

# COMMERCIAL DEVELOPMENT OF CLOSED LANDFILLS: CASE STUDIES AND TECHNICAL/REGULATORY ISSUES

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### ABSTRACT

The designated end uses for municipal solid waste landfills are most often relatively passive uses -- including designation as conservation land and various recreational uses. Some landfills, particularly smaller and older closed landfills, are simply left vacant with no designated function. Some closed landfills, however, present significant opportunities for high-intensity, high-value end uses. A few closed landfills have been used to develop shopping malls, office parks, hotels, drive-in theaters, amphitheaters, auto dealerships and airfields. The opportunity sometimes exists to integrate landfill gas utilization into the end use development plan.

The paper will present thumbnail sketches of eight commercial development projects located on closed landfills. The developments include a 20-building (5 million square feet) office park, a 5 million square foot shopping mall, a 250-room hotel and convention center, the West Coast Goodyear blimp landing field, an outdoor amphitheater, and a truck dealership/repair facility.

Technical challenges to be addressed in building on landfill property include building protection from the hazard of methane explosion, landfill settlement, and leachate management. The paper will discuss the typical measures employed to overcome these problems.

The attributes of landfills which make better candidates for high-intensity, high-value reuse will be summarized.

### OVERVIEW

The range of possible beneficial end uses for closed municipal solid waste landfills range from “relatively passive” uses, through a group of “relatively active” uses, and ultimately to high value “intense” end uses.

Examples of successfully applied municipal solid waste landfill end uses include:

- Relatively passive: Green space, wildlife habitat, and biking/walking/running trails.
- Relatively active: Golf courses, baseball/soccer fields, drive-in theaters, amphitheaters, and airfields.
- Intense: Office buildings, hotels, and shopping centers.

In selecting an end use for a landfill, the notion of the selection and application of the “highest and best” use is increasingly governing decisionmaking by landfill owners. The highest and best use for a closed landfill must be determined on a case-by-case basis. Individuals who are driven solely by economics will assume that the highest and best use for a particular landfill is always the most intense possible use at that landfill. A landfill owner might decide, however, that a regional park is the highest and best use for a landfill even if the site has great commercial potential.

It is not the purpose of this paper to describe the process through which highest and best use for a closed municipal solid waste landfill should be determined -- that process could be the subject of another paper. This paper will limit itself to a discussion of the implementation of relatively active and intense end uses at closed landfills. The purpose of mentioning the highest and best use concept is to emphasize that the most intense use possible for a site may not be the preferred use in many instances.

## POST-CLOSURE LANDFILL DEVELOPMENT ISSUES

The main problems to be addressed in landfill post-closure commercial development are landfill gas control and landfill settlement.

### *Landfill Gas Control*

Landfill gas control is driven primarily by safety concerns. The goal is to prevent explosive levels of methane from accumulating in buildings and in confined spaces. Building protection can employ one or more of the following approaches:

- A membrane below the building slab plus explosive gas monitoring (inside the building or under the building between the membrane and the slab);
- A membrane and gas monitoring system plus passive horizontal vents under the building slab/membrane;
- A membrane and gas monitoring system plus active horizontal vents under the building slab/membrane. Active horizontal vents take the form of a forced air blower feeding air injection pipes, which alternate with vent exhaust pipes, to flood and purge the subslab area with air;
- An active vertical extraction well system installed within the refuse mass;
- An active horizontal collector system located in the refuse mass;
- An active vertical extraction well system in soil;
- An air dike system located in soil;
- Passive vertical or horizontal vents in the refuse; and/or
- A passive trench barrier in the refuse and/or in the soil.

The approach employed on a specific project depends on:

- whether the building is actually located over the refuse mass;

- how close the building is to the edge of the refuse mass (if the building is not actually to be located over the refuse mass);
- how much refuse is present and the age of the refuse (these factors being reflective of how much landfill gas is actually being generated); and
- land use around the building (parking, recreational facilities, open space, etc.).

