CONTAINMENT SYSTEM DESIGN MODIFICATIONS FOR THE DISPOSAL OF POWER PLANT FILTER CAKE AT A MUNICIPAL WASTE LANDFILL IN CALIFORNIA

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Abstract: The City of Redlands, located in Southern California, owns and operates the California Street Landfill. The landfill is a permitted municipal waste disposal facility with a containment system composed of a 60-cm thick clay liner with a hydraulic conductivity of less than 1 x 10E-7 cm/sec overlain by a 1.5 mm high density polyethylene geomembrane. The above containment system is the prescriptive standard for municipal waste landfills in California. With the construction of an electrical power generation plant recently completed in the City of Redlands, the local power company was evaluating options for disposal of the filter cake waste produced at the plant. In accordance with the current permits at the California Street Landfill, acceptance of the filter cake at the landfill would require modifications to the existing containment system. In order to significantly reduce disposal costs, the power company and City of Redlands joined together to modify the permit and containment system at the landfill to allow for the acceptance of the power plant filter cake. The following paper will discuss the required modifications to the permit and liner system design in order to accept the filter cake waste. The proposed modifications to the liner system included the addition of a double liner composed of a primary geosynthetic clay liner and HDPE geomembrane overlying a clay-HDPE secondary liner. A geocomposite will be utilized as the leak detection layer between the two composite liners.

Keywords: design, landfill liner, HDPE geomembrane, geosynthetic clay liner, electrical leak detection.

INTRODUCTION

The California Street Landfill (CSL) is owned and operated by the City of Redlands (City), which is located about 120 kilometres east of Los Angeles in Southern California. The site began operations in 1963; therefore, the original waste management units are unlined, as provided for at that time in Title 23 of the old California Administrative Code (CAC). In 1963, construction of the first waste management unit at the landfill site began as a County-owned and operated site. No written records exist of early operations activities; it is likely that limited excavation was conducted to obtain the necessary cover material, provide a level deck to conduct unloading operations, and construct the necessary internal roads to access the unloading area. As operations progressed, it is assumed that the area was filled generally from side-to-side, rising in elevation to the present contours. The City took ownership and operational control of the facility in 1970.

With the enactment of new federal regulations under the Resource Conservation and Recovery Act (RCRA, also known as "Subtitle D") and new State of California regulations (27 CCR, Section 20330 aka Title 27), landfill operators are now required to install a composite liner system for any new or previously unused waste management units excavated over native ground. In 2002, a Joint Technical Document was prepared for the CSL in order to gain approval for a lined lateral expansion in the existing borrow area to the south of the unlined West Side Landfill area (Vector, November 2002). The City obtained approval for the expansion in 2003 and construction of the composite liner system in the Phase 1 area of the expansion (where current disposal operations are ongoing) was completed in May 2004 (Vector, July 2004).

Since the completion of the Phase 1 cell, an electrical power generation plant came on-line near the City of Redlands. The primary waste product produced from this power generation facility consists of filter cake material. This material requires special disposal methods and the power company entered into a joint agreement with the City to dispose of the waste. Following meetings with the Regional Water Quality Control Board (the regulatory agency), it was determined that modifications to the existing design plans for the landfill would be required in order to accept the filter cake.

The site's current development and waste handling areas are conducted in the West Side Landfill. These activities include placement of waste within the northern unlined portion of the landfill over existing old waste and the new lined expansion area (Phase 1). As part of the original expansion of the CSL, a single composite bottom liner system was developed and incorporated into the Phase 1 expansion. The Phase 1 liner and leachate collection and recovery system (LCRS) consist of the following components from bottom to top:

- A 60 cm thick low-permeability soil liner (1×10^{-7} cm/sec permeability);
- A 1.5 mm double-sided textured HDPE geomembrane;
- A single-sided geocomposite blanket LCRS drainage layer (on floor of cell);
- A double-side geocomposite blanket LCRS drainage Layer (on side slopes of cell only);
- Leachate collection trenches and sump, including gravel, HDPE piping, risers and cleanouts; and
- A 60 cm thick soil protection/operations layer.

