El Sobrante Landfill

Geologic and Hydrogeologic Investigation for Landfill Expansion

Corona, California

WASTE MANAGEMENT, INC.

Client:
Waste Management and Recycling Services of California, Inc.

Owner Address:
25772 Springbrook Rd.
Saugus, CA 91350

Contact Person:
Mr. Burrill McCoy
Engineer
(714) 685-6485

Services Provided:

- Review of Existing Data and Reports
- Geologic Mapping
- Hydrogeologic Investigation
- Exploratory Drilling, Continuous Rock Coring, and Logging
- Piezometer Installation, Development, and Groundwater Sampling
- Geodetic Surveying
- Spring (Seep) Water Sampling
- Geotechnical Analysis of Soil and Rock
- Preparation of Hydrogeologic Cross Sections
- Report Preparation

Project Background

El Sobrante Landfill is a Class III, non-hazardous Municipal Solid Waste (MSW) landfill located in Western Riverside County within the City of Corona, California. Owner and operator Waste Management of California have been expanding the existing 110 acre landfill footprint at El Sobrante in timely phases. Another 65 acres have since been added to the waste footprint out of the permitted 477 acres located within the foothills east of Temescal Valley, between Olsen Canyon and Dawson Canyon.

Services Provided by GeoSyntec

GeoSyntec has provided geologic and hydrogeologic information in support of landfill expansion base grade designs for two separate phases. Services performed for the expansion phases are as follows:

- geologic mapping and fracture analysis of exposed metamorphosed sedimentary and volcanic bedrock for geologic structure and site stratigraphy, and to evaluate the occurrence and movement of groundwater in site geologic units;
- drilled exploratory boreholes and collected continuous rock cores for lithologic logging, rock quality designation (RQD), and fracture characterization;
- designed, installed, and developed piezometers to evaluate and understand groundwater flow patterns within and adjacent to the expansion areas;
- analyzed inorganic water chemistry and isotope content of groundwater sampled from newly installed piezometers and surface spring water to:

  - identify the origin of recharge waters either from local precipitation or from regional recharge;
  - evaluate potential hydraulic separation and/or continuity of deep and shallow groundwater;
  - differentiate the deep groundwater from the shallow using tritium content for relative ages;

- evaluated historical groundwater elevations from existing wells within and adjacent areas to determine the maximum potential groundwater elevation conditions beneath the expansion area; and
- conducted geotechnical laboratory testing of rock core and bulk samples to evaluate excavation characteristics and geotechnical properties of excavated materials.
- prepared final hydrogeologic investigation report in support of facility permitting documents.

Department of the Navy, Southwest Division (AEC)

Design, Build, and Construction Support

Twenty Nine Palms Marine Corps Base, California

Client:
Naval Facilities
Engineering Command
(NAVFAC – Southwest)

Owner Address:
Twenty Nine Palms
Marine Corp Air Ground
Combat Center
TwentyNine Palms, CA

Contact Person:
Cindi Liu, PE., President,
Engineering/Remediation
Resources Group, Inc.
(ERRG)
(925) 969-0750
Fax (925) 969-0751

Mark Rogers, PG, CPG
Project Manager,
ERRG
(323) 224-8300
(323) 224-8954

Project Background

The Marine Corps Air Ground Combat Center contracted the team of ERRC and Geosyntec through a competitive bid process to construct a new lined landfill at their facility. The landfill is an 8 acre landfill with approximately 1,000,000 cubic yards of capacity to meet the base waste disposal needs. The landfill is located in an area that is seismically active and has extreme temperature variations. Geosyntec's capabilities in designing and construction quality assurance for these type of landfills were a significant factor in the award of the design build contract. ERRG is the prime contractor and construction contractor for the project. The new landfill will be built within an approximate 8-acre area that is bounded by an existing road, drainage channels, and a blast exclusion zone. The area is within the desert tortoise habitat region and all project activities will require a desert tortoise mitigation plan.

Services Provided by Geosyntec

Geosyntec, as subcontractor to ERRG, is providing design, construction quality assurance, and construction support services for the 8-acre new landfill. The design will include several cost saving strategies that will help the MCAGCC meet sustainability goals for the site. These include solar powered leachate pumping systems, balanced excavation and fill volumes, and minimal removal from the operations borrow source area. The project team has incorporated partnering sessions to help facilitate close inter action with the design team, construction team, regulators, and the Navy. The initial project plan had anticipated removal of thousands of cubic yards of borrow soil to construct the new landfill. By incorporating Geosyntec design modifications the project team is looking at providing a net gain in site soils available for ongoing operation. Geosyntec will provide construction quality assurance services throughout the construction of the landfill berms and during the installation of the geosynthetic liner. The project team has an excellent health and safety record for work within desert environments.

Project Success

The design has incorporated a deeper excavation for the base of the landfill. This chang to the conceptual design has lead to minimal import soil needs from the borrow area. The use of onsite soils for construction of the landfill berms will result in significant savings to the Navy and ERRG during construction. The use of solar powered pumps for the leachate control system will provide long term savings to the Navy. The stockpiling of excess soil from the excavation will extend the life of landfills at the base while saving on transportation costs to the landfill operator. Geosyntec's approach to define win-win

situations will result in long term cost savings to the Navy while reducing the cost of initial construction.

PROJECT TITLE: **NORTH RIDGE CUT GEOLOGICAL AND GEOTECHNICAL EXPLORATION CALABASAS LANDFILL, AGOURA, CALIFORNIA**

JOB DESCRIPTION:

Client and Owner:
County Sanitation Districts of Los Angeles County

Owner Address:
1955 Workman Mill Rd.
Whittier, CA 90601

Telephone Number:
(562) 699-7411

Contact Person:
Mr. Russell Yoshida,
Engineering Geologist
Solid Waste
Management Dept.

Contract Amount:
$1,598,345

Start Date:
April 2003

Completion Date:
Main project -March 2005; Follow-up work on-going

SERVICES PROVIDED:

- **Geologic Mapping**
- **Hydrogeologic Investigation**
- **Drilling, Logging, Sampling**
- **In Situ and Laboratory Testing**
- **Static and Pseudostatic Slope Stability Analysis**
- **Seismic Site Response and Seismic Deformation Analysis**

Project Description

The Calabasas Landfill is a Class III Municipal Solid Waste (MSW) landfill located near Agoura, California. The Landfill is owned and operated by the County Sanitation Districts of Los Angeles County (LACSD), which is developing the site in stages. The North Ridge Cut (NRC) stage will be developed in phases: NRC Phase 1 will form the western cell; whereas, NRC Phase 2 will form the eastern cell. Engineered cut slopes will range from 50 ft high on the eastern side of Phase 1 to 325 ft high on the northwest corner of Phase 2. In support of development of the NRC, LACSD contracted GeoSyntec to perform a comprehensive geological and geotechnical investigation and geotechnical analysis, to design the underdrain trench system, and to assist with the regulatory approval process.

Services Provided by GeoSyntec Consultants

GeoSyntec provided the following services: (i) exploration of subsurface conditions through coring, bucket auger drilling, Cone Penetration Test (CPT) sounding, in-hole physical and geophysical (ATV/OTV) logging, and in-hole and bulk soil sampling; (ii) characterization of local geologic materials through field mapping, in-situ and geotechnical laboratory testing; (iii) characterization of the local aquifer through periodic well monitoring and in situ (pump) testing. GeoSyntec also conducted a series of geotechnical engineering analyses, including static and seismic evaluation of native cut and fill slopes, soil liquefaction evaluation, steady-state seepage analysis, and seismic site response analyses of NRC Phase 1 and NRC Phase 2 waste fill mass.

Phone: (714) 969-0800 • Fax: (714) 969-0820

PROJECT TITLE: HEAPS PEAK SANITARY LANDFILL, SAN BERNARDINO COUNTY
STATIC AND SEISMIC SLOPE STABILITY EVALUATION

JOB DESCRIPTION:

Client:

San Bernardino County

Client Address:
Eastern 222 W.
Hospitality Lane
2nd Floor,
San Bernardino, CA
92415

Contact Person:
Mr. Art Rivera, P.E.
Chief Engineer
(909) 368-8775

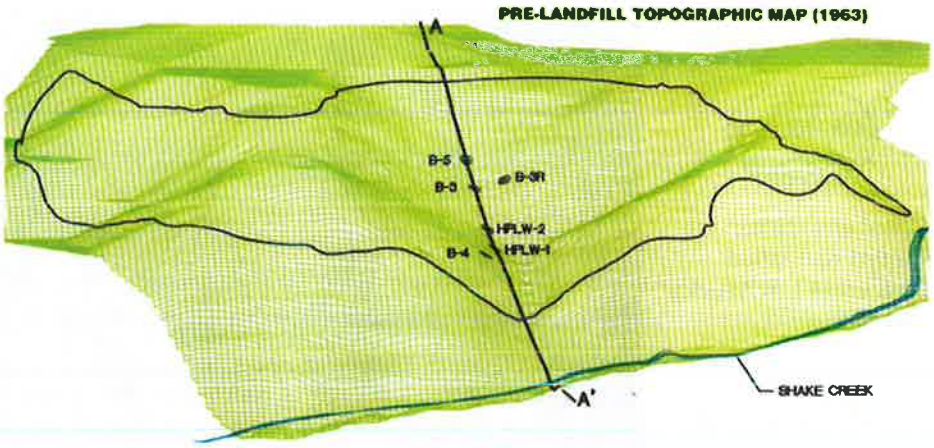
Contract Amount:
$18,000

Starting Date:
August 1999

Completion Date:
November 1999

SERVICES PROVIDED:

- **Seismic Hazard Evaluation**
- **Waste Mass Characterization**
- **3-D Static and Pseudostatic Slope Stability Analysis**
- **2-D Seismic Site Response Analysis**
- **Newmark-type Seismic Deformation Analysis**
- **Post-Earthquake Reconnaissance**



Project Highlights

The Heaps Peak Sanitary Landfill is a closed municipal solid waste landfill located in a mountainous portion of San Bernardino County between Lake Arrowhead and the community of Running Springs, California. The plan area of the waste footprint is approximately 20 acres. The toe of the waste fill is at an approximate elevation of 5,700 ft above mean sea level. The landfill ceased accepting waste on 1 November 1981 and was closed in accordance with an approved closure plan in 1985. The landfill is owned by the County of San Bernardino Waste Systems Division (WSD).

The 20-acre landfill was created by disposal of waste into a steep side canyon (canyon base as steep as 2.4H: 1V) without compaction. Natural seeps historically occurred along the canyon base and the landfill experiences perennial seeps through the cover. At the present time, 5-15 gpm of discharge is collected from the waste mass through a toe-drain system. This seepage, and the 1992 Moment Magnitude (M_w) 6.8 Big Bear Lake earthquake at a distance of 18 km, raised concerns about the long term stability of the landfill.

Services Provided by Geosyntec Consultants

Based upon results of previous hydrogeologic investigations at the site, Geosyntec developed a steady-state seepage model of the landfill. This steady-state seepage model was incorporated into a three-dimensional (3-D) limit equilibrium computer model of the site (CLARA™) and coupled with a two-dimensional (2-D) seismic site response model (QUAD4M™) and Newmark-type seismic deformation model (YSLIP_PM™) to evaluate the static and seismic stability of the landfill. The undrained shear strength parameters of the colluvium and residual soils at the landfill base were evaluated based upon available data and bounded by back-analysis of observed landfill response to the 1992 Big Bear earthquake (no observed displacement, PHGA = 0.20 g). The results of Geosyntec evaluations were used to established maximum allowable liquid level within the landfill.

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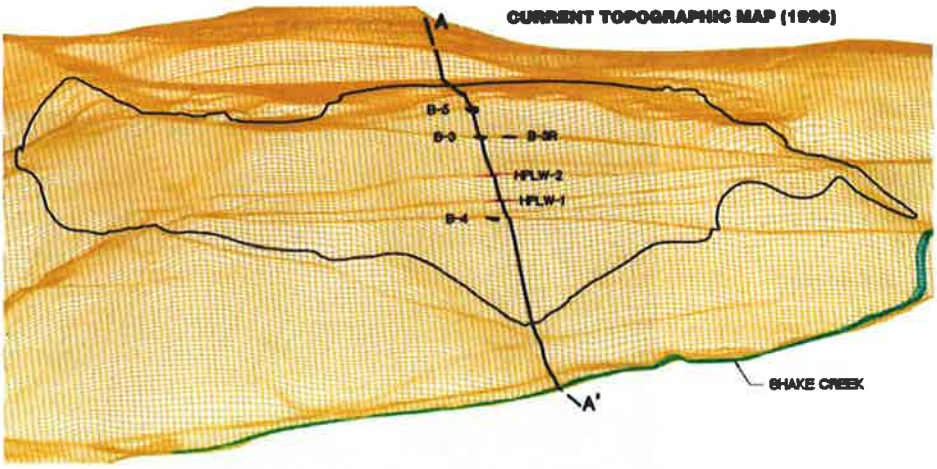


The Geosyntec stability evaluation was tested soon upon completion, by the 1999 M_w 7.1 Hector Mine earthquake. The Hector Mine earthquake occurred at a distance of 31 km with an estimated on-site PHGA of 0.15 g. The post earthquake reconnaissance team did not observe any signs of landfill mass movement two days after the event.

PROJECT TITLE: LANDFILL DESIGN AND PERMITTING

JOB DESCRIPTION: KETTLEMAN HILLS FACILITY
KETTLEMAN CITY, CALIFORNIA

Client:

WASTE MANAGEMENT

Client Address:

Contact Person:
Mr. Rodney Walter

SERVICES PROVIDED:

- **Expansion Permitting**
- **Cell Design**
- **Geotechnical Investigation**

Project Background

The Kettleman Hills Facility (KHF) is a hazardous (Class I) and non-hazardous (Class I/II) disposal facility including approximately 1,600 acres. The site is close to reaching capacity in its existing units and has initiated the process (preliminary design, CEQA, permitting, and final design) of expansions to both the hazardous and non-hazardous operations at the site. Our staff has been involved with the expansion design since its inception.. Expansion will include development of a new Class II/III unit, Landfill B-17, expansion of the existing Class I/II unit, Landfill B-18, and development of a new Class I/II unit, Landfill B-20.

Scope of Work

GeoSyntec has prepared a variety of services for the KHF site including permitting, conceptual design, detailed design, road realignment, and geotechnical investigations.

Geosyntec prepared conceptual level design for the 62-acre non-hazardous Landfill B-17 which will provide approximately 18.4 mcy of airspace. The design incorporates storm water drainage, site access, alternative liner system, alternative final cover system, and static and seismic stability. Geosyntec prepared the Joint Technical Document (JTD) for permitting with the RWQCB and CIWMB in accordance with Title 27 of the California Code of Regulations. Upon receipt of the required permits, Geosyntec completed the design of the first phase of development of Landfill B-17 (Phase A1), a lined, 14.2-acre cell, including development of the construction bid documents.

Geosyntec has also been involved in the hazardous landfill expansions at the site. The proposed Landfill B-18 expansion will encroach northward on the existing entrance road to the facility. Geosyntec has prepared construction bid documents for a revised alignment of this road, taking into account future expansion of Landfill B-18 and providing minimal disturbance to continued site operations. Construction bid documents for this project have been submitted and the project is expected to be constructed in 2008. Geosyntec is also currently completing an investigation to evaluate on-site clay sources for future use in the clay liner systems of the proposed hazardous landfill expansions. The investigation includes sampling and mapping of the identified clay seam, construction of a test pad and performing a Sealed Double Ring Infiltrometer (SDRI) test.

Notable Accomplishments

Both the Joint Technical Document (JTD) and the Phase A1 Design Report for Landfill B-17 received minimal comments and was readily approved by the regulatory agencies (RWQCB and LEA/CIWMB).

US Army Environmental Center (AEC)

Design and Construction Support

Los Alamitos, California

Client:
US Army Environmental Center (AEC)

Owner Address:
Los Alamitos Joint Forces Training Base,
Los Alamitos, CA

Contact Person:
Sandi Schafer, V.P.,
Western Operations,
Clayton Group Services
(714) 431-4131
(714) 825-0685

Doug Alvy, Manager
Construction Services,
Clayton Group Services
(714) 431-4100
(714) 825-0685

Project Background

The landfill area at the Los Alamitos Joint Forces Training Base (LAJFTB) occupies approximately 25 acres. The ultimate client was the US Army Environmental Center (AEC). The landfill accepted waste from the 1940s to 1980s and was constructed as a trench and fill landfill. The footprint of the existing waste trenches extends approximately 2,600 feet in the north-south direction with widths varying from 150 feet to 600 feet in the east-west direction. Evidence from previous investigations indicates that the bottom of the waste material in the existing waste trenches is below groundwater level. To improve the groundwater and consolidate the waste from the existing waste trenches, the AEC issued a performance-based contract (PBC) for the design and construction of an 8-acre waste consolidation cell (WCC).

Services Provided by Geosyntec

In 2005, Geosyntec, as subcontractor to Clayton Group Services, provided design and construction support services for an 8-acre WCC; services were completed in 2007. Geosyntec's responsibilities included pre-design field investigation, plan preparation, detailed design and construction level drawings, preparation of a focused feasibility study, engineering and geotechnical evaluations, design of the WCC, landfill closure design, and regulatory interface to achieve landfill closure in compliance with Title 27 CCR and Subtitle D. Geosyntec's design of the 8-acre WCC was approved by the regulators with no comment. Geosyntec also provided both leachate collection (LCRS) and landfill gas mitigation systems for the WCC. The design incorporated on site soils to minimize import materials and met regulatory requirements. To increase the environmental sustainability of the LCRS system installed at the site, Geosyntec's design incorporate the use of solar-powered leachate pump system. Geosyntec provided evaluation of prescriptive and evapotranspirative (ET) covers for the WCC. Additionally, Geosyntec provided CQA services during the installation of the geosynthetic liner and provided QA oversight and engineering support during the construction period, including providing technical assistance to the AEC and Clayton to resolve construction issues as they arose. Geosyntec engineering support services during construction included regular interaction with the Santa Ana RWQCB to expedite approval of design changes in response to changes in field conditions.

Project Success

The utilization of ET cover as an alternative to the prescriptive cover was both a sustainable and economical solution that utilized on-site material.. The elevated landfill berm provides a physical barrier to offsite line of sight activities to the flight line and taxi way for a portion of the airport. In addition, the design specifically was modified to allow a full crash recovery

zone off the end of the airport runway. Geosyntec's design was not only successfully efficient and environmentally responsible but also resulted in major cost savings to the client (AEC)

PROJECT TITLE:

HYDROGEOLOGIC INVESTIGATION AND GROUNDWATER MODELING MESQUITE REGIONAL LANDFILL, IMPERIAL COUNTY, CALIFORNIA

JOB DESCRIPTION:

Client and Owner:

County Sanitation Districts of Los Angeles County

Owner Address:
1955 Workman Mill Rd.
Whittier, CA 90601

Contact Person:
Mr. Alex Mena, P.E.
Project Engineer,
Technical Services Dept.
(562) 699-7411

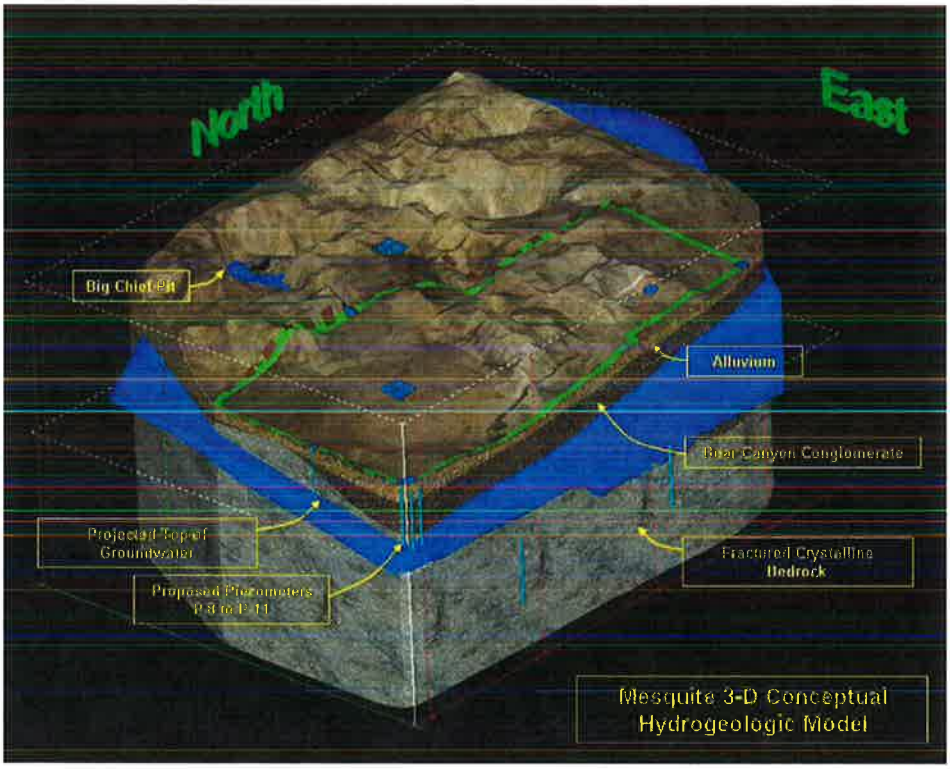
Contract Amount:
$3,335,000

Starting Date:
November 2004

Completion Date:
Ongoing

SERVICES PROVIDED:

- **Geologic Mapping**
- **Hydrogeologic Investigation**
- **Drilling, Logging, Sampling**
- **In Situ and Laboratory Testing**
- **Hydrogeologic Modeling**
- **Steady State Seepage (Saturated and Unsaturated Flow) Modeling**
- **Biologic Mitigation**



Project Description

The Mesquite Regional Landfill (MRL) is a Class III Municipal Solid Waste (MSW) landfill under development. The site is located in northeastern portion of the Imperial County, just north of Brawley, California. The Landfill is owned and operated by the County Sanitation Districts of Los Angeles County (LACSD). When completed, the landfill will occupy approximately 2,300 acres of the 4,200-acre site, have a 100-year capacity, and waste piles as high as 500 ft.

Services Provided by Geosyntec Consultants

Geosyntec is currently providing services required to obtain formal approval from the California Regional Water Quality Control Board – Colorado River Region (RWQCB) for the installation of a groundwater monitoring system at the MRL site. A key component of the project is an accurate interpretation the site hydrogeology based on field hydrogeologic investigation, hydrogeologic modeling, groundwater flow modeling (water particle movement simulation that represents a hypothetical release from the landfill), and calculation of appropriate detection monitoring well spacings for monitoring groundwater quality at the site in accordance with Title 27 of the California Code of Regulations.

The field hydrogeologic investigation includes the following:

- Procurement of well installation and decommissioning permits;
- Continuous core drilling and logging of 19 exploratory boreholes (over 9,300 linear feet)

- Geophysical logging of over 9,300 feet of coreholes by using optical televiewer (OTV), acoustic televiewer (ATV), electric resistivity and induction, spontaneous potential, temperature, caliper, radiometric and sonic continuous velocity logging methodologies;
- Geotechnical testing of soil and rock samples to support unsaturated and saturated groundwater flow modeling;
- Installation and development of 19 groundwater piezometers and 5 groundwater monitoring wells;
- Destruction of 10 groundwater piezometers;
- Conducting aquifer slug tests in 35 monitoring wells and piezometers;
- Conducting aquifer step-drawdown, constant-rate pumping, and recovery tests in three monitoring wells at low flow rates (<5 gpm) and three water supply wells at high flow rates (>800 gpm);
- Design and installation of dedicated QED Environmental Systems, Inc. bladder pumps;
- Conducting low flow groundwater sampling in using QED Environmental Systems, Inc. bladder pumps;
- Developing unsaturated zone flow models and saturated zone groundwater flow models and performing water particle tracking to support calculation of detection monitoring well spacings;
- Evaluation of the water supply well field capacity for the project;
- Participating in meetings to discuss technical findings with RWQCB personnel;
- Preparation of a comprehensive technical report describing the results of the investigation.

At the initial stage of the project, Geosyntec has prepared a preliminary three-dimensional (3-D) conceptual hydrogeologic computer model of the site based solely on a review of existing site data. The model, shown above, illustrates the complexities of the site hydrogeology in a user-friendly and pragmatic presentation. The model is continuously updated as more data become available during the site investigation.

PROJECT TITLE: NUWAY LIVE OAK SITE, IRWINDALE, CALIFORNIA
EVALUATION OF STABILITY OF CEMENTED GRAVEL SLOPES

Client:

WASTE MANAGEMENT, INC.

Client Address:
2050 N. Glassel Str.,
Orange, CA 92865

Contact Person:
Mr. Bo McCoy
Engineer
(714) 685-6498

Start Date:
August 2006

Completion Date:
October 2006

SERVICES PROVIDED:

- **Soil Mass Characterization**
- **Evaluation of Shear Strength Parameters**
- **Native Slope Stability Analysis**
- **Soil Erosion Potential Evaluation**
- **Preparation of Construction Documents**
- **Regulatory Interface (L.A. Region RQWCB & DWR)**

The cut slope on the north side of Nuway Live Oak Site was an unstable mass of cemented gravel.

Site Description

The site is a former sand and gravel mining pit just next to the 605 Freeway in Orange County, California. Upon completion of mining operations, cut slopes as high as 120 ft were left in place. Due to cementation, some of these slopes are nearly vertical. The site is presently occupied by several tenants. One of the tenants is still processing gravel. Processed gravel piles are inclined at approximately 43 degrees, and indication of friction angle of the material. Given that cemented slopes of the same material are nearly vertical, influence of cementation on these materials is apparently significant.

Geosyntec's Scope of Work

Geosyntec evaluated static and seismic stability of several slopes at the site. Project challenges included evaluation of shear strength of cemented materials and of the processed aggregate compacted to 95% of Modified Proctor Compaction Test (ASTM 1557). As it is not possible to sample these materials and/or transport "undisturbed" samples to the laboratory, Geosyntec assessed shear strength of in-situ material by back-analysis of steepest slopes. The shear strength of compacted soil was evaluated by interpretation of laboratory testing results considering presence of oversized particles.

