Prepared for:

Tennessee Valley Authority
1101 Market Street
Chattanooga, Tennessee 37402

ENGINEERING PEER REVIEW OF COAL BYPRODUCTS DISPOSAL PLANS

KINGSTON FOSSIL PLANT
KINGSTON, TENNESSEE

Prepared by:

GEOSYNTEC CONSULTANTS
1255 Roberts Boulevard, NW, Suite 200
Kennessaw, Georgia 30144

Project Number:

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EXECUTIVE SUMMARY

GeoSyntec Consultants, Inc. (GeoSyntec) of Atlanta, Georgia was retained by the Tennessee Valley Authority (TVA) to conduct an engineering peer review of coal by-product (gypsum and ash) disposal plans for TVA's Kingston Fossil Plant. Based on discussions with TVA representatives, it is GeoSyntec's understanding that the design for the Dredge Cell Lateral Expansion Project at the Kingston Fossil Plant is at a 50% level of completion. We further understand that TVA typically defines this point in the design development process at the point where permit applications and regulatory approvals can be sought. Accordingly, GeoSyntec understands that the permit application for the subject disposal plan was submitted to the Tennessee Department of Environment and Conservation (TDEC) in July 2004, and is currently under review.

GeoSyntec's scope is provide TVA with an independent peer review of the approach, theory used, constructability and operability of the disposal plan, drainage and seep controls, the operations plan and other components of the project. To meet these objectives, GeoSyntec performed a systematic and thorough review of the design documents and other supporting information provided to us. To facilitate TVA's review of this work product, our report is organized in a manner consistent with that of the Operations Manual and supporting appendices. While GeoSyntec recognizes that certain elements of the design may not be complete at this time, we have conducted our review and prepared comments assuming that the Operations Manual and supporting documents should be at a state of completion sufficient for submittal to TDEC.

In general, our findings and recommendations fall into the following general categories: (i) areas where in our professional opinion, we believe that additional detail would be beneficial in terms of securing regulatory approvals and making the documents more defensible in the event that any element is challenged during the permitting process; (ii) areas where inconsistencies exist that should be addressed prior to completing the final design; and (iii) areas where in our professional opinion, we believe that the engineering elevations are incomplete and/or additional engineering is needed for the purpose of completing the design. Most of the findings and recommendations described in this report relate to items that fall into categories (i) and (ii). The items that fall into category (iii) are generally centered around geotechnical-related issues, i.e., stability and seepage. Specific comments and recommendations relative to these issues are presented in Sections 9 and 13 of this report.

The Operations Plan provides a concise summary of proposed ash and gypsum disposal operations. One of the unique components of the proposed activities at the Kingston facility is the desire to manage both ash and gypsum in a common facility. We understand that this constraint results from the goal of keeping disposal operations within the general footprint of the existing disposal facility. In addition, certain geotechnical constraints have been imposed based on the knowledge that a recent "blowout" occurred on the face of one of the existing dredge cell dikes. GeoSyntec appreciates that these constraints introduce additional complexity in terms of developing and operating the disposal facility in a safe and efficient manner. Therefore, we have devoted significant effort to the review of the operating strategy and constructability of the currently proposed disposal facility configuration. These issues are specifically addressed in Section 2 of this report.

GeoSyntec believes that the geotechnical issues associated with the existing dredge cells can be readily addressed using conventional geotechnical engineering methods. Once these issues have been addressed, we believe that other disposal scenarios become feasible. To illustrate this, we have included the conceptual design of an alternative operating strategy in this report for consideration by TVA. This alternative conceptual design is presented and discussed in Section 2.4 of this report.

The key benefits provided by this alternative include: (i) the approach allows for the development of separate gypsum and ash monofills as opposed to a co-mingled disposal scenario; and (ii) the airspace available for disposal operations can be optimized. In fact, the conceptual design developed by GeoSyntec could provide up to 40 years of operational life while keeping disposal operations within the existing disposal area footprint. We also believe that the alternative presented provides for greater operational flexibility and imposes less complex construction requirements.

As indicated above, the majority of our review findings and recommendations focus on suggested improvements that would facilitate the review and approval of this project by TDEC while rendering the design more "defensible" in the event that the project is opposed. The organization of our report closely parallels the organization of the Operations Manual and supporting appendices to allow efficient review and consideration of our recommendations by TVA. Each section of this report from Section 3 onwards provides "stand-alone" review comments and recommendations with regard to each appendix of the Operations Manual. The final component of

GeoSyntec's review was to perform a check for consistency and completeness of the provided drawings. Appendix A of this report (bound separately) presents reduced-size "redline" copies of the drawing set. Our findings and recommendations are presented on these drawings for consideration by TVA.

Finally, GeoSyntec recommends that the specific geotechnical issues identified in Section 9 and 13 warrant additional engineering evaluation by the designer prior to completion of the design. GeoSyntec representatives are prepared to discuss our findings and recommendations with the TVA team and assist in addressing the items identified in this report.

TABLE OF CONTENTS

TABLE OF CONTENTS (Continued)

TABLE OF CONTENTS (Continued)

LIST OF APPENDICES

1. INTRODUCTION

1.1 Terms of Reference

GeoSyntec Consultants, Inc. (GeoSyntec) of Atlanta, Georgia was retained by the Tennessee Valley Authority (TVA) to conduct an engineering peer review of coal by-product (gypsum and ash) disposal plans for TVA's Kingston Fossil Plant. The scope of work was performed in accordance with Contract No. 39440, Attachment A. Specifically, our contracted scope of work included the following:

1. Read the Operations Manual, the Hydrogeologic Report, and overview the drawings.

2. Visit the site and become familiar with the current site and future plans.

3. Perform and in-depth peer review of the entire disposal and operation plans.

4. Provide a report that includes the following items:

    a. An exact description of each review component.

    b. A summary of findings.

    c. Recommendations for improvement (if any).

5. Participate in weekly telecoms.

6. Present the peer review findings to TVA.

This report has been prepared to document the findings of the peer review conducted by GeoSyntec and represents the completion of items one through four (above).

The engineering peer review was performed by Dr. Jay Beech, P.E., Dr. Robert Bachus, P.E., Mr. Neil Davies, P.E., and Mr. Charlie Spiers, P.G. with assistance from other GeoSyntec staff members.

1.2 Project Background

Based on discussions with TVA representatives, it is GeoSyntec's understanding that the design for the Dredge Cell Lateral Expansion Project at the Kingston Fossil Plant is at a 50% level of completion. We further understand that TVA typically defines this point in the design development process at the point where permit applications and regulatory approvals can be sought. Accordingly, GeoSyntec understands that the permit application for the subject disposal plan was submitted to the Tennessee Department of Environment and Conservation (TDEC) in July 2004, and is currently under review. JUNE

We understand that the intent of this project is to provide TVA with an independent peer review of the approach, theory used, constructability and operability of the of the disposal plan, drainage and seep controls, the operations plan and other components of the project.

GeoSyntec has performed a systematic and thorough review of the design documents and other supporting information provided to us. To facilitate TVA's review of this work product, our report is organized in a manner consistent with that of the Operations Manual. While GeoSyntec recognizes that certain elements of the design may not be complete at this time, we have conducted our review and prepared comments assuming that the Operations Manual and supporting documents should be at a state of completion sufficient for submittal to TDEC.

1.3 Report Organization

Our report on the engineering peer review is generally organized to align with the Operations Manual and supporting appendices, and includes the following sections:

- Section 2 – addresses our review comments on the Operations Manual. In this section of our report, we also outline a potential alternative operating strategy for consideration by TVA.
- Section 3 – addresses testing of fly ash and gypsum presented as Appendix A of the Operations Manual.

- Section 4 – addresses the vegetation specification presented as Appendix B of the Operations Manual.

- Section 5 – addresses the DSWM Policy Memorandum presented as Appendix C of the Operations Manual.

- Section 6 – addresses stormwater management and pond design as presented as Appendix D of the Operations Manual.

- Section 7 – addresses the hydrogeologic evaluation presented as Appendix E of the Operations Manual.

- Section 8 – addresses the work plan for groundwater monitoring presented as Appendix F of the Operations Manual.

- Section 9 – addresses stability and seismic impact evaluations presented as Appendix G of the Operations Manual.

- Section 10 – addresses the Closure/Post Closure Care Plan presented as Appendix H of the Operations Manual.

- Section 11 – addresses the Quality Assurance/Quality Control (CQA/QC) Plan presented as Appendix I of the Operations Manual.

- Section 12 – addresses construction specifications presented as Appendix J of the Operations Manual.

- Section 13 – addresses the seepage analysis performed on existing dredge cell dikes presented as Appendix K of the Operations Manual.

- Section 14 – provides a listing of inconsistencies identified on the drawings during the course of conducting our peer review.

2. OPERATIONS MANUAL

2.1 Introduction and Organization

The primary purpose of this section is to provide review comments regarding the document titled *Operations Manual, Dredge Cell Lateral Expansion, Tennessee Valley Authority, Kingston Fossil Plant, Revision 0* (Operations Manual) dated June 7, 2004. One of the most important components of the Operations Manual is the description of proposed ash and gypsum disposal operations. During the 29 September 2004 plant visit to the Kingston Fossil Plant (KIF), TVA requested that GeoSyntec offer relevant comments regarding potential operational difficulties (and alternatives) relative to the proposed ash and gypsum disposal areas. Accordingly, this section provides specific comments and recommendations regarding the design and operation of the ash and gypsum disposal areas. In addition, and as introduced during a recent teleconference between members of the GeoSyntec and TVA project team, an alternative ash and gypsum disposal strategy was developed. The conceptual design of this alternative is presented in this section. To facilitate TVA's review, the remainder of this section is organized to provide: (i) a summary of our review findings relative to specific sections of the Operations Manual; and (ii) a brief summary of the alternative disposal strategy developed by GeoSyntec.

2.2 Summary of Findings

The Operations Manual provides a concise summary of proposed ash and gypsum disposal operations. Since bottom ash and fly ash disposal is a common component of TVA operations at its fossil plants, GeoSyntec anticipates that the ash management activities described in the Operations Manual are consistent with procedures developed at these other facilities. One of the unique components of the proposed activities at the Kingston Plant is the desire to manage both ash and gypsum in a common facility. The majority of the comments presented in this section are specifically related to the operational issues involving these two waste streams. To facilitate both the discussion and the review of this section, the remainder is organized to present salient comments in a bulleted summary list, which identifies specific sections of the Operations Manual. Where no specific section is identified, GeoSyntec generally concurs with the information presented in the Operations Manual without comment.

- *Section 1.1*: The end of this section identifies Mr. Al Majors as the Tennessee Department of Environment and Conservation (TDEC) contact for the "manual" and Mr. Mike Apple as the TDEC contact for the "report". Only one TDEC primary contact should be identified.

- *Section 1.4*: There is a good discussion regarding the hydraulic conductivity of the in situ ash. The range of values presented in this discussion are representative of ash materials previously encountered by GeoSyntec. The values used in the reported seepage analyses, however, were consistently higher than the representative values reported in this section. The inconsistency of values used in the report and the subsequent analyses needs to be resolved. A more detailed discussion of the seepage analyses is presented in Section 13 of this report. Section 1.4 of the Operational Manual concludes with a discussion regarding the mounding of water caused by the sluicing of ash and/or placement of dredged ash. Internal water control (i.e., control of the mounded water) needs to be explicitly addressed in the disposal facility design. 7

- *Section 2.2*: As discussed during the referenced teleconference between GeoSyntec and TVA, to reported quantity of gypsum (i.e., 327,360 cubic yards (cy)) generated each year is approximately correct, however the reported conversion factor of 0.88 tons/cy is actually closer to 0.885 cy/ton or 1.13 ton/cy, yielding an anticipated annual disposal volume of approximately 329,000 cy.

- *Section 2.2.1*: The reported life of the existing dredge cells is based on a final cover design that was "revised", presumably because of the "recent seepage in the existing dredge cells" (see Section 3.1.2). It is recognized that if an alternative grading plan is adopted, the design life of the existing cells may change significantly.

