Project Design for the closure of Ta' Zwejra landfill

WasteServ Malta Ltd

February 2005

TABLE OF CONTENTS

A. INTRODUCTION

A.1 Title of the Project:

Ta' Zwejra landfill gas recovery system.

A.2. Brief description of the Project:

Ta Zwejra non- hazardous landfill is situated in closed proximity of former closed Maghtab damp and in January 2005 its first cell of the existing three, has reached 90 % of its full capacity. In order to achieve an optimal management of resources and to minimize environmental impacts, the WasteServ Malta Ltd as responsible operator of facility has decided to begin its closure and capping with installation of the 'Vertical Active Gas Extraction System'.

In parallel with this process next to this site the former inactive landfill of Maghtab shall begin process of rehabilitation which is a European co-funded Project. The rehabilitation of the ex-landfill will be the subject of a tender process in order to obtain maximum social and environmental benefits from the Project. The design of rehabilitation process which is mainly installation of active gas extraction system has been elaborated by UK Company Scott Wilson Ltd. and later was approved by MEPA. The Gas Compound of this project where gas is being treated and flared is designed to accommodate all quantities of Ta' Zwejra recovered gas. Site plan is presented in the figure 1.

Gas treatment and flaring (thermal destruction) compound is foreseen to accommodate for all gas collected within Maghtab, Zwejra and in the future the Ghallis waste management facilities. It is intended that the Project will be designed to a high specification including conformance with European Union (EU) policy on waste management and good gas management practice. The Project seeks to introduce the environmental measures necessary in order to enable the landfills to be fully rehabilitated and brought back to beneficial use at a future date.
Full restoration of these sites, which will include establishment of vegetation and development of after uses, will take place when the emissions from the site are under control and the waste masses have been fully stabilised.

The gas collected from the Ta' Zwejra facility will be added to the gas being collected from the rehabilitation process of the Maghtab landfill and utilized/flared according to the quantities and qualities. In addition, after the trial periods, on the base of gas quality it should be determined whether electricity generation can be the attractive course of action.

According to the Maltese regulation Environmental Impact Assessment is not required for such project.

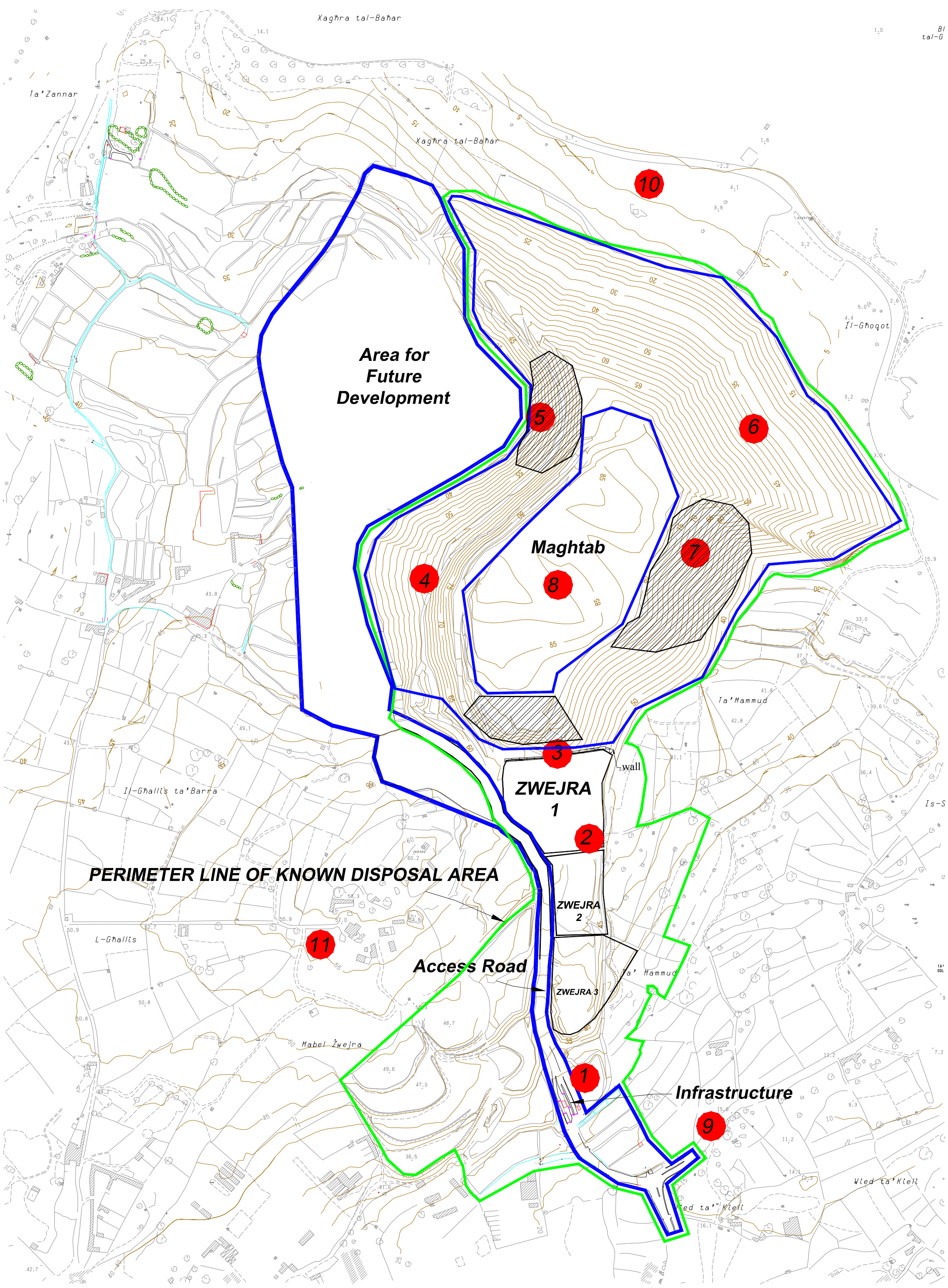

Xaghra tal-Bahar
Ta'Zannar
Area for Future Development
Maghtab
ZWEJRA 1
ZWEJRA 2
ZWEJRA 3
wall
PERIMETER LINE OF KNOWN DISPOSAL AREA
Access Road
Infrastructure
Il-Ghalli ta'Barra
L-Ghallis
Ta'Hammud
Il-Ghoqot
Wied ta'Klell
1
2
3
4
5
6
7
8
9
10
11

FIGURE 1.

A.3. Legislation Guidance & Standards

Malta form part of EU and current Maltese law and regulations with regard to landfills mostly follow the EU Directives. The development is subject to European and National legislation on the landfilling of waste, air quality, ground water protection, IPPC regulations, etc as follow:

- EU Framework Directive on Waste (75/442/EEC as amended by Directive 91/156/EEC). Member States must implement a system of authorisation for waste disposal with conditions to ensure waste is recovered or disposed of without harm to human health, pollution of the environment, or a nuisance through dust or odour.
- EU Framework Directive on Ambient Air Quality Assessment and Management (96/62/EC) provides the means for setting limit values, through daughter directives, on the concentrations of air pollutants including dust and odour. The first and second Air Quality Daughter Directives (1999/30/EC & 2000/69/EC) set standards and objectives to protect human health. World Health Organisation's (WHO) recommended air quality guidelines are the basis for EU air quality standards. The WHO's recommendations are not mandatory but generally accepted as being levels not to be exceeded if healthy air is to be maintained.
- Govt of Malta. Ambient Air Quality Assessment and Management Regulations, 2001: LN216. Competent Authority set limit values for pollutants. Standards based on the EU directive, except for carbon monoxide, which is based on a WHO guideline. Measuring stations installed and operated and Action Plans prepared to decrease concentrations.
- Govt of Malta. Various notices including limit values for VOC and substances that deplete the ozone layer, and for nitrogen dioxide, sulphur dioxide, oxides of nitrogen, particulate matter, lead, benzene and carbon monoxide in ambient air.
- Govt of Malta. Integrated Pollution Prevention and Control Regulation 2002 implement EU Directive (96/61/EC) and require listed activities to obtain a permit that can include emission limits and other operating conditions. Applications for permits must demonstrate that best available techniques are used to adequate measures are being undertaken to prevent dust and odours. The installation is likely to be regulated under the IPPC.
- Govt of Malta. The Waste Management (Landfill) Regulations 2002*:* LN 168 requires measures to minimise nuisances and hazards arising from landfills from the emission of odour and dust.
- The *Ambient Air Quality Assessment and Management Regulations, 2001: LN216* require the Competent Authority to establish limit values and alert thresholds for ambient air. Limit values have been set for pollutants including Particulate Matter (PM10). These standards are based on the EU directive standards, except for carbon monoxide, which is based on a WHO guideline.