Stability evaluations conducted in support of detention basin design included pseudo-static limit equilibrium evaluations and Newmark-type seismic deformation evaluation. Steady-state seepage through embankment slopes was considered in both static and pseudostatic evaluations.

PROJECT TITLE: **OPERATING INDUSTRIES, INC. (OII) LANDFILL SUPERFUND SITE MONTEREY PARK, CALIFORNIA**

JOB DESCRIPTION:

Client:
1995-1996
New Cure, Inc.

1996-1999
Foster Wheeler Environmental Corporation

San Bernardino County

Owner Address:
2550 Greenwood Ave.
Monterey Park, CA
91755

Contact Person:
Dr. Ian Webster,
New Cure Project Manager
(323) 720-9775

Dr. Les LaFountain
New Cure, Inc.
President.

Mr. John Loftus
FWENC
Program Manager

Joanne Cola
U.S. EPA
(415) 744-2238

Ram Ramanujam
DTSC
(916) 255-6662

Total Project Value:
Project Cost: $60M
Geosyntec: $2M

Contract Type:
Time and Materials

Starting Date:
May 1995

Completion Date:
October 1999

Services Provided:

Site and Project Description

The 190-acre (77-ha) inactive OII landfill site was formerly a sand and gravel pit. For 30 years, until 1984, the landfill received solid waste (refuse). For a limited period of time, hazardous liquids were also disposed of in the landfill. The refuse is up to 320 ft (100 m) thick, has slopes as steep as 1.25H:1V (horizontal:vertical), and is in an area of high seismic exposure. The site is surrounded by residential property to the south and west, a commercial shopping complex to the east, and California State Highway 60 to the north.

The 190-acre (77-ha) inactive OII landfill site was formerly a sand and gravel pit. For 30 years, until 1984, the landfill received solid waste (refuse). For a limited period of time, hazardous liquids were also disposed of in the landfill. The refuse is up to 320 ft (100 m) thick, has slopes as steep as 1.25H:1V (horizontal:vertical), and is in an area of high seismic exposure. The site is surrounded by residential property to the south and west, a commercial shopping complex to the east, and California State Highway 60 to the north.

Geosyntec Consultants' Role:

New Cure, Inc., (NCI) a consortium of Potentially Responsible Parties, manages remediation and closure of the site. Prior to August 1996, during predesign studies for landfill closure, Geosyntec Consultants (Geosyntec) was a consultant to NCI. In August 1996, NCI retained Foster Wheeler Environmental Corporation (FWENC) to prepare the final closure design, including the cover, surface water management, and gas control systems, and to construct the final closure systems. Geosyntec provided the FWENC team with geotechnical services, focusing on the design and construction of the cover system.

Services Provided By Geosyntec Consultants July 1994 to November 1996:

- **Pre-Design Seismic Analysis**
- **Final Cover Design**
- **Operation and Maintenance Plan Development**
- **Construction Quality Assurance**
- **Regulatory Interaction**

Geosyntec provided specialized technical services and regulatory assistance to NCI during predesign studies for landfill closure. Geosyntec services included the following:

- ***Waste Mass (Refuse) Characterization:*** Geosyntec conducted extensive waste mass characterization activities, including: non-intrusive geophysical profiling of the site using the spectral analyses of surface waves technique; recovery of bulk samples of waste from up to 150-ft (45-m)in 2-1/2-ft (0.75-m) diameter bucket auger borings; excavation of an 18-ft (5-m) deep, 3-ft (1-m) wide, 20-ft (6-m) long test trench; in-situ unit weight measurements in the borings and the test trench; and large-scale laboratory monotonic and cyclic testing of reconstituted samples of solid waste.

- ***Seismic Analyses:*** Geosyntec performed a seismic hazard evaluation to synthesize data from previous studies on regional tectonics and seismicity into a site-specific seismic exposure characterization. The results of the evaluation include a suite of time-histories for use in seismic site response analyses. Two-dimensional (2-D) finite element seismic response analyses were conducted to evaluate the response of the landfill when subjected to the design seismic loading.

- ***Static and Seismic Stability Analyses:*** Geosyntec performed static and seismic stability analyses of the side slopes and landfill waste mass. The seismic stability calculations included pseudostatic analyses and Newmark-type analyses of the cover system to quantify earthquake induced slope movement. Geosyntec evaluated the integrity of an existing reinforced toe buttress at the south side of the landfill. This involved both pseudo-static and 2-D finite element site response analyses of the toe buttress.

- ***Regulatory Interaction:*** Under the guidance of NCI, Geosyntec developed analysis and response strategies to address USEPA comments and establish that the NCI seismic technical approach is correct.

- ***Deformation Performance Analyses:*** Geosyntec used finite element analyses to quantify the time-dependent deformation of the refuse and evaluate potential settlements during the post-closure period.

Services Provided By Geosyntec Consultants, August 1996 and ongoing:

Geosyntec, as geotechnical consultant to FWENC, was part of the design/build team retained by NCI to prepare the cover, surface water management, and gas control system design and construct the site closure systems. Geosyntec activities included the following:

- ***Site Characterization:*** Geosyntec prepared Work Plans and excavated, profiled, and sampled over 250 test pits as part of an extensive characterization of existing cover conditions. Laboratory testing was done to define soil properties. Data were evaluated and a comprehensive report on the findings was prepared for and accepted by the EPA. Characterization work included off-site borrow source characterization and additional site characterization ahead of the construction crew as part of implementing the design/build approach.

- ***Conceptual Design:*** Geosyntec prepared the following aspects of the Final Predesign Report: (i) conceptual design of the cover system including the "monocover", a soil and vegetation cover that limits percolation by evapotranspiration, controls erosion with the vegetation, and is stable for static and seismic conditions; (ii) conceptual design of a detention basin; and (iii) the sections of reports submitted to and accepted by the EPA on geotechnical engineering, and cover system design and performance.

- ***Detailed Design:*** Geosyntec develop the detailed design of the following elements of the cover system: (i) the soil and vegetation cover system that includes the evapotranspiration monocover; (ii) geogrid reinforcement to achieve static and seismic stability on the steep North Slopes of the soil cover that includes the moncover; (iii) the Detention Basin including the compacted soil embankment and liners; (iv) a geogrid Reinforced Soil Walls along the North Slope Fire Break Road and the South Slope Iguala Park.

- ***Performance Calculations:*** To support the design and to demonstrate the performance of the cover system, Geosyntec compiled the following calculations: (i) cover infiltration and percolation using the computer codes HELP and LEACHM; (ii) sheet and gully erosion; (iii) static and seismic stability and deformation.

- ***Operations and Maintenance Plan Preparation:*** Geosyntec developed the geotechnical and soils engineering parts of the site Operation and Maintenance Plan and prepared detailed Standard Operating Procedures for cover system monitoring, maintenance, and repair.

- ***Construction:*** Geosyntec was the construction Soils and Geotechnical Engineer and in that capacity oversaw geotechnical aspects of construction, including provision of technical and engineering support for QA and QC. Geosyntec advised on and prepared engineering changes to deal with changed site conditions.

- ***Interaction With Regulatory Agencies:*** Geosyntec was involved in interaction with the regulators including the EPA and the US Corps of Engineers, on geotechnical and soils aspects of the work. This included attending meetings, making presentations, preparing reports, and responding to comments.

PROJECT TITLE: EAGLE MOUNTAIN LANDFILL AND RECYCLING CENTER

JOB DESCRIPTION:

Client:
Mine Reclamation Corporation

Client Address:
Eastern Riverside County, Los Angeles, CA

Contact Person:
Mr. Gary Johnson, P.E.
Vice President,
Landfill Development
(619) 779-5888

Contract Value:
Confidential

Change Orders $ Amt:
$0.00

Starting Date:
January 1991

Completion Date:
On-going

Site and Project Description

The proposed Eagle Mountain Landfill in eastern Riverside County, California, will be the largest landfill in the United States upon completion. The landfill site occupies approximately 2,000 acres and the projected capacity is almost 680,000,000 yd^3 of airspace. The project involves reclamation of the former Kaiser Eagle Mountain open pit iron mine. Because of the size of the facility and its location adjacent to Joshua Tree National Monument, the project has generated significant public comment.

Geosyntec Consultants' Role:

In 1994, Geosyntec completed preparation of the design and permit application for the proposed facility. All components of the facility were designed in accordance with Federal Subtitle D requirements. The Report of Waste Discharge by Geosyntec prepared for the facility included master planning for the entire 100-year life and detailed design for the first 25-year phase of landfill development. Because of the high visibility of the project, the master plan and detailed design were completed to an unprecedented level of detail for a permit document. As a reclamation project, landfill development will result in filling of the mine pit and a final closure that will return the property to a California desert setting. The landfill bottom will be underlain by a double-composite liner system. Other design components include a leachate collection and removal system, a leakage detection system, vadose zone and groundwater monitoring systems, operations and waste placement plans, a final cover system, and a surface water management system. Technically, the project was extremely challenging, due to steep mine pit slopes (1,000 ft high and as steep as 1H:1V (Horizontal:Vertical)) and the seismicity of the region.

Geosyntec performed probabilistic seismic hazard assessment and extensive, state-of-the-art 3-D stability analyses to assure landfill stability during the design earthquake. Evaluation of the recency of movement on faults crossing the site was an important component of the seismic hazard analysis. Detailed geo-chronological analyses indicated that the last episode of displacement across the faults was at least several million and possibly several hundred million years ago. In the strong shaking analysis, the design earthquake was established as having a peak horizontal ground acceleration of 0.58 g.

The location of the project site, in a former mine pit in the desert near the JTNP, necessitated many innovations in the design approach. The design was developed to use mine spoil as a major landfill construction material, employing mining and heavy civil construction techniques to grade rock slopes and excavate/transport the millions of cubic yards of spoil involved in landfill construction. The closeness of the JTNP influenced the design in important ways, including limiting final grades to use adjacent mountains as a visual buffer, special measures for dust suppression, traffic routing, and protection of indigenous wildlife habitat.

During the course of this project, Geosyntec personnel worked closely with client, making numerous presentations to various regulatory agencies responsible for permit approval and design review. Geosyntec project personnel also worked closely with the client in communicating with stakeholders to build consensus and confidence in the project. The design permit application for the landfill was approved on the first submittal by the lead regulatory agency in an 8 to 1 vote in May 1994.

PROJECT TITLE: **LANDFILL DESIGN AND PERMITTING**
ALTAMONTE LANDFILL AND RESOURCE RECOVERY FACILITY
LIVERMORE, CALIFORNIA

JOB DESCRIPTION:

Client:

WASTE MANAGEMENT

Client Address:
25772 Springbrook Road
Saugus, CA 91350

Contact Person:
Mr. Guy Petraborg

SERVICES PROVIDED:

- **Expansion Permitting**
- **Cell Design**
- **Geotechnical Investigation**

Project Highlights

The Altamont Landfill & Resource Recovery Facility (ALRRF) is a non-hazardous (Class II and Class III) disposal facility owned and operated by Waste Management of Alameda County (WMAC). WMAC owns approximately 2170 acres of land near Livermore, CA, of which approximately 235 acres compose the existing Fill Area 1 landfill, and approximately 237 acres will compose the proposed Fill Area 2 landfill in the adjacent canyon. Fill Area 1 is nearing its ultimate capacity, and construction of the first phase of Fill Area 2 is planned for the near future. The ALRRF is the San Francisco Bay Area's busiest landfill, utilizing on the order of 2 million cubic yards of airspace per year.

Scope of Work

Geosyntec has performed conceptual design of the new Fill Area 2 landfill, including layout of a mile long access road. Based on land use conditions, Fill Area 2 was limited to a maximum of 250 acres and 40 million tons of municipal solid waste. Based on a total design airspace of 60 million cubic yards, Geosyntec optimized the design to a lined waste footprint of 208 acres, with an option for a future 29 acre tie-in between Fill Area 1 and Fill Area 2.

Key features of the design of Fill Area 2 include:

- ~200 ft high toe berm at the mouth of the canyon;
- cutslopes in excess of 300 ft;
- design for both static and seismic stability conditions;
- design around several known or suspected landslides;
- optimized design around a single leachate collection sump; and
- 6% slope along landfill floor and double-lined leachate collection
- trenches to reduce the already very low potential for liner leakage.

In 2005, Geosyntec prepared the Joint Technical Document (JTD) for the entire landfill (Fill Areas 1 and 2) which was approved by the regulatory agencies later that year. Notable components of the JTD included:

- Conceptual design and analyses of Fill Area 2
- Monitoring & Reporting Program Plan Report
- Preliminary Closure and Post-Closure Maintenance Plan
- Liner Performance Demonstration

Geosyntec is currently performing detailed design of Stage 1 of Fill Area 2, and corresponding construction documents for the first cell, including development of an approximately 1 mile long access road from the existing landfill to the new site.

Antelope Valley Public Landfill

Construction Quality Assurance Monitoring, Cell IV, Steps 3 and 4

Palmdale, California

WASTE MANAGEMENT, INC.

Client:
Waste Management and Recycling Services of California, Inc. (Waste Management, Inc.)

Owner Address:
600 East Avenue F
Lancaster, CA 93535

Contact Person:
Mr. John Workman
Area Engineer
(770) 805-3362

Services Provided:

- Construction Quality Assurance Monitoring
- Review of Contractor Submittals
- CQA Report Preparation

Project Background

The Antelope Valley Public Landfill is an active municipal solid waste disposal facility west of Palmdale, California. The landfill is owned and operated by Waste Management of California, Inc. (WMI) a subsidiary of Waste Management, Inc. Cell IV is a lined lateral expansion of the existing waste fill.

Services Provided by GeoSyntec

GeoSyntec Consultants (GeoSyntec) provided Construction Quality Assurance (CQA) services for Steps 3 and 4 of the vertical expansion of Cell IV. Specifically, GeoSyntec performed CQA of the following:

- Gas extraction system installation.
- Shingled side-slope subgrade liner construction.
- 220,000 ft^2 of composite geosynthetic liner system installation.
- LCRS/operations layer placement over geosynthetic liner.

GeoSyntec conducted conformance testing on the materials used for construction. GeoSyntec reviewed contractor's submittals, provided communication and correspondence as appropriate, evaluated the design and submitted design clarifications.

Project Success

The final CQA report prepared by GeoSyntec for the Lahontan Region Regional Water Quality Control Board (RWQCB) was approved without comment.

Simi Valley Landfill and Recycling Center

Construction Quality Assurance Monitoring, Cell B3-A and Cell D-1

Simi Valley, California

WASTE MANAGEMENT, INC.

Client:
Waste Management and Recycling Services of California, Inc.

Owner Address:
2801 Madera Road
Simi Valley, CA 93065

Contact Person:
Mr. Jim Riley
Environmental Site Engineer
(805) 579-7479

Project Background

The Simi Valley Landfill and Recycling Center (SVLRC) is currently permitted as a Class III municipal solid waste disposal facility and is owned and operated by Waste Management of California a subsidiary of Waste Management, Inc. (WM). The landfill has a permitted disposal area of 186 acres and can receive up to 3,000 tons per day. To accommodate the incoming waste, the SVLRC has been expanding laterally by construction new cells with liner systems. Cell B3-A consisted of a 5.9 acre expansion that included a 2-ft. compacted clay liner for the base and geosynthetic clay liner (GCL) for the side slopes, a geomembrane liner, and a geocomposite LCRS. Cell D-1 was an 8.0 acre expansion with GCL placed on the base and side-slopes, a geomembrane liner, and a gravel LCRS.

Services Provided by GeoSyntec

GeoSyntec Consultants (GeoSyntec) provided Construction Quality Assurance (CQA) services during the construction of Cell B3-A and Cell D-1 expansions at SVLRC. GeoSyntec monitored the installation of over 600,000 ft^2 of liner and LCRS systems, tested approximately 320,000 yd^3 of engineer fill placement, observed the construction of surface water drainage structures, monitored and tested the operations layer, and conducted conformance testing on the concrete structures. In addition, GeoSyntec reviewed contractor's submittals, generated correspondence as appropriate, reevaluated and submitted design clarifications, and prepared the final CQA report for the Los Angeles Region Regional Water Quality Control Board (RWQCB) approval.

Geosyntec consultants

Attachment A-5

Geosyntec QA/QC Experience Table

EXHIBIT B to Consultant Agreement

GEOSYNTEC CONSULTANTS RELEVANT CONSTRUCTION MANAGEMENT CONSTRUCTION QUALITY ASSURANCE EXPERIENCE
(2001 to Present)

Year	Project Description	Location	State	Client/Owner
2010				
	BMI North Final Cover System, CQA	Henderson	NV	Basic Remediation Co.
	BMI South Final Cover System, CQA	Henderson	NV	Basic Remediation Co.
	Corrective Action Management Unit Final Cover System CQA	Henderson	NV	Basic Remediation Co.
	Tailings Disposal Cell 4B, CM/CQA	Blanding	UT	Denison Mines (USA) Corp.
	Bradley Landfill Final Cover System, CQA	Sun Valley	CA	Waste Management
	Asbestos Abatement and AST Removal, CM	Oakland	CA	Confidential
	Jacumba Burn Dump Closure, CQA	Jacumba	CA	San Diego County
	Municipal Solid Waste Closure, Titcomb Pit Landfill, CQA, LSP	Amesbury	MA	Waste Management Disposal Service of Massachusetts
	Municipal/C&D Greenwood Street Landfill, Stage II Closure, CM, CQA	Worcester	MA	Casella Waste Systems, Inc.
	Municipal Solid Waste Landfill, TLR-III LF Phase 9-14 Expansion,	Rochester	NH	Waste Management of New Hampshire
	Industrial Landfill, Stormwater Treatement System, CQA	Cementon	NY	Lehigh Cement
	Industrial Landfill, Stormwater Treatement System, CQA	Alsen	NY	Lehigh Cement
	MSW Landfill, Butterfield Station Facility, Cell 13C CQA	Mobile	AZ	Waste Management of Arizona, Inc.
	MSW Landfill, Gray Wolf Regional Landfill, Phase 9A CQA	Dewey	AZ	Waste Management of Arizona, Inc.
	Tesoro Golden Eagle Refinery WMU 5 Closure CQA	Martinez	CA	ART/ Tesoro
	MSW Landfill, Kekaha Landfill, Cell 1 Expansion and New Leacahte	Kekaha	HI	Waste Management of Hawaii/County of
	Tesoro Golden Eagle Refinery WMU 13 Closure CQA	Martinez	CA	ART/ Tesoro
2009				
	Alpine Burn Dump Closure, CQA	Alpine	CA	San Diego County
	MSW Landfill, Butterfield Station Facility, Cell 13B CQA	Mobile	AZ	Waste Management of Arizona, Inc.
	Class II Solid Waste Landfill, McKittrick Waste Treatment Site, Module B-2 Phase 1 CQA	McKittrick	CA	Liquid Waste Management, Inc.
	MSW Landfill, Redwood Landfill Leachate Pond CQA	Novato	CA	Redwood Landfill, Inc.
	Clean Harbors WMU 35 Cell 1 Final Cover, CQA	Buttonwillow	CA	Clean Harbors Environmental Services
	Clean Harbors WMU 35 Cell 3 Base Liner, CQA	Buttonwillow	CA	Clean Harbors Environmental Services
	Bradley Landfill Final Cover System, CQA	Sun Valley	CA	Waste Management
	Municipal Solid Waste Landfill, Richland Creek Landfill Stage 9, CQA	Buford	GA	Allied Waste Industries
	Municipal Solid Waste Hickory Hill Landfill Gas Expansion, CQA	DeKalb County	GA	Republic Services, Inc.
	Construction & Demolition Landfill Closure, Mount Pisgah Athletic Complex, Phses I & II CQA	City of Johns Creek	GA	Mount Pisgah Christian School
	Construction & Demolition Landfill Closure, Mount Pisgah Athletic Complex, LFG System, CQA	City of Johns Creek	GA	Mount Pisgah Christian School
	Municipal Solid Waste Closure, Titcomb Pit Landfill, CQA, LSP	Amesbury	MA	Waste Management Disposal Service of
	Municipal/C&D Southbridge Landfill, Phase VII, Cell 7.2B', CQA	Southbridge	MA	Casella Waste Systems, Inc.
	Municipal Solid Waste Landfill, Tri-Community Recycling and Sanitary Landfill Phase III, CQA	Fort Fairfield	ME	TCRSLF / Woodard & Curran
	Industrial Sludge Waste Landfill, Anson-Madison Sanitary Landfill Closure, CQA	Madison	ME	Woodard & Curran
	BMI South Final Cover System, CQA	Henderson	NV	Basic Remediation Co.
	BMI North Final Cover System, CQA	Henderson	NV	Basic Remediation Co.
	Corrective Action Management Unit, Phase IIIA, IIIB, IV and V, CQA	Henderson	NV	Basic Remediation Co.
	Municipal Solid Waste Landfill, TLR-III LF Phase 9-14 Expansion, CQA/CM	Rochester	NH	Waste Management of New Hampshire
	Municipal Solid Waste Landfill, Oakridge Landfill Phase II Cell 2, CQA	Dorchester	SC	Waste Management of South Carolina

EXHIBIT B to Consultant Agreement

GEOSYNTEC CONSULTANTS RELEVANT CONSTRUCTION MANAGEMENT CONSTRUCTION QUALITY ASSURANCE EXPERIENCE

(2001 to Present)

Year	Project Description	Location	State	Client/Owner
	Mesquite Creek Landfill, Unit 2 - Phase I Liner System Construction, CQA	New Braunfels	TX	Waste Management of Texas, Inc
	Tailings Disposal Cell 4B, CM/CQA	Blanding	UT	Denison Mines (USA) Corp.
2008				
	MSW Landfill Cell 3, CQA	Tucson	AZ	City of Tucson
	MSW Landfill, Butterfield Station Facility, Cell 13A CQA	Mobile	AZ	Waste Management of Arizona, Inc.
	MSW Landfill, Gray Wolf Regional Landfill, Phase 8B CQA	Dewey	AZ	Waste Management of Arizona, Inc.
	OII, CD-3, North Parcel Project, Design/Build, General Contractor	Monterey Park	CA	New Cure Industries
	Milliken Composting Facility, Closure, CQA	San Bernardino	CA	Synagro
	Environmental Conveyance Piping System, CQA	Long Beach	CA	Confidential
	Sierra Point Development, vapor control system, CQA	Brisbane	CA	HPC
	MSW Landfill Phase 17A1, CQA	Kettleman City	CA	Chemical Waste Management
	Home Depot Vapor Barrier	Huntington Beach	CA	Home Depot
	MSW Landfill, Anderson Landfill Partial Final Closure and Cell 4C, CQA	Anderson	CA	Waste Management, Inc.
	Tesoro Golden Eagle Refinery WMU 13 Closure CQA	Martinez	CA	ART/ Tesoro
	Industrial Landfill Area 3 Subcell 2, CQA	Augusta	GA	International Paper
	Municipal Solid Waste Landfill, Richland Creek Landfill Stage 10, CQA	Buford	GA	Allied Waste Industries
	Creek Bank Stabilization - Rock Vanes	Stone Mt	GA	Developers Diversified Reality
	MSW Landfill, West Hawaii Cell 9A/10A	Waikaloa	HI	Waste Management of Hawaii, Inc.
	Municipal Solid Waste Landfill Cell , Woodside, CQA	Walker	LA	Waste Management of Louisiana
	Municipal Solid Waste Landfill, Tri-Community Recycling and Sanitary Landfill Phase III, CQA	Fort Fairfield	ME	TCRSLF / Woodard & Curran
	Municipal Solid Waste Landfill, Phase II Secure Landfill Expansion, CQA/CM	Nashua	NH	City of Nashua
	Municipal Solid Waste Landfill, TLR-III LF Phase 9-14 Expansion, CQA/CM	Rochester	NH	Waste Management of New Hampshire
	Municipal Solid Waste Landfill, TLR-III LF Phase 5/8A Closure, CQA/CM	Rochester	NH	Waste Management of New Hampshire
	Corrective Action Management Unit, Phase I and II, CQA	Henderson	NV	Basic Remediation Company
	BMI North Final Cover System, CQA	Henderson	NV	Basic Remediation Company
	BMI South Final Cover System, CQA	Henderson	NV	Basic Remediation Company
	Municipal Solid Waste Landfill, Oakridge Landfill Phase II Cell 1, CQA	Dorchester	SC	Waste Management of South Carolina
	Tailings Disposal Cell 4A, CM/CQA	Blanding	UT	Denison Mines (USA) Corp.
	Tailings Disposal Cell 4B, CM/CQA	Blanding	UT	Denison Mines (USA) Corp.
2007				
	Industrial Closure, Ft. McClellan Cap, CQA/CM	Anniston	AL	Matrix Environmental Service
	Process Area Demolition, CM	Carson	CA	Shell Oil
	Municipal Solid Waste Landfill, Anderson Landfill Partial Final Closure and Cell 4B, CQA	Anderson	CA	Waste Management, Inc.
	Impacted Soil excavation, EISB, GC/CM/CQA	San Diego	CA	Confidential
	Los Alamitos MSW Landfill, CQA	Los Alamitos	CA	Bureau Veritas
	Home Depot Vapor Barrier	West Covina	CA	Home Depot
	Target Vapor Barrier	West Covina	CA	Target
	901 San Antonio Development, Vapor Control System, CQA	Mountainview	CA	901 San Antonio, LLC
	Cienega Field Demonstration, CQA	Irvine	CA	Irvine Ranch Water District

EXHIBIT B to Consultant Agreement

GEOSYNTEC CONSULTANTS RELEVANT CONSTRUCTION MANAGEMENT CONSTRUCTION QUALITY ASSURANCE EXPERIENCE
(2001 to Present)

