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PRIVATE PROVISION OF SOCIAL SERVICE
CITY OF TETOUAN, MOROCCO

LANDFILL MANAGEMENT PLAN

PREPARED FOR:

THE CITY OF TETOUAN

AND

U. S. AGENCY OF INTERNATIONAL DEVELOPMENT

BY:
JAMES A. DOHRMAN, P.E.
INTERNATIONAL CITY MANAGERS ASSOCIATION
WASHINGTON, D. C.

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CITY OF TETOUAN

LANDFILL MANAGEMENT PLAN

TABLE OF CONTENTS

	Starting Page No.
Table of Contents	1
List of Figures	2
1.0 Executive Summary	3
2.0 Existing Landfill	5
2.1 General Location	5
2.2 Operational Problems	5
2.3 Leachate Impacts	8
2.4 Remaining Life	9
2.5 Recommendations	13
3.0 Waste Generation	14
3.1 Population	14
3.2 Waste Generation Rates	14
3.3 Landfill Capacity	17
4.0 Waste Composition	18
4.1 General	18
4.2 Residential Waste	18
4.3 Industrial Waste	19
4.4 Special Wastes	20
5.0 Landfill Siting	21
5.1 General	21
5.2 Siting Criteria	22
5.3 Leachate Management	24
5.4 Potential Sites	27
5.5 Recommendations	32
6.0 Other Issues	32
6.1 Collection System	32
6.2 Privatization	33
APPENDIX A Operating Procedures	

LIST OF FIGURES

Figure Number	Description	Page Number
1	Location Map	6
2	Existing Landfill	7
3	Alternative 1	11
4	Alternative 2 - Fill Ravine	12
5	Population	15
6	Waste Generation	16
7	Typical Leachate System	26
8	Proposed Site 1	28
9	Proposed Site 3	31

1.0 EXECUTIVE SUMMARY

1.1 Existing Landfill

The current landfill is poorly located and lacks the manpower and equipment resources to improve operation. Constant fires, uncontrolled dumping and equipment breakdowns are continual problems. Based on the nature of the waste, the method of placement and the soil conditions, the environmental impacts to the City wells are assumed to be minimal. Major air pollution results from the burning waste, especially plastic bags which give off toxic fumes when burned.

Several alternatives are presented to improve the existing site and extend its life until a new site is constructed. Procedures for the proper placement and compaction of waste into daily cells are presented in Appendix A.

1.2 Waste Generation

Population projections and waste generation were evaluated for the City of Tetouan and the surrounding region. These were used to estimate the 20 year requirements of a new landfill and its size in hectares in order to begin the search for a new site.

Most local industries are currently dumping all of their liquid waste into sewers which drain to the rivers and sea without treatment. A waste collection and treatment system is being proposed that will require industries to pretreat their waste which will produce industrial waste sludge. The industrial sludge will be a future solid waste issue that the City will need to deal with.

Medical waste generated in Tetouan is collected and disposed of along with all other waste without special handling. This presents a hazard to sanitation workers and the potential of disease, spread by scavengers and livestock at the landfill. A "red bag" system should be instituted for collection of medical waste and consideration should be given to a medical waste incinerator located at a central hospital.

1.3 Landfill Siting

Landfill siting criteria were established and a preliminary screening of prospective sites was performed in June 1992. Using this study as a base and the long term capacities determined by the waste generation evaluation, three individual land parcels were identified that met the criteria. Each parcel was ranked in each criteria on a scale of 1 to 10 in order to compare the sites. Although total scores for all three site were similar, the highest ranked site is a 35 hectare parcel located west of Tetouan on the

road to Tanger. The second ranked site is located northeast of the City near the town of El Malahiyene. Both sites could be developed into acceptable landfills with good design and efficient operation.

Although the preferred site is upstream of the City wells in Tamouda, good clay soil and proper management will limit any potential impacts. A leachate management study will be required to determine an appropriate collection and treatment program, regardless of the site chosen.

1.4 Collection System

The city has made significant improvements in the collection system through an improved management structure that has upgraded the quality and quantity of middle supervisors. These improvements are resulting in greater collection efficiencies and better use of existing resources in the initial target areas including the City Center.

Plans to begin a privatization pilot project are be prepared and should be ready for competitive proposals in several months.

1.5 Recommendations

Proposals to improve operations of the existing landfill should be implemented as soon as possible. This includes following the procedures outlined in Appendix A and the acquisition of new equipment to compact and cover the waste. Privatization of the landfill operations should be considered to implement one or both of the alternatives to extend the life of the landfill until a new site can be developed.

The City should move quickly to select a site for a new landfill. After selection, a hydrogeology study should be performed to determine the subsurface soil types and potential impacts to surface and groundwater resources. After acceptable hydrogeologic features have been confirmed, a qualified engineer should be retained to design the new landfill and prepare a leachate management. Due to limited resources, the City should consider private construction and operation of the new landfill.

2.0 EXISTING LANDFILL

2.1 General Location

The existing landfill, shown in Figure 1, is located in a small valley approximately 1.5 kilometers south of the Martil River and the area known as of Tamouda. The site is accessed by a steep, narrow road off Route P. 28, which is the road to Chefchaouen. The most important feature of the landfill location is its proximity, 2,500 meters, to groundwater wells located in the sand aquifer of the Martil and Mhajrate rivers in Tamouda. Although the primary water source for Tetouan comes from high quality reservoirs located in the mountains surrounding Tetouan, the Tamouda wells are used as a standby source, especially during the summer months when the surface supplies are low. The standby well water is treated prior to use. In addition to the municipal wells there are several dug wells and springs in the immediate vicinity of the landfill. The potential effects on the groundwater wells will be discussed in Section 2.3.

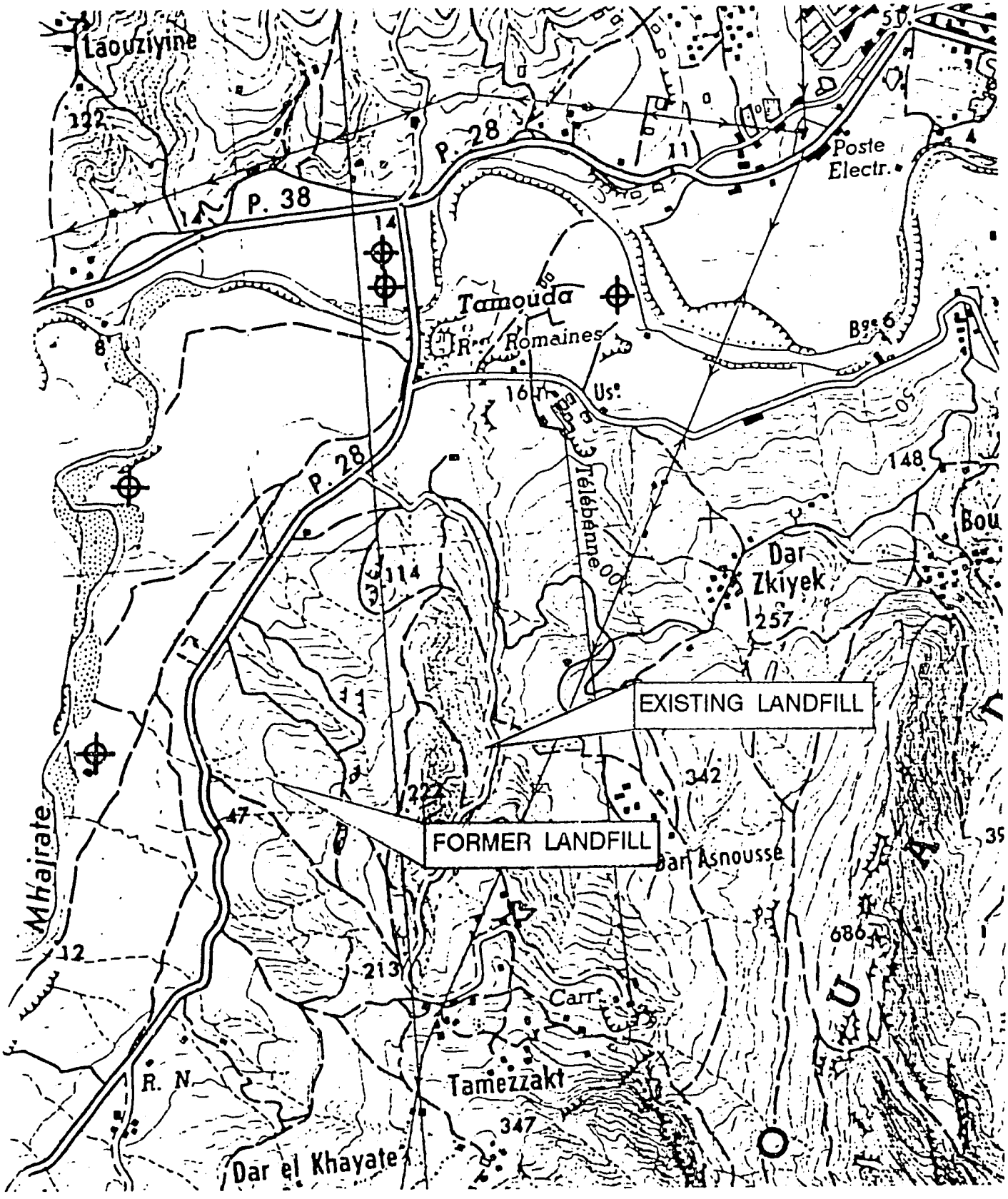
The location of the former landfill, which operated for approximately 15 years is also shown on Figure 1. This landfill is located on a hillside within the Mhajrate River valley and also presents a water quality threat to the groundwater wells.

2.2 Operational Problems

The existing landfill, which is only three years old, is suffering from many operational problems, most related to its poor location and some related to limited operating resources. Located on a relatively steep slope of a small valley, the landfill is accessed by a narrow winding road that is often difficult to negotiate, especially with an aging collection fleet. Frequent breakdowns occur and trucks often dump their waste along the road and make repairs.

As shown on Figure 2, the road into the landfill is also narrow, and often blocked with piles of waste and the many cattle and other livestock that feed on the organic rich waste. Waste is dumped along the east, downhill side of the road and periodically pushed over the embankment. The waste receives no cover material. Although this process is creating a flat area adjacent to the road, the waste embankment is very steep and will be difficult to cover when the landfill is eventually closed.

