Draft Report

Review of Documents Related to Final Closure of the Sunrise Mountain Landfill

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INTRODUCTION

The Desert Research Institute (DRI) is under contract to Science Applications International Corp. (SAIC) to provide assistance to the United States Environmental Protection Agency (USEPA) regarding the Sunrise Mt. Landfill near Las Vegas, NV. The issues of concern at Sunrise involve final closure of the site particularly with regard to the hydrologic performance of the final cover and a variety of topics associated with surface water flow and erosion. The DRI scientists involved in this project, Dr. Richard French and Mr. William Albright, are recognized experts in the relevant fields and have performed the evaluations reported in this document.

The primary task issued to Dr. French and Mr. Albright was to evaluate two proposals for closure of the site. One proposal was prepared by the consulting engineer for the site (Exponent, Inc.) and the other by the USEPA. Those two documents, along with approximately 65 additional supporting documents, were reviewed by DRI. This report summarizes the findings and recommendations of Dr. French and Mr. Albright regarding final closure of the Sunrise Mt. Landfill.

The documents supplied by USEPA were received by DRI on June 1, 2004. Dr. French and Mr. Albright traveled to Las Vegas on June 24, 2004 for a visit to the site and subsequent discussion with others involved in project.

This report is organized to reflect the two primary concerns at Sunrise: (1) erosion of the final cover, and (2) the hydrologic performance of the cover to limit percolation of precipitation into the underlying waste.

EROSION

Technical Introduction

From the viewpoint of protecting the closed Sunrise Mountain Landfill in Clark County, Nevada, from erosion, there are two issues. First, the site must be protected from run-on deriving from the watersheds tributary to the site; and second, the integrity of the landfill cap must be protected from runoff/erosion resulting from precipitation falling on the cap and sideslopes. As evidenced by past experience, these are equally important challenges, but require quite different approaches. In both cases, the critical step is establishing the return period, depth, and duration of the design precipitation event. It is pertinent to observe that throughout the semi- and arid Southwest, in general, and in Clark County, in particular, it is tacitly assumed that when the rainfall-runoff process is properly modeled the return period of the design precipitation event results in a runoff event having the same return period. This is not a valid assumption in all cases, but it is the approach that has been adopted by the Clark County Regional Flood Control District (CCRFCD, 1999) and its predecessor regulatory agencies.

In the following materials, the challenges of protecting the site from erosion caused by run-on and erosion resulting from precipitation directly on the closed landfill are discussed separately because the only relation between these processes is the causative precipitation event. Therefore, the causative (design) precipitation event and the data and information reviewed regarding this are critical.
Causative (design) Precipitation Event

As discussed in the Technical Introduction, the selection of a design precipitation event is, from the viewpoint of erosion mitigation, likely the most critical decision that must be made. That is, rainfall causes runoff, and runoff in combination with rain drop impact results in erosion. Therefore, the selection of an appropriate design event from the viewpoint of return period, duration, depth, and distribution in time is a critical decision. There are two reports that deal with this issue EMCON (1999) and Hamilton and Lyle (2003a). EMCON (1999) concluded that the guidance and data in CCRFCD (1999) was valid, after examining a number of “site specific” events. Certainly, using the guidance, methodologies, and data in CCRFCD (1999) meets the current standard of care and practice in Clark County. However, as is the case with most arid regions, the standard of care and practice changes as the period of record available analysis increases; and this has been the case in Clark County.

Given the conclusions of EMCON (1999), the approach to estimating the depth of the causative event used by Hamilton and Lyle (2003a) was a reasonable approach, and the results are also reasonable.

The first issue that requires consideration is the return period of the causative (design) precipitation event. As noted by both EMCON (1999) and Hamilton and Lyle (2003a), the return period of the causative precipitation event in Clark County is 100-years for general residential and commercial development. The selection of a causative event with a return period of 200-years is a matter that warrants careful consideration. For example, 40 CFR 1.9 (FEMA) requires that critical facilities (hospitals, retirement homes, etc. be protected from the event with a return period of 500-years. Therefore, the basis for the selection of a causative event with a return period of 200-years is unknown. If the closed Sunrise Mountain Landfill is a critical facility, then the return period of the causative event should be 500-years. It is acknowledged that an event with a return period of 200-years is conservative; but the fundamental question is, what is the technical/risk basis for the selection of an event with a return period of 200-years? The materials provided do not answer this question from a technical viewpoint. The second issue is the duration of the causative (design) precipitation event. This also is an important decision in that it relates to intensity. Hamilton and Lyle (2003a) choose an event with duration of 6-hours. This choice is in keeping with the CCRFCD (1999) guidance that suggests of all possible events a short duration convective precipitation event (thunderstorm) is likely to result in greatest hazard to public safety and property in Southern Nevada. With regard to the causative event, a reasonable event duration has been selected.

From the viewpoint of protecting the site from run-on reasonable decisions have been made regarding the depth and duration of the causative precipitation event.

