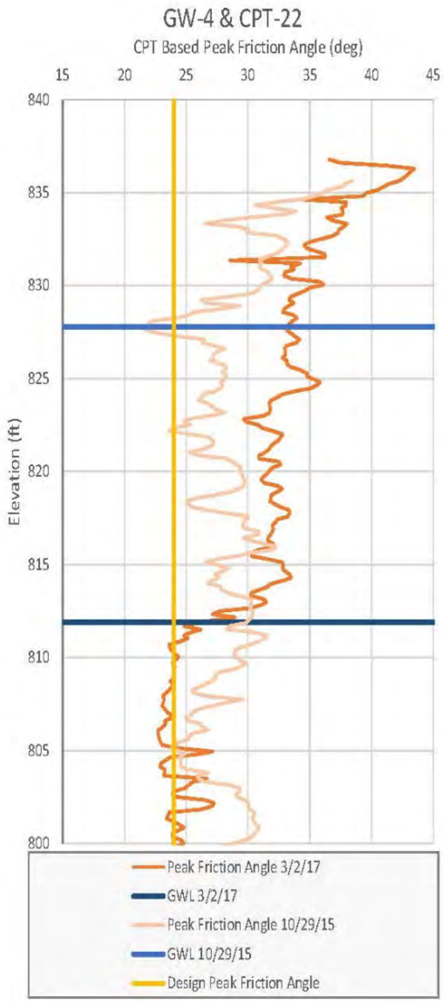
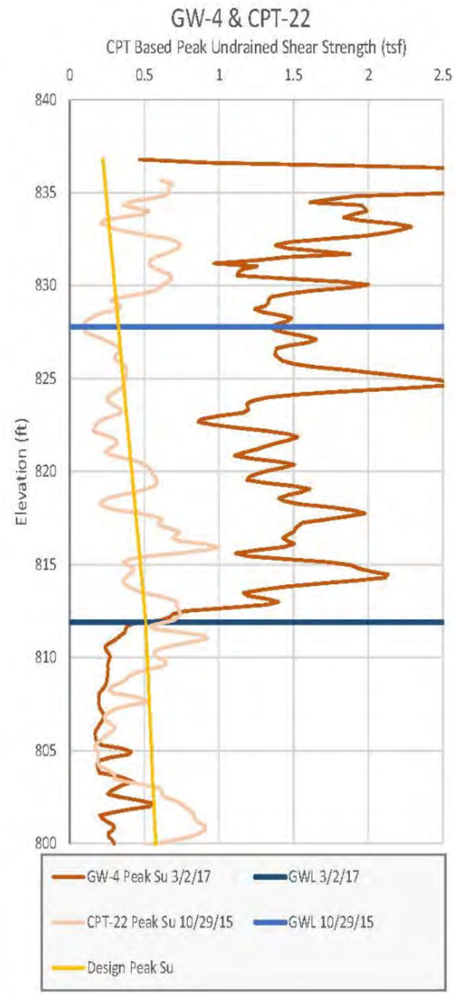
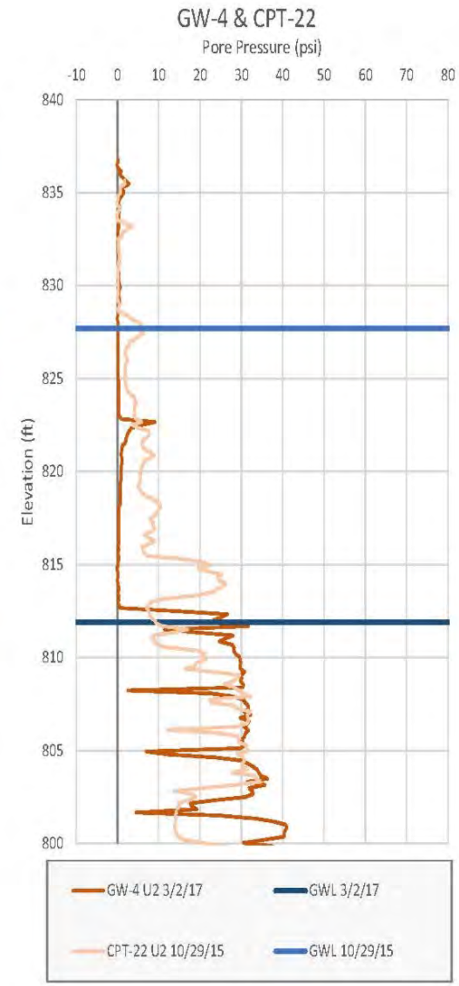
# Incremental Investigations w/ CPT

## Location #1 -

See very distinct changes in CPT pore pressure response and correspondent large increases in correlated friction angle and undrained shear strength over the dewatered zone.



# Importance of Incremental Reviews and Verification of Initial Assumptions

An incremental, performance-based approach to geotechnical characterization of ash basins recognizes that subsurface conditions on ***most CCR impoundments are unpredictable and changing*** during the construction process.  The methods described in this paper and presentation:

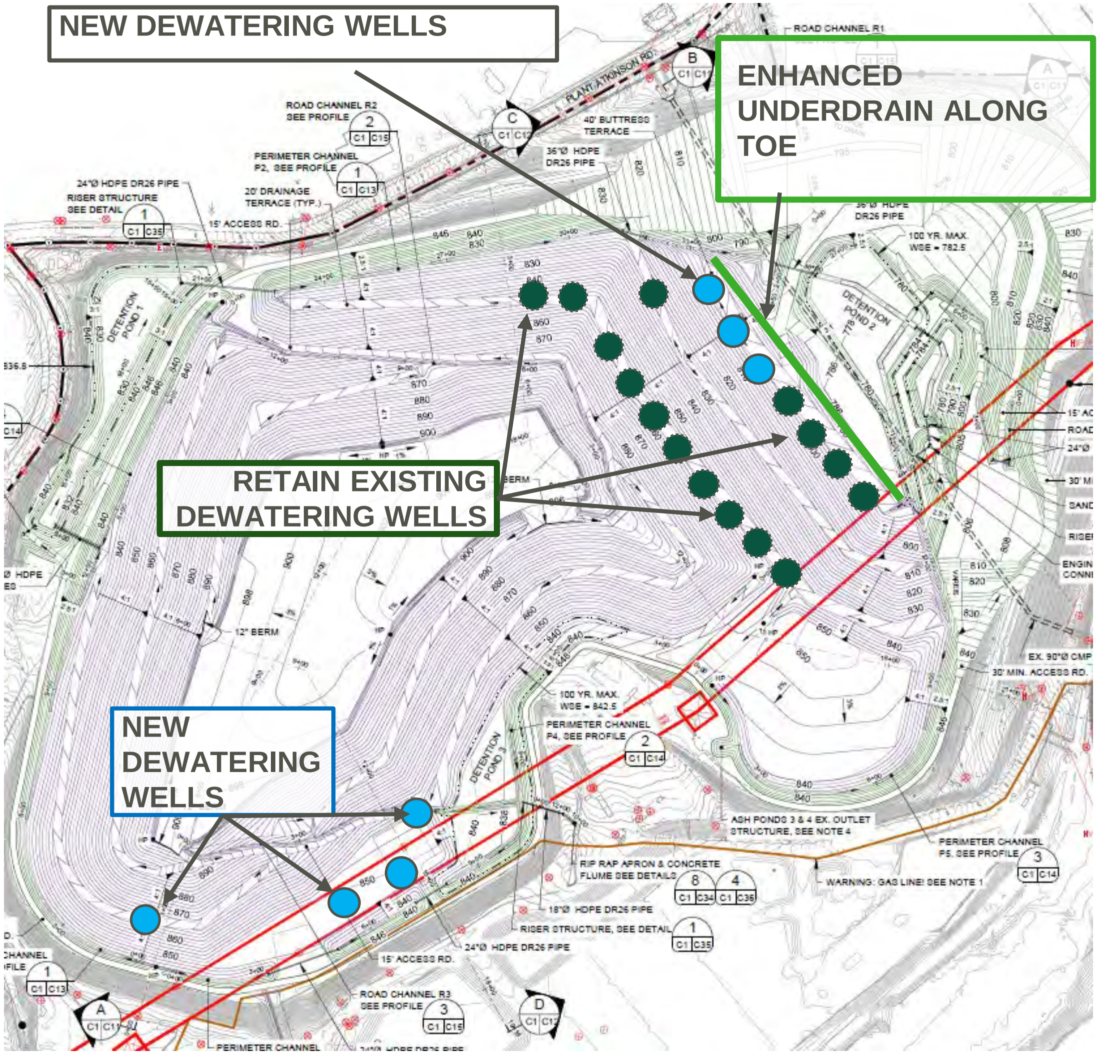
- Offers a practical approach and methods for “change management” in the project contract to identify and quantity the cost of additional dewatering and/or stabilization.
- Identifies potential problem areas early in the project, and allows the CCR closure design to be adjusted to account for unexpected or changing conditions.
- Reducing the risk of contractors assessing areas with an unstable crust by “trial and error” by offering a systematic method for identify unstable conditions before they impact the closure construction process.

# Long Term Post Closure Considerations

Enhanced Underdrain Along Toe of Slope

Continued Use of Existing Construction Dewatering Wells to Accelerate Reaching Long Term Steady State Drying of Ash

Additional Dewatering Wells to Further Accelerate Drying of Ash



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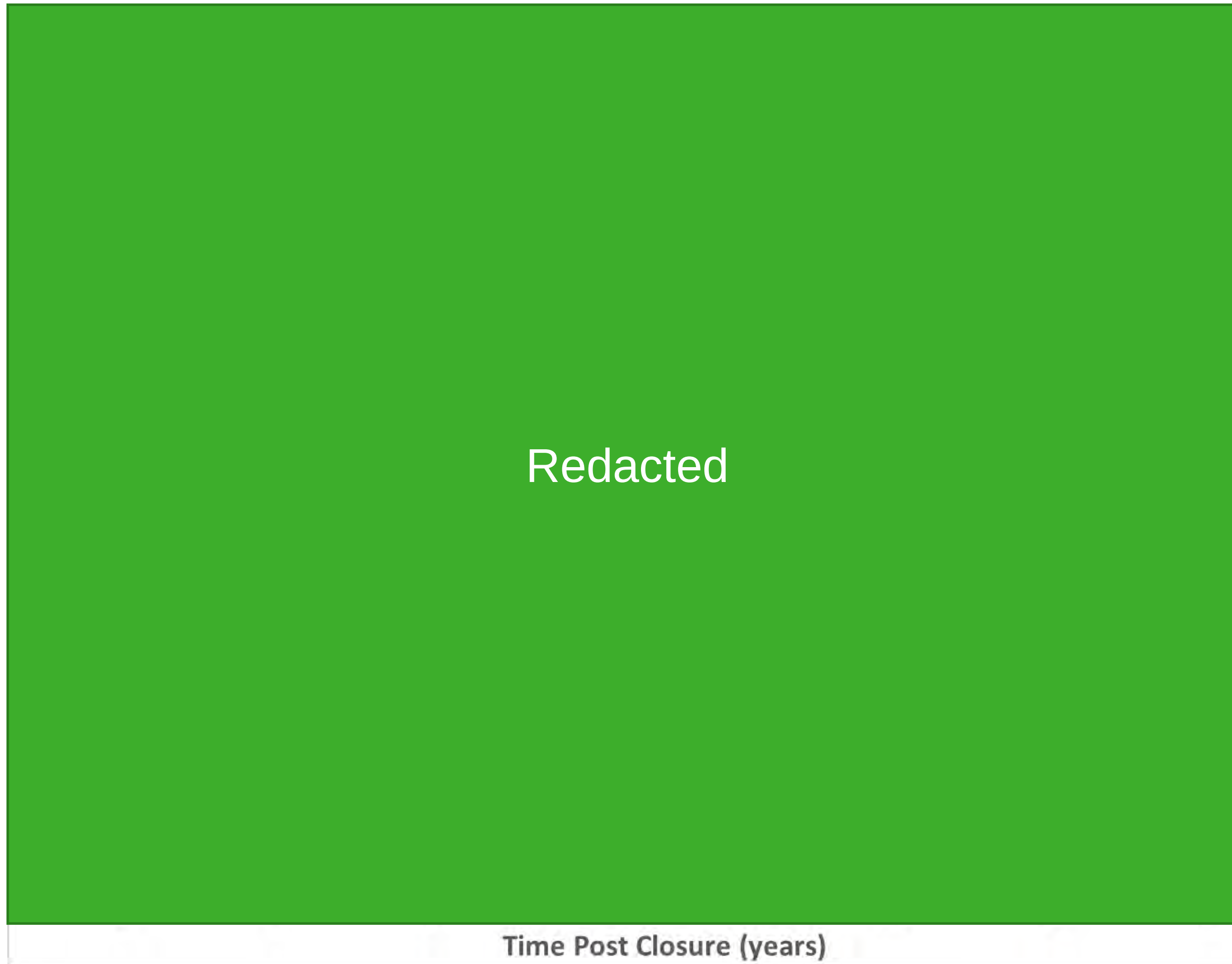
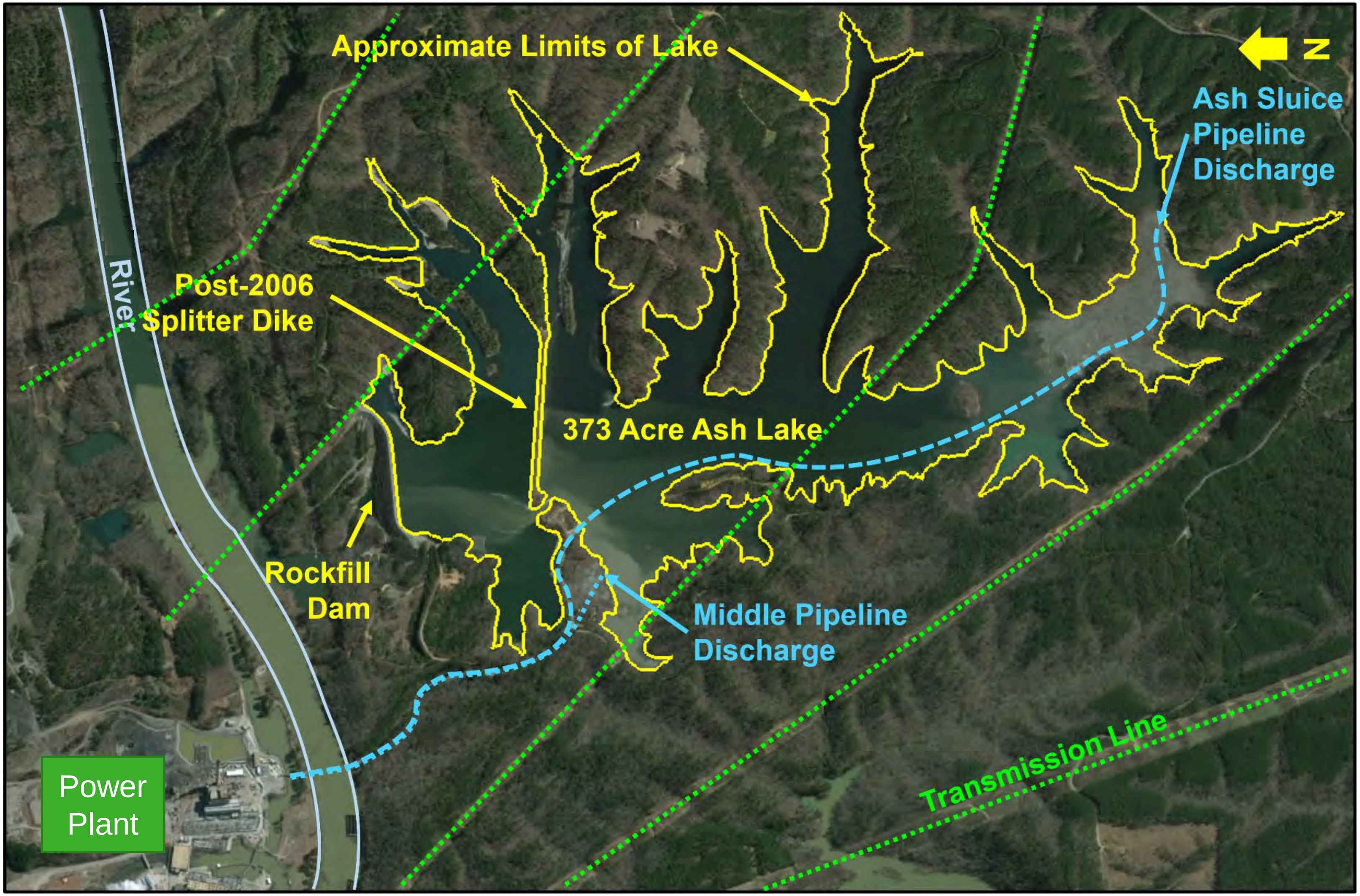
# Enhanced Underdrain & Accelerated Dewatering to Accelerate Achievement of Long Term Goals

