EXPANSION OF AN ACTIVE LANDFILL – A CASE STUDY

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Abstract

A landfill can run out of its airspace or storage capacity prematurely for a variety of reasons such as unanticipated population growth due to rapid urbanisation, response to huge amount of debris waste from a natural disaster like a topical storm or hurricane, poor waste placement operations, or unable to obtain permission or a longer than anitcipated regulatory approval process for a new landfill site. From the cost-benefit and timing standpoints, an expansion of an existing landfill laterally by piggyback approach or vertically between two existing landfill mounds provides an excellent and innovative waste management solution to solve the problem of airspace shortage as stated above. Some of the important technical considerations that need to be addressed are: slope geometry configuarion and its stability, foundation support and waste settlement due to additional loadings, existing bottom liner system integrity, connecting a new bottom liner system deployed between two mounds, additional leachate and landfill gas controls, stormwater drainage management, potential relocation of existing utility lines, constructability, filling operations and staging/phasing, and environmental or leak monitoring. A case study site located in South America was presented with key technical considerations and results of the landfill airspace gained and life span extended were evaluated and discussed.

Keywords: Landfill Expansion, Airspace, Lifespan, Slope Stability, Waste Settlement

Introduction

The vertical expansion, or the piggyback approach, is basically constructing a new landfill disposal area on top of one that is either closed or scheduled to be closed at an already-regualtory approved site. By placing waste on top of the existing landfill that has reached its capacity, it gains immediate airspace, extending the landfill lifespan, and also fully maximizing the utilization of an area that has already been disturbed for waste disposal, thus preserving pristine greenfield areas. Most waste regulations would allow a new solid waste unit or cell, or expansion, that is properly designed, permitted, constructed and operated over the side slopes or top areas of an existing solid waste landfill unit but in an environmentally protective and stable manner.

In addition to the above benefits, no new infrastructure, facilities, and monitoring systems are needed for a vertical expansion within the original footprint, unless the existing infrastructure is in the same expansion area and needs to be relocated. Some of the important technical considerations that need to be addressed are: slope stability, landfill base and waste settlement, liner integrity, foundation support, landfill leachate and gas controls, stormwater drainage, bottom liner design, constructability, operations and staging/phasing plans, and environmental or leak monitoring. In this paper, a case study site is presented with analyses of some of the key technical considerations listed above as the most important evaluation when considering vertical expansion of an existing active landfill.

Materials and methods

A case study site is located in the district of General San Martin, in Buenos Aires, Argentina. It is called the Norte III Final Disposal Environmental Complex (Complex) which is composed of Norte III (64.2 hectares), IIIA (62.8 hectares), IIIB (82.2 hectares), and IIIC (89.1 hectares) landfills. These landfill locations are shown on Figure 1. The landfill operations at the time of this expansion study occurred in Norte IIIB and Norte IIIB Expansion, which is a small piggy-back area in the mid-section of the IIIB landfill. The waste height before the expansion in Norte IIIA and IIIB ranges from about elevation 30 m to 35 m. The expansion area between IIIA and IIIB and including the existing mounds is shown in Figure 1. The site operates 24-hours per day, 7-days per week, 365-days per year and receives a daily average waste flow of approximately 15,000 tonnes. The landfill receives primarily municipal solid waste (MSW) from the capital district and other cities in the province of Buenos Aires.