Protection of the Site From Run-On

The most pertinent document dealing with protecting the site from run-on is the document produced by Exponent, Inc. (Hamilton and Lyle, 2003a). At this point, it should be revealed that Dr. French knows Mr. Hamilton and has worked with him in several instances. It is pertinent to note that, in his opinion, this is a preliminary design report, and it is likely that the proposed drainage mitigation plan would likely be refined before construction. In addition, the following observations are pertinent:
1. HEC-HMS, an industry standard model, was used to model the rainfall-runoff process. One of the problems with HEC-HMS is that unless the input data files are provided, you cannot examine the causative precipitation event hyetograph; that is, the distribution of precipitation as a function of time. The text is not clear on this issue and, as will be discussed subsequently, this is an important issue.

2. HEC-RAS, an industry standard model, was used to model the flows in the proposed channels. Sufficient output from this model was available to perform a preliminary review, but the input data files should be requested.

Positive Observations

Overall, the report is well written and complete, with the exceptions noted above. My positive observations are as follows:

1. The report makes a very convincing argument from the viewpoint of geologic engineering that conveyance of flood flows from the upstream watershed past the landfill in an open channel is not the best alternative for two reasons. First, the channel would likely require significant maintenance; and second, there is the potential for a catastrophic failure of the channel during extreme precipitation and flow events.

2. The proposal to use a detention basin to "meter" flows and retain the debris generated in the upstream watershed past the site in a closed conduit is a reasonable alternative, although this proposal is not without difficulties, as will be subsequently discussed.

3. The report is correct that watersheds along the eastern boundary of the Las Vegas Valley are much more geologically active relative to the watersheds on the western boundary of the Valley. This is an issue that will also be discussed in the following section.

4. The three channel locations for flow collection and conveyance are also reasonable.

5. The use of the Regional Regression Equations to check the rain-runoff modeling was a reasonable approach.

In conclusion, I would say that from a conceptual viewpoint, Hamilton and Lyle (2003a) have made a reasonable and well thought out proposal to mitigate the run-on and the potential erosion problems (likely catastrophic) associated with run-on. However, as discussed in the next section, there are a number of technical issues which were not addressed in this report and which require clarification, discussion, and additional work.

Issues

1. As noted above, the hyetograph used by Hamilton and Lyle (2003a) for the design precipitation event is at this point not known. A reasonable assumption is that the hyetograph in CCRFCD (1999) for a six hour precipitation event with a return period of 100-years was used. While this is a standard and justifiable assumption, it is likely not conservative for the extreme precipitation event considered. The most damaging 6-hour precipitation events in Southern Nevada are not stationary but move from the upper portions of the watershed to the lower portions at a rate such that the peak flows for all sub-basins coincide at junction points. One could argue that given usual track of convective storms through the Las Vegas Valley, the location of the landfill,
and the orientation of the upstream watershed this will not happen. However, the
design precipitation event has a large return period and must be considered a rare
event; and rare events often behave in unexpected ways. It would be my
recommendation that for an event with this return period a moving storm be
considered as an upper bound to the peak flows that need to be conveyed.

2. While I am in favor of a detention basin to control the flow from the upstream
watershed and retain debris and sediment, there are a number of issues associated
with the proposed detention basin that are not discussed; and among these issues are
the following:

- Hamilton and Lyle (2003a) do not address the issue of sediment/debris yield to
the detention basin. This issue affects the volume of the basin required to detain
the runoff volume resulting from the design precipitation event, and the
maintenance that will be required in the future. That is, debris will be transported
to the basin by all runoff events; and at some point this accumulation will need to
be removed to maintain volumetric capacity. Further, “the basin would be
underlain by an impermeable, synthetic liner” which will complicate future
maintenance activities; debris and sediment removal (It is realized that this
statement is partially in error since only a portion of the basin will be lined.). This
issue must be addressed, if this alternative is to be implemented. I would note that
this is a standard requirement for all detention basins in the Las Vegas Valley and
Clark County.

- There are no data within the report that demonstrate that volumetric capacity of
the proposed detention basin is sufficient to detain the runoff generated by the
causative precipitation event.

- No calculations were provided in the report to substantiate the statement “We
have designed the detention basin to drain within 24 hours after the 200-year
storm event has ended.” This statement appears to be contradictory of the next
sentence, “The total drainage time for the detention basin would be 30 hours.”
This apparent contradiction should be clarified.

- The outflow from the detention basin would be conveyed downstream in a
“durable, high-density polyethylene (HDPE) pipeline” on the ground surface and
supported by spread footings. With regard to this proposal, I have two concerns.
First, given that the proposed pipeline will be on the surface there is the potential
for erosion to damage the stability of the supports. The second concern regards
the durability of this pipeline in the long-term from the viewpoint of ultraviolet
radiation and the potentially erosive nature of the suspended sediment transported
in the pipe during extreme events. Note, I am not an expert in materials and their
durability under these conditions. Also, while the proposed detention basin will
remove coarse particles, fine-grained sediment in suspension will be transported
through the pipeline.