Year	Project Description	Location	State	Client/Owner
	Environmental Conveyance Piping System, CQA	Long Beach	CA	Confidential
	Campus for Jewish Life, Vapor Control System, CQA	Mountainview	CA	TKCJL
	Market Creek Development, Geotechnical, CQA	San Diego	CA	Diamond Management
	Brittania East Grand Development, Vapor Barrier, CQA	S. San Francisco	CA	Slough Estates
	Plymouth & Colony Development, Vapor Barrier, CQA	Mountainview	CA	Plymouth Colony LLC
	Municipal Solid Waste Landfill, Vasco Road Landfill, Disposal Unit 9, Phase 2, CQA	Alameda County	CA	Republic Services, Inc.
	Municipal Solid Waste, Cherry Island Landfill Expansion, CQA, CM	Wilmington	DE	Delaware Solid Waste Authority
	Municipal Solid Waste Landfill, Water Quality Monitoring, Oak Hammock Disposal Facility	Osceloa County	FL	Waste Services of Florida, Inc.
	C&D Landfill, Sun Country Materials Management Facility, Water Quality Monitoring	Hillsborough County	FL	Waste Services of Florida, Inc.
	C&D Landfill Expansion, Sun Country Materials Management Facility,	Hillsborough	FL	Waste Services of Florida, Inc.
	Municipal Solid Waste Landfill, Oak Hammock Disposal Facility Cell 5, CQA/CM	Osceloa County	FL	Waste Services of Florida, Inc.
	C&D Landfill, Water Quality Monitoring, SLD C&D Facility, CQA	Charolette Co.	FL	Waste Services of Florida, Inc.
	Municipal Solid Waste Closure, Class I LF Kingsway Road Landfill, CQA/CM	Hillsborough County	FL	D.J. Joseph Company
	Municipal Solid Waste Closure Trench 2, CQA	Levy County	FL	Mills Engineering Co.
	Municipal Solid Waste Landfill, Naples Sanitary Landfill Cell A2 - Phase 2, CQA	Naples	FL	Waste Management Inc. of Florida
	Municipal Solid Waste Closure, Naples Sanitary Landfill Cell 6 Cap Repairs, CQA	Naples	FL	Waste Management Inc. of Florida
	Municipal Solid Waste Closure, Orange County Landfill Cell 7B/8, CQC	Orlando	FL	Hewitt Contracting, Inc.
	Industrial Closure, Marine Logistics Base ET Cover	Albany	GA	Contaminant Control, Inc.
	SLNG Dredging Management, CQA/CM	Chatham County	GA	Southern Liquid Natural Gas
	Bedrock Collection Trench & Holding Basin, CQA/CM	Kankakee County	IL	Shell U.S. Products
	Municipal Solid Waste Landfill, Reliable Cell 14 & 15, CQA	Livonia	LA	Waste Management of Louisiana
	Municipal Solid Waste Landfill, Cell 4 A West, Woodside, CQA	Walker	LA	Waste Management of Louisiana
	Municipal Landfill, Phase A CAD Closure Construction, CQA	Hardwick	MA	Casella Waste Systems, Inc.
	Municipal/C&D Landfill, Phase VII, Cell 7.2B Cell & Piggyback Construction, CQA	Southbridge	MA	Casella Waste Systems, Inc.
	Municipal/C&D Landfill, Phase VII, Cell 7.2A Piggyback Construction, CQA	Southbridge	MA	Casella Waste Systems, Inc.
	Municipal Solid Waste Landfill, Newland Park Cells 5 and 6, CQA/CM	Salisbury	MD	Wicomico County Department of Public Works
	Contaminated Soil Removal and Disposal	Hagerstown	MD	CSXT
	Municipal Solid Waste Landfill, TLR-III LF Gas & South MSE Berm Expansion, CQA/CM	Rochester	NH	Waste Management of New Hampshire
	Entrance Facility Construction, Lanchester Landfill, CQA/CM	Honey Brook	PA	Chester County Solid Waste Authority
	Industrial Landfill Closure, CQA/CM	Danville	PA	Confidential
	Municipal Solid Waste Landfill, Oakridge Cell 7, CQA	Dorchester	SC	Waste Management of South Carolina
	Stabilize and Line CTP 1 and 2 Upgrades, Oconee Plant	Seneca	SC	Duke Energy
	Municipal Solid Waste Landfill, Blue Ridge LF Gas System, CQA	Harris County	TX	Allied Waste Industries
	Municipal Solid Waste Landfill, McCarty LF Gas System, CQA	Harris County	TX	Allied Waste Industries
	Municipal Solid Waste Landfill, Galveston County LF Gas System, CQA	Galveston County	TX	Allied Waste Industries

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GEOSYNTEC CONSULTANTS RELEVANT CONSTRUCTION MANAGEMENT CONSTRUCTION QUALITY ASSURANCE EXPERIENCE
(2001 to Present)

Year	Project Description	Location	State	Client/Owner
	Municipal Solid Waste Landfill, Golden Triangle LF Gas System, CQA	Jefferson County	TX	Allied Waste Industries
	Municipal Solid Waste Landfill, Lacy Lakeview R&DF Phase III Cell 3-4, CQA	McLennan County	TX	Waste Management of Texas
	Municipal Solid Waste Landfill, Covel Gardens R&DF Phase VII North, CQA	Bexar County	TX	Waste Management of Texas
	Tailings Disposal Cell 4A, CQA	Blanding	UT	Denison Mines (USA) Corp.
2006				
	Municipal Solid Waste Landfill, Butterfield Station Facility, Cell 12B, CQA	Mobile	AZ	Waste Management Arizona, Inc.
	Municipal Solid Waste Landfill, Gray Wolf Regional Landfill, Phase 7, CQA	Dewey	AZ	Waste Management Arizona, Inc.
	Municipal Solid Waste Landfill, Northwest Regional Phase 2, Module 1, CQA	Surprise	AZ	Waste Management Arizona Landfills, Inc.
	Install Methane Monitor Wells, CQA	New Milford	CT	Confidential
	Municipal Solid Waste, Cherry Island Landfill Expansion, CQA, CM	Wilmington	DE	Delaware Solid Waste Authority
	Municipal Solid Waste Landfill, Oak Hammock Disposal Facility Cell 2, CQA/CM	Osceloa County	FL	Waste Services of Florida, Inc.
	Municipal Solid Waste Landfill, Oak Hammock Disposal Facility Cell 3, CQA/CM	Osceloa County	FL	Waste Services of Florida, Inc.
	Municipal Solid Waste Landfill, Water Quality Monitoring, Oak Hammock Disposal Facility	Osceloa County	FL	Waste Services of Florida, Inc.
	C&D Landfill, Sun Country Materials Management Facility, Water Quality Monitoring	Hillsborough County	FL	Waste Services of Florida, Inc.
	Closed Municipal Solid Waste Landfill, Landfill Redevelopment Services for City Park	Boca Raton	FL	LBFH, Inc.
	Former Municipal Solid Waste Landfill, Biscayne Commons, Vapor Barrier, O&M/Groundwater and Gas Monitoring	North Miami Beach	FL	Taubco Development
	Water Treatment System, Taylor Creek Algal Turf Scrubber, CQA	Okeechobee Co.	FL	Hydromentia, Inc.
	Residential Development CQA	Miami-Dade Co.	FL	Lennar Homes, Inc.
	Dredge Spoil Containment Areas, Vertical Expansion, CQA/CM	Chatham County	GA	Southern Liquid Natural Gas
	Municipal Solid Waste Landfill, R & B Phase 1, Cells 1 and 2, CQA	Homer	GA	Waste Management of Georgia
	Municipal Solid Waste Closure, CQA	Homer	GA	Waste Management of Georgia
	Municipal Solid Waste Landfill, R & B Cell 8, CQA	Homer	GA	Waste Management of Georgia
	Municipal Solid Waste Landfill, Superior Cell 7 North, CQA	Savannah	GA	Waste Management of Georgia
	Municipal Solid Waste Landfill, Chesser Island Road, CQA	Folkston	GA	Waste Management of Georgia
	Wetlands Enhancement Project	Roswell	GA	City of Roswell
	Contaminated Soil Removal and Restoration	East Point	GA	General Chemical
	Marine Logistics Base Landfill Closure	Albany	GA	CCI
	Municipal Solid Waste Landfill, Cell 4 A West, Woodside, CQA	Walker	LA	Waste Management of Louisiana
	Environmental CQA Oversight	Sterlington	LA	Koch Nitrogen
	Contaminated Soil Remediation, Sheet Piles CQA	Taft	LA	Shell Chemical
	Municipal/C&D Landfill, Phase I-VII (South) Corrective Action Design, CQA	Southbridge	MA	Casella Waste Systems, Inc.
	Municipal Solid Waste Landfill, Crossroads Phase 8B Investigation	Norridgewock	ME	Waste Management Disposal Services of Maine, Inc.
	Industrial Landfill Cover (NPL), Bofors Nobel Phase 2 Final Cover Geotechnical Support	Muskegon	MI	PSD Group
	Municipal Solid Waste Closure, TLR-III Phase 3 & 4, CQA	Rochester	NH	Waste Management of New Hampshire
	Municipal Solid Waste LF Gas, TLR-III North Flare, CQA/CM	Rochester	NH	Waste Management of New Hampshire
	Perchlorate Mitigation System, CM	Henderson	NV	American Pacific
	On-Site Disposal Facility, Fernald, Cell 7 & 8 Caps, CQA/RE	Hamilton County	OH	Fluor Fernald/DOE

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GEOSYNTEC CONSULTANTS RELEVANT CONSTRUCTION MANAGEMENT CONSTRUCTION QUALITY ASSURANCE EXPERIENCE
(2001 to Present)

Year	Project Description	Location	State	Client/Owner
	Municipal Solid Waste Landfill, Canadian Valley Landfill Section 2-A Leachate Pond, CQA	Shawnee	OK	Shepherd Engineering and Design, Inc.
	CERCLA Landfill Closure, Evapotranspirative cover, Welsh Road Landfill CQA/CM	Honey Brook	PA	Welsh Road Respondents Group
	Municipal Solid Waste Landfill, Lanchester Landfill Area D, Cell 1	Honey Brook	PA	Chester County Solid Waste Authority
	Fuel Storage Tanks, H- Piles oversight	Newport	RI	TN & Associates
	Subsurface Investigation	Akin	SC	DOE
	Municipal Solid Waste Landfill, Richland County, Phase 4-C, Overlay, CQA	Elgin	SC	Waste Management of South Carolina
	Environmental Investigation and Sampling	Columbia	SC	Shaw Industry
	Phase II Environmental Assessment	Anderson	SC	Shaw Industry
	Green Site Subsurface Investigation	Spartanburg	SC	Waste Management of South Carolina
	Municipal Solid Waste Landfill, Covel Gardens R&DF Phase V & VI South, CQA	Bexar County	TX	Waste Management of Texas
	Municipal Solid Waste Landfill, Sunset Farms, CQA	Travis County	TX	Waste Management of Texas
	Municipal Solid Waste Landfill, Williamson County R&DF Phase 2C, CQA	Hutto	TX	Waste Management of Texas
	Municipal Solid Waste Landfill, Tucker County Landfill Cell 6, CQA	Tucker County	WV	Terradon Engineering

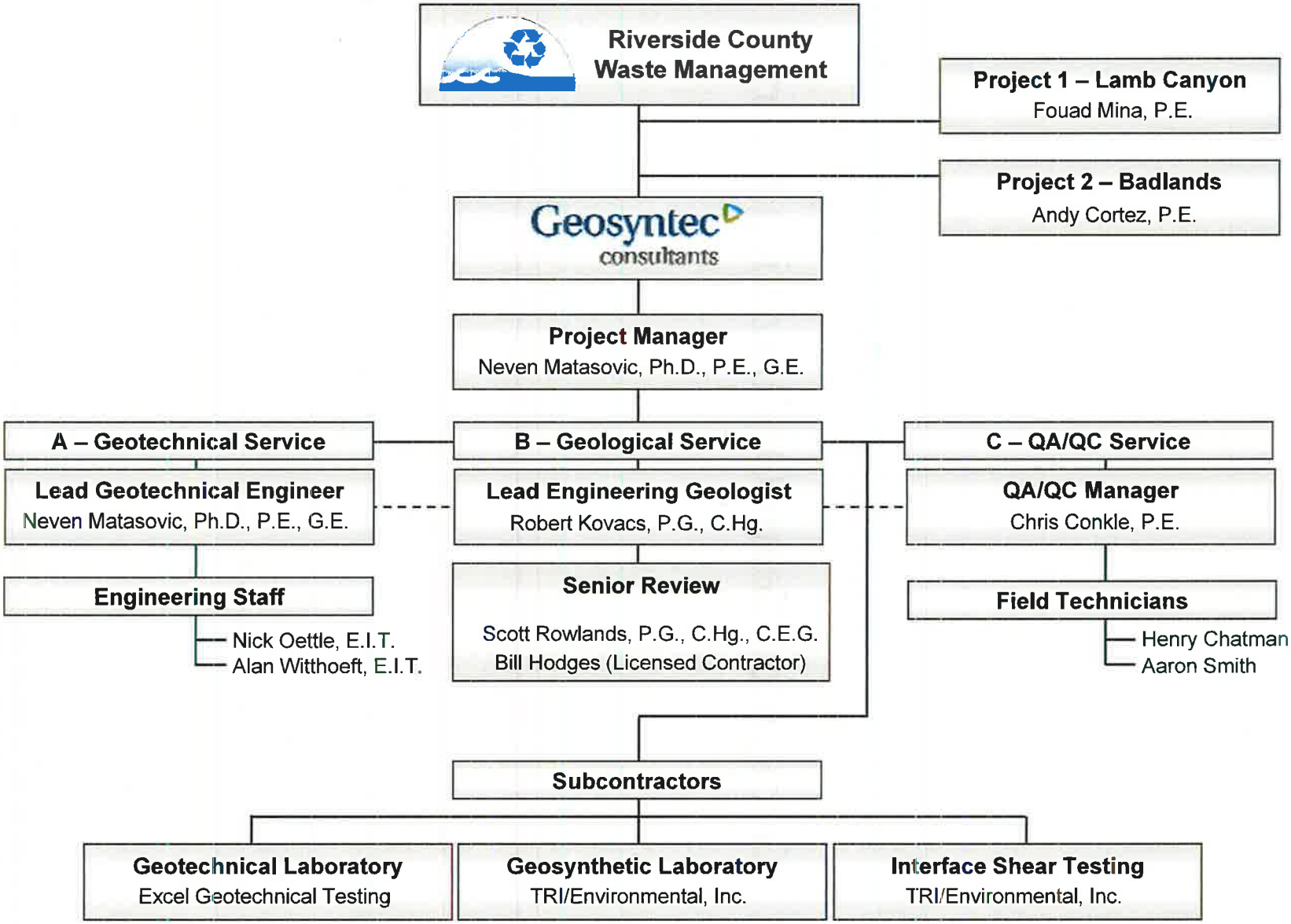
Geosyntec consultants

Attachment B-1

Geosyntec Team Organization Chart

EXHIBIT B to Consultant Agreement

Geosyntec Team - Organizational Chart



Riverside Proposal Org Chart.ppt

Geosyntec consultants

Attachment B-2

Resumes of Key Personnel

EXHIBIT B to Consultant Agreement

Geosyntec consultants

Summary of Relevant Expertise for Key Project Team Members

		Service A			Service B	Service C
Project Team Member	**Project Role**	**Stability Analysis**	**Geotechnical Lab. Testing and Data Evaluation**	**Design Review and Support**	**Geologic Mapping**	**Field QA/QC Testing**
Project Management						
Neven Matasovic, Ph.D., P.E., G.E.	Project Manager	Yes	Yes	Yes	-	-
Geotechnical Service						
Neven Matasovic, Ph.D., P.E., G.E.	Lead Geotechnical Engineer	Yes	Yes	Yes	-	-
Nick Oettle, E.I.T.	Engineering Staff	Yes	Yes	Yes	-	Yes
Alan Witthoeft, E.I.T.	Engineering Staff	Yes	Yes	Yes	-	Yes
Geological Service						
Robert Kovacs, P.G., C.Hg.	Lead Engineering Geologist	-	Yes	-	Yes	-
Scott Rowlands, P.G., C.Hg., C.E.G.	Senior Review	-	Yes	-	Yes	-
Bill Hodges (Licensed Contractor)	Senior Review	-	-	Yes	-	-
QA/QC Service						
Chris Conkle, P.E.	QA/QC Manager	Yes	Yes	Yes	-	Yes
Henry Chatman	Field Technician	-	-	-	-	Yes
Aaron Smith	Field Technician	-	-	-	-	Yes

Geosyntec
consultants

NEVEN MATASOVIC, Ph.D., P.E., G.E.
Associate

landfill engineering
geotechnical engineering
construction-related engineering

EDUCATION

University of California, Los Angeles: Ph.D., Geotechnical Engineering, 1993
University of Zagreb, Croatia: M.S., Geotechnical Engineering, 1986
University of Zagreb, Croatia: B.S., Civil Engineering, 1983

REGISTRATIONS AND CERTIFICATIONS

Registered Geotechnical Engineer, California, No. GE 2557
Registered Professional Engineer, California No. C 55861

CAREER SUMMARY

Dr. Matasovic has over 25 years of engineering design, analysis, and construction-related experience, including 16 years of relevant experience with landfill siting, permitting, conceptual and detailed cell and cover design, performance assessment, construction, construction and compliance monitoring, and landfill closure-related work. He has participated in more than 80 landfill-related projects as a task manager, lead engineer, and/or project manager. His expertise includes direction of wide range of site exploration and laboratory testing programs, interpretation of the in-situ and laboratory testing results, waste settlement analyses, steady-state seepage analyses, and two- and three-dimensional (2-D and 3-D) slope stability assessments conducted in support of landfill liner and cover design in areas of high seismicity. Dr. Matasovic's landfill experience also includes evaluation and implementation of slope stabilization techniques, including soil nailing, soil anchoring, soil buttressing, and geogrid reinforcing. He has also evaluated materials usage and stockpiling plans for several large California landfills; participated in the development of the construction specifications and plans; and designed leachate collection, removal and storage systems (LCRSs), surface-water and erosion control systems, anchor trenches, and geotextile-enhanced filters. Dr. Matasovic was the recipient of the 2001 Shamsher Prakash Foundation award for excellence in geotechnical engineering.

REPRESENTATIVE PROJECTS (IN ALPHABETICAL ORDER)

Antelope Valley Public Landfill No. 1, Palmdale, California. Project Manager and Lead Engineer responsible for the design and permitting of a "shingled" composite-lined side slope liner. The "shingled" liner configuration, with 45-ft high lined compacted soil shingles partially constructed over waste, was dictated by the site topography, the relative vicinity of the proposed expansion to the property line, and access restrictions to the site. Project challenges included extreme seismic design considerations (the site is less than one mile from the San Andreas fault), design of a passive landfill gas collection system that can be connected to an active gas control system in the future if necessary, and development of a shingled liner construction sequencing plan. Dr. Matasovic was also involved in CQA plan development and the review of technical specifications developed by the client to incorporate Geosyntec's design and construction recommendations. He also provided on-call engineering support during the construction of two consecutive "shingled" liners.

Azusa Landfill, Azusa, California – Landfill Liner. Lead Engineer and Task Manager responsible for the evaluation of an existing composite side slope liner system for conformance with the Federal Subtitle D requirements. The evaluation included performing a suite of hydrologic analyses using EPA's HELP Model, liner leakage rate, and puncture resistance calculations and preparation of a final report. Dr. Matasovic also helped prepare a revised Report of Waste Discharge (ROWD), Preliminary Closure and Post-Closure Maintenance Plans, a Report of Disposal Site Information (RDSI), and a Periodic Site Review Report for this landfill.

Azusa Landfill, Azusa, California – Landfill Cover. Lead Engineer and Task Manager responsible for the stability evaluation of a proposed composite (geosynthetic) cover system at the Azusa Landfill. Evaluation included deterministic evaluation of the Maximum Probable and Maximum Credible Earthquakes, evaluation of design ground motion parameters, development of design ground motions, site-specific analysis of the combined response of the landfill and foundation soils, pseudostatic stability analyses of the landfill cover system, and Newmark-type seismic deformation analysis of the cover system.

Azusa Landfill, Azusa, California – Litigation Support. One of the Azusa landfill lateral expansions was supposed to be constructed over a silt pond that was a by-product of a former on-site gravel mining operation. As the silt in the pond was saturated and of considerable thickness, a concern was expressed regarding how much liquid would be "squeezed" out from the silt lens upon placement of the waste. Dr. Matasovic directed non-intrusive geophysical Spectral Analysis of Surface Waves (SASW) measurements, delineated the extent of the former silt pond based upon the results of SASW

measurements, directed geotechnical sampling of the silt using thin-walled Shelby™ tubes, and developed a laboratory testing program to evaluate the physical characteristics of the silt. Subsequently, based upon the results of the in-situ and laboratory testing programs, using the finite element steady-state seepage model, Dr. Matasovic demonstrated that the volume of the "squeezed" liquid is insignificant and that the site is suitable for future development.

Badlands Sanitary Landfill, Riverside County, California – Canyon 4 Phase 2. Project Manager responsible for overall coordination of the project and Lead Engineer responsible for the geotechnical aspects of the project, including geotechnical laboratory testing; back analysis of an existing landslide; static and seismic analysis of native cut slopes; landslide remediation design; and static, pseudostatic, seismic site response and seismic deformation analyses for interim and final waste configurations. During the course of this project, Geosyntec demonstrated that native slopes can be safely cut at 1H: 1V (Horizontal: Vertical), which resulted in 188,000 cubic yards of additional air space. Geosyntec also demonstrated that a cushion geotextile is not needed at side slopes, which resulted in additional cost saving to the owner.

Badlands Sanitary Landfill, Riverside County, California – Canyon 3 Phase 1. Task Manager responsible for seismic site response and deformation analyses for the Canyon 3, Phase 1 Expansion of the Badlands landfill. Dr. Matasovic demonstrated the seismic stability of a proposed composite landfill liner system subjected to bedrock Peak Horizontal Ground Acceleration (PHGA) as high as 0.81 g. The stability demonstration was based upon the results of 3-D pseudostatic slope stability analysis conducted using the computer program CLARA and 2-D seismic site response analysis conducted using the computer program QUAD4M. Average acceleration time histories from the site response analysis were processed in a Newmark-type seismic deformation analysis to demonstrate that calculated permanent seismic displacements are lower than the 6-in stability criterion established by the California Department of Water Resources (DWR) and adopted by the Santa Ana RWQCB.

Badlands Sanitary Landfill, Riverside County, California – Final Buildout. Project Manager responsible for overall coordination of the project and Lead Engineer responsible for the geotechnical and civil aspects of the project. Project challenges included the demonstration of seismic stability of a proposed composite landfill liner system (an alternative liner and encapsulated and nonwoven GCL in lieu of prescriptive 2-ft compacted low perm soil) subjected to bedrock PHGA as high as 0.81 g. The stability demonstration was based upon the results of one-dimensional (1-D) seismic site response analysis conducted using the computer program D-MOD. Average acceleration time histories from the site response analysis were processed in a Newmark-type seismic deformation analysis to demonstrate that calculated permanent

seismic displacements are lower than the 6-in stability criterion established by the California DWR and adopted by the Santa Ana RWQCB.

Badlands Sanitary Landfill, Riverside County, California – CQA Services. Project Manager responsible for the coordination of the Construction Quality Assurance (CQA) activities during the repair of the Uppermost Slope of the Canyon 3, Phase 1 lateral expansion. The CQA activities included supervision of the excavation in municipal solid waste (MSW), supervision of the removal of the operations layer, repair of damaged GCL panels, and repair of 80-mil (2-mm) thick HDPE geomembrane placed on 1.5H:1V side slopes. The project requirements required several partial approvals and an intensive interaction with the Santa Ana RWQCB representatives.

Badlands Sanitary Landfill, Riverside County, California – Waste-on-Waste Liner Design. Project Manager responsible for the design of composite side slope liner over existing refuse slopes. Project challenges included detailed refuse settlement evaluations, evaluation of a "sudden" void collapse impact on the side slope composite liner subgrade, design of a "yielding" anchor bench (no excavation on the bench and no excess tension in geosynthetics were allowed), and demonstration that the bench grades would not reverse during the anticipated landfill post-closure period.

Badlands Sanitary Landfill, Riverside County, California – Soil Stockpile Evaluation. Project Manager. Temporary stockpiling was required for the excess soil generated by grading of the Canyon 4 Phase 2 lateral expansion. Geosyntec recommended that the soil be stockpiled over the nearby Canyon 3 Phase 1 waste face (3 Horizontal: 1 Vertical), developed stockpiling (keying) recommendations, and demonstrated the static and seismic stability of the stockpile/waste configuration. The work was subsequently approved by the Santa Ana RWQCB.

Badlands Sanitary Landfill, Riverside County, California – Temporary Detention Basin. Project Manager. The site development plan called for the construction of a temporary detention basing at the toe of a steeply-graded 270-ft high native cut slope. Geosyntec was asked to evaluate the static and seismic stability of the slope. As the slope was already cut, Geosyntec was able to recover representative samples of formational material using a limited-access concrete coring machine. This innovative sample recovery approach resulted in significant cost savings to the RCWMD and allowed Geosyntec to meet an aggressive project schedule. The subsequent slope stability evaluation was approved by the Santa Ana RWQCB.

Bena Landfill, Bakersfield, California – Network 4 Development. Task Manager responsible for the development of Network 4 at the landfill. Responsible for low-permeability soil sampling and testing, interface shear testing, and static and seismic

stability analyses in support of composite liner and LCRS design. Dr. Matasovic also evaluated the capacity of proposed anchor trenches, was responsible for specification of physical properties for the various elements of composite liner, and peer-reviewed all calculation packages.

Bena Landfill, Bakersfield, California – Modules 1 and 2. Engineer of Record (two subsequent projects). Responsible for static and seismic stability demonstration of Bena Landfill Modules 1 and 2. Both modules were lined with alternative liners (encapsulated GCL at the base and single composite liner on the side slopes). Project challenges included demonstrating that composite landfill liners can sustain very high seismic loading (peak horizontal bedrock acceleration as high as 0.81 g). The analysis in support of the design was approved by the Central Valley Region RWQCB.

Calabasas Landfill, Agoura, California – Landfill Liner CQA (3 Consecutive Projects). Project Manager responsible for overall coordination of the CQA activities for the '97-Cut (18 acres); '99-Cut (10.4 acres) and Southeastern Composite Liner System (13.3 acres) projects. The CQA activities at all three projects included subdrain and seep collection network construction; construction of a composite liner at the landfill floor; placing GCL overlain by 80-mil (2-mm) thick HDPE geomembrane on 2H:1V side slopes; construction of geonet, geocomposite, and granular drainage layers; and placement of protective geotextiles on steep side slopes. Dr. Matasovic was also responsible for the cost/time administration, CQA implementation plan development, value engineering, review of submittals, final CQA report preparation, and supplemental interface testing carried out as part of the overall CQA activities at the site.

