DESIGN AND ANALYSIS OF THE SURFACE WATER MANAGEMENT SYSTEM

GEOSYNTEC CONSULTANTS

COMPUTATION COVER SHEET

Client: TVA **Project:** KIP Gypsum Disposal Facility **Project/Proposal #:** GR3731 **Task #:** 06

TITLE OF COMPUTATIONS DESIGN & ANALYSIS OF THE SURFACE WATER MANAGEMENT SYSTEM / (See Note below)

COMPUTATIONS BY: Signature Alexander Maestre — DATE 12/7/06

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APPROVED BY: (PM or Designate) Signature R Neil D — DATE 1/15/2007

Printed Name and Title: Neil Davies, Principal/Vice President

APPROVAL NOTES: Calculations revised based on client-review to reflect re-routing storm water (previously passing through a culvert under the pond) around the pond. No revisions to ~~the~~ runoff from the cover system. Revisions only affect the run-on areas. GK 12/13/06

REVISIONS (Number and initial all revisions)

NO.	SHEET	DATE	BY	CHECKED BY	APPROVAL

GEOSYNTEC CONSULTANTS

COMPUTATION COVER SHEET

Client: TVA **Project:** KIF Gypsum Disposal Facility **Project/Proposal #:** GR3731 **Task #:** 06

TITLE OF COMPUTATIONS DESIGN & ANALYSIS OF THE SURFACE WATER MANAGEMENT SYSTEM

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See comment

APPROVAL NOTES: This was revised on 12/13/06. Please see new cover sheet dated 12/13/06.

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Written by: Sowmya Bulusu / Alexander Maestre Date: 12/07/06 Reviewed by: Ganesh Gopalakrishnan Date: 12/13/06

Client: TVA Project: Kingston Fossil Plant Gypsum Disposal Facility Project/Proposal No.: GR3731 Task No.: 06

DESIGN & ANALYSIS OF THE SURFACE WATER MANAGEMENT SYSTEM

BACKGROUND

This calculation package was prepared in support of the engineering design activities performed by GeoSyntec on behalf of Tennessee Valley Authority (TVA) for the proposed TVA Kingston Fossil Plant Gypsum Disposal Facility (herein referred as KIF Gypsum disposal facility), Roane County, Tennessee. GeoSyntec understands that TVA will submit this package (and other associated design packages) to the Tennessee Department of Environment and Conservation (TDEC).

PURPOSE

The purpose of this calculation package is to present the analyses and design of the proposed surface water management system for the KIF Gypsum Disposal Facility. The specific goals of this package are to present:

- an overview of the proposed surface water management system for the disposal facility;
- the regulatory requirements and the design criteria;
- the design of the various components of the surface water management system, including run-on control system, sediment basin, drainage benches, downdrains, downchutes, perimeter drainage channels, and culverts; and
- the results of the calculations for post-development peak discharges from the site.

SURFACE WATER MANAGEMENT SYSTEM - OVERVIEW

The proposed grading plan of the surface water management system for the KIF Gypsum Disposal Facility is provided in Attachment 1. The cover system will have a 4 percent slope from the crest to an elevation of 980 ft, and then a 33 percent (i.e., 3 horizontal: 1 vertical) slope from the elevation of 980 ft downwards. Benches will intercept surface water runoff from the cover slopes and convey the runoff to downdrain pipes, which will convey the runoff to the perimeter drainage channels located at the toe of the cover system. The perimeter drainage channels are sloped towards the south-west corner of the disposal facility and will connect to a drop-inlet and three 48-inch diameter culvert system under the perimeter access road conveying runoff to the stormwater pond located to the south-west of the disposal facility. The stormwater pond will not have a primary outlet structure. The water levels in the pond will be controlled by pumping. Storm water collected in the pond will be pumped using a storm water lift station and conveyed via a force main to the currently permitted National Pollutant Discharge Elimination System (NPDES) discharge point near the plant (i.e., plant discharge channel). The stormwater lift station was designed to have three pumps, each pump having a different turn-on elevation. The first pump is designed to start pumping out water when the water level in the pond reaches an elevation of 756 feet. The pump turnoff elevation is 755 feet.

Runoff from primarily undisturbed areas to the north of the disposal facility (hereinafter referred to as "run-on") will be intercepted by a system of drainage channels to prevent from "running-on" to the active portion of the disposal area. This system of drainage channels will collect and convey run-on to two different locations. Run-on from approximately 55.42 acres in the northwest portion of the site will be diverted and conveyed to Watts Bar Lake-Clinch River through an outfall that will be located in the southwestern corner of the site, west of the Proposed Gypsum Dewatering Facility Area. Run-on from approximately 43.18 acres in the northeastern portion of the site will be diverted and conveyed through a previously existing drainage path east of the disposal facility leading to the Clinch River. The stormwater management system for this facility is designed such that run-on from undisturbed areas (i.e., outside the limits of the disposal facility) will bypass the stormwater pond.