- An emergency spillway for the detention basin is shown in the drawings;
however, there are no engineering calculations for this spillway, and there is no
discussion of the conveyance of the water originating from this spillway
downstream.
3. The three conveyance channels are well thought out from the viewpoint of location and function. However, the hydraulic engineering information provided suggests reasons for concern. Among the concerns are the following:

- The HEC-RAS output provided with the report shows that flows in Channel No. 1 will be conveyed at approximately 12.5 ft/s and at a Froude number of 1.23. While the velocity is of concern, the Froude number is of greater concern; see for example, French (1985). The issue is at this Froude number small errors in modeling can result in large errors in the depth of flow.

- The HEC-RAS output provided with the report shows that flows in Channel No. 2 will be conveyed at approximately 14 ft/s and at a Froude number of 1.6. The concern with this channel is the same as with Channel No. 1.

- The HEC-RAS output provided with the report shows that flows in Channel No. 3 will be conveyed at approximately 20+ ft/s and at a Froude number of 2+. In this channel, there are two issues. First, the velocity is too high for channel stability (note, while the guidance manual was provided, no calculations were provided). Second, no calculations regarding flow stability were provided (CCRFCD, 1999).

In my opinion, while the proposed channels are properly located, further thought must be given to their design.

4. I have concerns regarding the point where the proposed drainage system returns the flow to the natural environment - the downstream end. Nevada Law specifically prohibits the concentration, diversion, and increase in flow (CCRFCD, 1999). While the flow may not have been increased, it certainly has been concentrated and diverted. There are ways to deal with this issue; however, the report is silent on this issue. Although a spreading and energy dissipation structure is shown in the drawings, there is no discussion of this structure in the reports.

**On-Site Erosion Mitigation**

The primary reports dealing with on-site erosion and mitigation are Hamilton and Lyle (2003b) and Mezzacappa and Smith (2003). From a philosophic viewpoint, the requirement to contain soil loss from the landfill cap to 2 tons/acre/year, while perhaps appropriate to a humid environment, is likely not appropriate to a semi- or arid and controlled environment where the soil will not be replenished by vegetation or deposition from upstream. Overall, my comments are:

1. From the viewpoint of on-cover erosion prediction, I am not convinced that the WEPP Model is the appropriate model to be used. WEPP was developed to predict erosion and pollutant transport from agricultural lands where by definition the landuse and slopes involved are very different than a landfill cap. Rather than using WEPP, an agricultural model, I would recommend using KINEROS (Woolhiser et al., 1990). However, this is a professional opinion, rather than a criticism.

2. In my opinion, focusing an erosion target of 2 tons/acre/year is likely an inappropriate goal for several reasons. First, from an engineering viewpoint, the target value should and likely will be interpreted in statistical terms; that is, on the average erosion will be limited to 2 tons/acre/year. Second, if the goal is couched in statistical terms, then
what is the period over which the average is achieved. Third, this average value is not meaningful in achieving the real and meaningful engineering goal; that is, preventing the movement of waste materials to the Las Vegas Wash during a single extreme event.

With regard to these documents, the following specific comments are pertinent:

1. It is quite clear that the WEPP is predicting erosion in certain areas of the landfill cap that exceeds the standard of 2 tons/acre/year (Mezzacappa and Smith, 2003).

2. I do not understand why the site is being protected from a 200-year return period event for run-on and an event of a lesser return period is being used to predict erosion from on-site erosion. This is not a consistent approach; that is, in my opinion one design storm of an established duration and return period should be used to protect the site.

3. I am very concerned about the very steep slope of the landfill that faces to the west. Hamilton and Lyle (2003b) are correct in noting that on this slope the distance sheetflow can continue without diversion must be limited. However, this distance is not quantified either in the drawings or the text. This is a critical issue. Further, the v-ditches to divert the flow are not discussed. Of all the issues involving erosion, this is likely the most critical issue, and the reports and drawings do not address this issue in detail. I am concerned that given the steepness of this slope it is not going to be possible to collect and turn the flow without a very sophisticated engineering design.

4. I would recommend that an analysis similar to that performed by Stormont (2003) be performed. While this analysis has limitations, it is technically very good and is applicable.

EPA Proposed Scope Of Work

Overall, I find no major issues EPA’s Proposed Scope of Work (2004). In point of fact, there are some very positive points made in this document; and among these are:

1. Task 4.1.2 I am in full agreement, as an engineer not a biologist, that the Sunrise Landfill is unlikely, for a variety of reasons, to become a vegetated cover. Therefore, asking for a cap “with sufficient capacity to hold incoming precipitation until the water can be removed by evaporation” is a reasonable erosion control alternative. The issue here is the design precipitation event, that is, the return period of the event and the depth of precipitation. Further, as noted previously the closed Sunrise Landfill is an erosional rather than a depositional feature; therefore, erosion of the cap will occur - it cannot be prevented only mitigated.

