FOR CONTRACT NO.: 11-402804
PROJECT ID. 1100000541

INFORMATION HANDOUT

MATERIALS INFORMATION

DISTRICT PRELIMINARY GEOTECHNICAL REPORT, DATED SEPTEMBER 15, 2009

ROUTE: 11-SD-52-5.0/6.2 (PM)

CALIFORNIA DEPARTMENT OF TRANSPORTATION

DISTRICT PRELIMINARY GEOTECHNICAL REPORT

Settlement Study for the Segment of State Route-52 Constructed Over the South Miramar Landfill in San Diego, California

11/San Diego/52/PM 4.9-6.2/EA 11-40280K

September 15, 2009

Prepared By:

OFFICE OF GEOTECHNICAL DESIGN-SOUTH 2
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State of California

Business, Transportation and Housing Agency

Memorandum

To: Mr. Bruce Lambert
District 11 Pavement Management

Date: September 15, 2009

File: 11-SD-52- PM 4.9-6.2
EA 11-40280K

From: **DEPARTMENT OF TRANSPORTATION**
DIVISION OF ENGINEERING SERVICES
Geotechnical Services
Office of Geotechnical Design – South 2

Subject: District Preliminary Geotechnical Report Settlement Study for the Segment of State Route-52 Constructed Over the South Miramar Landfill in San Diego, California.

Pursuant to your request, the Office of Geotechnical Design-South 2 (OGDS2) has prepared this report regarding evaluation and mitigation of the settlement of the sections State Route-52 (SR-52) Post-Mile (PM) 4.9 through 6.2, in the City of San Diego, in San Diego County, California that was constructed over the South Miramar Landfill.

This report presents the results of the research, limited field investigation, and analysis. This report defines the geotechnical conditions as evaluated from field test data and used in the development of the geotechnical site evaluation. The report provides recommendations for settlement mitigation.

OGDS2 staff will be available for further assistance. Should you have any questions or comments regarding this report, please contact Richard Rusnak at (858) 467-4065 or Brian Hinman at (858) 467-4051.

Richard Rusnak P.E.
Transportation Engineer (Civil)
Office of Geotechnical Design-South 2

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File

"Caltrans improves mobility across California"

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EXECUTIVE SUMMARY

The Office of Geotechnical Design-South 2 (OGDS2) has prepared this report regarding evaluation and remediation of the settlement of State Route-52 (SR-52) Post-Mile (PM) 4.9 through 6.2, in the City of San Diego, in San Diego County, California. Sections of SR-52 between PM 4.9 and 6.2 were constructed over the South Miramar Landfill. This report presents the results of the research, limited geotechnical investigation, and analysis. The report identifies and evaluates the locations, mechanisms, and the rate of settlement. The report evaluates long-term settlement mitigation strategies for the site.

Based on the age of the landfill the mechanism that is currently contributing to the majority of the settlement is biodegradative settlement. The rate and severity of the biodegradative settlement is exacerbated by the infiltration of runoff, perched groundwater, and Municipal Solid Waste composition. Overburden has little influence on the severity of settlement. Future overlays will have a negligible affect on settlement.

The maximum settlement since the construction of SR-52 is five and eight-tenths-feet (5.8ft). A maximum of three and seven-tenths-feet (3.7ft) of settlement is anticipated to occur over the next fifty-years (50yr). The current maximum rate of settlement is approximately three-tenths of a foot per year (0.3ft/yr). This rate is anticipated to diminish by approximately seven-percent per year (7%/yr).

The rates, geometry, and locations of settlement included in this report are estimated based on the best available data. These estimates have been developed and are sufficient to compare and contrast the different settlement mitigation strategies considered for review. These estimates are not intended to depict or determine detailed information of the highway time rate of settlement and or the precise geometry of the settlement.

It is highly recommended that consistent, long-term monitoring (surveying) of the highway and surrounding depressions in the landscape where ponding occurs be conducted to determine detailed information of the highway time rate of settlement and the precise geometry of the settlement. This data can be used to efficiently manage the periodic overlay program (e.g. calculate quantities of material needed for an overlay) and monitor the rate of settlement (e.g. predict future settlement).

Based on the comparative evaluation of settlement mitigation strategies, it is recommended that a strategy of Periodic Asphalt Concrete Overlays with Surface Drainage Improvements be utilized to mitigate the settlement of the section of SR-52 that crosses over the landfill. It is estimated that the overlays will occur in three-years (3yr) 2012, six-years (6yr) 2015, ten-years (10yr) 2019, twenty-years (20) 2029, and approximately forty-years (40yr) 2048. A sixth overlay is estimated to occur some time after 2059.

Recommended Surface Drainage Improvements include: asphalt-concrete overlay of unpaved areas, (e.g. median and gore points); curbing shoulders to eliminate sheet flow into surrounding soil; grading depressions into mounds; and eliminating irrigation in the area. Additionally, it is recommended that grading efforts be coordinated with the City of San Diego Environmental Services Department Refuse Disposal Division (City of San Diego ESD) to eliminate depressions that span Caltrans right-of-way and lead to storm water infiltration.

Following a period of precise settlement monitoring and additional consideration by District 11 functional units and management, it may be deemed of greater value to combine Limited Ground Improvement (e.g. compaction grouting or soil mixing) with Periodic Asphalt Concrete Overlay and Surface Drainage Improvements. The inclusion of Limited Ground Improvement would likely reduce the number and cost

of future overlays and may potentially mitigate uncertainty associated with the locations that demonstrate the most severe settlement. If Limited Ground Improvement is considered, a supplemental geotechnical investigation will be necessary to determine if the procedure is feasible and to accurately characterize the subsurface conditions for project bidders.

It is highly recommended that the trees, reeds, brush, and sediment that have obstructed the flow and aggraded the rock-lined culvert outfalls of the two large culverts that cross beneath SR-52 on either side of the Convoy Street Over Crossing be removed. It is anticipated that this action will lower the perched groundwater table that is contributing to the settlement of SR-52 with the additional benefit of restoring proper culvert operation. This will also reduce or eliminate standing water that is contributing to the corrosion of the storm drains. Regular inspection and maintenance of the storm drains should be conducted to ensure the backup of water does not occur in the future. This will require coordination with the City of San Diego ESD.

This report was developed for the purpose of evaluating and comparing settlement mitigation strategies. Any project plans with features that intrude into or otherwise disturb the landfill will require a supplemental geotechnical investigation and report based on the proposed features. Any project plans with features that widen SR-52 may require a supplemental geotechnical investigation and report based on the proposed features. Such investigations should be conducted to accurately characterize the subsurface conditions and/or define geotechnical parameters relevant to project design and construction.

1.0 INTRODUCTION

The Office of Geotechnical Design-South 2 (OGDS2) has prepared this report regarding evaluation and remediation of the settlement of State Route-52 (SR-52) Post-Mile (PM) 4.9 through 6.2, in the City of San Diego, in San Diego County, California. Sections of SR-52 between PM 4.9 and 6.2 were constructed over the South Miramar Landfill. Figure 1 depicts the location of the project site. This report presents the results of the research, limited geotechnical investigation, and analysis. The report identifies and evaluates the locations, mechanisms, and the rate of settlement. The report evaluates long-term settlement mitigation strategies for the site.

The limited geotechnical investigation included: research of archived data and project plans pertaining to SR-52 and the landfill, interviews with Caltrans staff and City of San Diego Environmental Services personnel, site reconnaissance and field investigation; engineering evaluation, and preparation of this report. These activities were deemed sufficient to: characterize settlement mechanisms such as, compression of the fill and/or decomposition of Municipal Solid Waste (MSW) and estimate future settlement for the purpose of evaluating remedial alternatives such as periodic overlays, bridging, grouting, and geogrid applications. The geotechnical investigation is described as limited because exploratory borings were not conducted. Exploratory borings were not conducted due to the hurried schedule and the regulatory constraints of drilling through MSW. It is believed that the information developed in this investigation is sufficient to characterize the site for the purpose of evaluating settlement mitigation strategies.

2.0 EXISTING FACILITIES

SR-52 is an eastbound/westbound highway extending from Interstate-5 easterly to State Route 125 (SR-125). SR-52 is a six-lane highway between Interstate 805 (I-805) and State Route 163 (SR-163). The section of SR-52 between I-805 and SR-163, originally a four-lane highway, was constructed in two phases. The first phase was completed in 1987 and included the lanes from west of I-805 at PM 3.1 to the Convoy Street Over Crossing (OC), bridge number 57-0922. The first phase also included the construction of the Convoy Street OC. The second phase was completed in 1988 and included the construction of SR-52 from the Convoy Street OC to SR-163. The Convoy Street OC has four lanes and is situated in the northbound and southbound direction. The Convoy Street OC was constructed on native soils.

Figures 2(a-e) depict the plan view of the project site. Caltrans right-of-way overlies approximately eight and one-tenth acres (8.1ac) of landfill to the west of the Convoy Street OC and sixteen and one-tenth acres (16.1ac) of landfill to the east of the Convoy Street OC. Figure 3 depicts a profile of the project site along the "SR-52 Line". The profile depicts the distribution of subterranean features underlying the highway.

The original project designers anticipated settlement of the highway. Surcharge was placed over the landfill and highway fill during the construction of SR-52. In a 1984 memo from Lloyd Hughes to Al Boost the recommendations for compacting the landfill included: three to five passes with a fifty-ton (50tn) roller and placement of ten-feet (10ft) of surcharge for a minimum waiting period of one hundred and eighty-days (180days). It is likely that the compaction with the roller and the surcharge of the landfill resulted in some, immediate compression of the MSW. But, the conclusions of landfill settlement studies indicate that the placement of surcharge atop the landfill had little affect on overall settlement of the highway. The average and maximum settlement due to the surcharge is estimated to be one-half of a foot (0.5ft) and eight-tenths of a foot (08.ft), respectively. Records provided by District 11 Minor Projects

indicate that the settlement of SR-52 had been repaired in 1990, 1994, 1997, 2000, 2003, 2005, and 2009. SR-52 was widened to a six-lane highway in 1994, by adding two lanes to the median. The overlay in 1994 coincided with the widening. The overlay in 2000 coincided with the installation of a median barrier. Relatively minor repairs to sections of the highway may have occurred between 1987 to present. These minor repairs that may have occurred are not documented in this report. Widening this section of SR-52 is being considered.

3.0 PERTINENT REPORTS AND INVESTIGATIONS

OGDS2 reviewed archived aerial photographs and topographic maps. Project files and as-built drawings related to the original design, construction and historic repair (overlays) of the highway were also reviewed. Interviews of the Caltrans Survey, Maintenance, Construction and Materials Departments regarding the overlay program and history of the highway were conducted. The District 11 Office of Surveys and OGDS2 compiled relevant survey data in an effort to determine the limits and depth of the landfill, as well as locations and depths of the dips in the highway. Caltrans reports reviewed included:

- Caltrans SR-52 Materials Report, PM 2.7-5.0, I-805-Convoy Street, 11208-047071, Prepared by Calman, E. District 11 Materials Laboratory, August 1974
- SR-52 Materials Report, PM 5.0-7.2, Convoy Street I-15, 11208-047071, Prepared by Calman, E. District 11 Materials Laboratory, November 1975
- Mini-Memorandum Regarding the Compaction and Surcharge of the Landfill to Al Boost, Prepared by Lloyd Hughes, June 1984
- Memorandum Regarding Design of SR-52 to Mr. Schmoldt D. R., District Design Engineer and Lloyd Hughes, Prepared by Douglas L Strauch, California Waste Management Board Executive Officer, July 1984
- Memorandum Drainage Unit 45 Foundation Recommendations, Prepared by Gibson, W. R., District Materials Engineer, May 1986
- Memorandum SR-52 Settlement Study Recommendations, to Mr. Marcon J., Prepared by Brian Hinman, December 1999
- Memorandum One Hundred and Fourteen-Inch (114in) Diameter Structural Steel Plate Pipe (SSPP) Culvert Inspection Report, Prepared by Carrington Fred, District 11 Hydraulics Department, March 2008
- DRAFT Geotechnical Report, SR-52 Settlement Study South Miramar Landfill Area, San Diego California, Prepared by Bureau Veritas North America, Contract No. 38008-17070.00, February 2009

Data provided by the City of San Diego Environmental Services Department Refuse Disposal Division (City of San Diego ESD) and the City of San Diego Solid Waste Local Enforcement Agency (City of San Diego LEA) pertaining to the landfill were reviewed. Gas well production and monitoring data at the landfill were reviewed. Interviews with City of San Diego ESD representatives regarding the history of the landfill were also conducted. Technical publications pertaining to landfill construction and rate of settlement were also reviewed. The technical publications are listed in the references section of this report.

4.0 PHYSICAL SETTING

This section describes data pertaining to the topography, drainage, geology, groundwater, and seismicity at the project site. This section also includes data pertaining to the landfill, facilities, and utilities in and around the project site.

4.1 Climate

San Diego has a Mediterranean to semi-arid climate, which is characterized by warm, dry summers and mild winters with some rain. San Diego has mild, mostly dry weather with approximately two hundred (200) days above seventy degrees Farenheit (70°F). The extended summer and dry period lasts from May to October. Temperatures are mild to warm in the summer. The average high and low temperatures during the summer are seventy to seventy-eight degrees Farenheit (70-78°F) and fifty-five to sixty-six degrees Farenheit (55–66°F), respectively. Temperatures exceed ninety degrees Farenheit (90°F) approximately four days a year. Winter is the rainy period and lasts from November to April. Temperatures are mild and somewhat rainy during the winter. The average high and low temperatures during the winter are sixty-six to seventy degrees Farenheit (66–70°F) and fifty to fifty-six degrees Farenheit (50–56°F) respectively. There is approximately ten-inches (10in) of rainfall in San Diego annually. However precipitation may range from three to thirty-inches (3.0-30.0in) during any given year.

4.2 Topography and Drainage

The project site is on Kearny Mesa. Kearny Mesa is a somewhat planar terrace dissected by incised canyons. The elevation of SR-52 at the project site is approximately four hundred-feet (400ft) above mean sea level (MSL). The site is located within the Miramar Hydrographic Subunit of the Peñasquitos Hydrographic Unit. The Peñasquitos Hydrographic Unit extends from Poway to La Jolla, encompassing approximately one hundred and seventy-square miles (170mi^2). The Miramar Subunit lies along the Peñasquitos Hydrographic Unit's southern boundary and extends north to Rose Canyon.

Storm water from the project site flows from the highway and either sheet flows from the edge of travel way into the landscape within the Caltrans right-of-way or is collected in a system of pipes that discharge into tributary canyons to the north of the highway. The tributary canyons drain to the northwest and discharge into the San Clemente Canyon. San Clemente Creek flows west-southwest and ultimately converges with the paralleling Rose Canyon.

Figures 2(a-e) depict components of the storm water conveyance system. The two main components of the storm water conveyance system at the project site are Storm Drain-40 and Storm Drain-45. The names of the storm drains are taken from the as-built plans. Storm Drain-40 is a hundred and fourteen-inch (114in) diameter SSPP crossing SR-52 beneath embankment fill to the west of the Convoy Street OC. Storm Drain-45 is a one hundred and fifty-six-inch (156in) diameter SSPP crossing SR-52 beneath embankment fill to the east of the Convoy Street OC. The exterior of theses pipes are bituminous coated. The bottom third (1/3) of the interior of both of these pipes is also bituminous coated. Storm Drain-40 and 45 collect storm water from the highway, onramps and offramps, and bridge. Storm water from the Kearny Mesa Industrial/Business District is also collected in these pipes. Prior to discharging into the Storm Drain-40, storm water form the Kearny Mesa Industrial/Business District is collected in an upstream, concrete, box culvert on the southwest side of the Convoy Street OC. Prior to discharging into Storm Drain-45, storm water from the Kearny Mesa Business District is collected in an upstream, tributary canyon on the southeast side of the Convoy Street OC.

Storm Drain-40 discharges into a box culvert on the northwest side of the Convoy Street OC. Storm Drain-45 crosses under Convoy Street to the north of the Convoy Street OC and discharges into a different box culvert on the northwest side of the Convoy Street OC. These box culverts discharge into parallel tributary canyons. These two tributary canyons ultimately combine and drain into San Clemente Canyon. Topographic maps and aerial photographs from 1952, 1963, and 1978 indicate that two tributary canyons were partially filled with MSW on both the west and east sides, of the Convoy Street OC. The 1952 topographic map is provided in Figure 4. The 1963 topographic map is provided in Figure 5. The 1978 aerial photograph/topographic map is provided in Figure 6. The bottoms of these tributary canyons coincide with where Storm Drain-40 and 45 were constructed. Highway embankment fill was placed above the MSW and storm drains in order to obtain the desired highway profile.

Soft, saturated, unsuitable soil was encountered below the proposed flow line elevation of Storm Drain-45 during construction. Class-1, Type-B, permeable material was recommended as suitable replacement material for the unsuitable material. The average depth and width of unsuitable material removal was eleven-feet (11ft) and thirty-feet (30ft), respectively. The width of unsuitable material excavation varied based on the confines of the natural hillside to the west and the landfill embankment to the east.

Another drain of note is Storm Drain 3-5. Storm Drain 3-5 is located approximately nine hundred-feet (900ft) to the east of the Convoy Street OC. Storm Drain 3-5 is depicted on Figures 2(a-e). Storm Drain 3-5 was repaired in 1997 due to a collapsed section. Figure 3 depicts the depth of Storm Drains 40, 45, and 3-5 along the "SR-52 Line".

4.3 Man-made and Natural Features of Engineering and Construction Significance

This section describes the landfill; other facilities around SR-52; and the utilities within and around SR-52 that may affect or may be affected by the proposed mitigation projects.

Miramar Landfill

The Miramar Landfill includes the North, West, and South Miramar Landfills. SR-52 was constructed over a portion of the South Miramar Landfill. The southern end of the North Landfill is located approximately five thousand-feet (5,000ft) to the northeast of the Convoy Street OC. The southern end of the West Miramar Landfill is located approximately four thousand five hundred-feet (4,500ft) to the northwest of the Convoy Street OC. The North and South Miramar Landfills are closed. There are two phases of the West Miramar Landfill. Both phases of the West Miramar Landfill are currently active. Access to the landfill is currently from Convoy Street.

Figure 7 depicts the approximate area of the South Miramar Landfill, hereafter referred to as the landfill. The area of the landfill is approximately one hundred and ninety-two acres (192ac). The volume of the MSW in the landfill is approximately four and two-tenths million-cubic-yards (4,200,000cy). The landfill received MSW from 1959 to 1973. Two and one-half million-tons (2,500,000tn) of MSW has been estimated to have been placed in the landfill during this period. It is also estimated that one to seven million-gallons (1,000,000-7,000,000gal) of various liquid industrial wastes may have been deposited in the landfill between 1959 and 1967.

Topographic maps and aerial photographs dated 1952, 1963, and 1978 indicate that the portion of the landfill to the east of the Convoy Street OC received MSW between 1959 and 1963. The Pre-Closure Study of the South Miramar Landfill prepared by SCS Engineering in 1987 reports that this area received MSW between 1959 and 1964. The portions of the landfill to the west of the Convoy Street OC received

MSW between 1963 and 1973. The Pre-Closure Study of the South Miramar Landfill prepared by SCS Engineering in 1987 reports that the area underlying SR-52 received MSW between 1964 and 1969.

Research indicates that areas within and around the canyons and mesas were excavated to produce cover materials utilized in the landfill. This excavation also served to widen the canyons for MSW disposal. No liner was placed at the bottom of the landfill. MSW was not segregated. MSW was end dumped into the canyons in eight to ten-foot (8-10ft) lifts and covered with six to twelve-inches (6-12in) of soil cover and compacted on a daily basis. Dumping continued in designated areas until the top of the landfill reached three hundred and ninety to four hundred-feet (390-400ft) above MSL. When a section of the landfill was completed, it was capped with approximately three-feet (3ft) of compacted, on-site or near-site derived soil.

Figure 3 depicts the profile of SR-52 and the estimated depths of the underlying highway embankment fill and the MSW along the "SR-52 Line". This profile was developed based on the 1952 topographic map and a profile of exploratory borings drilled by Caltrans in 1974. The maximum depth of the MSW is estimated to be fifty-feet (50ft). The bottom of the landfill ranges from three hundred and fifty to three hundred and ninety-feet (350-390ft) above MSL. Available CPT data appears to confirm the depth of the landfill. Prior to the construction of SR-52 access to the landfill was from Mercury Street. The landfill access road was approximately nine hundred-feet (900ft) to the east of the Convoy Street OC.

Other Facilities

A Household Hazardous Waste Transfer Facility, a Recycling Center, fee collection booths, and Miramar Landfill Administrative Offices are located to the northeast and within one thousand-feet of the Convoy Street OC. The Metro Biosolids Center and fuel storage tanks owned and operated by Kinder Morgan are approximately three thousand-feet (3,000ft) to the west-northwest of the Convoy Street OC. The Metro Biosolids Center owns and maintains the access road that is northwest of the Convoy Street. A segment of this road that parallels SR-52 and is in the vicinity of Storm Drain 40 is settling and shows evidence of repair.

The Kearny Mesa Industrial/Business District is located to the south of SR-52. The Kearny Mesa Industrial/Business District includes commercial services, restaurants, support industries, manufacturing and corporate offices. Directly to the south of SR-52 and west of the Convoy Street OC are the five and two-tenths-acre (5.2ac) Allred/Collins Business Park East; the one hundred and thirty-five-acre (135ac) Allred/Collins Business Park West; an Air National Guard facility; and the Hickman Fields Recreational Complex. A portion of the Allred/Collins Business Park East is also located over a portion of the landfill. The section of the business park that overlies the landfill has been developed as a Recreational Vehicle sales office.

Utilities

Caltrans operates landscape irrigation systems and an electrical system for highway lighting. These systems are within Caltrans right-of-way and adjacent to the outside shoulders of SR-52. The Caltrans landscape irrigation and electrical systems are not depicted in Figures 2(a-e). Electrical lines and a water pipe that service the landfill cross SR-52 within the Convoy Street OC. Figures 2(a-e) depict the electrical line and water pipe within the Convoy Street OC.

The owners of the Allred/Collins Business Park East and the City of San Diego ESD operate landfill gas (LFG) collection and monitoring systems within the landfill. The City of San Diego LFG collection

system is depicted in Figure 7. Caltrans does not operate a LFG collection system. The Allred/Collins Business Park East and the Miramar Landfill LFG collection and monitoring systems are located outside Caltrans right-of-way. The Allred/Collins LFG collection system is not depicted in Figure 7. The City of San Diego ESD LFG collection system is an active collection system; that is the LFG is pumped from the landfill. A City of San Diego ESD LFG collection system pipe crosses SR-52 approximately seventeen hundred and fifty-feet (1750ft) to the east of the Convoy Street OC. This pipe connects the LFG collection system to the southeast of the Convoy Street OC to the system to the northeast. The Allred/Collins Business Park East LFG collection system is independent and does not connect to the City of San Diego ESD gas collection system. The Allred/Collins Business Park East LFG collection system is a passive system; that is the LFG is not pumped from the landfill.

There are two ten-inch (10in) gas lines that that cross under SR-52 and trend in the southwest direction approximately three thousand-feet to the west of the Convoy Street OC. These lines are connected to the Kinder Morgan fuel storage tanks. Figures 2(a-e) depict the Kinder Morgan fuel lines. These pipes are outside the boundary of the landfill.

