Operations and Maintenance Guidelines for Coal Ash Landfills

Coal Ash Landfills are NOT the Same as Subtitle D Solid Waste Landfills

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1. INTRODUCTION:

The number of coal ash landfills that have been constructed in the past five years has increased substantially since the promulgation of new State regulations for the handling and long-term storage of coal combustion residuals (CCRs). Many of these recently constructed coal ash landfills were designed using methods and materials that are common for Subtitle D, lined, municipal solid waste (MSW) landfills. Review of several landfill designs indicate that many CCR landfills have geotextile filter layers, leachate collection pipes, liner systems, stormwater management features and operational plans that are often just "reformatted" of a MSW landfill design.

Owners and operators of coal ash landfills have experienced problems with the design and operational plans for their landfills that are attributable to a minor, but important differences between MSW, Subtitle D lined landfills and CCR landfills. This paper will discuss and evaluate these differences and provide practical solutions for providing a better design and operational control for coal ash landfills.

The overall purpose of this paper is to initiate discussion and technical interaction on what constitutes an effective CCR landfill design. It is recognized that CCR landfill design is a new and developing sub-field in the area of landfill design that merits additional discussion to develop best practices and design methods.

2. DIFFERENCES BETWEEN SOLID WASTE AND COAL ASH LANDFILLS

To understand coal ash landfills that have experienced design and operational problems, it is helpful to consider the primary differences between the waste materials at MSW landfills and those at coal ash or CCR landfills. A few of the key differences are:

Difference No.1 -- Particle Size:

- Coal ash is a homogeneous, mostly fine particle material that requires special sizing of the geotextile or aggregate drainage/filter layer to prevent clogging.
- MSW is a heterogeneous, large dimension, inconsistent size particles.

Difference No. 2 – Odors and Vector Control:

- Coal ash has very little organic fraction and therefore has almost no noticeable odor and off gases and minimal/no settlement issues.
- Coal ash typically does not need daily cover to prevent disease and rodent issues.
- MSW tends to have significant odor and vector issues if not placed, compacted and covered with daily cover soils or fabrics.
- After placement, the organic material in MSW will continue to degrade producing methane and odors that must be managed and settlement issues.

Difference No. 3 – Erodability and Moisture Sensitivity

- As a predominately silt-sized particle, coal ash is susceptible to erosion.
- Coal ash can lose strength quickly when in the presence of water if it is not compacted at or near the optimum moisture content.
- Most MSW comes to the landfill several percentage points below its saturation moisture content, and can absorb large amounts of moisture without an immediate loss in shear strength.
- MSW is not susceptible to erosion but is susceptible to blowing.

Difference No. 4 – Dust Control

- Coal ash can have significant issues with rapid surface drying, creation of dust and blowing of dust to off-site locations. These conditions can be difficult to control.
- At times, MSW is also difficult to contain with fences required to catch blowing trash.
- Most mixed MSW does not dry out as quickly as coal ash.

3. COMMON PROBLEMS AND SOLUTIONS

This section will highlight a few of the common problems that have been encountered by operators of coal ash landfills.

Problem No. 1: Ponded Surface Water above Leachate Collection Layers

It is common after the initial layers of ash have been placed for the surface water and runoff to build up in the landfill. This greatly reduces the collection system efficiency and the available storage volume in the landfill. It is often assumed that this is caused by plugged geocomposite and geonets. Recent testing indicates that the geocomposites and geonets still maintain a higher permeability than lose or compacted coal ash. This suggests that the problem is not with the geotextile or leachate collection layer, but the reduced infiltration rate of leachate through the compacted layers of coal ash.

To allow drainage of run-off from the surface of the coal ash to reach the .leachate collection layer, some type of vertical/horizontal connection to the leachate collection system using a "chimney drain" or a "drainage layer" is often required. Chimney drains are typically constructed in sections as the CCR is placed, and connected directly to the horizontal leachate collect system. See Figure 1.