2. Task 4.1.4 An erosion prevention layer is a reasonable request. At this point, I have no technical basis for evaluating the specific mixture to be used. I would recommend referring to Stormont (2003) to evaluate the mixture suggested. Making the surface as rough and erosion resistant as possible is, from the viewpoint of hydraulic engineering, very positive. That is, the Sunrise Landfill is and will remain a net erosional environment regardless of the erosion mitigation undertaken. However, a rough surface will slow the velocity of flow, minimizing erosion; and large gravel sizes minimize the transport capacity of flows.
3. **Task 4.1.7.9** This is a critical consideration! Everyone seems to be in agreement that terrace drains are needed to prevent on-site erosion. The critical issues are the spacing of the drains, the width of the terraces, and the depth and composition of the erosion prevention layer provided. Calculations along the lines performed in Stormont (2003) and Dwyer et al. (1999) should be performed. In addition, it is not only the spacing of the terraces that is critical, it is also their width. That is, the intention of the terrace drains is to capture water moving rapidly down a steep slope and turn it approximately ninety degrees; and therefore, momentum is a consideration.

My conclusion is that the Proposed Work Scope is logical and can be implemented.

**HYDROLOGIC PERFORMANCE OF THE FINAL COVER**

Given physical containment of solid waste, the most likely mechanism for the spread of contaminants from a solid waste landfill is through hydrologic processes. Federal regulations and rules promulgated by the USEPA and the states recognize this and specify design features for final covers intended to reduce the amount of water from precipitation that is allowed to pass through the cover into the waste. For purposes of this report the term "infiltration" will be used to describe water that passes from the atmosphere into the soil profile. The term "percolation" will be used to describe water that escapes the surface processes of evaporation and transpiration and passes from the cover into the underlying waste. "Alternative final cover" (AFC) will be used to describe designs that rely on the store-and-release concept to minimize percolation into waste.

**COVER DESIGN AND UNCERTAINTY**

There are major differences in the design procedures for conventional and alternative covers due to differences in design concept. Conventional cover design, which is based on placement of a low-conductivity material (geomembrane and/or fine-grained soil), typically begins with identification of a material with the required parameter value. Material selection is followed by preparation of a set of engineering specifications for placement of the material and a construction quality assurance plan. Performance is assumed based on material parameter description without consideration of the environmental conditions characteristic of the site.

In contrast, successful AFC design depends on thorough description of all design components (soil and plants) and their interactions with the site-specific environment (atmospheric conditions). Material selection and the range of site environmental conditions considered depend on clearly defined performance criteria. Following selection of appropriate performance criteria, alternative cover design often begins with preliminary design calculations that compare the water storage requirements of the cover (i.e. how much soil water storage capacity is required when the precipitation rate exceeds the rate of evapotranspiration) to the water storage capacity of the specific soil intended for use as the cover. The result of preliminary design is typically a depth, or thickness, of soil that will suffice to store the design precipitation event. This preliminary design is then often evaluated with the help of numerical simulations that demonstrate the performance of the design under...
different environmental stresses and help the design engineer understand the mechanisms important to cover function at the specific site.

Current design methodologies for alternative covers are based on consideration of the soil as a homogeneous profile without additional flow features such as macropores. Despite recent research that indicates that preferential flow can be an important, even dominant, feature of cover performance (Albright et al. 2004) estimation of the relative magnitude of preferential flow remains difficult. The soil at Sunrise shows evidence of cracking and these features may be important to the performance of the cover.

There is currently no specified or widely accepted detailed design procedure for alternative covers. The Interstate Technology Regulatory Council (ITRC) recently published a guidance document for design, construction, and post-closure care of alternative covers (ITRC 2003). The ITRC document will not be described in detail in this report but does form the basis for much of the discussion presented here.

Much of the design process suggested by the ITRC guidance document is prompted by recognition of the large uncertainties inherent in performance predictions for these complex systems. Unlike surface erosion (where problems or failure can be easily, usually visually, noted) the ramifications of excessive percolation can be difficult to determine and may not be apparent for years, even decades. In addition to the uncertainties in predicting the performance of covers there are multiple factors that complicate the relation of a landfill facility performance to environmental protection:

- Groundwater monitoring can fail to detect contaminant plumes, especially in a complex geologic environment.
- There is considerable water storage capacity available in waste. The waste at Sunrise may be 200 feet deep in some places and may be capable of absorbing excessive percolation through the cover for many years before water is transmitted to the groundwater system.
- Water is consumed by bacterial degradation of the organic fraction of waste. Excessive percolation through the cover may be consumed by these processes for many years before water is transmitted to the groundwater system.
- Landfill gas that escapes the facility is probably saturated with respect to water vapor. Excessive percolation through the cover may be controlled by gas-generating processes for many years.
- The release of contaminants from the waste facility to groundwater may depend on the timing of the chemical degradation of the waste mass. Contaminants become mobile at various states of the chemical evolution and this process may take decades.

These uncertainty issues often prompt either a conservative approach to design of a cover or extensive performance monitoring of a constructed cover. Following review of the Exponent and USEPA proposals are recommendations for both additional design procedures and monitoring methods.

