The Normandy Landfill: A Case Study in Solid Waste Management

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ABSTRACT

The Normandy Landfill is a by-product of the Lebanese civil strife (1975–1990). During those years, the city of Beirut discarded about 1090 Mg/d (1.200 t/d) of its municipal waste in the Normandy Bay along the Mediterranean coast. After the civil war, the general area of the fill became popular real estate because of its location at the historic and economic center of Beirut. Economic incentives pushed planners of the reconstruction effort to envisage reclaiming the fill area and develop it as an extension of the central business district. This decision was controversial from the outset and was not met with great enthusiasm in many quarters, particularly given its socio-political implications. Proponents of development stated that it would provide many environmental and economic benefits to the area in terms of job creation and elimination of health hazards associated with the existing landfill. Opponents argued that the historic coastline of Beirut should be rehabilitated to its original status, and that the cost of the newly reclaimed real estate would be prohibitive and would only result in the creation of a wealthy enclave, which would be inaccessible to the majority of the population. Despite opposition, the Council for Development and Reconstruction, the final decision maker regarding the development of the Central Business District of Beirut, adopted a policy aiming to reclaim and expand the fill area. The council was to decide the best reclamation alternative for the landfill, taking into consideration socio-economic factors as well as technical aspects.

IN LEBANON, as in most developing countries, municipal solid waste (MSW) disposal has been a chronic problem, particularly in areas with high population density, high production of refuse, and scarcity of land adequate for landfills. In such settings, uncontrolled waste dumping along the seashore has been an unfortunate, yet common practice for solid waste disposal in major urban centers. These practices along the Mediterranean coast resulted in serious sea pollution problems. Recently, efforts were made to rehabilitate and reclaim uncontrolled dumps and landfills, turning them in some instances into parks, recreational facilities such as drive-in theaters, or even service centers (Stearns and Petoyan, 1984).

This paper considers the decision of the Lebanese Council for Development and Reconstruction (CDR) regarding alternatives to remediate a waste disposal facility along the Mediterranean. The CDR coordinates major infrastructure and developmental projects with various ministries and municipalities across the country. It reports directly to the Council of Ministers, the highest executive branch in the country. While the CDR was initially conceived in the early 1970s as a policy planning entity, its role has progressed with time to develop, supervise, and implement policies and major projects. It consists of several departments responsible for various economic sectors including transportation, energy, industry, agriculture, and waste management. Its highest authority consists of a board of four members that are the ultimate decision makers who reach their decisions by majority votes. Their decisions can be overruled only by the president of the CDR and/or the Council of Ministers. At the end of the civil war in Lebanon, a private real estate holding company (SOLIDERE) was established to manage and implement the redevelopment of the Beirut downtown, which had suffered extreme levels of destruction. The seashore dump was included as part of the real estate portfolio of the newly created company. The CDR had final authority and constant supervision responsibilities for overseeing the work of SOLIDERE.

While the case presented in this paper was developed for use in senior and graduate level courses in environmental engineering and science, it is also suitable for students in related fields such as natural resource management if the design aspects are minimized. Besides the stress on the technical component of facility remediation alternatives, the case can serve to discuss solid waste management in the light of social perceptions in general, and limited economic resources in particular. Finally, an important aspect of the case study approach is to encourage students to seek additional information, data, or references that are needed to reach an educated scientific decision, thus allowing the simulation of real-time decision-making that has to often be made in the absence of some data due to economic or time constraints.

THE CASE

As years of civil unrest in the city of Beirut came to an end in the early 1990s, reconstruction and rehabilitation efforts were launched to remediate the impacts of nearly two decades of conflict. At the heart of the reconstruction area lay the historical and business center of the capital, which was in effect, the demarcation line during years of civil strife. A private company, SOLIDERE, was formed for the purpose of guiding this effort to completion, under the supervision of a CDR. A pressing issue that the newly created company had to consider was the Normandy Landfill, which was one of the most visible and controversial landmarks needing attention in the Beirut Central District (BCD).