By far the largest problem at the landfill is fires which burn almost constantly. These fires were most likely started by hot coals brought to the landfill during the winter or by small fires built by the scavengers or shepherds to keep warm. The smoldering fires are continually fed by pushing additional waste over the embankment and since the waste is not compacted or covered, the fires receive an ample supply of combustion air. Although the waste



GROUNDWATER WELLS ⊕

FIGURE 1
LOCATION MAP
LANDFILLS

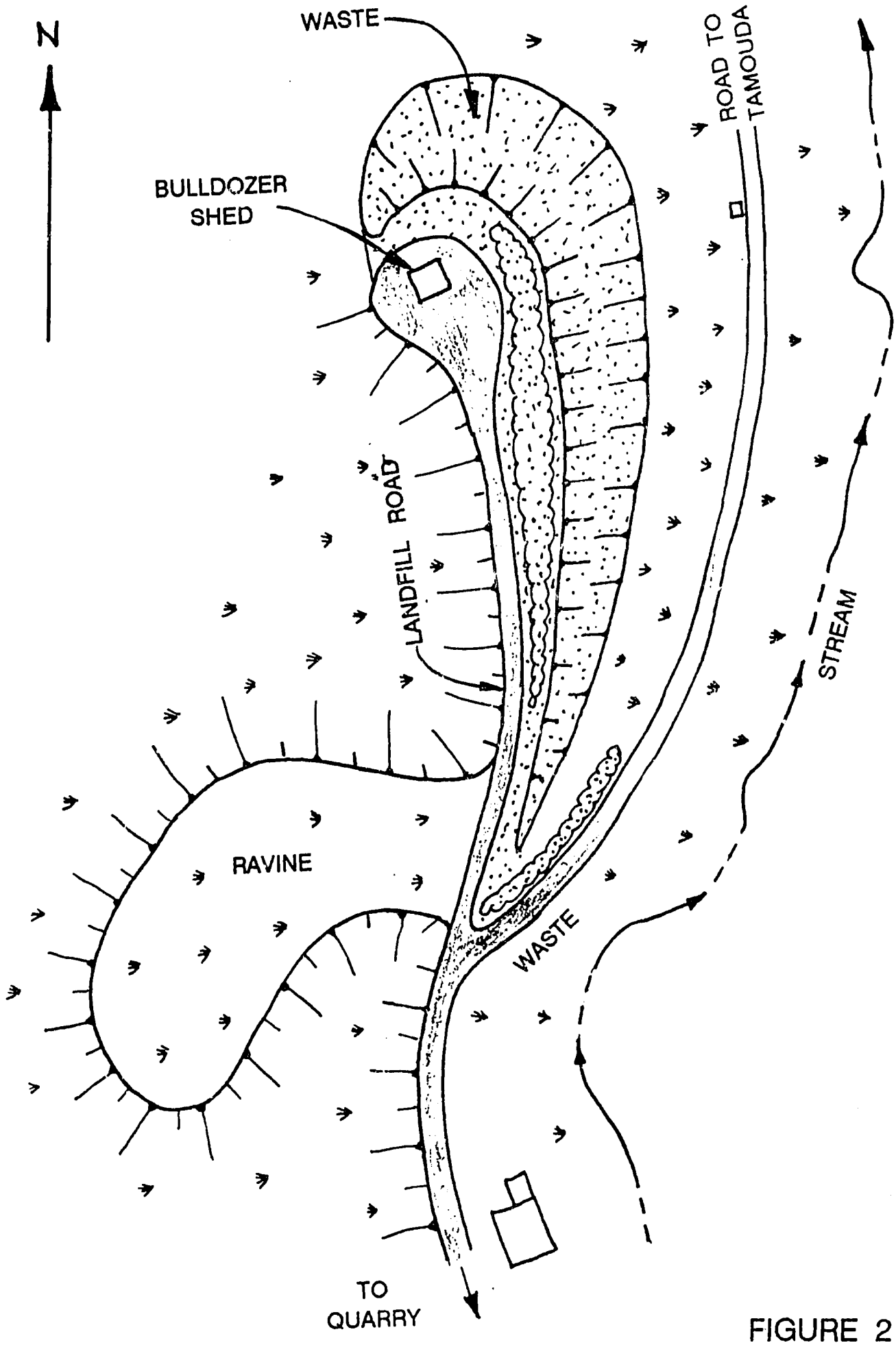


FIGURE 2
EXISTING LANDFILL

contains an estimated 70% wet organic material, it contains a considerable amount of low grade waste paper and plastic bags which burn quite easily. The fire eventually dries out the organic matter which then also burns. Most of the smoke appears to be coming from fires deep within the landfill rather than the surface. The smoke from these fires has a very foul odor and is likely to contain high amounts of toxic gases. Since most of the plastic bags are believed to be made of polyvinylchloride (PVC) film, the smoke will contain hydrochloric acid and other toxic chlorinated hydrocarbons, including dioxins and furans which are among the most toxic substances known to man. The smoke from the fires is breathed by sanitation workers, scavengers, nearby residents and an estimated 100 head of cattle and other livestock that feed on the landfilled waste.

2.3 Leachate Impacts

In addition to the toxic gases given off by the burning refuse, the production of leachate is also a primary concern, given the landfills proximity to the groundwater wells. Before considering the off-site movement of the landfill leachate, we must first consider the amount and composition of the leachate. Although a later discussion will provide a more thorough description of the waste composition, it appears that leachate produced by the existing landfill will have a strong organic content but is estimated to be low in the typical heavy metals and organic chemicals that are of primary concern in American landfills. This relates directly to the composition of the waste being placed in the landfill, the amount of annual rainfall and the fact that a considerable amount of the waste appears to burn rather than decompose.

The burning waste produces oxides and carbonates which are more stable alkaline compounds, as opposed to the strong organic acids produced by anaerobic decomposition. It is these organic acids that mobilize (dissolve) the heavy metals from other contents of the waste including printing inks, batteries and electrical equipment. Since the organic decomposition is limited in the landfill and the waste includes few of the items known to contain heavy metals, it is probable that the leachate produced at the existing landfill is relatively benign compared to a similar landfill in America.

The exception to the mobility of metals is iron. The burned waste was observed to contain many tin cans which were rusting, since the combustion has oxidized the tin coating protecting the steel. Normal rainfall and leachate will dissolve iron from the rusting cans resulting in high iron levels in the leachate.

The high organic content of the leachate originates from the high organic composition of the waste and its high water content. Organically rich leachate begins to flow from the waste as soon as it is placed in the landfill and begins to rot. This liquid is an

ideal breeding ground for bacteria including many of the disease organisms that are common in this region. In addition to harmful bacteria, the organic leachate will also provide food for a host of other biological organisms that will feed on the organic matter and eventual cleanse the liquid leachate. The cleansing of the leachate will be most effective when it flows slowly through fine grained soil such as silt, clay of very fine sand. The soil particles provide surfaces on which the biological organisms will grow. If the leachate travels quickly through coarse sand or fissures in bed rock, the cleansing will be very slow and ineffective in removing the organic matter.

The soil conditions observed at the landfill appear to be impermeable or low permeable clays and silts which are predominant throughout the area. Although it is not known whether these soils are continuous throughout the site, the low permeable soils would prevent the leachate from entering the groundwater or would provide an excellent medium for cleansing or treating the leachate as it moves though it.

An inspection of the toe of the landfill did not reveal any leachate seeps that would indicate overland flow of leachate toward the nearby stream which only flows during the wet winter months. The lack of seeps would indicate that the silt/clay base soil is absorbing the limited amount of leachate that is being produced. If the clay soil is continuous throughout the site, the leachate may not be having a negative impact on the downgradient wells. If, however, the clay soil is not continuous or had been removed prior to beginning the landfill, then leachate entering the bedrock is likely to impact groundwater sources, especially the wells and springs near the landfill. Several monitoring wells should be installed below the landfill to determine the quality of the groundwater.

2.4 Remaining Life

Although the existing landfill is poorly located and has many operating constraints, it is the only operating landfill in Tetouan and the location, design and construction of a new landfill will take several years to complete. If the current operating procedure continues it will continue to place waste along the landfill road and the waste embankment will grow and become steeper, making proper closure of the site virtually impossible. The following two alternatives are offered as options to the current operating procedures. Both alternatives will require improved operating procedures as outlined in Appendix A and an investment in new equipment.

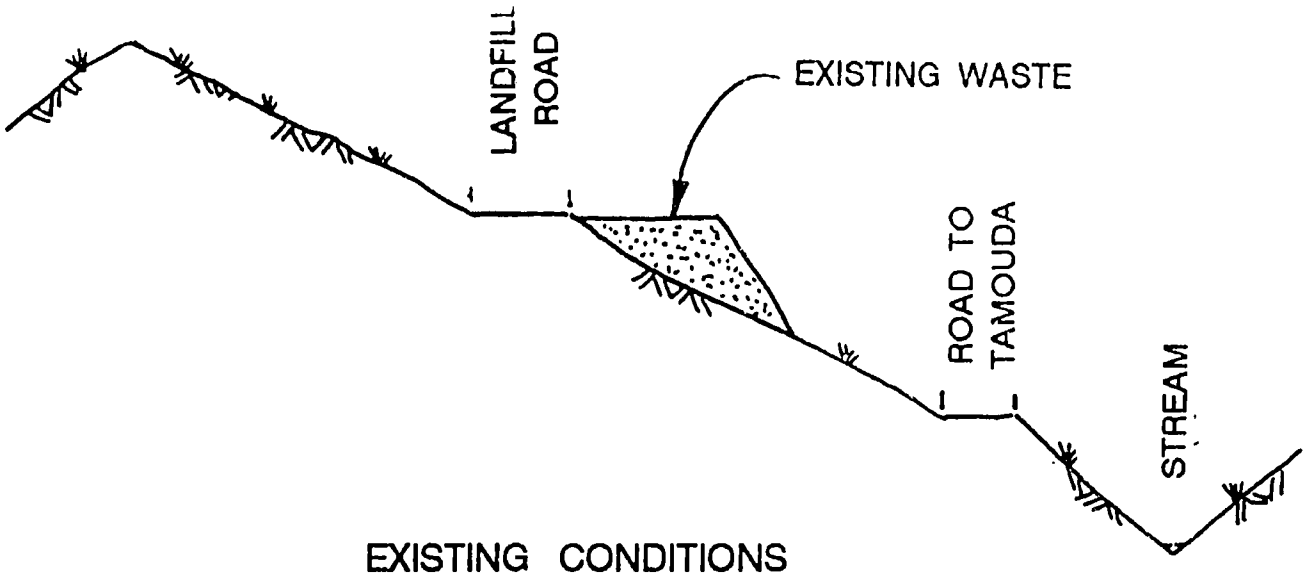
2.4.1 Alternate 1

The first alternative is summarized in Figure 3 and involves excavating the uphill embankment adjacent to the access road, providing cover soil for the existing waste and making room for a new cell of waste. The upper sketch of Figure 3 is a cross section of the existing landfill showing key features. The middle sketch shows the excavation of the uphill embankment and the placement of a 0.5 meter thick layer of the excavated material over the existing waste. The lower sketch shows the placement of an addition cell of waste in the area created by the excavation and the placement of a 0.5 meter layer of final cover soil. The amount of soil obtained by the excavation may not be sufficient to cover the existing waste and additional soil may have to be obtained from off-site sources. The success of this alternative depends on the upper embankment being soil and not bedrock.

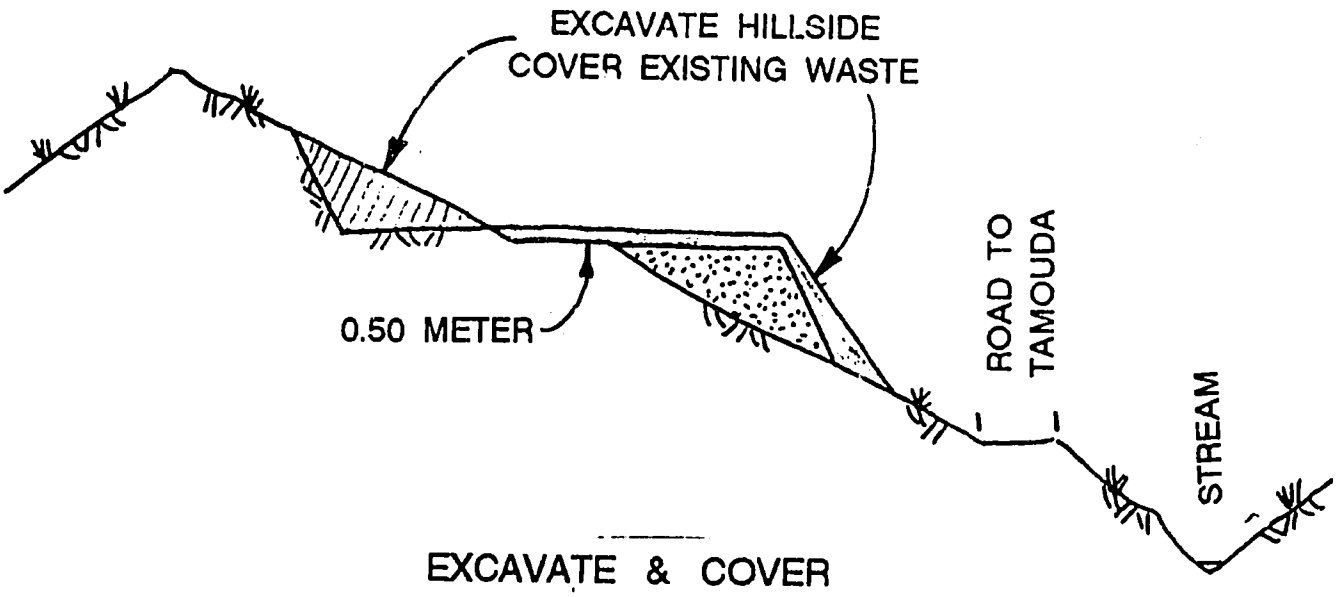
2.4.2 Alternate 2

Upon entering the landfill site, a large ravine is located on the left. Although a topographic survey would be required to determine exact dimensions, it is estimated that the ravine is approximately 90 meters wide by 150 meters deep. If properly designed and operated, this area could provide landfill space for approximately 1.5 years. As shown on Figure 4, preliminary construction would commence with the placement of an earth berm across the mouth of the ravine, leaving room for a Phase I entrance road. Initial filling would begin against the berm and southeastern ravine walls, leaving the entrance road on original ground. As the lower levels of the ravine are filled, a contractor should be retained to construct a Phase II access road to be used to fill the upper portions of the ravine. When completed, the waste should be graded to a 3:1 slope and covered with 0.5 meters of impermeable clay soil.

