E2707

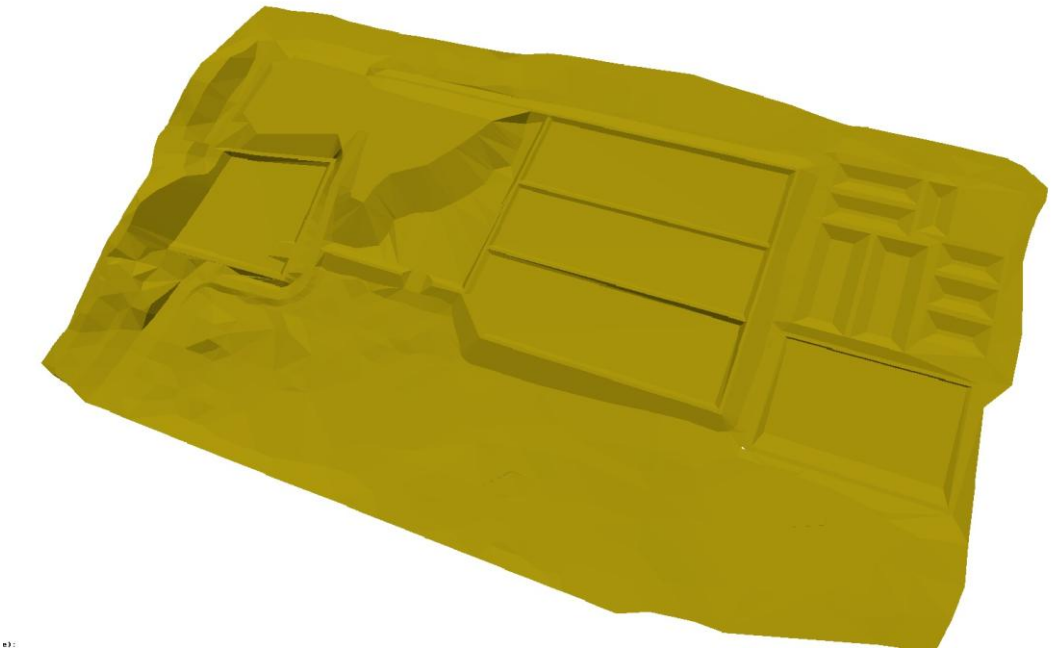
REPUBLIC OF LIBERIA

Monrovia City Corporation

Monrovia, Liberia

Emergency Monrovia Urban Sanitation Project (EMUS)

OPERATIONS AND MAINTENANCE GUIDELINES and ENVIRONMENTAL MANAGEMENT PLAN for THE WHEIN TOWN SANITARY LANDFILL FACILITY



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OPERATIONS AND MAINTENANCE GUIDELINES and ENVIRONMENTAL MANGEMENT PLAN for THE WHEIN TOWN SANITARY LANDFILL FACILITY

OPERATIONS AND MAINTENANCE GUIDELINES

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ABBREVIATIONS

BoQ	Bill of Quantities
CBO	Community Based Organisation
FIND	Foundation for International Dignity
IAPSO	Inter-Agency Procurement Services Office
LISGIS	Liberian Institute for Statistics and Geo-Information Services
LMA	Liberia Market Association
LWSC	Liberia Water and Sewer Corporation
MCC	Monrovia City Corporation
MOU	Memorandum of Understanding
MPW	Ministry of Public Works (of Liberia)
MTEF	Medium Term Expenditure Framework
NGO	Non Governmental Organisation
NIMAC	National Information Management Centre
REL	Rear-End Loaded Compaction Vehicle
SIU	Special Implementation Unit
SoW	Scope of Works
UNDP	United Nations Development Programme
WB	World Bank
TIDS	Temporary Intermediate Disposal Site
WIS	Waste Information System
MRD	Maximum Rate of Deposition
IRD	Initial Rate of Deposition
TS	Transfer Station

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OPERATIONS AND MAINTENANCE GUIDELINES and ENVIRONMENTAL MANGEMENT PLAN for THE WHEIN TOWN SANITARY LANDFILL FACILITY

1 INTRODUCTION

This document is a combined document that sets out both the general Operation and Maintenance (O&M) procedures and Environmental Management Plan (EMP) for the Whein Town Landfill facility.

The layout of this document starts by stating the site and environmental conditions. Chapters 3 to 15 deal with the operations, maintenance and management requirements for the site and facilities ending off with decommissioning and closure requirements. It thus describes the general landfilling principles, management of the leachate and health and safety requirements that should be adopted for an environmentally acceptable process. Chapters 16 to 19 deal with the environmental management and monitoring plan ending off with the reporting procedures. Chapter 20 provides a summary of the landfill and leachate specifications.

This document has to be read in conjunction with the Final approved EPA Permit, EIA compiled by Messrs Earthtime Inc and Geohydrological Investigation Report compiled by Messrs GeoSurv.

The document should is seen as a "live" document and should be updated and revised as and when new operational information becomes available or procedures are revised after approval by the authorities.

For equipment that is supplied for use at the Landfill the manufacturer's instructions should be consulted. These instructions should be included in this document once received. Unless otherwise stated, particular equipment specifications should take precedence over this document.

2 DISCRIPTION OF PROPOSED SITE

2.1 Introduction

In this section, Whein Town Landfill is described with a view to providing a brief overview of its location, the current owner, climate, topography and drainage, fauna and flora, existing infrastructure, land-use and settlement. Most of the information described in this section was extracted from the EIA report.

The Whein Town site is located near the telecom facility along the Monrovia/Kakata road. The site has a very prominent hillock which has been eroded extensively due to borrowing of the laterite from the surface leaving the sub soils exposed.

As the Whein Town site is bound by a road and encroaching development to the South East, as well as developments from the south and north-west, it offers limited space for further development. There would thus only be sufficient airspace on this procured 10 ha site for the short term until the permanent or long term Landfill is developed.

Figure 1 below shows the extent of the city of Monrovia and the location of the Whein Town site.

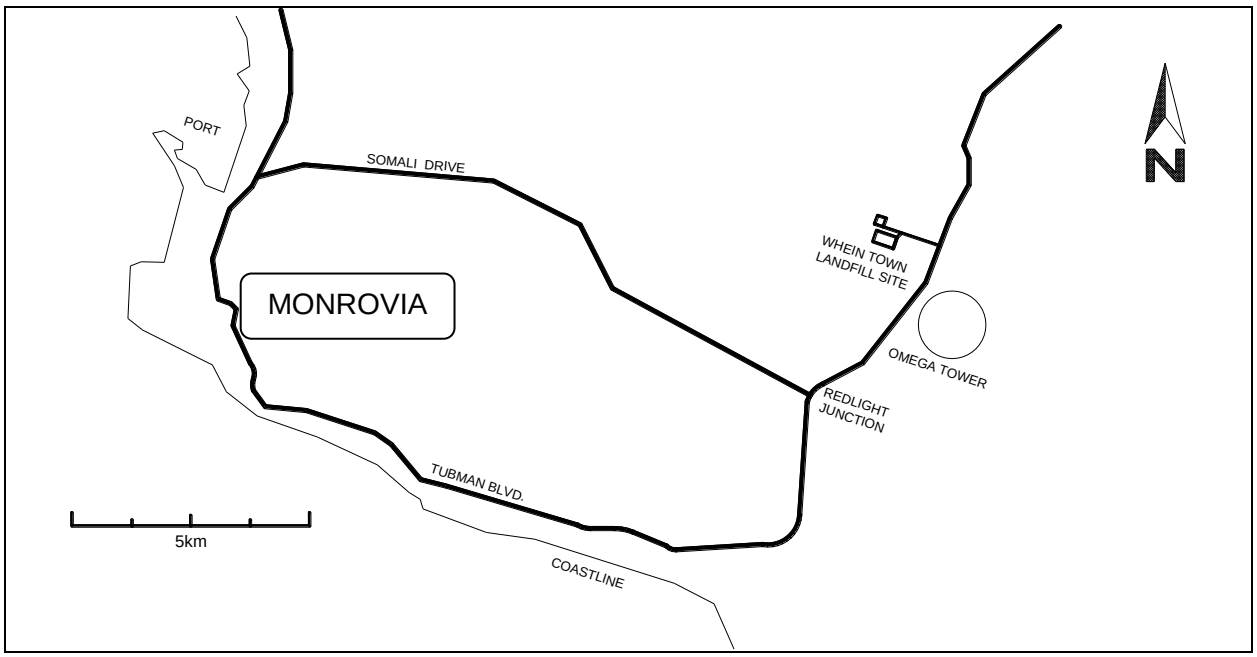


Figure 1: Location of the Site and City of Monrovia

2.2 Location

The Whein Town facility where solid waste from the Greater Monrovia is deposited is located at the outskirts of Monrovia City in Mesurado County. The town lies 13 km north-east of Monrovia, 7.5 km east of Gardnersville, 3.9 km south-west of Mount Barclay and 7 km north-north-east of Paynesville. The site falls approximately on the coordinates: 29 N 0314899 UTM 0698921 (Figure 2 and 3). The elevation ranges between 10 and 20 m above sea level. It is also 16 km east of the Atlantic Ocean, 12 km north-west of St. Paul River and 4 km west of Muu Creek. The site area is approximately 10 ha in size (See Appendix L for the Cadastral layout of the site).

The site is surrounded by residential settlements at a distance ranging between 0.5 km and 1.5 km. Agricultural activities are also present in the surrounding area. The site is accessible through a secondary road branching off the Monrovia-Kakata

Highway approximately 0.9 km in length and is an asphalt surfaced road and in good condition. In addition to Whein Town itself where the Landfill is located, the nearest villages/towns to the site are:

- Konke Town: 3 Km north;
- Dome Town: 4.9 Km north-east
- Gaakpee Town: 5.1 Km east
- Dwe Town: 3.7 Km south-east.
- Kaiph Town: 3.3 Km south
- Nizohn: 3.7 Km south-west
- Johnsonville: 4.8 Km north-west

The site coordinates are shown in Table 1 below.

Table 1: Coordinate List of Site Corner Stones

		Lo System 29°
Corner peg	**E**	**N**
A	314 568.29	699 239.48
B	315 028.46	699 024.19
C	314 943.79	698 843.54
D	314 484.35	699 060.05

Figure 2 Orthophoto layout

Topographical Survey of Site: (Detailed plan to be included when operation starts).

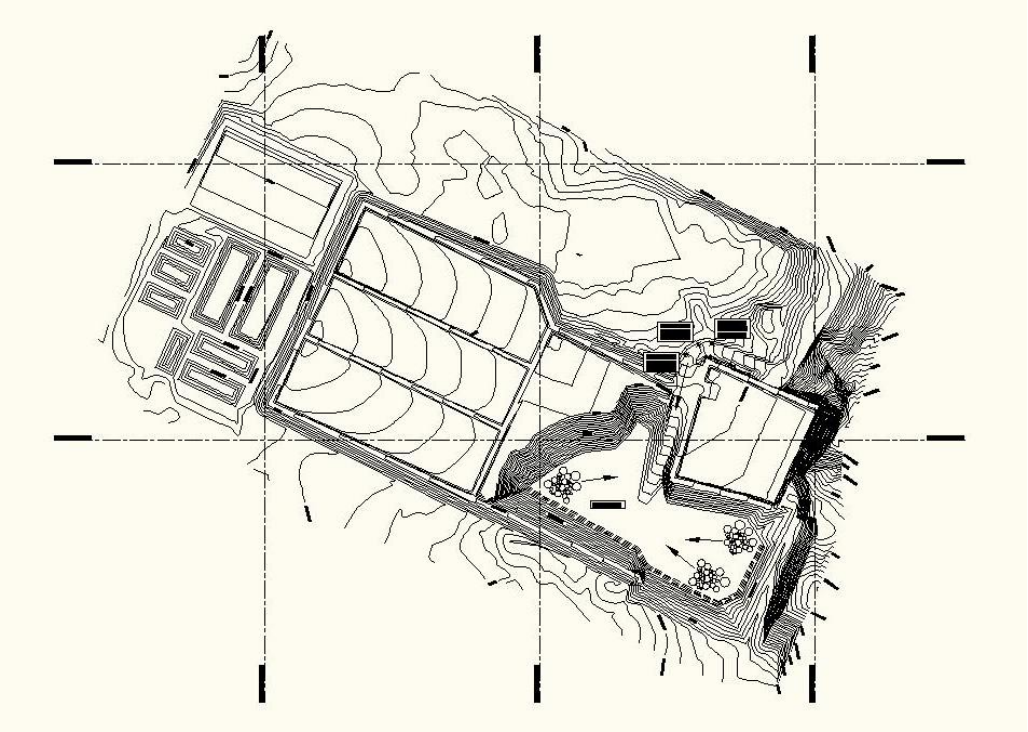


Figure 3: Site Layout

2.3 Ownership

The land on which the site is located was purchased by the MCC in 2007 with remaining private properties bordering on the site. The area of land initially proposed for the development of the Landfill site was 10ha due to the emergency status. It is too small to act as a long term facility and highlights the need to expedite the development of a long term facility.

2.4 Climate

The area falls within the transitional wet semi-equatorial climatic region. It has a mean annual rainfall of approximately 4500mm. The major rainy season starts in May and end in October, with the heaviest rain in June/July. The area has a high humidity range between 90% and 100% (some records seem to state humidity records ranging between 75% and 90%). Average daily temperatures vary from a minimum of 20°C to a maximum of 34°C. Table 2 gives the climatic statistics that could be expected at Whein Town.

The dominant wind directions are the NE and SW Monsoons as well as the Harmattan, which is a dust laden wind from the Sahara Desert. The south-westerly winds rain baring winds hits the coastline of Liberia at a right angle. As the air reaches the coast it rises and cools resulting in heavy rainfall. On the other hand in the immediate vicinity of the coast another air circulation takes place. It is a daily change in land and sea breezes (UNDP, 2006).

The total wind speed is lowest in the dry season and greatest in the rainy season. The greatest wind speed is between July and September and the lowest is in December and July. The coastal area has much more wind than the interior of the country. High vegetation cover in the interior serves as windbreak in the interior (UNDP, 2006).

According to UNDP, 2006 average wind speeds of 6.8 mph have been recorded at Harbel (Firestone). The highest wind speed is 45 miles/hour was recorded in Buchanan in April and May 1988. The average annual wind speed was 19.5 mph (UNDP, 2006).

Table 2: Climatic Statistics for Whein Town

MONTH	Average Rainfall mm	Average Rainfall mm (from EIA report)	**Average Rainfall (Spriggs Payne 1969-1981) JICA MP**	Average Temp ºC	Daily Sunshine (hrs)	Mean Humidity (%)
JANUARY	178,5	30	**45**	29	9.0	95
FEBRUARY	204,7	50	**38**	29	9.0	95
MARCH	209,0	98	**65**	30	8.5	95
APRIL	235,5	225	**150**	30	7.5	97
MAY	469,3	520	**405**	29	7.3	98
JUNE	394,5	970	**707**	32	7.4	98
JULY	310,5	1000	**625**	30	7.2	99
AUGUST	374,0	375	**618**	31	7	96
SEPTEMBER	313,5	750	**698**	29	6.8	97
OCTOBER	284,4	780	**570**	28	7	98
NOVEMBER	237,4	250	**183**	28	7.5	96
DECEMBER	210,3	140	**95**	31	8.5	95
TOTAL	3417	5188	**4199**			

2.5 Topography and drainage

The site gently slopes towards the west, with a topographic high (hillock) of approximately 20m above mean sea level. The hillock runs from north north-east to south south-west along the eastern boundary of the site (see Figure 4). There is a shallow valley across the north western extreme portion of the site, and is the start of the upper catchment area of a local seasonal stream. The hill on the site also forms the water shed of the larger catchment area flowing southwest.

Figure 4: Whein Town Landfill Location and Local Drainage

The surface water run-off drains to adjacent mangroves and on to a seasonal watercourse that runs west and eventually south to the Atlantic Ocean. An adjacent hillock to the east and south shields the site from nearby existing residential areas. However, with the urban sprawl residential units are developing all around the site.

Typical of the landscape the regional area hosting the Landfill is characterized by the presence of several surface water bodies ranging from mangroves, springs, seasonal drainage systems and creeks. These creeks flow in the region especially to the eastern side of the proposed Landfill site on the opposite side of the regional water shed. Most of these creeks flow in the N-S direction. The distances between the creeks and the proposed site range between 3 and 4 km.

2.6 Soil characteristics

As with the rehabilitation of the previous Fiamah dumpsite, cover material/soil will be required as part of the intermediate Landfilling process and also to finally cover and to shape/slope the rehabilitated Landfill site. This resource will be partly obtained from the site itself or otherwise obtained from outside sources. The ideal would be always to obtain all cover material from the site as part of the development which would be stockpiled for future use.

On account of the clay and silt content, the soils on site would tend to be easily erodible, and care should be taken to ensure that exposed non-vegetated areas are kept to a minimum.

2.7 Existing water usage

As the development of the Landfill facility could impact on the water quality of receiving surface water and ground water bodies, superficial surveys/inspections were carried out to determine the extent of water usage in the area. As indicated in the EIA an existing spring in the hill side area was used by the local population as a water source. The establishment of the intermediate Landfill has led to the disuse of the spring which was entirely damaged. A water supply well was installed to replace the damaged spring.

Table 3: Coordinate list of Monitoring Boreholes

Station	E	N
Water Well 1	314 568.29	699 230.48
Water Well 1		
Monitoring BH 1		
Monitoring BH 2		

To be completed when installed

2.8 Fauna and flora

The site location in particular is flat and swampy mainly during the rainy season which starts in May and ends in October. The swampy area which characterizes wetlands has some piasawa tree, palm tree (Elaeis guineesis), bamboo, and rare mangrove species (Rhizophora mangle). Besides, the dry land vegetation consisting of low bush is indicative of endemic flora, such as Mango species (Mangnifera indica) commonly known as plum tree, and mimosas grass (Mimosa pigra) locally called "Touch-Me-Not".

Cow birds (Molothrus ater), African Village Weavers (locally referred to as rice birds), common Bulbul locally named as pepper bird (Pycanontus barbatus), pigeons, and other migratory birds routinely inhabit the area. The renaissance field assessment showed other small animal species to include ants, green snakes, squirrels, rat, rodents and other micro-organisms. Moreover, several flowerless, seedless vascular plants (e.g. Ferns) and savannah grass occupy most of the hills and basin.

The *fauna and flora* have already been disturbed by agricultural activities, and as indicated in the EIA it is not believed that Landfilling activities will threaten any unique species or habitats.

2.9 Existing land use, settlement and infrastructure

The land use and land cover of the Whein Town area, which hosts the proposed Landfill, consists of agricultural plots (mainly vegetables) and some features of tropical vegetation. Due to urban sprauling residential units are now found in close proximity to the site. The neighbouring properties and communities thus have to be considered when operating the Landfill.

2.10 Environmental Impacts

An analysis of potential impacts that could be incurred due to implementation of the Whein Town facility revealed limited adverse environmental impacts during the short-term facility construction and site preparation phase. However during the operation and post closure phases, the facility may be associated with negative impacts due mainly to leachate generation with potential surface and/or groundwater contamination, visual/landscape intrusion, biodiversity, air quality, traffic as well as health and safety issues. Other less serious impacts of concern include odorous emissions, soil contamination, Landfill stability/settlement and socio-economics.

All identified impacts can either be avoided or minimized by careful planning of design construction activities as well as by adopting a proper environmental management plan including mitigation and monitoring measures during the facility construction and site preparation phase, the operation phase, and post closure phase of the proposed facility.

The proposed operating plan and thus mitigation measures are discussed further in the following sections.

3 GENERAL OPERATIONAL PROCEDURES

3.1 Introduction

The Monrovia City has endeavored to develop an environmentally acceptable Landfill in Whein Town since 2008. In the republic of Liberia Waste management facilities are regulated by the EPA.

3.2 Landfilling Procedures

The following operational procedures should thus be adopted for the Whein Town general waste Landfill facility in order to comply with sanitary Landfill engineering principles:

- All refuse should be deposited in layers
- No cell or fill lift is to exceed 600 mm in depth without being covered with a daily cover layer and should be built up in layers of 250 – 300mm and compacted
- All waste is to be covered at the end of the working day and no waste should be left uncovered for a period greater than 24 hours
- Waste is to be covered with a layer of earth or similar material of minimum thickness 100mm preferably 150 mm
- Suitable screens or alternative measures should be provided to collect windblown refuse, paper and plastic
- No waste should be tipped into water
- Every precaution should be taken to prevent outbreak of fire. All fires are to be extinguished - burning waste should be exposed, spread and smothered and covered with cover material, soil or other non-combustible material. This should preferably not be done during high winds and water should not be used. The fire fighting services are always to be called immediately when a fire is detected as it could still be burning due to the presence of Landfill-gas. Smoking on site should be forbidden but if allowed should be restricted to designated smoking areas
- The site should be regularly inspected for vermin and appropriate measures taken to prevent infestation; all hollow containers should be flattened

- If any deposit consists of mainly organic or small quantities of households hazardous material, it should be covered with at least 600 mm of earth (or other material) e.g. neon light bulbs, batteries and paints or detergents

- Every deposit of waste must be kept tidy

- All areas of the site outside the Landfill should be kept free of litter. As a minimum, the site should be inspected every week to ensure that this is carried out

- The access road to the site should also be kept free of litter and mud. Similar inspections to the above should be carried out

- All drainage pipes and ditches should be kept in working order

- All site roads should be maintained and potholes filled (Heavy wear and tear on collection vehicle tyres with a high incidence of punctures is a feature of Landfill operations)

- The site fencing should be inspected and repaired on a regular basis by permanent on-site guarding.

- Monitoring for leachate and Landfill gas should be undertaken and the results recorded in the site records.

- Members of the public should not be allowed on the site except for private contractors.

- A safety code of practice should be prepared and one member of each working shift should be trained in first aid. Safety apparatus such as ear, breathing and head as well as face and eye protection should be present on site. Safety clothing and shoes or boots are required. Showers and reasonable lodging should be provided for the Landfill staff.

- Any breaches of the clay or geomembrane liner in the Landfill should be reported to the Site Supervisor immediately.

- Hospital waste such as potentially hazardous waste containing sharp materials (needles, blades, contaminated glass etc) should be collected and removed through the District/ Provincial/ or National controlled service and never disposed at a general Landfill.

- Animal carcasses should be buried on site and covered with lime.

3.3 Leachate Treatment Procedures

Ponds have been constructed at the Landfill to treat the inflow of Leachate produced from the adjoining Landfill site.

Leachate will be collected by subsurface drains located beneath the Landfill cells and gravitate to the leachate treatment ponds for treatment. Before any effluent reaches the local water course systems it will have been treated to meet the required disposal standards.

The leachate treatment ponds are sized to treat the hydraulic leachate load produced in the Whein Town Landfill facility estimated at 300 m^3/day. It was also assumed that corresponding BOD (organic) loadings of 1800 kg/day be used in the design.The corresponding combined BOD loading of the influent is estimated at 6 000 mg/ℓ. The acceptable effluent standard from the leachate treatment pond system accepted in the design is a BOD loading of < 75 mg/ℓ.

The leachate treatment pond system will consist of the following ponds:

To ensure acceptable BOD effluent loadings of less than 50 mg/l, the leachate treatment pond system will consist of the following treatment ponds:

- Anaerobic pond 2x
- Facultative pond 2x
- Maturation pond 4x
- To "polish" the effluent a constructed wetland is introduced.

Leachate, which is collected via subsurface drainage pipes located beneath the Landfill cells, discharges 24 hours per day into anaerobic pond 1A or anaerobic pond 1B. A flow control structure is located prior to discharge into the first of the anaerobic ponds. Flow can be diverted to either anaerobic pond 1A or anaerobic pond 1B by means of a hand stop which is located in the flow control structure.

A schematic layout of the leachate treatment pond system is illustrated in Figure 5.

Normal Flow Route

Alternate Flow Route to by-pass a Pond

Normal Flow Sequencing
Alternate between ponds A1 and A2. One of them should be empty in April at the start of the wet season.
Alternate flow between ponds F1 and F2.

Total flow to pond M1 then M2, M3 and M4.
Any of ponds A1or A2, F1 or F2 can be by-passed.

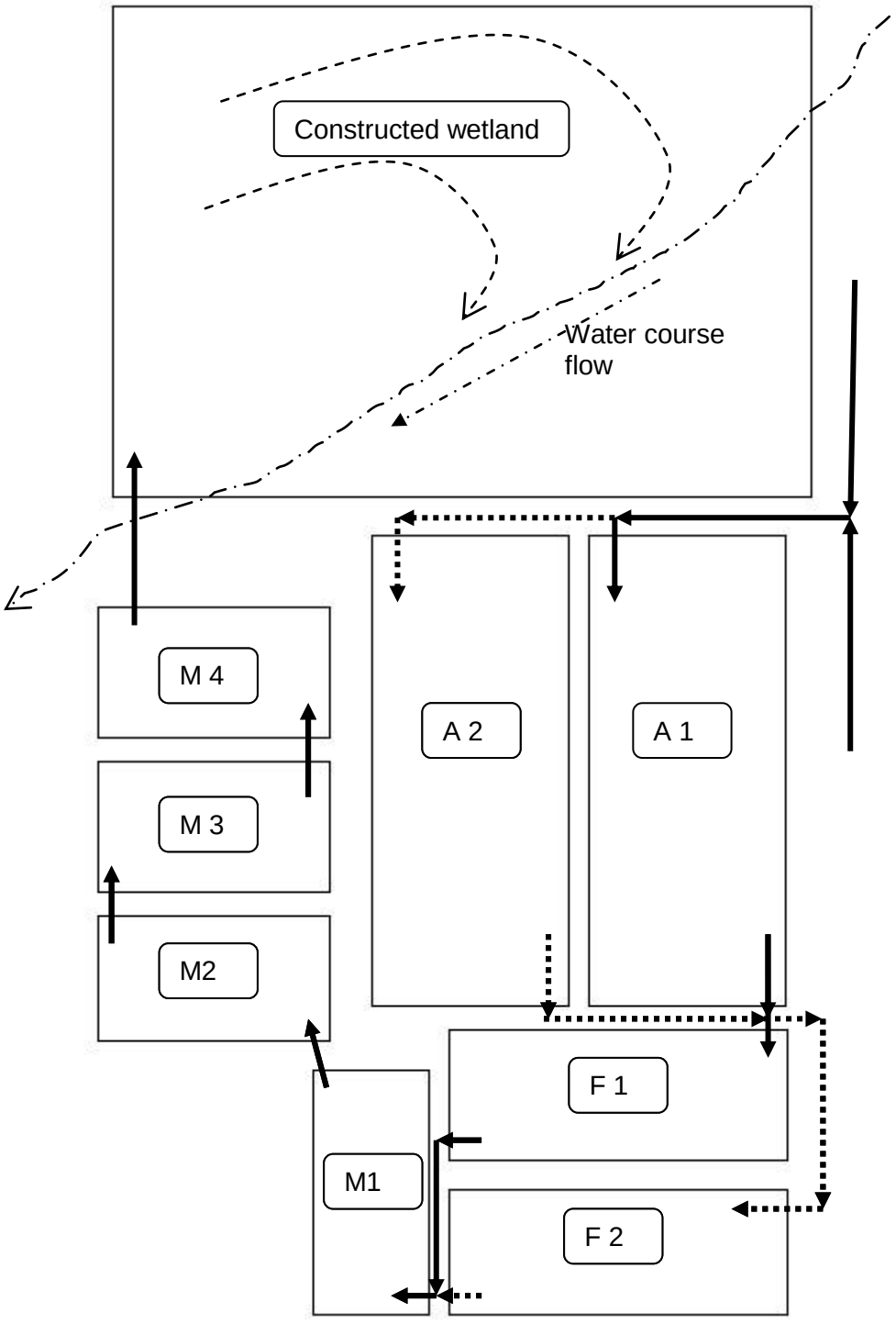


Figure 5: Schematic layout of the leachate treatment pond system

Under normal operating conditions, influent flow will either be discharged into anaerobic pond 1A or Anaerobic pond 1B depending on which pond is being desludged. Flow will proceed to outlet flow control structure type 4, which sets the water level in the preceding anaerobic ponds (1A and 1B). The flow then proceeds to Facultative pond F1 or Facultative pond F2. Flow from Facultative pond F1 and Facultative pond F2 is collected in outlet flow control structure type 3 which similarly sets the water level in the preceding Facultative ponds (F1 and F2). Flow proceeds to Maturation pond M1. Flow from Maturation pond M1 is collected by outlet flow control structure type 1, which sets the water level in the preceding Facultative pond (F1). Flow proceeds to Maturation pond M2, M3 and M4. Flow from the Maturation ponds is collected by outlet flow control structure type 1, which sets the water level in the preceding Maturation ponds. Flow finally discharges into the nearby stream.

The above-mentioned flow sequencing is applicable to normal operating conditions. However, any of the following ponds can be bypassed for desludging:

- Anaerobic pond A1
- Anaerobic pond A2
- Facultative pond F1
- Facultative pond F2

Should any of the above-mentioned ponds require desludging, the normal flow route will be affected. Flow routing is controlled by hand stops in each of the flow control structure types.

4 HEALTH AND SAFETY

4.1 General

Health and safety matters are the responsibility of all members of the staff of the facility operator. A safety officer should be appointed to ensure that safe procedures are being adopted. The safety officer may be the site supervisor of his/her immediate superior. A safety plan should be compiled and displayed for all staff to follow. The safety plan should cover the following topics:

- Smoking will be restricted to designated smoking areas
- Awareness of vehicle movements particularly on or near the working face
- Protective clothing requirements
- Keeping the site clear of mud and rubbish
- Dust suppression
- Ensuring that vehicles at the working area have a firm riding surface
- Ensuring the stability of permanent and temporary embankments
- Fire prevention and control procedures
- First aid and accident procedures
- Any other applicable working regulations
- Dangers of Landfill gas and leachate

It will be necessary to train both the supervisors and operatives in safety matters.

4.2 Protective Clothing

The following protective clothing should be provided for each site operative:

- Overalls
- Heavy duty boots
- Gloves
- Goggles
- Dust masks

4.3 Training

Various training schemes are available to site operating and supervisory staff. Operator training normally takes place on site, whereas supervisor training

may take place at training institutes. The need for training has been identified and should be addressed continuously.

4.4 Emergency Procedures

Suitable training of personnel, along with well-planned emergency procedures, is imperative right from the outset of the operation of the Landfill.

Because it is impossible to anticipate and formalise every emergency and because emergencies are, by nature, unpredictable, a decision flow chart defining only broad emergency strategies should be readily available to all site personnel. This flow chart should incorporate a set of trigger and completion parameters, i.e. a set of parameters that will trigger and end an emergency procedure respectively. Possible example emergency scenarios should be displayed along with the flow chart and a list of actions and information common to all emergencies should be provided. This list would include detail like:

- Names of persons involved in dealing with and the name of the person in control of an emergency
- Emergency contacts (fire, police, ambulance, telephone number of any responsible person not on site)
- Flow of information (who should be notified and when)

It is important to accumulate and maintain a database of extraordinary events occurring on site which may be linked to emergency occurrences. These events must in turn be matched with other circumstances (e.g. weather conditions, site operations etc.). A statistically valid pattern can then be sought to help with the forecasting and prevention of similar emergencies.

5 OVERALL PLAN AND PHASING

5.1 Landfill Area

The extent of the Landfill area to be filled during the working life of the site including the leachate ponds, account for approximately 80% of the overall site area. The remaining portion of the site, which has not been prepared for filling, will house the site entrance facilities and a vacant part. The area not prepared has been left with the original vegetation. Available site area is approximately 10ha.

5.2 Airspace Available and Site life

The site life of a Landfill is determined by comparing the total available airspace with the forecast airspace utilisation based on quantities of waste deposited. In addition, as daily cover is required, site life will also be determined by the total quantity of available cover material.

5.2.1 Cover availability

The site was built up to raise it clear of the wet season ground water level (unsaturated zone). With the hillock on the eastern side to be excavated down to the level of the proposed landfill surface bed, approximately 55 000m^3 was obtained through excavation. A further approximately 50 000m^3 was excavated in the leachate treatment ponds. More than 60% of the excavated material was required to raise the site. Approximately 40 000m^3 of the overall excavated material will be available as cover material which is well short of the 120 000m^3 required.

Experience has shown that additional cover material is often included in the incoming waste in the form of builders' rubble and waste soil which could then supplement the shortfall.

5.2.2 Total available airspace

The total airspace available for waste deposition is generally determined by the shape of the final landform. For the Whein Town Landfill, this has been determined from the base area of the Landfill, the recommended slopes of the sides (1:3), and the maximum acceptable height. To achieve the required airspace of 890 000 m^3, a proposed final landform has been designed as shown on Drawing WT-CIV-602 (see Appendix).

Based on the levels as shown on Drawing WT-CIV-121, the average height of the Landfill will be about 15 m above original ground level at the highest point.

Using a digital terrain modelling (DTM) computer program, the calculated airspace between the excavated and prepared liner and the final landform surface is 890 000 m^3. This represents an airspace availability of only 5 years

at the assumed disposal rates. With provision having to be made for the planting of trees and shrubs around the perimeter of the site for screening purposes, additional airspace has been created by the deepening of landfill excavations in some places, the increase of its intended height and the creation of additional landfilling area on the entrance facilities area once the site has reached its maximum. These additions will provide an additional 15% in airspace. However final available cover material will determine the actual final airspace capacity.

5.3 Phasing

The site has been divided into four stage of development, which are shown on Figure 7 - Landfill Development Plan. Stages 0, 1 and 2 have been developed as part of the emergency requirements for the City. Stage 3 is the last and full development of the remainder of the site after general dumping of waste and development of two intermediate cells.

The concept is to fill the site in phases so that areas can be completed and returned to a vegetated state as soon as possible after filling has been completed. More important though is the control of uncontaminated rainwater in the constructed cells not filled with waste. Phase 1 of the stage 3 development has been prepared and is described in Section 8. The available airspace volumes are shown in Table 4.

Table 4: Available Airspace

Time	Nr	Annual Disposal Tonnage	Remaining Airspace
Years		**t/a**	**m³**
			861000
2010	1	118917	721098
2011	2	135567	561607
2012	3	153009	381596
2013	4	171267	180106
2014	**5**	**190372**	**-43861**
2015	6	210222	-291181
2016	7	230814	-562727
2017	8	252151	-859375

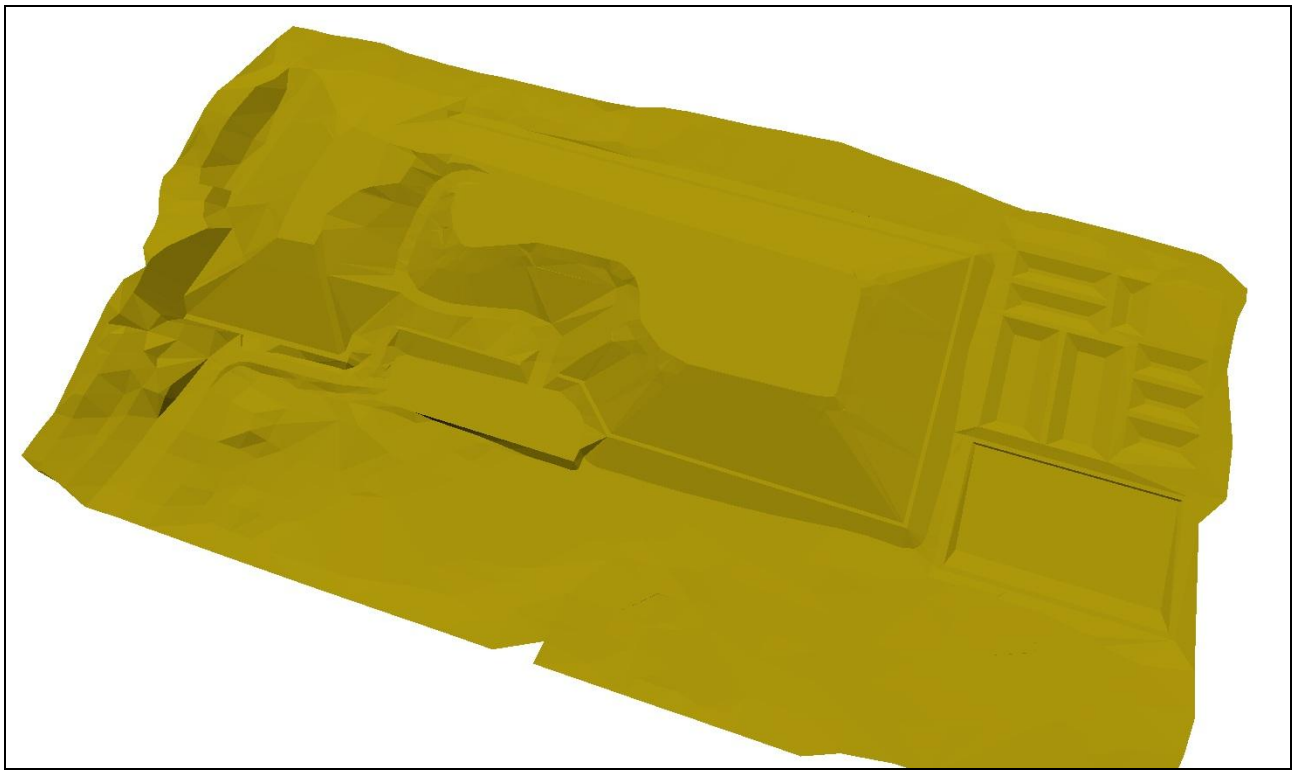


Figure 6: Final Landform (from the North)

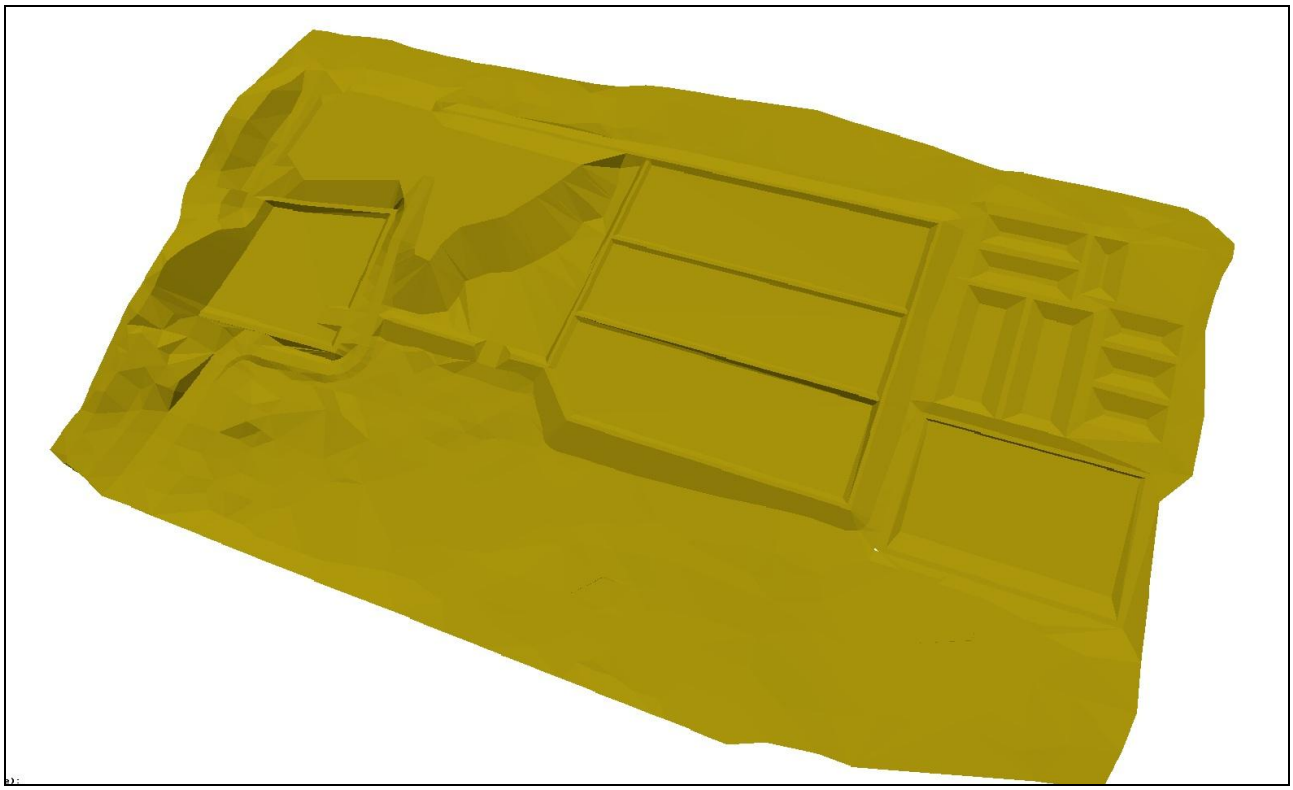


Figure 7: Stage 2 and 3 Cell Developments

5.4 Daily intake of Waste

The current population figure for the study area of Monrovia is estimated at approximately 1 050 000. The overall household waste generation rate during 2010 is estimated at 724 t/d for the Greater Monrovia.

Based on the current experience and an achievable goal, the city has adopted to collect 30% of all waste generated in 2007 and to improve on the collection system up to say 95% of all waste by 2020. Based on this approach it is anticipated that approximately 45% of waste be collected by 2010. It assumed that this would increase to about 60% in the next 5 years.