History and Background Information

The site known as the Normandy Landfill is located along the northern coast of Beirut, Lebanon (Exhibit 1). It literally forms the sea façade of the BCD. It was created as a result of dumping municipal and other wastes into the Mediterranean sea during 15 yr of civil unrest. The original site consisted of a small bay that used to cut 200 m into the mainland (Exhibit

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Abbreviations: MSW, municipal solid waste; CDR, Council for Development and Resonstruction; BCD, Beirut Central District; NIMBY, not in my backyard; AUB, American University of Beirut; PU, Purdue University; JUST, Jordanian University of Science and Technology; ISWM, integrated solid waste management.

Exhibit 1. General map of Beirut.

2). Random disposal activities began around 1975 and were suspended in 1994. Initially, the waste was limited to household wastes and later included inert fill and construction material. The site currently covers about 360 000 m^2 and extends about 600 m beyond the original shoreline (Exhibit 3).

During the period 1975 to 1982, the material dumped was mostly municipal waste with some construction rubble. At that point 30 000 m^2 land area had been deposited into the sea (Exhibit 4). Between 1982 and 1983, large quantities of demolition debris were dumped into the sea north of the existing waste piles. The haphazard nature of the dumping type and location continued until 1994, resulting in a heterogeneous fill with areas of inert and organic materials alternating and mixing in no clear pattern.

By 1994 the volume of the landfill reached about 5 million m^3. Half of this volume was below sea level, reaching water depths of 20 m. Above the water line the fill reached heights of 35 m in some locations (Exhibit 5). In addition, the years of war resulted in significant damages to the city infrastructure, including sewage and wastewater disposal, resulting in the discharge of large volumes of untreated wastewater at the edge of the fill.

Site Characterization

The first step undertaken by SOLIDERE was to conduct a comprehensive site characterization study, which included estimating the deposited waste quantity and composition, and subsurface properties as well as leachate and gas formation potential.

Waste Quantity and Composition

The total amount of municipal waste dumped in the fill since 1975 cannot be established with any degree of certainty. During the last 2 yr beforte site closure, about 1090 Mg/d (1200 t/d) were disposed of at the site. The composition of the municipal waste generated in the greater Beirut area was typical of developing countries and was characterized by a high content of food waste compared with developed countries where paper waste predominates (Exhibit 6). Waste composition may affect the possible alternatives for disposal and/or treatment of the already existing and still active materials within the landfill.

Although most waste received at the Normandy Landfill consisted of municipal waste, the landfill also received sig-

Exhibit 2. Aerial view of the Normandy Bay before landfilling activities (1970).

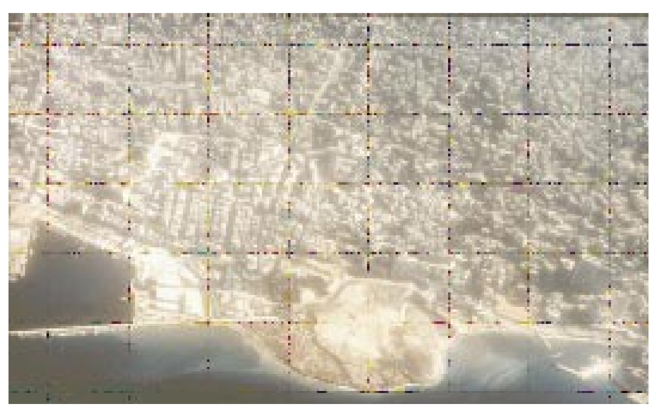

Exhibit 3. Aerial view of the Normandy Bay after landfilling activities (1993).