Both the Exponent and USEPA proposals for the Sunrise Mt. Landfill include alternative designs for the final cover. Both seem to rely on the assumption that the warm
arid climate of Las Vegas will prevent significant percolation through the cover into the waste. Since neither proposal specifically addresses the question of predicted performance of the cover it is reasonable to evaluate the published literature for conservative values of percolation through unvegetated soil profiles. Gee et al. (1992) found at the U.S. Department of Energy facility at Hanford in semi-arid south-central Washington that percolation through an unvegetated soil profile with a layer of coarse soil as the surface treatment was nearly one half of the average annual precipitation. The quantity of percolation in the Hanford study was certainly influenced by the interaction of several site-specific factors including the coarse soil surface. The following reviews of the Exponent and USEPA proposals for the final cover at Sunrise point out that neither is the result of a thorough design procedure with calculations and numerical simulations to predict the performance of the cover. Without such supporting studies it must be concluded that approval of either design must be accompanied by the knowledge that percolation through the cover may represent a significant fraction of precipitation at the site.

REVIEW OF BACKGROUND DOCUMENTS

Included here is a brief review of selected documents made available to DRI. Many of the documents are draft versions, questions, or clarifications and are not specifically mentioned. The emphasis here is on selected documents that contribute to an acceptable final design or raise issues that require correction or future resolution. This section reviews only those documents relevant to percolation through the cover and does not include those that address erosion issues.

Sunrise Mountain Landfill Final Cover Evaluation by Dwyer (11/13/97). This report is a summary of the status of the Sunrise issues in 1997. Dwyer notes several issues including gas emissions, soil cracking, cover thickness, and erosion problems. His recommendations in section 7 include mention that the current cover does not meet requirements and that a final cover should be installed.

Final Cover Evaluation Report, SCS (11/21/01). This document reports the results of three activities of value to cover design: (1) soil testing at Sunrise, (2) preliminary design (called “screening calculations” in the document) with and without consideration of surface runoff, and (3) numerical modeling. The results from the laboratory soil testing program are required to support the other two activities. The screening calculations, or preliminary design, are recommended by the ITRC guidance document as a first step to determine the ability of the available borrow soils to store the design precipitation event at the site and to allow a preliminary economic analysis. Disregarding a few obvious outliers, the range of soil depths (3-6 feet) derived from the preliminary calculations are representative of alternative cover designs elsewhere. This screening process can also be regarded as an initial delineation of acceptable borrow soil sources. The SCS document also reports results of screening calculations made with the same soil properties and design precipitation event but with the precipitation reduced by the quantity assumed to run off. The method used to estimate runoff determined that more than half the precipitation would be thus removed and the calculated depths of soil were reduced in direct proportion. The SCS document cites results of modeling with UNSAT-H in support of the idea that relatively large fractions of precipitation would run off and thus not infiltrate into the soil profile. As mentioned in subsequent documents, this method of determining runoff is subject to substantial uncertainty, thus the reduction of precipitation in the preliminary design calculations is likely of questionable validity. There
remains the question of selection of an appropriate critical design precipitation event. The SCS report also describes UNSAT-H modeling for several scenarios existing at the site for multiple depths of selected soil types. Most of the simulations predict very low rates of percolation. The few exceptions involve the soil samples mentioned in the comments regarding the screening calculations that seem to be outliers. Soil parameters used in the modeling are from laboratory analysis of samples. The hydrologic properties of the surface layer in the model were not modified to allow all or most of the precipitation to infiltrate. Roesler and Benson (2002) reported results of a nation-wide study and found that the quantities of runoff predicted by UNSAT-H simulations were often much larger than measured in the field. Roesler and Benson found improved agreement between simulated and measured water balance quantities when the surface layers of the models were made more permeable but also noted inconsistent results over time. The SCS report notes discrepancies between predicted performance from the UNSAT-H modeling and the screening calculations and concludes that the screening calculations may not be an accurate indicator of performance. Two points should be noted with regard to this conclusion. First, the screening calculations are intended for use as a feasibility tool to allow an economic analysis based on the water holding capacity of the soil and a selected design precipitation event; the use of models is intended for use as a tool to refine a design based on the response of a proposed cover to imposed environmental stresses. Second, the two methods of performance prediction are based on different sets of inputs and assumptions. Because the two methods are intended for different purposes and use different inputs, the results of neither should be used to discount the use and importance of the other.

**UNSAT-H Simulations for Existing Cover at Sunrise Mt. Landfill**, by Craig Benson (July 5, 2002). This document summarizes results of a modeling exercise by Craig Benson of existing and potential cover profiles at Sunrise. Benson described three groups of results dependent on soil type used in the simulations. Flux was independent of cover thickness for one group of soils and was dependent on cover thickness for the other two groups differing only in whether flux was directly or inversely related to cover thickness. There are a few aspects of this modeling study that deserve mention. First is that, discounting a few obvious outliers, the quantities of runoff predicted with the models represent large percentages (approximately 25-90%) of the precipitation. This is very likely unrealistic of field conditions and probably resulted from lack of modification of the hydrologic properties of the surficial soils in the models as mentioned above in the notes about the SCS report. Another point of interest in this document is that for several of the soil samples the hydrologic regime in the profile was characterized by annual net upward fluxes through the cover. These results are likely the product of performing analyses of several depths of covers by monitoring flux past multiple observation nodes in a single deep soil profile. Water that passes an observation node in the downward direction may be returned to the atmosphere along with water placed below that observation node as an initial condition or as a result of the time at which the test year is started. In contrast, water that passes through the bottom of the model domain boundary is not available for evaporation and is counted by the code as percolation. A primary issue here is a definition of the point of compliance. If that point is defined to be the bottom of the cover then each of these different cover depths should be evaluated in a model domain of that depth. In this way, water that passes the point of interest is counted as percolation and is not later available for evaporation. The assumption inherent in the model structure, that the material immediately below the bottom boundary of the model domain can
contribute to water storage in a manner similar to the cover soils, may not be appropriate for this application.