While some county and city governments have regulations governing building protection, many jurisdictions do not have regulations. In these instances, it is necessary to rely solely on engineering judgment. Even when regulations exist, they are usually not thoroughly prescriptive. An example of a fairly typical nonprescriptive code is the Los Angeles County Uniform Building Code in §110.3, which states:

### ***Fills Containing Decomposable Material.***

*Permits shall not be issued for buildings or structures regulated by this code within 1,000 feet (304.8 m) of fills containing rubbish or other decomposable material unless the fill is isolated by approved natural or artificial protective systems or unless designed according to the recommendation contained in a report prepared by a licensed civil engineer. Such report shall contain a description of the investigation, study and recommendation to minimize the possible intrusion, and to prevent the accumulation of explosive concentrations of decomposition gases within or under enclosed portions of such building or structure. At the time of the final inspection, the civil engineer shall furnish a signed statement attesting that the building or structure has been constructed in accordance with the civil engineer's recommendations as to decomposition gases required herein.*

*Buildings or structures regulated by this code shall not be constructed on fills containing rubbish or other decomposable material unless provision is made to prevent damage to the structure, floors, underground piping and utilities due to*

*uneven settlement of the fill. One-story light-frame accessory structures not exceeding 400 square feet (37.2 m<sup>2</sup>) in area or 12 feet (3658 mm) in height may be constructed without special provision for foundation stability.*

### **Settlement**

If possible, the buildings should be located on native soil. Generally, this is not possible unless the site has a refuse footprint which is accompanied by a large undisturbed native soil area. When the building is located on refuse, it will be necessary to install piles to support the building. The problem with piles is that while the building is stable, the surface around the building settles, producing what some architects refer to as a “hard edge” settlement problem.

The principal problems associated with settlement are: 1) building ingress/egress is ultimately impaired; and 2) utility connections to the building begin to shear off. Architects have developed innovative solutions to these problems, including:

1. Hinged slabs at entryways to buildings (which greatly decrease the intervals between the need to regrade around the building entries while still maintaining a seamless entry);
2. Flexible utility connections for both pressure and gravity utilities (which can accommodate all of the expected vertical settlement); and
3. Hangers embedded in the slab (which attach to utility pipes located under the slab). The hangers allow the pipe to hold its horizontal position, with respect to the building, as the landfill cover and refuse moves downward.

The areas surrounding commercial buildings are generally parking areas. Settlement of these areas is a concern for three main reasons:

1. Drainage patterns can change (due to differential settlement);
2. The grade of below-surface gravity utilities (wastewater and stormwater) can change; and
3. The slope of the surface may change to exceed the grade required by a specific project architectural design standard. As an example, the slope of a parking lot may not be permitted to exceed a

certain grade because of the damage which could be done by runaway shopping carts. Such a standard would apply to a shopping center, but would not to an office building.

Architects sometimes call the above types of settlement problems “soft edge” settlement problems. These problems are best addressed through grading plans developed which fully consider landfill settlement projections. Settlement projections are generally summarized in the form of a site map which shows projected differential settlement in a contour format. Areas of high settlement can be somewhat overfilled with cover soil to partially compensate for long-term settlement.

### **ENERGY RECOVERY OPPORTUNITIES**

More often than not, landfills associated with commercial developments are relatively old and small. The size of these landfills limits their potential for energy recovery. It is often possible, however, to satisfy part or all of the energy requirements of building tenants at small landfills in several ways:

- Fire landfill gas alone or co-fire landfill gas with natural gas in boilers to generate steam and/or hot water;
- Use the hot water or steam to produce chilled water; and/or
- Fire landfill gas alone or co-fire landfill gas with natural gas to generate electric power using “distributed generation” technologies.

Reciprocating engines have been widely used for landfill gas fired electric power plants. Reciprocating engines do not tolerate low methane content landfill gas and are not routinely equipped for landfill gas service in sizes below 800 kW. The applications under consideration herein would generally be less than 500 kW. Reciprocating engines emit relatively high levels of NO<sub>x</sub>.

A potential solution to the difficulties associated with the use of reciprocating engines is to employ microturbines. Microturbines are currently available as 30 kW and 70 kW modular units. They can be marshalled in parallel to match the power requirements of a tenant and to work within the

limitations imposed by the landfill gas availability. Microturbines can operate on methane contents as low as 30 to 35 percent versus the 40 to 45 percent typically required by reciprocating engines. Microturbine NO<sub>x</sub> emissions are as low as one-tenth the NO<sub>x</sub> emissions from reciprocating engines. Microturbines can easily be equipped to cogenerate electric power and hot water. SCS currently has one landfill gas-fired microturbine power plant in operation, two under construction, and two under design.

#### **DESIRABLE LANDFILL ATTRIBUTES**

Desirable landfill attributes for commercial end use projects include the following:

- High potential property value as a commercial site. This is largely a function of location;
- High native soil to refuse footprint ratio; and
- Older, shallower, mound-type landfills are generally preferred. These conditions result in reduced landfill gas production and settlement concerns.

#### **CASE STUDIES**

The following paragraphs provide information on eight relatively active or intense landfill end use projects located in California.

