Government of Malta
Ministry for Resources and Infrastructure

Development of Rehabilitation Strategies Magħtab, Qortin and Wied Fulija Landfills

Stage II Report

Final

February 2003

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EXECUTIVE SUMMARY

Site investigations as part of the contract awarded to Scott Wilson in May 2002 to develop strategies for the rehabilitation of three landfills in Malta and Gozo (Magħtab, Qortin and Wied Fulija) have recently been completed. The works form the second stage of a four-phase programme.

Purpose

The ground investigation focussed on identifying the hazards to human health and the environment presented by each of the sites. The principal concerns were:

- the extent of subterranean combustion;
- the polluting potential of the waste materials;
- aerial emissions;
- the potential for landfill gas generation and off-site migration;
- the quantity and potential rates of leachate generation, leachate quality and potential for pollution of surface water, groundwater and the near shore marine environment; and
- the potential for ground instability.

The field surveys and associated laboratory testing were carried out by the specialist local sub-contractor Harrison Group (Malta) Ltd and its associated local partner Malta National Laboratories together with the UK laboratory Alcontrol Geochem under the direction of Scott Wilson personnel between July 2002 and January 2003.

Scope of Work Undertaken and Preliminary Findings

Identification of subterranean combustion

All three sites were surveyed from the air using infrared thermal imaging to identify areas of heating. This was followed up by ground based survey work including measurements of temperatures over the surface of each site. Heating within the landfills was measured using a sensor lowered into boreholes drilled into the waste.

Evidence of heating as a result of current or historic waste combustion was observed at all three sites. Heating appeared to be restricted to very localised areas at Qortin and the eastern part Wied Fulija. More extensive heating was observed in the western part of Wied Fulija and across much of Magħtab where significant heating probably indicative of widespread subterranean combustion was observed, particularly in the northern and western parts of the landfill.

Hazardous Waste Materials

Sampling of waste materials, inspection of wastes encountered during drilling and knowledge of waste inputs to the sites indicates that potentially hazardous materials are present within each landfill. Contaminants identified in waste materials principally comprise toxic metals and a range of volatile and semi-volatile organic compounds. Combustion processes have generated other hazardous materials; wider ranges of organic compounds (including dioxins) were found to be elevated in areas where combustion gases were venting to the ground surface.

Aerial Emissions

Aerial emissions from each of the landfills have been quantified by:

- measuring the concentrations of gases emanating from, and within, each landfill;
- sampling of dust and gases from each site;
- sampling and analysis of soil in adjacent areas to assess whether aerially transported contaminants from each site may have been deposited on the surrounding land and in the wider Maltese environment.

Gases associated with combustion were identified in areas of heating and the concentrations identified generally related to the degree of heating observed.

The potential for emissions of potentially hazardous dusts from the sites (particularly Magħtab) is limited by the practice of rapid covering of wastes with inert fill. However, surface sampling has identified potential contaminants on the surface of the landfills where waste is exposed and where subterranean combustion gases vent to the surface (principally on the top, northern and western sides of the landfill). However, monitoring of ambient air quality at Magħtab landfill has identified elevated concentrations of particulates, dioxins, polyaromatic hydrocarbons and toxic metals at the landfill.

Analysis of off-site soils immediately surrounding the sites has not identified significantly elevated concentrations of contaminants (including dioxins). The presence of low concentrations of dioxins and phenols in soils adjacent to the landfills are most likely to be related to current and historic waste combustion at each site. Elevated concentrations of lead on surrounding land may be related to hunting or vehicular emissions rather than the landfill. Sampling of marine sediments near to Magħtab or Qortin did not indicate any significant elevations of contaminants in the environment marine attributable to either landfill.

Landfill Gas

Measurement of landfill gas concentrations and generation rates in boreholes within the waste together with the results of the surface monitoring suggest methane generation rates are low at Magħtab and Wied Fulija probably as a result of the aerobic conditions and extensive subterranean combustion that is occurring. At Qortin, where combustion is much less significant, generation of landfill gases (including methane) at concentrations more typical of municipal landfills is occurring. Surface monitoring has shown that these gases currently readily vent to the atmosphere at all sites.

Leachate Generation and Potential for Pollution of the Water Environment

Leachate was not identified in any of the landfills during the investigations but a sample of liquor produced from condensate within a borehole was taken from Magħtab for analysis. The results of this analysis indicate the presence of elevated concentrations of metals, ammonia and semi-volatile organic compounds within (water) vapour inside Magħtab.. The potential impact of each landfill on the local water environment at the time of the investigation was characterised by:

- monitoring groundwater quality in newly installed boreholes around Magħtab and Qortin and from existing boreholes at Wied Fulija;
- monitoring groundwater quality in existing agricultural wells and boreholes at Magħtab and Qortin;
- monitoring sea water quality at all three sites;
- monitoring the quality of the public groundwater supply nearest to Magħtab.

Water quality in the vicinity of each landfill is generally found to be similar to elsewhere in the Maltese Islands particularly with respect to heavy metals. However, there are indications that concentrations of lead and cadmium in groundwater near Magħtab may be influenced by the landfill. Traces of organic contaminants and organotin likely to have originated from the landfill were identified in a number of locations near Magħtab but not in significant concentrations when compared to available standards indicating acceptable quality. Traces of organic compounds in groundwater were also noted near Wied Fulija.

There was, however, evidence of general bacteriological contamination of groundwater, which could relate to either to the presence of the landfill or local agricultural practices (such as the use of animal slurry as fertiliser).

It should be noted that the very limited impacts identified in this study could reflect monitoring during the summer months following a prolonged period of dry weather in Malta. It is possible that impacts will be greater during or after periods of heavier rainfall. Determination of whether this is the case will require additional monitoring over a period of time covering a range of climatic conditions.

Potential for Ground Instability

An inspection of each of the waste mounds focussing on identifying areas of subsurface combustion and areas of instability or potential instability was undertaken. In addition, particularly at Qortin but also at the other sites an inspection of the underlying strata was conducted.

There is evidence of continued settlement of each of the waste mounds. This occurs generally as a result of self-weight consolidation and localised differential surface movements caused by waste collapsing into voids left by combusted material. Side slopes are generally steep and some spalling of debris down these surfaces into adjacent land occurs although generally waste slopes are considered to be reasonably stable.

At Qortin and Wied Fulija the waste masses have encroached of to within a few metres of the crests of precipitous cliffs. There is historical evidence of failure of sections of these cliffs and such occurrences will inevitably occur in the future (although the timescale over which such events will occur is unknown at present). Should localised cliff failure occur the potential exists for waste materials to be deposited onto the foreshore and possibly into the sea.

The Next Steps

The next stage of the project is to take the results of the investigations in combination with other available information to form the basis of formal risk assessments.

These risk assessments will adopt the *source-pathway-receptor* approach to identify the likely impacts of the identified hazards on a series of potential receptors. The conceptual ground models developed and refined by the results of the site investigation will identify the nature and general magnitude of the hazards presented by each site. The quantification of the risks associated with the hazards (*sources*) will concentrate on the following key areas:

- combustion and associated aerial emissions and their likely impact on the environment (including local ecology), public health and potential redevelopment options;
- ground stability, particularly with respect to potential catastrophic collapse of slopes;
- leachate escape into groundwater and the sea and its potential impact on water quality, the marine environment and the local ecology;
- gas migration and its potential to build up in surrounding areas to dangerous levels or to adversely impact on the proposed after-uses.

Likely *pathways* by which potential human, ecological and environmental receptors may be impacted will be defined. These may principally be related to aerial dispersion of contaminants related to combustion and disturbance of the site surface but also through migration of groundwater and landfill gas.

Receptors will be identified are likely to include nearby dwellings, local water resources, flora and fauna and also less tangible issues such as tourism in the vicinity of the sites.

Based on the results of the risk assessments and consultation with local stakeholders appropriate rehabilitation strategies for each of the three sites will be devised.

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1. INTRODUCTION

1.1 Context

The solid waste disposal sites at Magħtab, Qortin and Wied Fulija were developed at a time when the full environmental impacts of such operations were not known. As a result, the Maltese Islands are left with a legacy of landfill sites that have no systems in place for the proper control of landfill leachate or gas and the presence of fires is common. The Ministry for Resources and Infrastructure has expressed concern over the potential human health and environmental impacts of these sites and the need to raise the environmental standards associated with the management of wastes in Malta. Movement has been made towards this with the implementation of *A Solid Waste Management Strategy for the Maltese Islands* (October 2001) and the imminent letting of contracts for the appropriate management of wastes. This current project is being executed in line with this overall strategy and involves the rehabilitation of the three largest landfills.

As a country due to accede to the European Union, the Republic of Malta is obliged to implement the full requirements of EU legislation. The relevant European legislation has been considered and, where relevant, will be applied to this project. The Environmental Protection Act 2001 (and associated legislation), where appropriate, will be utilised in the development of strategies for the rehabilitation of the landfills.

In addition to European and national legislation, national policies have been consulted and will be taken into account. In particular, the *Structure Plan (1990-2010) for the Maltese Islands*, *Space for Waste – The Waste Management Subject Plan (2001)* and discussions with the Malta Environment and Planning Authority (MEPA) will be considered for the after-use and development options for all three sites.

1.2 Project Objectives

The overall objective of this project is to contribute to the implementation of the rehabilitation proposals specified in *A Solid Waste Management Strategy for the Maltese Islands*. Principally, these are to close down the Magħtab and Qortin landfill sites and bring these sites, together with the closed landfill at Wied Fulija, back into beneficial use.

The Ministry for Resources and Infrastructure has commissioned Scott Wilson to develop environmentally sound restoration strategies for three landfill sites. This is a four-stage project beginning with an investigation of the sites through to production of designs and documentation to implement the rehabilitation strategies. The ground investigation works described in this report form the second stage of this programme, which comprises:

Stage I: Consultation, data collation and review;

Stage II: Ground investigation;

Stage III: Risk assessments;

Stage IV: Design and specification of rehabilitation strategies.

This report outlines the rationale behind the investigation, describes the methods used, and provides summaries of the results of the investigations and preliminary assessments of the significance of these results. Recommendations for the risk assessments to be undertaken in Stage III of the project are also made. The full results of the investigations are appended to the report.

1.3 Outline Methodology

The ground investigation works have focussed on identifying the hazards to human health and the environment presented by each of the sites. The principal concerns identified in the Stage I Report (July 2002) were:

- the extent of subterranean combustion;
- the polluting potential of the waste materials;
- aerial emissions;
- the potential for landfill gas generation and off-site migration;
- the quantity and potential rates of leachate generation, leachate quality and potential for pollution of surface water, groundwater and the near shore marine environment; and
- the potential for ground instability.

The field surveys and associated laboratory testing were carried out by the specialist local sub-contractor Harrison Group (Malta) Ltd and its associated local partner Malta National Laboratories together with the UK laboratory Alcontrol Geochem under the direction of Scott Wilson personnel between July 2002 and January 2003.

Details of the techniques adopted are listed below and there is a summary for each site detailed in the subsequent sections. The locations of all sampling points were identified using a GPS (eTrex Vista) accurate to <5 m.

2. GENERAL SCOPE OF INVESTIGATION WORKS

2.1 Thermal imaging

Aerial thermal imaging using a thermal camera coupled with a digital video camera was undertaken using a light aircraft to identify general areas of heating on each landfill. This was supplemented with 'walkover' imaging surveys using the thermal camera to obtain specific measurements of surface temperature (Plate 2.1). The aerial thermal and visual imaging of each landfill is reproduced as a digital video file (MPEG format) on the appended CD-ROM. The results from the thermal survey were verified by physical measurement of surface temperatures using a hand held temperature probe on a notional 50 m grid pattern across each site. In addition temperature measurements were recorded at 1m depth intervals in the boreholes drilled through the waste mass at each site (see below).

2.2 Drilling

Landfill Monitoring Wells

Holes were drilled within the waste mass at each site with the objectives of:

- identifying the thickness of wastes present and, if possible, their composition;
- monitoring concentrations and flow rates of hazardous and toxic gases;
- monitoring leachate levels and composition (if present); and
- measuring vertical variations in temperature within the waste mass.

The holes were drilled using a rotary drilling rig at a variety of diameters using fresh water flush and with temporary steel casing to keep the hole open during drilling (Plate 2.2). Galvanised steel monitoring wells with gravel pack and bentonite seal were installed in each hole. Full details of each of the monitoring wells are summarised in Sections 4-6.

Off-site Monitoring Boreholes

Off-site monitoring boreholes were drilled in natural bedrock strata adjacent to the waste masses at Magħtab and Qortin with the objective of monitoring groundwater level and composition. Existing monitoring wells at Wied Fulija were used for the same purpose.

The holes were drilled using a rotary drilling rig at a variety of diameters using fresh water flush. No temporary casing was required. PVC monitoring wells with gravel pack and bentonite seal were installed in each hole. Full details of each of the monitoring wells are summarised in Sections 4-6.

2.3 Monitoring

Landfill Gases

Landfill gases were monitored in monitoring wells within the wastes by direct connection to a gas tap mounted on the monitoring well. Gases emitted from the landfill surface were also monitored on a notional 50 m grid over the surface of each site using a hollow stainless steel probe (Plate 2.3).

The following landfill gases were monitored using a GA2000 portable landfill gas analyser:

- methane
- carbon monoxide
- carbon dioxide
- hydrogen sulphide

Measurements of gas flow rate, atmospheric and differential pressure were also taken in monitoring wells.

Concentrations of total volatile organic compound (VOC) concentrations were measured using a MiniRAE 2000 Portable VOC Monitor.

A GA94 analyser was used to monitor for sulphur dioxide and nitrogen oxides.

Air

Monitoring of concentrations of total suspended particulates (TSP) was undertaken using Andersen high volume particulate samplers at two locations on Magħtab. The samplers were run continuously for two weeks in each location with filters changed daily to enable daily concentrations of TSP to be measured.

2.4 Sampling

Soil and Waste

Samples of surface soil (to 5 cm depth) were taken from around each of the three sites using a stainless steel trowel and stored in appropriate sample containers (Table 2.1 and Plate 2.4). Sampling equipment was cleaned with hexane between samples. Representative samples of waste and cover materials on the surfaces of each site were taken using the same method.

Marine Sediment

Marine sediments were sampled along the coast near Magħtab and Qortin. Samples were taken using brown borosilicate glass jars in accessible locations (maximum water depth 0.5m). No suitably accessible sediment was identified at Wied Fulija due to water depth.

Marine Water

Marine water samples were taken at each of the sites. At Magħtab and Qortin samples were taken from accessible coastal locations (maximum water depth 0.5m). At Wied Fulija a sample was taken from a boat due to the depth of water. Samples were stored and preserved using the bottles and preservatives listed in Table 2.1.

Table 2.1: Sample Storage and Preservation

Determinand	*Sample Bottle*	*Preservative*
Soil		
All soil analysis except volatile organics	1 kg plastic snap-lid tubs	Non required
Volatile organic compounds by GC-MS	40 ml glass volatile vials	Non required
Marine Sediment		
All analyses	1 kg brown borosilicate glass jars	Non required
Water		
Organics	1 litre glass	Non required
Inorganics	1 litre plastic	Non required
Cyanides	250 ml plastic	NaOH
Sulphide	250 ml plastic	Zinc Acetate
Ammoniacal Nitrogen	250 ml plastic	H_2SO_4
Phenol (total)	250 ml plastic	H_2SO_4
Metals (field filtered)	250 ml plastic	HNO_3
Volatile organic compounds by GC-MS	40 ml glass volatile vial	Non required
BOD	1 l sterilised plastic	Non required
Other bacteriological parameters	250 ml sterilised glass for each deteminand	Non required

Groundwater

Groundwater samples were taken from:

- newly installed monitoring boreholes at Magħtab and Qortin;
- existing monitoring boreholes at Wied Fulija;
- nearby agricultural abstractions at Magħtab and Qortin;

- a spring near Qortin; and
- the public water supply pumping station near Magħtab (Wied il-Għasel).

Samples from newly installed monitoring boreholes were taken using a Grundfoss MP1 submersible pump (Plate 2.5). Due to their large diameter and great depth existing boreholes at Wied Fulija could not be sampled using the Grundfoss pump. Instead a high capacity submersible pump (Caprari EFOR XGS 26, maximum flow rate 15,000 l/hr) was used. New and existing boreholes were purged for three well volumes before sampling.

Samples from existing agricultural abstractions were sampled using existing pumping equipment (electrical powered) where present (Plate 2.6). In two locations, it was necessary to lower a stainless steel bucket into the well to sample. The public water supply at Wied-il-Għasel was sampled from the dedicated sampling point within the pumping station. Samples were taken directly from the spring at Qortin.

Samples taken were stored in dedicated sample bottles with preservatives as set out in Table 2.1. Samples for metals analysis were filtered on-site using a 45µm in-line filter before preservation. Field measurements were made of pH and electrical conductivity.

Landfill Gases

Landfill gases from monitoring wells within wastes and from selected locations of surface gas venting were sampled with Gresham tubes (Plate 2.7). Each Gresham tube was purged three-times with borehole gas before the sample was taken.

Leachate

No discrete leachate was identified in any of the monitoring wells at any site (see Sections 4-6). However, very hot and moist conditions were identified at Magħtab and the resulting condensate was found to collect within the basal sump of some of the monitoring wells installed. Later wells were modified to include an enlarged sump to allow capture of condensate for sampling purposes. Condensate was sampled using a stainless steel bailer.

Air

The high volume samplers at Magħtab allowed sampling of particulate matter captured on the filters for subsequent chemical analysis (Plate 2.8). The high volume samplers were also fitted with a polyurethane foam plug that allowed sampling of gaseous semi-volatile organic compounds, in particular polyaromatic hydrocarbons (PAHs) and dioxins. These were changed weekly during the monitoring.

2.5 Laboratory testing

With the exception of bacteriological analysis in water sampling all laboratory testing was carried out in the UK by Alcontrol Geochem in Chester, a UKAS accredited laboratory. Samples were air freighted to the UK in cool boxes containing frozen ice packs. Water samples were stored in a refrigerator in Malta prior to dispatch. Samples for bacteriological analysis were analysed by Malta National Laboratories in Valetta.

Soil Samples

Off-site soil samples were analysed for the following determinands:

- pH, arsenic, cadmium, chromium, lead, mercury, selenium, copper, nickel, zinc, boron, total PAHs, total phenols, free and complex cyanides, thiocyanate, sulphate, sulphide and sulphur.

- total organic carbon

- Dioxins (PCDD/Fs as both speciated and EC/NATO/CCMS/I-TEQ concentrations)

Waste Samples

Waste samples were analysed for the following determinands:

- pH, arsenic, cadmium, chromium, lead, mercury, selenium, copper, nickel, zinc, boron, total PAHs, total phenols, free and complex cyanides, thiocyanate, sulphate, sulphide and sulphur.

- total organic carbon

- asbestos

- semi-volatile organic compounds by GC-MS

- volatile organic compounds by GC-MS

- dioxins (PCDD/Fs as both speciated and EC/NATO/CCMS/I-TEQ concentrations) in selected samples only

- organotin (tri-butyl and tri-phenyl tin) in selected samples only

Marine Sediment Samples

Marine sediment samples were analysed for the following suite of determinands:

- pH, arsenic, cadmium, chromium, lead, mercury, selenium, copper, nickel, zinc, boron, total PAHs, total phenols, free and complex cyanides, thiocyanate, sulphate, sulphide and sulphur.

