已关闭填埋场土地的利用与开发：相关技术及成功案例

Closed Landfill Post-Closure End Uses and Development: Technical Issues and Case Studies

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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. Other closed landfills, however, present significant opportunities for high-intensity, high-value end uses, especially if the site is located within city limits and is a high-value for prime real estate development. 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 technical challenges to be addressed in building on landfill property including building protection from the hazard of methane explosion, landfill settlement, and leachate management. Typical measures employed to overcome these problems will discuss. The paper also presents brief discussion of several commercial development projects located on top of old closed landfills. The developments include a 20-building (5 million square feet) office park, a 5 million square foot shopping mall, and a 250-room hotel and convention center.

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

INTRODUCTION

There has been much recent interest in reclaiming real estate formerly occupied by municipal landfills. Recent changes to U.S. regulatory programs offer both opportunity and new challenges for converting old landfills into productive real estate development.

Throughout North America, agencies of Federal, State and Local government have begun new initiatives to redevelop formerly used sites which are "tainted" environmentally. The initiatives have been given various names, including Land Recycling in Pennsylvania, and Brownfield at the U.S. Environmental Protection Agency.

From the legal perspective, there are several concerns which must be addressed when redeveloping a former landfill site for a productive use. Liability concerns regarding potential environmental claims under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA, or Superfund) can dissuade private developers and their lenders. Technical challenges to reusing landfills include the problems presented by settlement, foundation support, gas generation, and worker health and safety.

CLOSED LANDFILL END USES

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 decision making 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. 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.

TECHNICAL ISSUES

Settlement and Foundation Systems

As it ages, municipal solid waste in a landfill decomposes and consolidates. Active settlement can take place for many years, depending upon the depth of the trash fill, the types of wastes present (e.g., construction and demolition waste versus municipal solid waste), and the method of placement (e.g., trench versus area fill). Before buildings or other improvements can be constructed on a landfill site, estimates of expected settlement must be made based upon experience, empirical settlement observations, and numerical models.

Heavy loads will surcharge the waste mass and accelerate consolidation and settlement. Many site operators stockpile cover soils or excess waste, on portions of the landfill prior to final closure; such operating practices should be identified and considered when estimating settlement and differential settlement rates.

Although some buildings have been constructed using floating foundations (normally after replacing a few feet of the underlying trash with structural fill), most larger buildings and sensitive structures constructed over landfills utilize deep foundations (e.g., piles or caissons. A combination of the two approaches has been used over old shallow landfills, in which building walls are constructed on piles or caissons, while a floating slab is used for the building floor.

The result often is a stable building, surrounded by a settling ground surface as the underlying landfill consolidates. At one California landfill, a hinged slab was connected to a retail building on one side, and allowed to "float" with the land surface on the other side. If settlement causes the slab to sink too far on the floating side, it can be jacked up and the land surface regraded to create a proper entranceway to the building.

Where utilities enter natural ground or fixed structures supported on deep foundations, allowance must be made for differential settlement. Flexible utility connections have been developed for such applications. Pipe runs beneath buildings constructed on deep foundations should be hung from the overlying structural concrete slabs with non-corrosive hangers, and surrounded by non-cohesive backfill material. Otherwise, settlement of the underlying fill could cause the pipe to be pulled away from the building.

LFG Control

As solid waste decomposes, landfill gas (LFG), consisting of methane and carbon dioxide, is produced. If allowed to accumulate within a confined area in the presence of an ignition source, methane can explode. Any improvements constructed on or near a landfill should incorporate appropriate LFG protection measures. Several approaches are available to protect structures from LFG. Active control technologies include LFG extraction (normally followed by flaring, if gas production rates warrant treatment) to remove landfill gases before they reach structures, and air injection or air curtain systems to create positive pressures, driving landfill gases away from structures.

Passive control technologies include use of membrane barriers and vents to prevent gases from entering structures, and monitoring and alarm systems to warn of accumulating gases. Passive systems are commonly used where the landfill is old, and most of the decomposition has occurred (i.e., gas production rates are low). Passive systems also may be appropriate where the building will have limited usage, or is of open construction (e.g. open parking structures having six or more air changes per hour).