##### ***Don Kott Ford***

One of SCS's earliest closed landfill, commercial use design assignments was a project built in Carson, California in 1980. A truck sales and maintenance center was installed on top of 9.5 acres of an 18-acre landfill. The landfill operated between 1962 and 1964. It was a 35-ft deep, mound-type landfill. A landfill gas collection system consisting of 14 vertical extraction wells and a flare was installed. The building's structural slab is supported by piles (concrete in steel pipes) which extend to native soil. A 30-mil chlorinated polyethylene (CPE) membrane was installed inside the building's concrete slab. A methane gas detection system was installed in the building to automatically announce the presence of methane at 25 percent of its lower explosive limit.

The truck sales and maintenance center is currently in operation. SCS continues to provide landfill gas operation, maintenance, and monitoring services at this site.

##### ***South Bay Six Drive-In Theater***

The South Bay Six Drive-In Theater was constructed in Carson, California in 1981. The drive-in was built atop a 24-acre, 50-ft deep, mound-type landfill. The landfill was open between 1964 and 1971.

A landfill gas collection system consisting of 50 vertical extraction wells and a flare station was installed to control surface emissions and to aid in protection of on-site buildings. The on-site buildings included a large concession building located in the center of the site. The concession building's structural concrete slab is supported by concrete piles which extend to native soil. The building was equipped with a 30-mil CPE membrane inside the structural concrete slab. Gas sampling probes were installed under the slab and were connected by PVC pipe to sample valve boxes surrounding the building. A methane gas detection system was installed in the concession building to automatically announce the presence of methane at 25 percent of its lower explosive limit. The main roadways on the site are asphalt and the parking areas are paved with rock and oil.

SCS designed and installed landfill gas collection and building protection systems for this project, and in doing so further established the firm's reputation in the areas of landfill gas control and in closed landfill beneficial use. SCS operated the landfill gas collection system into the mid-1990s, at which time the drive-in closed for economic reasons.

##### ***Industry Hills Convention Center***

A 600-acre site, located in the City of Industry, California was used for refuse disposal between 1951 and 1969. During that time, approximately 3.5 million tons of refuse was accumulated using the valley fill and mound-type methods of refuse disposal. The waste is typically 35 to 40 ft deep; however, in some canyons, the depth to refuse exceeds 100 ft. The City of Industry has developed a major commercial and recreational complex at this site. The complex was completed in 1981 and includes the following:

- 400-room hotel
- Convention center
- Two championship golf courses
- Tennis center

- Olympic-sized swimming pool

The above facilities were built on native soil and on the refuse footprint--with only the facilities least sensitive to refuse settlement located over the refuse footprint.

The site was one of the first to put landfill gas to a beneficial use. The landfill gas collection system consists of 50 vertical extraction wells and a flare station. A portion of the landfill gas is compressed and used to fire boilers which have been used to supply hot water, to heat the swimming pool, and to provide building space heating. The landfill gas collection and processing facilities at Industry Hills were designed by SCS and have been operated by SCS for 20 years.

SCS recently conducted a feasibility evaluation addressing the technical and economic feasibility of cogeneration to satisfy part of the hotel's electric load. The plant would employ a 1 MW reciprocating engine. The engine will be equipped with waste heat recovery equipment (hot water generators) to mitigate the impact of the diversion of landfill gas from the existing boilers to the engine. The engine will be fired primarily with landfill gas, with some supplemental natural gas firing.

#### ***Westport Office Park***

The Westport Office Park is a 20-building, 980,000 sq. ft. project located in Redwood City, California. It is a park-like, campus-style setting with office, research and development, biotech and dot.com tenants. Construction of the office park was completed last year. The office park consists primarily of two-story structures located on top of an 85-acre landfill which operated from the 1940s through 1970.

The site is not equipped with an active landfill gas collection system. SCS designed the following landfill gas control/protection/monitoring features into the project:

- A subslab membrane, a subslab passive-gas venting system, and continuous, automated combustible gas sensors installed in each building.
- Subsurface gas migration barriers installed in site utility corridors.
- A venting system to relieve gas pressure buildup in parking lot areas overlying the deeper portions of the landfill.

- A leachate cut-off trench and subsurface gas venting/monitoring system installed at the property line.

In addition to the above, SCS developed a comprehensive landscaping and drainage plan which protects the landfill's cap from water infiltration and root damage, and promotes healthy long-term plant growth in a distressed environment.

#### ***Los Angeles Metro Mall***

The Cal-Compact Landfill is a 157-acre landfill located in Carson, California, adjacent to Interstate 405 (San Diego Freeway) just south of Los Angeles. Its prime location has led to several proposals for commercial development. A recent proposal called for the development of an 810,000 sq. ft. shopping center on top of the landfill.