A.4. Project activities:

The WasteServ Malta Ltd. as the project developer intends to achieve full compliance with current local and EU legislation. The process of closure of Ta'Zwejra waste management facility will take place gradually in phases for each of three cells. The main phases in closure and installation of gas recovery system will consist of following components:

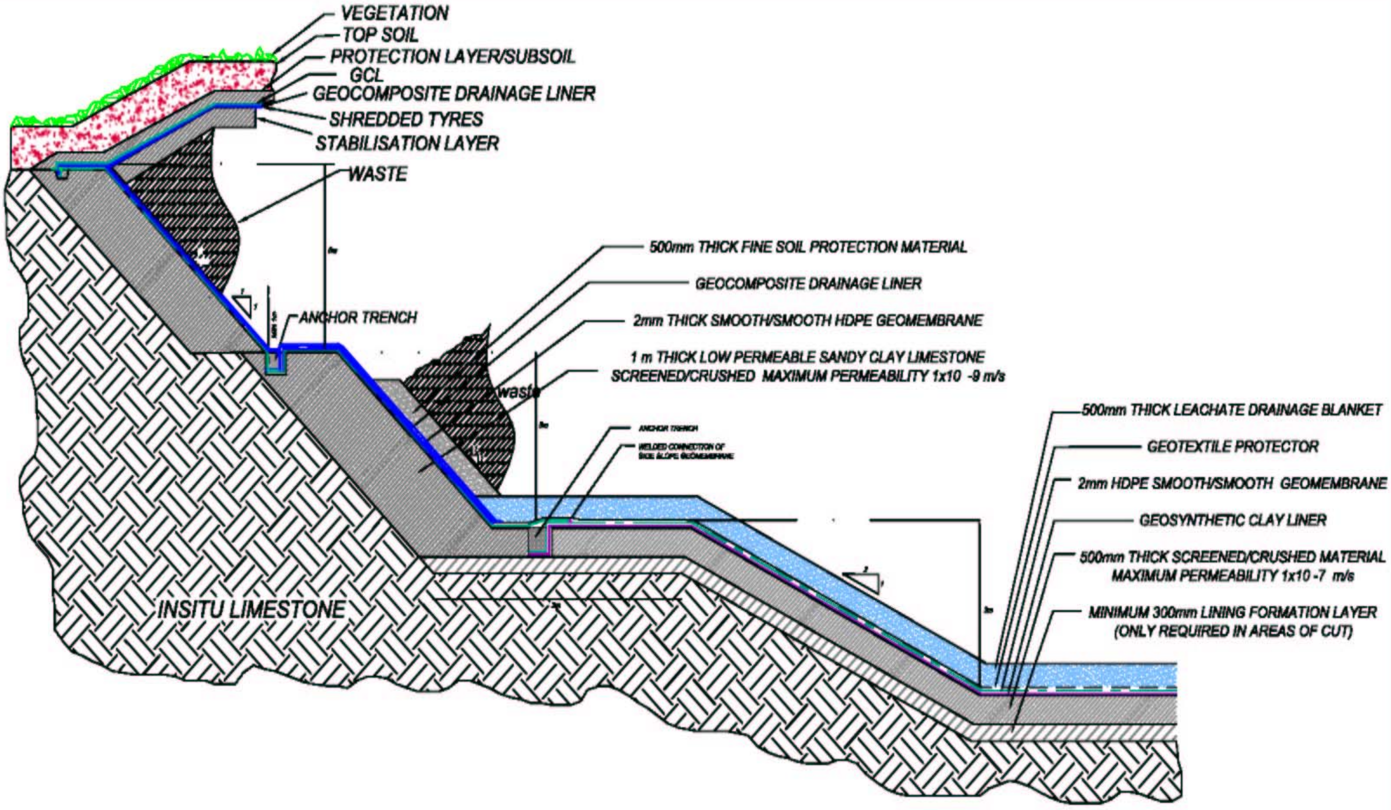
- ***RE-CONTOURING / TERRACING***
- ***CAPPING***
- ***INSTALLATION OF GAS RECOVERY SYSTEM***
- ***RE-CULTIVATION***
- ***AFTER CARE / MAINTENANCE***

As a first measure a layer of min 300 mm thick stabilisation layer shall be placed over the waste masses. Material should be inert limestone fines possibly sourced from the nearby excavation for construction of Cell 3. This layer should accommodate for future settlement movements and should be laid, compacted and reprofiled to the maximum angle on slopes to 20 deg.
Above this layer another layer of shredded tyres to act for compensation of settlements should be laid. Another function of this material is to give uniform distribution of LFG and complementary gas drainage layer to the geosynthetic drainage liner. Since the landfill gas (LFG) pressure underneath a lined cover system can significantly reduce the effective normal stress on the liner, which can affect cover soil stability then this layer of shredded tyres shall provide an adequate LFG venting layer. This landfill gas pressure relief layer is to provide the required gas transmissivity for LFG dependant on generation rate, maximum LFG pressure, and spacing between gas wells.

Time frame for the implementation of the Project activities are presented in next table:

No.	ACTIVITY	START DATE	FINISH DATE
1	RE-CONTOURING/ TERRACING	01/01/2005	01/03/2005
2	CAPPING	01/03/2005	01/05/2005
3	INSTALLATION OF GAS EXTRACTION SYSTEM	01/06/2005	01/08/2005
4	RE-CULTIVATION	01/09/2005	01/12/2005
5	AFTER CARE / MAINTENANCE	01/01/2006	01/01/2021

Dates above are indicative and will depend on procurement of material and Contracting Companies. Process of re-shaping to achieve final landform as it was presented in IPPC application is currently taking place and is carried by WasteServ. The core of the activities are to bring slopes to satisfactory levels in the terms of stability and to create final landform. .



TYPICAL SECTION THROUGH SIDE SLOPE LINER TIE-IN WITH BASAL LINER OF ZWEJRA 3

Figure 2

The figure above showing the lining system to be installed in the Zwejra waste facility. The basal liners now being in place and capping lining system to commence as scheduled. This approach of lining system was adopted to ensure the total physical containment of waste and its physical isolation from environment providing an effective leachate collection and gas capture scheme in place.

B. TECHNOLOGY TO BE EMPLOYED BY THE PROJECT ACTIVITY:

B.1. Capping:

All conventional techniques have been considered as to which one best suit for local condition. Malta has dry, arid climate which is not in favour of gas generation at landfill giving typically “dry tomb” condition. Until today, after 10 months of waste disposal in the cell, still it was not observed a drop of leachate in the riser. Another fact for example, there are few area with steep slopes, where it is necessary to place horizontal layers, compact with a compactor and, finally, excavate the exceeding material to form final slope .
For the necessary function of capping system to provide collection and drainage of biogas from the bottom typical solution will consists in the use of sand and gravel, with difficulties in term of lay down and an important reduction in the landfill total available volume.
The use of geosynthetics offers a more economical and practical solution for landfill capping. It was decided that best solution is to use composite, versatile lining system which will include other functions as to provide low permeable barrier and physical isolation of waste from environment. The system will contain (from the bottom to top):

- **300 mm stabilization layer locally sourced inert material**
- **250 mm complementary gas drainage layer (shredded tyres)**
- **Drainage geocomposite (connected to gas collection pipes),**
- **Geosynthetic clay liner (GCL),**
- **300 mm protection layer coarse soil/limestone fines**
- **1000 mm of final layer of top soil**
- **Vegetation supported by irrigation system**

Technical design of lining system as it was considered within IPPC application is presented in figure 2 (above).
As it concerns the lining system consist of like a sandwiched composed two geosynthetic liners with the interposition of a particular type of natural material and some alternatives such as shredded tyres.
The function of the two geosynthetics next to each other (GCL and Geodrainage) has multiple functions.
GCL on its own can acts as a physical, low permeable barrier. Containing a layer of natural waterproofing material, in fact, allows the attainment of the advantages of a natural material with the easiness of installation peculiar of geosynthetics.
The danger of perforation and difficulties with welding the sheets represent the main problems connected with the use of HDPE geomembranes. With GCL this problem is overcome. The product selected on the base of these criteria is made up of two 200 g/m2 woven geotextiles, which contain natural sodium bentonite (5.5 kg/m2 minimum): it guarantees a permeability coefficient k = 1x10-11 m/s. Since 1.00 m clay can provide a permeability k = 1x10-9 m/s, this GCL is perfectly suitable.