4.4 Geology and Seismicity

The project site is located in the La Jolla Quadrangle in San Diego County California to the north of Kearny Mesa. The geology of the project site includes Quaternary and Tertiary sedimentary marine and non-marine sediments, alluvium, slope wash, and soils of the Eocene, Pleistocene, and Holocene periods. These deposits are generally flat lying. The surface of the site prior to the landfill and construction of SR-52 consisted of the partially dissected mesa surface with tributary canyons trending to the north.

Geologic units listed from youngest to oldest include: the Alluvium and Slope Wash (Qal +Qsw), Linda Vista Formation (Qln/Qlb), Mission Valley Formation (Tmv), Stadium Conglomerate (Tst), Friars Formation (Tf). Figure 3 depicts the soil profile that underlies SR-52.

- Alluvium (Qal) consists primarily of poorly consolidated stream deposits of silt, sand, and cobble-sized particles derived from bedrock sources that lie within or near the area. (Kennedy/Peterson 1975)
- Slope Wash (Qsw) is poorly consolidated surficial materials derived chiefly from nearby soil and decomposed bedrock sources. It is deposited along the flanks of the lower valley slopes by the actions of gravity and surface water. (Kennedy/Peterson 1975)
- The Linda Vista formation (Qln) generally forms the mesa top. This formation consists of nearshore marine and nonmarine sediments deposited on a wave-cut platform. It is predominantly composed of moderate reddish-brown interbedded sandstone and conglomerate. (Kennedy/Peterson 1975)
- The Mission Valley Formation (Tmv) is comprised of marine, lagoonal, and non-marine, soft, friable, fine to medium grained, light olive gray sandstone with cobble conglomerate tongues identical to the lithology of the Stadium Conglomerate (Tst). (Kennedy/Peterson 1975)
- The Stadium Conglomerate (Tst) consists of a massive cobble conglomerate with dark yellowish-brown coarse-grained sandstone matrix and dispersed lenses of fossiliferous, crossbedded sandstone. (Kennedy/Peterson 1975)
- The Friars Formation (Tf) is predominantly a non-marine and nearshore marine, lagoonal, sandstone and claystome. (Kennedy/Peterson 1975)

Table 1 includes the active faults in the project region as indicated by the Caltrans California Seismic Hazard Map 1996.

TABLE 1: REGIONAL ACTIVE FAULTS

Fault Name (Initials)	Fault Style	Fault Trend	Distance and Direction From Project Site	Maximum Credible Earthquake (MCE)
Newport Inglewood-Rose Canyon East (NIE)	Strike Slip	Northwest	4 to 6 Miles West	7.00
Newport Inglewood-Rose Canyon West (NIW)	Strike Slip	North and Northwest	12 Miles Southwest	7.00
Point Loma (PTL)	Unknown	North and Northwest	7 Miles West	6.50
Palos Verdes Hills-Coronado Bank (PVC)	Strike Slip	Northwest	22 Miles West	7.75
San Diego Trough (SDT)	Unknown	Northwest	34 Miles West	7.25
San Clemente (SCE)	Strike Slip	Northwest	70 Miles West	7.25
Whittier-Elsinore (WEE)	Strike Slip	Northwest	62 Miles East	7.25

4.5 Groundwater

There is a perched (shallow) groundwater and a regional groundwater table underlying the site. Figure 8 depicts the 2009 regional groundwater contours. Figure 9 depicts the historical regional groundwater elevations. Figure 10 depicts the 2009 perched groundwater elevations. Figure 11 depicts the historical perched groundwater elevations. The figures were acquired from the City of San Diego ESD Water Quality Monitoring Report for the South Miramar Landfill, 2009.

Perched Groundwater

The perched groundwater is located in and above alluvium along the drainage bottoms of the original canyons and confined by the impenetrable conglomerate below. Figure 4 depicts the 1952 topographic map prior to the construction of the landfill and SR-52 as well as the highway boundary. The gradient of the perched groundwater is to the west and northwest and mimics the topography and drainage of the area. Since 1993, when the groundwater elevations were first recorded, the majority of perched groundwater wells exhibit groundwater elevations that are consistent over time. A slight increase in the perched groundwater table was realized and has remained since 2004-2005. This consistent increase in the perched groundwater elevation for all of the wells could be a true increase due to high rainfall or it could an aberration caused by a change in the testing equipment.

Note that there is a deep confluence of three canyons, two westerly and one northwesterly, to the east of the Convoy Street OC over which SR-52 was constructed. There is also the confluence of two canyons, one northeasterly and one northwesterly, to the west of the Convoy Street OC over which SR-52 was constructed. Perched groundwater is concentrated in these relic canyon bottoms.

The removal and replacement of the soft, saturated, unsuitable soil below the proposed flow line of Storm Drain-45 with Class-1, Type B permeable material indicates that the perched groundwater collected in the canyons prior to the construction of the landfill and SR-52. The perched groundwater is slowly migrating to the northwest at or above the spring line of Storm Drains 40 and 45.

Regional Groundwater

The regional groundwater table is located between one hundred and sixty-five and one hundred and seventy-four-feet (165-175ft) above MSL at the site. The regional groundwater is roughly one hundred and seventy-five-feet (175ft) below the bottom of the landfill. The gradient of the regional groundwater table is to the south. Since 1993, when the groundwater elevations were first recorded, an overall long-term increasing trend in the regional groundwater table elevation has been observed.

5.0 EXPLORATION

The exploration program included site reconnaissance, facility inspection, and pavement coring. Existing archived information was used to the greatest extent possible. Exploratory borings were not conducted due to the hurried schedule and the regulatory constraints of drilling through MSW. However, useful data from previous borings were acquired from the materials reports listed in Section 3.0. Cone penetration test (CPT) data gathered during the defunct Bureau Veritas North America investigation and reported in the draft report listed in Section 3.0 were also considered.

5.1 Site Reconnaissance

A site reconnaissance with Pedro Aguilar, the RE responsible for the most recent overlay was conducted on May 7, 2009 to determine where settlement of the highway was most prevalent. Mr. Aguilar and OGDS2 staff drove and walked the site. Mr. Aguilar revealed numerous insights concerning the recent overlay. Among those insights, he indicated that the thickest pavement placed in the westbound lanes were in an area three hundred to seventeen hundred-feet (300-1700ft) east of the Convoy Street OC. The thickest amounts of pavement placed in the eastbound lanes were in an area five hundred to twelve hundred-feet (500-1200ft) to the west of the Convoy Street OC. OGDS2 staff was informed that the estimated cost of the recent overlay was one million five hundred thousand-dollars ($1,500,000).

5.2 Culvert Inspections

OGDS2 interviewed District 11 Hydraulics staff regarding the storm water conveyance system at the project site. District 11 Hydraulics staff had inspected Storm Drain-40 on March 25, 2008 and documented the inspection in a memorandum. The memorandum listed in Section 3.0 described the structural condition of Storm Drain-40 as very good and recommended coating the lower half of the entire length of SSPP to guard against further rusting.

OGDS2 inspected Storm Drain-40 to the west of the Convoy Street OC on May 28, 2009. The inspection started at the outfall. Standing water and sediment were observed in the downstream, concrete, box culvert. Trees, reeds, brush, and sediment have obstructed the flow and aggraded the rock-lined culvert outfall. The depth of the standing water was estimated to be two to three-feet (2.0-3.0ft). The depth of the sediment in the downstream, concrete, box culvert was variable and was not measured. Due to the depth of the standing water entrance into the culvert was restricted at the outfall. OGDS2 staff moved to the inlet of Storm Drain-40 to continue the inspection. OGDS2 staff entered the system from a metal grate on the southwest side of the Convoy Street OC. This entry point coincides with the transition from

the upstream, concrete, box culvert to the upstream side of Storm Drain-40. The transition from the upstream, concrete, box culvert to Storm Drain-40 appeared to be in good condition. Water was observed flowing into Storm Drain-40 from the box culvert. The depth of the water flowing into Storm Drain-40 was approximately one to three-inches (1.0-3.0in).

Surficial rust was observed in the bottom one-third (1/3) of Storm Drain-40. It appears that a bed load of sandy-silt, rock, and debris have removed the bituminous coating. No rust or degradation of the upper two-thirds (2/3) of Storm Drain-40 was observed. Some water was observed percolating from what appears to be a small hole in Storm Drain-40 approximately fifty-feet (50ft) upstream of the downstream transition to the box culvert. Minimal amounts of liquid were observed leaching from some of the pipe's seams. This percolation of water and leaching of liquid indicates that the perched groundwater elevation may be slightly higher than the water elevation observed in the bottom of the pipe. No differential settlement of the pipe was observed. The overall condition of Storm Drain-40 appears to be good.

OGDS2 inspected Storm Drain-45 to the east of the Convoy Street OC on May 28, 2009. The inspection proceeded from the outfall to the inlet. A similar condition of standing water and sediment was observed in the downstream, concrete, box culvert. Trees, reeds, brush, and sediment have obstructed the flow and aggraded the rock-lined culvert outfall. The depth of the standing water was estimated to be two to two and one-half-feet (2.0-2.5ft). The depth of the standing water in the concrete, box culvert decreased upstream. The depth of the sediment in the box culvert was variable and was not measured. The transition from the downstream box culvert to Storm Drain-45 appeared to be in good condition. The depth of the water in Storm Drain-45 was estimated to be two to three-inches (2.0-3.0in).

Surficial rust was observed in the bottom third (1/3) of Storm Drain-45. It appears that a bed load of sandy-silt, rock, and debris have removed the bituminous coating. No rust or degradation of the upper two-thirds (2/3) of Storm Drain-45 was observed. Minimal amounts of liquid were observed leaching from some of the pipe's seams. This leaching of liquid indicates that the perched groundwater elevation may be slightly higher than the water elevation observed in the bottom of the pipe. No differential settlement of the pipe was observed. The condition of Storm Drain-45 appears to be good. Water was observed flowing into Storm Drain-45 from the tributary canyon. Trees and brush were observed at the inlet of Storm Drain-45. Based on the results of the inspection, OGDS2 concurs with the assessment of District 11 Hydraulics.

5.3 Pavement Coring

Pavement corings were drilled to estimate the depth of the highway pavement, to determine the locations of settlement, and establish a settlement history. Two hundred and six (206) pavement-corings were drilled between the dates of June 2-25, 2009. Figures 2(a-e) depict the approximate locations of the pavement corings in plan view. Figure 3 depicts the approximate locations of the pavement corings and the depth of each core. Figure 3 also depicts the profile of the landfill for comparison.

Due to the logistics of closing the lanes of SR-52 while maintaining public access to the landfill and providing a safe work environment for the Caltrans staff conducting the coring, operations were limited to coring in the outside shoulders and the westbound median. The locations of the pavement corings were determined in the field. Pavement cores were drilled at locations selected to provide the most useful information on settlement. The information obtained during the site visit with Mr. Aguilar; the visual evidence of the recent overlay; and the irregular profile of both the north and south right-of-way fence indicated where settlement was anticipated to be greatest. The result of the ongoing pavement core operation also influenced determination of the pavement coring locations.

The results of the pavement coring are listed in Table 2. The table includes the approximate station and depth of the cores. The table also describes the location at which the cores were drilled. The pavement cores were named according to GS protocol.

Pavement core depths are estimated to the nearest quarter inch. The minimum pavement core depth is two and three-quarter-inches (2.75in). The maximum pavement core depth is sixty-nine-inches (69.0in). The average pavement core depth is eighteen and three-tenths-inches (18.3in). The information obtained from the pavement cores was utilized to establish a settlement history presented later in the report. SR-52 was originally constructed as a four-lane highway and was widened to a six-lane highway in 1994 by adding two lanes in the median. Therefore, it was anticipated that the pavements cores taken from the median would not be as deep. The average depth of the pavement cores from the original highway is twenty and three tenths-inches (20.3in). The average depth of the pavement in the newer median is thirteen and three-tenths-inches (13.3in).

The pavement cores were also used to develop contours of highway settlement. Figures 12(a-b) depict highway settlement contours. These contours were developed based on pavement core depths. Initial pavement thickness was not subtracted from the core depths to simplify calculations. The highway settlement contours indicate that there are locations to the west and east of the Convoy Street OC where settlement of five-feet (5.0ft) or greater occurs.

TABLE 2: PAVEMENT CORE LOCATIONS AND DEPTHS

Coring No#	Station	Depth (in)	Coring No#	Station	Depth (in)	Coring No#	Station	Depth (in)	Coring No#	Station	Depth (in)	Coring No#	Station	Depth (in)
	1		142	294+94	12.00	182	297+15	60.75	223	299+18	6.00	264	310+00	10.25
101	341+18	5.50	143	293+88	15.00	183	296+82	43.25	224	298+45	24.00	265	310+40	12.25
102	336+87	7.25	144	292+86	12.75	184	296+49	17.75	225	298+28	36.00	266	310+96	19.00
103	335+68	7.50	145	292+16	21.50	185	295+98	15.00	226	297+69	33.00	267	311+52	26.25
104	334+94	7.50	146	291+13	17.75	186	295+52	12.50	227	297+32	23.25	268	312+06	26.50
105	334+05	7.50	147	290+43	18.25	187	295+06	17.50	228	297+00	26.25	269	312+58	27.50
106	332+34	7.50	148	289+65	9.00	188	294+68	22.50	229	296+70	19.25	270	313+08	36.25
107	331+50	7.50	149	288+77	9.25		3		230	296+20	7.75	271	313+58	28.75
108	330+71	10.25	150	287+52	9.50	189	341+16	3.50	231	295+70	6.75	272	313+98	40.00
109	330+02	14.50	151	286+76	9.00	191	336+66	3.00	232	294+94	6.00		5	
110	329+60	14.50	152	286+16	12.25	192	335+16	4.00	233	294+20	6.00	273	314+58	44.50
111	329+02	14.00	153	285+50	8.50	193	333+66	3.50	234	293+20	7.00	274	315+40	45.75
112	328+38	13.00	154	284+77	7.75	194	331+56	4.75	235	292+44	5.75	275	316+01	29.50
113	327+74	12.50	155	284+00	7.25	195	330+16	11.00	236	291+96	6.75	276	316+64	54.25
114	327+08	12.75		2		196	328+66	6.25	237	291+44	7.75	277	317+16	61.50
115	326+51	12.75	156	317+93	49.00	197	327+16	8.25	238	290+96	13.25	278	317+74	35.25
116	325+89	10.25	157	317+26	24.50	198	326+16	4.75	239	289+76	4.25	279	318+49	19.50
117	325+31	12.00	158	316+67	24.00	199	325+16	6.00	240	288+72	4.00	280	319+32	26.73
118	324+73	18.00	159	316+03	33.50	200	324+16	7.75	241	287+22	4.25	281	320+18	34.50
119	324+22	22.00	160	315+58	39.50	201	323+16	13.00	242	286+72	4.00	282	286+38	8.25
120	323+65	22.25	161	314+86	33.00	202	322+16	17.00	243	286+22	5.25	283	288+82	7.50
121	323+08	20.00	162	314+26	69.00	203	321+16	24.25	244	285+72	4.00	284	290+31	6.25
122	322+51	23.50	163	313+50	68.50	204	320+16	24.50	245	285+24	3.50	285	291+94	9.75
123	321+77	28.00	164	312+69	51.25	205	319+16	25.50	246	284+48	4.50	286	293+36	9.50
124	320+76	31.50	165	311+98	50.25	206	318+16	19.00	247	284+02	4.00	287	294+84	8.25
125	319+66	43.25	166	311+16	40.50	207	317+16	19.00		4		288	295+83	8.25
126	318+98	50.00	167	310+26	36.50	208	316+66	30.25	248	294+04	14.00	289	297+07	7.00
127	318+03	39.00	168	309+41	18.00	209	315+66	47.25	249	294+65	15.75	290	297+88	9.25
128	316+76	7.75	168.5	309+07	12.75	210	314+66	50.00	250	295+21	12.00	291	298+43	9.50
129	315+66	42.00	169	308+21	7.50	211	314+16	48.50	251	295+75	17.25	292	299+13	9.50
130	314+81	26.34	170	305+76	7.25	211.5	313+66	38.25	252	296+36	10.75	293	299+69	11.75
131	314+21	23.00	171	304+74	7.50	212	312+66	37.00	253	297+00	16.75	294	300+51	9.25
132	313+76	19.00	172	303+68	8.50	213	311+66	17.00	254	297+61	22.50	295	301+21	5.00
133	313+05	16.00	173	302+71	8.50	214	310+66	14.00	255	298+23	39.25	296	321+26	33.25
134	311+80	5.50	174	301+81	8.00	215	309+66	7.25	256	298+65	64.00	297	323+78	31.00
135	311+41	5.50	175	300+93	7.50	216	309+16	4.25	257	299+29	26.00	298	325+08	25.25
136	310+71	6.00	176	300+18	8.00	217	307+66	3.50	258	299+90	10.25	299	326+21	16.75
137	298+83	4.25	177	299+29	8.00	218	305+76	4.00	259	300+24	7.75	300	328+26	24.00
138	297+96	5.25	178	298+74	13.50	219	303+68	5.00	260	300+82	7.50	301	330+46	15.50
139	296+77	30.50	179	298+17	24.75	220	301+68	5.25	261	303+04	7.50	302	333+26	10.75
140	296+22	10.50	180	297+76	45.75	221	300+68	5.50	262	305+76	10.50	303	336+26	8.00
141	295+66	5.50	181	297+43	59.50	222	299+70	3.50	263	307+93	7.00	304	341+33	5.50

Notes:

1, Pavement cores 101-155 were drilled in the westbound shoulder adjacent to the Convoy Street OC auxiliary lane and in the off and on ramps.

2, Pavement cores 156-188 were drilled in the westbound shoulder adjacent to the No. 3 lane and under the Convoy Street OC.

3, Pavement cores 189-247 were drilled in the westbound median.

4, Pavement cores 248-272 were drilled in the eastbound shoulder adjacent to the No. 3 lane and under the Convoy Street OC.

5, Pavement cores 273-304 were drilled in the eastbound shoulder in the on and off ramps and adjacent to the SR-163 South auxiliary lane. Pavement cores 273-304 were not drilled consecutively from the west to east.

6.0 LANDFILL SETTLEMENT

Landfills undergo a complex settlement process. Settlement is generally differential due to the heterogeneous nature of the MSW. MSW typically contains about twenty-two to twenty-six-percent (22-26%) by weight of decomposable materials including: putrescible waste, paper products, and green waste. (SWANA, 1991) (Leonard & Floom, 1999). MSW landfills are generally not well compacted during placement. Short and long-term settlement is expected. This section describes the mechanisms of landfill settlement; factors affecting settlement, and an estimate of historical and future settlement.

6.1 Settlement Mechanisms

Mechanisms that cause the majority of settlement in landfills include short-term mechanical compression and biodegradation. Mechanisms that cause small amounts of settlement include long-term mechanical compression, creep, physical/chemical corrosion and interaction, and consolidation.

Mechanical compression occurs due to the distortion, bending, crushing, and reorientation of highly deformable MSW. Mechanical compression is a primary, short-term settlement mechanism. Settlement due to mechanical compression usually occurs during landfill construction. Settlement due to mechanical compression is moderate in the short-term. The weight of overburden can affect mechanical compression but is considered small in the long-term compared to settlement due to biodegradation.

Biodegradation is the process of aerobic and anaerobic decomposition of organic material by bacteria. The initial stage of the decomposition of organic material is aerobic, due to the relative abundance of oxygen in a newly placed landfill. The oxygen content within the MSW depletes gradually as aerobic biodegradation proceeds. Anaerobic decomposition begins when the oxygen is depleted. Since aerobic decomposition is generally short, the primary mechanism of decomposition of organic materials within a landfill is anaerobic. Bacteria convert carbon-based solid material and water into intermediate liquid products and LFG. The transformation of solid mass to liquid byproducts and LFG results in vertical settlement. Settlement due to biodegradation is large and is the dominant, long-term, landfill settlement mechanism.

Creep is the movement of materials into voids and continued elastic deformation. The support of MSW is weakened due to voids created by biodegradation and corrosion, in turn causing a reduction in the rigidity of landfill materials. Settlement due to creep is generally low to moderate.

The mechanism of physical and chemical corrosion and interaction includes the corrosion of metals and the combustion of organics. Examples include methane supported combustion, spontaneous combustion, and corrosion by organic acids. Alone these methods generally create small, localized settlement compared to other settlement mechanisms. Settlement due to corrosion and interaction are generally low, but can be increased in localized areas.

Consolidation is settlement caused by excess liquid squeezed from pore spaces in soil mixed and layered within the landfill. Consolidation is not likely to occur in landfills that are dry. Settlement due to consolidation is generally low, but can be increased with the introduction of water.

Figure 13 depicts the typical time-settlement curve for a landfill under load. (Liu, Chen, & Chen, 2006 recreated from Grisolia & Napoleoni, 1995). The curve is divided into five stages:

Stage I: Initial Settlement, instant mechanical compression due to the movement of highly deformable waste.

Stage II: Primary Settlement, deformation due to continuous mechanical compression and adjustment of waste.

Stage III: Secondary Settlement, deformation due to the initial biodegradation.

Stage IV: Biodegradative Settlement, deformation due to the biodegradation.

Stage V: Residual Settlement, deformation due to the residual biodegradation and creep.

6.2 Factors Affecting Settlement

Factors that potentially affect the settlement of landfills include: the age of the landfill; initial compaction; overburden; MSW moisture content; and type and thickness of the MSW and the distribution of biodegradable and non-biodegradable wastes.

Age of Landfill

Younger landfills contain more biodegradable MSW than older landfills and therefore will undergo settlement for a longer period of time. The landfill under SR-52 is considered old and has likely experienced a large portion of the settlement it will undergo.

Initial Compaction

Settlement due to poor initial compaction generally occurs during and immediately after the placement of the MSW. Initial compaction of the MSW occurred prior to the construction of the highway. The three to five passes with a fifty-ton (50tn) roller and surcharge during construction likely had little affect on the long-term settlement of the underlying MSW. The affects of settlement due to initial compaction are not factors that are currently affecting settlement of SR-52.

Overburden

The landfill under SR-52 was capped by approximately three-feet (3ft) of soil. The highway embankment fill over the landfill varies in thickness and adds overburden to the MSW. Surcharge was placed over the highway embankment fill during construction of the highway. While the initial placement of the surcharge and the highway embankment fill during construction likely resulted in a renewed episode of landfill settlement due to mechanical compression, the current affect of the overburden is relatively small, since the most active settlement mechanism is biodegradation.

Areas of thicker highway embankment and distributed load placed over the landfill, for example on and offramps, may display somewhat accelerated and/or more acute settlement. These large distributed loads will have a shallow and deep influence. Overburden has a small affect on the long-term settlement. Long-term settlement is generally independent of overburden and is primarily due to biodegradation.

More concentrated locations of increased overburden, such as broad areas of deep accumulated asphalt-concrete, will have a small affect on settlement since the concentrated loads are distributed with depth. The increase in overburden pressure applied by continued asphalt-concrete overlays is generally small in comparison to the existing effective stress from the weight of landfill material and highway embankment

acting on the MSW. Vehicle loads and any future asphalt-concrete overlays will have a negligible affect on settlement.

Moisture Content

The introduction of moisture into a landfill can result in increased settlement by two mechanisms, biodegradation and consolidation. Water that carries oxygen will accelerate the activity of the microbes in the landfill and in turn aerobic biodegradation. Settlement due to consolidation is caused by excess liquid squeezed from pore spaces in MSW and soil used to cap and cover the landfill material.

Leachate is the byproduct of water coming in contact with MSW. Leachate contains suspended and dissolved materials associated with the MSW and byproducts from biological and chemical reactions. Leachate can migrate from the bottom of unlined landfills and contaminate underlying groundwater.