Selected AEM = Enhanced Underdrain + Dewatering System 2B

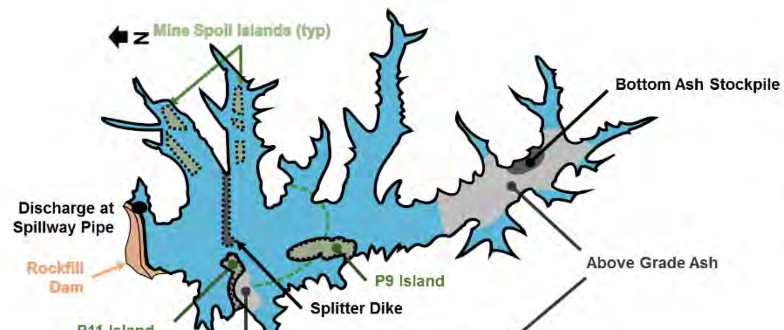
Decreases Time to Dry Ash from ~ 36 Years w/ enhanced Underdrain Alone to < 10 years



# Example Project Site



# Example Hybrid Closure Site

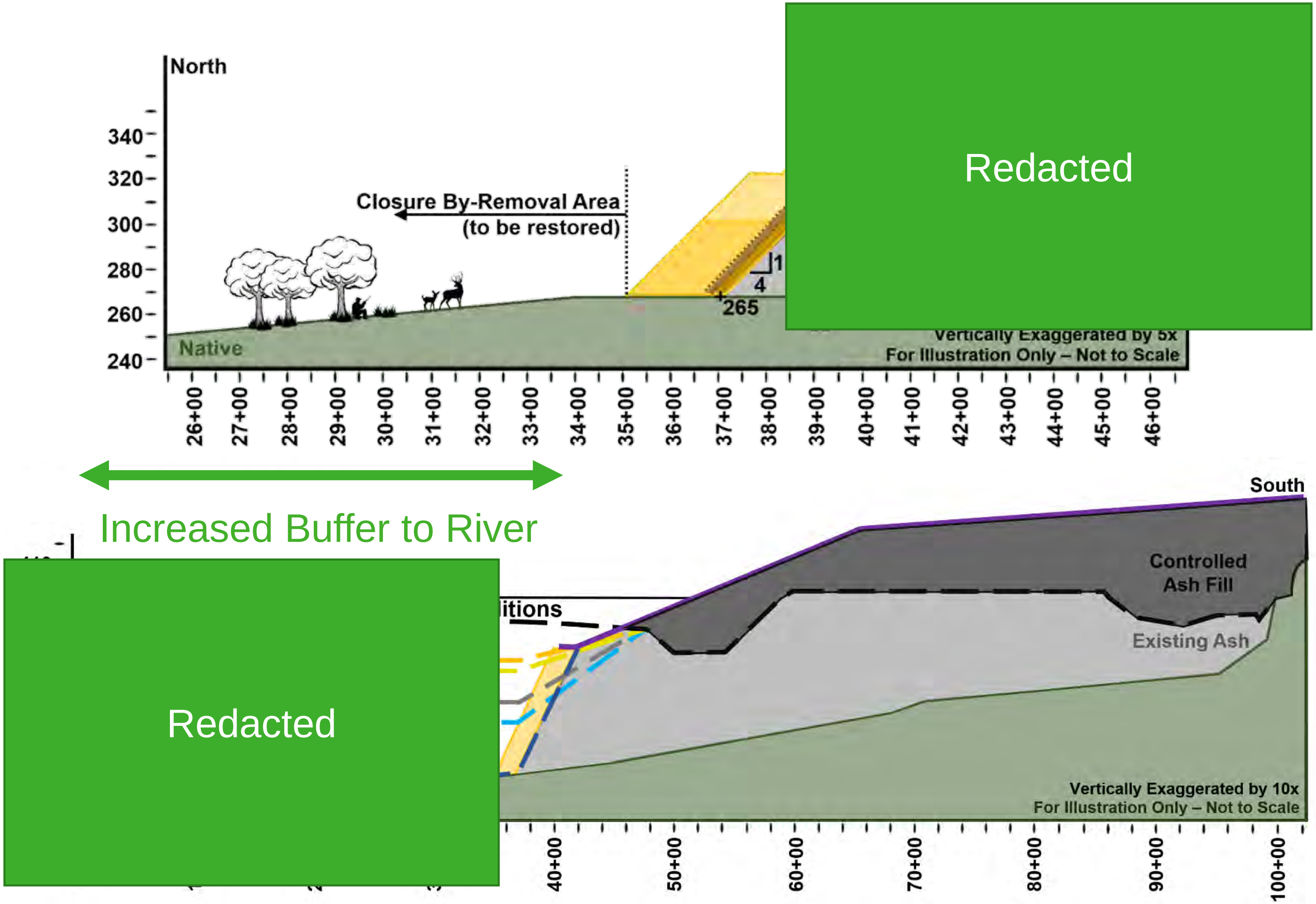



## Existing Conditions

- The existing outfall is a concrete weir structure with a sharp crested weir at elevation 382 ft msl controlling flow into a 48 in. corrugated metal pipe (CMP) with an invert elevation of 371 ft msl. Additionally an auxiliary spillway with invert elevation 385 ft msl was constructed as part of the final raise, however it has reportedly never been engaged.
- Normal Pool elevation is 383 ft msl in front of Pond.
- Top of Dam elevation is at 395 ft msl.
- Approximately 25 MCY of ash and mine spoils are estimated to be within the Gorgas Ash Pond.

Redacted

# Potential Post Closure Conditions



# Site Hydrology and Hydraulics

Basin Area: 1,302 ac

Req. Storm: 100% PMP, 6-hr

| Storm | Peak Inflow (gpm) |
|---|---|
| 2-yr, 24-hr | 716,300 |
| 5-yr, 24-hr | 966,300 |
| 10-yr, 24-hr | 1,205,100 |
| 25-yr, 24-hr | 1,584,400 |
| 50-yr, 24-hr | 1,913,800 |
| 100-yr, 24-hr | 22,69,700 |
| 1,000-yr, 24-hr | 3,680,900 |
| **PMP, 6-hr** | **9,818,600** |

*Flows into pond, not discharge flows

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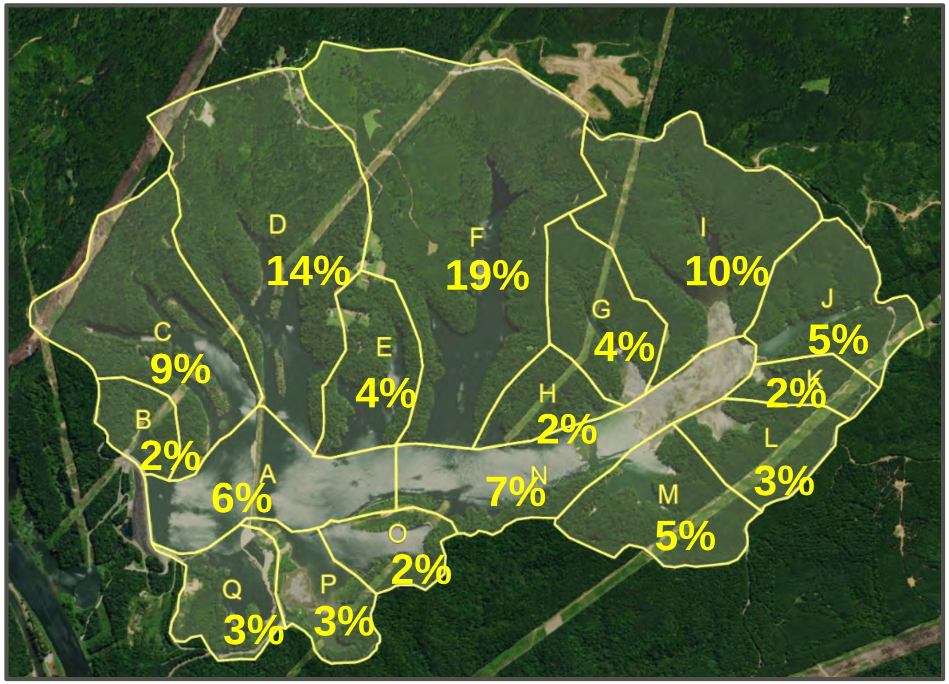
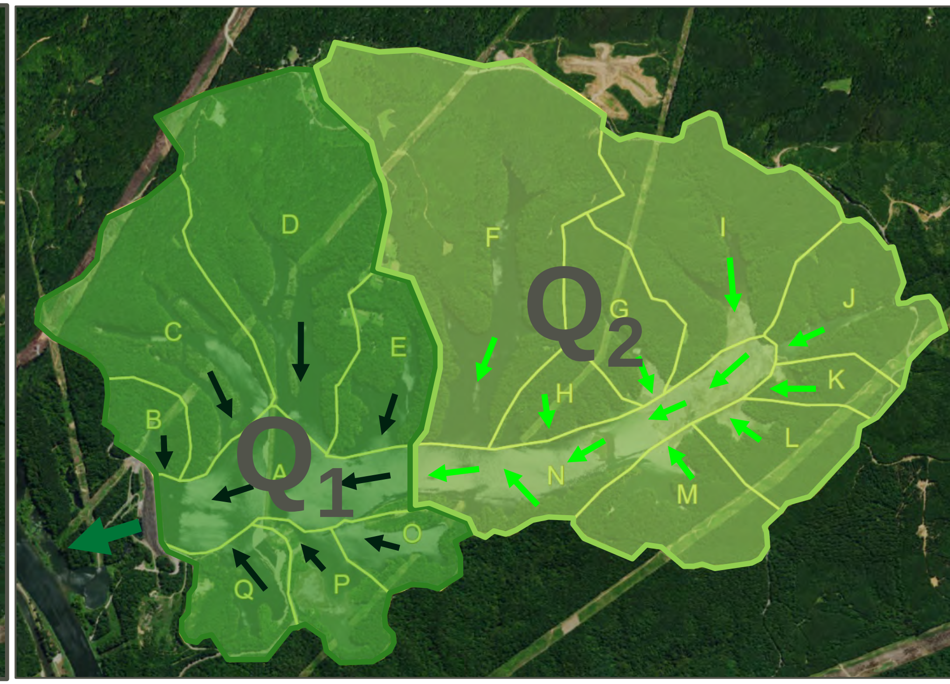
# Site H&H Summary – Watershed Basins




Note: The total basin flows calculated as part of the H&H analysis (separate project) have been allocated to each sub-basin based on each sub-basin's area contribution to the overall watershed, denoted as 'Area (%)' in the chart below.

| | | | | | |
|---|---|---|---|---|---|
| $Q_{1Peak}$: | Base | 2,000 gpm | $Q_{2Peak}$: | Base | 2,600 gpm |
| | 2-yr | 307,500 gpm | | 2-yr | 408,900 gpm |
| | 100-yr | 974,900 gpm | | 100-yr | 1,294,900 gpm |
| | 1,000-yr | 1,580,800 gpm | | 1,000-yr | 2,100,500 gpm |
| | **PMP** | **4,216,300 gpm** | | **PMP** | **5,601,900 gpm** |

# Design with not Against Site Conditions

Traditional dewater and excavate not ideal, due to:

- Size, shape, depth, and volume of ash
- Watershed and surrounding topography with 4,500 gpm base flow

- Closure method chosen to optimize time-dependent costs:
  - Water treatment
  - Construction management
  - Quality assurance
  - Owners’ costs
  - Contractor general costs

***Select closure methods that***

***work with the wet nature of the site not against it.***

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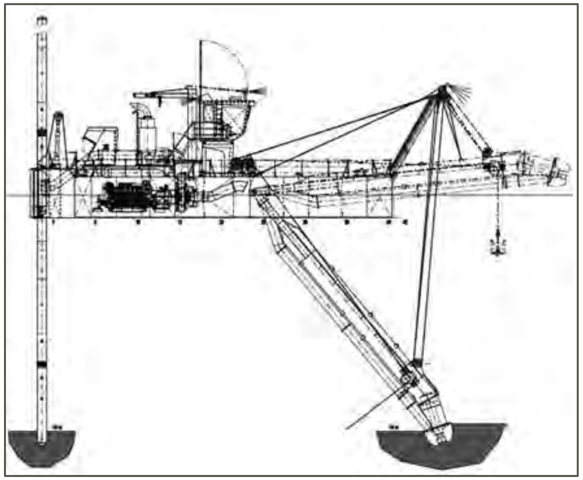
# Wet Handling – Dredging Benefits

Wet closure using dredging permits:

