SITE SELECTION AND MANAGEMENT OF SOLID WASTES DISPOSAL SITE. CASE STUDY, GHABAWI LANDFILL/JORDAN

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SUMMARY: Rusiefa landfill is located on the north east of Amman, the capital of Jordan. The landfill was opened in 1987, and served around one fourth of million of capita. A serious of environmental problems occurred at Rusiefa landfill.

Ghabawai landfill was selected for a short-term period (15-25 years), and Mshash landfill for a long-term period (25-50years), as new location for solid waste disposal sites. A series of scientific studies were done as to select the best new location of new sanitary landfill of solid wastes.

Many factors control the selection of solid wastes disposal sites, such as, environmental protection of surface and ground water resources by pollutants like leachates, characteristics of geological layers, type and depths of aquifers, climatological data, capacity and the access to the landfill.

Ghabawi landfill has an area of 2000dunums(1dumum=1000m^2), and it was divided into cells in order to facilate the dumpimg process.

Particular attention was given to the access point to each cell. Whereas, it is important that the access routes do not put the liner at risk. Typical access ramps would be up to 6m in width, and have slopes up to 10%.

In order to collect the biogases and the leachates, that generate from the solid wastes, a set of different pipes were settled at the base of the land fill. In addition of geomembrane, made up of HDPE material, was used as lining material.

1. INTRODUCTION

Amman occupies an area of 528 km square, representing 3.2% of the total area in Jordan. Whereas the average population reached 1.8 million in 2003, and expected to reach 3 million in 2010. Greater Amman Municipality services around 40% of the total population, which is about 4.6 million of capita.

The old closed dump occupies 340 dunums (1dunum=1000m^2) in Wadi el Qattar, and it lays between 155-157 N° and 248-251 E°, according to Palestinian Grid, (Tadros, 1995).

The beginning of dumping process in the location was not defined, but it was estimated more than thirty years ago, till the closure of the dump in 1989. And the opening of Rusiefa landfill in

Proceedings Sardinia 2007, Eleventh International Waste Management and Landfill Symposium
S. Margherita di Pula, Cagliari, Italy; 1 - 5 October 2007

1987.Rusiefa landfill served around 2500000 capita, living in Amman, Zarqa, Rusiefa and other districts. The quantity of solid wastes generated from the capital of Amman was estimated to be 1525 tons/day for the year 1998, whereas the total quantity generated from several districts in addition to Amman was about 2282 tons/day, with an average quantity of 926 gm/day/person (Greater Amman Municipality, 1998).

All kinds of solid wastes were dumped like cartoon, paper, glass, organic matter, metals, except for liquid wastes, and hazardous wastes. New Sanitary landfill was opened in May 2003, located 15 km south of Amman, in the Ghabawai area, see figure (1) (Greater Amman Municipality, 2003; Tadros, 2001).

Generally, three main aquifers are differentiated in the study area, the upper aquifer Amman and Wadi Sir Formations (All- B2/A7), which is composed of the Alluvial Deposits. The Middle Aquifer System represents the Hummar Formation (A4), which is separated from the Upper Aquifer by an aquiclude (Shuieb Formation, A5/A6). The groundwater depths are considered shallow, ranging between 35 – 50 m below the land surface. Detecting the ground water depths and directions are important since they affect the selection of solid waste sites and percolation of leachates, which pollute the water bodies, see Figure (2), Tadros (2004).