- *Section 2.2.3*: While the overall total capacity of the various stages in the Phase 2/3 areas appears to be correct and consistent with the drawings, it is recognized that Phase 2 construction to approximate elevation of 870 feet or the end of Stage 3 (see Table 2.2 and other sections of the Operations Manual) will precede commencement of the first stage of Phase 3. It is recommended that Table 2.1 be modified to explicitly reference a timeline for the development of specific stages within Phase 2 and Phase 3. This timeline is absolutely necessary for implementation of the proposed design. Additional discussion will be presented during presentation of the alternative design.

- *Section 2.2.4*: To compliment the recommended modification to Table 2.1, it is also recommended to similarly modify Table 2.2 to reflect an actual projected timeline for Phase/Stage development. As indicated in this section, it is difficult for TVA to appropriately predict the disposal volumes of ash and gypsum due primarily to unknown factors related to coal supply and marketing success. This difficulty contributes to the potential operational difficulty of the proposed disposal facility. In the proposed design, ash and gypsum are effectively co-managed in a single facility. To facilitate the co-management, it is strongly desired to have explicit annual disposal volumes within the facility. Since this is difficult to accomplish because of the reasons stated by TVA in this section, it supports the view that independent waste-stream management alternatives would be operationally more feasible and potentially more desirable.

- *Section 3.1.1*: The fourth paragraph discusses the design water levels in the dredge cells and the minimum required freeboard volume. When the Phase 2 construction commences, the size of the ash pond will decrease significantly, relative to the current size. Under these future design conditions, it is difficult to envision that this minimum freeboard volume is still being provided. In the last paragraph, it is referenced that in lieu of dredging, conventional earthmoving equipment may be used to excavate, haul, and place the ash. It is recognized that conventional excavation techniques are extremely difficult unless the water in the pond is lowered below the level of the ash or unless operations are focused near the entrance to the pond where the deposition of the larger particle sizes of ash is possible.

- *Section 3.1.3*: This section indicates that "slope drains can be retrofitted on the slopes". It appears that these drains are either at the surface of the slope or are relatively shallow. This point is addressed in more detail in the discussion regarding the seepage and slope stability analyses subsequently presented by GeoSyntec (see Section 9 and 13 of this report). Seepage and slope stability analyses need to be conducted in companion with each other to establish the proper depth and orientation of the drains.

- *Section 3.1.4*: Two aspects of the initial Phase 2 operations warrant discussion. First, it is recognized that grading a cell floor (i.e., the base of the slope) to a consistent grade of less than 1 percent is very difficult and requires careful construction monitoring. Second, the proposed drainage layer that consists of the combination of bottom and fly ash seems particularly problematic. GeoSyntec's experience with "typical" bottom ash and fly ash mixes result in a gap-graded material that is inherently unstable as a filter medium. There is a potential for segregation of fines within the filter, internal erosion of the fines, and/or clogging. Each of these has the potential to severely compromise performance of the filter. GeoSyntec requests the opportunity to thoroughly review the Boschuk, 2004 report before final selection of the filter is made. The discussion regarding gypsum placement in Phase 2/Stage 1 implies that ash and gypsum may be co-mingled within each specific stage. It is recognized that many states do not allow the co-mingling of the two waste streams, preferring to have operators manage monofill facilities. Furthermore, it is acknowledged that co-mingled ash and gypsum likely will never have a beneficial reuse, so marketing this blend will be nearly impossible. Finally, the final paragraph references that TVA "may decide to sluice fly ash into Phase 2". This will undoubtedly increase the amount of water that ponds within the Phase 2 disposal area and the potential impact of the water must be explicitly assessed from the aspect of seepage and stability. The discussion regarding Phase 2/Stage 3 acknowledges that plant operations will need to transition to dry ash management upon commencement of Phase 3. As indicated in the "Drawing Consistency" discussion (see Section 14), this is inconsistent with portions of the Phase 3 drawings that reference the disposal of "dredged ash". In this same section, it is referenced that "dry fly ash can be stacked". In reality, the "dry" flu ash needs to be moisture conditioned prior to placement in the disposal cell to facilitate handling and compaction, while minimizing the potential need for dust management practices. Finally, in the discussion regarding Stages 4 through 6, the use of blanket, vertical, and lateral drains are referenced. There does not appear to be a reference related to the "design" of these important components. If design calculations and seepage analyses have not been conducted, it is recommended that these analyses be performed.

Fly

Were they

- *Section 3.2.1*: While TVA is correct that no soil cover is needed for vector control, both fly ash and gypsum (particularly fly ash) are very erodeable and the exposed surfaces need to be covered and protected to minimize the potential for erosion.

- *Section 3.2.4*: The alternative cover references "low density polyethylene" as the geomembrane component of the final cover. GeoSyntec often utilizes linear low density polyethylene (LLDPE) for final covers.

- *Section 3.3*: It is referenced that "ash is sluiced from the powerhouse with a solids content approximately 60 to 70 percent". This is inconsistent with GeoSyntec experience that typically sees approximately 5 percent solids in the sluice water. It is recommended that this sentence be clarified or corrected.

- *Section 3.4*: The reference to the JOF plant should be corrected to identify the Kingston plant. In addition, GeoSyntec, typically does not utilize soil cement for dust and litter control.

- *Section 3.5*: As mentioned previously in the discussion relative to Section 3.2.1, non-covered slopes are vulnerable to surface erosion and the formation of erosion gullies and rills.

- *Section 3.6*: Given the excessive seepage that has been encountered at the site, it is recommended that leachate management practices be implemented, even if this means passive conveyance from the cell. It is recommended that leachate not be allowed to accumulate indefinitely in the cell.

- *Section 3.7*: As an additional safety precaution, equipment operators and site personnel should be alerted to the potential danger of working and walking near water-saturated fly ash that can have insufficient shear strength to support equipment of human traffic. Additionally, it is recommended that the need for personnel who work near dry fly ash to utilize a respirator be evaluated.

- *Section 4.2.1*: It should be stated that the ground water monitoring wells are screened "across relevant or pertinent zones of interest" and not a simple and generic reference to a "screened section".

- *Section 4.2.2*: It can likely be proposed to reduce the semi-annual monitoring frequency and testing during closure and post-closure care, particularly if the previous results during the operating (and closure) life of the facility have not indicated potential releases. For consistency within the Operations Manual, Table 1 and 2 should be changed to Table 4.1 and 4.2, respectively.
- *Section 5.1*: The value of "elevation XXX" should be inserted.
- *Section 5.2*: It is acknowledged that current operations are within the "existing footprint of the ash pond and the existing dredge disposal cells".

2.3 Recommendations for Improvement

Based on our review of the Operations Manual, GeoSyntec believes that the document generally satisfies appropriate regulatory requirements. Improvements to the document that would facilitate the regulatory review and approval process could be made by addressing the specific comments and issues identified in Section 2.2 of this report. In addition, specific comments are also provided on the supporting appendices and drawings. Comments specific to these elements of the design package are provided in Sections 3 through 14 of this report.

2.4 Alternative Disposal Strategy

2.4.1. Overview

Based on GeoSyntec's review of the Operations Manual, the Drawings, and discussions with TVA personnel, it appears that the proposed ash and gypsum disposal facility is both feasible and constructible, albeit relatively complex to operate. Given TVA's presumptive concern regarding seepage and slope stability within the existing dredge ash disposal areas and the need to maximize the on-site disposal capacity of both ash and fly ash, the proposed design may be optimal given the geometric constraints inherent to the site.

As discussed with TVA team members during a recent teleconference GeoSyntec has developed an alternative disposal strategy for the ash and gypsum waste streams for consideration by TVA. The conceptual design of this alternative was presented on a recent teleconference and in an internal memorandum distributed to members of the project team. As part of our review of the Kingston project, GeoSyntec has provided additional information regarding the alternative design. A discussion of this alternative is presented in the remainder of this section.

2.4.2 Description of Alternative

While the currently proposed design is constructible, there are the following inherent disadvantages of the design: (i) the design requires the careful co-management of ash and gypsum waste streams in close proximity to each other; (ii) due to site geometric constraints, the ratio of gypsum to ash disposal volumes varies from about 2.6 to 0.6 between various phases and stages; (iii) to balance the ratio of gypsum to fly ash, we believe it will likely be necessary to co-mingle the ash and gypsum in several (if not all) stages, thus adversely impacting the beneficial re-use of the materials, should market conditions change over time; (iv) because the size and geometry of the disposal areas change with each incremental dike raising, the operations will have to be constantly adjusted during the life of the facility; (v) because of these site constraints, the vertical raising of the ponds will likely exceed more than 10 to 20 feet per year, particularly in the latter development stages, thus raising potential concerns regarding undrained loading on the previously placed ash/gypsum; and (vi) the maximum potential disposal capacity of the existing dredge ash disposal cells will not be realized. The alternative disposal strategy described below addresses each of these disadvantages.

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The two key components of the alternative disposal strategy are to: (i) address and resolve seepage and slope stability issues within the existing dredge ash disposal areas to maximize the disposal capacity of dredged ash in these areas; and (ii) develop and operate a gypsum monofill within portions of the existing ash pond footprint. The concept for implementing these two components are briefly summarized as follows:

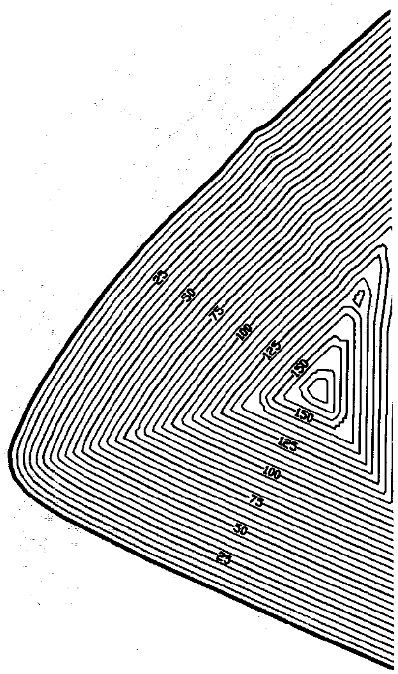
- *Stability of the Existing Dredged Ash Areas*: Based on review of the seepage and slope stability analyses presented in the report, it appears to GeoSyntec that the recent seepage/stability problem that occurred in the existing dredge cells was caused by water that had inadvertently ponded within the dredge cells. Independent slope stability calculations performed by GeoSyntec as part of this review indicate that the calculated factor of safety can be shown to vary from approximately 1.7 for "dry" conditions in the slope, to 0.7 for a condition where a high phreatic surface exists within the outboard ash slopes. Clearly water plays a critical role in the calculated stability. Further preliminary analyses indicate that by maintaining a phreatic surface at a distance of approximately 30 feet from the slope surface is sufficient to retain a calculated factor of safety of >1.5. Control of the phreatic surface can be provided by the installation of drains near the toe of the outboard slope and progressive installation of additional toe drains during subsequent ash placement operations. This will allow placement of ash sufficient to capture approximately 10,400,000 cy in the ash monofill, as shown in the isopach presented in Figure 1. It is noted that the current design reflects a total ash disposal capacity of approximately 7, 200,000 cy.

- *Development of Gypsum Monofill*: Since ash will be disposed in its own dedicated monofill, it will be possible to develop a gypsum monofill in a portion of the existing ash pond. Two disposal strategies are introduced, both being constructed using a conventional incrementally filled, two-pond disposal basin constructed by inboard dike construction using either a rim ditch or wet casting techniques. In both cases the gypsum stacks are relatively large to facilitate operations and minimize concerns for undrained loading. The two options are summarized as follows.

    - The first option is shown in Figure 2 and was previously presented to TVA during the teleconference. This figure presents the final cover grades for both the ash and gypsum monofills. The concept maintains a 25 acre ash pond within the northwest portion of the existing ash pond and provides disposal capacity for approximately 3,000,000 cy of gypsum.

    - The second option is shown in Figure 3 and was developed after the referenced teleconference. This figure also presents the final cover grades for both the ash and gypsum monofill. This concept presented on this figure also maintains the 25 acre ash pond, but limits gypsum disposal to the northeastern portion of the existing pond. Because this latter option takes advantage of the "layover" against the future ash monofill, the disposal capacity increases significantly to approximately 7,300,000 cy.