A few important considerations for the design and installation of chimney drains:

- ✓ Locate the drains at a frequent enough spacing to handle runoff from large interior drainage areas that could occur during a wide variety of interim fill conditions.
- ✓ Size the chimney drain pipe and inlet for Peak Flow with a percentage of the surface water diverted to chimney drains and leachate collection system, based on a 10-year to 25-year storm.
- ✓ Divert most of the surface water away from the chimney drains and to surface water collectors without contacting the CCR material. This may require the installation of soil berms to control runoff/run-on, and rain covers to prevent infiltration of surface water.
- ✓ Provide adequate surface water diversion to direct large storm events to stormwater management ponds instead of overtopping the CCR landfill embankments. This may require redundant stormwater channels and/or interim soil diversion berms as part of the CCR landfill plans.
- ✓ Include daily inspection, cleanout and maintenance of chimney drain inlets in the operation and maintenance plan for the CCR landfill.

Drainage layers are typically constructed as the CCR is placed, and connected directly to the leachate collect system. See Figure 2.

A few important considerations for the design and installation of drainage layers:

- ✓ Generally, CCR is placed in 15-30 foot–thick lifts sandwiched between 1-2 foot–thick drainage layers of granular drainage material. The drainage layer is placed at a minimum 5-percent slope, toward exterior and interior berms, to promote drainage and dewatering of the CCR layers.
- ✓ The CCR is placed and compacted in a controlled manner such that stormwater sheets off toward the leachate collection system.
- ✓ The granular drainage material may be segregated bottom ash or other waste byproduct that exhibits a homogeneous particle size suitable.
- ✓ Perform annual NDG testing to document CCR is placed and compacted in accordance with the approved design.
- ✓ Perform as-built surveys to document each drainage layer has been constructed in accordance with the approved design.

Problem No. 2: Undersized Stormwater Management and Sediment Control Structures

As mentioned in the previous section, coal ash is a silt-sized particle that is highly susceptible to erosion and changes in moisture content. This material characteristic frequently results in stormwater management ponds (SWMP) and erosion control (E&S) devices that are filled with coal ash to capacity at more frequent intervals. These tendencies must be accounted for in the design by providing additional storage capacity and/or more frequent pond cleanouts and maintenance.

A few important items to consider in the design of SWM ponds and E&S devices on CCR landfills include:

- ✓ More frequent rock check dams in the surface water channels draining to the SWM ponds. Require more maintenance and cleanout of devices to account for silt-sized, more erodible coal ash.
- ✓ Consider the design of a two-stage SWM pond with smaller fore-bay structure that can be cleaned at more frequent intervals.
- ✓ Consider the use of turbidity curtains and other methods to promote settling and removal of silt-sized particles
- ✓ Oversize SWM ponds and E&S devices to account for the increased volume of silt-sized coal ash particles.
- ✓ Monitor the levels in ponds to verify when it is time to clean.

Problem No. 3: Dust Control and Blowing Ash

As a silt-sized material, coal ash is "notorious" for rapid surface drying that produces dust within a few hours after the initial placement and compaction. Common solutions include continuous spraying with water and covering with cover soils. Other solutions include:

- ✓ Minimizing the size of the "working face" or CCR placement area so that wetter, partially saturated ash is placed over drying layers.
- ✓ Placement of surface encapsulation product like Posi-shell and Gorilla Snot at the end daily operations.
- ✓ Covering with temporary geotextile or raincovers that can be reused and moved to new placement areas as the fill placement progresses.

4. DESIGN SOLUTIONS FOR COAL ASH LANDFILLS

This section provides a summary of a few design methods that have been used on coal ash landfills to increase the efficiency of CCR placement and compaction. By providing this summary the authors of the paper also recognize that there are many new and innovative ideas that are currently being used on other sites that are not mentioned.

4.1 Leachate Collection and Geotextile Design

To avoid the potential of a clogged and/or blocked leachate collection system during a major storm event, the components of the leachate collection system must be designed to handle silt-sized particles. The design may include a combination of redundant measures like over-sized silt traps and/or more frequent maintenance of the inlet structures and geotextile surface.

A few important items to consider for the design of the leachate collection system on CCR Landfills:

- ✓ Use laboratory clog tests to determine the geotextile and CCR clogging potential (ASTM D5101) and use the reduced drainage value for selection of the geotextile/geonet drainage materials.