- semi-volatile organic compounds (SVOCs) by GC-MS in Magħtab samples only

- volatile organic compounds (VOCs) by GC-MS in Magħtab samples only

- dioxins (PCDD/Fs as both speciated and EC/NATO/CCMS/I-TEQ concentrations) in Magħtab samples only

- organotin (tri-butyl and tri-phenyl tin) in Magħtab samples only.

Groundwater and Sea Water

Groundwater and seawater samples were analysed for the following determinands:

- pH
- Electrical conductivity
- Total Dissolved Solids
- Total Suspended Solids
- Chemical Oxygen Demand
- Bacteriological Testing (Biochemical Oxygen Demand, *Salmonella, E-Coli, Listeria monocytogenes, Candida albicans, and Bacillus stearothermophilus*)
- Phenols
- Total Kjeldahl Nitrogen
- Ammoniacal Nitrogen
- Metals (As, Cd, Cr, Hg, Pb, Se, Cu, Ni, Zn, B)*
- Major Ions (Na^+, K^+, Ca^{2+}, Mg^{2+}, Cl^- SO_4^{2-}, NO_3^-,HCO_3^-)
- Sulphide
- VOCs
- SVOCs (including PAHs)

* saline samples required specific low-level analysis to be undertaken for metals.

Particulate Matter in Air

Particulate matter retained on the High Volume Sampler filters were analysed for:

- PAHs
- Toxic Metals (As, Cd, Co, Cr, Cu, Hg, Mn, Pb, Ni, Sb, Se, Sn, Th, V)

Gases in Ambient Air

Polyurethane foam plugs from the high volume samplers at Magħtab were analysed for:

- dioxins (PCDD/Fs as both speciated and EC/NATO/CCMS/I-TEQ concentrations) in Magħtab samples only

- PAHs

Landfill Gases

Gresham tube samples of gas emissions on the landfill surfaces and from monitoring boreholes in waste were analysed for speciated volatile organic compounds by GC-MS.

3. MAGĦTAB

3.1 Scope of Works

3.1.1 Thermal Survey

Thermal Imaging

The aerial thermal imaging survey was undertaken at dawn on 16 July 2002 with follow-up ground surveys at dawn on 17 and 18 July 2002.

Surface Temperature

Surface temperatures were measured at 139 locations over the landfill surface (top and benches) using a digital thermometer and surface probe inserted into the ground (Figure 3.1). Particular attention was paid to areas of current or former combustion where hot gases were being emitted from cracks or vents.

Borehole Temperature

Temperature logs were recorded in all five monitoring wells within the wastes (see below) using a combined dip-meter – digital thermometer. Readings of borehole air temperature were taken at 1m intervals from the top of each instrument to the base.

3.1.2 Boreholes

Six boreholes were drilled through the in-situ Lower Coralline Limestone strata (locally overlain by Lower Globigerina Limestone) around the periphery of the waste (Figure 3.2 and Table 3.1). Each hole was completed with a perforated well pipe to enable monitoring of groundwater quality and levels. Drilling records are included in Appendix A.

Table 3.1: Summary of Peripheral Monitoring Boreholes

Hole	*Depth*	*Estimated Ground Elevation (mASL)*	*Comments*
MBH1	40	22	No drilling difficulties. Slotted PVC standpipe installed.
MBH2	71	50	No drilling difficulties. Slotted PVC standpipe installed.
MBH3	50	41	No drilling difficulties. Slotted PVC standpipe installed.
MBH4	15	3	No drilling difficulties. Slotted PVC standpipe installed.
MBH5	20	3	No drilling difficulties. Slotted PVC standpipe installed.
MBH6	57	41	No drilling difficulties. Slotted PVC standpipe installed.

A further five holes were drilled through the waste mound to varying depths (Figure 3.2 and). Perforated galvanised steel well casing was installed to the full depth of each hole to enable monitoring of leachate, landfill gases and temperature. Drilling records are included in Appendix A.

Table 3.2: Summary of Landfill Monitoring Wells.

Hole	*Depth*	*Comments*
MW1	45	Driller recorded difficult ground conditions in waste at 12m, 16m, 18m, 24-26m, 36m (probable top of bedrock). Hole dry. Elevated H2S concentrations recorded on surface from 18 m to base (peak concentrations > 500 ppm). Casing required sealing with bentonite to reduce emissions.
MW2	18	Driller recorded difficult ground conditions in waste at 5m, 9m, 15m and 18m including difficult penetration of casing and hole collapse. Black slurry noted in 1% returns at 16m depth. Hole terminated at 18 m due to difficulty in making progress. Hole dry. Elevated H2S recorded recorded at shallow depths (>9m, peak concentration 67 ppm).
MW3	41	High torque with bit damage occurring. Driller records borehole as being very hot with evidence of burning.
MW4	57	No difficulties recorded during drilling. Well casing too hot to handle during installation
MW5	51	Driller records borehole burning with very hot conditions

3.1.3 Monitoring

Landfill Gases

Landfill Gas Monitoring Results from monitoring wells on the Magħtab site are summarised in Table 3.3

Table 3.3: Summary of Landfill Gas Monitoring Results*

	Date	*LEL (%)*	*CH4 (%)*	*Peak CH4 (%)*	*CO2 (%)*	*O2 (%)*	*CO (ppm)*	*H2S (ppm)*	*VOCs (ppm)*	*Flow Rate (l/hr)*	*Atmospheric Pressure (mb)*
MW1	09/09/2002	10	0.5	0.5	1.1	16.3	35	2	nd	nd	nd
MW1	23/09/2002	nd	0	0	1.8	16.2	332	0	nd	nd	997
MW1	02/10/2002	0	0.0	0.1	1.1	17.3	95	0	0	0.3	1014
MW2	23/09/2002	nd	1.4	1.4	9.8	7.0	450	0	nd	nd	997
MW2	02/10/2002	36	1.8	1.8	10.2	7	436	0	0	1.8	1014
MW3	15/10/2002	100+	11.6	11.6	19.7	4.3	nd	nd	nd	0.9	1009
MW4	03/10/2002	5	0.3	0.3	7.2	12.2	1111	0	0	0.2	1014
MW5	20/09/2002	nd	1.2	1.2	15.6	3.9	1210	2	nd	nd	996
MW5	02/10/2002	19	0.9	1.0	13.9	4.7	1086	0	0	0	1015

*SOx and NOx not detected.

Surface Gas Monitoring

Concentrations of landfill gases were measured at 139 locations over the landfill surface (top and benches) using a surface probe (Table 3.4 and Figure 3.1). Particular attention was paid to areas of current or former combustion where hot gases were being emitted from cracks or vents. The results of the gas monitoring are summarised in and presented in full in Appendix C.

Table 3.4: Magħtab Surface Gas Monitoring

	Minimum	*Maximum*
Methane %	0	6.8
CO2 %	0	22.1
O2 %	1.7	24
CO ppm	7	>2999
H_2S ppm	0	28
VOCs ppm	0	5900

Air

Monitoring of particulate dust concentrations was made at two locations on Magħtab using high-volume samplers (MHVS1 and 2). The sampling locations are shown on Figure 3.5.

3.1.4 Field Sampling

Surface Soil

Surface soil samples were taken at 15 off-site locations (MSS 1-15) immediately adjacent to the waste mass (Figure 3.3). An additional 12 samples were taken from further away from Magħtab (Figure 3.4):

- 6 approximately 0.5 – 1 km from the site (MSS 16-21); and
- 6 approximately 2 km from the site (MSS 22-27).

These samples were taken with the objective of determining whether off-site contaminant migration (principally by aerial emissions) was impacting on soil quality in the area around Magħtab.

An additional reference sample (MSS 28) was taken from central Malta between Zebbuġ and Rabat (Figure 3.4). This location, some 7 km to the south or the landfill is cross gradient from the prevailing principal wind direction axis (NW-SE for the *Majjistral* and *Xlokk* winds). This sample together with the four off-site samples also located to the south or south-west of the landfill (MSS18, 19, 24 and 25), was chosen as potentially representative of background conditions in soil in central Malta.

Waste Samples

Representative samples of waste materials exposed on the surface of Magħtab landfill were sampled in 25 locations (Figure 3.3). The waste types sampled are summarised in Table 3.5. No obvious industrial or drummed wastes were visible on the landfill at the time of sampling. There were no returns from drilling within the waste mass that were suitable for sampling.

Marine Sediment

Marine sediment samples were taken in three locations (Figure 3.4):

- bay to south of Għallis rocks (MMS1);
- Qalet Marku Bay (MMS2); and
- Baħar iċ-Ċagħaq Bay (MMS3).

MMS1, MMS2 and MMS3 correspond to marine sediment sampling locations 3, 2 and 1 in Saliba (1999) respectively.

Marine Water

A marine water sample, MMW1, was taken from Qalet Marku Bay (Figure 3.4).

Groundwater

Groundwater was sampled from the peripheral monitoring holes MBH1-6 (Figure 3.2) and from the following boreholes (Figure 3.4):

- Agricultural Abstraction (Water Services Corporation Registration No. 2026);
- Agricultural Abstraction (Water Services Corporation Registration No. 2027);
- Irrigation Abstraction (Water Services Corporation Registration No. 3308); and
- Wied il-Għasel Public Water Supply Pumping Station.

These locations were sampled with the co-operation and assistance of the owners, the Water Services Corporation (Tony Mallia) and Malta Resources Authority (Dr John Mangion).

Saliba (1999) sampled from locations 2026 and 2027 whilst location 3308 is close to the location of well 2041 sampled by Saliba. Other licensed abstractions sampled by Saliba were visited but access was not possible as the licence holders were not present.

[1] *Environmental Impact Assessment of the Magħtab Landfill on the Marine Environment*, Mario Saliba (1999), BSc. Dissertation, University of Malta.

Table 3.5: Summary of Surface Waste Samples

Sample ID	*Description*
MSW01	Dark grey granular cover materials with waste (ash? and crushed limestone)
MSW02	Decomposing domestic waste
MSW03	Black/grey organic sludge with strong odour
MSW04	grey/dark brown sludge with strong odour
MSW05	Light grey surface cover material
MSW06	Dark brown vent condensate
MSW07	Surface cover (crushed limestone)
MSW08	Surface cover from bulldozer access track
MSW09	Pale blue dried slurry/filter cake
MSW10	Daily cover with domestic waste
MSW11	Daily cover with domestic waste
MSW12	Daily cover (crushed limestone)
MSW13	Grey silt (dried slurry)
MSW14	Recently burnt waste
MSW15	Surface staining of cover associated with burning
MSW16	Pale grey dried sludge
MSW17	Pale grey/pink sludge from lower slurry lagoon.
MSW18	Pink ochre silt
MSW19	Black sooty material in crushed drum
MSW20	Old ashy degraded waste and plastic
MSW21	Crushed limestone dust from main haul road
MSW22	Old degraded waste
MSW23	Stained and burnt cover materials
MSW24	Burnt waste
MSW25	Burnt domestic waste

Landfill Gases

Samples of landfill gas were taken using Gresham Tubes from the monitoring wells MMW1-5. In addition, 7 samples were taken from locations of surface venting of gases (MGS 1-7, Figure 3.5).

Leachate

As discussed in Section 2, no discrete bodies of leachate were identified within the landfill. However, water was found to be condensing within the casing of the boreholes and collecting in the small basal sumps. The last two boreholes to be drilled (MW3 and MW4) were modified to include a 2 m long sump at the base of the well to allow collection of this condensate for analysis. A volume of condensate sufficiently large to allow sampling was only collected in the sump in MW3.

Air

Samples of particulate matter were collected on the filter of the high volume sampler locations MHVS 1 and MHVS2 (Figure 3.5) and samples of semi-volatile gaseous organic pollutants (dioxins and PAHs) were collected on a polyurethane foam plug in each HVS.

3.1.5 Laboratory Testing

Testing schedules for all soil, water, gas (Gresham) and air monitoring samples are presented in Appendix B with results contained in Appendices C-G respectively.

3.1.6 Visual Inspections

An inspection of the waste mound focussing on identifying areas of combustion, evidence of subsurface combustion and areas of instability or potential instability was undertaken.

3.1.7 Ecology

Information on the ecology of the area surrounding the landfill site was gathered using a desk study supplemented by a walkover survey by local ecologists in January 2003. The aim of the survey was to determine the broad vegetation communities, to highlight any communities or species of particular value, e.g. endemic or red data book species (Schembri and Sultana, 1989) or Areas of Ecological Importance (Malta Structure Plan, 1992), and to obtain information on any impacts that the landfill may be having on the ecology of the surrounding area. As with most of the Maltese Islands, much of the habitat has undergone intense anthropogenic influence, and as such there is little of the natural climax vegetation in the area.

3.2 Conceptual Site Model

3.2.1 Waste mass

Advancement of the boreholes through the waste proved difficult as a result of the frequent obstructions encountered and the thickness of the wastes. The waste mass was fully penetrated in four of the five holes (all except MW2) and a maximum thickness of 57 m of waste was identified in MW4. This agrees with the thickness estimated from a review of the survey data. It is estimated that the total maximum thickness of the waste is currently (February 2003) up to 70 m thick (allowing for up to four additional layers of waste deposition approximately 3 m thick since the commencement of the investigation in July 2002).

Evidence from the drilling suggests that the wastes are reasonably consistent throughout their depth comprising layers of domestic and industrial waste intermingled with inert excavation, construction and demolition wastes. No evidence of leachate or other bodies of fluid within the waste mass were encountered. However, gas emitted from monitoring boreholes was saturated with hot vapour indicating that wastes at depth are moist.

Apart from end tipping and being dozed into position, the waste has not undergone any significant compaction. This has resulted in a largely open textured waste mound with high porosity and significantly differing local densities; ranging from low values associated with the municipal solid waste up to reasonably high densities in areas where excavation waste has been deposited. This high internal permeability has allowed internal fires to migrate upwards and sideways when fresh combustible waste has been placed over hot areas or zones venting hot combustion gasses from depth. The construction and demolition waste, particularly excavated limestone, is capable of retaining heat for considerable periods and also for acting as conductor of heat away from the original source.

The entire waste mass is likely to be undergoing settlement as a result of self-weight consolidation (with burial i.e. the newer layers of waste compressing the underlying materials). Generally combustible and decomposable wastes have been placed as discrete zones within the waste body surrounded by largely inert material. There is evidence of significant differential surface settlement occurring as a result of waste decomposition and combustion. Numerous tension cracks exist, frequently in areas showing either surface staining or direct evidence of subterranean combustion. Surface depressions from settlement of waste are found associated with areas of combustion (Plate 3.1) and there is anecdotal evidence that some of these surface movements are sudden.

The outer surfaces of the waste mound comprise almost entirely of construction and demolition wastes, largely crushed inert material processed from on site sources (Plates 3.1 - 3.7). Typically local slope angles within these materials are 36^o but range up to around 42^o and locally steeper where there is significant quantities of large demolition wastes. Spalling of waste materials occurs around the entire site as the materials regrade to angles of repose and large items become dislodged from the waste mound.

The site has developed in a series of horizontal layers resulting in 'benching' of the outer slopes. These benches have assisted in maintaining stability of the waste mass essentially as reducing overall slope angles and have acted as catch-berms for spalling waste. Over recent months overfilling of some of the flanks of the waste mound has reduced the width of a number of these benches and reduced their efficiency in maintaining stability and preventing spalling waste tumbling down the entire slopes.

Despite the minor surface movements there is no visual or recorded evidence of significant mass slope movements. The waste mass is sited directly onto competent solid rock, which is horizontally bedded.

3.2.2 Surface Contamination

Samples of exposed waste contained elevated concentrations of the following determinands either when compared to background concentrations in Malta (Table 3.6):

- chromium;
- copper;
- nickel;
- zinc;
- lead;
- cadmium;
- mercury;
- PAHs;
- Total phenols;
- tri-butyl tin (organic sludge)
- 4-methyl phenol (organic sludges);
- phenol (burnt wastes);
- PAHs: naphthalene, phenanthrene, fluoranthene, pyrene, benzo(a)anthracene, chrysene (burnt waste and stained cover);
- 2-methyl-naphthalene (burnt waste); and
- dibenzofuran (burnt waste).

Table 3.6: Comparison of Magħtab Samples with Maltese Background Concentrations (all mg/kg except where noted)

	Maltese Background	*Soils on Adjacent Land*	*Cover on Landfill*	*Waste*
Arsenic	5	2	<1	<1
Chromium	34	37	16	58
Copper	21	9	19	73
Nickel	18	25	16	134
Lead	19	266	38	136
Sulphate	1787	1860	2400	4378
Zinc	83	55	78	212
Acid Soluble Sulphide	<10	<10	11	50
Complex Cyanide	<2.5	<2.5	<2.5	<2.5
Thiocyanate	3	3	5	5
Total PAH	3.8	2.0	48.9	13.5
Total Phenols	<0.01	0.02	26.40	1.09
Cadmium	0.5	0.6	0.5	0.7
Mercury	<0.3	<0.3	0.5	<0.3
Selenium	2.8	<0.5	<0.5	<0.5
Total Organic Matter	2.5	2.5	1.5	6.4
pH Value In Soil	7.8	7.8	7.7	8.1
Total Cyanide	<2.5	<2.5	2.5	2.5
Free Cyanide Soil	<2.5	<2.5	2.5	2.5
Total Dioxin ng/kg I-TEQ	<0.01	13.49	NA	297.8

Areas where combustion gases vent to the ground surface are typically stained brown and a brown-black, viscous condensate is often found immediately surrounding the vent (Plates 3.1 and 3.2). This condensate typically contains a wide range of volatile and semi-volatile organic compounds resulting from combustion of wastes:

- trichlorofluoromethane;
- chloroform;

- benzene, toluene, ethylbenzene and xylene;
- tetrachloroethene;
- alkyl benzenes;
- chlorobenzenes;
- dioxins;
- other unresolved organic compounds.

A number of samples of visually clean cover materials on the landfill (crushed limestone) were analysed. These samples, which are considered representative of the majority of the surface cover at Magħtab, contained similar concentrations of contaminants to those detected in off-site soil samples immediately adjacent to the landfill.

3.2.3 Heating / Combustion

The results of the thermographic imaging coupled with the results of the gas monitoring (most importantly notably the CO measurements) and the surface temperature monitoring indicate that areas of the landfill mass are either currently undergoing combustion or have combusted in the past and remain hot.

Thermographic Imaging

Thermographic images of the landfill indicate four main areas of interest (Figure 3.7):

- northern face (Plate 3.3);
- western side (Plate 3.4);
- landfill top (Plate 3.5); and
- eastern and southern sides (Plates 3.6 and 3.7).

The northern face is characterised by significant evidence of temperatures elevated above background wherever relatively recent waste (characterised by unvegetated cover) is present down to elevations at least 30 m below the top of the landfill (Plate 3.3b). However, there is no evidence of elevated temperatures in the older, vegetated waste at the base of the northern face (Plate 3.3b).