The landfill is a mound-type landfill with an average refuse depth of 40 ft. The design of the mall calls for over 3,000 piles to support the building. SCS designed the landfill gas collection and building protection systems for this project. SCS completed design work on this project in 1997. The landfill gas collection system incorporated vertical extraction wells, a network of horizontal collectors, and a 1,500 scfm flare. The building protection system consists of passive horizontal vents above the landfill cap and below a membrane, a membrane below the structural slab, and methane sensors inside the buildings.

The Metro Mall project did not proceed due to the developer's problems in securing financing. This project has been mentioned herein because it illustrates that very large retail space beneficial use projects are under consideration at closed landfills.

#### ***Shoreline Park and Amphitheater***

The City of Mountainview, California has converted its landfill into a mixed-use recreational facility. The landfill is located on San Francisco Bay, and it is a mound-type landfill. Facilities within Shoreline Park include a golf course, jogging trails, a sailing lake and an open-air amphitheater. The amphitheater has a seating capacity of 8,000 and is partially covered with canvas roofing. The principal protective feature for the amphitheater is a landfill gas collection system consisting of vertical extraction wells and a flare. The City maintains a

landfill gas collection system throughout the balance of the landfill. SCS has operated the amphitheater's landfill gas collection system since 1986.

### ***Goodyear Airship Operations Center***

The Goodyear Airship Operations Center in Carson, California represents a somewhat unusual landfill end use. The facility serves as the western landing field for the Goodyear blimp. The facility includes a 2,600 sq. ft. office and maintenance center located on native soil. The landing field itself is over refuse. The landing field is located over a small portion of a 348-acre landfill which used the trench-fill method of disposal. The landfill operated between 1949 and 1959. The depth of refuse generally varies from 10 to 30 ft.

A landfill gas collection system was not installed at this site. The office and maintenance center are protected by a membrane and a methane detection system designed by SCS. The facility was installed in 1984.

### ***Montebello Town Square***

A decision was made in 1990 to construct a 400,000 sq. ft. shopping plaza immediately adjacent to the 145-acre Operating Industries, Inc. (OII) landfill in Montebello, California. The OII landfill is a mound-type landfill on top of valley-fill landfill segments. The OII landfill is a Superfund site which contains 29 million tons of municipal solid waste and immediately abuts the property used for the shopping center. One of the largest buildings in the shopping center is only 200 feet from the edge of refuse, and the refuse is as much as 100 feet below the level of the building slab within 500 feet of one of the larger buildings. At the time the shopping center was constructed, the OII landfill had a partial, aged landfill gas collection system, and landfill gas was migrating off site. The property underlying the landfill and the shopping center is not under common ownership; however, the proximity of the refuse to the development provides a good illustration of building protection measures which can be taken if a development is located only on the native soil portion of a landfill parcel.

SCS designed a system consisting of:

- Eight in-soil landfill gas extraction wells and a 500 scfm flare. The wells are located between the landfill and the shopping center, on property owned by the shopping center, and they create a barrier to landfill gas migration;

- Eleven landfill gas migration monitoring wells located between the extraction wells and the buildings to monitor the effectiveness of the landfill gas extraction system;
- Building protection consisting of an underslab 80-mil high density polyethylene (HDPE) liner and subfloor passive venting system; and
- A novel automated methane sensor system which relies on a detection system installed between the slab and the membrane. The subslab monitoring provision eliminated the need to install sensors inside the buildings.

The landfill gas migration control system went into operation in 1990, and the last building was installed in 1994. Under a separate engagement for the owner of the OII Landfill in 1999, SCS designed comprehensive improvements to the OII Landfill's landfill gas collection and control system. When placed in service in 2000, the upgraded system arrested landfill gas migration at its source, and the shopping center's migration control extraction wells and flare were shut down due to lack of landfill gas. The shopping center's landfill gas migration control system has been placed in a standby mode, and the migration and building monitoring components remain in service.

### **CONCLUSIONS**

This paper highlights eight of the many successful commercial landfill end use projects which now exist in California. The eight projects discussed herein cover a broad range of commercial end uses. Many have operated up to two decades without incident.

Owners of closed landfills may find that some of their older landfills are assets rather than liabilities.