- ✓ Design inlets to the leachate collection system and chimney drains with sufficient freeboard to allow settling and minimize material transport into horizontal drain pipes.
- ✓ Include frequent inspections of the geotextile surface of the leachate collection and/or chimney drain in the landfill operation and maintenance plan to prevent clogging of the leachate collection system

4.2 Leachate Collection and Aggregate Filter Design

Also used to avoid the potential of a clogged and/or blocked leachate collection system during a major storm event, the inclusion of an aggregate filter in combination with the leachate collection system.

A few important items to consider for this design of the leachate collection system on CCR Landfills:

- ✓ Proper selection of stone/gravel/sand to place directly over and around leachate collection piping to meet the required piping and hydraulic conductivity ratios which will help maintain long-term transmission of the leachate as well as not clogging and pipe protection.
- ✓ A 1-foot–thick granular drainage material is placed above the liner to act as a conduit for leachate, to provide efficient collection, and to protect the liner from operational loads and climatic effects
- ✓ Use heavy wall perforated and non-perforated piping with cleanouts that can be jetted annually to ensure pipe hydraulic capacity.

4.3 Interim Fill and Stormwater Management Plans

The placement and compaction of CCR materials can vary from site to site depending on the moisture content of the coal ash, the distance from the point of generation, and the need to provide dewatering or drying prior to placement. One of the best ways to avoid the common problems listed in the previous section is to develop carefully thought out fill plans that show the contractor where to install haul roads, place and compaction of CCR materials, and how to route stormwater from the working face. A few important items to remember for the development of CCR fill plans are:

- ✓ Design the haul roads and stormwater management channels so that surface water is directed away from the working face and to sediment traps, chimney drain inlets and/or drainage layers.
- ✓ Attempt to work the placement and compaction of CCR materials as compacted embankment instead of an "end dumped" waste material.
- ✓ Specify a maximum lift thickness and range of acceptable moisture contents for CCR materials prior to compaction.
- ✓ Provide locations for moving stockpiles of interim cover materials and/or staging areas for dust control methods and materials.
- ✓ DO NOT submit the interim fill plans as an item for regulatory approval. Fill plans are an operations activity that requires flexibility for the Contractor to account for changing weather and site conditions.
- ✓ Include probable location for interim stormwater management and E&S control measures, but allow Contractor flexibility to account for changing conditions.
- ✓ Design drainage channel slopes that reduce erosion and haul road grades that can be safely handled by standard construction equipment. Hint: Gradual drainage and haul roads flatter than 10 percent work best.

5. SUMMARY AND CONCLUSIONS

This paper and presentation was developed to provide a few ideas of what the authors have used effectively on CCR landfills and other industrial waste landfill designs. The information presented is by no means meant to provide the "final word" and/or a "checklist" for CCR landfill design. The main purpose of this paper is to encourage fellow landfill design engineers and CCR landfill owners and operators to STOP and THINK about the current methods used for CCR landfills. It is the author's opinion that simply using "reformatted" MSW landfill designs will not work for the design, construction, operation and closure of CCR landfills.

A secondary purpose of this paper is to initiate discussion and technical interaction on what has worked effectively for CCR landfill design and construction. It is our hope that this discussion and technical interaction will result in even better CCR landfill designs, and continued protection of the environment.

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INTRODUCTION

Coal Ash Landfills are NOT the Same as Subtitle D Solid Waste Landfills

- The number of CCR landfills has increased substantially with recent State and Federal regulations.
- Many recently constructed CCR landfills were designed using methods and materials from Subtitle D lined, municipal solid waste (MSW) landfills.
- Review of multiple designs indicate that many design features in CCR landfills are often just “reformatted” from a MSW landfill design.
- CCR owners and operators have experienced problems that are attributable to the minor, but important differences between CCR and MSW Subtitle D lined landfills.