EXISTING I



0 500

SCALE IN FEET

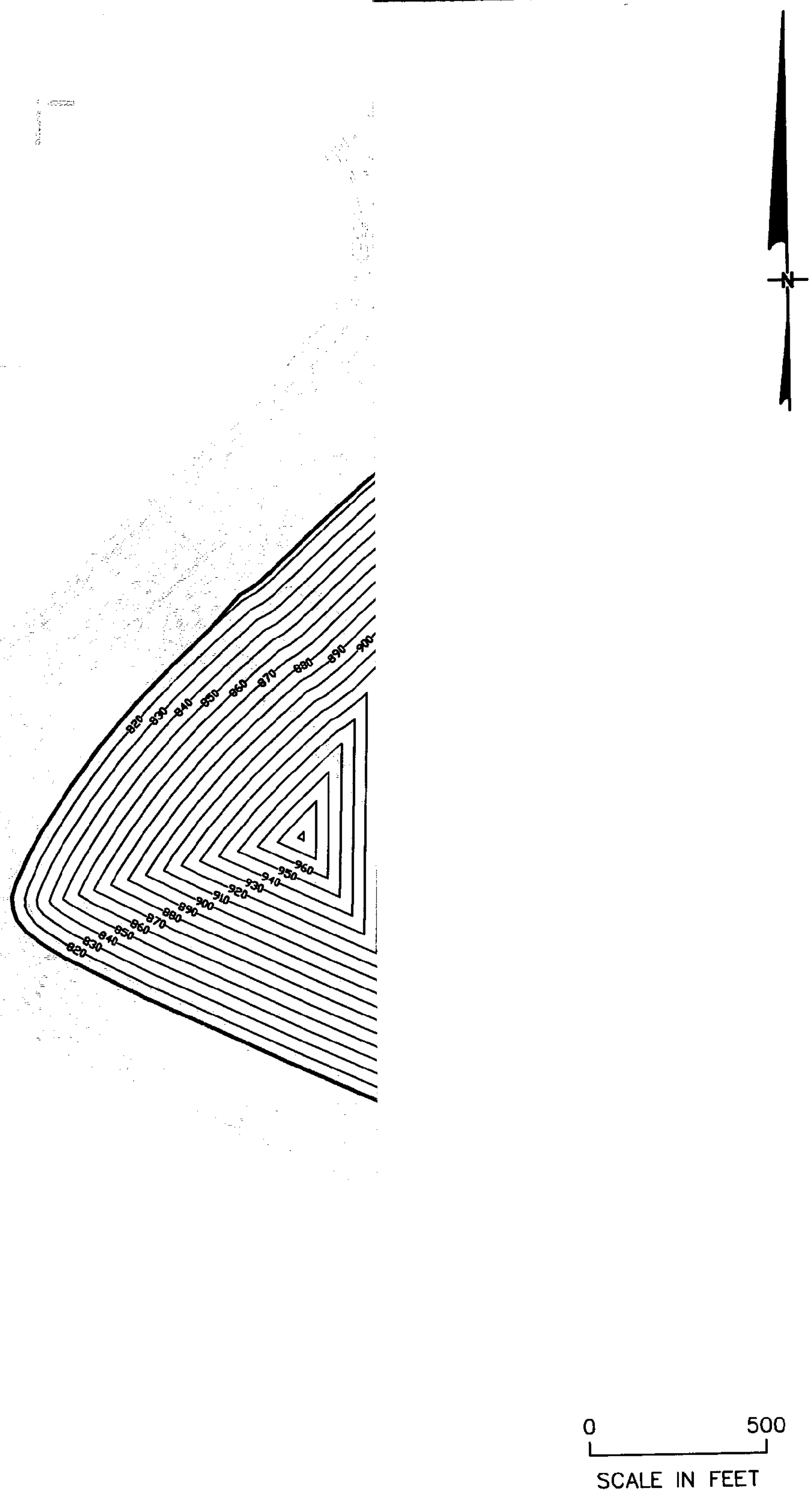
Site Vol

Site	Stratum	Surf1	Surf2
GR3471-01	O base vs cover opt1		bo

GEOSYNTEC CONSULTANTS

ATLANTA, GA

TE:	27 OCT 2004	SCALE:	1"=500'
OJECT NO.	GR3471-01	FILE NO.	3471F001.DWG
CUMENT NO.	–	FIGURE NO.	1



Site Volume Table

Site	Stratum	Surf1	Surf2	cu.
parcel 1				
	base opt 2 vs cover opt 3			ba

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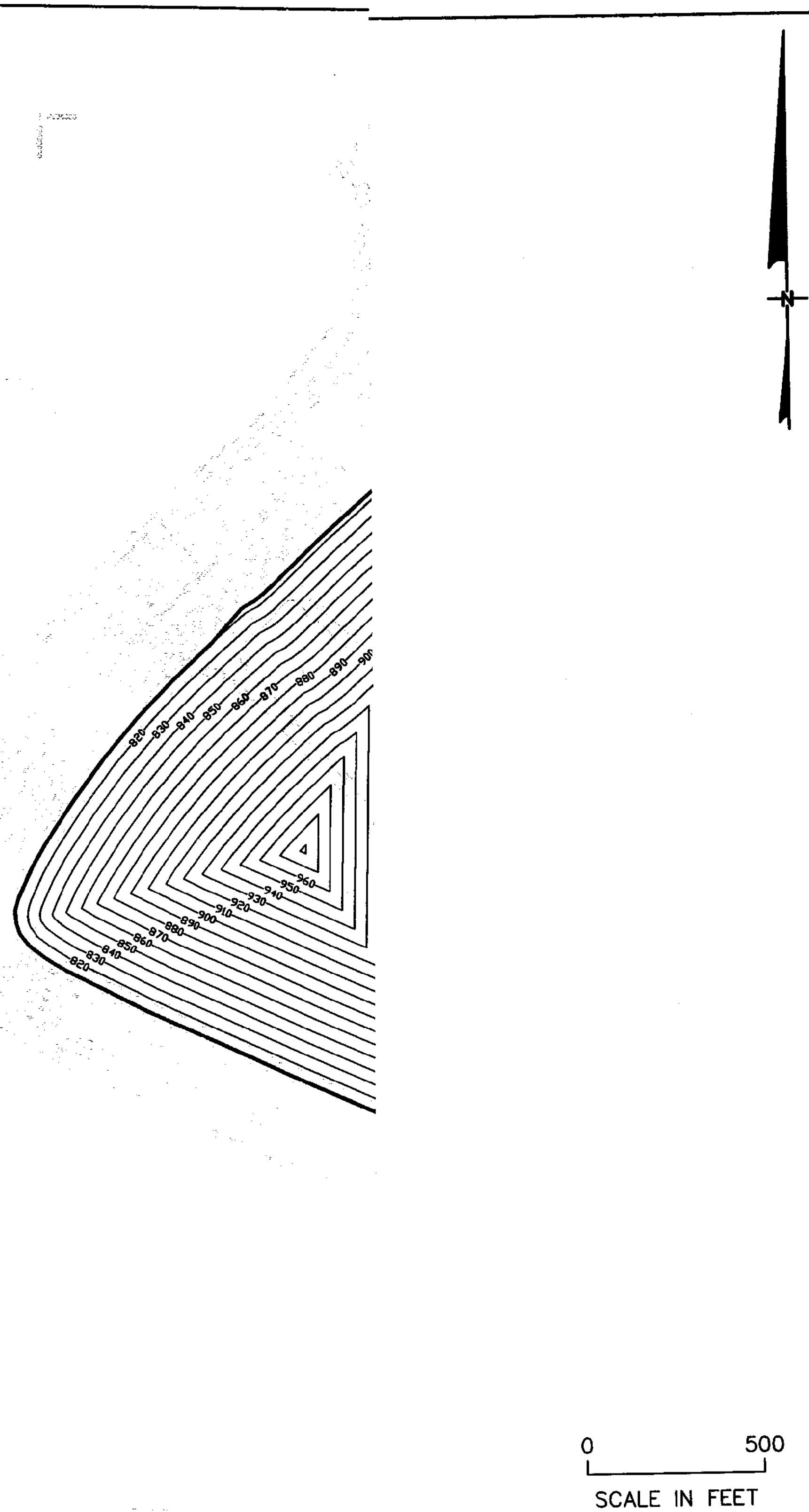
TE:	27 OCT 2004	SCALE:	1"=
JECT NO.	GR3471-01	FILE NO.	3471F004.DWG
CUMENT NO.	–	FIGURE NO.	2



Site Volume Tabl

Site	Stratum	Surf1	Surf2	cu
GR3471-01				
	base opt 3 vs cover opt 4			ba

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ATLANTA, GA

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)JECT NO.	GR3471-01	FILE NO.	3471F004.DWG
:UMENT NO.	—	FIGURE NO.	3

It is noted that the total gypsum disposal capacity reflected in the currently proposed disposal option is approximately 5,700,000 cy, but that to achieve this capacity it was necessary to transition to dry-ash management after Phase 2/Stage 3 operations. In both of the alternative strategies, the current wet-ash management strategy is maintained, thus delaying the need to transition to dry ash storage management practices. When the transition to dry-ash management occurs, the ash pond will be decommissioned, allowing the completion of the disposal area. When fully developed the isopach of the final disposal area as shown in Figure 4 will result in a total potential disposal capacity of nearly 31,500,000 cy. For reference purposes, the currently proposed strategy has a total disposal capacity of approximately 13,000,000 cy. The operation of the disposal area when dry-ash management commences will likely be similar to the latter stages of the currently proposed option, where ash and gypsum are managed in contiguous areas.

The concepts incorporated in these alternatives address all of the disadvantages identified previously as related to the currently proposed option described in the Operations Manual. It is significant to note that the alternatives presented herein should be able to realistically accommodate nearly 40 years of additional disposal life based on current ash and gypsum generation rates. Specific details, including the size of the ash pond, and the desired transition date from wet- to dry-ash management practice, can be developed to further refine the alternative disposal concept based on discussion and input from members of the TVA team. The primary purpose of this discussion is to demonstrate that alternative disposal techniques are possible and feasible while addressing site-specific constraints.

DREDGE CELLS AND LATERAL EXPANSION CLOSURE ISOPACH

0 500
SCALE IN FEET

Site Volume Table: Unadjusted

Site	Stratum	Surf1	Surf2	Cut cu.yds	Fill cu.yds	Net cu.yds	Method
GR3471-01	base vs cover opt 2	base opt2	cover opt2	0	31465659	31465659 (F)	Grid

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ATLANTA, GA

DATE: 27 OCT 2004	SCALE: 1"= 500'		
PROJECT NO. GR3471-01	FILE NO. 3471F002.DWG		
DOCUMENT NO. –	FIGURE NO. 4		

3. ASH AND GYPSUM TESTING

Appendix A provides various testing reports relating to the characteristics of ash samples from the Kingston Fossil Plant, and gypsum from TVA's Cumberland Fossil Plant. Since this information is "factual data" GeoSyntec has not prepared comments on this information.

4. VEGETATION SPECIFICATION

4.1 Description of Review Process

GeoSyntec reviewed the standard TVA specification included in Appendix B of the Operations Manual. The review consisted of comparing the requirements of the specification to requirements routinely specified by GeoSyntec.

4.2 Summary of Findings

The specification is very complete. The types of vegetation specified are familiar to GeoSyntec. GeoSyntec assumes that the mixtures specified have been developed by TVA through experience and were not evaluated. The procedures for quality control of seeds are good. Procedures for sowing, fertilizing, et cetera appear reasonable. Again it is assumed that these procedures and fertilizer mixtures have been developed through experience and were not evaluated.

4.3 Recommendations for Improvement (if any)

No improvements are recommended.

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5. DSWM POLICY MEMORANDUM

Appendix C provides a copy of a memorandum from TDEC, Division of Solid Waste Management describing five variances that are relevant to fossil fuel ash and bottom ash disposal facilities. No comments are appropriate on this Appendix.

6. STORMWATER MANAGEMENT

GeoSyntec performed a review of the stormwater management system described in Section 3.10 of the Operations Manual. Specific details of the stormwater management system are presented in Appendix D of the Operations Manual. Stormwater management is addressed in terms of the existing dredge cell surface waster management and for the planned Phase 1 and Phase 2 lateral expansion.