Typically as the socio–economical status of the community rises and the service level improves so does the generation rate and rate of deposition. This is further exacerbated by the population growth which implies a double growth factor. Planning for future containers and collection systems will thus be affected by this exponential growth situation.

Table 5 Daily Solid Waste Generation Rates and Collection per Annum

Year	Population	Generation	Collection Coverage	Collection	Collection
		[t/d]	[%]	[t/d]	[t/a]
2010	**1 058 478**	724	**45**	**326**	**118 917**
2011	1 086 015	743	50	371	135 567
2012	1 114 305	762	55	419	153 009
2013	1 143 333	782	60	469	171 267
2014	1 173 117	802	65	522	190 372
2015	**1 202 902**	823	**70**	**576**	**210 222**
2016	1 232 687	843	75	632	230 814
2017	1 262 471	864	80	691	252 151
2018	1 292 256	884	85	751	274 231
2019	1 322 041	904	90	814	297 055
2020	**1 351 825**	925	**95**	**878**	**320 622**
2021	1 381 610	945	95	898	327 686

It is thus estimated that the waste generation in the first year of the Landfill's life could be approximately 326 tons per day in 2010, increasing to approximately 576 tons per day in the year 2015.

5.5 Cell Arrangements

The initial cell arrangements are shown on the overall site layout. The sequence of filling the cells is shown on the detailed plans. Details of cell construction after the initial cells have been filled are given in Section 7. Cells will be filled sequentially. It is envisaged in the design that a layered filling pattern will be adopted, see Section 8.

5.6 Number of Site Personnel

The proposed minimum number of site personnel to run the site is twenty three as detailed in Table 6. Due to the size of operations the site does not have to be manned 24 per day.

Table 6: Site Personnel

Position	Landfill	Leachate Ponds
Site manager	1	
Site supervisor	1	1
Weighbridge attendant	2	
Gate controller	1	
Landfill compactor operator	1	
Track type loader operator	1	
Tipper truck drivers	2	
Water cart driver	1	
Labourers / Litter pickers	7	2
Night watchman	3	
TOTAL	20	3

5.7 Equipment Provided

The equipment provided to operate the site is listed below. (Operating manuals and Specifications will be appended to this document once the equipment has been purchased). Some of the equipment and facilities don't necessary have to be available on site but say at the Municipal depots.

5.7.1 Personnel Equipment Required

Minimum personnel equipment required during operations would be:

- Ear muffs
- Dust masks
- Head protection
- Eye Protection
- Safety boots/Wellington boots

- Overalls
- Shower equipment
- Reasonable shelters (as described below)
- Safety gloves.

5.7.2 Mobile Equipment

Minimum equipment or plant required on site would be:

- Waste compactor/Dozer (min D7)
- Front end loader (FEL)
- Water cart and spray bar (bowser)
- Tipper truck
- Utility vehicle for Landfill management

As waste collection improves and the waste volume increases a waste compactor as a minimum suited for waste management will have to be procured to achieve the required performances in operations at the Landfill.

5.7.3 Fixed and Other Equipment:

- Mobile litter screens
- Diesel Fuel Storage Tank

5.7.4 Monitoring Equipment:

- Leachate measuring device
- Leachate effluent sampling device.
- Gas detection device.

5.8 Site Operating Hours

The site will be open from Monday to Saturday during the following hours:

7 a.m. to 4 p.m.

The site will remain operational for a further hour**, to 5 p.m. to allow tidying up and the final part of the daily covering of the waste.**

The first waste load will arrive at about 9 a.m. and the last load at about 4 p.m. Before and after these loads, site preparation and closing operations must be done.

Collection from low to medium income areas could be high during weekends and should any sort of closure of the site be necessary, it should be scheduled for a weekday.

6 SITE PREPARATORY WORK

6.1 General

A plan showing the constructed Landfill prior to the commencement of filling is shown in Appendix J. Once the first phase of stage 3 of the site has been prepared to receive waste, the following engineering works will have been completed.

The following facilities are to be constructed on the site and are shown in Figure 11:

- Guard house
- Water supply tank
- Fencing and security boom
- Weighbridge, kiosk/guard house
- Office and welfare building
- Wheel cleaning bay
- Covered bay for Landfill equipment (Garage)
- Diesel Fuel Storage Tank (to be provided by supplier of diesel)

6.2 Site layout and planned development

The arrangement and sequence of development has been determined according to topography, drainage requirements, the distribution of excavation and fill as well as cover material over the site and access to the site.

To ensure an adequate depth of unsaturated zone beneath the Landfill (minimum 2m) the Landfilling activities are to be kept out of the western valley. Landfilling will proceed on excavated and prepared terraces, starting from the bottom of the floor slope working upwards with the drainage layer beneath the waste. This is opposed to the cells with no drainage layer and limited liner where filling is done from the top of the slope working downwards. Excavated material is to be stockpiled for use as daily cover and strategically placed close to the operation. The terraces are to be constructed roughly along the contour on both sides of the ridge.

The first order leachate treatment facility (oxidation ponds and constructed wetland) is to be located on the western side low lying area of the site. The wetland and future leachate ponds are conveniently located to accept leachate from the Landfilling operation without the need for pumping.

6.3 Access Roads

The access road to the site is as shown on Fig. 8

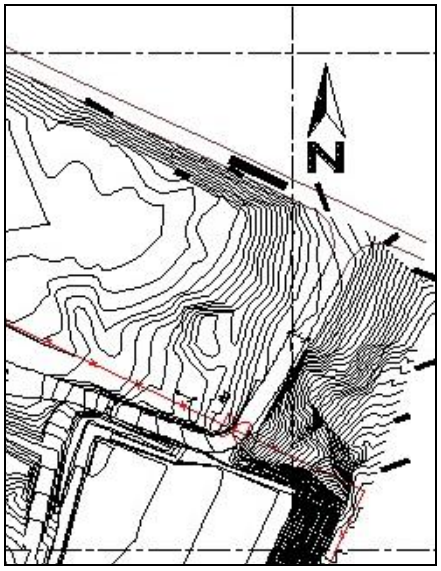


Figure 8: Access Road to the Landfill Site

A typical cross section of the access road is shown in Fig 9. Although the access road partly exists large sections has to be reconstructed and or upgraded.

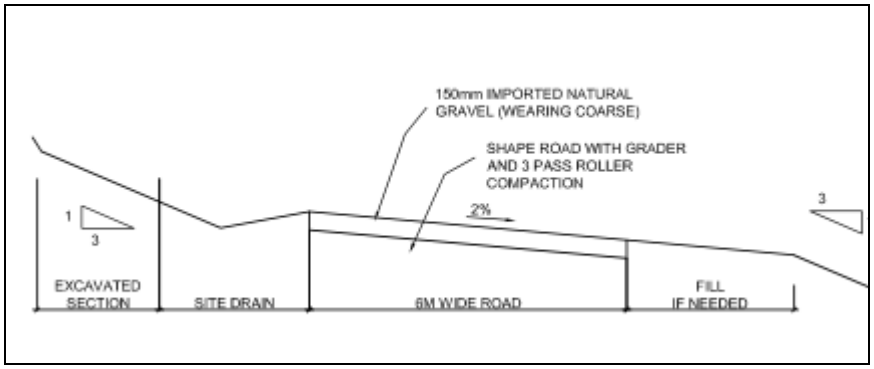


Figure 9: Typical gravel road cross section

Cover material will be carted from the stockpile to the cell via access and haul roads.

6.4 Fencing

The entire site is to be fenced with a 1,8m high security fence to prevent unauthorised access. Gates are to be provided at the entrance to the site and two other gates at the opposite side to allow access to the leachate ponds.

6.5 Facilities and Infrastructure

6.5.1 Access

Access to the site is currently through a newly developing residential area along a newly constructed asphalt road. A new short section of access road is to be constructed and surfaced with a double-seal bitumen surface from the access road up to the entrance to the site.

6.5.2 Infrastructure

A weighbridge and gatehouse are to be provided at the entrance to the site to control access and record quantities and types of incoming waste. This weighbridge can and should be moved to the new long term future site once the Whein Town site is exhausted and rehabilitated. The area around the entrance is to be paved and a vehicle mud trap (wheel wash) is to be provided.

Adjacent to the entrance, a fenced maintenance and administration area is to be provided. This would include an office building, and ablution, equipment storage and maintenance facilities.

Water and electricity is to be brought to the site. Potable water is to be provided either from a newly constructed borehole or tanker service provided by the MCC into a storage tank. Electricity is to be provided through an on site generator owned and operated by the Landfill operator. Area lighting is to be provided at the entrance and maintenance area.

Figure 10: Access and facilities

A partial ring road is to be constructed within the boundary of the site as well as outside on the southern side, surfaced with gravel wearing coarse, utilising locally available gravels.

6.5.3 Office and toilet

A shower, toilet and hand wash basin are included in the guardhouse toilet building.

6.5.4 Weighbridge, Kiosk/Guard house, Mobile Shelter

An 18m long weighbridge is positioned so that all waste vehicles entering and leaving the site can be weighed. Adjacent to the weighbridge is a kiosk where the weighing computer, visual display screen and printer will be located. The kiosk also acts as the reception point and guardhouse. Manual raising arm barriers are provided on either side of the kiosk to increase the security of the site. The gates at the entrance to the facilities area are controlled manually. A mobile shelter near the work face is to be provided by the contractor for use by personnel that will require it. The shelter will act as a rudimentary sun/rain cover and will be in addition to the permanent gatehouse shelter.

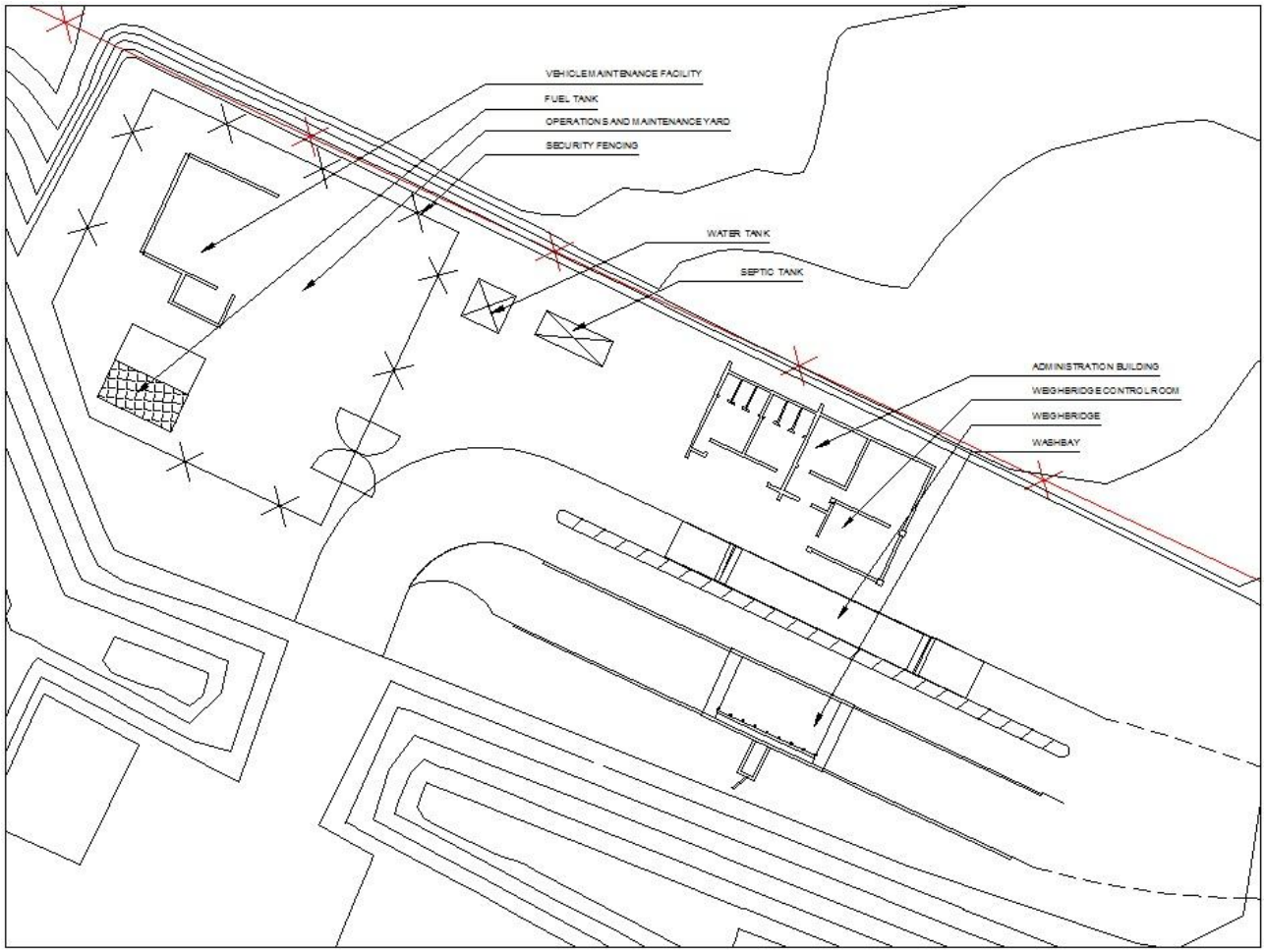


Figure 11: Facility Layout

6.5.5 Office and Welfare Building

This building houses the supervisors' office and mess room for the site personnel. A shower, toilet and handwash basin are included in the building. An enclosed storeroom has also been provided.

6.5.6 Wheel Cleaning Bay

Wheel cleaning is required because during wet conditions, litter and mud can be picked up at the tipping face by the collection vehicles. The release of this mud and particularly litter on the site access road creates an unacceptable environmental impact. A drained concrete hardstand for a high-pressure washer has been provided.

6.5.7 Site Information Boards

A notice board is to be positioned inside the entrance gates. Traffic and other relevant signs to assist with site movements are to be placed around the site in accordance with good engineering practice.

6.5.8 Lighting

Site lighting has been provided for the facilities areas to be supplied with electricity via a generator also housed in the workshop area.

6.5.9 Covered Bay for Landfill Equipment & Diesel Storage Tank

Allowance has been made for sheltering the equipment and plant on site in a cover bay inside a secured yard. Full time security will however have to be provided by the Landfill operator. To allow for some protection of the Landfill equipment a covered bay with sufficient space for three vehicles has been provided. A diesel storage tank with a hand-operated pump has been provided adjacent to the garage. Spillage from the tank will end up in the sand trap thus created. The polluted sand must be replaced from time to time and disposed of on the Landfill. This oil from the vehicles must be kept in suitable containers and taken to the oil suppliers for further processing.

6.6 Surface Water Cut-off Drain

A surface water cut-off drain has been constructed around the working area on the northern and eastern side of the site. This drain discharges to the water course/stream, which leaves the south-eastern and north western boundaries of the site. For future phases, the surface water drainage works should be extended as the site develops, to avoid pollution, as no surface water from the higher lying areas to the south-east should come into contact with the waste.

6.7 Subsurface Drains

During the soils investigation process it was established that the site had a high groundwater level. All structure thus built on site be it lined Landfill cells or soil platform has been provided with a subsoil drainage system.

6.8 Site Lining

A clay liner (augmented by a geomembrane) has been laid as a base lining to prevent leachate entering the groundwater. It is important that when filling commences, care is taken not to disturb the stone drainage layer, as this has been provided to protect the liner and act as a drainage layer. Within this drainage layer are leachate collection pipes, which carry leachate to the low points of the site within the Landfill cells. (See Figure 12 for leachate drainage layout) From here, the leachate flows through a pipe that breaches the clay liner at one location. The pipe discharges into a manhole and from there into the septage ponds via a collector system.

The leachate ponds are situated below the Landfill in the low lying area.

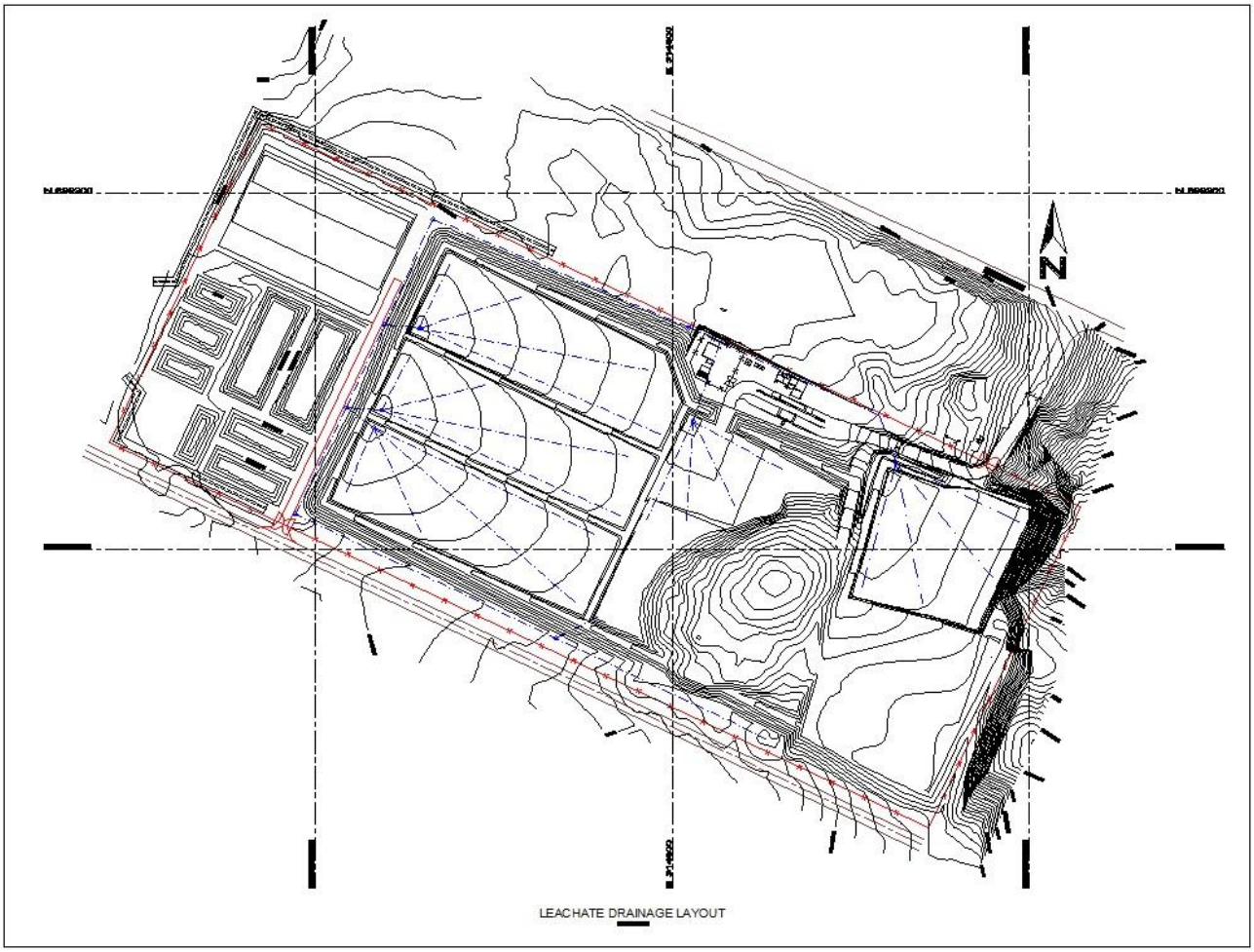


Figure 12: Leachate drainage system towards the leachate ponds.

The leachate ponds have been built with a combination of clay layer, a Geosynthetic clay liner (GCL) and HDPE liners. A subsurface drainage system has been provided below the clay liner, which will lead to a leakage-detection manhole. Monitoring details are discussed in Section 14.

6.9 Monitoring Borehole

A monitoring borehole (LIB 1) was sunk west of the site during the site investigation phase and is shown on the locality layouts. Monitoring details are discussed in Section 14.

6.10 Site or Haul Roads

The site roads have been extended to the working area (See Figure 18). Further roads for access to future lifts are shown on drawings in Appendix J.

The three haul roads provided on the site are indicated on Figure 13. Waste vehicles will generally enter the site and travel to the disposal area along haul road no 1. They will return via the same route and when necessary utilise the wheel-cleaning bay (if available) before leaving the site.

Cover material will be carted from the stockpile to the cell via haul road 2. A separate road has been provided for the compactor. Due care should be taken when driving the compactor on the haul roads to prevent excessive damage to these roads.

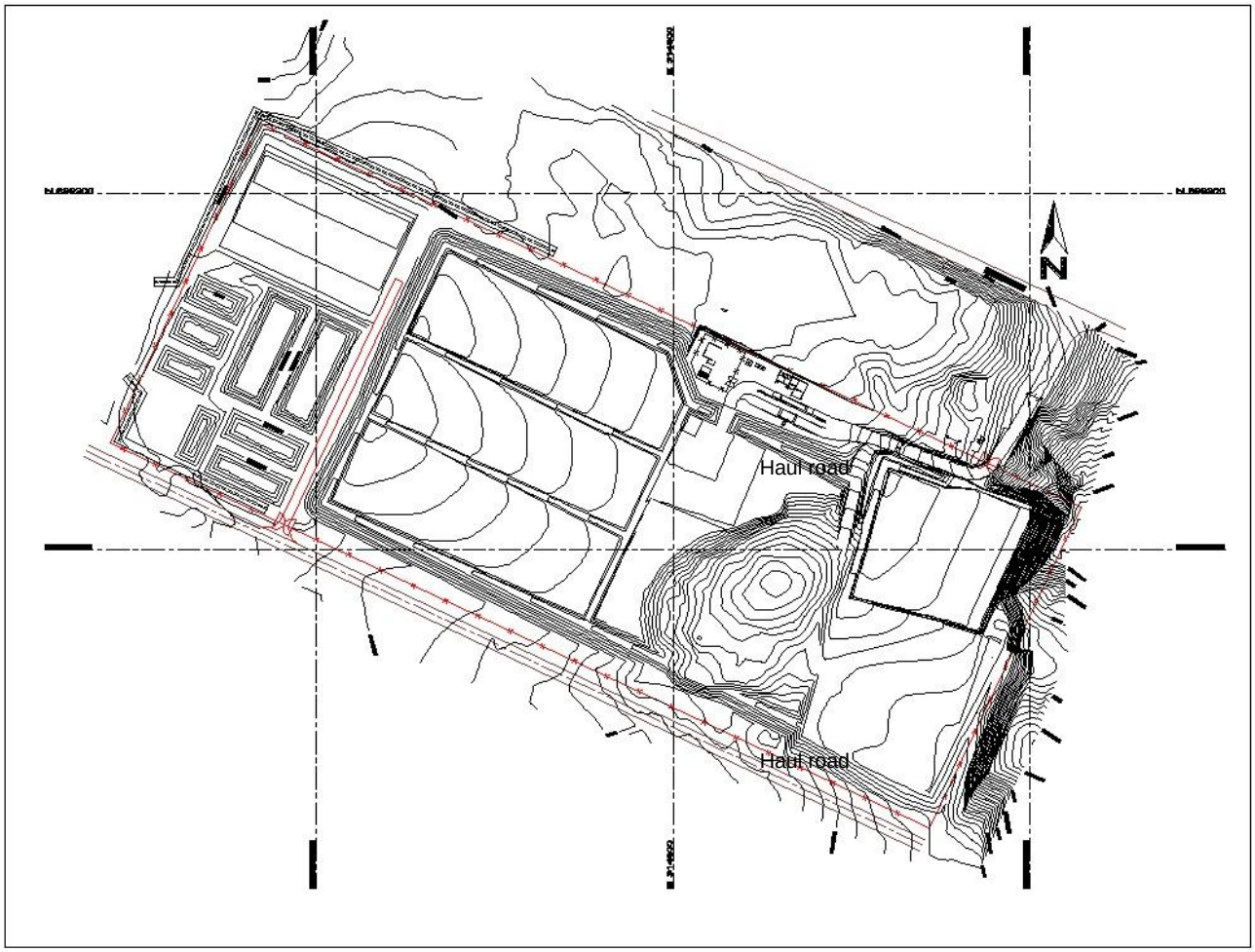


Figure 13: Site roads north and south

6.11 Greens Disposal Area

Certain waste types that will be brought to the Landfill are very suitable for producing compost, which could be enhanced by the co-disposal of the wastewater treatment sludge. The process is furthermore of a technical nature when considering that temperature, moisture content, rotation time of the windrows and drainage of the site has to be monitored and controlled.

Of particular importance is the necessity to provide proper drainage structures such as channels, a cut-off drain and a sump to collect and drain the contaminated water and collect the solids before the fluids enter the drainage pipes that will lead to the contaminate water ponds. This is of importance as no contaminated water must be able to impact on the groundwater.

Yard trimmings brought in by the parks department have to be chipped and will also act as a bulking agent for the wastewater treatment sludge to be co-composted. Once this has been done windrows from the potential compost must be formed over a perforated pipe (which is to provide aeration via a

compressor located at one end) and a temperature of approximately 65°C has to be maintained in the windrow. A moisture content of approximately 55% is ideal for composting. The turning of the windrows will be dictated by the required temperature and moisture content and to aid in its aeration.

Composting should only be considered at the early stage of the Landfill development once the Landfill is operational and a good understanding of the waste and composting market has been achieved. Compost that is made on site can be used as part of the cover material on the Landfill when doing the final capping.

6.12 Leachate Ponds

The following parameters were used in the construction of the leachate treatment ponds:

- Concrete access ramp slopes of 1:6 into anaerobic ponds A1 and A2, for desludging purposes.
- Pond embankment side slopes of 1:3.
- 200 mm diameter interconnecting pipework.

Table 8 summarises the leachate treatment pond design invert levels and corresponding top water levels.

Table 7: Invert Levels and Corresponding Top Water Levels

Pond	I.L. (m)	Top Water Level (m)
Anaerobic pond A1	77,0	80,0
Anaerobic pond A2	77,0	80,0
Facultative pond F1	77,0	79,5
Facultative pond F2	77,0	79,5
Maturation pond M1	76,0	77,5
Maturation pond M2	75,5	77,0
Maturation pond M3	77,0	79,0
Maturation pond M4	76,5	78,5

7 LANDFILLING OPERATIONS - WORKING FACE PRACTICE

The pre-forming of cells has been discussed in the previous section. This section discusses the method of Landfilling.

7.1 Vehicle Movements

In order to protect the liner system no vehicles are to drive on top of the stone drainage layers unless protected by a layer of waste.

Vehicles entering the site will be directed to the operating cell. The truck will enter the cell and be directed to the unloading area. The preformed cell width should be sufficiently wide so as to allow three vehicles to unload simultaneously. The truck will back up to the working area, taking due care and attention, and at this point it will discharge its load. The site personnel will assist in dislodging any waste that is hung up in the vehicle body. Once empty the vehicle will leave the cell. Vehicle movements are shown in Figure 14.

7.2 Waste Compactor Operations

The compactor (initially potentially a heavy dozer) will spread the waste over the short distance of the area being filled, driving backwards and forwards over the waste between two and six times depending on the type of waste being compacted. The waste should be built up in shallow layers, no more than 250 - 300 mm deep at a time, so that compaction is maximised. The daily work area should be kept to a minimum in order to conserve cover material. The optimum slope of the waste should be 1 in 12. The cell geometry is shown in Figure 15 and the Landfilling layers in Figure 16.

At all times care should be taken to avoid accidents involving collection vehicles and site personnel. If private collection contractors are allowed on site they should stay in their vehicles. Personnel should keep away from the compactor due to the possibility of flying objects shot out by the steel wheels.

7.3 Difficult Wastes

7.3.1 Categories

Certain wastes require special care when Landfilling. These wastes may be categorized as follows:

- bulky crushable items: furniture, white goods (cookers, refrigerators, washing machines and other appliances)
- car bodies, engines, sheet and metal sections, tyres
- tree stumps, boulders, other large items
- wire and other similar material

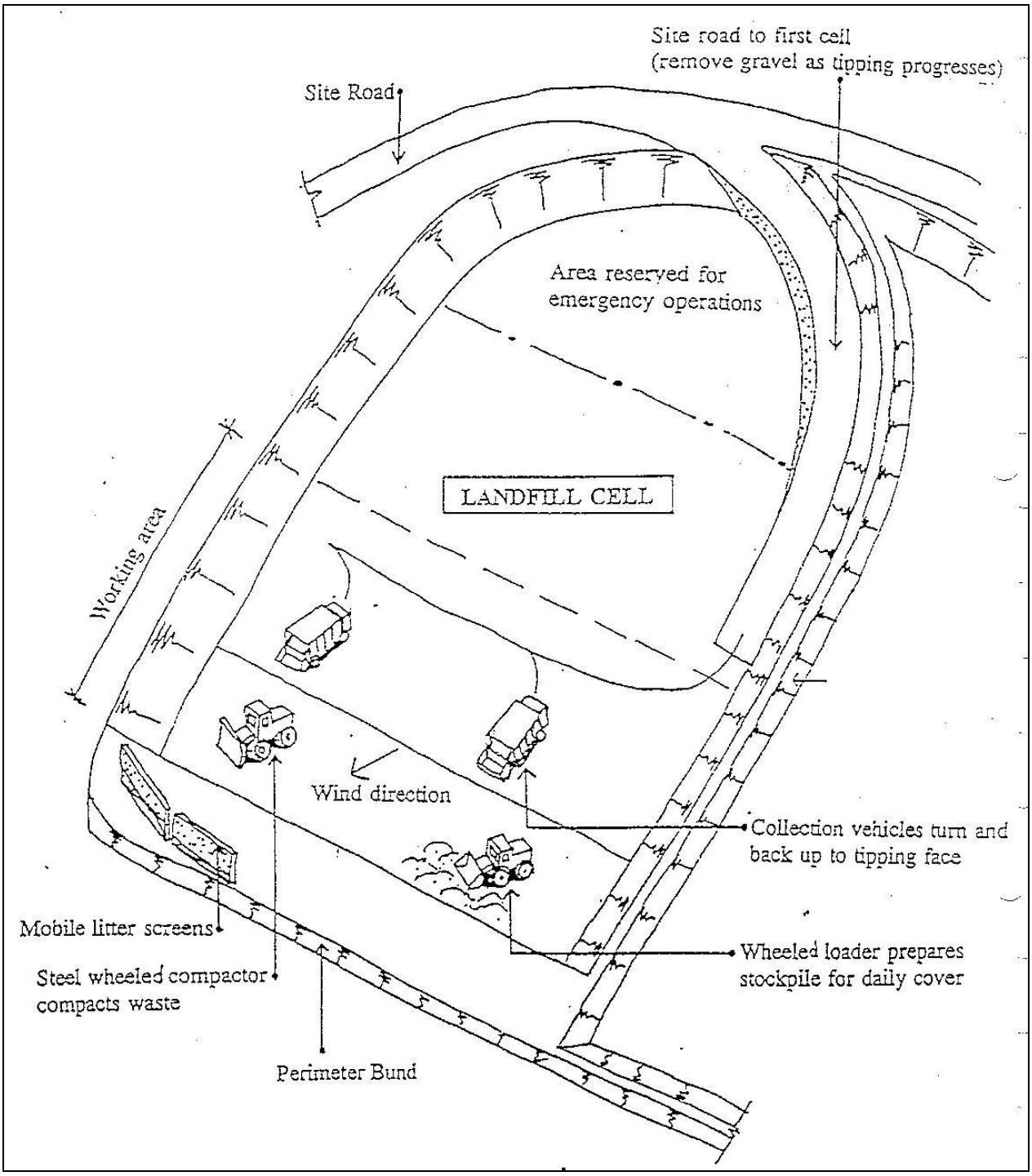


Figure 14: Typical Vehicle Movements

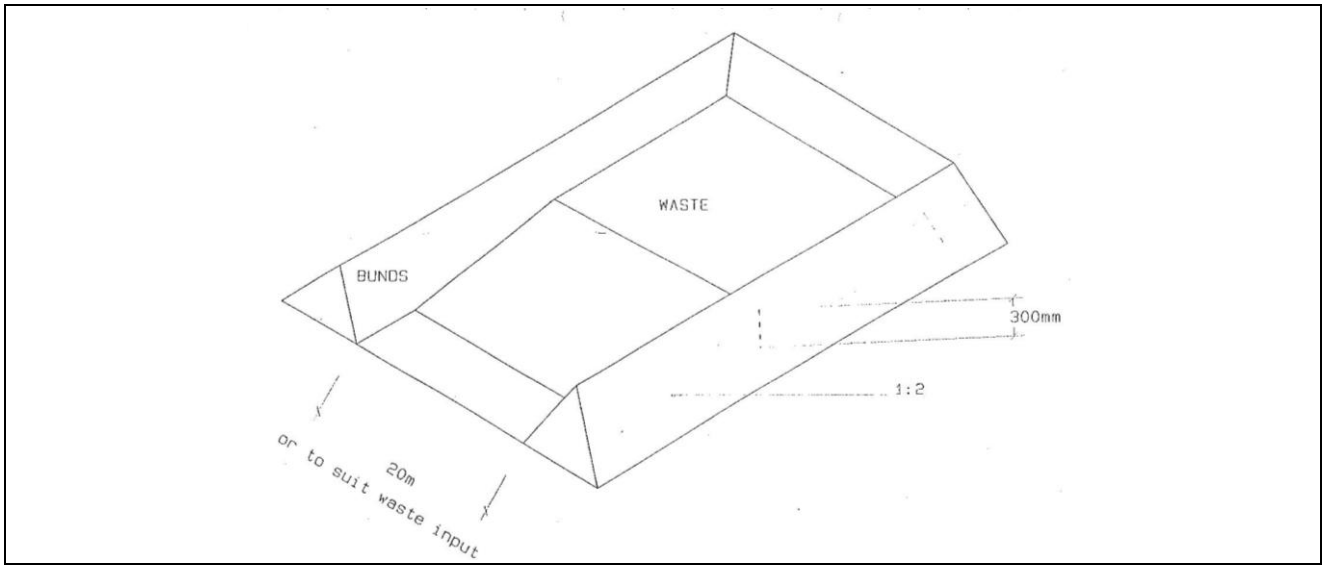


Figure 15: Typical Cell Geometry

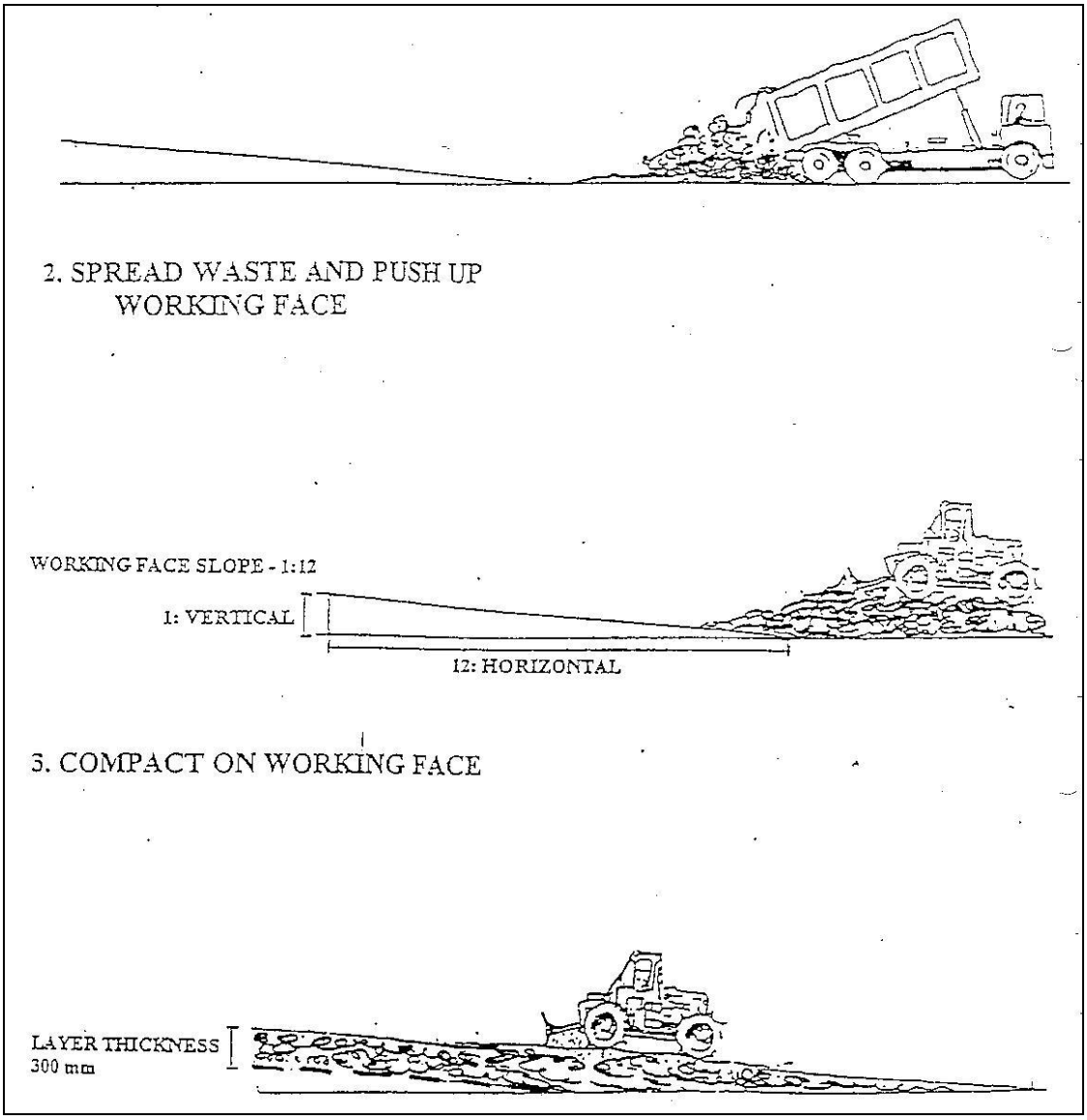


Figure 16: Typical Landfilling Layers

- condemned food, dead animals, offal, odorous matter
- drums and containers
- mud, sludge's, dust, light weight and fluffy material, waste oil
- permitted chemical waste

Regulations may be in force prohibiting some of the above wastes from being deposited. These regulations should be consulted regularly and respected. As a general guide the wastes described in Appendix D should not be landfilled.

7.3.2 Methods of placing

The main options for dealing with any of the permitted difficult types of waste is either to locate them near one of the inner cell dividing walls or to ensure that they are covered as soon as possible after arrival at the site. Particular methods that should be followed are as follows:

- Hollow items should be crushed

- Fridge and freezers should have their coolant removed and recycled as the gas used depletes the ozone layer. If stored in public access areas their doors should be removed as children have been known to suffocate whilst playing and hiding in discarded units.

- Tyres should be cut up as they have a tendency to rise to the surface if left intact (see new **Tyre Regulations**)

- Items needing to be speedily covered, which should be buried using other waste or cover, or placed in trenches are as follows:

    - Animal carcasses
    - Animal or fish waste, condemned food or other obnoxious material
    - Permitted medical waste

- When not forming compost the sludge from the wastewater treatment ponds, when desludging, should be co-disposed with the general waste in the Landfill by digging a long 2m trench and once the sludge is disposed of in the trench, it should be filled with waste and cover material.

7.3.3 Safety

Generally all difficult types of waste should not be located near the outer side, base or surface of the Landfill, a buffer of at least 5 m of other waste should be provided between the difficult waste and the boundary of the fill. With all these types of materials extreme care must be taken to ensure that the waste

is deposited in a safe manner. The general rule is to locate difficult (dangerous) wastes in such a way that it could be retrieved at a later stage when other techniques of waste handling are available locally.

7.4 Covering Waste

The most important aspect of solid waste disposal is the daily covering of waste

During the working day the FEL will be stockpiling cover material adjacent to the working area. This material will be used to spread over the day's waste input. The daily waste covering will form a sub-cell within the main cell. The layer should be kept as thin as possible to conserve material and void space. Typically a layer approximately 250 - 300 mm should be deposited. Under certain circumstances, for example if any builders waste or sub-soil is brought to the site, it may be possible to use this material as part of the daily cover. The criteria for use as cover is that it should be inert, for example soil, sub-soil, sand, clay, bricks, broken concrete, hard-core or a mixture of these materials.

When a cell is filled to the full height and it is anticipated that some time will elapse before a further layer is built on the waste, the top surface of the cell should be covered with an intermediate layer of cover 300mm thick. Some of this layer can be removed and reused as daily cover immediately prior to commencement of filling of the next layer.

7.5 Wet Weather Disposal

Under certain weather conditions, during exceptional storms for example, it may not be possible to use the normal cell being filled. A cell near the entrance of each lift should be designated for use during these conditions. The cell shall operate on a surface, which is of coarse material and well drained, such as builders' rubble.

Notwithstanding the above, the bottom of the working face area should at all times be shaped to ensure drainage of stormwater away from the working area.

Certain abnormally high amounts of waste may be directed to the site, for example debris from natural disasters. Under these circumstances the advice of the senior management should be taken with respect to the method of disposal.