AGENDA

- Intent and purpose of this presentation
- Discuss and evaluate the differences between coal ash and MSW as a waste material
- Identify common problems and recommended solutions
- Drill down on three important design solutions
- Few hints and recommendations for CCR landfill O&M Plans
- Summary and Discussion: Ideas and questions from the attendees

INTENT AND PURPOSE

- Initiate discussion and technical interaction on what constitutes an effective CCR landfill design.
- Recognize that CCR landfill design is a new and developing sub-field in the area of landfill design, that merits additional discussion to develop best practices and design methods.
- Encourage participation in the ACAA technical committee and possible subcommittee for CCR landfills
- Encourage additional research on issues unique to CCR landfills

DIFFERENCES BETWEEN SOLID WASTE AND COAL ASH LANDFILLS

- To understand why coal ash landfills that have experienced design and operational problems, it is helpful to consider the primary differences.
- **Difference No.1 -- Particle Size:**
  - Coal ash is a homogeneous, mostly fine particle material that requires special sizing of the geotextile or aggregate drainage/filter layer to prevent clogging.
  - MSW is a heterogeneous, large dimension, inconsistent particle size material.

DIFFERENCES BETWEEN SOLID WASTE AND COAL ASH LANDFILLS

- **Difference No. 2 – Odors and Vector Control:**
  - Coal ash has very little organic fraction and therefore has almost no noticeable odor and off gases and minimal/no settlement issues.
  - Coal ash typically does not need daily cover to prevent disease and rodent issues.
  - MSW tends to have significant odor and vector issues if not placed, compacted and covered with daily cover soils or geotextiles.
  - After placement, the organic material in MSW will continue to degrade producing methane, odors and settlement issues that must be managed.

DIFFERENCES BETWEEN SOLID WASTE AND COAL ASH LANDFILLS

- **Difference No. 3 – Erodability and Moisture Sensitivity**
  - As a predominately silt-sized particle, coal ash is susceptible to erosion.
  - Coal ash can lose strength quickly when in the presence of water, if it is not compacted at or near the optimum moisture content.
  - Most MSW comes to the landfill several percentage points below its saturation moisture content, and can absorb large amounts of moisture without an immediate loss in shear strength.

DIFFERENCES BETWEEN SOLID WASTE AND COAL ASH LANDFILLS

- **Difference No. 4 – Dust Control**
  - Coal ash can have significant issues with rapid surface drying, creation of dust and blowing of dust to off-site locations. These conditions can be difficult to control.
  - At times, MSW is also difficult to contain with fences required to catch blowing trash.
  - Most mixed MSW does not dry out as quickly as coal ash.

COMMON PROBLEMS AND SOLUTIONS

- Problem No. 1: Ponded Surface Water above Leachate Collection Layers
  - It is common after the initial layers of ash have been placed for the surface water and stormwater runoff to build up in the landfill.
  - This greatly reduces the collection system efficiency and the available storage volume in the landfill.
  - It is often assumed that this is caused by plugged geocomposite and geonets.
  - Recent testing indicates that geocomposite geonets still maintain a higher permeability than lose or compacted coal ash.