As part of the regulatory requirements for accepting the power plant filter cake within the proposed Phase 2 expansion and any future expansions to the landfill, the single composite liner had to be upgraded with a composite double-liner system. The liner system in the proposed Phase 2 expansion and all remaining expansion phases will consist of the following layers, from bottom to top:

- A 60 cm thick clay liner with 1 x 10^{-7} cm/sec permeability;
- A textured 1.5 mm thick HDPE geomembrane secondary liner;
- A double-sided geocomposite blanket leak detection layer;
- A geosynthetic clay liner (GCL) with a 1 mm HDPE geomembrane vapour barrier backing. A geomembrane backed GCL or a multilayer fabric encased GCL with a separate geomembrane may be used;
- A textured 1.5 mm thick HDPE geomembrane primary liner;
- A double sided geocomposite blanket LCRS drainage layer; and
- A 60 cm thick soil protection/operations layer.

Figure 1 below shows the components of the proposed Phase 2 bottom liner system. The following sections of this paper describe the modifications conducted on the Phase 2 liner system and the required engineering evaluations that were required to obtain regulatory approval. While numerous design elements were evaluated for the Phase 2 expansion, this case study focuses on the use of a GCL in place of a compacted clay primary liner, utilizing an alternative LCRS, liner system performance, and stability.

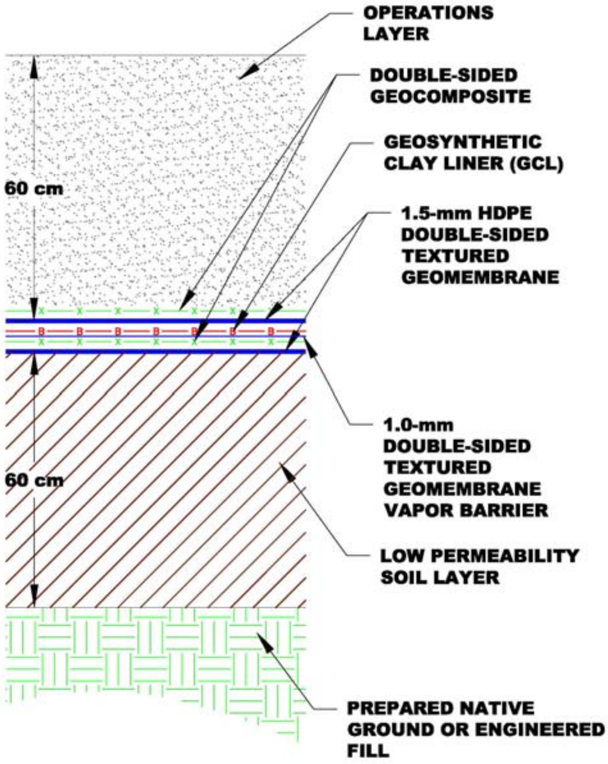

Figure 1. CSL double-composite liner and LCRS System

GEOSYNTHETIC CLAY LINER (GCL)

GCLs have been used in liner systems and cover systems for landfills, surface impoundments, and tank farms, as well as in other structures. When used in landfills, GCLs are often substituted for the compacted low-permeability soil component of a composite liner. The function of the GCL in the composite liner is identical to that of a compacted soil liner which is to provide a low-permeability barrier to liquid flow through any defect in the overlying geomembrane.

The type of clay typically used in GCLs is sodium bentonite. Sodium bentonite is the name given to the highly plastic clay mineral montmorillonite, with sodium as the primary exchangeable cation. Bentonites used to fabricate GCLs are processed in an unhydrated state such that they appear to have a granular consistency. Upon hydration with water, the bentonite swells to form a continuous clay layer.

Geotextile encapsulated GCLs are shipped in rolls typically 3.7- to 5.3-m wide and 25- to 60-m long. They are installed by unrolling to form panels. Adjacent panels are overlapped, and for some products powdered bentonite is placed between the panels at overlaps. Large-scale laboratory testing (Daniel 1991) has shown that, when installed in accordance with the manufacturer's specifications, GCL overlaps are self-sealing and do not create a preferential pathway for liquid flow.