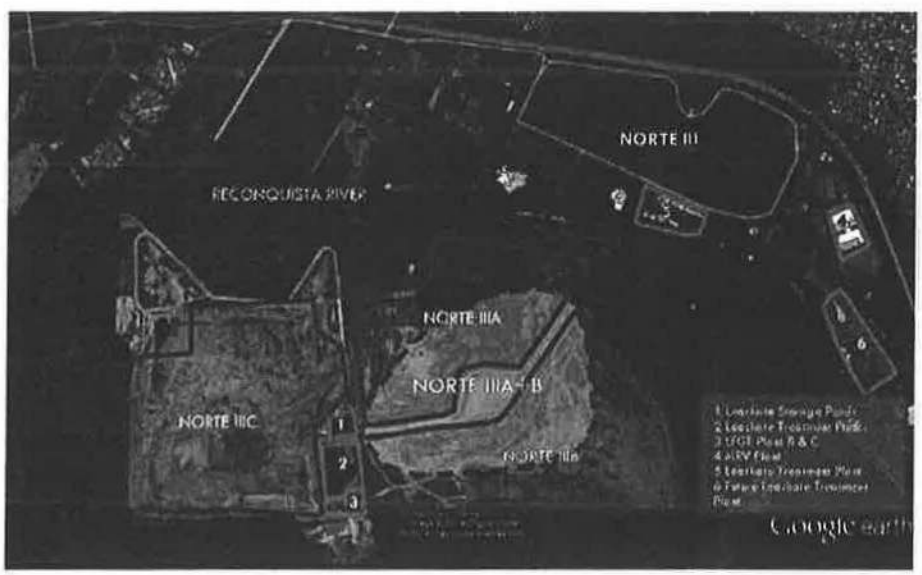


Figure 1. Site Plan

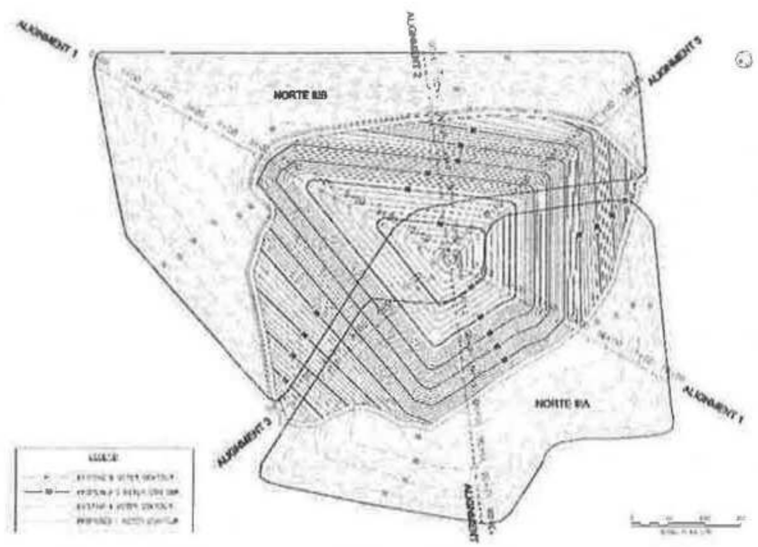
The climate in this region is characterised as humid subtropical, with an average annual rainfall of 1,145 millimeters (mm), an average annual temperature of 16.6°C with a maximum average temperature of 21°C, and a minimum average temperature of 12°C (Source: World Climate: www.worldclimate.com).

In order to evaluate the possibility of implementing a vertical landfill expansion, the important technical considerations that need to be addressed are: global slope stability under static loading conditions, landfill base settlement, integrity of the bottom liner system and leachate piping, landfill gas and stormwater management. Only the global slope stability and the landfill base settlement and liner integrity are presented in this paper. The results of the landfill airspace gained in cubic meters and the landfill life span extended in years are presented and discussed below.

Results and Discussion

Global Slope Stability

Global slope stability analysis was performed using the new landfill expansion final grading plan with higher waste height and waste fill slopes. As shown in Figure 2, a section profile along Alignment 2 was selected for this evaluation. Circular failure surfaces were used to evaluate landfill base and waste fill slope stability, while sliding block failure surfaces were used to analyse its stability along critical interfaces within the base liner system. Based on current industry practice, an acceptable minimum factor of safety (taken from the US EPA's "Technical Guidance Manual for Design of Solid Waste Disposal Facilities") is 1.5 for static slope stability analysis, using peak shear strength values of the critical interfaces or materials.



Profile View of Alignment 2

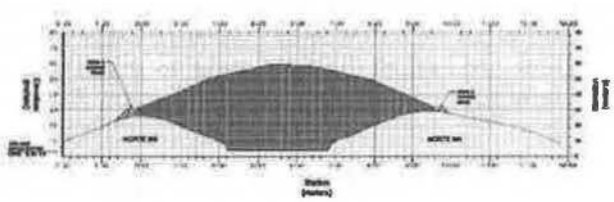


Figure 2. Section Location and Profile View

There is always a potential for leachate mounding above the bottom liner system, especially during wet seasons and when soil cover is not used. Therefore, the effect of various amount of leachate mounding on the bottom liner system was evaluated, namely at 0.3 m, 1.0 m, and 3.0 m of leachate head above the liner system.