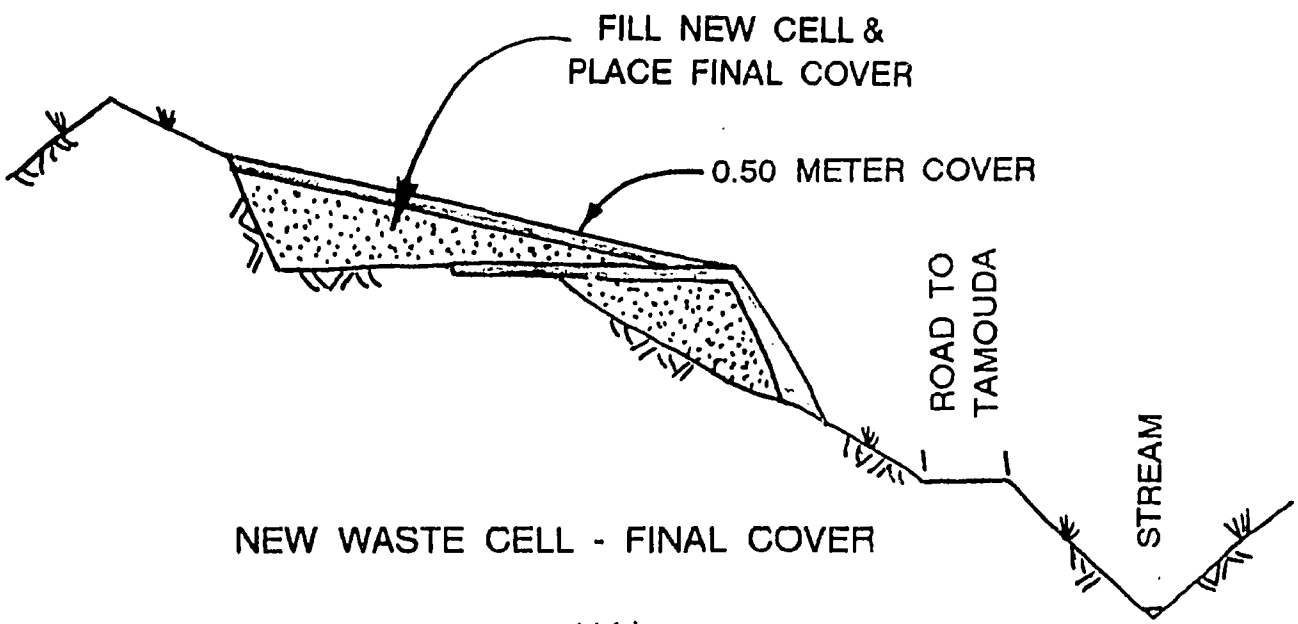
The above alternate will require working in a relatively confined space. In order for this alternative to be effective, the procedures outlined in Appendix A must be followed. Waste must be compacted and pushed into daily cells as soon as it is dumped in order to maintain sufficient room for other waste. The current method of dumping waste and pushing it at the end of each day is not acceptable.



EXISTING CONDITIONS



EXCAVATE & COVER



NEW WASTE CELL - FINAL COVER

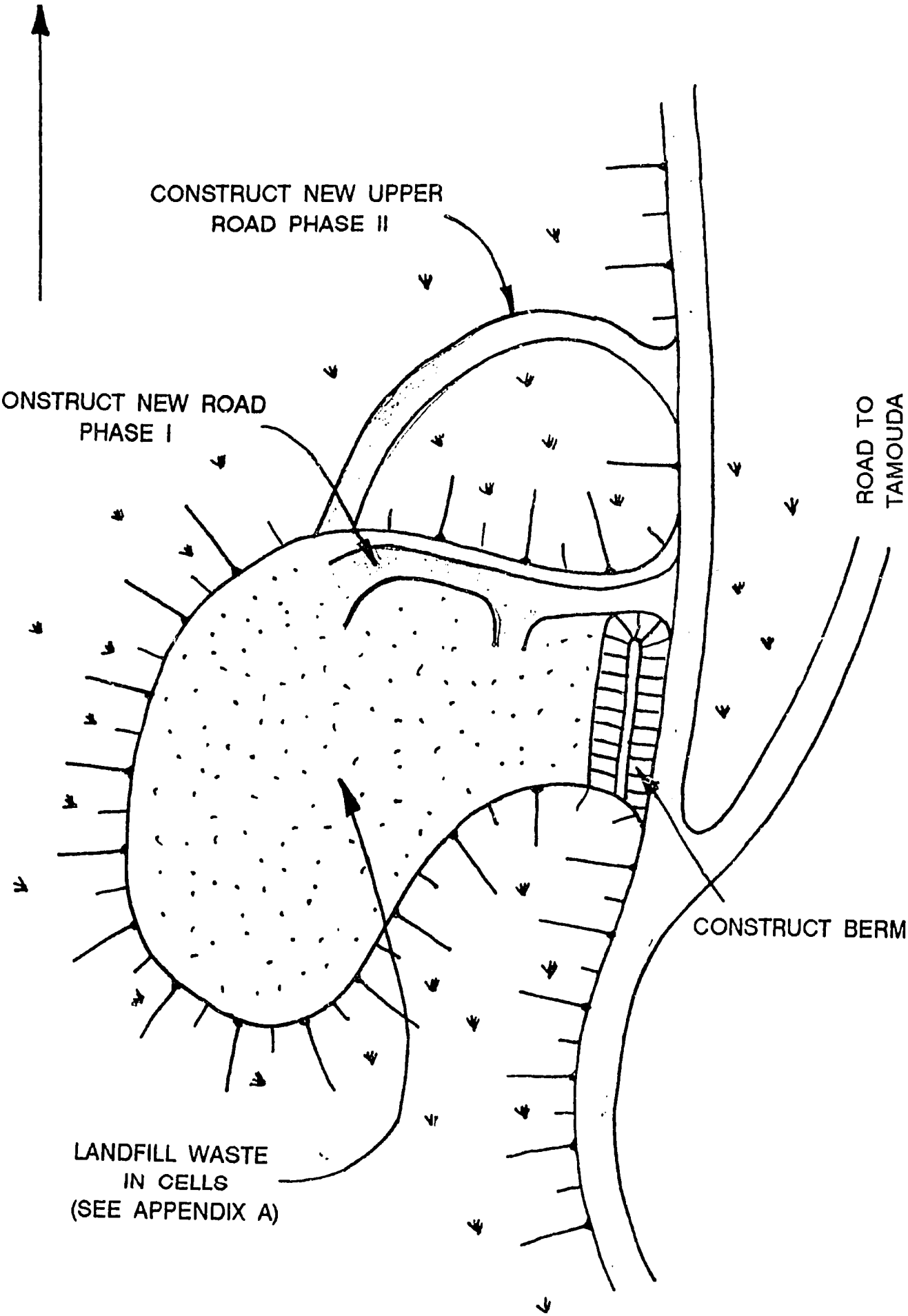


FIGURE 4
ALTERNATE 2
FILL RAVINE

2.5 Recommendations

The existing landfill is a poor site and current operating procedures are well below acceptable standards. Two alternatives have been presented that will extend the life of the landfill for one or two years until another site can be developed. Revised operating procedures are presented in Appendix A. These procedures rely on compaction of the waste, placement of cover soil and good equipment in operating condition. By properly compacting and covering the waste, the constant fires at the landfill will gradually cease to become a problem.

Space at the existing landfill is very limited and the practice of permitting cattle and other livestock to feed on the waste will make proper operation of the landfill impossible. This practice should be discontinued as soon as possible.

3.0 WASTE GENERATION

3.1 Population

Although the current landfill provides disposal services only for the City of Tetouan, the Department of Urbanization has requested that any work performed on future landfill sites should include the entire region surrounding Tetouan. The Tetouan Region includes the three small satellite communities of Martil, M'diq, and Fnidek and several rural communities. Martil is only 8 kilometers from Tetouan and could directly access a new regional landfill but the other two communities would require transfer stations to transfer waste to a regional landfill located near Tetouan.

Previous reports have provided a long term projection of population growth in Tetouan but projections of the growth in the three satellite communities and rural areas is limited. Long term plans call for extensive growth in the coastal areas, driven by tourism. For the purposes of this report we have assumed a 30% increase in population between the City of Tetouan and the Region. Although this increase may appear conservatively high, it is better to plan for a landfill site that is too large than to suffer the results of one that is too small. A larger landfill will provide a longer period of service but a landfill that has been undersized will impact future development plans and capital financing.

The long term population projections for Tetouan and the Region are shown in Figure 5. Assuming that a new landfill site will take several years to locate, design and construct, a 20 year planning period has been selected beginning in 1995 and ending in 2015. This period will be used as a minimum benchmark on which landfill capacities will be based.

3.2 Waste Generation Rates

The existing landfill is not equipped with a scale and therefore historic waste generation information is not available. Using the population projections as a base, waste generation rates developed by the City were applied to obtain daily waste generation amounts. The per capita waste generation rates were determined by the city during a weighing program that concluded that generation in the Medina and high density residential areas was approximately 0.5 kg per person per day and 0.7 kg per person per day in the commercial City center. For planning purposes, the per capita generation rates were increased through the 20 year design period to account for increased commercial/industrial development and tourism. These generation rates were applied to the population districts within Tetouan to obtain the daily generation rates in tonnes per day (TPD) that are shown in Figure 6. The estimated Region rates were determined by multiplying the Tetouan rates by 1.30. Daily generation in Tetouan is estimated at 160 TPD in 1995, rising to