REGULATORY CRITERIA & DESIGN APPROACH

The surface water management system is designed to meet (and exceed) regulatory requirements of the "Rules of TDEC, Division of Solid Waste Management" [TDEC, 2005]. Specifically, the following requirements of TDEC Rule Chapter 1200-1-7 were considered in the design.

- *The operator must design, construct, operate, and maintain a run-off management system to collect and control at least the peak flow volume resulting from a 24 hour, 25 year storm.*

- *Holding facilities (e.g., sediment basins) associated with run-on and run-off control systems must be designed to detain at least the water volume resulting from a 24-hour, 25-year storm, and to divert through emergency spillways at least the peak flow resulting from a 24-hour, 100-year storm.*

- *The operator must design, construct, operate, and maintain a run-on control system capable of preventing flow onto the active portion of the facility for all flow up to and including the peak discharge from a 24-hour, 25-year storm.*

In addition to the above, sediment storage requirements provided in the "Tennessee Erosion and Sediment Control Handbook" [TDEC, 2002] were considered in the design of the stormwater pond. Specifically, the handbook states that "*In order to maximize trapping and* *retaining the incoming sediment, the basin should have a permanent pool, or wet storage component and a dry storage component that dewaters over time. The volume of permanent pool (needed to protect against re-suspension of sediment and to promote better settling conditions between runoff events) must be at least 67 cubic yard per acre of drainage area and the volume of dry storage above the permanent pool (needed to prevent "short-circuiting" of the basin during larger storm events) must be at least an additional 67 cubic yards per acre of drainage area*".

The runoff and run-on management system for the facility was designed such that all conveyances (such as channels and pipes) will be able to convey calculated peak discharges from a 25-year 24-hour design storm with sufficient free-board, and will be able to convey calculated peak discharge from a 100-year 24-hour design storm without reaching full capacity (i.e., overtopping in the case of channels). The stormwater pond for the site is designed to detain flows from the cover system of the disposal facility, and will be able to hold the calculated sediment storage volume and the calculated runoff volume from a 25-year 24-hour design storm without the water elevation reaching the elevation of the emergency spillway. For the 100-year 24-hour storm event, discharge from the emergency spillway is negligible (i.e., 0.14 cfs).

ANALYSIS METHODS & SOFTWARE

Hydrologic analysis procedures presented in TR-55 [SCS, 1986] are adopted for analyses performed for the design of the stormwater management system for this project. Standard hydraulic design procedures (as identified subsequently within this package) are adopted to design the various components of the stormwater management system based on the results of hydrologic analyses.

Computer program HydroCAD™ [2004] is used as a tool to perform hydrologic analyses. The program uses hydrology procedures provided in TR-55, combined with other hydrology and hydraulics calculations. In addition to the hydrologic analyses performed using HydroCAD, culverts were modeled using CulvertMaster® [1986]. This computer program uses Federal Highway Administration (FHWA) recommended methodologies for analyses/design of culvert systems.

MAJOR CALCULATION PARAMETERS

- **Drainage Area Delineation:** Attachment 2 presents a schematic plan of the post development surface water management system for the disposal facility. The plan shows the delineation of subareas on the cover system and adjoining runon areas. The schematic plan also shows other design components such as channels and pipes.

- **Rainfall Distribution**: Attachment 3A [SCS TR-55, 1986] shows the location of the site on a rainfall distribution map of the United States. The site is located in Roane County, Tennessee, which is categorized by SCS Type II Rainfall Distribution.

- **Rainfall Depths:** Attachment 3B presents the site location and the rainfall depth for the 2-year, 25-year, and 100-year 24-hour design storms. The 2-year rainfall depth is used for calculating the times of concentration for hydrologic modeling. The rainfall depths are shown in the following table.

Return Period (years)	Design Rainfall Depth (inches)
2	3.4
25	5.7
100	6.7

- **Hydrologic Soil Groups (HSG):** Attachment 4 presents the regional soils map for the vicinity of the site. Major soil units found within the areas of interest are listed in the table in Attachment 4. Hydrologic Soil Group B was used for the run-on areas for analyses performed in this package. For the final cover subareas, it is anticipated that the vegetative/ protective cover of the final cover, will consist of permeable silty sands of hydrologic soil group C, to promote growth of vegetation; however hydrologic soil group D was used in the analyses to represent the more conservative condition (i.e., higher runoff).