- Dredge access across most of pond & no need for complicated water diversion and dewatering operations.  24 Hour Operations Possible.
- Safer than dry closure methods
  - Better site conditions (reduced risk from temporary slopes cut in sluiced ash, and less work on wet / unstable ash areas)
  - Reduced dust
  - Less Personnel with Higher Throughput
- Reduced water treatment timeframe / variability
  - Pond provides retention time / equalization
  - Allows for initial in-pond water treatment
- Faster ash handling rate (12,000 CY/day)
- Increased schedule and cost confidence
  - Not burdened by stormwater management & weather delays if partnered with Paste Deposition



***FASTER***

***SAFER***

***CHEAPER***

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# Closure Concept – Paste Thickening Benefits

Employing paste technology provides **additional** benefits:

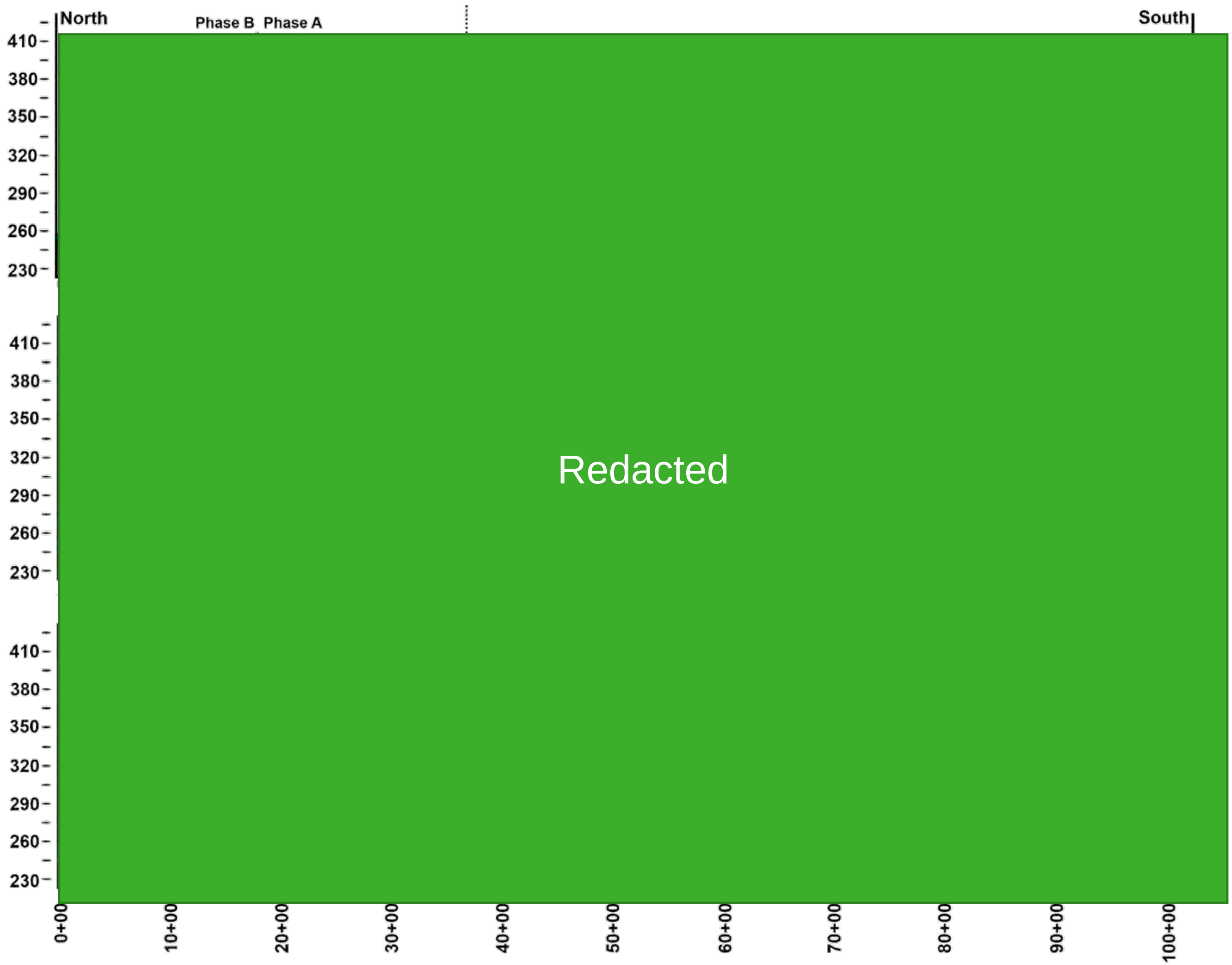
- Increased safety
  - Fewer crews / equipment
  - Directly Deposited / Stacked without additional handling
- Improved schedule duration and confidence
  - Lessens burden from weather delays
  - Allows project to match dredge throughput (12k CY/day) vs. land based operations handling (6k CY/day)
- Sig. positive change to geotech. properties & stability
  - Homogeneous consistency & behavior
  - Reduced permeability (i.e., leachate gen.)
  - Higher density / reduced volume
  - Increased Strength
- Potential simplification to water treatment
  - Point sources vs dredge cell areas
  - Separate WT streams
  - Faster deposition, reduces WT timeframe


***FASTER++***

***SAFER++***

***CHEAPER++***

# Construction Phasing



# Options Assessment & Decision Making Tools

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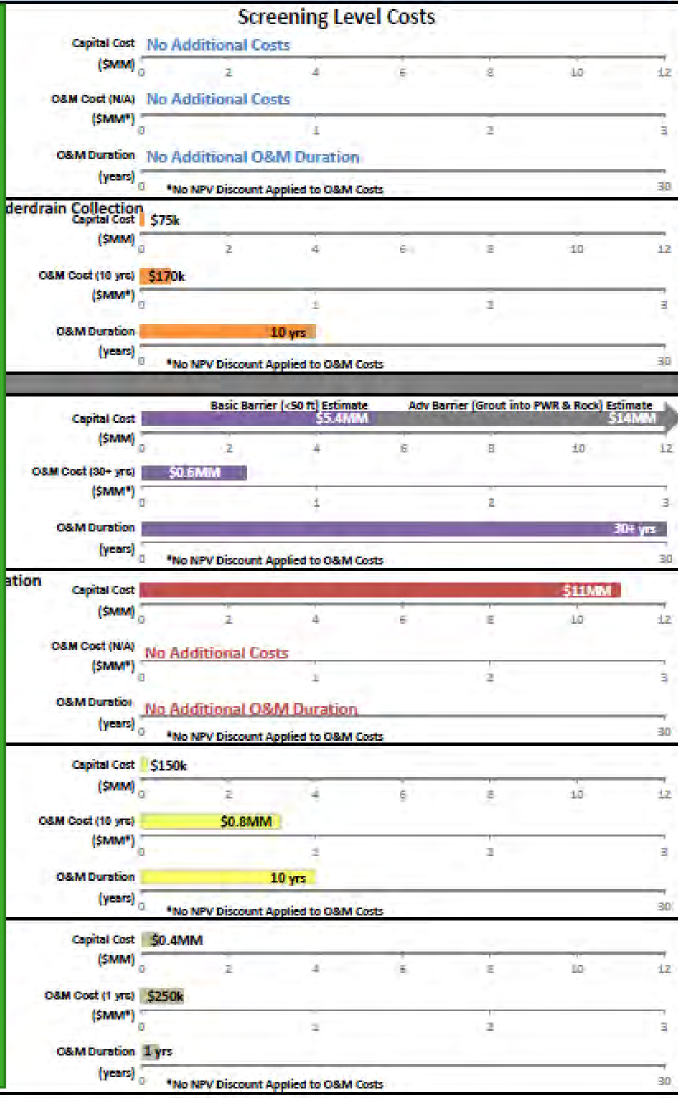
# Options Evaluations – Dashboard Presentations

**Base Options**

Option G/K4/L4 | Option G'/K4/L4 | Add-on A | Add-on D | Add-on J | Add-on K3

Redacted




### Option G/K4/L4: Current Plan

**Strategy**

In Pond 4, collect CCR contact water using drain system (G), combined with temporary dewatering wells (K) combined with geotechnical monitoring (L). Additionally the ash in the lowest and most environmentally vulnerable areas are being removed from

**Key Features**

1. Permanent drain system at toe of large slope in east
2. Temporary dewatering wells in ash in east slope
3. Geotechnical monitoring of Category 1 dam & east slope of cover
4. On site treatment system for impacted groundwater

### Option G'/K4/L4: Enhanced Underdrain Collection

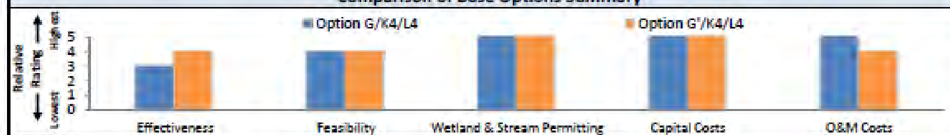
**Strategy**

In Pond 4, collect CCR contact water using drain system (G), combined with temporary dewatering wells (K) combined with geotechnical monitoring (L). Additionally the ash in the lowest and most environmentally vulnerable areas are being removed from AP4.

**Key Features**

1. Permanent drain system on east slope of cover
2. Temporary dewatering wells in ash in east slope
3. Geotechnical monitoring of Category 1 dam & east slope of cover
4. On site treatment system for impacted groundwater

**Comparison of Base Options Summary**




**Add-Ons**

**Strategy**

Reduce or eliminate upgradient groundwater from entering ash by constructing upgradient barrier (A)

**Key Features**

1. Upgradient barrier wall through overburden & into PWR
2. Grouting of highly weathered upper bedrock horizon
3. Natural drainage away / around wall estimated to occur.

**Strategy**

Stabilize/solidify ash below the long-term groundwater levels (D)

**Key Features**

1. Deep soil mix of ash in areas with ash below long-term groundwater levels

**Strategy**

Targeted approach to address localized MCL exceedance with chemical injection (J)

**Key Features**

1. Upgradient injection wells at locations of MCL exceedance with downstream confirmation wells

**Strategy**

To either of the options, add active dewatering of ash using wells (K) in Pond 3

**Key Features**

1. Active dewatering wells in ash
2. Would rely on existing water treatment infrastructure

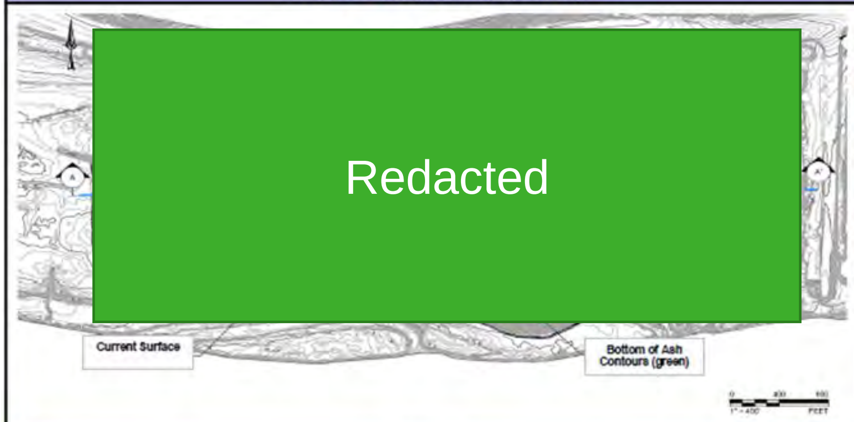
**Comparison of Add-ons**

Redacted

# Beneficial Use Resource Evaluations

## CCR Unit Beneficial Use Dashboards

**SITE PLAN WITH BORINGS AND SECTION LOCATION**




**QUANTITIES**

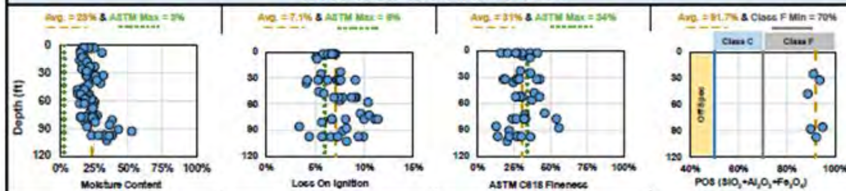
| | |
|---|---|
| Pond 3D Area (AC) | 62.6 |
| Total Vol. (CY) | 4,044,650 |
| Cover Soil Vol. (CY) | 136,000 |
| Top Soil Vol. (CY) | 34,000 |
| Coal Ash Vol. (CY) | 3,874,650 |

**SAMPLING AND TESTING SUMMARY**

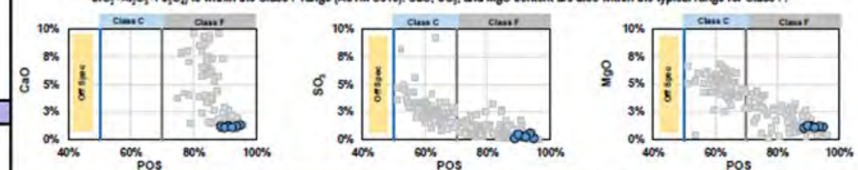
Fly ash samples from were collected by Southern Company and delivered to the Golder Atlanta Laboratory. Samples were analyzed for physical and chemical characteristics following ASTM C618 specifications for fly ash beneficial use in concrete. A representative bulk, blended sample was used in concrete mortar tests following ASTM C311 guidelines. Some samples were also tested for general geotechnical properties.

| | | | | | |
|---|---|---|---|---|---|
| Total Samples Received | 235 | Bag Samples Received | 184 | Shelby Tubes Received | 51 |
| Total Samples Tested | 90 | Bag Samples Tested | 39 | Shelby Tubes Tested | 51 |

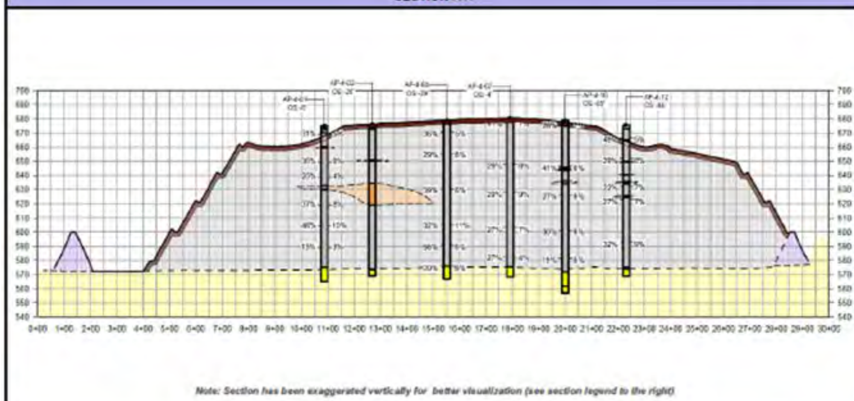
**PHYSICAL & CHEMICAL CHARACTERISTICS**



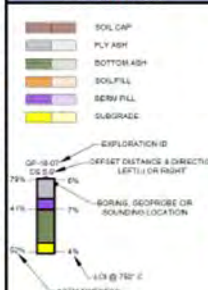

Sample chemistry (plotted in blue circles) was compared with a database of 216 ash samples (plotted in gray squares). Primary Oxide Sum (POS = $SiO_2+Al_2O_3+Fe_2O_3$) is within the Class F range (ASTM C618). CaO, $SO_3$, and MgO content are also within the typical range for Class F.