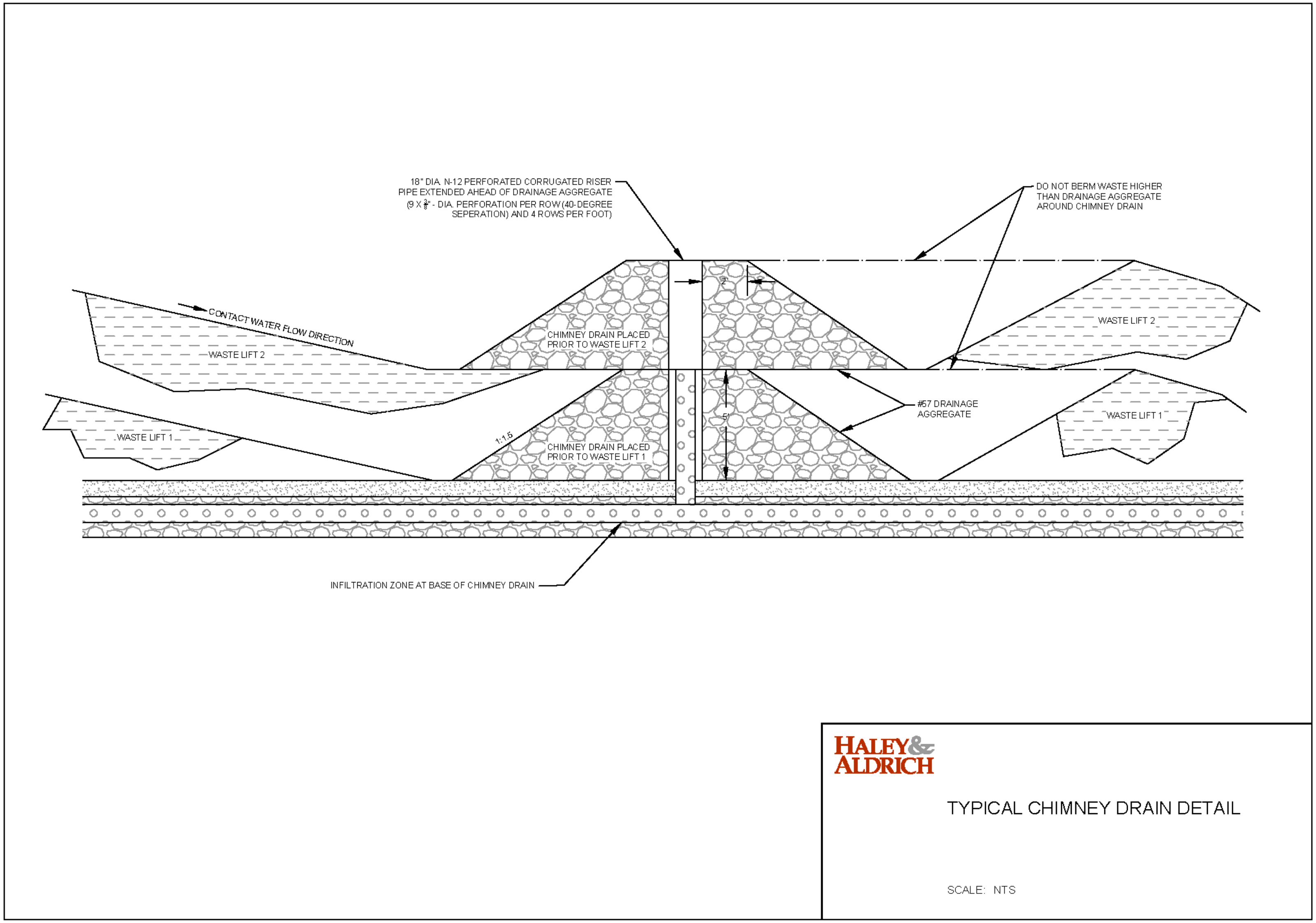
COMMON PROBLEMS AND SOLUTIONS

- Problem No. 1: Ponded Surface Water above Leachate Collection Layers
  - This suggests that the problem is not with the geotextile or leachate collection layer, but attributable to the reduced infiltration rate of leachate through the compacted layers of coal ash.
  - To allow drainage of run-off from the surface of the coal ash to reach the leachate collection layer, some type of vertical/horizontal connection to the leachate collection system using a “chimney drain” or a “drainage layer” is often required.
  - Chimney drains and drainage layers are typically constructed in sections as the CCR is placed, and connected directly to the horizontal leachate collect system.
  - See Solutions A, B, and C. Figures 1 and 2.

COMMON PROBLEMS AND SOLUTIONS

- Problem No. 1: Solution A -- Chimney Drains
- A few important considerations for the design and installation of chimney drains:
  - ✓ Locate the drains at a frequent enough spacing to handle runoff from large interior drainage areas that could occur during a wide variety of interim fill conditions.
  - ✓ Size the chimney drain pipe and inlet for Peak Flow with a smaller percentage of the surface water diverted to chimney drains and leachate collection system, based on a 10-year to 25-year storm.
  - ✓ Divert most of the surface water away from the chimney drains and to surface water collectors without contacting the CCR material. This may require the installation of soil berms to control runoff/run-on, and rain covers to prevent infiltration of surface water.