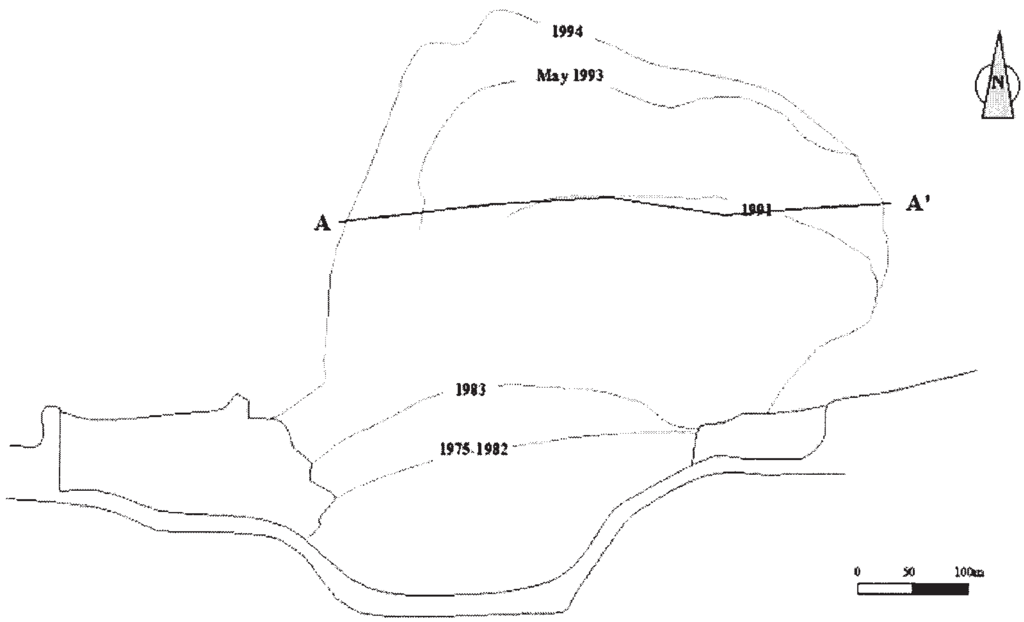

Exhibit 4. Historical development of landfill encroachment into the Mediterranean.

nificant amounts of old household appliances, wrecked cars and car parts, old tires, medical wastes, and industrial wastes including lubricants and cleaning agents (Exhibit 7). In addition, serious consideration had to be given to the possible presence of mines or unexploded ordinance on site. The inert fill that was deposited at the site consisted mainly of cohesionless soil excavated from various construction sites in and around Beirut, and of destruction rubble such as reinforced concrete slabs, boulders, and ceramic tiles and bricks.

Soil, Gas, and Leachate

Characterization tests were conducted on the soil, gas, and leachate within the fill. This effort was designed to establish the location, depth, and age of the waste material present within the landfill. Such data define the zones that require extensive or immediate treatment and help in selecting the appropriate treatment methodologies. The subsurface profiles were characterized by drilling 16 boreholes to maximum depths of 50 m and excavating 40 surface trenches to depths of 5 m. More than 200 gas probes were installed across the site to assess gas generation and composition (Exhibit 8). Monitoring wells were extended below the landfill into the natural strata. Samples of ground water and landfill leachate were collected and chemically analyzed (Exhibit 9). Finally, samples from the inert soils in the landfill were tested for various geotechnical properties (Exhibit 10).

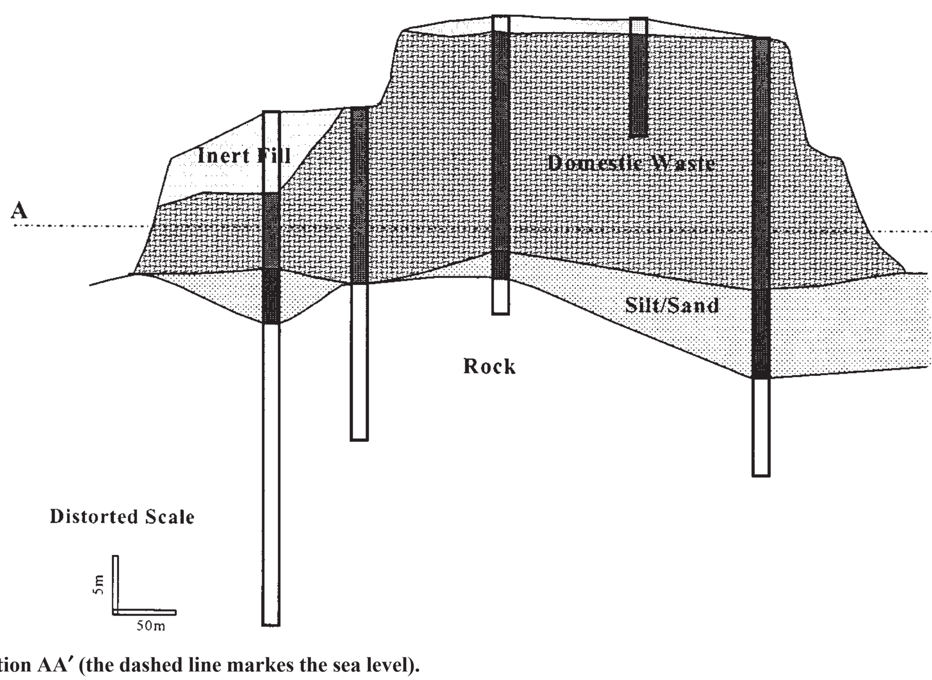

Exhibit 5. Cross-section AA′ (the dashed line markes the sea level).