- The use of GCL offers the following advantages:

First of all, the GCL is able, by swelling, to self seal any perforation that may occur, even after the landfill has been closed down. Second, in using at least one geotextile of a woven type, part of the bentonite is able to migrate through the geotextile and, swelling, automatically seals the joints between adjacent layers. This considerably simplifies the placement operation because it provides tightness through a simple overlap of the placed sheet edges.
The self-sealing capacity of GCLs in long term is real benefit comparing to FML (flexible membrane liner).
Moreover, in order to be hydrated, the GCLs will be covered with at least 1.30 m of soil to retain moister provided by installed a proper irrigation system on the top of the landfill, thus allowing a proper control of grass growth as well (and so, a proper control of the environmental impact of the landfill after closure).
Drainage geocomposites placed under GCL shall be fundamental for providing positive drainage of gas and water, by allowing a proper Factor of Safety versus the maximum expected flux along the capped slope. In conjunction with layer of shredded tyres beneath it should be sufficient in giving preferable gas flow and keeping and negative pressure drop between the inside of landfill body and outer atmosphere.

Hydraulic properties are very important for the top geocomposite, which is designed to discharge the maximum anticipated quantity of Landfill gas. Properly chosen drainage geocomposite allows to be consider, in the design calculation of the top soil stability, an interface friction angle greater than zero degrees.
In addition to above mentioned properties an important feature is incorporated within layers of GCL and Geo-drainage and that are effect of Capillary barrier. The barrier in this type of cover is created by the large change in pore sizes between the layers of fine and coarse material. Capillary forces cause the layer of fine particles of bentonite overlying the coarser material of geo-drainage to hold more water than if there were no change in particle size between the layers. Osmotic pressure is developed on the surface between two layers giving a permanent water and gas low permeable feature.

GCL was selected material for the lining because it has a low permeability and a good tensile resistance. Stitching is not continuous, to avoid that an accidental tear can propagate progressively to the whole GCL length.
The two woven geotextiles are connected with diamond shaped polypropylene loop stitching, all separated and independent from each other. In this way any tear cannot propagate, but remains confined to the loop where it occurs. Direct shear tests, performed at a nominal pressure of 55 kPa, provided an equivalent internal friction angle of 36 deg. The tensile strength of this GCL is equal to 20 kN/m.

B.2. Stability analysis

The capping system is subject to a set of forces which, if not in static equilibrium, would trigger the sliding of the geosynthetics layers and/or of the topsoil. The diagram illustrating this type of problem is shown in Fig. 3. As already mentioned the direct shear tests, performed at a nominal pressure of 55 kPa, provided an equivalent internal friction angle of 36 deg. The tensile strength of this GCL is equal to 20 kN/m.

The active force, which is the destabilising one, having direction tangent to the slope and downward is the component along the slope of the weight W of the soil block, given:

W = t x L x y

Where: t = thickness of the topsoil
L = slope length
ɣ = unit weight of the saturated topsoil

W = 1.3 x 1 x 1.8 = 23 kN

The component Fs along the slope which is projected to be at max 1:3 (18.5deg)

$Fs = W \sin \beta$

where: β = slope angle.

$Fs = 23 \text{ kN} \times \sin 18.5 = 7 \text{ kN}$

$N = W \cos \beta = 21 \text{kN},$

$R = N \, tg\, \theta = 3.7 \text{ kN}$

The stability analysis has taken into account the fact that the granular soil on the berms has been placed only up to 1.00 m distance from the slope edge. The resisting forces are: the friction force R at the geocomposite clay liner - subsoil interface; the passive resistance at the toe; the strength of the reinforcement Rg from the anchor trench.
The passive resistance at the toe has not been considered, since it's not possible to guarantee an adequate compaction and density of this soil; this choice is, in any case, in favour of safety.

It is evident that the critical interface is not between GCL and geodrainage since they are anchored together. The friction angle is too low to guarantee the anchorage of the geosynthetic layers just along the intermediate berm without the excavation of a deep anchoring trench. But if we can assume that the GCL and the draining geocomposites are solid and will deform or move together, then the top GCL - topsoil interface becomes the critical one, with a friction angle equal or lower than the friction angle of the topsoil itself.

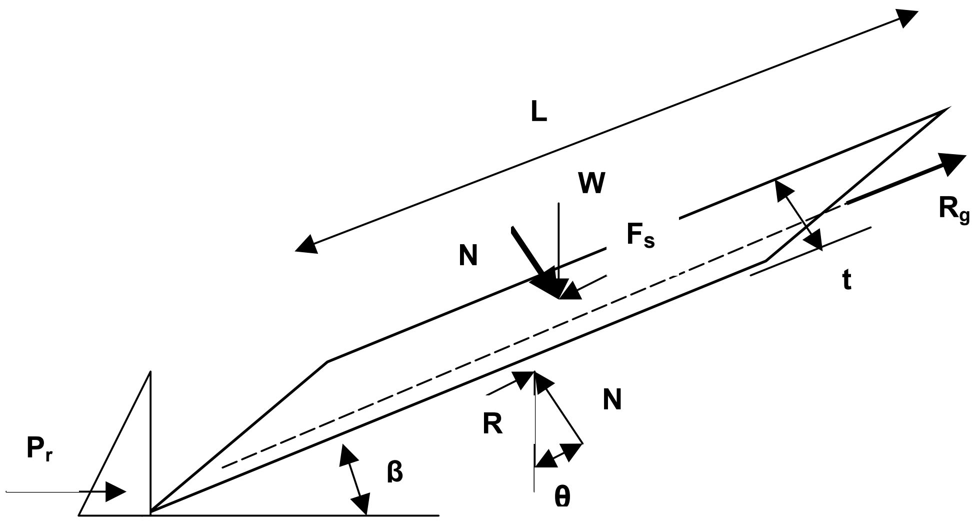


FIGURE 3

where: L - slope length, t – top soil thickness, W – weight of the soil, Fs – component of W along the slope, N – component of W normal to the slope, Pr – passive resistance at the toe, Rg – strength of the reinforcement,

FS = Fres/Fact = R + Rg / Fs

To ensure adequate Factor of Safety (FS) the ratio between real forces expected in reinforcement at critical value of shear angle (between GCL and soil) and anchorage resistance developed in the trench have to be over 1.3.

FS = (3.7 + 20/3) / 7 = 1.48

The lateral tensile force of GCL along the slope has been reduced to 1/3 to take into account the low pressure produced by the topsoil. Along the berms it is intended to excavate anchoring trenches (0, 50 m x 0, 50 m section) and to overfill it with a 1.0 m thick layer of well compacted granular soil, able, with its weight, to anchor the GCL and the draining geosynthetics.

B.3. Gas Extraction System

Gas collection system shall be installed in accordance to specifications provided in **Annex 1**. This specification reflect requirements for the Aerial emission project of Maghtab.The Zwejra gas collection system shall be compatible with Gas extraction system to be installed at Maghtab as a part of Aerial emissions control work (EU funded project). Installation of Gas extraction system shall consist of following activities:

- **The installation of approximately 13 drilled gas wells (as shown on the figure 4)**
- **The installation of wellheads onto the gas wells**
- **The installation of manifolds to connect the gas wells to the gas mains**
- **The installation of condensate drain legs in the gas mains**
- **The installation of the first part of the gas ring mains in MDPE connecting the manifolds to the gas plant**

The installed system will be constructed to facilitate inspection, cleaning and repair to ensure continuity of satisfactory operation under all working conditions for a period of at least fifteen years. All plant and apparatus supplied under this Project shall be of a make, type, material and construction approved by the Company Engineer and, unless specified to the contrary, shall comply with the most recent applicable British Standard or other equivalent approved National, European or International Standards.

MDPE Pipes are to be joined using either butt fusion or electro-fusion welding techniques in accordance with the conditions laid in Annex 1. Logs will be maintained of all tests, failed and completed joints by the Contractor to pass on to the Company Engineer. When installing pipes they must be laid to fall back to dewatering points. An as-built drawing will be used to check this.

Materials used in the construction of the works shall be suitable for the duty. In particular, components in contact with saturated gas or condensate shall be inherently corrosion resistant. The use of brass, copper and aluminium shall not generally be acceptable. Seals shall be nitrile rubber or a material proven acceptable for landfill gas and condensate duty. Materials shall be selected to ensure satisfactory operation for a period of at least fifteen years.
The main ring connecting the gas well heads shall be laid above the topsoil layer at the surface and should consist of flexible piping system with 10 % extra length allowing for future settlements and soil movements. The pipe system will be manufactured of high density polyetilen or similar approved by Company engineer.