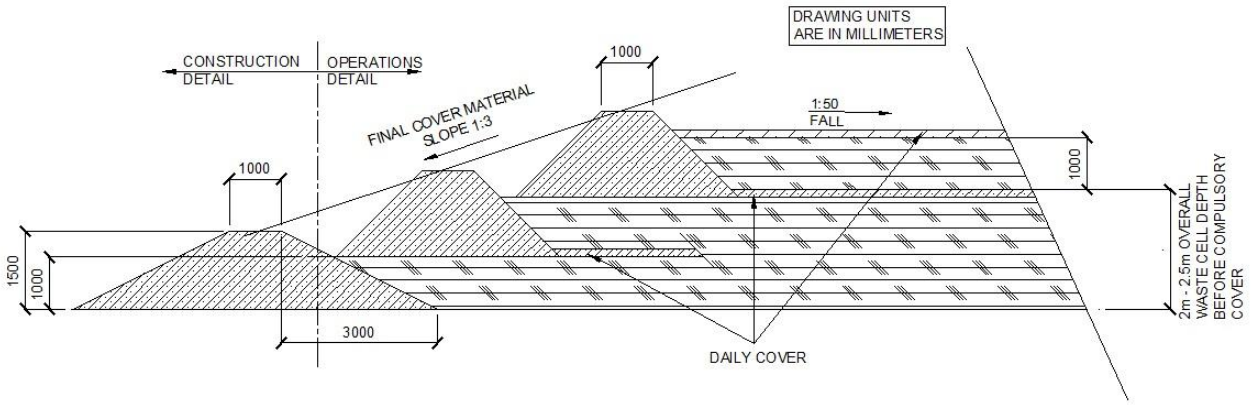


Figure 17: External Bund Construction

7.6 Long Term Settlement

Owing to the poor available data on the waste stream, long term settlement cannot be accurately predicted and the full benefit of the creation of extra airspace cannot be fully utilised. Consequently, it is suggested that analyses of the waste stream be conducted at regular intervals to establish its composition in terms of being rapidly biodegradable, slowly biodegradable or non-biodegradable and its moisture content.

The extent of long term settlement is subject to a wide variety of variables, the most important of which are the composition and moisture content of the incoming waste stream. Under current knowledge of the waste stream, long term settlement is expected to be in the order of 20%. This will have the effect of creating the same amount of additional airspace (over the entire life of the site) and of allowing for a steepening of the side slope gradient during the operational phase of the Landfill. This slope will then decrease in steepness according to the amount of settlement. A table, showing the appropriate slope at which the Landfill should be built, for various settlement percentages, is presented below.

Table 8: Required Initial Landfill Slopes

$V_1 / V_2 = f$	s_1
1.05	2.86
1.1	2.73
1.15	2.61
1.2	2.50
1.25	2.40

V2 and V1 are the Landfill volumes with, and without, settlement, respectively. S1 is the required Landfill construction slope (i.e. 1:s) to allow a final Landfill slope of 1:3.

8 LANDFILL OPERATION - CELL CONSTRUCTION AND SEQUENCING

8.1 Cell Construction

8.1.1 Cell construction and bund formation should be within the capabilities of the site operating staff, using the equipment and plant proposed for normal operations. The initial cells have been constructed as part of the site preparation works. Details of bund construction are given in Figure 17. Remaining drawings show a lift by lift filling profile for the various landfilling operation phases are shown in Appendix J.

8.1.2 The size has been determined to allow say two vehicles to back up to the working face at the same time, and for the site to be divided into a convenient number of bays. The size of the cells can be varied to suit actual waste inputs and seasonal variations as determined by actual working practice.

8.1.3 Additional perimeter bunds should be constructed using basic construction methods. These details are given in Appendix C. The use of a tipper truck on an occasional basis when the perimeter bunds are being formed may be advantageous as larger quantities of soil can be moved around the site by using a truck.

8.1.4 For internal bunds forming daily cell walls, the material used should be taken from the site spoil stockpile. The walls should be 1.5 m high with 1 vertical to 1.5 horizontal sides.

8.1.5 As work progresses across the site it may be possible to reuse some of the intermediate bund material as daily cover to maximise the available void space. Alternatively, the central core of the bunds can be formed using incoming refuse. Where builders' rubble comes into the site, this material can also be used for bund construction or daily cover of refuse. Extreme caution should be taken not to damage the liner when constructing the bunds, using building rubble, during the first lift.

8.1.6 When the cell has been filled to its full 1.5m depth above ground level, the remaining half meter of the intermediate and perimeter (Lift 2 onwards) cell bunds should be removed and spread over the waste as cover.

8.2 Development Sequencing

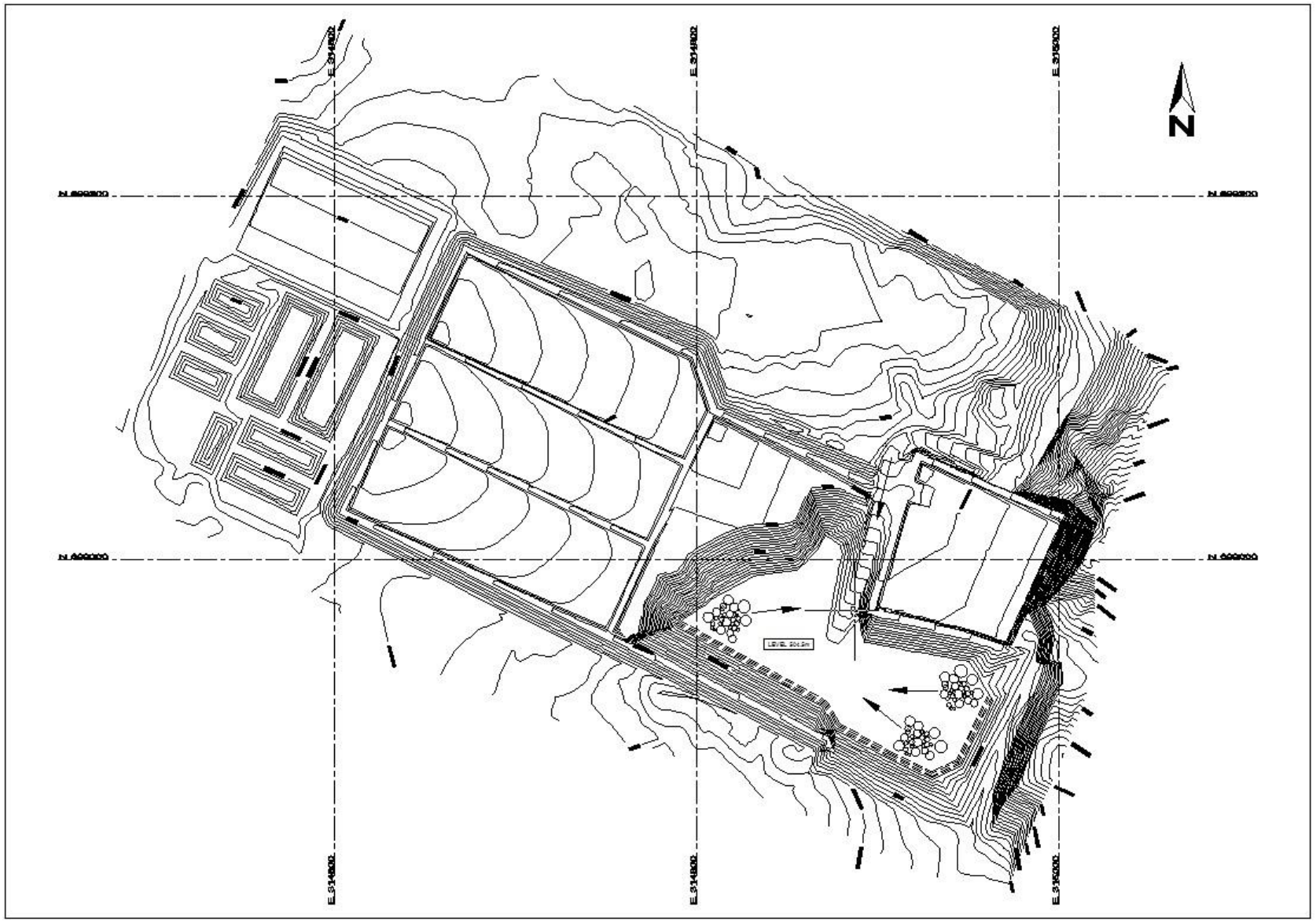
8.2.1 The sequencing of the development stages have been developed to ensure that waste is deposited on the high ground and thus not in any potential rain runoff. Run off from earlier stage development as well as phases 1, 2 and so on also discharges away from the waste body.

8.2.2 Phase 1 is to be landfilled with waste to its maximum practicable height before commencing with landfill in subsequent phases. This will be determined by vehicle accessibility and by the containment of surface runoff from the waste body within phase 1. Prior to reaching the top of the perimeter bund, a new perimeter bund must be constructed as per detail on Figure 17. (Refer also to Appendix J figures).

8.2.3 Similarly phase 2 is to be landfilled with waste to its maximum practicable height before commencing with landfill in phase 3.

8.2.4 Care must be taken to limit the noise created at working face. Scheduling the stockpiling of the cover material during a time when the off loading of the collected waste is not taking place, which is generally before 9 a.m, should aid in minimising the noise. The compaction of the waste and the spreading of the cover material can then take place. The spreading of the cover material should also be arranged when the disposal vehicles are off site.

Figure 18: Start of Phased Fill Operations (All remaining drawings in Appendix J)



9 LANDFILLING OPERATIONS - ANCILLARY OPERATIONS

9.1 Landfill Gas

As the Landfill and waste to be received is anticipated to be very dry with no or limited moisture no Landfill gas is expected at the Landfill facility.

Caution: Accumulations of Landfill gas can be extremely dangerous. Concentrations higher than 5% can result in fires or even explosions. Furthermore Landfill gas can cause suffocation and possibly poisoning. Extreme care should therefore be taken when entering / working in enclosed confinements such as manholes, rooms, etc.

9.2 Leachate Management - Water Balance

9.2.1 Analyses of the climatic water balance for this region show that significant leachate is expected at the Landfill facilities.

9.2.2 When the rain falls on the waste a certain amount is absorbed into the waste mass. When this absorptive capacity (field capacity) is reached the excess liquid percolates through the waste becoming leachate. This liquid is a source of pollution. Leachate is brown or black in colour and has a high chemical and biochemical oxygen demand. Before discharging to a watercourse it should be treated to an acceptable standard.

Caution: Leachate can be infectious and/or toxic. Extreme care should therefore be taken when working with Leachate to minimise contact with skin. Protective equipment such as rubber gloves and boots should be worn.

9.2.3 The method of treatment proposed is to drain the leachate down to the leachate ponds. Ponds have been provided where the leachate will be treated based on an attenuation/oxidation process.

9.2.4 The calculation of leachate production and sizing of the ponds are theoretical. The production rate needs careful monitoring, as it is imperative that no leachate be allowed to enter the surface or groundwater streams flowing through the Landfill site. For this reason leachate ponds were constructed as the treatment facility to process the leachate on-site to an acceptable standard thus enabling its discharge into the near-by watercourse without subsequent environmental damage.

9.2.5 Typical water balance calculations are contained in Appendix E.

9.3 Site Roads

From time to time it will be necessary to extend the site haul roads to obtain access to successive lifts. The roads should be at least 5 m wide and made of either stone or crushed aggregate or selected hard-core (broken bricks or concrete) delivered to the site as part of the waste input. Site roads should be maintained and kept in good order to minimise damage to the refuse vehicles.

9.4 Site Drainage

All drainage structures such as manholes, inlet/outlet structures, channels etc. should be inspected to ensure functionality at all times. Attention should be given to control erosion.

9.5 Composting Area

The proposed composting area will require the operation of a compressor forcing air into the composting heap through a 100mm perforated pipe placed at the bottom of the windrow. Some 350kg of air per cubic metre of waste are required. This will aid in aeration of the compost. Operation of the pump will have to be according to a schedule, so that it is not left running for excessively long periods. For this reason it is also necessary to conduct maintenance on the pump. Guidelines on both maintenance and acceptable operating periods should be obtained from the manufacturer.

10 LEACHATE TREATMENT POND – PROCESS OPERATIONS

The operation and maintenance of the leachate treatment pond system is discussed in detail in the subsequent sections.

10.1 Desludge matrix and flow routing

Flow sequencing through the leachate treatment ponds is determined by desludging operations. The process of desludging will begin with a submersible pump pumping fluids through a flexible hose out of the treatment pond to be cleared. The exposed sludge layer is removed by front-end-loader (FEL). Sludge solids can be taken to the Landfill site for disposal either by the FEL itself or by a tipper truck which is to be loaded by the FEL.

It is recommended that the anaerobic ponds A1 and A2, and possibly Facultative pond F1 and F2 be desludged only when necessary and no sooner. The concentrated form of the leachate will create sludge in anaerobic ponds 1A and 1B relatively rapidly and it is thus suggested that these ponds be operated as settling ponds. The level of sludge build-up in A1 and A2, in this particular instance, is governed by the outlet pipe leading to the outlet structure and whether it is blocked or not. Control should thus be exercised in this regard.

Upon the ponds' commissioning, it is suggested that the following operating procedure be followed:

- Full flow should be allowed into *either* pond A1 or A2 until it begins overflowing into the second set of ponds, i.e. facultative pond F1 and F2. Flow will then be shared between the two ponds A1 and A2.
- The second set of ponds will then receive influent and, as before, the flow will initially be diverted into only one pond until that pond overflows into the Maturation pond 1. Flow will then be shared between the two ponds F1 and F2.
- The effluent will then pass through maturation Ponds M1, M2, M3 and M4 over a period of time.

Once the system has been running for some time, it will be necessary to begin desludging ponds A1 and A2 in an alternating pattern. It should be remembered that there is no maximum permissible level of sludge except one which ensures the prevention of blockage of the inlet pipe into the outlet structure.

When desludging does eventually prove necessary in ponds A1 and A2, it is suggested that it be done at the end of the rainy season.

Since any of the following ponds can be bypassed;

- Anaerobic pond A1
- Anaerobic pond A2
- Facultative pond F1
- Facultative pond F2

flow sequencing is dependent on which leachate pond is being desludged. Table 9 lists flow sequencing routes, should one of the ponds need to be desludged.

Table 9: Flow sequencing routes

Pond being desludged	Flow route
Anaerobic pond A1	A2 to F1 and/or F2 to M1 to M2 to M3 to M4 to Constructed wetland
Anaerobic pond A2	A1 to F1 and/or F2 to M1 to M2 to M3 to M4 to Constructed wetland
Facultative pond F1	A1 and/or A2 to F2 to M1 to M2 to M3 to M4 to Constructed wetland
Facultative pond F2	A1 and/or A2 to F1 to M1 to M2 to M3 to M4 to Constructed wetland

Flow routing is achieved by removing or inserting the relevant handstop in one of the flow control structures, which are, located between the Leachate treatment ponds.

10.2 Testing of effluent

Testing of effluent will be done off site in a laboratory that is familiar with the required tests. BOD and COD loading levels, nitrate and phosphate levels etc. will be tested.

Regular testing of effluent will be necessary during the phase in which the process establishes an equilibrium. Effluent loading levels must at no time exceed 75mg/l BOD. Testing could thus be done monthly or bimonthly. Once equilibrium has been established, testing can be done less regularly, perhaps annually or twice annually.

10.3 Disposal of sludge

Disposal of sludge can occur either by co-disposal on the Landfill site or by use in the composting process. Co-disposal of sludge should occur during the driest months when leachate flow through the waste body is at its minimum.

Because of the uncertain nature of both the compost material i.e. organic matter, and of the sludge to be disposed, precise quantities of sludge for composting cannot be prescribed. Rather, this is an operational problem which must be dealt with once greater clarity has been reached on the composition of both components for composting and of the availability of sludge from the ponds. Cognisance must also be taken, when calculating suitable sludge/compost ratios, of other factors such as odour nuisance, time of year (affecting weather) etc. Of importance, too, is the sensitivity of the calculations to the assumed evaporation factor (0.7) and field capacity (0.6) of the waste.

In the case of desludging for co-disposal on the Landfill, the sludge is to be taken to the Landfill either by a tipper truck working in conjunction with a front end loader (FEL) or by an FEL alone (if the offloading point is close enough) once the ponds have been properly drained and the sludge is of such a form that it can be handled by earthmoving equipment. Disposal on the Landfill will occur in trenches made in *in situ* waste where the sludge will be mixed with waste to an acceptable co-disposal ratio. The co-disposal ratio is the volumetric ratio of compacted solid waste to liquid waste. The fairly rapid formation of sludge in the anaerobic ponds 1A and 1B will necessitate desludging fairly early on and it should be noted that the sludge should only be disposed of in areas of the cell which already have adequate waste disposed to allow for mixing with the sludge. Sludge can thus only be disposed of in these regions.

A sludge liquid content of 80% is accepted and has been allowed for in the calculation of co-disposal ratios. The ratios are shown for different heights of the trench bottom above the Landfill base.

Table 10: Co-Disposal Ratios

H(m)	Ratio
10	24.4
12.5	20.9
15	19.1
17.5	18.0
20	17.2
22.5	16.7
25	16.3
27.5	16.0
30	15.7
31.5	15.6

If odours prove a problem with the co-disposed sludge, it is recommended that LDPE be used to line the trench and, at the end of each day of deposition of co-disposed sludge, the trench be covered with the LDPE. This alternative is, naturally, costlier than ordinary co-disposal and should only be employed should conditions dictate it.

11 LEACHATE TREATMENT POND OPERATIONS – ANCILLARY OPERATIONS

11.1 Flow Control Structures and Pipework

There are 4 types of flow control structures. The four flow control structures perform the same function of:

- Determining the preceding pond top water level, and
- Diverting flow by means of handstops to facilitate bypassing of succeeding ponds for desludging.

The four flow control structures vary only in their layout and subsequent size. To ensure that the flow control structures operate as designed, daily inspections at each structure are to occur.

Weir plates are to be checked, and if any solids are fouling the flow over the weirs, these are to be dislodged.

Any solids which may get lodged in the handstops frames and foul the smooth operation of the handstops are to be removed.

All pipework is to be rodded regularly, to prevent any blockages in the pipes.

11.2 Access Ramps

The concrete access ramps at Anaerobic pond 1A and Anaerobic pond 1B are to be kept clean.

The access ramps are to be swept clean of any possible spills, thereby preventing a spill build-up and subsequent accumulation of scavenging birds e.g. vultures and crows.

When desludging of the ponds take place the disposal of the sludge should be done as described in Section 10

12 SITE MAINTENANCE & GENERAL ENVIRONMENTAL CONSIDERATIONS

12.1 Site Maintenance

The site should be kept clean and tidy at all times. Part of the duties of the site staff should be regular site maintenance activities. The following items should be regularly inspected, once a week for example, and problems reported so that repairs can be undertaken:

- Site fencing and security gates
- Access road
- Buildings
- Fixed equipment

12.2 Environmental Evaluation

An environmental evaluation was undertaken prior to the design of the site, the findings and recommendations of this evaluation are referred to and salient issues are contained in Appendix F. The Environmental Management Plan that addresses the environmental impacts is discussed in section 16 and further.

12.3 Litter, Mud and Dust

12.3.1 With the cell method, the Landfilling activity is undertaken in a protected area as the cell walls help to minimise the effect the wind has on the placed refuse. However, when the site is operational it will become apparent that under certain wind conditions light waste, paper, plastic film etc. will be lifted from the working area. Under these circumstances the mobile litter fencing should be positioned to trap the waste. These fences should be cleaned at the end of each working day.

12.3.2 Similarly, waste will be dropped on and around the access and site roads by badly laden vehicles. Litter may also become lodged in parts of the boundary fence and surrounding vegetation. This litter should also be removed on a daily basis.

12.3.3 Dust may also become a nuisance in the dry months. A bowser (water tanker with ground spray bar) should be issued so that the site roads can be damped down to suppress dust generation.

12.4 Bird Control

Birds, particularly crows, can be a problem at Landfill sites. They are undesirable as they pick up and deposit unwanted remnants, which may be obnoxious, on the surrounding area. The bird problem will be minimised by good working practice, keeping the working area to a minimum and covering the waste at the end of each working day.

12.5 Pest Control

If the recommendations for Landfilling are followed problems with infestations of flies and rats should be minimised. Covering of the waste is the most important requirement. Should vermin infestation occur the public health department should be contacted and pesticides applied. Personnel need to be trained in pesticide application and protective clothing should be worn. The rodent control officer should be contacted should these pests become a nuisance.

12.6 Odours

12.6.1 The characteristic Landfill odour is generated by the decomposition of putrescible (decomposable food and vegetable) matter. Odours are minimised by covering waste. It is known that tipping waste into standing water increases the possibility of odour generation; therefore depositing waste into water should not be practised.

12.6.2 If it becomes necessary to prevent odours leaving the site for the sake of reducing the nuisance created, the following action may be taken – spreading hydrated lime over newly filled or saturated wastes or in the long term flaring off Landfill gas.

12.7 Fires

12.7.1 Waste materials should not be burnt. The natural degradation within the Landfill will reduce the volume of organic material. The following should also be noted in particular:

- Burning plastics is an environmental hazard.
- Any hot or burning waste that arrives on the site should not be deposited with the waste. It should be allowed to burn out and cool before being deposited.
- Smoking will be restricted to designated smoking areas.
- If any fire occurs the Fire Service should be called.

12.7.2 If safe to do so the waste on fire should be isolated before the Fire Service arrives and covered with earth or cover material to smother the flames. Fire extinguishers may be used on small fires.

12.7.3 The personnel should be trained in procedures to be adopted if a fire is noticed on the site. Local Fire Services should be consulted on the best procedures to be adopted.

12.8 Existing Vegetation

All existing vegetation should be retained as far as possible to help control soil erosion; to regulate catchment outflow; to provide visual screening; and to buffer noise emissions from disposal operations. It is envisaged that the Environmental Department should be involved to attend to any site cultivation work such as planting of trees around the site as screening mechanism.

All existing vegetation should be retained as far as possible to help control soil erosion; to regulate catchment outflow; to provide visual screening; and to buffer noise emissions from disposal operations. It is envisaged that the Parks Department will attend to any site cultivation work.

Vegetation which encroaches on the pond embankments is to be cut back regularly. No trees, bushes or grass taller than 300 mm is allowed on or around the leachate treatment pond embankments. Flow control structures are to be kept clean of encroaching weeds or any vegetation growth.

12.9 Drainage systems

The drainage systems normally associated with a Landfill site address three components:

i) Uncontaminated upslope run-off
ii) Contaminated run-off from the Landfill itself, and
iii) Highly contaminated leachate generated within the Landfill.

Generally, the uncontaminated upslope run-off is diverted around the site into a natural drainage course. Surface run-off from uncovered waste on the Landfill is considered to be contaminated, and should not enter natural drainage courses without prior treatment or sufficient dilution. Leachate should similarly not enter the natural water regime without prior treatment or purification.

12.9.1 Uncontaminated run-off

Uncontaminated run-off is to be prevented from entering the Landfill by means of a 2,5m high berm/bund constructed along the boundary of the site. This

berm/bund together with the ring road would also act as a drainage control for upslope run-off and as a screen for the Landfill operation. In particular, flow from the seasonal stream upslope of the north-western side of the site is to be diverted along the northern boundary in a westerly direction.

Uncontaminated run-off from virgin areas of the Landfill site, from completed covered areas of the Landfill and from within the cover excavations are to be directed off the Landfill site into the natural stream.

Uncontaminated water might also need to be discharged into the contaminated water dam for dilution purposes.

12.9.2 Contaminated run-off

Contaminated run-off from exposed portions of the Landfill is to be collected in open earth toe-drains along the inside of the bunds around the toe of the Landfill. These drains would discharge into the leachate ponds. The main contaminated water dam or leachate pond is located at the lower western end of the site including a constructed wetland. The water quality in these ponds would have to be monitored before release into the stream.

Once the Landfill has reached its final height and has been suitably covered and vegetated, run-off from the Landfill would be considered as uncon-taminated, and would by-pass the toe drains to discharge directly into the environment.

12.9.3 Leachate drainage

Since it has been established that the Landfill will produce significant volumes of leachate, a comprehensive leachate management system for the collection, treatment and disposal of leachate is to be provided. This would include a lining system between the waste body and the in situ soils to minimise infiltration of leachate into the ground water. The details of the lining system and the leachate collection system are discussed separately below.

12.10 Leachate management

12.10.1 Geomembrane liner

The Landfill cells have been lined with 1,5mm HDPE geomembrane liners. The geomembrane liner specification for the general waste Landfill is as follows:

- Compact 150mm clay base.
- 1,5mm thick HDPE lining.
- A geotextile fabric over geomembrane as protective layer.
- A 300mm thick layer of selected gravel as a leachate drainage layer.
- A geotextile fabric over the stone drainage layer.

Installation of the liner required skilled labour and expertise and care should be taken not to damage the liner in any way.

12.10.2 Leachate collection and treatment

Leachate emanating from the waste will appear in the gravel drainage layer over the geomembrane liner and will flow down-slope beneath the Landfill towards the secondary leachate collector pipes. These pipes consist of 100 and 150mm dia. perforated PVC pipes placed at approximately 30m centres.

The secondary collector pipes will discharge into primary collector drains running along the toe of each terrace (see Drawings WT/101). The primary collector drains will comprise 200mm dia. perforated pipes set in a 0.6m x 0.6m trench filled with gravel.

These primary collectors will discharge into a 200mm dia. leachate gravity drains running along the toe of the Landfill to discharge into the head of the leachate treatment facility. Manholes are to be provided at the junction of each primary collector with the leachate drain, for inspection and maintenance purposes.

Note that the leachate collector and discharge pipes have been sized from a practical point of view and can therefore handle flow rates far greater than the expected maximum flow rate of 10l/sec (see Appendix E).

12.11 Gas management

On account of the high organic content and high moisture content of the waste stream, it is highly likely that the When Town Landfill will produce Landfill gas. Since the site is to be operated according to sanitary Landfilling principles with daily covering of waste, proper ventilation has to be provided. This is necessary to prevent the build-up of gas not to reach potentially explosive levels and to prohibit the lateral migration of gas from the site. To achieve this, rock filled gabion chimneys are to be constructed within the waste body, extending upwards as the Landfill rises. A soil berm is to be placed around each chimney to prevent ingress of surface run-off. These gas chimneys are to be spaced at approximately 1 per 0,1 hectare.

When the Landfill has reached its capping level the gas vents need to be sealed off with bent vent pipe and clay seal over the stone chimneys (see details on drawings).

12.12 Water quality monitoring system

As the Landfill is expected to produce significant quantities of leachate, a long term water quality monitoring programme is to be implemented. This would involve background analyses, detection monitoring, investigative monitoring and post closure monitoring.

The objectives of the water quality monitoring system are:

- to indicate any escape of leachate into the environment and to quantify its effect
- to serve as an early warning system so that pollution problems that arise can be timeously identified and rectified.

The water quality monitoring system therefore includes the monitoring of surface water bodies, ground water, leachate and leachate effluent. Water and leachate samples are to be collected and analysed for the water quality parameters normally associated with Landfill sites as listed below. The details of the water quality monitoring system are as follows:

12.12.1 Background analyses

Ground water and surface water samples are to be taken from all the current and proposed boreholes on the site and from the existing streams prior to Landfilling. These samples are to be analysed to obtain background water quality data. A set of baseline tests have been carried out as part of the EIA but will be supplemented with the establishment of new monitoring boreholes.

12.12.2 Surface water

The surface water bodies in the vicinity of the site are the nearby tributaries.

Sampling points should be established in the nearby stream and its tributaries, both upstream and downstream of the Landfill.

Samples should be taken and analysed every 3 months.

12.12.3 Ground water

The ground water monitoring system design should comprise a minimum of three boreholes for this size of Landfill. One borehole would be up gradient of the site where there is no risk of pollution from the Landfill and two would be down gradient where pollutants would most likely migrate. In the siting of the proposed investigative boreholes for the next phase, cognisance must be taken of these long term monitoring needs, so that the boreholes can serve a dual purpose.

Ground water should be sampled and analysed at six monthly intervals; once at the end of the wet season and again at the end of the dry season.

12.12.4 Contaminated run-off dam

The water contained in the contaminated run-off dams is to be sampled and analysed regularly, particularly during the wet season, to determine whether or not the water can be discharged into the adjacent streams. Sampling should be done at least every three months. If the water is too contaminated for release into the environment, it must be diverted into the leachate collection system for treatment in the leachate treatment system. Alternatively it could be sprayed onto reclaimed sections of the Landfill using a mobile pumping system – only possible in the dry months.

12.12.5 Leachate

The leachate which is discharged into the leachate treatment system is to be monitored on a three monthly basis to determine its quantity and quality.

12.12.6 Treated leachate effluent

The treated effluent from the leachate system is to be monitored on a weekly basis to ensure that the quality complies with the accepted effluent standard for discharge into a natural water course. This, together with the leachate monitoring results, will be used to monitor the performance of the leachate treatment system.

12.12.7 Water quality analysis parameters

For background monitoring the following chemical analyses should be done:

Mercury (Hg)	Electrical conductivity
Alkalinity (P Alk)	Potassium (K)
Cyanide (CN)	Calcium (Ca)
Nitrate as N	Free and Saline Ammonia (NH_4)
Boron (B)	Sodium (Na)
Total Chromium (Cr)	Chemical Oxygen Demand (COD)
pH	Sulphate (SO_4)
Cadmium (Cd)	Chloride (Cl)
Lead (Pb)	Magnesium (Mg)

Detection monitoring on a three or six monthly cycle should include the following chemical analyses:

Alkalinity (P Alk)	pH
Chemical Oxygen Demand (COD)	Potassium (K)
Chlorine (Cl)	Total Dissolved Solids (TDS)
Nitrate as N	

On an annual basis, however, the analyses should include the following:

Calcium (Ca)	Magnesium (Mg)
Electrical Conductivity (EC)	Sodium (Na)
Fluoride (F)	Sulphate (SO_4)

12.12.8 Reporting

The analyses of all samples should be submitted to the MCC, to be forwarded to the appropriate environmental authorities.

12.13 Composting

Referring to the composition of the waste stream almost 40% of the waste stream in Monrovia consists of organic or vegetable matter. By composting the organic fraction, not only will valuable Landfill airspace be saved but will a valuable resource be produced.

12.13.1 Compost Benefits

The following benefits are presented when compost is mixed with soil:

- Physical benefits
  - Improved soil structure, reduced density, increased permeability (less erosion potential)
  - Resists compaction, increased water holding capacity
- Chemical Benefits
  - Modifies and stabilizes pH in the soil
  - Increases cation exchange capacity (enables soils to retain nutrients longer, reduces nutrient leaching)
- Biological Benefits
  - Provides soil biota –healthier soils
  - Suppresses plant diseases

Having organic waste in the Landfill could create negative impacts on the environment. Organic wastes decompose anaerobically in Landfills and produce methane.

- Methane is a leading contributor to global warming, and Landfills are leading sources of methane in the U.S.
- Methane is expensive to manage at Landfills
- Organics also contribute to "leachate" (the liquids that seep through Landfills) which is also expensive to manage.
- Composting produces neither methane nor leachate

By composting organics the following benefits will be created:

- Composting creates a value-added product with excellent environmental benefits
- Reduces dependence on expensive and polluting Landfills and helps postpone need for new Landfills.
- Saves money for companies and communities that discard organics.
- Creates jobs, tax base, and capital investment.

- Compost improves soil "tilth", provides nutrients, and helps control plant disease.

In terms of Landfilling the following benefits would be generated apart from saving of Landfill airspace:

- Compost would enhance/ameliorate the soil cover material which would be required as part of the final Landfill cover. This in turn would ensure the speedy vegetation of the surface of the Landfill. Should composting be done closer to the generation source will transportation costs of the collected organics be reduced. However, a balance has to be struck between the distances travelled from the organic waste generator and the end user of compost.

12.13.2 Negative issues associated with composting

To enable to production of composting large areas of land are required to allow stockpiling in windrows of the compost material during the periods of fermentation. The compost material furthermore has to be rotated and watered for a period - anywhere between 6 weeks and 4 months. With the Whein Town site already extremely limited no additional land will be available on site to set up a compost plant. Should a section of the Landfill be identified for composting purposes then two operations will effectively have to be run on the Whein town site. The biggest challenge then to face the MCC would be to separate the organics from the incoming general waste (plastics, metal, wood, textiles, etc.) steam as the collection and disposal is done in mixed form in Monrovia. Two operators will then effectively have to manage the site(s) at an increased cost.

Where large pieces of land are available the two processes (Landfilling and composting) can be run simultaneous and divorced from one another. A programme for separate waste collection and or disposal should then be initiated. At present and with the extreme pressure to have the Landfill facility up and running it is not considered practical and thus feasible to develop a composting process in parallel to the Landfilling at the Whein Town site other than informal composting as a secondary process to the Landfill operations.

12.13.3 Future composting

It would without a doubt be advantageous to consider composting as part of waste management in the future planning of Landfills for Monrovia. As with all waste management aspects planning is essential and in this case provision for additional land has to be planned and provided for to accommodate the production of compost. Planning would include the logistics in transporting the organic material to and from the compost site. Also how waste will be separately collected so that the combined waste stream does not have to be segregated at cost to extract the organic fraction from the stream. The process of separate collection should start without delay before the development of a new Landfill so that plans for a composting facility whether

combined with the Landfill or a separate site could be based on actual waste stream composition and collected volumes.

12.14 End-use and rehabilitation of the Landfill

The objectives of the end-use design of the Landfill are as follows:

i) To create an aesthetically acceptable landform with gentle slopes (not exceeding 1:3) that, as far as possible, blends in with the surrounding terrain.

ii) To maximise the Landfill airspace available for waste disposal and hence the site life.

12.14.1 Final landform and end-use

As an initial approach, the proposed final shape of the Landfill has been determined according to drainage and end-use requirements.

The Landfill is to be shaped to final contour levels, roughly following the original topography in the low lying area up to the same level as the local hill. Due to the gentle topography and the depth of available cover, the maximum height of the Landfill is to be about 20m above the original ground profile. The upper surface of the Landfill is to have general slopes of at least 1:20 to promote rapid drainage of the Landfill surface.

Regarding the end-use of the site, it is recommended that it be returned to the local people for open space or for the resumption of agricultural activities. The end-use of the site should, however, be discussed with all stakeholders as part of the ongoing public participation programme to ensure that the rehabilitated site is acceptable to them.

12.14.2 Closure and rehabilitation

As the different sections of the Landfill are completed to final height, these are to be appropriately shaped, graded and covered with a final capping layer comprising two 150mm thick layers of compacted clayey material. This capping is to be covered with a 300mm thick layer of the original topsoil.

Re vegetation of the completed areas is to commence as soon as possible after capping. Indigenous trees and shrubs are to be planted around the site for screening purposes, as well as in any areas where the substrate will support tree growth. Over the rest of the site, grass is to be established using indigenous grass types.

The intention is to implement what is known as "the rising green wall effect" by progressively grading and vegetating the side bunds and then working behind them.

Provided the vegetation is always maintained during operations, there should be no need for later rehabilitation. After closure, ongoing maintenance of the Landfill capping and vegetation will be required.

13 EQUIPMENT MAINTENANCE

13.1 Manufacturer's Instructions

All site equipment should be maintained in accordance with the manufacturer's instructions. Copies of the equipment instruction booklets should be available on site for reference.

13.2 Daily Inspection

13.2.1 At the commencement of each working day a walk around check should be undertaken. Points to check are shown in Figure 19. In addition to this check, a daily and weekly maintenance check should be carried out. Points to check are itemised below. All checking operations of equipment should be carried out on level ground with all hydraulic equipment at its lowest level.

13.2.2 Typical Operators Maintenance Schedule - Loading Shovel

(For guidance only, refer to manufacturer's instruction book and schedule as necessary)

THINK and ACT SAFELY at all times. If in doubt ASK.

Lower all raised equipment before carrying out any checks or servicing.

Daily Tasks:

- ***Check - before starting engine:***
  Radiator coolant level
  Engine oil level
  Fuel level
  Precleaner (Dust filter)

- ***Check - with engine at low idle:***
  Engine oil level
  Hydraulic oil level
  Transmission oil level
  Bevel gear and steering clutch oil level

- ***Walk around check and report any defects***

- ***Grease*** *Grease Points*

Bucket lift arms *4*
Bucket pivots *6*

Weekly Tasks:

- ***Check -***

Batteries
Fan belt tension and condition
Final drive oil level

- ***Grease*** Grease points

Bucket linkage	18
Track frame outer bearing	2
Fan pulley bearing	1
Steering pedals	5
Governor control	1

- Oil
- Bucket positioner
- Drain sediment from fuel tank if necessary

13.3 Equipment Cleaning

At the end of each week all equipment should be cleaned. In particular windows, rear view mirrors and lights should be kept clean at all times.

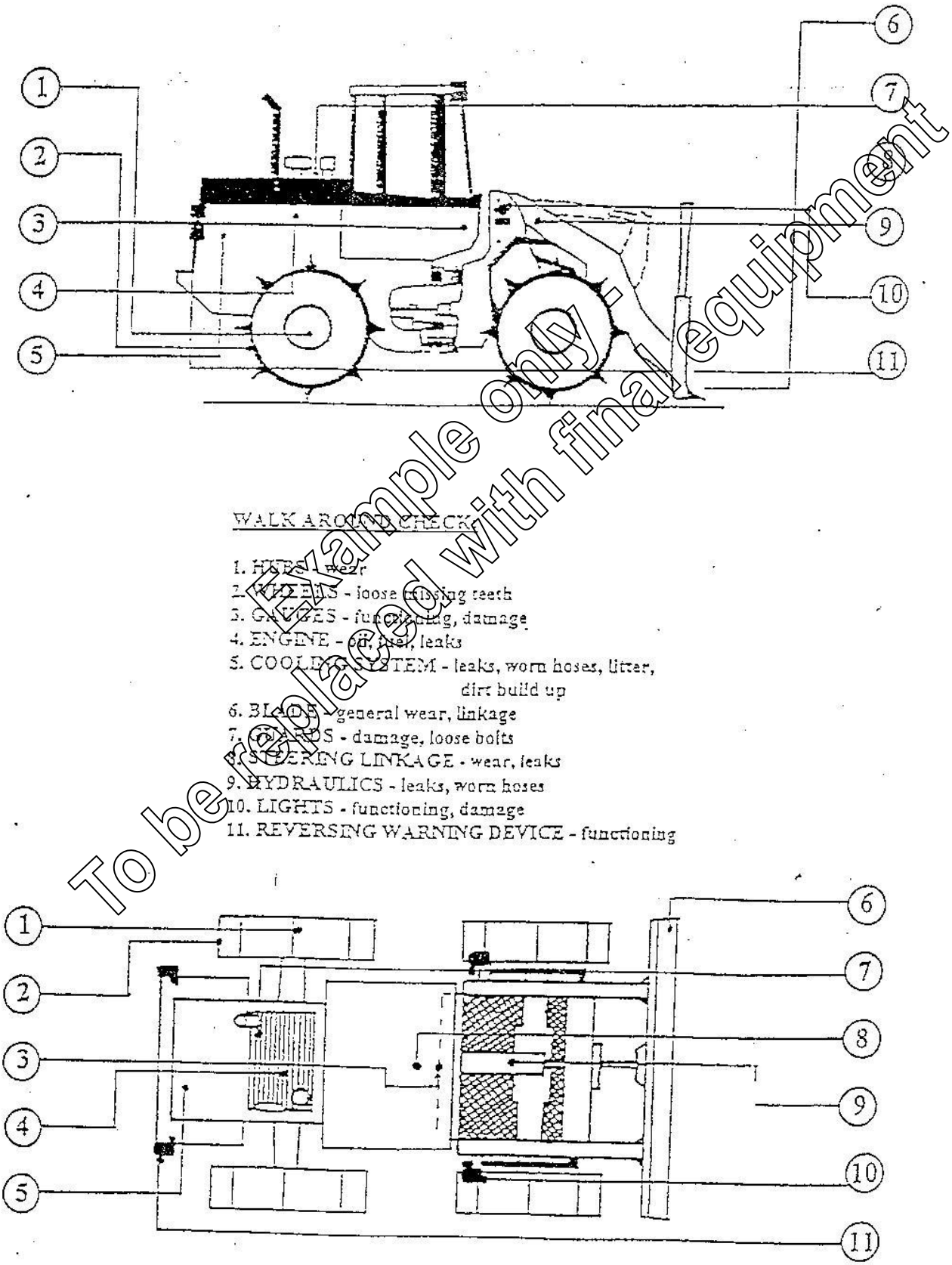


Figure 19: Equipment Walk-around Checks

14 RECORDS AND MONITORING

The EMP is discussed in Section 16 and onwards which details the monitoring requirements for operation of the site and must therefore be read in conjunction with this section.

14.1 <u>During operation of Landfill site</u>

14.1.1 Waste input records

Daily records of the waste entering the site should be kept. Where a weighbridge is not present tallies or estimate of truck loads could be taken or made. Table 11 shows details of how the records should typically be kept. A daily summation of the amounts of different categories of wastes should be kept, together with monthly and yearly totals. This information is important for amongst other things the future planning and design of the Landfill can be made more accurate.

Table 11: Daily Waste Input Records

Vehicle no	Time	Wastes		Weigh in	Weigh out (tare weight)	Amount delivered	
		Source*	Type**			Solid waste	Cover material
					TOTAL		

Whein Town Landfill Facility **Date:**

Signature ……..

Instructions:
[To be completed for each vehicle each time it makes a delivery]

* R = Residential C = Commercial
I = Industrial A = Agricultural

Other codes as appropriate
**H = Household
B = Bulky waste - Furniture, Refrigerators, etc.
D = Demolition / construction
T = Tyres

14.1.2 Daily Activity Summary

A daily activity summary showing the amount of waste Landfilled, the daily cover used and machine and man hours, should be completed by the site supervisor. Details to be recorded are shown in Table 12.