**SECTION A-A'**




**SECTION LEGEND**




**USE IN CONCRETE TESTING (ASTM C618, ASTM C311)**

A set of mortar samples (2-inch blocks) were prepared with 20% replacement of Portland cement with fly ash from AP-4 (a representative composit sample). Test samples were compared to a control set of samples prepared with no ash replacement.

| Test | Result (3 block avg, ASTM C311) | | ASTM C618 Requirement | |
|---|---|---|---|---|
| Strength Activity Index | 7 Day | 74% | 75% (min) | ✗ |
| | 28 Day | 84% | 75% (min) | ✓ |
| Water Requirement | 99% | | 105% (max) | ✓ |
| Autoclave Soundness | 0.02% | | 0.8% (max) | ✓ |

**CHARACTERIZATION AND BENEFICIAL USE DISCUSSION**

| AP- 4 BENEFICIAL USE SUMMARY | | | |
|---|---|---|---|
| | Physical Characteristics | Some Beneficiation Required | – |
| | Mineralogical Characteristics | Typical | ✓ |
| | Chemical Characteristics | Typical | ✓ |
| | ASTM C618 Specification | Typical | ✓ |

**AVERAGE PHYSICAL, MINERALOGICAL, AND CHEMICAL CHARACTERISTICS**

| Physical Characteristics | | Mineralogy (mass %) | | Major Oxides Content (mass %) | | Fly Ash Classification |
|---|---|---|---|---|---|---|
| Moisture (%) | 23 | Amorphous | 80.4% | $SiO_2$ | 52.6% | ASTM C618 CLASS F |
| Specific Gravity | 2.31 | Quartz | 5.45% | $Al_2O_3$ | 26.7% | |
| LOI (@ 750 °C, %) | 7.1 | Mullite | 8.55% | $Fe_2O_3$ | 12.3% | |
| Fineness (ASTM C618, %) | 31 | Hematite | 1.25% | CaO | 1.21% | |
| D50 (micron) | 22 | Magnetite | 0.55% | MgO | 1.17% | |
| Dry Unit Weight (pcf) | 76 | Magnesioferrite | 0.76% | $SO_3$ | 0.31% | |

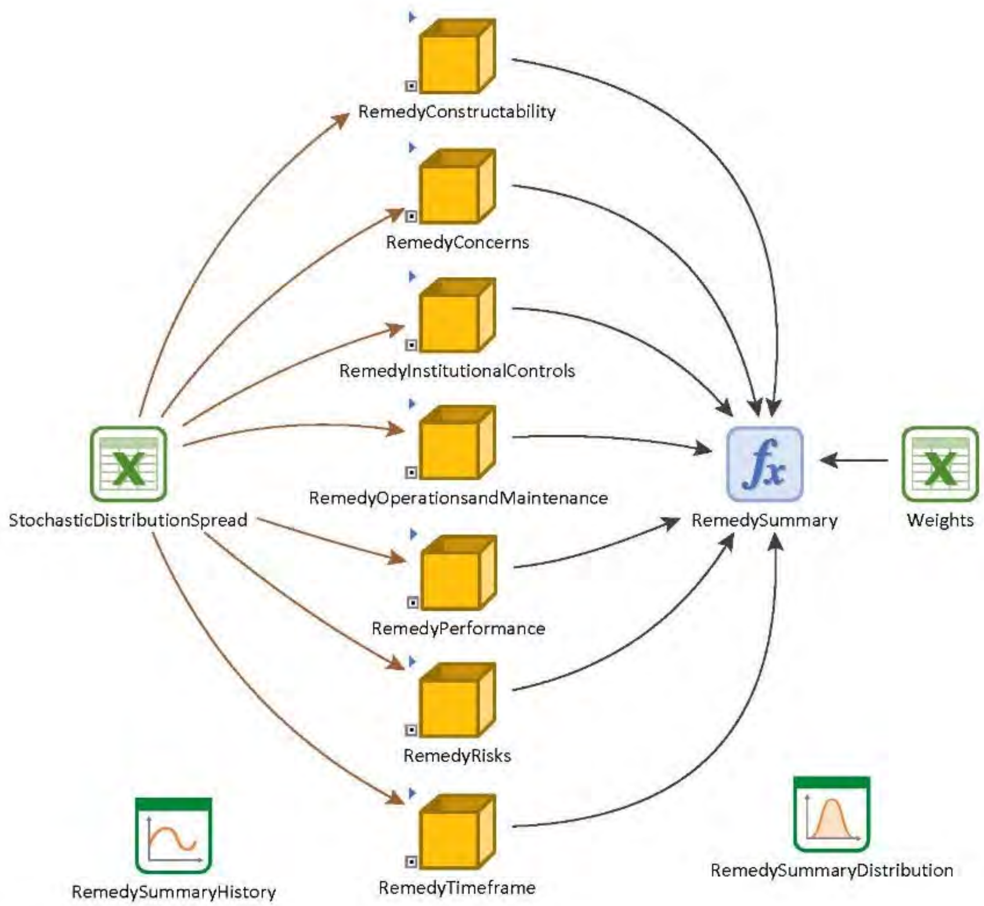
DRAFT

| CONSULTANT | | | TITLE | |
|---|---|---|---|---|
| GOLDER | YYYY-MM-DD | 2019-05-10 | ASH POND 4 BENEFICIAL USE DASHBOARD | |
| | DESIGNED | N. Yeboah | | |
| | PREPARED | N. Yeboah | PROJECT NO. | FIG |
| | REVIEWED | R. Sullivan | 18114309 | 03 |
| | APPROVED | – | | |

# Monte Carlo Assessments - GoldSIM

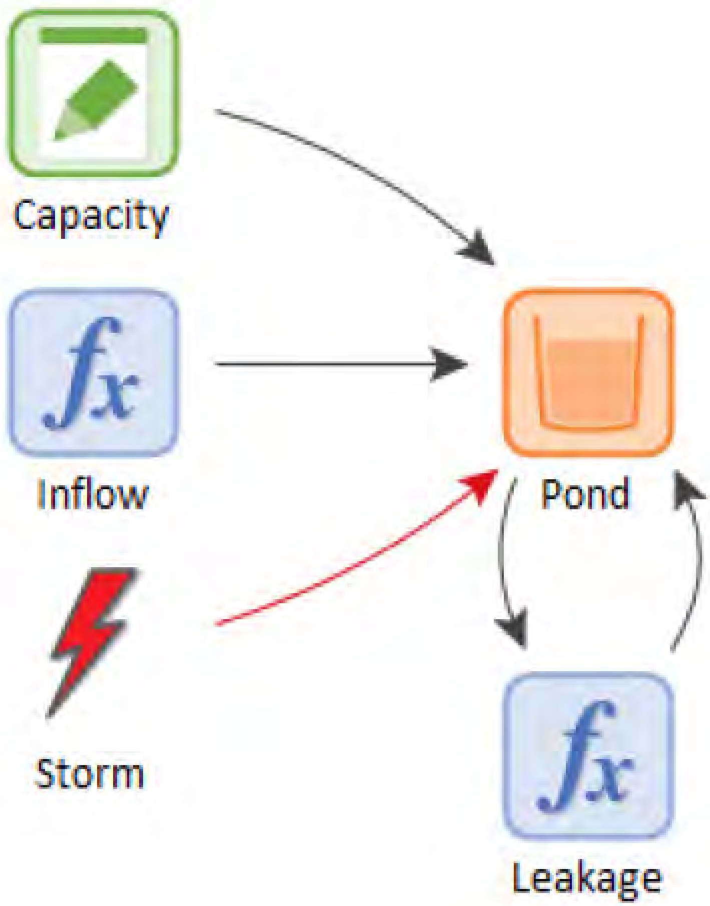
## GOLDSIM

- Dynamic Monte-Carlo simulation software
- GoldSim is a graphical, object-oriented program for dynamic, probabilistic simulations of complex systems
- GoldSim has a wide variety of specialized elements
- You build a model by connecting the outputs of elements to the inputs of another element



# What is GoldSim?

- **VISUAL SPREADSHEET**

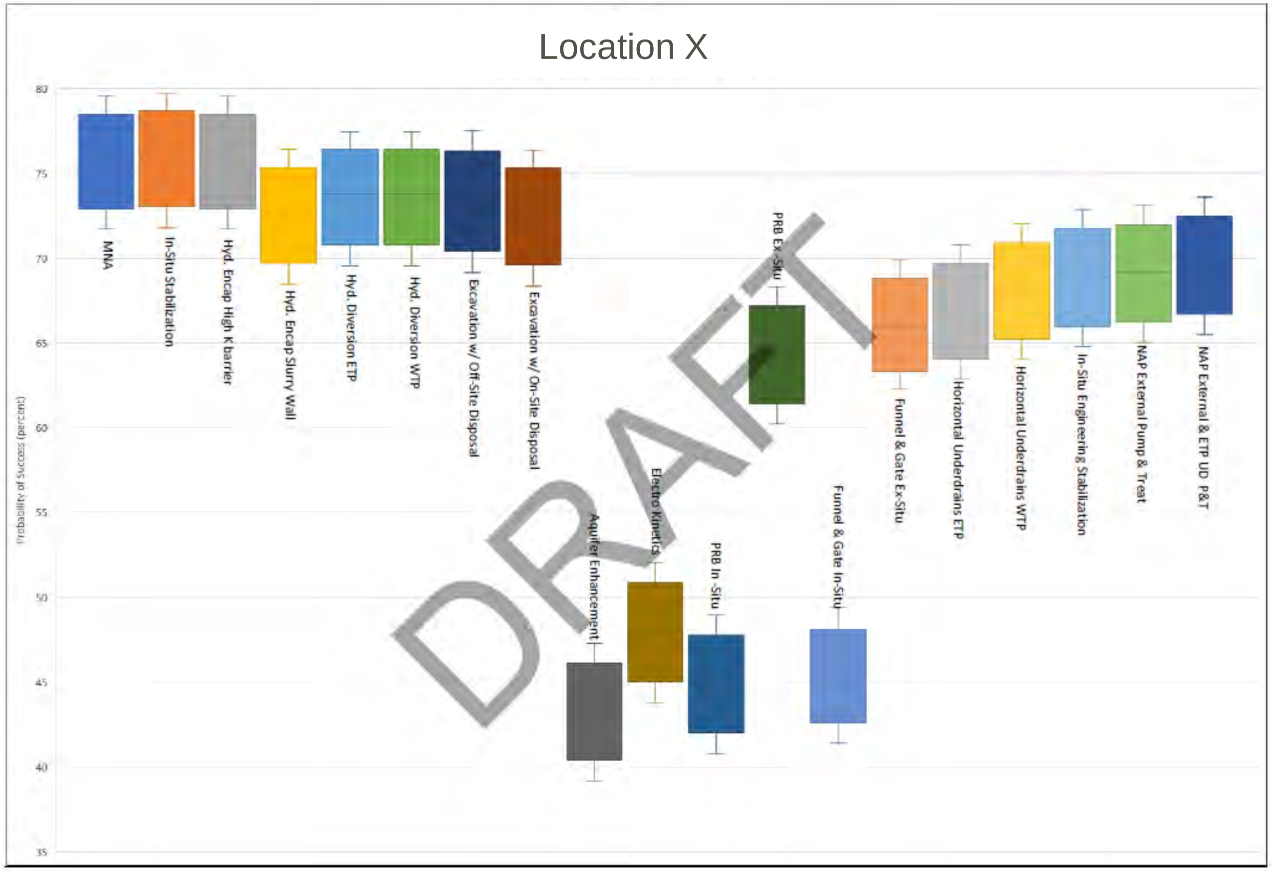



- GoldSim is a graphical, object-oriented program for dynamic, probabilistic simulations of complex systems
- Wide variety of specialized elements
- You build a model by connecting the outputs of elements to the inputs of another element.

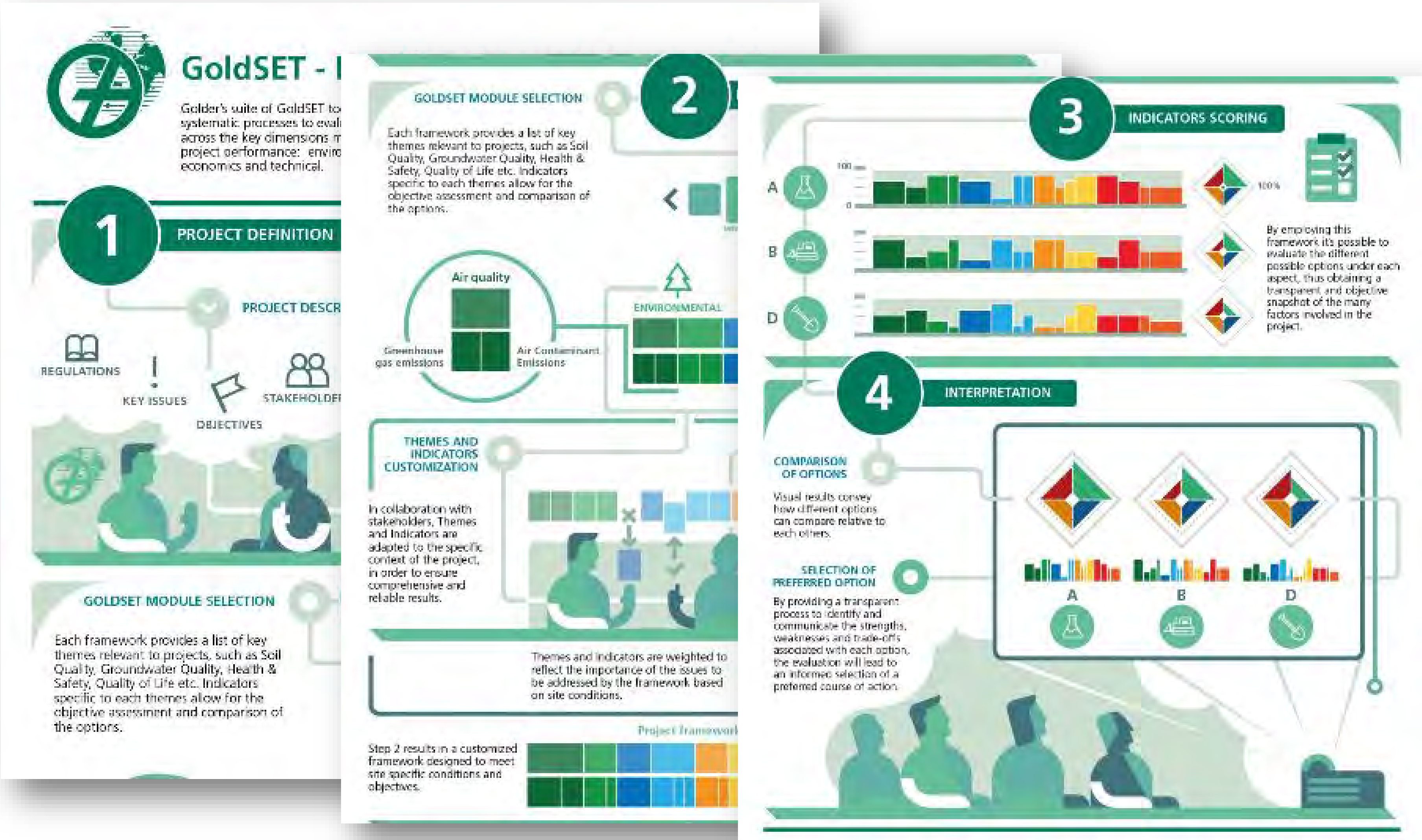
# Scenario Assessment for Corrective Measures