GCLs are inherently weak when subjected to high moisture conditions. Therefore, it is important that the design of a liner system take into account the potential ways that moisture can be introduced into the system. Moisture can be introduced by placement of the GCL on top of a high moisture laden soil, by allowing the GCL to be exposed during precipitation events, and by leakage from overlying liners. In order to minimize the potential wetting of the GCL at the CSL, the GCL will be encased by the top primary 1.5 mm HDPE geomembrane and a lower 1 mm HDPE geomembrane vapour barrier. The vapour barrier maybe part of a bentonite glued product or the vapour barrier maybe a separate geomembrane used in contact with a geotextile (fabric) encased product.

Both GCL types are manufactured under strict quality control (QC) guidelines. The QC requirements include conducting index and performance testing on both the supplied materials and finished product at specified frequencies. After the material is approved at the manufacturing plant, care will be taken to keep the rolls dry, not stack them too high, and keep them from damage during handling. Prior to acceptance in the field, information concerning the manufacturer's name, product name, lot and roll number, and length, width, and weight must be submitted to the on-site CQA firm.

The onsite earthen materials at the CSL consist primarily of silty soils with minor amounts of sand and gravel. Geotechnical testing of these materials indicated that they would not be suitable for use as a compacted clay liner without the addition of bentonite. During the Phase 1 installation, a bentonite add-mix program was conducted resulting in a final product that was suitable for use as a low permeability soil liner. During the Phase 1 design, the use of an alternative GCL in place of the compacted clay was proposed due to its significant cost savings. The regulatory agency at that time rejected the use of a GCL. During the submittal of the Phase 2 design, a GCL was again proposed to replace the compacted clay liner in the primary composite liner system with compacted clay being utilized in the secondary composite liner. The regulatory agency had concerns that the GCL would become saturated from the moisture being carried by the underlying geocomposite leak detection layer. By adding a vapour barrier below the GCL, the moisture was kept from contacting the GCL and the higher strength properties of the non-hydrated bentonite could be utilized. The use of a GCL with an underlying vapour barrier satisfied the concerns of the agency and the GCL was accepted for the primary composite liner.

ALTERNATIVE LEACHATE COLLECTION AND REMOVAL SYSTEM (LCRS)

The LCRS constructed in the Phase 1 design and also proposed for the remaining phases for the CSL has been designed to be free-draining throughout the life of the landfill and will maintain less head over the primary liner system than the standard system prescribed by Title 27 (which consists of 30 cm of gravel). The alternative LCRS consists of the replacement of the typical gravel drainage layer with a geocomposite drainage media. A similar system will be installed between the primary and secondary liner systems to be used as a leak detection layer in the Phase 2 design. This layer will be placed between the GCL with a vapour barrier and the secondary geomembrane liner.

The Phase 2 cell is located immediately south of the existing Phase 1 area that only has a single composite liner system. The side slopes of the Phase 2 excavation will be graded similar to Phase 1 at a 3 to 1, horizontal to vertical, (H:V) slope. The bottom of Phase 2 will be graded to drain at 2% away from Phase 1 toward an LCRS sump to be located in the southeast corner of the cell. In addition to the blanket drainage geocomposite, the LCRS will include a central header pipe connected with lateral collection pipes placed in v-notch trenches laid out in a herringbone pattern across the cell floor. These collection pipes and trenches will be backfilled with gravel to aid in leachate recovery. The gravel will also be wrapped with geotextile to prevent the infiltration of fine-grained soils from the operations layer into the LCRS.

The geocomposite consists of a geotextile bonded on both sides to a high density polyethylene geonet lateral drainage layer. This product is considered to be superior to the standard gravel system because of its greater flow capacity and ease of installation. In order to approve the use of a geocomposite in lieu of a gravel drainage layer, the regulatory agency requested that specific issues be addressed. As discussed in the following paragraphs, the CSL design takes into account the issues raised by the regulatory agency including the potential for restricted flow caused by intrusion of the geotextile into the drainage net channel and chemical or mechanical clogging from biological actions, chemical precipitates, or fine sediments.