Table 12: Daily Activity Summary

Date	Solid waste		Cover Material				Man hours	Machine hours		Site Hours
	Loads	Tonnes	Begin 50 000 m^3	Received	Used	Remain		Use	Down	
1st										
2nd										
3rd										
etc.										
TOTAL										

Whein Town Landfill Facility Month Year

Date	Operator	Man hours	Vehicle Identity	Machine hours		Site hours
				Use	Down	
1st						
2nd						
3rd						
etc.						
TOTAL						

Signature ……..

Instructions:

[To be completed by the site supervisor at the end of each day. The record of cover material should be in either tonnes or cubic metres. Today's beginning material equals yesterday's remaining. The cover material on site at the end of the construction of phase 1 is approximately 50 000 m^3.]

14.1.3 Filling

The rate of filling of the site should be monitored by surveying the site at three monthly intervals to determine the rate of airspace utilisation.

14.1.4 Settlement

Areas of the site that have reached the final level and have been finally covered should be monitored for settlement (see final restoration section for their method of construction). A suggested settlement monitoring programme is given in Table 13 below.

Table 13: Settlement Monitoring Guideline

Activity	Interval
General inspection of covered areas, looking for obvious depressions, cracks, and pools of water.	Weekly
More **rigorous inspection** of Landfill, looking for smaller cracks and depressions.	Monthly
Checking of level of survey benchmarks on Landfill cover using survey equipment.	Annual

To minimise settlement, it is necessary that good, uniform compaction of waste is achieved.

14.1.5 Leachate

The BOD loading of effluent from Maturation pond 4 is to be monitored on a monthly basis. An approved local testing authority is to be appointed to conduct monthly BOD loading tests on the effluent. An effluent BOD loading of < 75 mg/ℓ was designed for.

Refer to Tables 17 and 18 for the monitoring and testing of leachate.

14.1.6 Surface Water and Groundwater

Refer to Table 17 for the monitoring and testing of surface and groundwater. The surface water monitoring points as well as the groundwater monitoring wells are shown on Figure 19. These points have been marked and numbered on site. Borehole nr. xx and Well nr. yy were placed as a background check well.

14.1.7 Landfill gas

As stated in Section 9, the Landfill gas vents will be constructed and extended upwards as filling progresses. Each month, or more frequently as directed, the composition of the Landfill gas should be analysed. Other parameters,

apart from composition, which are of importance, and which can be readily monitored, are temperature, pressure and flow. Concentration measurements require greater expense and technology. The gases to be monitored are methane, carbon dioxide and oxygen.

Composition

Catalytic oxidation units are the most suitable and the most inexpensive way of detecting flammable gases. However, owing to their fairly coarse detection capability, they should not be used for more than detection purposes. Carbon dioxide, another important Landfill gas, can be detected with chemical indicator tubes. This method is uncomplicated and relatively inexpensive although it is also important here that they not be used for anything more than detection purposes.

Pressure

A simple manometer is sufficient for measuring Landfill gas pressure levels. As suggested in the British guideline "The Monitoring of Landfill Gas – Second Edition" released by the British IWM, a simple U-tube with a measuring tape could be used judiciously. Pressure build up is an obvious warning of potentially dangerous gas accumulation.

Flow

Gas flow and velocity are most easily measured by instruments using a differential pressure method, such as a Pitot tube or orifice plate. Gas flow and velocity are important in investigating gas migration.

Temperature

Temperature is the most readily measurable gas characteristic.

Concentration

Measuring of concentration is performed with any number of instruments, some of which are inhibitively expensive. It is once again stressed that chemical indicator tubes and catalytic oxidation detection units be used only for detection purposes.

Caution: Accumulations of Landfill gas can be extremely dangerous. Concentrations higher than 5% can result in fires or even explosions. Furthermore, Landfill gas can cause suffocation and possibly poisoning. Extreme care should therefore be taken when entering / working in leachate manholes. Standard confined space entry procedures should be posted at the site, and workers should be trained in them and properly equipped.

Standard confined space entry procedures would include gas monitoring prior to entry, no smoking or open flame, always at least two people working with one outside the confined space to rescue the one inside, use of a harness and rope so that the person in the space can be pulled out without another person having to enter, use of ventilating fans, and, if appropriate, use breathing equipment.

14.1.8 Surface Water

The surface water monitoring points are shown on Figure 19. These points have been marked and numbered on site.

14.1.9 Diesel Spillage

Diesel that is spilled from the diesel storage tank will collect in the sand bed constructed around the diesel filling area. The sand must be inspected on a regular basis and replaced with clean sand. Spillage must be minimised and pipes must be kept leak free.

Any soil or gravel around the diesel tank that becomes contaminated should be removed to the Landfill cell and replaced with clean soil or gravel.

14.1.10 Performance Evaluation

From time to time the operations will be audited by senior management or an outside agency to check and ensure compliance with the requirements of the EMP (see Section 16). Typically the list of items that should be examined is shown in Table 15 and 16 in checklist form.

14.1.11 Costing – Tipping Fees

Due to the nature and methods of disposing of the different waste types expected at the Landfill, a differentiating fee scale is proposed to recover costs that have been incurred to establish the facility as well as the daily costs to operate the Landfill facility. (See Table 14 for proposed tipping fees). A study rate setting for the site should be consulted for a clearer understanding of the costing/tipping fee relationship.

A rate differentiation has been made between the waste delivered by private concerns and the local authority, to promote the use of the public service on the one hand, but also due to the erratic flow of waste by the large private concerns.

Waste that is seen to enhance the Landfill operations such as clean topsoil and clean building rubble could be disposed of free of charge. Tyres, due to their tendencies to float upward, as well as other difficult waste should be charged a specific fee. Materials such as asbestos should be charged high rates so as to promote the principle of "producer has to take responsibility for his product from cradle to grave".

In order to promote the separation of clean greens waste from the general waste stream, a reduction in the disposal fees should be given. This would enhance the production of compost at a later stage.

Finally a levy should be imposed on the waste that is delivered to site that should cover the cost of closure of the Landfill (end capping etc.)

Table 14: Tipping Fee

Item	Disposer	Waste Type	Rate – US$* e.g.
1	Local authority	Clean dry waste	8 / ton
2	Local authority	Clean compostable waste	6 / ton
3	Public	Clean dry waste < 1000 kg	Free
4	Public	Clean waste > 1000 kg	6 / ton
5	Public	Clean compostable waste	4 / ton
6	All	Clean building rubble	Free
7	All	Clean topsoil	Free
8	All	Tyres < 40cm	1 / tyre
9	All	Tyres > 40cm	2 / tyre
10	All	Difficult waste (Asbestos etc.)	45 / ton (item)

* Rates to be based on final assessment of municipal rates.

14.1.12 Leachate

Leachate monitoring is of primary importance during operation of the Landfill site. The following requirements for leachate monitoring are included in Table 18 and Figure 20 giving an holistic monitoring plan for the site which should include groundwater and gas monitoring.

Table 15: General monitoring requirements

Monitoring requirement	**Frequency of monitoring**
At or near surface monitoring	
Rainfall	Daily
Runoff (Volume, quantity)	Daily
Toe seepage from waste	Monthly
Soil cover on waste	Annually
Vegetation on waste or soil	Annually
Bioassaying	Annually
Within waste or unsaturated zone	
Gas samplers	Monthly
Leachate collectors	Monthly
Groundwater monitoring	
Special monitoring holes	Necessary
Other holes	Necessary
Groundwater levels	Three monthly
Groundwater chemistry	Three monthly
Borehole yield	Annually
Groundwater usage	Annually
Fountain seepage	Monthly
Water balance	Monthly

Table 16: Performance Evaluation

		Satisfactory	Not satisfactory	Remarks
1	General method of working in accordance with plan and specification			
2	Site security			
3	Condition of site roads			
4	Control of tipping area width of face			
5	Compaction and formation of layers to specified depth			
6	Depth of primary cover			
7	Primary cover completed each day			
8	Measures for handling difficult waste			
9	Litter control			
10	General site tidiness			
11	Arrangements for bad weather or emergency working			
12	Employee's amenities			

13	Fire precautions			
14	Pest control measures			
15	General Remarks			
	Etc.			

14.2 Post-closure monitoring

All gas and water monitoring should continue into the post-closure phase.

All gas and water monitoring should continue into the post-closure phase. Water monitoring should be conducted for both surface and groundwater although emphasis should be placed on groundwater monitoring. Post-closure monitoring should continue for some 30 years after closure unless some other period is required by Liberian regulations. It is also necessary that the administrative requirements for closure of a Landfill site, as laid out by the EPA, be met.

Table 17: Parameters for Background and Investigative Monitoring

Ammonia (NH_3 as N)	Electrical Conductivity (EC)
Alkalinity (Total Alkalinity)	Free and Saline Ammonia as N (NH_4-N)
Lead (Pb)	Magnesium (Mg)
Boron (B)	Mercury (Hg)
Cadmium (Cd)	Nitrate (as N) (NO_3-N)
Calcium (Ca)	pH
Chemical Oxygen Demand (COD)	Phenolic Compounds (Phen)
Chloride (Cl)	Potassium (K)
Chromium Hexavalent (Cr^{6+})	Sodium (Na)
Chromium (Total) (Cr)	Sulphate (SO_4)
Cyanide (CN)	Total Dissolved Solids (TDS)
E-Coli	Other Pathogenic Organisms

Table 18: Parameters For Detection Monitoring

Bi-annually for:	Annually for:
Ammonia (NH_3 as N)	Magnesium (Mg)
Alkalinity (Total Alkalinity)	Calcium (Ca)
Nitrate (as N) (NO_3-N)	Sodium (Na)
Electrical Conductivity (EC)	Sulphate (SO_4)

pH	E-Coli
Chemical Oxygen Demand (COD)	Other Pathogenic Organisms
Chlorides (Cl)	
Potassium (K)	
Total Dissolved Solids (TDS)	
E-Coli	
Other Pathogenic Organisms	

Figure 20: Water monitoring points (to be updated after final field work)

15 FINAL RESTORATION AND DECOMMISSIONING

15.1 General

15.1.1 Several months before completion of the first phase of tipping, the site preparatory work for the second phase will be completed. Upon completion of the first phase, tipping will proceed to the first cell of the second phase. At this stage the final restoration of the cover to the first phase can be commenced.

15.1.2 The final cover proposed will consist of a gas permeable gravel layer 300 mm thick, a 300 mm thick clay liner to stop water entering the waste. Finally, the topsoil stored on site from the first phase will be spread over the surface, a minimum layer thickness of 500mm or as directed by the agricultural advisor will be formed.

15.1.3 Into this surface at 30m spacing will be set the settlement monitoring benchmark. These will consist of concrete slabs 300mm square and 300mm deep. Grass seeding of the completed surface will be the final cover.

15.1.4 Completed areas of the site may be left fallow or used for grazing purposes. No trees should be planted on the areas filled as their roots could damage the capping layer.

15.1.5 The final contours envisaged for the site for Phase 1 and for all subsequent phases are shown on Figure 21 and 22.

15.1.6 Upon the facility's decommissioning, notice should be given that the site has been used for solid waste disposal. This notice should be posted on site and recorded on all legal descriptions to avoid its premature use for purposes other than open space, sporting greens or livestock grazing. At such time that the site is certified to be safe for built structures and human occupation (probably 50 to 100 years after closure), the cautionary notices and use prohibitions can be waived.

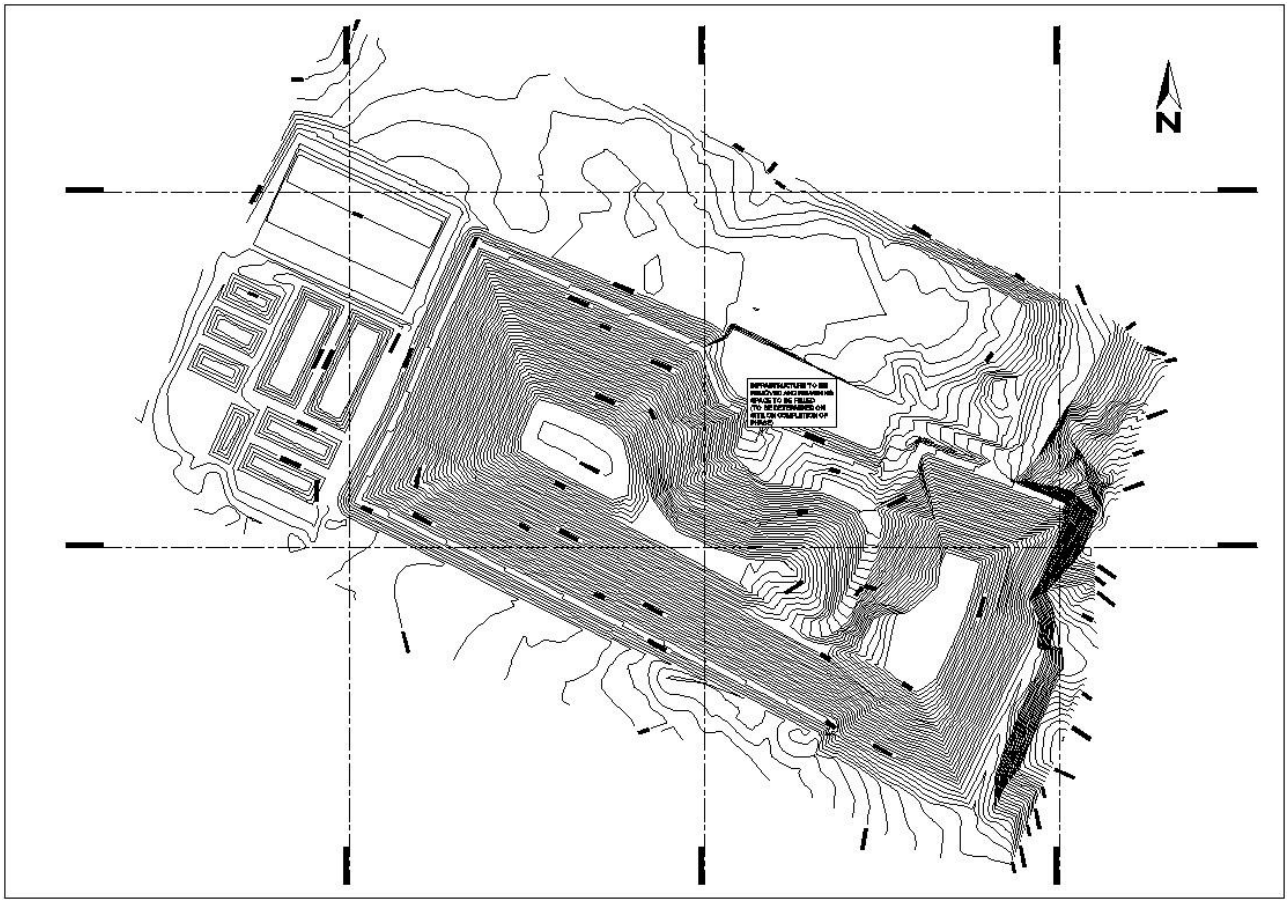


Figure 21: Final landform contours (Option 1)

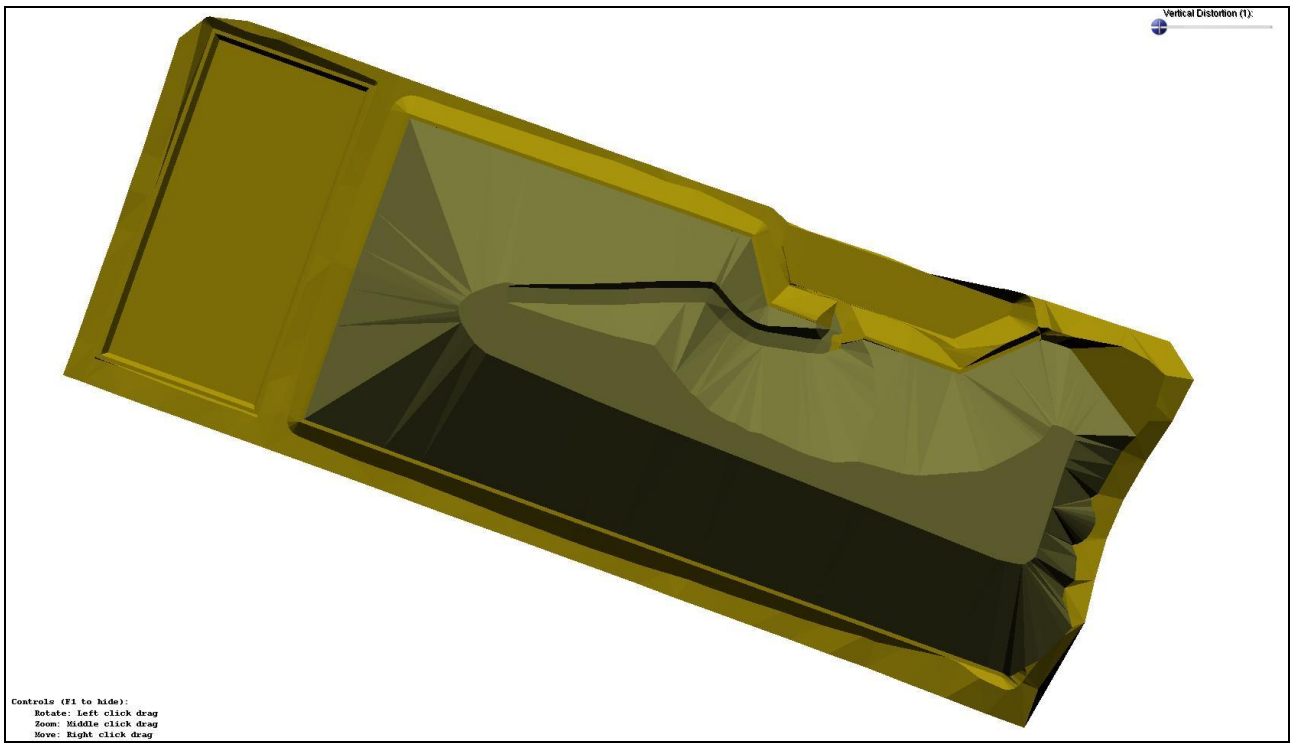


Figure 22: Final landform (Option 2)

16 ENVIRONMENTAL MANAGEMENT PLAN

16.1 Introduction

An Environmental Impact Assessment (EIA) was prepared by Messrs Earthtime Inc consultants at the time that the Whein Town site was being considered for the temporary Landfill for Monrovia. The EIA is used to identify the various ways in which the proposed Monrovia Landfill/leachate development will affect the receiving environment. The objective is thus to ensure that significant impacts are identified so that they can be addressed in the Design and the Operating Plan, with a view to minimising the future impacts of the Landfill.

Based on the aforementioned documents, the investigations of the proposed site, and the draft detail design developed for the Landfill and leachate facility, this Environmental Management Plan has been developed to summarise the key management actions required to ensure the implementation of the required mitigation measures. The objectives of this site specific Environmental Management Plan (EMP) are therefore to:

- Summarise the key negative impacts that were identified.
- List the associated management actions necessary to minimise negative impacts
- Identify the responsible person/party for implementing the required actions.
- Identify monitoring requirements to ensure the management actions are implemented.

16.2 The Plan

The lack of proper sanitary Landfill and leachate treatment facilities for Whein Town in the past has resulted in a negative perception by the public regarding the proposed new facility. In addition, there are a number of negative environmental impacts associated with any Landfill and leachate treatment operation, most of which relate to aesthetics and public attitudes. However, the design of the proposed new sanitary Landfill and leachate treatment facility is aimed at addressing the potential negative impacts, and would therefore represent a significant positive mitigating measure in addressing current waste disposal problems and public attitudes.

If the recommendations made in this Environmental Management Plan, regarding the planning, construction and operation of the new disposal facility, are adhered to and implemented, many of the current negative impacts and perceptions of waste disposal would be overcome.

To ensure that all actions detailed in this section and elsewhere are implemented, it is recommended that all engineering measures be inspected to ensure compliance with the design criteria. Regular auditing of the operation of the facility should further ensure that all actions are implemented, and that unforeseeable impacts are identified and addressed in the operation, rehabilitation and closure phases. Apart from the above, all actions for which the operation contractor or any other subcontractor is responsible should be included in the tender documentation.

The identified impacts and required management actions, responsibilities and monitoring actions at Upper Management Level are included in the EMP Table 19 below. Mitigation and monitoring at middle management, consultants and operator level are discussed in Section 17 and shown in Table 20.

Table 19: Environmental Management and Monitoring Plan (Management Level)

IMPACTS REQUIRING MITIGATION &/OR OPTIMISATION	KEY MANAGEMENT ACTIONS	KEY RESPONSIBILITY: IMPLEMENTATION	MONITORING PLAN
ATTITUDES AND EXPECTATIONS Public tends to have a negative attitude towards waste disposal operations. There are high expectations of a cleaner city, as well as job opportunities and compost from the Landfill.	**TARGET**: Public support for the project. Public understanding of the Landfill process. **PLANNING AND CONSTRUCTION** • All authority requirements and relevant regulations must be met in the public participation process. • Take into account all stakeholders concerns in planning and construction stages. **OPERATION** • Operate Landfill and leachate facility to acceptable sanitary Landfilling practice, and EPA guidelines. • Audit operation regularly • Set up a Community Monitoring Committee to monitor the operation and resolve complaints from the public. **STANDARD/GUIDELINE** • No standard or guideline.	Monrovia City corporation (MCC)	**MONITORING ACTIONS** • During planning and construction ensure management actions are implemented. • During operation, EPA and MCC to inspect operation on a regular basis. • MCC to ensure that Monitoring committee is set up and functioning. • MCC to appoint Landfill auditors. **MONITORING METHOD** • On site observations.

IMPACTS REQUIRING MITIGATION &/OR OPTIMISATION	KEY MANAGEMENT ACTIONS	KEY RESPONSIBILITY: IMPLEMENTATION	MONITORING PLAN
CONTAMINATION OF GROUNDWATER	**TARGET**: Maintain current ambient water quality of underground aquifer.	Monrovia City corporation (MCC)	**MONITORING ACTIONS** • Establish a pre-operational

Leachate from the waste body and leachate from the ponds could contaminate ground water.	**PLANNING AND CONSTRUCTION** • Install a low permeability lining system beneath the Landfill. • Install a leachate collection and treatment system. • Ensure that the leachate ponds are effectively lined. • Install at least three permanent (capped) groundwater monitoring wells, upstream and downstream of the site. • Determine a pre-occupation water quality baseline. **OPERATION** • Ensure that the leachate management system is functioning correctly. • Maintain the groundwater monitoring wells throughout the life of the waste disposal site. • Ensure proper site drainage. • Prevent disposal of hazardous wastes. **STANDARD/GUIDELINE** • The new Guidelines for the Development and Management of Landfill in Liberia to be developed by the Environmental Protection Agency (EPA). • Liberia Water Act. • Operation and Maintenance Guidelines for the Whein Town Landfill/Leachate facility.		water quality baseline of the underground aquifer (i.e. before any waste is disposed on the site). • Sample the groundwater monitoring wells on a regular basis in order to be able to timeously detect any changes in ambient water quality. • Compare results of water samples with standard/guideline. • Implement corrective action if there is a change. • Annual status report. **MONITORING METHOD** • Take water samples before construction and during operation (every six months) to determine water quality. • Groundwater sampling should be extended to any local wells used for water supply that are within the zone of possible contamination

IMPACTS REQUIRING MITIGATION &/OR OPTIMISATION	**KEY MANAGEMENT ACTIONS**	**KEY RESPONSIBILITY: IMPLEMENTATION**	**MONITORING PLAN**

CONTAMINATION OF SURFACE WATER Leachate from the Landfill and untreated effluent from the leachate ponds contaminate the adjacent streams.	**TARGET**: Maintain current ambient water quality of adjacent streams. **PLANNING AND CONSTRUCTION** • Design and install upslope drains to divert surface run-off around the Landfill. • Existing stream in valley on site to be piped through beneath the facilities or diverted around. • Ensure that the leachate ponds have sufficient capacity to treat the total expected leachate and leachate generated. • Determine a pre-operation water quality baseline. • Alternative potable water supply to be provided to current users in Whein Town (new water well). **OPERATION** • Ensure that surface drains are maintained. • Ensure that subsurface drains function correctly. • Ensure that leachate drains are flowing freely. • Ensure that leachate ponds are operated correctly. • Ensure that on-site drainage at the working cell is away from the tip face to prevent ponding. **STANDARD/GUIDELINE** • The new Guidelines for the Development and Management of Landfill in Liberia to be developed by the Environmental Protection Agency (EPA). • Liberia Water Act.	Monrovia City corporation (MCC)	**MONITORING ACTIONS** • Establish a pre-operational surface water quality baseline • Sample the adjacent streams on a monthly basis in order to be able to timeously detect any changes in ambient water quality. • Compare results of water samples with standard/guideline. • Implement corrective action if there is a change. • Annual status report. **MONITORING METHOD** • Take water samples before construction and during operation (every month) to determine water quality.

IMPACTS REQUIRING MITIGATION &/OR	**KEY MANAGEMENT ACTIONS**	**KEY RESPONSIBILITY: IMPLEMENTATION**	**MONITORING PLAN**

OPTIMISATION			
LANDFILL GAS Accumulations of Landfill gas (methane) can result in fires and explosions.	**TARGET**: Methane gas concentrations within safe limits of less than 5%. **PLANNING AND CONSTRUCTION** • Design and install gas venting chimneys to vent gas on an ongoing basis. • Design final cover for Landfill to diffuse accumulations of Landfill gas. **OPERATION** • Extend gas chimneys progressively through the waste body as part of the operation. • Install venting caps to gas chimneys as part of final cover to Landfill. **STANDARD/GUIDELINE** • The new Guidelines for the Development and Management of Landfill in Liberia to be developed by the Environmental Protection Agency(EPA). • Operation and Maintenance Guidelines for the Whein Town Landfill/Leachate facility.	Monrovia City corporation (MCC)	**MONITORING ACTIONS** • Ensure that gas chimneys are installed to specification. • Monitor effectiveness of gas chimneys during operation. **MONITORING METHOD** • Field observation visually during site visits and by measurement on a monthly basis.

IMPACTS REQUIRING MITIGATION &/OR OPTIMISATION	**KEY MANAGEMENT ACTIONS**	**KEY RESPONSIBILITY: IMPLEMENTATION**	**MONITORING PLAN**
***FAUNA, FLORA* & NATURAL HABITS**	**TARGET**: Minimise destruction of indigenous *fauna, flora* and natural habitat.	Monrovia City corporation (MCC)	**MONITORING ACTIONS** • During planning and construction ensure

Construction and Waste disposal operations affect nearby *fauna, flora* and natural habitat.	**PLANNING AND CONSTRUCTION** • Confine site facilities and operation to the smallest possible area. • Design to clearly demarcate site clearance areas. • Establish (and maintain) well defined, single access roads. • Retain as much natural habitat as possible. **OPERATION** • Restrict vehicle movement to defined roads. • Clear litter and waste from area around the site on a daily basis. **STANDARD/GUIDELINE** • The new Guidelines for the Development and Management of Landfill in Liberia to be developed by the Environmental Protection Agency (EPA). • Operation and Maintenance Guidelines for the Whein Town Landfill/Leachate facility.		management actions are implemented. • During operation, monitor on-site traffic and litter in surrounding habitat **MONITORING METHOD** • Field observation during site visits and/or formal site audits

IMPACTS REQUIRING MITIGATION &/OR OPTIMISATION	**KEY MANAGEMENT ACTIONS**	**KEY RESPONSIBILITY: IMPLEMENTATION**	**MONITORING PLAN**
AESTHETICS Uncontrolled waste disposal operations have an adverse aesthetic impact as a result of windblown litter,	**TARGET**: To ensure that the Landfill operation remains aesthetically acceptable to public and authorities. Minimise windblown materials from the Landfill operation site which will degrade the surrounding natural habitat. **PLANNING AND CONSTRUCTION** • Promote separation and recycling at source	Monrovia City corporation (MCC)	**MONITORING ACTIONS** • During planning ensure management actions are implemented. • During operation daily monitor the presence of waste materials and mud on the site and adjacent

untidy work area, burning of waste, waste and mud deposited on the public roads. Uncontrolled salvaging of waste materials on the Landfill.	(thereby facilitating the effective management of light weight materials at site). • Provide truck and wheel washing facilities on site. • Provide litter fences on site. • Minimise the size of the work face area. **OPERATION** • Cover dumped waste as quickly as possible. • Make use of mobile litter fences. • Litter pickers to collect all litter on and around the site, and along the access road on a daily basis. • Ensure that waste vehicles are cleaned before leaving the site. • Implement formalised salvaging and recycling. • Completed portions of the Landfill to be covered, topsoiled and vegetated progressively. **STANDARD/GUIDELINE** • Operation and Maintenance Guidelines for the Whein Town Landfill/Leachate facility.		roads. • Undertake regular clean-ups. **MONITORING METHOD** • Field observation during site visits and/or formal audits.

IMPACTS REQUIRING MITIGATION &/OR OPTIMISATION	**KEY MANAGEMENT ACTIONS**	**KEY RESPONSIBILITY: IMPLEMENTATION**	**MONITORING PLAN**
SECURITY & ACCESS CONTROL Uncontrolled access to the working face area results in health and safety risks to public and	**TARGET**: No accidents or injuries on site. No damage to vehicles and equipment. No theft of equipment. **PLANNING AND OPERATION** • Implement the following management actions to mitigate health and safety threats at the new site. • Erect a security fence with lock-up gates to prevent	Monrovia City corporation (MCC)	**MONITORING ACTIONS** • During planning ensure management actions are implemented. • During construction and operation undertake monthly site visits to inspect adequacy of site security.

site staff risk of accidents and damage to vehicles and equipment informal salvaging and related aesthetics problems Theft of equipment.	unauthorised access to the site. • Provide access control facilities at the site entrance. • Provide area lighting of entrance area for night time security. • Erect suitable signage to warn personnel and visitors of the potential dangers of the hazardous Landfill site. **OPERATION** • Establish a 24 hour security permit system. • Restrict access to work face area to authorised personnel. **STANDARD/GUIDELINE** • No standard/guideline.		• Implement corrective action to improve security and access control if necessary. **MONITORING METHOD** • Obtain quantitative data regarding incidence and consequences of trespassing from site management.

IMPACTS REQUIRING MITIGATION &/OR OPTIMISATION	**KEY MANAGEMENT ACTIONS**	**KEY RESPONSIBILITY: IMPLEMENTATION**	**MONITORING PLAN**
ODOURS Odours from decomposing waste are offensive and can pose a health risk.	**TARGET**: Control odours to the extent that no complaints emanate from the general public and surrounding residents **PLANNING AND CONSTRUCTION** • Prevent public access to Landfill workface area and leachate discharge area. • Ensure adequate buffer zone. **OPERATION** • Minimise the surface area of the work face • Minimise the exposure time of waste to air • Cover all waste on a daily basis.	Monrovia City corporation (MCC)	**MONITORING ACTIONS** • During planning and operation ensure management actions are implemented. • During operation, monitor the effectiveness of odour control measures in a monthly basis. • Institute corrective action if necessary. **MONITORING METHOD**

	• Cover odorous and problem wastes such as animal carcasses, abattoir waste and condemned food stuffs immediately. • Ensure an adequate scum layer on the leachate anaerobic ponds. **STANDARD/GUIDELINE** • The new Guidelines for the Development and Management of Landfill in Liberia to be developed by the Environmental Protection Agency (EPA). • Operation and Maintenance Guidelines for the Whein Town Landfill/Leachate facility		• Site visits for odour tests. • Use complaints received from the public as a gauge of the presence of an odour problem.

IMPACTS REQUIRING MITIGATION &/OR OPTIMISATION	**KEY MANAGEMENT ACTIONS**	**KEY RESPONSIBILITY: IMPLEMENTATION**	**MONITORING PLAN**
HEALTH & SAFETY Exposure to decomposing and infectious wastes, as well as untreated leachate, poses a health risk to public and workers on site. Breeding of flies and rodents increases health risks. Landfill equipment	**TARGET**: No accidents or injuries on-site. No illness or disease resulting from the Landfill or leachate facility operation. **PLANNING AND CONSTRUCTION** Reduce occupational health and safety risks by: • Providing security fencing, gate and guards to control public access. • Erecting suitable signage to warn public and personnel of dangers. • Providing suitable ablution facilities for workers. **OPERATION** Reduce occupational health and safety risks by: • Preventing access by the general public to the	Monrovia City corporation (MCC)	**MONITORING ACTIONS** • During operation, ensure management actions are implemented. • Weekly monitor frequency and cause of accidents and injuries. • During monthly meetings assess findings and if needed take corrective action to prevent similar accidents. • Annual internal and external performance audit. • Annual status report.

and large vehicles operating on site poses a safety risk for workers and members of the public.	working face(s). • Providing workers and salvages with adequate personal protective equipment (PPE) (e.g. gloves, overalls, boots, respirators where necessary); • Educating workers regarding the risks involved in working with hazardous and non hazardous waste they will be exposed to • Establishing biological health monitoring programme for workers • Minimising the numbers of workers working on the work face • Compacting and covering waste quickly to prevent breeding of vectors and disease • Managing and controlling vectors of disease through regular spraying and dosing • Establishing and ongoing health and safety education programme **STANDARD/GUIDELINE** • The new Guidelines for the Development and Management of Landfill in Liberia to be developed by the Environmental Protection Agency (EPA). • Operation and Maintenance Guidelines for the Whein Town Landfill/Leachate facility		**MONITORING METHOD** • Observation and report backs by safety representatives.

17 ADVERSE MITIGATION MEASURES AND ACTION PLANS

17.1 Introduction

This section describes the proposed detailed mitigation and action plan for middle management, consultants and operators is broken down into three phases, viz:

- Design and preconstruction phase
- Construction phase
- Operational phase

17.1.1 Design and Preconstruction phase

To mitigate the permanent environmental impacts the following action plans are required in the design of the Landfill, as shown in Table 20. An audit should be carried out on the design before commencement of construction to ensure that the mitigation measures have been incorporated in the design.

Table 20: Mitigation Measures Required in the Design and Preconstruction Phase

Protection of ground water	Objective	• To minimise the risk of ground water pollution resulting from the landfill. • To monitor ground water quality to ensure that it is fit for consumption by ground water users in the area.
	Target	• No pollution of ground water from the Landfill.
	Actions	• Design to include ground water monitoring wells (**Design Consultant**). • A monitoring well to be installed according to specification, under supervision of the construction consultant, at the commencement of the construction period (**Contractor**). • Monitoring well to be sampled and analyses at commencement of construction to establish background ground water quality (**Consultants**) (see Annexure G for water quality parameters to be analysed).
Protection of surface water quality	Objective	• To minimise the risk of pollution to surface water bodies resulting from the landfill. • To monitor surface water quality to minimise the health risk to downstream users.
	Target	• No pollution of nearby surface water bodies from the landfill.
	Actions	• Drains to be designed to contain surface run-off from the landfill into sewer system (**Design Consultant**). • Existing stream to be sampled and analysed at commencement of construction to establish background water quality (**Design Consultant**) (see Annexure G for water quality parameters to be analysed for).

Dust and traffic control	Objective	• To minimise the impact of dust on health of workers and nearby residents. • To minimise the impact of odours as an inconvenience on workers and nearby residents. • To mitigate the effect of traffic to the site.
	Target	• Dust levels below 300μgm-3 at closest residences. • Traffic noise below 75dB(A) at site boundary.
	Actions	• Access road to be paved (**Design Consultant**). • Allow for hose pipe to suppress dust when necessary (**Consultant)** • Restrict site clearance and retain existing vegetation along perimeter of site (**Design Consultant/Contractor**).

17.1.2 Construction Phase

To mitigate the temporary adverse impacts during the construction phase of the project, the following action plans have to be implemented as shown in Table 21. These measures should have been included in the relevant construction specifications.

Table 21: Mitigation Measures Required During the Construction Phase

Contractor's establishment	Objective	• To reduce the visual and environmental impact of the Contractor's temporary facilities. • To ensure hygienic facilities for Contractor's workers. • To minimise the risk of pollution by contractor's temporary facilities.
	Target	• To ensure acceptance of contractor's facilities by workers, authorities and public in the area.
	Action	• Contractor's establishment and siting to be to approval of the Construction Consultant (**Contractor/Construction Consultant**). • Contractor to provide potable water and approved sanitation facilities for workers (**Contractor**). • Contractor to construct fuel spill containment bund around temporary fuel storage tanks (**Contractor**). • Waste oil and other waste to be disposed of at approved disposal facilities (**Contractor**).
Safety awareness	Objective	• To reduce the risk of accident/injury to workers. • To reduce the risk of damage to equipment/plant resulting from construction accidents. • To prevent injury to members of the public.
	Target	• No injuries to workers. • No lost time accidents. • No injuries to public.
	Actions	• Contractor to provide appropriate safety equipment to workers (**Contractor**).

		• Safety training programme for all workers to be implemented (**Contractor**). • Statutory safety regulations to be enforced on site. All people (visitors and operators) shall be equipped with PPE as indicated in section 4 when moving around on site. (**Contractor/Construction Consultant**). • Contractor to prevent unauthorised access to the site by members of the public. Fences and signs to be erected (**Contractor**).
Emergency procedures and response	Objective	• To ensure that the Contractor is prepared to respond to any foreseeable emergency in an ordered and rational manner.
	Target	• Emergency plans to be in place at commencement of construction.
	Action	• Site Agent, with input from Group Safety Office, to draw up emergency plans which allocate specific responsibilities to respond appropriately to any foreseeable emergency situation such as fire, explosion, accident, fuel/oil spillage, outbreak of infectious diseases (**Contractor**). • Information on local emergency services (Police, Fire, Ambulance) to be clearly displayed at site office and all workers advised accordingly (**Site Agent/Contractor**) • Fire extinguishers to be provided at site offices and fuel tanks (**Contractor**). • Regular "tool box" discussions be held with workers as part of the safety training programme, to keep all staff and workers aware of the emergency plans (**Contractor**). • Basic first aid courses be held for all supervisors and selected workers (**Contractor**).
Local employment	Objective	• To employ as many local workers as possible. • To minimise the risk of friction between the contractor and the local labour force. • To improve local skills.
	Target	• To make a tangible improvement to local employment and skills.
	Action	• All unskilled positions on site to be filled with local labour (**Contractor**). • Semi-skilled/skilled positions to be filled by locals as far as practically possible (**Contractor**). • Programme of skills training within the scope and schedule of the project to be implemented (**Contractor**).
Site clearance activities	Objective	• To minimise the biophysical impact of vegetation and topsoil removal.

	Target	• Avoid disturbance of flora and topsoil beyond limits of permanent works.
	Actions	• Areas for vegetation and topsoil removal to be clearly specified and demarcated before commencement of operations (**Construction Consultant/Contractor**). • Areas for topsoil stockpiles to be clearly demarcated and kept to a minimum (**Contractor**). • Cleared trees to be stockpiled for fuel wood uses by local residents.
Noise control	Objective	• To minimise the impact of construction noise on workers and the nearby community.
	Target	• Control noise below 75dB(A) at site boundary.
	Actions	• Contractor's equipment to be silenced within limits (**Contractor**). • Construction operations to be restricted to normal working hours (No Sunday or night working) (**Contractor**). • Operators and workers close to noisy equipment to be provided with ear muffs or plugs (**Contractors**).
Dust control	Objective	• To minimise the impact of dust on health of workers and nearby residents.
	Target	• Dust levels below 300μgm-3 at closest residences.
	Actions	• Contractor to control dust through regular wetting of roads and earthwork activities (**Contractor**). • Operators and workers to be provided with dust masks (**Contractor**). • Topsoil stockpiles and completed earthworks to be vegetated as soon as possible after completion (**Contractor**).
Erosion/pollution of streams	Objective	• To prevent erosion of cleared areas, soil stockpiles and completed earthworks. • To minimise pollution of streams through soil erosion.
	Target	• No significant turbidity in the adjacent streams.
	Actions	• Completed earthworks and soil stockpiles to be vegetated as soon as possible after completion (**Contractor**). • Temporary drainage to be provided. • Site to be inspected and monitored after heavy rains to identify and remedy areas of soil erosion (**Contractor**). • Filter fences to be erected as appropriate to prevent silt from entering streams (**Contractor**).
Site aesthetics	Objective	• To minimise the visual impact of construction activities.

	Target	• Public acceptability of construction activities
	Actions	• Site to be hoarded off from the public eye during construction (**Contractor**). • Cleared material (vegetation, rock etc) to be disposed of in designated areas and kept neat and tidy (**Contractor**). • Construction waste and litter to be disposed of at the current waste site (**Contractor**). • Programme to accept and address complaints by the public to be instituted (**Contractor**).
Traffic control	Objective	• To minimise the risk of accidents on route and in close proximity to the landfill.
	Target	• No accidents.
	Actions	• Temporary road traffic signs to be erected at the intersection, in accordance with the republic of Liberia traffic regulations (**Contractor**).
Protection of adjacent properties	Objective	• To minimise the risk of trespassing on adjacent properties.
	Target	• No complaints from adjacent landowners.
	Actions	• Contractor's workers to be instructed not to trespass (**Contractor**). • Site boundary fence to be erected as early as possible in the contract (**Contractor**).

17.1.3 Operational phase

Initially, the environmental monitoring during the operational phase of the projects is to be carried out only during the 12 months Defects Liability Stage by Pöyry. However, it is motivated that the environmental monitoring be continued throughout the operational life of the landfill.

As the impact of the landfill on the environment is very much dependent on the standard of operation, the monitoring of environmental issues during the operational phase will take the form of operational auditing and environmental monitoring. The mitigation measures to be audited and monitored during the operation of the landfill are summarized in Tables 22 and 23.