## GOLDSIM EXAMPLE

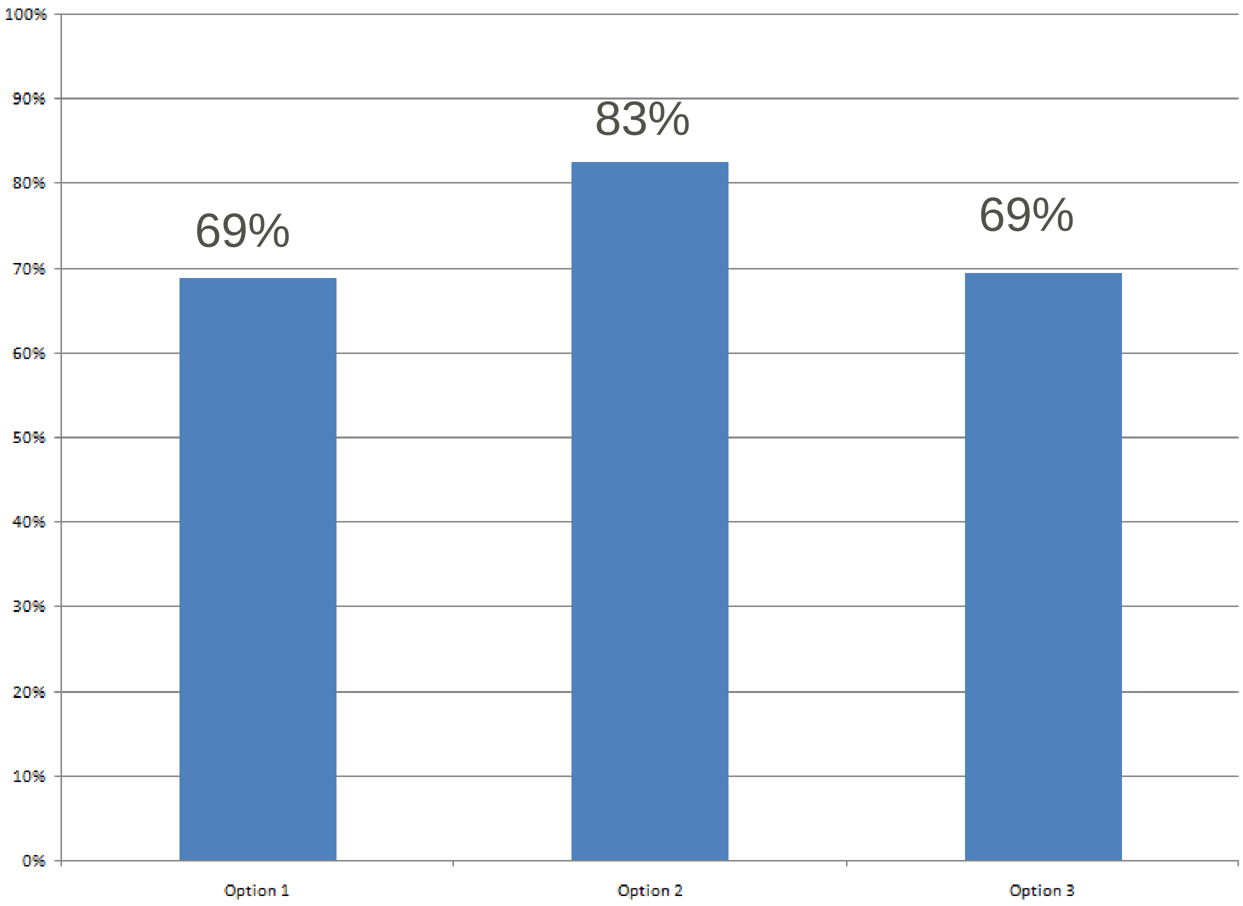
- Multi-criteria analysis by ranking objects
- Different COIs, site specific
- Upfront engineering and design costs considered
- Rankings based on pump and treat as the “average” option
- Risk is considered as 30% of weighting (e.g., risk of well failure, COI release, dam failures



# GoldSET Multi-Criteria Assessment Tool



# Multi-Criteria Analysis (MCA) - Conventional




**How do we make meaning from this?**

**Is Option 2 really the best?**

**Are Options 1 and 3 actually equivalent?**

# Multi-Criteria Analysis (MCA)

A structured MCA approach explicitly defines:

- **Indicators** against which to measure options
- **Scoring schemes** for the indicators to use for measuring
- A mechanism to account for the **relative importance** of indicators

And in doing so, a thorough MCA:

- Provides **traceability and accountability**
- Allows us to **explicitly identify** our **priorities** in decisions
- **Removes subjectivity** from the decision making process
- Make an **informed decision** based upon the **factors** that we consider to be the **most important**

# GoldSET approach in a Nutshell


| Environmental Aspect | | | | | |
|---|---|---|---|---|---|
| **Code** | **Indicator** | **OPTION 1** | **OPTION 2** | **OPTION 3** | **Weight** |
| ENV-1 | Are offset gains additional to future trajectory based on status quo? | 50 | 100 | 50 | 3 |
| ENV-2 | Can the offset site be expanded upon, or, the method intensified, to incorporate future offsets? | 150 | 50 | 100 | 2 |
| ENV-3 | Complimentarity of offset with regional conservation goals. | 50 | 100 | 0 | 1 |
| ENV-4 | Does the offset site create the opportunity for buffering of important site(s), or, to enhance connectivity in landscape? | 50 | 100 | 50 | 2 |
| ENV-5 | Ratio of impact footprint area versus area required for NNL offset . (= 'offset efficiency'). | 25 | 50 | 25 | 1 |
| ENV-6 | Offset enhancement technology performance risk. | 100 | 100 | 50 | 2 |
| Social Aspect | | | | | |
| Economic Aspect | | | | | |

OPTION A

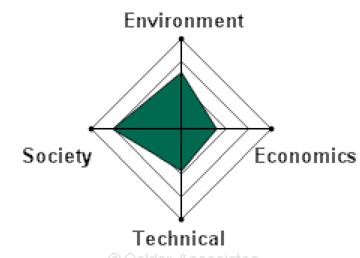
| | |
|---|---|
| ENVIRONMENT | 62% |
| SOCIETY | 75% |
| ECONOMICS | 39% |
| TECHNICAL | 46% |

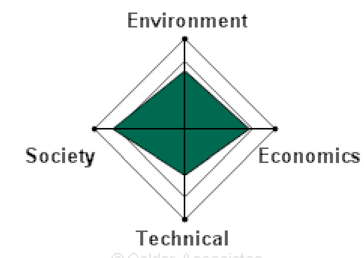
OPTION B

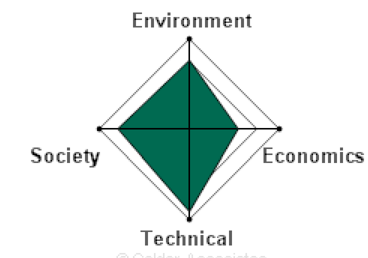
| | |
|---|---|
| ENVIRONMENT | 64% |
| SOCIETY | 79% |
| ECONOMICS | 71% |
| TECHNICAL | 51% |

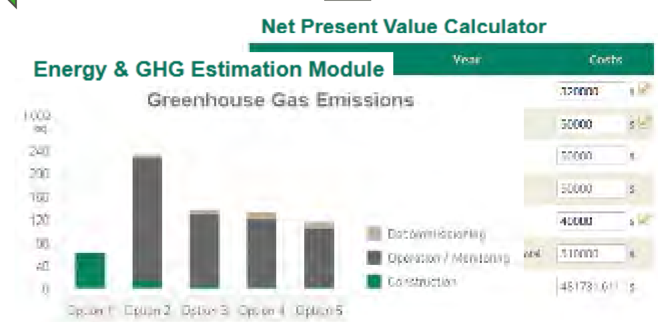
OPTION C

| | |
|---|---|
| ENVIRONMENT | 75% |
| SOCIETY | 79% |
| ECONOMICS | 54% |
| TECHNICAL | 91% |



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# Example CCR Pond Closure Options