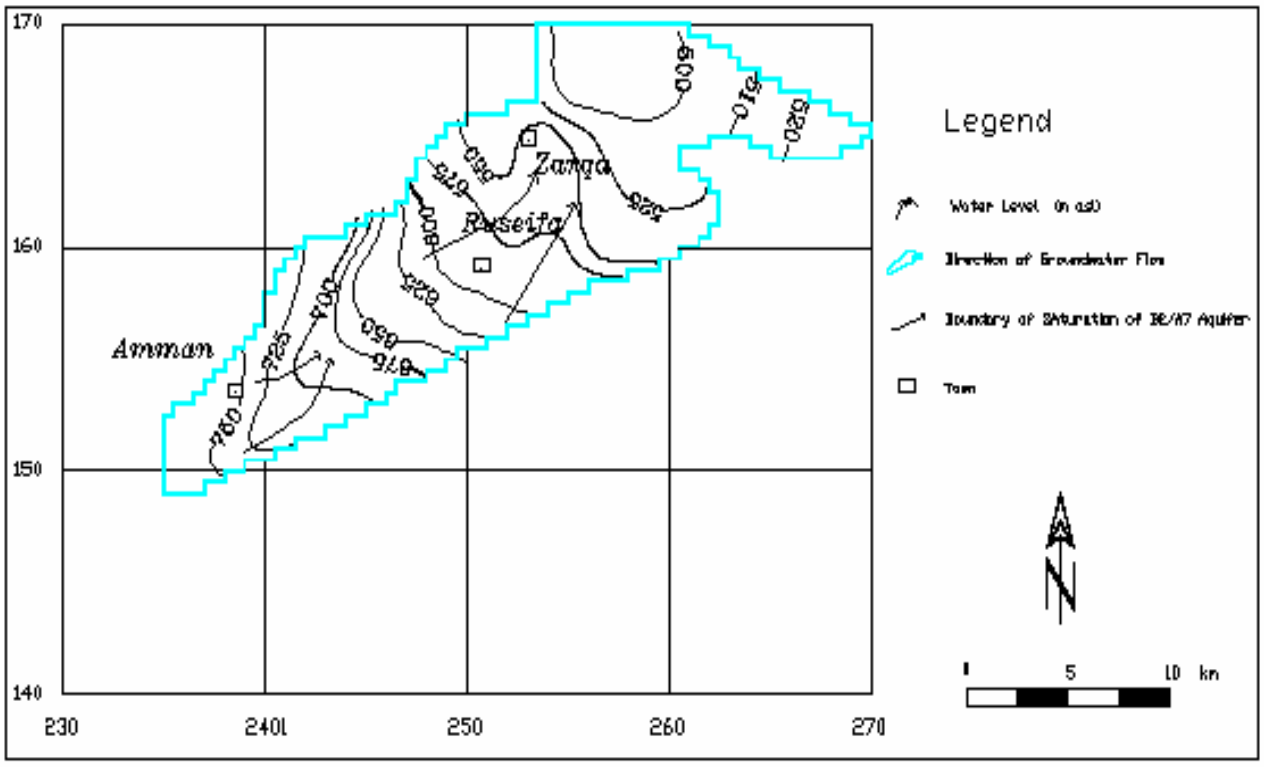

Figure 1. Ground water movement in the study area

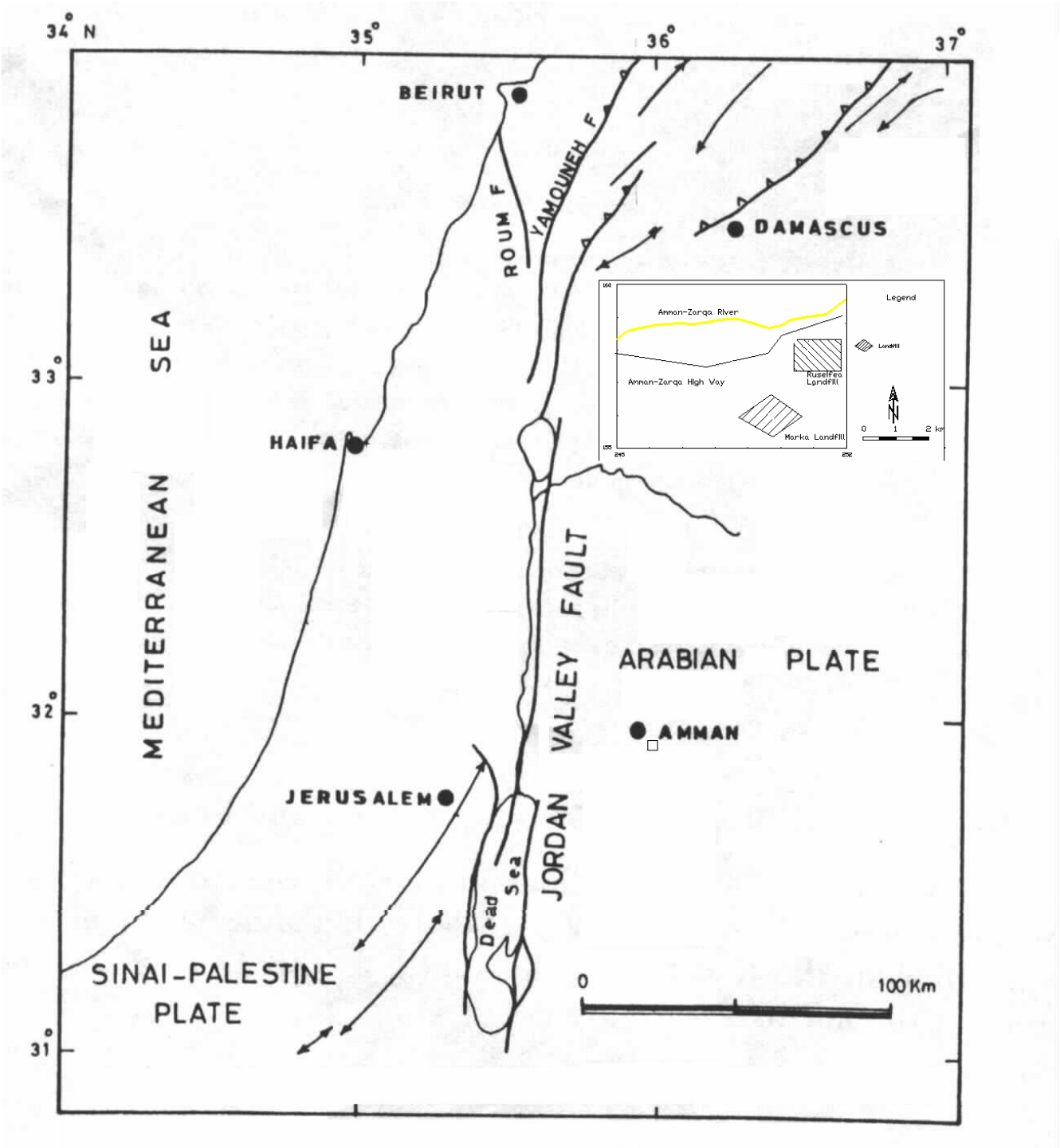

Figure 2. Location of landfills

The surface water budget was calculated for the period 1927/1928-1996/1997, whereas the maximum percentages of runoff, evaporation and infiltration rate were 14.0, 92.0 and 21.0% respectively. Tadros (2001).

A serious of environmental problems occurred since the dumping process began in Rusiefa landfill. The leachates started to generate which started to affect the soil and the ground water properties. In addition to the air pollution that was affected by the gas emissions from the solid wastes, (formation of biogases).

The following are the characteristics of Rusiefa landfill, based upon various data (BGR, WAJ, 1989; Greater Amman Municipality, 1998).

- The solid wastes were directly dumped on the upper boundary of the B_2/A_7 Aquifer, as it is shown in figure(3),(Tadros, 2001).
- The water depth in the landfill does not exceed 22 m.
- The rocks forming the different formations, contain sets of joints and faults.
- There is no suitable barrier at the base of the landfill.
- There is no subsurface drainage system to collect the leachates generated from the solid wastes.
- The land filling activity lacks using the good designed cells.
- There are no geotextile layers to prevent the percolation of leachates and the dispersion of the biogases.