- **Curve Numbers (CN):** CNs were selected based on Attachment 5 [SCS TR-55, 1986]. The following table summarizes the CNs chosen for the analyses performed in this package.

Area Description	Condition	HSG	CN
Run-on Areas Outside Cover Limits	Woods – Grass combination	B	73
Disposal Area Cover System	Open Space, Good Hydrologic Condition (Grass Cover>75%)	D	80
Streets and Roads	Impervious – Paved Areas	D	98
Stormwater Pond	N/A	N/A	98

- **Nodal Network Diagram:** Attachment 6 presents a diagram of the nodal network used in HydroCAD for hydrologic analyses which parallels the schematic plan shown in Attachment 2.

- **Properties of Subareas:** Attachment 7 presents the properties of the subareas of included in the nodal network above. The calculated areas (in acres) of each subarea, curve number, and computations for the times of concentration are included in Attachment 7.

  Time of concentration for each area was calculated as the travel time along the assumed longest flow line within the subarea. Along each flow line, the flow was subdivided into various segments based on the flow type (i.e., sheet flow, shallow concentrated flow, ditch flow, and culvert/pipe flow). Computations for travel time for sheet flow are performed using the equation for Manning's kinematic solution [SCS TR-55, 1986]:

$$T_t = \frac{0.007(nL)^{0.8}}{(P)^{0.5} S^{0.4}}$$

  where, T_t=travel time (hr), n=Manning's roughness coefficient, L=flow length (ft), P=2-year, 24-hour rainfall depth (inches), and S=land slope (ft/ft). After a maximum of 300 feet, sheet flow is assumed to become shallow concentrated flow. After calculating the average velocity, travel time is calculated using the following equation [SCS TR-55, 1986]:

$$\mathrm{T_t} = \frac{\mathrm{L}}{3600 \times \mathrm{V}}$$

  where, T_t=travel time (hr), L=flow length (ft), and V=velocity (ft/s).

COMPUTATIONS USING HydroCAD

Calculations were performed using HydroCAD for the input parameters discussed in the previous section for the 25-year, 24-hour design storm, and the 100-year, 24-hour storm. The computer program results are presented in Attachment 8.

DESIGN OF SURFACE WATER MANAGEMENT SYSTEM COMPONENTS

Stormwater Pond

A sediment storage capacity of 67 cubic yards per acre of disturbed area is recommended by the TDEC in the "Tennessee Erosion and Sediment Control Handbook" [TDEC, 2002]. This translates to a minimum required sediment storage volume of 4.01 acre-ft for the stormwater pond (referred to as SP in HydroCAD analyses) based on the disturbed area draining storm water into the pond. It is recommended that the sediment be cleaned out when two-thirds (66 percent) of the required sediment storage volume has been filled with sediment. Based on a stage-storage relationship as shown in Attachment 9, a sediment cleanout elevation of 753.2 feet is recommended. As stated earlier, the first pump for the stormwater pond is designed to turn on at an elevation of 756 feet. Therefore, the analysis was performed assuming that the available storage capacity of the pond is from elevation 756 feet to the elevation of the emergency spillway (i.e., 764 feet).

Drainage Benches

Drainage benches on the cover system are designed as V-shaped with a minimum longitudinal slope of 1 percent. Benches will have left and right side slopes of 3H:1V (i.e. 33.3 percent) and 10H:1V (10 percent), respectively, and an available flow depth of 1.5 feet. The design methodology is presented in Attachment 13. The allowable discharge in the drainage benches is estimated using Manning's equation [Chow, 1959] which is expressed as:

$$Q = \frac{1.49}{n} AR^{2/3} S_o^{\ 1/2}$$

where, Q=discharge (cfs), n=Manning's roughness coefficient, A=area of cross-section of flow (ft^2), R=hydraulic radius=A/P, P=wetted perimeter (ft), and S_o=longitudinal slope (ft/ft).

The final cover area contributing to the critical drainage bench is 2.33 acres. The peak discharge of 12.98 cfs is calculated for the critical drainage bench as shown in Attachment 10. The drainage benches shall be vegetated to prevent scour during peak flows. The calculated depth of flow from a 25-year, 24-hour design storm is 0.75 ft, resulting in a freeboard of 0.75 ft.