Modern landfills are covered and lined with impermeable layers that restrict the percolation of water into the MSW. The landfill under SR-52 was not lined and capped to prevent changes in moisture content. Surface water infiltrates and percolates through the landfill. Perched groundwater is cradled within and migrates along the relic canyon bottoms.

Ponding of storm water occurs in depressions within and outside Caltrans right-of-way. Some of the depressions span the right-of-way boundary. The depressions are the result of the settlement of the landfill. Ponding storm water has no means of flowing out of the depressions and therefore evaporates into the atmosphere and infiltrates into the landfill. The increased moisture content of the MSW accelerates the rate of aerobic biodegradation and results in localized settlement. The resulting settlement and deepening ponds exacerbate the settlement of the MSW at these locations. The amount of water infiltrating into the soil and MSW below the highway is contingent upon the amount of rainfall; the volume of runoff from the roadway; and the contribution from surrounding properties.

A letter from the California Waste Management Board dated July 5, 1984 states:

> *"Any drainage from the roadway or road fill should be directed away from the landfill and not be allowed to cross or pond on landfill."*

Figure 4, the 1952 topographic map, depicts the canyons in which the MSW was placed. Figure 6, the 1978 aerial photograph depicts the landfill after completion and prior to the construction of SR-52. Figures 12(a-b) depict the locations of maximum settlement. Water percolates through the landfill and accumulates at the bottoms of these relic canyons. It is significant to note that the locations of maximum settlement coincide with the confluence of multiple tributaries and the directional trend of the drainage. The perched groundwater collecting in the bottoms of the canyons comes in contact with and accelerates the biodegradation of the MSW. As the MSW biodegrades and settles, adjacent MSW creeps vertically and comes in contact with the leachate, thereby perpetuating the cycle.

MSW Type, Thickness, and Distribution

The type and thickness of the MSW and the distribution of biodegradable and non-biodegradable wastes will affect settlement. Household and green wastes have more biodegradable material than construction or demolition debris. The introduction of liquid wastes will also accelerate biodegradation and/or physical and chemical corrosion.

The Pre-Closure Study of the South Miramar Landfill prepared by SCS Engineers in 1987 reports that the area to the east of the Mercury Street landfill access road is comprised mainly of demolition debris with some refuse. The pre-closure report also states that one to seven million-gallons (1,000,000-7,000,000gal) various, liquid industrial wastes may have been deposited in the area to the east of the access road and in the southwest quadrant of the section of the landfill to the east of the Convoy Street OC.

These materials would have additional affects on the settlement of the landfill. Refer to Figure 3, the demolition debris deposited to the east of the Mercury Street landfill access road (Station 314+50) would likely have less biodegradable material and are therefore anticipated to settle less. Available CPT data appears to confirm the relative distribution of demolition debris. Settlement decreases to the east of Station 320+00. Areas where household, green, and various liquid wastes were deposited may incur more settlement due to biodegradation and/or physical/chemical corrosion and interaction.

6.3 Settlement Estimate

The portion of the landfill to the west of the Convoy Street OC was placed between 1963 and 1973. The portion of the highway to the west of the Convoy Street OC was constructed in 1987. Therefore, the landfill had been settling for approximately fourteen-years (14yr) prior to the construction of the portion of the highway to the west of the Convoy Street OC and settling thirty-six-years (36yr) to the present. The portion of the landfill to the east of the Convoy Street OC was placed between 1959 and 1964. The portion of the SR-52 to the east of the Convoy Street OC was constructed in 1988. Therefore, the landfill had been settling for approximately twenty-four-years (24yr) prior to the construction of the portion of the highway to the east of the Convoy Street OC and settling forty-five-years (45yr) to the present.

Based on these periods, it can be inferred that SR-52 was constructed while the landfill was in Stage IV of the Typical Time-Settlement Curve, Figure 13. It can also be inferred that the landfill is currently in Stage IV of the Typical Time Settlement Curve, where biodegradation is the predominant landfill settlement mechanism. Estimates for the remaining landfill settlement due to biodegradation and creep have been calculated for this report.

Settlement due to long-term mechanical compression, physical/chemical corrosion and interaction, and/or consolidation have not been calculated due to the lack of detailed information regarding the MSW deposited and the soil mixed and layered in the landfill. Settlement due to these factors is not anticipated to be significant.

Future Settlement Due to Biodegradation

The following Estimate of Future Settlement due to biodegradation was prepared based on the Estimating Method and Use of Landfill Settlement by Leonard & Floom.

$S_T = O \times T_R \times S_F$

S_T = Estimated future settlement due to biodegradation

O = The decimal equivalent of the percentage of decomposable organics by weight within the prism at time placement. Municipal Solid Waste typically contains about twenty-two to twenty-six-percent (22-26%) by weight of decomposable materials including: putrescible waste, paper products, and green waste. (SWANA, 1991) (Leonard & Floom, 1999) [Assume "O" is twenty-six-percent (26%)]

T_R = The thickness of the trash [Assume the maximum depth of the South Miramar Landfill "T_R" is fifty-feet (50ft)]

S_F = The settlement factor [Assume S_F is 0.27, a value provided by Leonard & Floom for a landfill located in Monterey County, CA that was opened in 1955. "S_F" of 0.27 correlates to the future gas generation of the Monterey County Landfill from 1995 to 2040, forty-five-years (45 years). Based on the age of the South Miramar Landfill and a fifty-year (50yr) future settlement, "S_F" of 0.27 is considered reasonable.]

S_T = 0.26 x 50ft x 0.27 = 3.51ft

Future Settlement Due to Creep

Settlement due to creep is estimated to be about two-percent (2%) of the fill thickness per log cycle of time. The estimates were based on a period of time that most of the biodegradation would have taken place within forty to fifty-years (40-50yr). (Leonard & Floom, 1999)

Creep/yr = 0.02 X T_R X (365days/yr) / 100,000days

Creep/yr = 0.02 X 50ft X (365days/yr) / 100,000days

Creep/yr = 0.004ft/yr

Estimated Creep to year 2059

Creep/yr X (50yr) = 0.004ft/yrX (50yr) = 0.18ft

Table 3 includes the fifty-year (50yr) settlement estimates due to biodegradation and creep as a function of MSW depth.

TABLE 3: ESTIMATED FUTURE SETTLEMENT

MSW Depth (ft)	50	40	30	20	10
Future Settlement Biodegradation (ft)	3.51	2.81	2.11	1.40	0.70
Future Settlement Creep (ft)	0.18	0.15	0.11	0.07	0.04
Total Future Settlement (ft)	3.69	2.96	2.22	1.47	0.74

The reduction in biodegradable MSW in the landfill and thus settlement due to biodegradation and creep will likely diminish over time.

A Time-Settlement Curve for SR-52 has been estimated based on available data and references. Figure 14 depicts the Estimated Time-Settlement Curve for SR-52. The average settlement and the maximum settlement are depicted in the figure. These settlement curves are based on landfill settlement Stages I-V previously described and depicted in the Typical Landfill Time-Settlement Curve. The curves estimate the settlement that occurred prior to the construction of the highway; the settlement that has occurred since the construction of the highway; and the settlement anticipated to occur over the next fifty-years (50yr).

Settlement due to Stage I, II, III, and IV, which occurred prior to the construction of the landfill, were estimated based on the chronological development of the landfill and the anticipated percent of settlement due to these stages.

The settlement due to the surcharge is estimated to be a maximum of eight-tenths of a foot (0.8ft) and an average of one-half of a foot (0.5ft) between 1987 and 1988.

Settlement of the highway from post construction to the present was estimated based on a linear rate of settlement calculated by dividing the depth of the pavement core by the number of years since the first layer of pavement was placed. The maximum rate of settlement was based on a maximum pavement core depth. The average rate of settlement was estimated using the average depth of pavement cores from the original highway. Comparison of the rate of settlement of the outside shoulders to the rate of settlement of the median revealed that settlement of the highway has proceeded at a constant rate.

A rate of future settlement was estimated by projecting the estimated future settlement listed in Table 3 over fifty-years (50yr). The maximum rate of future settlement was projected using the fifty-foot (50ft) landfill depth estimated future settlement. The average rate of future settlement was projected using the thirty-foot (30ft) landfill depth estimated future settlement.

The Estimated SR-52 Time-Settlement Curve depicts depth of settlement in feet versus years, as opposed to a percentage of settlement versus logarithmic time as depicted in the Typical Landfill Time-Settlement Curve. Additionally, no distinction between the dates of MSW placement in the landfill to the east and west of the Convoy Street OC were made when preparing the settlement estimates. The curve does not distinguish portions of years. It is assumed that a rate or amount of settlement occurs for one full year.

7.0 LANDFILL GAS (LFG)

LFG are the byproducts of biological decomposition of organic material by microorganisms in MSW. LFG is explosive and the trace components can be toxic and odor causing. LFG contains approximately fifty to sixty-percent (50-60%) methane, forty to fifty-percent (40-50%) carbon dioxide, and trace quantities of other gases. The other gases are the odorous gases associated with a LFG. LFG migrates vertically through pathways in the landfill and surrounding geology and vents from the landfill. LFG will also migrate through subsurface soil. A LFG collection system reduces the amount of LFG that migrates, collects, and escapes from the landfill.

Methane is a colorless, odorless gas and is lighter than air. The concentration at which methane has the potential to explode is the explosive limit. The explosive limit is defined in the terms of the Lower Explosive Limit (LEL) and Upper Explosive Limit (UEL). The LEL and UEL are measure of the volume of a gas in the air. Methane has the potential to ignite if the concentration is between the LEL and UEL and there is a source of ignition. Methane is not explosive at concentrations below the LEL and above the UEL. Methane gas can be explosive at concentrations between five and fifteen-percent (5-15%) by volume if it accumulates in enclosed spaces and has a source of ignition. Table 4 provides the average LFG well production data at the Miramar Landfill LFG Wells to the east of the Convoy Street OC for 2008. The locations of the wells listed in Table 4 are depicted on Figure 7. The wells were installed in 1995.

A LFG collection system collects LFG from the landfill and draws in oxygen from the atmosphere. Balance gas is the percent of inflow of oxygen to outflow of LFG. Twenty to thirty-percent (20-30%) is generally considered acceptable percent balance gas. (Per discussion with City of San Diego ESD representative) But, due to the dynamic nature of landfills, and the multiple factors affecting a landfill, balance gas can be variable from well to well. In general it can be assumed, based on the age of the landfill and the LFG collection system, that the wells are balanced and are collecting the maximum amount of methane possible drawing in the minimum amount of oxygen.

TABLE 4: SOUTH MIRAMAR LANDFILL LFG COLLECTION SYSTEM DATA

Well ID	CH4 (Methane) (%)	CO2 (Carbon Dioxide) (%)	O2 (Oxygen) (%)	Balance Gas (%)	Differential Pressure (H_2O)	Well Temperature (F°)	Static Pressure (H_2O)	Initial Flow (SCFM)	Adjusted Flow (SCFM)
SM-30D	58.2	38.2	0.0	3.6	24.6	31.7	18.8	1.9	2.7
SM-30S	40.1	31.7	0.0	28.2	24.1	32.8	22.0	2.6	2.6
SM-31D	39.8	20.2	7.3	32.7	24.4	30.1	17.7	0.0	0.2
SM-31S	53.0	35.7	0.1	11.2	23.6	26.8	17.4	-1.6	0.0
SM-40X	52.0	37.0	1.3	9.7	24.6	32.9	23.2	5.3	8.0
SM-41X	34.8	30.9	0.4	33.9	29.6	28.4	20.8	1.5	0.7
SM-42X	40.0	34.2	0.0	25.8	24.5	30.8	20.8	2.9	2.7
SM-43D	29.3	26.7	2.6	41.4	23.7	31.5	23.1	-0.5	0.1
SM-43S	38.0	32.1	0.0	29.9	24.5	31.5	21.3	3.2	2.0
SM-44X	9.5	20.9	1.0	68.5	25.8	30.1	19.1	0.0	0.0
SM-45X	11.1	20.4	0.1	68.5	25.2	29.3	22.8	0.0	0.0
SM-46D	20.6	22.8	2.1	54.5	25.5	29.4	21.0	0.0	0.0
SM-46S	21.1	23.2	0.7	55.0	26.7	30.5	22.7	0.2	0.3
SM-47D	21.2	25.2	0.3	53.3	24.7	31.0	19.8	0.0	0.0
SM-47S	24.8	25.3	0.3	49.6	24.9	30.8	21.7	-0.1	0.0
SM-48X	19.3	24.3	0.1	56.3	26.4	30.8	19.5	0.0	0.0
SM-49X	19.5	18.8	4.3	57.5	25.8	31.4	22.2	-0.2	0.0
SM-52X	40.4	30.6	0.9	28.0	26.3	28.1	20.2	-0.2	0.4
SM-53X	31.4	29.5	0.2	38.8	27.0	32.4	19.8	0.9	0.7
SM-54X	34.5	27.3	6.8	31.5	25.8	26.2	22.3	2.4	0.3
SM-55X	10.9	13.1	12.6	63.4	27.6	30.2	21.5	0.1	0.0
SM-56X	42.5	35.4	0.1	21.9	25.1	30.7	22.0	5.5	4.3
SM-57X	13.0	23.4	2.3	61.3	25.9	29.1	22.4	0.0	0.0
SM-58X	23.9	19.3	9.9	46.9	27.0	33.4	22.5	1.7	3.7
SM-61X	25.6	22.0	6.6	45.8	27.8	29.5	20.7	0.3	0.0
SM-62X	22.8	18.2	10.2	48.7	27.5	29.7	21.8	-0.2	0.6
SM-63X	36.1	30.0	0.3	33.7	27.6	29.2	20.9	0.6	0.6

Notes:
Data provided by the City of San Diego ESD
SM=South Miramar Landfill
A D in the alphanumeric designation indicates a deep well screen from which the LFG is collected.
An S in the alphanumeric designation indicates a shallow well screen from which the LFG is collected.
An X in the alphanumeric designation indicates that one screen is installed the well and the depth of the screen is uncertain.
SCFM = Standard Cubic Feet Per Minute

A review of the data provided in Table 4 indicates that that there is more methane collected from the westerly wells (e.g. wells SM-30 through SM-43) compared to those wells that are on the easterly side of this portion of the landfill (e.g. wells SM-44 through SM-49). This could lead to the conclusion that the MSW in the westerly side is more biodegradative than that on the easterly side of this portion of the landfill. If accurate, this would coincide with the understanding that the MSW on the easterly side of this portion of the landfill includes less biodegradative demolition debris and is therefore settling less. However, there are many factors that can affect the LFG collection system and resulting data at the landfill. Research of such factors is beyond the scope of this report.

It is significant to note that Bureau Veritas North America reported measuring one hundred-percent (100%) LEL of LFG at seven (7) of the thirty-two (32) CPTs. These readings occurred to the north of SR-52 on both sides of the Convoy Street OC. This is significant because it indicates that LFG will likely be encountered if any construction method used to mitigate the settlement includes puncturing the landfill cap. Special measures would need to be implemented to control the toxic and odorous affects of LFG, as well as prevent an explosion or subsurface fire during and after construction of any mitigation measure that intrudes into the landfill material.

8.0 CONCEPTUAL SETTLEMENT MITIGATION STRATEGIES

Numerous strategies have been conceived and advocated to mitigate the impact of landfill and highway settlement. These strategies have been extensively reviewed. The following is a list of the conceptual mitigation strategies. The following sections include brief descriptions and discussions of each conceptual strategy and why it was considered or rejected for further review. A solid bullet precedes strategies rejected for further review. A check precedes strategies considered for further review.

Strategies to Preclude or Circumvent Landfill Settlement

- Remove and Replace Landfill Material Beneath Highway
- Reconstruct Highway on New Alignment
- ✓ Bridge Landfill with an At-Grade Viaduct
- ✓ Reconstruct Highway as a Structural Slab on Grade Supported by Driven Piles

Strategies to Regulate Landfill Settlement

- Remove Upper Highway Embankment and Replace with Light Weight Embankment Fill
- Remove Upper Highway Embankment and Replace with Geogrid Reinforced Embankment
- Lower Highway Profile
- ✓ Construct Surface Drainage Improvements to Prevent Storm Water Ponding and Infiltration
- Construct Subsurface Drainage Improvements to Control Perched Groundwater and Leachate
- Expedite Remaining Settlement by Air and Water Injection
- Expedite Remaining Settlement by Surcharging Highway Embankment
- Expedite Remaining Settlement by Deep Dynamic Compaction
- Consolidate Landfill Material and Provide Embankment Support by Vibro Compaction/Replacement (Stone Columns)
- ✓ Provide Embankment Support by Soil Mixing (Soil Cement)
- ✓ Fill Voids within Landfill Material by Slurry Grouting
- ✓ Consolidate Landfill Material and Provide Embankment Support by Compaction Grouting

Strategies to Compensate for Landfill Settlement

- Lift Pavement by Mud Jacking or Expanding Polyurethane Foam
- ✓ Periodically Restore Highway Profile by Asphalt Concrete Overlays

8.1 Strategies to Preclude or Circumvent Landfill Settlement

- *Remove and Replace Landfill Material Beneath Highway*

The entire prism of supporting embankment and landfill beneath the highway would be excavated to stable sedimentary formation. Excavated landfill MSW would have to be handled according to strict controls and regulations and hauled to appropriate facility. Suitable highway embankment would be transported from borrow site and placed to current standard. The highway facility would be subsequently reconstructed.

This strategy is judged to be impractical due to disruption of the existing facilities, extremely high hazardous waste issues, and extremely high cost. No further consideration of this strategy is warranted.

- *Reconstruct Highway on New Alignment*

The highway would be reconstructed to the north or south on an alignment that traverses stable sedimentary formation. The new alignment may require revisions of the interchanges at I-805 and SR-163. A new Convoy Street Interchange would be necessary as well as the construction of other bridges to accommodate access to the active landfill.

This strategy is judged to be impractical due to extremely high cost of land acquisition and project construction. This strategy is also considered impractical from a technical perspective. No further consideration of this strategy is warranted.

✓ *Bridge Landfill with At-Grade Viaduct*

An at-grade highway viaduct comprised of box girders supported on bents with drilled shaft or driven pile foundations would be constructed to span the landfill. The highway would thereby be isolated from the settlement occurring below. This strategy may be considered for the entire landfill or for portions of the landfill experiencing the most severe settlement.

Although very costly and coupled with serious technical and environmental constraints, this strategy is evaluated further in comparison to other strategies.

✓ *Reconstruct Highway as a Structural Slab on Grade Supported by Driven Piles*

This strategy is comparable to the at-grade viaduct. A regular grid of tightly spaced driven piles would be constructed through the landfill into the underlying sedimentary formation. The highway would be reestablished as a structural slab on grade.

Although very costly and coupled with serious technical and environmental constraints, this strategy is evaluated further in comparison to other strategies. Geopiers or Cast-In-Drill-Hole (CIDH) reinforced concrete piles were judged to be less practical foundation support elements due to the excavation and hauling of MSW.

8.2 Strategies to Regulate Landfill Settlement

- *Remove Upper Highway Embankment and Replace with Light Weight Embankment Fill*

The upper highway embankment would be removed and replaced with light weight fill that may consist of various alternative materials including but not limited to expanded shale aggregate, tire shreds, or extruded polystyrene blocks. The decrease of embankment weight would result in a decrease of overburden, a driving force that contributes to settlement.

This strategy is judged to be impractical due to disruption of the existing facilities, potential hazardous waste issues, and extremely high cost. Additionally, the currently active settlement mechanism is largely independent of the weight of overburden. No further consideration of this strategy is warranted.

- *Remove Upper Highway Embankment and Replace with Geogrid Reinforced Embankment*

The upper highway embankment would be removed and replaced with a layered system of soil and geotextile fabric. Abrupt differential settlement would be minimized; however, total settlement at particular location would be unaffected. This strategy would be applied only to those locations experiencing severe settlement.

This strategy is judged to be ineffective at confining differential settlement to tolerable limits that result in a less frequent need to adjust the roadway profile with pavement overlays. This strategy will not mitigate deep settlement. Additionally, the construction of a layered geogrid embankment involves moderate disruption of the existing facilities and potential hazardous waste issues. No further consideration of this strategy is warranted.

- *Lower Highway Profile*

The highway would be reconstructed to a lower profile elevation over the landfill. The elimination of embankment would result in a decrease of embankment weight and a decrease of driving force that contributes to settlement.

This strategy is considered to be ineffective because thee active settlement mechanism is biodegradation and is largely independent of the weight of overburden. This strategy is judged to be impractical due to disruption of the existing facilities, potential hazardous waste issues, and extremely high cost. No further consideration of this strategy is warranted.

✓ *Construct Surface Drainage Improvements to Prevent Storm Water Ponding and Infiltration*

Landfill settlement has resulted in poor surface drainage characteristics of the terrain surrounding the highway. The ponding and infiltration of storm water enhances landfill settlement. Subsurface water percolating through landfill material accelerates biodegradation and the settlement. Providing positive drainage and appropriate storm water collection systems would minimize infiltration and percolation.

Although difficult to quantify the affects, the implementation of this strategy will likely have desirable consequences on the magnitude and rate of severe settlement. Due to the currently active settlement mechanism, this strategy alone would be unlikely to eliminate settlement, but used in conjunction with other strategies, drainage improvements would be beneficial. Additionally, surface drainage improvements are relatively practical to implement in comparison to other concepts. This strategy is

evaluated further in conjunction with other strategies.

- *Construct Subsurface Drainage Improvements to Control Perched Groundwater and Leachate*

Over time, a rise in the perched groundwater table may be adversely impacting the landfill material and/or other embankment foundation soils. Horizontal drains or well points would be installed to intercept and remove leachate that collects at the bottom of the landfill and influences settlement.

This strategy is judged to be impractical due to low reliability to mitigate settlement and the creation of potential hazardous waste collection and disposal issues. Additionally, the source of the perched groundwater may originate and be affected by elements out of Caltrans control. Implementation of this strategy is likely to require significant construction outside Caltrans right-of-way and face prohibitive environmental constraints. No further consideration of this strategy is warranted at this time.

- *Expedite Remaining Settlement by Air and Water Injection*

A network of injection wells would be established to diffuse water and air throughout the landfill beneath the highway embankment. Biodegradation, creep, and consolidation of the landfill material would be artificially accelerated to expedite the remaining settlement prior to a final restoration of the highway profile.

This strategy is judged to be impractical due to the inability to predict ground performance while simultaneously maintaining traffic flow on the highway. Additional prohibitive considerations include the cost and complexity of the injection network, the rapid leaching of hazardous soluble substances from the landfill, and network construction within a potentially hazardous environment. No further consideration of this strategy is warranted.

- *Expedite Remaining Settlement by Surcharging Highway Embankment*

A surcharge load of soil would be placed over the highway embankment to increase the effective stress at depth thereby accelerating the consolidation of the MSW. The roadway profile and pavement would be reestablished following settlement.

This strategy is not applicable to the current settlement condition. The primary mechanism of settlement is biodegradation not compression. An increase of overburden pressure will not mitigate biodegradation. Additionally, only clays are subject to significant consolidation due to an increase of effective stress. Further, this strategy will result in extreme disruption of the existing facility. At best, years will pass before significant settlement due to surcharging is realized. No further consideration of this strategy is warranted.

- *Expedite Remaining Settlement by Deep Dynamic Compaction*

After removal of the pavement and placement of a soil surcharge, a large weight would be hoisted and dropped repeatedly onto the highway embankment. Dynamic stress imparted into the embankment would act to compact the embankment and MSW. The roadway profile and pavement would be reestablished following settlement.