Table 22: Mitigation Measures to be audited during the Operational Stage

Access Control	Objective	• To prevent unauthorized persons from entering the site. • To ensure that the entire operation of the landfill is controlled in an orderly manner.
	Target	• Control system to be in place at commencement of

		operation • Public and Environmental Authorities acceptance of the operation.
	Actions	• All access to the site to be controlled through a security fence and gate (**Operator/Gate Controller**). • Gate controllers to be trained in identifying unauthorised visitors if manned throughout the day (**Operator**). • Site reporting structure and lines of authority to be clearly defined (**Operator**). • Public and Environmental Authorities to be involved in auditing of operation (**Monitoring Consultants**).
Access/Traffic	Objective	• To prevent traffic congestion on/at site. • To prevent vehicle accidents on/at site. • To reduce vehicle wear and tear. • To reduce waste spillage from vehicles.
	Target	• Traffic control system to be in place at commencement of operation. • No vehicle accidents on site.
	Actions	• Roads on site and in landfill area to be maintained in trafficable condition at all times, including wet weather (**Operator**). • Direction signs to be placed to direct traffic to and from the site (**Operator**).
Landfill operation	Objective	• To prevent nuisances such as odours, flies, vermin and fires, resulting from dirty environment such as screening material. • To minimise dust resulting from the landfill operation. • To minimise noise resulting from the landfill operation. • To minimise generation of pollutants as a result of exposed waste material. • To minimise generation of leachate as a result of exposed waste at the work face and associated with poor drainage
	Target	• Public and Environmental Authorities acceptance of the operation. • Compliance with Liberian Legislation.
	Actions	• Ensure proper landfill daily (**Operator**). • Use odour control chemical if odours become a problem (**Operator**). • Ensure landfill equipment is properly maintained in good working order (**Operator**). • Ensure workfront is kept to a minimum and that waste is covered regularly (**Operator)** • Ensure adequate dust control by wetting on-site roads and waste if necessary (**Operator**). • Ensure silencing of landfill equipment is within limits

		such as power generators and vehicles carting the screenings to the Landfill (**Operator**). • Public and Environmental Authorities to be involved in auditing of operation (**Monitoring Consultant**).
Aesthetics	Objective	• To ensure that the landfill operation remains aesthetically acceptable to nearby residents, the general public and the Environmental Authorities.
	Target	• Complete public acceptability
	Actions	• Ensure that all broken or damaged building parts are repaired without delay when observed and noted. (**Operator**). • Ensure that damaged security fencing is repaired without delay when observed and noted. (**Operator**).
Drainage Controls	Objective	• To ensure that the designed rainwater drainage systems function correctly, thereby minimising any ponding and erosion or flooding. • To ensure that no waste is deposited in water thereby minimising the potential for water pollution. • To ensure that all liquids inside the facility end up in the leachate pond system. •
	Target	• No pollution of ground water or adjacent streams that would render the water unsafe for domestic use.
	Actions	• Ensure that upslope cut-off drains and drainage paths are maintained (vegetation/erosion) and functioning correctly (**Operator**). • Ensure leachate drainage system is operating correctly **(Operator)** • Ensure that subsurface drains on the downstream site of the landfill are functioning correctly (**Operator**). • Ensure that all road side drains are maintained (cleaned and free of litter, silt etc) and functioning correctly (**Operator**).
Safety and Health	Objective	• To prevent accidents and injury to workers and visitors to the landfill. • To prevent damage to equipment, vehicles and site facilities resulting from accidents. • To prevent the risk of illness or disease to workers and members of the public as a result of the landfill operation.
	Target	• No accidents on site • No injury or loss of life as a result of accidents on site. • No damage to equipment, vehicles or facilities resulting from accidents. • No illness or disease from the landfill operation.
	Actions	• A safety officer responsible for all aspects of safety and health on site to be appointed (**Operator**).

		• Safety procedures to be enforced by the Safety Officer (**Operator**). • A detailed safety plan as outlined in the Operation and Maintenance Guidelines must be implemented from commencement of operations (**Operator**). • An emergency response plan to be in place from commencement of operations (**Operator**). • Safety training commensurate with the different levels of responsibility to be provided for all landfill staff (**Operator**). • Appropriate safety awareness signs to be prominently displayed on the site (**Operator**). • All workers to be provided with appropriate protective clothing as recommended in the Operation and Maintenance Guidelines (**Operator**). • First aid facilities to be provided on site. Key personnel to be trained in first aid and emergency procedures (**Operator**). • Serviceable fire extinguishers to be provided on site (**Operator**). • Site staff to be trained in fire drills (**Operator/Safety Officer**). • Ablution and eating facilities to be maintained in a clean condition at all times (**Operator/Safety officer**).

Table 23: Mitigation Measures to be monitored during the Operational Stage

Surface water monitoring	Objective	• To detect any contamination of the adjacent streams or rivers as a result of the landfill operation. • To provide an early warning system to downstream users of possible water contamination. • To facilitate timeous implementation of remedial measures in the event of surface water contamination.
	Target	• No contamination of adjacent streams or rivers. • No consumption of contaminated water from the streams which is unfit for human consumption.
	Actions	• Streams or rivers to be sampled upstream and downstream of the landfill on a 6 monthly basis, and analysed for the water quality parameters listed in Annexure G, (**Operator/Monitoring Consultant**). • Results of water quality analyses to be compared with the background values as well as the WHO/LWSC Specification for Water for Domestic Supplies, to evaluate water quality changes resulting from the landfill operation (**Operator/Monitoring Consultant**). • Should surface water quality deteriorate as a result of the landfill operation to the extent that it is no longer fit for domestic use, steps shall be taken to prevent its human consumption by downstream users. Alternative supplies of drinking water shall immediately be provided to downstream users by means of tanker and possibly piped water (**Operator**).

		• Investigations to be initiated to determine the cause of surface water contamination, and remedial measures to be implemented (**Operator/Monitoring Consultant**).
Ground water monitoring	Objective	• To detect any contamination of ground water beneath the site resulting from the landfill operation. • To provide an early warning system to ground water users in the area of potential ground water contamination. • To facilitate timeous implementation of ground water remediation measures if deemed necessary.
	Target	• No contamination of underlying ground water. • No human consumption of contaminated ground water.
	Actions	• Monitoring boreholes to be sampled every 12 months, and analysed for the water quality parameters listed in Annexure G (**Operator/Monitoring Consultant**). • Ground water quality results to be compared with the background values, as well as WHO/LWSC specification, to evaluate ground water quality changes resulting from the landfill operation (**Operator/Monitoring Consultant**). • Should ground water quality deteriorate to the extent that it is no longer fit for domestic use, steps shall be taken to prevent its further consumption. Alternative supplies of drinking water shall be provided to affected users (**Operator**). • Investigations to be initiated to determine the cause of ground water contamination and remedial measures to be implemented (**Operator/Monitoring Consultant**).

18 OPERATIONS MONITORING PLAN

This section describes the environmental monitoring of the operation and maintenance procedures of the landfill for the city of Monrovia.

18.1 Introduction

The monitoring plan for the proposed landfill identify measures to monitor implementation effectiveness of mitigation measures, and specifies the responsible party(ies). The monitoring plan outlines monitoring procedures and indicator parameters.

The objective of the monitoring is to provide information on impact in terms of:

- Nature
- Magnitude
- Geographical extent
- Timescale
- Probability of occurrence
- Significance
- Confidence in prediction

The effectiveness of the monitoring programmes will be determined by and has to:

- Have realistic sampling programmes
- Use relevant sampling methods
- Collect quality data
- Have compatibility of old and new data
- Have cost-effective data collection
- Are innovative
- Use appropriate databases
- Use multi-disciplinary interpretation
- Report internally and have external checks
- Respond to third party input
- Present data to the public

The proposed monitoring plan for the landfill is as shown in Table 24.

Table 24: Monitoring Plan

Impact	Monitoring means	Parameter	Phase	Location	Frequency	Approximate cost
Local climatic conditions	Permanent weather monitoring station	• Temperature, humidity, rainfall and wind speed and direction • Volume of precipitation • Evaporation (lysimeter) • Atmospheric humidity	• Pre-works • Facility construction & site preparation • Operation • Post-closure	• Facility site	• Daily	• $4,000/weather station
Ambient Air Quality	Portable sampling	• Total suspended particulates (TSP) • Particulates < 10 microns (PM10) • See Appendix	• Facility construction & site preparation • Operation • Post-closure	• Facility site • Nearby receptors	• Once at start of construction • Daily and quarterly depending on parameter or upon complaints • Annually	• $7,000/portable sampling device
Noise levels	Noise levels	• Leq (dBA)	• Facility construction & site Preparation • Operation	• Facility site • 3 monitoring locations around the perimeter of the site	• Monthly • Upon Complaints	• $5,000/portable sampling device
Groundwater quality	Sampling	• Conductivity (EC) • Ammonia, Nitrate, • Manganese, Total • Phosphorous, Total	• Pre-works • Operation • Post Closure	• From monitoring borehole as determined	• Bi-Annually for 20 years	• $400/sample

		• Suspended Solids • (TSS), Biochemical oxygen demand (BOD) / Dissolved oxygen (DO), • Total Organic Carbon (TOC) • Total Coliform, • Salmonellae • Metals (Chromium, Cadmium, Copper, Zinc, Nickel, Mercury, Lead)		through geophysical and geohydrological investigation		
Surface water quality	Sampling	• Conductivity (EC) • Ammonia, Nitrate, • Manganese, Total • Phosphorous, Total • Suspended Solids • (TSS), Biochemical oxygen demand (BOD) / Dissolved oxygen (DO), • Total Organic Carbon (TOC) • Total Coliform, • Salmonellae • Metals (Chromium, Cadmium, Copper, Zinc, Nickel, Mercury, Lead)	• Pre-works • Operation • Post Closure	• At least two sample locations should be conducted one upstream and Surface drainage recuperation canal • Exact location should be determined prior to work initiation by the contractor in collaboration with local authorities	• Bi-Annually for 10 years	• $400/sample
Waste generation	• Generated waste checklist • Incoming waste assessment	• Quantity and Composition • Quantity • Categorization: quantity and percent	• Facility construction & site Preparation • Operation	• Facility site • Incoming wastes	• Quarterly • Daily	• Priced within operations

	• Incoming waste assessment (upon need)	composition by weight and volume of organic waste, paper, cardboard, plastic products, glass, fabrics/textiles, metals	• Operation	• (Weighbridge) • Uploading area	• Quarterly	
Odour emissions	Olfactory test	• Unpleasant/noxious smells	• Operation	• Facility site Sensitive receivers	• Daily • Upon complaints	•
Leachate quality	Sampling	• Conductivity (EC) • Ammonia, Nitrate, • Manganese, Total • Phosphorous, Total • Suspended Solids • (TSS), Biochemical oxygen demand (BOD) / Dissolved oxygen (DO), • Total Organic Carbon (TOC) • Total Coliform, • Salmonellae • Metals (Chromium, Cadmium, Copper, Zinc, Nickel, Mercury, Lead)	• Pre-works • Operation • Post Closure	• At least two sample locations should be conducted - one at inlet of ponds and one at outlet. • Additional points such as outlet of the different ponds should also monitored	• Monthly (initially) gradually extending the time to then bimonthly for 10 years. • After closure of landfill sampling to be done Bi-annually	• $400/sample
Health and safety	Health and safety surveys, documentation of injuries and accidents	• Proper use of PPE, • presence of signs, first aid kit, and fire fighting devices	• Facility construction & site preparation • Operation	• Facility site	• Continuous	•
Socio-economics	Field Questionnaires and interviews	• Population perception • Employment record • Reported cases of	• Pre-works • Facility construction & site Preparation	• Region of influence	• Once • Once	• $500/visit

		affected psychological stresses	• Operation • Post-closure		• Annually • Annually for 5 years	

19 REPORTING PROCEDURES AND DOCUMENTATION

On the basis of this EMP, a review of the detailed construction drawings for the landfill has been carried out to confirm that the necessary mitigation measures have been adequately addressed in the design. Where deemed necessary, a number of design changes were made, the most important of which are:

- Oil and sand traps inside the facility
- Weighbridge for proper recording of waste generation and disposal information.
- Polluted water drainage point.
- Noise dissipation through wall cladding or block wall construction

During the construction of the landfill, Pöyry will have had a full time Resident Engineer on site to supervise construction and ensure that the works are constructed in accordance with the design, and that all the mitigation measures tabled in the EMP are implemented. In addition, Pöyry's environmental consultant has visited the site regularly to check on the implementation of the EMP, particularly regarding environmental issues. Ground water and surface water samples will be taken and analysed for background data.

At the monthly construction progress meeting with the Contractor, a separate item relating to Environmental Issues will be discussed on the agenda. Non-compliances with the EMP have been brought to the attention of the Contractor for rectification, and additional environmental impacts identified have been addressed. At the end of construction, Pöyry will, should the work comply, issue a "Certificate of Completion of the Works", to certify that the landfill has been satisfactorily constructed in accordance with the design and specifications. This certificate would therefore serve as the Project Compliance Report (PCR) for the construction stage.

Once the landfill is commissioned, the operation is to be audited and environmental monitoring carried out every six months.

After each audit, a report is to be submitted giving the results of the audit, comments on the status quo and recommendations for improvement of the operation. The results of each monitoring exercise, as well as an interpretation of the results, are to be included in the report. This report would constitute the PCR for the operation of the landfill.

Where more regular monitoring is required as stated in the EMP, this is to be carried out by the site operator and recorded in the weekly/monthly site report.

Table 25 gives a summary of the reporting documentation to be produced.

Table 25: Summary of Documentation to Be Produced

Document/report	Frequency	Responsibility	Details
Certificate of Completion of the Works	At completion of construction and handover of the facility.	Pöyry	Certification that landfill was constructed to design and specifications.
Emergency Response Plans	At start of operation, to be reviewed and updated every six months.	Site Operator	Details of all emergency procedures for accidents, fires, fuel spillages, gas explosions, hazardous waste dumping etc.
Minutes of Public/Community meetings	As required. Probably every six months.	LWSC/MCC	Meetings with public/community liaison Committee to discuss issues relating to the operation of the TS, and address concerns.
Operational Audit and Monitoring Report	Every six months	Pöyry/ MCC	Results of audit of operation and water quality monitoring including non-compliances and recommendations for improvement.
Landfill Operation Reports	Monthly	Site Operator	Cumulative details of hours pumped, leachate levels, fuel usage, maintenance inspection carried out, accident/incident reports.
Accident/Incident Report	As required after every accident/incident.	Site Operator	Details of all accidents/incidents as required in terms of the Occupational Health and Safety Regulation.
Gate Register	Daily	Site Operator	Record of all persons entering and leaving the site.
Updating of EMP	Annually	LWSC/MCC	New issues to be captures for future monitoring

To implement such an EMP would require the involvement of ideally an environmental practitioner (independent body) and representatives from the government departments. The only financial requirements would be that for the private sector involvement as it is accepted that the monitoring process would form part of the normal activities of the personnel from the government departments

19.1 Reporting

The shift leaders in charge of operation during the 24 hour day should prepare a daily facility monitoring report during both the facility construction and site preparation phase and operation phase containing the following information:

- Personal log
- Incoming waste (total daily quantity). Ideally a waste composition analysis must be done every 6 months.
- Waste transportation truck information (truck number, truck type, arrival time, departure point, total weight, nett waste weight)
- Staff accidents and failure during operation
- Equipment and machinery monitoring data

Monitoring reports should be submitted quarterly during both the construction and operation phases. In addition, yearly comprehensive reports should be generated to present results of the monitoring activities and assess the adequacy of environmental control measures.

Monitoring reports should be submitted to the EPA, and the respective local authority for feedback on the overall monitoring program. These reports should summarize monitoring data with full interpretation illustrating the acceptability or otherwise of environmental impacts and identification or assessment of the implementation status of agreed mitigation measures. The annual monitoring reports should include at least the following sections/information:

a. Executive summary

b. Transportation vehicles
   - Days used/not used
   - Reasons for non-usage of vehicles
   - Average payloads
   - Incoming vehicle IDs, weights (with incoming wastes, empty, with outgoing wastes or products)
   - Distance driven
   - Replacement of vehicles, containers or staff
   - Log of problems, outages, breakdowns, etc.

c. Sorting facility
   - Received waste types and quantities
   - Material types separated and products produced and their qualities
   - Replacement of vehicles, machinery or staff
   - Report on marketing activities
   - Log of problems, outages, breakdowns, etc.

d. Transfer station operation

- Processed waste types and qualities
- Results on annual survey
- Replacements of vehicles, machinery or staff
- Log of problems, outages, breakdowns, etc.

e. Environmental parameters
- Location of sensitive receivers and monitoring stations
- Implementation of status of environmental mitigation measures as recommended in the EIA
- Monitoring results
- Monitoring methodology
- Parameters monitored
- Monitoring date, time frequency, and duration
- Weather conditions during the period
- Monitoring results tabulated with maximum and minimum values

f. Landfill construction and site preparation
- Implementation schedule and achieved position
- Achievements in construction
- Construction materials used
- Log on problems and solutions
- Status of complete Landfill

g. Mass balance and ratios
- Mass balance, showing all mass flows within the disposal services

h. Other parameters
- Daily consumption figures of electricity and chemicals
- Statistics of staff members and labour utilization
- Report of all non compliance or exceeding of the environmental standards
- Record of all complaints received including location, nature, actions, and
- Follow-up procedures
- Records of health and safety accidents on-site

19.2 Contingency Plan

The design and environmental management plan for the proposed landfill has been developed in order to minimize and mitigate the effects of potential impacts that might arise during the preparation, operation and post closure phases. However, unexpected accidents and emergencies might occur that require additional measures during transportation, handling and Landfilling of the solid waste. In this case, a contingency plan should be developed.

The contingency plan includes the identification of likely accidents and emergencies, outlining response scenarios, delegating responsibilities, and

co-ordination with the proper authorities. Furthermore, the plan would serve as a reference for risk assessment and employee training.

The following are potential emergencies that may occur thereby requiring effective contingency planning:

- Accidental leakage and/or spillage of the solid waste, liquid waste and leachate
- Sorting line breakdown
- Power failure
- Vehicle/truck breakdown
- Fire events
- Staff absence

In the case of any accidents and emergencies, the required response should be implemented in a timely fashion in order to minimize the impacts of the accident and it must be undertaken by qualified individuals, experienced in emergency response actions.

Table 26: Estimated costs of EMP implementation and monitoring

ACTIVITY	FEQUENCY	INVOLVEMENT	COST
EMP implementation			
Construction stage	Ongoing during construction stage	Contractor	No cost - Part of contractual obligation and specifications
Water sampling from surface and ground water	Once as background sample before construction commences	Laboratory	US$ 100 000
Monitoring		Environmental Practitioner/LWSC/EPA/ MCC	Travel and time cost covering all 2 stations: US$ 45 000/a
Operational stage	Ongoing during construction stage	Operator – requirements built into the operational procedures	No cost – Part of contractual obligation and specifications for the operations
Long term monitoring			
Meet with the local communities through their representatives	Every 6 months	LWSC/MCC Managers, Environmental Practitioner, Operators, Co-opted Member	Travel and time cost covering all 9 stations: US$ 25 000/a
Recording and documentation	(See Table 25)	Site Operator/ LWSC/MCC	No Charge – part of normal activities
Updating of EMP	Annually	Environmental Practitioner	US$ 15 000/a
Annual water sampling from ground water and surface water	Annually	Laboratory	US$ 100 000/a

20 SUMMARY - LANDFILL SITE SPECIFICATIONS

A summary of the landfill development and operations is shown in this section in the form of a specification. For reference the section in the manual referring to the particular subject is shown in brackets.

MONROVIA CITY CORPORATION

WHEIN TOWN LANDFILL SITE SPECIFICATIONS

1. Name of site: Whein Town Landfill Facility

2. Address and telephone number: Whein Town
Kakata/Monrovia Main Road

3. Location Co-ordinates: To be determined as the site was set out and located based on a local system

		Lo System 29^0
Corner peg	**E**	**N**
A	314 568.29	699 239.48
B	315 028.46	699 024.19
C	314 943.79	698 843.54
D	314 484.35	699 060.05

4. Intended After use: Livestock Grazing or Public Open Space
(Section 15)

5. Maximum ground water level: Groundwater present on site in rainy season. All engineering works above ground water table.
(Section 6)

6. Site storm water drainage: Perimeter drain around site
(Section 6)

7. Water protection measures: Engineered insitu liner with perimeter bund up to 1,5 metres high. Liner comprises 150-mm thick natural clayey material.
(Section 6)

8.	Boundary Fencing:	Post and diamond mesh fencing 1.8 m high with barbed wire on top. Double entry gates to same specification. (Section 6)
9.	Site security arrangements:	Vehicle gates and entry guardhouse. Site manned part time. (Sections 6)
10.	Site information boards:	Entry sign as follows:6 Monrovia City Whein Town Landfill Facility Hours of Opening: 7 a.m. to 4 p.m. All visitors to report to guardhouse An emergency telephone Waste Management Department's number.
11	Other notice boards to suit traffic movements to public road's standard (Section 6)	
12.	Fixed installations:	Guardhouse Toilet (Section 6)
13.	Landfilling plan:	1 Volume of space available 890000 m^3 2 Approximate daily intake of solid waste: 2010 – 325 tonnes 2011 – 371 tonnes 2012 – 419 tonnes 2013 – 469 tonnes 2014 – 521 tonnes 3 Direction of working: Phases arranged in an east to west configuration. See Figure 4.2 4 Maximum width of working face: 20 metres 5 Bad-weather or emergency working areas: Adjacent to site haul road, dependent upon cell in use 6 Number of layers and depth of layer after initial consolidation: 4 & 600 mm

7 Thickness of daily cover: 100mm
8 Thickness of primary cover: 300mm
9 Thickness of final cover: 600 mm
(Sections 7)

14	Types of waste excluded:	Certain hazardous wastes as directed by Municipal Assembly and regulating authority (Appendix D)
15	Instructions for disposal of hazardous and toxic waste:	As directed by regulating authority (Section 7)
16	Litter screens:	Mobile Litter screens provided (Sections 8)
17	Fire-fighting arrangements:	Localised fires by isolation and smothering. Fire Services to be called in all fire events (Section 12)
18	Pest control measures:	Waste to be covered each working day Infestations to be controlled by pest control officer (Section 12)
19	Weed control:	Completed areas to be seeded with *Eragrostis curvula.* Environment Department to tend cultivation (Section 12)
20	Final restoration:	Site capped with material engineered to the same specification as the site lining, sub-soiled, top soiled and planted with grass seed (Section 15)
23	Special instructions:	No vegetation other than areas used for site operational purposes to be removed. Avoid all construction and operational activities where indigenous plant species grow (Section 12 and Appendix F)

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APPENDIX A

POPULATION, WASTE QUANTITIES AND VOID SPACE REQUIREMENTS

Based on the current experience and an achievable goal, a suggested starting point as per the proposed strategy for the city was to collect 30% of all waste generated in 2007 and to improve on the collection system up to say 95% of all waste by 2020. Based on this approach it is anticipated that approximately 45% of waste be collected by 2010. It assumed that this would increase to about 60% in the next 5 years.

Typically as the socio–economical status of the community rises and the service level improves so does the generation rate and rate of deposition. This is further exacerbated by the population growth which implies a double growth factor. Planning for future containers and collection systems will thus be affected by this exponential growth situation.

Table 27: Daily Solid Waste Generation and Collection per Annum

Year	Population	Generation	Collection Coverage	Collection	Collection
		[t/d]	[%]	[t/d]	[t/a]
2010	**1 058 478**	724	**45**	**326**	**118 917**
2011	1 086 015	743	50	371	135 567
2012	1 114 305	762	55	419	153 009
2013	1 143 333	782	60	469	171 267
2014	1 173 117	802	65	522	190 372
2015	**1 202 902**	823	**70**	**576**	**210 222**
2016	1 232 687	843	75	632	230 814
2017	1 262 471	864	80	691	252 151
2018	1 292 256	884	85	751	274 231
2019	1 322 041	904	90	814	297 055
2020	**1 351 825**	925	**95**	**878**	**320 622**
2021	1 381 610	945	95	898	327 686

In terms of the proposed strategy the waste collected and to be disposed will gradually increase as shown in Table 2. It is thus estimated that the waste generation in the first year of the landfill's life could be approximately 326 tons per day in 2010, increasing to approximately 576 tons per day in the year 2015.

Based on the requirements as stated in the terms of reference and to be able to determine the waste generation rates and hence the airspace utilisation at the landfill sites, the following assumptions (see Table 4) were thus made:

Table 28: Design Assumptions for Waste Generation and Deposition for Monrovia

CITY	MONROVIA
POPULATION	
Urban population	(2010) 1 058 500
Population growth rate (per yr)	2,8% (2,0% in 20years)
Urban population (2020)	1 352 000
WASTE GENERATION	

Residential and market (kg/capita/day)	0,57
Industrial and drains (kg/capita/day)	0,11
Total generation rate (kg/capita/day)	0,68
Waste generation (2010) (t/day)	724,0
Waste generation (2015) (t/day)	802,0
WASTE DEPOSITION	
Percentage deposition (2010)	45%
Percentage deposition (2015)	60%
Waste deposition (2010) (t/day)	326
Waste deposition (2015) (t/day)	576
Cover to waste ratio (Vol:vol compacted *in situ*)	1: 6
Average landfill density (kg/m^3)	900

As directed in the terms of reference, the landfill is to be designed to accommodate the waste stream deposited for the full lifespan of the site, estimated presently at between 5 and 8 years i.e. assuming a 45% level of service collection initially, improving to 60% in 2015.

The above figures form the basis for determining the landfill airspace availability for the design period. Based on these figures, it is estimated that a total of some 770 000 tonnes of waste will be deposited over the 5 years design life. Using an in situ landfill density of 900 kg/m^3 and a volumetric cover to waste ratio of 1:6, it is estimated that the total airspace required would be between 0,8 - 1,0 million m^3. This would require approximately 130 000 m^3 of cover material for a proper sanitary landfill operation.

APPENDIX B

Geohydrological and Geotechnical and Information

1. GEOHYDROLOGICAL REPORT (Extract from the earlier report)

1.1 Introduction

Limited geohydrological and geotechnical investigations were done to date and the results and observations of some geotechnical, geophysical and geohydrological observation were largely based on desktop studies of the proposed When Town Landfill site. The objectives of the geohydrological investigations are:

i) To determine the nature, distribution and characteristics of the site soils and bedrock.
ii) To determine the nature of any underlying aquifer.
iii) To determine ground water quality and flow direction, and thus
iv) To determine whether the proposed Landfill can be safely developed and operated, with limited impacts upon the ground water regime.

1.2 Methodology

Detailed geohydrological mapping is not available in Liberia as yet to understand the groundwater situation in the area.
Figure 6-2 and Table 6-5 summarizes the hydrogeological setting in the study area. The Landfill site is located on the Paynesville Sandstone Formation (Dp), which are brownish knobs in broad savannas underlain by white or brown unconsolidated sand deposits.

1.3 Geotechnical investigations

As part of a geotechnical investigation undertaken by the MPW, extensive geotechnical laboratory testing was carried out on soil samples from the different soil horizons in each of the 5 test pits dug on site. Laboratory tests included Grading, Atterberg Limits, moisture content and permeability to determine soil properties. The results of these laboratory tests are included in the Geotechnical Report.
A first attempt at having a geological / geotechnical investigation done in order to provide the geological / hydrogeological baseline data was unsuccessful. Such baseline data would help provide the environmental description of the site and hence provide the best assessment of the potential risks and how to mitigate them. A request was lodged with the MPW to have another thorough geohydrological investigation done. At the time of this report the process was still ongoing and the results will be captured in the detail design. A small very basic geological investigation was however conducted by the Earthtime team to better understand the problem at hand and identify any major problems should they be present.

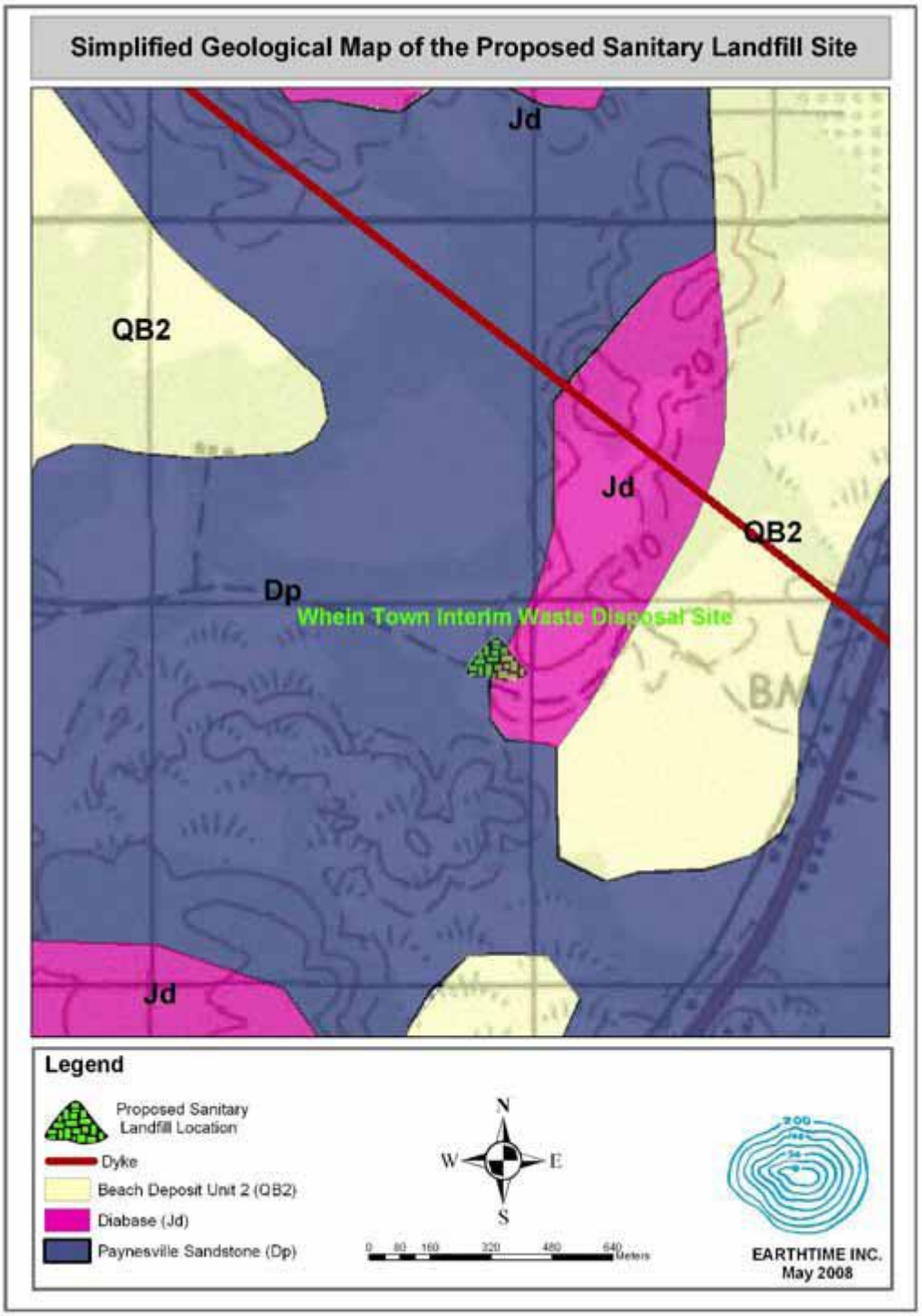


Figure 6-23: Geology of the area

Geologically, the site is located on the Paynesville Sandstone Formation (Dp). This formation typically forms low rounded brownish knobs in broad savannas underlain by white or brown unconsolidated sand deposits with a thickness up to 1,000 m (Behrendt and Wotorson, 1974a, b). The formation is no conformable on gneiss. It is intruded by Jurassic diabase sills and dikes, and an amygdaloidal basalt flow appears to overlie it. The Paynesville Formation is tentatively considered to be Devonian in age. A north-west trending tholeiitic diabase dyke (jd) is outcropping in the area (Figure 6-2). This is dominant feature of the Liberian geology. The dykes form long continuous ridges; these dykes also intrude the Paynesville Sandstone formation. The diabase occur mainly as dykes but also forms large sill-like bodies in

the coastal area near Monrovia, and are dark-gray, dominantly diabasic but locally gabbroic in texture; consist primarily of calcic plagioclase and clinopyroxene with minor amounts of magnetite and ilmenite. Pure white quartz sand averaging one meter in thickness, forming large savannah known as Beach Deposits Unit 2 (QB2) is also outcropping in the area.

1.4 Geophysical investigations

No geophysical investigation had been done to date and will be addressed as part of the detail design phase. The MPW is addressing this aspect as part of the establishment of monitoring boreholes.

1.5 Results of investigations

Based on the results of the different investigations (mainly desktop), the following information has been obtained concerning the geology and geohydrology of the proposed site.
Geology and site soils

The table below shows the formation and hydrogeological characteristics of the site.

Table 6-29: Hydrostratigraphic table of the area surrounding the site

Period	Formation	Lithology	Thickness (m)	Hydrogeological Characteristics	Remarks
Jurassic	Paynesville (Dp)	Brownish knobs in broad savannas underlain by brown unconsolidated sand deposits	1000 m	Aquifer	The formation is non conformable on Gneiss (Pre Jurassic)
	Diabase and basalt (Jd)	North west trending tholeiitic diabase dike. Tholeiitic amygdaloidal basalt overlie the Dp at two localities a long the coast	173 to 192 m	Fracture Aquifer	Early Jurassic
Quaternary	Lacustrine and beach deposits (Qb2)	White quartz sand	1 m	Semi Aquifer	Quaternary

Source: EIA report – Earthtime Inc

2.5.2 Cover availability and characteristics

From the results of the geotechnical and geophysical investigations, it is estimated that cover excavations could extend down to at least 10m depth. If the top 0,3m of topsoil is removed and stockpiled for final topsoiling and rehabilitation, this would leave an average depth of 9,7m of cover material across the site.
However, with the ground water level being shallow especially during the rain season resulting in a potential shallow vadose zone, the Landfill site will have to be constructed above ground level with fill soil obtained from the hill side and pond excavations on site.

The total area of the site (including the extension) is 10ha, of which approximately 2ha would be used for roads, infrastructure and the leachate treatment facility. This would leave 8ha available for Landfilling. To meet the cover material requirement of 120 000m^3, cover material is ideally excavated from site or brought in from outside which is costly and thus not ideal. It is not considered a balanced situation and thus not an economical design.
Where excavation is done such as in the hillside areas no problems are anticipated in the excavation of cover material down to the required depth using conventional excavation equipment. The stiff, unsaturated nature of the soils would tend to allow relatively steep cut slopes. However, due to voids in the soil structure in the hill area, slip failures of the cut faces occur thus lot allowing for steep excavations. A maximum slope ratio of 1:1 vertical to horizontal excavation would be allowed. Ideally this should be to a ratio of 1:2.
Due to the sandy/silty nature of the site soils, trafficability problems may also be experienced in wet conditions. It will therefore be necessary to occasionally add lateritic gravels to the cover material to ensure trafficability. On-site roads would need to be surfaced with imported gravel if not available from the excavation of the hillside.

2.5.3 Soil and bedrock permeabilities

No permeability and percolation tests have been done to date but based on the limited information on the geology and geotechnical assessment of the site (predominantly sandstone), the *in situ* residual soils (silty sandy material) are expected have coefficients of permeability considered as medium to high permeabilities. The reworked soils would thus not prevent leachate infiltration into the ground water, particularly in view of the high potential for leachate generation and would have to be enhanced. This could be by supplementing the natural sandy soil with either natural clay or the raw Bentonite powder. The latter is however very difficult to construct and the introduction of a GCL (geotextiles containing Bentonite powder in a confined space) would be preferred. The use of a geomembrane HDPE liner could also be considered.

1.6 Ground water

2.6.1 Ground water hydrology

Two boreholes drilled by Boimah Engineering were expected to tap the Paynesville Sandstone aquifer. However a geological log was not provided. Measurements taken on site indicated that the static water level in both wells ranged between 3 m and 3.45 m, while the depth of each borehole was around 25 m. The static and dynamic water levels under pumping conditions were not provided. The distance between the two wells is 200 meters. According to the environmental consultant, the physical, chemical and biological constituents of the water bodies in the area are influenced by the surface runoff from the surrounding hills.
The character of ground water occurrence and movement therefore needs to be studied further and it is recommended that further boreholes be drilled in the next phase of the project. These boreholes should be carefully sited to verify the results of the geophysics, and they should be deep enough to intersect the ground water

level. Some of these additional boreholes should be located in the site extension, and should be positioned according to known geophysical methods.

2.6.2 Ground water quality

Samples of the ground water from the boreholes were collected and analysed for a number of water quality parameters. The results of these are shown in Table 6-6 and were taken by two different consulting companies. High levels of Iron and Lead were observed in the samples.

2.6.2 Surface Water

The wider area hosting the Landfill is characterized by the presence of several surface water bodies ranging from swamps, springs, seasonal drainage systems, creeks, as well as small rivers.

Several springs originating from the Paynesville Sandstone Formation were observed at different locations within the site proximity. These springs are being used by local residents for drinking and domestic purposes.

2. GEOTECHNICAL INFORMATION

Soil Stability

Cut Slopes

Due to the high density, the insitu residual soils in the vicinity of the proposed Landfill site it is expected to remain stable when cut to angles of up to 2 horizontal to 1 vertical, provided the cuts are situated above the water table.

To reduce slope erosion by surface waters, it is considered expedient to place cut-off drains at the top of permanent cut slopes, so that rain water can be channelled away from them. For slopes maintained for short periods of time, the drain may be considered unnecessary.

Embankments

Although no specific testing was conducted to ascertain stability of recompacted material, it is anticipated that instu material used to form embankments will be stable if compacted in layers of maximum thickness 150 mm to 93% mod. AASHTO density. Embankments slopes constructed at slopes of 2 horizontal to 1 vertical are considered reasonable. However final slopes on the Landfill should be in the order of 3 horizontal to 1 vertical

It is considered likely that embankments will be susceptible to erosion, and consequently will need to be periodically maintained. Compaction of the institu material will reduce permeabilities to about 10^{-7} to 10^{-6} cm/sec, depending on compaction achieved. The insitu material on site would thus provide for a good quality natural clay barrier when compacted to 95% proctor density at +2% wet of optimum moisture content.

APPENDIX C

Perimeter Bund Specification

Appendix C - Perimeter Bund Construction

C1 The perimeter bunds should be constructed from engineered fill selected for uniformity from the stockpile. The bunds are required to stand until either the next phase of development or the construction of the final cover, soon after the next phase is commenced. The profile of the bund has been chosen as 1 vertical to 3 horizontal on the outside face and 1 vertical to 2 horizontal on the inside face. A steeper slope on the inside face is acceptable as the waste supports this slope. The shape of the perimeter bund is shown on Figure 7.1

C2 The portion of the bund will be set out using pegs. The base area will first be pegged out in the correct position as shown on the layout drawings of the landform. Simple triangular planks set up at 1 in 3 and 1 in 2 can assist in forming the battered slope.

C3 It is anticipated that the perimeter bunds will be constructed by using the track type loader. It will excavate material from the stockpile and spread it out in layer about 150 mm thick. To compact the layer the track type loader should run over the material 8 times, making sure that the whole surface has been given the compaction treatment.

C4 The next layer will follow, and so on until the 3 metre height of the bund has been reached. The addition of water may be desirable to aid compaction. The water bowser for damping down the site roads may be used for this purpose. Compaction density tests can be carried out to determine the optimum moisture content and to experiment with the number of passes of the track loader to achieve the best results.

C5 It may be that the track loader is fully occupied in the daily covering of the waste, in which case the perimeter bunds may be constructed by the public works section or by private contractor.

APPENDIX D

Wastes that should not be Landfilled

EXAMPLE - Government Gazette RSA, 7 September 2001

LIST OF HAZARDOUS OR TOXIC MATERIAL WHICH MAY NOT BE DISPOSED OF ON A GENERAL DISPOSAL SITE.

- Waste where specific control has been established in terms of the Nuclear Energy Act, 1993 (Act 131 of 1993).
- Waste types controlled in terms of the Minerals Act, 1991 (act 50 of 1991) and the Electricity Act, 1987 (Act 41 of 1987), unless written permission has been obtained from the Regional Director.
- Waste which is defined, according to the Minimum Requirements, as an extreme hazard or Hazard Group 1 (HG1); High hazard or Hazard Group 2 (HG2); moderate hazard or Hazard Group 3 (HG3) and low hazard or Hazard Group 4 (HG4), unless an application for delisting has been successfully submitted to the regional Director and written approval was obtained from the Regional Director for the disposal of the waste on the Site.
- Flammable wastes, with a closed cup flash point less than 61°C.
- Corrosive substances, as defined and described in the Minimum Requirements as Class 8 (1998 edition: page 6-8, Diagram III).
- Oxidising substances and organic peroxides, as defined and described in the Minimum Requirements as Class 5 (1998 edition: page 6-8, Diagram III)
- Any waste with a substance which is a Group A and /or Group B carcinogen/mutagen. Group A carcinogens/mutagens have been proven in humans, both clinical and epidermiological. Group B carcinogens/mutagens have been proven without a doubt in laboratory animals.
- Any waste with a substance at a concentration greater than 1% where the substance is a Group C and/or Group D carcinogen/mutagen. Group C carcinogens/mutagens have shown limited evidence in animals. Group D carcinogen/mutagen – the available data is inadequate and doubtful.
- Any infectious waste, unless it has been incinerated in 800°C or higher for at least 1 second. Infectious waste is waste which is generated during the diagnosis, treatment or immunisation of humans or animals; in the research pertaining to this; in the manufacturing or testing of biological agents including blood, blood products and contaminated blood products, cultures, pathological wastes, sharps, human and animal anatomical waste and isolation waste that contain or may contain infectious substances.
- All materials which falls in Class 1 (explosives), Class 2 (compressed gasses) and Class 7 (radioactive materials), as defined and described in the Minimum Requirements.
- Any waste with a pH less than 6 or greater than 12.
- Any waste which is difficult to analyse and classify.
- Any complexes of heavy metal cations, paint and paint sludge, or laboratory chemicals.