LFG control systems protecting higher occupancy buildings often have redundant systems (e.g., barriers, active extraction, and monitoring alarms), especially when the landfill is not old. Special care must be taken where utilities or other site features penetrate barrier systems; LFG will follow preferential flow paths along utility trenches and enter buildings at points of penetration unless properly sealed.

LFG protection systems require proper operation, monitoring, and maintenance. Monitoring alarm sensors can become "poisoned" by LFG constituents and rendered useless. LFG condensate and corrosive gas constituents can affect mechanical systems. As the closed landfill ages, LFG production patterns change, requiring adjustments in extraction system operation.

Landfills contain wastes, some of which may be hazardous. Older landfills--those which predate regulations requiring hazardous wastes to be managed in separate hazardous waste facilities--can contain a variety of industrial wastes such as solvents and sludges which require special handling and care if excavated. Many landfills were used to dispose asbestos-containing building materials, which also require special handling and regulatory notifications.

Workers who may be exposed to hazardous substances during excavation of utility trenches or other subsurface site features should be properly trained to handle such materials safely. Work space air monitoring and perimeter air monitoring may be necessary to assure that site workers and neighbors are not harmed by migrating chemicals. Documentation of training, monitoring, and medical monitoring may be required by Federal or state regulations. If drums of liquid wastes or other special materials are encountered during the construction activities, special contingency plans should be put into effect to characterize and stockpile such materials.

A written health and safety plan, specific for work on landfills, should be prepared and followed during construction. The Solid Waste Association of North America has published "A Compilation of Landfill Gas Field Practices and Procedures" (March 1992) which provides some common-sense elements for such plans.

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.).

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_x.

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 marshaled 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_x emissions are as low as one-tenth the NO_x 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

This section presents brief descriptions of case studies of end uses and re-development atop closed landfills. The individual case studies address applications such as golf courses, greenhouses, and other commercial office building construction as below.

City of Industry

A 600-acre site is located in the City of Industry, California, where a total of 155 acres 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. The Industry Hills Recreation and Conference Center is located on the same development as two of southern California's most prestigious golf courses. The development also contains a conference center, Olympic-sized swimming pool, a tennis complex, equestrian center, laundry facility, and 11-story hotel.

The facility is located approximately 10 miles east of downtown Los Angeles, California. About 3.6 million tons of municipal waste were deposited into the landfill, which has an average refuse fill depth of approximately 35 ft. 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.

The LFG management facilities at the project consist of two main systems, with the initial installation in February 1974. The first system prevents the accumulation of methane gas beneath on-site structures, and migration beyond property lines. Migrating LFG is collected and then destroyed at a blower/flare station capable of burning 500 cfm of LFG.

The second gas control system was designed for LFG energy recovery. While this system aids in LFG migration and surface emission control, it also supplies medium Btu fuel for convention center boilers and water heaters for the Olympic-size pool and laundry complex. The LFG process facility compresses and cools the gas to remove free liquids, and is capable of supplying approximately 2,100 MM Btu fuel each month. This saves the City of Industry approximately $10,000 to $15,000 each month in displacing natural gas demands.

Operation and maintenance of the gas system is regulated by strict guidelines from a number of different state and local enforcement agencies. In addition to these strict guidelines, the design engineers have developed numerous operating criteria that present unique challenges to the facility's operators. Some of the major challenges are health and safety; coordination with numerous on-site personnel like security guards and ground maintenance crews; odor control; and maintenance repair and access.

Evidence of the development's success is apparent in the project having received two separate prestigious awards. The facility was awarded the "ASCE Outstanding Civil Engineering Achievement Award" in 1981. In 1997, it received the "SWANA Gold Award for Landfill Gas Projects".

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.

Renaissance Park

Renaissance Park is a community recreation complex constructed atop a closed landfill in Charlotte, North Carolina. Facilities over the former landfill include soccer fields, softball fields, and a tournament level golf course. The City of Charlotte had owned and operated the site as a municipal solid waste landfill since the late 1960's. The landfilling operation was closed in 1986. The landfill comprises several discrete areas totaling approximately 375 acres of landfill footprint.