- The usage of unsuitable soil cover. Sometimes friable sand was used which is highly permeable, other times using phosphate remains regardless the phosphorous and high radioactive content.
- The landfill is located in a downstream direction.

Upon the mentioned environmental problems, Greater Amman Municipality started to identify the different studies and designs to select new location for a sanitary landfill.

Ghabawi area was selected as a new sanitary landfill for a short -term period (15-25) years, with initial costs 16.622.000JD, excluding waste management, cost of land for the landfill or cost of land where the transfer stations are located in, whereas Mshash area was selected as location of the landfill for a long-term period (25-50) years.

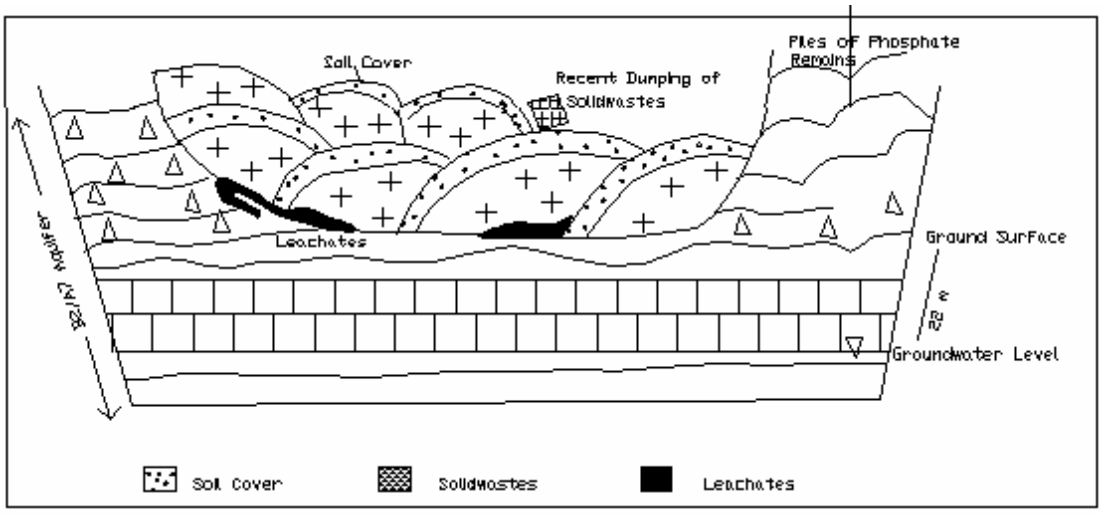

Figure 3. A schematic sketch representing the environmental problems in the closed Rusiefa landfill

2. SITE SELECTION

Environmental protection and public health considerations should be the principle concerns in site selection. Selection of an appropriate site will minimize potential environmental impacts and provide a sound basis for effective management. The factors which need to be addressed during site selection include the potential for the creation of public health hazards or nuisance, the potential for the pollution of water bodies, local topography and soil erosion risk, the suitability of soils for earthworks and containment of leachates, the adjacent land uses and the accessibility of the site to users.