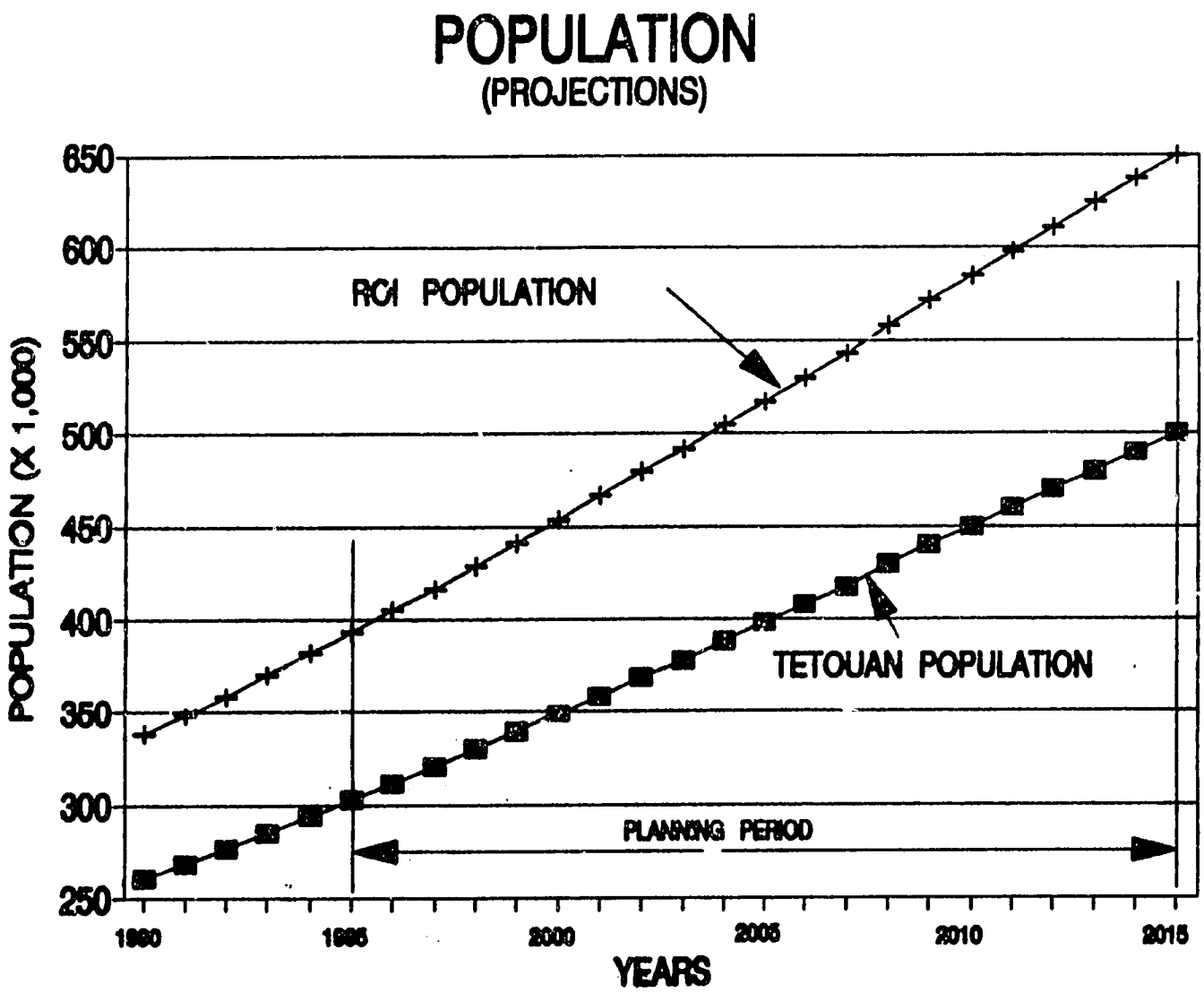


FIGURE 5
POPULATION

WASTE GENERATION
(TONNES PER DAY)

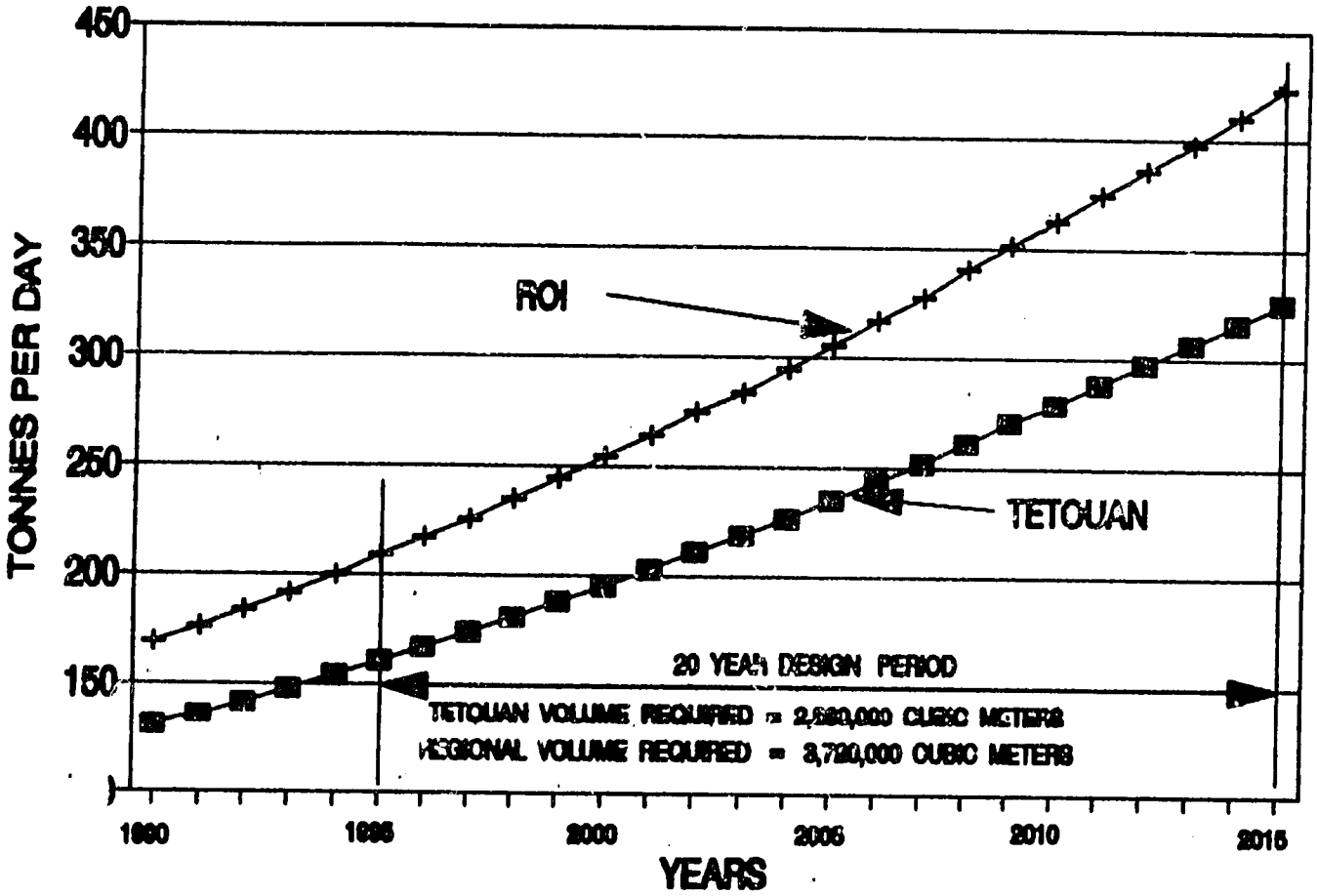


FIGURE 6
WASTE GENERATION

325 TPD in the year 2015. Region rates are estimated at 208 TPD in 1995 and 423 in 2015. These rates represent total generation and do not account for waste that is not collected or is burned in unauthorized areas. Since uncollected waste can be as high as 20% in some areas of the City, these figures are conservatively high.

3.3 Landfill Capacity

The estimated density of the waste is the critical factor in determining the volume that the waste will occupy in the landfill. During the waste collection weighing program, densities were determined for several types of vehicles. In general, the non-compaction vehicles collected waste that weighed an average of 500 kg per cubic meter, while the compactor trucks increased the density to 700 kg per cubic meter. When the waste is placed in the landfill, its density will increase due to several variable conditions.

In a controlled landfill the waste will be compacted by a bulldozer or steel wheeled compactor. Further compaction will occur due to the construction of vertical cells, placing additional weight on top of the previously completed waste cell. Additional densification will also occur as the waste decomposes, losing up to 15 to 20 percent of the original volume when fully decomposed. For the purposes of this report we will assume an in-place landfill density of 800 kg per cubic meter.

In addition to the volume taken up by the waste, a controlled landfill will require periodic covering with soil in order to control odors, insect infestation and fires. The amount and frequency of covering will vary with the season and availability of cover material. Landfill operations will be discussed in a later section of this report. The calculation of landfill capacity will assume that 10% of the landfill volume will be consumed by cover material.

Using the above factors, the current (1992) waste generation in City of Tetouan of 142 TPD will require an estimated volume of 71,000 cubic meters. If the entire Region were to use the landfill, an annual volume of 92,000 cubic meters would be required.

The computer data base used to calculate waste capacities, also calculates the cumulative volume required for the entire 20 year planning period. For Tetouan, a volume of 2,860,000 cubic meters will be required and 3,720,000 if the entire Region were included.

The actual area of the landfill will depend on the specific site and the vertical height or depth of the landfill itself. The following table summarizes the landfill area, assuming several vertical depths.

	Landfill Volume (cubic meters)	Area Require in Hectares At Depths Indicated			
		5 M	10 M	15 M	20 M
Tetouan	2,860,000	57	28	19	20
Region	3,720,000	74	37	25	18

In addition to the actual landfill areas shown above, the landfill will require areas for access roads, administration facilities, equipment maintenance and storage, and buffer areas from neighboring properties. In general, a 20 to 50 percent factor should be added to the above areas for related facilities and buffer areas. Therefore, depending on specific site conditions, an area between 27 and 111 hectares will be required for a Regional landfill.

4.0 WASTE COMPOSITION

4.1 General

Before considering new landfill sites it is important to consider the composition of the waste, especially as it affects the air and water impacts that may result from a new landfill. This is especially important since the waste is very different than that shown in American reference material and is expected to change in the next 5 to 10 years as a new sewerage treatment system is constructed and industrial waste discharges shift from liquid to solid waste.

4.2 Residential Waste

At the present time, the waste being placed at the current landfill is primarily residential waste. Although there is a significant industrial base in Tetouan, they are responsible for their own waste disposal and most dispose of their waste on-site or into the existing sewer system which dumps directly into the Martil River.

Residential life in Tetouan, including food purchasing and preparation, is very different from more developed countries. Most food is purchased fresh at small local markets. As a result, there is very little packaging in the waste. Since many of these markets lack refrigeration, much of the food spoils before it is sold and is discarded. Lack of refrigeration in many of the homes also results in a high percentage of discarded food waste.

In addition to the relatively high percentage of food waste, paper in the waste is very low. Magazines and newspapers are a much smaller percentage of the waste than in more developed countries and magazines are often scavenged and resold several times in the local markets. Heavy metals used in colored printing ink are known to be a primary source of heavy metals in landfill leachate.

As a result of these waste generation patterns, the waste in Tetouan is very high in organic food waste and low in many of the other components that normally result in undesirable leachate. For instance, the volatile organic cleaning solutions have not found their way into residential use, with traditional phosphate solutions still being widely used. Batteries and electrical equipment are limited due to lower living standards and are usually repaired and resold rather than discarded in the landfill. Discarded batteries are a primary source of heavy metals in landfill leachate.

Based on these residential waste patterns, it is assumed that the leachate produced by the decomposition of this waste will be relatively high in organic material and moisture but low in heavy metals and volatile organic chemicals. A series of monitoring wells should be installed and chemical tests performed on leachate to confirm these assumptions.

4.3 Industrial Waste

As stated above, Tetouan has a considerable industrial base which includes the following industries:

- Paper Manufacturing (35,000 tonnes per year)
- Tannery (4,000 to 5,000 skins per month)
- Cleaning solutions (primarily phosphates)
- Textiles
- Nail manufacturing including galvanizing
- Abattoir
- Dairy Processing

At the present time, Tetouan does not have a central wastewater collection and treatment system and wastes from these industries are simply discharged into local sewers which discharge into the river and eventually the sea. Although these types of industries are known to generate problem wastes, including heavy metals, they are being discharged with the wastewater and are not a concern at the existing landfill.

The City of Tetouan is nearing completion of a Wastewater Master Plan which will change the way industries handle their waste. This plan will include a sewer collection network and one or more treatment facilities. Preliminary work on the master plan included the inventory and chemical analysis of all industries within Tetouan. Although the final treatment processes are still being

analyzed, it is certain that most of the industries listed above will be required to pretreat their wastewater prior to discharging to the new collection and treatment system. For instance, the paper company will be required to remove waste fibers and clay fillers prior to discharge and the tannery will be required to lower existing mercury and chromium levels.

The important aspect in the above discussion is that most of the pretreatment processes to be employed will result is a solid byproduct in the form of a wet sludge that will require disposal as a solid waste rather than a liquid as is presently practiced. This change in industrial waste disposal is expected to begin in the next 3 to 5 years and will have an impact on solid waste facilities, especially leachate management. If these sludges are accepted at the landfill, the leachate will have higher levels of heavy metals. Ideally, a separate landfill should be located for hazardous wastes, including industrial sludges.