The western side of the landfill is characterised by development of elevated temperatures along the uppermost benches of this area. Wastes lower down show no evidence of heating from a distance (Plate 3.4b). Heating on the eastern and northern faces continue along the benches of the western ridge at Għallis (Plate 3.4c).

The upper surface of the landfill at the time of the survey (since covered with waste) contained isolated hotspots concentrated toward the northern end of the site around the area of then current waste deposition (Plate 3.5b). Heating of the top of the landfill was concentrated in curved zones reflecting the practice of burying municipal solid waste along a curved disposal front (Plate 3.5c) and then covering with inert waste.

The survey identified evidence of localised heating on the eastern (Plate 3.6) and southern (Plate 3.7) sides of the landfill. The thermographic survey suggested that the heat sources on these sides of the landfill were less intense than observed elsewhere.

The following areas showed no evidence of heating in the thermographic survey:

- terraces of old waste in the south of the site (Plate 3.7b);
- terraces of old waste at the base of the north face (Plate 3.3b);
- new arm of inert waste at the eastern extremity of the site (Plate 3.3c); and
- the lower parts of the western (Plate 3.4b) and eastern (Plate 3.6b) faces.

Surface Temperature Measurements

Surface measurements of elevated temperatures where gases and vapours are vent to surface correlated well with the heat distribution measured with the thermographic survey (Figure 3.8); i.e. concentrated on the western and northern faces and the upper surface of the landfill rather than the southern or eastern faces (although local elevations of temperature associated with venting were observed in these areas).

Typically measured temperatures of venting gases were between 60 and 149 °C. Temperatures in this range are usually taken as being indicative of active combustion at depth within the landfill. In localised areas temperatures at the surface exceeded 150°C and a peak value of 331°C was recorded at a combustion vent on the northern part of the upper surface of the landfill.

Temperature Measurements in Boreholes

Temperature measurements with depth in the five boreholes on Magħtab are shown in Figure 3.9. Borehole temperatures in excess of 60°C were observed in all holes and hole temperatures were typically above 75°C. Temperatures in this range are abnormal in municipal solid waste landfills (maximum temperature typically <55°C) and are usually taken as indicating potential combustion nearby. The variations in the temperature distribution within the boreholes that mirror the observed variation during the aerial survey and during the surface temperature monitoring.

The highest temperatures were identified in the two boreholes behind the north face of the landfill. In MW5 temperatures remained elevated (>80°) to bedrock and generally increased with depth (locally exceeding 100°C). In MW4, located above the lobe of hot waste at low levels in the landfill (Plate 3.3b), temperatures were greater than 90°C throughout and locally (particularly toward the base) were in excess of 120°C and peak temperatures of over 180°C were recorded in this borehole.

Lower (but still high) temperatures were observed in those boreholes located in the southern half of the main waste mass. MW1 temperatures were generally around 80°C dropping to below 60°C some 28 m below the ground surface (around 8 m above original ground level. Temperatures in MW3 were elevated to the base of the waste varying from 70 to 90 °C with a number of distinct peaks in temperature. In MW2, which failed to penetrate the full depth of waste, temperatures varied little with depth but were above 80° throughout.

Gas Monitoring

The results of the surface gas monitoring are summarised as dot-density plots on Figures 3.10 - 3.13 for carbon monoxide, carbon dioxide, methane and hydrogen sulphide respectively.

The presence of elevated surface concentrations of carbon monoxide, a gas indicative of the presence of subterranean fires, correlated well with high surface temperature measurements and the areas where the thermographic survey indicated heating. The most highly elevated concentrations (taken to be indicative of very active combustion causing a low oxygen atmosphere) were observed in the uppermost levels of the landfill. Lower, but still very elevated concentrations were generally observed over the upper parts of the western side of the landfill and unvegetated areas of the north face of the landfill. Low concentrations of carbon monoxide were restricted to areas where there was little other evidence of current heating. Measured concentrations of carbon monoxide in boreholes (Table 3.3) were generally lower than observed by the surface monitoring but the measured values were of a similar order of magnitude to nearby surface measurements (implying that near surface conditions may extend to depth within the landfill).

Methane concentrations at the ground surface were generally very low, indicating that the anaerobic waste decomposition processes typical of landfills used for disposal of municipal solid wastes are not occurring. Slightly elevated methane concentrations were only identified in a small number of locations generally on the western side of the landfill. Presumably these were associated with pockets of putrescible waste at shallow depths. More elevated concentrations were observed in the single measurement from MW3 on the eastern side of the landfill.

Carbon dioxide concentrations were generally high in those areas where elevated temperature and carbon monoxide concentrations were also recorded both on the surface and in borehole measurements. These concentrations confirm that aerobic decomposition of waste (including, but not necessarily restricted to, combustion processes) is operating in the landfill. However, in contrast to carbon monoxide concentrations, the most elevated carbon dioxide measurements were restricted to the uppermost areas of the landfill. These are areas where the supply of oxygen to the waste (thus allowing complete combustion) would be greatest.

Elevated concentrations of hydrogen sulphide (over 20 ppm in places) were observed on the south-western corner of the main waste mound. Very elevated concentrations of hydrogen sulphide (peak >500 ppm) were also observed during the drilling of borehole MW1 in this area (although subsequent monitoring for H_2S in the monitoring well installed in MW1 measured low but detectable concentrations). Lower concentrations were also detected during drilling of MW2. The localised distribution of this gas implies that a source of sulphate or sulphur containing wastes is present within the landfill in this area.

Interpretation

The combination of the thermographic survey, surface temperature and gas monitoring has allowed the following conclusions to be drawn regarding the extent of combustion at Magħtab:

- there is extensive evidence of heating at Magħtab;
- whilst most of this evidence relates to the surface of the landfill, evidence from boreholes shows that significant heating extends through the full depth of waste within the landfill in widely separated locations in the main body of waste;
- the most highly elevated temperatures in boreholes were recorded at depth near the base of the north face (MW4) and behind the junction of the western ridge and western side of the landfill at Għallis (MW5);
- the nature of temperature measurements in these boreholes implied the presence of very localised and significant sources of heat at depth, an interpretation supported by the thermographic imaging of the western half of the north face of the landfill (Plate 3.3b);
- the distribution of heating and landfill and combustion gases suggests that actual combustion may be restricted to areas where oxygen supply is more plentiful i.e. to the outer edges and upper surfaces of the landfill in general and where combustible material is present. (This includes material at relatively low elevations on the north face of the landfill where aerial photographic records indicate relatively recent waste deposition.)
- it is likely that the burning waste is being supplied with oxygen from the prevailing wind (NW) through the open textured waste materials and funnelled by the geometry of the site in this direction leading to significantly enhanced combustion (e.g. MW5), it is also possible that air is entering the waste mound through the fractured underlying strata;
- elsewhere, heating of the waste mass may be maintained by an ongoing process of waste smouldering combined with heat retention in the inert limestone waste;
- lower temperatures recorded both on surface and in MW1-3 in the southern half of the main waste mass may reflect either a lack of combustible material in this area (which may have burnt out) or a lack of oxygen or both;

- there is currently insufficient evidence to understand in-detail how the temperature-depth profiles observed in MW4 and 5 relate to those measured in MWs1, 2 and 3, i.e. the extent to which layered heating of wastes at depth extends into the body of the landfill (installation of monitoring boreholes within the centre of the main waste mass being impractical due to operational constraints). However, it is likely that the vigorous, albeit localised, evidence of combustion observed in MW4 and MW5 gradually decreases within the body of the landfill as the deposited waste becomes progressively older to the south and oxygen concentrations decrease.

This interpretation is illustrated diagrammatically in Figures 3.6(a-c) and 3.7.

3.2.4 Air Quality

The high volume sampler was run continuously between the following dates at a constant flow rate of 285 l air/min:

Location MHVS1: from 16 October 2002 to 30 October 2002

Location MHVS2: from 31 October 2002 to 16 November 2002.

The filters were changed daily and weighed to calculate daily average concentrations of total suspended particulates (TSP) in dust. For each location and for each week of operation the dust collected on all except two filters and the gaseous pollutants retained on the polyurethane foam plugs were combined to allow laboratory measurement of concentrations of PAHs and dioxins as weekly average concentrations in air. For each week of operation, two of the filters were analysed for metals to produce average concentrations of metals in air on those days.

The data are presented in Appendix G and summarised in Table 3.7.

Results indicate that dioxins, metals (in particular copper, chromium, mercury, manganese, nickel and lead) and PAHs are emitted from landfill both as dust and vapours. Total suspended particulate concentrations on the landfill site greatly exceed the 50 $\mu g/m^3$ limit for PM_{10} according to EU Directive 1999/30/EC. The significance of these results will be considered in the Stage III risk assessments.

Measurements of volatile organic compounds in Gresham tubes are summarised in Table 3.8 together with associated PID readings. Only a limited number of volatile organic compounds were identified in surface soil gas samples despite elevated concentrations of VOCs indicated by the PID readings (which may be affected either by gas temperature or moisture content). Individual VOCs were not detected in borehole samples.

For reference, the measured concentrations are compared to the UK maximum exposure limits (long term 8 hr TWA) or the occupational exposure limits (long term 8 hr TWA) in UK HSE document EH40/2002. Benzene in soil gas is present consistently in greater concentrations than this guidance value whilst other VOCs detected locally exceed the relevant MEL/OEL.

Table 3.7: Summary of HVS Analyses

Sample	*MHVS1A*	*MHVS1B*	*MHVS2A*	*MHVS2B*
Mean TSP Conc. (µg/m³)	880	539	355	73
Dioxins (fg I-TE/m³)	1392	3046	305	168
PAHs (fg/m³):				
Naphthalene	592	203	152	137
Acenaphthylene	<17	61	122	46
Acenaphthene	<17	<17	<17	<17
Fluorene	818	365	701	959
Phenanthrene	13924	9950	487	4112
Anthracene	1271	1401	183	137
Fluoranthene	11835	16650	1401	426
Pyrene	6962	13605	<17	<17
Benz(a)anthracene	2089	3046	670	168
Chrysene	8006	9950	701	168
Benzo(b/k)fluoranthene	2611	2640	396	<17
Benzo(a)pyrene	2263	2234	<17	<17
Indeno(123cd)pyrene	296	406	61	<17
Dibenzo(ah)anthracene	261	305	<17	<17
Benzo(ghi)perylene	453	589	152	<17
Metals (ng/m³):				
Arsenic	<1	1	<1	<1
Cadmium	4	1	<1	<1
Cobalt	<1	<1	<1	<1
Chromium	15	27	11	7
Copper	19	26	26	13
Mercury	6	4	<1	<1
Manganese	19	51	4	10
Nickel	10	17	9	10
Lead	50	51	9	4
Antimony	<1	<1	<1	<1
Tin	4	1	<1	<1
Thallium	2	4	<1	<1
Vanadium	6	10	1	2

Table 3.8: Volatile Organic Compound Measurements (ppm)

	Total VOCs (PID)	*trans-1,2-Dichloro-ethene*	*Carbon Disulphide*	*1,1,1-Trichloro-ethane*	*Benzene*	*All other VOCs*
UK MEL /OEL (8 hr TWA)		5	10	100	3	
MW1	0	<10	<10	<10	<10	<10
MW2	0	<10	<10	<10	<10	<10
MW3						
MW4		<10	<10	<10	<10	<10
MW5						
MGS01	369					
MGS02	74					
MGS03	>9999					
MGS04	5772	<10	<10	<10	**25**	<10
MGS05	8571	<10	<10	<10	**40**	<10
MGS06	>9999	<10	<10	<10	**15**	<10
MGS07	8212	**45**	**45**	**870**	**15**	<10

MEL – maximum exposure limit
OEL – Occupational Exposure Limit
TWA – Time Weighted Average
PID – Photoionisation detector

3.2.5 Other Impacts

Soil

Impacts on the soils in the area surrounding Magħtab have been assessed by comparing chemical analyses of soil with measured background concentrations in central Malta (Table 3.6). Soils in the immediate vicinity of Magħtab landfill show concentrations of the following potential contaminants in concentrations exceeding the measured background:

- lead
- total phenols
- dioxins

The fact that concentrations exceed the measured background value does not necessarily mean that the presence of these substances is a risk to human health. The concentrations of phenols detected are very low and unlikely to represent a risk to human health and concentrations of dioxins in soil are not generally elevated when compared to German standards of acceptability in agricultural soils. A full assessment of any risks to human health presented by these substances will be included in Stage III of this project (see Section 7).

Saliba (1999) demonstrated by laboratory simulation that landfilled materials from Magħtab had the potential to generate leachate contaminated with heavy metals. However, monitoring of the quality of intercepted surface run-off from Magħtab by Saliba did not identify the presence of metals in detectable concentrations. It is therefore considered unlikely that surface run-off from Magħtab during rainfall events is a source of the contamination of adjacent land. However, as demonstrated by the results of the HVS monitoring aerial deposition of dust or combustion products may be occurring.

Although it is considered unlikely that dioxins or phenols originate from sources other than the landfill, it should be emphasised that the presence of at least some of the lead in soils near the landfill may not be related to the presence of landfill. Other local potential sources of lead contamination in the environment near Magħtab are:

- lead shot from hunting; and
- aerial deposition of vehicular exhaust emissions from the coast road.

Marine Environment

The presence of Magħtab landfill close to the coastline has prompted concerns that contaminated rainfall run-off from the landfill is entering the marine environment with potentially damaging consequences. In particular, there is anecdotal evidence of surface run-off from the landfill during rainstorms travelling through the site entrance and passing northward down the minor road from Magħtab to the coast at Qalet Marku. This has been observed to cause a plume of sediment in Qalet Marku bay. There are also concerns that once in the marine environment this transported material can migrate along the coastline to accumulate at other locations such as Baħar iċ-Ċagħaq bay. There is also concern that surface run-off from the northern face of the landfill could potentially reach the sea at Għallis Rocks.

Saliba (1999) measured sediment quality along the coast near Magħtab rocks and identified greater than background concentrations of metallic contaminants in sediments at Baħar iċ-Ċagħaq and Għallis Rocks but not at Qalet Marku. Monitoring of heavy metals in sediments at Baħar iċ-Ċagħaq, Qalet Marku and Għallis Rocks during this study (samples MMS3, MMS2 and MMS1 respectively) is compared with the results of metals analyses at the same locations by Saliba in Table 3.9. In addition the Pollution Coordination and Control Unit (PCCU) of MEPA routinely measure metal concentrations in sediments at a large number of locations around the Maltese coastline including Qalet Marku. This data too is summarised in Table 3.8 together with background values for some metallic contaminants for the Mediterranean in general (from Axiak and Sammut, 2002) and Malta in particular (Ramla l-Hamra, Saliba, 1999).

Measured concentrations of metals at Qalet Marku (sample MMS2) were lower than the monitoring of both Saliba and the PCCU (although of a similar order of magnitude). Monitoring by MEPA PCCU indicates that concentrations of metals in sediment at Qalet Marku are generally low by Maltese standards and comparable to Mediterranean

[2] Axiak, V. and Sammut, A. 2002. The Coast and Freshwater Resources. In: *State of the Environment Report for Malta, 2002.* Ministry for Home Affairs and the Environment, August 2002.

background values (Table 5.5 in Axiak and Sammut, 2002). Measured metal concentrations at Baħar iċ-Ċagħaq (MMS3) and Għallis Rocks (MMS1) in this study were lower than observed by Saliba (1999) and similar to those observed at Qalet Marku and Maltese background.

Traces of the organic compounds PAHs and phenols were noted at all three sites monitored and unspecified aromatic organic contaminants were also identified in sediment at Baħar iċ-Ċagħaq. Whilst these could potentially derive from the landfill it might be anticipated that they would be expected to be associated with the presence other organic landfill contaminants such as dioxins, PCBs or organotin (TBT), none of which were detected. Plausible alternative sources for the presence of these species in marine sediments contaminants are:

- run-off from the coast road containing products of particulate vehicular exhaust emissions, leaking oil and diesel fuel and particulates from tyre wear to the sea; and

- marine oil pollution (see Table 5.4 in Axiak and Sammut, 2002).

This study has therefore found no conclusive evidence of any significant impact of landfill-derived contamination on sediment quality. This result is consistent with:

- the fact that Saliba (1999) did not detect metallic contamination in intercepted surface run-off from Magħtab; and

- visual observation indicates that the area of Magħtab that drains to the site entrance, and ultimately Qalet Marku bay, is the southern half of the site which is covered with crushed limestone cover materials which chemical analysis has indicated are clean (exposed waste materials and condensate around combustion vents are generally restricted to the top, northern and western faces of the landfill).

The lack of traces of contamination recorded in sediments at Għallis Rocks may indicate that surface run-off from the north-face of the landfill does not reach the sea in significant quantities, but instead infiltrates either into the waste or exposed bedrock between the landfill and the coast.

The marine water sample taken from Qalet Marku was very similar to that taken near Qortin on Gozo (which would be expected to be relatively clean and representative of Maltese background conditions – see Section 4). However, both the Qalet Marku and Gozo sample both contained slightly elevated concentrations of ammoniacal nitrogen. Whilst this substance can be produced by landfill leachate other potential sources, including sewage discharges to the marine environment or fish farms, may perhaps be more likely given that concentrations of ammoniacal nitrogen in groundwater (see below) are lower than detected in the marine environment.

Table 3.9: Summary of Metal Concentrations in Marine Sediment near Magħtab

	Mediterranean Background[1]	*Baħar iċ-Ċagħaq*		*Qalet Marku*			*Għallis Rocks*		*Ramla L-Hamra*
		Saliba[2]	*Scott Wilson*	*Saliba*	*Scott Wilson*	*MEPA PCCU*[1]	*Saliba*	*Scott Wilson*	*Saliba*
Lead	20	77	9	12	9	18.4	37	4	4.62
Nickel		5	<1	5	1		5	<1	6.71
Copper	5	11	2	3	1	8.6	5	<1	2.7
Chromium		14	5	12	5		11	9	13.92
Manganese		23		20			16		42.68
Zinc	50		9		14	65		25	
Cadmium	0.25	0.018	<0.5	BDL	<0.5	0.4	BDL	<0.5	BDL
Arsenic		3	<1	1	<1		3	<1	8.53

BDL – below detection limit

[1]Axiak and Sammut (2002).

[2] Saliba (1999)

Groundwater

The identification of potentially elevated concentrations of potential contaminants in groundwater were assessed by comparison with EU Council Directive 98/83/EC on the quality of water intended for human consumption. Groundwater quality was also compared with water quality from Wied il-Għasel Public Water Supply pumping station (Figure 3.4), which is assumed to represent background groundwater quality for northern Malta.

The following determinands were found to be elevated above the drinking water standards:

- iron (MBH2);
- chloride (all samples);
- sodium (all samples);
- manganese (MBH5);
- sulphate (all except MBH2, 2027 and Wied il-Għasel);
- ammoniacal nitrogen (MBH5);
- total coliforms (all except Wied il-Għasel);
- E.coli (MBH4 and 2027); and
- Bacillus stearothermophilus (MBH4 and 2027).

Iron and manganese are only slightly elevated and are not likely to be of significance being commonly elevated in Maltese groundwater (Water Services Corporation Annual Report 2001).