The results of the global slope stability analysis for both a final grading plan at 1(V):7(H) slope and a leachate mounding above the bottom liner system scenarios are presented in Table 1. The computed factors of safety are relatively high, in the range of 3.1 to 3.9. It is due to the fact that the proposed final waste fill slope is fairly flat (12%) when compared to a typical landfill with 1(V):3(H) final slope (33%) in the USA.

As shown in Table 1, the factor of safety calculated assuming a block-type failure surface within the liner system is lower than that of a circular failure surface within the waste mass. Therefore, the most critical failure surface will occur within the base liner interface. The calculated factors of safety indicate that the slope is very stable under the conditions used in the analysis.

Table 1. Global Slope Stability Evaluation

Scenario	Failure Surface Type	Factor of Safety (FS)
Final Grading with 1(V):7(H) Slope & Waste height at El. 59.5 m	Block	3.62
	Circle	3.92
Effect of Leachate Head: 0.3 m 1.0 m	Block	3.52

The effect of leachate mounding ranging from 0.3 m to 3.0 m was evaluated against the landfill slope stability. The results shown in Table 1 indicate that the factor of safety will decrease as the leachate head above the liner system increases. Although the factor of safety calculated was above the recommended minimum value of 1.5, it is important to point out that constant removal of leachate head to maintain less than 0.3 m head during landfill operation is always a good landfill leachate management practice.

Based on the results presented, a minimum FS of 1.5 for static slope stability analysis can be obtained for the new landfill expansion 1(V):7(H) final side slopes and with a new waste height at Elevation 59.5 m. These FS values depend on the critical shear strength parameters used in the analysis for both liner interfaces and the waste mass.

Landfill Base Settlement & Liner Integrity

Every landfill that contains organic material is at some stage of the decomposition process. As subsequent lifts of trash and soil are placed on top of a landfill, the underlying layers will be pressed down or consolidated. Over time as the waste decomposes, it releases moisture and heat and the landfill will settle further. The settlement process could be further enhanced by stockpiling soil, green waste, compost, rubble, or other material on top of the underlying waste.

Foundation settlement (landfill base) was predicted using one-dimensional consolidation theory for soils. A settlement analysis was performed using soil parameters presented in a geotechnical report entitled "Centro de Disposocion Final Norte III Ampliacion sector entre Modulos Norte IIIA y Norte IIIB – Estudio de Estabilidad de Pila de Residuos y Suelos" preparad by GADEF S.R.L Ingeniería Ambiental date 9 January 2013. An estimate of settlement within the uppermost 3-meter clayey silty soil stratum underlying the landfill liner system was made using assumed settlement characteristics as presented in the referenced report. The settlement calculation was based on the proposed maximum waste height to elevation 59.5 IGM for loading conditions at the peak of the expansion and with a typical side slope of 1(V):7(H) approximately. Loads were calculated based on an assumed overburden unit weight of 9.8 KN/m3, which incorporates the solid waste, daily cover (if used), and final cover materials of 1.5 m. The results of the analyses are summarized in Table 2.

The maximum settlement within the landfill foundation will occur at the peak of the landfill, with a total calculated settlement of approximately 25 cm. Differential settlement is most pronounced around the toe of the existing IIIB cell perimeter berm and the new expansion base. For the expansion area slope, the differential settlement will result in 16 cm, which represents a differential strain within the base liner of approximately 0.23 percent.

Table 2. Landfill Expansion Base Settlement

Scenario	Maximum Settlement at landfill Base (cm)	Differential Settlement (cm)	Change in Base Slope (%)
Final Waste Fill Slope at 1(V):7(H) & Waste Height to El. 59.5 m	25	16	0.23

This liner strain values are relatively low and well within the tolerance for the components incorporated into the bottom liner system and are much less than a typical allowable yield elongation value of 8 percent for HDPE liners.

The result also suggests that for the new landfill base slope of the expansion area should be designed to account for this differential settlement in order to maintain positive drainage as designed. Based on the foregoing discussion, the calculated foundation settlement and associated strain will not adversely affect the performance of the bottom liner or leachate collection system.

It should be noted that consolidation of the solid waste was not evaluated here since it does not impact the foundation settlement. However, for the final cover system design; this analysis should be performed such that the post-settlement final top slope should maintain at a slope that promotes positive drainage from the top of the landfill. Typically the consolidation of solid waste will occur in two components, primary and secondary, and modeled similar to soils. Primary consolidation is a function of stress increase and occurs within the first few months after load application. Secondary consolidation results from the decomposition of solid waste and can be modeled as a log-time relationship.