Factors Affecting Geocomposite Performance

As mentioned above, many factors can affect geocomposite performance including geotextile intrusion, chemistry of the leachate, migration of fine sediments, and biological activity. These factors have all been examined in the design of the LCRS at the CSL.

Intrusion of the geotextile into the geonet can be caused by pressures from the overlying materials on the geocomposite. Intrusion occurs almost immediately in the form of elastic deformation or stretching of the geotextile and under long term conditions such as creep deformation. Short and long-term testing (in excess of 10,000 hours) have been performed to examine the effects on the transmissivity of gecomposites (Richardson and Zhao, 1999). The results of the testing indicated that the flow could be reduced by as much as a factor of 2. Therefore, a factor of safety between 1.5 and 2 is recommended by industry experts to account for intrusion into a geocomposite LCRS.

Clogging of the geocomposite can occur when chemicals within the leachate cause precipitation of soluble constituents, fine sediments migrate from the overlying materials, or biological actions cause the build-up of algae or similar products. Clogging by these materials is related to the leachate environment, which is controlled by site-specific conditions such as waste, soil type, and operations. Industry experts (Koerner 1998, Richardson and Zhao 1999) recommend that additional factors of safety be applied to the design of any given LCRS to account for these issues. Factors of safety ranging from 1.5 to 2 are recommended. Therefore, considering factors of safety ranging from 1.5 to 2 for each of these conditions (short-term intrusion, long-term creep, clogging by chemical precipitates or sediments, and clogging by biological means), a minimum factor of safety of 5 should be applied for design purposes.

Leachate Generation Analysis

As required by the California regulations, the amount of leachate that may be generated during operations of the CSL must be determined. The amount of leachate that may be generated during operations of the CSL was estimated by modeling the water balance of the waste and daily cover materials. Leachate generation potential for the West Side Landfill expansion was estimated using the Hydrologic Evaluation of Landfill Performance Model (HELP), Version 3.06 (Schroeder, et. al., 1994).

The results of the HELP analyses indicate that leachate generation is predicted to be minor (less than 0.12 l/s) during normal operations and the head over the liner is predicted to be very low (less than 1.8 mm) even during peak periods. This is based on the assumption that a high flow geocomposite is used as a drainage layer above the geomembrane for the LCRS in the Phase 2 expansion area.

LCRS Flow Capacity Determination

Flow capacity calculations were performed for the LCRS in the Phase 2 expansion area of the CSL. The calculations were based on the HELP model predictions described above for the side slope area that is uncovered when a 2.4 m lift of waste is in place on the floor the cell. Under this configuration the side slopes will be contributing the greatest amount of leachate to the cell because waste has not yet been placed over the side slopes and storm water will have a high rate of infiltration. The results of the calculations indicate that the proposed LCRS system has a flow capacity in excess of about 31 times the required drainage layer capacity and will maintain the head over the liner system to less than the thickness of the geocomposite, during peak periods of leachate generation. Details of the analysis are provided in the following text.

Based on the estimated leachate generation described above, drainage into the leachate collection layer will be about 4.86 l/s at its maximum or 0.12 l/s on average during the wettest year. Given an operational cell area of 1.4 hectares, this equates to infiltration rates of approximately 3.5×10^{-4} l/s and 8.8×10^{-6} l/s per square metre of disposal area, respectively.

The collection system has been designed with lateral collection pipes connected to a main header at a spacing of approximately 30 m as well as lateral collection pipes place along the toe of the slope face. Multiplying the spacing distance times the infiltration rates, the peak (required) flow within the geocomposite will be about 1.1×10^{-2} l/s per linear metre of pipe and the average will be about 2.7×10^{-4} l/s per linear metre. A high-flow, single-sided geocomposite has an allowable transmissivity of approximately 5×10^{-3} m^3/s per meter width (Richardson and Zhao 1999). To be conservative, our analysis used a value of 1×10^{-3} m^3/s per meter width or a capacity of about 1.0 l/s per metre of width at a design slope (gradient) of 33.33%. Dividing the allowable by the required capacity shows that the geocomposite has about 31 times the capacity required under peak conditions and over 1,249 times the capacity under average conditions during the wet year. Since it was determined that the design FS should be at least 5, the actual minimum FS of 31 is sufficient. Regulations in California require that the LCRS handle twice the peak leachate flow; therefore, the geocomposite exceeds the regulatory requirements.