6.1 Description of Review Process

Our review focused on general approach and methodology. A review of the mathematical correctness and of the specific input and output data was not performed. The following specific steps were performed as part of our peer review process:

- Chapter 1200-1-7 of TDEC rules were reviewed to establish design criteria that are accepted by TDEC.
- Sections 3.5 (Erosion Control) and 3.10 (Stormwater Management System) of the Operations Manual were reviewed.
- Appendix D of the Operations Manual titled "Stormwater Calculations" was reviewed.
- Design drawings that were referenced within the calculation package were reviewed for content.

6.2 Summary of Findings

The following section summarizes the findings of our peer review of the stormwater management system:

- *Overall Philosophy for Erosion and Sediment Control.* The overall philosophy adopted in this package is that erosion and sediment control during construction/development of the ash facility is not essential. It is explicitly stated that erosion control practices such as silt fences would not be required.

The reason cited is that the potential areas for erosion are well contained within the limits of the pond (where the whole construction would take place). There is a brief mention of how to maintain the pond from silting up in Appendix H (Closure/Post Closure Plan) but no details on when and how.

- *Overall Philosophy for Stormwater Management.* As understood from the package, stormwater detention and peak attenuation of runoff leaving the site is not an issue in this design. The design is therefore focused on managing stormwater runoff from the cover system to be conveyed to the stilling basin, i.e., "design of a conveyance system".

- *Stormwater Conveyance System.* The overall design concept is to use terrace ditches at 30-foot vertical intervals as the height of the fill is progressed – a commonly accepted practice. Terrace ditches will drain down to rip-rap lined let down channels (down chutes) which will convey the runoff to the stilling basin. TDEC Rule 1200-1-7 is cited as the basis for design. In general, TDEC rule requires that stormwater runoff control be provided for the 25-year 24-hour design storm with safe bypass capability for the 100-year storm.

- *Design Calculations.*

  - Design was performed in general accordance with the 25-year 24-hour design criteria by TDEC.

  - TR-55 hydrograph procedure, which is a widely accepted methodology, was used for calculating peak runoff from the cover system.

  - Calculation procedure adopted included delineating drainage areas, creating a computer network model of the drainage system, determining curve numbers, estimating times of concentration, and applying to TR-55 hydrograph model. In general, this is standard procedure.

  - The package is organized to address the hydrology, design of ditches, riprap, and downchute in separate appendices. In general, this includes all major design components.

- Hydraulic design of ditches was performed using the peak flows calculated by hydrograph calculations and Manning's equation for open channel flows. In general, this is standard procedure.

- Design of riprap was performed using FHWA procedures. In general, this is standard procedure.

- Design of rock downchutes was performed using a recent technical publication referenced within the package.

6.3 Recommendations for Improvements

In general the procedures for designing stormwater conveyances on the landfill are consistent with standard procedures and the current state of practice. Based on our review, our only significant recommendation for improvement would be to consider expanding the narrative descriptions of the procedures used for the purpose of facilitating the regulatory review.

7. HYDROGEOLOGY

7.1 Description of Review Process

This Section has been prepared to summarize GeoSyntec's activities regarding the peer review of the Hydrogeologic Report for the Kingston Fossil Plant. Our initial peer review activities consisted of a detailed review of the Report prepared by Mark Boggs and Hank Julian of TVA and a review of the Geotechnical Exploration Report (Mactec, 2004) for the Ash Disposal Area of the Kingston Fossil Plant.

Contents of the Report were compared to TDEC's Guidance Document for Performing Hydrogeologic Investigations (1991) and to the TDEC's Rules for permitting solid waste disposal facilities (Rule 1200-1-7-.04).

Part of the review process included the preparation of a checklist of the Hydrogeologic Guidance Document requirements and the siting and Hydrogeologic Report requirements of Rule 1200-7-.04.9(a). The checklist was used to compare the major items presented in the Report with requirements of the Hydrogeologic Guidance Document and the TDEC Rules. In preparing the checklist, GeoSyntec assumed the role of an outside reviewer or possible "intervener" in the permitting process in order to identify elements of the report that may not completely comply with the letter or intent of the regulations and guidance document.

Key items identified in the review process and included in the preparation of the checklist include:

- number and spacing of boreholes;
- location of piezometers;
- rock coring and hydraulic conductivity testing;
- siting criteria such as endangered species, floodplains, wetlands, Karst terrain, fault areas, seismic impact zones and location in unstable areas;
- geologic buffer standards or alternatives to the geologic buffer;

- soil sampling and testing techniques;
- identification of the seasonal high water table;
- groundwater recharge and discharge areas;
- location of springs, wells and public water supplies; and
- a presentation of the suitability of the site.

7.2 Summary of Findings

The peer review checklist (presented as Table 1) was prepared by GeoSyntec and submitted to TVA on October 1, 2004. A conference call was held between Charles Spiers of GeoSyntec and Larry Bowers, Amos Smith and Mark Boggs of TVA on October 4, 2004. The purpose of the call was to go over each of the checklist items and discuss TVA's proposed revisions to the Report. It was concluded that many of the data requirements not met in the checklist could be obtained from the Geotechnical Exploration of the Ash Disposal Area (Mactec, 2004). Also, recent review of the Operations Manual for the Kingston plant indicated that some of the siting criteria such as the buffer zone set back, not discussed in the Report, are found in the Operations Manual. At the conclusion of the conference call TVA agreed that the Hydrogeologic Report should be revised to provide a more complete description of the siting requirements, mean annual high water table, geologic buffer alternative and site suitability summary statement. Additionally, TVA stated that the submittal of the Hydrogeologic Report would have to be delayed to early November so that revisions could be completed.

TABLE 1

CHECK LIST FOR TDEC HYDROGEOLOGIC INVESTIGATION GUIDANCE DOCUMENT (January 1993)

Requirements	Report Meets Requirement		Remarks
	Yes	No	
(A) Sites shall be drilled on a 200 foot spacing between boreholes to a depth of 20 feet below the bottom of the clay liner		X	Borehole locations may be limited to the ring dike areas.
(B) One boring per every 10 acres drilled to 70 feet below top of clay liner or 20 feet into bedrock		X	Borehole locations may be limited to ring dikes. Only a few boreholes drilled into rock.
(C) One hole drilled in sediment pond area 20 feet below base of pond		X	Expansion area may not require sediment pond(s).
(D) Additional holes drilled in borrow areas for liner		X	Borrow areas not identified.
(E) Borings completed into piezometers		X	Not all borings left as piezometers.
Logging and Testing Requirements			
(A) Continuous core samples in bedrock borings		X	No rock coring performed.
(B) Grain size, natural moisture content, and Atterberg limit tests from different stratums		X	May be found in MACTEC Report.
(C) For each (3) acres of landfilling, a minimum of one hydraulic conductivity test from the geologic buffer		X	Some hydraulic conductivity testing performed but may conform to one per 3 acres.
(D) Hydraulic conductivity tests in soils proposed for liner		X	Liner material not specified in report.
(E) Two Stage Boutwell permeability test may be required		X	May be found in MACTEC Report.
(F) Testing and sampling procedures shall be identified	X		

CHECK LIST FOR TDEC RULE (1200-1-7-.04) SPECIFIC REQUIREMENTS FOR CLASS I, II, III, AND IV DISPOSAL FACILITIES

Requirements	Report Meets Requirement		Remarks
	Yes	No	
(m) Location affects endangered species		X	Not discussed in report.
(n) Location in floodplains (100 year floodplain)	X		
(o) Permanent benchmark		X	
(p) Wetlands -		X	Not discussed in report.
(q) Karst Terrane	X	?	Karst not found in boreholes – no rock cores or regional geologic discussion in report about Karst or absence of Karst.
(r) Airport Proximity		X	Not discussed in report.
(u) Fault areas - Proximity		X	Not discussed in report.
(v) Seismic Impact Zones		X	Not discussed in report.
(w) Located in an unstable area		X	Not discussed in report – may be included in MACTEC report.
(3) Buffer Zone Standards		X	Not shown or discussed in report.
(4)2 Geologic buffer of at least three feet with a maximum saturated hydraulic conductivity of 1×10^{-6} centimeters per second between base of fill and seasonal high water table		X	Report does not discuss characteristics of existing geologic buffer or alternate or equivalent to geologic buffer standards.
9(a) Hydrogeologic Report			
1. Certified by geologist or engineer	X		
2. Soil borings and analysis of existing data	X	?	Report may not meet number, distribution and rock core requirements for boreholes.
3(i) Soil sampling and testing techniques	X		Report may not meet number, distribution and rock core requirements for boreholes.
3(ii) Tabulations of water levels to show seasonal high water table		X	MACTEC Report has additional information. Seasonal high water table not defined.
3(iii) Boundary Plat locating all soil borings with boundary of proposed fill areas		X	
3(iv) A potentiometric map of uppermost aquifer	X	?	Map does not show seasonal high water table.
3(v) A description of groundwater recharge and	X	?	MACTEC Report may have a better description.

CHECK LIST FOR TDEC RULE (1200-1-7-.04) SPECIFIC REQUIREMENTS FOR CLASS I, II, III, AND IV DISPOSAL FACILITIES (Continued)

Requirements	Report Meets Requirement		Remarks
	Yes	No	
discharge features compared to regional groundwater regime			
3(vi) Locations of springs and well within one mile	X		
3(vii) Location of public water supplies within two miles	X		
3(viii) Narrative summary and analysis of geological and hydrological evaluations performed as they relate to the suitability of the site for disposal addressing in particular compliance with appropriate standards of the rule		X	Report does not address each of the standards and does not clearly discuss how the site meets the standards or alternatives to the standards.
9(b) Engineering Plans (Needed in Hydrogeological Report)			
1. Site plans with one inch equal to 100 or 200 feet that shows contour interval not greater than five feet		X	
(i) Proposed waste disposal areas		X	MACTEC Report may include this.
(ii)Existing topography of the site and pertinent geological features (drainage, streams, springs, sinks, and outcrops)		X	
(iii) Location of benchmarks		X	
(v) Soil borings monitoring wells, and piezometer locations		X	

7.3 Recommendations for Improvements

GeoSyntec has had extensive experience working with TDEC and preparing hydrogeologic reports to support permitting of solid waste landfills in Tennessee. We have found, through this process, that TDEC regulators typically adopt a "checklist" mentality when reviewing permit application documents. This was the premise used to develop the peer review checklist and compare the regulatory requirements to the major items found in the Report.

One of the major criteria for a coal-ash project in the TDEC regulations is a demonstration that the proposed landfill meet the geologic buffer requirements. These requirements are "*the geologic buffer be at least three feet with a maximum saturated hydraulic conductivity of 1 x* 10^{-6} *cm/sec between the base of the fill and the seasonal high water table of the uppermost aquifer on top of the formation of a confined aquifer, or such other protection as approved by the Commissioner taking into account site specific coal ash and soil characteristics, ambient groundwater quality, and projected flows in and around the site.*" We recognize that the purpose of Section 4 of the Hydrogeologic Report, "Evaluation of Potential Water Quality Impacts", is to evaluate the water quality of the landfill discharge with and without a geologic buffer. Although this section of the Report is well presented, it offers several scenarios for water quality impacts to nearby streams. Because of the uncertainties in the modeling exercises discussed in Section 4, GeoSyntec recommends that this section of the Report be deleted and bound in a separate internal TVA document that can be used at a later date, if needed. This section could be replaced with an equivalency demonstration that is used to demonstrate that the hydraulic conductivity and thickness of the ash placed in the landfill meet the geologic buffer requirements.

This demonstration could be developed using a simple one-dimensional flow model (i.e. HELP Model) that would result in a graph that relates ash thickness and equivalent hydraulic conductivity. In-situ vertical hydraulic conductivity tests on ash at the site found in the Mactec report show K_v between 3.59 and 5.13 x 10^{-6} cm/sec. These values are close to meeting the geologic buffer requirements without additional analyses to support the proposition that the ash thickness (greater than 3 feet) above the water table meets buffer requirements. This conclusion can be further supported by a brief discussion of the current ground-water monitoring data results that show that concentrations of Appendix I inorganic constituents were below Maximum Contaminant Levels (MCLs) in all samples.