Option 1


Option 2

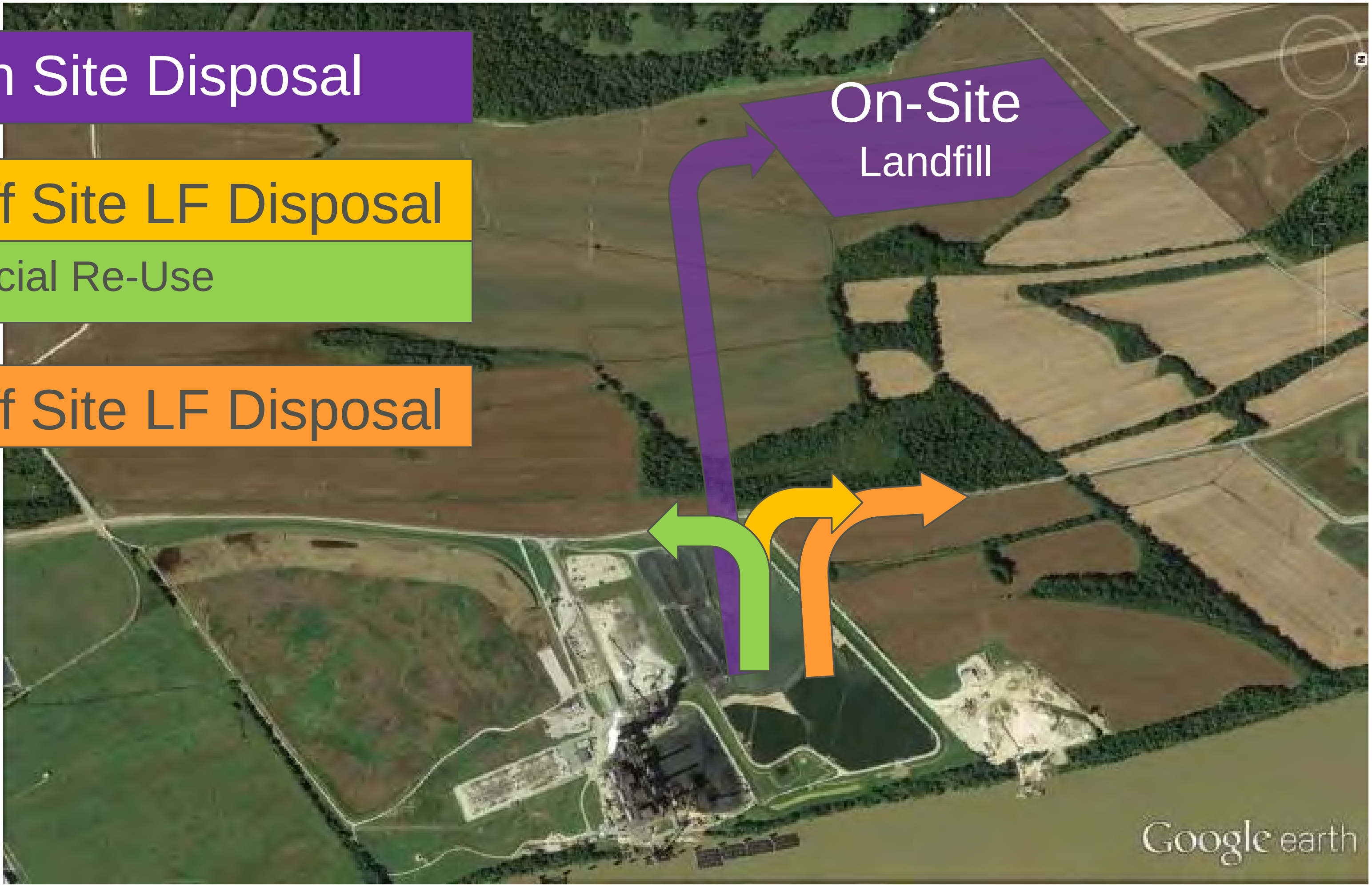
# Example CCR Pond Closure Options

Opt 3: On Site Disposal

Opt 4: Off Site LF Disposal

w/ % Beneficial Re-Use

Opt 5: Off Site LF Disposal



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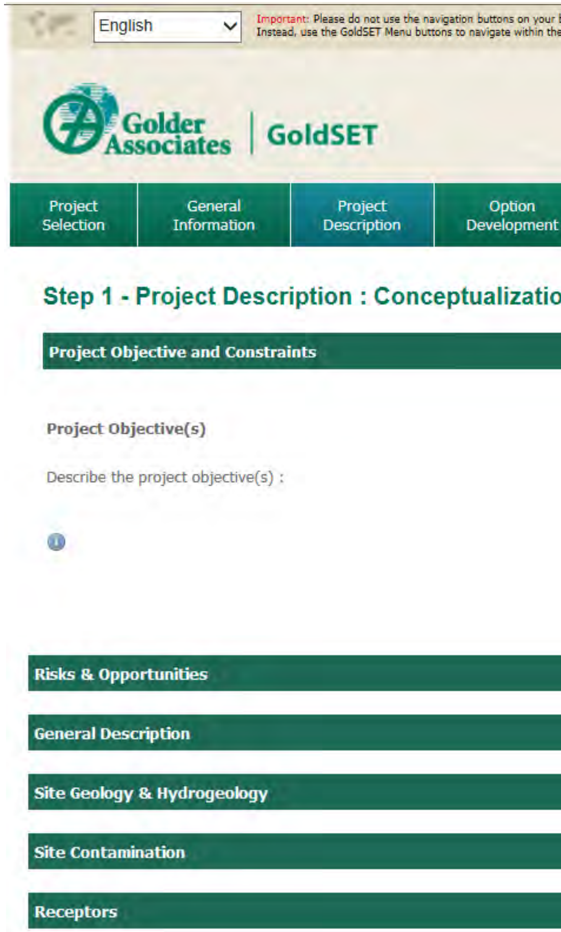
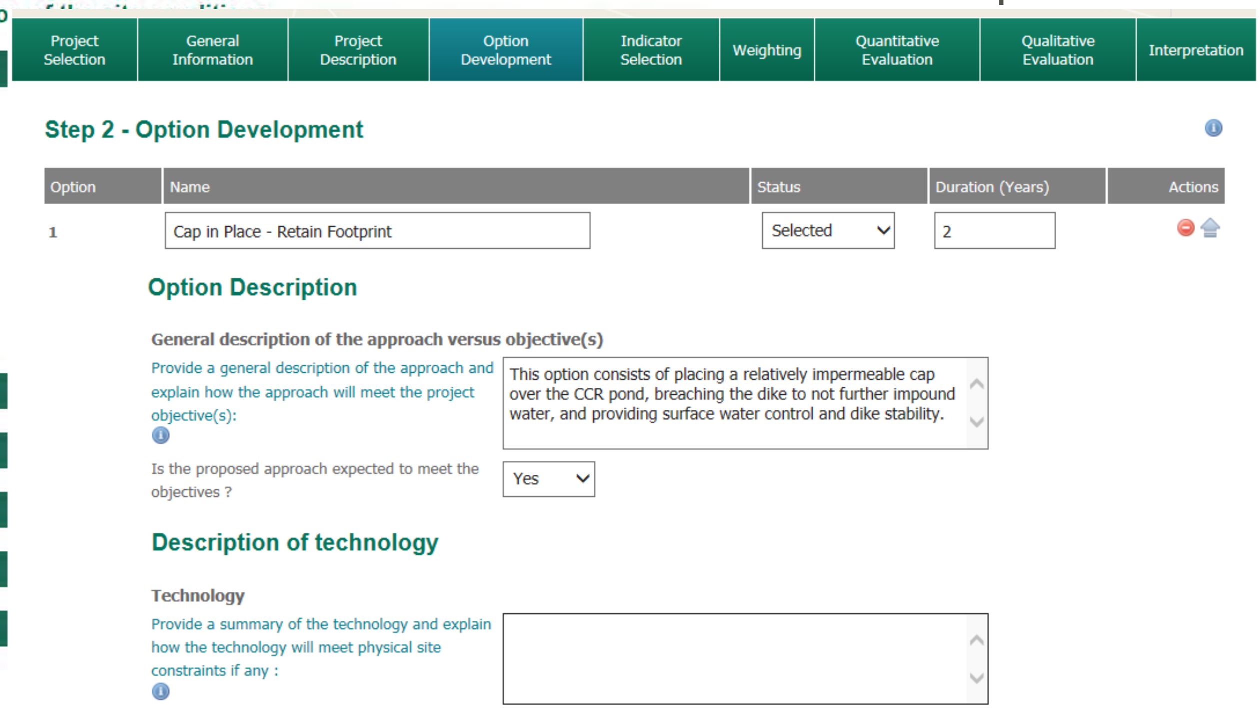
# Project Description and Option Development




GoldSET is tailored for a wide variety of uses. Data entered in the tool is exported while creating the evaluation report.



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# Indicator Selection and Weighting

**Environmental**

| Selection | Theme | Indicator | Description |
|---|---|---|---|
| ☑ | Soil Quality | Soil Quality | |
| ☐ | Sediment Quality | Sediment Quality | |
| ☑ | Sediment Quality | Sediment Quality | |
| ☐ | Soil Vapour Intrusion | Soil Vapour Intrusion | |
| ☑ | Water | Groundwater Quality | |
| ☐ | Water | Free Product | |
| ☑ | Water | Surface Water Quality | |
| ☑ | Water | Waterborne Contaminant Migration | |
| ☐ | Water | Water Usage | |
| ☑ | Atmosphere | Greenhouse Gas Emissions | |
| ☑ | Energy Consumption | Energy Consumption | |
| ☑ | Waste | Quantity of Wastes | |
| ☐ | Waste | Hazardous Wastes | |
| ☑ | Soil | Contaminated Soil Erosion and Transport | |
| ☑ | Fauna and Flora | Impacts on Fauna and Flora Resulting from the Proj | |
| ☑ | Fauna and Flora | Impacts on Fauna and Flora During the Project | |
| ☑ | Impact of Technology | Residual Impact of Technology | |
| ☑ | Groundwater Quality | Groundwater Quality | |

**Social**

**Economic**

**Technical**

**Economic Performance**
Potential Litigation

Evaluates the likelihood that potential litigation will be avoided by implemeting the option.

**Scoring Scheme :**
0 = Legal action likely not avoided
50 = Likely to reduce potential for legal action
90 = Legal action likely avoided
100 = Legal action avoided

**Reference :**

**Social**

| Selection | Theme | Indicator | Description |
|---|---|---|---|
| ☑ | Water | Drinking Water Supply | |
| ☑ | Health & Safety | Community Health and Safety | |
| ☑ | Health & Safety | Worker's Health and Safety | |
| ☑ | Impact on Community | Direct Local Employment | |
| ☑ | Impact on Community | Opportunities for Local Business Generation | |
| ☑ | Impact on Community | Public Disruption (Duration of Work) | |
| ☑ | Impact on Community | Quality of Life (During the Project) | |
| ☑ | Impact on Community | Public Use | |
| ☐ | Impact on Community | Cultural Heritage | |
| ☑ | Impact on the Lanscape | Impact on the Landscape | |
| ☑ | Management Practices | Management Practices | |

**Economic**

| Selection | Theme | Indicator | Description |
|---|---|---|---|
| ☑ | Corporate Image | Corporate Image | |
| ☑ | Standards, Laws & Regulations | Standards, Laws and Regulations | |
| ☑ | Economic Performance | Net Present Value of Options' Costs | |

<u>Four dimensions to be evaluated</u>:

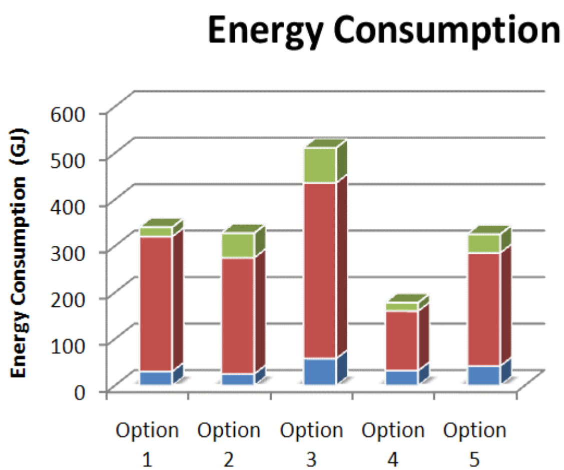
Environmental – Direct & Indirect Impacts

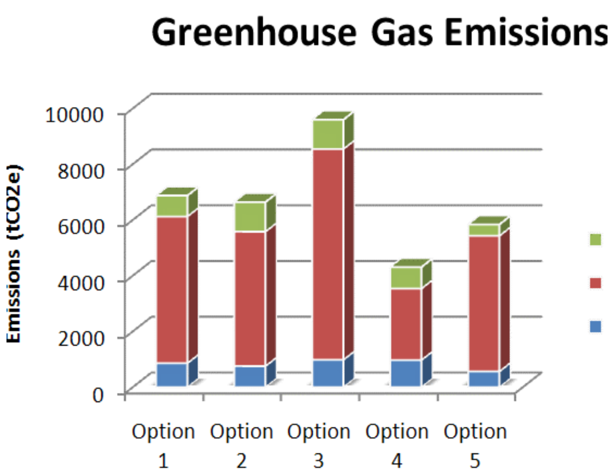
Social – Benefits & Nuisances

Economics – Bottom Line

Technical – Reliability Vs. Complexity

# Evaluation of Options (Quantitative and Qualitative)




| | Units | Cap in Place - Retain Footprint | Cap in Place - Reduced Footprint Away from River | Excavate and Disposal in On-Site Landfill | Excavate and Offsite Disposal with Ben. Re-Use |
|---|---|---|---|---|---|
| **Environmental Aspect** | | | | | |
| ENV-6 Greenhouse Gas Emissions | Tonnes CO2 e. | 7.36 | 8.28 | 58.64 | 54.53 |
| ENV-7 Energy Consumption | MMBTU (PFE) | 105.02 | 119.2 | 846.41 | 790.23 |
| ENV-8 Quantity of Wastes | Tons | 1000000 | 1000000 | 1000000 | 500000 |
| **Social Aspect** | | | | | |
| SOC-6 Public Disruption (Duration of Work) | Years | 2 | 3 | 12 | 8 |
| **Economic Aspect** | | | | | |
| ECONO-3 Net Present Value of Options' Costs | $ | 2818182 | 3190083 | 4983316 | 6295732 |
| **Technical Aspect** | | | | | |

Quantitative evaluation



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# Results & Interpretation (Hypothetical Case)

***Process is Systematic, Repeatable, Defensible –*** inputs, trade-offs, relationships and assumptions explicit & fully documented

***Avoiding unintended consequences*** by systematically considering environmental, social, economic and technical factors

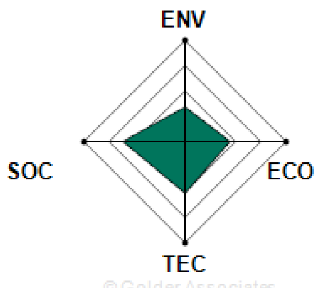
***Obtaining support & buy-in*** from stakeholders through a collaborative process → greater potential for community approval

***Model is reusable with a long "shelf life"*** once the cost/suitability surface is developed, it may be used repeatedly for similar applications

Detailed Results

**Cap in Place - Retain Footprint**

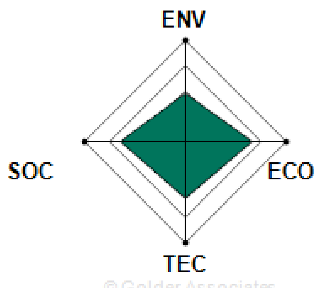
| | |
|---|---|
| Environmental | 34% |
| Social | 61% |
| Economic | 44% |
| Technical | 51% |




Public Disruption (Duration of Work) :
2 Years
Net Present Value of Options' Costs :
2,800,000 $

**Cap in Place - Reduced Footprint Away from River**

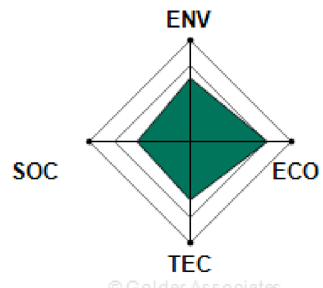
| | |
|---|---|
| Environmental | 48% |
| Social | 64% |
| Economic | 65% |
| Technical | 56% |




Public Disruption (Duration of Work) :
3 Years
Net Present Value of Options' Costs :
3,200,000 $

**Excavate and Disposal in On-Site Landfill**

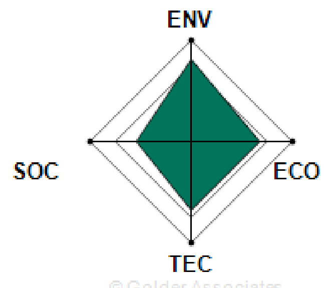
| | |
|---|---|
| Environmental | 63% |
| Social | 53% |
| Economic | 76% |
| Technical | 58% |




Public Disruption (Duration of Work) :
12 Years
Net Present Value of Options' Costs :
5,000,000 $

**Excavate and Offsite Disposal with Ben. Re-Use**

| | |
|---|---|
| Environmental | 80% |
| Social | 54% |
| Economic | 67% |
| Technical | 68% |




Public Disruption (Duration of Work) :
8 Years
Net Present Value of Options' Costs :
6,300,000 $

# Landfill / Project Siting with GoldSET Spatial

# Documentation of Selection Process

INDICATORS

1 . BIRD HAZARD PISTON AIRPORTS
2 . BIRD HAZARD TURBOJET AIRPORTS
3 . FEMA 100YR FLOOD ZONES
4 . GROUNDWATER RECHARGE AREAS
5 . SURFACE WATER INTAKES
6 . WETLANDS

CONSTRAINTS

7 . FAULT ZONES
8 . PERENNIAL STREAMS
9 . TROUT STREAM EROSION CONTROL
10 . WELLHEAD PROTECTION

ENVIRONMENTAL

# Documentation of Selection Process

## GROUNDWATER RECHARGE AREAS

Avoid development in Groundwater Recharge Areas

4.

**REFERENCE**

EPD Circular 14 §6-J

**SOURCE**

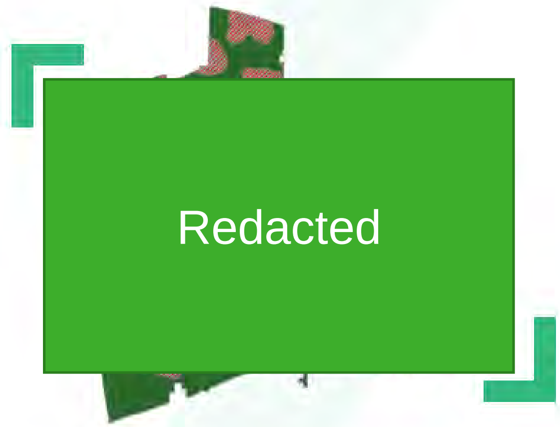
Georgia Department of Natural Resources (DNR) http://epd.georgia.gov/geographic-information-systems-gis-databases-and-documentation

**LAYER PRE-PROCESSING AND COMMENTS**

Land within the Ground Water Recharge Area(s) (GRWA) recieved the lowest suitability score of 0. Suitability increases from the edge of the GRWA boundary outward to a max score of 100 (distances not based on regulatory requirements).

**DESCRIPTION**

The Georgia EPD has standards that give significant ground water recharge areas special protection (Chapter 391-3-16-.02). Landfill facilities sited within significant groundwater recharge areas must have a synthetic liner and a leachate collection system. While it is understood the current landfill being sited will have a liner and leachate collection system, preference away from groundwater recharge areas was still scored preferentially.