With this extra flow capacity, the geocomposite will have the ability to maintain flow in the event that some clogging or reduced capacity occurs as a result of migration of fines into the layer, biological and chemical activity, or excessive crushing.

The excess capacity calculated above was also predicted by the HELP modeling, described above. The HELP model predicted that the maximum head over the liner would be 1.8 mm, about 25% of the actual thickness of the geocomposite. This predicted head value is significantly lower than the 30 cm of head typically allowed by Title 27 and 40 CFR of the United States Federal guidelines. Given this significant decrease in head over the liner and the added flow capacity, the alternative geocomposite drainage layer is suitable for the CSL expansion and was approved by the regulatory agency pending the LCRS performance demonstration described below.

LCRS Performance Demonstration

At the request of the regulatory agency, a demonstration program will be implemented to examine the efficiency of the geocomposite and LCRS. For the demonstration program, the Phase 2 design contains a system that will introduce water into the LCRS and a method for monitoring its performance.

For the demonstration program, water will be added to a discharge pipe along the north side of Phase 2; about 1.5 m from the boundary of Phase 1. This pipe will consist of a 10-cm diameter high density polyethylene pipe that is perforated in order to introduce water along the liner system. The pipe will be perforated with four rows of 1-cm diameter holes spaced every 3 m within the portion of the pipe that lays on the floor of the cell. A solid (non-perforated) pipe will extend up the eastern slope portion and will terminate just past the geomembrane liner anchor trench. The pipe will have a removable end cap (or blind flange) and be protected with steel posts (bollards). This will allow a water truck to connect to the pipe and discharge a known volume of water into the system.

In order to determine whether the LCRS is functioning properly, two issues must be addressed: 1) water introduced to the system must flow into the collection sump; and 2) the water head over the primary liner must be less than 30 cm. The first issue will be addressed by normal observation methods (water that is put into the system will be compared to the water that comes out). The head over the Phase 2 liner will be measured by installing electrical pressure transducers at ten (10) designated locations across the bottom liner (one of them in the sump). These transducers will be connected to electrical transmission lines that will traverse across the liner and up to a central readout (control) panel or hub. The transmission lines will be placed inside a 4 cm diameter Schedule 80 polyvinyl chloride (PVC) pipe or other material suggested by the manufacturer to protect them from damage. Each transducer will be placed above the geocomposite drainage layer and be protected in a manner recommended by the manufacturer. If the water builds up more than 30 cm above the geomembrane liner, the transducers will indicate that the system is malfunctioning.

The LCRS test program will include an initial water test of the system upon completion of the construction of the Phase 2 liner system. This program will be used as the baseline for all future testing at the site. For the future program, the system will be tested annually in accordance with the California regulations for solid waste landfills and the CSL permit documents. Results of the testing will be forwarded to the regulatory agency in accordance with the monitoring and reporting program established as part of the permitting for the CSL.

The system will be tested by introducing water at a specified rate for a period to be determined based on the final design approved by the regulatory agency. Future test periods will be based on the initial test at the completion of construction. Once the water is introduced, the sump will be monitored continuously to determine when the water first arrives. The rate that the water enters the sump will then be determined by initially monitoring the water level. Once the sump is filled, water will be pumped out at a known rate and the flow rate recalculated. Due to the absorptive properties of the LCRS components (geocomposite, geotextile, and gravel), the flow rate is not expected to reach a completely steady-state condition within the testing time-frame. However, the final measured flow rate should be a high percentage of the input flow.