B.4. Input Parameters

Ta' Zwejra landfill is occupying the place which is historically dedicated for waste management situated near Maghtab; it is characterized by a surface of about 4.3 Ha and a depth varying from 15 to 25 m.
The main parameters of the first cell which could have influence on the design of Gas recovery system are as follow:

Site characteristic

landfill cell footprint	18,000 sq.m
max cell depth at center point	25 m
cell side slopes	1 : 3 (v :h)
cell top slope	5 %
cell cover area	21,000 sq.m
waste volume	180,000 cu.m
waste quantity	144,000 tons

Waste characteristics

type of waste	MSW
age of waste	10 months
waste bulk density	800 kg/cu.m
ratio waste/cover	5 : 1
waste void ratio	5 %

Gas characteristics

gas constant	8.31
gas production potential	120 Nm3/t
concentration of methane	50 %
Radius of influence/well	40 m
vacuum pressure at wellhead	100 kPa
temperature of LFG	45 d C
LFG density	1,31 kg/m3

Estimation of Gas Flux

The mass flux of gas from the surface of a landfill is site specific and varies specially and temporally in a given landfill. Hence the amount of gas produced from the waste depends on the waste's type, age, temperature, moisture, other avenues of gas extraction or venting, and barometric pressure. For controlled landfills in enhanced decomposition mode values go up to 0.037 standard cubic meters per wet kilogram of waste per year (m^3/kg/yr), however for purposes of cover design typically at the end of the cell's life, R.S. Thiel recommends a gas generation rate of 6.24×10^{-3} m^3/kg/yr for municipal solid waste landfills which is for Zwejra typical conditions a very conservative value.

$$\theta_{lfg} = r_g * H_{avg\ waste} * y_{waste} = 6.24*12*800 = 60\ m3/y/m2$$

$$\theta_{lfg} = 138E\text{-}06\ \ m3/min/m2$$

Φ_{LFG}	LFG mass flux($m^3/s/m^2$)
r_g	Landfill gas generation rate(m^3/kg/yr)
$H_{avg\ waste}$	Average waste depth(m)
γ_{waste}	Unit weight of waste(kN/m^3)

The amount of LFG gas estimated above will be used in sizing the pipe work and blowers capacity once the Contractor on site begin with procurement of equipment. This is done by estimating the total amount of LFGs that a site can generate, and the amount of LFGs that the gas collection systems in place are capable of extracting and flaring in relation to how much a state-of-the-art system would collect.

Actual fine tuning of the quantities will be determined on site by verification tests. Calculations above are indicative since the rate of gas generation at landfill site is dependant on many factors. The local conditions which could influence the rate of gas generation are mainly : waste types and depths, moisture content, degree of compaction, landfill pH, temperature, age of waste etc. Therefore predicting the gas quantity is subject to significant uncertainty. The sizing of the pipe work will take into account contingency due to this uncertainty.

C. GAS COLLECTION DESIGN

C.1. Starting date

Estimated as 01/06/2005

Once the waste in cell one is covered with layer of inert material and re-contoured as to obtain accepted slope angels and 5 % fall of the top surface , the capping components can be placed.

Next phase is drilling of boreholes for the installation of gas well's piping system and their connection in the grid.

C.2 Duration of the project activity

Estimated as from 01/06/2005. It is forecasted to be installed contemporary with installation of Maghtab gas extraction system. All work on Zwejra site will be subject to Construction Quality Assurance monitoring programme and approval by independent agency. At completion the QCA Report will be issued to verify the quality of installation.

C.3. Expected operational lifetime of the project activity

Expected: 15 years.

It is expected that Gas recovery system will be operating until final stabilisation of waste mass in the landfill.

C.4. Design principles

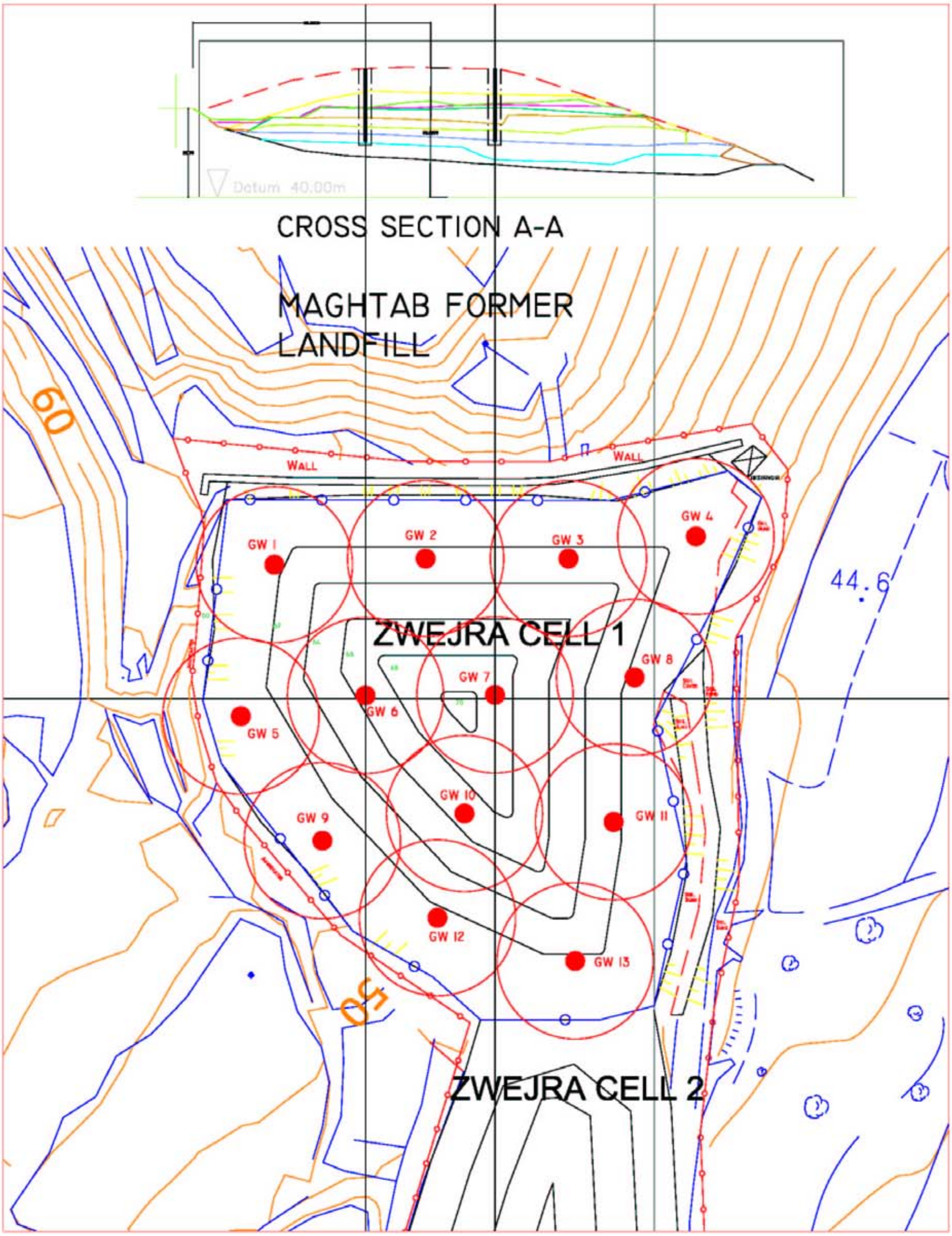
As previously mentioned the system will follow design principles of Aerial emission control Project of Maghtab. In general, the basic environmental controls proposed relate to management of gas emissions by installing gas collections systems linked to flares and treatment plant. Some waste re-contouring will be required to allow access to all parts of the sites to install the control systems

A landfill gas capture system shall be installed including sealed landfill gas wells and chambers connected to headers and pipework. Landfill gas shall be treated by combustion. The gas capture system would be connected to the gas treatment system on completion of infilling of each area.

The System shall be fabricated, constructed and installed to facilitate inspection, cleaning and repair to ensure continuity of satisfactory operation under all working conditions for a period of at least fifteen years. All plant and apparatus supplied for this project shall be of a make, type, material and construction as approved by the Company and, unless specified to the contrary, shall comply with the most recent applicable British Standard or other equivalent approved National, European or International Standards.

It has been assumed that the gas collection system installed will have an efficiency of 90%. Therefore 10% will continue to escape as fugitive emissions. The only source of project emissions identified within the system boundary is fugitive methane emissions from the landfill.

The system is designed as an active vertical gas collection system. The well which are approximately 13 for the first cell are spaced in Ri = 40 m grid distance. Design principle of well construction is presented in figure 3.