The presence of elevated concentrations of sulphate, chloride and sodium reflects the general salinity of Maltese groundwater particularly where affected by up-coning related to abstraction. The lowest salinity samples were identified in the public water supply (which is derived from a different part of the mean-sea level aquifer to the remaining samples), MBH 2 and 2027, both of which are located furthest from the sea and the influence of marine saline intrusion. Chloride concentrations at Wied il-Għasel agree with WSC monitoring data on groundwater quality at this abstraction for the last 5 years reported by Axiak and Sammut (2002)[3] whilst concentrations all other boreholes except MBH 4 and 5 are within the range recorded for other pumping stations in Malta. Chloride concentrations at MBH 4 and 5 are similar to those sea water sampled at Qalet Marku (MMW1). These boreholes are very close to the coast may extend below the base of the freshwater lens - which will be very thin in this area.

[3] Axiak, V. and Sammut, A. 2002. The Coast and Freshwater Resources. In: *State of the Environment Report for Malta, 2002.* Ministry for Home Affairs and the Environment, August 2002.

Concentrations of metals in groundwater are not elevated either when compared to the values in the drinking water directive or concentrations at measured at Wied il-Għasel. However, there is evidence that some of the metals are present in groundwater as a result of the presence of the landfill. For most metallic species monitored concentrations in groundwater and salinity increase toward the coast. This implies that the distributions of the majority of metallic species in groundwater is controlled by the quality of seawater and the degree of mixing with the freshwater lens rather than the landfill.

In contrast, lead and cadmium concentrations, whilst not elevated when compared to the drinking water directive, are present greater concentrations in groundwater than in seawater and may therefore be related to the presence of the landfill. Of particular note is that cadmium concentrations around the landfill are greatest in the direction of Agricultural Abstractions 2026 and 2027. These boreholes also contain trace quantities of organotin (TBT), a species associated with shipyard wastes that is unlikely to be derived from any other source than landfill.

Bacteriological contamination of groundwater was identified near the landfill but not at Wied il-Għasel. There are considered to be two possible sources:

a) the landfill; and

b) animal slurries at nearby animal husbandry units and spread on fields.

Whilst the former cannot be excluded, the presence of very significantly elevated total coliform counts in the two farm abstractions sampled (2026 and 2027) may indicate an agricultural origin for this contamination.

Traces of the following volatile organic compounds were identified in the following off-site monitoring boreholes but not the agricultural abstractions or Wied il-Għasel pumping station:

- 2-methyl-naphthalene (MBH1);
- Naphthalene (MBH5);
- 1,1,1-Trichloroethane (MBH1 and MBH3).

Given the semi-rural location of the landfill, the presence of these determinands in groundwater implies that their source is likely to be within the landfill.

The distribution of traces of contamination in groundwater in a number of directions around the landfill cannot be explained using a simple model of groundwater flow from inland, under the landfill and to the sea. In particular, the presence of chemical species that may derive from the landfill in boreholes 2026 and 2027 implies groundwater flow perpendicular to the regional groundwater flow direction which is likely to be to the north-east in the vicinity of Magħtab (BRGM, 1991). This behaviour is not surprising in a karstic aquifer where groundwater flow will be driven by, but not necessarily parallel to, the regional groundwater flow direction. Instead, local groundwater flow directions will be controlled by the orientation of fractures and solution features.

In addition, the identification of potential contaminants, which may originate from the landfill, in some locations rather than others may reflect localised linkages between areas of waste disposal within the landfill (e.g. areas used for disposal of shipyard wastes) and particular boreholes by individual fractures or solution features in bedrock. In addition, the absence of detected organic contaminants away from the immediate vicinity of the landfill may reflect:

- increased dilution with distance from the landfill;
- naturally occurring biodegradation processes in the aquifer (of naphthalenes for example); or
- downward rather than horizontal migration of contaminants that are denser than water (e.g. trichloroethane).

3.2.6 Ecology

Background information on the ecology of this area is given in the Stage I report (Scott Wilson, July 2002).

Vegetation

A copy of the full ecological survey report is included as Appendix H and the findings are summarised in this section. The surface of the landfill area itself comprises mainly unconsolidated construction waste, with the older portions of infill in the south-east corner of the site covered by vegetation and trees, mainly *Eucalyptus sp.* More recently utilised areas and the edges of the landfill where it meets the natural vegetation are colonised by ruderal species typical of disturbed areas e.g. Cape Sorrel (*Oxalis pes-caprae*) and Crown Daisy (*Chrysanthemum coronarium*), and early succession communities, dominated by Shrub Tobacco (*Nicotiana glauca*) and Rice Grass (*Piptatherum miliaceum*).

Most of the land surrounding the landfill is either active or derelict agricultural land, with scattered clumps of carob trees throughout.Data on the vegetation communities to the west of the landfill were limited, and therefore no comments can me made as to the value or importance of this area. To the north and east of the landfill, karstic (limestone) terrain occurs, comprising mainly rocky steppe communities. The community to the north shows characteristics of a mixed steppe/garrigue vegetation structure.

Derelict agricultural land contains plant communities at different stages of succession, depending on the length of time that it has been uncultivated. Communities indicative of secondary succession at Magħtab are often characterised by Spiny Asparagus (*Asparagus aphyllus*) and Caper (*Capparis orientalis*) mixed with opportunistic, ruderal species such as Cape Sorrel. More recently cultivated areas contain early pioneer species, such as Sticky Fleabane (*Dittrichia viscosa*) and Fennel (*Foeniculum vulgare*), while areas derelict for longer contain late pioneer stage species, including Great Sage (*Phlomis* fruticosa), which has a special mention in the Red Data Book (RDB) (Schembri and Sultana, 1989). Agricultural land is generally considered to be of lower ecological value than other less disturbed communities.

Of the more "natural" vegetation types, rocky steppe makes up a large proportion of the area to the east of the landfill, adjacent to the coast. Steppe communities are widespread in Malta, are diverse and are generally relatively species-rich. It is unclear whether this community is indicative of succession from agricultural communities or regression from maritime garrigue. The rocky steppe community around Magħtab is dominated by characteristic grass species including Hispid Beard Grass (*Hyparrhenia hirta*) and Mediterranean Steppe Grass (*Stipa capensis*). Several ecologically valuable species, noted in the RDB, occur in the rocky steppe around Magħtab, including Carline Thistle (*Carlina involucrata*), Olive-leaved Bindweed (*Convulvulus oleifolius*), Seaside Squill (*Urginea pancration*) and Mediterranean Thyme (*Thymbra capitata*). Some patches of habitat within the rocky steppe are colonised by species characteristic of maquis or garrigue, including Evergreen Honeysuckle (*Lonicera implexa*), Lentisk (*Pistacia lentiscus*) and Common Smilax (*Smilax aspersa*), which may be indicative of succession between the community types.

Small areas of woodland dominated by Carob (*Ceratonia siliqua*) are widespread throughout the area. Some thickets also include secondary dominant species including Prickly Pear (*Opuntia ficus-indica*). The structure of these woodlands and thickets creates a microclimate that supports the development of vegetation characteristic of pseudomaquis. In addition to these woodlands, a single woodland of mixed Tamarisk/Acacia (*Tamarix* spp./*Acacia* spp.) and a mixed Tamarisk/Shrubby Orache (*Atriplex halimus*) hedge occur adjacent to the coastal road to the north-east of the landfill.

To the north of the site is an area of steppe/garrigue, which has been isolated, by the landfill area, from the steppe community already described. The vegetation structure of this area suggests that it may be in transition between the two vegetation types. Dominant species in this area include Mediterranean Thyme, Olive-leaved Germander (*Teucrium fruticans*) and in some areas Sea Squill achieves local dominance. Vegetation characteristic of maquis includes Evergreen Honeysuckle, Lentisk and Rosemary (*Rosmarinus officinalis*), which is a RDB species with restricted distribution in the Maltese Islands. There is a large area dominated by stands of *Agave sp.* which contains a single Aleppo Pine. Another RDB species found in this area is Maltese Dwarf Spurge (*Euphorbia exigua* var. *pycnophylla*).

Within the steppe/garrigue community, there are a number of freshwater pools, which are important because of the rarity of aquatic habitats on the islands and therefore for the highly specialised communities they support. These ecologically significant areas include several RDB species, including Mediterranean Starfruit (*Damasonium bourgaei*) and Southern Water Starwort (*Callitriche truncata*).

In addition to the freshwater rock pools, there is a seasonally flooded marshland on the north eastern coast at Ghadira s-Safra, which is characterised by a generally halophilic terrestrial flora and ephemeral fresh and brackish water species during the wet season. This area is of international importance for its rare and endangered liverwort *Riella helicophylla*, a species listed under Appendix 1 of the Berne Convention as a "species to be strictly protected". *Crypsis aculeata* (a grass species found only at this site) is also a key species here. This area has been described in detail in Lanfranco (1995).

Along the rocky coast, a maritime garrigue/steppe community is dominated by Golden Samphire (*Inula crithmoides*). Halophytic species colonising the area include Shrubby Glasswort (*Arthrocnemum macrostachyum*) and Sea Fennel (*Crithmum maritimum*). Several RDB species are present in the community, including Carline Thistle, Seaside Squill, Mediterranean Thyme, Eastern Phagnalon (*Phagnalon graecum*), Pignatti's Fern Grass (*Desmazeria pignattii*) and Rock Crosswort (*Crucianella rupestris*), all of which have restricted distribution in the Mediterranean. Seaside Lavender (*Limonium virgatum*) is in the RDB for its restricted distribution in the Maltese Islands and at Qalet Marku the endemic Maltese Sea Chamomile (*Anthemis urvilleana*) is also present in the community.

Fauna

The freshwater pools within the steppe/garrigue communities at the north of the area are very important for a number of species of crustaceans. The most abundant species in the water was the cladoceran species *Ceriodaphnia quadrangula* with *Pleuroxus letourneuxi* present in the sediments. Significant species found in the pools include the calanoid copepod *Diaptomus* sp., the first record of this genus from the Maltese Islands and the conchostracan *Cyzicus tetracerus*, another RDB species.

The seasonal coastal wetland at Ghadira s-Safra is also important for its faunal community, supporting locally rare species of crustaceans, including *Triops cancriformis* and *Branchipus visnyai.*

Faunal records for this area are limited, but it should be assumed that there are established faunal communities associated with the garrigue and steppe communities, as well as the woodlots and thickets, which would be impacted by changes to the vegetation community.

The only other community of note is an extensive bed of Lesser Reed (*Phragmites australis*) and stand of Greater Reed (*Arundo donax*), which is expected to support species such as Reed, Sedge and Marsh Warblers (*Acrocephalus* spp.).

Ecological value

Several areas near the landfill site at Magħtab have been recognised as having ecological value in the Malta Structure Plan (1992). The two major designations that are used in the Plan are Area of Ecological Importance (AEI) and Site of Scientific Importance (SSI).

The transitional coastal wetland at Ghadira s-Safra has been recognised as qualifying to be both an AEI and SSI for its rare species. The maritime steppe/garrigue qualifies for AEI status for its freshwater pools, and the presence of garrigue assemblages within the rocky steppe community around the landfill site qualify it as an AEI also.

The coastal fringe at Ghallis qualifies to be an SSI for its suitability for the Siculo-Maltese endemic woodlouse *Miktoniscus melitensis*, which is rare and has restricted Maltese Island distribution.

Several individual tree species have special protection under Maltese legislation, including Lentisk and Aleppo Pine (*Pinus halepensis*), which are "strictly protected trees" and Carob, Olive (*Olea europea* s.l.) and Mulberry (*Morus* spp.), which are "protected trees". With some restrictions, trees over 50 years old are also listed as "protected trees".

4. QORTIN

4.1 Scope of Works

4.1.1 Thermal Survey

Thermal Imaging

The aerial thermal imaging survey was undertaken at dawn on 16 July 2002. Following preliminary assessment of the results no follow-up ground survey was deemed necessary.

Surface Temperature

Surface temperatures were measured at 30 locations over the landfill surface (top and lower benches) using a digital thermometer and surface probe inserted into the ground (Figure 4.1). Particular attention was paid to areas of current or former combustion where hot gases were being emitted from cracks or vents.

Borehole Temperature

A downhole temperature log was recorded in monitoring well QW1 (see below) using a combined dip-meter – digital thermometer. Readings of temperature were taken at 1m intervals from the top of the instrument to the base.

4.1.2 Boreholes

One borehole (QBH1) was drilled through the in-situ Upper Coralline Limestone Formation strata and into the underlying Blue Clay Formation near the entrance to the site (Figure 4.2 and Table 4.1). The hole was completed with a perforated well pipe to enable monitoring of groundwater quality and levels. Drilling records are included in Appendix A.

Table 4.1: Summary of Peripheral Monitoring Boreholes

Hole	*Depth*	*Estimated Ground Elevation (mASL)*	*Comments*
QBH1	23	96 m	No drilling difficulties. Driller reports top of Blue Clay at 12 mbgl. Slotted PVC standpipe installed.

A borehole (QW1) was drilled through the waste mound (Figure 4.2 and Table 4.2). Perforated steel well casing was installed to the full depth of the hole to enable monitoring of leachate, landfill gases and temperature. Drilling records are included in Appendix A.

Table 4.2: Summary of Landfill Monitoring Wells.

Hole	*Depth*	*Comments*
QW1	18	No significant difficulties. Hole dry. Base of hole within 1 m of base of waste.

4.1.3 Monitoring

Landfill Gases

Landfill Gas Monitoring Results from the monitoring well on the Qortin site is summarised in Table 4.3

Table 4.3: Summary of Landfill Gas Monitoring Results

	Date	*LEL (%)*	*CH4 (%)*	*Peak CH4 (%)*	*CO2 (%)*	*O2 (%)*	*CO (ppm)*	*H2S (ppm)*	*VOCs (ppm)*	*Flow Rate (l/hr)*	*Atmospheric Pressure (mb)*
QW1	25/09/2002	100+	20.4	20.4	24.5	0.5	51	0	nd	nd	994
QW1	02/10/2002	100+	15.2	15.3	23.0	0.6	32	0	0	0.7	1009

Surface Gas Monitoring

Concentrations of landfill gases were measured at 30 locations over the landfill surface (top and benches) using a surface probe (particular attention was paid to areas of current or former combustion where hot gases were being emitted from cracks or vents). The results of the gas monitoring are summarised in Table 4.4 and presented in full in Appendix C.

Table 4.4: Qortin Surface Gas Monitoring*

	Minimum	*Maximum*
Methane %	0	18.5
CO2 %	0	18.8
O2 %	5.3	20.9
CO ppm	6	2172
H_2S ppm	0	0
VOCs ppm	0	448

*no SOx and NOx detected

4.1.4 Field Sampling

Surface Soil

Surface soil samples were taken at four off-site locations (QSS 1-4, Figure 4.3). Two were taken immediately adjacent to the north-west and south-east of the waste mass (QSS4 and QSS 1 respectively). A further two were taken on the Blue Clay slope to the north of the landfill: QSS2 taken from directly beneath the waste and QSS3 taken in a location unlikely to be affected by the waste.

Waste Samples

Representative samples of waste materials exposed on the surface of Qortin landfill were sampled in five locations (Figure 4.3). The waste types sampled are summarised in Table 4.5. No obvious industrial or drummed wastes were visible on the landfill at the time of sampling.

Table 4.5: Summary of Surface Waste Samples

Sample ID	*Description*
QSW01	Dried grey silty run-off from north end of landfill
QSW02	Construction and demolition waste
QSW03	Burnt waste dust
QSW04	Burnt waste
QSW05	Mixed capping domestic waste on top

Marine Sediment

The marine sediment sample could not be taken from the proposed as no accessible sediment was present on the foreshore at Għajn Barrani. Instead, a sample of sediment was taken from a small unnamed beach to the east of the landfill below the cliffs of Rdum tax-Xagħra between Għajin Barrani and Ramla bay.

Marine Water

A single marine water sample, MMW1 was taken to the west of Għajn Barrani immediately below the landfill (Figure 4.3).

Groundwater

Groundwater was sampled from the peripheral monitoring holes QBH1 (Figure 4.2) and from the following agricultural wells (Figure 4.4):

- well on land owned by Michael Zammit - sample directly from water surface using stainless steel bucket (QOW1) and from base of well using wind pump (QOW1D);

- well on land owned by Savior Bonello - directly from water surface using stainless steel bucket (QOW2).

A sample was also taken from a spring from the base of the Upper Coralline Limestone Formation where it reaches the foreshore at Għajin Barrani.

These off-site locations were sampled with the co-operation and assistance of the local farmers, Tony Attard the Mayor of Xagħra and Eucharist Mizzi of the Ministry for Gozo.

Landfill Gases

Samples of landfill gas were taken using Gresham Tubes from the monitoring well QMW1. In addition, two samples were taken from locations of surface venting of gases (QGS 1-2, Figure 4.3).

Leachate

As discussed in Section 2, no discrete bodies of leachate were identified within the landfill and none could therefore be sampled.

4.1.5 Laboratory Testing

Testing schedules for all soil, water, and gas (Gresham) are presented in Appendix B with results contained in Appendices C-F respectively.

4.1.6 Visual Inspections

An inspection of the waste mound focussing on identifying areas of combustion, evidence of subsurface combustion and areas of instability or potential instability was undertaken.

4.1.7 Ecology

Information on the ecology of the area surrounding the landfill site was gathered using a desk study supplemented by a walkover survey by local ecologists in December 2002. The aim of the survey was to determine the broad vegetation communities, to highlight any communities or species of particular value, e.g. endemic or red data book species (Schembri and Sultana, 1989) or Areas of Ecological Importance (Malta Structure Plan, 1992), and to obtain information on any impacts that the landfill may be having on the ecology of the surrounding area. As with most of the Maltese Islands, much of the habitat has undergone intense anthropogenic influence, and as such there is little of the natural climax vegetation in the area.

4.2 Conceptual Site Model

4.2.1 Waste mass

The waste mound encroaches to within only one or two metres of the approximately 18 – 20m high, near vertical scarp formed by the Upper Coralline Limestone Formation . This overlies the Blue Clay, which makes up the 80m high, undulating, sparsely vegetated (1v:3h)slope down to sea level (Plate 4.1 and 4.2). The near horizontally bedded limestone strata comprises three layers (the Tal Pitkal, Mtarfa and Għajn Melel Members), all of which are fractured to varying degrees. Locally the upper bed overhangs the lower ones (Plate 4.3). The underlying clay is significantly softer and is known to be prone to the effects of weathering and mass movement (slope instability) particularly when wetted. There are a number of minor seepages at the toe of the cliff (at the juncture where permeable limestone overlies the less permeable clay deposits). This is visible in Plate 4.3 in the form of the extensive vegetation developed along the course of Għajn Barrani spring from where it emerges from the base of the Upper Coralline Limestone to the sea.

There is much evidence of earlier minor shallow failures / movements of the clay slope and there are many blocks of limestone (some of significant size) on the clay slope that appear to have become detached from the cliff face. In addition there are open fissures on the surface of the limestone particularly around the western end of the waste mound and locally there are wide fractures in the face of the cliff, particularly in areas where blocks appear to have become detached (Plate 4.3). The extent of cambering of the limestone plateau in response to the gradual lateral movement of the underlying Blue Clay is shown on Plate 4.4.

The waste mass was fully penetrated in the hole drilled indicating a maximum thickness of 18 m. This accords with the postulated thickness determined by a review of the survey data.