As a general guide the wastes described as follows should not be Landfilled:

- Waste with high percentages of volatile organic content

- Waste with high percentages of aromatic, halogenated and nonhalogenated compounds

- Wastes with high percentages of metals, especially arsenic, cadmium, lead, mercury and selenium

- Wastes with a high percentage of cyanide and sulphide

- Powdery hazardous waste that may cause dust problems in and around the Landfill

- Large amounts of waste with very low shear strength that may preclude settlement particularly on the final lifts, near the surface (for example sewage sludge with a high moisture content)

- Waste with high percentages of liquid that may generate too much leachate (for example tankers of liquid waste)

It should be understood that any recommendation of specific acceptable concentration levels of hazardous materials is not viable because of the fairly unregulated manner in which waste enters a Landfill and in which a Landfill is operated. The wastes mentioned above are permissible on the Landfill site but in amounts which are not potentially harmful. In this regard, it will be necessary for a Hazard Rating System, perhaps according to the United States EPA's methodology, to be drawn up. The South African Minimum Requirements series could also act as an excellent guideline.

Wastes, which should, under no circumstances, be allowed onto the site in any form, are:

- Strong Acids and Alkalis (these should be diluted to a pH of 8-9)
- PCB's
- Explosive materials
- Compressed gases
- Radioactive material

APPENDIX E

Water Balance Calculations

LEACHATE QUANTITY AND QUALITY

LEACHATE QUANTITY CALCULATIONS

INTRODUCTION

The leachate quantities for the Whein Town Landfill site were calculated using a water balance. This water balance was based on that used to calculate leachate quantities for Phase 1: Feasibility Study and Preliminary Design Reports. The water balance developed for the detailed design of the sites is more detailed, and takes into consideration the phasing and planned operation of each site. The water balance is also in accordance with the inception reports for the sites.

WATER BALANCE

A water balance for a Landfill is generally accepted as including the following components:

Leachate = Precipitation + Moisture Content of Incoming Wastes + Inflows of Ground and Surface Water - Runoff - Evapotranspiration - Field Capacity of Waste.

For a sanitary Landfill operation, the drainage design and practice should assume that no inflows of ground and surface water into the site occur.

ASSUMPTIONS

The following assumptions were made in the development of the water balance model:

- Due to the high rainfall in most areas of Liberia, it has been assumed that the moisture content of the waste body is 10% lower than its field capacity. While this assumption may be considered somewhat conservative, it would generally be true for the wet season months. The maximum quantities of leachate calculated using the model are therefore not considered to be affected by this conservative assumption, while the drier month calculations would be.

- In calculating the expected quantities of leachate to be generated at the Landfills, the following assumptions have been made, based on past experience, literature research and engineering judgement.

- Evapotranspiration (or soil evaporation) is taken as 0.7 x A pan evaporation.
  Runoff from final landform cover is taken as 60%, i.e. 40% infiltration occurs.
  Runoff from daily cover is taken as 12%, i.e. 88% infiltration occurs.
  Runoff from open waste is taken as 0%, i.e. 100% infiltration occurs.

- It has been assumed for the Landfill sites that final capping occurs one year after a phase has been completed. While this may appear conservative, this is frequently the case at Landfills in South Africa.

- The maximum area of open waste at any one time is 3000 to 5000 m^2.

- Contaminated water enters the leachate system for treatment, and is not contained separately. The contaminated water, however, is assumed to drain directly into such systems and leaves the system prior to evaporation occurring, as opposed to the leachate, for which flow-through allows evaporation to occur.

- All clean upslope run-off is drained off site, and does not enter the leachate system.

- All clean runoff from cells constructed but not yet used for waste disposal is diverted off site, and does not enter the leachate system.

- The wet weather cell is located in the cell presently operating, and not in the next cell. The maximum lined cell are is assumed to be 15000m^2

- Minor factors in the water balance model such as storage in the cover material, and infiltration through the liner have been calculated to be negligible, and have therefore been excluded from the calculations.

- Average monthly rainfall and evaporation figures have been used, so that the model calculations may or may not be conservative depending on the actual values.

CALCULATIONS

The calculations used in the water balance model are as follows: (The reader is referred to the tables following for the calculation results):

- The average precipitation and average evaporation figures were obtained from various source.
- The waste mass deposited figures were taken from the figures given in the inception reports.
- The phasing status, as well as the areas of open liner, open waste, intermediate cover and final cover was calculated using the phasing of the operations, the geometry of the sites and the airspace used per month. The maximum area of open waste at any one time was assumed to be half a hectare (5 000m^2).

- The contaminated runoff was calculated as the precipitation multiplied by the sum of the areas with open liner, open waste, and intermediate cover multiplied by their respective runoff factors.
- The clean runoff was calculated as the precipitation multiplied by the sum of the area with final cover multiplied by the runoff factor for the area.
- The potential evaporation was calculated by multiplying the average evaporation by the soil evaporation factor, 0.7.
- The leachate sub-total was calculated as the precipitation multiplied by the areas of the Landfill listed minus the contaminated and clean runoff minus the potential evaporation multiplied by the areas of open waste, intermediate cover and final cover. Where the result is less than zero, the result is taken as zero, using a nested IF statement.
- The potential storage in new waste (i.e. in waste deposited that month) was calculated as the waste mass deposited multiplied by the assumed differential between the field capacity and the moisture content of the waste (0.1) multiplied by the average number of days in a month.
- The excess as leachate is calculated as the leachate sub-total minus the potential storage in new waste. Where the result is less than zero, the result is taken as zero, using a nested IF statement.
- Leachate plus Runoff into ponds was calculated as the sum of the excess as leachate plus the contaminated runoff.
- The cumulative leachate plus runoff into ponds was taken as the cumulative total of the previous column.
- Leachate plus Runoff into ponds was then converted from a monthly flow to a daily flow.
- The Average for 4 month period is calculated as the average of the leachate plus runoff into ponds using the wettest consecutive four months.

Based on the climatic statistics for Monrovia as shown in Table 2 of Section 3.4, the area has a water surplus climatic water balance. This means that significant leachate generation can be expected at any Landfill site developed in the area. This fact was confirmed by the Consultants' involvement with an existing Landfill site in Monrovia. The proposed new Monrovia Landfill site will therefore require leachate management.
In Landfill design, there are two distinct methods of leachate management. The first involves complete containment, concentration and treatment of the leachate. The second relies on attenuation of the leachate by the subsurface soils and ground water through inter alia dispersion, dilution, adsorption and chemical modification.

One of the objectives of the project is to provide a Landfill design based on appropriate technology. To this end, three different design options for leachate management have been considered. The first design is based on

limited containment by means of a clay enhanced in-situ soil liner, and the ability of the subsurface environment to attenuate any leakage of leachate. The second design is based on improved containment by means of a bentonite contained GCL liner. The third design provides maximum containment by means of a geomembrane plastic or HDPE lining system.

To address the possible impact of leachate leakage on the ground water and surface water bodies, and to facilitate the design of the leachate collection system and the leachate/leachate treatment plant, an understanding is required of the quality and quantity of leachate to be expected at the Whein Town site. The expected leachate quantity has been calculated according to the water balance for the Landfill site. The leachate quality has been assessed from analyses of leachate sampled from other Landfill sites (Ghana and Swaziland) as no information on the leachate in Monrovia is available yet.

LEACHATE QUALITY

LEACHATE SAMPLING

Composite samples of leachate were obtained from three existing Landfill sites in Ghana in July 1996. These samples were analysed by the Water Resources Research Institute of the CSIR for a number of water quality parameters, the results of which are shown in Table A.4.1. The aim of the leachate sampling and analyses was to gain an understanding of the typical quality of the leachate from the three existing Landfill sites, with a view to:

i) establishing whether any hazardous substances were present in the leachate.
ii) determining the treatability of the leachate, and
iii) determining the possible impacts the untreated leachate might have on the environment.

Samples were also taken from Landfill in Swaziland to enable comparison of leachate from developing communities' Landfills.

TABLE A.4.1
RESULTS OF WATER QUALITY ANALYSES ON LEACHATE SAMPLES

Typical composition of raw leachate from Ghana dumpsite

PARAMETER	SAMPLE
	Ghana
pH	7,2
Conductivity (mS/m)	895
Suspended Solids	960
Sodium (Na)	975
Potassium (K)	1 520
Calcium (Ca)	190
Iron (Fe)	4,7
Chloride (C/)	1 345
Sulphate	15,3
Nitrate	<0,03
Ammonia (NH_3 - N)	213
Phosphate	1,33
Total Alkalinity	828
Chemical Oxygen Demand	6 325
Lead (Pb)	0,08

Results are in mg// except where otherwise stated.

Typical composition of raw leachate from new and mature Landfills (Swaziland)

Constituent	Range (mg/l)	New Landfill (less than 2 years Typical Value (mg/l)	Mature Landfill (Greater than 10 years) Typical Value (mg/l)	Mbabane Landfill (Swaziland) ** (mg/l)
Physical				
pH	4.5-7.5	6	6.6-7.5	**8.1 – 8.8**
Conductivity		480 – 72500		**94 – 254**
Organic				
COD (chemical oxygen demand)	3000-60 000	18 000	100-500	**80 – 327**
BOD_5/COD	0.4-0.6	0.5	0.05-0.2	**0.17 - 0.47**
TOC (total organic carbon)	1500-20 000	6000	80-160	
Dissolved Organic Carbon as C				**25 – 29**
Inorganic				
Total suspended solids	200-2000	500	100-400	
TDS		584 – 55000		**473 – 1124**
Organic nitrogen	10-800	200	80-120	**17 – 106**
Ammonia nitrogen	10-800	200	20-40	**4 – 91**
Nitrate	5-40	25	5-10	**0.2 – 3.8**
Total phosphorus	5-100	30	5-10	**0.05**
Ortho phosphorus	4-80	20	4-8	**0.20**
Alkalinity as $CaCO_3$	1000-10 000	3000	200-1000	**40 – 745**
Total hardness as $CaCO_3$	300-10 000	3500	200-500	**13 – 28**
Calcium	200-3000	1000	100-400	**23 – 53**

Calcium hardness				**9 - 24**
Magnesium	50-1500	250	50-200	**20 – 26**
Potassium	200-1000	300	50-400	
Sodium	200-2500	500	100-200	**123 - 250**
Chloride	200-3000	500	100-400	**158 – 376**
Sulphate	50-1000	300	20-50	**5 – 22**
Total iron	50-1200	60	20-200	**0.34 – 3.0**
Biological				
BOD_5 (5-day biochemical oxygen demand)	2000-30 000	10 000	100-200	**14 – 152**
Coliform				**0 - 10800**
Faecal coliform				**0 – 100**
Streptococci				**0 – 900**

Source: Integrated solid waste management, George Tchobanoglous et. al., 1993, McGraw-hill
** Analyses done by Waterlab (Pty) Ltd (Pretoria) and SWSC (Mbabane, Swaziland)

AGE OF LEACHATE

The pH of the leachate ranged between 7,2 (Ghana Landfill) in July 1996. This indicates that the "Landfill" or rather dumpsite is in the methanogenic phase of decomposition. The fairly low COD concentrations, at approximately 6 500mg/*l*, support this deduction. This figure in Ghana is considered high as it suspected that sewage sludge is also disposed in the solid waste. The leachate characteristics are typical of domestic waste with little evidence of heavy metals, although a full analysis on these was not done.

ENVIRONMENTAL IMPACTS OF LEACHATE

The leachate definitely does not comply with drinking water standards and should not be used for domestic purposes. If the untreated leachate is discharged into public streams, the high ammonia concentrations could have a negative effect on aquatic biota. The recommended maximum concentration of ammonia for streams is 16 µg/*l* (Kempster *et al*, 1980:10). The toxic effects of ammonia are, however, dependent on the pH of the water, i.e. it is more toxic at higher pH's than at low pH's.

The high salt content of the leachate could also have an impact on the receiving environment, but this would depend on the quantity of leachate discharge, the flow of the receiving stream and its salt content.

The high phosphate concentration in the leachate of both the Ghana leachate would tend to promote the growth of excessive algal and bacterial blooms in the receiving water. However, once again the assimilative capacity of the receiving water body should be considered.

LEACHATE TREATABILITY

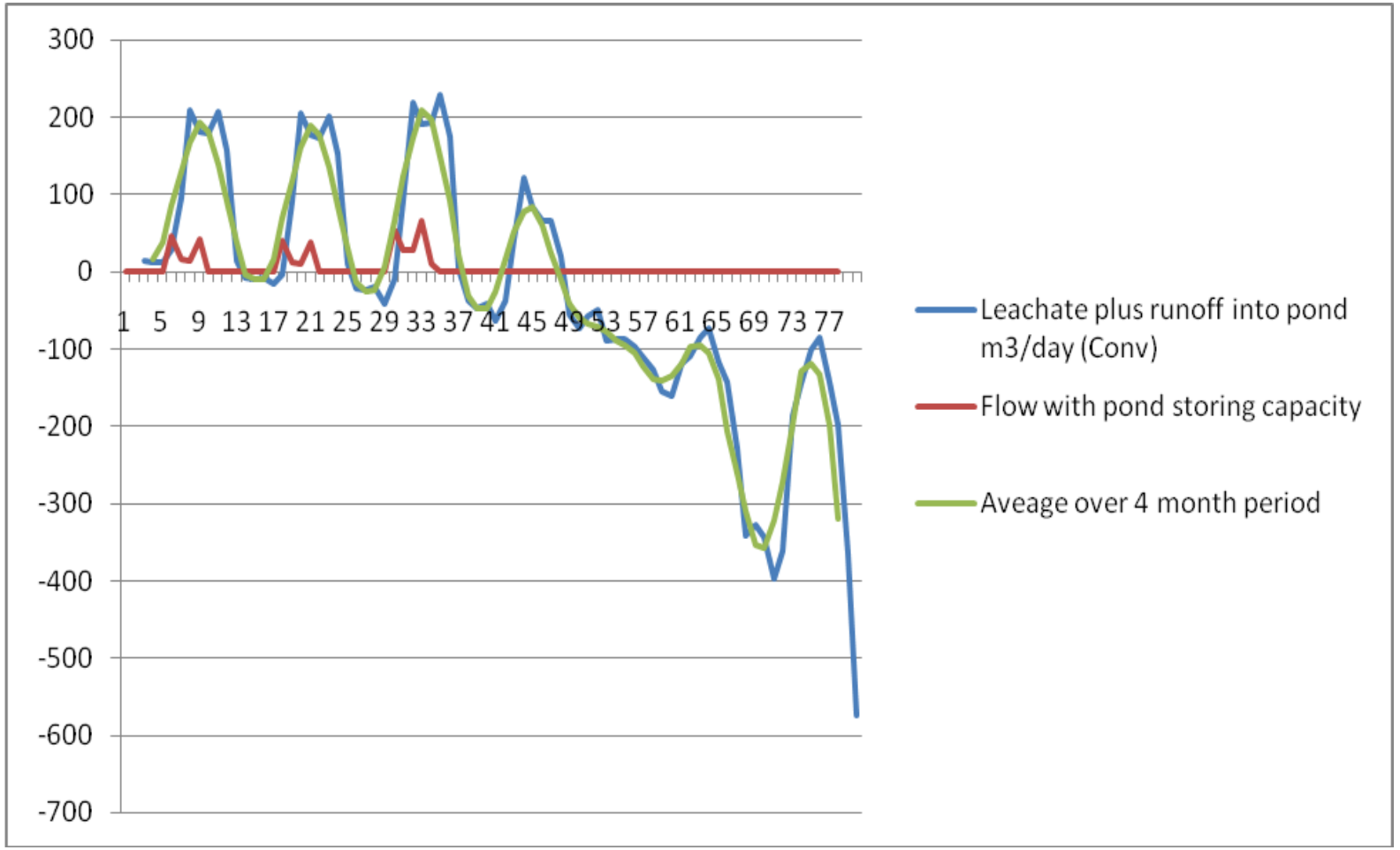
The leachate has a COD concentration that is approximately ten times higher than that of average water borne domestic sewage (Institute of Water Pollution Control, 1985:1,5). The sewage is, however, much weaker than the leachate, which typically has a COD of approximately 20 000mg/*l*. The sewage could therefore be treated in a similar system as the leachate. Because of the high COD concentrations of the leachate an anaerobic treatment system, such as an oxidation dam system with deep primary ponds could be considered

LEACHATE QUANTITY CALCULATIONS

*** Evaporation figures for Sekondi-Takoradi used (Coastal city in Ghana)

+++ Operator has to ensure minimum open waste surface

--- Liner clean water drainage very critical - ensure contaminated area not larger than area shown ie. 15000m^2



Water Balance Calculations: Monrovia

Month	Yr	Average precipitation	Pan evaporation ***	Waste mass deposited	Operations strategy	Area with open liner ---	Area of open waste +++	Area with inter-mediate cover	Area with final cover	Uncontaminated runoff	Clean runoff from final cover	Potential evapo-ration E x Factor	Leachate sub-total	Potential storage in new waste	Excess as leachate	Leachate plus runoff into pond	Cumulative leachate plus runoff	Leachate plus runoff into pond	Average over 4 month period	Actual evaporation	Actual evaporation	Cumulative leachate left in pond	Flow with pond storing capacity
		P	E			A_l	A_o	A_i	A_f	Areas x factors													
Units				Tpd		m^2	m^2	m^2	m^2	m^3	m^3	mm		m^3	m^3	m^3	m^3	m^3/day		m^3/day	m^3	m^3	m^3/day
Status		(Input)	(Input)	(Input)		(Input)	(Input)	(Input)	(Input)	(Calc)	(Calc)	(Calc)	(Calc)	(Calc)	(Calc)	(Calc)	(Calc)	(Conv)		(Calc)	(Conv)	(Calc)	(Conv)
Factors						100%	0%	15%	75%			70 %		10%						16000 pond size			5 000.0 holding cap
						runoff	runoff	runoff	runoff														
Jan	1	45	80	325.8	5000.0	10000.0	1000.0	0.0	0.0	450.0	0.0	56	0.0	991.0	0.0	450	450	14.8		29.5	896.0	0.0	0.0
Feb		38	80	325.8	0.0	10000.0	1000.0	0.0	0.0	380.0	0.0	56	0.0	991.0	0.0	380	830	12.5		29.5	896.0	0.0	0.0
Mar		65	83	325.8	5000.0	5000.0	1000.0	5000.0	0.0	373.8	0.0	58	0.0	991.0	0.0	374	1204	12.3		30.6	929.6	0.0	0.0
Apr		150	80	325.8	0.0	5000.0	1000.0	5000.0	0.0	862.5	0.0	56	171.5	991.0	0.0	863	2066	28.4	17.0	0.0	0.0	862.5	0.0
May		405	70	325.8	0.0	5000.0	1000.0	5000.0	0.0	2328.8	0.0	49	1 587.3	991.0	596.3	2925	4991	96.2	37.3	0.0	0.0	3 787.5	0.0
Jun		707	54	325.8	5000.0	0.0	1000.0	10000.0	0.0	1060.5	0.0	38	6 300.7	991.0	5309.7	6370	11362	209.4	86.6	0.0	0.0	10 157.8	45.0
Jul		625	50	325.8	0.0	0.0	1000.0	10000.0	0.0	937.5	0.0	35	5 552.5	991.0	4561.5	5499	16861	180.8	128.7	0.0	0.0	15 656.8	16.4
Aug		618	50	325.8	0.0	0.0	1000.0	10000.0	0.0	927.0	0.0	35	5 486.0	991.0	4495.0	5422	22283	178.3	166.2	0.0	0.0	21 078.8	13.9
Sep		698	53	325.8	0.0	0.0	1000.0	10000.0	0.0	1047.0	0.0	37	6 222.9	991.0	5231.9	6279	28561	206.4	193.7	0.0	0.0	27 357.7	42.0
Oct		570	63	325.8	5000.0	-5000.0	1000.0	15000.0	0.0	-1567.5	0.0	44	7 352.4	991.0	6361.4	4794	33355	157.6	180.8	0.0	0.0	32 151.7	0.0
Nov		183	75	325.8	0.0	-5000.0	1000.0	15000.0	0.0	-503.3	0.0	53	1 938.8	991.0	947.8	445	33800	14.6	139.2	0.0	0.0	32 596.2	0.0
Dec		95	77	325.8	0.0	-5000.0	1000.0	15000.0	0.0	-261.3	0.0	54	713.4	991.0	0.0	-261	33539	-8.6	92.5	0.0	0.0	32 334.9	0.0
Jan	2	45	80	371.4	5000.0	-10000.0	1000.0	20000.0	0.0	-315.0	0.0	56	194.0	1129.7	0.0	-315	33224	-10.4	38.3	29.5	896.0	31 123.9	0.0
Feb		38	80	371.4	0.0	-10000.0	1000.0	20000.0	0.0	-266.0	0.0	56	68.0	1129.7	0.0	-266	32958	-8.7	-3.3	29.5	896.0	29 961.9	0.0
Mar		65	83	371.4	0.0	-10000.0	1000.0	20000.0	0.0	-455.0	0.0	58	530.9	1129.7	0.0	-455	32503	-15.0	-10.7	30.6	929.6	28 577.3	0.0
Apr		150	80	371.4	5000.0	-15000.0	1000.0	25000.0	0.0	-1687.5	0.0	56	2 721.5	1129.7	1591.8	-96	32407	-3.1	-9.3	0.0	0.0	28 481.6	0.0
May		405	70	371.4	0.0	-15000.0	1000.0	25000.0	0.0	-4556.3	0.0	49	8 472.3	1129.7	7342.5	2786	35193	91.6	16.2	0.0	0.0	31 267.9	0.0
Jun		707	54	371.4	0.0	-15000.0	1000.0	25000.0	0.0	-7953.8	0.0	38	15 315.0	1129.7	14185.2	6231	41425	204.9	69.6	0.0	0.0	37 499.4	40.5
Jul		625	50	371.4	0.0	-	1000.0	25000.0	0.0	-7031.3	0.0	35	13 521.3	1129.7	12391.5	5360	46785	176.2	117.4	0.0	0.0	42 859.6	11.8

						-15000.0																	
Aug		618	50	371.4	0.0	-15000.0	1000.0	25000.0	0.0	-6952.5	0.0	35	13 365.5	1129.7	12235.8	5283	52068	173.7	161.6	0.0	0.0	48 142.9	9.3
Sep		698	53	371.4	0.0	-15000.0	1000.0	25000.0	0.0	-7852.5	0.0	37	15 122.4	1129.7	13992.7	6140	58208	201.9	189.2	0.0	0.0	54 283.1	37.5
Oct		570	63	371.4	0.0	-15000.0	1000.0	25000.0	0.0	-6412.5	0.0	44	12 197.4	1129.7	11067.7	4655	62864	153.0	176.2	0.0	0.0	58 938.2	0.0
Nov		183	75	371.4	0.0	-15000.0	1000.0	25000.0	0.0	-2058.8	0.0	53	3 494.3	1129.7	2364.5	306	63169	10.1	134.7	0.0	0.0	59 244.0	0.0
Dec		95	77	371.4	0.0	-15000.0	1000.0	25000.0	0.0	-1068.8	0.0	54	1 520.9	1129.7	391.1	-678	62492	-22.3	85.7	0.0	0.0	58 566.4	0.0
Jan	3	45	80	419.2	5000.0	-20000.0	1000.0	30000.0	0.0	-697.5	0.0	56	576.5	1275.1	0.0	-698	61794	-22.9	29.5	29.5	896.0	56 972.9	0.0
Feb		38	80	419.2	0.0	-20000.0	1000.0	30000.0	750.0	-589.0	21.4	56	356.1	1275.1	0.0	-589	61205	-19.4	-13.6	29.5	896.0	55 487.9	0.0
Mar		65	83	419.2	5000.0	-25000.0	1000.0	35000.0	1500.0	-1283.8	73.1	58	1 296.9	1275.1	21.8	-1262	59943	-41.5	-26.5	30.6	929.6	53 296.3	0.0
Apr		150	80	419.2	0.0	-25000.0	1000.0	35000.0	2375.0	-2962.5	267.2	56	3 952.6	1275.1	2677.5	-285	59658	-9.4	-23.3	0.0	0.0	53 011.3	0.0
May		405	70	419.2	0.0	-25000.0	1000.0	35000.0	3250.0	-7998.8	987.2	49	12 084.6	1275.1	10809.5	2811	62469	92.4	5.5	0.0	0.0	55 822.1	0.0
Jun		707	54	419.2	5000.0	-30000.0	1000.0	40000.0	4125.0	-16968.0	2187.3	38	24 902.4	1275.1	23627.3	6659	69128	218.9	65.1	0.0	0.0	62 481.4	54.6
Jul		625	50	419.2	0.0	-30000.0	1000.0	40000.0	5125.0	-15000.0	2402.3	35	22 111.4	1275.1	20836.3	5836	74965	191.9	123.5	0.0	0.0	68 317.7	27.5
Aug		618	50	419.2	0.0	-30000.0	1000.0	40000.0	6125.0	-14832.0	2838.9	35	21 976.9	1275.1	20701.9	5870	80835	193.0	174.1	0.0	0.0	74 187.6	28.6
Sep		698	53	419.2	0.0	-30000.0	1000.0	40000.0	7125.0	-16752.0	3729.9	37	25 000.9	1275.1	23725.8	6974	87808	229.3	208.3	0.0	0.0	81 161.4	64.9
Oct		570	63	419.2	5000.0	-35000.0	1000.0	45000.0	8125.0	-16102.5	3473.4	44	22 686.9	1275.1	21411.8	5309	93118	174.6	197.2	0.0	0.0	86 470.7	10.2
Nov		183	75	419.2	0.0	-35000.0	1000.0	45000.0	9250.0	-5169.8	1269.6	53	6 542.8	1275.1	5267.7	98	93216	3.2	150.0	0.0	0.0	86 568.7	0.0
Dec		95	77	419.2	0.0	-35000.0	1000.0	45000.0	10375.0	-2683.8	739.2	54	2 823.0	1275.1	1548.0	-1136	92080	-37.3	92.4	0.0	0.0	85 432.9	0.0
Jan	4	45	80	469.2	5000.0	-40000.0	1000.0	48875.0	11500.0	-1470.1	388.1	56	846.8	1427.2	0.0	-1470	90610	-48.3	23.0	29.5	896.0	83 066.8	0.0
Feb		38	80	469.2	0.0	-40000.0	1000.0	47653.1	12721.9	-1248.4	362.6	56	501.1	1427.2	0.0	-1248	89361	-41.0	-30.9	29.5	896.0	80 922.4	0.0
Mar		65	83	469.2	0.0	-40000.0	1000.0	46461.8	13913.2	-2147.0	678.3	58	1 616.2	1427.2	189.0	-1958	87403	-64.4	-47.8	30.6	929.6	78 034.8	0.0
Apr		150	80	469.2	0.0	-40000.0	1000.0	45300.3	15074.7	-4980.7	1695.9	56	5 294.1	1427.2	3866.9	-1114	86290	-36.6	-47.6	0.0	0.0	76 921.0	0.0
May		405	70	469.2	0.0	-40000.0	1000.0	44167.7	16207.3	-13516.8	4923.0	49	16 203.4	1427.2	14776.1	1259	87549	41.4	-25.2	0.0	0.0	78 180.3	0.0
Jun		707	54	469.2	0.0	-40000.0	1000.0	43063.6	17311.4	-23713.1	9179.4	38	28 837.9	1427.2	27410.6	3698	91246	121.6	15.5	0.0	0.0	81 877.8	0.0
Jul		625	50	469.2	0.0	-40000.0	1000.0	41987.0	18388.0	-21063.7	8619.4	35	25 055.6	1427.2	23628.4	2565	93811	84.3	52.7	0.0	0.0	84 442.5	0.0
Aug		618	50	469.2	0.0	-40000.0	1000.0	40937.3	19437.7	-20925.1	9009.4	35	24 377.4	1427.2	22950.1	2025	95836	66.6	78.5	0.0	0.0	86 467.5	0.0

Sep		698	53	469.2	0.0	-40000.0	1000.0	39913.9	20461.1	-23741.0	10711.4	37	27 156.3	1427.2	25729.1	1988	97824	65.4	84.5	0.0	0.0	88 455.6	0.0
Oct		570	63	469.2	0.0	-40000.0	1000.0	38916.0	21459.0	-19472.7	9173.7	44	21 540.1	1427.2	20112.9	640	98464	21.0	59.3	0.0	0.0	89 095.8	0.0
Nov		183	75	469.2	0.0	-40000.0	1000.0	37943.1	22431.9	-6278.5	3078.8	53	5 989.1	1427.2	4561.9	-1717	96748	-56.4	24.1	0.0	0.0	87 379.2	0.0
Dec		95	77	469.2	0.0	-40000.0	1000.0	36994.5	23380.5	-3272.8	1665.9	54	2 485.5	1427.2	1058.3	-2215	94533	-72.8	-10.7	0.0	0.0	85 164.6	0.0
Jan	5	45	80	521.6	5000.0	-45000.0	1000.0	41069.7	24305.3	-1747.8	820.3	56	692.3	1586.4	0.0	-1748	92785	-57.5	-41.4	29.5	896.0	82 520.9	0.0
Feb		38	80	521.6	0.0	-45000.0	1000.0	40042.9	25332.1	-1481.8	722.0	56	375.0	1586.4	0.0	-1482	91304	-48.7	-58.9	29.5	896.0	80 143.1	0.0
Mar		65	83	521.6	5000.0	-50000.0	1000.0	44041.9	26333.1	-2820.6	1283.7	58	1 684.3	1586.4	97.9	-2723	88581	-89.5	-67.1	30.6	929.6	76 490.8	0.0
Apr		150	80	521.6	0.0	-50000.0	1000.0	42940.8	27434.2	-6533.8	3086.3	56	5 456.7	1586.4	3870.3	-2664	85917	-87.6	-70.8	0.0	0.0	73 827.3	0.0
May		405	70	521.6	0.0	-50000.0	1000.0	41867.3	28507.7	-17706.6	8659.2	49	16 656.8	1586.4	15070.4	-2636	83281	-86.7	-78.1	0.0	0.0	71 191.1	0.0
Jun		707	54	521.6	5000.0	-55000.0	1000.0	45820.6	29554.4	-34025.7	15671.2	38	32 658.7	1586.4	31072.2	-2954	80328	-97.1	-90.2	0.0	0.0	68 237.6	0.0
Jul		625	50	521.6	0.0	-55000.0	1000.0	44675.1	30699.9	-30186.7	14390.6	35	28 407.4	1586.4	26820.9	-3366	76962	-110.7	-95.5	0.0	0.0	64 871.8	0.0
Aug		618	50	521.6	0.0	-55000.0	1000.0	43558.2	31816.8	-29952.2	14747.1	35	27 666.7	1586.4	26080.3	-3872	73090	-127.3	-105.4	0.0	0.0	61 000.0	0.0
Sep		698	53	521.6	0.0	-55000.0	1000.0	42469.3	32905.7	-33943.5	17226.2	37	30 844.1	1586.4	29257.6	-4686	68404	-154.1	-122.3	0.0	0.0	56 314.1	0.0
Oct		570	63	521.6	5000.0	-60000.0	1000.0	46407.5	33967.5	-30232.2	14521.1	44	26 952.2	1586.4	25365.7	-4866	63538	-160.0	-138.0	0.0	0.0	51 447.7	0.0
Nov		183	75	521.6	0.0	-60000.0	1000.0	45247.3	35127.7	-9738.0	4821.3	53	7 706.1	1586.4	6119.7	-3618	59920	-119.0	-140.1	0.0	0.0	47 829.4	0.0
Dec		95	77	521.6	0.0	-60000.0	1000.0	44116.2	36258.8	-5071.3	2583.4	54	3 366.4	1586.4	1780.0	-3291	56628	-108.2	-135.3	0.0	0.0	44 538.0	0.0
Jan	6	45	80	575.9	5000.0	-65000.0	1000.0	48013.3	37361.7	-2600.9	1261.0	56	1 104.8	1751.8	0.0	-2601	54027	-85.5	-118.2	29.5	896.0	41 041.1	0.0
Feb		38	80	575.9	0.0	-65000.0	1000.0	46812.9	38562.1	-2203.2	1099.0	56	719.4	1751.8	0.0	-2203	51824	-72.4	-96.3	29.5	896.0	37 942.0	0.0
Mar		65	83	575.9	0.0	-65000.0	1000.0	45642.6	39732.4	-3780.0	1937.0	58	1 990.5	1751.8	238.7	-3541	48283	-116.4	-95.6	30.6	929.6	33 471.1	0.0
Apr		150	80	575.9	5000.0	-70000.0	1000.0	49501.5	40873.5	-9386.2	4598.3	56	6 797.2	1751.8	5045.4	-4341	43942	-142.7	-104.3	0.0	0.0	29 130.2	0.0
May		405	70	575.9	0.0	-70000.0	1000.0	48264.0	42111.0	-25418.0	12791.2	49	20 236.2	1751.8	18484.4	-6934	37008	-228.0	-139.9	0.0	0.0	22 196.6	0.0
Jun		707	54	575.9	0.0	-70000.0	1000.0	47057.4	43317.6	-44499.6	22969.2	38	35 834.6	1751.8	34082.7	-10417	26592	-342.5	-207.4	0.0	0.0	11 779.8	0.0
Jul		625	50	575.9	0.0	-70000.0	1000.0	45881.0	44494.0	-39448.7	20856.6	35	31 203.3	1751.8	29451.5	-9997	16594	-328.7	-260.5	0.0	0.0	1 782.6	0.0
Aug		618	50	575.9	0.0	-70000.0	1000.0	44733.9	45641.1	-39113.2	21154.6	35	30 420.2	1751.8	28668.3	-10445	6149	-343.4	-310.6	0.0	0.0	0.0	0.0
Sep		698	53	575.9	0.0	-70000.0	1000.0	43615.6	46759.4	-44293.4	24478.6	37	33 941.6	1751.8	32189.8	-12104	-5954	-397.9	-353.1	0.0	0.0	0.0	0.0
Oct		570	63	575.9	0.0	-70000.0	1000.0	42525.2	47849.8	-36264.1	20455.8	44	27 049.4	1751.8	25297.6	-10967	-16921	-360.5	-357.6	0.0	0.0	0.0	0.0

Nov		183	75	575.9	0.0	-70000.0	1000.0	41462.1	48912.9	-11671.9	6713.3	53	7 748.0	1751.8	5996.2	-5676	-22596	-186.6	-322.1	0.0	0.0	0.0	0.0
Dec		95	77	575.9	0.0	-70000.0	1000.0	40425.5	49949.5	-6073.9	3558.9	54	3 393.5	1751.8	1641.7	-4432	-27029	-145.7	-272.7	0.0	0.0	0.0	0.0
Jan	7	45	80	632.4	5000.0	-75000.0	1000.0	44414.9	50960.1	-3075.2	1719.9	56	1 120.2	1923.5	0.0	-3075	-30104	-101.1	-198.5	29.5	896.0	0.0	0.0
Feb		38	80	632.4	0.0	-75000.0	1000.0	43304.5	52070.5	-2603.2	1484.0	56	734.4	1923.5	0.0	-2603	-32707	-85.6	-129.8	29.5	896.0	0.0	0.0
Mar		65	83	632.4	0.0	-75000.0	1000.0	42221.9	53153.1	-4463.3	2591.2	58	2 019.6	1923.5	96.2	-4367	-37074	-143.6	-119.0	30.6	929.6	0.0	0.0
Apr		150	80	632.4	0.0	-75000.0	1000.0	41166.3	54208.7	-10323.8	6098.5	56	6 234.5	1923.5	4311.1	-6013	-43087	-197.7	-132.0	0.0	0.0	0.0	0.0
May		405	70	632.4	0.0	-75000.0	1000.0	40137.2	55237.8	-27936.7	16778.5	49	18 767.7	1923.5	16844.2	-11092	-54179	-364.7	-197.9	0.0	0.0	0.0	0.0
Jun		707	54	632.4	0.0	-75000.0	1000.0	39133.8	56241.2	-48874.9	29821.9	38	33 357.1	1923.5	31433.6	-17441	-71621	-573.4	-319.8	0.0	0.0	0.0	0.0

APPENDIX F

Environmental Evaluation

ENVIRONMENTAL IMPACT ASSESSMENT (Salient issues extracted from the EIA report (Earthtime)

2.1 Introduction

An Environmental Impact Assessment (EIA) was prepared by Messrs Earthtime Inc consultants at the time that the Whein Town site was being considered for the temporary Landfill for Monrovia. The EIA is used to identify the various ways in which the proposed Monrovia Landfill/leachate development will affect the receiving environment. The objective is thus to ensure that significant impacts are identified so that they can be addressed in the Design and the Operating Plan, with a view to minimising the future impacts of the Landfill.

In the event that any critical factors identified cannot be accommodated in the design or operation, they would represent fatal flaws that would render the site or development non-feasible.

As the environment is seen in a holistic sense, the EIA considered the physical, biological, social and aesthetic, as well as institutional concerns.

2.2 Assessment and mitigation of Landfill impacts

The findings of the EIA as conducted by Messrs Earthtime Inc are shown in Table 7-30 below:

Table 7-30: Summary potential environmental impacts

Parameter	**Potential Impacts According to Development Phase**		
	Construction	**Operation**	**Post-closure**
Source & groundwater quality	-	---	--/-/0
Soil quality	-	---	0
Odours	0	---	-/0
Air quality	-	--	-/0
Health and Safety	-	--	-/0
Nose	-	-	0
Waste Management	-	+++	0
Landscape & Visual Intrusion	-/0	-	++
Biodiversity	-/0	-/0	-/0
Landfill Stability	-	-	--
Socio-economic	-/+	-/+ +	++
Traffic	-	-	0
Cultural Heritage	N/A	N/A	N/A

+++: High potential positive impact
++: Moderate potential positive impact
+: Low potential positive impact
0: No significant potential impact
---: High potential negative impact
--: Moderate potential negative impact
-: Low potential negative impact
NA: Not Applicable

The EIA states that the impacts are scored from --- to +++, with a score of - indicating a negative impact and + a positive impact. Negative impacts constitute

critical factors that need to be eliminated or suitably ameliorated by design at acceptable cost to the project.
The EIA also states that the negative impacts identified can be divided into two main categories, short term impacts and long term impacts. The short term impacts are those associated with development of the Landfill. Long term impacts are those generally associated with incorrect Landfill site selection, design, preparation or operation, and these could persist long after the Landfill site has been closed.
The various impacts as identified in the EIA are addressed below by the Consultant (Pöyry) as proposed design measures to mitigation the identified impacts.

2.2.1 Short term negative impacts

The potential short term negative impacts identified, such as odours, fires, pests and plagues, unsightliness and wind blown litter, will be controlled by a properly implemented sanitary Landfill operation as prescribed by the Consultant (see Section 12). A sanitary Landfill operation requires compaction and daily covering of waste. Although in terms of the design the potential cover material is limited that would be obtained through site excavations, possibilities do exist to obtain the cover material from sources nearby or by selecting certain type of inert waste. Such a sanitary operation is thus possible at Whein Town although potentially expensive. This is an important aspect of the operations and attempts have to be made to stockpile all available disposed soils on site for later use as part of the daily operations. Due to the geohydrological constraints of the site not all cover material will be obtained and thus stockpiled on site (Site cannot be excavated to deep).
Dust, often a problem associated with an operating Landfill, is not seen to be a major factor of concern, because of the high rainfall of this area and the distance of the site from residential areas.
Because of the height of the surrounding areas, the site will be visible to future development only towards the west and immediately north of the site. However, this will be mitigated by use of the 'rising green wall' approach, where, as far as possible, the waste disposal operation is screened by vegetated berms and trees planted along the site boundary.

2.2.2 Long term negative impacts

The most significant long term potential negative impact of the Whein Town Landfill would be the leachate polluting the groundwater. This would be on account of the high rainfall in the area, and the adjacent water courses into which run-off from the site would drain and the high potential and good quality of the ground water. This is a particularly significant impact, as the ground water at the nearby villages is used for irrigation and also occasionally for drinking purposes.
In order to prevent water pollution, Landfilling will be done in lined cells and the operations will be such that water will drain away from the waste body. Any seepage on account of the perched water table will be collected and drained through a subsoil drainage system. Leachate will be drained through the Landfill drainage

system. Since the Landfill is located in a humid climate, where significant leachate generation will occur, cut-off trenches and storm water channels, leachate collection and treatment systems will be included (see Section 9). The objective would be to ensure that leachate and contaminated water are contained on the site, while clean uncontaminated water is allowed to flow off the site as fast as possible or is diverted away from the waste body.