The HELP model simulations found in section 4 of the Report could be used to form the basis of the modeling exercise for the geologic buffer demonstration. If this method of an alternative geologic buffer demonstration can be successfully performed and accepted by TDEC at the Kingston Plant, then it could be used as a basis for similar demonstrations at other ash landfill sites operated by TVA in Tennessee.

Based on our checklist submitted to TVA, discussions with TVA regarding the Report revisions and the recommendation to modify the alternant geologic buffer demonstration, we are suggesting a modified outline for the Report as presented below:

EXECUTIVE SUMMARY

1. INTRODUCTION
    - 1.1 Background
    - 1.2 Purpose and Scope
    - 1.3 Previous Studies
    - 1.4 Report Organization

2. REGIONAL SETTING
    - 2.1 Topography and Drainage
    - 2.2 Climate
    - 2.3 Geology and Hydrogeology
    - 2.4 Springs, Water Wells and Public Supplies
    - 2.5 Summary of Regional Setting

3. SITE INVESTIGATIVE PROCEDURES
    - 3.1 Investigative Procedures
        - 3.1.1 Drilling Program and Well Installation
        - 3.1.2 Geotechnical Testing Program
        - 3.1.3 Summary of Water Level Measurements

4. SITE HYDROGEOLOGIC CONDITIONS
    - 4.1 Site Topography

4.2 Site Geology
4.3 Soil Characteristics
4.4 Groundwater Occurrence
4.4.1 Hydraulic Properties
4.4.2 Seasonal High Water Table
4.4.3 Ground-Water Recharge and Flow

5. ALTERNANT GEOLOGIC BUFFER DEMONSTRATION
5.1 Geotechnical Properties of Fly Ash
5.2 Model Setup
5.3 Results of Modeling
5.4 Summary

6. SITE SUITABILITY

7. REFERENCES

GeoSyntec is aware of TVA's short time frame to make revisions to the Hydrogeologic Report and present it to TDEC in early November 2004. We are committed to provide timely technical assistance to supplement TVA resources on an "as required" basis to modify the Hydrogeologic Report.

IN PROGRESS

8. WORK PLAN FOR GROUNDWATER MONITORING

GeoSyntec performed a review of the groundwater monitoring program described in Section 4 of the Operations Manual and the Work Plan for Groundwater Monitoring presented as Appendix F of the Operations Manual. Results of our peer review are presented in this section.

8.1 Description of Review Process

Our review focused on general approach and methodology, and compliance with regulatory requirements. The following specific steps were performed as part of our peer review process:

- Chapter 1200-1-7 of TDEC rules were reviewed for with regard to groundwater monitoring requirements.

- Appendix F (Work Plan – Groundwater Monitoring) of the Operations Manual was reviewed.

- The quality assurance procedure, *Groundwater Sample Collection Techniques* was reviewed. Note that this document was not included in the Operations Manual, but is referenced in the Operations Manual and Appendix F.

8.2 Summary of Findings

The discussion of the groundwater monitoring program presented in Section 4 of the Operations Manual generally meets the requirements of the regulations. We assume that the groundwater parameters and analytical methods presented in Table 1 and 2, Section 4 of the Operations Manual are consistent with the currently approved monitoring groundwater program. The sample collection procedure included as Appendix F of the Operations Manual consists of a very brief summary/overview of the procedures referenced in the quality assurance manual, *Groundwater Sample Collection Techniques*. Appendix F is structured as a step by step procedure with some site specific details related to the TVA Kingston Site.

In general, the procedure presented in the Work Plan (Appendix F) contains very little detail. Many of the salient details of *Groundwater Sample Collection Techniques*, especially those related to prevention of sample contamination, sample labeling, sample packing, and equipment decontamination are not included. An experienced field technician should be familiar with these aspects of sample collection. However, the procedure does not give sufficient detail to a field technician that is unfamiliar with sample collection at the Kingston Site.

Specific issues identified in Appendix F include the following:

- The statements "The pump will be lowered with the drop in water surface. This ensures that no stagnant water remains in the well after pumping." are unclear. These statements likely mean that in cases of excessive drawdown, the pump should be lowered below the original 0.5 meter depth below the water table. Also, this procedure step (3) does not instruct the field technician to periodically measure the water level in the well during purging, so that drawdown can be determined.

- Procedure step 5 does not adequately describe the decanting process used to avoid transfer of settled particulates.

- The procedure does not discuss the range that constitutes stability in the field parameters measured by the Hydrolab system.

- The procedure does not address the collection of quality assurance samples such as duplicates, field blanks, and equipment blanks.

- The procedure does not discuss what type of sample pump is used, how it is operated, and how its level in the well is measured and maintained.

- The procedure does not discuss chain of custody forms, custody seals temperature blanks, or other guidelines for sample handling and packing.

8.3 Recommendations for Improvements

In general the procedures for groundwater sample collection at the Kingston Site included in Appendix F are consistent with standard procedures. We recommend that the procedure should be expanded to contain more of the details of sample collection procedures included in *Groundwater Sample Collection Techniques* to facilitate the regulatory review and approval process.

9. STABILITY EVALUATIONS

9.1 Description of Review Process

GeoSyntec performed a review of the stability calculations included in Appendix G. The review focused on general approach and methodology. A review of the mathematical correctness of the calculations was not be performed, as sufficient level of detail regrading the conducted analyses was not included in the calculation package. The following documents were included in the review:

- The Operations Manual with specific emphasis on the sections pertaining to stability.
- The calculation package that forms Appendix G of the Operations Manual.
- The drawings for familiarization with the various details proposed.
- The subsurface report (Mactec, 2004) and Hydrogeologic Report included in Appendix E for general understanding of subsurface conditions at the site.

A summary of findings is presented in the next section. The summary of findings parallels the key sections in Appendix G. Comments are provided on site stratigraphy, design material/soil properties, slope stability evaluations, veneer stability, liquefaction analysis, and bottom ash drainage layer. Recommendations for improvement are provided in the following section.

9.2 Summary of Findings

9.2.1 Site Stratigraphy

A simplified site stratigraphy is presented on pages 10 through 12 of Appendix G. The stratigraphy reportedly accounts for past exploratory work conducted at the site and the most recent work conducted by Mactec. A review of the Mactec boring logs generally agree with the stratigraphy. It is difficult to evaluate the subtleties of the site stratigraphy as detailed cross-sections that correlate to the CPT logs and boring logs are not included. While the site stratigraphy developed for the stability analyses appears to be more detailed than that presented in the Hydrogeologic Report, the composition of the natural materials underlying the ash do not appear to be consistent.

The stratigraphy used in the stability analysis in Appendix G shows all of the various layers as horizontal. The stability analysis in the Phase I report shows many of the layers as inclined. The basis for this difference can not be discerned from the available information.

9.2.2 Design Material/Soil Properties

The design material/soil properties used in the stability analysis are derived from literature values and site specific testing. In general this approach is reasonable and consistent with the state of practice. Typically, for cohesive or fined grained soils, undrained strength parameters are developed for short-term loading conditions and drained parameters are typically developed for long-term loading conditions. In the event that loading is very slow then the need for short-term properties may not be warranted. The text infers that loading will be slow for foundation soils and only long-term conditions are analyzed. While this may be true and reasonable for the foundation soils, it may not be true for some of the interim conditions, particularly in the latter stages of gypsum placement. For example, the gypsum will be sedimented into the various phases and allowed to drain. In the latter stages the gypsum level could be raised on the order of 30 ft. in one year. At this filling rate it is unclear if the material will behave as drained or undrained material. Therefore, it may be more appropriate to model both undrained and drained conditions. Experience indicates that in many cases, the undrained strength of granular gypsum exceeds the drained strength. However, it may be beneficial to conduct some limited site specific undrained shear tests. In the event it has already been confirmed that the drained strength parameters control stability, it should be clearly stated in the text.

As noted above, the text infers that drained strength parameters are required. However, the approach used to establish these parameters appears to result in a quasi-undrained/drained series of strength parameters. For example, for the natural clay stratum the CPT test data is used to derive an undrained strength for the material. A friction angle is then assumed for the material, and these two parameters are used to derive a friction angle and cohesion. This derivation does not appear to be consistent with conventional soil mechanics. Also, the basis for the assumed friction angle is not stated. While the value assumed is reasonable for lean clay material, good practice would predicate the use of soil index properties such as Atterberg limits to support the basis for selection of the friction angle.

The loose ash in the foundation soils is modeled as a purely frictional material with no cohesion. This is done to account for the loose state of the material. Modeling this material as a frictional material may not accurately account for its behavior during short-term loading. If thick sections of dredged ash are placed quickly during operations, the undrained strength of the loose ash may govern design.

9.2.3 Slope Stability Evaluations

Slope stability evaluations were conducted for four analysis cross-sections. Three of the analyzed cross-sections pertained to the interim and final conditions of the expansion, and the fourth pertained to the "blowout" area in the existing cell area. The three cross-sections are presented on Drawings 34A, 34B, and 34C of the drawings. The analyzed cross-sections for interim conditions are generally consistent with the cross-sections on Drawings 34A and 34B. The analyzed cross-section for final conditions appears to be for an interim rather than the final elevation shown on Drawing 34C. The detailed outputs for the stability analyses are not included. In the calculation package, only the pictorial showing the slip surfaces analyzed are included in the calculation package. Based on a review of the available output, we have developed the following comments relative to slope stability:

- The three sections that pertain to the expansion were reportedly selected because they were considered critical sections. It is not clear that all critical sections were looked at. For example, Section 2-2 is for an interim condition in Phase 2 at an elevation of 840 ft. It appears that a more critical Section is in the Southeast Corner (based on the Assumed North Arrow shown on Drawing 10W425-46) of Phase 3 at an elevation of 840 ft. For a design of this complexity we would typically expect that on the order of 5 to 10 cross-sections would be evaluated to address the potential critical sections for stability analysis.

- On page 10 of the text it is stated that the cast gypsum zone is conservatively assumed to be on the order of 150 ft wide. This zone appears to be

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approximately 100 ft wide based on a review of the construction drawings. The thickness of this zone in the stability analysis should be the same thickness or thinner than what is intended to be conservative.

- Both static and pseudo static stability analyses were conducted. The pseudo static conditions model the performance of the dredge cells under seismic loading conditions. This approach is an acceptable approach for analyzing stability. The Tennessee Guidance Document provides a simplified version of the USGS National Seismic Map of Horizontal Accelerations. The USGS map predicts a peak ground acceleration of 0.25g versus 0.22g based on the Tennessee Guidance Document. This difference is small, and while it appears to be consistent with the Tennessee Guidance Document, will under predict the impact of a seismic event. An average effective acceleration of 0.11g is established by taking half of the peak ground acceleration. The basis for this is unclear. Common practice is to use the peak ground acceleration as the acceleration in the waste mass unless a formal analysis is performed to calculate an acceleration that takes into account any dampening affect of the waste mass. Therefore, the basis for the acceleration of 0.11g needs to be documented. Document This

- It is anticipated that for a predominately frictional material the calculated factors of safety for slope stability are controlled by the slope geometry and assumed water levels within the analyzed cross-section. Independent analysis of the blowout area performed by GeoSyntec as part of this review confirmed that the anticipated failure surface can be relatively shallow and that water plays a critical role in the associated calculated factor of safety.

9.2.4 Veneer Stability

Cover OK

A veneer stability analysis was conducted for the cover system. This analysis appears to have only been performed for the soil cover; the alternative cover system incorporating geosynthetics does not appear to have been analyzed. Both cover systems need to be analyzed. Based on our review of the available information, we have developed the following comments related to veneer stability:

- The basis for selecting the soil properties used in the analysis are not noted.

- The interface strength properties for the geosynthetics specified in Appendix J are less than the assumed soil strength properties in the analysis described in Appendix G. A cover system constructed using geosynthetics with the specified strength parameters will have a lower calculated factor of safety than that calculated in Appendix G.

- Stability analyses need to account for the build up of water on the cover system. The build up water is typically calculated using a water balance model such as the HELP model. This is particularly important for the cover system incorporating a geomembrane and geocomposite drainage layer, because very little water will infiltrate through the geomembrane and must be removed by the drainage layer. The calculated flow capacity for the geocomposite drainage layer should then be incorporated in the specifications in Appendix G. Experience has shown that cover system drainage is important and often controls the design. Based on our review of the calculation package, this does not appear to have been done.