This strategy is judged to be impractical due to disruption of the existing facilities, unsettling vibration, and extremely high cost. Additionally, dynamic compaction is likely of little benefit as dynamic stress

attenuates with depth and will therefore have little effect on locations experiencing the most severe settlement. Dynamic compaction will not mitigate biodegradation. No further consideration of this strategy is warranted.

- *Consolidate Landfill Material and Provide Embankment Support by Vibro Compaction/Replacement (Stone Columns)*

A large vibrating or oscillating probe would be hoisted and worked into the ground possibly assisted by water jetting. The probe would compact material in a rough cylindrical zone around its path of travel. As the probe is withdrawn, gravel would be compacted into the created space. A regular grid of stone columns would be constructed through the embankment and MSW. The process would both compact the MSW and provide enhanced support to the embankment. The highway pavement would be reconstructed following placement of the stone columns.

This strategy is judged to be impractical. Vibro compaction has not been demonstrated as a proven tool for the compaction of municipal landfill material and mitigation of settlement. Expensive and hazardous pre-drilling of probe holes will be necessary. Additional prohibitive considerations include the resulting increase in and the rapid leaching of hazardous soluble substances from the landfill caused by water jetting and construction within a potentially hazardous environment. The process will result in significant cost and disruption of the existing facilities. No further consideration of this strategy is warranted.

✓ *Provide Embankment Support by Soil Mixing (Soil Cement)*

Columns composed of soil, cement, and MSW would be constructed by mechanical mixing without excavation or removal of material. The mixing method would likely combine rotary energy enhanced by a high-pressure jet. A regular grid of soil/cement/MSW columns would be constructed through the MSW. Cured and hardened columns would stabilize material within the mixed zones. Columns through the landfill would transfer embankment loads to the underlying sedimentary formation. Biodegradation of the MSW cemented within the columns would be inhibited due to cement entombment.

Although extremely costly to apply to the entire MSW zone beneath the highway, the implementation of this strategy will likely have desirable consequences on the magnitude and rate of severe settlement if applied to specific locations. Serious pavement disruption or removal would be avoided. Traffic disruption would be minimized. This strategy is evaluated further in comparison to other strategies.

✓ *Fill Voids within Landfill Material by Slurry Grouting*

A highly flowable slurry grout with the common constituents of cement, fly ash, bentonite, and water would be injected through driven probes into the landfill to fill void space created by the loose compaction of MSW and decomposition. Grout injection would occur in a three-dimensional grid pattern.

Although extremely costly to apply to the entire MSW zone beneath the highway, the implementation of this strategy will likely have desirable consequences on the magnitude and rate of severe settlement if applied to specific locations. Serious pavement disruption or removal would be avoided. Traffic disruption would be minimized. This strategy is evaluated further in comparison to other strategies.

✓ *Consolidate Landfill Material and Provide Embankment Support by Compaction Grouting*

A low slump grout composed primarily of sand, cement, and water would be injected through driven probes to form discreet columns of grout bulbs within the landfill. The expanding bulbs would locally squeeze (compact) the intervening MSW. Grout injection would occur in a three-dimensional grid pattern. Grout columns through the landfill would have the added benefit of transferring embankment loads to the underlying sedimentary formation.

Although extremely costly to apply to the entire MSW zone beneath the highway, the implementation of this strategy will likely have desirable consequences on the magnitude and rate of severe settlement if applied to specific locations. Serious pavement disruption or removal would be avoided. Traffic disruption would be minimized. This strategy is evaluated further in comparison to other strategies.

Note that expanding polyurethane foam has been utilized to effectively perform compaction grouting. However, large accumulations of curing polyurethane foam may generate extreme heat and could be adversely affected by physical/chemical corrosion and interaction within the MSW.

8.3 Strategies to Compensate for Landfill Settlement

- *Lift Pavement by Mud Jacking or Expanding Polyurethane Foam*

The highway settlement would be allowed to continue with no attempt at regulation. A program of shallow grout injection to lift the pavement would be periodically performed to reestablish the pavement profile.

This strategy is judged to be impractical. The existing asphalt concrete pavement has flexibly deformed by gravity and live loads over time to follow the contours of settlement. However the tick rigid pavement behaves rigidly in response to short term stress. The short-term application of upward pressure beneath the pavement will not strain the highway back into a suitable vertical alignment. No further consideration of this strategy is warranted.

✓ *Periodically Restore Highway Profile by Asphalt Concrete Overlays*

A program of asphalt-concrete overlays periodically reestablishes the pavement profile. This is a proven strategy that has successfully mitigated settlement since construction of SR-52 was completed. Asphalt-concrete overlays require no contact with or disturbance of landfill material. An overlay program is adaptable to random settlement. Overlays may be used in combination with other strategies. This strategy is evaluated further for comparison to other strategies.

9.0 COMPARATIVE EVALUATION OF SETTLEMENT MITIGATION STRATEGIES

Seven settlement mitigation strategies are considered for further review. Strategies judged to be similar in scope are combined and further described and evaluated as one strategy. Similar strategies are judged to have similar costs. Bridging the landfill with an at-grade viaduct comprised of box girders supported on bents with driven pile foundations is similar to reconstructing the highway as a structural slab on grade supported by driven piles, geopiers, or reinforced concrete columns. These strategies propose bridging the landfill to circumvent the affects of landfill settlement on SR-52. Therefore, these strategies are hereafter referred to in this report as "Landfill Bridging".

Providing embankment support by soil mixing (Soil Cement); filling voids within landfill material by slurry grouting (Slurry Grouting); and consolidating landfill material and providing embankment support by compaction grouting (Compaction Grouting) are all similar strategies. They all propose improving the subsurface conditions to regulate affects of the landfill settlement on SR-52. Therefore, these strategies are hereafter referred to in this report as "Limited Ground Improvement".

The periodic asphalt concrete overlays are currently implemented with some elements of surface drainage improvement. Therefore, this strategy is hereafter referred to as "Periodic Asphalt Concrete Overlays with Surface Drainage Improvement.

The factors that were evaluated when considering the mitigation strategies are Reliability, Complexity, and Relative Cost.

"Reliability" corresponds to how well settlement and highway operation are managed by the strategy. For example, does the strategy eliminate or control the effects of settlement? Does the strategy have the flexibility to adjust to unforeseen changes in the settlement pattern?

"Complexity" combines multiple project factors pertaining to design, construction, environmental, regulatory, safety, and traffic. "Design" refers to the relative design difficulty of the proposed strategies. "Construction" refers to the relative construction difficulty of the proposed strategies. "Environmental" refers to the complexity of the environmental impacts of the proposed strategies, as well as document preparation and permitting issues. "Regulatory" refers to the complexity of the regulatory obstacles to the proposed strategies development and implementation. "Safety" refers to the safety issues pertaining to the implementation of the project strategies, including highway operations and repetitive worker exposure to traffic. "Traffic" refers to the traffic control considerations associated with implementing the proposed strategies.

"Relative Cost" is the relative value derived from rough construction cost estimates prepared for the proposed strategies. The estimated costs for the proposed strategies or combinations of strategies described in the following sections are included in Table 5.

The SR-52 Settlement Mitigation Strategies Decision Matrix is included in Table 6. This decision matrix applies and sums numeric values to factors considered in determining the best possible strategy to mitigate the settlement of SR-52. The higher numeric value reflects a superior position of consideration. The maximum numeric value for Reliability is twenty (20). The maximum numeric value for Complexity is twenty-five (25). The subcategories of Complexity sum to twenty-five (25) and have the following maximum numeric values: Design is three (3); Construction is five (5); Environmental is three (3); Regulatory is five (5); Safety is five (5); and Traffic is four (4). The maximum numeric value for Relative Cost is twenty (20).

9.1 Landfill Bridging

Landfill bridging would require that portions of the highway be reconstructed as at-grade viaducts. The viaducts would consist of bridge decks supported on structural elements placed through the MSW to competent soil below the landfill on both the east and the west sides of the Convoy Street OC. The support elements may be driven as opposed to drilled in order to avoid MSW removal and relocation. Two options are considered for bridging. Either bridge the entire landfill or bridge only the areas with severe settlement. Bridging the entire landfill would result in two bridges, approximately three thousand-feet (3,000ft) and two thousand-feet (2,000ft) in length on the east and west side of the Convoy Street

OC, respectively. Partial bridging would result in two bridges approximately one thousand seven hundred-feet (1,700ft) and one thousand four hundred-feet (1,400ft) in length on the east and west side of the Convoy Street OC, respectively. Portions of ramps would also require bridging. In both scenarios the ramp bridges would be approximately one thousand two hundred-feet (1,200ft) and one thousand four hundred-feet (1,400ft) to the east and west of the Convoy Street OC, respectively.

Reliability

Bridging the entire landfill scored very high as a reliable strategy because it would isolate SR-52 from the affects of landfill settlement. Partial bridging of the landfill scored moderately as a reliable strategy because settlement in areas that are not bridged would likely still occur in some capacity. Settlement likely to occur outside the bridged areas could affect not only the highway, but also the bridge approach slabs. Periodic slab jacking and periodic overlays should be anticipated.

Complexity

Bridging the entire landfill scored very low for factors pertaining to complexity. Design scored low because designing a bridge is a complex undertaking compounded by unique problems associated with the landfill. Construction scored low because the bridge would be a very complicated structure to construct compared to other strategies considered. Hazardous materials and LFG would compound construction issues. Change orders and claims would be likely due to the extreme variability in subsurface conditions and the obstacles of implementing a thorough subsurface exploration plan. Considerable additional costs should be anticipated due to the inability to accurately define the subsurface conditions, the handling of hazardous materials, and LFG encountered during construction. Environmental scored low due to the materials that would be contacted and emitted during construction. The preparation and acquisition, of environmental documents and permits would further complicate the project. Regulatory scored low due to the complexity of obstacles that would need to be overcome to develop and implement the strategy. Safety scored low due to the large equipment necessary for construction and the potential repeated exposure of workers and public to hazardous wastes and LFG. Traffic scored low due to what would amount to the total disruption of the existing facility and rerouting of traffic.

Partial landfill bridging also scored low for factors pertaining to complexity. Construction considerations for partial bridging scored slightly higher than construction considerations for entire bridging because the total area of the bridges would be less.

Relative Cost

The relative cost of bridging the landfill scored very low because the cost to construct the structures would be exceptionally high.

9.2 Limited Ground Improvement

Limited ground improvement is defined as grouting or soil-cement mixing of the landfill material. Ground improvements would be conducted at depth within the areas that have demonstrated the most severe settlement. Refer to Figures 3 and 12(a-b). The most severe settlement to the east of the Convoy Street OC encompasses an area of approximately two hundred thousand-square feet (200,000ft^2). The most severe settlement to the west of the Convoy Street OC encompasses an area of approximately sixty thousand-square feet (60,000ft^2).

Reliability

Ground improvements scored very low as a reliable strategy as this strategy alone would not entirely eliminate settlement or account for the uncertainty in the location and magnitude of the settlement. It is anticipated that this strategy would be most beneficial if it were implemented in conjunction with periodic asphalt concrete overlays and surface drainage improvements.

Complexity

Ground Improvements scored moderately high for factors pertaining to complexity. Design scored moderately due to the moderate complexity of designing the grouting plan. Construction scored moderately due to moderate complexity of injecting ground improvement materials within a potentially hazardous environment. Environmental scored high because the alteration occurs in-situ within the MSW. Regulatory scored moderately high because the regulatory obstacles to develop and implement ground improvements are less than bridging. Safety scored moderately high because some handling of hazardous materials would occur, although the amount would be considerable less than bridging. Additionally, since the implementation would only occur on one occasion, repeated exposure of workers to safety hazards such as traffic would be low. Traffic scored high because implementation would only occur on one occasion reducing motorist exposure to traffic controls.

Relative Cost

Limited Ground Improvement scored high for relative cost because it is relatively inexpensive to implement.

9.3 Periodic Asphalt-Concrete Overlays with Surface Drainage Improvements

Asphalt concrete overlays are the default settlement mitigation strategy that has been implemented since the construction of SR-52. Some of the surface drainage improvements strategies described in this section (e.g. landscape grading) have also been implemented. Drainage improvements may include:

- Asphalt-concrete overlay of unpaved areas, (e.g. median and gore points). Paving these areas would reduce infiltration of water into the landfill. An added benefit to paving the median is the addition of lanes to accommodate future traffic diversion.
- Curbing shoulders to eliminate sheet flow into surrounding soil.
- Grading depressions into mounds as opposed to filling and flattening to drain water, eliminate ponding, and proactively account for future settlement. Surfacing with clay soils would especially be useful in reducing the percolation of water. Collaborative grading operations with surrounding landowners to eliminate ponding that span the right-of-way boundary should also be considered.
- Eliminate irrigation in the area, particularly in areas where the settlement is most severe.

Reliability

Asphalt-concrete overlays in conjunction with surface drainage improvements scored moderately high as a reliable strategy because historically the placement of asphalt-concrete overlays is a proven strategy for managing settlement. It is anticipated that the program will become even more reliable if additional surface drainage improvements are included with the program. The periodic overlay strategy also has the flexibility be applied to unanticipated settlement.

Complexity

Periodic asphalt-concrete overlays with surface drainage improvements scored moderately high for factors pertaining to complexity. Design scored high because it is relatively simple to design the asphalt-concrete overlay and surface drainage improvements. Construction scored very high because historically it has been relatively simple to overlay the roadway. Proposed surface drainage improvements would not greatly complicate the strategy. Environmental scored moderately because contact with or emission of potentially hazardous materials does not occur. However, drainage improvements would complicate the environmental issues. Regulatory scored very high because historically there have been limited regulatory hurdles to overcome. Safety scored low because of repeated worker exposure to traffic and motorist exposure to traffic control. Motorists may also be intermittently exposed to uneven pavement prior to and during overlays. Traffic scored low due to repeated exposure of the public to highway closure during repair.

Relative Cost

Periodic asphalt-concrete overlays with surface drainage improvements scored high for relative cost because it is relatively inexpensive to implement.

TABLE 5: ESTIAMTED COSTS OF SETLLEMENT MITIGATION STRATEGIES

Strategy or Combination of Strategies	Cost/Implementation ($ X 1,000,000)	50 year Cost ($ X 1,000,000)
Bridging (Entire Landfill)	110	110
Bridging (Areas of Severe Settlement Only)	68	68
Ground Improvement at Areas of Severe Settlement (Soil Mixing or Compaction Grouting)	3.8	3.8[a]
Periodic AC Overlays	1.5[b]	9[c]
Surface Drainage Improvements	0.5	3[c]
Periodic AC Overlays with Surface Drainage Improvements	2	12[c]
Periodic AC Overlays Combined with Surface Drainage Improvements and Limited Ground Improvement	5.8[d]	11.8[e]

Notes:
Future costs are not adjusted for inflation.
Costs reported are rough construction estimates.
Cost Estimates for Landfill Bridging and Limited Ground Improvement are provided in the Appendix.
a. Assumes Limited Ground Improvements are implemented on one (1) occasion in fifty-years (50yr).
b. Reflects the cost of the most recent overlay.
c. Assumes the strategy is implemented on six (6) occasions in fifty-years (50yr). Assumes an overlay occurs for approximately seven-tenths of a foot (0.7ft) of settlement at the most severe locations.
d. Reflects the cost of implementing Limited Ground Improvement, Periodic Asphalt-Concrete Overlays, and Surface Drainage Improvements on one (1) occasion. 3.8 + 1.5 + 0.5 = 5.8
e. Assumes Limited Ground Improvements are implemented on one (1) occasion in fifty-years (50yr). Assumes Periodic Asphalt-Concrete Overlays and Surface Drainage Improvements are implemented on four (4) occasions in fifty-years (50yr). 3.8 X 1 + 2 X 4 = 11.8

TABLE 6: SETTLEMENT MITIGATION STRATEGIES DECISION MATRIX

Strategy (Highest Score Possible)	Reliability (20)	Complexity (25)							Relative Cost (20)	Strategy Score
		Design (3)	Construction (5)	Environmental (3)	Regulatory (5)	Safety (5)	Traffic (4)	Sub-Total (25)		
Bridging (Entire Landfill)	20	1	1	1	1	1	1	6	1	27
Bridging (Areas of Severe Settlement Only)	10	1	2	1	1	1	1	7	6	23
Ground Improvement at Areas of Severe Settlement (Soil Mixing or Compaction Grouting)	6	2	3	2	4	4	4	19	15	40
Periodic AC Overlays and Surface Drainage Improvements	16	3	5	2	5	2	2	19	12	47
Periodic AC Overlays Combined, Surface Drainage Improvements, and Limited Ground Improvement	17	2	2	2	4	3	3	16	13	46

Notes:
Higher numerical values reflect a superior position of consideration.

10.0 RECOMMENDATIONS

Based on the evaluation presented in Section 9.0, it is recommended that a strategy of Periodic Asphalt Concrete Overlays with Surface Drainage Improvements be utilized to mitigate the settlement of the section of SR-52 that crosses over the landfill. Assuming an overlay will be placed every seven-tenths of a foot (0.7ft) of maximum settlement, the SR-52 Estimated Time-Settlement Curve Data indicates that the number of overlays that will be needed over next fifty-years (50yr) is six (6). It is estimated that the overlays will occur in approximately three-years (3yr) 2012, six-years (6yr) 2015, ten-years (10yr) 2019, twenty-years (20) 2029, and approximately forty-years (40yr) 2048, respectively. A sixth overlay is estimated to occur some time after 2059.

The rates, geometry, and locations of settlement included in this report are estimated based on the best available data. These estimates have been developed and are sufficient to compare and contrast the different settlement mitigation strategies considered for review. These estimates are not intended to depict or determine detailed information of the highway time rate of settlement and or the precise geometry of the settlement.

It is highly recommended that consistent, long-term monitoring of the highway and surrounding depressions in the landscape where ponding occurs be conducted to determine detailed information of the highway time rate of settlement and the precise geometry of the settlement. This data can be used to efficiently manage the periodic overlay program (e.g. calculate quantities of material needed for an overlay) and monitor the rate of settlement (e.g. predict future settlement). Long term settlement monitoring may consist of:

- Quarterly mobile surveying of the highway.
- Conduct surveying immediately prior to and after an overlay.
- Semi-annual surveying of the surrounding depressions in the landscape and between the gore points.
- Annual acquisition and evaluation of LFG collection data pertaining to South Miramar Landfill and Allred/Collins Business Park to monitor LFG production.
- Annual acquisition and evaluation of the City of San Diego Water Quality Monitoring Report for the South Miramar Landfill.

Following a period of precise settlement monitoring and additional consideration by District 11 functional units and management, it may be deemed of greater value to combine Limited Ground Improvement (e.g. compaction grouting or soil mixing) with Periodic Asphalt Concrete Overlay and Surface Drainage Improvements. The inclusion of Limited Ground Improvement would likely reduce the number and cost of future overlays and may potentially mitigate uncertainty associated with the locations that demonstrate the most severe settlement. If Limited Ground Improvement is considered, a supplemental geotechnical investigation will be necessary to determine if the procedure is feasible and to accurately characterize the subsurface conditions for project bidders.

It is highly recommended that the trees, reeds, brush, and sediment that have obstructed the flow and aggraded the rock-lined culvert outfalls of Storm Drains 40 and 45 be removed. It is anticipated that this action will lower the perched groundwater table that is contributing to the settlement of SR-52 with the additional benefit of restoring proper culvert operation. This will also reduce or eliminate standing water that is contributing to the corrosion of the storm drains. Regular inspection and maintenance of Storm

Drains 40 and 45 should be conducted to ensure the backup of water does not occur in the future. This will require coordination with the City of San Diego ESD.

Recommended Surface Drainage Improvements include: asphalt-concrete overlay of unpaved areas, (e.g. median and gore points); curbing shoulders to eliminate sheet flow into surrounding soil; grading depressions into mounds; and eliminating irrigation in the area. Additionally, it is recommended that grading efforts be coordinated with the City of San Diego Environmental Services Department Refuse Disposal Division (City of San Diego ESD) to eliminate depressions that span Caltrans right-of-way and lead to storm water infiltration.

This report has been prepared from a geotechnical perspective. Other functional units within Caltrans may have different perspectives and/or additional considerations that may result in different prioritization of alternatives.

11.0 ACTUAL VS. REPORTED SITE CONDITIONS

The information used to characterize the geotechnical conditions in this area was gathered from project plans, pertinent maps, geologic literature, archived reports, field reconnaissance, pavement coring, testing, and engineering analysis. Project design features may change, and localized soil and/or landfill conditions may vary from those described in this report. Due to the inability to perform exploratory drilling, uncertainty exists regarding the exact character of the landfill material. Localized concentrations of biodegradable material may be greater than those estimated for this investigation.

This report was developed for the purpose of evaluating and comparing settlement mitigation strategies. Any project plans with features that intrude into or otherwise disturb the landfill may require a supplemental geotechnical investigation and report based on the proposed features. Any project plans with features that widen SR-52 may also require a supplemental geotechnical investigation and report based on the proposed features. Such investigations should be conducted to accurately characterize the subsurface conditions and/or define geotechnical parameters relevant to project design and construction.