Evidence from the drilling suggests that the wastes are reasonably consistent throughout their depth comprising layers of conventional domestic and agricultural waste intermingled with construction debris.

The waste has not been subjected to any significant compaction during placement and is likely to be undergoing settlement as a result of self-weight consolidation (i.e. the newer layers of waste compressing the underlying materials) and general organic waste decomposition. There is evidence of some differential surface settlement probably occurring as a result of waste decomposition and the effects of subsurface combustion. There is also evidence of some tension cracks in areas showing either surface staining or direct evidence of combustion.

The waste mound has slope angles of typically 25^o but range up to around 35^o locally. Spalling of waste materials occurs around the entire site as the materials ‘regrade’ to angles of repose and some material has fallen over the limestone cliff to the northeast and onto the underlying clay slope. There is some evidence of waste instability in the form of cracking of the surface behind the top of the steep slopes on the western side of the landfill.

4.2.2 Surface Contamination

Samples of exposed waste contained concentrations of the following determinands at concentrations greater than the Maltese background samples (Table 4.6):

- chromium;
- copper;
- nickel;
- zinc;
- lead;
- cadmium;
- mercury;
- 2-methyl-naphthalene (burnt waste);
- dibenzofuran (burnt waste)

The areas immediately surrounding vents where combustion gases vent to the ground surface were stained with condensate. This typically contains a wide range of volatile and semi-volatile organic compounds resulting from combustion of wastes:

- chloroform
- benzene, toluene, ethylbenzene and xylene
- tetrachloroethene
- alkyl benzenes
- chloroalkanes
- chlorobenzenes
- PAHs;
- Total phenols;
- alkyl phenols;
- dioxins;
- other unresolved organic compounds.

Table 4.6: Comparison of Qortin Samples with Maltese Background Concentrations (all mg/kg except where noted)

	Maltese Background	*Soils on Adjacent Land*	*Waste*
Arsenic	5	3	<1
Chromium	34	24	62
Copper	21	6	374
Nickel	18	21	21
Lead	19	275	114
Sulphate	1787	6100	6540
Zinc	83	59	275
Acid Soluble Sulphide	<10	<10	33
Complex Cyanide	<2.5	<2.5	<2.5
Thiocyanate	3	3	3.6
Total PAH	3.8	<1.6	10.0
Total Phenols	<0.01	<0.01	0.81
Cadmium	0.5	<0.5	3.8
Mercury	<0.3	<0.3	<0.3
Selenium	2.8	<0.5	<0.5
Total Organic Matter	2.5	2.7	2.4
pH Value In Soil	7.8	7.8	8.5
Total Cyanide	<2.5	<2.5	<2.5
Free Cyanide Soil	<2.5	<2.5	<2.5
Total Dioxin ng/kg I-TEQ	<0.01	0.7	61

4.2.3 Heating / Combustion

The results of the thermographic imaging coupled with the results of the gas monitoring (notably the CO measurements) and the surface temperature monitoring indicate that only minor areas of the landfill mass are undergoing heating with localised combustion. The results are summarised on Figures 4.5 and 4.6

Thermographic Imaging

Thermographic images of the landfill indicate that combustion is restricted to the uppermost layers of the landfill and concentrated around the rim of the upper waste surface (Figure 4.6, Plate 4.1).

Temperature Measurements

Surface measurements of elevated temperatures where gases and vapours are vent to surface correlated well with the heat distribution measured with the thermographic survey (Figure 4.7). Locally temperatures of venting gases were around 60 °C, temperatures potentially indicative of aerobic waste decomposition or possible combustion.

Borehole temperatures within the waste were generally constant between 43 and 46 °C, decreasing slightly to around 40 °C at the base of the landfill. Temperatures in this range are normal for landfills containing decomposing municipal solid wastes and indicate that significant combustion within the waste mass is unlikely to be occurring.

Gas Monitoring

The results of the surface gas monitoring are summarised as dot-density plots on Figures 4.8 - 4.10 for carbon monoxide, carbon dioxide and methane (no hydrogen sulphide was detected).

Elevated concentrations of carbon monoxide correlated well with surface temperature measurements and the thermographic survey being concentrated around the upper outer margins of the landfill and, to a lesser extent, in the centre of the landfill surface. In contrast, methane concentrations were elevated (up to 18% on the surface and 20% in the monitoring well). These concentrations indicate that anaerobic decomposition of waste is occurring within the depths of the landfill. Carbon dioxide concentrations were also generally high in those areas where elevated temperature and carbon monoxide concentrations were also recorded. These concentrations confirm that aerobic decomposition of waste (including but not necessarily restricted to combustion processes) are operating in the outer edges of the landfill where the supply of oxygen to the waste is greatest.

Interpretation

The combination of the thermographic survey, surface temperature and gas monitoring has allowed the following conclusions to be drawn regarding the extent of combustion at Qortin:

- there is evidence of limited combustion at Qortin toward the top and edges of all sides of the landfill where oxygen supply is greatest;
- there is no evidence of abnormal heating through the full depth of waste within the landfill;
- normal landfill waste decomposition processes appear to be active within the main waste mass.

4.2.4 Air Quality

Measurements of volatile organic compounds in Gresham tubes are summarised in Table 4.7 together with associated PID readings. Only a limited number of volatile organic compounds were identified in surface soil gas samples despite elevated concentrations of VOCs indicated by the PID readings (which may be affected either by gas temperature or moisture content). Individual VOCs were not detected in borehole samples. The reason for this difference in behaviour between borehole gas from deep within the landfill and surface gas sampling is not clear at present.

For reference the measured concentrations are compared to the UK maximum exposure limits (long term 8 hr TWA) or the occupational exposure limits (long term 8 hr TWA) in UK HSE document EH40/2002. Benzene and trichloroethane in soil gas both locally exceed the relevant MEL/OEL.

Table 4.7: Volatile Organic Compound Measurements (ppm)

	Total VOCs (PID)	*trans-1,2-Dichloro-ethene*	*Carbon Disulphide*	*1,1,1-Trichloro-ethane*	*Benzene*	*All other VOCs*
UK OEL/MEL (8 hr TWA)		5	10	100	3	
QW1	0	<10	<10	<10	<10	<10
QGS1	2349	<100	<10	**275**	**25**	<10
QGS2	621					

MEL – maximum exposure limit
OEL – Occupational Exposure Limit
TWA – Time Weighted Average
PID – Photoionisation detector

4.2.5 Other Impacts

Soil

Impacts on the soils in the area surrounding Qortin have been assessed by comparing chemical analyses of these materials with background samples of soil from Malta. Soils around Qortin around show concentrations of lead exceeding background in two locations:

- from the Blue Clay slope immediately below the waste; and
- from the garigue plateau to the west of the waste.

No other determinands were present in elevated concentrations. However, it should be noted that dioxins were detected in a single sample but not at concentrations considered elevated in agricultural soils.

The fact that recorded concentrations of lead exceeded the background concentration does not mean this substance is a risk to human health. A full assessment of any risks to human health presented by these substances will be included in Stage III of the project (see Section 6). Although, the presence of elevated lead does not indicate it is derived from the landfill, the samples affected may reflect either the impact of waste materials on adjacent land or the presence in soil of lead shot from shooting on land adjacent to the landfill.

Groundwater

The identification of potentially elevated concentrations of potential groundwater contaminants were assessed by comparison with EU Council Directive 98/83/EC on the quality of water intended for human consumption.

The following determinands were found to be elevated above the drinking water standards:

- iron (QBH1 and all agricultural wells);
- chloride (QBH1, all agricultural wells and spring);
- sodium (all agricultural wells);
- sulphate (one agricultural well – QOW2);
- total coliforms and *E.coli* and (QBH1 and all agricultural wells tested).

Elevated concentrations of iron are likely to relate to the ferruginous nature of the basal unit of the Upper Coralline Limestone Formation (the glauconitic limestones of the Għajn Melel Member). Chloride, sodium and sulphate concentrations were only slightly elevated. Sodium and sulphate could be naturally occurring. However, slightly elevated chloride concentrations could suggest an impact from the landfill.

Concentrations of metals in groundwater were not elevated when compared to the values in the drinking water directive. Bacteriological contamination of groundwater was identified near the landfill in both QBH1 and the agricultural wells where bacteriological determinands were measured. There are considered to be two possible sources:

c) the landfill; and

d) animal slurries at nearby animal husbandry units and spread on fields.

Both may potentially contribute to the presence of bacteriological contamination identified.

Marine Environment

The marine water sample from contained slightly elevated concentrations of ammoniacal nitrogen only. This substance can be produced by landfill leachate or in sewage deposited in the sea. The latter seems more likely given that any leachate migration would have to occur by flow over the Blue Clay slope from springs at the base of the Upper Coralline Limestone scarp. A more likely source could be the sewage outfall in San Blas bay to the east. Given the lack of plausible hydraulic connections between the marine environment and the landfill at Qortin it is considered that this marine sample is the most representative of the samples taken of background water quality in the Maltese islands.

4.2.6 Ecology

Background information on the ecology of this area is given in the Development of rehabilitation Strategies Stage 1 report (Scott Wilson 2002).

*Vegetatio*n

A copy of the full ecological survey report is included as Appendix H and the findings are summarised in this section. Much of the area around this site is agricultural land, with non-agricultural communities mainly restricted to the southernmost portion of the scarp community at il-Mielħa and part of area at il-Qortin ta' Għajn Damma. To the west of the dump, between the landfill site and derelict agricultural land, there is a substantial area of garrigue, moving into rdum base vegetation and narrow band of clay steppe. To the north and east of the landfill, clay steppe dominates the landscape with a small area of rocky steppe adjacent to the tip on the northeast side.

A steppe/garrigue community exists at il-Qortin ta' Għajn Damma, adjacent to the landfill on the west. This is considered to be a previous maritime garrigue, which has been degraded by its proximity to the landfill and by encroachment. Dominant plants included the Red Data Book (RDB) (Schembri and Sultana, 1989) species Seaside Squill (*Urginea pancration*) and Mediterranean Thyme (*Thymbra capitata*), as well as Pitch Clover (*Psoralea bituminosa*), Branched Asphodel (*Asphodelus aestivus*), Olive-leaved Germander (*Teucrium fruticans*), Spiny Asparagus (*Asparagus aphyllus*), Caper (*Capparis orientalis*), Tree Spurge (*Euphorbia dendroides*), Mediterranean Heath (*Erica multiflora*) and Carob. In areas of severe disturbance around the periphery of the landfill, ruderal species such as Crown Daisy (*Chrysanthymum* coronarium) and Cape Sorrel (*Oxalis pes-caprae*) have become dominant.

The agricultural land to the west of the garrigue around il-Mielħa has been derelict for a long time and shows some characteristics of a steppe community. It comprises mainly late pioneer vegetation including Fennel (*Foeniculum vulgare*) and Giant Fennel (*Ferula communis*), with Cape Sorrel being the most abundant species throughout the area. Solitary Tamarisk (*Tamarix africana*), an RDB species which is rare and has restricted distribution in the Maltese Islands is present in scattered pockets throughout the derelict agricultural land in the west, north and east of the study area.

The west-facing scree in this derelict agricultural area is colonised by the endemic Maltese Salt-tree (*Darniella melitensis*), Caper and Golden Samphire (*Inula crithmoides*) on steep rock faces, with the base of the scree comprising dense Carob and Great Reed (*Arundo donax*) vegetation, with agricultural species such as Almond (*Prunus dulcis*), Fig (*Ficus carica*) and Pomegranate (*Punica granatum*). Thickets of Carob (*Ceratonia siliqua*) with associated development of pseudomaquis are scattered in various locations around the agricultural area, particularly to the south of the landfill site.

Throughout the clay steppe, to the north and east of the landfill, there are stands of individual shrub species, including Solitary Tamarisk, Maltese Salt-tree, Shrubby Orache (*Atriplex halimus*) and Great Reed in wetter areas. Some slopes to the north of the landfill site contain *Eucalyptus* sp.stands that were introduced for shooting purposes, and there are remnants of cultivated plots containing Prickly Pear (*Opuntia ficus-indica*), Almond and Fig trees.

The steep coastal slopes to the north and east of the area are colonised by species including Golden Samphire and Maltese Salt Tree. Several other ecologically valuable species, noted in the RDB, occur in the area, including Mediterranean Stocks (*Matthiola incana melitensis*), Carline Thistle (*Carlina involucrata*), Seaside Squill and Mediterranean Thyme. Along the shoreline and in the clay steppe community at Għajn Barrani, the rare Chaste Tree (*Vitax agnus-castus*), an RDB species with restricted distribution in the Maltese Islands is present, as are stands of Solitary Tamarisk.

Fauna

Faunal records from the area are restricted, but it is known from the literature (Schembri *et al*, 2002) that a small colony of Levantine Shearwater (*Puffinus yelkouan*) breeds in the locality and that Jackdaws (*Corvus monedula*) and Barn Owls (*Tyto alba*) previously lived in the area.

Despite the paucity of information, it must be assumed that there are established faunal communities associated with the different plant communities, which would be impacted by changes to the vegetation.

Ecological value

The Gozo and Comino Local Plan (2001) lists only a single site in the locality as an Area of Ecological Interest (AEI). This is the sand dune complex at Ramla-l-Hamra Bay, which was designated in 1995, for its dune ecology.

Notwithstanding the lack of designations, there are several features of ecological value around the landfill. The garrigue to the west of the landfill has important conservation potential, and the presence of several species with restricted distribution, such as Solitary Tamarisk and Levatine Shearwaters around the landfill site, should also make the area an important ecological resource.

5. WEID FULIJA

5.1 Scope of Works

5.1.1 Thermal Survey

Thermal Imaging

The aerial thermal imaging survey was undertaken at dawn on 16 July 2002. A follow up ground survey was undertaken at dawn on 19 July 2002.

Surface Temperature

Surface temperatures were measured at 44 locations over the landfill surface (top and lower benches) using a digital thermometer and surface probe inserted into the ground (Figure 5.1). Particular attention was paid to areas of current or former combustion where hot gases were being emitted from cracks or vents.

Borehole Temperature

Downhole temperature logs were recorded in the two monitoring well (WFW1 and 2, see below) using a combined dip-meter – digital thermometer. Readings of temperature were taken at 1m intervals from the top of the well to the base.

5.1.2 Boreholes

No boreholes were drilled through the in-situ Lower Coralline Limestone Formation at Wied Fulija as three existing monitoring boreholes were available (Figure 5.2 and Table 5.1).

Table 5.1: Summary of Existing Wied Fulija Boreholes

	Approximate Ground Level (mASL)	*Depth of Borehole (m)*	*Depth to Water Level (m)*	*Approximate Water Level (mASL)*
WFBH1	108	154.7	108.3	0
WFBH2	95	123.0	95.7	0
WFBH3	102	124.2	101.9	0

A further two holes were drilled, one through each of the waste mounds (Figure 5.2 and Table 5.2). Perforated steel well casing was installed to the full depth of each hole to enable monitoring of leachate, landfill gases and temperature. Drilling records are included in Appendix A.

Table 5.2: Summary of Landfill Monitoring Wells.

Hole	*Depth*	*Comments*
WFW1	20.5	Located on western waste mound. No significant difficulties during drilling. Hole dry. Estimated base of waste at 20.5 mbgl.
WFW2	21.25	Located on eastern waste mound. No significant difficulties during drilling. Hole dry. Estimated base of waste at 7.5 mbgl.

5.1.3 Monitoring

Landfill Gases

Landfill Gas Monitoring Results from the monitoring wells on the site are summarised in Table 5.3.

Table 5.3: Summary of Landfill Gas Monitoring Results

	Date	*LEL (%)*	*CH4 (%)*	*Peak CH4 (%)*	*CO2 (%)*	*O2 (%)*	*CO (ppm)*	*H2S (ppm)*	*VOCs (ppm)*	*Flow Rate (l/hr)*	*Atmospheric Pressure (mb)*
WFW1	25/09/2002	nd	1.2	1.2	12.7	6.0	nd	0	nd	nd	998
WFW1	03/10/2002	17	0.8	2.0	11.3	7.1	92	0	0	0	1010
WFW2	25/09/2002	100+	14.9	18.5	23.0	4.7	164	0	nd	nd	998
WFW2	03/10/2002	100+	12.6	13.0	14.7	9.2	31	0	0	-0.1	1011

Table 5.4: Wied Fulija Surface Gas Monitoring*

	Minimum	*Maximum*
Methane %	0	1.1
CO2 %	0	11.1
O2 %	8.9	21.0
CO ppm	15	>2999
H_2S ppm	0	3
VOCs ppm	0	1040

*SOx and NOx not detected

Surface Gas Monitoring

Concentrations of landfill gases were measured at 30 locations over the landfill surface (top and benches) using a surface probe (particular attention was paid to areas of current or former combustion where hot gases were being emitted from cracks or vents). The results of the gas monitoring are summarised in Table 5.4 and presented in full in Appendix C.

5.1.4 Field Sampling

Surface Soil

Surface soil samples were taken at six off-site locations (WFSS 1-6, Figure 5.3), all located on areas of agricultural land.

Waste Samples

Representative samples of waste materials exposed on the surface of Wied Fulija landfill were sampled in nine locations (Figure 5.3). The waste types sampled are summarised in Table 5.5. No obvious industrial or drummed wastes were visible on the landfill at the time of sampling.

Table 5.5: Summary of Surface Waste Samples

Sample ID	*Description*
WFSW01	North east end and top of east mound
WFSW02	South end of east mound
WFSW03	Burnt material near top of ridge
WFSW04	Burnt waste
WFSW05	Silt with waste and limestone in base of valley between waste mounds
WFSW06	South end at top of west mound
WFSW07	On top, beneath layer of compost

Marine Sediment

The water depth at Wied Fulija is too deep to allow marine sediment samples to be obtained.

Marine Water

A single marine water sample, WFMW1 was taken from the sea below the cliffs at Wied Fulija. Access was achieved using a boat (Figure 5.3).

Groundwater

Groundwater was sampled from the existing peripheral monitoring holes WFBH1-3.

Landfill Gases

Samples of landfill gas were taken using Gresham Tubes from the two monitoring wells WFW1 and 2. In addition, three samples were taken from locations of surface venting of gases (WFGS 1-3, 5.4) (Figure 5.3).

Leachate

As discussed in Section 2, no discrete bodies of leachate were identified within the landfill.

5.1.5 Laboratory Testing

Testing schedules for all soil, water, and gas (Gresham) are presented in Appendix B with results contained in Appendices C-F respectively.

5.1.6 Visual Inspections

An inspection of the waste mound focussing on identifying areas of combustion, evidence of subsurface combustion and areas of instability or potential instability was undertaken.

5.1.7 Ecology

Information on the ecology of the area surrounding the landfill site was gathered using a desk study supplemented by a walkover survey in January 2003. The aim of the survey was to determine the broad vegetation communities, to highlight any communities or species of particular value, e.g. endemic or red data book species (Schembri, 1989) or Areas of Ecological Importance (Malta Structure Plan, 1992), and to obtain information on any impacts that the landfill may be having on the ecology of the surrounding area. As with most of the Maltese Islands, much of the habitat has undergone intense anthropogenic influence, and as such there is little of the natural climax vegetation in the area.