- A geomembrane liner is placed on the outboard slopes of Phase 1 that are common to Phases 2 and 3. A bottom ash drainage layer is placed on this geomembrane. It appears the geomembrane will be placed on an approximately 2.5H:1V slope. A stability analysis for this liner system is not included. Until the liner system is covered, the bottom ash drainage layer will be subjected to precipitation. Precipitation entering this layer will induce seepage pressures in the drainage layer as it moves down slope. These seepage pressures will result in a decrease in the factor of safety for stability of the bottom ash layer. The stability of this liner system needs to account for these seepage pressures. In the event the bottom ash drainage layer is not expected to be stable under the calculated seepage pressures, it can be placed incrementally on the slope as part of dike construction. At a minimum, interim analysis that considers seepage forces within the drainage layer needs to be performed, and if required, incremental placement needs to be incorporated in the Phasing Plan.

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9.2.5 Liquefaction Analysis

A discussion of liquefaction potential is included on pages 26 and 27. Rather than performing a liquefaction analysis using a method accepted as state of practice, drains are included to mitigate liquefaction potential. Based on our review of the available information, we have developed the following comments on the liquefaction analysis:

- As a first step, the liquefaction potential of the ash layer should be performed in accordance with USEPA guidance [1995]. If this preliminary analysis indicates the ash layer has a potential to liquefy, then a more rigorous liquefaction layer analysis should be performed. At this point a decision can then be made regarding the need to implement ground improvement procedures such as the proposed drains. If liquefaction potential at the site is low or not of serious consequences as indicated in the text, the drains may not be needed. However, it should be noted that the drains may be added to improve overall stability under static loading conditions. In this case, the drains serve a dual function of improving static stability and mitigating liquefaction conditions.

- Columns of bottom ash are recommended to act as drains. To be effective for liquefaction mitigation the drains will need to be spaced close enough to dissipate excess pore pressures that are generated due to seismic loading. The basis for the location and number of drains is not reported. The zone of influence of the drains is not calculated. Therefore, it is unclear if the drains will be effective at mitigating liquefaction.

- To improve overall stability under static loading conditions the drains will need to be effective at removing water form [from] the surrounding ash. As shown in Section A65 on Sheet 10W425-65, water that migrates out of the ash will need to move [thru] the column into the proposed bottom ash drainage system at the bottom of the proposed gypsum-ash stack. This drainage layer is located several feet above the top of the ash. It is unclear if there will be sufficient hydraulic head generated in the ash to drive the water in the bottom ash column up into the drainage layer. If sufficient hydraulic head is not generated the drains will not be effective. To be effective the drains may need have a separate discharge point at a lower elevation. It may also be necessary to install drains along the entire edge of the lateral expansion not just in the corners of Phases 2 and 3, as shown on Drawings 10W425-30 and 31.

9.2.6 Bottom Ash Drainage Layer

Bottom ash drainage layers are to be installed at the base of the proposed gypsum-ash stack and at elevations 810 feet, 870 ft and 930 feet with in the stack. The purpose of the drainage layer is apparently to facilitate drainage in the overlying ash and gypsum layers. Drainage of these layers will facilitate consolidation by helping dissipation of excess pore pressures generated during subsequent filling and will allow the material to move more quickly from an undrained to drained state. Based on our review of the available information, we have developed the following comments on this element of the design:

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- Calculations are not provided to support the proposed vertical spacing of the drainage layers. If the drains are spaced too far apart water may not be able to drain at a rate necessary to maintain stability as the ash and gypsum are stacked. Seepage analysis regarding the improvement from or need for drainage were not provided.

- The drainage layer is sloped at approximately one percent across the proposed ash and gypsum stack. The simplified stratigraphy presented on pages 11 and 12 includes 50 to 60 feet of various mixtures of loose ash, 15 feet of soft to stiff natural clay, and 11 feet of clayey silty sand residuum. These materials will undergo compression and consolidation as ash and gypsum are placed in the stack. This compression and consolidation will result in settlement of the various drainage layers over time. Although no settlement analyses were performed, settlement is expected to be close to zero at the toe of the slope and could be several feet under the maximum height of the stack. If the settlement is large enough, the slope of the drain could reverse rendering it inoperable. It should be noted that settlement of the drains should be based on their design operating life, which could be shorter than the time it takes to reach final stack height. ?

- The required flow capacity of the design slope (drainage layer) needs to be calculated. The testing conducted to date indicates that the proposed drainage layer is more permeable than the gypsum. However, the bottom ash drainage layer needs to have sufficient lateral hydraulic capacity (i.e., hydraulic transmissivity) to remove the water that enters along its drainage length.

9.3 Recommendations for Improvements

The following recommendations for improvement are made:

- The general stratigraphy used for stability analyses and hydrogeologic should be the same. It is recognized that one case may need to be more refined than the other. The two models need to be reviewed for consistency.
- The method for establishing strength parameters should be reviewed. If necessary, the parameters should be reestablished using more conventional approach. When appropriate both drained and undrained soil strength parameters should be developed. If the parameters change, an update of the stability analyses may be required.
- Additional sections should be analyzed to ensure all critical sections have been identified. The sections should be consistent with the design drawings.
- The general approach for seismic analysis appears to be acceptable. The average acceleration of 0.11g for the waste mass needs to be confirmed. If this parameter changes other calculations should be updated to account for the new value.
- Veneer stability needs to be expanded to include the alternate geosynthetic cover system. A water balance analysis should be performed to establish the seepage conditions in the cover system.
- The potential for liquefactions should be estimated. Depending on the results of this estimate, a liquefaction analysis may be required. If the site is expected to liquefy then ground improvement techniques need to be implemented.
- The bottom ash drainage layer needs to be designed, addressing both settlement and hydraulic capacity.

10. CLOSURE/POST-CLOSURE PLAN

10.1 Description of Review Process

GeoSyntec has completed a review of the Closure/Post-Closure Plan (Plan) for the Dredge Cell Lateral Expansion project at the Tennessee Valley Authority (TVA) Kingston Fossil Plant facility. The review process consisted of comparing the Plan with the closure and post-closure care requirements and design standards of Rules 1200-1-7-.03(2) and 1200-1-7-.04(8) of the Tennessee Solid Waste Regulations (TSWR). Rule 1200-1-7-.03(2) of TSWR requires the contents of the closure/post-closure care plan to identify and describe: (i) the steps necessary to completely or partially close the facility; and (ii) the activities and frequencies to be carried out during the post-closure care period. The closure and post-closure standards are presented in Rule 1200-1-7-.03(8) of TSWR. These include the design requirements for the cover system as well as the post-closure monitoring, inspection and maintenance activities to be performed during the 30-year post-closure care period.

For the purpose of the review, it was inferred from the available project documents that the Kingston facility is a Class II disposal facility with five variances. These variances were documented in a 27 February 1991 TDEC internal memorandum with the subject "Variance Agreement for Fossil Fuel Fly Ash and Bottom Ash Disposal within a Class II Facility" (presented as Appendix C). The five variances pertain to the geologic buffer, leachate migration control system, gas migration control system, final cover system components, and random inspection program requirements for the ash disposal facility. In particular, the final cover variance allowed the thickness of the final cover to be 24 inches of compacted soil with a minimum of 6 inches vegetative support layer in lieu of the 36 inches of compacted soil and 12 inches of vegetative support layer specified in the regulations.

The review was conducted to confirm whether the Plan met the closure and post-closure requirements of the regulations. Also, GeoSyntec reviewed the Plan to confirm that final cover system design, closure schedule and phasing, as well as the post-closure activities and responsibilities were adequately addressed in the Plan. A check list of the applicable regulations was therefore developed to use as a basis for the review. The check list is attached as Table 2

TABLE 2

CHECK LIST FOR CLOSURE AND POST-CLOSURE PLAN PER TENNESSEE SOLID WASTE REGULATIONS (RULES 1200-1-7-.03(2) & 1200-1-7-.04(8)) (April 2004 (Revised))

Rule 1200-1-7-.03(2)(b) – Contents of Plan

Regulatory Requirements	Report Meets Requirement		Remarks
	Yes	No	
1-1. Identify steps for complete or partial closure of facility		X	Partial closure not anticipated and therefore not addressed completely
1-2. Identify post-closure care activities and frequency of activities		X	Frequency of activities not identified
2 (i) Description of partial and final closure procedures and schedule and how closure standards of Rule 1200-17-0.4(8) will be met		X	Closure year and schedule for expansion areas not specified. Also, compliance with applicable closure standards not described.
2(ii) Description of monitoring and maintenance activities and frequencies during post-closure care		X	Not detailed enough
2(iii) Name, address and telephone number of contact person	X		
2(iv) Cost estimates for closure and post-closure care activities by a third party		X	
2(v) Planned use of property	X		
(3) Financial Assurance Requirements			TVA is exempt from this rule.

Rule 1200-1-7-.04(8) – Closure and Post-Closure Requirements

(c)1. Notify TDEC of intent to close at least 60 days prior to final closure date	X		
(c)2. Complete closure activities	X		

TABLE 2 (Continued)

Regulatory Requirements	Report Meets Requirement		Remarks
	Yes	No	
within 180 days			
(c)3. Place cover soil in the shortest practicable time, but not to exceed 90 days	X		
(c)3(i) Cover soil thickness shall be 36 inches total with top 12 inches for vegetation support. Infiltration volume analysis or 24-in. soil shall have k ≤ 1 × 10^{-7} cm/s. Alternative designs allowed with equivalency demonstration		X	Variance allowed total thickness to be reduced to 24 inches with top 6 inches for vegetation support. However, k value not specified. Alternative cover systems provided with no equivalency demonstrations
(c)4. Cover system design to minimize precipitation run-on, minimize erosion of cover, and provides drainage of infiltration water		X	No design analyses or calculations to demonstrate
(c)5. Establish vegetation cover to minimize soil erosion as soon as practicable		X	Not addressed in detail
(c)6. Other measures to minimize and control erosion and sedimentation at the site		X	No details
(c)9. Closure Certification and Notification	X		
(d) 30 year Post-closure care period	X		
(e) Post-Closure Care Activities		X	Plan basically listed requirements
(f) Notice in Deed to Property	X		

I ? THIS A

MINOR PROBLEM

10.2 Summary of Findings

- The closure procedures and schedule required by Rule 1200-1-7-.03(2)(b)2(i) of TSWR are not completely addressed in the Plan. Only the closure year for the existing ash dredge cell is included in Section 1.3 of the Plan even though the permit application is for the lateral expansion. The Plan refers the reviewer to the Operation Plan for the phased and complete closure of the facility; this information should be included in the closure/post-closure plan as required by the regulations.

- There is no information on the design of the final cover system that is required by the general performance standard of Rule 1200-1-7-.03(8)(a). Section 2.1 of the Plan describes two final cover system alternatives for the facility: (i) compacted soil (clay) final cover; and (ii) geocomposite final cover alternative. There is no rationale or basis for the proposed design. Also, the permeability requirement of the compacted clay layer is not specified.

- The reference drawings show other alternatives within the two proposed final cover system alternatives. For example, there is an "alternative geocomposite final cover compacted clay final cover" shown on Detail G74 as an alternative to the compacted clay final cover (Detail F74) of Drawing 10W425-74. A similar geocomposite alternative is shown on Drawing 10W425-75. It is presumed that the purpose of this geocomposite drainage layer is to function as an underdrain layer below the final cover system, but the Plan does not address the need for an underdrain layer in the cover system. Also, a geosynthetic clay liner (GCL) is shown as a component of the final cover on some of the drawings (e.g. see Detail A74 of Drawing 10W425-74), and it is not clear whether the "GCL alternative" is part of the final cover system design.

- An equivalency demonstration indicating that the alternative final cover system provides equivalent or superior performance to the minimum performance standard of the regulations was not provided.