12.0 REFERENCES

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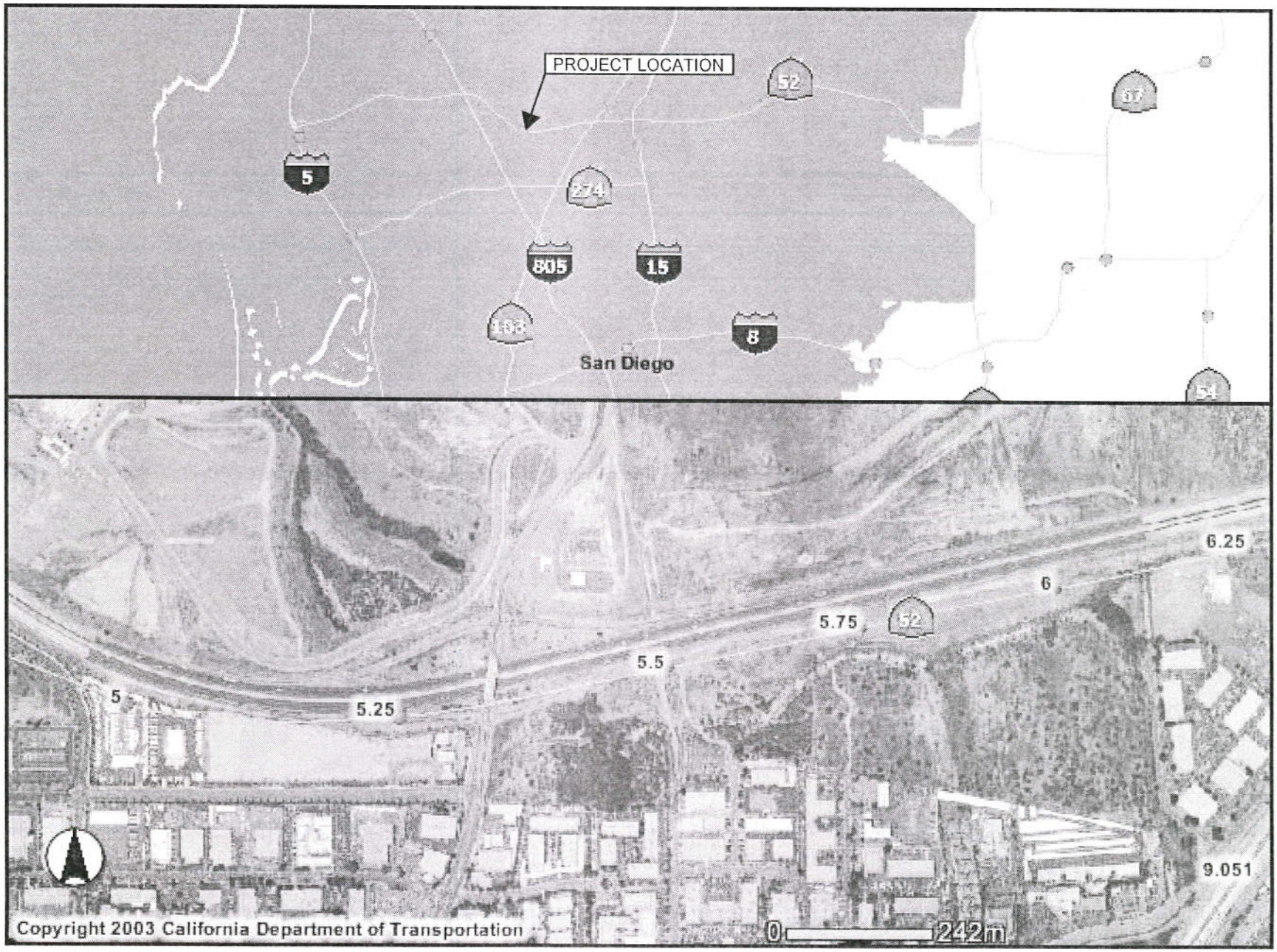
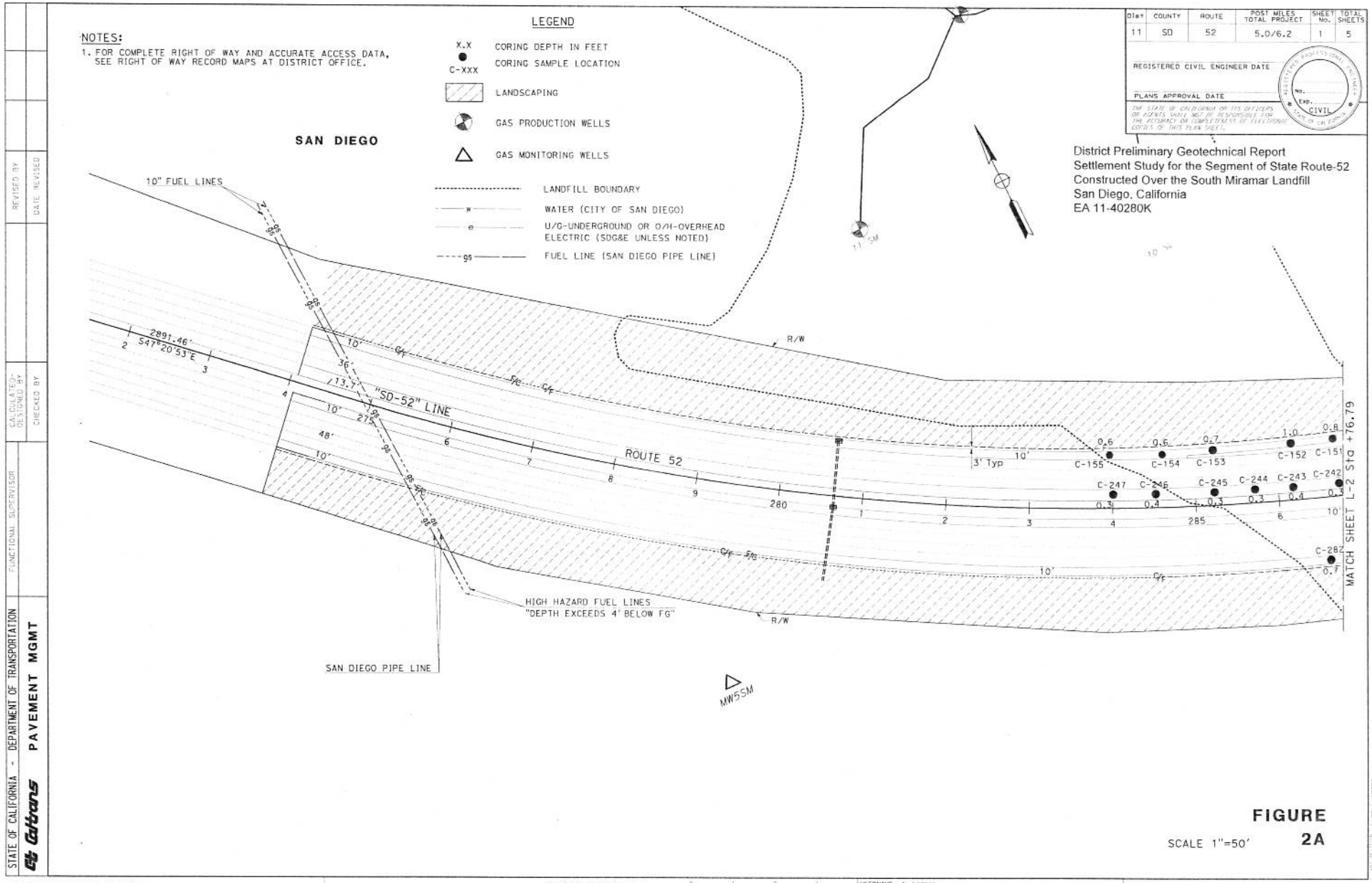


District Preliminary Geotechnical Report
Settlement Study for the Segment of State Route-52
Constructed Over the South Miramar Landfill
San Diego, California
EA 11-40280K

FIGURE 1: PROJECT LOCATION


NOTES:
1. FOR COMPLETE RIGHT OF WAY AND ACCURATE ACCESS DATA, SEE RIGHT OF WAY RECORD MAPS AT DISTRICT OFFICE.
LEGEND
X.X CORING DEPTH IN FEET
C-XXX CORING SAMPLE LOCATION
LANDSCAPING
GAS PRODUCTION WELLS
GAS MONITORING WELLS
LANDFILL BOUNDARY
WATER (CITY OF SAN DIEGO)
U/G-UNDERGROUND OR O/H-OVERHEAD ELECTRIC (SDG&E UNLESS NOTED)
FUEL LINE (SAN DIEGO PIPE LINE)
SAN DIEGO
10" FUEL LINES
2891.46'
S47°20'53"E
"SD-52" LINE
ROUTE 52
R/W
3' Typ
HIGH HAZARD FUEL LINES "DEPTH EXCEEDS 4' BELOW FG"
SAN DIEGO PIPE LINE
MATCH SHEET L-2 Sta +76.79
C-155
C-154
C-153
C-152
C-151
C-247
C-246
C-245
C-244
C-243
C-242
C-287
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Constructed Over the South Miramar Landfill
San Diego, California
EA 11-40280K
Dist 11 | COUNTY SD | ROUTE 52 | POST MILES TOTAL PROJECT 5.0/6.2 | SHEET No. 1 | TOTAL SHEETS 5
REGISTERED CIVIL ENGINEER DATE
PLANS APPROVAL DATE
THE STATE OF CALIFORNIA OR ITS OFFICERS OR AGENTS SHALL NOT BE RESPONSIBLE FOR THE ACCURACY OR COMPLETENESS OF ELECTRONIC COPIES OF THIS PLAN SHEET.
REGISTERED PROFESSIONAL ENGINEER
No.
Exp.
CIVIL
STATE OF CALIFORNIA
REVISED BY
DATE REVISED
CALCULATED-DESIGNED BY
CHECKED BY
FUNCTIONAL SUPERVISOR
STATE OF CALIFORNIA - DEPARTMENT OF TRANSPORTATION
Caltrans
PAVEMENT MGMT
FIGURE
SCALE 1"=50'
2A
BORDER LAST REVISED 3/1/2007
RELATIVE BORDER SCALE IS IN INCHES
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CU 06261
EA 40280K
DATE PLOTTED => 09-SEP-2009
TIME PLOTTED => 16:46
06-30-08

NOTE: FOR COMPLETE RIGHT OF WAY AND ACCURATE ACCESS DATA, SEE RIGHT OF WAY RECORD MAPS AT DISTRICT OFFICE.

Dist	COUNTY	ROUTE	POST MILES TOTAL PROJECT	SHEET No.	TOTAL SHEETS
11	SD	52	5.0/6.2	2	5

REGISTERED CIVIL ENGINEER DATE

PLANS APPROVAL DATE

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Constructed Over the South Miramar Landfill
San Diego, California
EA 11-40280K

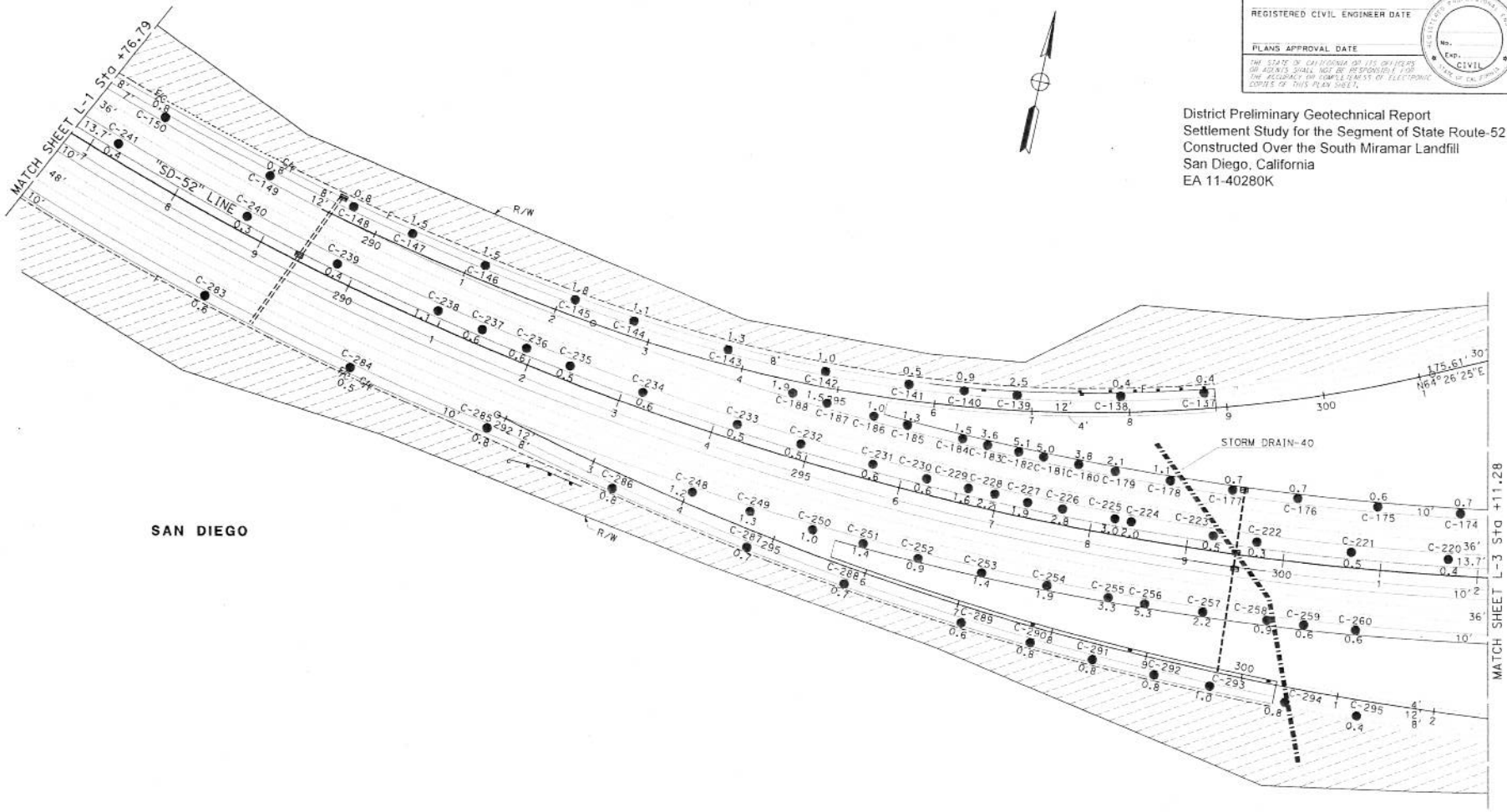

FIGURE 2B

SCALE 1"=50'

STATE OF CALIFORNIA - DEPARTMENT OF TRANSPORTATION
Caltrans
06-DESIGN
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CALCULATED-DESIGNED BY: TRIET LY
CHECKED BY: WILLIAM LEON
REVISED BY
DATE REVISED

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District	COUNTY	ROUTE	POST MILES TOTAL PROJECT	SHEET No.	TOTAL SHEETS
11	SD	52	5.0/6.2	3	5

REGISTERED CIVIL ENGINEER DATE

PLANS APPROVAL DATE

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Constructed Over the South Miramar Landfill
San Diego, California
EA 11-40280K

NOTE:
FOR COMPLETE RIGHT OF WAY AND ACCURATE ACCESS DATA, SEE RIGHT OF WAY RECORD MAPS AT DISTRICT OFFICE.

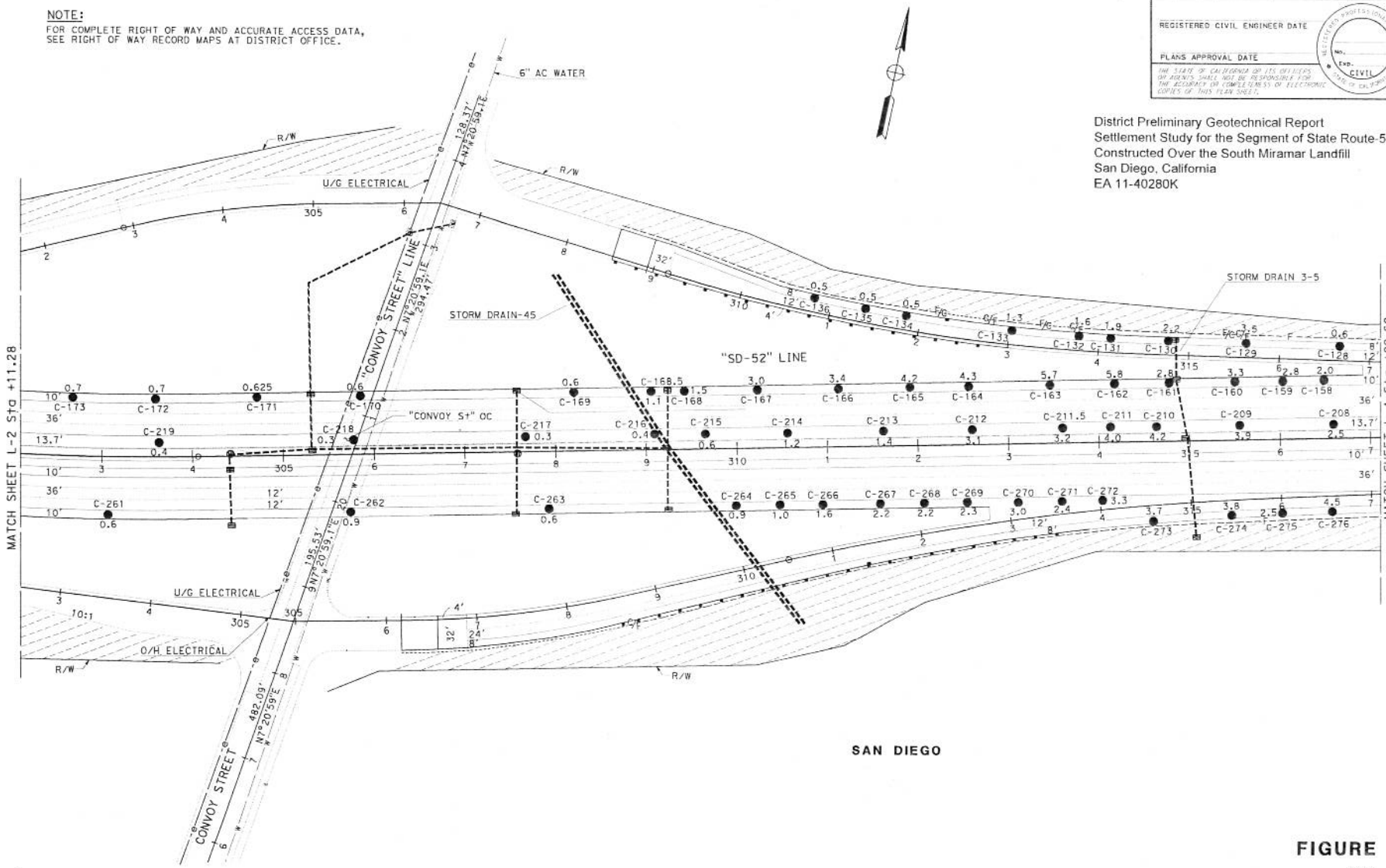

FIGURE 2C

SCALE 1"=50'

STATE OF CALIFORNIA - DEPARTMENT OF TRANSPORTATION
Caltrans 06-DESIGN

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CALCULATED/DESIGNED BY: TRIET LY
CHECKED BY: WILLIAM LEON
REVISED BY / DATE REVISED

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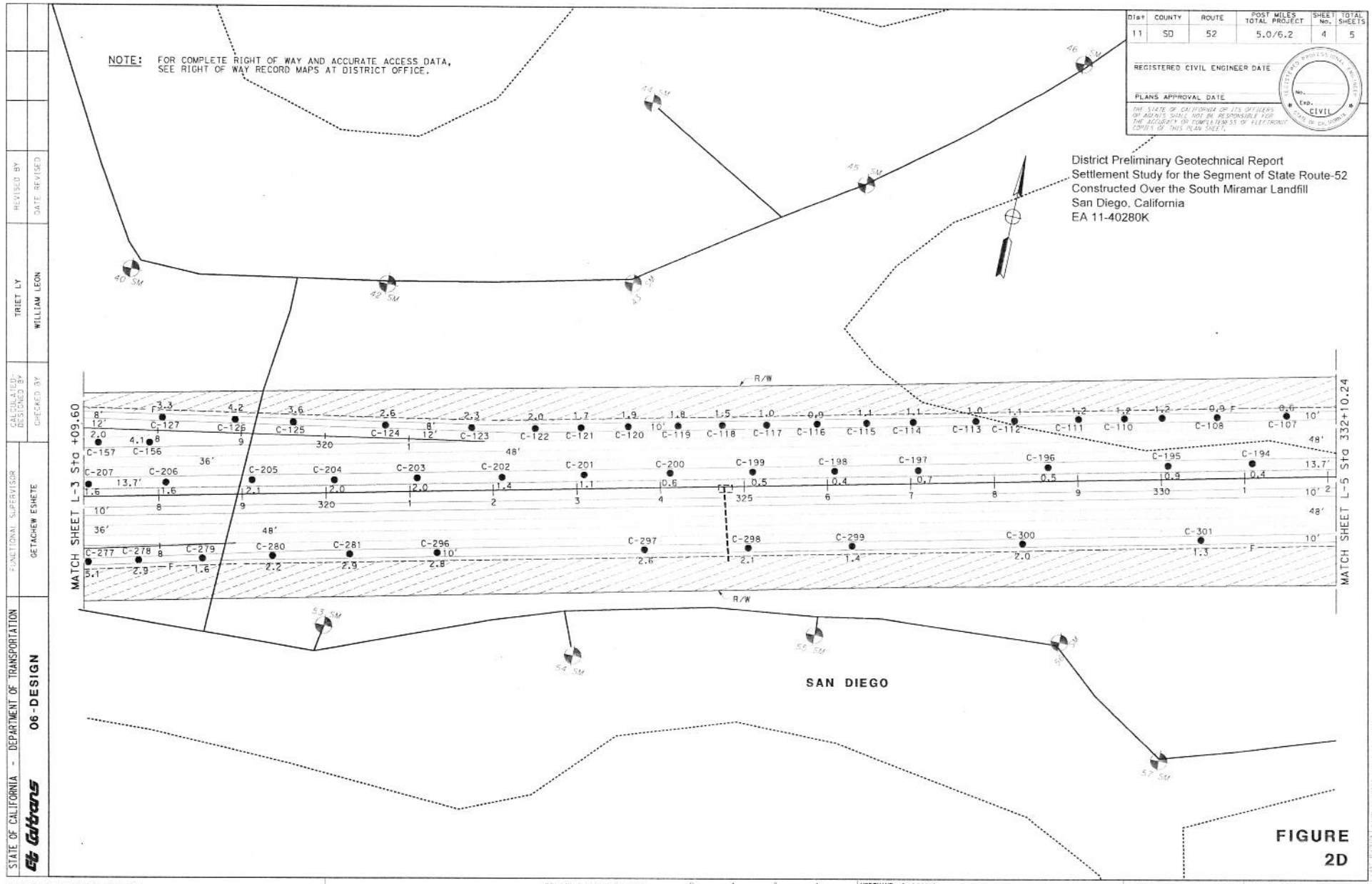
NOTE: FOR COMPLETE RIGHT OF WAY AND ACCURATE ACCESS DATA, SEE RIGHT OF WAY RECORD MAPS AT DISTRICT OFFICE.
District Preliminary Geotechnical Report
Settlement Study for the Segment of State Route-52
Constructed Over the South Miramar Landfill
San Diego, California
EA 11-40280K
MATCH SHEET L-3 Sta +09.60
MATCH SHEET L-5 Sta 332+10.24
R/W
SAN DIEGO
Dist 11 | COUNTY SD | ROUTE 52 | POST MILES TOTAL PROJECT 5.0/6.2 | SHEET No. 4 | TOTAL SHEETS 5
REGISTERED CIVIL ENGINEER DATE
PLANS APPROVAL DATE
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STATE OF CALIFORNIA - DEPARTMENT OF TRANSPORTATION
Caltrans
06-DESIGN
FUNCTIONAL SUPERVISOR GETACHEW ESHETE
CALCULATED/DESIGNED BY TRIET LY
CHECKED BY WILLIAM LEON
REVISED BY
DATE REVISED
FIGURE 2D
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Dist	COUNTY	ROUTE	POST MILES TOTAL PROJECT	SHEET No.	TOTAL SHEETS
11	SD	52	5.0/6.2	5	5

REGISTERED CIVIL ENGINEER DATE

PLANS APPROVAL DATE

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REGISTERED PROFESSIONAL ENGINEER No. Exp. CIVIL STATE OF CALIFORNIA

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Constructed Over the South Miramar Landfill
San Diego, California
EA 11-40280K

NOTE:

FOR COMPLETE RIGHT OF WAY AND ACCURATE ACCESS DATA, SEE RIGHT OF WAY RECORD MAPS AT DISTRICT OFFICE.