Calabasas Landfill, Agoura, California – Seam Separation. Dr. Matasovic was retained as an expert to evaluate the cause of failure of an interior HDPE geomembrane berm flap used to separate the LCRS from an adjacent surface water collection channel. Later, when Geosyntec was retained to develop and implement a CQA program for seam repair, Dr. Matasovic served as a Project Manager responsible for the cost/time administration of the project, review of submittals and preparation of the final CQA report.

Calabasas Landfill, Agoura, California – Seismic Slope Stability Evaluation. Project Manager and Lead Engineer responsible for execution of the project, stability demonstration, coordination with the Districts, and writing of the report. The stability demonstration included static and seismic slope stability evaluation of the *Northern Slopes* area, including seismic site response analysis of landslide deposits and evaluation of maximum calculated permanent seismic displacements for failure surfaces engaging landfill liner (limited by the California DWR to 6 in). Project challenges

included evaluation of the dynamic material properties of both weathered Modelo shale and local (cemented) landslide deposits, and back analysis of site performance in the Northridge earthquake to demonstrate that the results of the seismic deformation analyses are adequate and conservative.

Calabasas Landfill, Agoura, California – Clay Soil Borrow Source Evaluation. Project Manager for evaluation of several candidate borrow sources (clay lenses) at the site. Work included direction and evaluation of soil compaction (ASTM D1557), saturated hydraulic conductivity (ASTM D5084), and soil gradation (ASTM D 422 & 1140) testing results. The work also included the coordination of several field geologists, monitoring and testing of the on-site clay borrow source excavation, and monitoring of the clay processing operations, which included particle size reduction and moisture conditioning for soil compaction purposes. Dr. Matasovic was also responsible for the development of site-specific density and moisture correlations and the modification of acceptance criteria based on actual borrow source characteristics.

Calabasas Landfill, Agoura, California – North Ridge Cut Expansion. Project Manager and Lead Engineer responsible for the execution of this $1.6-million^{+} geotechnical investigation and analysis project. The work included coordination of several drilling, CPT sounding and geophysical logging contractors; aquifer testing; groundwater sampling; soil and rock sampling; interpretation of field and laboratory testing results; engineering analyses and evaluations; and management and coordination of 24 professionals involved in the project. Dr. Matasovic is also responsible for a engineering report that will document the results of engineering analyses, including static and seismic slope stability evaluation (of cut, man-made and waste slopes), seismic site response analyses (landslide deposits and waste fill), steady-state seepage analyses (to design and optimize the landfill underdrain system), static and seismic settlement analyses, and soil liquefaction analyses.

Calabasas Landfill, Agoura, California – On-Call Engineering Support. Project Manager and Lead Engineer for the on-call engineering support services. The support was provided during construction of the North Ridge Cut (NRC) Phases I, IIA and IIB. The work included buttress fill keying design, seep mitigation design, in-grading monitoring, development of interface shear strength parameters from the results of conformance testing, re-evaluation of the final waste fill stability to accommodate use of white geomembrane, and update of the seismic parameters for the site.

Calabasas Landfill, Agoura, California – OL-1 Monitoring Well Installation. Project Manager responsible for construction, development, and commissioning of this 110-ft deep groundwater monitoring well installed at the southern end of the Calabasas Landfill SEC cell. Project challenges included a "continuous" sampling using the

California-modified split-spoon sampler. The "continuous" sampling was required in order to precisely identify a relatively thin groundwater-bearing strata. The well installation was completed in August 2003 and subsequently approved by the Environmental Health Division of the Los Angeles County.

Chiquita Canyon Landfill, Valencia, California. Task Manager for stability evaluations conducted in support of developing construction drawings and specifications for the Area C, Cell II, Phase 2B expansion. For Canyons A, C, and D, Dr. Matasovic was responsible for stability analyses conducted to support the revised landfill cover design and final cover grading plans. Along the course of Geosyntec/University of California, Berkeley National Science Foundation (NSF)-sponsored research projects on the performance of solid waste landfills in the 17 January 1994 Northridge earthquake, Dr. Matasovic was involved in back analyses of Canyon A and Canyon D response to the earthquake. The back analyses involved pseudostatic slope stability, 2-D seismic site response, and Newmark-type seismic deformation analysis.

Eagle Mountain Landfill and Recycling Center, Riverside County, California. Assisted with the preparation of materials for demonstration of regulatory compliance, carried out seismic analyses in support of project design alternatives, and conducted analyses required to respond to comments on the EIR. He also helped with evaluation of site and waste characteristics, evaluated on-site borrow materials for granular drainage layers and low-permeability clay liners, and evaluated settlement and constructability for several alternatives. Dr. Matasovic prepared portions of a 5,000-page Report of Waste Discharge, including the CQA Plan, Operations Plan, and Emergency Response Plan.

Georgia Pacific East Landfill, Crossett, Arkansas. Project Manager and Lead Engineer responsible for directing static and seismic slope stability evaluation of the landfill waste mass/composite liner system and landfill subgrade. The stability evaluations were based upon the results of site-specific shear wave velocity measurements, 2-D (2-D) static and pseudostatic slope stability evaluation, 1-D seismic site response analysis (SHAKE91), and Newmark-type seismic deformation analysis. Demonstration of seismic stability of the waste mass/composite liner system also required evaluation of the soil liquefaction-induced residual shear strength and settlement potential of underlying soils.

Heaps Peak Sanitary Landfill, San Bernardino County, California. Project Manager and Lead Engineer responsible for directing static and seismic slope stability evaluation of this "mountain" side hill-fill landfill in the San Bernardino County. Project challenges included a landfill base as steep as 2.4H: 1V (Horizontal: Vertical), perennial

steady state seepage parallel to the landfill base, and the relatively high seismicity of the site (design bedrock PHGA = 0.4 g). Dr. Matasovic evaluated shear strength parameters at the landfill base by back-analyzing observed landfill behavior in the 1992 Big Bear earthquake and subsequently demonstrated that the landfill can sustain design seismic loads provided that the liquid levels are maintained below certain elevation. The stability evaluation was based upon the results of 3-D pseudostatic slope stability evaluation, 2-D seismic site response and steady-state seepage analyses, and 1-D Newmark-type seismic deformation analysis. In 1999, Dr. Matasovic led the post M_w 7.1 Hector Mine earthquake reconnaissance team at the site.

Lamb Canyon Sanitary Landfill, Riverside County, California (2 Consecutive Projects). Project Manager responsible for seismic site response and deformation analyses for the Phase 2 Stage 2 (P2S2) expansion of the Lamb Canyon Sanitary Landfill. Project challenges included demonstration of the static stability of proposed cut slopes with out-of-slope bedding and demonstration of seismic stability of a composite landfill liner system subjected to bedrock PHGA of 0.6 g. The seismic stability demonstration was based upon the results of site-specific interface testing of encapsulated GCL and a non-linear seismic site response analysis. Average acceleration time histories from the non-linear seismic site response analysis were processed in a Newmark-type seismic deformation analysis to demonstrate that calculated permanent seismic displacements are lower than the 6-in stability criterion established by the California DWR and adopted by the Santa Ana RWQCB. A subsequent project included the evaluation of seeps and wet spots in the P2S2 expansion area, development of the underdrain system design, and evaluation of the underdrain system's effect on the interim waste fill stability.

Lopez Canyon Landfill, Lake View Terrace, California – Liner Performance Demonstration. Project Engineer responsible for performance demonstrations of the Lopez Canyon Area "C" alternative side slope liner system. This work included infiltration analyses, evaluation of leachate generation rates, evaluation of the tension in the geosynthetics due to wind uplift (construction phase), and liner anchor trench design, as well as various tasks related to the liner puncture protection, geotextile selection (based on flow and filtration properties), and demonstration of the leachate collection system mechanical resistivity to landfill loads. Dr. Matasovic also helped prepare construction specifications and a CQA Plan for the composite liner construction and participated in the development of the Final Closure and Post-Closure Maintenance Plans, Report of Disposal Site Information, Periodic Site Review Reports, and construction documents for the final closure of the Disposal Area "C."

Lopez Canyon Landfill, Lake View Terrace, California – ECB Foundation Design. Engineer of Record. The City of Los Angeles Bureau of Sanitation plans to construct an Equipment Control Building (ECB) at the Lopez Canyon Landfill Area AB+ top deck. The project requirements call for a safe working environment with controlled total and differential settlements. Given that the site is in an area of high seismicity (the site is overlying the San Fernando fault that ruptured in 1971) and will be constructed over 300 ft of MSW, the design challenges included: (i) seismic design of the foundations in accordance with the UBC '97 requirements; (ii) total and differential settlement control and mitigation; and (iii) landfill gas mitigation and control. In order to meet project and regulatory requirements, Geosyntec conducted an extensive numerical analysis, including seismic site response analysis and finite element method soil-structure-interaction (SSI) analysis. The detailed foundation design is currently under review by the City of Los Angeles Public Works Department.

Lopez Canyon Sanitary Landfill, Los Angeles, California. Lopez Canyon Landfill (LCF) is owned and operated by the city of Los Angeles as a Class III waste disposal facility. Geosyntec recently completed a moisture monitoring and performance demonstration study for the evapotranspirative final cover. Dr. Matasovic directed water balance analyses and parametric evaluations by using the computer program UNSAT-H to calibrate and validate a numerical model of the cover. He als directed the installation process of the moisture monitoring and weather stations and was involved in preparation of the Alternative Final Cover Performance Analysis Report (AFCPAR). The AFCPAR was approved by the RWQCB in June 2007.

Los Alamitos Landfill, Los Alamitos Joint Forces Training Base, Orange County, California. The Los Alamitos Landfill (LALF) is owned by the U.S. Government. The LALF is classified as a Class III waste disposal facility. Before clean closure, the LALF was composed of approximately 12 waste trenches that were used for waste disposal from the 1940s to the 1980s. Geosyntec provided a full-design service that includes design of the new waste consolidation cell, grading and drainage works, landfill gas and leachate collection system, and design of an evapotranspirative soil final cover. Dr. Matasovic was Geotechnical Engineer of Record for the project and participated in all stages of project (site) development.

McKittrick Waste Treatment Site, Kern County, California. Lead Engineer responsible for liner performance demonstrations for the Landfill 1Module C-1. The work included evaluation of the anticipated leachate generation rates in California Class II waste to be disposed of at the site and liner performance (equivalency) demonstrations based upon both EPA analogy with observed behavior of double-lined landfills and the Giroud and Bonaparte method. Dr. Matasovic also evaluated seismic

hazards for the site and was responsible for the preparation of construction specifications and a CQA plan for the composite liner construction.

Mesquite Regional Landfill, Imperial County, California. Project Manager during the initial (field investigation) stage of the project. The scope of the work consisted of geologic, hydrogeologic, and geotechnical field investigation, including field mapping, advancement of 32 core holes through conglomerate and basalt to an average depth of 500 ft below ground surface, geophysical in-hole sounding, and installation and development of temporary piezometers in most of the core holes. Rigorous biologic mitigation (endangered desert tortoise) and Mine Safety programs were implemented during this initial stage of the project.

National Science Foundation-Funded Research Projects. Project Manager (Geosyntec part only) for the Geosyntec/University of California, Berkeley/University of Texas at Austin NSF-funded project on the static and dynamic properties of MSW. The project focused on in-situ density testing of MSW and laboratory testing (classification, Triaxial, Resonant Column, Direct Shear, Cyclic Simple Shear, and Consolidation) of various MSW/soil mixtures. Dr. Matasovic also served as co-principal investigator for the Geosyntec/University of California, Berkeley project on evaluation of the performance of solid waste landfills in the Northridge earthquake of 17 January 1994, including compilation of damage reports, development of a damage classification system, and back analysis of landfill performance.

Operating Industries, Inc. (OII) Landfill, Monterey Park, California. Task Manager for the seismic site exposure evaluation, seismic site response analysis, and seismic deformation assessment of the site tasks. His responsibilities included seismic hazard evaluation, evaluation of design ground motions, planning and supervision of geophysical Spectral Analysis of Surface Waves (SASW) investigations, planning and supervision of large-diameter Cyclic Direct Simple Shear testing, 1-D and 2-D dynamic response analyses of the landfill, and for seismic deformation analyses of the waste mass and for various alternatives of the landfill cover system. Dr. Matasovic was also responsible for stability analyses carried out in support of landfill final cover construction and provided continuous technical support to the landfill cover construction manager.

Olinda Alpha Sanitary Landfill, Orange County, California. Involved in the design of a composite liner system for the back canyon area, including the geotechnical investigation, stability analyses in support of composite liner system design, LCRS and leachate storage tank foundations design, and cut slope stability analyses. The composite liner system designed for the steep side slopes included a geosynthetic clay liner, geomembrane, geonet, geotextiles, and collection piping. Dr. Matasovic also

helped prepare construction documents, including the general and supplementary conditions, bid documents, specifications, drawings, and CQA Implementation Plan for the Back Canyon Area.

Olympic View Sanitary Landfill, Port Orchard, Washington – Composite Cover Design. Project Manager and Lead Engineer responsible for Phase I North and Phase II composite landfill cover design. Project challenges included composite cover design in an area of high seismicity (the site was severely shaken by the 2001 M_w 6.8 Nisqually, Washington earthquake) and high precipitation (100-year storm = 6.3 in./24 hr). Dr. Matasovic was also responsible for seismic site response and deformation analyses for the site, interaction with the regulatory agencies (Kitsap County and State of Washington Dept. of Ecology), and development of a site-specific GCL panel layout plan.

Ox Mountain Sanitary Landfill, Half Moon Bay, California. The landfill was partially constructed over alluvial soils that required improvement. Geosyntec scope included pre- and post-improvement characterization of potentially liquefiable soils using the Cone Penetration Test (CPT) and Standard Penetration Test (SPT) soundings and Becker Test, numerical modeling, and evaluation of soil improvement options (stone columns and deep dynamic compaction). Dr. Matasovic was responsible for demonstration of stability of earthen structures constructed over unimproved and improved subgrade. His work included selection of design ground motions, performance of Two-Dimensional (2-D) site response analysis (QUAD4M), and interpretation of the results in terms of average acceleration time histories required for evaluation of lateral spreading and deformation potential of landfill composite liner, cover and berms.

Puente Hills Landfill, Whittier, California – Phase 1B and Eastern Canyons Expansions. Task Manager responsible for static and pseudostatic slope stability and deformation analyses conducted in support of design and construction of *Phase 1B expansion*. The analyses were conducted to evaluate several subgrade configurations considered and included evaluation of remedial measures. The work also included assessment of costs and benefits for each remedial measure considered, including the selected stabilization with rock anchors. For the Eastern Canyons, at a professional level, Dr. Matasovic provided support during development of the conceptual grading design. He was also involved in the review of available data for the site, the planning of geotechnical investigations, and geotechnical laboratory testing, and was responsible for the execution of a supplemental field investigation program, which included drilling of a borehole with a large-diameter bucket auger, downhole logging of the borehole, and excavation of several trenches in local Puente formation.

Puente Hills Landfill, Whittier, California – Strong Motion Instrumentation of the Site. Project Manager and Lead Engineer responsible for development of the Strong Motion (SM) instrumentation plan for the site. Given the 1995 state of landfill development (the main Canyon had reached only 50 percent of permitted height) and budget constraints, Geosyntec developed a two-phase implementation plan based upon the single, dual-sensor SM instrument. In PHASE 1, implemented by Dr. Matasovic, the main sensor was placed in an instrument shelter on a bedrock outcrop at the base of Main Canyon, and the remote sensor was placed on a bench on the Main Canyon side slope. PHASE 2 called for relocation of the remote sensor to landfill top deck after the final elevation is achieved, with provision for adding another sensor on the landfill side slope. Dr. Matasovic also developed and organized a training seminar for LACSD staff involved in the project.

Puente Hills Landfill, Whittier, California – SASW Geophysical Surveying. Project Manager for a comprehensive geophysical surveying program at the site. The surveying was conducted using non-intrusive Spectral Analysis of Surface Waves (SASW) technique and was partly supported from the NSF grant to Geosyntec. The work was divided in two parts: (i) SASW measurements on the base and side slope of the Main Canyon area to characterize bedrock/solid waste conditions below the base and side slope SM stations installed previously; and (ii) SASW measurements in alluvial gravel for soil liquefaction evaluation. Dr. Matasovic's responsibility also included evaluation of soil liquefaction potential based upon the results of SASW measurements in gravels and development of remedial measures against soil liquefaction within the Eastern Canyon's "Visual Berm" area.

Puente Hills Landfill, Whittier, California – 2003 and 2013 Configurations. Project Manager responsible for static and pseudostatic slope stability and deformation analyses. The work required in-depth review of available site data and development of representative cross sections for static analyses and seismic evaluations. The evaluations included: (i) an update of the seismic hazard for the site to establish the Maximum Credible Earthquake (MCE) bedrock PHGA, target acceleration response spectra, and significant duration of strong shaking (D_s); (ii) selection of a suite of significant duration- and target spectrum-compatible accelerograms; (iii) static and pseudostatic limit equilibrium stability evaluations for the waste mass / liner system; (iv) three 1-D non-linear and three 2-D equivalent linear seismic site response analyses; and (v) Newmark-type seismic deformation analysis for waste mass / liner system sliding blocks.

Puente Hills Landfill, Whittier, California – Phase V Liner. Project Manager and Lead Engineer for seismic deformation analyses conducted in support of Phase V Liner design. The work required close coordination with LACSD staff (who provided static

and pseudostatic input for the seismic deformation analyses) and development of a site-specific seismic deformation chart for native slopes at the site. The analyses were recently reviewed and approved by the California DWR.

Redwood Landfill, Marin County, California. Redwood Landfill is a solid waste landfill located approximately 4 miles (6.5 km) north of Novato, California. The landfill is founded on a marine deposit consisting of alternating layers of San Francisco Bay Mud (SFBM) and liquefiable sands. Since the site is in an area of high seismicity (design PHGA in underlying bedrock was 0.58 g), seismic design of the proposed lateral expansion was one of the major concerns. Dr. Matasovic calculated seismic response of the site using the computer program D-MOD. D-MOD is a fully non-linear effective-stress site response computer program with provisions to simulate both soil liquefaction and cyclic degradation of soft (SFBM) layers. The program was developed at the University of California, Los Angeles, modified and improved at Geosyntec, and used by Dr. Matasovic to demonstrate the seismic stability of the proposed expansion.

Republic Landfill, Imperial County, California. Assisted in a landfill litigation case related to the disposal of special wastes in a California Class III (MSW) landfill. Work included the review of over 1,500 documents, development of a quick reference guide for technical experts, technical presentations, technical analyses using the United States Environmental Protection Agency-approved computer models HELP and MULTIMED, and assistance during depositions.

Sunshine Canyon Landfill, Los Angeles County, California – Multiple Projects. Lead Engineer responsible for static seismic analyses in support of site development since 1995 (Phase I; Phase II Stage 1; Phase II Final Buildout; Existing City Landfill; JTD). Analyses included: cut and fill slope stability analyses, stability analyses in support of a composite liner system design that included 1-D and 2-D seismic site response analyses, seismic deformation analyses of the landfill mass, composite liner system, and landfill cover (for JTD). Dr. Matasovic was an engineer of record for several phases of site development, including the Phase II Stage 1, Phase II Final Buildout, Existing City Landfill, and JTD for the site.

Tajiguas Landfill, Santa Barbara County, California. Project Manager and Lead Engineer for seismic deformation analyses conducted in support of Phase 2A composite liner design. The work required close coordination with Geosyntec teaming partner, SWT Engineering staff who developed grading design.

Vasco Road Landfill, Livermore, California. Lead Engineer responsible for demonstration of seismic stability of the site. Seismic evaluations conducted by Dr. Matasovic included seismic hazard evaluation in accordance with Federal Subtitle D

and California Title 27 requirements, evaluation of design ground motions, non-linear seismic site response analyses, and Newmark-type seismic deformation analyses conducted for both waste mass (landfill liner) and landfill cover.

CERTIFICATIONS AND PROFESSIONAL AFFILIATIONS

OSHA-Certified, 40-Hour Emergency Response and Hazardous Waste (29 CFR 1910.120)

OSHA-Certified for Access to Hazardous Waste Sites

OSHA-Certified Supervisor for Hazardous Waste Operations

North American Geosynthetics Society (NAGS)

International Geosynthetics Society (IGS)

American Society of Civil Engineers (ASCE)

International Society of Soil Mechanics and Foundation Engineering (ISSMFE)

SELECTED PUBLICATIONS (LANDFILL ENGINEERING)

The following list illustrates Dr. Matasovic's recent publications in the areas of landfill and geoenvironmental engineering. A complete list, containing over 70 refereed publications, is posted at:
http://www.geosyntec.com/UI/Default.aspx?m=ViewPerson&p=62

Athanasopoulus, A., Zekkos, D. P., and Matasovic, N. (2008), "Validation of Generic Municipal Solid Waste Material Properties for Seismic Design of Landfills," In: *Geotechnical Earthquake Engineering and Soil Dynamics IV*, ASCE Geotechnical Special Publication No. 181, 10 p. (188).

Zekkos, D. P., Bray, J. D., Stokoe, K. H., II., Kavazanjian, E., Rathje, E., Athanasopoulos, G.A Riemer, M., Matasovic, N., Lee, J. J. and Seos, B. (2008), "Recent Findings on the Static and Dynamic Properties of Municipal Solid Waste," In: *Geotechnics of Waste Management and Remediation*, ASCE Geotechnical Special Publication No. 177, pp. 176-183.

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EXHIBIT B to Consultant Agreement

Geosyntec
consultants

ROBERT KOVACS, P.G., C.Hg.

hydrogeologic investigations
environmental and geotechnical investigations
subsurface remediaton

EDUCATION

B.S., Geological Sciences, California State University, Fullerton, 1999

REGISTRATIONS AND CERTIFICATIONS

Professional Geologist, California No. 7708
Certified Hydrogeologist, California, No. 852
OSHA-Certified, 40-Hour Emergency Response and Hazardous Waste
(29 CFR 1910.120)

CAREER SUMMARY

Mr. Kovacs has over 11 years of experience in consulting, including oversight and management of comprehensive soil, soil vapor and groundwater characterization and remediation programs. Mr. Kovacs has been responsible for environmental site assessment for various sites, including harbor sediment, soil, soil vapor, sea water and groundwater sampling, shallow and deep groundwater monitoring well and soil vapor monitoring well installation programs and associated deliverable preparation. Mr. Kovacs worked on a number of hydrogeologic investigations involving subsurface flow characterization utilizing slug tests and pumping tests.

Mr. Kovacs has experience working with various subsurface investigation techniques including roto-sonic, air-rotary, reverse and conventional mud-rotary, air-casing-hammer, odex, hollow stem auger, solid stem auger, bucket auger, geoprobe, and CPT drilling.

Mr. Kovacs has worked with several treatment methods, including soil vapor extraction and treatment, bio-farming of hydrocarbon-impacted soils, groundwater extraction, air/methane sparging systems, potassium permanganate, hydrogen peroxide, and ORC injection programs.

Mr. Kovacs has a strong background in mapping, geophysical surveys and analysis, lithologic logging and interpretation of stratigraphy, including structural and sedimentoligical features.

Mr. Kovacs has strong geotechnical field experience performing various geotechnical/environmental tasks including exploratory boring and trench logging, down-hole stratigraphy logging, grading foundation and footing inspections, and soil and asphalt concrete density testing.

Mr. Kovacs has performed and managed various preliminary grading investigations. He has prepared various geotechnical reports, which included grading and foundation planning reviews.

Hydrogeologic Investigations

- ***Seal Beach NWS, Seal Beach, California.*** Project Geologist during installation of over 200 injection and monitoring wells for insitu enhanced bioremediation of TCE impacted groundwater and soil.
- ***Former Operating Industries Landfill, Monterey Park, California.*** Project Geologist during various hydrogeologic investigation programs aimed at groundwater containment and remediation. As part of the above work rock core and groundwater samples were collected for lithologic assessment and chemical testing. Sonic drilling technique was used to install a line of extraction wells, downgradient sentinel wells and MNA monitoring wells.
- ***City of Rialto, California.*** Oversight of deep drilling operations and well installations into unconsolidated and semi consolidated alluvial formation Rialto, California.
- ***Westway Terminal, San Pedro, Los Angeles Harbor, California***. Oversight of harbor sediment coring, and sediment and sea water sampling program.

Environmental and Geotechnical Investigations

- ***Former Cornell-Dubilier Electronics Inc., Marina del Ray, California.*** Oversight and management of ambient air, indoor air, and sub-slab soil gas sampling program for human health risk assessment, former Cornell-Dubilier Electronics Inc., facility, Marina del Ray, CA.
- ***McMillen Oil Field Decommissioning, Gardena, California.*** Oversight and management of the soil remediation program at RDB Developers' McMillen Oil Field Decommissioning and Soil Remediation Program.
- ***Bank of America, Hill Side Reconstruction, North Hollywood, California***. Supervised grading operations, as well as mapping geological features, including location of joints, bedding/strike and soil/rock type changes

Subsurface Remediation

- ***Papermate, Santa Monica, California.*** Oversight and management of soil vapor extraction pilot study and soil vapor monitoring well installation program at the former Papermate Facility.
- ***J.C. Penney Distribution Center, Buena Park, California***. Management of groundwater monitoring and remediation program at the site.
- ***Brunswick Corporation, Anaheim, California.***Oversight and management of groundwater well installation programs and quarterly groundwater monitoring program.
- ***Pacific Scientific Company, Anaheim, California.*** Oversight and management of quarterly groundwater monitoring program.
- ***LAUSD, South Region High School #15, Los Angles, California.*** Oversight and management of complex multi disciplinary site investigation program and development of remediation program.