Exhibit 6. Typical average solid waste composition: Lebanon vs. USA (World Bank, 1995).

Waste type	Beirut	USA
	% by wet wt.	
Food remains	62	20
Plastics	12	5
Paper/cardboard	13	43
Glass	5	9
Metals	3	7
Other	5	16

Exhibit 7. Car carcasses and wrecks as part of the Normandy fill.

Exhibit 8. Landfill gas composition in selected gas probes.

Major gases	%	Trace gases	μg/m^3
Hydrogen	<5	Total volatiles	0.6–22.8
Oxygen	<0.05	Aliphatics	2.7–20.8
Methane	36–47	Chlorinated	0.1–2
Carbon dioxide	36–49	Aromatics	0.1–0.4
		Sulfur	0.1–1

Exhibit 9. Ground water and leachate chemical composition.

Physical		Chemical	mg/L	Biological	Col/100 mL
pH	6.1–8	Chloride	240–17 650	Total coliforms	2 500–680 000
Conductivity, mS	2–57	Sodium	228–14 000	Fecal coliforms	0–350 000
Alkalinity, mg/L	145–16 800	Potassium	30–3 380		
		Magnesium	25–945		
		Calcium	20–4 500		
		Lead	<0.04–0.43		
		Iron	2.5–28		

Exhibit 10. Soil properties within the fill.

Moisture content, %	18–33
Liquid limit, %	22–76
Plastic limit, %	15.5–29.6
Plasticity index, %	3.5–47.6
Dry density, Mg/m^3	1.65–2.00

The degree of compaction of the fill was difficult to establish, given the history of the site and the inherent heterogeneities. Furthermore, the internal structure and character of materials forming the fill are constantly changing as a result of the active degradation as indicated by the gas generation and composition results. Therefore, settlements are expected to occur with continuous variation in fill density. In addition, leachate formed within the landfill seeped away from the direct fill area.

Political and Socio-Economic Context

The location of the landfill along the old demarcation line of the civil war and at the heart of the historic, commercial, touristic, and cultural center of the city of Beirut, placed the Normandy dump at the center of a unique political, social, and economic situation. Implications associated with any envisaged solution were as complex and as varied as the fabric of the Lebanese society emerging from its strife. Politically, the controversy was mainly associated with the allegiances of the entity that was responsible for planning and implementing any solution. This was further exacerbated by concerns regarding the inevitable demographic changes in the newly developed zones. An area that was traditionally the center for a large number of small businesses, artisans, and low to moderate-income housing, was to be potentially transformed into a high-cost, high-end business district, luxury tourist resorts, and housing complexes. On the other hand, leaving the festering problem at the heart of the city with its associated environmental hazards was not an option. The impact the landfill was having on the center of the city could not be tolerated and nothing short of a radical solution would be acceptable. The NIMBY (not in my backyard) syndrome was clearly evident in discussions with residents of nearby areas. The heart of the dilemma was that without the economic incentive of the new high-end development on the reclaimed lands, the cost of rehabilitation could not be born by the government alone, but that the transformation of the area and the changes in demographics and land use would profoundly change the fabric of a city that was thousands of years in the making.

The Decision

The board of directors of the company for the reconstruction of the BCD, SOLIDERE, had to develop an appropriate and cost-effective plan to reclaim the Normandy Landfill. The plan needed to be approved by the CDR. Different strategies entailed varying cost and environmental impacts. Any course of action SOLIDERE adopted had to consider environmental, economic, socio-political, and technical aspects, as well as anticipate potential long-term effects of coastal degradation. What alternatives were available to SOLIDERE and CDR to reclaim this site and what should they have done?