While the flow within the sump is being monitored, the transducer panel will be monitored for the presence of head build-up over the liner. As mentioned previously, a head build-up, recorded by a transducer, of over 30 cm would mean that the system may be malfunctioning at that transducer location. In the event that the system does not appear to be functioning properly, the City will examine the condition and propose a work plan to the regulatory agency to monitor and regulate leachate build-up within the LCRS.

LINER SYSTEM PERFORMANCE

In order to allow the disposal of the filter cake sludge from the nearby power plant, the Phase 2 design required the installation of a double composite system with a leak detection system. In order to determine the performance (anticipated leakage) through the liner system, a leakage rate calculation was performed.

Two documents that discuss leakage rates through liners have been published by the U.S. Environmental Protection Agency, Office of Solid Waste (EPA 1987, 1992). The purpose of these reports was to provide other governing agencies background information to assist in the development of performance standards and allowable leakage rates for operating facilities. The "background" document (EPA 1987) describes the development of leakage rate formulae and presents corresponding calculated results for many liner system configurations. The following equation was used to estimate leakage rate through the secondary composite liner system (Giroud 1989):

$$Q = 0.21h^{0.9}a^{0.1}k_s^{0.74}$$

Where,

Q = flow or leakage rate (m^3/s)

h = head over liner (m)

a = area of hole (m^2)

k_s = permeability of the material below the geomembrane (m/s)

The 0.21 factor assumes that there is good contact between the geomembrane and the underlying low permeability liner. In addition, it assumes that there is not a large difference between the head above the liner and thickness of the liner. The secondary composite HDPE/compacted clay base liner system was modeled as part of this evaluation. The secondary composite system utilizes a 60-cm thick, low permeability compacted soil with a permeability of 1×10^{-7} cm/sec overlain by a 1.5 mm HDPE geomembrane. The analysis used the conservative assumptions that there is a standard one-square centimeter hole in the geomembrane and that it is in good contact with the material below it. Further, it was assumed that the overlying head was 6 mm, the equivalent thickness of the geocomposite leak detection layer installed above the secondary geomembrane. This is considered conservative because the leakage into the layer is expected to be extremely low (i.e. disregarding the added function of the primary composite liner system of GCL overlain by another 1.5 mm HDPE geomembrane). The head on this bottom layer will also be reduced by collecting and recovering the leaked solution within a low-lying leak detection and collection sump. Previous HELP modeling also indicated that the head over the primary liner will be a maximum of 1.8 mm. Therefore, the head over the secondary liner will be much less.

The California regulations require the membrane in single composite liner systems to be underlain by 60 cm of low permeability soil with a permeability of less than 1×10^{-7} cm/sec. Using the leakage rate equation shown above, the expected leakage would be 1×10^{-7} l/s from a standard 1 cm^2 hole in the liner.

As demonstrated by the above paragraphs, the leakage that is anticipated from the prescriptive geomembrane/compacted clay composite liner system is very low, without considering the added protection provided by the primary composite liner system. In addition, potential leakage in the liner caused by construction defects or damage is going to be examined. An electrical leak location survey (LLS) is going to be performed on the primary liner before and after placement of the LCRS and operations layer. A water-puddle LLS will be performed on the bare primary geomembrane and a dipole LLS will be performed after placement of the operations soil. These surveys will ensure that the liner is essentially defect-free before placement of any wastes.

SEISMIC DESIGN AND SLOPE STABILITY ANALYSES

The final issue addressed in this paper related to the design modifications to the Phase 2 double composite liner at the CSL concerned the stability of the system. This section presents the results of slope stability studies performed for the landfill in accordance with the California regulations. Analyses were performed to determine the global stability of the Phase 2 expansion at the CSL. The results of these analyses are summarized below.