In addition to the industrial pretreatment sludges, the central municipal treatment plant will produce sludge that also will require disposal. The wastewater master plan will include alternatives for wastewater sludge disposal, which may included disposal at the city landfill.

4.4 Special Wastes

4.4.1 Medical Wastes

Medical waste from hospitals, clinics and doctors offices is currently collected with other wastes without any special handling or treatment. This presents a significant threat to collection workers and those individuals who scavenge the waste for food or reusable items. Animals that feed on the waste at the landfill could also contract and spread infectious diseases.

The potential impacts of improper medical waste disposal are obvious and there are many documented cases of major epidemics traced to improper medical waste disposal practices. As a minimum, all infectious medical wastes should be placed in easily recognizable containers with a label, warning workers and scavengers of the contents. Typically these are heavy weight "red" plastic bags with a universal "logo" indicating hazardous contents. Beyond implementing a "red bag" system for separation and collection, the City should consider an infectious waste incinerator located at one of the central hospitals. After incineration, the ash can be safely disposed in the landfill.

4.4.2 Waste Oil

In any urbanized area, the generation and collection of waste drain oil from cars, trucks and heavy equipment can be a problem. Although waste oil is collected and recycled in many developing

countries, this is apparently not being done in Tetouan. A limited evaluation suggests that the common practice is to merely dump the oil on the ground in a secluded location or into the sewer system. Although the heavy clay soil has the ability to absorb the oil, it will eventually become saturated and leach into groundwater or surface water. The practice should be discontinued and made illegal through an appropriate regulation.

As an alternative, the City should investigate markets for used oil. This material can either be re-refined into new oil or filtered and blended with fuel oil for a lower quality heating use such as asphalt production. In America, specialized furnaces have been developed that burn the waste oil for space heating of factories or garages. Since the waste oil has a positive value as a recycled product, the private sector could be involved in instituting a collection and processing system.

5.0 LANDFILL SITING

5.1 General

The siting of a new landfill is never an easy process. Whether a rural area of New England or a suburb of Tetouan the issues are surprisingly similar. Past experience has found landfills that were poorly located in areas that seemed to have no other useful purpose such as wetlands or steep slopes or a hidden ravine. These landfills often create difficult operating conditions and significant environmental harm. The following discussions will show that the criteria for a good landfill are also good for other land uses such as agriculture, recreation or housing. If the City of Tetouan is to be successful in finding a new landfill, it must be prepared to make some compromises between competing land uses and an environmentally safe and cost efficient landfill.

5.2 Siting Criteria

A preliminary siting study prepared in June, 1992 identified six criteria to be used to in siting a landfill as follows:

1. Distance from Tetouan Center
2. Urbanization
3. Accessibility
4. Wind direction
5. Soil type
6. Protection of Resources

5.2.1 Distance from Tetouan

This criteria relates to the time it will take a collection truck to travel to the landfill. discharge its load and then return to its collection route. If the landfill is too far distant from the

collection routes, the process will be inefficient and costly, not only in transportation costs but in worker efficiency since the collection crews will be idle while the trucks are making the trip to the landfill. The June 1992 study established a round trip travel time of 45 to 90 minutes as a siting guideline. This equated to a distance of approximately 10 kilometers from the City center.

During a meeting with the Department of Urbanization, it became evident that the disposal of solid waste is a problem throughout the region and that the new landfill should also consider accepting waste from other communities in the region, including Martil, M'diq, Restinga Smir and Fnidek. Since these communities all lie to the east and north of Tetouan, this would impact the regional transportation routes to access the new landfill. Due to the distances involved, the remote communities would require the use of transfer stations to access the new landfill.

5.2.2 Urbanization

Urbanization is the local term used to describe the amount of residential development in the area. This would include not only the urbanization surrounding the landfill but also urbanization along major access routes to the landfill, and the visibility of the landfill. It is obvious that existing residents will not like to have a landfill located next to them or have garbage trucks driving past them on roads that were intended for residential traffic only.

Since all of the areas surrounding Tetouan are urbanized to some degree it will not be possible to find a site that will have no urbanization impacts. The challenge to the City will be to find a site where those impacts are "manageable". Urbanization impacts can be managed by relocating families, planting trees to limit direct visibility or providing financial or material compensation for the affected families.

5.2.3 Accessibility

The new landfill site should not be difficult to access for the collection vehicles. Access difficulty includes not only the quality of major access routes but also the distance and slope into the site. Accessibility is often a compromise issue for other impacts such as urbanization. A remote site, selected to limit urbanization impacts is often a difficult site to access.

5.2.4 Wind Direction

One of the major operational problems with the existing landfill is wind blown debris, especially plastic bags which are used extensively in Tetouan. Predominant winds are from the Northeast and Southwest and are effected by the valley configuration of the region. Potential landfill sites should avoid unrestricted exposure

to these dominant winds, or have the potential to manage the effects of the high winds. The ability to plant trees, the use of temporary fencing and application of daily cover soil are effective methods of handling wind blown debris.

5.2.5 Land Use - Topography - Soil

The June 1992 study identified certain land uses and topographic features that should be avoided in siting a landfill. Prime agricultural landfill is scarce in the Tetouan region and should be avoided in siting a landfill. In addition to agricultural land, areas of bedrock and steep slopes above 20% should also be avoided. The ideal landfill slope is in the 5% to 8% range. The slope will facilitate the collection of leachate within the controlled landfill and also allow rainfall run-off to be diverted around the landfill to limit leachate production.

By far the most important criteria of a controlled landfill is soil type. The ideal landfill base soil will consist of impermeable or very low permeable soil such as clay of silt. This will block the flow of leachate into ground or surface water resources or insure that they are adequately filtered before entering the groundwater. After selection of a preferred site, a detailed hydrogeology study should be performed to properly identify the base soil characteristics. Leachate management options will be discussed in a later section of this report.

Another major selection criteria is the availability of cover soil. A well operated, controlled landfill should be covered periodically with soil to control wind blown debris, insect infestation and fires. Although the American standard is to apply cover at the end of each day, the actual frequency should depend on the availability and cost of the material and available resources to excavate and compact the cover. As an absolute minimum I would recommend the application of periodic cover once per week.

The soil used for periodic cover does not have to be impermeable and can be sand if easily available. This should not be confused with the application of final cover which should be impermeable clay to block the infiltration of rainwater.

5.2.6 Protection of Resources

Due to the limited annual rainfall, high run-off percentage and seasonal rainfall variation, the management of water resources for human consumption and agriculture is a constant challenge for the Tetouan region. The region relies on a combination of surface and groundwater resources. Surface water comes from several dams located in the mountains and valleys outside of Tetouan. As mentioned previously the primary groundwater wells are located within a sand aquifer in Tamouda, near the intersection of the Martil and Mhajrate rivers. In addition to these major sources that

feed into the regional treatment and distribution system, there are many smaller wells and springs in rural areas where there is no central distribution system.

Any potential landfill site must take into account the potential impacts on these important water resources.

5.3 Leachate Management

5.3.1 General

An earlier discussion presented information relative to leachate generation in the existing landfill which is assumed to be limited by the constant burning of much of the waste. In a controlled landfill, waste burning should be eliminated by proper compaction, the application of periodic and final cover, and a high strength organic leachate will be produced as the waste decomposes. This leachate will be collected in the bottom of the landfill and drained to a central location. The quantity and estimated strength of the leachate will require a comprehensive analysis which should be performed during the final design of the landfill.

In chemical terms, the leachate will resemble high strength sewage, with possibly 5 to 10 times the organic strength measured in BOD. Depending on the handling of industrial wastes, the leachate may also include significant amounts of heavy metals. The leachate will also include many microorganisms that were in the waste, including many infectious diseases.

Since the leachate is an organic liquid it can be treated by biological processes including those being considered in the Wastewater Master Plan. In America, it is common practice to collect and pump the leachate to a wastewater treatment plant for treatment. Since there is no wastewater treatment plant in Tetouan and the construction of the new facility may be many years away, the new landfill must provide for some treatment of the leachate to minimize its effect on the environment. The following leachate management practices are presented for consideration.

5.3.2 Recirculation

The recirculation of leachate back into the waste cell is a management practice that is gaining popularity with many landfill operators. If the landfill is compared to a sponge the theory behind leachate recirculation can be better understood. A landfill acts much like a sponge which can hold a large quantity of water. The rainwater that falls on the sponge uses only a portion of the water holding capacity of the sponge. This rainwater flows through the decomposing refuse and become leachate that is collected at the bottom of the landfill. After collecting the leachate it can be pumped back into the landfill, using some of the unused storage capacity of the sponge. Since the landfilled waste contains

bacteria and other microorganisms that feed on organic matter, the additional leachate will accelerate the decomposition. In technical terms, the landfill will become an anaerobic digester, producing additional leachate and methane gas which must be vented to the atmosphere.

The two major problems with leachate recirculation are that it cannot start until sufficient waste has been landfilled and eventually the sponge will fill up, requiring the removal and disposal of a portion of the leachate. If, however, the landfill cell can be completed and covered before the sponge fills, the recirculation could continue indefinitely. Since the Tetouan waste and rainfall patterns are unique, a separate evaluation would be required to design the leachate recirculation system.

5.3.3 Biological Treatment

As an alternate or in addition to recirculation, the leachate could be treated by a biological process. There are several processes which would be applicable to a new landfill in Tetouan, all of which would require further study to properly design. These systems vary in complexity from a natural biological filter system consisting of an engineered wetland and native plants, to complex mechanical facilities employing both biological treatment and physical-chemical treatment for removal of heavy metals.

5.3.4 Land Application - Discharge

The final step in the leachate handling system would be final discharge of the treated leachate to the environment. Due to the potential impacts to surface water, the discharge could take the form of land application. The land to receive the treated leachate should be carefully evaluated to insure that it contains low permeability soils and is not near groundwater or surface water resources. Since land application may not be advisable during the wet weather, adequate storage should be provided.

5.3.5 Typical System

A typical leachate management system, using the above management techniques is shown on Figure 7. The landfill will be constructed in cells, each having an approximate capacity of 5 years. Each cell will consist of an impermeable clay bottom and impermeable clay dikes to control leachate. The leachate will be collected from the bottom of the cell by a collection system composed of perforated pipes. The collected leachate will then be drained through the dike into the recirculation pump station. If adequate waste exists in the waste cell, the leachate is recirculated back to the waste. If there is insufficient waste in the landfill or the waste cell is saturated, the leachate is permitted to flow into the biological filter.