Several migration control systems were installed subsequent to landfill closure, including a passive LFG venting system around the golf club house, a passive vent trench along the northeast property line, and an active LFG migration control system along York Road (which contains several subterranean utility pathways and has occupied office buildings beyond).

Due to the open air nature of the recreational facilities placed atop the landfill, the original design concept did not entail comprehensive LFG collection through the landfill's interior surface areas. As a result, recreational facilities and other site improvements were left largely unprotected by LFG control systems. Theoretically, the absence of occupied structures atop the landfill proper, mitigated the opportunity for LFG combustion hazards, or other deleterious impacts due to landfill settlement.
In practice, several hazards have developed since the time the recreational facility at Renaissance Park (atop the landfill) was placed in service in the late 1980's. These problems, and their accompanying solutions, are

delineated below:

- Periodic Fire Hazards. Renaissance Park has experienced periodic ground fires caused by the ignition of LFG emitting through surface cracks. Reports of periodic fires have developed over the years. Normally, LFG dissipates quickly into the atmosphere, so that such instances are not anticipated and do not occur. Other precautions have been taken including banning of open air fires and camp-outs atop the closed landfill, for obvious reasons. Continued attentiveness to this matter is required for the future.
- Fencing. Chain link fencing is common around the ball fields at Renaissance Park, and typically includes galvanized steel pipe for the fencing posts. These posts invariably fill with LFG, and present a potentially hazardous condition. Technicians have monitored methane accumulations in the fence posts to levels approaching 50 percent gas around the soft ball fields at Renaissance Park. As with many such conditions, the chances for ignition or other human hazards are low, unless fencing post caps are intentionally removed by vandals. An easy solution to this problem is to specify that each column fence post not have a hollow interior in which LFG can accumulate.
- Electric Boxes. Electric power is most often used for lighting and concession stands at recreational facilities. Panel box explosions have occurred at landfills due to the accumulation of methane entering via underground electrical conduit. Conduit seals should be used between underground conduits and electric panel boxes, to prevent this pathway for LFG migration. Outdoor panel boxes atop the landfill are not normally considered to be in a classified location per the National Electric Code. Hence, conduit seals are not required for the purpose of isolating combustible hazards, but rather serve as a barrier to block LFG potentially migrating through the conduit.

In 1993, a woman was injured in an explosion at Renaissance Park when she lit a cigarette lighter to find a soccer ball that had rolled under a flood light footer pad. The explosion is believed to have been fueled by LFG entering the void space created by landfill settlement around the footer pad. Several other fires on the golf course, and within an off-site utility trench have also resulted with the ignition of LFG accumulations and emissions.

As a solution, the City of Charlotte responded with an intense investigation of LFG hazards at Renaissance Park. With identification of areas in which combustible gas can accumulate, a remediation program was designed, and is routinely implemented. The key is to avoid the accumulation of combustible gas inside settlement cracks, settlement cavities, and other man-made structures as delineated previously.

Willow Run Farms

Development of greenhouses atop and adjacent to sanitary landfills has been suggested for many years. Energy represents a significant cost of operation for greenhouse installations. The availability of cheap energy from LFG recovery operation can create an opportunity to provide energy to greenhouse operations on a discounted basis. In addition, the settlement and other environmental and technical impacts from sanitary landfills can be better accommodated by most greenhouse operations, than would be the case with other more rigid structures.

Still, the opportunity exists for the uncontrolled entry of combustible gas to the greenhouse operation, due to its proximity to the landfill. Under these circumstances, the LFG collection system used for energy supply must be examined, and its comprehensive performance ensured for the safe occupancy of the greenhouse operation.

With these conditions as background, Wayne Disposal developed a greenhouse operation known as Willow Run Farms in Belleville, Michigan (Detroit metro area). The greenhouse consists of a 45,000 sq ft development, atop a 70-acre closed municipal solid waste landfill cell.