Review of UNSAT-H Simulations, by Dwyer (July 28, 2002). In addition to a number of comments related to the modeling effort, Dwyer mentions the possibility of preferential flow through cracks in the soil surface. Flux under these circumstances is not modeled by UNSAT-H yet is possibly a significant mechanism for movement of water into the waste.

12/12/2002 e-mail from Steve Wall. Wall describes research from the USEPA ACAP program that points to large discrepancies between field measurements and simulated predictions of water balance in covers. Wall also notes suggestions in the recently published ITRC guidance document that models be used to understand the interactions between design parameters and environmental stresses. Although both points are valid no further modeling efforts were applied to the cover at Sunrise. See recommendations at end of this report for possible additional model efforts.

Following are brief reviews of the Exponent and USEPA proposals for final closure of the Sunrise site.

Review of the Exponent Inc. Proposed Cover

Section 3 of the Exponent report (Cover Plan, Sunrise Mountain Landfill, Clark County, Nevada) is titled “Potential for Infiltration and Flux of Water into the Waste Mass” and provides the design basis for Exponent’s proposal. Section 3 describes in general terms the components of the soil water balance relevant to landfill cover design (sections 3.1 through 3.7) and concludes with section 3.8, which is titled “Potential for Flux of Water through Landfill Cover”. The anticipated performance of the cover described in section 3.8 seems to be based on three statements: (1) that there was general agreement not to use modeling to predict performance of the cover, (2) that there was general agreement that increased surface runoff from the cover reduces the potential for percolation through the cover, and (3) that borings through the cover did not show evidence of percolation through the cover.

The three issues discussed in Section 3.8 of the Exponent report do not form a reasonable basis for design of a cover for Sunrise and do not address the ability of the proposed cover to limit percolation to acceptable levels.

Section 3 also contains a number of statements that are either incorrect or misleading:

• Page 14, section 3.1. The first paragraph states “Water that infiltrates is temporarily stored in the pore spaces of the earthen cover, until it is removed by evaporation from heat, wind, and vegetation.” In fact, some of the water may not be stored in the pore spaces until removal by evapotranspiration, some may pass through the cover as percolation. Vegetation is mentioned in this sentence although no vegetation is planned for the site.

• Page 14, Section 3.2. This section equates a negative net flux with a zero net flux. Zero net flux conditions occur when the total amount of water entering the soil profile from the atmosphere equals the amount leaving via evaporation and transpiration. Net negative flux conditions occurs when the waste mass dries through evaporation of water through the cover soils.
• Page 15, Section 3.5. This section states that “A subsequent period of dry weather *would* restore the storage capacity of the soil”. In the non-vegetated cover proposed by Exponent evaporation alone may not be capable of restoring the entire storage capacity. No calculations are offered to support this concept.

• Page 16, section 3.8. This section states “...increasing the amount of runoff from the landfill surface equates to a reduction in potential flux...” When applied to a small portion of the landfill cover this statement is accurate. Surface runoff can collect in ponds at downslope portions of the landfill cover, however, and at those points can greatly increase the potential for percolation. Surface flow also increases the likelihood of flow through preferential flow paths formed by cracks in the cover surface. Increased surface runoff also decreases the water available for plant growth. Despite the intent of both Exponent and the USEPA to proceed with a cover design that does not include plants, the possibility of plant growth on the cover should be considered.

• Page 16, section 3.8. This section states that during boring activities at the site “waste material below the soil cover was effectively dry and did not exhibit the presence of significant water flux.” The conclusion that no water passed through the cover may be true for the points at which borings were made but can be misleading if extrapolated to the entire cover.

Section 5 of the Exponent proposal describes fifteen “Potential Management Practices” that have been considered to improve the performance of the final cover. Section 5.3 summarizes those potential actions and recommends against several. Of the potential practices judged acceptable four directly influence the hydrologic performance of the cover. Following is a brief discussion of those four.

• #7 Soil Crete Application on Surface. As is the case for all surface hardening treatments, soil crete application can result in a surface that is resistant to infiltration. Water that is rejected as infiltration contributes to surface runoff. For localized areas this may be a valid management strategy but there are two substantial concerns. Most important is that the waste mass at Sunrise will continue to consolidate and the resulting subsidence will likely crack any hardened surface of the landfill. Second is that increased surface runoff increases problems associated with localized ponding and cracking of the soil or soil crete surface.

• #12 Fill in local depressions. This is a very good idea as localized surface ponding will have a substantial effect on percolation.