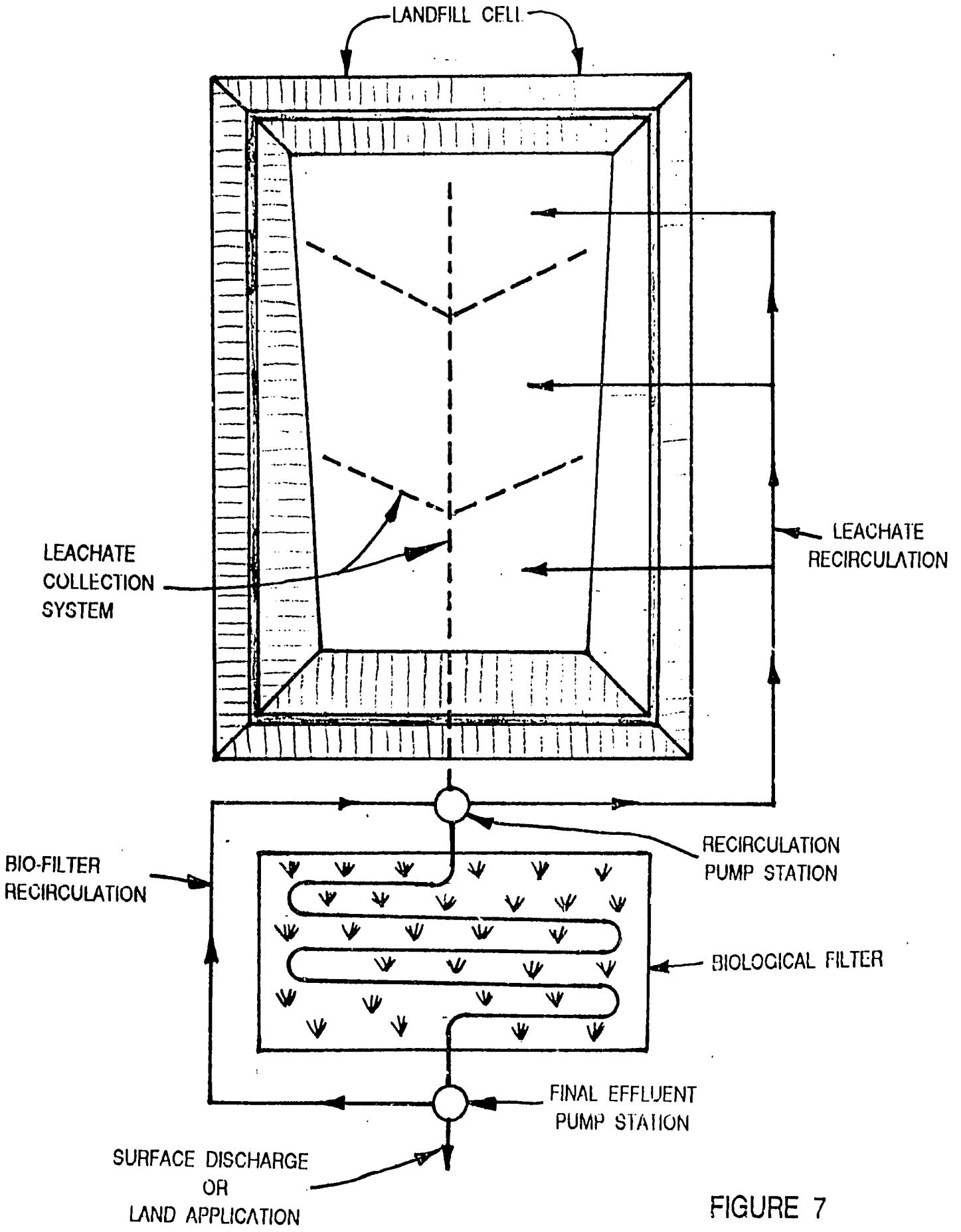


FIGURE 7
TYPICAL LEACHATE MANAGEMENT SYSTEM

The biological filter shown has a serpentine flow path through a manufactured wetland, planted with native plants, selected for their tolerance to highly organic liquids, and dry weather. Depending on the strength and contents of the leachate, diluting water may be required at this point before entering the biological filter. Nutrients, that may be lacking in the leachate, such as nitrogen, phosphorous and potassium may also be required prior to entering the biological filter. After leaving the biological filter the treated leachate enters a second pumping station where the leachate can be tested before final discharge. During dry weather, it may be desirable to recirculate the treated leachate through the biological filter to maintain the plant life or to dilute the leachate draining from the landfill cell.

After passing through the biological filter, the treated leachate could be discharged to a river or stream or pumped into a tank truck for land application at a remote site.

The system shown in Figure 7 is very simplified and will require further study to determine the size and configuration of each component. The design of the biological filter system may be a good project for a university research project. Although there is a significant amount of reference material available on biological filters, the data must be specifically applied to the estimated quantity and quality of the Tetouan leachate and meteorological data.

5.4 Potential Sites

5.4.1 General

The June 1992 report identified three general areas of Tetouan that meet the six criteria outlined in Sections 5.2.1 through 5.2.6. The remaining areas within 10 kilometers of Tetouan were eliminated.

5.4.2 Site 1

Site 1 is located west of the City along the road to Tanger. The area is characterized by rolling hills with slopes from 5 to 15 percent. Two potential land parcels exist in this area as shown on Figure 8. The first site, Site 1A is approximately 15 hectares in size, and is located adjacent to the existing power station and approximately 300 meters east of the Khemis River. The soil type appears to be clay as evidenced by a brick manufacturing facility nearby, but coarser sand and gravel were observed in an excavation along side the road. The sand and gravel formation appeared to be cemented together with clay. Due to the dry nature of the soil, it was difficult to estimate the permeability of the soil. The site appears to be pasture land of minimal agricultural value and there are only a few residences nearby.

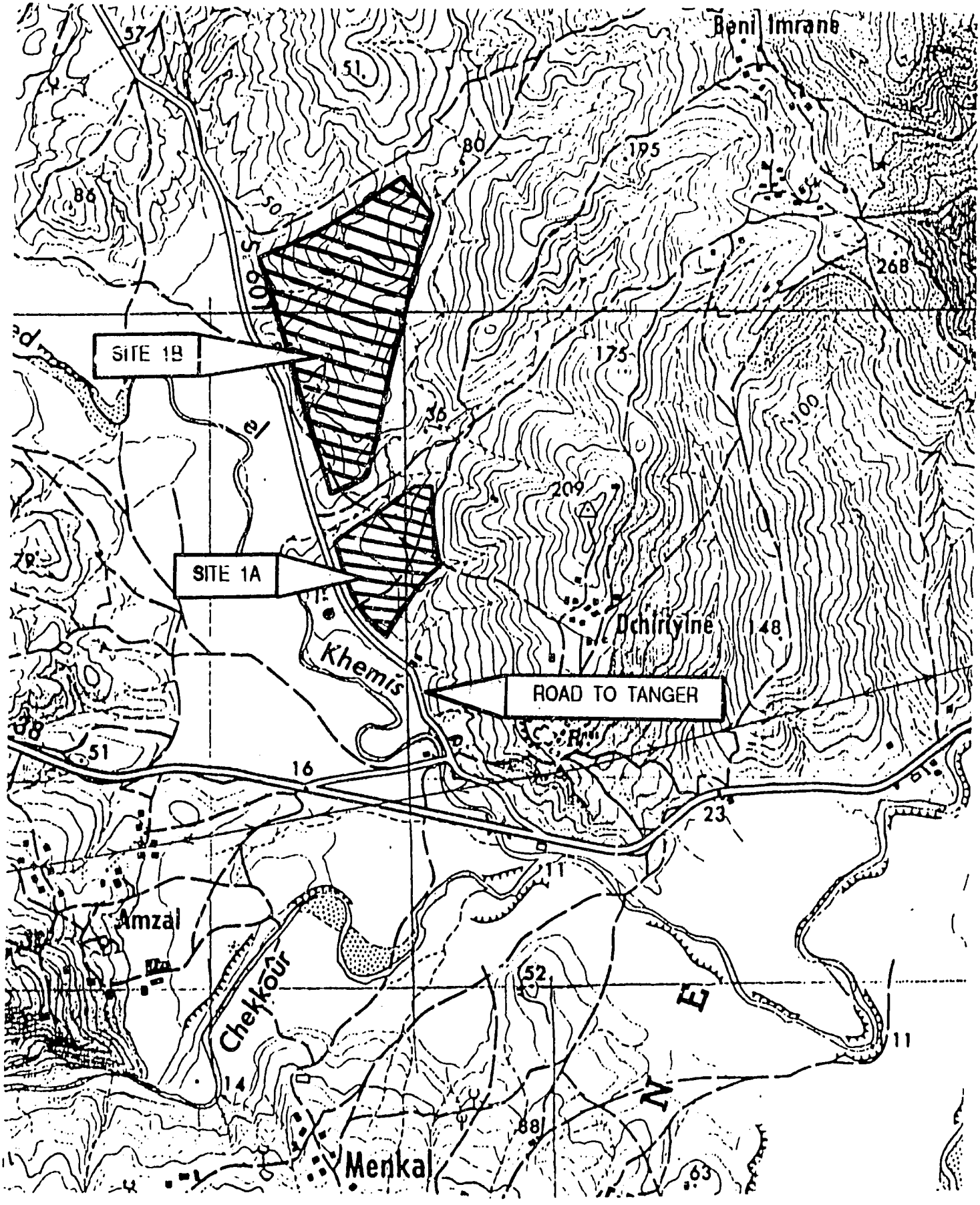


FIGURE 8
SITE 1

The second site, Site 1B, is located just north of Site 1A across a small stream. Site 1B is considerably larger than Site 1A at an estimated 42 hectares. The site includes two small ravines which should not affect the landfill design. All other characteristics are similar to those described for Site 1A.

Although both sites rank relatively high in four of the six criteria, their location upstream of the major groundwater wells in Tamouda would rank them low in protection of resources. Design of a landfill at either of these sites would require a high degree of soil investigation and leachate management to insure that the landfill would not impact the Tamouda Wells. This would include an extensive hydrogeology study to confirm the continuous nature of the clay soil and several deep borings to confirm the depth to groundwater. Since the Khemis River flows through the sand aquifer at Tamouda, final leachate discharge should be land application on the slopes above the landfill sites.

The two sites are easily accessible from the City of Tetouan but access from the coastal region will be more difficult. Due to the hillside location the base of the landfill would require excavation to a depth of 3 to 5 meters and construction of a dike to control leachate. Excavated soil would be stockpiled and used for cover material. The depth of the landfill would be limited to approximately 10 meters due to visibility from the road to Tanger and neighboring urbanization.

In order to obtain at a comparison of sites, each site is ranked from 1 to 10 in each criteria with 1 being poor and 10 being good. Sites 1A and 1B are ranked as follows:

	Site 1A	Site 1B
1. Distance from Tetouan	8	8
2. Urbanization	9	9
3. Accessibility	5	5
4. Wind	6	6
5. Topography - Soils	6	8
6. Protection of Resources	4	4
TOTAL SCORE	38	40

5.4.3 Site 2

This general area, identified by the June 1992 study, is between Tamouda and Dar Ben Karrich east of the road to Chefchaouen. This area is characterized by steeper slopes in the 10 to 15 percent range, with many long ravines running down the mountain. These long ravines are not suitable for landfill siting, due to high water run-off during the wet season. This site is also the general area of the existing and former landfills.

An inspection of this area and a review of topographic maps did not locate any land parcels of sufficient size that meet the 6 siting criteria. The area contains a greater degree of urbanization than Site 1 and is much closer to the groundwater wells in Tamouda. Due to the lack of suitable parcels in Site 2 it was not considered further in this study.

5.4.4 Site 3

Site 3 is located northeast of the City off the road to Sebta, west of the Village of El Malaliyine. As shown on Figure 9, the actual parcel is located on the road to Chouikhene. The site is a large ravine of approximately 32 hectares. The ravine has a small watershed and rainfall flows would appear to be manageable. Due to the potential depth of waste, the capacity of the landfill site is large, estimated at 30 to 40 years even for the regional site.

Although the site is located near the agricultural area west of Bennouna, along the Alila River, the actual site is pasture land. Green grass near the bottom of the ravine indicates a high water table, probably within 1 or 2 meters of the surface at this location. A hydrogeologic study would be required to determine if the groundwater is connected to the aquifer that is being pumped in Bennouna.

A considerable amount of hydrogeologic data exists in this area regarding existing wells and the extent of the aquifer under the Alila river. The approximate boundary between the permeable aquifer and the impermeable clay soil is also shown on Figure 9. Although many wells exist in this aquifer for irrigation, only one well is connected to the City water system. The location of this well is indicated on Figure 9. If this site is chosen, a more detailed investigation should be performed to determine the potential impacts to the Alila aquifer and the city well.

Since Site 3 is a ravine, construction of landfill cells will be much easier than the hillside locations of Sites 1A and 1B. Excavation of cells should be designed to provide periodic and final cover soil for the landfill.

Current access to the site by a paved road, through the village of El Malaiyine. This road is heavily traveled as it is the route to Chouikhene and other small villages in the mountains. Due to the existing and proposed urbanization of the area, this access route to the landfill will have many negative impacts. Several unimproved roads could be used to access the site through the agricultural area of Bennouna. In order to maintain access during the winter wet season, these roads would require extensive improvement.