Settlement characteristics for solid waste are not readily available, and vary according to waste composition, moisture, placement methods, and other factors. A common method of calculating settlement within solid waste is to assume solid waste exhibits consolidation characteristics similar to organic peats and soils.

Hence, for this analysis, published consolidation data for organic peats should be used to estimate the primary and secondary consolidation characteristics for the solid waste.

Extended Landfill Life Span

The design parameters for the Norte IIIA+B landfill expansion are summarized in Table 3. The vertical expansion, using a final side slope of 1(V):7(H) and a maximum waste height at elevation 59.5 resulted in a landfill capacity gain of about 16.3 million m3, which extends the landfill lifespan about 3 years or 36 months.

Table 3. Volume Gained and Extended Landfill Life Span

Parameters	Results of Landfill Expansion
Maximum Closure Side Slope Angle	12%
Maximum Waste Height	59.5 meters
Landfill Expansion New Base Area	11.6 hectares
Total Landfill Base Area (IIIA+B Expansion)	156.6 hectares
Total Landfill Closure Area - Final Surface (IIIA+B Expansion)	1,559,926 m2
Closure Top Area with Surface Slopes ≤6%	15.6 hectares
Estimated Airspace Gain	16,272,630 m3
Extended Landfill Life Span (1)	36 months

(1) Based on a 2015 projected annual waste disposal of 5.5 million tonnes and a waste in-place density of 1.0 tonnes per cubic meter.

Conclusion

A typical landfill expansion project should contain an engineering evaluation and analyses addressing important technical considerations which include the existing hydrogeologic conditions, global slope stability, landfill base settlement, geomembrane compression and strain, leachate pipe strength, useful life of the existing infrastructure and utility lines, stormwater management, leachate and landfill gas system expansion. In this case study site, it shows that the vertical or piggyback expansion of a landfill is a unique way of solving landfill airspace shortage problem. Its feasibility is always site-specific and depending on the existing waste types, slopes, liners, design capacity of leachate and gas collection, and stormwater management systems. In addition, the landfill design needs to be thoroughly investigated, engineered, and operated.

From the results of the global final slope stability and the landfill base settlement analyses, it concluded that a vertical expansion at the case study landfill will not increase the risk to human health or the environment over the existing regulatory approved conditions. A vertical expansion provides the landfill owner with an opportunity to increase the landfill volume and provide the residents with the maximum service life within the existing footprint of the permitted Landfill. This maximisation of available resources does not expand the environmental footprint of the site and provides better environmental protection and at the same time creates a sustainable landfill site.

Reference

Achilleos, Eftychios (1988). User Guide for PCSTABL5M. Joint Highway Research Project No. JHRP 88-19, School of Civil Engineering, Purdue University, West Lafayette, IN.

Centro de Disposicion Final Norte III Ampliacion sector entre Modulos Norte IIIA y Norte IIIB – Estudio de Estabilidad de Pila de Residuos y Suelos" preparad by GADEF S.R.L Ingeniería Ambiental, January 2013.

Conceptual Final Grades Expansion Norte IIIA+B Design Drawings, Benito Roggio ambiental (BRa), June 2014.

Feasibility Study Report for Norte IIIA+B Landfill Expansion, Buenos Aires, Argentina, prepared for Benito Roggio Associated (BRa) by SCS Engineers, August 2014.

Law, James, Isenberg, Robert, and Reed, Jeffrey. "Effects of Liquid Levels to Interim Slope Stability during Sustainable Landfill Practice." Global Waste Management Symposium sponsored by National Waste & Recycling Association and Environmental Research and Education Foundation, Orlando, FL, June 22-25, 2014.

Law, H. James. "Impact of Leachate Level above Liner System on Slope Stability during Landfill Operation." 2014 ISWA World Congress, Sao Paulo, Brazil, 8 – 11 September, 2014.

Law, James. "Sanitary Landfill Mining – Operational Interim Slope Stability Aspects." 2013 Sardinia Symposium, Cagliari, Sardinia, Italy, September 30 – October 4, 2013.

Slope Stability Study for Norte IIIB Expansion, GADEF S.R.L., January 2013.

Soils Study in the Norte IIIB Area, GADEF S.R.L., February 14, 2005.