Downdrains

The downdrains are designed as 24-inch diameter, corrugated High Density Polyethylene (HDPE) pipes with smooth interiors and will be installed on the top of the final cover system. The downdrains will have longitudinal slopes varying from 17.3 percent to 27.2 percent on the final cover, with the slope being 4 percent at the drainage bench intersections on the final cover. Downdrains are designed in this package using a 4 percent longitudinal slope representing the most critical design condition. For design purposes the highest peak discharge from a subarea on the final cover (58.2 cfs from Subarea 202; obtained from HydroCAD) is assumed as the peak discharge for downdrain design. The design methodology is presented in Attachment 11. The capacity of a 24-inch diameter pipe sloped at 4 percent (70.47 cfs) is greater than the highest flow from a subarea (i.e., 58.2 from Subarea 202) to a downdrain as presented in Attachment 11.

Drainage Channels

Drainage channels were modeled in HydroCAD in the post-development analysis of the cover system as "reaches". The summary of drainage channel properties is presented in Attachment 12 along with the related output of the HydroCAD analysis.

In order to design the type of lining, the following procedure was followed. According to [ASCE 1992], the permissible tractive stress for Class B grass was 1 psf. The tractive stress at design discharge is calculated for each reach, and grass lining was recommended for those with a tractive stress less than 1 psf. At reaches, where tractive stresses higher than 1 psf were calculated, riprap lining was recommended. The following equation was used to calculate the size of riprap [ASCE 1992] required for lining the channels:

$$d_{50} = 12\left[64.4QS_o^{\frac{13}{6}}\left(\frac{z}{z^2+1}\right)\right]^{\frac{2}{5}}$$

where, d_{50}=minimum median riprap diameter (in), Q=discharge (cfs), S_o=longitudinal slope (ft/ft), and z=side slope of the channel.

The d_{50} of the recommended riprap is also presented in Attachment 12.

Culverts

Geometric properties and other calculation parameters of culverts were input in HydroCAD as reaches: C1, C2, C3, C4, C5, C6, C7, and C8 for overall hydrologic analyses. The summary of the culvert sizes and geometric properties is presented in Table 1 of Attachment 13. Table 1 also shows the 25-year, 24-hour peak discharge from hydrologic analyses and demonstrates that each culvert pipe will have sufficient capacity to convey the 25-year, 24-hour design storm when analyzed using the Manning's Equation.

In addition to the above, CulvertMaster® was used to analyze the hydraulic condition for each culvert system for the 100-year, 24-hour peak discharge, such that the design would not result in headwater buildup in the inlets that would overtop the inflow channels. All the culverts were controlled at the entrance except for C1 that conveys the runoff collected from the final cover system of the disposal area to the stormwater pond. For the 100-year, 24-hour peak design discharge, it was assumed that the tailwater elevation of C1 corresponded to the invert elevation of the emergency spillway (a conservative assumption representing the worst case water level in the pond). The summary of outputs from CulvertMaster, for culverts C1 through C8, is presented in Table 2 in Attachment 13. The ditches will be provided with sufficient depth at the culvert intersections to accommodate the headwater buildup without overtopping.

REFERENCES

ASCE, "*Design and Construction of Urban Stormwater Management Systems*", ASCE Manuals and Reports of Engineering Practice No. 77, New York, 1992.

Chow, V.T, "*Open Channel-Hydraulics*", McGraw-Hill, 1959.

CulvertMaster, "*CulvertMaster®: Culvert Design and Analysis Software, Version 3 for Windows*", Haestad Methods, Inc., Waterbury, Connecticut, 1986.

HydroCAD, "*HydroCAD™: Stormwater Modeling System, Version 7*", HydroCAD Software Solutions LLC., 2nd ed., Chocorua, New Hampshire, 2004.

SCS, "*TR-55 Urban Hydrology for Small Watersheds, Technical Release 55 (TR-55)*", United States Department of Agriculture, Soil Conservation Service, 2nd ed., Washington, D.C., 1986.

TDEC, "*Rules of Tennessee Department of Environment and Conservation, Chapter 1200-1-7 – Solid Waste Processing and Disposal*", Division of Solid Waste Management, January 2005.

TDEC, "*Tennessee Erosion and Sediment Control Handbook*", Division of Water Pollution Control, Tennessee Department of Environment and Conservation, 2nd ed., March 2002.

Written by: Sowmya Bulusu / Alexander Maestre Date: 12/07/06 Reviewed by: Ganesh Gopalakrishnan Date: 12/13/06

Client: TVA Project: Kingston Fossil Plant Gypsum Disposal Facility Project/Proposal No.: GR3731 Task No.: 06

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