PROFESSIONAL EXPERIENCE

Geosyntec Consultants, Huntington Beach, California 2004 to present
URS Corporation, Santa Ana, California, 2001 to 2004
Allwest Geoscience, Inc., Anaheim, California 1998 to 2001

AFFILIATIONS

Geologic Society of America

Geosyntec
consultants

CHRISTOPHER S. CONKLE, P.E.
Project Engineer

geotechnical engineering
construction quality assurance

EDUCATION

University of California, Berkeley, M.S., GeoEngineering, 2006
2006 Harry Bolton Seed Award Recipient, Most Outstanding M.S. student
University of California, Berkeley, B.S., Civil Engineering, 2003

REGISTRATIONS AND CERTIFICATIONS

Registered Professional Engineer, State of California, No. C070923

CAREER SUMMARY

Mr. Conkle is a civil engineer engaged in the practice of geotechnical and construction related engineering. He has managed and executed geotechnical investigation, analysis, design, and quality assurance monitoring projects for a variety of geotechnical and structural systems including earth retaining structures, engineered slopes, and foundations.

He has directed design and construction of excavation support systems using techniques such as mechanically stabilized earth, shallow soil mixing, and soil nails throughout the western US.

Mr. Conkle also has experience with the installation and monitoring of geotechnical instruments and as a soils laboratory technician.

These projects are outlined in the "Representative Projects" section below.

Prior to joining Geosyntec, Mr. Conkle was employed with Los Angeles County Department of Public Works, where he gained extensive experience in a variety of civil engineering disciplines.

REPRESENTATIVE PROJECTS

Geotechnical Construction Observation

- ***Final Groundwater Remedy, Metaline Falls, Washington.*** Mr. Conkle provided on site engineering oversight of a specialty geotechnical contractor during the construction of a shallow soil mixed excavation support system. A series of shallow

soil mixed wall were constructed to form a "bathtub" excavation support and groundwater control system for a 10-foot deep excavation with an area of 5000 square feet. This excavation was required for installation of groundwater treatment process equipment. Mr. Conkle worked closely with the contractor to evaluate performance of the as-built system and institute remedial measures where unfavorable site conditions were identified

- ***Operating Industries, Inc. (OII) Landfill, Monterey Park, California***. Mr. Conkle provided geotechnical engineering design services during construction as part of Geosyntec's design-build team for the closure of the landfill on the North Parcel portion of the OII landfill Superfund site. Concurrent with Geosyntec's construction of the closure, Mr. Conkle performed calculations, developed responses to Requests for Information, reviewed submittals, and developed supplemental design drawings and technical specifications. Mr. Conkle was frequently on site, participated in construction meetings as a design representative, and coordinated with owner's representatives, and regulators from US EPA, Cal EPA, and the Army Corps of Engineers.

  This closure construction involved significant complexity as the end use of the site will include a brown fields redevelopment project. Mr. Conkle was involved in the design of the following project components: landfill gas and leachate conveyance systems, surface water drainage system design, GCL cover system specifications, monocover system slope stability, waste excavation and processing.

- ***Mechanically Stabilized Earth Wall, Sunshine Canyon Landfill, Sylmar, California.*** Mr. Conkle performed CQA services and monitoring during the construction of a mechanically stabilized earth retaining wall system. These services included in-situ nuclear density testing of reinforced backfill soil, monitoring of installation of precast concrete elements and reinforcing materials, and monitoring of construction of back of wall gutter and drain system. In addition to the CQA role, Mr. Conkle worked closely with the contractor, project manager, and city inspector as an on-site representative of the designer. Additionally, Mr. Conkle prepared the CQA final report for this project

- ***Tajiguas Sanitary Landfill Phase IIA, Goleta, California.*** During the construction of the Phase IIA liner system (total construction cost approximately $7,000,000), Mr. Conkle served as Construction Quality Assurance manager for the earthworks and lining system construction. In addition to preparation of the Construction Quality assurance manual for this phase, he reviewed contractor's submittals, supervised field monitoring personnel, and prepared a certification report

documenting conformance with the Construction Drawings and Technical Specifications.

Mr. Conkle also led Geosyntec's engineering support effort during the Phase IIA construction providing geotechnical evaluations during the construction. Mr. Conkle's efforts to assist the contractor in mitigation of slope movements encountered during construction kept the project on schedule.

Mr. Conkle continued work for the same client during Phase IIB (described below).

- ***Shell Hydrogen Station, West Los Angeles, California***. As Geosyntec's project manager, Mr. Conkle oversaw construction quality assurance and geotechnical engineering support during construction for this hydrogen vehicle fueling station, one of the first such installations in Southern California. Mr. Conkle provided critical value engineering support during the selection of a shoring method for construction of the foundations for the hydrogen generation and storage facilities. Additionally, Mr. Conkle prepared reports for review by the City of Los Angeles Department of Building and Safety.

- ***Tank Foundation, Metaline Falls, Washington.*** Mr. Conkle provided continuous observation and engineering support during the construction of a concrete mat foundation for a compressed gas tank system. Construction was complicated by the low ambient temperatures at the site during excavation, reinforcing bar erection, and concreting.

- ***Antelope Valley Landfill, Palmdale, California.*** Mr. Conkle performed CQA services and monitoring during the construction of the Phase V-A-1 expansion of the landfill. These services included in situ nuclear density testing of compacted fill and monitoring of geosynthetics installation and repairs.

Geotechnical Instrumentation

- ***Ellis Avenue Sewer Replacement, Fountain Valley, California.*** Mr. Conkle oversaw the installation of Geotechnical Instrumentation as part of an approximately 2 mile long tunneling project for installation of 66-in. diameter gravity sewer. Nested extensometers were installed at critical locations along the tunnel alignment to monitor settlement during tunneling and provide feedback on potential damage to sensitive utilities.

- ***La Pata Avenue Landslide, Orange County, California.*** Mr. Conkle gathered slope inclinometer data at the La Pata Avenue landside. Signs of an incipient landslide which threatened to close the main access road for the Prima Deshecha Landfill

prompted Geosyntec' installation and monitoring of slope inclinometers. Mr. Conkle assisted with data collection and interpretation.

Excavation Support and Retaining Wall Systems

- ***United States Courthouse, Las Cruces, New Mexico.*** Mr. Conkle was Geosyntec's project manager and lead designer, for approximately 9000 vertical square feet of soil nail wall constructed as temporary support for construction of a basement at the site of a new United States Courthouse in Las Cruces, New Mexico. This temporary support was constructed in difficult loose sand conditions. Geosyntec was retained by a nationwide geotechnical contractor to perform this work.

- ***Mechanically Stabilized Earth Wall, Hanson Pipe and Precast, Tacoma, Washington.*** Mr. Conkle was task manager for geotechnical investigation and retaining wall design at the site of precast concrete manufacturing facility. As part of a plan to improve surface water runoff quality at the site two pH neutralization ponds were proposed. Mr. Conkle prepared a geotechnical report for the project, and managed the design of several mechanically stabilized earth (MSE) retaining walls up to 25 feet high. Additionally he prepared geotechnical and structural designs for a concrete treatment flume including design of deep foundations.

- ***Final Groundwater Remedy, Metaline Falls, Washington.*** Mr. Conkle assisted in preparing designs for the geotechnical components of a groundwater cutoff system in Metaline Falls, Washington. This included a thorough review of available technologies and evaluation of their relative advantages and disadvantages. The system consists of several key components: a 15-foot deep groundwater cutoff wall, an adjacent permeable drainage trench, and shallow soil mixed excavation support. (Mr. Conkle's role during construction is described above.) All of this construction took place adjacent to a creek in an area of high groundwater.

Landfill Engineering

- ***Tajiguas Sanitary Landfill Phase IIB, Goleta, California.*** During the construction of Phase IIB, Mr. Conkle served as Construction Quality Assurance manager for the earthworks and lining system construction. In addition to preparation of the Construction Quality assurance manual for this phase, he reviewed contractor's submittals, supervised field monitoring personnel, and prepared a certification report documenting conformance with the Construction Drawings and Technical Specifications.

- ***Tajiguas Sanitary Landfill, Supplemental Environmental Impact Report for Proposed Reconfiguration Project, Goleta, California.*** Mr. Conkle was the task manager for geotechnical evaluations including cut slope and liner stability for the Proposed Reconfiguration project at Tajiguas Sanitary Landfill. He prepared the evaluations necessary to accompany the supplemental environmental impact report for this reconfiguration.

- ***Los Alamitos Joint Forces Training Base, Los Alamitos, California*** Mr. Conkle assisted in preparation of detailed design plans and specification for a new 10-acre solid waste landfill as part of a closure of an existing landfill at the Los Alamitos JFTB. This design included all geotechnical aspects of the project, including geosynthetics, embankment stability, and seismic design. Additionally, Mr. Conkle assisted with the design hydrology, surface water management feature design, and selection of construction best management practices.

- ***North Ridge Cut, Calabasas Landfill, Agoura, California.*** As a follow on to a comprehensive geological and geotechnical investigation of the North Ridge Cut (NRC) area completed by Geosyntec in 2005, Mr. Conkle performed a detailed three dimensional (3-D) slope stability analysis of the proposed waste fill configuration of the NRC. This analysis included development of a 3-D site model; assessment of shear strength properties of on site earth materials and proposed geosynthetics; and static and pseudostatic limit equilibrium slope stability analyses with estimates of permanent seismic displacement.

- ***Bradley Landfill, Sun Valley, California.*** Mr. Conkle designed a flood management system for the final closure of this 126-acre landfill. This design included analyzing the site by using the LACDPW hydrology method and sizing of culverts and open channels.

- ***Nuway Live Oak Landfill, Irwindale, California.*** Mr. Conkle performed a coupled seepage and stability analysis for a proposed detention basin at the Nuway Live Oak Facility, a construction and demolition debris landfill. He conducted static and pseudo-static limit equilibrium slope stability analyses of the detention embankment and evaluated maximum calculated permanent seismic displacements. Based on the results of this analysis, Mr. Conkle proposed modifications to the embankment design to enhance its stability.

- ***Badlands Sanitary Landfill, Riverside County, California.*** Mr. Conkle has performed a number of geotechnical slope stability analyses for proposed grading within the Badlands Sanitary Landfill.

Specifically, he has performed stability analysis for a proposed detention basin and a revised waste fill plan. He conducted static and pseudo-static limit equilibrium slope stability analyses for both of these configurations and evaluated maximum calculated permanent seismic displacements. In the case of the proposed detention basin, Mr. Conkle also executed a seepage analysis coupled with the stability analysis.

Foundation Engineering

- ***Vernon Data Center, Vernon, California.*** Mr. Conkle was task manager for the geotechnical investigation at the location of the proposed Vernon Data Center, a 3 story, 300,000 square foot facility used to house computer systems. Geosyntec's field investigation included the use of both cone penetration test sounding and hollow stem auger borings. Of particular concern at this site were the large column loadings inherent in the construction of a data center (up to 1750 kips). Geosyntec worked with project structural engineer to develop a deep foundation system consisting of over 400 piles that will limit expected settlements to acceptable levels.

- ***Browns Creek Bridge, Woodland Hills, California***. Mr. Conkle performed the geotechnical investigation and foundation design for this pedestrian bridge on a site including potentially liquefiable soils. Responsibilities included field classification of soils, observation of field penetrometer testing, collection of samples for laboratory testing, assignment of laboratory testing program, interpretation of laboratory testing results, preparation of cross sections for geotechnical analysis, liquefaction triggering analysis, axial and lateral drilled pier analysis, and preparation of the geotechnical report.

- ***Tank Foundation, Metaline Falls, Washington.*** Mr. Conkle prepared a 2-D plane strain Finite Element Method (FEM) model of the proposed mat slab foundation system for a carbon dioxide tank at the site of an environmental remediation project in eastern Washington. By using the results of this FEM analysis, Mr. Conkle prepared an appropriate foundation slab design.

Geotechnical Engineering for Water Resources

- ***Chavez Streetscape Project, Los Angeles, California.*** Mr. Conkle was Geosyntec's Project Manager for this Community Development Agency of Los Angeles project which involves a geotechnical and infiltration investigation in support of design of 1.3 miles of streetscape along Caesar Chavez Ave. Significant project components include permeable pavements and vegetated infiltration areas.

- ***City of Los Angeles Westchester Stormwater BMP Project.*** Mr. Conkle was the task manager for the infiltration modeling for this project involving storm water diversion, treatment and infiltration for Bacteria TMDL compliance in the Santa Monica Bay. Geosyntec's Project scope involves concept design validation, pre-design, geotechnical investigations, survey, environmental clearance, permitting, final design, and construction-phase support. Infiltration modeling was conducted to determine the effects of long term operation of the spreading grounds on the groundwater aquifer.

- ***Malibu Legacy Park, Malibu, California.*** Mr. Conkle performed a geotechnical site investigation and subsequent interpretation of subsurface conditions in support of the predesign of this park for the city of Malibu. This park is envisioned as a multipurpose (water resources, water quality, flood management) facility which will also serve a recreational purpose. The project may require that runoff from area storm drains and a storm water treatment facility be infiltration at the site to meet storm water TMDL's. Therefore the infiltration capacity of the onsite soils was characterized. Mr. Conkle interpreted existing data, performed the field investigation, interpreted geotechnical laboratory testing results, and prepared a report outlining the investigation findings and their implications for design of the facility.

- ***Mill Creek Wetlands, Chino, California***. Mr. Conkle prepared the geotechnical investigation plan for this proposed 200 acre multi-use engineered wetlands. When completed the wetlands will serve a number of purposes including: water quality improvement, infiltration, and recreation

- ***Bolsa Chica Wetlands, Orange County, California.*** Mr. Conkle performed a steady-state seepage analysis to investigate seepage under an existing levee at this large wetlands restoration project. The levee was modeled to evaluate the likelihood of piping in the levee's foundation due to large flow gradients.

- ***Palmer Canyon, Los Angeles County, California***. Subsequent to a large fire in the San Gabriel Mountains, Mr. Conkle performed a detailed hydraulic analysis to delineate a floodway in the Palmer Canyon area. Mr. Conkle's responsibilities included characterization of hydraulic features along more than a mile of natural channel with development along the banks, preparation of a one-dimensional steady flow model of the reach, and reporting of the resulting floodway boundaries.

LIST OF PUBLICATIONS

Conkle, C., Moyer, J., Willardson, B., Walden, A. and Nasseri, I. (2006), "Hydrology Manual," *Technical Manual*, Los Angeles County Department of Public Works, Alhambra, California, 206 p.

PROFESSIONAL AFFILIATIONS AND CERTIFICATIONS

- Registered Professional Engineer (Civil), California # 70923
- Associate Member, American Society of Civil Engineers (ASCE).
- Reviewer, ASCE Journal of Geotechnical Geoenvironmental Engineering
- Chi Epsilon, National Civil Engineering Honor Society
- Certified, 40-hr OSHA HAZWOPER (29 CFR 1910.120(e))
- Certified, 24-hr First Responder: Operations Level (29 CFR 1910.120(q))
- Certified, 8-hr OSHA HAZWOPER Supervisor (29 CFR 1910.120)
- Certified, First Aid and Adult CPR
- Certified Nuclear Moisture/Density Gauge Operator

PROFESSIONAL EXPERIENCE

Geosyntec Consultants, 2006 to present

Los Angeles County, Department of Public Works, Senior Civil Engineering Assistant, 2003 to 2006

EXHIBIT B to Consultant Agreement

Geosyntec
consultants

J. SCOTT ROWLANDS, P.G., C.Hg., C.E.G.

groundwater assessments and remediation
site investigation and remediation

EDUCATION

B.S., Geological Sciences (Hydrogeology emphasis), California State University at Fullerton, 2000
B.A., Business Economics, University of California, Santa Barbara:, 1987

REGISTRATIONS AND CERTIFICATIONS

Professional Geologist, California, No. 7013
Certified Hydrogeologist, California, No. 715
Certified Engineering Geologist, California, No. 2380

CAREER SUMMARY

Mr. Rowlands has over 20 years of experience in the areas of geology, hydrogeology, environmental and geotechnical consulting. Mr. Rowlands specializes in the collection, synthesis, and interpretation of analytical, geologic, and hydrogeologic data for the assessment and remediation of sites impacted with various contaminants including petroleum hydrocarbons and chlorinated volatile organic compounds (VOCs). His responsibilities have entailed scoping, managing, and conducting environmental assessments and remedial actions primarily in the Southern California area. He has extensive knowledge of federal, state, county, and city regulatory oversight agencies and guidelines for environmental compliance. His area of practice is focused on contaminant hydrogeology and the delineation and cleanup of organic and inorganic compounds within the aquifer systems of various groundwater basins. His past and present clients include landfill operators, commercial real estate management companies, financial institutions, municipalities, petro-chemical and manufacturing companies.

Mr. Rowlands' experience encompasses project management of comprehensive geologic and groundwater characterization studies, the design and implementation of feasibility studies and remedial action programs for sites impacted with organic and inorganic compounds, and other toxic and hazardous materials. He is also adept at providing litigation support and environmental liability valuation services to clients. He has prepared, analyzed, and estimated costs for small to large scale environmental projects including underground storage tank (UST) sites, petro-chemical and manufacturing facilities, oil fields, refineries, and landfills. Mr. Rowlands has communicated, interfaced, and negotiated with various environmental oversight agencies, including the United States Environmental Protection Agency (USEPA), State of California Department of Toxic Substances and Controls (DTSC), California Regional Water Quality Control Board (RWQCB), and Department of

Oil, Gas, and Geothermal Resources (DOGGR). Mr. Rowlands representative project experience is presented below.

- **Operating Industries, Inc, (OII) Landfill, Monterey Park, CA** – Current project manager for groundwater related issues at an inactive 190-acre landfill and Superfund site. The site operated from 1948 until 1984 and received both solid waste and liquid hazardous waste including many types of chlorinated VOCs. Geosyntec conducts the work on behalf of a multi-party PRP group that is implementing the prescriptive site remedies under multiple Consent Decrees with EPA oversight. Project tasks include the evaluation of liquid flow patterns from the landfill that are controlled by folded and faulted sedimentary units, and the design and installation of perimeter liquid control systems in strategic locations to contain and capture the landfill associated liquids. This approach provides effective containment and limits the volume of liquids requiring extraction and treatment. Ongoing tasks include offsite groundwater assessments and hydrostratigraphic evaluations, aquifer testing, capture analysis and compliance testing of perimeter liquid control systems, groundwater monitoring, and evaluation of the monitored natural attenuation (MNA) remedy for down gradient areas.

- **Former Precision Plastics Facility, Irvine, CA** – Project manager for soil and groundwater investigations at a former plastics molding manufacturing facility. The property has been sold and redeveloped but the client retains responsibility for soils and groundwater impacts associated with former site operations. Shallow groundwater beneath the site is impacted with tetrachloroethene (PCE) and trichloroethene (TCE) which are also detected in up gradient wells and are constituents of a large comingled plume in the site vicinity. Remedial activities have been completed at the site and a site closure assessment work plan has been prepared and submitted to RWQCB. Future activities include soil sampling of former onsite source areas, additional groundwater monitoring, further assessment of up gradient sources, and potential litigation support and environmental liability valuation.

- **Former Memorex Facility, Westlake Village, CA** – Project manager for soil and groundwater related issues at a former computer components manufacturing site. The 33-acre site is impacted with multiple chlorinated VOCs and petroleum hydrocarbons and is under the regulatory oversight of RWQCB. Project responsibilities included development of project scope and cost estimates, permitting, interfacing with the client, developer, regulatory and permitting agencies, management of field staff, preparing work plans and reports. Various source areas were associated with 17 USTs, four clarifiers, and two sumps. Tasks supporting construction of a Hotel and Spa on the site included conducting a comprehensive soil and soil vapor assessment, completing a health risk analysis, removal and re-installation of a groundwater monitoring well network, preparing a soil management plan; excavation and handling of approximately 150,000 cubic yards of soil. Providing analysis and recommendations for installation of sub-slab vapor collection and vapor barrier systems, dewatering and treatment systems. The assessments and remedial activities were conducted over a 5-year period. The site is

currently under closure review with RWQCB for soil impacts and undergoing long-term MNA of groundwater for residual VOC impacts.

- **Cal Compact Landfill, Carson, CA** – Project manager of soil and groundwater investigations at a 160-acre landfill site in Carson, California under DTSC oversight. The project work was conducted in support of planned site redevelopment activities and regulatory requirements. Oversight and analysis were provided for soil and multi-layer aquifer groundwater assessments, which included, well design and installations, geophysical testing, soil vapor surveys, aquifer and water quality analysis, light non-aqueous phase liquid (LNAPL) and dense non-aqueous phase liquid (DNAPL) investigations, installation and sampling of numerous groundwater monitoring wells, and project reporting, including geologic and hydrostratigraphic correlations and interpretations. Other tasks included preparation of landfill mitigation costs, including estimated costs for landfill gas extraction and treatment systems, groundwater extraction and treatment systems, and the installation of engineered landfill covers.

- **Former Westway Terminal, San Pedro, CA** - Project hydrogeologist for a former chemicals storage facility on a man-made pier constructed in Los Angeles Harbor. During the site's 100 hundred year history a wide variety of chemicals including chlorinated VOCs were stored at the facility. Soil, groundwater, and sediments beneath and adjacent the facility have been impacted and LNAPL and DNAPL are present beneath the facility. Project work included review of previous investigations, development of a site conceptual model, completing a comprehensive groundwater assessment to assess LNAPL and DNAPL source areas, and developing a remedial action plan for submittal to RWQCB.

- **Former Circle Seal Facility, Anaheim, CA** - Project hydrogeologist for groundwater related issues at a former aerospace manufacturing facility. Two groundwater zones beneath and downgradient of the 14-acre site were primarily impacted with TCE. Responsibilities included oversight of groundwater assessment, monitoring, and remediation for a multi-layered aquifer zone, conducting regional hydrogeologic research, preparing a site hydrogeologic conceptual model and site closure strategy plan, oversight of groundwater modeling efforts, rehabilitation of groundwater injection wells, interfacing with the RWQCB and the Orange County Water District and negotiating site-specific clean up goals.

- **Former Pacific Scientific Facility, Anaheim, CA** - Project hydrogeologist for groundwater related issues at a former aircraft component manufacturing facility. Groundwater beneath and downgradient of the 13-acre site were primarily impacted with PCE and TCE. Responsibilities included oversight of groundwater assessment and monitoring for a multi-layered aquifer zone, conducting regional hydrogeologic research, preparing a site hydrogelogic conceptual model and interfacing with the RWQCB and the Orange County Water District and negotiating site-specific clean up goals.

J. Scott Rowlands, P.G., C.Hg., C.E.G.

Geosyntec consultants

- **Former McMillan Oil Field, Gardena, CA**– Environmental project manager for the commercial redevelopment of a 13-acre oil field site impacted with petroleum hydrocarbons and metals under the regulatory oversight of RWQCB. Project responsibilities included development of project scope and cost estimates, permitting, interfacing with the developer, regulatory and permitting agencies, management of field staff, preparing work plans and reports. Oil field redevelopment tasks included conducting a comprehensive Phase 1 assessment, completing several extensive soil assessments and groundwater studies, preparing clean-up to closure cost estimates including a risk analysis to assist the developer in securing financing for the project; abandoning oil wells and removing ASTs; excavation and onsite treatment of approximately 10,000 cubic yards crude-oil impacted soil, and completing groundwater studies. The site has been redeveloped as a Federal Express facility. The assessments and remedial activities were conducted over a 5-year period. The site is currently under closure review with RWQCB.

PROFESSIONAL EXPERIENCE

Geosyntec Consultants, Huntington Beach, California, Senior Geologist,
Nov. 2005 to present
URS Corporation, Santa Ana, California, Principal Geologist, Nov. 2000 to Nov. 2005
Other firms, 1988-Nov. 2000

AFFILIATIONS

National Groundwater Association
California Board of Geologists and Geophysicists – Hydrogeology Subject Matter Expert

EXHIBIT B to Consultant Agreement

Geosyntec
consultants

WILLIAM HODGES

construction management
environmental remediation

PROFESSIONAL EXPERIENCE

Geosyntec Consultants, Riverside, Senior Construction Manager, 2008 – present
Shaw Environmental and Infrastructure, Construction Manager, 2000 – 2008
Shaw Environmental and Infrastructure (formerly IT Corporation and OHM),
Site Health and Safety Officer/Site Superintendent, 1996 – 2000

CAREER SUMMARY

William Hodges has 20+ years experience in multiple aspects of environmental remediation, civil engineering industry and construction. Experience includes project construction management, proposals, supervision, quality assurance/quality control and health and safety in fixed-price commercial and government remediation, hazardous waste disposal, heavy civil construction and demolition.

Mr. Hodges has provided construction management, estimating and value engineering services. He has developed client project capitol budgets and drafted construction plans, contractor statements of work, and permitting documents. Mr. Hodges has performed constructability review of designs and acted client's representative for construction phases of projects, including cost management and tracking, schedule, change management, quality assurance and overall production.

Mr. Hodges has provided construction management and supervision, including planning and coordination, developing and maintaining production schedules, and managed production costs by tracking and reporting real-time production costs. He has initiated and implemented cost-saving measures by devising innovative solutions to technical challenges, identified changing conditions and developed and coordinated schedule change proposals. Mr. Hodges has organized and supervised fieldwork, including craft labor, subcontractors, and vendors. He has conducted and/or supervised quality control, including compliance with design, testing, sampling and analysis, third-party inspection and on-site monitoring and use of monitoring instruments.

Representative examples of Mr. Hodges' project experience include:

Ascon Landfill Site, *Huntington Beach, California*. Currently providing conceptual design, construction execution plan and estimate for Remedial Construction Conceptual Design. Execution to be conducted within a structure under negative air with filtration

to mitigate odor and in compliance with SCAQMD Rule 1150 and Rule 1166. Assume the project may require the purchase and/or monitoring of air credits.

Also provided a constructability and feasibility review of Request for Proposal, Interim Removal Measure-Lagoons 1 and 2.

General Electric Company for Pre-demolition Abatement and Decommissioning, GE Oakland Power Systems Facility in Oakland, California. Provided on-site construction management/owner's representative services. Identified the scope of work per client's constraints and planned the general execution of the scope. Produced the project estimate, budget, schedule, execution and general work plan. Produced a Request for Proposal package to procure a General Contractor, solicited bids, reviewed bid packages and recommended award for General Contractor services. Execution required compliance with the Bay Area Air Quality Management District requirements and regulations. Conducted oversight and direction of the General Contractor acting as the owner's representative from award to completion of project.