5.2 Conceptual Site Model

5.2.1 Waste mass

The two waste mounds encroach to within a few metres of the crest of vertical or overhanging sea cliffs approximately 100m high. Waste also infills the line of the former Wied Ħallelin valley and forms a large, sloping, wedge-shaped face where this is exposed above the cliff (Plate 5.2). The near horizontally bedded rock in the cliffs comprises strata of the Lower Coralline Limestone Formation.

There is evidence of previous cliff failure where significant blocks have fallen into the sea beneath the eastern waste mound (Plate 5.1).

The waste mass was fully penetrated in both the holes drilled indicating a maximum thickness of around 20m. This accords with the postulated thickness determined by a review of the survey data. However, there is a significantly greater thickness locally where the former valley has been infilled (up to 37 m below the crest of the western waste mound).

Evidence from the drilling suggests that the wastes are reasonably consistent throughout their depth comprising layers of conventional domestic and industrial waste intermingled with some construction waste.

The waste is likely to be undergoing settlement as a result of self-weight consolidation (i.e. the newer layers of waste compressing the underlying materials) and general organic waste decomposition. There is evidence of some differential surface settlement probably occurring as a result of waste decomposition and the effects of subsurface combustion. There is also evidence of some tension cracks in areas showing either surface staining or direct evidence of combustion. There is evidence of spalling of material from the face of the valley infill but no evidence of any significant mass movement.

The waste mound has slope angles of typically 31° but range up to around 38° (locally) between the flat benches. Spalling of waste materials occurs around the entire site as the materials 'regrade' to angles of repose. There is some evidence of waste instability in the form of cracking of the surface and differential settlement at the western extremity of the landfill.

5.2.2 Surface Contamination

Samples of exposed waste contained elevated concentrations of the following determinands:

- chromium;
- copper;
- zinc;
- lead;
- cadmium;
- PAHs (burnt waste);
- Total phenols (burnt waste);
- dioxins (burnt waste);
- other unresolved organic compounds (burnt waste).

Condensate around venting combustion gases also contained elevated concentrations of toluene.

Visibly uncontaminated cover materials contained similar concentrations of determinands to background samples in Malta with the exception of the presence of detectable (but not elevated) concentrations of dioxins.

5.2.3 Heating / Combustion

The results of the thermographic imaging coupled with the results of the gas monitoring (notably the CO measurements) and the surface temperature monitoring indicate that areas of the western landfill mass are undergoing significant heating (with localised combustion). There is evidence of localised heating and combustion on the crest of the eastern waste mound. The results are summarised on Figures 5.4 and 5.5.

Thermographic Imaging

Thermographic images of the landfill indicate four main areas of interest (Figure 5.5):

- The western end of the east mound (Plate 5.1);
- southern and south-eastern face of the west mound (Plate 5.2b);
- the central face of the west mound (Plate 5.2c); and
- western end of the west mound (Plate 5.2d and e);

The southern and south-eastern face of the west mound is characterised by localised evidence of heating both along the crest and toward the base of the waste mound, particularly the corner between the southern and south-eastern sides. There is more widespread heating at the western end of the west mound. In contrast there is only limited evidence of localised heating of the crest of the south-western side of the east mound in approximately three locations. The remaining areas of the site showed no evidence of significant heating in the thermographic survey.

Temperature Measurements

Surface measurements of elevated temperatures where gases and vapours are vent to surface correlated reasonably well with the heat distribution measured with the thermographic survey (Figure 5.6). Typically temperatures of venting gases were between 50 and 80 °C, temperatures potentially indicative of active combustion in areas of the site where thermographic imaging had identified heating. In localised areas temperatures at the surface exceeded 140°C (peak 243°C). These very elevated temperatures were concentrated on the western end and south-eastern corner of the western mound and in one location on the crest of the eastern mound. In these areas at least, combustion is still likely to be occurring.

Borehole temperatures in the east mound (WFW2) were typical of municipal waste landfills (45-52°C within waste) declining toward the base of the waste (40 °C). Higher temperatures would be expected closer to the limited zones of combustion in the west and south-west of this mound. In contrast, on the west mound, borehole temperatures in WFW1 were higher (77°C decreasing to 65°C at base) indicating the proximity of areas of combustion in the eastern face of the western mound.

Gas Monitoring

The results of the surface gas monitoring are summarised as dot-density plots on Figures 5.7 – 5.10 for carbon monoxide, carbon dioxide, methane and hydrogen sulphide respectively.

Elevated concentrations of carbon monoxide correlated well with surface temperature measurements and the thermographic survey. The most highly elevated concentrations (taken to be indicative of active combustion causing a low oxygen atmosphere) were observed at the base of the south-eastern corner of the western waste mound). Generally elevated concentrations were generally observed over the seaward faces of both mounds of the landfill. Low concentrations of carbon monoxide were restricted to areas where there was little other evidence of current heating.

Methane concentrations were generally low, indicating that the anaerobic waste decomposition processes typical of normal landfills are not occurring to a significant extent.

Carbon dioxide concentrations were generally high in those areas where elevated temperature and carbon monoxide concentrations were also recorded. These concentrations confirm that aerobic decomposition of waste (including but not necessarily restricted to combustion processes) predominate in the landfill. However, in contrast to carbon monoxide concentrations, the most elevated carbon dioxide measurements were restricted to the uppermost areas of the landfill. These are areas where the supply of oxygen to the waste (thus allowing complete combustion) would be greatest.

Interpretation

The combination of the thermographic survey, surface temperature and gas monitoring has allowed the following conclusions to be drawn regarding the extent of combustion at Wied Fulija:

- there is evidence of combustion (or at least active smouldering) on the landfill;
- the principal areas affected are the western end of the west mound, localised areas along the seaward crest and base of the west mound and localised areas on the south-western crest of the eastern mound;
- the distribution of heating and landfill and combustion gases suggests that actual combustion is restricted to the outer edges and upper surfaces of the landfill in general. The presence of heat at low levels on the seaward side of the western mound may resulting from upward oxygen penetration from cracks and fissures in the underlying limestone bedrock or funnelled up through permeable wastes in the infilled valley of the Wied Ħallelin;
- the presence of the most significant heating on the western end of the west mound is likely to relate to the narrow width of the waste mound in this area (thus allowing greater oxygen access) and its being located up-wind of the remainder of the site.

The extent of heating and possible combustion may reflect:

- the proportion of municipal solid waste in the original waste deposited;
- the retention of heat by inert waste within the landfill;
- the exposed situation of the landfill allowing oxygen migration both laterally and upward through underlying strata and into the open textured waste.

5.2.4 Air Quality

Measurements of volatile organic compounds in Gresham tubes are summarised in Table 5.6 together with associated PID readings. Only a limited number of volatile organic compounds were identified in surface soil gas samples despite elevated concentrations of VOCs indicated by the PID readings (which may be affected either by gas temperature or moisture content). At Wied Fulija, in contrast to the other sites VOCs were detected in both borehole and surface gas samples. The reason for this difference in behaviour is not clear at present.

For reference the measured concentrations are compared to the UK maximum exposure limits (long term 8 hr TWA) or the occupational exposure limits (long term 8 hr TWA) in UK HSE document EH40/2002. Benzene in soil gas is present consistently in greater concentrations than this guidance value whilst other VOCs detected locally exceed the relevant MEL/OEL.

Table 5.6: Volatile Organic Compound Measurements (ppm)

	Total VOCs by PID	*trans-1,2-Dichloro-ethene*	*Carbon Disulphide*	*1,1,1-Trichloro-ethane*	*Benzene*	*All other VOCs*
UK MEL /OEL (8 hr TWA)		5	10	100	3	
WFW1	0	<10	<10	<10	**80**	<10
WFW2	0	<10	<10	<10	**15**	<10
WFGS1	>9999	<10	<10	10	<10	<10
WFGS2	0	**370**	<10	**6675**	**20**	<10

MEL – maximum exposure limit
OEL – Occupational Exposure Limit
TWA – Time Weighted Average
PID – Photoionisation detector

5.2.5 Other Impacts

Soil

Impacts on the soils in the area surrounding Wied Fulija have been assessed by comparing chemical analyses of soil with analysis of background samples of soil from Malta.

Soils around Wied Fulija around show concentrations of the following determinands exceeding the Target Value:

- copper;
- nickel;
- zinc;
- lead;
- cadmium; and
- PAHs.

In addition, dioxins were detected in the two off-site samples analysed, but not at concentrations considered significantly elevated in agricultural soils.

The fact that concentrations exceed the target value does not mean either that the presence of these substances is a risk to human health. A full assessment of any risks to human health presented by these substances will be included in Phase III of the project (see Section 6). However a preliminary assessment of the contaminants listed suggests that of the contaminants listed above only lead is likely to present in sufficient concentrations to represent any potential risk to human health.

It should also be emphasised that the presence of the potential contaminants listed above does not indicate that they derive from the landfill alone (although data from the high volume sampler at Magħtab suggests this is plausible). Other local potential sources of the contaminants that need to be considered are:

- lead shot (lead);
- steel shot (copper, nickel and zinc);
- pig slurry application to land (copper and zinc).

Groundwater

The identification of potentially elevated concentrations of potential groundwater contaminants were assessed by comparison with EU Council Directive 98/83/EC on the quality of water intended for human consumption.

The following determinands were found to be elevated above the drinking water standards:

- chloride, sodium and sulphate (all boreholes);
- ammoniacal nitrogen (WFBH1);
- total coliforms (WFBH3); and
- Bacillus *stearothermophilus* (present in WFBH1).

Elevated chloride, sodium and sulphate concentrations reflect the salinity of the mean sea level aquifer (Lower Coralline Limestone Formation) as the boreholes extend beyond the base of the fresh-water lens (measured salinity was lowest in WFBH3 the borehole furthest from the sea).

Trace concentrations of the volatile organic compounds cis-1,2-dichloroethene, chloroform and trichloroethene were identified in WFBH3. Although, the presence of these compare only likely to have an anthropogenic origin, at first glance a source within the landfill appears unlikely given the inland location of the sample, upgradient of the site. However, groundwater flow patterns in karstic aquifers are complex and it is plausible that water quality in WFBH3 could be impacted by contaminants deriving from the landfill travelling via fractures or solution features against the prevailing hydraulic gradient.

Concentrations of metals in groundwater are not elevated when compared to the values in the drinking water directive.

Bacteriological contamination of groundwater was identified near the landfill in both WFBH1 and WFBH3. There are considered to be two possible sources:

e) the landfill; and

f) animal slurries at nearby animal husbandry units and spread on fields.

Both may potentially contribute to the presence of bacteriological contamination identified.

Marine Environment

The marine water sample from Wied Fulija contained slightly elevated concentrations of ammoniacal nitrogen only in similar concentrations to those observed near both Magħtab and Qortin.

5.2.6 Ecology

Background information on the ecology of this area is given in the Stage 1 report (Scott Wilson, July 2002).

Vegetation

A copy of the full ecological survey report is included as Appendix H and the findings are summarised in this section. Most of the landfill itself is unconsolidated construction waste, interspersed with mounds of fragmented glass and compacted metal containers. The vegetation on the recently disturbed landfill is dominated by oportunistic species characteristic of disturbed ground, such as Crown Daisy (*Chrysanthymum* coronarium) and Cape Sorrel (*Oxalis pes-caprae*). Areas that have not been recently disturbed show species composition that includes the endemic Maltese Salt-tree (*Darniella melitensis*).

[4] Axiak, V. and Sammut, A. 2002. The Coast and Freshwater Resources. In: *State of the Environment Report for Malta, 2002.* Ministry for Home Affairs and the Environment, August 2002.

The narrow coastal fringe to the south of the landfill is an important ecological habitat, which shows the characteristics of a degraded maritime garrigue. Close to the landfill, opportunistic species are mixed with original garrigue species, such as the RDB species Egyptian St Johns Wort (*Hypericum aegyptiacum*), as well as Olive-leaved Germander (*Teucrium fruticans*) and other species indicative of regressive or progressive succession, such as Branched Asphodel (*Asphodelus aestivus*) and the RDB species Seaside Squill (*Urginea pancration*). Close to the cliff edge, the endemic, rare Maltese Rock Centaury (*Palaeocyanus crassifolius*) was present. Other RDB species encountered on the clifftop included the rare Crystal Plant (*Mesembryanthemum crystallinum*), whose distribution is restricted in the Maltese Islands, as well as African Wolfblane (*Periploca angustifolia*) and Carline Thistle (*Carlina involucrata*), which both have restricted distribution in Mediterranean. Two endemic species, namely Maltese Fleabane (*Chiliadenus bocconei*) and Maltese Sea Lavender (*Limonium melitensis*) were also found in this area.

On the west face of the narrow ravine, Wied il Ħallelin, that interrupts the cliff face, there is a similar assemblage of species to that described above. This site has a high density of African Wolfblane, but does not include the Crystal Plant. Given its similarity to the cliff top vegetation, it is also considered to be ecologically important.

Although there are no sources of permanent water at this site, there is a single, temporal freshwater pool in the karst slope on the coastal fringe. The pool vegetation is typically ephemeral and includes Maltese Waterwort (*Elatine gussonei*) and filamentous algae (*Spirogyra* sp. and *Zygnema* sp.).

Fauna

The only faunal information available is of a Fairy Shrimp (*Branchipus schaefferi*) population in the freshwater pool. However, it must be assumed that there are specialised faunal communities associated with the cliff top vegetation community, which would be impacted by changes to the vegetation.

The South Malta Local Plan indicates that several species of birds utilise the coastal cliffs around this area also (SMLP, 2001).

Ecological value

The cliff top and ravine is of high ecological value and the coastal fringe is recognised for its ecological value in the South Malta Local Plan for its coastal cliffs and for its freshwater pools. It also qualifies as a Site of Scientific Interest for its populations of Maltese Rock Centaury and Crystal Plant.

The Maltese Salt Tree, African Wolfblane and Lentisk found in the coastal fringe are listed as “Strictly Protected Trees” in the Trees and Woodlands (Protection) Regulations 2001.

6. RISK ASSESSMENTS

6.1 Objectives

As part of the next Stage of the project, the refinement of the conceptual models for each of the sites described in the preceding sections will be used to obtain the parameters upon which the assessment of the risks that the sites present to the health of nearby inhabitants and workers and also to the wider environment can be made. Where it has not been possible (or necessary) to obtain site-specific information upon which to base the risk assessments, the parameters will be obtained using available background information.

The quantitative risk assessments will follow the principles identified in the Terms of Reference and, following good practice, will adopt a tiered approach. This promotes the use of iterative, successively more detailed phases of risk assessment. These allow the level of risks to be quantified to a degree sufficient to allow the selection and design of cost-effective rehabilitation strategies that are not overly conservative but nevertheless protective of human health and the environment. Initially, the hazards identified in the ground investigation will be ranked in order of severity to identify the critical issues before full analysis (quantitative or qualitative) is undertaken.

The threshold criteria for acceptability of a particular impact will be based generally on European or internationally recognised standards, notably those recently embodied in the Maltese islands under the air and water regulations.

Methodologies to assess risks to the following receptors have been devised:

- groundwater quality
- air quality
- landfill gas migration (principally to buildings)
- human health
- local ecology; and
- landscape.

The proposed methodologies for undertaking these assessments are summarised below. In addition, geotechnical risks associated with failure, either of landfill slopes or the underlying strata, will require assessment as part of the development of a successful rehabilitation scheme.

6.2 Geotechnics

A simple geometric model of each of the sites based on the schematic survey information, the results of the intrusive investigations and the waste input data is shown in Figures 3.6a-c, 4.5 and 5.4. Based on these, critical sections (particularly over-steepened slopes) with respect to stability will be noted and, where applicable, possible failure mechanisms will be identified.

There are a number of stability aspects of the sites that will require assessment; the general integrity of the surface of the sites as a result of waste consolidation, potential localised collapse caused by void creation due to subsurface combustion and also the stability of over-steepened side slopes. At Qortin and Wied Fulija the risk of potential collapse of sections of the limestone cliff underlying parts the landfills will require assessment. Such a failure scenario could lead to the deposition of significant quantities of waste material on the clay slope / foreshore area at Qortin and into the sea at Wied Fulija.

At all three sites computer modelling or specific analysis to determine the potential for surface settlement or localised collapse is unlikely to produce precise results. However, zoning based on waste input data and the results of the thermographic investigations will be used to identify the varying degree of hazard across the site. At Qortin and Wied Fulija the stability of the limestone cliffs (and consequently the outer flanks of the waste mounds) will be assessed by reviewing the potential failure mechanisms and determining the impact the weight of the waste may be having on the integrity of the cliffs.

Stability will be assessed adopting a limit equilibrium approach using conventional computer modelled analyses to determine a 'factor of safety' for critical slopes. It is proposed that the computer model *Slope/W* be used for the analyses and appropriate factors of safety determined for each case. For other, more dynamic, processes such as cambering, stream/seepage erosion or cliff recession a "probability" approach based on judgements, likely return period and event frequency will be used.

Based on a knowledge of the ground conditions beneath each of the sites there is not considered to be any potential for either base failure or mass movement along the waste / ground surface interfaces although this will also be reviewed.

Where unacceptable conditions are identified, safe slope angles and waste loadings will be determined to assist in the development of suitable remedial works.

6.3 Groundwater

Based on the results of the investigation, the initial assessment of the potential impacts of the landfills on groundwater quality has identified only limited evidence of contaminant migration to groundwater. Whilst no significant leachate was identified in any of the landfills during the investigation it is likely that the process of contaminant migration into groundwater is a transient process driven by rainfall induced leachate generation. In this case it is perhaps not surprising that no leachate was observed in an investigation undertaken during the summer and also after a prolonged period without significant rainfall.

Another factor that must be taken into consideration is the effect of elevated temperatures observed within the landfills (Magħtab in particular but also within the western mound at Wied Fulija), which may prevent or restrict the formation of discrete leachate within the body of the landfill even after rainfall events. Lower temperatures in the eastern mound at Wied Fulija and Qortin may mean that volatilisation of rainfall occurs to a lesser extent and that transient flushing by rainfall of contaminants within the waste is more likely to occur.

Ultimately, there will be an eventual reduction of the internal temperature of the landfills whether rehabilitated or not as combustion ceases with burning out of waste (although remedial works may affect the timescale over which this process occurs). There is therefore the possibility that contaminant migration in rainfall generated leachate could increase in the future, leading to potentially greater impacts on groundwater quality than exist at present unless mitigation measures are included in the landfill rehabilitation scheme.

It is proposed that the groundwater risk assessment models risks following rehabilitation with no specific measures to prevent leachate generation and migration. This will allow assessment of the extent to which control measures to limit the impacts of contamination of groundwater rainfall are required following rehabilitation. It is proposed to use the software package *ConSim* for the assessment of risks of groundwater pollution that could potentially be associated with waste management activities.

6.4 Air Quality Impacts

Scope of Work and Data Requirements

The purpose of the air quality assessment work is firstly to quantify the emissions from the three landfill sites and then to assess the impact on human health of these emissions (see Section 6.6).

Emissions to Atmosphere

For each of the three landfills sites, three emission scenarios are considered

- Existing (routine) conditions (current level of subterranean fires)
- Mass fire; these occur on an infrequent basis typically covering an area of approximately 0.25 ha)
- During (and after) restoration work following extinguishing of the subterranean fires.