TEACHING NOTE

Case Objectives

The objective of the case presented in this paper was to expose the students to issues and concerns related to the disposal of solid wastes. Upon completion of this case, students should be able to:

- Identify adverse environmental impacts of the uncontrolled dumping of solid wastes.
- Identify and evaluate landfill remediation and rehabilitation techniques.
- Identify socio-economic factors in solid waste management.
- Define and evaluate alternatives for solid waste disposal.
- Define siting criteria for landfills.
- Develop a monitoring plan for waste disposal facilities.

Uses of the Case

The case was developed for senior and graduate level students in environmental engineering and science. However, students of lower levels can benefit from some of the simple and fundamental core issues raised in the case. Design questions are intended for students with some technical background in relation to landfill facility components.

The case, based on country-specific data and events, provides students with the opportunity to conduct a preliminary evaluation of a closure plan for a solid waste disposal facility in a developing and high-growth coastal city, given insufficient and inadequate data in some areas. The students would need to complement the information presented to them with searches ranging from literature sources to local firms, or even field surveys to collect their own data. In evaluating the information, students should learn to sort through and critically evaluate the reliability of the data and their sources.

The case presents a very good opportunity for highlighting and discussing the importance of social and political considerations in deciding community issues, particularly in the context of a developing nation. Further discussion may tackle the role of governments in the face of public opposition for certain developmental projects, which may have important economic implications and benefits.

Implementation of the Case

The Normandy Landfill case was tested in a number of courses on solid waste and natural resources management at the American University of Beirut (AUB), Purdue University (PU), and the Jordanian University of Science and Technology (JUST). The student makeup of the classes in which the case was tested was quite varied. Students ranged from sophomore level to Ph.D. candidates and had diverse backgrounds (civil engineering, environmental science, agriculture, and liberal arts).

The feedback of students was positive regarding the case study approach. Suggestions were made, some of which led to modifications in the case content and method of implementation. The strategies adopted by various teachers in the different courses and institutions involved, were not identical.

Any one of a number of implementation methods may be used. The case documentation can be assigned as outside reading followed by a general class discussion of the important issues raised and some aspects controlling the decision that needs to be reached. Students may then be asked to submit reports in which they propose solutions with proper justifications. After instructor feedback has been provided, student answers can be discussed in class in the context of the final decision that has been planned or implemented. Some socially oriented questions lend themselves to role-playing where students assume the roles of the various interests in the case, namely the private company (SOLIDERE), the public interest as represented by the government agency (CDR), and the community-based nongovernment organizations and environmental groups. Testing the students in an exam setting on some of the questions may be considered as well. Note that some questions can be eliminated from the case study if the course is not intended to train students in the design of various waste management schemes and landfill components. Examples of solid waste management textbooks that might be used in conjunction with this case include Robinson (1986) and Tchobanoglous et al. (1993).

DISCUSSION QUESTIONS AND ANSWERS

1. Describe environmental impacts associated with uncontrolled dumping of solid waste. Student answers should discuss typical environmental impacts associated with landfilling such as health hazards either by direct contact, or through contact with vermin, rodents, flies, or pathogens; fire and explosion hazards due to landfill gas generation; air pollution from landfill gas emissions; greenhouse effect; water pollution; effects on vegetation; and offensive odors.

2. How can these impacts be eliminated or minimized? Landfills are inherently engineered structures. Provisions must be included in the design to minimize negative environmental impacts and ensure efficient operation at the landfill facility. These measures include a liner system, a leachate collection and treatment system, a gas collection and treatment system, and a final cover system. A summary paper on environmental impacts of solid waste landfilling with control measures can be distributed to students in addressing Questions 1 and 2 (El-Fadel et al., 1997).

3. Devise a long-term monitoring plan for the Normandy site or for landfills in general. Landfill processes are dynamic in nature and hence there is a need to continuously monitor the behavior of a landfill to assess its impact on the environment and ensure its progress toward stabilization. The components to be monitored at a landfill site include: waste deposited in the landfill, leachate, landfill gas, surface water, and ground water.

The operator should develop and implement a site monitoring plan to ensure environmental protection during all phases of landfill operations and at least 10 yr after site closure and rehabilitation. A typical monitoring program for the elements listed above is shown in Exhibit 11.