GAS WELL INDICATIVE LOCATIONS /ZWEJRA I

FIGURE 3

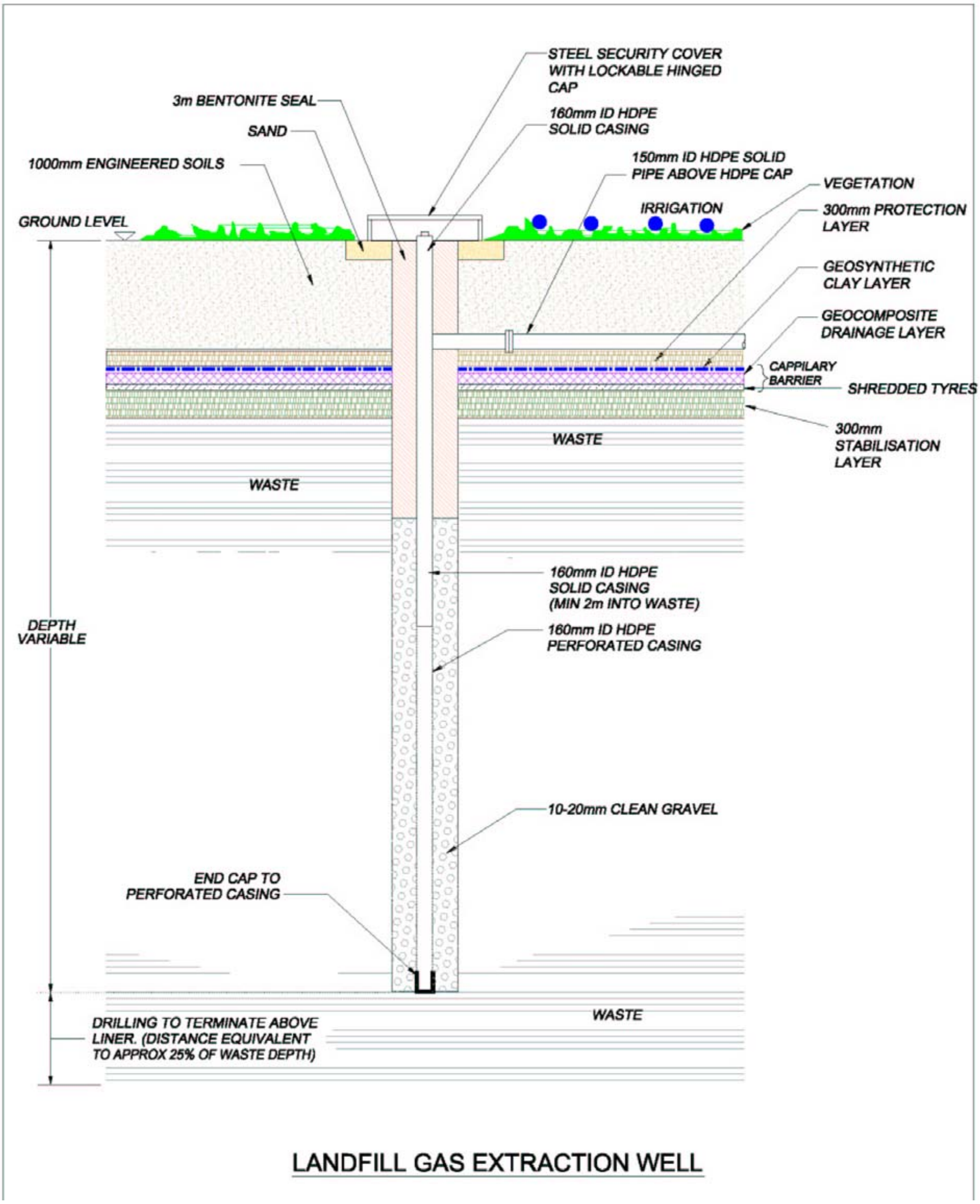


Figure 4

The wellheads shall be made of HDPE and of such design as to allow for settlment compensation. They must have a measuring LFG connection point and flow regulating valve.

D. JUSTIFICATION OF THE CHOICE

D.1. Guiding principles

The project is expected to result in significant beneficiary impacts on the environment.
It should be noted that the inhabitants in the region are often complaining about bad odour caused by the landfill. This smell will be substantially reduced by the implementation of the proposed project in conjunction with Aerial emission control Project of the Maghtab.

As stated earlier the Maghtab former waste dump is without proper management for gas collection, or water (leachate) treatment whatsoever. By rehabilitation of the Maghtab site and installation of Active Gas extraction System at Ta' Zwejra through collection of the landfill gas and potentially using it to generate electricity the project will reduce the impacts on the environment at the global as well as the local level.

The total costs of the gas collection system, the gas flaring system and installation of environmental monitoring equipment with necessary after care maintenance for the two sites Qortin and Wied Fullija inclusive) are estimated to be in a range of 10,000,000 EUR. These costs cannot be recovered as the investment does not generate any other revenues than revenues from the environmental benefits. The results of the preliminary investigations and financial analysis clearly indicate that the implementation of the project includes the possibility of generation of electricity.

The project can be characterised as a pilot project as it will be the first of its kind in Malta. It can serve as an example for future landfill sites in Malta. The experience gained and data collected on landfill gas etc. for this project can be used for similar projects in the Maltese or generally Mediterranean context. The replication of this project concept to other sites will increase the benefits.

D.2. Benefits

The main benefits from the installation of Gas recovery system are:

- Reduction of greenhouse gas emissions by transforming methane emission into CO_2 emissions (and potentially using the gas to generate electricity, resulting in zero emissions);
- Reduce risks of explosions and fires due to controlled landfill gas collection;
- The appropriate management of the Zwejra and Maghtab site will result in a reduction of health risks for the local population, which is caused by toxic effects and the bad odour of the gases emitted with the methane. This will be eliminated if the project is implemented because the major components of landfill gas, methane and carbon dioxide, are colourless and odourless.;
- The proper management of surface and run-off water. Surface water runoff from a landfill site can also cause unacceptable sediment loads in receiving

waters, while uncontrolled surface water run-on can lead to excessive generation of leachate and migration of contaminated waters off-site. With Zwejra providing appropriate management on the site, these potential problems should be avoided.

- Faster stabilisation of the wastes and provision of after use choices for the reclaimed land.
- At some time in the future, when the environmental hazards from both sites are reduced and it is considered safe, the sites will be fully rehabilitated. This would involve re-contouring and the placement of soils and landscape planting.
- An extensive environmental monitoring scheme will be conducted at the same time as construction works in order to identify and rectify any problems at an early stage.
- In addition, every effort will be taken to ensure there are no adverse impacts on the surrounding environment, site workers and nearby residents caused by the construction of this gas extraction system.

E. MONITORING METHODOLOGY AND PLAN

The Zwejra project will be similar in kind to the Maghtab aerial emission control project, for which this monitoring methodology has been used. For a landfill gas capture project such as this type it is most appropriate to accurately measure the methane combusted in flares and generators, i.e. the emission reductions attributable to the project.

E.1. Methodology

Characteristic for Landfill gas collection and utilization projects of the kind described above is that the emissions not released to the atmosphere can directly be monitored. The emissions reductions achieved by the project do not have to be derived from a comparison between baseline and project emissions, because every ton of gas collected and destroyed equals one ton of gas not released to the atmosphere and thus one tone of LFG gas emissions reduced.

The Zwejra monitoring plan sets out a number of monitoring tasks in order to ensure that all aspects of projected LFG emission reductions for the project are controlled and reported. This requires an ongoing monitoring of the project to ensure performance according to its design and that claimed emission reductions are actually achieved.

E.2. Monitoring parameters

The variables and parameters to be monitored shall include the following**:**

- **surface gas emissions and temperature**
- **aerial emissions from gas control systems**
- **groundwater level and quality**
- **off-site air quality (dust)**
- **personal protective monitoring**
- **meteorological data**
- **noise**

The baseline scenario is defined as the continued uncontrolled release of landfill gas to the atmosphere, similar to Maghtab landfill sufficient to reconfirm the baseline assumptions at seven-year intervals. However, to account for the implementation of regulatory requirements, or improvements in waste management practices, a control regime will be formed and surveyed at each baseline revision point in the future. The survey will aim at estimating the amount of LFG flaring taking place as part of common industry practices at that point in the future. At every baseline revision point in the future, an expert consultant will provide an estimation of:

- **Whether there are sufficient gas collection wells in place;**
- **The depth of the wells in relation to the depth of the sites;**
- **The number of gas collection wells operating satisfactorily i.e. gas is flowing;**
- **The number of gas collection wells not operating i.e. blocked by leachate, poorly maintained etc.;**

- **The number of flares operating satisfactorily i.e. burning landfill gas;**
- **Whether the site applies suction to the wells;**
- **Whether the site is appropriately capped, to avoid venting;**
- **The efficiency of the flares utilized.**

Based on the data collected, the expert will estimate the percentage of gas being flared at each of the control group landfills and decisions will be made.