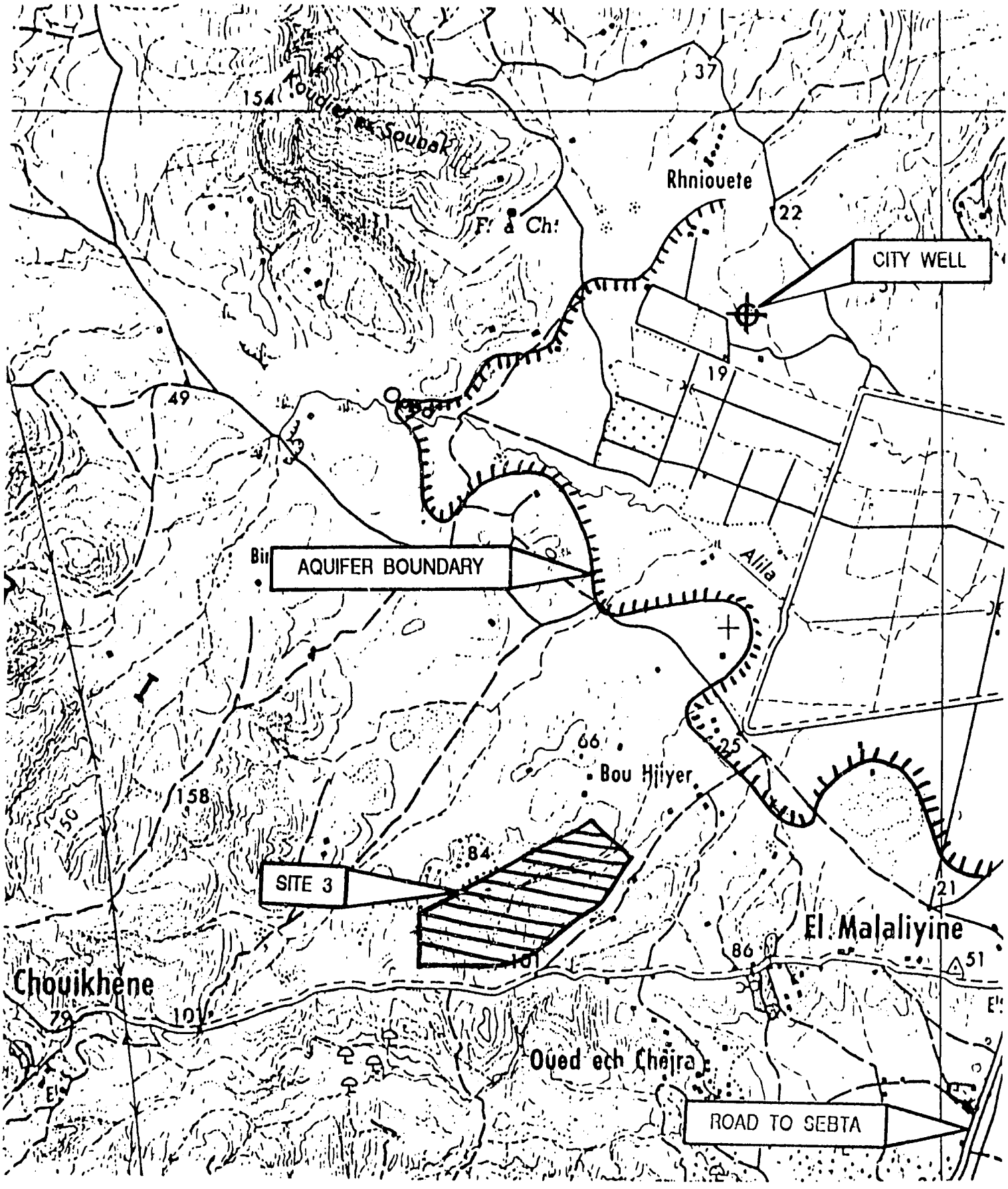


FIGURE 9
SITE 3

Site 3 is ranked as follows:

	Rank
1. Distance from Tetouan	8
2. Urbanization	4
3. Accessibility	5
4. Wind	6
5. Topography - Soils	7
6. Protection of Resources	6
TOTAL SCORE	36

5.4.5 Recommendations

Based on the above discussions and the criteria developed by the City, Site 1B appears to be the most appropriate site to investigate for a future landfill. The soils are mapped as impermeable clay and the site appears to offer minimum impacts to urbanization. Although the site is located upstream of the major wells in Tamouda the soil conditions appear favorable to control the leachate generated by the landfill. A thorough hydrogeological investigation and leachate management study should be performed before a final decision is reached regarding the site. This should include test pits and deep borings to identify all subsurface conditions.

6.0 OTHER ISSUES

6.1 Collection System

6.1.1 General

A previous report prepared by the International City Manager's Association (ICMA) in June 1991, described the various collection systems in Tetouan and made recommendations for improvements. Many of the problems were based on inefficient equipment and lack of middle management while other problems originate with a basic lack of environmental awareness and traditional practices and life styles. The improvement in equipment and management has begun and are showing good signs of success but the problems based on environmental awareness and life styles will require a long term educational effort.

6.1.2 Management

One recommendation of the ICMA report was to improve management practices, especially at the supervisory level. Through training programs and additional staff, significant improvements have been

made. The City is now divided into 3 sectors with 3 zones in each sector. Each zone in now supervised by a manager, who is able to evaluate performance efficiencies and make recommendations for improvements.

One example is the collection system in the City Center which has seen significant improvement in the past 12 months. Previous practice required 2 trucks and 20 workers to collect the 14 tonnes generated. Due to the commercial nature of the area, the collection must be accomplished before 9:00 am. The previous practice, using traditional baskets was replaced with plastic carts which allowed the workers to be more efficient. The increased efficiency permits one truck to make two collections using only 14 workers, a significant improvement in efficiency. The speed of collection improved from 1.25 km/hr to 2 km/hr and worker production increased from 0.70 tonnes/day to 1.00 tonnes/day. Other similar improvements are being planned in other areas.

6.1.3 Equipment

Although improvements in efficiency are being made, maintenance of the department's aging collection vehicles continues to be a problem. Due to different physical requirements of collection, many different types of vehicles are required. A total of 35 vehicles are used in the collection of waste but an average of 40% are out of order at any one time. As a minimum, 24 vehicles are necessary to complete the collection service.

6.1.4 Collection Costs

With the reorganization of the Technical Department, cost data is being assembled to better determine the total costs of collection. Separate labor and equipment costs are now being recorded. Although this process is still on-going, a preliminary annual cost estimate of 10,000,000 dirhams has been determined which equates to approximately 200 dirhams per tonne of waste collected. These estimates do not include disposal costs.

6.2 Privatization

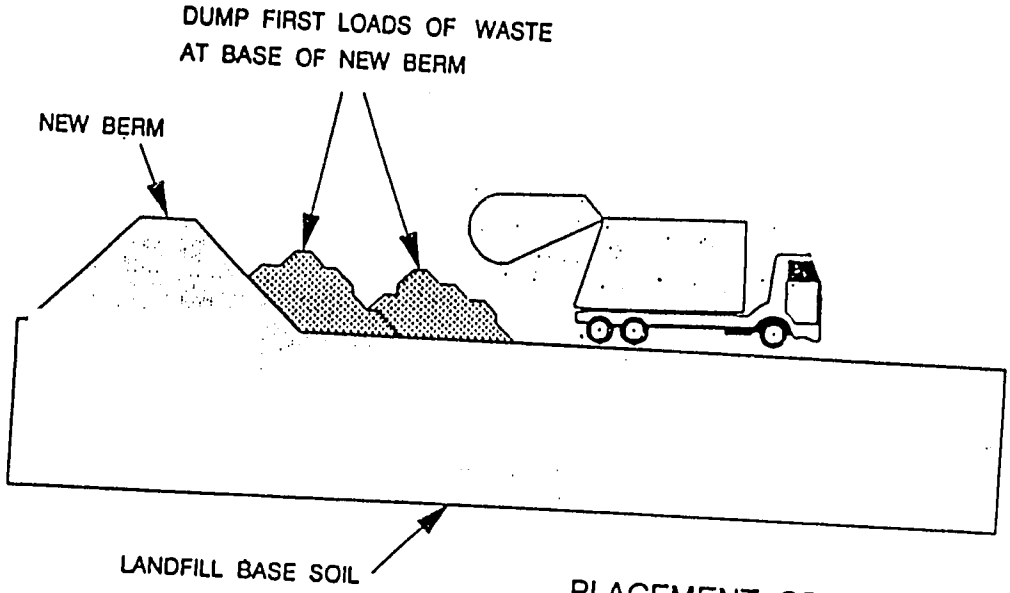
The Technical Department is preparing a Request For Proposal (RFP) to privatize one area of the City as a pilot project to compare the relative costs and effectiveness of privatization. This area will be in the newer section of the City where population, waste generation and current costs can be determined with reasonable accuracy. This will allow for a better comparison between public and private collection. Neither the Medina nor City Center were selected for the privatization project since a valid comparison would be difficult due to the variable nature of the area and services required.

Although the RFP was not reviewed, components of it were discussed with the department and all of the major ingredients appear to have been included.

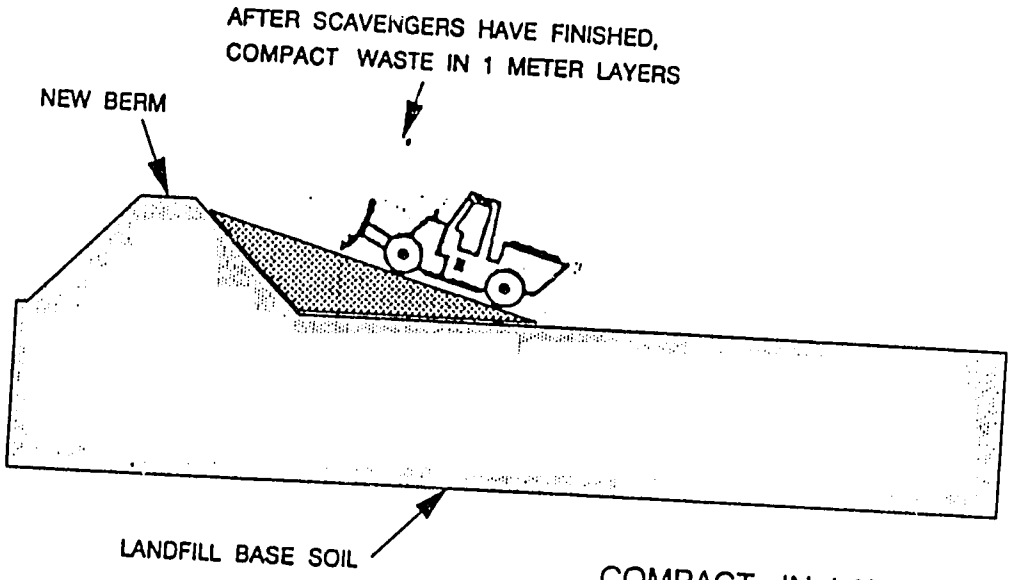
By starting the privatization process with a pilot project, the Department is not likely to attract any of the internationally experienced firms to submit a proposal. This presents several issues in preparing the RFP in terms of contractor qualifications, experience and equipment necessary to perform the work. The Department is aware of these issues and will take them into account in preparing the RFP and overseeing the contract.

A local contractor specializing in civil construction projects is the only contractor to have expressed an interest in submitting a proposal for this work. He maintains a large number of construction vehicles including bulldozers and dump trucks, but does not own any refuse collection trucks. The Department is considering leasing one or more of its trucks to the contractor to perform the pilot project.