• #13 Increase soil cover thickness where less than 2 feet thick. Increased thickness tends to improve performance of a cover up to a point that is dependant on local conditions (soil quality, climate, plant activities) at the site. As mentioned above, there is no design basis for the selection of two feet as the optimal thickness for the cover. The description of this task (section 5.2.13) states that the soil will be selected to “achieve properties similar to the existing cover soil”. That the existing cover is adequate for the intended purpose is not supported.
• #14 Repair cracks in cover layer. This is a very good idea. Cracks greatly increase the potential for excessive percolation. Many of the cracks in the cover will be very small and not easily identified and this practice will demand very careful evaluation of the soil cover.

Section 6 of the Exponent proposal details proposed activities for several portions of the landfill selected from the management practices described in section 5. As stated above, these are generally acceptable approaches to establishing a suitable cover for Sunrise. The issues of most concern, the thickness and properties of the cover soils, are not supported by analysis.

**Review of the USEPA Proposed Cover**

Section 4 of the USEPA report (Proposed Scope of Work for Amended Orders, Sunrise Mountain Landfill) is titled “Corrective Action and Storm water Control Tasks” and lists corrective actions proposed by the agency. Sections 4.1.2 through 4.1.7 are specific to the hydrologic performance of the final landfill cover.

Section 4.1.2 describes a non-vegetated cover with a minimum thickness of 3 feet. Other than preliminary design calculations there are no calculations or simulations listed or cited to support the proposed thickness of the cover.

Section 4.1.3 describes the soil barrier layer of the proposed cover. This is the portion of the cover that absorbs and retains water from precipitation until it can be returned to the atmosphere via evaporation. Two items in this section are discussed here. The requirement that the layer soil contain fines in the range from 35 to 50% cites the ITRC guidance document. This particular section of the ITRC document is based on work by Jorge Zomberg and George Chadwick in support of the final cover at the Rocky Mountain Arsenal (RMA) near Denver CO. Selection of soil with those particular properties at RMA was the result of extensive soil testing, field evaluation, and numerical modeling and should be regarded as specific to RMA. There are other studies (e.g. Albright 1995) that conclude that soil with less fines (5-10 percent) may be adequate for cover purposes at specific sites and may largely avoid the problem with cracking. A comparison of the field results and laboratory analysis of soil from the Alternative Cover Assessment Program might be used to investigate the relation between grain size distribution and cover performance. Acceptable values of plasticity index for the soil are given as ranging between 5 and 30. Soils with these properties are likely to develop cracks in the surface. There is also mentioned the requirement that the soil used be screened to remove all rock and gravel (all soil must pass the No. 4 sieve). This is an extremely strict requirement that will either severely limit the selection of soils available for use at Sunrise or be quite expensive to achieve by screening.

Section 4.1.4 describes the erosion layer, the minimum thickness of that layer and the properties of the soil to be used for that purpose. The erosion layer is described for slopes that are less than 6% (6 inches thick) and slopes greater than 6% (18 inches thick). The proposed erosion layer will be amended with gravel to stabilize the layer against surface flows. Two issues concerning this layer are discussed here. The specification for gravel (33% by weight) should be a range of values to avoid excessive expense and construction quality assurance problems during placement of the soil. The topsoil that is specified for this layer includes a very large percentage of fine particles. The concern with this percentage of fines is similar to that noted above in the discussion of the soil barrier layer.
Section 4.1.5 describes the need to evaluate the cover for cracks and gives specifications for repairing those found. As noted in the review of the Exponent proposal this is an excellent idea.

Section 4.1.6 describes required construction and compaction methods. Lift thickness and dry bulk density requirements are taken from the ITRC guidance manual and are appropriate for the Sunrise cover.

Tasks 4.1.7.1 and 4.1.7.2 specify minimum 3% grade and appear to accept the argument that increased surface runoff would be beneficial to maintenance of a favorable water balance. See comments above related to surface flow.

**Conclusions and Recommendations**

The primary conclusion of this report is that neither proposed cover is the result of an appropriately quantitative design process for an alternative final landfill cover. As noted in the introduction, alternative cover design should begin with clearly identified performance criteria with regard to acceptable rates of percolation. Preliminary design should result in a calculated depth of soil required to store the design precipitation event and numerical simulations should be used to understand the mechanisms important to cover function at the site. Without this logical progression it is difficult to determine if either design is appropriate with regard to regulatory requirements and environmental protection. In the absence of an appropriate design process the estimates for potential percolation through the cover can represent a substantial fraction of the average annual precipitation. Proposals based on the concept that a thicker cover necessarily performs to a higher standard also should be substantiated. It should be noted that current modeling methods do not account for flux through the cover as a result of preferential flow through surface cracks or as a result of local ponding. Cracking of the soil is evident at Sunrise and differential settlement in the future will likely result in localized ponding. There is also some question related to the salt content of the cover soil currently at Sunrise and the propensity of that soil to form a low-conductivity crust. The effects of crusting may not be evident in laboratory analyses of the soil but may have a substantial influence on cover performance in the field.