Furthermore, when cover material is excavated on site, the depth of the excavation will be controlled to ensure that an adequate separation is maintained between the waste body and the wet season high elevation of the ground water (see Section 10). Where this is not possible, the area will be excluded from Landfill activities. Excavations will be properly drained to avoid ponding.

Regular monitoring of both surface water and boreholes is essential and will be monitored as part of the monitoring plan to confirm that the design is functioning as planned and that any escape of leachate into the water regime is timeously identified. Although the one known group of water users will be accommodated through the construction of a newly approved water well, all new comers to the area will have to be informed of the possible impact of the Landfill on water quality. They will need to seek an alternative supply of drinking water.

Another potential long term problem is the potential for odour and explosion associated with the operation and with the migration of Landfill gas. This will be addressed in the design, operation and ongoing monitoring of the Landfill. Options are being explored by outside consultants (in collaboration with the EPA) to actively exploit the use of the Landfill gas. Until finality is reached on this option, passive venting of the gas will be exercised.

In order to ensure that significant erosion does not occur once vegetation is removed, the site will be progressively rehabilitated with final cover being applied to a fill area as soon as it is complete.

2.3 Assessment and mitigation of leachate impacts

Negative impacts associated with a leachate flow and treatment could include odours, water pollution from leakages and overloading of the system, flies and mosquitoes. None of these impacts should be significant if the system is adequately designed, constructed and operated. The most significant impact of the leachate plant would be the possible degradation of the surface water quality in nearby water streams, on account of the quality of the discharged effluent. This effect would be further exacerbated by poor operation and overloading. The negative effects are to be addressed through proper design of the leachate treatment system (see Section 9).

2.4 Conclusion

As pointed out above it can be seen that none of the identified significant negative impacts of the Landfill identified in the EIA were of such a nature that they could not be satisfactorily mitigated by proper design and/or operation as prescribed by the Consultant.

The most important potential negative impact of the Landfill/leachate treatment facility identified is water pollution by leachate flow and treated leachate effluent. This is particularly important as both surface water and ground water are used for agricultural and in one case for drinking purposes. This impact has therefore been addressed in both the public participation process and the design. A new potable water supply well is to be provided to the village directly affected as a result of the spring that was damaged through Landfilling operations.

The problem of gas is addressed in the design and operation of the Landfill through the provision of gas ventilation shafts which will require ongoing monitoring. Active venting is being pursued to be used as an alternative energy source.

It is the consultant's opinion that with proper operation, the Landfill should not negatively impact upon the environment on and adjacent to the Landfill site. However, the general nuisances of noise, dust, wind-blown litter and the activity associated with heavy vehicles and equipment need to be taken into account when establishing people or industries in close proximity to the site. As the proposed future land-use of the surrounding area is still residential, it would be important to ensure that an adequate buffer zone is provided.

To ensure a professional Landfill operation, the MCC will have to make the necessary operational budget available. In addition, proper resources will have to be made available, in terms of trained personnel and equipment. Should this not be the case, the identified negative impacts could become critical and an unacceptable situation, not unlike the *status quo*, could rapidly develop.

In addition to proper operations and good housekeeping the possible negative impacts must be regularly controlled and monitored through a set of procedures supported by regular audits.

Recommendations relating to Construction and Operation

- In order to prevent habitat destruction, the area of construction and operation should be confined to the smallest possible space and well-defined access roads established.

- To prevent unauthorised access, a security fence with a lockup gate must be erected around the operating area of the site, 24-hour security established based on the permit conditions.

- Waste material should be separated at source thereby facilitating the effective management of lightweight materials at site.

- Implement management actions to mitigate the visual impact of windblown materials carried from the proposed waste disposal site

- Implement management actions to mitigate odours generated by waste materials.

- Implement management actions to reduce occupational health and safety risks at the waste disposal site.

- Manage and control vectors of disease through compaction and application of daily cover.

Recommendations relating to Construction and Operation

- Regularly monitor the new system to ensure that it is working efficiently.

- Recommendations Related To Overall Cumulative Impacts

- Care should be taken not to raise expectations regarding perceived employment opportunities in order to minimise added pressure on existing social and infrastructural services because of mass in-migration.

APPENDIX G

Environmental Management Plan Parameters

BASELINE INFORMATION ON WATER QUALITY

Chemical analyses of ground water samples collected during the site investigation in September 2008

Groundwater

The groundwater sample obtained from borehole **LIB 1 & 2** was subjected to the performance of chemical electro- chemical and contamination tests for the determination of:

- **pH**
- **Conductivity**
- **Total Dissolved Solids (TDS)**
- **Suspended Solids (SS)**
- **Sodium (Na)**
- **Potassium (K)**
- **Calcium (Ca)**
- **Iron (Fe)**
- **Chloride (Cl)**
- **Sulphate (SO_4)**
- **Nitrate (as NO_3-N)**
- **Ammonia (as NH_3-N)**
- **Total alkalinity (as $CaCO_3$)**
- **Chemical Oxygen Demand (COD)**

The results of these tests are presented in the table below.

BASELINE INFORMATION ON WATER QUALITY

Chemical Analysis of Ground Water Seepage Taken from the Whein Town Landfill Site

Parameter				
Type	**Surface water**	**Ground water**		
Location	**Nearby creek**	**Well #1 - East**	**Well # 2 - West**	**WHO Guideline**
Date	**10 April 2008**	**10 April 2008**	**10 April 2008**	
pH	6,01	6,5	6,6	
Temp ºC	27,4	28	28	
Turbidity (NTU)	12	2	10	5
Total Hardness (ppm)	10	0	50	
Total Iron (ppm)	1,5	0	1	0.3
Nitrite (ppm)	0	0	0	11
Nitrate (ppm)	0	0	0	0.3
Phosphate (ppm)	15	15	15	
Ammonia (ppm)	0	0,25	0	
Conductivity (µS/m)	45,8	31,5	110	
TDS (ppm)	25,5	14,08	58,8	1000
Lead (ppm)	0	0	0	10
Alkalinity (ppm)	0	80	0	
Alternative Sampling	**23 September 2008**	**23 September 2008**	**23 September 2008**	
Conductivity µS/m	179,6	194,7	14,41	
pH	6,17	6,87	5,44	
Suspended Solids (SS) mg/l				
Nitrates (NO_3) mg/l	<0,5	6,7	3,2	11
Sodium (Na) mg/l	53	9,7	4,0	
Potassium (K) mg/l	22	2,3	0,1	
Magnesium (Mg) mg/l	4,86	4,1	1,2	
Calcium (Ca) mg/l	24,5	48	<0,5	
Sulphate (SO_4) mg/l	<7	<7	<7	250
Ammonia (NH_3-N)	0,50	0,01	0,01	
Bicarbonate Alkalinity (as $CaCO_3$)	102	150	11,2	
Chloride (Cl) mg/l	23	7,4	6,4	
Fluoride (F) mg/l	0,13	0,07	0,12	
Chemical Oxygen Demand (COD) mg/l	222	5	5	
Total Dissolved Solids mg/l	89,7	97,4	7,17	1000
Arsenic µg/l	0,52	0,33	1,1	10
Chromium µg/l	4,27	0,31	0,46	50
Iron (Fe) mg/l	2,66	0,83	0,30	0.3

Lead (Pb) µg/l	<10	362	39	10
Zinc (Zn) mg/l	0,09	<0,05	0,05	
Cyanide (Cn) mg/l	<0,05	<0,05	<0,05	0.07
Phenols mg/l	0,67	0,36	0,25	
Boron (B) mg/l	0,002	0,002	0,002	0.5
Mercury (Hg)	0,001	0,001	0,001	0.001
Total Coliforms (TC counts/100ml)	Not tested	Not tested	Not tested	0
Faecal Coliforms (FC counts/100ml)	Not tested	Not tested	Not tested	0