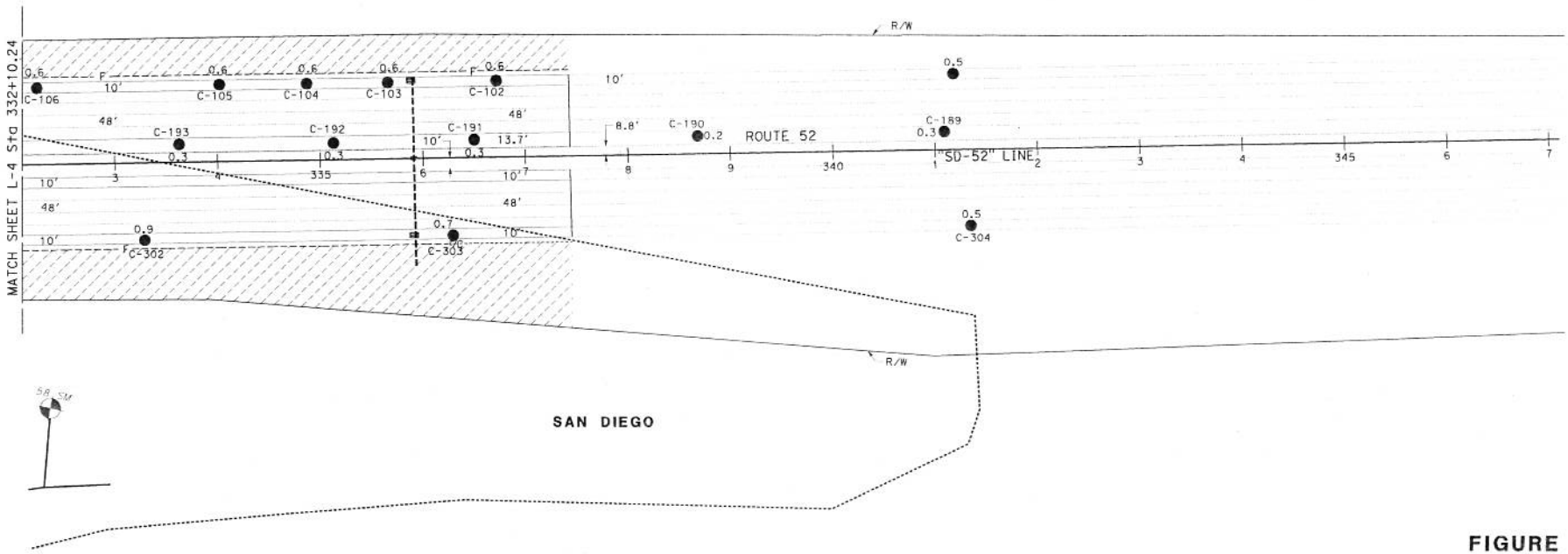

FIGURE 2E

SCALE 1"=50'

STATE OF CALIFORNIA - DEPARTMENT OF TRANSPORTATION
Caltrans PAVEMENT MANAGEMENT

FUNCTIONAL SUPERVISOR | CALCULATED/DESIGNED BY | CHECKED BY | REVISED BY | DATE REVISED

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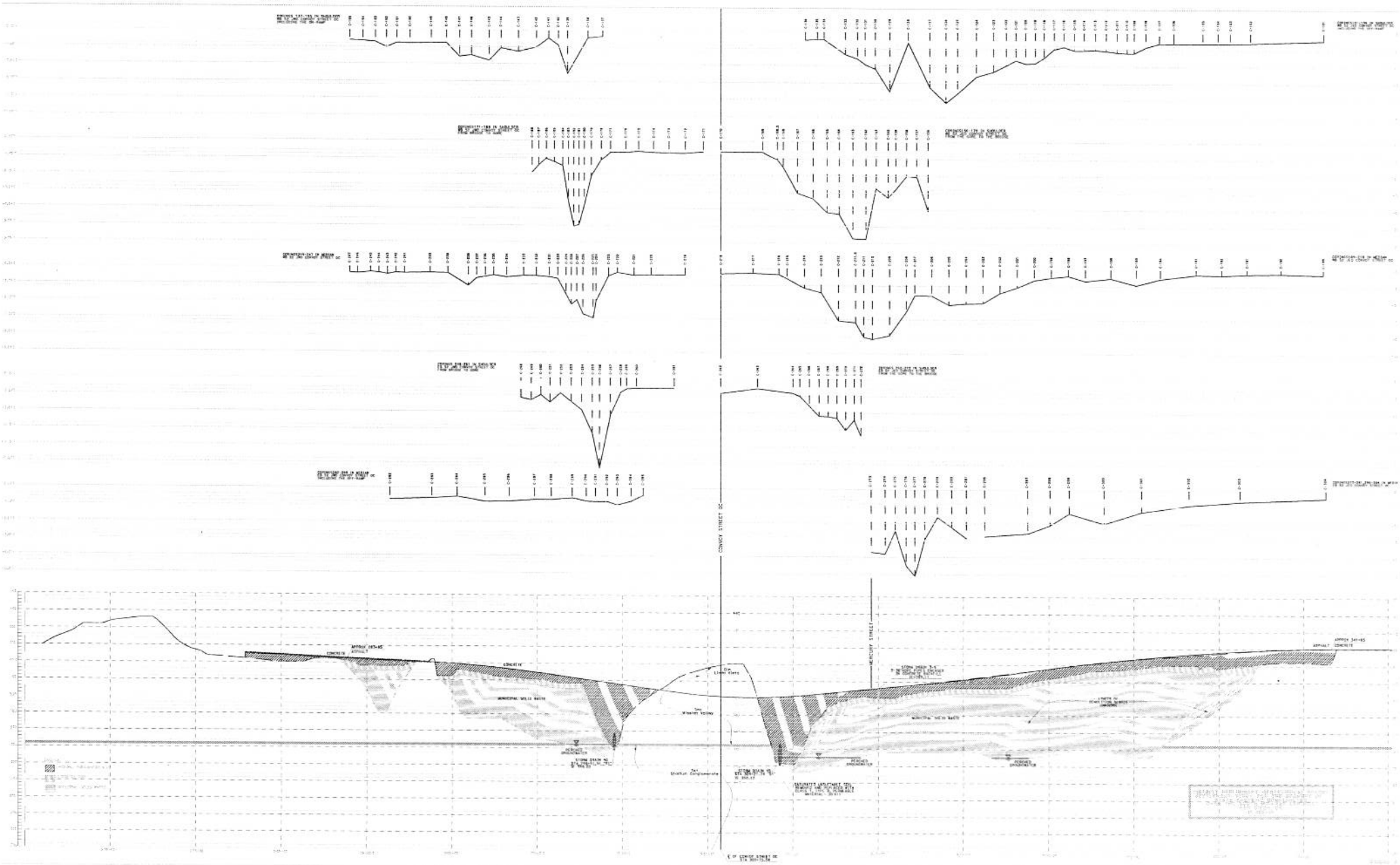
CONVOY STREET
MERCHANT STREET
CONCRETE
ASPHALT
MUNICIPAL SOLID WASTE
Stanton Conglomerate

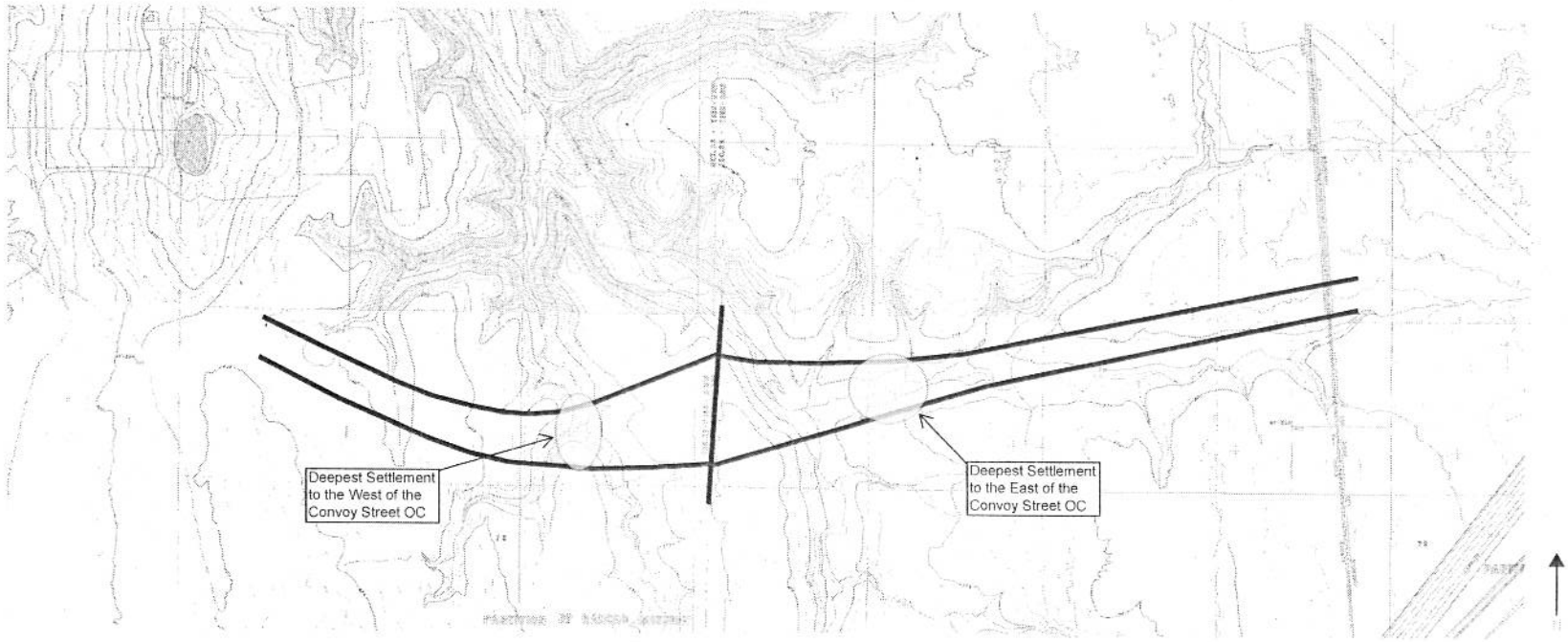

FIGURE 4: 1952 TOPOGRAPHIC MAP

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Constructed Over the South Miramar Landfill
San Diego, California
EA 11-40280K

FIGURE 5: 1963 AERIAL PHOTOGRAPH /TOPOGRAPHIC MAP

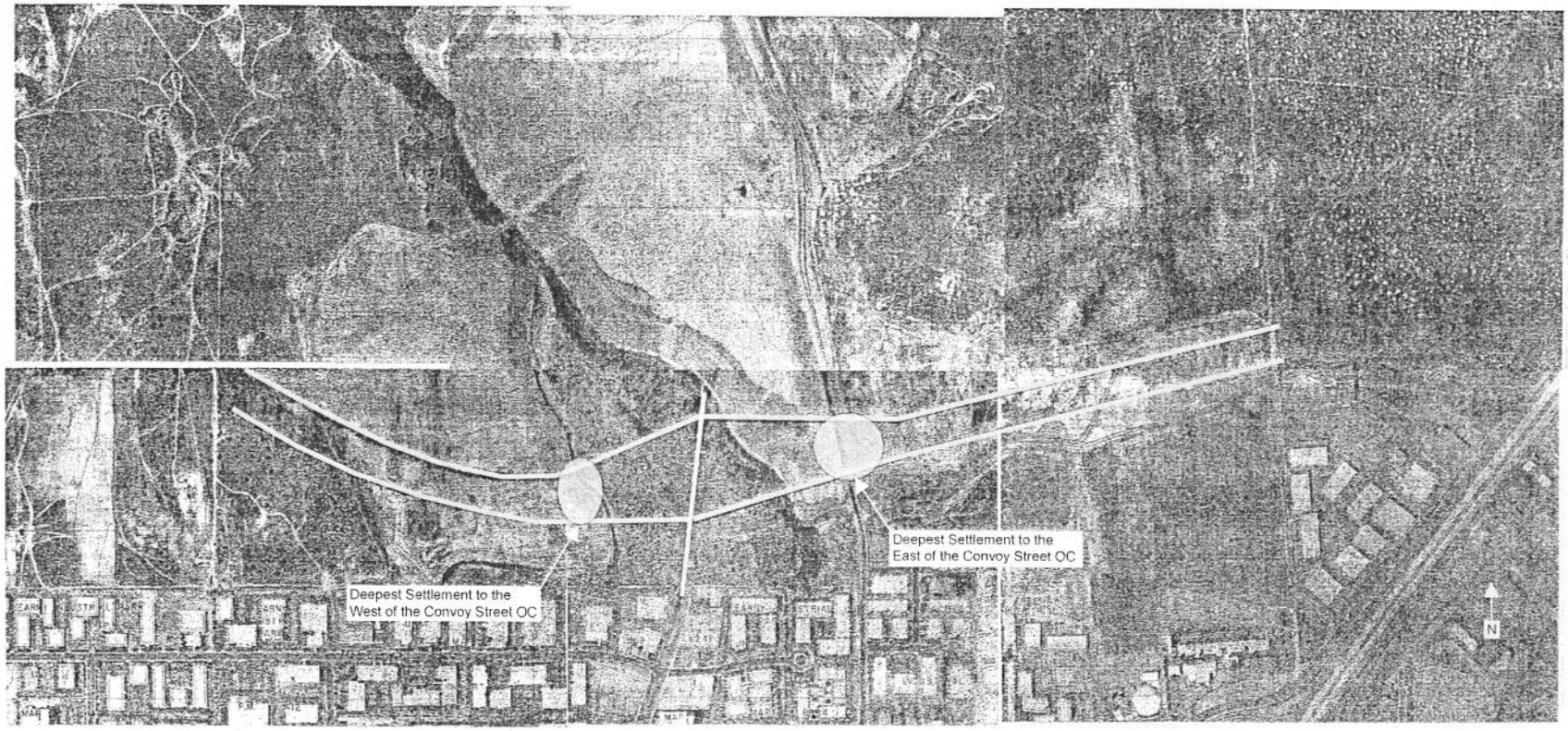

FIGURE 6: 1978 AERIAL PHOTOGRAPH

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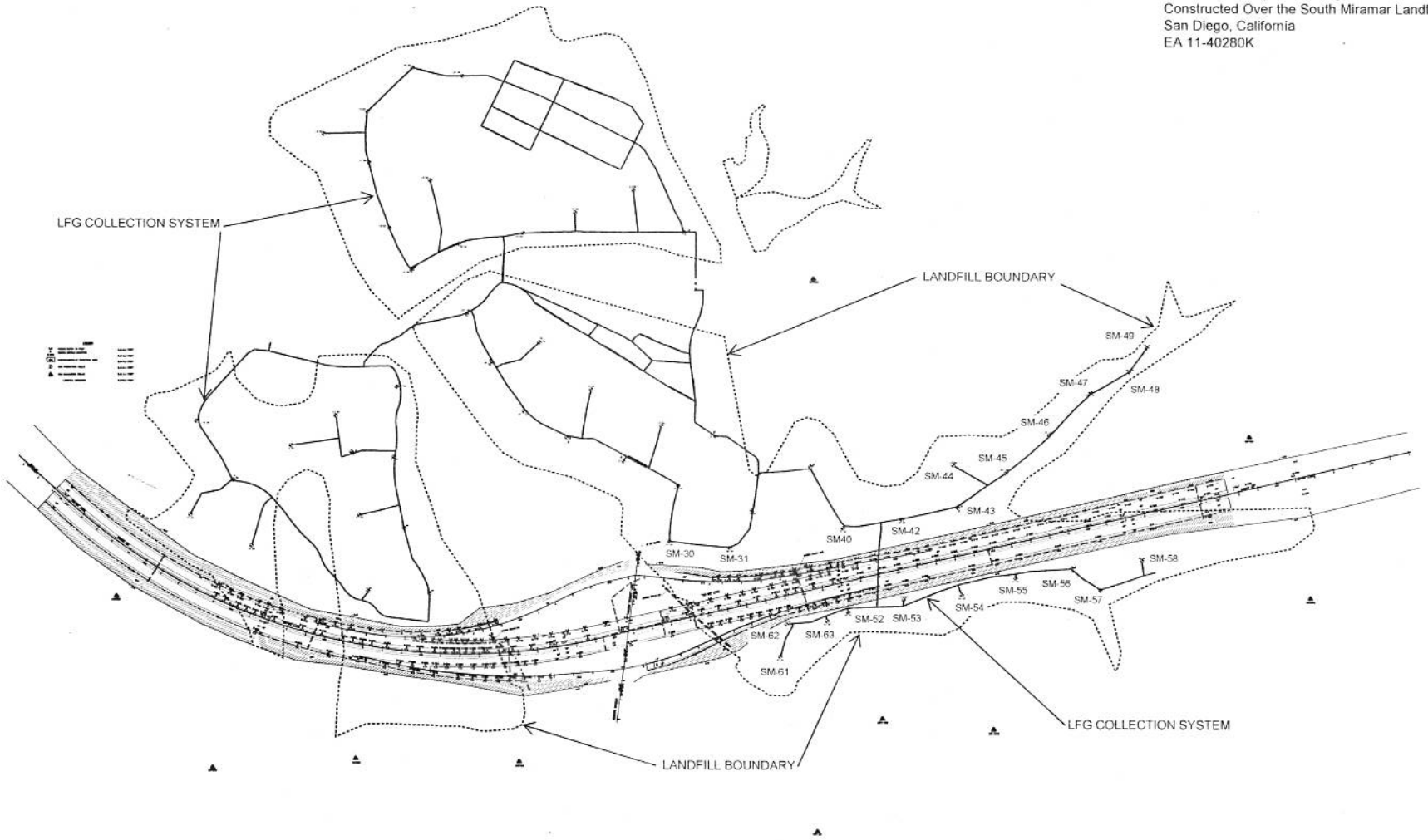
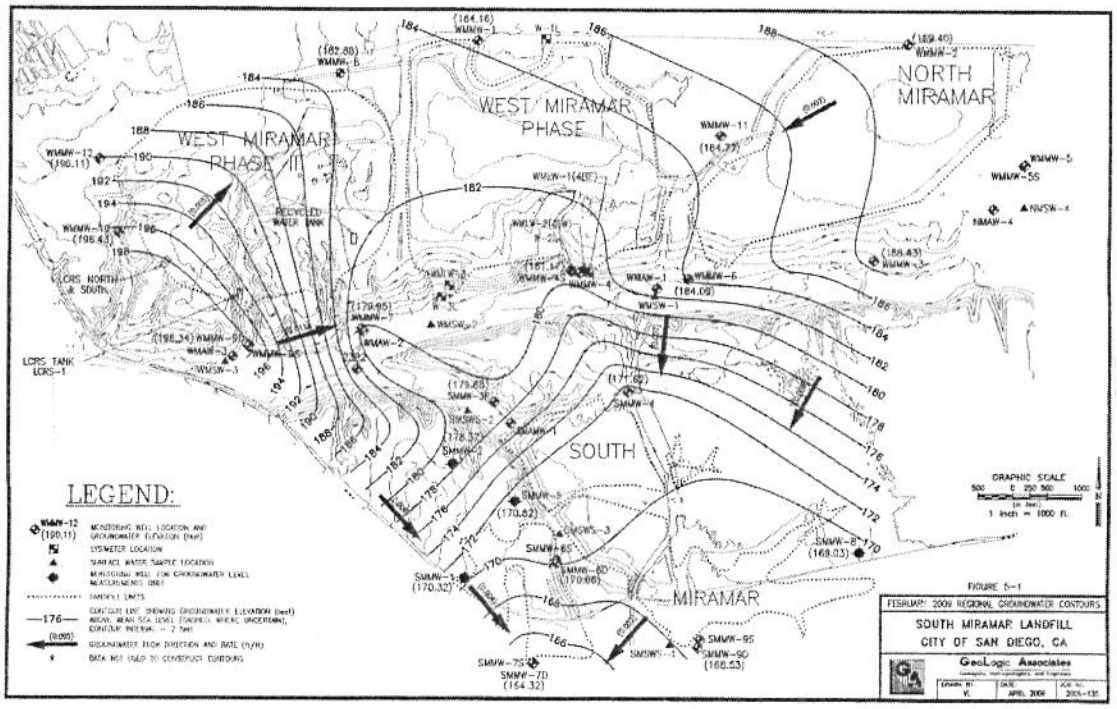
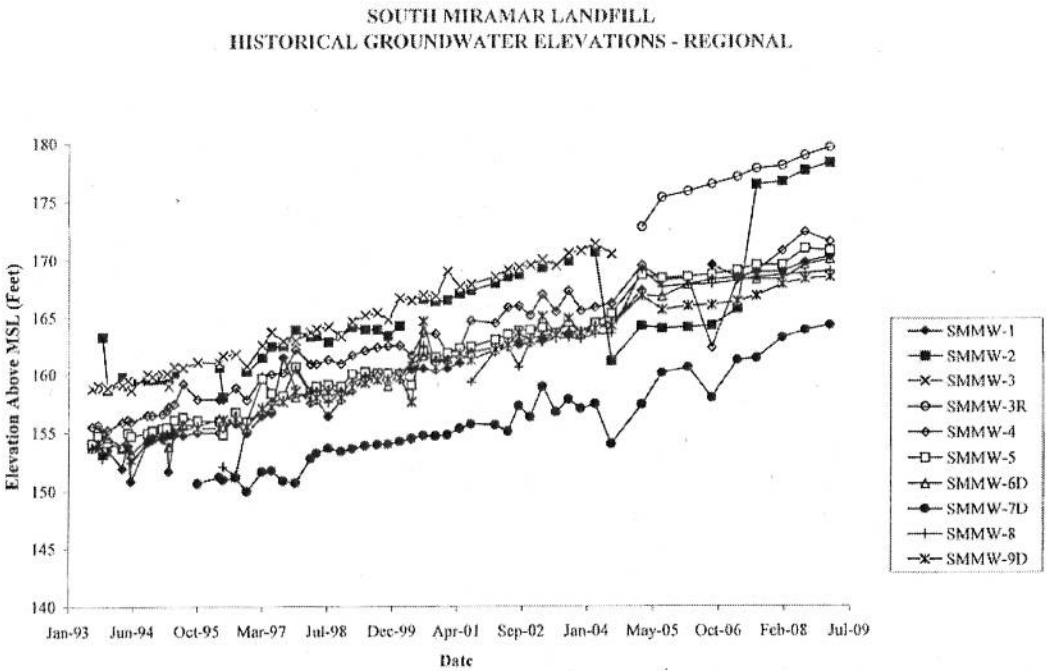


FIGURE 7:
LANDFILL BOUNDARY AND
LANDFILL GAS COLLECTION SYSTEM



City of San Diego Water Quality Monitoring Report, South Miramar Landfill, April 2009

FIGURE 8: REGIONAL GROUNDWATER CONTOUR MAP



City of San Diego Water Quality Monitoring Report, South Miramar Landfill, April 2009