Data to be collected in order to monitor emissions from the project activity, and how this data will be archived:

ID number *(Please use numbers to ease cross-referencing to table D.6)*	**Data variable**	**Data unit**	**Measured (m), calculated (c) or estimated (e)**	**Recording frequency**	**Proportion of data to be monitored**	**How will the data be archived? (electronic/ paper)**	**Comment**
1	**Flow of landfill gas to flares**	**M^3**	**m**	**Continuous**	**100%**	**Electronic (spreadsheet)**	***Data will be aggregated monthly and yearly***
2	**Electricity potential**	**MWh**	**M**	**Continuous**	**100%**	**Electronic (spreadsheet)**	***Data will be aggregated monthly and yearly***
3	**Flare efficiency**	**%**	**M & C**	**Semi-annual determination of flare efficiency (if significant variation since last monitoring, monitoring repeated every month)**	**Semi-annually or more frequent depending on observed deviation from previous rating**	**Electronic (spreadsheet)**	***Data will be used to test and, if necessary correct the flares' efficiency ratings.***
4	**Methane fraction in LFG**	**%**	**M & C**	**Continuous**	**100%**	**Electronic (spreadsheet)**	***Data will be aggregated monthly and yearly.***
5	**LFG collected**	**%**	**E**	**Every 7 years**	**A minimum of 10 control sites**	**Electronic (spreadsheet)**	**-**

The quality assurance practices that will be implemented in the context of the Zwejra project are as follows:

Daily Monitoring Records**: These readings are then checked for any anomalies before being filed for future reference. The readings are taken at weekly and monthly set periods depending on the activity and consistency of the gas field and engine**

operation. All engines will have telemetry links back to a central computer at head office, which continually monitors the performance of the engine detecting problems and highlighting them for attention.

Gas Field Monitoring Records: Taken on a weekly basis or at periods to be determined. The Site Technician walks the gas field taking readings at each gas well and recording these on a form, which is then faxed to head office. These readings are then checked for any anomalies before being filed for future reference. A gas analyser will be installed in order to enable accurate measurement of the methane content on the landfill gas. These gas field inspections will also observe occurrence of any unintended releases of landfill gas. In case unintended releases are observed, appropriate corrective action will be taken immediately.

Routine Reminders for Site Technicians: All Site Technicians are issued with a reminder list to guide them through their daily, weekly and monthly routine. The Engineering Manager, Operations Manager and Training and Health & Safety Co-ordinator go through this routine during site visits to ensure all aspects of the role are being performed. In addition paperwork due at head office is checked to ensure it has arrived. This includes monitoring records, oil sample reports and meter readings. Again the telemetry link records a lot of the data automatically.

F. ANNEX 1

F.1. Part A - Gas Collection System - General

3.4.1 Gas Wells – Impact

3.4.1.1 Impact gas wells shall be constructed using a ‘push in’ technique to create the well. A minimum well depth of 5 meters is required. Gas wells shall be constructed using 3m lengths of 3” nominal bore heavy-duty gauge steel pipe. Connections shall be made using 3” BSP threaded fittings. The bottom 3 m section shall be a perforated section drilled with 5% open area. The bottom of the perforated section shall be formed into a spike to allow the casing to be driven into the ground.

3.4.1.2 In order to allow the casing to be driven into the ground without deforming the top thread a ram plate shall be fabricated to connect onto the 3” BSP thread during installation. This shall ensure that the force of the piling rig or excavator during installation shall be passed into the casing and shall not deform the thread.

3.4.2 Gas Wells - Drilled

3.4.2.1 Drilled gas wells shall be drilled to 300 mm diameter or greater using a rotary barrel auger or other approved technique. Drilled gas wells shall be constructed using 3m lengths of 3” nominal bore steel pipe. Connections shall be made using threaded connections. Gas wells shall be drilled to a depth of 12m. The bottom 6 m shall be a perforated section with 5% open area. An end cap shall be installed and secured on the bottom of the perforated section of well casing. The annulus of the gas well shall be filled with a washed, non-calcareous, rounded gravel pack of 20 mm single size stone. Care shall be taken during installation to prevent bridging. The top 2m of the gas well annulus shall be sealed with a chemical sealant such as polyurethane foam.

3.4.3 Gas Wellheads

3.4.3.1 The gas wells shall be connected using wellheads of the design shown in the Drawings. The wellheads shall be fabricated from galvanised steel. They shall be based around a 3”: 1½” BSP reducer and 1½” BSP tee. The top part of the tee shall be fitted with 1½” BSP screw in end cap. The connecting pipe shall connect onto the arm of the tee via a 1½” BSP ball valve and length of flexible braided stainless steel hose. This shall allow for movement of the gas well in horizontal and vertical directions and take up any expansion of the connecting pipe.

Each well shall be given a unique reference number. The numbering system shall be agreed with the Engineer and marked clearly on (or by) each well head.

3.4.4 Connecting Pipework

3.4.4.1 The connecting pipework will be constructed from 1½” nominal bore galvanised steel pipe and joined using 1½” BSP threaded fittings.

3.4.4.2 Where the pipe and the thread are cut for making connections the exposed steel shall be treated with a suitable coating (to be agreed with the Engineer) to protect the exposed steel from corrosion by landfill gas condensate. Connecting pipe shall be delivered to site in suitable lengths as desired by the Contractor.

3.4.4.3 Connecting pipework shall be laid on the surface and secured in place by suitable steel hoops driven into the ground at the location of every joint. All connecting pipework shall be laid to maximise the fall to the manifolds. Ideally falls should be 1:25 or greater. Where this is not achievable, connecting pipeline routes shall be agreed on site with the Engineer. The Contractor will be required to survey proposed connecting pipeline routes to determine levels and falls. The results of the survey and the levels and connecting pipe line falls achieved shall be recorded on an "as installed" drawing to be supplied by the Contractor on completion of the Works.

3.4.5 Single Manifolds

3.4.5.1 Single manifolds shall be installed to collect gas from the connecting pipes. Manifolds shall be fabricated from 4” nominal bore galvanised steel pipe. The steel pipe shall be a suitable gauge rated to at least 16 bar. Each manifold shall have a single valve outlet for connection to the gas main and an end blank as shown on the Drawings. Each manifold shall include a 1½” BSP inlet for each gas well connecting pipe.

3.4.5.2 Isolating and control valves shall be provided for each incoming gas line. The valves shall be 1½” stainless steel ball valve type (or similar subject to agreement of the Engineer). The inlets shall be permanently marked as to the well number on each line with a suitable durable label. Gas sample points shall be installed upstream of the valves.

3.4.5.3 The outlet of the manifold shall comprise a 4" butterfly valve for isolation and control and a flame arrestor (to comply with BS EN 12874:2001 and the ATEX Directive). A blank plate shall be installed at the opposite end to the valve. All connections shall have flanged joints to BS 4504 PN16 and be fastened using plated bolts. Gas sample points shall be provided immediately upstream (gas well side) and downstream (gas plant side) of the manifold isolating and control valve and the flame arrestor.

3.4.5.4 Each gas sample point shall comprise a ¼” BSP stainless steel ball valve with a barb to allow gas samples to be taken. A dust cap shall be fitted on the barb and shall be attached by a non-perishable line, of a type and quality agreed by the Engineer, to the base of the valve.

3.4.5.5 In case of an explosion in the manifold a pressure relief device and vent pipe shall be fitted to the manifold. This shall take the form of a bursting disc (to comply with BS EN ISO 4125-2:2003) and a 3 m tall vent pipe. The vent pipe shall be supported using suitable struts. The bursting disc shall rupture at a pressure of 3 bar at a temperature of 50 °C. The disc shall have a minimum rupture pressure of 1 bar at a temperature of 90 °C and a maximum rupture pressure of 6 bar at a temperature of 0°C. On the 6” manifold (see below) the bursting disc shall be 3” diameter and on the 4” manifolds the bursting disc shall be 2” diameter.

3.4.5.6 Manifolds shall be factory tested to 1 bar gauge and supplied to site with a pressure test certificate. Incoming lines shall fall towards the manifold. The manifold shall be laid to fall towards the outlet to facilitate drainage of condensate. Manifolds shall be laid on a bed of crushed rock bedding material.

3.4.6 Dual Manifolds

3.4.6.1 Dual manifolds shall be installed to collect gas from the connecting pipes and send it to dual gas mains. At each location one manifold shall be fabricated from 4” nominal bore galvanised steel pipe and the second fabricated from 6” nominal bore galvanised steel pipe. The steel pipe shall be a suitable gauge rated to at least 16 bar. Each manifold shall have a single valved outlet for connection to the gas main and an end blank as shown in the Drawings. Each manifold shall include a 1½” BSP inlet for each gas well connecting pipe to allow twenty-five gas wells to be connected per manifold. The incoming gas collection pipe shall be split using a 1½” BSP tee prior to the manifolds. This will allow gas to be extracted via either of the two extraction systems. Gas sample points shall be provided immediately upstream of these tees.

3.4.6.2 Isolating and control valves shall be provided for each incoming gas line. The valves shall be 1½” stainless steel ball valve type (or similar subject to agreement of the Engineer). The inlets shall be permanently marked as to the well number on each line with a suitable durable label. Gas sample points shall be installed upstream of the valves.