FIGURE 1 – Typical Chimney Drain



COMMON PROBLEMS AND SOLUTIONS

Problem No. 1: Solution B – Divert Stormwater & Maintenance

A few important design and operation considerations for SWM devices at CCR landfills include:

- ✓ Provide adequate surface water diversion to direct large storm events to stormwater management ponds instead of overtopping the CCR landfill embankments.
- ✓ Do not exclusively rely on pumping or siphons to control ponded stormwater water over leachate lines. Pumps can fail, siphons plug.
- ✓ Require redundant stormwater channels and/or interim soil diversion berms as part of the CCR landfill plans.
- ✓ Include daily inspection, cleanout and maintenance of chimney drain inlets in the O&M plan for the CCR landfill.

Hint: When considering the cost of additional leachate control measure, remember to look at the life cycle cost of an NOV.

COMMON PROBLEMS AND SOLUTIONS

- Problem No. 1: Solution C – Drainage Layers
- A few important considerations for the design and installation of drainage layers:
  - ✓ Generally, CCR is placed in 15 to 20 foot–thick layers (1 to 2 foot lifts) sandwiched between 1-2 foot–thick drainage layers of granular drainage material. The drainage layer is placed at a minimum 5-percent slope, toward exterior and interior berms, to promote drainage and dewatering of the CCR layers.
  - ✓ The CCR is placed and compacted in a controlled manner such that stormwater sheets off toward the leachate collection system.
  - ✓ The granular drainage material may be segregated bottom ash or other waste byproducts that have a consistent particle size.
  - ✓ Perform regular moisture density/compaction testing to document how the CCR is placed and compacted in accordance with the approved design.
  - ✓ Perform as-built surveys to document that the drainage layers have been constructed in accordance with the approved design and at the recommended locations.

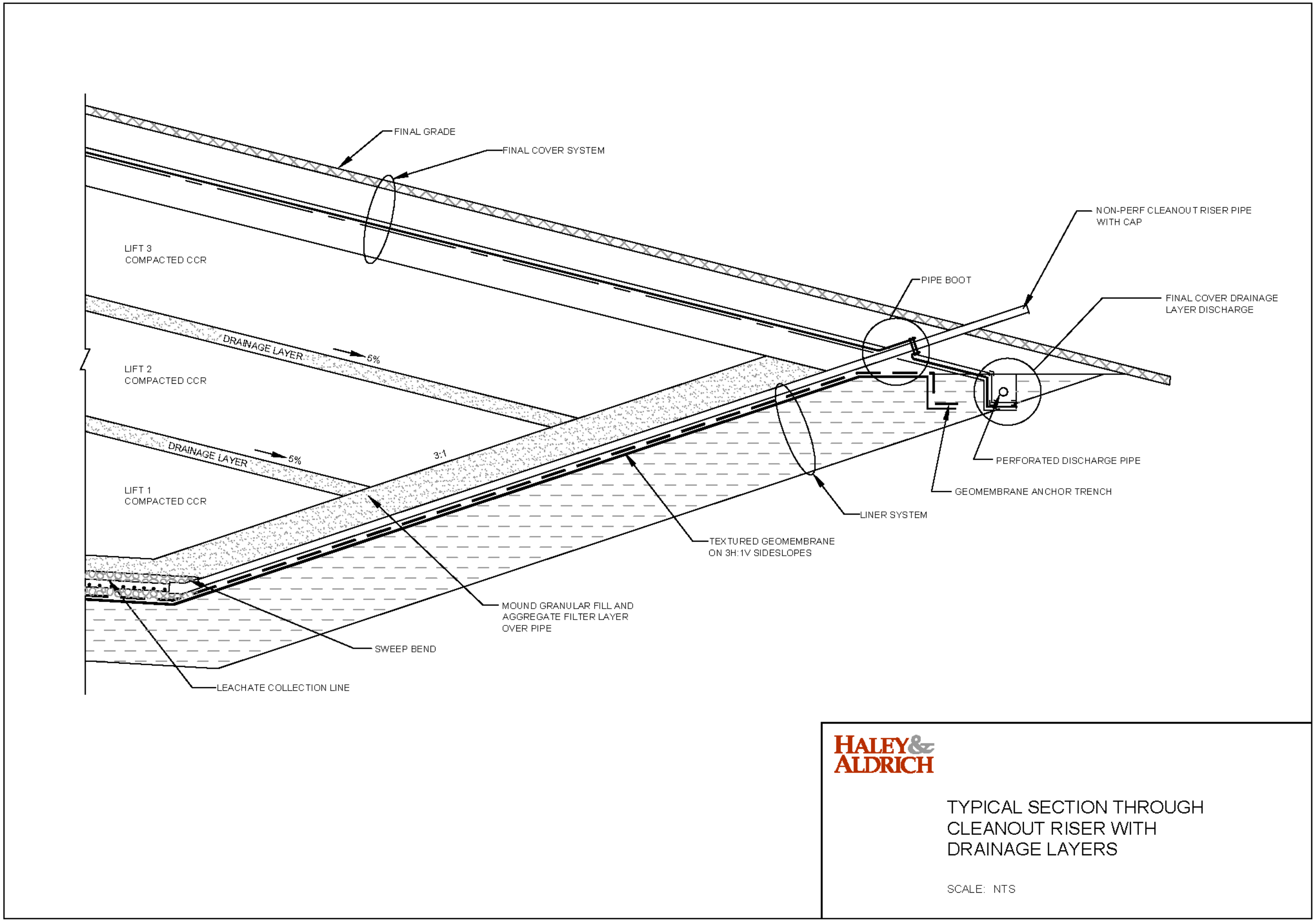
Quality Control Testing for CCR Placement