An active LFG extraction system including vertical wells has been installed throughout the 70-acre landfill development. LFG collected from this system is used to generate electricity on year-round basis. However, the LFG-to-electricity-operation generates revenue at a poor rate of only $0.02 per kW-hour. During winter months when demand for cheap energy is highest from greenhouse operations, part of this fuel is diverted to a medium Btu application of greenhouse heating.

Willow Run Farms has spent more than $500,000 on capital and operating costs associated with the greenhouse operation through its first four years. The investment includes the cost of erecting a 1 acre, 10-bay greenhouse supplied by Clover Greenhouse of Smyrna, Tennessee. Specialty crops including watercress, chives, basil, osaka red mustard, bib lettuce, and other items are grown in the greenhouse. Growth is enhanced at the Willow Run operation hydroponically, in a medium of water and nutrients. Thanks to this controlled environment, no herbicides or insecticides are needed. Since this is such a highly productive method, the farm is able to grow a crop from seed to package in only 5 to 8 weeks.

Colma Home Depot

Closed landfill sites present new building opportunities, but knowing that foundation support, landfill gas control and liner maintenance will be required can cause developers to shy away. However, the Junipero Serra (Colma) landfill in San Mateo County, California, is proving that landfill development, maintenance and monitoring challenges are not insurmountable. The sites now are home to successful commercial businesses.

Ten years after closing in 1983, the Colma landfill site was selected by Bocci-Schneider Interests, Colma, California, to be developed as a Home Depot. Due to changes in California landfill regulations that made it more difficult to install deep foundations through closed landfill sites, the civil engineering firm Brian Kangas Faulk (now BKF Engineers), Redwood City, California, had to prepare an innovative foundation design for the redevelopment. The design included placing the building and structured parking atop a deep pile foundation, and allowing a hinged slab attached to the building to “float” with the settlement of the landfill, providing a controlled transition between the parking lot and the building.

Before buildings or other improvements can be constructed on a closed landfill, estimates of expected settlement must be made, based on experience, empirical observations and numerical models. The age of the landfill must be considered, given that active settlement takes place for many years depending on the depth of the fill, the types of waste present and the placement method.

For the Colma landfill, the designers used empirical settlement monitoring data, and used a 20-year, straight-line projection to estimate future settlement. This approach yielded a conservative estimate of settlement. Based on this information, designers at Colma called for a deep-pile foundation to support the building. Piles consisted of 150-foot long steel "H" piles that extended through the buried trash and 20 feet into the Colma formation below the landfill. A cathodic protection system was used to protect the steel piles from the corrosive environment of the landfill.

To protect structures from landfill gas, engineers must determine whether to use active control technologies, which remove gases before they reach structures; air injection or air curtain systems, which use pressure to drive gases away from structures; or passive control technologies, which use membrane barriers and vents to prevent gases from entering structures. At the Colma site, an active landfill gas extraction system was installed in 1995 to control off-site gas migration and for building protection. LFG is collected and combusted in a fully-enclosed ground flare. The system consists of the following major components:

- A network of 9 vertical gas extraction wells, installed in the refuse mass to depths of up to 100 ft below grade. Five wells are installed in the northern perimeter of the site in the parking lot. The wells are accessible through vault boxes installed flush with grade. The other four wells are installed in the landfill slope near the southern property line. These wells are accessible from beneath the floating structural slab and driveway apron overhang.
- A series of eight parallel extraction trenches installed below the building structural slab. The trenches are approximately 285 feet long each, and are fitted with alternating sections of 4- and 6-inch diameter collection pipe.
- Approximately 1,850 lineal feet of gas collection header piping, installed both above- and below-grade, or below the building slab.
- One pneumatically-operated sump and one knock-out vessel for condensate. Collected liquids are pumped to an above-ground storage tank, and hauled off-site for disposal.
- Two extraction blowers, rated at 7.5 horsepower each and capable of a maximum flow rate of 700 standard cubic feet per minute (scfm) at 40 inches water column (in-wc) inlet vacuum. One blower is used as stand-by.
- Sur-lite Corporation (Santa Fe Springs, California) fully-enclosed ground flare, designed to operate over a flow range of 50 to 250 scfm and maximum heat input of 5.25 million BTU/hour. The flare was installed in 1999 and replaced the originally-installed unit. The flare can operate continuously (24 hours/day) or on a timer basis.