3. HYDROLOGY

Pollution of surface and ground water resources by leachates is a principle concern in relation to landfill location. Leachates are generated by water passing through waste materials in landfills and becoming exposed to and mobilizing a range of contaminants. Contaminants may be removed or reduced in concentration as they pass through soil surrounding the landfill, by processes involving filtration, dilution, absorption and microbial decomposition (Vogelslang.1995)

In many cases the presence of water courses, drainage lines and underground aquifers will limit the utility of sites.

Although site design and management can reduce the potential for water pollution, some sites are not suitable due to the potential for inundation by floodwaters and/or the proximity to water bodies.

The following areas are generally not appropriate:

- Groundwater recharge areas
- Coastal and estuarine areas subject to storm surge
- Water supply catchments
- Sites adjacent to water courses
- Sites adjacent to open drains
- Wetlands

4. TOPOGRAPHY AND SOILS

Landform in the vicinity of disposal sites will influence drainage, potential ground water problems, soil erosion risk, access, site visibility and protection from prevailing winds

A suitable site will have sufficient grade to provide drainage of surface runoff and adequate level areas to enable excavation of trenches and associated earthworks and the construction of service facilities. Sites with slopes exceeding 1 in 5 are generally not suitable because of soil erosion risk.

Soil structure should be suitable for the excavation of landfill cells or trenches and the construction of drainage works and, should also be of sufficiently low permeability to slow the passage of leachates from the site. Sites in clay-rich environments are preferable, as their low permeability will allow more time for natural attenuation of leachates to occur. In establishing the suitability of a site, several test pits should be dug to determine the ease of excavation of the insitu material and the suitability of soil types.

5. ADJACENT LAND USE

Consideration should be given to existing and possible future developments adjacent to the site. Sites with potential for higher value uses such as nature conservation, agriculture and residential development should not be used.

Rehabilitated landfill sites are not suitable for many redevelopment options. Consideration must therefore be given to long term planning projections to ensure that the establishment of the site will jeopardize any environmentally sensitive areas or have a negative impact on existing or future land uses.

The impact of landfill operations on neighboring residential, commercial or public developments should be minimized, by including a buffer zone around the landfill. Adequate buffer distances should also be provided between landfill sites and airfields to minimise the risk of bird strike.

Buffer distances should be measured from the closest proposed tipping face to any development.Where a sensitive development already exists within the buffer zone, the tipping schedule should be planned so that the landfill face moves progressively away from the sensitive land use.

6. CLIMATE

Rain and wind are major climatic factors influencing site selection. For high rainfall areas, effective storm water diversion is essential if leachates production is to be avoided. Litter and dust will be more difficult to control where the site is not protected from prevailing winds.

7. FLORA AND FAUNA

Some areas may contain protected or important natural flora and fauna, which causes the site to assume a special significance that may render it unsuitable for landfill.

Wetlands are also important for nature conservation and selection of a site near a wetland may increase the risk of spreading disease through scavenging birds. The presence of a wetland may also indicate special drainage characteristics of the area.

Control of insect, bird and animal pests is an important factor in maintaining both public health and environmental stability. Poorly designed and managed landfill sites can provide an ideal situation for rapid breeding of insects and vermin. These increases in vermin populations, including cats and rodents, can cause major disruption to local native flora and fauna. Plant wastes may be a source of invasive species such as coffee bush.

Furthermore, persistent pathogenic microorganisms such as, Salmonella bacteria are readily transferred by pests either directly to food, or humans or to previously uncontaminated insect or animal populations.

8. SITE CAPACITY

Generally sites should have enough capacity to allow for at least 10 years of dumping. This will allow establishment costs to be written off over a reasonable period and thus provide for greater

capital expenditure on access roads, fencing, drainage, landscaping and machinery. However, there may be cases where shorter-term sites are feasible.

The following calculation provides an example of how site capacity can be estimated based on an average per capita waste generation rate and an estimated waste compaction rate.

- If we assume that the average waste generation rate = 800 kg/person/year
- If a waste compaction rate at landfill of 400 kg/cubic meter is achieved,then average volume of landfill space per head of population = 800 kg/person/year / 400 kg /cubic meters = 2.0m^3 /person/ year
- Space m^3 required for a population of 1000 = 2000 m^3 / year
- If the trench dimensions were 2.5 meters high by 6 meters wide, then the trench would need to be approximately 154 meters long to dispose of the waste from 1000 people over a one-year period. (Given that the recommended maximum trench length is 50 meters, at least 3 trenches would be required).
- If a compaction rate is 600 kg/m^3 and all else remains the same, then the trench would need to be approximately 100 meters long.