- For slope stability, decreased permeability and reduced erodability specify the percent compaction and moisture content.
- Typical values for CCR are 90 to 95 percent of the Standard Proctor at +/-5 percent of the OMC.
- Verify placement and compaction by a system of regular observation and testing.

Reference: http://www.google.com/imgres?imgurl=http://www.leomo.info/leomobg2010

Reference: http://www.ifandp.com/article/001894.html

FIGURE 2 – Typical Interim Drainage Layers



COMMON PROBLEMS AND SOLUTIONS

- Problem No. 2: Undersized Stormwater Management and Sediment Control Structures
  - Coal ash is a silt-sized particle that is highly susceptible to erosion and changes in moisture content.
  - This material characteristic frequently results in stormwater management ponds (SWMP) and erosion control (E&S) devices that are filled with coal ash to capacity at more frequent intervals.
  - These tendencies must be accounted for in the design by providing additional storage capacity and/or more frequent pond cleanouts and maintenance.

COMMON PROBLEMS AND SOLUTIONS

- Problem No. 2: Solutions
- A few important items to consider in the design of SWM ponds and E&S devices on CCR landfills include:
  - ✓ More frequent rock check dams in the surface water channels draining to the SWM ponds. Require more maintenance and cleanout of devices to account for silt-sized, more erodible coal ash.
  - ✓ Consider the design of a two-stage SWM pond with smaller fore-bay structure that can be cleaned at more frequent intervals.
  - ✓ Consider the use of turbidity curtains and other methods to promote settling and removal of silt-sized particles before the outlet structure.
  - ✓ Oversize SWM ponds and E&S devices to account for the increased volume of silt-sized coal ash particles.
  - ✓ Monitor the levels in ponds at more frequent intervals to verify when it is time to clean. SWM ponds at CCR landfills can fill up **FAST** with sediment!

COMMON PROBLEMS AND SOLUTIONS

- Problem No. 3: Dust Control and Blowing Ash
  - As a silt-sized material, coal ash is “notorious” for rapid surface drying that produces dust within a few hours after the initial placement and compaction.
  - Problem No. 3: Solutions
  - A few important considerations for dust control and blowing ash:
    - ✓ Common solutions include continuous spraying with water and covering with cover soils. Maybe a full time sprinkling system.
    - ✓ Minimizing the size of the “working face” or CCR placement area so that wetter, partially saturated ash is placed over drying layers.
    - ✓ Placement of surface encapsulation product like Posi-shell and Gorilla Snot at the end daily operations.
    - ✓ Covering with temporary geotextile or raincovers that can be reused and moved to new placement areas as the fill placement progresses.