Montrose Chemical Corporation for the Montrose Soils Program, *Torrance, California.* Provided conceptual designs, construction execution plans, detailed estimates with cost justification and schedules for four separate remediation options. General remediation options included excavation for either consolidation and cap-in-place or removal and disposal of impacted material within the Montrose facility and adjacent facilities owned by others. Each remedial option required limits to daily production and operations based on air emissions limits including compliance with SCAQMD and DTSC regulations.

Engineered Natural Treatment Systems Project, **Boeing Santa Susana Field Laboratory.** Provided on-site construction management/ owner's representative services. Coordinated operational and production limits based on air emissions limits. The project was performed in compliance with SCAQMD Rule 1150 and Rule 1166.

City of Los Angeles. Provided value engineering services and constructability review for $23M heavy civil construction project.

Chevron, *Huntington Beach, California.* Planned and managed the installation of a 30,000 CY soil surcharge prior to construction of a sports park. The location of the surcharge was previously the site of a crude oil and natural gas well. The site was immediately adjacent to and surrounded by residential areas. Engineering and administrative controls were utilized to control and mitigate VOC and mercaptan odors. Acted as the primary point of contact for local resident concerns regarding odor issues.

Davis-Monthan AFB. Provided onsite construction management services for consolidation of a 32 acre landfill at a cost of approximately $8.4 million dollars. Project work included location of LF interface, consolidation of trash, construction of a low permeable monolithic cap and excavation through trash to 40 feet adjacent to the 8 story air traffic control tower foundation to mitigate methane migration into the tower.

Pasadena Water and Power (PWP). Provided construction management/owner's representative services to for two electrical substation expansion projects that met schedule and were within budget. PWP stated that these were technically and operationally their most successful transformer, switchgear, capacitor bank installations in the last 30 years.

- Planned and managed technically challenging field work for successful removal and disposal of approximately 500,000 gallons of radio-isotope impacted water under companies' NRC license.
- Other projects include remediation, demolition and de-commissioning projects involving fuel, crude oil, lead, beryllium, chrome, mercury, and asbestos, unexploded ordinance, engineered landfill capping and gas collection projects, membrane liner installation, dig and haul remediation, marine construction, bulk fuel facility distribution and storage construction and retrofit and other remediation/construction projects.
- Planned and supervised implementation of engineering controls to control odor release during excavation and removal naphthalene-impacted material. Engineering controls included a tent, negative air and air filtration.
- Provided for worker and community safety for field operations including high hazard work and work with potential for release of hazardous substances into the surrounding community.
- Planned, conducted and supervised others conducting various types of air monitoring required for airborne migration of impacted substances, worker health and safety and gas-free engineering for hot work in confined spaces.

ADDITIONAL WORK EXPERIENCE

United States Marine Corps:

- Deputy program Manager, Environmental and Safety Program, First Marine Division, 1973-1996

- Nuclear, Biological, Chemical Warfare Defense Specialist, Various Commands and Locations, 1973-1996

TRAINING

40 hour HAZWOPER course
Hazardous Waste Site Supervisor Course

EXHIBIT B to Consultant Agreement

Geosyntec consultants

NICOLAS OETTLE
Staff Engineer

geotechnical engineering
geoenvironmental engineering

EDUCATION

California Polytechnic State University – San Luis Obispo, M.S. in Civil and Environmental Engineering, 2008

California Polytechnic State University – San Luis Obispo, B.S. in Civil Engineering, 2007

REGISTRATIONS AND CERTIFICATIONS

Engineer-in-Training, California, Number 127573

CAREER SUMMARY

Geotechnical Engineering

El Monte, California. Mr. Oettle is the task manager for providing geotechnical support services to a large groundwater remediation project. This project includes permitting for construction around an existing 81 in. storm drain, development of a geotechnical report, evaluation of seismic hazards, and development of recommendations for the construction of a groundwater treatment facility. Site complications include designing the facility to accommodate over 1 ft of liquefaction-induced lateral spreading and 8 in. of seismically induced settlement.

Tesoro Petroleum Refinery, Los Angeles. He was responsible for several geotechnical reports, including the design of new crude oil storage tanks in liquefiable alluvial deposits with significant risk of lateral spreading. Soft fat clays were also encountered with expected settlements on the order of liquefaction-induced settlements.

Mr. Oettle is experienced with geotechnical field investigation techniques including hollow stem auger drilling, Shelby tube sampling, Cone Penetration Testing (CPT), and trenching. He has conducted field investigations for a variety of clients including Tesoro Corporation, Waste Management, California State Lands Commission, Marsulex, a Superfund group, and the City of Los Angeles.

Bolsa Chica Wetlands, Orange County, California. Mr. Oettle worked as an assistant project manager to study a levee at the Bolsa Chica Wetlands. This study included two-dimensional, unsaturated-flow modeling using the finite element method. Results of the numerical modeling and site investigation were reviewed by at least six parties, including Jon Bray, Professor of GeoEngineering at UC Berkeley.

He is also experienced with providing construction related services such as engineering support and Construction Quality Assurance (CQA). Mr. Oettle was the lead field engineer for the construction of a 2,300-ft horizontal gas collection system at an abandoned landfill in Huntington Beach, California. Mr. Oettle oversaw compliance with the project documents; soil, asphalt, and concrete materials testing; and provided in-field engineering support.

While a graduate student at Cal Poly San Luis Obispo, Mr. Oettle served as the instructor for an undergraduate geotechnical laboratory course offered at Cal Poly. Mr. Oettle was responsible for providing the weekly lecture, overseeing laboratory activities, and assigning homework and class grades.

Mr. Oettle was also the Captain of the first ASCE GeoChallenge team from Cal Poly. The team consisted of three undergraduate geotechnical students and a graduate student, Mr. Oettle. He employed a risk-based design methodology which enabled the team to participate at the national level in New Orleans.

Geoenvironmental Engineering

Mr. Oettle has conducted landfill stability evaluations at seven landfills across Southern California. These sites include the Taft Sanitary Landfill, Bena Landfill, U.S.M.C. Twentynine Palms Waste Disposal Facility, Operating Industries Inc., Simi Valley Landfill and Recycling Center, Tajiguas Sanitary Landfill, and Calabasas Landfill. Mr. Oettle has utilized limit equilibrium approaches in both two- and three-dimensions.

Mr. Oettle has assisted with landfill design and permitting at many disposal facilities in Southern California. These sites include the Taft Sanitary Landfill, Lancaster Landfill and Recycling Center, Bena Landfill, eSolar, U.S.M.C. Twentynine Palms Waste Disposal Facility, Operating Industries Inc., Simi Valley Landfill and Recycling Center, Lopez Canyon Landfill, Los Alamitos Joint Forces Training Base Landfill, and Badlands Landfill.

For a proposed evaporation pond at a solar power generating station in Lancaster, California, Mr. Oettle performed a regulatory-required cost estimate as part of a Preliminary Closure and Post-Closure Maintenance Plan (PCPCMP). This type of cost estimate is required by the Integrated Waste Management Board (IWMB) before the development of a Class II or III Landfill.

Mr. Oettle conducted a waste characterization investigation in anticipation of a commercial development over a landfill at an EPA Superfund Site in Monterey Park, California. The investigation included excavation and sampling of waste; visual classification, sorting, and separation of waste components; and specialized geotechnical and compositional laboratory testing.

As a staff engineer, Mr. Oettle has been involved in providing Construction Quality Assurance (CQA) for both landfill liner and cover systems. CQA of these large earthwork projects has included field moisture and density testing, in-situ hydraulic conductivity testing, undisturbed Shelby tube sampling, and sampling of representative soil for geotechnical laboratory testing. Mr. Oettle is also familiar with documenting CQA activities in reports suitable to the RWQCBs.

He conducted a study to evaluate the potential for a "free-liquid" release as a result of a planned vertical expansion at a landfill in Taft, California. Mr. Oettle also conducted an evaluation of the long-term settlement potential for the existing waste fill and the proposal vertical expansion fill.

As a graduate student, Mr. Oettle conducted research into the thermal behavior of Municipal Solid Waste (MSW) landfills. In addition to creating guidelines for landfill-cover thermal problems, Mr. Oettle analyzed landfill-liner temperatures both experimentally and using the finite element code ABAQUS. Heat generation functions for the finite element model were calibrated using measured data from a number of landfills across the United States and Canada. The result of this research was a predictive model for temperature variation throughout a landfill based upon a number of input parameters.

Mr. Oettle participated in a project which developed optimum waste compaction procedures for MSW landfills. Laboratory tests were conducted to investigate the fundamental influence of moisture addition on the compaction characteristics of manufactured waste. Mr. Oettle used custom-built large-scale compaction molds for this testing program. Special guidelines were developed that adapted normal modified Proctor (ASTM D1557) compaction test procedures for large-scale testing of waste.

LIST OF PUBLICATIONS

Hanson, J. L., Yesiller, N., and Oettle, N. K., [2010], "Spatial and Temporal Temperature Distributions in Municipal Solid Waste Landfills," *Journal of Environmental Engineering*, in press.

Oettle, N. K., Matasovic, N., Kavazanjian, E. Jr., Rad, N. S., and Conkle, C. S. [2010], "Characterization of Municipal Solid Waste for Placement as Engineered Fill," *Global Waste Management Symposium 2010*, in review.

Yesiller, N., Hanson, J. L., Oettle, N. K., and Liu, W. [2008], "Thermal Analysis of Cover Systems in Municipal Solid Waste Landfills," *Journal of Geotechnical and Geoenvironmental Engineering*, Vol. 134, No. 11, pp. 1655–1664.

Hanson, J. L., Yesiller, N., and Oettle, N. K. [2008], "Spatial Variability of Waste Temperatures in MSW Landfills," *Proceedings, Global Waste Management Symposium 2008.*

Oettle, N. K., Hanson, J. L., and Yesiller, N. [2008], "Experimental Determination of Cover Surface Temperature Functions at MSW Landfills," *Proceedings, Global Waste Management Symposium 2008.*

Oettle, N. K. [2008], "Thermal Analysis of Landfill Barriers," *M.S. Thesis*, California Polytechnic State University, San Luis Obispo, CA.

AWARDS, PROFESSIONAL AFFILIATIONS, AND CERTIFICATIONS

- Distinguished Graduate Student, Cal Poly (2008)
- Nominated to be US Delegate for the Geo-Institute
- Associate Member, American Society of Civil Engineers
- Reviewer, Journal Geotechnical and Geoenvironmental Engineering
- Reviewer, Journal of the International Society for Soil Mechanics and Geotechnical Engineering
- Reviewer, ASCE GeoCongress 2008
- Certified, 40-hr OSHA HAZWOPER (29 CFR 1910.120(e))
- Certified, 24-hr First Responder: Operations Level (29 CFR 1910.120(q))
- Certified, First Aid and Adult CPR
- Certified Nuclear Moisture/Density Gauge Operator

PROFESSIONAL HISTORY

Geosyntec Consultants, Staff Engineer, 2008–present
Cal Poly San Luis Obispo, Research Assistant and Graduate Instructor, 2006–2008

EXHIBIT B to Consultant Agreement

Geosyntec
consultants

ALAN F. WITTHOEFT
Staff Engineer

geotechnical engineering
geoenvironmental engineering

EDUCATION

Purdue University, M.S.C.E., Civil Engineering, 2009
University of Oklahoma, B.S.C.E., Civil Engineering, 2007
University of Oklahoma, B.B.A., Economics, 2007

REGISTRATIONS AND CERTIFICATIONS

Engineer Intern No. 13967, State of Oklahoma

CAREER SUMMARY

Mr. Witthoeft received his Master of Science in Civil Engineering degree with geotechnical focus from Purdue University in 2009. He completed his undergraduate work at the University of Oklahoma (OU), where he earned both a Bachelor of Science degree in Civil Engineering and a Bachelor of Business Administration degree in Economics. As an undergraduate, Mr. Witthoeft co-authored three peer-reviewed technical papers. He was active with his universities' student professional organizations. His awards include the Frederick N. Andrews Fellowship in 2007, the ASCE GeoDenver Student Paper Competition in 2007, and the National Merit Scholarship in 2001.

His analysis proficiencies include ABAQUS, AutoCAD, FLAC, GeoStudio, and MATLAB. Mr. Witthoeft has worked as a research assistant at both Purdue University and the University of Oklahoma and worked part-time over five years as a survey technician. He joined Geosyntec Consultants in 2009, and hopes to advance his professional capabilities in geotechnical and geoenvironmental engineering.

REPRESENTATIVE PROJECTS

Marine Corps Air Ground Combat Center Landfill No. 2 Southern Expansion, Twentynine Palms, California. Updated calculation packages in support of design. Assisted on-site QC activities during construction of liner system.

Lopez Canyon Landfill, Sylmar, California. Assisted on- and off-site QC activities during construction of monolithic cover system.

Bradley Landfill, Sun Valley, California. Developed a rational design method for the anchorage of erosion protection mats.

Cesar Chavez Streetscape, Los Angeles, California. Supervised on-site geotechnical exploration activities. Evaluated suitability of the site for proposed infiltration features.

Badlands Sanitary Landfill, Riverside County, California. Performed static and pseudostatic slope stability analyses. Contributed to reports conveying the analysis results to the client.

LIST OF PUBLICATIONS

Witthoeft, A.F. (2009), "Modeling of Liquefaction Mitigation using Bentonite," *M.S. Thesis,* Purdue University, West Lafayette, IN.

Hatami, K., and Witthoeft, A.F. (2008), "A Numerical Study on the Use of Geofoam to Increase the External Stability of Reinforced Soil Walls," *Geosynthetics International*, Vol. 15, No. 6.

Hatami, K., Witthoeft, A.F., and Jenkins, L.M. (2008), "Influence of Inadequate Compaction near the Facing on the Construction Response of Wrapped-Face MSE Walls," *TRR*, No. 2045.

Hatami, K., and Witthoeft, A.F. (2007), "Reduction of Backfill Earth Pressure in Reinforced Soil Walls using Geofoam," *TRB 86th Annual Meeting*.

PROFESSIONAL AFFILIATIONS AND CERTIFICATIONS

- Associate Member, ASCE
- Engineer Intern, State of Oklahoma
- Certified, 40-hr OSHA HAZWOPER (29 CFR 1910.120(e))
- Certified, First Aid and Adult CPR
- Certified, Nuclear Moisture/Density Gauge Operator
- Chi Epsilon National Civil Engineering Honor Society

EXHIBIT B to Consultant Agreement

Geosyntec consultants

HENRY CHATMAN III
Site Manager

health and safety
solid waste management
Construction management
air water quality management
Construction Quality Assurance

EDUCATION

U.S. Army Chemical School, Ft. McClellan, AL: Chemical Operations, 1998

Cal Poly Pomona, Pomona, California, 1997

Polytechnic High School, Long Beach, California, 1997

REGISTRATIONS AND CERTIFICATIONS

Completion of Toxic Agent Training, Chemical Defense Training Facility, Ft. McClellan, AL, 1998

Radioactive Material Handling Safety, Armament and Chemical Acquisition and Logistics Activity (ACALA), Ft. Polk, LA, 1999

Environmental Compliance Officer Certification Course, EPA, Ft. Polk, LA, 2000

First Aid/CPR Blood borne Pathogen Awareness

OSHA Hazardous Waste Operators and Emergency Response Standard (29 CFR 1910.120(e)(8),(q)(8) and 8 CCR 5192(e)(q))

CAREER SUMMARY

Mr. Chatman has five years of experience as a chemical specialist in the U.S. Army, wherein he managed solid waste, hazardous materials, and hazardous waste. He also has over three years experience in groundwater monitoring with Blaine Tech Services. He is trained in pollution prevention, health and safety, and solid waste and air water quality management.

As a senior field technician Mr. Chatman used sampling methods such as MNA, micropurge, and flow well sampling. He has performed shallow soil sampling and dissolved hydrogen sampling. He is also proficient in developing wells and executing wellhead maintenance. Conventional methods used for purging groundwater are the 2-inch Grundfos Readiflo II pump; however, Mr. Chatman is readily familiar with the 3-inch electric sub pump, the peristaltic pump, the Wattera pump, QED bladder pumps, Sample Pro QED pumps and positive air displacement pumps. Mr. Chatman also has

experience setting packers at particular zones in various wells. He has also supervised field technicians and conducted pre-applicant screening in the interview process in the field.

Mr. Chatman has specialized in sites (including USEPA superfund and RCRA sites), refineries such as the Shell Oil Refinery in Bakersfield, California, and the Kinder Morgan Oil Refinery in Carson, California. He is unquestionably efficient in sampling chemical plants and terminals including, but not limited to, the Shell-Signal Hill Terminal, Shell Carson Plant Terminal, the Chevron Plant in Montebello, the Kinder-Morgan Terminal in Barstow, and the Port of Long Beach, the Shell Mormon Island terminal (also located in the Port of Long Beach), various naval and marine bases, such as Point Hueneme and Camp Pendleton, and multiple Honeywell sites. He is accomplished in gathering sampling data for landfills, DOE & DOD-USACE, AFCE, Navy Clean and Navy RAC sites. Mr. Chatman also has experience in geotechnical investigations, construction management, field CQA management, groundwater monitoring, soil sampling, contaminated soil excavations and gas extraction systems.

Home Depot, Burbank, California. Mr. Chatman has conducted weekly operation and maintenance on two soil vapor extraction and carbon treatment systems and one dual-phase extraction and carbon treatment systems designed to treat volatile organic compounds (VOCs) in site soil and groundwater. Operation and maintenance includes adjusting and maintaining vacuum blowers, transfer pumps, and an air compressor. He conducted weekly and monthly vapor monitoring and sampling of the carbon trains to maintain compliance with the SCAQMD permit and monthly sampling of the water carbon train to maintain compliance with the City of Burbank Sanitary Sewer permit. In addition, Mr. Chatman also conducted monthly SVE well field monitoring, monthly water level measurements in the groundwater monitoring well network, and quarterly groundwater sampling.

Hi-Shear, Torrance, California. Mr. Chatman conducted the operation and maintenance of a Catox System, designed to treat chlorinated hydrocarbons (PCE and TCE) at the site. Operation and maintenance includes water level monitoring, calibration and repair (as necessary) of float switches, pH probes, thermocouples, recirculation pumps and making general system electrical upgrades. He also conducted vapor monitoring of the Catox system on a weekly basis and conducts monthly sampling for laboratory analysis in accordance with the SCAQMD permit. In addition, Mr. Chatman completes the tri-annual groundwater monitoring of 12 groundwater monitoring wells at the Site.

Weiser Lock, Huntington Beach, California. Mr. Chatman conducted weekly maintenance of the ozone/hydrogen peroxide and granular activated carbon groundwater treatment system, including bag filter replacement, electrical component upgrades, and general system repair. He completes semi-annual sampling of 30 groundwater monitoring wells contaminated with PCE, TCE, 1,1,1-TCA, 1,4-dioxane, and other chlorinated hydrocarbons.

Concerto Groundwater Monitoring, Anaheim, California. Mr. Chatman conducted quarterly groundwater monitoring at the Site, which includes the sampling of 16 Continuous Multi-channel Tubing wells. Accordingly, he implements health and safety measures associated with Site-specific conditions, including traffic control.

Mesquite Landfill Groundwater Monitoring, Brawley, California. Mr. Chatman assisted in the installation of a groundwater monitoring network at the Site. His duties included: installation and development of groundwater piezometers and groundwater monitoring wells; conducting aquifer slug tests in monitoring wells and piezometers; and conducting aquifer step-drawdown, constant-rate pumping, and recovery tests in monitoring wells at low and high flow rates (<5 gpm and >800 gpm). Mr. Chatman also installed dedicated QED Environmental Systems, Inc. bladder pumps into Site groundwater monitoring wells, and conducts low flow groundwater sampling of the bladder pumps.

OII Landfill Superfund Site, Monterey Park, California – North Parcel Remedy. The North Parcel Remedy is a 8 million dollar design-build project that consists of relocation of waste, construction of surface water drainage features, relocation of gas, electric, and water conveyance system, and the construction of three cover systems (evapotranspirative, clay barrier, and GCL) over the waste mass. Mr. Chatman assisted the project manager by overseeing construction progress, management of subcontractors, tracking schedule progress and cost, and coordination of project documentation.

OII Landfill Superfund Site, Monterey Park, CA – Perimeter Liquid Control System. Mr. Chatman took the lead role of providing construction over site and management in the field to construct the North Central Perimeter Liquid Control (PLC) System, which consist of pumping subsurface liquids from extraction wells to the existing Liquid Treatment Plant. Control panels and a leak detection system was installed to automate the pumps and flow rates. Mr. Chatman worked closely with project manager to resolve field design modifications, managing the subcontractors' schedule and budget, and implementing a strict on site safety program.

Kettleman Hills Facility, Kettleman City, California – Landfill B-17 Phase A-1. Landfill B-17, Phase A-1 involved constructing a new 9-acre landfill at the Kettleman Hills Facility. This new landfill consisted of a double composite cell floor liner, new access roads, and a leachate collection facility. Mr. Chatman provided CQA for the liner installation.

Los Alamitos Landfill, Los Alamitos Joint Forces Training Base, Orange County, California. The Los Alamitos Landfill (LALF) is a Class III waste disposal facility owned by the U.S. Government. Mr. Chatman provided CQA assistance during the clear closure of the existing landfill and the development of a new landfill cell to contain the adjacent excavated wastes. Mr. Chatman conducted Nuclear Density test with the Troxler Nuclear Gauge and sand cone test along the foundation layer and Berm of the cell.

Olinda Alpha Landfill, Orange County, California – Additional Reservoir Storage. The Additional Reservoir Storage Project consisted of erecting a 100,000 gallon potable water tank and installing its associated piping and valves at the Olinda Alpha Landfill for Integrated Waste Management Department (IWMD) of Orange County. Mr. Chatman duties included monitoring and documenting project progress, and providing CQA services.

Bolsa Chica Lowlands Restoration, Huntington Beach, California – CQA Support. The Bolsa Chica site is approximately 1,250 acres of degraded coastal wetland that has been affected by oil field activities for 80 years. Mr. Chatman provided CQA services, which included the monitoring of approximately 2.7 million cubic yards of excavation/dredging, observing the removal and encapsulating of contaminated soils, soil sampling, performing conformance testing on over 4 miles of levees and three nesting sites for endangered birds, and addressing design changes brought forth by the contractor.

Fieldstone Property, Orange County, California – PCB Remediation. This project included the assessment, delineation, and remediation of a PCB-impacted parcel between residences and a sensitive wetlands ecosystem. The Department of Toxic Substances Control (DTSC), U.S. Fish and Wildlife Service, and the California State Lands Commission played significant roles in the project due to the sensitive nature of the site. Mr. Chatman monitored the removal of approximately 12,000 cubic yards of PCB impacted soils to hazardous and inert waste landfills.

Naval Weapons Station, Seal Beach, California – TCE Plume Remediation. GeoSyntec was contracted by the Navy to remediate the TCE plume found in the groundwater beneath the site using cultured bacteria to augment the natural degradation

of chlorinated solvents. Mr. Chatman assisted with the groundwater well development used to inject the KB-1 bacteria and monitor the progress of the TCE degradation.

Antelope Valley Public Landfill, Palmdale, California – Phase VA – 1 and 2. Waste Management is expanding laterally into Phase VA at the Antelope Valley Landfill. Mr. Chatman provided CQA services during the Phase VA-1 and VA-2 landfill expansions. The project consisted of excavating 2 million cubic yards of soil, constructing a 1-million cubic yard earthen berm, and installing a composite liner system. The composite liner system is comprised of a clay liner, geomembrane liner, and a geocomposite drainage system that was installed over 7 and 5 acres of prepared subgrade for Phase VA-1 and VA-2, respectively.

Waste Management - Bradley Landfill. Work on this project includes soils and compactions testing using nuke gauge and sand cone testing, contractor oversight, soil cover CQA, regulatory compliance and documentation.

Lisi Aerospace / Hi-Shear. Work on this project includes ground water sampling, well monitoring and maintenance and O&M on a soil vapor and ground water extraction systems.

Irvine Ranch Water District. Work on this project includes storm water remediation systems implementation and maintenance, contractor oversight and regulatory compliance and documentation.

Big Bear MDPA inspection. Work on this site includes construction oversight, SWPPP, storm water management, silt curtain monitoring, site observation and documentation.

Riverside Community College. Work on this site includes Phase 1 evaluation and soils testing, documentation and report compilation.

Montecito Storm water Sampling. Work on this site includes storm water sampling, SWPPP implementation, site runoff mitigation, observation and documentation.

Newport Banning Ranch. Work on this project includes operation and maintenance of a groundwater free-product skimmer unit, which is a solar-powered belt skimmer.

University of Riverside. At a previous employer Mr. Smith operated and maintained a T-100 mobile thermal remediation unit on a daily basis. He was responsible for the clarifier, oxidizer, scrubber, sludge pump, and auger systems, and his work included heavy equipment operation using loaders and excavators as well as welding, electrical troubleshooting, and general mechanics.

Riverside Community College. At a previous employer Mr. Smith preformed work on this site that included environmental sampling, storm water mitigation, Haz-Waste lab packing shipping and manifesting and drum removal.

East LA Battery Manufacturing Facility. At a previous employer Mr. Smith preformed work at this site that included corrosive spill containment and clean-up, site excavation and demolition, shipment and manifesting, backhoe and forklift operation, and worked with county and state officials to maintain regulatory compliance.

Lemon Grove Plating Facility. At a previous employer Mr. Smith preformed work on this site that included environmental sampling, packaging and transport of bulk liquid Hazardous Materials, building decontamination and demolition, and regulatory compliance.

PROFESSIONAL HISTORY

Geosyntec Consultants, Huntington Beach, California, 2007 to Present
Environmental Management Technologies, Riverside, California, 2005 to 2007
American Remedial Technologies, Lynwood, California, 2000 to 2002
Varner Construction Company, Riverside, California, 1999 to 2006

Geosyntec consultants

Attachment B-3

Dr. Matasovic's Landfill Experience Table

EXHIBIT B to Consultant Agreement

Neven Matasovic, Ph.D., P.E., G.E. ***Lead Geotechnical Engineer***

Education: University of California at Los Angeles: Ph.D., Geotechnical Engineering, 1993

Registration: Registered Geotechnical Engineer, California No. GE 2557

Registered Civil Engineer, California No. C 55861

Certification: 40-Hour OSHA-Trained 29 CRF 1910.120(e)(2) 8 CCR 5192

Years of Experience: 20

Relevant Project Experience: 15 years of landfill engineering in southern California; 20 years in geotechnical and earthquake engineering.