4. Since the Normandy Landfill is located on prime land in the BCD, what are remedial closure alternatives for the site? Because the landfill is located in downtown Beirut, levels of treatment and associated specifications for final closure should be very stringent. High real estate values in the area can support the great expense of achieving final closure. The following are potential alternatives that students should evaluate.

Do Nothing Strategy. This strategy is not applicable in this particular case, given the need for development of the Normandy area as part of the reconstruction of downtown Beirut. Under different circumstances, all treatment alternatives and approaches should be assessed in reference to this benchmark.

Exhibit 11. Typical monitoring program at a landfill site.

Element	Monitoring frequency	Type of analysis†
Waste constituents	Monthly	Paper, cardboard, plastics, textiles, rubber, leather, wood, food wastes, glass, metals, etc.
Waste chemical analysis	Quarterly (leaching test)	pH, As, Pb, Cd, Cr, Cu, Ni, Hg, Zn, Phen, Cn, Mn, Fe, Mg, Ca, K, Na, TOC, and Cl
Surface water downstream	Monthly (depending on water body and flow rate)	pH, Temp, EC, DO, NH_4–N, Cl, COD
Ground water upstream and downstream	Monthly	Water level, pH, Temp, EC, DO, NH_4–N, Cl
	Quarterly (may be reduced to 6 monthly if there is evidence of stable conditions).	As monthly plus: SO_4, Alk, TON, TOC, Na, K, Ca, Mg, Fe, Mn, Cd, Cr, Cl, Ni, Pb, Zn
Leachate at collection system discharge points	Weekly discharge volume	pH, Temp, EC
	Monthly (reduce to quarterly or annually if stable conditions prevail)	As weekly plus: NH_4–N, Cl, BOD, COD
	Quarterly	As monthly plus: DO, Alk, TON, TOC, NA, K, Ca, Mg
	Six-monthly (may be reduced to annually if there is evidence of stable conditions)	As quarterly plus: Fe, Mn, Cd, Cr, Cu, Ni, Pb, Zn
Leachate at monitoring points within landfill	Monthly leachate level	pH, Temp, EC
	Quarterly (may be reduced to annually if there is evidence of stable conditions).	As monthly plus: Cl, NH_4–N, SO_4, Alk, COD, BOD, TON, TOC, Na, K, Ca, Mg
	Annually	As quarterly plus: Fe, Mn, Cd, Cr, Cu, Ni, Pb, Zn
Landfill gas	Generally weekly to six-monthly depending on site specific factors	CH_4, CO_2, O_2, AP, OMD, Temp. VOCs
Other parameters	Annually	Void utilization, settlement

† COD, chemical oxygen demand; TON, total organic nitrogen; TOC, total organic carbon; Temp, temperature; EC, electrical conductivity; BOD, biochemical oxygen demand; DO, dissolved oxygen; VOC, volatile organic carbon.

Isolation/Containment. Containment and control typically involve surface and subsurface systems. The objective is to minimize contaminant migration and transport by surface water, typically runoff, and through migration in the subsurface. The former is achieved by placing covers over the area of interest and the latter through vertical cutoff walls.

Excavation and Removal. Complete excavation and total removal of the waste at the landfill site is an option. Such an approach will resolve the problem; however, a number of issues will need to be addressed. If the material is to be removed, what cost will be incurred? Where will it be disposed of and at what cost? What are the impacts of the removal and disposal activities, both from an environmental perspective and sociopolitical considerations? What is the availability and cost of replacement backfilling material to develop the area gained on the sea? Finally, the cost of proper placement and densification of the inert material should be factored in the decision.

Composting. Composting is appropriate for solid waste rich in organic material and moisture, which is the case for some of the waste at this site. This alternative would have worked better before waste deposition and mixing with inert construction waste. In the current context, it may not be a feasible or efficient option since most food waste is commingled with inerts or would have partially degraded since the landfill was closed.

Incineration. Incineration is most suitable for waste with high thermal energy content and low moisture content. Both of these criteria are not characteristics of the Lebanese waste, thus decreasing the feasibility of this option.