FIGURE 9: HISTORICAL REGIONAL GROUNDWATER ELEVATION

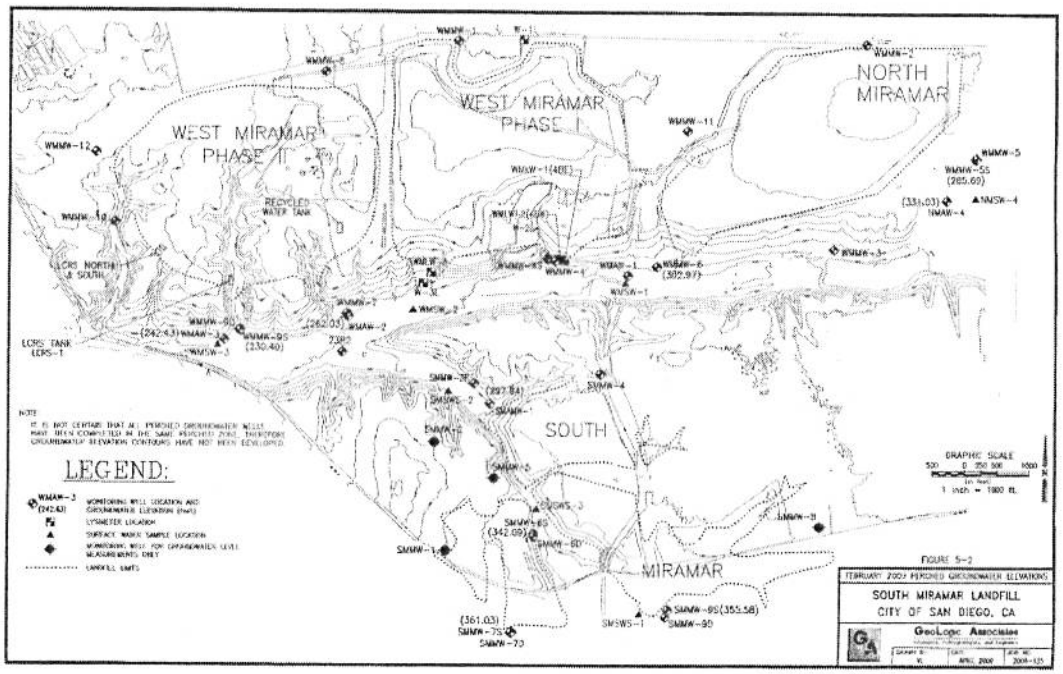


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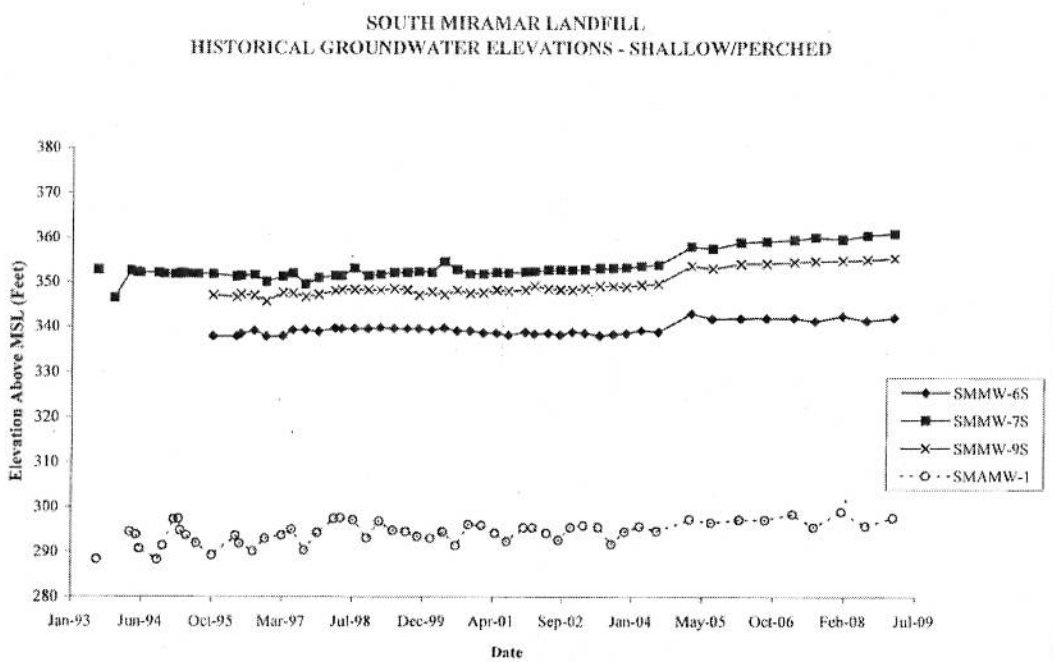
FIGURE 10: PERCHED GROUNDWATER ELEVATIONS



City of San Diego Water Quality Monitoring Report, South Miramar Landfill, April 2009

FIGURE 11: HISTORICAL PERCHED GROUNDWATER ELEVATION

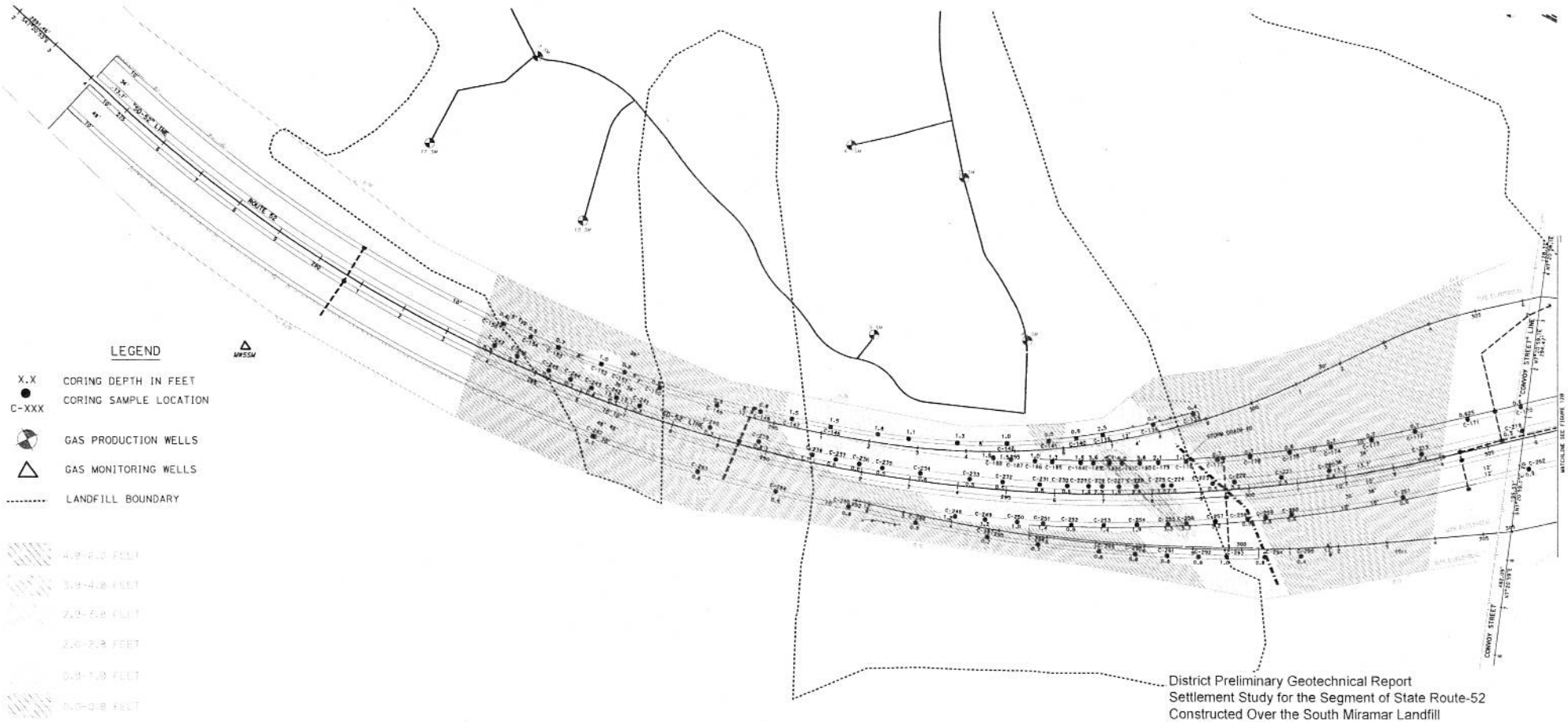


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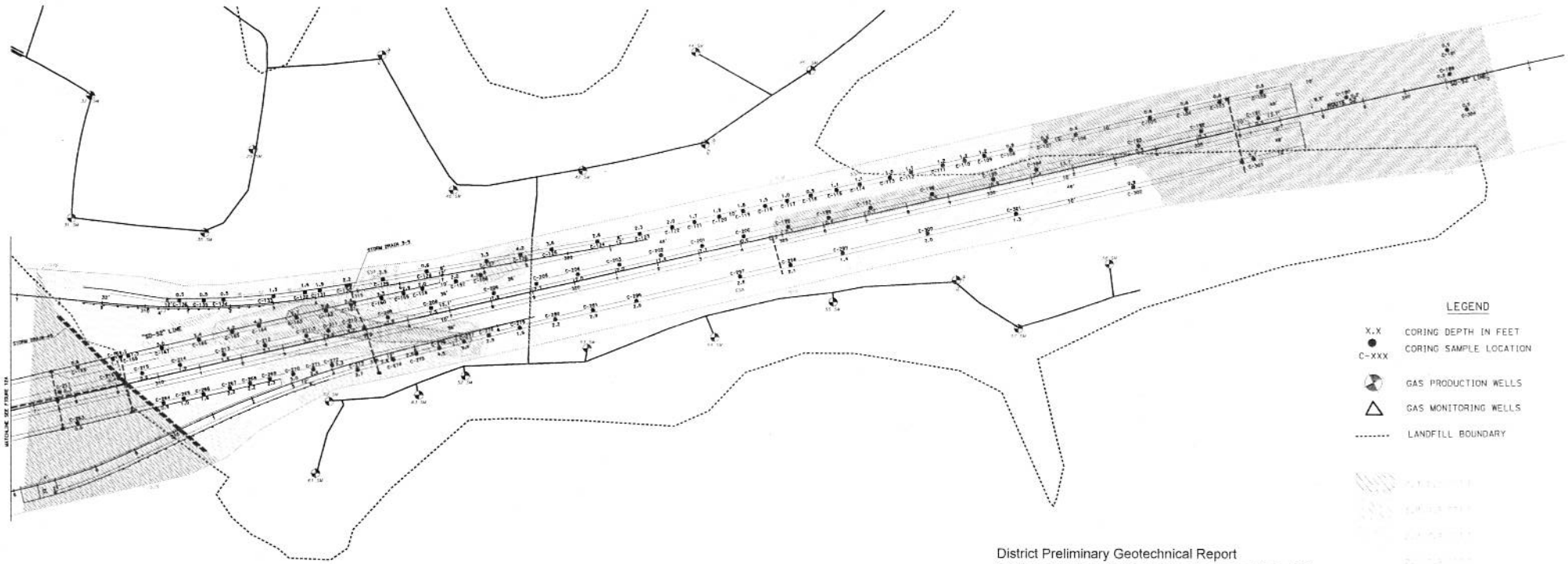
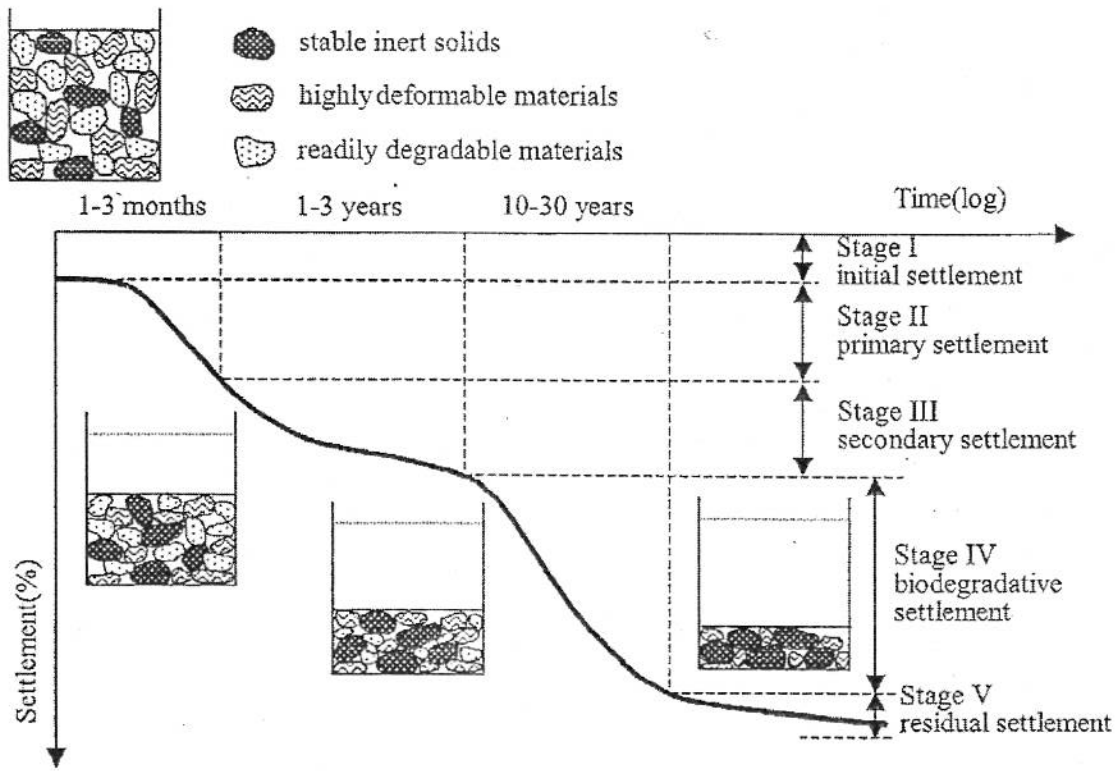
FIGURE 12A



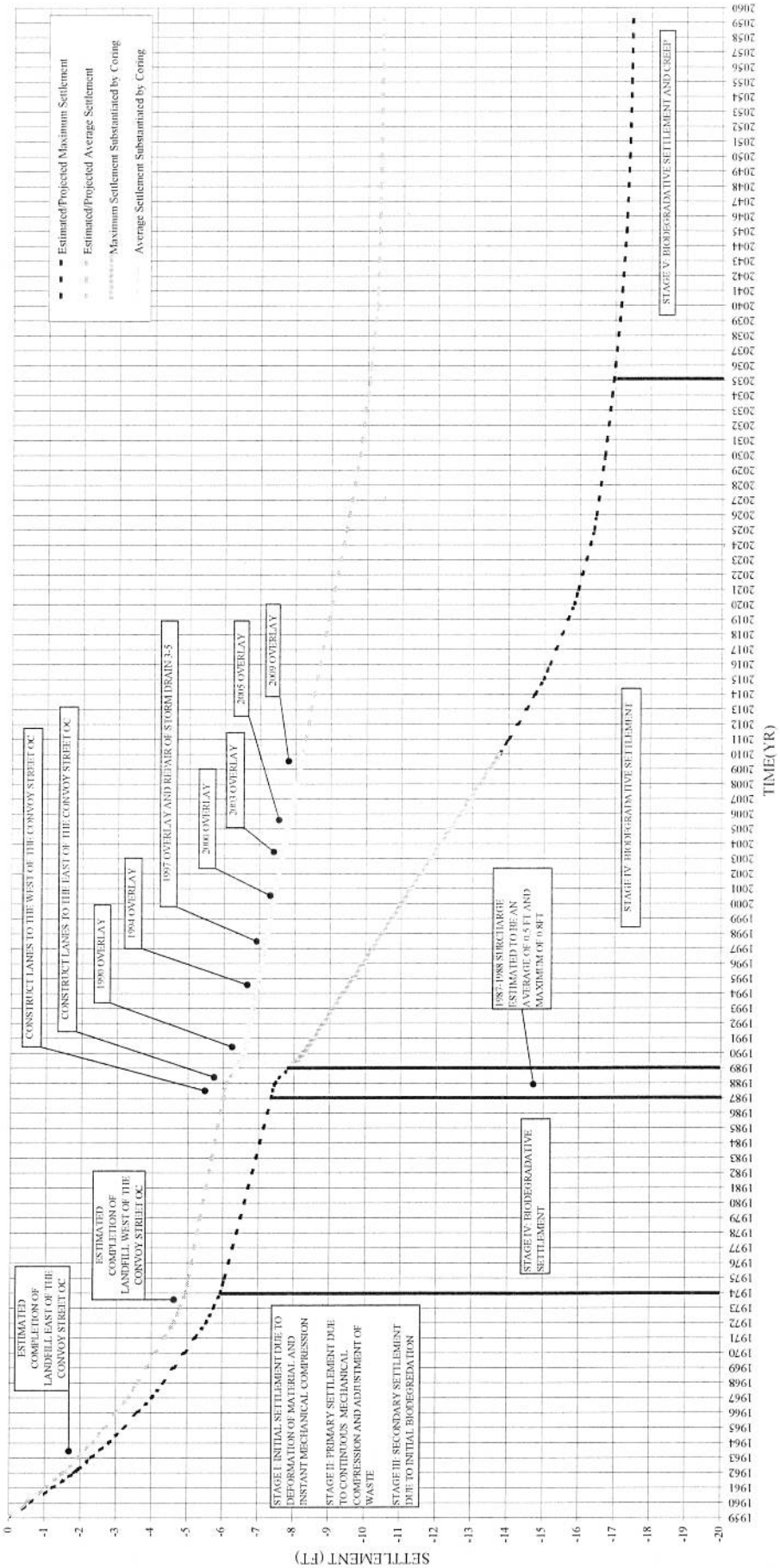
District Preliminary Geotechnical Report
Settlement Study for the Segment of State Route-52
Constructed Over the South Miramar Landfill
San Diego, California
EA 11-40280K

FIGURE 12B



Unsaturated Consolidation Theory for the Prediction of Long-Term Municipal Solid Waste Landfill Settlement (Lui & Chen, 2006) (Redrawn from Grisolia and Napoleoni, 1995)

FIGURE 13: TYPICAL LANDFILL TIME-SETTLEMENT CURVE


Estimated/Projected Maximum Settlement
Estimated/Projected Average Settlement
Maximum Settlement Substantiated by Coring
Average Settlement Substantiated by Coring
CONSTRUCT LANES TO THE WEST OF THE CONVOY STREET OC
CONSTRUCT LANES TO THE EAST OF THE CONVOY STREET OC
1990 OVERLAY
1994 OVERLAY
1997 OVERLAY AND REPAIR OF STORM DRAIN 3-5
2000 OVERLAY
2003 OVERLAY
2008 OVERLAY
2009 OVERLAY
ESTIMATED COMPLETION OF LANDFILL EAST OF THE CONVOY STREET OC
ESTIMATED COMPLETION OF LANDFILL WEST OF THE CONVOY STREET OC
STAGE I: INITIAL SETTLEMENT DUE TO DEFORMATION OF MATERIAL AND INSTANT MECHANICAL COMPRESSION
STAGE II: PRIMARY SETTLEMENT DUE TO CONTINUOUS MECHANICAL COMPRESSION AND ADJUSTMENT OF WASTE
STAGE III: SECONDARY SETTLEMENT DUE TO INITIAL BIODEGREDATION
STAGE IV: BIODEGRADATIVE SETTLEMENT
1987-1988 SURCHARGE ESTIMATED TO HEAN AVERAGE OF 0.5 FT AND MAXIMUM OF 0.8 FT
STAGE IV: BIODEGRADATIVE SETTLEMENT
STAGE V: BIODEGRADATIVE SETTLEMENT AND CREEP
SETTLEMENT (FT)
TIME (YR)

APPENDIX

SR-52 ESTIMATED TIME-SETTLEMENT CURVE DATA

	Maximum Settlement		Average Settlement	
Time (yr)	Annual Settlement (ft)	Total Settlement (ft)	Annual Settlement (ft)	Total Settlement (ft)
1959	0.61	-0.6	0.51	-0.5
1960	0.61	-1.2	0.51	-1.0
1961	0.61	-1.8	0.51	-1.5
1962	0.49	-2.3	0.41	-1.9
1963	0.49	-2.8	0.41	-2.3
1964	0.41	-3.2	0.34	-2.7
1965	0.41	-3.6	0.34	-3.0
1966	0.41	-4.0	0.34	-3.3
1967	0.30	-4.3	0.25	-3.6
1968	0.30	-4.6	0.25	-3.9
1969	0.30	-4.9	0.25	-4.1
1970	0.30	-5.2	0.25	-4.4
1971	0.30	-5.5	0.25	-4.6
1972	0.20	-5.7	0.17	-4.8
1973	0.20	-5.9	0.17	-5.0
1974	0.11	-6.1	0.08	-5.0
1975	0.11	-6.2	0.08	-5.1
1976	0.11	-6.3	0.08	-5.2
1977	0.11	-6.4	0.08	-5.3
1978	0.11	-6.5	0.08	-5.4
1979	0.11	-6.6	0.08	-5.4
1980	0.11	-6.7	0.08	-5.5
1981	0.11	-6.8	0.08	-5.6
1982	0.11	-6.9	0.08	-5.7
1983	0.11	-7.0	0.08	-5.8
1984	0.11	-7.1	0.08	-5.8
1985	0.11	-7.3	0.08	-5.9
1986	0.11	-7.4	0.08	-6.0
1987	0.11	-7.5	0.08	-6.1
1988	0.40	-7.9	0.25	-6.3
1989	0.40	-8.3	0.25	-6.6
1990	0.27	-8.5	0.08	-6.7
1991	0.27	-8.8	0.08	-6.7
1992	0.27	-9.1	0.08	-6.8
1993	0.27	-9.4	0.08	-6.9
1994	0.27	-9.6	0.08	-7.0
1995	0.27	-9.9	0.08	-7.1
1996	0.27	-10.2	0.08	-7.2
1997	0.27	-10.5	0.08	-7.2
1998	0.27	-10.7	0.08	-7.3
1999	0.27	-11.0	0.08	-7.4
2000	0.27	-11.3	0.08	-7.5
2001	0.27	-11.6	0.08	-7.6
2002	0.27	-11.8	0.08	-7.6
2003	0.27	-12.1	0.08	-7.7
2004	0.27	-12.4	0.08	-7.8
2005	0.27	-12.7	0.08	-7.9
2006	0.27	-12.9	0.08	-8.0
2007	0.27	-13.2	0.08	-8.0
2008	0.27	-13.5	0.08	-8.1
2009	0.27	-13.7	0.08	-8.2
2010	0.25	-14.0	0.08	-8.3
2011	0.25	-14.2	0.08	-8.4
2012	0.25	-14.5	0.08	-8.4
2013	0.25	-14.7	0.08	-8.5
2014	0.25	-15.0	0.08	-8.6
2015	0.17	-15.2	0.08	-8.7
2016	0.17	-15.3	0.08	-8.8
2017	0.17	-15.5	0.08	-8.9
2018	0.17	-15.7	0.08	-8.9
2019	0.17	-15.8	0.08	-9.0
2020	0.11	-16.0	0.08	-9.1
2021	0.11	-16.1	0.08	-9.2
2022	0.11	-16.2	0.08	-9.3
2023	0.11	-16.3	0.08	-9.3
2024	0.11	-16.4	0.08	-9.4
2025	0.06	-16.5	0.07	-9.5
2026	0.06	-16.5	0.07	-9.6
2027	0.06	-16.6	0.07	-9.6
2028	0.06	-16.6	0.07	-9.7
2029	0.06	-16.7	0.07	-9.8
2030	0.05	-16.8	0.06	-9.8
2031	0.05	-16.8	0.06	-9.9
2032	0.05	-16.9	0.06	-10.0
2033	0.05	-16.9	0.06	-10.0
2034	0.05	-17.0	0.06	-10.1
2035	0.04	-17.0	0.04	-10.1
2036	0.04	-17.0	0.04	-10.1
2037	0.04	-17.1	0.04	-10.2
2038	0.04	-17.1	0.04	-10.2
2039	0.04	-17.2	0.04	-10.3
2040	0.03	-17.2	0.01	-10.3
2041	0.03	-17.2	0.01	-10.3
2042	0.03	-17.2	0.01	-10.3
2043	0.03	-17.3	0.01	-10.3
2044	0.03	-17.3	0.01	-10.3
2045	0.02	-17.3	0.008	-10.3
2046	0.02	-17.3	0.008	-10.3
2047	0.02	-17.3	0.008	-10.4
2048	0.02	-17.4	0.008	-10.4
2049	0.02	-17.4	0.008	-10.4
2050	0.01	-17.4	0.006	-10.4
2051	0.01	-17.4	0.006	-10.4
2052	0.01	-17.4	0.006	-10.4
2053	0.01	-17.4	0.006	-10.4
2054	0.01	-17.4	0.006	-10.4
2055	0.01	-17.5	0.004	-10.4
2056	0.01	-17.5	0.004	-10.4
2057	0.01	-17.5	0.004	-10.4
2058	0.01	-17.5	0.004	-10.4
2059	0.01	-17.5	0.004	-10.4

STATE OF CALIFORNIA
DEPARTMENT OF TRANSPORTATION
DIVISION OF ENGINEERING SERVICES
DIVISION OF STRUCTURE EARTHQUAKE ENGINEERING & DESIGN SUPPORT
OFFICE OF SPECIFICATIONS & ESTIMATES
P. O. BOX 942874
SACRAMENTO, CA 94274-0001

COMPARATIVE BRIDGE COSTS

JANUARY 2008

The following tabular data gives some **general guidelines** for structure type selection and its relative cost. These costs should be used just for **preliminary estimates** until more detailed information is developed.