9. ROAD ACCESS

Access to the site should be as direct as possible to ensure that people are not tempted to dump their rubbish before getting to the landfill, and to minimize waste spillage from vehicles. Roads leading to the site should be in good condition and wide enough to handle the anticipated traffic load. A minimum buffer distance of 100 meters should be maintained to ensure that landfill operations are adequately screened from the nearest main road. Scenic and tourist routes should be avoided and access roads should be flood free. Where scenic routes cannot be avoided additional visual buffers should be provided.

The potential for soil erosion and alteration of drainage systems should be considered when access roads are located and aligned.

10. CASE STUDY (GHABAWI LANDFILL)

The study area of Wadi Madonna is located about 15 Km east of Amman and 8 Km south east of Ruseifa Figure (1). The geotectonic processes acting along the Amman-Hallabat structure largely affect its geology. The outcropping rocks in the study area are all of sedimentary of the upper-cretaceous, which comprise a succession of shallow marine carbonates of different facies.

10.1 Geology and structure

The proposed solid waste disposal site is lying over the chalk marl unit, which is called Muwaqqar formation, and surrounded by chert – limestone rocks (Umm Rijam Formation) at the east hills and towards the Wadi by Silicified – and Phosphorus units (Amman and Al-Hisa formations in the west). Figure (4) (Atalla, and Mikbel, 1983).

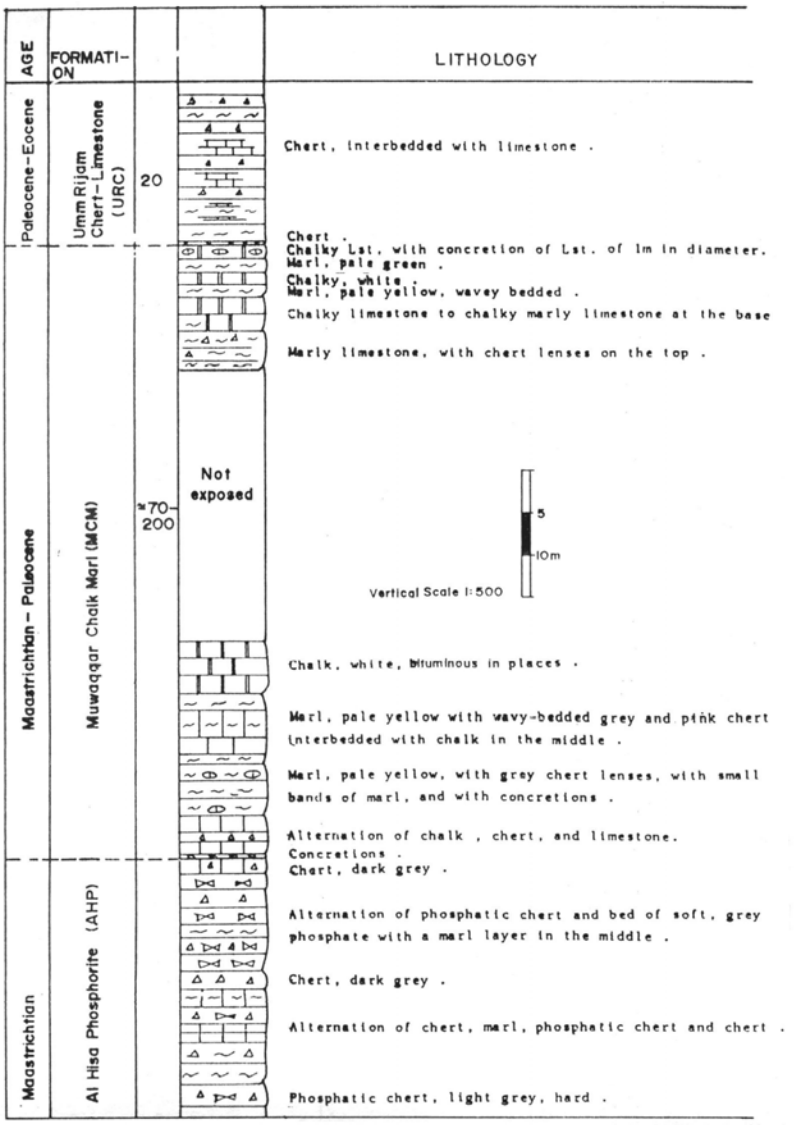

Figure 4. A geological column representing the formation at Ghabawi landfill

Wadi Madoneh and the surrounded areas, form a part of the regional Amman-Hallabat structure. Structures comprise linear folds and normal faults with a general NE-SW trend.