4. GROUNDWATER RECHARGE AREAS

# Documentation of Selection Process

INDICATORS

11 . COMPATIBLE ZONING ORDINANCE

12 . COUNTY BOUNDARIES

13 . HISTORICAL SITES INDICATOR

CONSTRAINTS

14 . FEDERAL MANAGED LANDS

15 . STATE MANAGED LANDS

16 . AIRPORTS

17 . NATIONAL HISTORICAL SITES

18 . HISTORICAL SITES CONSTRAINT

19 . RECREATIONAL CAMPS

20 . INCOMPATIBLE ZONING ORDNANCE

21 . ROADS CONSTRAINT

22 . RAIL CONSTRAINT

SOCIAL

# Documentation of Selection Process

## INCOMPATIBLE ZONING ORDNANCE

Reduce potential conflict with incompatible zoning

**20.**

### REFERENCE

391-3-4-.05 1(a), EPD Circular 14 §6-A

### SOURCE

Carroll, Coweta, and Heard County Property Parcel Data, 2015.

*Note - County Zoning Data not Directly Available Electronically*

### LAYER PRE-PROCESSING AND COMMENTS

Extract all residential and planned unit development (PUD) zoning from zoning layer.

### DESCRIPTION

Georgia's Department of Natural Resources Criteria for Performing site Acceptability Studies for Solid Waste Landfills in Georgia provides guidance for following local zoning requirements. Derived from County Comprehensive Plans the following zoning categories represent areas of land deemed incompatible for the development of industrial facilities: Residential and Planned Unit Development (PUD).


PURE CONSTRAINT

20. INCOMPATIBLE ZONING ORDNANCE

# Documentation of Selection Process

INDICATORS

23 . TOPOGRAPHIC SLOPES

24 . FAULT ZONES

25 . SEISMIC IMPACT ZONES

26 . ENGINEERING SOIL QUALITY

CONSTRAINTS

27 . KARST TERRAINS

# Documentation of Selection Process

## KARST TERRAINS

Avoid Karst topography

27

**REFERENCE**

EPD Circular 14 §6-K(5)

**SOURCE**

Georgia Department of Natural Resources (DNR)

**LAYER PRE-PROCESSING AND COMMENTS**

Confirmed that there is no Karst terrain in Carroll, Coweta, and Heard Counties.

**DESCRIPTION**

Georgia's Department of Natural Resources Criteria for Performing site Acceptability Studies for Solid Waste Landfills in Georgia provides guidance for avoid siting a landfill on topography that is likely to have sinkholes, sinking streams, caves, large springs, and blind valleys. Landfills sited on this terrain have a higher potential to develop structural integrity issues. No karst terrane was identified in Carroll, Coweta, and Heard Counties.

N/A

PURE CONSTRAINT

27. KARST TERRAINS

# Documentation of Selection Process

INDICATORS

28 . EXISTING PLANT LOCATION

29 . ROADS INDICATOR

30 . RAIL INDICATOR

# Documentation of Selection Process

# ROADS INDICATOR

Minimize distance to roads

29

### REFERENCE

Not required by regulation

### SOURCE

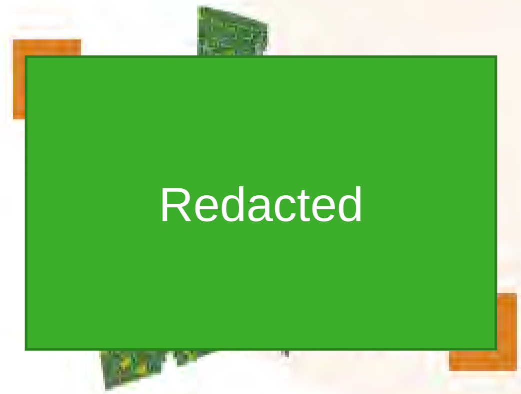
Georgia Department of Transportation (GDOT), 2013 Metadata
Online Link https://data.georgiaspatial.org/data/basemap/roads/road045.html

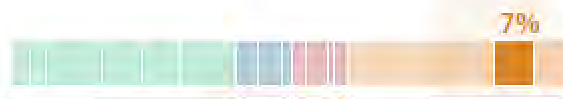
### LAYER PRE-PROCESSING AND COMMENTS

Land between 0-0.25 miles from a road recieves the max suitability score of 100. For land 0.25 miles and greater, suitability decreases out to 0.

### DESCRIPTION

Roads provide access to and from the site both during construction and operation of the facility. Minimizing the distance that trucks and operational traffic have to travel can significantly reduce costs. This criteria is designed to minimize the distance to existing roads.

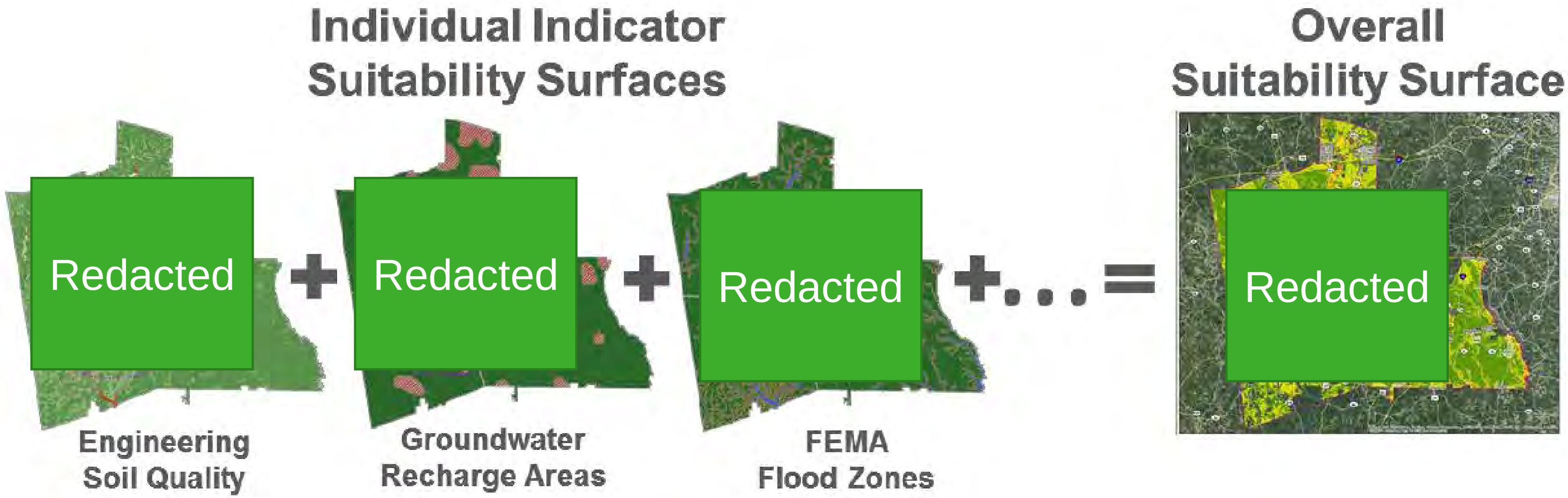



INDICATOR WEIGHT

29. ROADS INDICATOR

# Documentation of Selection Process

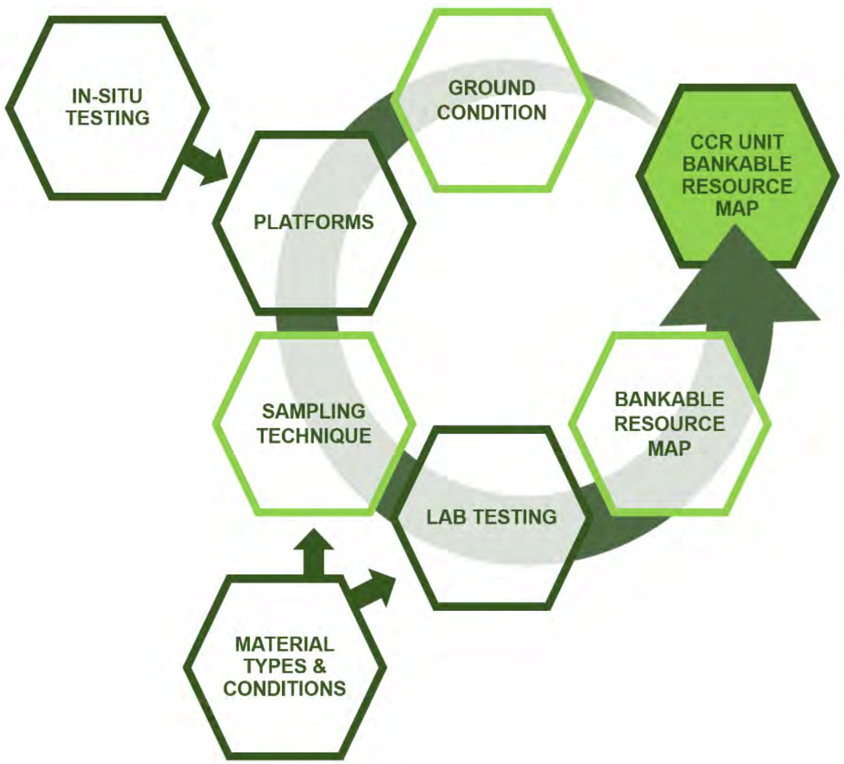


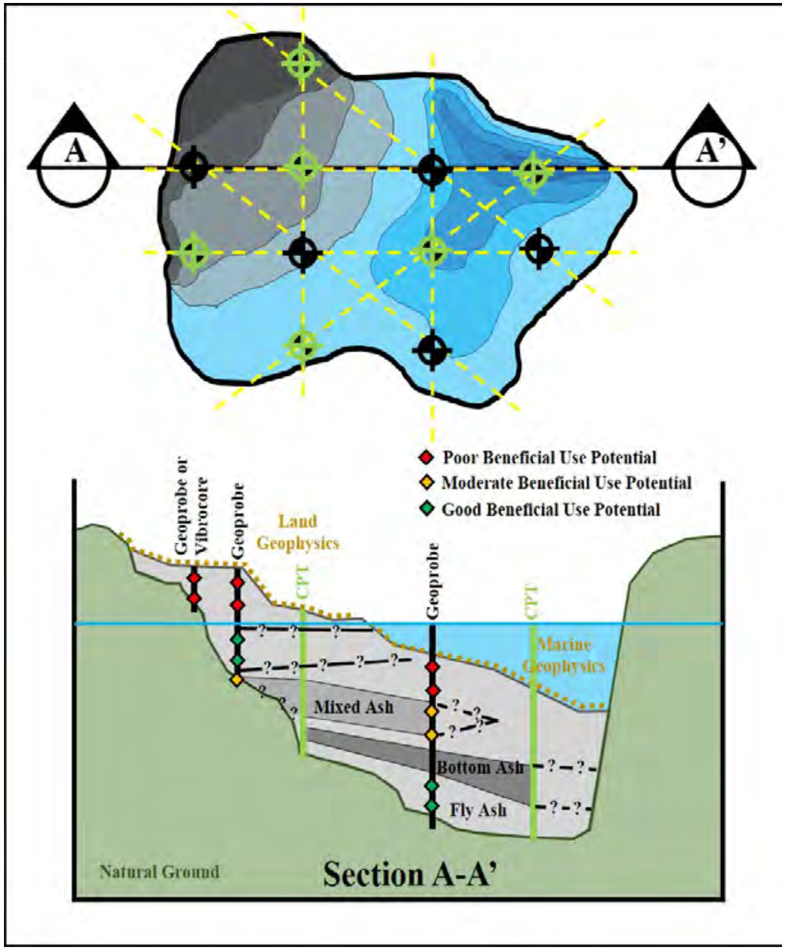

GOLDER

# Incorporating Beneficial Use Characterization and Planning Into Closure

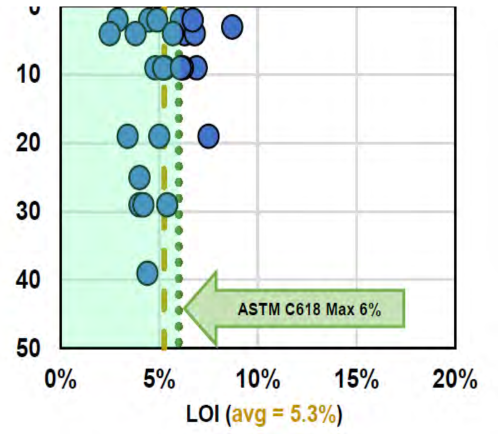
# Beneficial Use Evaluations

## EPRI Report – 3002013740 Under Program 78



# Beneficial Reuse Characterization




## Evaluate the CCR Resource

- Quantity – Develop Volumetric Estimates / Models by Material Type
  - Resource Map the CCR Unit
- **Quality of CRR for reuse**
  - Material Variability Vertically and Laterally
  - Disturbed samples typically fine for Beneficial Use Evaluations
- **Application / Use Options Evaluations (→ Concrete, → Fill, → other)**
- **Define the Market, Transportation, and Other Conditions**

## Is Beneficiation Required ?

- What kind (Carbon control, drying, material separation, thermal, etc.)
- Constraints on use opportunities

**Leverage operations, construction activities, and other investigation programs** to systematically obtain samples for beneficial use characterization.