- There are no calculations or analyses on the design of the final cover such as infiltration analysis through the cover system and drainage layer design. These analyses are required for selection of the material types and properties of the final cover system components and also serve as the basis for developing the specifications. In particular, the Plan should reference or include the details on the vegetative soil layer and its ability to support vegetation and minimize erosion of the final cover materials as required by the regulations. At a minimum the vegetation specification in Appendix B and the discussion of erosion control requirements in Appendix D needs to be referenced.

- Stability of the final cover is not addressed in the Plan; however, at a minimum reference should be made to Appendix G of the Operation Plan. Please refer to Section 9 for any additional review comments on the stability of the final cover.

- Partial closure procedures for the existing and expansion dredge cells are not addressed in detail except that TVA would submit revisions of the Plan and coordinate with TDEC should that become necessary. OKAY FOR OUR NEEDS

- The Plan lacks details on the monitoring and maintenance activities and their frequencies to be performed during the post-closure care period. The applicable post-closure care activities listed in Rule 1200-1-7-.04(e) of TSWR are basically repeated in Section 3 of the Plan.

- Rule 1200-1-7-.03(2)2.(iv) of TSWR requires the closure/post-closure plan to include "an itemized estimate in current dollars of the cost based on hiring a third party to perform the closure and post-closure care activities". There are no closure and post-closure cost estimates in the Plan. Section 4 of the Plan notes that TVA is an agency of the Federal Government and does not have to file and maintain financial assurance for closure and post-closure, as required by Rule 1200-1-7-.03(1)(b)2 of TSWR. ✓ OKAY FOR TVA

10.3 Recommendations for Improvement

The Plan addressed the closure and post-closure care plan requirements for the TVA Kingston facility but does not contain all details required by the regulations. In particular, the Plan does not describe how the applicable closure standards of Rule 1200-1-7-.04(8) will be met. The permeability of the compacted clay layer component of the cover system is not specified. Alternative cover system designs are proposed but there are no analyses or calculations to demonstrate their equivalency to the minimum design requirements.

Section 2 of the Plan could be expanded to include the following:

- Complete description of the components of the final cover system and alternatives, including material types and summary properties or specifications;
- Reference to design analyses performed to evaluate performance of the final cover system, including equivalency demonstrations, to meet the minimum regulatory standards (analysis should include stability, infiltration and drainage system design, and erosion control analysis);
- Closure procedures and schedule with details on closure date, final cover phasing, closure schedule, partial closure procedures and final closure procedures); and
- Closure certification process, including deed notation.

Section 3 of the Plan could be expanded to include the following:

- Detail description of the inspection and maintenance activities to be performed during the post-closure;
- Discussion of the post-closure monitoring activities for ground water and surface water;
- Record keeping program, land use plan, and contact person during ~~pot~~-closure; and post
- Post-closure certification process.

11. QA/QC PLAN

11.1 Description of Review Process

GeoSyntec has completed review of the Construction Quality Assurance/Quality Control (QA/QC) Plan for QA/QC PLAN

The review process consisted of comparing the Plan with the construction quality assurance plan requirements of Rule 1200-1-7-.04(9)(c)19 of the Tennessee Solid Waste Regulations (TSWR) as well as GeoSyntec's experience with preparing similar plans in the state of Tennessee. Rule 1200-1-7-.04(9)(c)19 requires the construction quality assurance (CQA) plan to describe:

(i) How each new "as-built" solid waste landfill unit(s) liner(s) and/or lateral expansion liner(s) and cover system(s) will be inspected and/or tested by a registered engineer as required at rule 1200-1-7-.04(1)c during construction or installation for uniformity, damage, and imperfections, and

(ii) How each constructed section of the liner system or final cover system will be certified by a registered engineer.

Rule 1200-1-7-.04(1)c referenced above provides the requirements for project supervision, that a registered engineer licensed in the state of Tennessee must plan, design, and inspect the construction of a disposal facility.

Because the above regulations do not include detailed requirements for preparing a CQA Plan, GeoSyntec reviewed the QA/QC Plan for the TVA Kingston facility using its experience with preparing similar plans for waste disposal facilities. Some of these facilities are in Tennessee and were permitted and approved by TDEC. Based on our experience, the scope of a CQA Plan should include the following:

- defining the duties and responsibilities of parties involved with the construction of the disposal facility;
- monitoring of construction activities for the major components of the facility;
- establishing testing protocols for the evaluation of the landfill components;

- establishing guidelines for construction documentation; and
- providing the means for assuring that the overall construction conforms to the project design plans, specifications, permit conditions, and construction drawings.

Therefore, the review process consisted of reviewing the QA/QC Plan to confirm whether the above requirements were adequately addressed.

11.2 Summary of Findings

The duties and responsibilities of the parties involved with the construction were not clearly defined. Section 2 provided definitions for the terms used in the QA/QC Plan and Section 3 presented the duties and responsibilities for the Certification Engineer only. The qualifications, duties and responsibilities of the other parties involved with the construction are not defined in the QA/QC Plan.

Based on the definitions, it appears the Certification Engineer is not part of the CQA Consultant. The Certification Engineer is an individual that will be selected by the TVA Fossil Engineering Services (FES), serving as the Design Engineer. The CQA Consultant on the other hand is an individual appointed by the Constructor. Based on our experience, the Certification Engineer should be part of the CQA Consultant, which should be a third party independent from Owner and Contractor.

It is also not clear whether the technicians referenced later in QA/QC Plan work for the Certification Engineer or CQA Consultant. The qualifications, duties and responsibilities of the technicians are not defined in the QA/QC Plan.

Terminologies are inconsistently used in the QA/QC Plan. For example, Constructor versus Contractor, Certification Engineer versus Certifying Engineer or Certification Officer, etc.

Sections 6 through 10 contain both specifications and CQA procedures (inspection and testing) for construction of the ash dikes and final cover system. It appears that there no separate specifications for the ash and soils components of the lateral expansion. A separate, stand alone, specifications for the soils and ash materials used for final cover and dike construction should have been prepared. The QA/QC plan should only include the CQA procedures and frequencies for monitoring, testing, and documentation during construction and should be considered as a supplement to the Specifications.

Additional findings from the review are described below.

- *Section 5 – Under Drainage System.* The material specifications for installation of the under drainage (i.e., underdrain) system for the existing dredge cells are supposedly shown on the Drawings. This is inconsistent with the rest of the construction where the specifications are included in the QA/QC Plan.

- *Sections 6 – Fly Ash & Bottom Ash Dike Raising.* The dikes are to be constructed with a mixture of fly ash and bottom ash. The construction procedure involves placing alternating 6-inch lifts of fly ash and bottom ash to a 1 foot layer, and using a roto-tiller to blend the two layers together, and then compacting the material to a specified Proctor maximum density. A suggested procedure for establishing moisture compaction window for bottom ash and fly ash is included as Attachment 3 (but sometimes referred to as Attachment 4). A suggested compaction procedure is referred to in the Plan as Attachment 4 (sometimes referred to as Attachment 3). Since only one (Attachment 3) was found in the document it is presumed that Attachment 3 and 4 are the same document. The construction procedure outlined in this section including testing frequency and acceptance of completed work relies solely on judgment by the Certification Engineer. This makes the qualification of the Certification Engineer important for successful completion of the work.

- *Section 7 – Fly Ash Base and Drainage/Filter Layer.* Material selection, placement, compaction and testing procedures are similar to that presented in Section 6 and rely on the discretion of the Certification Engineer. For example, Tensar geogrids can be used to facilitate construction of the fly ash base beneath Phases 2 and 3 if approved by the Certification Engineer. No specifications for the geogrid are included. Construction of the filter layer requires laboratory hydraulic conductivity testing to "...be performed initially to ensure performance meets the design parameters..." The design parameters are not specified.

- *Section 8 – Starter Dike for Dredge Cell Expansion.* See comments on Sections 6 and 7.

- *Section 9 – Wet Cast Gypsum Dike Construction.* Inspection, testing frequency and acceptance rely on the discretion of the Certification Engineer. The Plan suggests that strength testing of the placed gypsum material may be performed to determine any variation in strength parameters. Type of strength testing and details are not provided.

- *Section 10 – Final Cover.* The minimum testing frequencies for the clay liner construction in Table 1 seems to be too strict for the index properties tests (sieves, Atterberg Limits, etc.). Also, the procedures used to establish the acceptable permeability zone (APZ) are confusing and need to be clarified. At a minimum, the APZ should include a minimum compaction requirement (e.g. 95 percent of the maximum dry unit weight of the standard Proctor compaction (ASTM D 698)). Section 10.4.1 specifies the foot length of the compactor to be a minimum four inches and the compacted thickness to be a maximum of 6 inches. To achieve bonding between lifts the state of practice requires the loose lift thickness to be at least 1 to 2 inches less than the foot length of the compactor. Table 2 requires that Shelby tube samples be collected on the compacted clay for laboratory hydraulic conductivity determination per ASTM D 5084. Note 6 under the table states that the test method "…is not acceptable for soils with more than 20% retained on the number 4 sieve…" No recommendations are given in the Plan to address the case where more rock particles are encountered.

- *Section 11 – Construction Tolerances.* No tolerances are provided for the various layers of the final cover system.

- *Section 12 – Surveying.* Surveying requirements for the various components are described and are generally okay.

- *Section 13 – Reporting.* The documentation and reporting process for construction of the project is described and generally contains all the elements required for a CQA Plan. The Plan does not state whether the certification reports described in Section 13.2.7 would be submitted to TDEC for review and approval.

- *Attachment 1 – Specification KIF-O-TS-02778 Revision 0 for LLDPE Geomembrane Construction Quality Assurance*

  - The CQA Plan for the LLDPE geomembrane includes detailed material and installation specifications. These detailed specifications are also duplicated in the Specifications section (see Section 12).

  - The terminologies used in the CQA Plan such as Geomembrane Manufacturer, Installer, Geosynthetic CQA Laboratory, are not defined in Section 2 of the QA/QC Plan. It appears that the Geosynthetic CQA plans (including geocomposite) were prepared as stand alone documents.

  - Qualifications and training requirements of the installation crew as outlined in Section 2.2.1 are inconsistent with those listed in Section 2.3.2 for the seaming crew and in Specification 02777 for geomembrane installation.

  - The clothing requirements (smooth-soled shoes, gloves, etc.) listed in Sections 2.2.2 and 2.3.3 are not appropriate in this document. They could be made part of the contract documents.

  - Section 2.11.2 specifies a minimum frequency for taking destructive seam samples of one test location per 2,000 feet of seam length. The state of practice is to take one sample per 500 ft of seam length.

  - Table 1 – LLDPE Minimum Material Requirements – is more appropriate to be in Specifications section. See Section 12 for comments on the minimum property values.

  - Table 2 – Manufacturer's Testing Frequency in accordance with GRI GM 17 is appropriate.

  - Table 3 – CQA Conformance Testing Frequency – shows one test per 50,000 square feet (with the exception of interface-friction angle). The state of practice is one test per 100,000 square feet. The basis for two tests for interface-friction is not clear.

- Table 4 – LLDPE Liner Minimum Weld Values – is more appropriate to be in the Specifications section. The frequency for taking destructive seam samples should be on this table. See Section 12 for comments on the specified seam strength values.

- *Attachment 1 – Specification KIF-0-TS-02622 Revision 0 for Geocomposite Drainage Layer Construction Quality Assurance*

  - The CQA Plan for the geocomposite drainage layer includes detailed material and installation specifications. These detailed specifications are also duplicated in the Specifications section (see Section 12).

  - The terminologies used in the CQA Plan such as Geocomposite Manufacturer, Installer, Geosynthetic CQA Laboratory, are not defined in Section 2 of the QA/QC Plan. It appears that the Geosynthetic CQA plans (including geocomposite) were prepared as stand alone documents.

  - Table 1 – Geocomposite Material Requirements – is more appropriate to be in the Specifications section. See Section 12 for comments on the minimum property values.

  - Table 3 – CQA Testing Frequency for Geocomposite – shows one test per 80,000 square feet (with the exception of interface-friction angle). The state of practice is one test per 100,000 square feet. The basis for two interface-friction tests for each interface is not clear.

11.3 Recommendations for Improvement

The QA/QC Plan contains detailed material and construction/installation specifications for the soils and geosynthetic components of the project. The QA/QC plan should only include the CQA procedures and frequencies for monitoring, testing, and documentation during construction and should be considered as a supplement to the Specifications. In particular the materials and construction specifications for construction of dikes using fly ash and bottom ash material should be separated from the QA/QC and placed in a separate technical specifications document.