3.4.6.3 The outlet of the 4” manifolds shall comprise a 4" butterfly valve and the 6” manifolds a 6” butterfly valve for isolation and control and a flame arrestor (to comply with BS EN 12874:2001 and the ATEX Directive). A blank plate shall be installed at the opposite end to the valve. All connections shall have flanged joints to BS 4504 PN16 and be fastened using plated bolts. Gas sample points shall be provided immediately upstream (gas well side) and downstream (gas plant side) of the manifold isolating and control valve and the flame arrestor.

3.4.6.4 Each gas sample point shall comprise a ¼" BSP stainless steel ball valve with a barb to allow gas samples to be taken. A dust cap shall be fitted on the barb and shall be attached by a non-perishable line, of a type and quality agreed by the Engineer, to the base of the valve.

3.4.6.5 In case of an explosion in the manifold a pressure relief device and vent pipe shall be fitted to the manifold. This shall take the form of a bursting disc (to comply with BS EN ISO 4125-2:2003) and a 3 m tall vent pipe. The vent pipe shall be supported using suitable struts. The bursting disc shall rupture at a pressure of 3 bar at a temperature of 50 °C. The disc shall have a minimum rupture pressure of 1 bar at a temperature of 90 °C and a maximum rupture pressure of 6 bar at a temperature of 0°C. On the 6" manifold the bursting disc shall be 3" diameter and on the 4" manifolds the bursting disc shall be 2" diameter.

3.4.6.6 Manifolds shall be factory tested to 1 bar gauge and supplied to site with a pressure test certificate. Incoming lines shall fall towards the manifold. The manifold shall be laid to fall towards the outlet to facilitate drainage of condensate. Manifolds shall be laid on a bed of crushed rock bedding material.

3.4.7 Gas Mains

3.4.7.1 The gas mains shall be constructed either from MDPE or galvanised steel pipe. MDPE Pipe shall be 355mm, 250 mm, 180 mm and 125 mm black MDPE (PE80) pipe to SDR 17.6 and joined using electro fusion or fully automatic butt-welding techniques. Only moulded fittings shall be used, fabricated fittings will not be accepted. Galvanised steel pipe shall have a nominal bore of 300 mm, 200 mm, 150 mm or 100 mm. The galvanised pipe shall be connected using flanged fittings to BS 4504 PN16 and be fastened using plated bolts. Fabricated galvanised steel bends shall be installed to allow bends in the pipe. The location and route of the gas mains are shown on the Drawings, they shall be agreed on Site with the Engineer.

3.4.7.2 The Contractor will survey the proposed gas main routes, mark out the proposed routes and check the falls. The results of the survey and the proposed routes will be verified by the Engineer and the Contractor before installation. The Contractor shall survey the final location and levels of the gas pipes at intervals of at least every 20 metres. Ideally falls should be 1:50 or greater on the landfill and 1:100 on virgin ground. Where this is not achievable, gas main routes shall be agreed on site with the Engineer.

3.4.8 Condensate Dewatering Legs

3.4.8.1 Self draining condensate dewatering legs shall be installed in all low spots on the gas mains on the waste. These shall be based around a 300 mm ID galvanised steel tee. The condensate dewatering legs shall consist of an upper and a lower chamber as shown in the Drawings. The top chamber shall be fabricated around a 300 mm tee. The lower chamber shall be fabricated of 150 mm ID galvanised steel. Condensate shall drain back into the waste from where it came via drainage holes on the outer lower chamber.

3.4.8.2 The condensate dewatering legs will drain via a 75 mm ID galvanised steel pipe connected from the base of the upper chamber and which terminates 200 mm from the base of the lower chamber. Condensate will drain from this lower chamber through ten rows of 10 mm holes on 25 mm spacing, into a host sump.

3.4.8.3 The length of the lower chamber and the 90 mm drain leg, together with the height of the holes from the base of the condensate dewatering legs, will be such that a water seal can be maintained at a suction of 150 mb.

3.4.8.4 The dewatering legs shall include a 100 mm ID galvanised steel flanged access/inspection arm brought to the surface. A ¼" BSP stainless steel ball valve with a barb shall be installed to allow gas samples to be taken. A 1" BSP dip cap shall also be installed to allow liquid levels to be measured.

3.4.8.5 The condensate dewatering legs shall be located in sumps drilled or excavated to a diameter of at least 350 mm and to a depth of 6 m. The sumps shall be backfilled with a clean non-calcareous rounded 20-30 mm gravel pack to 0.5 m above the drainage area of the lower chamber. Care shall be taken to avoid bridging. The remaining hole shall be sealed with a chemical sealant such as polyurethane foam.

3.4.9 Condensate Knockout Pots

3.4.9.1 Pumped condensate knockout pots shall be installed in all low spots of the gas mains located off the waste mass. The condensate knockout pots shall be fabricated around a 355mm MDPE equal tee, as shown in the drawings

3.4.9.2 The design shall consist of an internal and external chamber. The internal chamber shall be fabricated with a lower section of 180mm SDR 17.6 MDPE reducing to 125mm SDR 17.6 MDPE in the upper section. The 125mm section will be brought through the top of the external chamber. The 125mm section shall include a flanged access/inspection port brought to the surface. The top blanking flange shall also include monitoring facilities that shall comprise of a 1" BSP dipping point with a threaded cap, which must be removable by hand.

3.4.9.3 The external chamber shall be fabricated from a 355mm equal tee (SDR 17.6), the lower section of which shall reduce to 250mm SDR 17.6 MDPE. At the point at which the 125mm internal section is brought through the 355mm tee a 250mm flanged section shall be 'stabbed' into the 355mm tee. The flange shall be extrusion welded to the 125mm internal chamber to allow its removal for cleaning etc.

3.4.9.4 The base of the internal chamber shall rest on the flat cap end of the external chamber and shall have a spacer around the outside diameter of the pipe to support it within the external chamber. The base of the internal chamber in shall be finished with 10 rows of 10 mm holes on 20 mm spacings. All joints on the inner chambers of the knockout pots will be internally debeaded.

3.4.9.5 During commissioning the 1" BSP dipping point shall be opened to allow the internal chamber pressure to equalise with the barometric pressure.

3.4.9.6 Condensate will drain into the external chamber because of the falls into the pot. The condensate will be removed by means of a compressed air driven pump.

3.4.9.7 The pots will be located in a sump drilled or excavated to a minimum diameter of 500 mm and a depth to suit the installation. The sump shall be backfilled with a washed, non calcareous 5 mm to 10 mm gravel pack or suitable bedding material as available and agreed with the Engineer. The final 750 mm below the 355 mm tee will be finished with saturated bentonite granules. The use of the reducer for the knockout pot will mean that the top of the bore will have to be widened to ensure the gravel/bedding material is installed without bridging.

3.4.9.8 In restored areas or virgin ground the top of the knockout pot shall finish at ground level and shall be protected by a wellhead type chamber. The chamber shall be of a robust construction and able to protect the wellhead against damage from farm animals. The chamber shall be sealed with a lockable lid of robust design capable of being easily lifted by one person. The lid must be designed in such a way that it forms a watertight seal when closed to prevent the ingress of water into the chamber.

3.4.10 Compressed air line

3.4.10.1 Compressed air lines shall be installed to the pumped condensate knockout pots. The compressed air lines shall be constructed from 63 mm and 32 mm SDR 11 black MDPE. All pipe work will be joined using electrofusion or fully automatic butt welding techniques. Compressed air warning tape shall be wrapped around the compressed air lines.

3.4.10.2 At the knockout pots the air line shall terminate with an isolation valve. The air line shall be connected using a compression type fitting. This will be supported on a galvanised steel or MDPE plate attached to the external side of the access flange. The support plate will not hinder removal of the access flange.

3.4.11 Condensate discharge lines

3.4.11.1 Condensate discharge lines shall be installed from the pumped condensate knockout pots. Condensate discharge lines will be installed in 90 mm and 32 mm blue MDPE to SDR 11. All pipe work will be joined using electrofusion or fully automatic butt-welding techniques.

3.4.11.2 At the knockout pots the line shall terminate with an isolation valve. The valve shall be connected using a compression type fitting. This will be supported on a galvanised steel or MDPE plate attached to the external side of the access flange. The support plate will not hinder removal of the access flange.

3.4.12 Condensate discharge pumps

3.4.12.1 The pumps used in the knockout pots must be compressed air driven, capable of achieving a pumping rate of at least 10 m3 per day, with automatic level controlled operation and capable of withstanding the aggressive nature of condensate. They shall fit easily inside the 125 mm MDPE casing. Ideally the pumps shall have a length of between 500 and 850 mm. The liquid inlet shall be at the base of the pump. A suitable filter shall be fitted to strain large suspended solids from the inlet. Details of the proposed pump shall be supplied with the tender.