### **REFERENCES**

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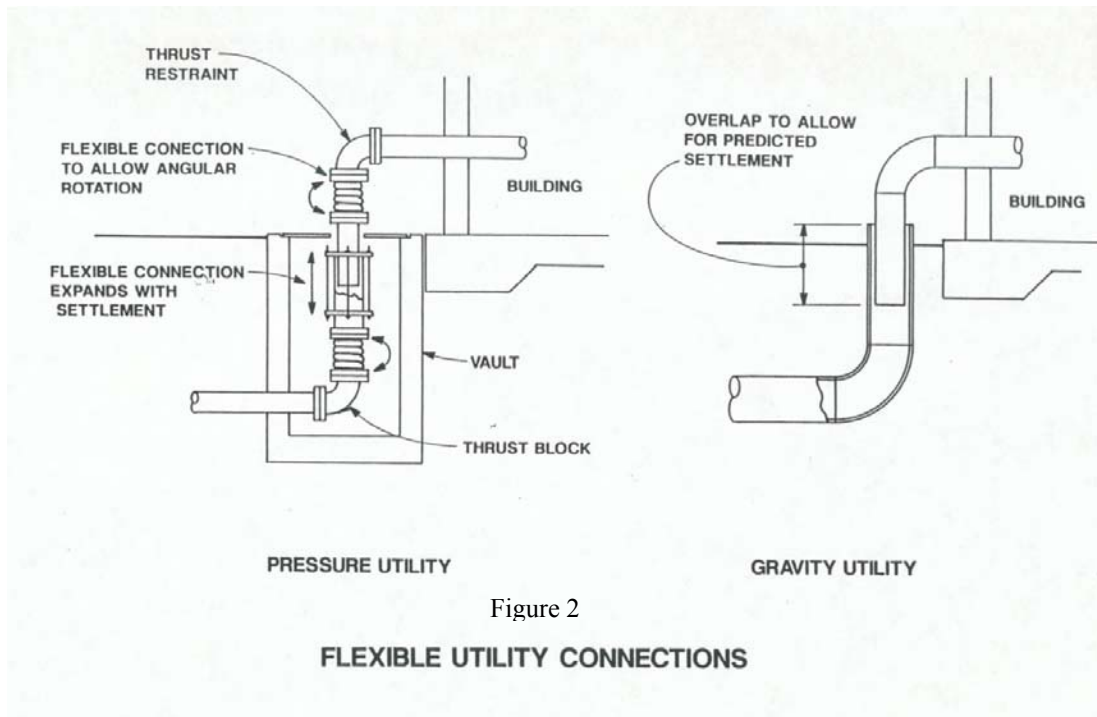
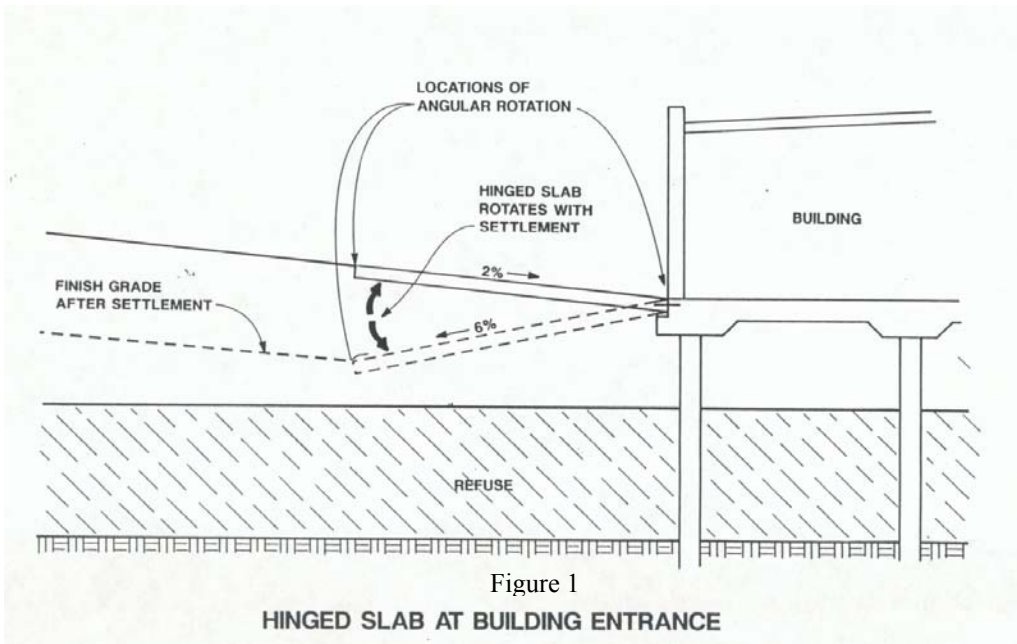




Figure 3

Don Kott Ford -- showing effect of settlement and lack of maintenance during a period when building was not occupied



Figure 4

Industry Hills Convention Center