Project	Project/Task Management (PM/TM)	RWQCB & DWR Interaction	Large-Scale Exploratory Drilling	Geotechnical Lab. Testing and Data Evaluation	Slope Stability Evaluation	Pseudostatic Slope Stability Evaluation	Groundwater Flow Modeling	Seismic Hazard Evaluation	Seismic Site Response Analysis	Seismic Deformation Analysis
Altamont Sanitary Landfill	-	-	-	-	-	-	N/A	Yes	Yes	Yes
Anderson Landfill Modules 4 and 5	-	-	-	-	-	-	N/A	Yes	Yes	Yes
Antelope Valley Pub. Landfill No. 1	PM	Yes	Yes	Yes	Yes	Yes	-	Yes	Yes (2-D)	Yes
Arvin Sanitary Landfill	-	-	-	-	Yes	Yes	N/A	Yes	-	Yes
Azusa Landfill - Landfill Liner	TM	Yes	-	Yes	Yes	Yes	N/A	Yes	Yes	Yes
Azusa Landfill - Landfill Cover	TM	Yes	-	Yes	Yes	Yes	N/A	Yes	Yes	Yes
Azusa Landfill – Litigation Support	-	-	-	Yes	-	-	Yes	-	-	-
B&J Drop Box Landfill	-	-	-	-	-	-	N/A	Yes	Yes	Yes
Badlands Landfill Canyon 3 Phase 1 Liner	TM	Yes (DWR)	-	Yes	Yes (3-D)	Yes (3-D)	N/A	Yes	Yes (2-D)	Yes
Badlands Landfill Canyon 4 Phase 2 Liner	PM	Yes (DWR)	Yes	Yes	Yes	Yes	N/A	Yes	Yes	Yes
Badlands Landfill Final Buildout	PM	Yes (DWR)	Yes	Yes	Yes	Yes	N/A	Yes	Yes	Yes

Project	Project/Task Management (PM/TM)	RWQCB & DWR Interaction	Large-Scale Exploratory Drilling	Geotechnical Lab. Testing and Data Evaluation	Slope Stability Evaluation	Pseudostatic Slope Stability Evaluation	Groundwater Flow Modeling	Seismic Hazard Evaluation	Seismic Site Response Analysis	Seismic Deformation Analysis
Badlands Landfill Canyon 3 Phase 1 Uppermost Slopes Liner Repair CQA	PM	Yes	-	Yes	-	-	-	-	-	-
Badlands Landfill Stockpile Evaluation	PM	Yes	-	Yes	Yes	-	N/A	-	-	-
Bena Landfill Network 4	TM	-	Yes	Yes	Yes	Yes	N/A	Yes	Yes	Yes
Beriolas Landfill	-	-	-	Yes	Yes	Yes	-	Yes	Yes	Yes
Blackburn Landfill	-	-	-	-	-	-	N/A	Yes	Yes	-
Borrego Landfill	-	-	-	-	-	-	N/A	Yes	Yes	-
Bradley West Landfill	-	-	-	-	Yes	-	N/A	Yes	Yes	Yes
BRC Landfill	-	-	-	-	-	-	N/A	Yes	Yes	Yes
Brisbane Landfill	-	-	-	-	-	-	N/A	Yes	-	-
Buena Vista Drive Landfill	-	Yes (DWR)	-	-	-	-	N/A	Yes	Yes	Yes
Cajon Landfill	-	-	-	Yes	Yes	-	N/A	Yes	Yes	Yes
Calabasas Landfill '97 Cut CQA	PM	Yes	-	Yes	-	-	-	-	-	-
Calabasas Landfill '99 Cut CQA	PM	Yes	-	Yes	-	-	-	-	-	-
Calabasas Landfill Northern Slopes	PM	Yes (DWR)	-	-	Yes	Yes	N/A	Yes	Yes	Yes
Calabasas Landfill Clay Borrow Source Evaluation	PM	Yes	-	Yes	N/A	N/A	N/A	N/A	N/A	N/A
Calabasas Landfill SEC CQA	PM	Yes	-	Yes	-	-	-	-	-	-
Calabasas Landfill NRC Cut Geologic & Geotechnical Investigation	PM	Yes (DWR)	Yes	Yes	Yes (3-D)	Yes (3-D)	Yes	Yes	Yes	Yes
Calabasas Landfill OL-1 Monitoring Well Installation	PM	-	Yes (one well)	Yes	N/A	N/A	N/A	N/A	N/A	N/A

Project	Project/Task Management (PM/TM)	RWQCB & DWR Interaction	Large-Scale Exploratory Drilling	Geotechnical Lab. Testing and Data Evaluation	Slope Stability Evaluation	Pseudostatic Slope Stability Evaluation	Groundwater Flow Modeling	Seismic Hazard Evaluation	Seismic Site Response Analysis	Seismic Deformation Analysis
Casmalia Hazardous Waste Management Facility	TM	Yes (EPA)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Chateau Fresno Landfill	TM	-	-	Yes	Yes	-	N/A	Yes	-	-
Chiquita Canyon Landfill	TM	Yes	-	Yes	Yes	Yes	N/A	Yes	Yes	Yes
Coqui Landfill	TM	-	-	-	-	-	N/A	Yes	-	-
Cummings Road Landfill	TM	Yes (DWR)	-	-	Yes	-	N/A	Yes	Yes	Yes
Davis Street MRF	-	-	-	-	-	-	N/A	Yes	Yes	Yes
Decatur Landfill	-	-	-	-	-	-	N/A	Yes	Yes	Yes
Eagle Mountain Landfill	-	-	-	Yes	Yes	Yes	N/A	Yes	Yes	Yes
El Sobrante Landfill Phase VII Liner , Phase IX Expansion	TM	Yes	-	Yes	-	-	-	Yes	Yes (Phase IX)	Yes (Phase IX)
Forward Landfill	-	-	-	-	Yes	-	N/A	Yes	Yes	Yes
FRB Landfill	-	-	-	-	-	-	N/A	Yes	Yes	Yes
Fresno Sanitary Landfill	-	-	-	-	Yes	-	N/A	Yes	Yes	Yes
Gaffey Street Landfill	-	-	-	-	-	Yes	-	Yes	Yes	Yes
Georgia–Pacific East Landfill	PM	-	-	-	Yes	-	N/A	Yes	Yes	Yes
Gray Wolf Landfill	-	-	-	-	-	-	N/A	Yes	Yes	Yes
Heaps Peak Sanitary Landfill	PM	Yes	-	-	Yes (3-D)	Yes (3-D)	Yes	Yes	Yes (2-D)	Yes
Hillsboro Landfill, Cell IV	-	-	-	-	-	-	-	Yes	Yes	Yes
Keller Canyon Landfill	-	-	-	Yes	-	-	N/A	Yes	Yes	Yes
Kirby Canyon Landfill	-	Yes (DWR)	-	-	-	-	N/A	Yes	Yes	Yes
Lamb Canyon Landfill	PM	Yes (DWR)	Yes	Yes	Yes	Yes	N/A	Yes	Yes	Yes
Lancaster Landfill	PM	Yes	-	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Project	Project/Task Management (PM/TM)	RWQCB & DWR Interaction	Large-Scale Exploratory Drilling	Geotechnical Lab. Testing and Data Evaluation	Slope Stability Evaluation	Pseudostatic Slope Stability Evaluation	Groundwater Flow Modeling	Seismic Hazard Evaluation	Seismic Site Response Analysis	Seismic Deformation Analysis
Lopez Canyon Landfill	TM	Yes	Yes	Yes	Yes	Yes	N/A	Yes	Yes	Yes
Los Alamitos JFTB Waste Consolidation Cell	TM	Yes	Yes	Yes	Yes	Yes	-	Yes	Yes	Yes
McKittrick Waste Treatment Site	TM	Yes	-	-	-	-	Yes	Yes	Yes	Yes
Metaline Falls	-	-	-	Yes	Yes	-	Yes	-	-	-
Milliken Landfill	TM	-	-	-	Yes	-	N/A	Yes	Yes	Yes
NSF-Sponsored Project on Behavior of Landfills in Northridge Earthquake	TM	N/A	-	Yes	Yes	Yes	N/A	Yes	Yes (2-D)	Yes
NSF-Sponsored Project on Stat. And Dynamic Properties of MSW	PM	N/A	Yes	Yes	N/A	N/A	N/A	N/A	N/A	N/A
North Shelby Landfill	-	-	-	Yes	Yes	Yes	N/A	Yes	Yes	Yes
Oak Ridge Sanitary Landfill	TM	N/A	-	Yes	-	-	-	Yes	Yes	-
OII Landfill Superfund Site	TM (3 Tasks)	Yes (EPA)	Yes	Yes	Yes	Yes	-	Yes	Yes (2-D)	Yes
Olinda Alpha Sanitary Landfill	-	-	-	Yes	Yes	Yes	N/A	Yes	Yes	Yes
Olympic View Sanitary Landfill Phase I and Phase II North	PM	Yes (SOW)	-	Yes	Yes	Yes	N/A	Yes	Yes	Yes
Olympic View Sanitary Landfill Phase II Stage B Liner	-	-	-	-	Yes	Yes	N/A	Yes	Yes	Yes
Ox Mountain Landfill	-	-	-	Yes	-	-	-	Yes	Yes (2-D)	Yes
Pacheco Pass Landfill	-	-	-	Yes	-	-	-	Yes	Yes	Yes
Puente Hills Landfill 2003 & 2013 Configurations	PM	Yes (DWR)	-	Yes	Yes	Yes	N/A	Yes	Yes (2-D)	Yes
Puente Hills Landfill Phase V Liner	PM	Yes	-	Yes	Yes	Yes	N/A	Yes	Yes	Yes
Puente Hills Landfill Phase 1 B	TM	-	-	Yes	Yes	Yes	-	Yes	Yes	Yes

Project	Project/Task Management (PM/TM)	RWQCB & DWR Interaction	Large-Scale Exploratory Drilling	Geotechnical Lab. Testing and Data Evaluation	Slope Stability Evaluation	Pseudostatic Slope Stability Evaluation	Groundwater Flow Modeling	Seismic Hazard Evaluation	Seismic Site Response Analysis	Seismic Deformation Analysis
Puente Hills Landfill SASW Surveying	TM	N/A	-	Yes	-	-	-	-	-	-
Puente Hills Landfill Strong Motion Network (Accelerometer)	PM	Yes	-	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Redwood Landfill	-	-	-	Yes	Yes	Yes	N/A	Yes	Yes	Yes
Riverbend Landfill	-	-	-	-	-	-	-	Yes	Yes	Yes
Shafter-Wasco Landfill	-	-	-	-	Yes	Yes	-	Yes	Yes	Yes
Simi Valley Landfill	-	-	-	-	-	-	-	Yes	Yes	Yes
Sonoma County Central Landfill	-	Yes (DWR)	-	-	-	-	-	Yes	Yes	Yes
State Roads 41 and 91 San. Landfill	-	-	-	Yes	Yes	Yes	-	Yes	Yes	Yes
Sunshine Canyon Landfill (County Extension Phases I, II & III; City JTD; City / County JTD)	PM (Phase II Fnl. Buildout) TM (7 Tasks)	Yes (DWR on 6 projects)	Yes	Yes	Yes (3-D)	Yes (3-D)	Yes (one project)	Yes	Yes (six 2-D models)	Yes
Sycamore Landfill	-	-	-	-	-	-	-	Yes	Yes	Yes
Taft Landfill	-	-	-	-	-	-	-	Yes	-	-
Tajiguas Landfill Phase 2A	PM	Yes	-	Yes	Yes	Yes	-	Yes	Yes	Yes
Tri-Cities Landfill	-	-	Yes (NSF)	Yes	-	-	-	Yes	Yes	Yes
Toland Road Lfd. (Final Cover)	TM	-	-	-	Yes	Yes	-	Yes	Yes	-
Vasco Road Landfill	-	-	-	Yes	Yes	Yes	N/A	Yes	Yes	Yes
Waimanalo Gulch Sanitary Landfill	-	-	-	-	-	-	-	Yes	Yes	Yes

N/A=Not Applicable; TM=Task Manager; PM=Project Manager; 2-D=Two-Dimensional Seismic Site Response Analysis; 3-D=Three-Dimensional Slope Stability Analysis; EPA=US Environmental Protection Agency; RWQCB=Regional Water Quality Control Board; DWR=Department of Water Resources; SOW=State of Washington Department of Ecology; NSF=National Science Foundation.

Geosyntec
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Attachment B-4

2010 State-of-the-Art Paper / Presentation on Seismic Design of Landfills by Dr. Matasovic

EXHIBIT B to Consultant Agreement

Fifth International Conference on
Recent Advances in Geotechnical Earthquake Engineering and Soil Dynamics
and Symposium in Honor of Professor I.M. Idriss
May 24-29, 2010 • San Diego, California

RECENT ADVANCES IN SEISMIC DESIGN OF GEOSYNTHETICALLY-LINED WASTE CONTAINMENT FACILITIES

Neven Matasovic
Geosyntec Consultants
2100 Main Street, Suite 150
Huntington Beach, California-USA 92648

ABSTRACT

Geosynthetic materials are essential elements of almost all modern landfill barrier systems. Materials such as geomembranes and geosynthetic clay liners are widely used as resistive barrier elements while geotextiles, drainage nets, and geocomposites are widely employed in modern composite barrier systems for both landfill liners and covers. The ability of these geosynthetic elements to maintain their integrity when subject to deformations due to waste settlement and seismic loading is a major uncertainty with respect to the performance of modern landfills. Over past years, advances have been made in understanding of material behavior under cyclic loading, modeling of modern landfill response to strong ground shaking, and interpretation of the analysis results. This paper presents, by reference, results of relevant recent research including advances in evaluation of dynamic material properties of municipal solid waste (MSW) and special wastes, dynamic testing of barrier system interfaces, understanding of decoupled and fully coupled response analysis, and advances in constitutive and numerical modeling relevant to better modeling of seismic response of modern landfills. Based upon the synthesis of this information, it is concluded that the commonly used decoupled approach is reasonably conservative and can be used for seismic design of modern waste containment facilities until fully coupled approach and associated evaluation and modeling of interface parameters evolve to be usable from both the practical and economic points of view.

INTRODUCTION

Modern solid and hazardous waste landfills are lined, and in many cases capped by composite barrier systems. The term composite barrier system refers to a liner or cover system composed of either compacted clay liner (CCL), or Geosynthetic Clay Liner (GCL), overlain by a geomembrane (GM). This type of barrier systems has been mandated for hazardous waste landfill liner and final cover systems in the United States since 1985 (Subtitle C Regulations), and for new construction and lateral expansions of municipal solid waste (MSW) landfills since 1993. The 1993 regulations for MSW landfills, commonly referred to as Subtitle D, imply that MSW landfills with geomembranes in the basal liner system should be capped with a cover system that includes a GM. Composite final cover systems, or caps, that contain GMs are also widely used for remediation at Federally-mandated corrective action sites, including Superfund sites. Subtitle D regulations mandate that landfills in approximately 40% of the continental United States must be designed to resist seismic loading.

While the regulations mandating geosynthetic liner and cover systems typically prescribe that the GM be underlain by a compacted clay liner (CCL), they also usually allow for the use of engineered alternatives to the prescriptive barrier. Under these provisions, GCLs, which are 6 mm-thick layers of sodium bentonite sewn or needle-punched between two geotextiles or glued to a carrier geomembrane, have become established as a preferred alternative to a CCL in the composite barrier. This substitution is particularly advantageous for side-slope liner systems in canyon landfills where steep slopes make construction of a CCL difficult and expensive, if not prohibitive. GCLs also offer the benefits of faster construction, more consistent quality, lower cost if high quality clay is not locally available, increased useable airspace, and reduced environmental impacts during construction.

Other geosynthetic elements routinely used in landfill liner and final cover construction include geotextile filters to protect drainage layers from clogging, geotextile cushions to protect geomembranes from puncture, drainage nets and

prefabricated drainage geocomposites. Stacked cylindrical geotextile tubes and bags (geotubes) have also been used for containerized disposal of special wastes, sludges, and contaminated sediments. Figure 1 shows a typical base and side-slope liner system for a canyon landfill in California. The base liner employs a CCL and GM to form a composite liner while two alternative configurations (with GCL and CCL) are shown for the side-slope liner. Base liner systems and composite final cover systems of modern landfills outside California often have configurations similar to Fig 1.

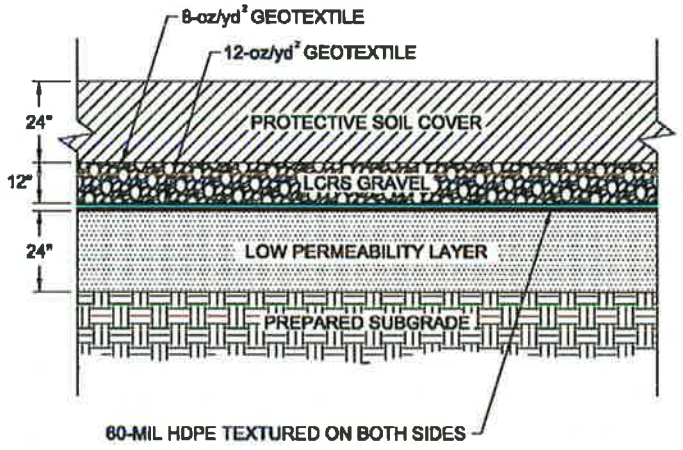

Fig. 1a. Typical composite base liner system of modern landfill.

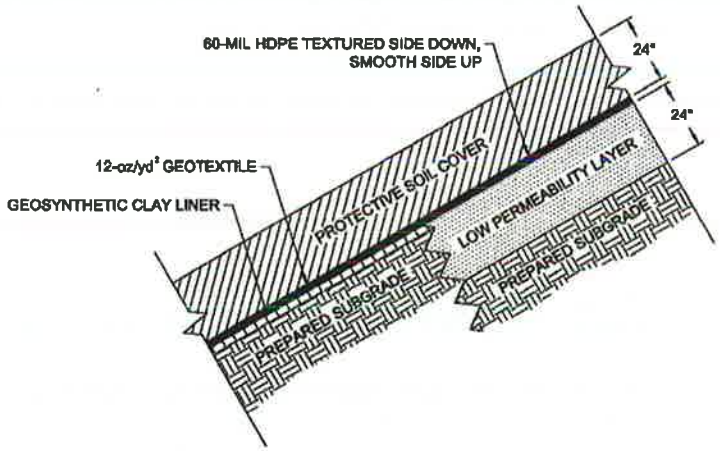

Fig. 1b. Typical composite side-slope liner system of modern landfill.

Seismic analysis techniques conducted in support of closure design of existing landfills and design of modern landfills are essentially the same as those used for seismic design and analysis of earthfill and rockfill dams. However, as seismic response of modern landfills is governed by response along the composite liner interfaces, special considerations are required to evaluate the response. These considerations include evaluation of the material properties of the liner system, modeling of liner system interfaces, evaluation of the material properties of waste, and numerical modeling considerations that are explained in this paper.

DYNAMIC MATERIAL PROPERTIES

General

The material properties required for evaluation of seismic response of modern landfills include the unit weight, shear modulus, internal (material) damping, and Poisson's ratio of waste. The variation of these properties with shear strain amplitude and effective confining pressure is also important. For the decoupled site response – seismic deformation analysis explained below, an extended set of material properties is required. This extended set includes, in addition to the properties listed above, the shear strength parameters of waste and along the composite liner and cover interfaces. Both peak and residual shear strength parameters may be required for evaluation of the stability of the composite liner and cover interfaces.

Fig. 2. MSW landfilling operation at a canyon landfill.

Municipal Solid Waste and Bioreactor Landfills

Most of the waste generated in the United States and abroad is MSW. MSW disposed of in modern landfills is often stripped of paper, glass and other recyclables, is subject to a certain disposal restrictions, and is often compacted during placement in approximately 3-m thick lifts. Typical waste disposal procedures call for placement of at least 150-mm of soil or an approved alternative material over the waste at the end of each day. After placement in a landfill, MSW undergoes significant volumetric compression under self-weight and is subject to decomposition and additional compressibility. This results in a relatively large settlement not only during filling operations but also after landfill closure (e.g., Edil et al. 1990, El Fadel et al. 1999, Park et al. 2002). A MSW landfill will typically settle

approximately 15 to 20% of the overall waste thickness after closure, and these settlements are in addition to the significant settlement (due to both self-weight and decomposition) that occurs during waste placement. As the maximum earthquake, i.e., design seismic event with return period of 500 to 2,500 years is likely to occur following landfill closure, many engineers choose to base the seismic design of MSW landfills upon dynamic material properties evaluated by testing "older" (50 to 60 year old) waste.

Several researchers tested samples of "older" MSW for various purposes. Kavazanjian (2006) and Zekkos et al. (2007) provide a recent summary and interpretation of relevant testing programs. Matasovic and Kavazanjian (1998), Matasovic et al. (1998), and Kavazanjian et al. (1999) developed a consistent (i.e., properties developed by in-situ and laboratory testing and back-analysis of response of the same waste to ground shaking) set of dynamic and static (shear strength) material properties suitable for seismic design of MSW landfills. This work included development of 457-mm diameter Cyclic Direct Simple Shear (CyDSS) and Cyclic Direct Shear (CyDS) devices suitable for testing of MSW samples recovered by large-diameter bucket auger drilling. The CyDSS device developed for this work is shown in Figure 3 and is described in greater detail in Matasovic et al. (1998).

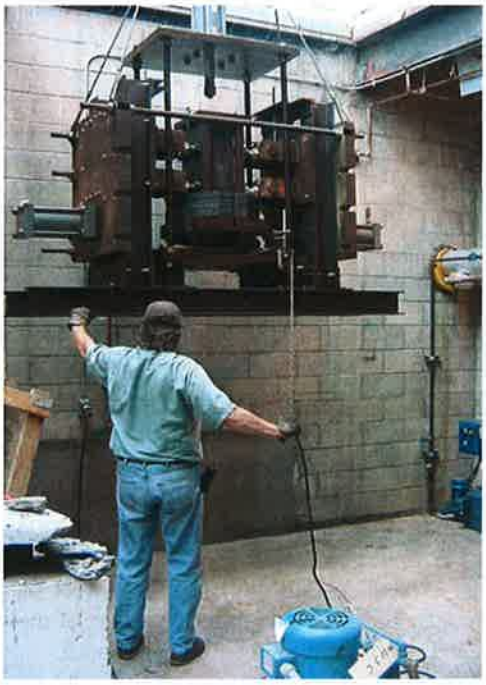

Fig. 3. Large-diameter CyDSS apparatus (currently at Arizona State University).

The in-situ testing program coupled with the laboratory testing program conducted using the above shown and described CyDSS and CyDS devices, and supplemented by back analysis of on-site recorded strong motions resulted in a consistent set of MSW properties, including the unit weight, Poisson's ratio, and shear wave velocity profiles for "older" waste. This set of material properties is presented, along with the modulus reduction and damping curves of the same waste, in Matasovic and Kavazanjian (1998). The shear strength envelope of this waste is presented in Kavazanjian et al. (1999).

In the areas of high seismicity, such as the West Coast of the United States, seismic design of modern MSW landfills often includes evaluation of interim stability of lined waste fills. As interim condition of landfill development is not anticipated to last more than few years, material properties of "young" waste may be appropriate for interim seismic design evaluations. Zekkos et al. (2007a) performed over 90 large-scale cyclic triaxial (CTX) tests on 300-mm diameter specimens for three sample groups of solid waste with ages ranging from less than 2 years old to 15 years old collected from a northern California landfill. The generic material properties from this study include unit weight profile, modulus reduction and damping curves (up to approximately 0.8 percent shear strain) and shear strength envelope.

It is not clear if seismic design of MSW landfills based upon generic (both "young" and "older" MSW) material properties is reasonably conservative, and if it is, to what degree. Athanasopoulos-Zekkos et al. (2008) attempted to evaluate how adequate (i.e., conservative) seismic design of MSW landfills based upon published generic material properties is. The basis for the evaluation was one of very few well documented landfill case histories, the OII Landfill, California case history (see, e.g., Augello et al., 1995; Matasovic and Kavazanjian, 1998; Elgamal, 2004) and generic material parameter sets. The results indicated that the use of generic material parameter sets, at this site results (bedrock Peak Horizontal Ground Acceleration, PHGA $\approx$ 0.1 g), in either reasonable prediction or slight over-prediction of recorded ground motions.

Bioreactor landfills are MSW landfills where significant amount of liquid is injected into waste mass to enhance and speed-up volumetric compression due to decomposition. Shear strength parameters of waste disposed of in bioreactor landfills are discussed in Kavazanjian (2001), Bachus et al. (2004), Gabr et al. (2007), and Reddy et al. (2009). The available data indicate that the primary impact of leachate recirculation and bioreactor technology on the mechanical properties of MSW is an increase in waste unit weight. Kavazanjian (2006) postulated that MSW shear strength is largely unaffected by liquid addition or enhanced degradation when viewed on an effective stress basis while stiffness (i.e., modulus reduction and damping) is impacted only to the extent that stiffness depends upon unit weight.

Kavazanjian et al. (1999) measured relatively large volumetric strains of up to 5% during large-diameter CyDSS testing of MSW recovered from saturated zones of the OII Landfill. These measurements suggest that there is a potential for development of excess porewater pressure due to cyclic loading of saturated waste. The magnitude of this pressure and its impact on landfill stability may require special

attention with respect to seismic design of bioreactor landfills in areas of high seismicity.

Special Wastes

The special waste category includes wastes ranging from asbestos, fly ash, and shredded tires to containerized liquid waste and fine grained contaminated sediments and sludges disposed of by means of geotubes Typical containerized liquid waste disposal practice is shown in Figure 4. The disposal (consolidation) of contaminated sediments by means of stacked geotubes is shown in Figure 5.

Fig. 4. Disposal of containerized liquid waste (Matasovic et al., 2006).