If the regulatory agencies involved conclude without further analysis that percolation through the cover is likely to be of an acceptable quantity, then the conclusion of this reviewer is that the erosion resistance of a constructed cover is the primary consideration. The USEPA cover includes a surface layer amended with gravel and the cover includes greater depth of soil. Both of these design features may add to the ability of the cover to withstand erosion from wind and water and to maintain physical containment of the solid waste but little quantitative information is offered to support this concept. The final soil surface is also very important to the ability of the cover to withstand erosion. The current (July 2004) surface of the cover is very smooth and was probably designed to decrease infiltration by increasing surface runoff. The parties involved may well consider a surface treatment (i.e. gravel mulch or increased surface roughness) designed to increase infiltration and decrease surface flow.

If either of the proposed designs (or a modified design) is constructed without further evaluation, the hydrologic performance of that cover should be evaluated by field monitoring. There are a few commonly employed techniques for monitoring cover performance but only one, lysimetry, provides reliable measurement (Dwyer 2001, Benson et
The regulatory agencies should reject any proposal to monitor the cover performance solely by use of soil moisture probes. Such measurements of soil moisture provide only an estimate of performance and those estimates have a very high degree of uncertainty and can be misleading. Soil moisture probes can offer valuable information when combined with large-scale drainage lysimeters. If monitoring is performed at Sunrise with lysimeters they should be of sufficient size to include the scale of important processes at the site. Visual observations of cracks in the soil surface at Sunrise indicate that the appropriate scale is likely on the order of several meters.

The parties involved may decide to conduct further investigation into the design of an alternative cover. Following are several recommendations for tasks than can be done relatively quickly and will support agreement for an acceptable cover design. Suggestions 2-5 follow, in general, guidance described in the ITRC document. The activities described here can be largely based on already existing data and evaluations and can be performed in a fairly short time frame.

1. Conduct a thorough evaluation of the ability of the existing cover soils and available borrow soils to support plants. Plant activities are very important to alternative cover function. If the soil chemical properties do not prevent the possibility of establishment of a viable plant community then the cover should consider features that will promote plant establishment and growth.

2. Identify and evaluate borrow soils that may be used for cover construction. Knowledge of the properties of these soils is very important to cover design.

3. Perform preliminary design calculations and economic analyses based on the possible borrow soil parameters and an identified design precipitation event.

4. Evaluate the processes and mechanisms important to cover function with numerical simulations. The ITRC guidance document refers to the use of systematic simulations as design sensitivity analysis, or DSA. As mentioned above, the results of these simulations will include a degree of uncertainty and should not be used exclusively for permitting activities. A well-designed strategy for conducting simulations can help describe the design features and environmental stresses important to cover function and, perhaps of most importance, provide sufficient information for the regulators and the site consulting engineers to negotiate an acceptable design. This process of conducting numerical simulations to elucidate the important features of the cover includes multiple features.

   a. Design sensitivity analysis (DSA) is based on evaluation of the change in simulations results (average annual percolation) as a function of a systematic change in a single design parameter or environmental stress. Design parameters can include cover thickness, soil type, and plant community function. The most important environmental stresses are precipitation quantity and timing.

   b. All simulations should be performed using a finite element or finite difference model based on Richards' equation and should follow the widely accepted features (i.e. multi-year simulations, sufficient temporal and spatial discretization) used by Benson in the earlier simulations.
c. Soil properties used in the simulations should reflect measured values except for the properties of the soil simulated in the surface elements or nodes. Those properties should be adjusted to allow all precipitation to infiltrate the soil surface. This practice gives a conservative estimate of performance and is technically justified by field observations.

d. The first parameter evaluated should be the nature of the design precipitation event. Daily precipitation values from a nearby weather station should be used for storms that may represent extreme tests of the ability of the cover to limit percolation. These may include such events as a summer thunderstorm and a multi-day winter frontal passage.

e. Following determination of the critical precipitation event for the cover, DSA should be performed using those precipitation data on the cover for cover thickness and soil quality. The iterations over several values of cover thickness will establish the depth of soil beyond which there is no expected improvement in performance. Simulations with the range of soil properties will allow design engineers to select appropriate soils and can be used to develop a performance-based construction quality assurance plan. DSA simulations involving cover thickness should include examples of very thin (i.e., 5 or 15 cm) covers to demonstrate the expected performance of unacceptably thin designs.

5. Final design should include an engineering factor of safety. One technically justified approach is based on the findings of Albright et al. (2004) that suggest that the water storage capacity (i.e. the depth) of a soil profile should be increased by 20-30 percent to account for uncertainties in the design process.

A final note is required regarding the performance of any cover, including the cover currently in place. The best method available for design of an appropriate cover is to collect field-scale performance data for proposed (or even existing) designs. If it is found that flux quantities that are significant fractions of precipitation at the site are unacceptable, this reviewer suggests collection of such field data to decrease uncertainty in any cover finally constructed. In the absence of data suggesting current contamination of ground water there is likely little immediate danger from a delay of final construction until such time as sufficient data can be collected for an acceptable design.

REFERENCES


Wall, S., 2002. E-mail Regarding EPA Review of Cover Data Submittals. Sent to Alan Gaddy and Craig Benson. (Document #26).