**Can closure be situated / staged to improve potential future harvesting?**

# Beneficial Use Evaluations

## Optimizing your Investigation Program

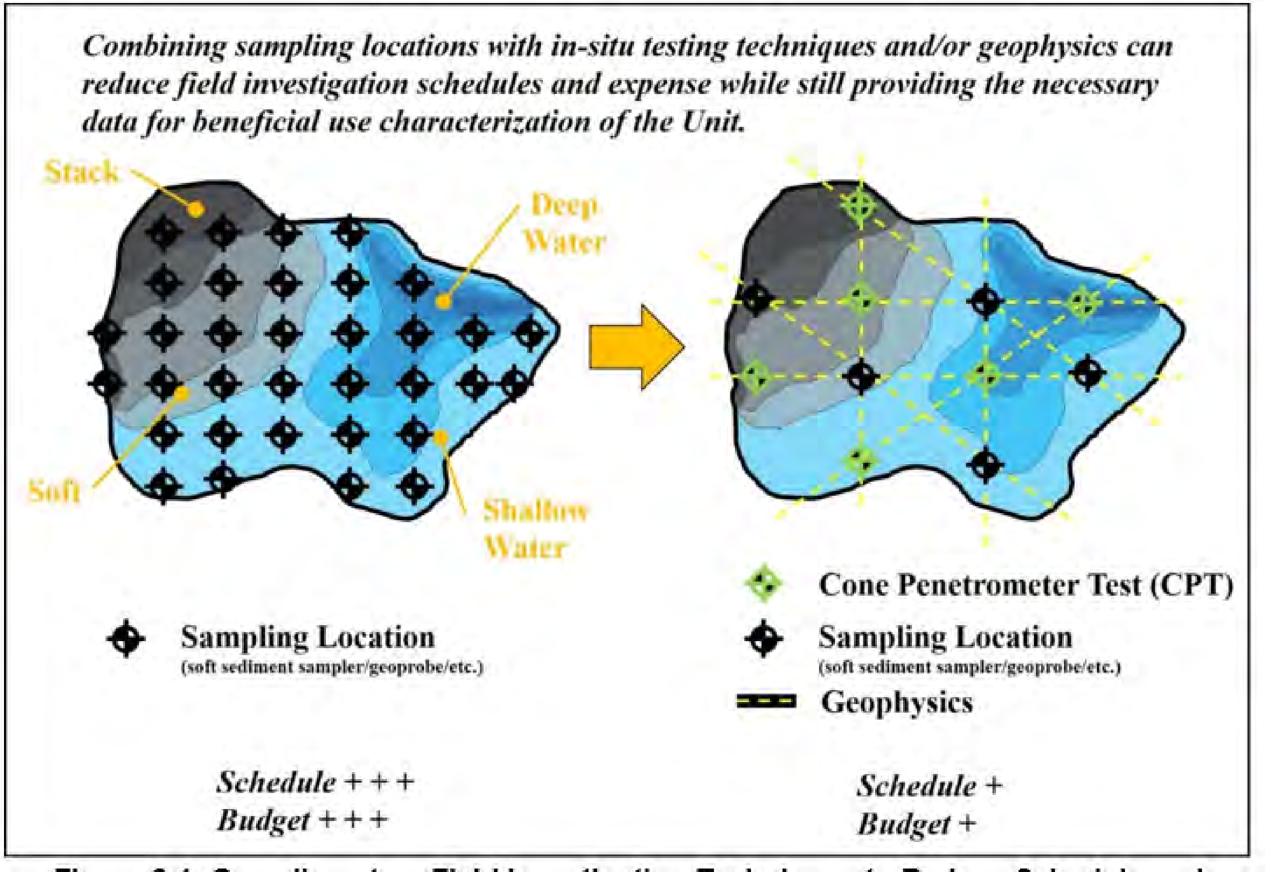
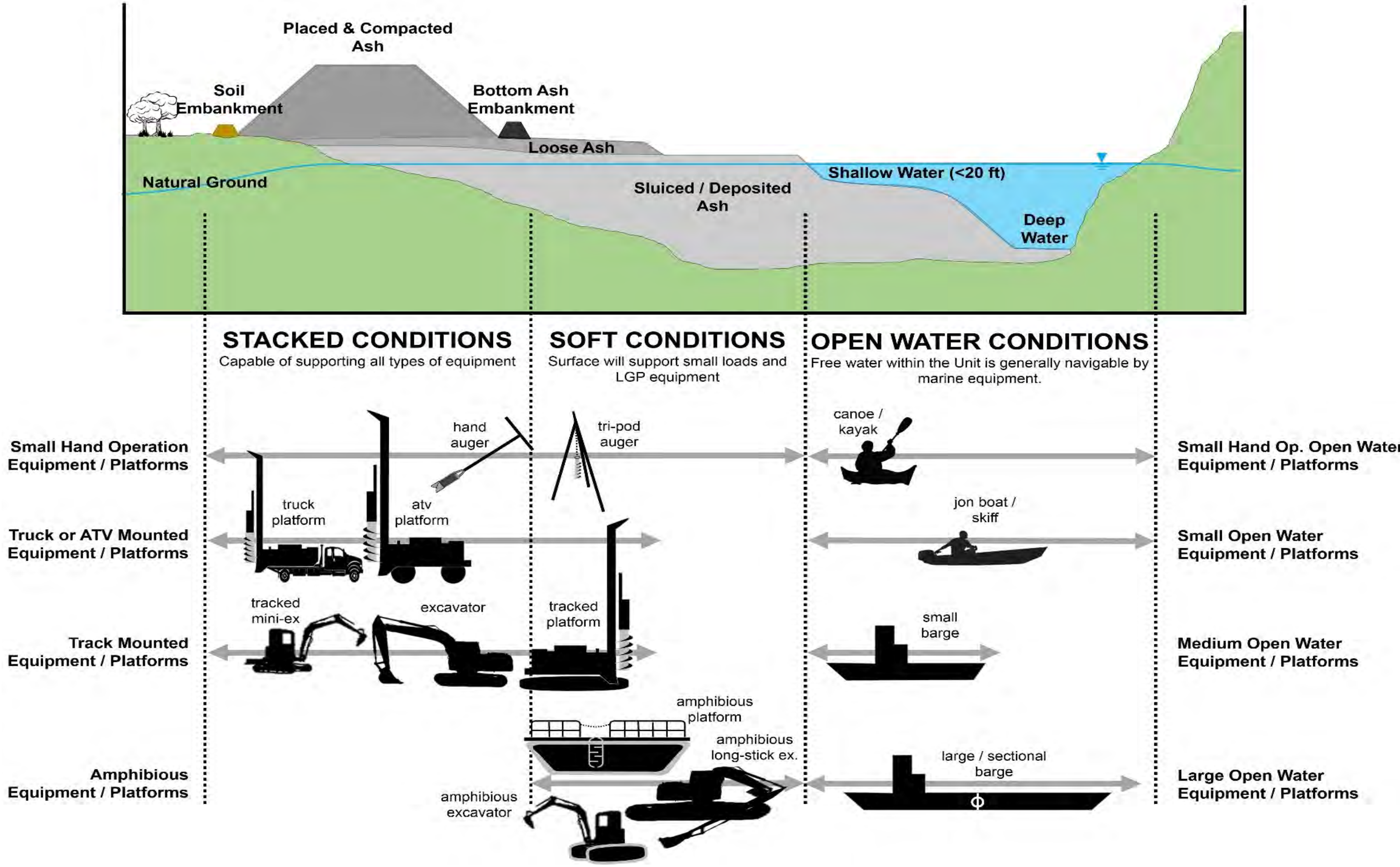



Figure 6-1: Complimentary Field Investigation Techniques to Reduce Schedule and Expense

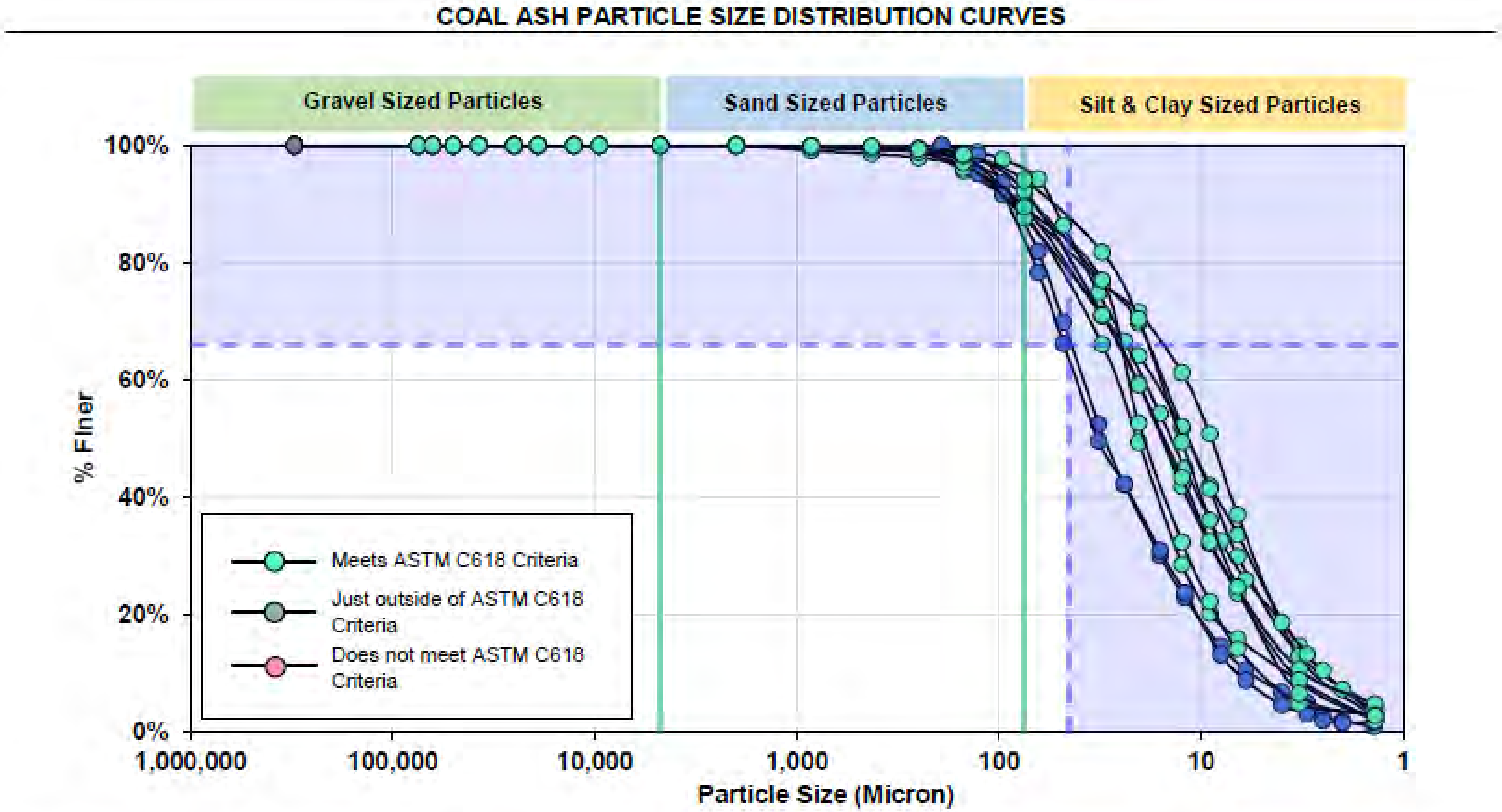
# Beneficial Use Evaluations

## Evaluation of Safe and Cost Effective Sampling Methods



# Beneficial Use Resource Evaluations

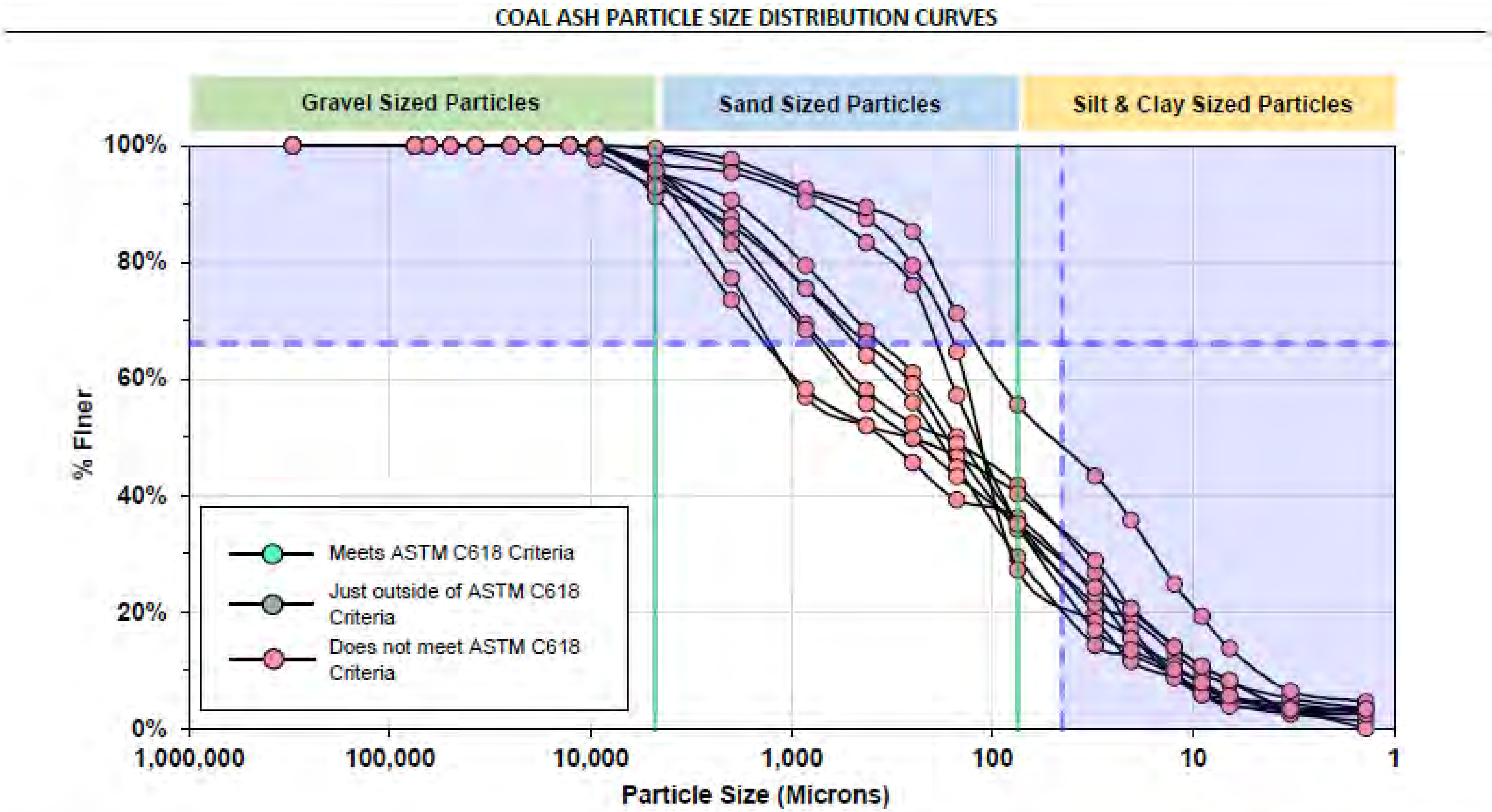
## CCR Unit Beneficial Use Data




**Note: (1)** Dashed blue lines show the ASTM C618 maximum criteria for Fineness, i.e. a minimum of 66% by mass of the sample should be finer than 45 microns. **(2)** The blue zone represents the allowable region of the PSD plot that is within the ASTM requirement for fineness. If any portion of the PSD plot is outside the blue zone, the sample does not meet the ATSM fineness criteria. **(3)** The green lines delineate the particle size transitions from gravel to sand size, and from sand to silt and clay sized particles.

# Beneficial Use Resource Evaluations

## CCR Unit Beneficial Use Data




**Note:** **(1)** Dashed blue lines show the ASTM C618 maximum criteria for Fineness, i.e. a minimum of 66% by mass of the sample should be finer than 45 microns. **(2)** The blue zone represents the allowable region of the PSD plot that is within the ASTM requirement for fineness. If any portion of the PSD plot is outside the blue zone, the sample does not meet the ATSM fineness criteria. **(3)** The green lines delineate the particle size transitions from gravel to sand size, and from sand to silt and clay sized particles.

# Follow up
# Questions & Discussion

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