The local effect of the Amman-Hallabat structure caused the Wadi As Sir formation to be in the core of a regional anticline. Generally the folds are related to the two dominent fault sets (NW-SE and NE-SW) and bedding dips tend to steepen near the faults.

10.2 Hydrology and hydrogeology

Ghabawi lies east of Eastern Highlands of Jordan, with a climate characterized by hot summers and cold winters. The precipitation occurs periodically, with low amounts, during winter time from October to May. Precipitation data for the period (1974-1994) indicate that the average annual

precipitation ranges from approximately 120 to 150 mm. On the other hand the annual evaporation in this area averages approximately 1075 mm.

Analyses of rainfall – runoff relationship indicate that 25-year events correspond to a 24-hour rainfall of 59 mm, the total runoff at the outlet of the wadi Madoneh of about 1.25 MCM.

The principal groundwater aquifer in the study area is, Wadi Sir formation (A_7), which outcrops in the area. This is the lower part of the extensive B_2/A_7 groundwater aquifer system, and is a major source of groundwater in Jordan. The B_2/A_7 aquifer is underlain at depth by the A_4 and A_1-$_2$ aquifer system. The B_2/A_7 aquifer is generally unconfined, but in the study area the expected situation that the aquifer is confined. The depths to groundwater in the area range from about 80m to more than 200m. The saturated thickness of the main aquifer ranges from 20 –120m.

The hydrogeological studies refered that Ghabawi site lies just south of potential groundwater divide in the B_2/A_7 aquifer, that seperates flow to the Wadi Zarqa drainage system to the north of the site from flow toward the Azraq Basin to the south of the site. To the north of the site, toward Wadi Zarqa, the Amman flexture appears to act the geologic control for the potentiometric divide, therefore the groundwater flow for the B_2/A_7 aquifer immediately south of this divide is to the east and southeast

The landfill has an area of 2000dunums, and it was divided into nine cells inorder to facilate the dumpimg process

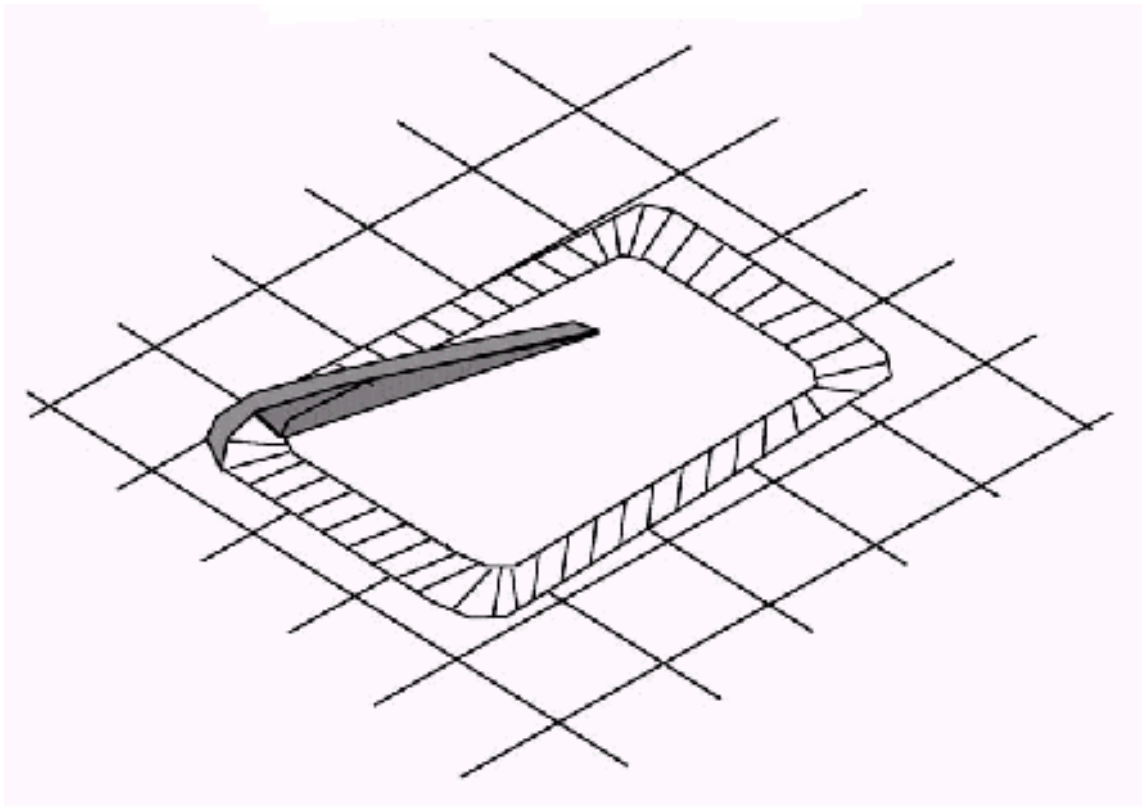

Figure 5. Geometry of a typical access ramp to a cell in a sanitary landfill (EPA, 2000)

Particular attention is given to the access point to each cell. Whereas it is important that the access routes do not put the liner at risk.