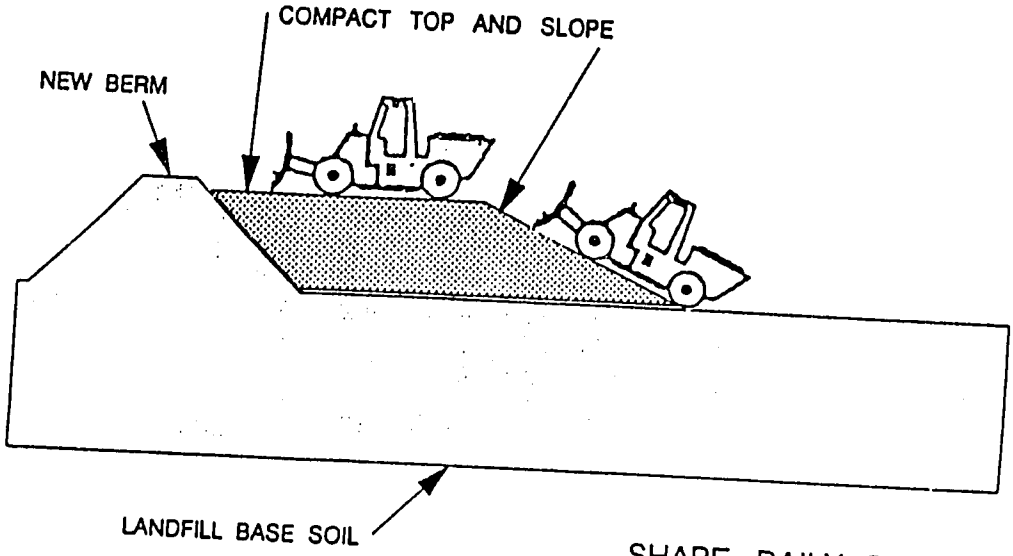
APPENDIX A



PLACEMENT OF WASTE



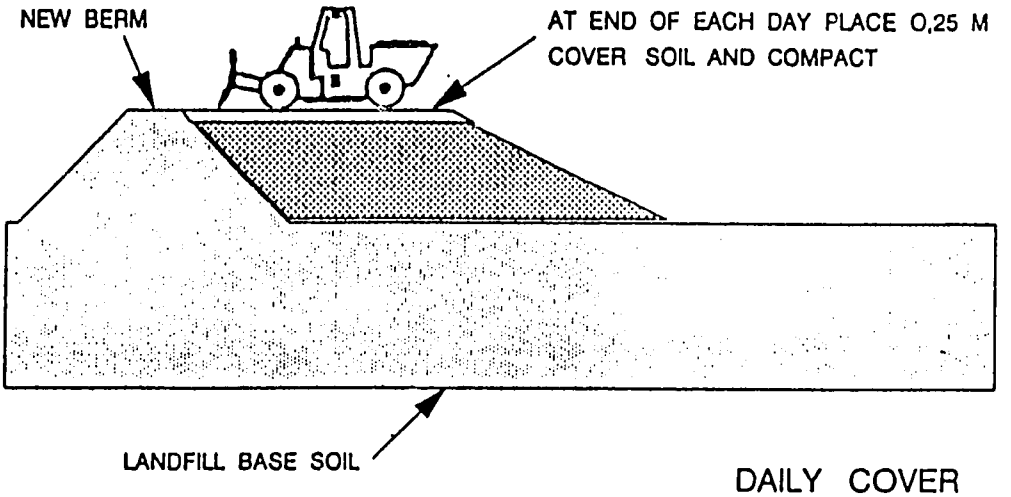
COMPACT IN LAYERS



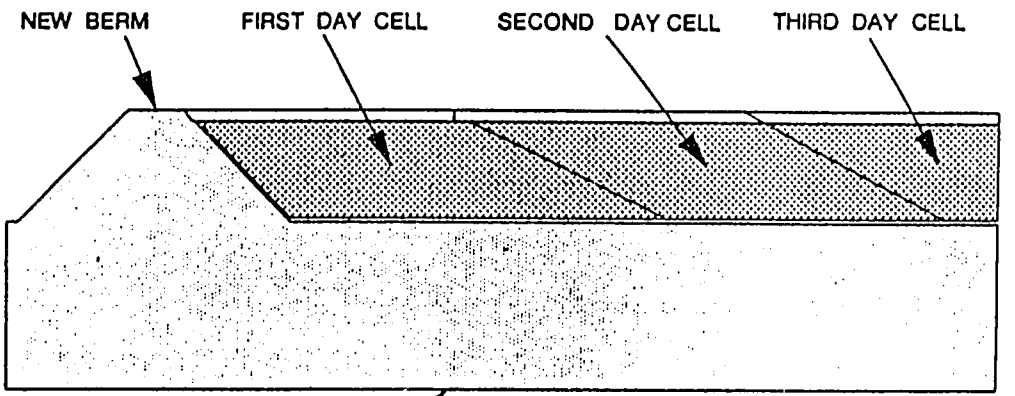
SHAPE DAILY CELLS

FIGURE A-1

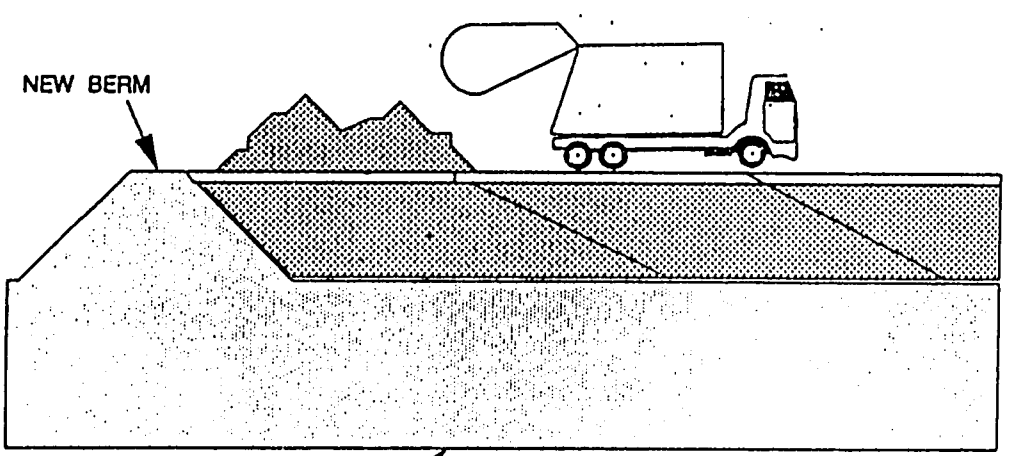
OPERATING PROCEDURE



DAILY COVER

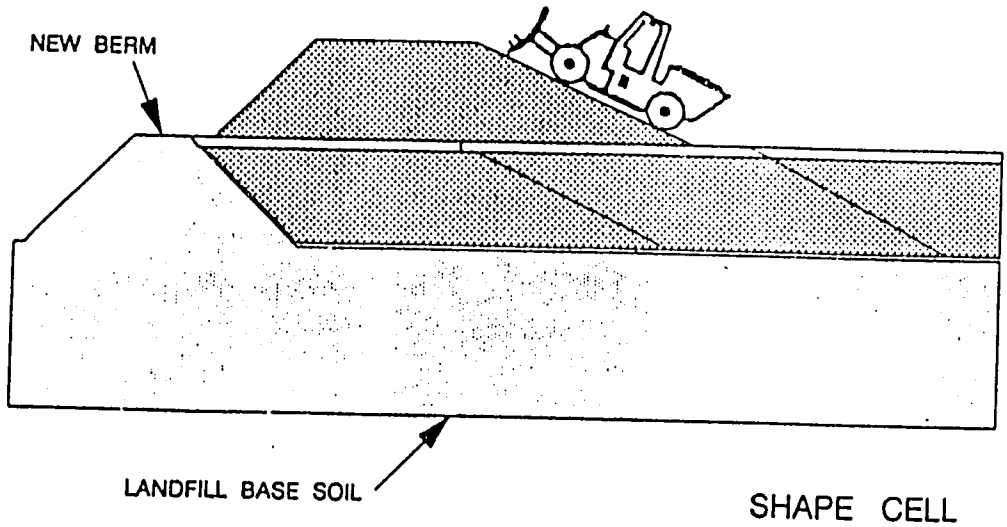


COMPLETE FIRST LIFT

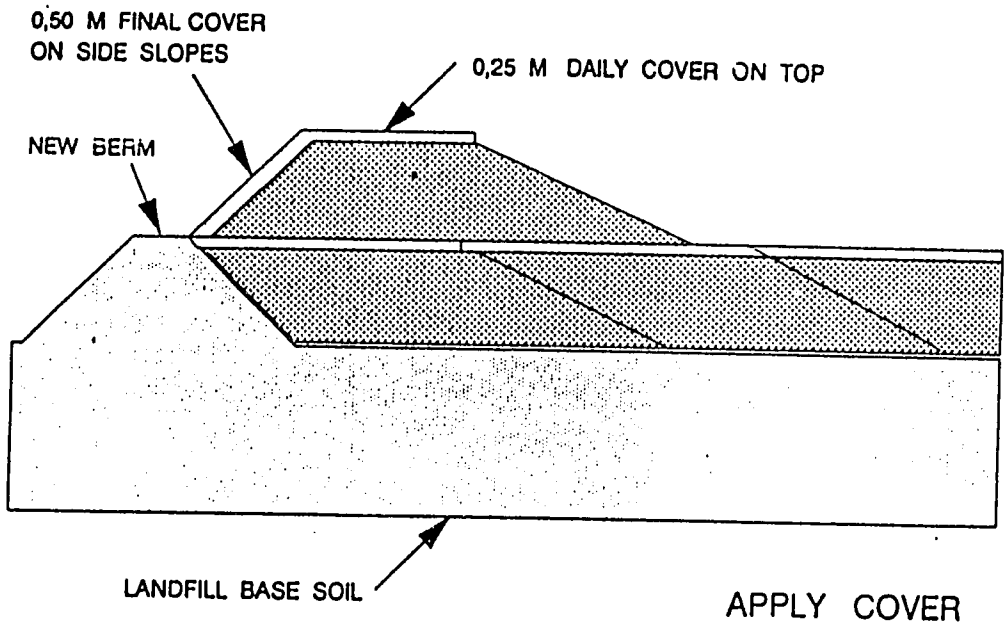


INITIAL WASTE
SECOND LIFT

FIGURE A-1
OPERATING PROCEDURES



SHAPE CELL



APPLY COVER

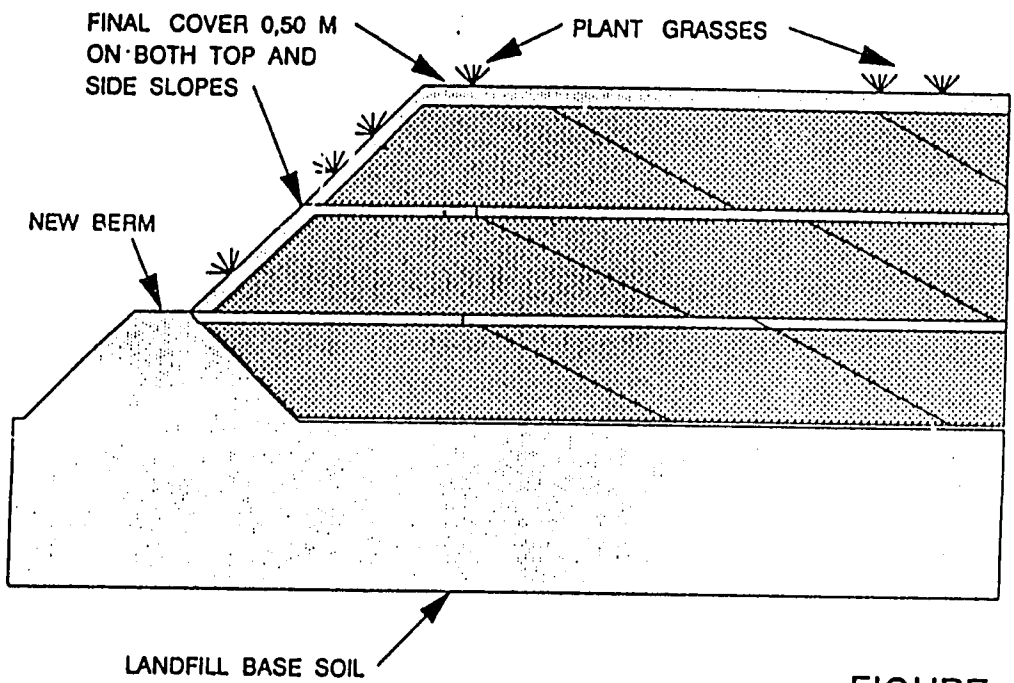


FIGURE A-1

OPERATING PROCEDURES