These costs reflect the **'bridge cost'** only and ***do not*** include items such as: bridge removal, approach slabs, slope paving, soundwalls or retaining walls.

The following factors *must* be taken into account when determining a price within the cost range:

Factors for Lower end of Price Range	Factors for Higher end of Price Range
Short spans, Low Structure Height, No Environmental Constraints, Large Project, No Aesthetic Issues, Dry Conditions, No Bridge Skew	Long spans, High Structure Height, Environmental Constraints, Small Project, Aesthetic Issues, Wet Conditons (cofferdams required), Skewed Bridges
Urban Location	Remote Location
Seat Abutment	Cantilever Abutment
Spread Footing	Pile Footing (Large Diameter Piling)
No Stage Construction	2 Stage Construction

Factors that will increase the price over the high end of the Price Range 25%-150%

Structures with more than 2 construction stages
Unique substructure construction
Widenings less than 15 Ft.

STRUCTURAL SECTION	(STR. DEPTH / MAX SPAN) SIMPLE	CONTINUOUS	COMMON SPAN RANGE **feet**	COST RANGE **$ / Square foot**	REMARKS
RC SLAB	0.06	0.045	16 - 44	160-280	THESE ARE THE MOST COMMON TYPES AND ACCOUNT FOR ABOUT 80% OF BRIDGES ON CALIFORNIA STATE HIGHWAYS.
RC T-BEAM	0.07	0.065	40 - 60	180-300	
RC BOX	0.06	0.055	50 - 120	180-280	
CIP/PS SLAB	0.03	0.03	40 - 65	170-250	
CIP/PS BOX	0.045	0.04	100 - 250	180-280	
PC/PS SLAB	0.03 (+3" AC)	0.03 (+3" AC)	20 - 50	210-290	NO FALSEWORK REQUIRED.
PC/PS	0.06 (+3" AC)	0.055 (+3" AC)	30 - 120	220-290	
BULB T GIRDER	0.05	0.045	90 - 145	220-310	
PC/PS I	0.055	0.05	50 - 120	210-280	
PC/PS BOX	0.06	0.045	120 - 200	250-400	
STRUCT STEEL I GIRDER	0.045	0.04	60 - 300	250-380	NO FALSEWORK REQUIRED.

NOTE: Removal of a box girder structure costs from $15 - $20 per square foot.

COSTS INCLUDE 10% MOBILIZATION

District Preliminary Geotechnical Report
Settlement Study for the Segment of State Route-52
Constructed Over the South Miramar Landfill
San Diego, California
EA 11-40280K

SR-52 Landfill Bridging Cost Estimates Between PM 4.9 Through PM 6.2, San Diego CA
Prepared by the Office of Geotechnical Design-South 2
6/30/2009

Direction from Convoy Street OC	Length Travelling East/West to Gore (ft)	Width to Gore (ft)	Area Travelling East/West to Gore (ft^2)	Length Travelling from Gore to Convoy (ft)	Width to Convoy (ft)	Area Travelling from Gore to Convoy (ft^2)	Length Ramps (ft)	Width Ramps (ft)	Area Ramps (ft^2)	Total Area (ft^2)
Total Landfill Bridging										
West	700	133	93,100	1,300	116	150,800	1,400	24	33,600	277,500
East	1,500	140	210,000	1,500	116	174,000	1,200	24	28,800	412,800
Partial Landfill Bridging										
West	100	133	13,300	1,300	116	150,800	1,400	24	33,600	197,700
East	200	140	28,000	1,500	116	174,000	1,200	24	28,800	230,800

Structural Section	Cost (ft^2)	Total West	Total East	Total Bridging Cost
RC SLAB	$ 160	$ 44,400,000	$ 66,048,000	$ 110,448,000
RC T-BEAM	$ 180	$ 49,950,000	$ 74,304,000	$ 124,254,000
RC BOX	$ 180	$ 49,950,000	$ 74,304,000	$ 124,254,000
CIP/PS SLAB	$ 170	$ 47,175,000	$ 70,176,000	$ 117,351,000
CIP/PS BOX	$ 180	$ 49,950,000	$ 74,304,000	$ 124,254,000
PC/PS SLAB	$ 210	$ 58,275,000	$ 86,688,000	$ 144,963,000
PC/PS	$ 220	$ 61,050,000	$ 90,816,000	$ 151,866,000
BULB T GIRDER	$ 220	$ 61,050,000	$ 90,816,000	$ 151,866,000
PC/PS I	$ 210	$ 58,275,000	$ 86,688,000	$ 144,963,000
PC/PS BOX	$ 250	$ 69,375,000	$ 103,200,000	$ 172,575,000
STRUCT STEEL	$ 250	$ 69,375,000	$ 103,200,000	$ 172,575,000

Partial West	Partial East	Partial Bridging Cost
$ 31,632,000	$ 36,928,000	$ 68,560,000
$ 35,586,000	$ 41,544,000	$ 77,130,000
$ 35,586,000	$ 41,544,000	$ 77,130,000
$ 33,609,000	$ 39,236,000	$ 72,845,000
$ 35,586,000	$ 41,544,000	$ 77,130,000
$ 41,517,000	$ 48,468,000	$ 89,985,000
$ 43,494,000	$ 50,776,000	$ 94,270,000
$ 43,494,000	$ 50,776,000	$ 94,270,000
$ 41,517,000	$ 48,468,000	$ 89,985,000
$ 49,425,000	$ 57,700,000	$107,125,000
$ 49,425,000	$ 57,700,000	$107,125,000

District Preliminary Geotechnical Report
Settlement Study for the Segment of State Route-52
Constructed Over the South Miramar Landfill
San Diego, California
EA 11-40280K

Limited Ground Improvement Cost Estimate
Prepared by the Office of Geotechnical Design-South 2
6/30/2009

	Area to the East of the Convoy Street OC (ft^2)	200,000
	Area to the West of the Convoy Street OC (ft^2	60,000
Area	Total Area of Ground Improvement (ft^2)	260,000
Depth	Depth of Improvement (ft)	50
Grout Take	Percent by Volume of Typical Grout Take	7%
Cost	Cost of Grouting ($/$yd^3$)	90
Conversion	Conversion (ft^3/yd^3)	27
	Total Cost = [(Area) X (Depth) X (Grout Take) X (Cost)] / Conversion	
	Subtotal $	3,033,333
	Contingency (25%)	758,333
	Total Cost $	3,791,667

Note:

Twenty-five-percent (25%) contingency estimated for potential area adjustment, traffic control, and additional geotechnical and environmental investigations.

Comments by G. Vettese

1. Was any of the Bureau Veritas North America (BV) study work utilized in the District's investigative work for the geotechnical report or was it all throw away?

Cone Penetration Test (CPT) data appears to confirm that the bottom elevation of the landfill is the same as the elevation mapped in the 1974 and 1975 Caltrans Materials Reports. The following comment will be included in Section 4.3 of the report.

> *"Available CPT data appears to confirm the elevation of the depth of the landfill."*

The following comment is already included in section 5.0 of the report.

> *"Cone penetration test (CPT) data gathered during the defunct Bureau Veritas North America investigation and reported in the draft report listed in Section 3.0 were also considered."*

CPT data appears to confirm that the relative distribution of the demolition debris is comparable to what was described in the Pre-Closure Study of the South Miramar Landfill prepared by SCS Engineers in 1987. The following comment is already included in Section 6.2 of the report.

> *"Available CPT data appears to confirm the relative distribution of demolition debris."*

BV Landfill Gas (LFG) monitoring measured one hundred-percent (100%) Lower Explosive Limit (LEL) in seven (7) of thirty-two (32) CPTs. This is significant because it indicates that LFG will likely be encountered if any construction method used to mitigate the settlement includes puncturing the landfill cap. This information is already described in Section 7.0 of the report.

2. Since 1990 it looks like pavement overlays have occurred on the average every 3 years. Based on the amount of overlay material placed at similar locations over this timeframe, and taking into consideration where the settlement is at on the settlement curve, is it reasonable to assume that the periodic overlays will likely continue at this same rate (every 3 years) or be of longer of duration between overlays (every __ years) over the next ___ to ___ year timeframe? Can this be estimated?

Multiple factors including: the age of the landfill, initial compaction, overburden, moisture content, and Municipal Solid Waste (MSW) type, thickness, and distribution are affecting the rate of settlement. With the exception of the age of the landfill, there is very little information available regarding these factors that limit the ability to accurately estimate the future time rate of settlement. Additionally, surveys conducted in the past do not provide sufficient data to accurately determine or estimate the actual rate of settlement and the precise geometry of the settlement.

The estimated rate of settlement developed for this report and depicted in Figure 14: SR-52 Estimated Time-Settlement Curve is based on the typical landfill time-settlement curve, the age of the landfill, the depths of the cores collected during the field investigation, the age of the highway, the estimated future settlement, and engineering judgment.

Based on the age of the landfill and Figure 13: Typical Time-Settlement Curve, the mechanism that is currently contributing to the majority of the settlement is Stage IV Biodegradative Settlement. As depicted in Figure 13, it is anticipated that this mechanism will slow down in the future as the amount of biodegradative material diminishes.

According to Figure 13 biodegradative settlement generally occurs for ten to thirty-years (10-30yr), which based on the age of SR-52 would be 1973 to 2003. Since there have been two more overlays since 2003, it was determined that biodegradation is and will likely continue to be the active settlement mechanism. To develop a conservative estimate that takes into account the estimated future settlement provided in Table, the period in which biodegradation occurs was doubled from thirty-years (30yr) to sixty-years (60yr) 1973 to 2034.

The maximum and average linear rates of settlement substantiated by coring are depicted on Figure 14. Theses rates depict the settlement that has occurred since the highway was constructed. The maximum and average linear rates of settlement substantiated by coring were calculated by dividing the maximum depth of core, five and eight-tenths-feet (5.8ft), and the average depth of core from the original four-lane highway, one and seven-tenths-feet (1.7ft), by the number of years since the highway was constructed, twenty-one-years (21yr). The maximum linear rate of settlement that has occurred since the completion of the highway is approximately twenty-seven one hundredths of a foot per year (0.27ft/yr). The average linear rate of settlement that has occurred since the completion of the highway is approximately eight one hundredths of a foot per year (0.08ft/yr).

The estimate of future Stage IV and V settlement was developed by projecting the maximum future settlement provided in Table 3 over fifty-years (50yr). The values of three and seven-tenths-feet (3.7ft) and two and two-tenths-feet (2.2ft), which correspond to the estimated future settlement of the fifty-foot (50ft) and thirty-foot (30ft) MSW depths, were used for the maximum and average estimated future settlement, respectively. Engineering judgment was used to develop the curves that consider a reduction in the rate of settlement as is expected.

Based on the estimated maximum settlement curve data provided in the report and assuming an overlay will be laced every seven-tenths of a foot (0.7ft) of settlement, the number of overlays that will be needed over the next fifty-years (50yr) is approximately six (6). It is estimated that the overlays will occur in approximately three-years (3yr) 2012, six-years (6yr) 2015, ten-years (10yr) 2019, twenty-years (20) 2029, and forty-five-years (45yr) 2054, respectively. A sixth overlay is estimated to occur some time after 2059. The cost estimate was prepared assuming there would be six (6) overlays conducted over the next fifty-years (50yr).

Please refer to the recommendations in Section 10.0 of the report.

3. The landfill settlement has been occurring for 36 years to the west of Convoy, and 45 years to the east. Based on the settlement curves, should stage IV settlement occur for another 25 to 35 years, and what would that mean in terms of annual settlement rate when compared to that period of time from when that portion of the highway was constructed until today?

Please refer to the response to Comment 2.

4. Is the rate of settlement flattening out?

Due to the lack of detailed historical survey data collected before, during, and after overlays it cannot be said with certainty that settlement is currently "flattening out". It is likely that the rate of settlement is slowing or will begin to slow in the near future. The settlement is expected to flatten out in the future as the biodegradable waste in the landfill diminishes.

Settlement of the roadway is differential, it occurs at different rates at different locations. This is because of the multiple factors that are affecting the rate of settlement including: the age of the landfill; initial compaction; overburden; moisture content; and Municipal Solid Waste (MSW) type, thickness, and distribution.

Based on the age of the landfill, the mechanism that is currently contributing to the majority of the settlement is Stage IV Biodegradative Settlement. It is anticipated that the settlement will slow down as the amount of biodegradative material diminishes.

Please refer to the response to Comment 2.

5. How much additional annual settlement could be estimated during stage V?

Stage V settlement is projected to occur between 2034 and 2059. Stage V is estimated to contribute a maximum settlement of five-tenths of a foot (0.5ft) and an average settlement of four-tenths of a foot (0.4ft) during that time. The annual Stage V rate of settlement is approximately two-hundredths of a foot per year (0.02ft/yr).

6. Does the amount of settlement west of Convoy tend to be greater than that east of Convoy because the landfill is not as old?

It cannot be said with certainty that the amount of settlement to the west of the Convoy Street OC tends to be greater than the area to the east due to the age of the landfill.

Since the landfill to the east of the Convoy Street OC is older, it can be postulated that more biodegradation has occurred; it has settled more prior to the construction of the highway; and therefore, the rate settlement could be slowing in comparison to the younger landfill to the west of the Convoy Street OC.

But other factors, besides the age of the landfill, such as: initial compaction, overburden, moisture content, and MSW type, thickness, and distribution also affect the settlement. Settlement of the roadway is differential. Due to these multiple factors, it occurs at different rates at different locations. The lack of detailed information regarding these factors makes it difficult to determine the exact cause(s) of settlement at any particular location.

Long term monitoring of the highway, and surrounding depressions where ponding occurs should be conducted to determine detailed information of the rate of settlement and the precise geometry of the settlement. This data can be used to better predict future settlement.

7. Does the amount of settlement on the ramps tend to be greater due to the additional embankment?

There are likely some affects on settlement due to the additional overburden of the ramps. The affect of overburden on long-term settlement is small in comparison to the affects of biodegradation. Long-term settlement is generally independent of overburden and is primarily due to biodegradation. Other factors that affect settlement, such as: initial compaction, moisture content, and MSW type, thickness, and distribution, must also be considered.

8. Does the report assume that overall settlement (stage IV into V) will occur for another 50 years, and should this be used for life cycle cost comparisons of the various mitigation strategies?

The report projects settlement for another fifty-years (50yr) and does not assume that overall settlement (Stage V) will stop in fifty-years (50yr). The life cycle cost comparisons were also projected to fifty-years (50yr), but were not adjusted for inflation. Settlement beyond fifty-years (50yr) is anticipated to be minimal.

9. It would be very helpful to know what the annual settlement estimates would be over the next 50 years when compared to the annual rate of settlement that has already occurred since the highway was constructed. Can this be estimated?

The maximum linear rate of settlement that has occurred since the completion of the highway is approximately twenty-seven one hundredths of a foot per year (0.27ft/yr). The average linear rate of settlement that has occurred since the completion of the highway is eight one hundredths of a foot per year (0.08ft/yr).

Estimated SR-52 Time-Settlement Curve Data that projects the settlement for the next fifty-years (50yr) has been included in the report.

10. The report seems to indicate that the perched groundwater is a problem in that it exacerbates biodegradation. Is this more of a problem with respect to drainage problems outside the roadway or due to surface drainage from the roadway itself (we have more control of the later)?

The factors affecting the perched groundwater are from both internal contributors (within Caltrans right-of-way) and external contributors (outside Caltrans right-of-way).

Contributors to the perched groundwater include water from the inside and outside Caltrans right-of-way that seeps through pervious surfaces into the landfill and collects in the bottoms of the relic canyons. The internal seepage can be mitigated from Caltrans right-of-way by eliminating ponding in the landscaping; curbing the roadway to collect water that sheet flows from the edge of pavement into the surrounding landscape; and paving as much of the area as possible to eliminate pervious surfaces (e.g. the median and gore points). Caltrans cannot mitigate the affects of water that seeps into the MSW and relic canyons that originates outside Caltrans right-of-way.

Another contributor is the water that is collecting in the Storm Drain 40 and 45 systems. These drainage systems are partially blocked at the downstream ends that are outside Caltrans right-of-way. SR-52 and Kearny Mesa discharge storm water and non-storm water into Storm Drain 40 and 45. Non-storm water was observed flowing into the upstream ends of Storm Drain 40 and 45 during the culvert inspections on May 28, 2009. Ponding water was observed in the systems.

The ponding water in these drainage systems elevates the perched groundwater table by a few feet and increases the moisture content of the MSW. Unblocking the downstream ends of Storm Drain 40 and 45 and eliminating the ponding of water in the systems can mitigate this contributor. Returning the downstream ends of these systems to their designed hydraulic grade line is recommended to not only mitigate the influence the standing water has on the on the perched groundwater table and MSW, but also to reduce the corrosion (maintain the integrity) of the metal portions of the drainage systems.

The migration of perched groundwater is beyond the scope of this report. It cannot be said with certainty whether internal or external contributors have a greater affect on the settlement. But, based on the area of the Caltrans right-of-way in comparison to the external contributing areas, it is likely that the external contributors have a greater affect on the level of the ponding water in Storm Drain 40 and 45 and its affect on the perched groundwater table.

11. Would use of a geogrid mat (or similar technology) within the areas of greatest settlement be a strategy to control the consistency of settlement to make it more uniform over a larger area? For example... Having fewer and more gradual dip sections by better controlling the area of settlement in lieu of overlaying a larger number of small dip areas?

It is not anticipated that the use of geogrid will substantially change the character of the settlement or bring differential settlement to within some tolerable limit for operation of the highway.

Comments by H. Gascon

12. I feel the recommendation to periodic asphalt concrete overlay with surface drainage improvements is a good recommendation. But, I would like to know if the other alternative that scored almost in the same category shown on the settlement mitigation strategies decision matrix (table 6) can be more effective. The periodic AC overlays combined, surface drainage improvements, and limited ground improvement might be a better alternative and can be looked at more closely.

The final report recommends that following a period of precise settlement monitoring consideration may be given to Limited Ground Improvement if the settlement exceeds the estimates included in the report. A supplemental geotechnical investigation would be necessary to validate that the procedure is feasible and to accurately characterize the subsurface conditions for project bidders.

This report has been prepared from a geotechnical perspective. Other functional units within Caltrans may have different perspectives and/or additional considerations that may result in different prioritization of alternatives.

13. For the limited ground improvements there are 3 types recommended. Among the 3 types shown what would be most effective and least expensive (soil mixing, slurry grouting, or compaction grouting)?

For the purpose of comparing and contrasting the different settlement mitigation alternatives in this report, the three types of Limited Ground Improvement alternatives are considered to have comparable costs. Compaction grouting is likely to be the least complicated and therefore the least expensive. Soil mixing would likely be the most effective followed by compaction grouting. Without a subsurface investigation that includes exploratory drilling of the landfill it is only possible to estimate the relative effectiveness and cost of ground improvement.

14. Table 5 I believe the 50-year cost for the last strategy (Periodic AC overlays combined with Surface Drainage Improvements and limited ground improvement) should be revised and should be higher. It should be at least $15, 000,000 plus the $ for the four more drainage improvements that will need to be implemented as stated in note 4.

There is a typographic error in Note 4. The note has been changed to read as follows:

> *"d. Assumes Limited Ground Improvements are implemented one (1) time in fifty-years (50yr). Assumes Periodic Asphalt-Concrete Overlays and Surface Drainage Improvements are implemented on ~~two~~ four (4) occasions in fifty-years (50yr)."*

It is assumed that the number of overlays would be reduced by two (2) if Limited Ground Improvement were implemented. The cost for cost for Periodic Asphalt-Concrete Overlays with Surface Drainage Improvements and Limited Ground Improvement is calculated as follows:

	Cost ($ X 1,000,000)	No. Times Implemented	Cost ($X 1,000,000)
AC Overlay	1.5	4	6
Surface Drainage Improvements	0.5	4	2
Limited Ground Improvement	3.8	1	3.8
		Total	11.8

Corresponding notes in Table 5 have been added or adjusted to better describe the calculations.

15. To determine if limited ground improvement may be added as part of the preferred alternative do you believe the suggestion to do a supplemental geotechnical investigation is feasible and should be considered?

A period of precise settlement monitoring is recommended prior to considering the Limited Ground Improvement and any additional geotechnical investigations.

The information developed for this report should be sufficient to select the preferred alternative. A supplemental geotechnical investigation would, more precisely define the active settlement mechanism(s), provide information for selecting the preferred Limited Ground Improvement strategy, and provide necessary data to prospective bidders and contractors to avoid claims.

16. In the appendix for the estimate of the limited ground improvement the area and full 50 ft depth helped calculated the cost of $3 would this be the worst cost if we approach this idea?

The areas included in the Limited Ground Improvement Cost Estimate in the appendix are based on the contours depicted in Figures 12A and 12B: Settlement Contours. These values may be adjusted based on the actual rate of settlement and settlement geometry determined by precise monitoring.

The cost estimate for Limited Ground Improvement has been adjusted to include a twenty-five-percent (25%) contingency to account for potential area adjustment, traffic control, and additional geotechnical and environmental investigations.

17. For the drainage improvements, which do you believe would be most effective?

Combining all of the recommended drainage improvements would be most effective.

Please refer to response to Comment 10.

Comments by B. Lambert

18. I think it would be helpful if you added an Executive Summary for those that will not read through the details that are in this report.

An executive summary has been included in the report.

19. I think this summary should include how much the landfill has settled and what it is expected to settle over the next 50 years. This would then substantiate that we have been through the worst of it.

The executive summary describes how much the landfill has settled and the estimated settlement for the next fifty-years (50yr).

The maximum settlement since the highway was constructed, five and eight-tenths-feet (5.8ft), correlates to the maximum core depth collected. The average depth of settlement since the highway was constructed, one and seven-tenths feet (1.7ft), correlates to the average core depths collected from locations within the original four-lane highway.

The maximum and average future settlement of three and seven-tenths-feet (3.7ft) and two and two-tenths-feet (2.2ft) correspond to the calculated future settlement as a function of fifty-foot (50ft) and thirty-foot (30ft) depths of MSW, respectively.

20. The summary should state the preferred alternative solution, which looks to be a combination of fixing drainage, and performing more overlays.

The executive summary describes the preferred alternative.

21. If I comprehend the report correctly, we should be expecting to do fewer overlays as time moves on because the rate of settlement should be slowing down.

Yes, please refer to the response to Comment 2.

22. Can you state what further studies would be needed in a PSR particularly as it relates to geotechnical studies?

The report provided is the District Preliminary Geotechnical Report (DPGR), no additional geotechnical studies are required for the PSR.

It is highly recommended that long term monitoring of the highway, and surrounding depressions where ponding occurs be conducted to determine detailed information of the rate of settlement and the precise geometry of the settlement. This data can be used to manage the periodic overlay program and monitor the rate of settlement.

If a project goes to design and depending on the project design features a Geotechnical Design Report (GDR) may be required.

23. ***I am assuming that if SR-52 is ever widened that the settlement that would take place by biodegradation and not by overburden. If this is true or not true, it should be mentioned in the executive summary.***

Some affects due to overburden may be experienced if SR-52 were widened, but the effects would likely be small in comparison to the dominant mode of settlement (biodegradation) and would only occur where significant embankment may be placed, such as at ramps.