DESIGN SOLUTIONS FOR COAL ASH LANDFILLS

- Leachate Collection: Inlet Design and Geotextiles
- Leachate Collection: Aggregate Filter Design
- Interim Fill and Stormwater Management Plans

CCR Leachate Collection System

- To avoid the potential of a clogged and/or blocked leachate collection system during a major storm event, the components of the leachate collection system must be designed to handle silt-sized particles.
- Two design considerations are discussed:
  - Inlet structures and geotextile surface.
  - Aggregate filter.

Leachate Collection: Inlet Design and Geotextiles

- A few important items to consider for the design of the inlets, geotextile selection and maintenance.
  - ✓ Design inlets to the leachate collection system and chimney drains with sufficient freeboard to allow settling and minimize material transport into horizontal drain pipes.
  - ✓ Apparent Opening Size (AOS) relative to the particle size of the coal ash becomes an important design parameter.
  - ✓ Use laboratory clog tests to determine the geotextile and CCR clogging potential (ASTM D5101) and use the reduced drainage value for selection of the geotextile/geonet drainage materials.
  - ✓ Include more frequent inspections of the geotextile surface of the leachate collection and/or chimney drain in the landfill O&M plan to prevent clogging of the leachate collection system.

Leachate Collection: Aggregate Filter Design

- A few important items to consider for the design of aggregate filters:
  - ✓ Proper selection of stone/gravel/sand that is placed directly over and around leachate collection piping to meet the required piping and hydraulic conductivity ratios.   This will help maintain long-term transmission of the leachate, minimize clogging and provide pipe protection.
  - ✓ A 1-foot–thick granular drainage material is placed above the liner to act as a conduit for leachate, to provide efficient collection, and to protect the liner from operational loads and climatic effects
  - ✓ Use heavy wall perforated and non-perforated leachate pipe with cleanouts that can be jetted annually to maintain pipe hydraulic capacity.

Interim Fill and Stormwater Management Plans

- One of the best ways to avoid common problems is to develop carefully thought out fill plans that show the contractor where to install haul roads, place and compaction of CCR materials, and how to route stormwater from the working face.
- A few important items to remember for the development of CCR fill plans are:
  - ✓ Design the haul roads and stormwater management channels so that surface water is directed away from the working face and to sediment traps, chimney drain inlets and/or drainage layers.
  - ✓ Attempt to work the placement and compaction of CCR materials as a compacted embankment instead of an “end dumped” waste material.
  - ✓ Show the location and sizing of larger stormwater management channels along haul roads to avoid overtopping and erosive velocities.

DESIGN SOLUTIONS FOR COAL ASH LANDFILLS – Other Items

- ✓ Specify a maximum lift thickness and range of acceptable moisture content for CCR materials prior to compaction.
- ✓ Provide locations for stockpiles of interim cover materials and/or staging areas for dust control methods and materials.
- ✓ DO NOT submit the interim fill plans as an item for regulatory approval. Fill plans are an ***operations activity*** that requires flexibility for the Contractor to account for changing weather and site conditions.
- ✓ Include probable location for interim stormwater management and E&S control measures, but allow Contractor flexibility to account for changing conditions.
- ✓ Design drainage channel slopes that reduce erosion and haul road grades that can be safely handled by standard construction equipment. Hint: Gradual drainage channels and haul roads flatter than 10 percent work best.

SUMMARY AND DISCUSSION:

- This paper and presentation provides a summary of methods that have been used successfully on CCR Landfills primarily in the Southeastern US. By no means the final word!
- Primary purpose of this paper and presentation:
  - To encourage fellow landfill design engineers and CCR landfill owners and operators to STOP and THINK about the current methods used for CCR landfills.
  - Our opinion is that simply using "reformatted" MSW landfill designs will not work for the design, construction, operation and closure of CCR landfills.
- A secondary purpose:
  - Initiate discussion and technical interaction on what has worked effectively for CCR landfill design and construction.
  - Our hope that this discussion and technical interaction will result in even better CCR landfill designs, and continued protection of the environment.