Global Landfill Stability

The stability of the Phase 2 liner system and future expansions to the site are critical to the operation and long term performance of the proposed liner and leachate collection system for the CSL. Stability analyses under both static and pseudo-static (earthquake) conditions were performed to ensure that these systems would perform adequately during the operational life and after closure of the CSL. Circular and block failure surfaces were analyzed to determine the most critical failure mode. A minimum static FS of 1.5 is considered the industry standard for long-term stability of a given slope. In accordance with Title 27 (the California Landfill regulations), calculated pseudo-static factors of safety less than 1.5 were analyzed for potential displacement during seismic events. These regulations require that seismic analyses be performed on Class III landfills utilizing the Maximum Probable Earthquake (MPE). Seismic studies for the CSL indicate that the peak ground acceleration (PGA) due to an MPE is 0.28 g. Using this seismic data and the other information described above, stability analyses were performed using a current industry standard computer program, Slide 5.03 (Rocscience, 2007).

The results of the static and pseudo-static stability analyses are summarized in Table 1 for three cross sections through the West Side Landfill (including the Phase 2 area). The critical condition was modeled as a "wedge" style failure, with a slip plane along the weakest interface of the geosynthetics. The minimum FS for static, long-term conditions was determined to be 1.72. The results of the pseudo-static stability analyses using the PGA of 0.28g indicated that the factor of safety under earthquake loading is less than 1.5. Therefore, as required by California regulation, additional seismic displacement analyses were performed.

Table 1. Results of Stability Analyses

	Static		**Seismic**
Section	**Circle**	**Block**	**Yield Acceleration**
	(FS)	**(FS)**	**(acc.)**
AA	2.26		0.18
BB	2.23	1.72	0.16
CC	2.68	2.10	0.20

Seismic Response and Displacement Analyses for the Landfill

Displacement analyses were performed using a current industry standard simplified method developed by Bray in 2007 (Bray 2007). This method calculates potential displacements based on the probability that the estimated ground acceleration from the design earthquake will be exceeded. As recommended by the Southern California Earthquake Center (SCEC), median values of displacement were estimated and reported. The yield acceleration was subsequently calculated in the limit equilibrium analyses for each section considered, since it is a required input for the displacement analysis. The yield acceleration is defined as the horizontal coefficient of acceleration that, when applied to the slope in the limit equilibrium (seismic) analysis, results in a seismic factor of safety equal to one. The yield acceleration for each section is shown in Table 1.

Section BB was the only section analyzed for potential displacement, as this section was the most seismically unstable as determined during the limit equilibrium stability analyses. The potential displacement resulting from five different seismic events originating along the nearby San Andreas (San Bernardino and Southern sections), San Jacinto (San Bernardino and San Jacinto Valley sections), and the Crafton Hills fault zones were calculated for Section BB.

Results from the displacement analyses are summarized in Table 2. Bray et al. (1998) defined calculated displacements of less than 5cm as "small", displacements from 15-30 cm as "moderate", and displacements greater than 30 cm as "large" displacements. The results above show that for the median values (50% chance of exceedance given the design event) the landfill should only experience small to moderate displacements.

Table 2. Results of Displacement Analyses for the CSL

Fault	**Section**	**Mw**	**Dist (km)**	**Median Displacement (Bray 2007)**			
				P(D=0)	**P(D>15cm)**	**(in)**	**(cm)**
San Jacinto	San Bernardino	6.7	6.8	9.3%	4.5%	1.8	4.7
San Jacinto	SJ Valley	6.9	8.1	9.3%	5.4%	1.9	4.9
San Andreas	San Bernardino/Southern*	7.5	6.0	0.5%	50%	5.9	14.9
Crafton Hills	Fault Zone	7.0	13.7	4.9%	0.1%	<1.0	0.6

* Both the Southern and the San Bernardino sections of the San Andreas Fault considered essentially the same.

CONCLUSION

The disposal of filter cake material from the operation of a new power plant in the City of Redlands could have resulted in significant costs for the electrical rate payers. However, by working together as a cooperative team the City of Redlands and local power company found a means to dispose of the material in the local solid waste landfill. In order to meet more stringent regulatory requirements, modifications to the existing permitted liner system design were necessary. The City, the power company, the City's landfill consultant, and the regulatory agency worked together to design a modified system that was protective of the environment and provided for the least costs of disposal for the filter cake.

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