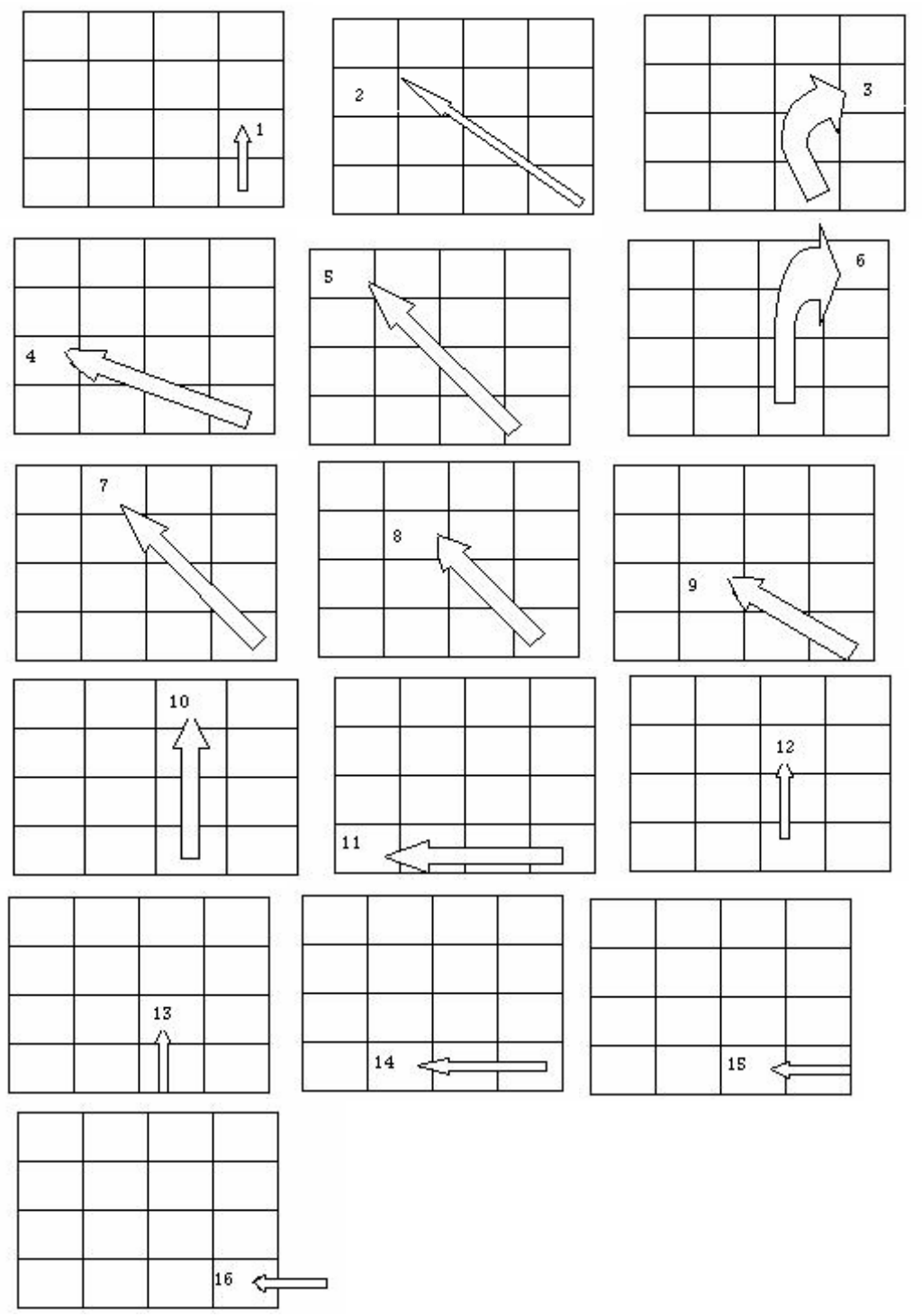

Figure 6. Suggestion of vehicles routes in the cell at Ghabawi landfill.

Typically access ramps will be up to 6m in width, and have slopes up to 10%, as it is shown in figure(5).

As for the best-suggested routes within the cell, at Ghabawi landfill, see figure (6). Entrance of cars should be one by one. It is important to minimize the disturbance of the infrastructure so as to maintain the safety of the underlain pipes.

Consulting companies specialized in landfill lining, together with Amman Greater staff, applied the design, supply and the installation of the geosynthetic composite lining system.