Emissions to atmosphere from the landfills will include the products of combustion from the various fires, routine emission of dust due to wind erosion from exposed areas and dust generated from both vehicle movements and tipping operations. The air quality assessment work will focus on a number of principal pollutants (fine particulate matter, a range of heavy metals, volatile and semi-volatile organic compounds and a range of dioxins/furans). It is considered that assessment of these pollutants will be sufficient to understand the overall effects on air quality and human health of these sites.

Given onsite pollutant concentrations, the source emission rates can be estimated using a "back calculation" approach by dispersion modelling techniques, utilising with the measured concentrations on the landfills and known weather conditions during the monitoring period. (Alternatively the US EPA AP42 emission factors may be used to estimate source emission factors.) It is also possible that a combination of the modelling method and emission factors will be used to estimate the emission source terms for existing (routine) emissions. The estimate of source terms will make allowance for onsite conditions such as the approximate location of haul roads and the varying nature of the surface of the landfill. Estimates will require the measured onsite concentrations and the prevailing weather conditions during the monitoring period.

Emission source terms for the mass fire and restoration work scenarios will be estimated using the routine emissions as a basis. It should be noted that there will be considerable uncertainty in the estimated emission rates. These uncertainties are due to a number of factors: which include the variable nature of the source (in both time and space), the short duration and limited number of locations of the monitoring, and difficulties in estimating emission rates from ambient concentrations.

Subsequent modelling and risk assessment work will recognize these uncertainties.

Dispersion Modelling

For each site, the US EPA dispersion model AERMOD will be used to estimate the offsite ground level concentrations of the pollutant considered. Off site predictions of particulate matter and heavy metal concentrations will be made for the three scenarios at each landfill site. Predictions of the off site concentrations of dioxins and furans will be limited to the existing (routine) emissions scenario as it is only the long term effects on human health that are of concern. The routine emissions for dioxins will take account of the frequency of mass fires.

The results of the modelling will be presented as a representative number of contour plots showing the distribution of predicted offsite concentrations. These plots will be overlaid on a base map of the area showing the locations of receptors.

The predicted contribution to air quality made by emissions to atmosphere from the three landfills will be compared to relevant EU air quality standards. Predictions will also be compared to available measured ambient air quality. Hourly sequential meteorological data are required as input for the dispersion modelling. The use of three years of meteorological data will increase the accuracy of the assessment. The effects of local topography will be considered.

6.5 Landfill Gas

The assessment of whether landfill gas generation is currently causing significant risk to the environment and selection of the most appropriate and effective gas collection and treatment system will be assessed using a qualitative approach, including:

- definition of waste inputs (source term)
- assessment of gas generation potential (current and future) based on consideration of source term and emissions monitoring

- identification of gas migration pathways
- identification of gas collection and barrier systems
- options for flaring (or energy production) of collected gas

This assessment will incorporate an assessment of likely future gas generation concentrations and quantities following restoration to determine the potential impacts on proposed afteruses.

6.6 Human Health

6.6.1 Assessment Objectives

Potential impacts of the landfills on human health can be broadly divided into three categories:

- ingestion of contaminated groundwater;
- direct contact with contaminated materials and inhalation of vapours;
- off-site impacts associated with inhalation of aerial emissions from the landfills in their current state and during rehabilitation works;

Risks associated with groundwater ingestion have been dealt with separately above in the groundwater risk assessment. Assessment of possible health impacts associated with direct contact and inhalation are discussed in the following sections.

6.6.2 Direct Contact

A formal assessment of chronic risks associated with ingestion, inhalation or dermal contact with contaminated material is only considered necessary should the proposed rehabilitation strategy include options for the closure of the sites with no requirement for capping (i.e. leaving wastes exposed). In this case, a formal assessment of chronic risks associated with ingestion, inhalation or dermal contact with contaminated material, either on or off-site could be undertaken using the US RBCA framework.

6.6.3 Aerial Emissions

The options for health risk assessment of the effects of emissions to atmosphere from the routine operation of the landfills are:

- Health Risk Assessment (dioxins/metals);
- Assessment of effects of fine particulate matter (PM10);

Dioxins and Metals

For dioxins/furans, the estimated long-term off-site inhalation intake due to emissions from each landfill sites will be compared to the World Health Organisation's Tolerable Daily Intake . Metals intake can also be compared to the normal dietary intake of these metals if the baseline data are available for Malta.

For both these assessments it is possible that the outcome might suggest that the risk associated with exposure to the emissions from the landfill is unacceptable. This approach is very much a screening and makes a number of pessimistic assumptions. This leads to overestimation of the effects, as is required of a screening model. It may therefore be necessary to refine the inputs or model assumptions at a later date.

Particulate Matter

Modelled distributions of particulate matter concentrations around the landfills will be compared with the Stage 1 limit values set out in EC Directive (1999/30/EC) which will allow an informed decision to be made whether additional assessment (for example, using the UK Department of Health Committee on the Medical Effects of Air Pollutants (COMEAP) methodology) is required.

6.7 Landscape

Using the data and visual records gathered during the Stage I phase of the works, the key effects of the site on the landscape and visual receptors (people or natural or built features of landscape importance) will be determined at three points in time - currently, following restoration and in the future (i.e. once vegetation cover has become established). A preliminary assessment will be undertaken of landscape and planting proposals. A matrix will be developed which highlights the key landscape receptors and the scale of impact anticipated.

In considering mitigation measures our approach will be to avoid adverse impacts where possible and where this is not possible to identify measures to reduce the scale or duration of impacts (e.g. by modifications to design, route etc.). Mitigation proposals will be drawn up in sufficient detail so as to allow their effects to be judged, which will include outline specification and typical species that may be used for rehabilitation.

6.8 Ecology

Adverse ecological effects will generally arise from changes to key habitat features, dust deposition, changes in hydrology and water quality, and severance of wildlife corridors. Effects will be predicted by setting the severity of impact against the status or sensitivity of the resource in each case. Severity of impact is influenced by factors such as its extent (land take), duration, time of occurrence (since the vulnerability of species and habitats varies with season), and means of transmission (e.g. via water, air etc.).

The threshold of significance will generally reflect the interaction between the severity of impact and the status of the resource. Hence, major changes to statutory designated sites are likely to be significant, whilst minor changes to undesignated sites are unlikely to be significant.

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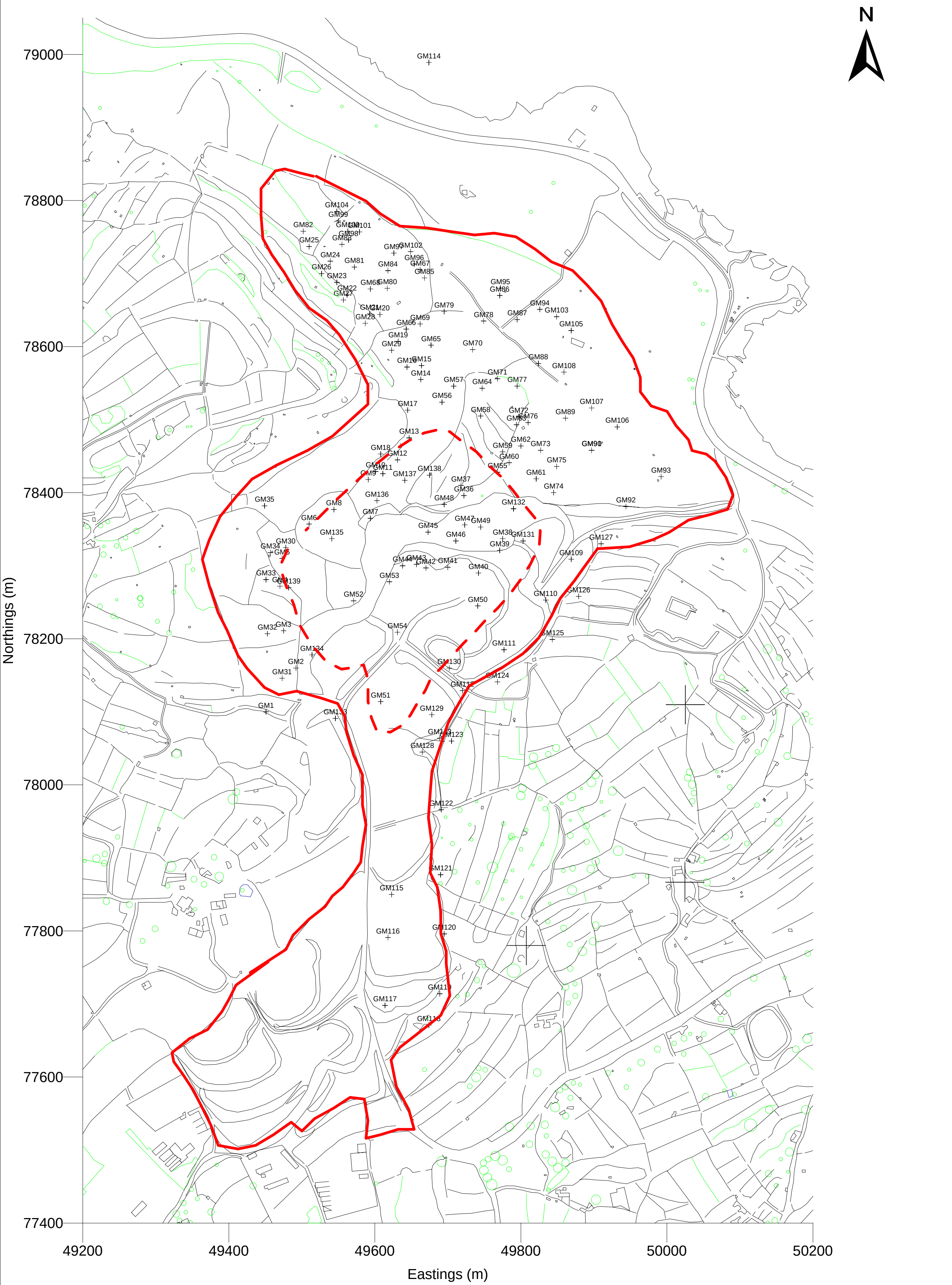
Figures



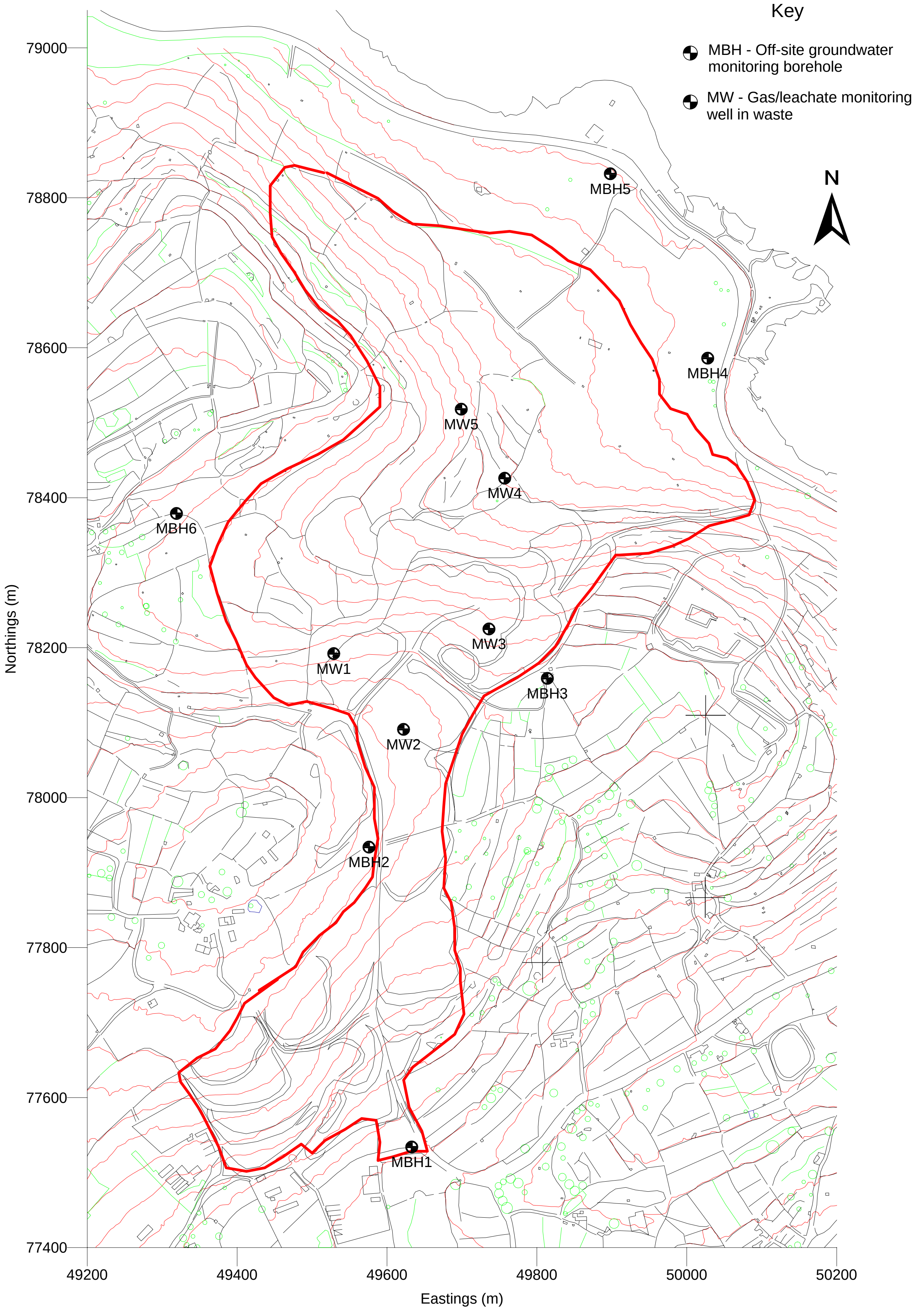
Drawing Title

Maghtab Landfill Surface Gas/Temperature Monitoring Locations

Figure No 3.1

Scale at A4 : As Shown		
Drawn IMC	Approved _	Revised
Checked _	Date 07/10/02	Date

Scott Wilson



Drawing Title

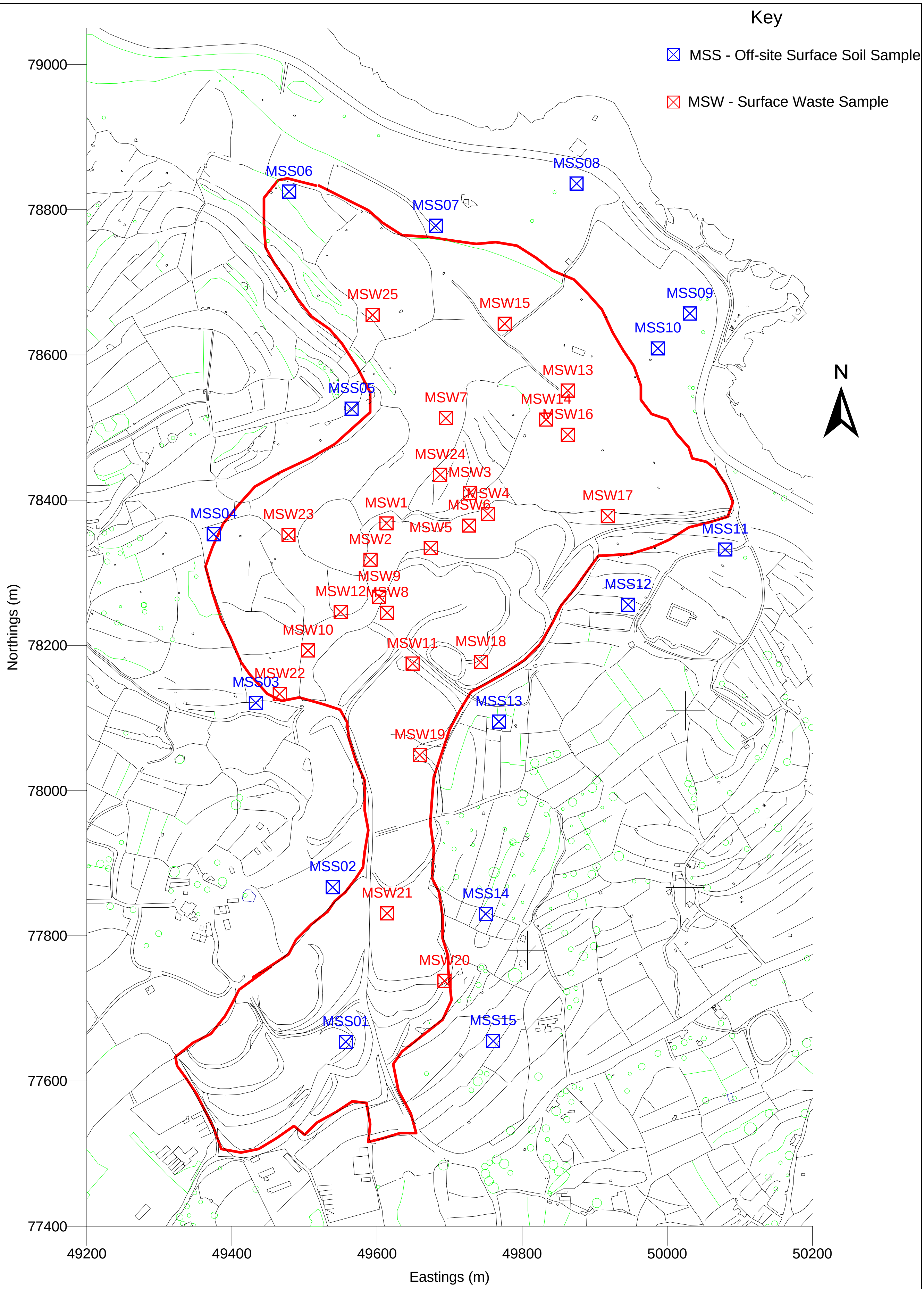
Maghtab Landfill
Borehole Location Plan

Figure No. 3.2

Scale at A4 : As Shown

Drawn IMC	Approved	Revised
Checked	Date 07/10/02	Date

Scott Wilson



Drawing Title

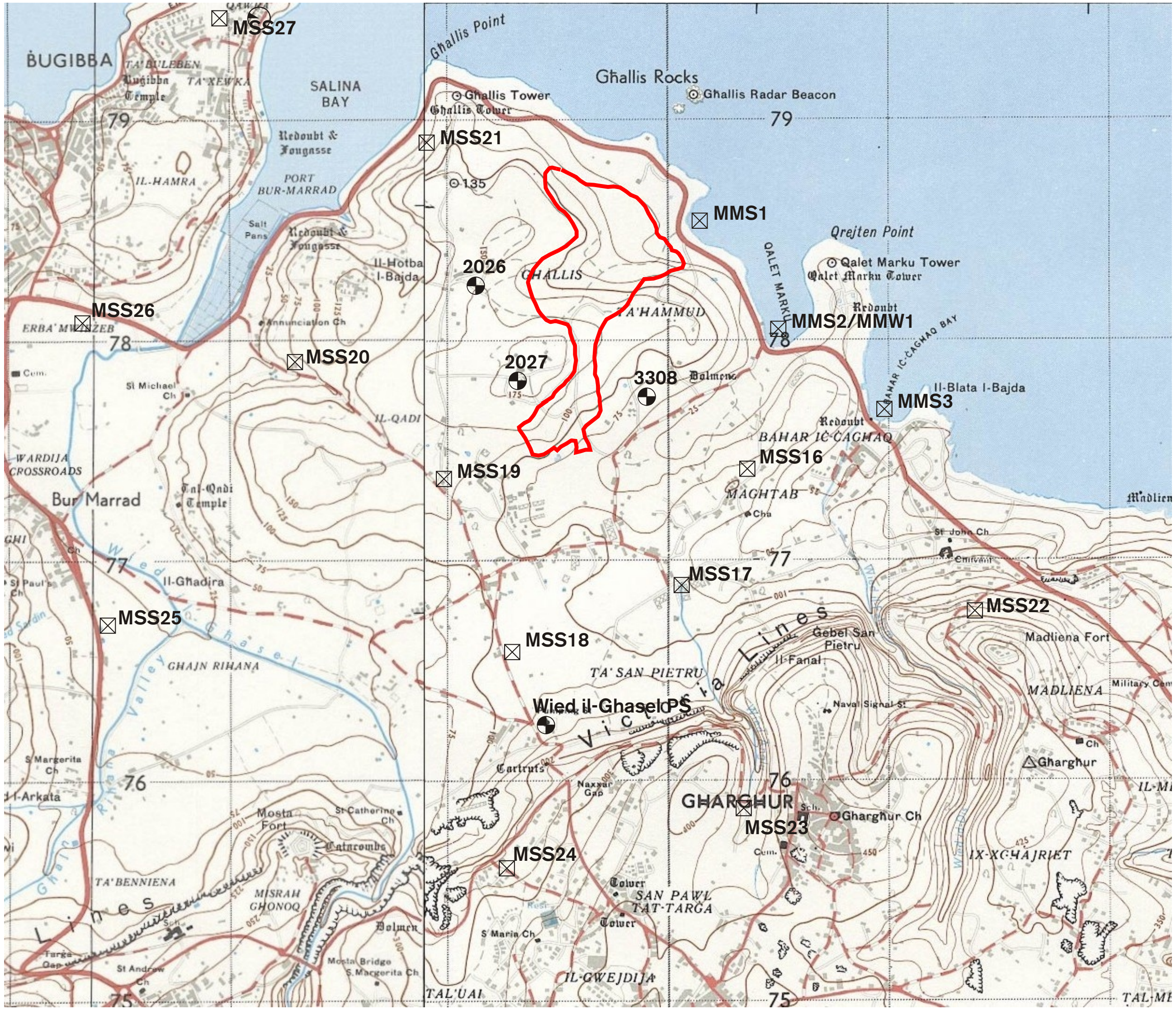
Maghtab Landfill
Surface Sampling Locations