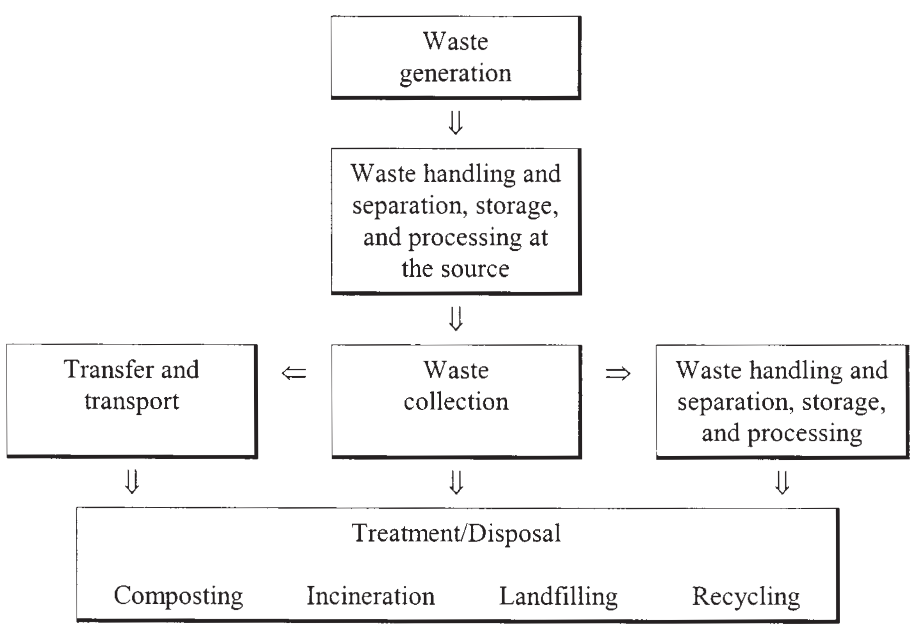

Exhibit 12. Functional elements of an ISWM plan (Tchobanoglous et al., 1993).

Combinations of Two or More of the Above. This alternative forms the basis of integrated solid waste management (ISWM), particularly prior to waste deposition. Exhibit 12 is a simplified diagram showing the interrelationships between the functional elements of an ISWM system. In the context of the Normandy Landfill, many of these elements can be readily eliminated. The options of containment and excavation appear most feasible.

5. Identify potential limitations associated with developing former landfill sites. The student should cite and discuss total and differential settlements; gas and leachate generation and transport; gas and leachate recovery, control and treatment systems; foundations of structures built on landfills. Examples of references that might be used in conjunction with developing answers to this question include Sowers (1968), Blacklock (1987), Isaacson (1991), and Bonaparte (1995).

6. Since the Normandy Landfill was closed, what would be proper siting criteria to locate a new landfill? Siting new landfills is one of the most difficult tasks in implementing a solid waste management program. Factors that must be considered in evaluating potential new landfill sites include (Tchobanoglous et al., 1993):

- Haul distance (long-distance hauling is becoming a routine)
- Location restrictions (airports, flood plains, wetlands, fault areas or seismic impact zone, unstable areas)
- Available land area (sufficient area with buffer zone with at least 5 yr of operation)
- Site access
- Soil conditions and topography
- Climatologic conditions
- Surface water hydrology
- Geologic and hydrogeologic conditions
- Local environmental conditions
- Ultimate use of completed landfill

7. Discuss the socio-economic aspects associated with the solid waste management in general and the reclamation of the Normandy site in particular. Students could identify various contributors to the total cost of managing the solid waste stream generated by any given community in particular in reference to treatment and disposal costs. In the case of the Normandy Landfill, the added elements associated with the economic incentive of developing all or part of the reclaimed areas need to be addressed. Further, the contrasting interests of the various players in the case can be discussed, namely the private real estate holding company (SOLIDERE), the government agency (CDR), and the nongovernmental and environmental organizations. At the time SOLIDERE was formed, the country faced a number of serious and daunting challenges. The company was established with the stated aim of reconstructing and rehabilitating the downtown area, which was ravaged in the war years. It inherited a waste dump, located along the shoreline of the downtown area, which at the time was the major destination for the solid waste generated in the whole of Beirut. The landfill at the Normandy Bay posed two problems: the first related to the fact that if it were to be closed, alternative disposal or management sites were needed, and the second had to do with the need to reclaim and rehabilitate the landfill area to integrate it into the downtown reconstruction project.

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