There are also a number of inconsistencies and redundancies in the QA/QC Plan. Different terms are used in different sections of the Plan. The Plan therefore should be revised for consistency.

13. SEEPAGE ANALYSIS

GeoSyntec performed a review of the seepage analyses described in Section 3.1.3 of the Operations Manual. Specific details of the seepage analyses are presented in Appendix K of the Operations Manual. Seepage analyses were performed with the objective of evaluating the conditions that led to a "blow-out" in the dike of the existing dredge cells adjacent to Swan Pond Road. Based on information presented in Appendix K, we understand that a finite element seepage model was developed using the TIMES software code (developed by Tri-hydro). The resulting model was used to evaluate existing conditions and to evaluate the effects of proposed remedial measures under both existing and future conditions.

13.1 Description of Review Process

GeoSyntec performed a review of the seepage analysis package included in Appendix K of the Operations Manual. Our review focused on general approach and methodology. A review of the mathematical correctness and of the specific input and output data could not be performed as sufficient level of detail was not included in the calculation package. The following specific steps were performed as part of our peer review process:

- we performed a "spot check" of the data obtained ~~fro~~ from the subsurface explorations, as presented in the report titled, "Report of Geotechnical Evaluation" (Mactec, 2004);
- we performed a "spot check" of the critical section used for the seepage evaluations (presented graphically as Figure 1 of Appendix K), including general geometry and stratigraphy used;
- we reviewed the material properties used in developing the model (Table 2, Appendix K) in terms of reasonableness and our experience with other similar materials

- we reviewed the graphical output from the TIMES seepage model simulations for reasonableness (note: specific input and output data was not provided in the calculation package);

A summary of GeoSyntec's findings is presented in the next section. Recommendations for Improvement are provided in Section 13.3.

13.2 <u>Summary of Findings</u>

The following subsections describe the findings of our peer review of the seepage analyses.

13.2.1 Critical Section and Material Properties

In reviewing the critical section used for the various seepage analyses, GeoSyntec compared the figures presented in Appendix K with information presented in the subsurface evaluation report (Mactec, 2004). We assume that the critical section approximately aligns with Section A-A', as indicated on Figure 2 of the Mactec report. Based on our review of the subsurface report we initially attempted to reproduce/verify the approximate stratigraphy presented on Figure 1 of Appendix K. Our comments specific to the stratigraphy (referred to as "soil zones" on Figure 1, Appendix K) are as follows:

- The relative boundaries indicated for each of the soil zones appear to be reasonable based on a review of the borings and CPT data. We assume that the conceptual cross section presented as Figure 1, Appendix K was drawn with the benefit of additional information (e.g., as built information from the construction of the existing dike and dredge ponds) since all soil zone boundaries could not readily be interpreted using just the information in the subsurface report (Mactec, 2004).

- The geometry of the boundary between soil zone #5 and soil zone #6 (i.e., "loose fly ash and bottom ash interior" versus "natural clay, soft to stiff (CL) at toe") would appear to be critical to the seepage analyses; we assume this boundary is derived from as-built information.

- Section 4 of Appendix K states, ".....simplifications are needed because of bandwidth difficulties introduced with sharp corners in development of a finite element mesh...."; a discussion of the specific "simplifications" would be helpful to provide the reviewer an assurance that the section is representative; and

- Section 5 of Appendix K states, "We performed an extensive review of data from all past and recent borings and CPT soundings to determine a representative subsurface stratigraphy near the "blowout" for use in a seepage analysis"; the past borings do not appear to be referenced.

GeoSyntec's comments specific to the material/soil properties used in the seepage analysis are as follows:

- The values of hydraulic conductivity presented in Table 2 of Appendix K for zones 1 through 6 appear to be very high when compared to typical values that we have seen for fly ash and bottom ash. For example, the hydraulic conductivities of zones 2 and 3 (defined as "loose fly ash" and "medium dense to dense fly ash and bottom ash") are shown to be 0.0071 and 0.0027 cm/sec respectively. These hydraulic conductivities are more representative of gravel-like material as opposed to ash materials. Similarly, the ratio of horizontal to vertical hydraulic connectivity seems high. The text of Section 7, Appendix K states that, "the hydraulic conductivities for the seepage analyses come from CPT hydraulic conductivity measurements with depth at soundings CPT 1, 1A, and 4". The text further states that, "Freeze and Cherry (Ref.4) (1979, Pg. 37, Equations 2.31 and 2.32) describe how to calculate the horizontal and vertical hydraulic conductivities for the layers shown in Figure 2". Based on our review of the methodology used, we believe the resulting values of hydraulic conductivity may be erroneous based on the following:

    - In reviewing the CPT data contained in Appendix B of the Cone Tec Field Report (contained in Mactec, 2004), we note a wide range in reported values of hydraulic conductivity (k) (e.g., in the case of CPT-1, reported values range from 5.0×10^{-6} cm/sec to 1.0×0^{-15} cm/sec). Table 1 of this Appendix implies that k is an assigned value based on the Soil Behavior Type (SBT). We therefore assume that values of k were not specifically calculated for the in-situ ash materials, and were derived for typical soils based on SBT characteristics.

- GeoSyntec's experience indicates that the estimation of hydraulic conductivity of ash materials using CPT methods is difficult to achieve due to rapid dissipation of pore pressures. In such situations, values of k are often assigned based on the assigned SBT. In these situations, the assigned k values may be derived for soils and may not be applicable to ash materials.

- We note that in-situ vertical and horizontal hydraulic conductivity was measured at borings B-1 and B-2. These values are reported as maximum $k_v = 5.13 \times 10^{-6}$ and 3.59×10^{-6} cm/sec; and minimum $k_h = 5.42 \times 10^{-6}$ and 5.38×10^{-6} cm/sec respectively (Appendix C, Mactec 2004). These values were obtained at approximate depths of 5 ft. in the vicinity of the reported blowout and do not appear to have been considered in the analyses.

- Additionally, it seems odd that compacted fly ash (i.e., zone 1) would have essentially the same permeability as the ponded ash (i.e., zone 2).

- It seems somewhat "refined" in these initial runs to consider partially saturated flow, particularly when the van Genuchten parameters are the same for all strata AND since the model is driven to a steady state initial condition for the initial analyses. ?

13.2.2 Analytical Results

The issues raised in Section 13.2.1, may explain some of the graphical results, which suggest little dissipation of energy (i.e., head) as flow proceeds towards the toe. We are not familiar with the TIMES code, nor could we find information on the TriHydro web site. On initial review, we are curious as to why a fate and transport model was selected, in lieu of a porous media seepage code. The selected finite element mesh seems extremely fine for the relatively simple stratigraphy. It also seems that the "coarseness" and "fineness" of the mesh were not adjusted to reflect differences in hydraulic conductivity. This alone can lead to numerical instabilities and potentially erroneous results. In our review of Figure 3, Appendix K (Initial Conditions) we had the following additional questions and comments:

- Why is the ponded water not considered a constant head boundary condition?

- There does not seem to be a discontinuity in slope of the pressure head as it crosses different strata which is peculiar. Similarly, when the "water table" pressure head approaches the ground surface near the lower berm (i.e., at station 920 approximately) we would expect that it would tend to "daylight" rather than continuing within the fly ash layer.

The peculiarities of these initial conditions raise some concerns regarding the subsequent analysis results. The results presented on Figure 4 and 4A (Appendix K) seem strange and raise the following questions/issues:

- For the pressure head contours shown in Figure 4, are the perimeter drains explicitly considered? If so, why is there no change in pressure when seepage encounters a drain?

- The uniformity of the pressure head contours from Station 750 to 950 seems to suggest little dissipation of energy with flow. This result appears strange.

- The fact that the pressure head contours at 10 and 20 feet exit the downstream slope is odd and definitely unusual. If these are confirmed, then we agree that seepage is a MAJOR issue, but we have never seen field conditions that are represented by these conclusions.

- Why is there such a significant drop in the 40-foot pressure head within the clay toe but no loss until flow travels 50 to 60 feet in this material?.

The results presented on Figure 4A are equally confusing. And raise the following issues/questions:

- The results indicate significant dissipation in head even above the 0 ft pressure head. Is this correct?

- Are there no results beyond the total pressure head of 792? What is happening in the toe area at Station 1000?

- The flow line regime presented in this figure is very unusual and the authors provide no discussion of these implications.

The authors recommend the use of slope drains and geonet composite drains to address high subsurface water pressures. While these techniques can help control water near the surface, they do little to dissipate high subsurface water pressures, should they actually exist. We strongly recommend that the measures proposed be re-evaluated once the analytical issues (above) have been addressed.

13.3 Recommendations for Improvements

The analyses presented in Appendix K raise a number of concerns and questions as identified in Section 13.2. GeoSyntec recommends that these questions and issues should be brought to the attention of the designers and addressed. At a minimum, we recommend that the following actions should be taken:

- Address the specific questions and concerns identified in Section 13.2 of this report.

- Review the input data (particularly hydraulic conductivity values), adjust as needed, and re-run the simulations.

- Check the output for reasonableness.

- Verify the output by constructing a conventional flow net or other independent means.

As an alternative (and likely more appropriate) approach, GeoSyntec recommends the following approach as a more robust analytical procedure:

- Develop an independent porous flow model using more widely accepted software code (note: GeoSyntec recommends the use of a finite difference code such as SEEP-W).

- Review CPT data thoroughly and select hydraulic conductivity values more representative of typical ash materials.
- Run the model to simulate existing conditions and calibrate to known conditions (e.g., water elevations).
- Run a series of simulations (representing existing and future conditions) incorporating bench drains and a toe drain located at a variety of elevations in order to optimize the selection of drain elevations.
- Incorporate calculated internal pore water pressures at strategic locations within the dike into stability calculations at the critical section and re-check stability.

TWO SEP. ANALYSIS

REVIEW + SELECT
K VALUES,
BOUNDARY CONDITIONS

PARSONS	GEO SYNTEC
TIMES	SEEP-W

14 CONSISTENCY/COMPLETENESS OF DRAWINGS

14.1 Introduction and Organization

A final component of the GeoSyntec's review was to perform a check for consistency and completeness of the documents. To facilitate TVA review, a marked set of 11 x 17 inch drawings is provided as Appendix A to this report. Please note that a color pdf file is also included on the attached disk to facilitate review of "redline" comments. In general, GeoSyntec found the drawings to be extremely detailed, containing more detail than would normally appear in a permit document. This level of detail, however, can be beneficial in the development of construction-level drawings. One overall comment is that it would have been helpful to present a plan view of each stage on a single drawing at a scale of 1:200 (or smaller) in companion with the typically eight-sheet drawings needed to visualize the design. This would have greatly facilitated understanding and conveying the design concept. Since this package will be provided to TDEC for review, it is GeoSyntec's opinion that incorporation of these few additional sheets will be helpful to TDEC and will facilitate review and approval of the project. Additional discussion regarding the review comments beyond those expressed on the marked drawings is not provided at this time, as the notes on the drawings are meant to be stand-alone. It may be helpful to meet with TVA to review these comments face-to-face at one of the upcoming meetings.

15. REFERENCES

Mactec (2004) "*Report of Geotechnical Exploration, Ash disposal Area Kingston fossil Plant, Kingston, Tennessee*".

Parsons E&C (2004), "*Tennessee Valley Authority Kinston Fossil Plant, Proposed Scrubber Addition, Gypsum Stack Disposal Options, Phase I Report*".

United States Environmental Protection Agency (USEPA). "*RCRA Subtitle D (258) Seismic Design Guidance for Municipal Solid Waste Landfill Facilities*", Office of Research and Development, EPA/600/R-95/051, April 1995.

Tennessee Valley Authority (TVA). "*Hydrogeologic Evaluation of Ash Pond Area, Kingston Fossil Plant, Report No. WR28-2-36-124*", J.M. Boggs, A.J. Danzig, J.A. Schroeder.

Freeze, R.A., and J.A. Cherry. "*Groundwater*". Prentice-Hall, Inc., Englewood Cliffs, New Jersey 07632.