A dual membrane liner system was installed below the Home Depot building structural slab. The liner system consists of the following components (from bottom to top):

- Geotextile material (weight 10 oz/sq. yard), initially installed over the compacted subgrade/landfill cover soils.

- 60-mil thick high density polyethylene (HDPE) membrane (primary liner), installed above the geotextile layer.
- HDPE drainage net, installed above the primary liner.
- Secondary 60-mil HDPE liner, installed above the drainage net.
- Protective geotextile material, installed above the secondary liner. The structural slab was poured above the geotextile.

The membrane underlies the entire building footprint, except at the locations of foundation pile caps or grade beams. Both membrane liners are anchored to the bottom of the structural slab using a "Gundlock" system. The liner ends are welded to the Gundlock anchors, which were installed around and centered between all pile caps.

Utility penetrations through the slab are sealed using butyl rubber tape, polyurethane sealant, or special boots. The type of seal is dependent on the utility conduit size and shape. Key utilities are double-cased to reduce the potential for leaks into the landfill. Flexible utility connections were provided both where utilities joined the building and where utilities left the site.

SCS Field Services, Long Beach, California, provided the operation, monitoring and maintenance services for the landfill gas extraction, treatment and sensor systems. Landfill gas generation rates decreased over time, with the result that the original gas flare system was over-sized and inefficient. SCS designed, permitted and installed a replacement gas flare that had a higher turn-down ratio (to accommodate lower flows), and that operated intermittently using a timer.

SCS also provided health and safety support and construction oversight for below-grade repairs to site utilities and the hinged slab, which doubles as a store entrance. Such repairs had been anticipated to be relatively frequent in the early years of store operation, and the first such repair was made in 1997. Repairs included exposing a grade beam at one side of the hinged slab, and jacking and shimming the slab to restore it to design grade. A second round of repairs is scheduled for later this year.

In 2002, the Colma project received the Solid Waste Association's Silver Award for landfill gas control, in recognition for successful long-term operations and monitoring of the landfill gas control system that allowed this former landfill site to be redeveloped and returned to productive use for the community.

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 the 85-acre landfill.

The Westport project is one of the most ambitious projects ever undertaken on a former landfill site. The estimated site development cost of over $100 million makes it the fifth largest project under construction in northern California. The Project completion date is 1999.

The 85-acre Redwood Shores site served as a municipal waste landfill from the 1940s to 1970. Approximately 4 to 10 feet of fill soils were placed over the waste in 1978. The site remained vacant until 1998, when general contractor Vance Brown, Inc., Palo Alto, California, asked SCS Engineers to provide landfill engineering, permitting and construction management services for the planned $150 million, one-million square foot Westport Office Park. The presence of underlying refuse has created challenging engineering issues for site development, including protection of structures from explosive gases, site settlement, and preservation of the clay liner.

SCS Engineers was retained by the general construction contractor to provide various landfill engineering, permitting, and construction management services. SCS prepared design plans and specifications for protecting site structures from potential explosive hazards associated with LFG infiltration. Construction observation services were provided thereafter to verify that the protection features were installed per the design plans and regulatory requirements.

The Westport Office Park was one of the largest and most ambitious landfill redevelopment projects ever undertaken. Because waste lies beneath the site, the engineers had to design protections for the 20-building development. This included providing management systems for explosive gases, site settlement, site utilities and preserving the landfill clay liner.

The key protection and monitoring features include:

- Subfloor membrane, passive-gas venting system and continuous, automated combustible gas sensors installed at each building;
- Subsurface gas migration barriers installed in site utility corridors;
- Venting system to relieve gas pressure buildup in parking lots overlying the deeper portions of the landfill; and
- Subsurface gas venting and monitoring system and a leachate cut-off trench 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.