The followings are description of the components of the lining system (from bottom to top). Figure 7, shows the components as follows:

- Needlepunched Bentofix® Geosynthetic Clay Liner (GCL) with Thermal Lock.
- HDPE Carbofol® 2mm thick (smooth for the base and structured for the slopes).
- Secutex® protection nonwoven.
- A gravel leachate collection system with 30cm of thickness.

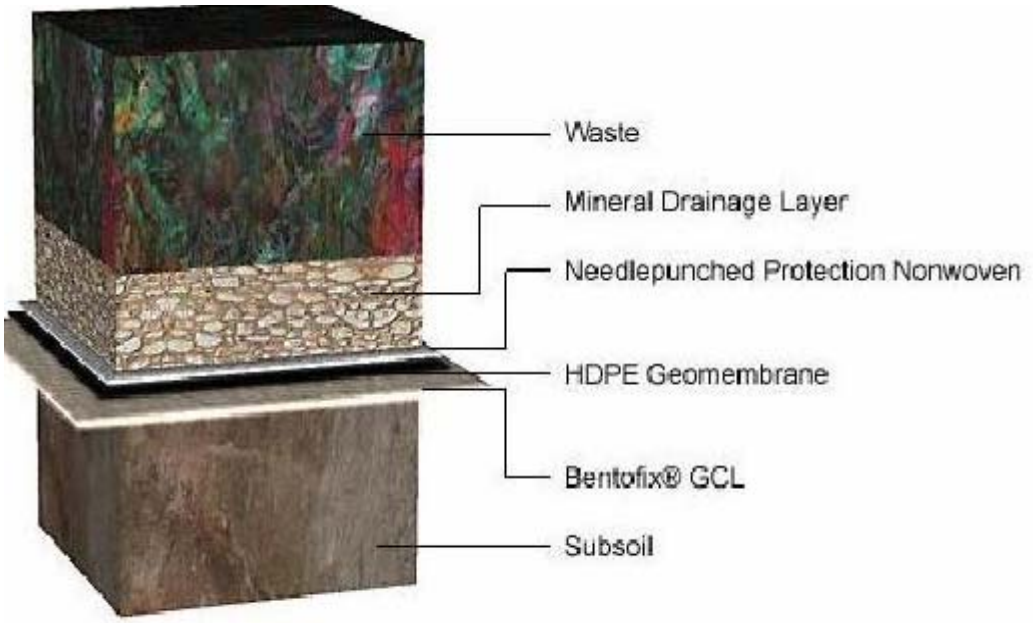

Figure (7): a detailed description of the lineation at Ghabawi landfill

The first test was applied on a 200,000m2 cell, and it was fully tested with leak detection test of Carbofol®, from March 2003 till May of the same year. See figure (8).whereas installation of Carbofol® geomembrane was done at base of landfill figure (9).

Figure (8): Installation of the geomembrane at the base of the first cell

Figure (9): Final stage of lineation at the cell of Ghabawi landfill

The lining of the landfill base by the previous physical characteristics are important for the following reasons:

- The sealing system with Carbofol® geomembrane and Bentofix®GCL, is the considered the ultimate sealing of the landfill base, concerning the properties of the dumped solid wastes.
- The sealing system increases void space which gives additional waste storage capacity.
- Long durability time and resistance of HDPE Carbofol® geomembrane and Bentofix® GCL

The Ghabawi sanitary landfill is considred the first experiment in the middle east,especially in the arab countries. Whereas the environmental impact assissment elements were applied, since the selection of landfill, till the dumping process, and further on the rehabilitation after closure. Greater

Amman Municipality has proven a sucsseful experiment in the sustinable development in Ghabawi landfill, in addition to other different projects.

11. RECOMMENDATIONS

Since Ghabawi landfill is considered the first sanitary landfill in the middle east. And since there is no actual usage of the landfill products, such as biogases and leachates. The followings are recommended for the benift of sustainability of the resources at the solidwastes:

- Ghabawi landfill produces daily more than $40m^3$ of leachates. It is highly recommended to construct a waste treatment plant for the leachates, the treated leachates can be used for irrigation of plants and watering of animals.
- Ghabawi landfill produces great amounts of biogases, and yet are not collected properably, and forming an environmental impact threat, and tending to spontaneous explosions of the biogases. It is recommended to collect the biogases in attempt to produce electricity.
- In order to monitor the environmental impact, and economically to determine the gas stages, it is most important to analyze leachate samples. So it is important to construct labs at Ghabawi to apply the different chemical and biological analyses on the leachates.
- It is important to construct chemical labs at Ghabawi landfill in order to monitor the ground water quality, so as to protect the water bodies from leachate poluttion.
- Vehichile movement at landfill cells should follow the suggested route system, so as to protect the infra structure of the pipes located at the bottom of the cell.

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