The seismic design of geosynthetically-lined special and mixed waste landfills is based, like its MSW counterpart, upon generic material properties. However, limited information on dynamic and shear strength properties of special wastes is available. Matasovic et al. (2006) provided a shear wave velocity profile for design of containerized liquid waste landfills and undrained shear strength of these materials. Zhu et al. (2010) developed generic shear strength parameters and a method for evaluating the stability of a landfill constructed from stacked Geotubes filled with fine-grained sediments.

Fig 5. Sediment disposal using flat geotubes (Zhu et al., 2010).

Poran et al. (1994) measured shear wave velocity in the Town of Babylon, New York, ashfill. Ash disposed of at that site was generated by the Town's waste-to-energy facility. Results from the Poran et al. (1994) measurements are compiled in Figure 6 and are further processed to include a "recommended" curve for seismic design of ashfills. Cappai et al. (1999) report shear strength parameters for incinerated MSW (ash from waste-to-energy facilities) that can be used for design until more data on ashfill shear strength and other properties become available.

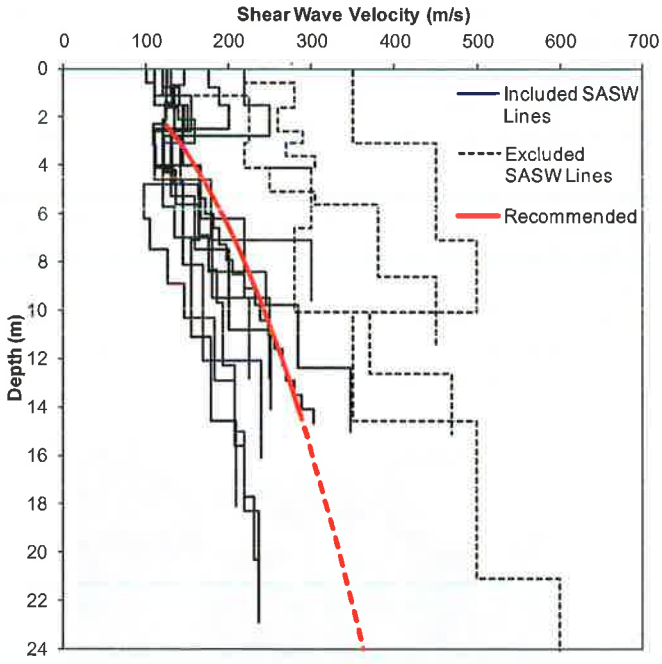

Fig 6. Shear wave velocity measurements in Town of Babylon, New York ashfill and "recommended" curve for seismic design of ashfills.

DYNAMIC IN-PLANE SHEAR STRENGTH

There is ample information on the in-plane (interface and internal) static shear strength of modern composite liner systems (e.g., Mitchell et al. 1990, Stark and Poeppel 1994, Stark et al. 1996, Chiu and Fox 2004). This body of information is constantly expanding as (static) interface direct shear testing is routinely mandated and performed as a part of modern landfill design and construction quality assurance. However, information on dynamic interface and internal shear behavior (e.g., on interface strength under cyclic loading conditions), is sparse. Information vital to dynamic analysis such as rate-dependent effects, cyclic stress ratio versus number of cycles to failure, hysteretic stress-strain relationships, and shear stiffness and damping, is almost non-existent for composite liner interfaces.

In a few cases, composite landfill liner and cover interfaces have been tested under dynamic loading conditions. Most of

these studies have been conducted using shaking tables or centrifuges. Representative studies include work by Kavazanjian et al. (1991), Yegian and Lahlaf (1992), De and Zimmie (1998), Yegian et al. (1998), Yegian and Kadakal (1998a and 1998b), and Kim et al. (1995). Most of these tests are shaking table tests, which due to the equipment limitations, are constrained to very low normal stresses (< 50 kPa), dry conditions, and/or small specimens (300 by 300 mm). Furthermore, these studies have generally investigated interfaces between geomembranes, geonets, and geotextiles, and did not include GM-CCL or GM-GCL interfaces, which are the most critical interfaces in many cases. For example, prior to the recent large diameter cyclic shear test results on a needle-punched GCL reported by Nye and Fox (2007) and Fox et al. (2009) (see Figures 7 and 8), the only detailed information available on the dynamic behavior of GCLs was from direct simple shear tests performed on small specimens of an unreinforced GM-supported GCL by Lai et al. (1998).

Fig 7. Large-diameter cyclic direct shear machine used by Nye and Fox (2007).

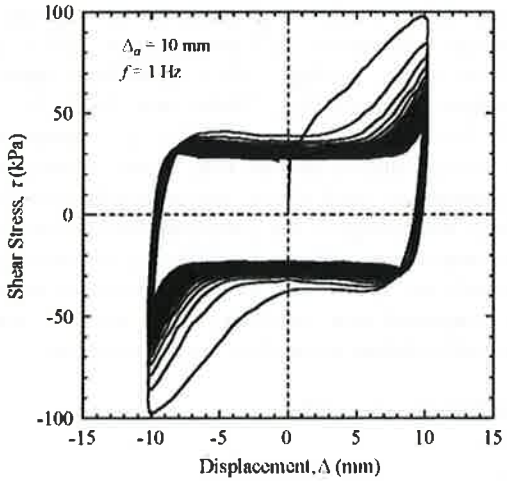

Fig 8. Dynamic internal shear test of GCL results by Nye and Fox (2007).

While the Nye and Fox study is the most informative study on the dynamic behavior of GCLs to date, these tests were all conducted at a normal stress of 141 kPa and thus are of limited use for design of modern lined landfills where design normal stresses may range from 500 to 2,000 kPa. Additional test data are needed on the load-deformation behavior of many other potentially critical landfill liner materials and interfaces during dynamic loading, particularly under moderate and high normal stress conditions.

SIMULATIONS, PHYSICAL MODELING, AND OBSERVATIONS

Simulations of MSW Settlement Impact

Fowmes et al. (2005; 2006) simulated the behavior of a side-slope composite landfill liner system subject to MSW settlement. The simulation was performed by means of the finite difference method as coded in the computer program FLAC™ (www.Itasca.com). The results of Fowmes et al. (2005; 2006) study numerically confirmed what many engineers suspected, but few have observed – that MSW settlement can induce significant tensile strains in geosynthetic components of side-slope composite liner system. The consequences of this finding are twofold: (i) cushion geotextile, with its relatively low axial strength, may lose its integrity and hence leave portions of the primary barrier (GM) unprotected, as illustrated by Dixon and Jones (2005) and reproduced in Figure 9; and (ii) significant axial stress (and strain) in GM may develop. Both of these consequences may be exacerbated by seismic loading. Besides inducing the MSW settlement, seismic loading may induce transient and residual strains in GM, as demonstrated by the centrifuge testing discussed below.

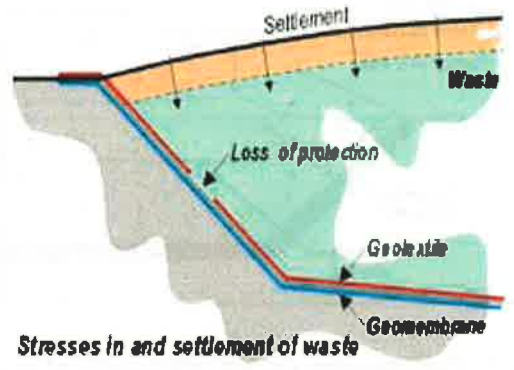

Fig.9. Impact on side-slope liner geomembrane due to static (and seismic) settlement (Dixon and Jones 2005).

Physical Modeling of Landfill Response

To achieve model similitude, "model" waste is required for use in centrifuge simulations of modern landfill response to strong ground shaking. Thusyanthan et al. (2006a; 2006b) developed "model" waste and, by the means of the Cambridge University,

United Kingdom, centrifuge and modified Equivalent Shear Beam (ESB) container (shown in Figure 10), conducted a series of static and dynamic tests. The models were of general configuration shown in Figure 11 and included 15-m thick waste fill with relatively steep (1Horizontal: 1Vertical) side-slopes. The later series of tests included a composite liner system placed over landfill base and side-slopes. Partial test results are presented in Figure 11 while test details and a full set of results are presented in Thusyanthan et al., (2006a; 2006b; and 2007).

Fig. 10. Equivalent Shear Beam (ESB) container (Thusyanthan et al., 2007).

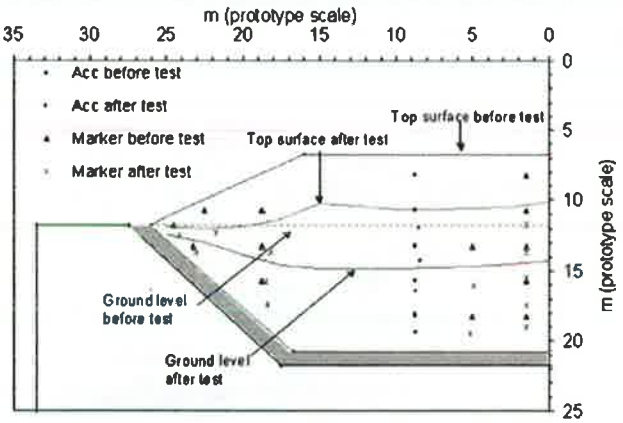

Fig. 11. Post-centrifuge test settlement profile of the landfill model (Thusyanthan et al., 2006b).

The tests were validated by comparing the measured material properties to their counterparts evaluated by testing actual MSW. The interpretation of the initial test results in terms of recorded acceleration and settlement values. Cracking corresponding to approximately 500 mm of prototype displacement at the toe of waste slope was also observed. The observed settlement profile and cracking indicated that notable tension may develop in the landfill side-slope liner. The results of subsequent centrifuge testing with instrumented side-slope liner indicated that significant transient and residual strains in the GM of the side-slope liner can be induced by shaking. For the model base excitation of 0.08 g, during shaking, the relative increase (i.e., compared to the static settlement induced strain) was up to 25%. The residual value was 15%. For model base excitation of 0.2 - 0.3 g, the transient increase was up to 40%, with residual value of up to 25%.

Observations

Interpretation and analysis of observational data on the performance of solid waste landfills during earthquakes is the most reliable source of information on the seismic response of solid waste landfills. The data from several major earthquakes (see, e.g., Matasovic et al. 1995; Augello et al., 1995; Matasovic and Kavazanjian, 1996; Matasovic et al., 1998; Matasovic and Kavazanjian, 2006) indicate that the general performance of landfills during earthquakes is from good to excellent. However, only two landfills lined with geosynthetic liner systems designed in compliance with modern (e.g., EPA Subtitle D) standards have been subjected to strong ground shaking (bedrock PHGA in excess of 0.3 g) in a large magnitude (**M** 6.7) earthquake. The only modern geosynthetically-lined landfill that suffered some limited damage to the containment system (Chiquita Canyon Landfill in greater Los Angeles) was subject to bedrock PHGA of approximately 0.25 g. The observed damage (i.e., tear in 1.5-mm thick, smooth GM) was above the waste and hence did not result in a release of contaminants to the environment).

Implications

Studies by Fowmes et al. (2005; 2006) and Thusyanthan et al., (2006a; 2006b; and 2007) indicate that relatively large MSW settlement may induce relatively large (initial) shear and axial stress in GM and GCL of side-slope composite liner system, and that both stresses (and axial strain) can be exacerbated by strong ground shaking. Both studies are limited, however, to certain waste fill thickness, waste material properties, side-slope liner material properties and geometry as explained above. Furthermore, simulations by Fowmes et al. (2005; 2006) are limited to static loading, while centrifuge modeling by Thusyanthan et al. (2006a; 2006b; and 2007), is limited to bedrock PHGA of approximately 0.3 g. Nevertheless, the results of these studies indicate that, under certain combination of the parameters listed above, and especially in areas of high seismicity, the damage to the composite landfill side-slope liner systems may occur. Given the difficulty of detecting damage in a burred liner system, the National Research Council (NRC, 2007) recognized that possibility as a serious concern and recommended further research of the phenomenon.

METHODS OF ANALYSIS

General

The seismic design of modern geosynthetically-lined and capped waste containment facilities is not bound by a single

method of analysis. The conventional, stress-based pseudostatic analysis with the seismic coefficient treated as an empirical constant and applied in a horizontal direction is widely used in areas of low to moderate seismicity. Modern, performance-based analysis, is more frequently used in the areas of high seismicity. However, performance-based analysis is rapidly gaining acceptance in areas of moderate seismicity.

In the performance-based analysis of landfill response to strong ground shaking, a performance criterion is established in terms of maximum allowable calculated permanent seismic displacement. The performance analysis may be conducted as either a decoupled analysis or as a fully coupled analysis, as explained below.

Decoupled Approach

The *decoupled* approach to seismic analysis was originally developed by Seed and Martin (1966) for earth dams. The approach was further improved by Ambraseys and Sarma (1967), and Makdisi and Seed (1978). Since promulgation of Subtitle D in 1993, this approach has been used for seismic design and analysis of existing landfills (e.g., Kavazanjian et al., 1995; Augello, et al., 1995; Kavazanjian and Matasovic, 1995). Recently, this approach has been used to develop a chart (spreadsheet) solution applicable to seismic deformation analysis of modern landfills by Bray and Travasarou (2007).

In the decoupled approach, the deformation potential of the failure (sliding) mass and seismic response of the earthern structure are evaluated independently. The two are then "coupled" together via the Newmark-type (Newmark, 1965) seismic deformation analysis which is based upon double integration of average acceleration of sliding mass above a pseudostatically-evaluated yield acceleration. Even though this decoupled approach is a significant improvement over conventional pseudostatic analysis, it has significant limitations. Furthermore, when compared to more rigorous *fully coupled* seismic deformation analysis methods and results of physical modeling, the decoupled approach has been shown to be generally conservative. Relevant studies include Lin and Whitman (1983), Gazetas and Uddin (1994), Kramer and Smith (1997), Rathje and Bray (1998; 2000), and Wartman et al. (1999; 2003; and 2005). These authors have demonstrated that, when applied to typical waste fills (up to 100 m thick), the decoupled approach typically overestimates the calculated permanent seismic displacements by at least a factor of two.

Indirect improvements of the decoupled approach include a better understanding of dynamic in-plane interface shear strength testing (see above), the ability to test composite liner and cover interfaces at larger displacements, and improvements in selection of design ground motions. The direct improvements include advances in and promulgation of the advanced site response analysis methods (see, e.g., Hashash et al., 2010), improvements to pseudostatic evaluation of yield acceleration, and improvements of the conventional Newmark-type analysis. Improvements in evaluation of the yield acceleration of the sliding mass are modest, at best, and include such improvements as a search for the lowest calculated yield acceleration by means of the conjugated gradient method and composite (straight line – circle, see Figure 12) failure surfaces. However, these improvements typically only marginally affect the results of the seismic deformation analysis.

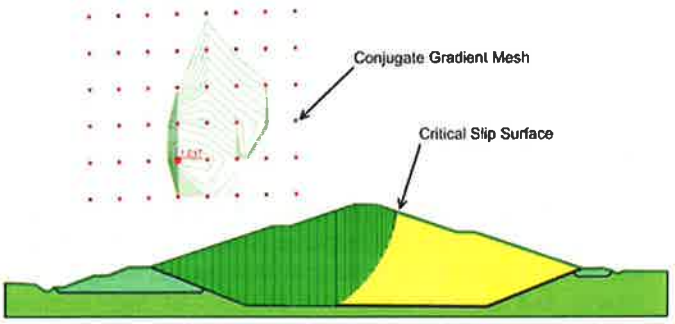

Fig 12. Pseudostatic limit equilibrium analysis of lined landfill with composite failure surface and conjugated gradient method-based search algorithm (GeoSlope International).

Enhancements to the Newmark-type analysis include introduction of the vertical acceleration component into the analysis by Yan et al. (1996) and use of a degrading yield acceleration by Matasovic et al. (1996). Figure 13 schematically compares the conventional Newmark analysis and Newmark analysis with degrading yield acceleration.

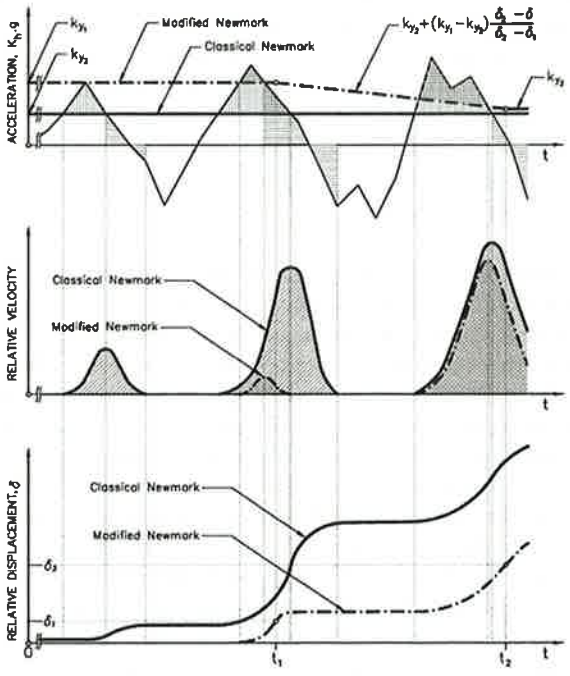

Fig 13. Comparison of the classical and modified (degrading yield acceleration) Newmark-type integration schemes Matasovic et al. 1998).

Matasovic et al. (1998) further extended the Newmark-type analysis to include the effects of two-way sliding. The study by Matasovic et al. (1998) demonstrated that the conventional Newmark-type seismic deformation analysis is conservative when applied to composite liner and cover interfaces with a pronounced difference between peak and residual shear strength. The degree of conservatism depends to a large extent upon the value of the calculated seismic deformation compared to the threshold deformations at which the peak and residual strengths are mobilized.

Fully Coupled Analysis

Fully coupled analysis, with seismic deformation evaluated as an integral part of the site response analysis, is being used with increasing regularity for seismic evaluation and design of dams, wharfs, and earthern structures in areas of high seismicity. However, the implementation of this approach in the seismic design of modern, geosynthetically lined landfills has been slow. This is primarily due to the difficulties associated with modeling of the dynamic behavior of liner and cover interfaces and the assessment of the relevant material properties along those interfaces.

The fully coupled approach is extremely powerful as it allows consideration of the potential beneficial impact of sliding at geosynthetic interfaces on the response of the overlying waste and final cover. It also facilitates direct assessment of the stresses induced in liner system elements. Both are factors not assessed in current state-of-the-practice analyses. The beneficial effect of sliding at an interface, commonly referred to as the "base isolation effect," was first discussed by Kavazanjian et al. (1991) and Yegian and Lahlaf (1992) for geosynthetic base isolation of structures. Kavazanjian and Matasovic (1995) demonstrated by numerical modeling (program D-MOD2000; www.GeoMotions.com), that this beneficial effect significantly reduces the acceleration and displacement response of a waste mass overlying a modern landfill barrier system.

In addition to accommodation of the base isolation effects, the fully coupled approach allows for calculation of dynamically induced stresses and inclusion of the initial static (shear and axial) stress into the analysis. Fowmes et al. (2005) have shown that, even without a dynamic stress increment, the initial static stresses may cause tensile tearing of composite liner components. When seismically-induced shear and axial stresses are superimposed on the static stress, the potential for liner rupture increases. Both the static and seismic components of stress on the liner system have generally been ignored in landfill design. Sometimes, based upon intuition, designers place a "sacrificial" slip layer above a critical interface to limit the shear stress transferred to the liner system and control where slip occurs. The fully coupled approach, however, allows for the stresses and strains on the liner resulting from waste settlement to be included into dynamic analysis and hence the response of the landfill barrier system to be assessed quantitatively.

As a prelude to fully coupled analysis of composite liner system stresses under dynamic loading, Arab et al. (2010) developed a time-domain finite difference model of a rigid block sliding on a plane. A simple elastic-perfectly plastic constitutive model and the Mohr-Coulomb failure criterion was used to simulate the load-displacement behavior of the interface between the block and the plane. This model, illustrated in Figure 14, has been shown by Arab et al. (2010) to accurately reproduce the slip-stick and slip-slip behavior described by Westermo and Udwadia (1983) for frictional sliding of a rigid block on a horizontal plane. The model accurately predicts shaking table tests of a sliding block on horizontal and inclined planes subject to uniform and non-uniform motions provided the appropriate friction angle is used to characterize the interface. Comparison of physical model test results to the results of best-fit numerical analyses demonstrated that the appropriate friction angle may depend upon the velocity of sliding.

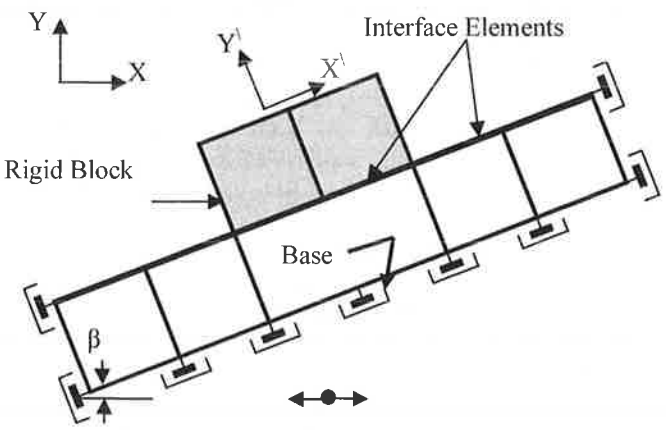

Fig. 14. Finite difference model (only FLAC™ macro elements shown) of an inclined base shaking table test (Arab et al. 2010).

The numerical model by Arab et al. (2010) provides a basis for fully coupled analysis of modern landfills with well-defined sliding surfaces in a more rigorous manner than currently employed in engineering practice. In addition to assessment of the cumulative seismic displacement of landfills, this and similar fully coupled models can be used to evaluate the stress induced in geosynthetic elements of landfill liner and cover systems by strong ground shaking.

STABILITY CRITERIA

Stability criteria are an essential part of seismic analysis and design of modern composite landfill liners and covers. A comprehensive review of stability criteria for seismic design of modern landfills is presented in Kavazanjian et al. (1998).

Although several performance requirements are typically imposed on ancillary structures, the most common seismic

design criterion for solid waste landfills is to limit the calculated maximum permanent seismic displacement along liner interfaces to "150 to 300 mm." This criterion, based upon a survey of consulting firms involved in landfill design by Seed and Bonaparte (1992), is commonly referred to as the Seed and Bonaparte stability criterion. At that time, no firm basis was given for the "150 to 300 mm" value other than that it was commonly used in practice. However, this criterion was cited as the accepted seismic performance criterion in the 1995 United States Environmental Protection Agency (EPA) guidance document *RCRA Subtitle D (258) Seismic Design Guidance for Municipal Solid Waste Landfill Facilities* (Richardson et al. 1995).

Subsequent to publication of the 1995 EPA guidance document, several researchers used conventional methods (i.e., decoupled site response and seismic deformation analysis) to conduct back analyses of landfills subject to seismic loading to assess the validity of the Seed and Bonaparte stability criterion. These researchers, including Matasovic et al. (1995), Augello et al. (1995), Matasovic et al. (1998), and Matasovic and Kavazanjian (2006), have found that landfills have survived up to 300 mm of calculated seismic displacement without any visible displacement. Thus, these analyses lend credence to the Seed and Bonaparte performance criterion.

When designing modern, geosynthetically-lined and covered landfills, one should recognize that the Seed and Bonaparte criterion is empirical and is valid only for conventional analysis methods due to the inherent conservatism in such methods. Indeed, if several hundred thousand cubic meters of waste slide 150 mm on top of a geomembrane, it is highly likely that the primary barrier (geomembrane) will tear. Furthermore, transient seismic loads and displacements in the liner system may overstress system components without any visible indications at the ground surface. Therefore, as application of modern, fully-coupled methods gains its acceptance in engineering practice, revision and/or extension of the Seed and Bonaparte criterion will be required. Options include establishment of allowable, seismically-induced strains and/or stresses in geosynthetics components of composite liner systems calculated in fully coupled analyses and limits on landfill surface deformation based upon performance criteria such as drainage. These options are consistent with current regulations that require the landfill containment system withstand – "without damage" – the design earthquake.

CONCLUSIONS AND RECOMMENDATIONS

Modern geosynthetically-lined and covered waste containment facilities are complex and sophisticated engineering systems designed to provide cost-effective waste disposal in a manner that is highly protective of human health and the environment. Changes in waste streams (e.g., due to recycling, waste reduction initiatives, and new products and processes), changes in operational practices at modern landfills (e.g., increased use of alternative daily covers, leachate reinjection, changes in the composition and manufacturing of geosynthetic materials, and the advent of bioreactor technology) suggest that the properties of waste fill and liner materials will continue to evolve for the foreseeable future.

The positive experience with the performance of modern compositely-lined solid waste landfill facilities subject to strong ground shaking (up to approximate bedrock PHGA = 0.4 g), although limited, indicates that these facilities perform well in earthquakes, i.e., can sustain damage to containment system components without a harmful discharge of contaminants to the environment. However, our ability to observe the damage and quantify the stresses and strains induced in the buried components of the modern landfill barrier systems by cyclic loading is still limited.

The seismic design of landfills has evolved since its inception in 1985. Numerous studies have shown that commonly-used de-coupled approach is conservative with respect to assessment of overall deformation. The material parameters required for these analyses (e.g., the dynamic properties of waste) are, following completion of several recent studies, better constrained. The database of material properties, although limited, has expanded. Understanding of the composite liner interface response subject to cyclic (dynamic) loading has improved, while advanced numerical methods for seismic response and deformation analysis are becoming more common. Charts and spreadsheet solutions are based upon hundreds of accelerograms and, if correctly employed, can result in less conservative assessment of landfill seismic performance. However, uncertainty still exists and is related not only to evaluation of design ground motions, but also to numerous factors such as availability of material properties applicable for special wastes, the presence of an initial static shear stress in the liner system induced by waste settlement, the inability to quantify dynamic shear stresses induced in the liner, and a limited ability to test the dynamic shear behavior of the critical elements and interfaces that typically govern the stability of modern landfills.

The concept of allowable seismically-induced deformation provides a rational and practical basis for design of modern waste containment facilities to resist strong ground motion from earthquakes without a harmful discharge of contaminants to the environment. However, whenever possible, allowable deformations should be established on a facility-specific basis due to the many site and project-specific factors that enter into their determination.

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