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.

<u>Lakeside MarketPlace Landfill Redevelopment</u>

The site is located in Acworth, just outside of Atlanta, Georgia. It is a 40-acre closed site was used as an "inert" landfill for disposal of land clearing wastes and rubble. A portion of the subsurface fill was on fire. Target Corporation, interested in establishing a SuperTarget in the area, turned to retail developer North American Properties to make the project happen. North American Properties, in turn, retained SCS to control the subsurface fire and mitigate methane gas.

SCS performed a peer review of conceptual plans for controlling the subsurface fire and mitigating methane gas, and suggested several changes. SCS then provided engineering, construction, and health & safety monitoring for the fire control and methane mitigation aspects of the project. Mitigation measures included injecting carbon dioxide to help control combustion, and a passive methane mitigation system for most of the buildings, consisting of a vent layer vented to the roof and a 60 mil Liquid Boot spray-applied barrier membrane. For one building, SCS designed and installed an active ventilation system, using a 2,300 scfm blower and automated controls mounted on the roof.

Stores over the deepest part of the fill (60 feet) were supported on H-piles, as were utilities that would be adversely affected by differential settlement. Dynamic deep compaction was used to stabilize high traffic areas and building footprints where fill was relatively shallow. Aggregate piers were used for other buildings at the site. All stores were protected by an SCS methane management system.

With construction now complete in 2006, Lakeside MarketPlace tenants include SuperTarget, Circuit City, Ross, PETCO, Books-A-Million, OfficeMax, and Famous Footwear. This project serves as a prototype for landfill redevelopment: a combination of investigation, design, construction oversight, and construction services with an ultimate goal of superior risk management. SCS expertise in both subsurface fire control and methane management, as well as an understanding of retail construction and development were keys to the project's success.

CONCLUSIONS

This paper highlights some of the many successful closed landfill end use projects which now exist in California. The 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.

Scores of closed landfills in the United States have been successfully developed into productive land uses. Development ranges from institutional and residential to a wide variety of commercial, retail, and industrial land uses, in addition to more traditional closed landfill uses (e.g., passive recreation, golf courses, etc.). However, the challenges inherent in development of a closed landfill can be significant. Experience has shown that technical challenges such as settlement, deep foundations, and gas protection can be met. In U.S., legal liability challenges continue to present impediments to landfill redevelopment; however, recent Brownfield policy initiatives at the Federal and state levels suggest that such impediments also can be overcome.

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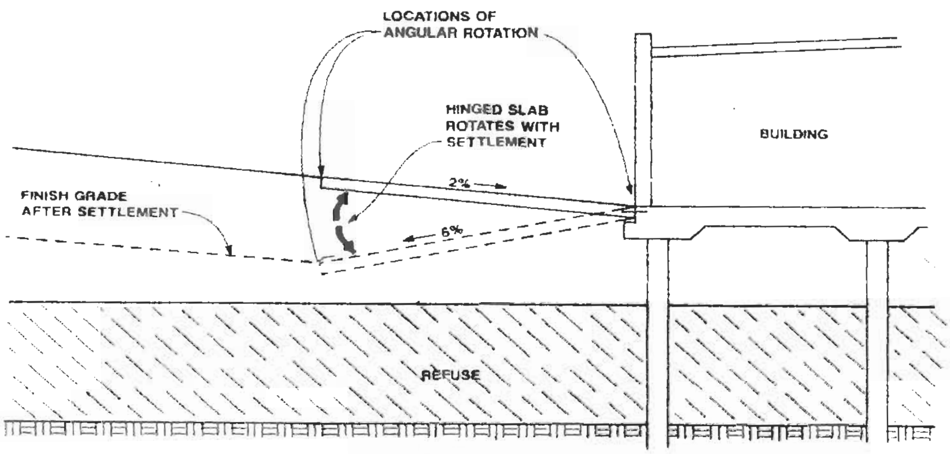