3.4.12.2 The pumps shall be installed so that the activation level of the pump is 900 mm above the base of the knockout pot. The pumps supplied shall be capable of pumping against a head of 30m at a minimum pumping rate of 5 m3 per day.

3.4.12.3 The pumps shall be supplied with all the required fitting to connect to the 32 mm condensate discharge lines and 32 mm compressed air lines. Suitable condensate discharge, compressed air line and air discharge pipework shall be supplied and installed. The pumps shall be supplied with a stroke counter and pressure regulator with an auto-drain and filter on the air supply line. On the condensate discharge line a suitable non-return valve shall be supplied and installed.

3.4.12.4 In the knockout pots the pumps shall be installed in the internal chamber after the pressure test of the gas main is successful. The pumps shall not be installed until after the pot has been primed to at least the levels indicated by the equilibrium level in the drawings.

3.4.13 Part A - Completion Files

3.4.13.1 The Contractor will be required to produce a completion file containing all the relevant paper work from each Phase of the Works. This shall include, but not be limited to, the following:

Details of any amendments to the original design

CQA information including: Butt fusion log sheets, electro fusion log sheets, failed joint log sheets, pressure test certificates for fabrications and gas mains

As built drawings (see below)

Relevant instruction / maintenance manuals

3.4.14 Part A - As Built Drawings

3.4.14.1 The Contractor shall carry out a survey of the completed schemes at the end of each Phase. All pipeline routes, gas wells and other fabrications should be located and levelled. The survey shall be carried out to an accuracy approved by the Engineer and, shall be referenced to the Maltese datum.

3.4.14.2 The following drawings shall be produced at a recognised scale to show the required information clearly. All drawings shall be provided as a hard copy and in *.DXF or *.DWG digital format.

3.4.14.3 Gas Scheme – As Built

Showing the scheme in its entirety, including all wellhead references, pipe sizes etc. Differing pipe sizes should be indicated by different line styles.

3.4.14.4 Sections

Section shall be produced along all gas line routes and shall show ground level, pipe level, CQA joint numbers and location of joints, chainage, location of junctions and schematic details of wellheads and knockout pots etc. The Contractor should agree with the Engineer a method of referencing the pipe depth to ground level prior to the survey.

3.4.14.5 Fabricated Components – As Built

Accurate drawings shall be produced for all individual fabricated components such as wellheads, manifolds, condensate dewatering legs, pumped condensate knockout pots and chambers. A drawing shall be produced for each component stating the component reference number etc for identification.

3.4.15 Details with Tender

The following details are required to be provided with the Tender:

Pre-Construction drawings of Gas Plant (Section 3.3.8)

Details of proposed VOC thermal destructor (including heating method)

Details of proposed condensate pumps

F.2. Phase I Part A

3.5.1 The following shall be installed under Phase I as a minimum as shown in the drawings.

3.5.2 Gas Wells - Drilled

3.5.2.1 50 drilled gas wells shall be installed as shown on the Drawings.

3.5.3 Gas Wellheads

3.5.3.1 50 wellheads shall be installed on the drilled gas wells

3.5.4 Connecting Pipework

3.5.4.1 Surface laid galvanised steel connecting pipework shall be laid to connect each individual well to an inlet on the manifolds.

3.5.5 Dual Manifolds

3.5.5.1 A minimum of five dual manifolds shall be installed to allow suction control on the gas wells. The dual arrangement shall allow gas to be extracted and sent either to the VOC thermal destructor or the flare.

3.5.6 Gas Mains

3.5.6.1 The gas mains shall be constructed from MDPE and galvanised steel pipe. The preliminary sections of a dual ring main shall be installed on the boundary of the site in the virgin ground. The system supplying the VOC thermal oxidiser on the gas plant shall form a 355 mm MDPE ring main around the site with 150 mm ID galvanised steel pipe to connect to the manifolds. Mirroring this shall be a 250 mm MDPE ring main with 100 mm ID galvanised steel connections to the manifolds to the flare. Only the first part of these ring mains shall be installed under Phase I as shown on the Drawings. Isolation flanged butterfly valves (6" and 8") shall be installed at the temporary ends of the ring mains.

3.5.6.2 The ring mains shall be buried to a maximum trench depth of 1000 mm and a minimum cover of 500 mm. The connecting lines to the manifolds shall be surface laid. Where the pipes are surface laid they shall be secured on the surface by steel loops every 20m. Where pipes are buried and beneath vehicular crossing points measures shall be taken to prevent damage to the pipes to the approval of the Engineer.

3.5.7 Condensate Knockout Pots

3.5.7.1 Pumped condensate knockout pots shall be installed in all low spots of the gas mains.

3.5.8 Compressed air line

3.5.8.1 The initial part of a compressed air ring main shall be installed in 63 mm MDPE to mirror the gas main to supply compressed air to the knockout pot pumps. At each knockout pot a spur shall tee off in 32 mm MDPE.

3.5.9 Condensate discharge lines

3.5.9.1 The initial part of a condensate discharge ring main shall be installed in 90 mm blue MDPE to mirror the gas main. At each knockout pot a spur shall tee off in 32 mm blue MDPE.

3.5.10 Condensate discharge pumps

3.5.10.1 One pump shall be installed in each knockout pot. Two spare pumps shall also be supplied.

3.5.11 Phase I - Extraction Trial

3.5.11.1 The Contractor shall carry out an extraction trial on the system installed in Phase I. This shall consist of monitoring the following parameters on a twice-weekly basis once the system has been commissioned and activated:

Temperature for each gas well at the wellhead (using an infrared temperature probe)

Flow at the wellhead using a pitotube

CH4, CO2, O2, CO, balance, temperature and suction for each gas well at the manifold valves

CH4, CO2, O2, CO, balance, temperature and suction for each manifold outlet

CH4, CO2, O2, CO, balance, temperature, suction and flow for each incoming line at the gas plant

CH4, CO2, O2, CO, balance, temperature, pressure and flow for each outlet line at the gas plant (i.e. the flare and VOC thermal oxidiser)

3.5.11.2 Portable monitoring equipment used to measure gas concentrations shall be as required by Section 6.3.4 of the Employer's Requirements.

3.5.11.3 Initially a low level of suction (<1mBar at the wellhead) shall be applied to the field and a full set of readings taken from each well. The system shall then be balanced as follows:

If CH4 concentration on a well is greater then CO2 initially then the well is anaerobic and shall be dealt with as such. Every effort should be made to keep wells anaerobic but extract the maximum amount of CH4. CH4 levels shall be kept above CO2 levels.

If CO2 is greater than methane concentration initially the well is aerobic. The well shall be balanced to extract the maximum volume of CO2 and CH4 combined.

If CH4 concentration is less than 25% on all the wells on the site every well shall be sent to the VOC thermal oxidiser.

If CH4 concentration is above 25% in some wells consideration shall be given to use the flare for destruction of VOCs and methane. In this instance an assessment shall be made as to which wells to send to the VOC thermal oxidiser and which to the flare. Generally if methane concentration is above 25% it should be sent to the flare.

If the CH4 concentration for the VOC thermal oxidiser is above 4% then air will be bled into the system. This shall be done by opening the air bleed valve on the gas plant to give methane quality between 1 and 4%. It will be necessary to increase or decrease the overall suction at the gas plant to keep the suction on the field constant.

3.5.11.3 A surface gas survey shall be carried out in the area of the Phase 1 gas collection system on a weekly basis from the commencement of the works until the gas extraction system is commissioned. This survey is to determine levels of gas egress from the Phase 1 area of the site and will be undertaken using the methodology described in Section 6.3 of the Employer's Requirements. Gas samples shall be taken using a stainless steel probe from ground level. This shall not penetrate the ground but measure gas levels being emitted from the ground surface. CH4, CO2, O2, CO, balance and temperature shall be recorded at each location on a nominal 20 m triangular grid. The grid shall be offset compared to the well locations to prevent samples being taken next to any of the wells. In addition locations of possible surface venting of landfill or combustion gases shall be tested (e.g. cracks and fissures) and recorded as above.

3.5.11.4 Because of the complex iterative nature of balancing the extraction system for the trial, operatives shall have suitable experience and knowledge of monitoring and balancing landfill gas extraction systems and the use of the specialist equipment necessary for taking readings. CVs of the personnel to be used shall be submitted to the Engineer prior to commencement of the trial. In addition preliminary results shall be supplied to the Engineer on a weekly basis to allow a review of the balancing.

3.5.11.5 The trial shall last for an aggregated period of two months of operation. Upon completion of the trial four 6" sections of collection pipe shall be removed and delivered to the Engineer for analysis. Upon analysis of the extraction data and pipe samples the emissions control system may be modified.