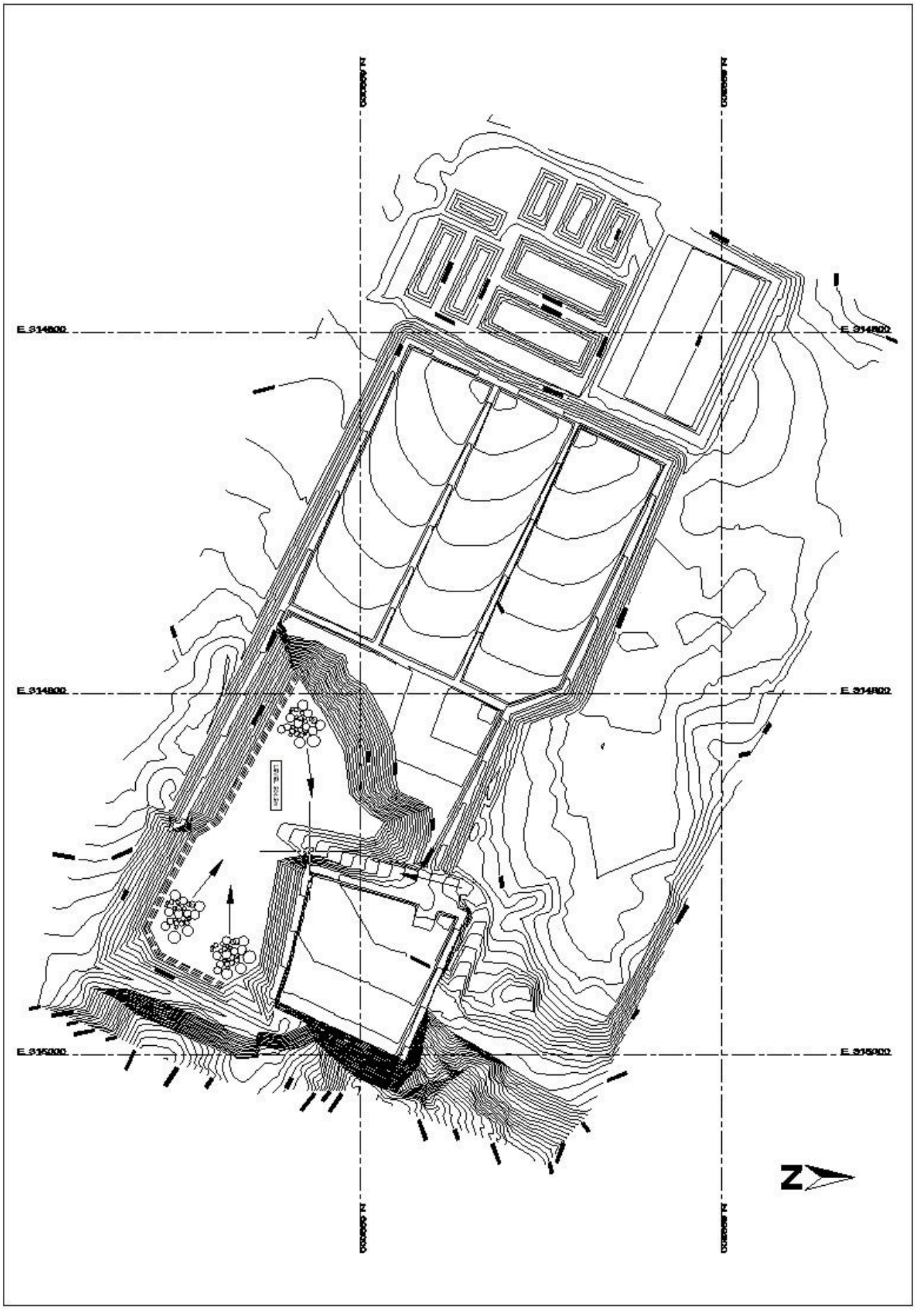
APPENDIX I

Equipment Operating and Maintenance Manuals

To be added

APPENDIX J

Landfill Phase Development Drawings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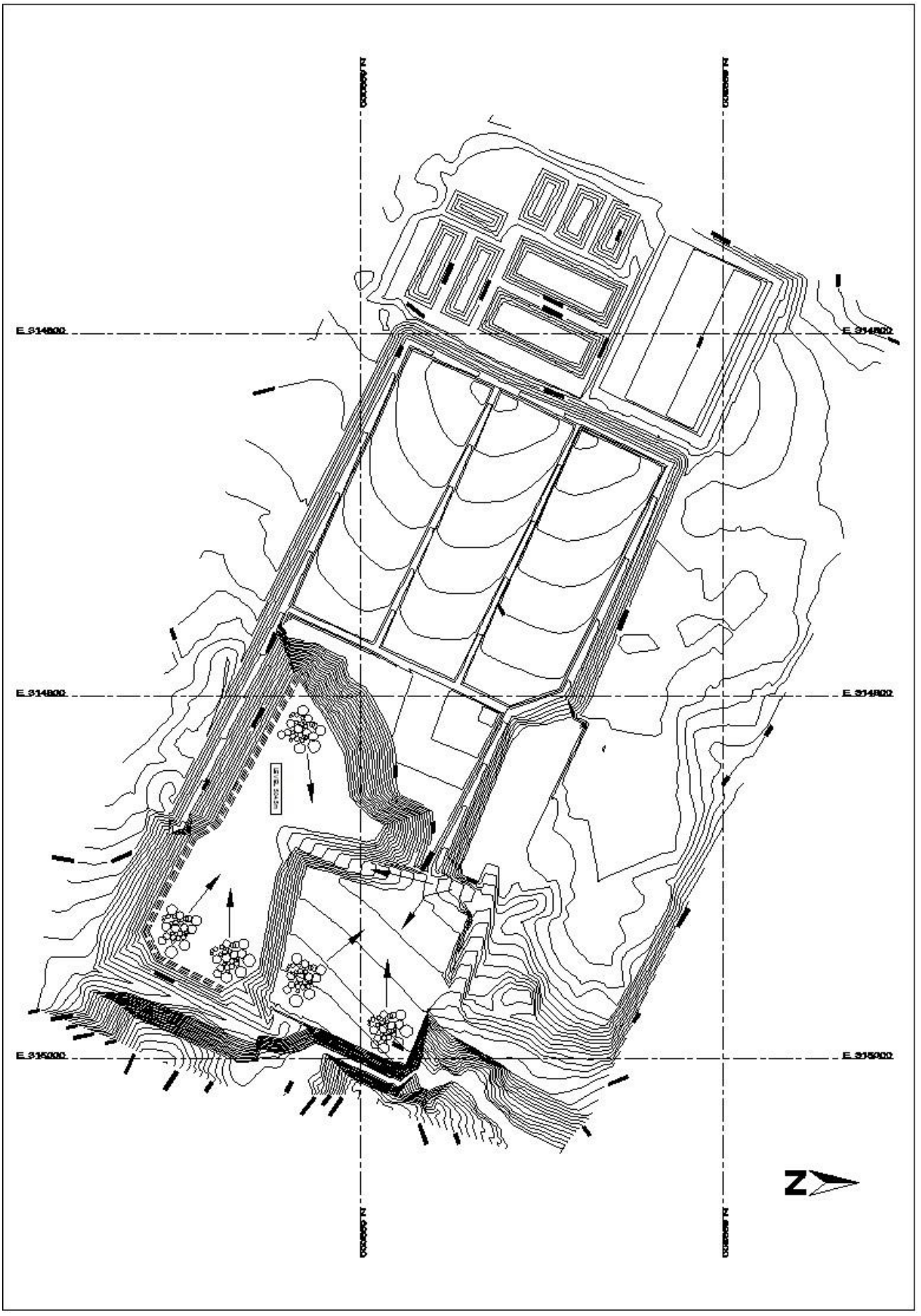
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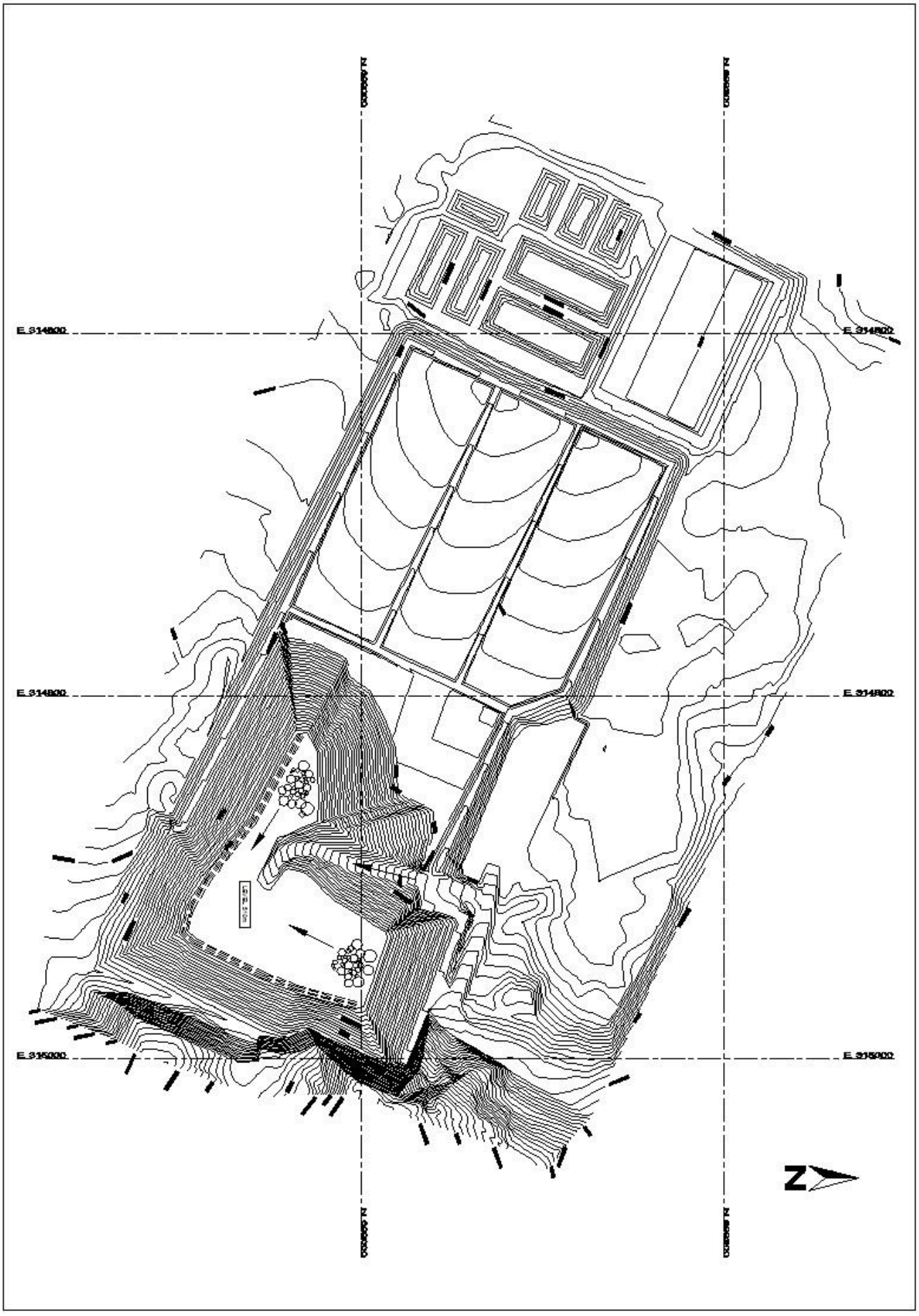
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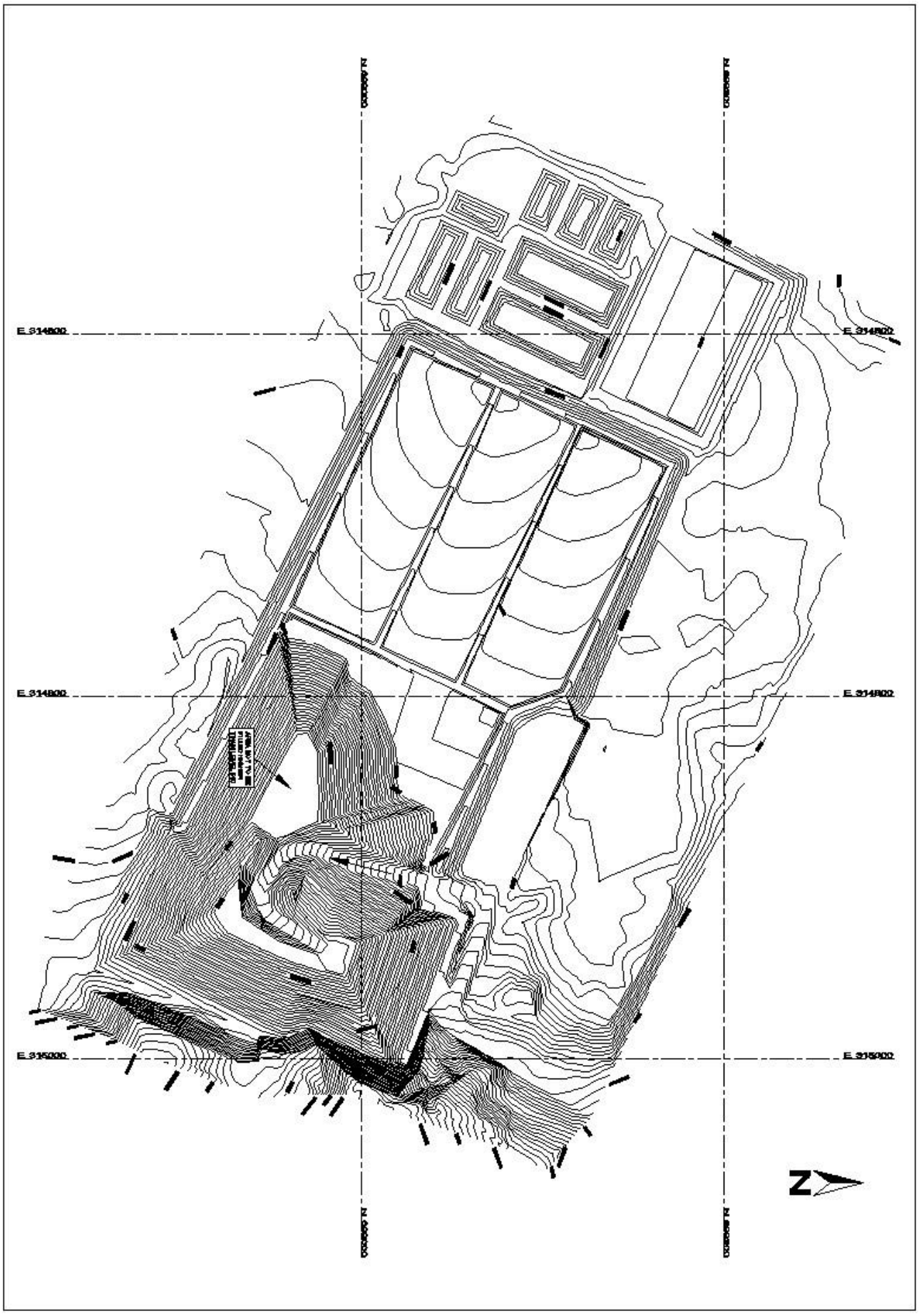
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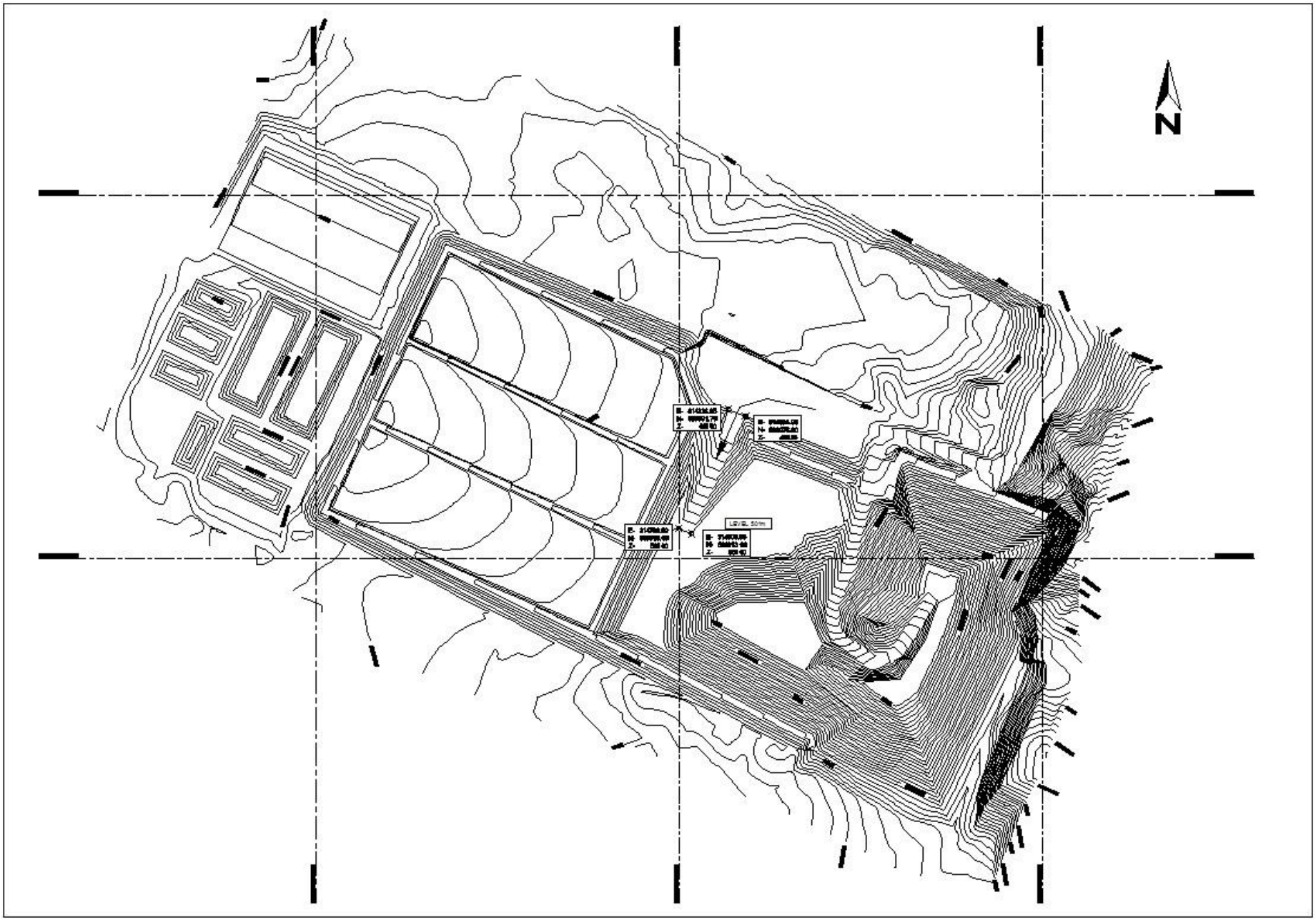
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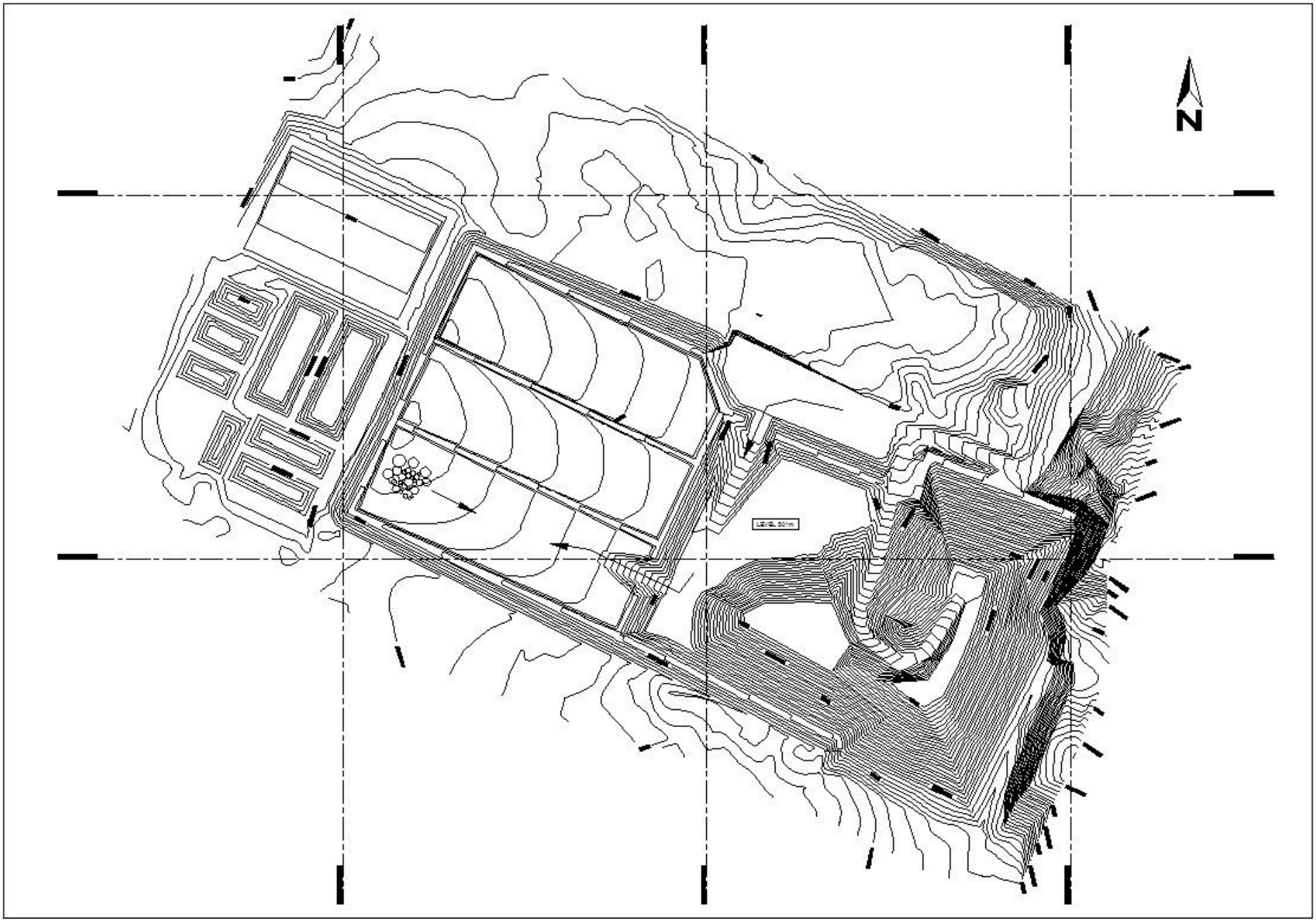
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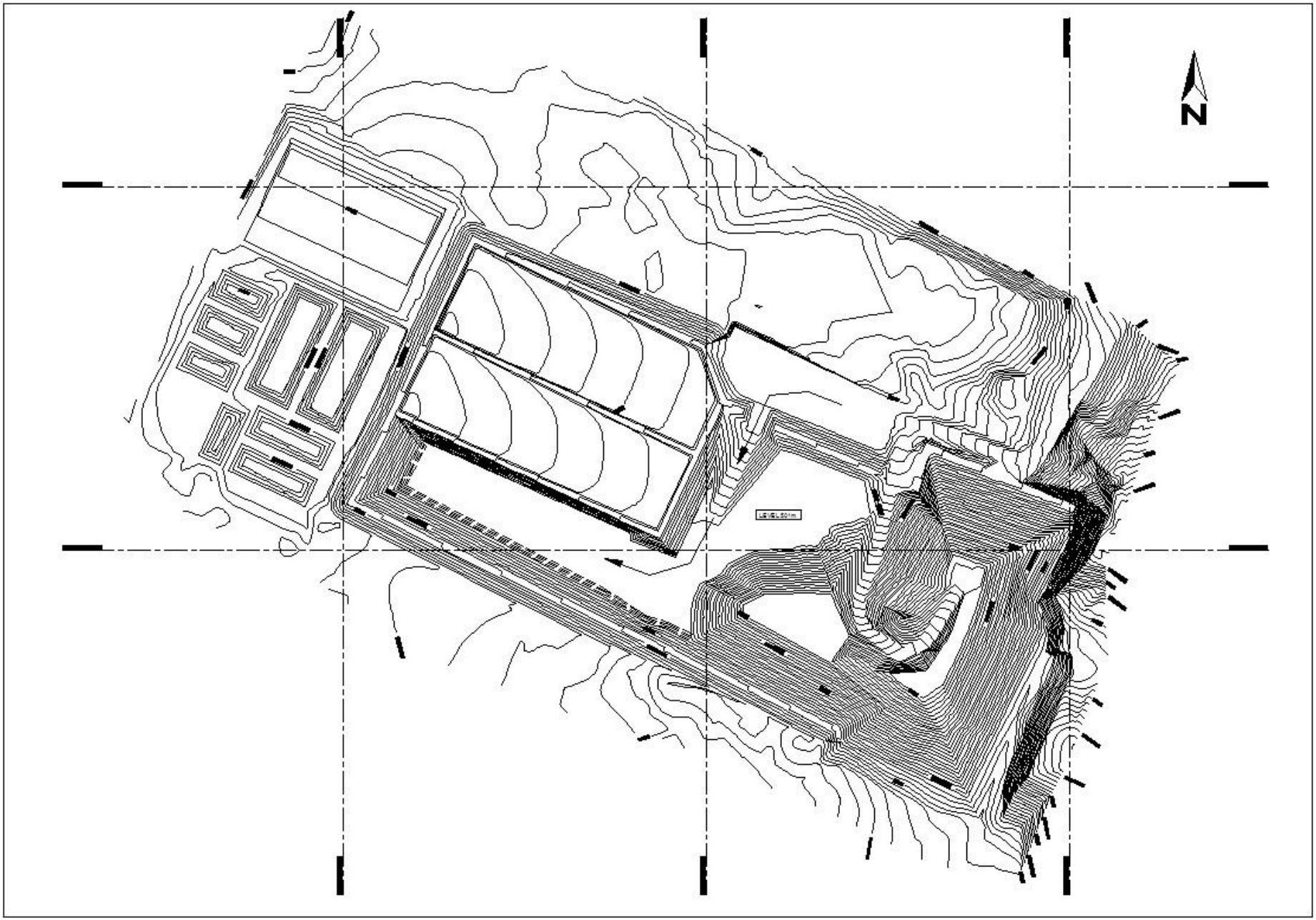
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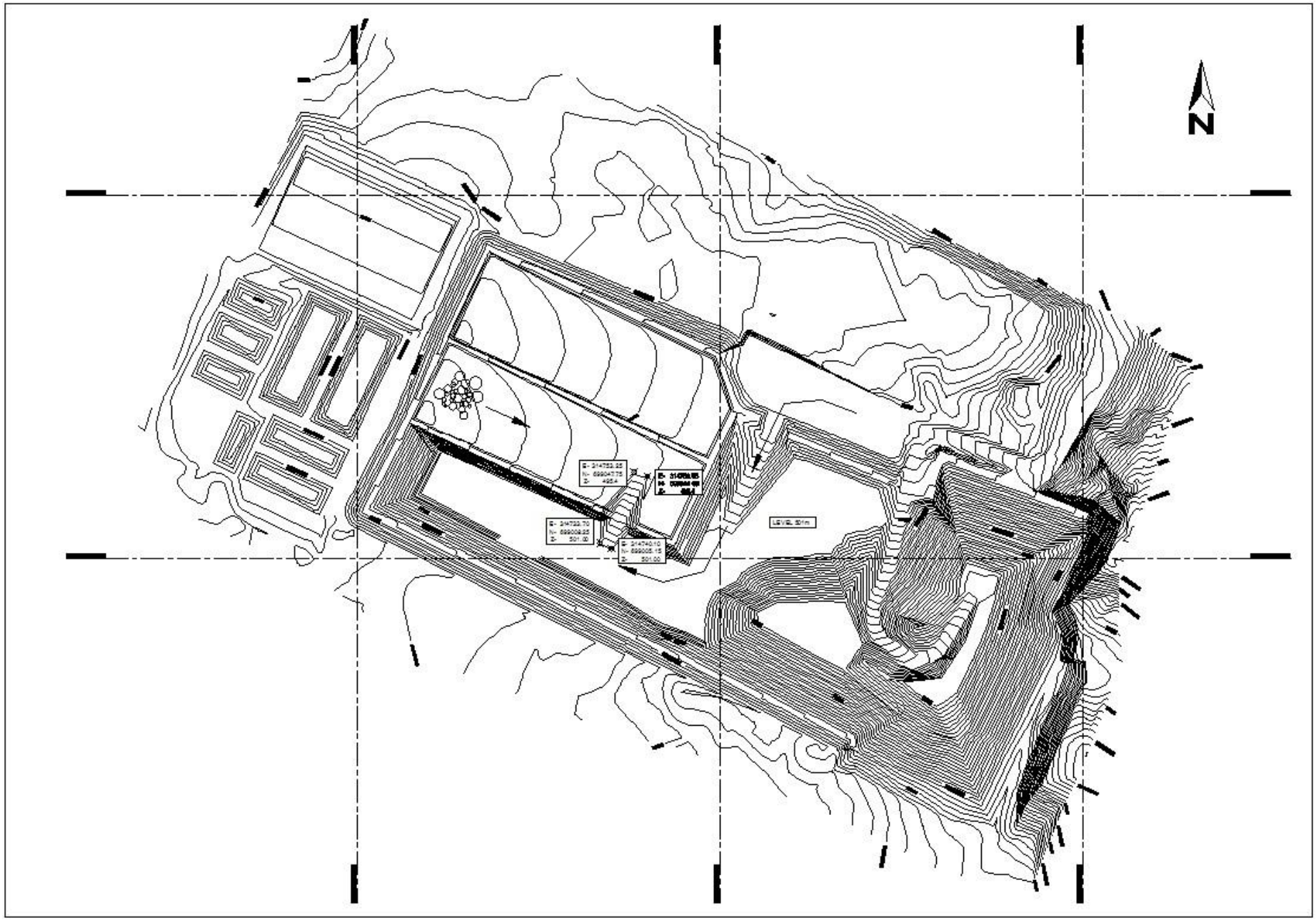
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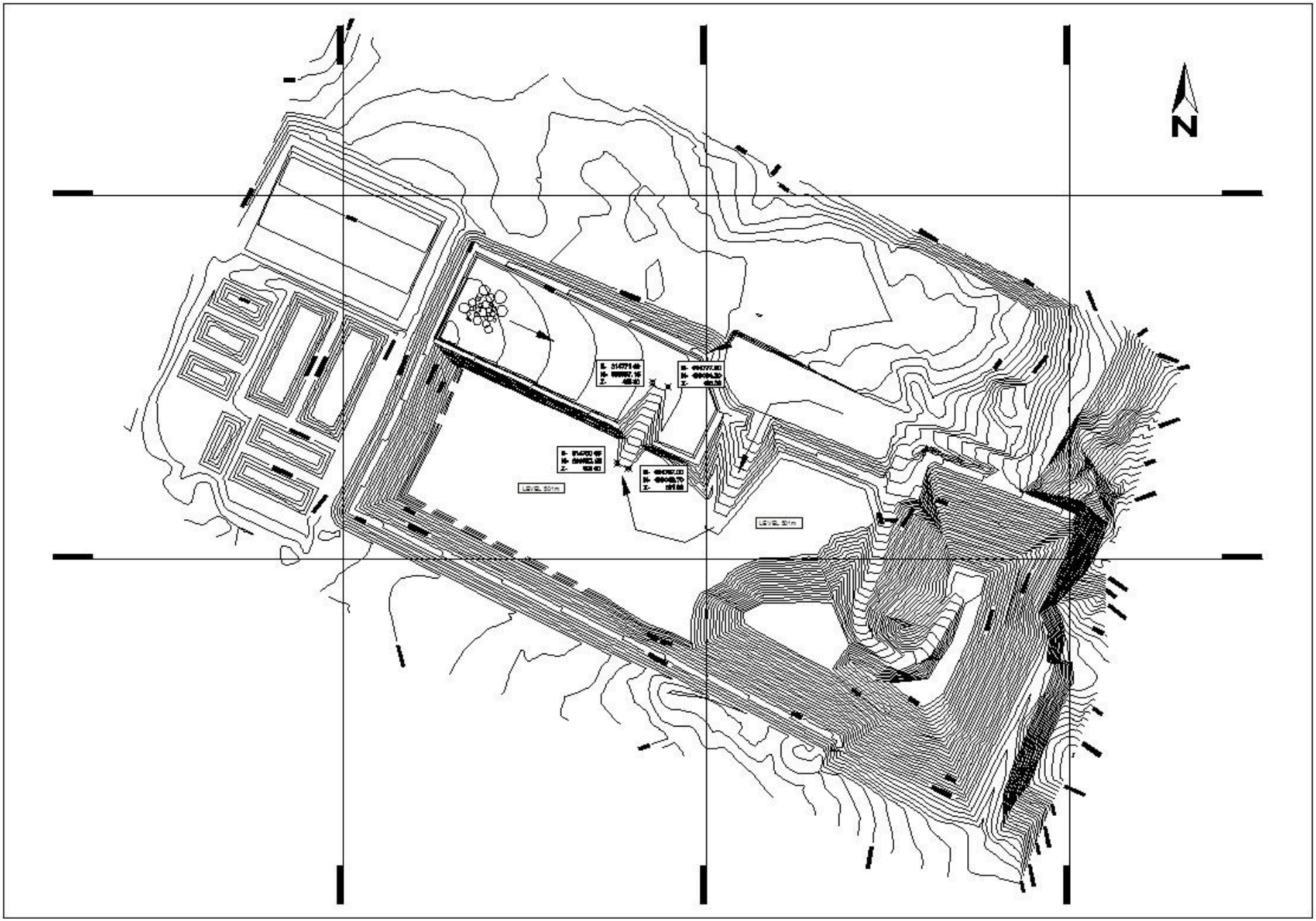
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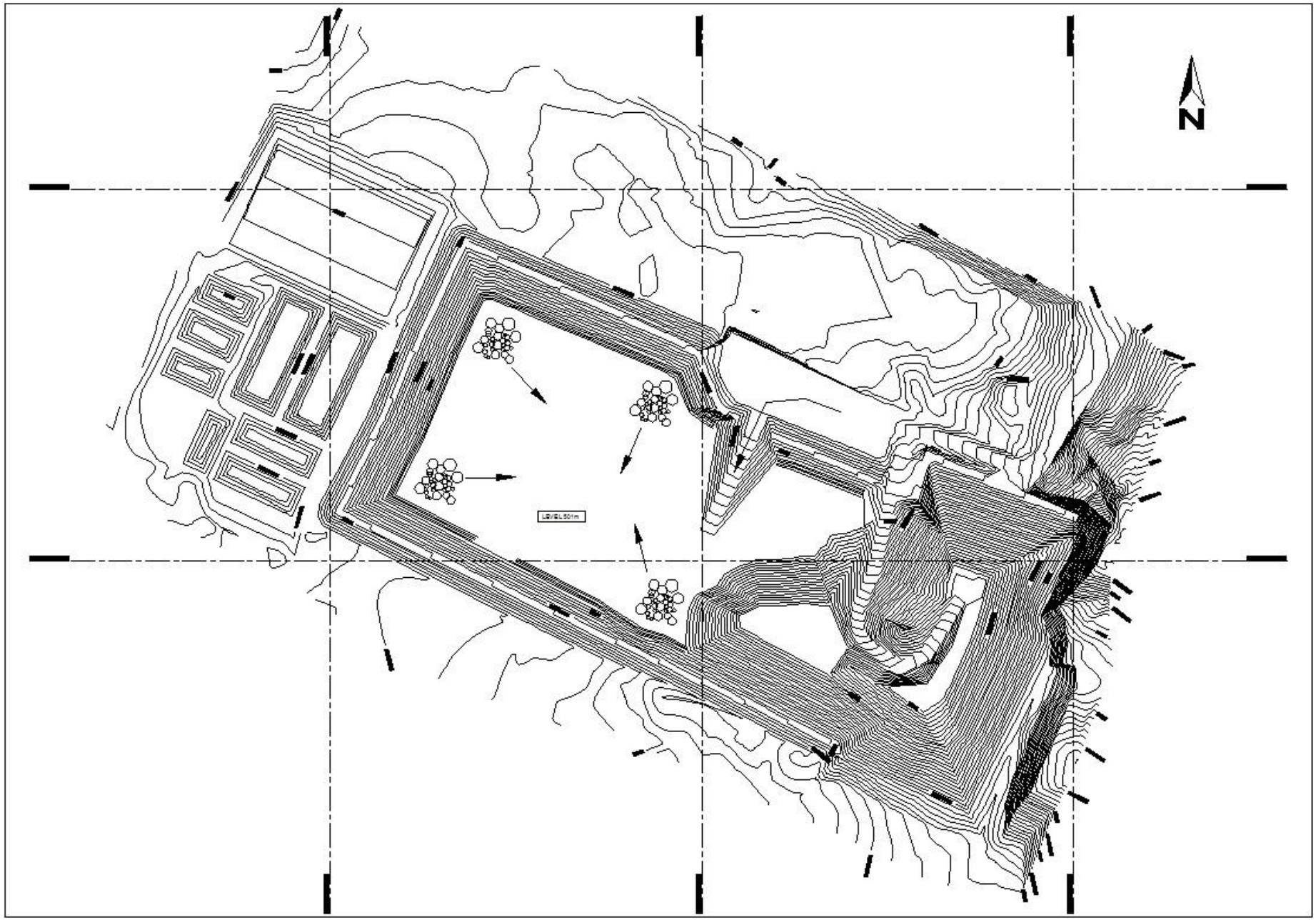
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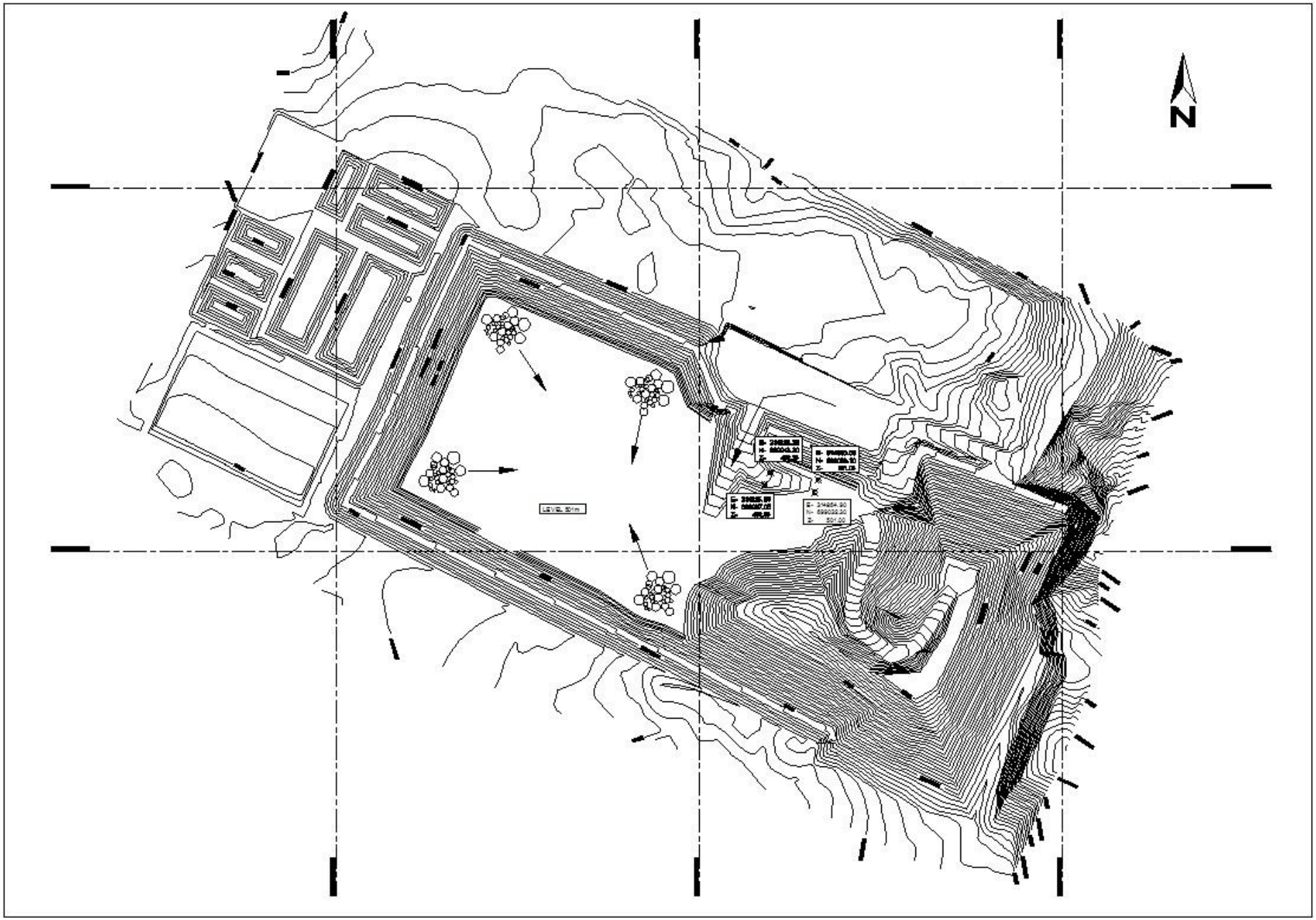
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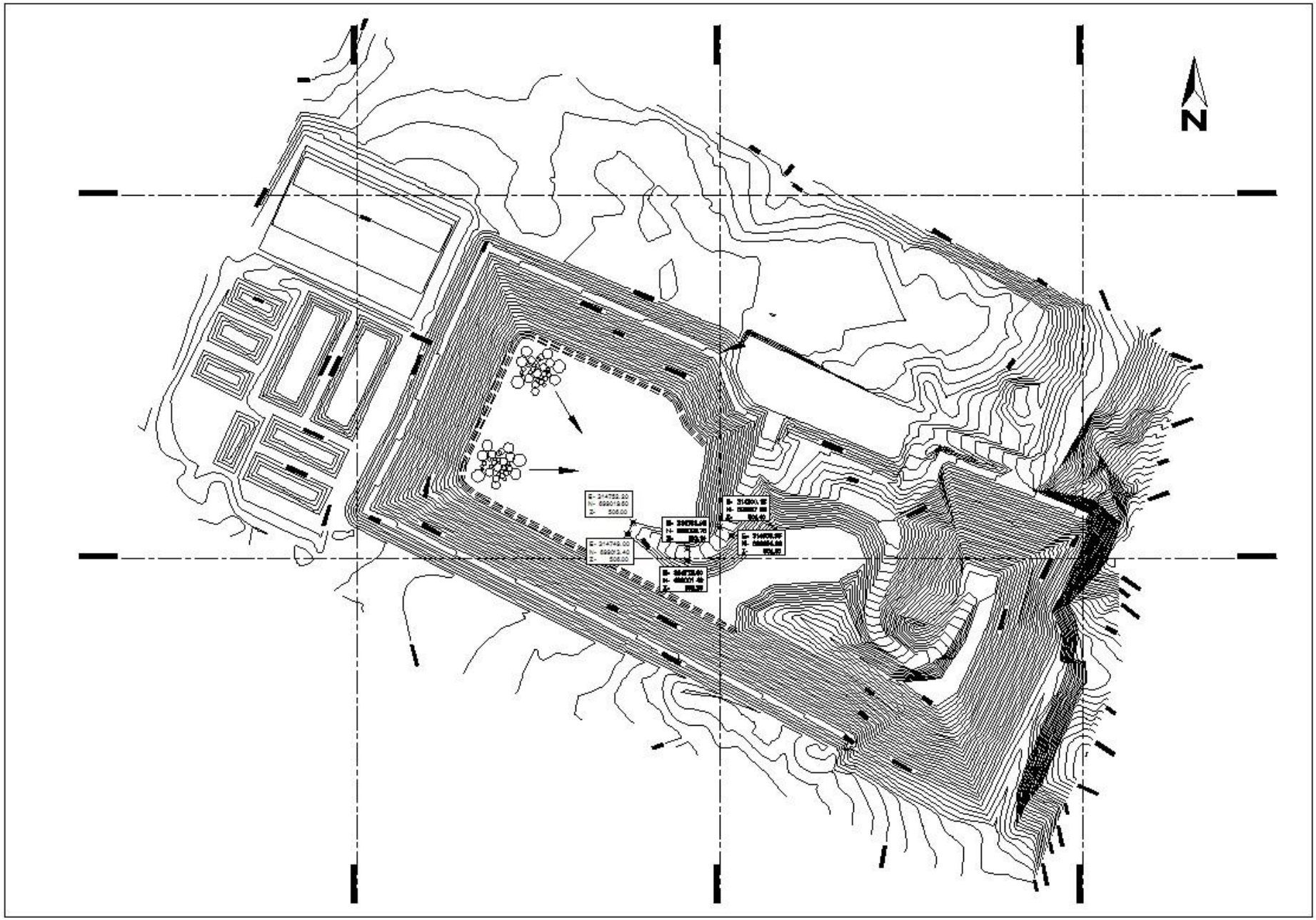
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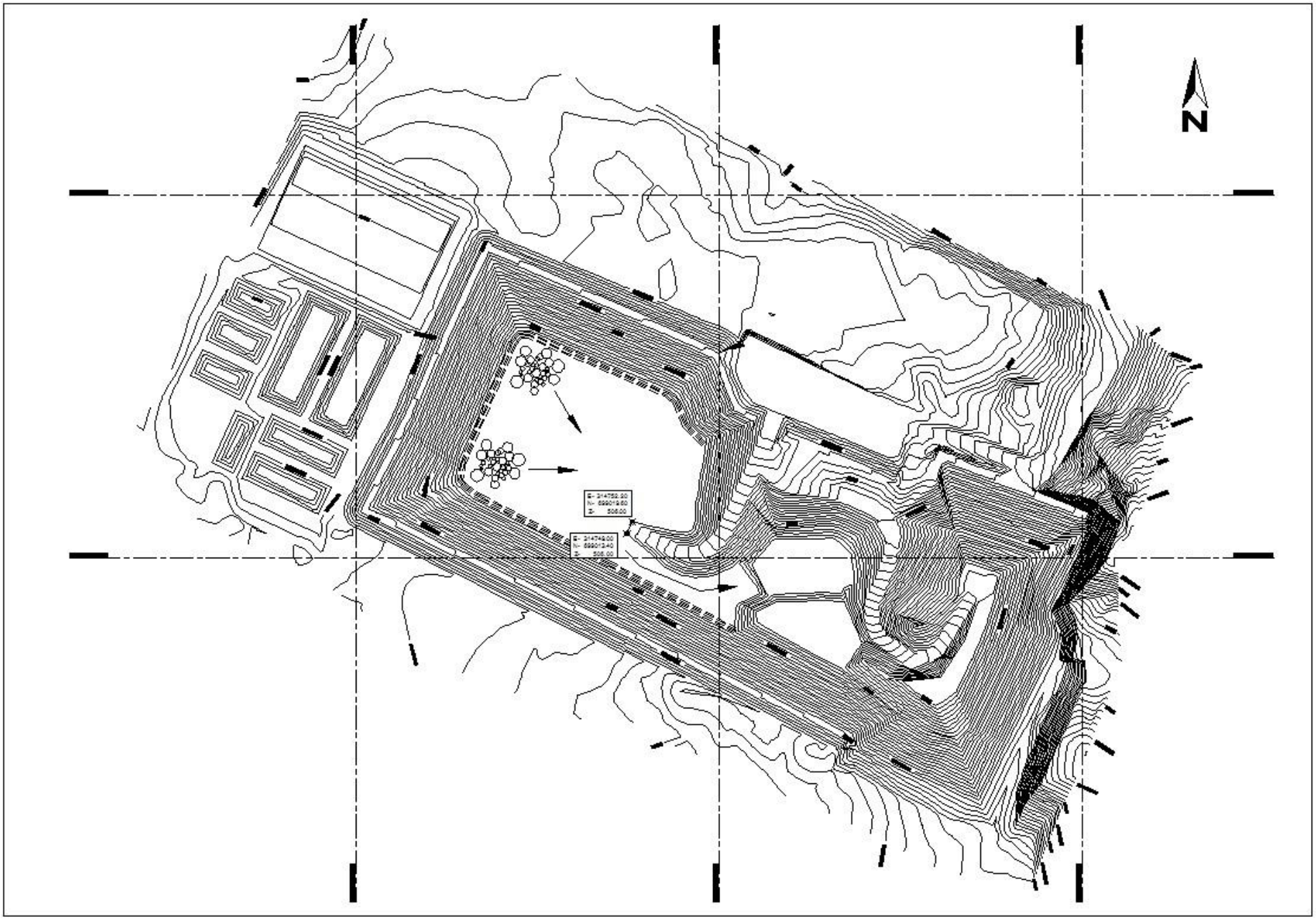
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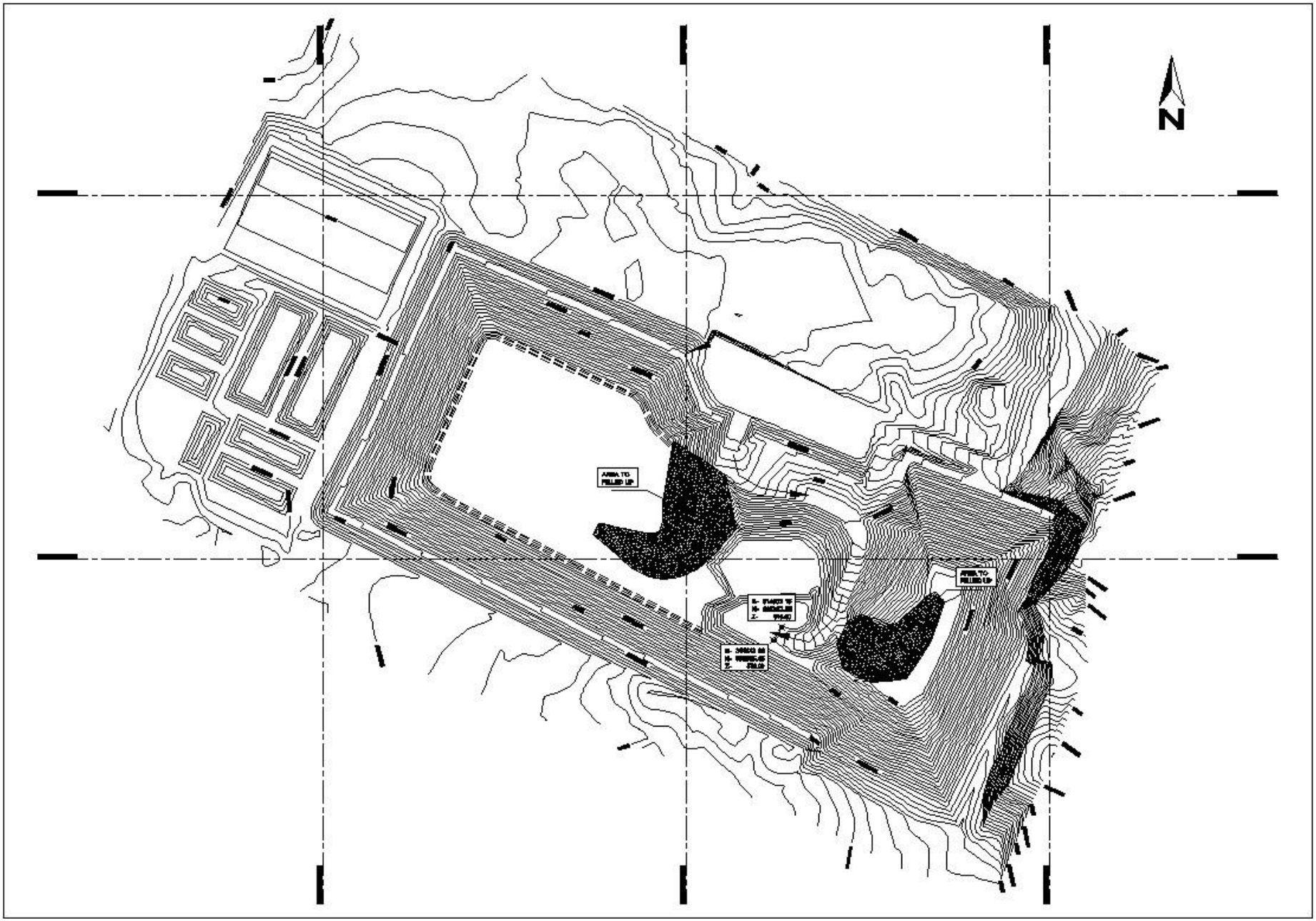
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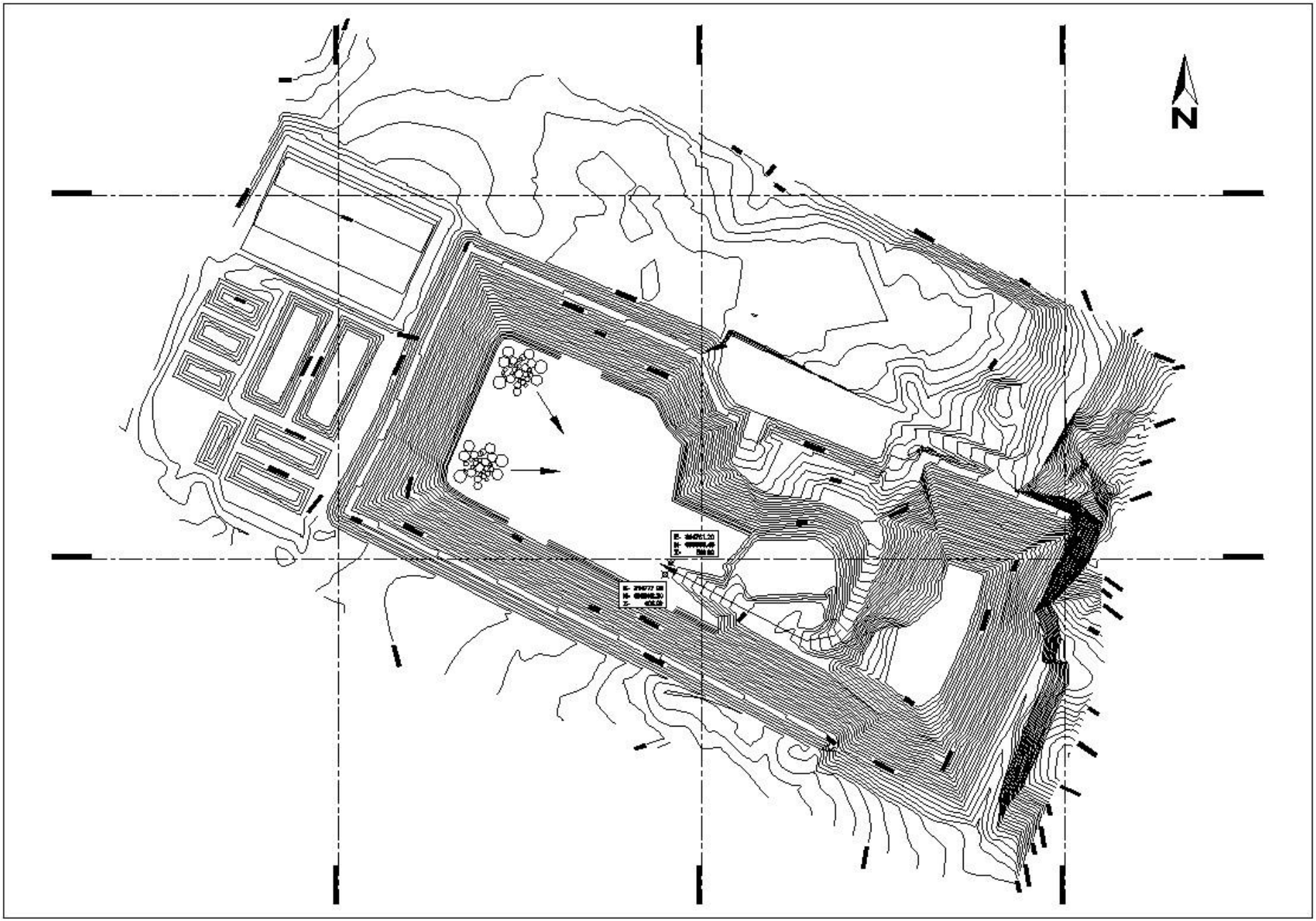
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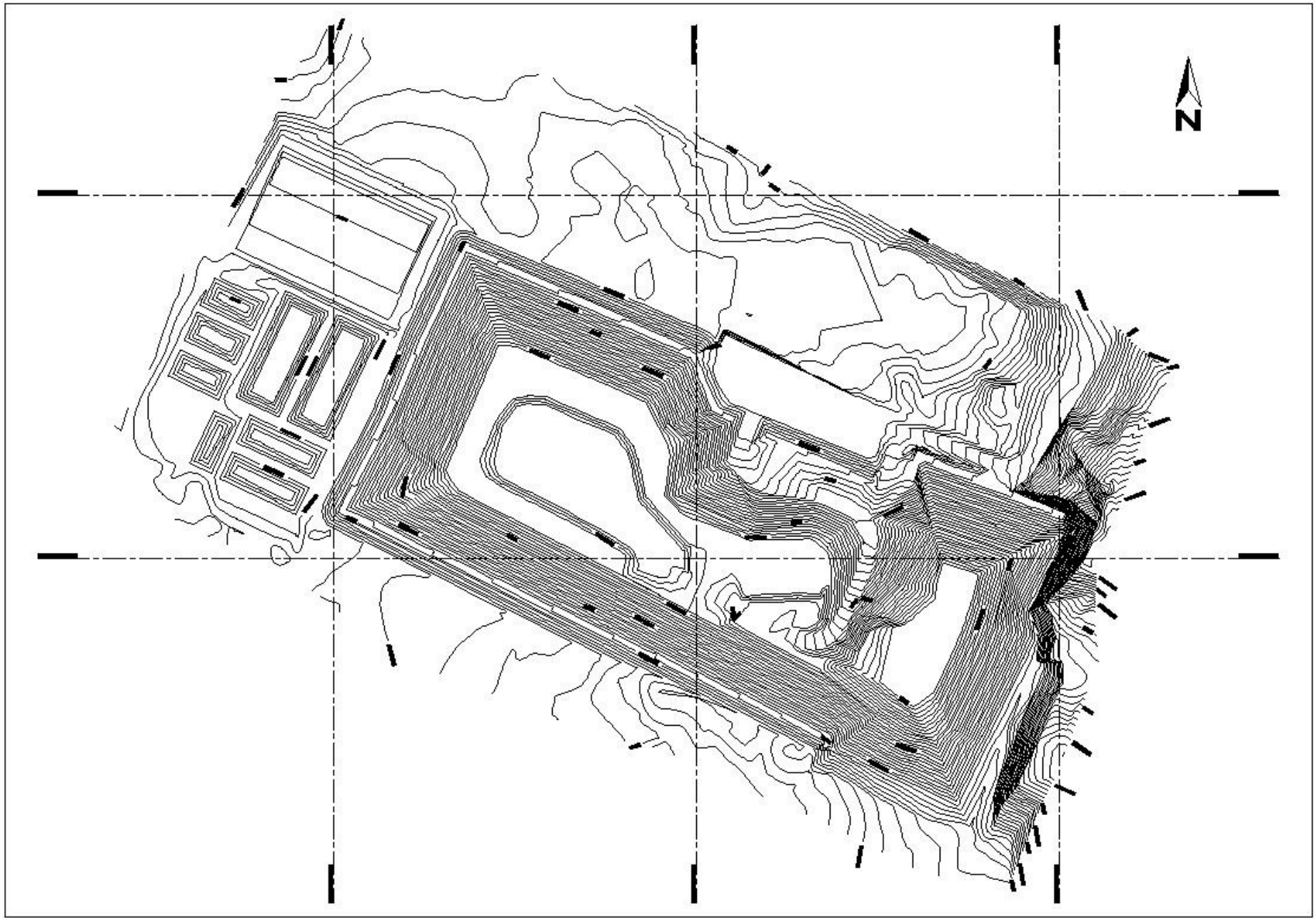
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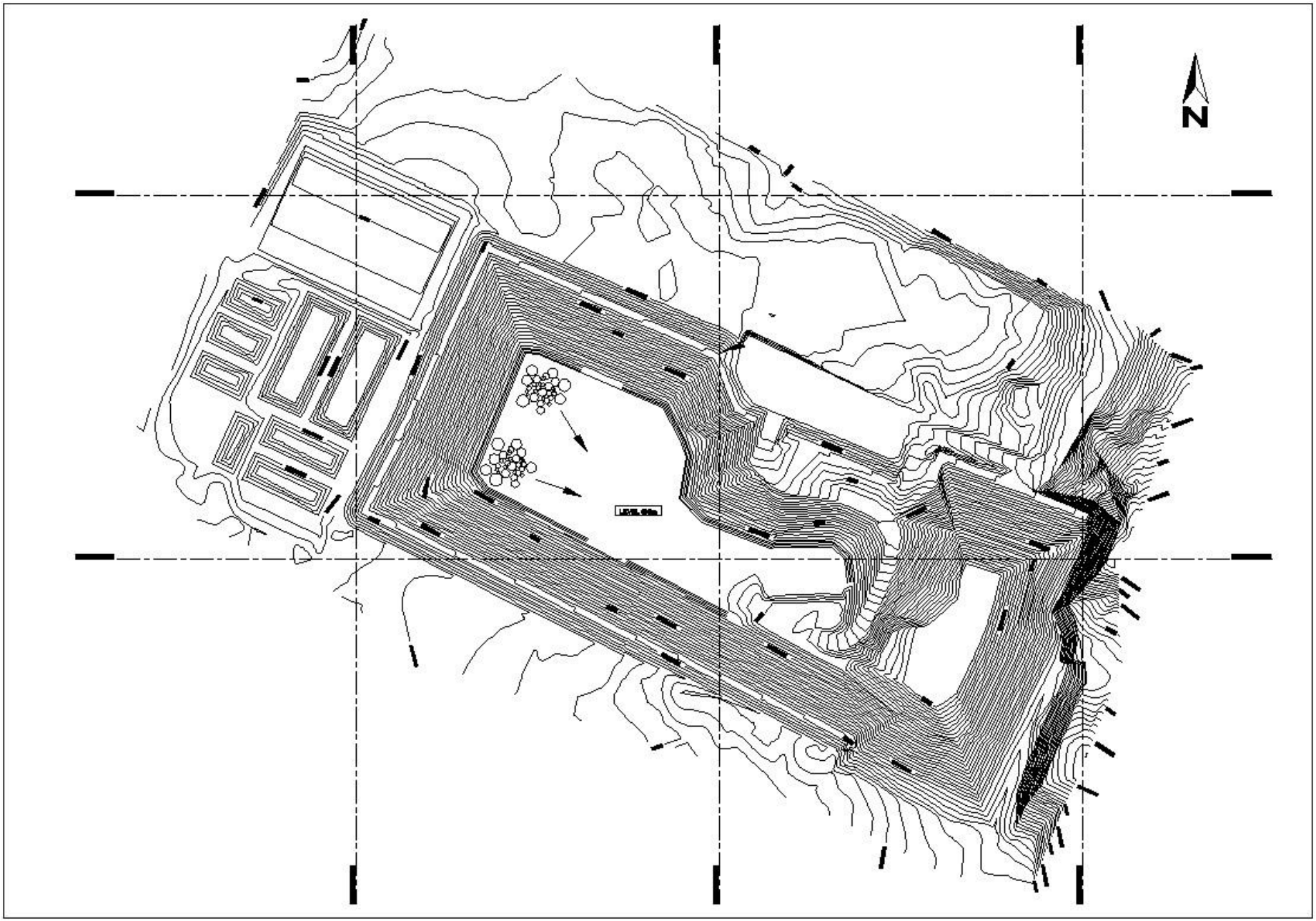
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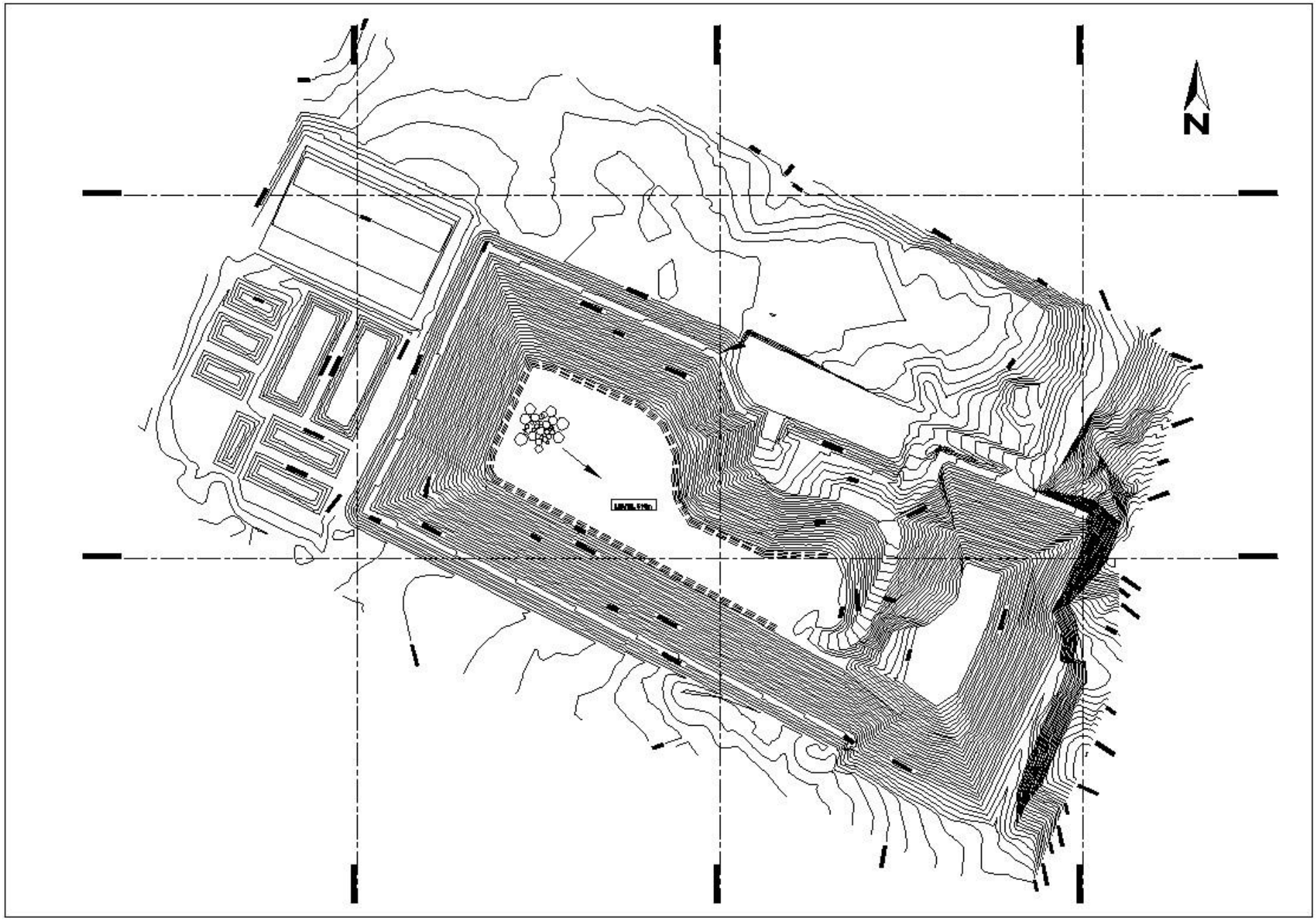
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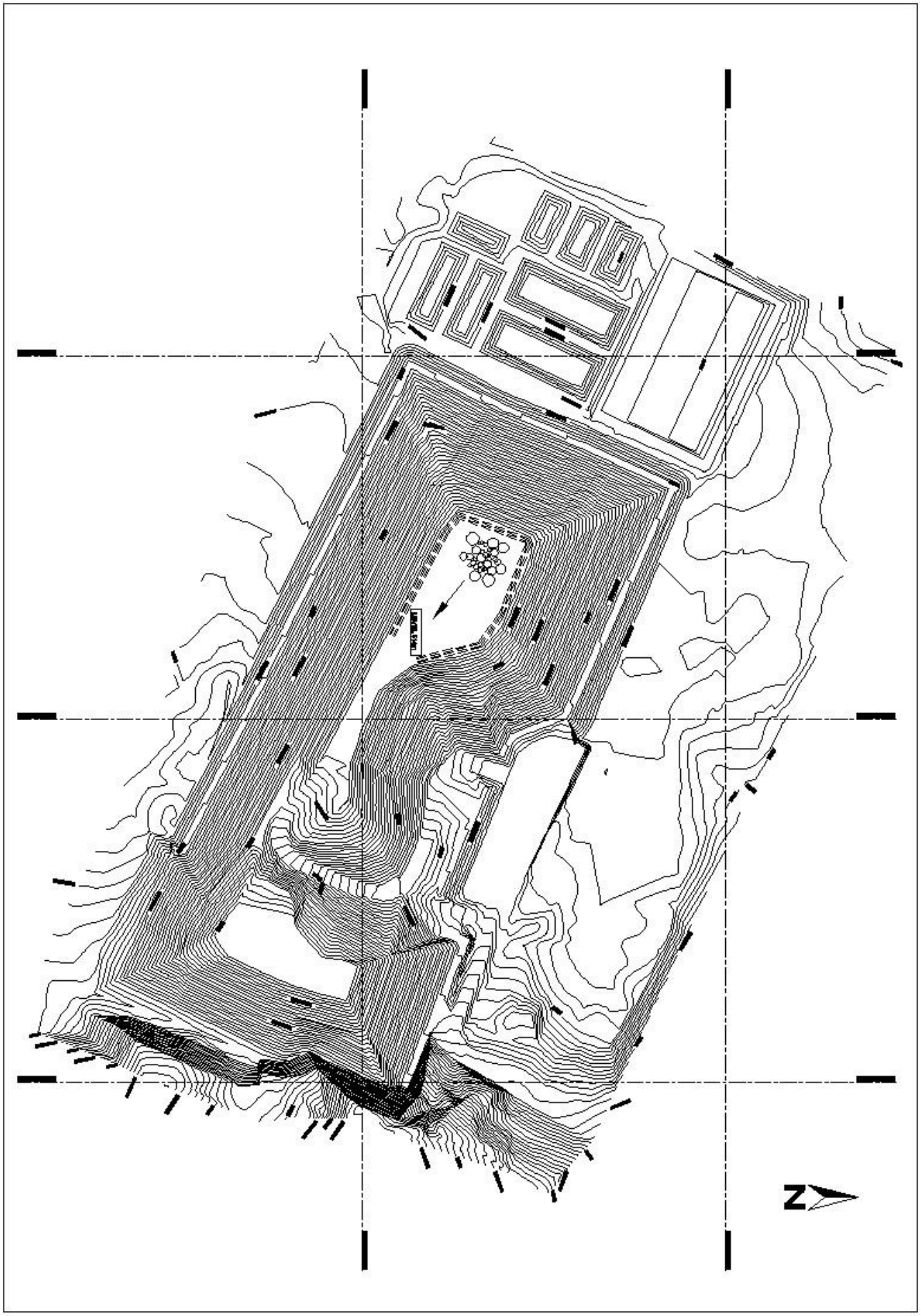
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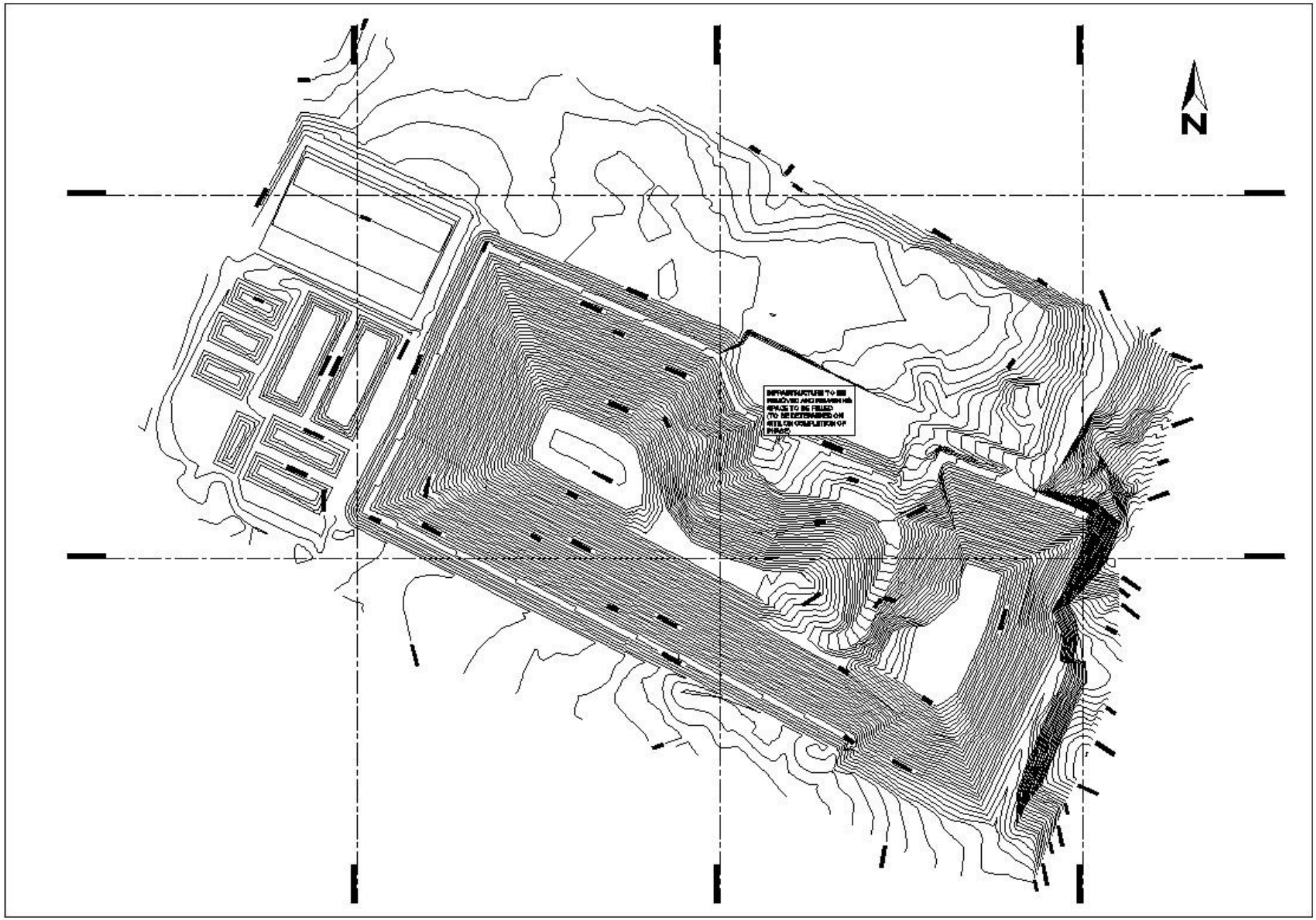
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APPENDIX K

As Built Drawings

To be added

APPENDIX L

Cadastral Layout of the Site

CADASTRAL LAYOUT OF THE SITE