Figure 1
HINGED SLAB AT BUILDING ENTRANCE

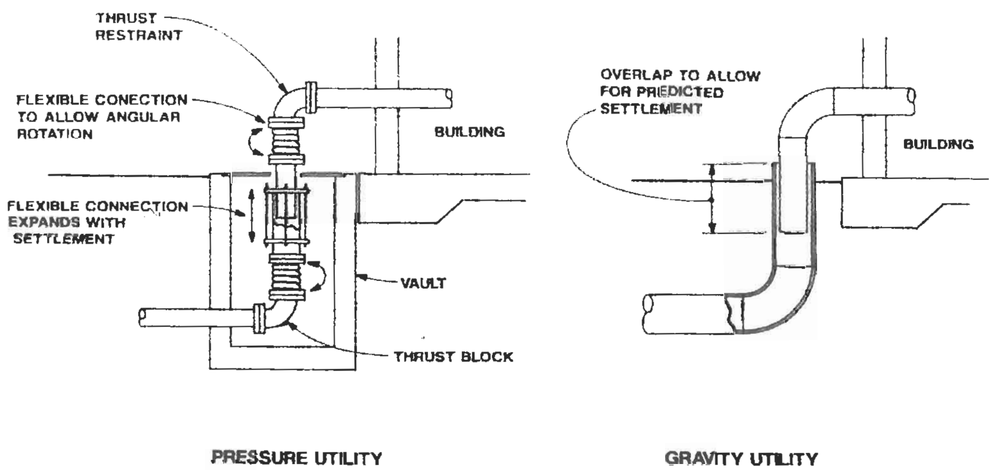

Figure 2
FLEXIBLE UTILITY CONNECTIONS

Figure 3

Effect of settlement and lack of maintenance during a period when building was not occupied

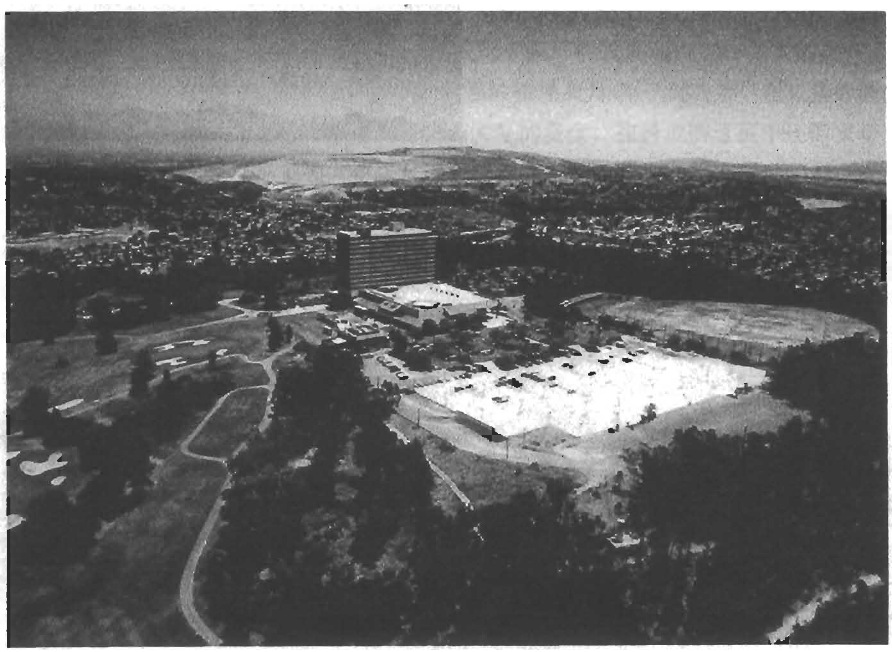

Figure 4

Industry Hills Convention Center

Figure 5

Lakeside Marketplace Landfill Redevelopment

2007

北京固体废弃物处理及资源化利用技术研讨会

时间：2007年6月7日　地点：北京创业大厦


主办单位：北京市科学技术委员会

承办单位：北京新材料发展中心

北京市固体废物管理中心

北京节能和资源综合利用协会

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支持媒体：新材料产业杂志社

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