Figure No. 3.3

Scale at A4 : As Shown

Drawn IMC	Approved –	Revised
Checked –	Date 07/10/02	Date

Scott Wilson



Key

- ☒ MSSS- Surface Soil Sample
- ☒ MMW - Marine Water Sample
- ☒ MMS- Marine Sediment Sample
- ◕ Off-site borehole (as named)

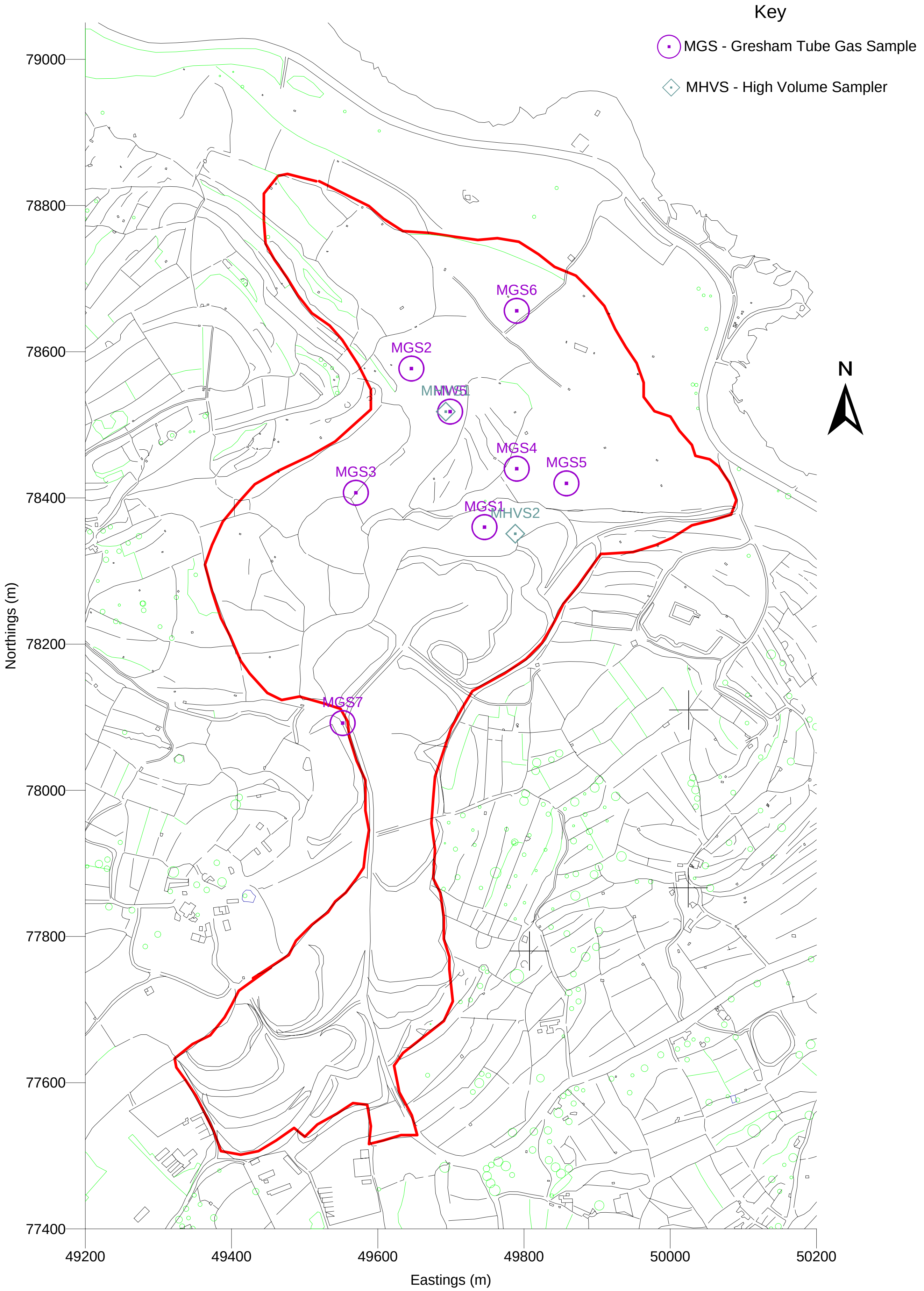
MSS28 - Not Shown -control sample located between Zebbug and Rabat

Drawing Title

Maghtab: Off-site sampling locations

Figure No 3.4		
Scale at A4 : NTS		
Drawn IMC	Approved	Revised
Checked	Date 10/11/02	Date

Scott Wilson



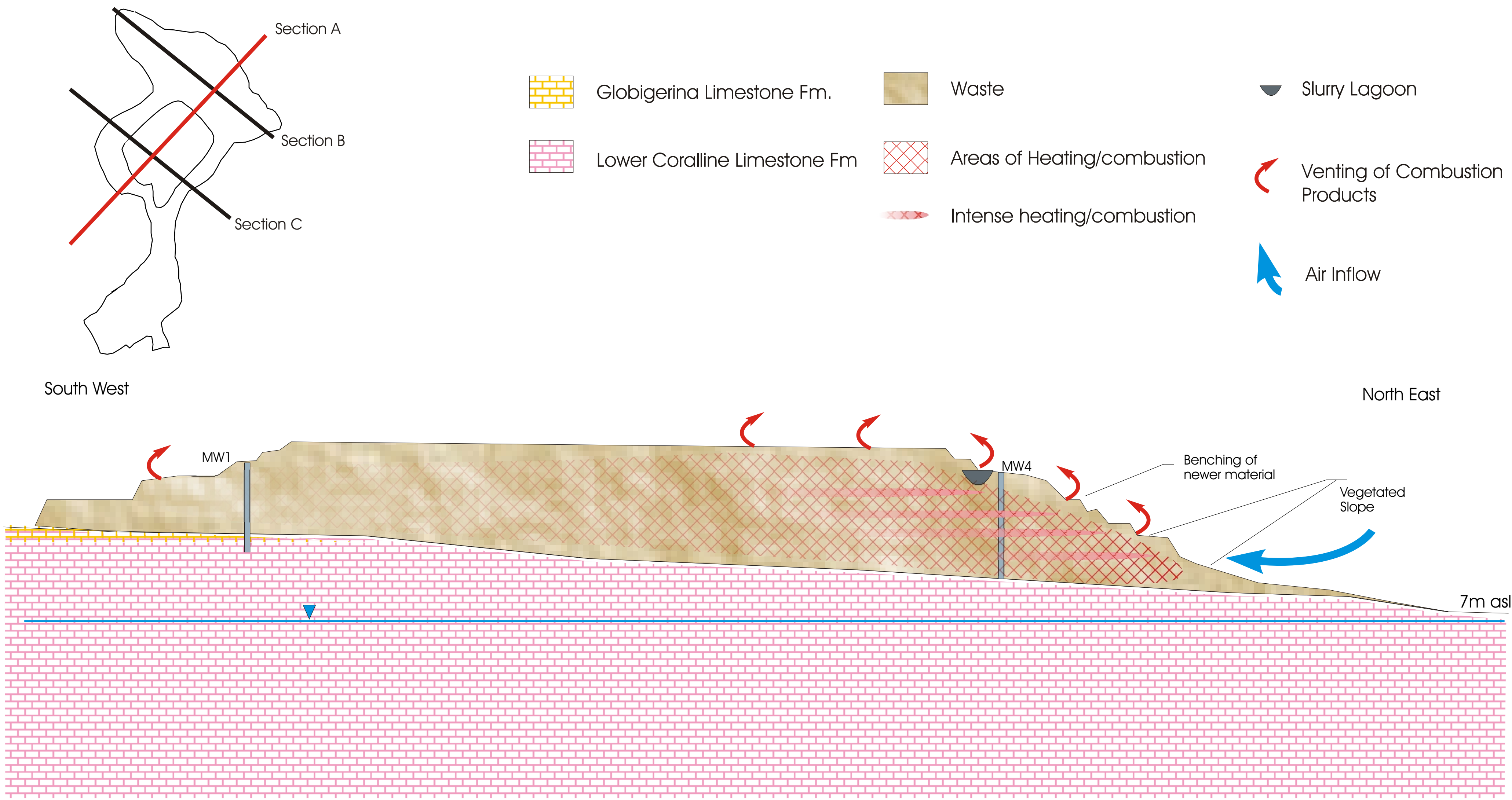
Drawing Title

Maghtab Landfill
Surface Sampling Locations

Figure No. 3.5

Scale at A4 : As Shown

Drawn IMC	Approved –	Revised
Checked –	Date 07/10/02	Date

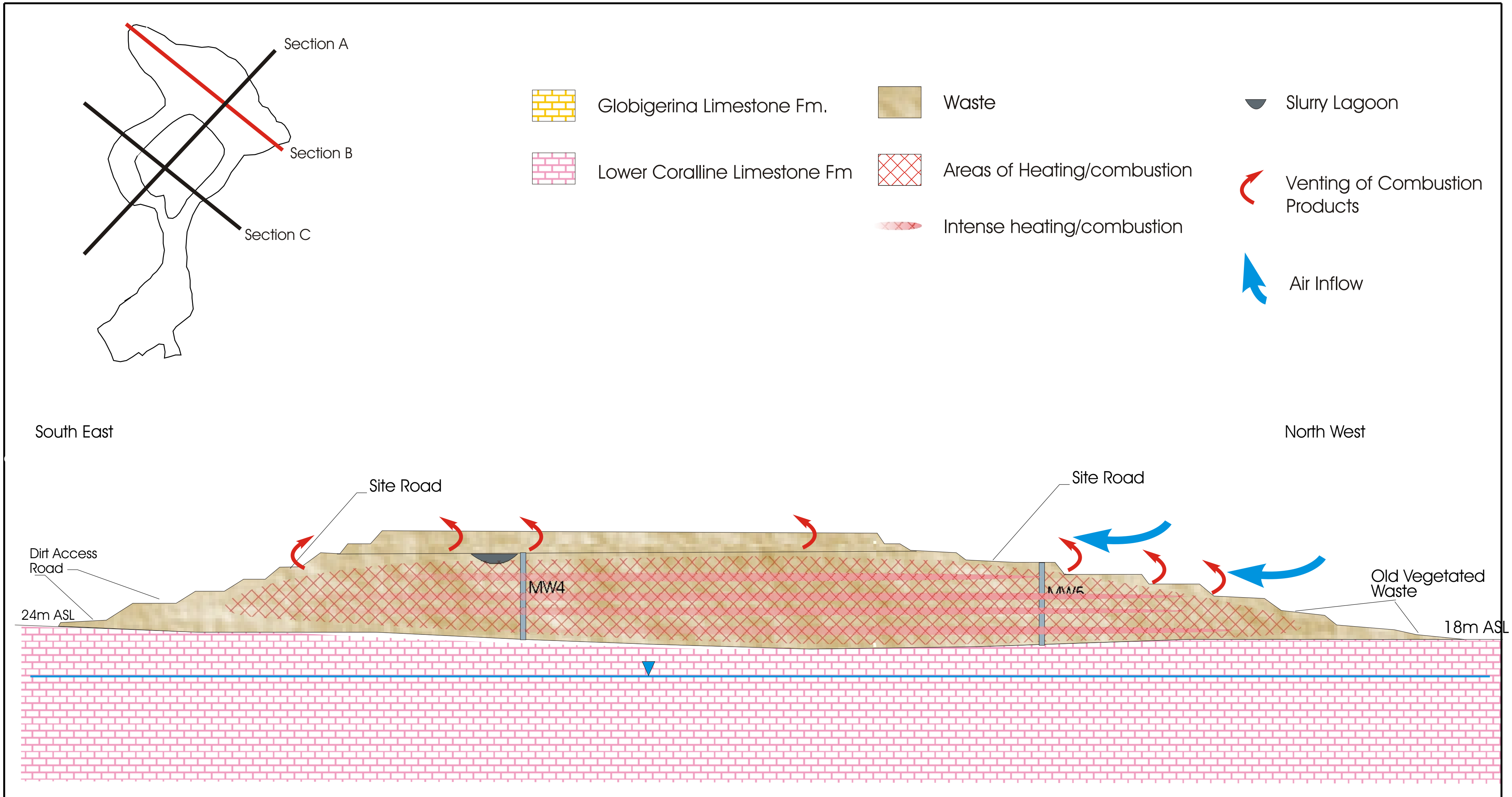


Drawing Title

Maghtab Landfill: Conceptual Site Model Section A

Figure No 3.6a		
Scale at A4 : NTS		
Drawn IMC	Approved	Revised
Checked	Date 18/11/02	Date

Scott Wilson



Drawing Title

Maghtab Landfill: Conceptual Site Model Section B

Figure No 3.6b		
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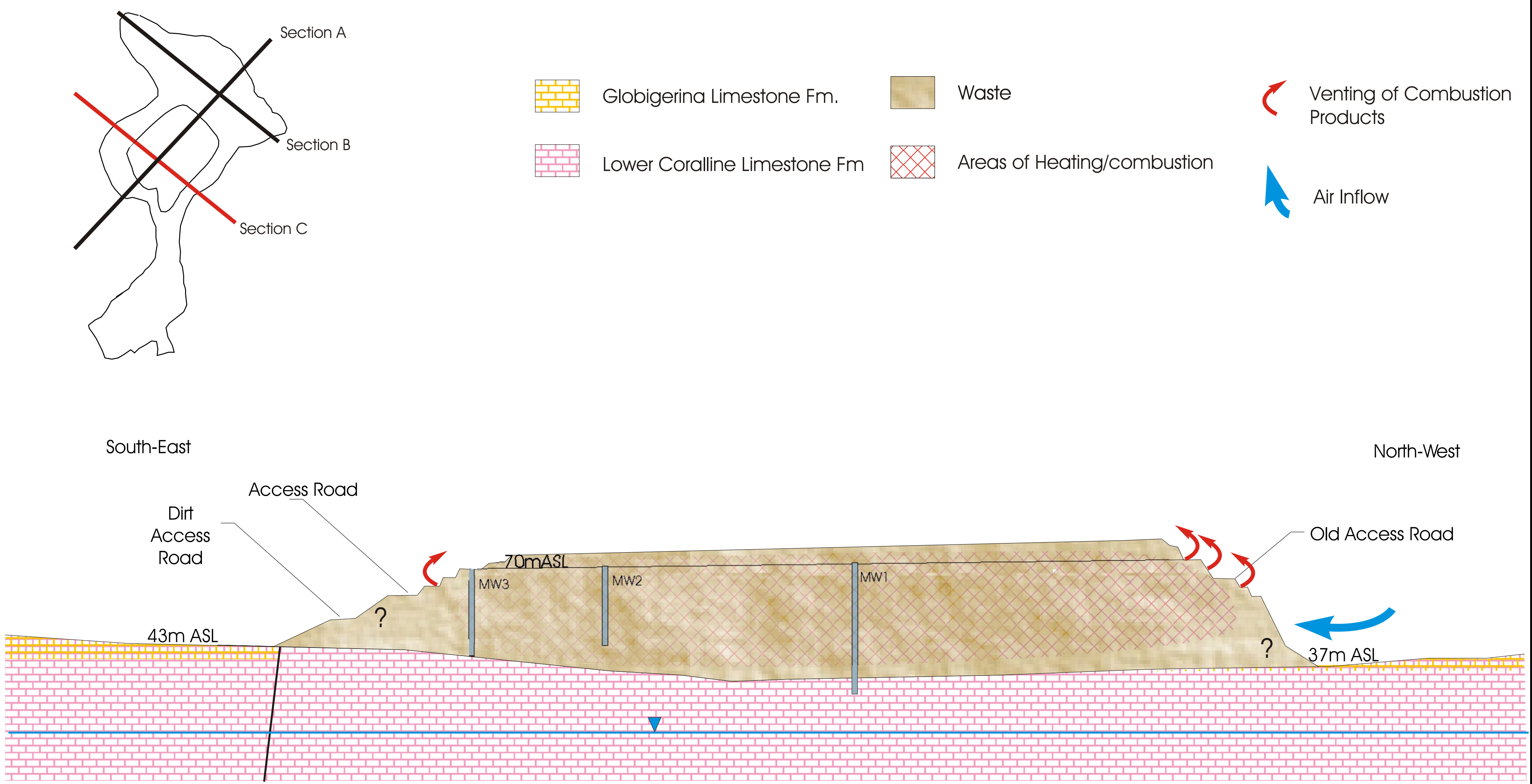
Drawn IMC	Approved	Revised
Checked	Date 18/11/02	Date

Scott Wilson

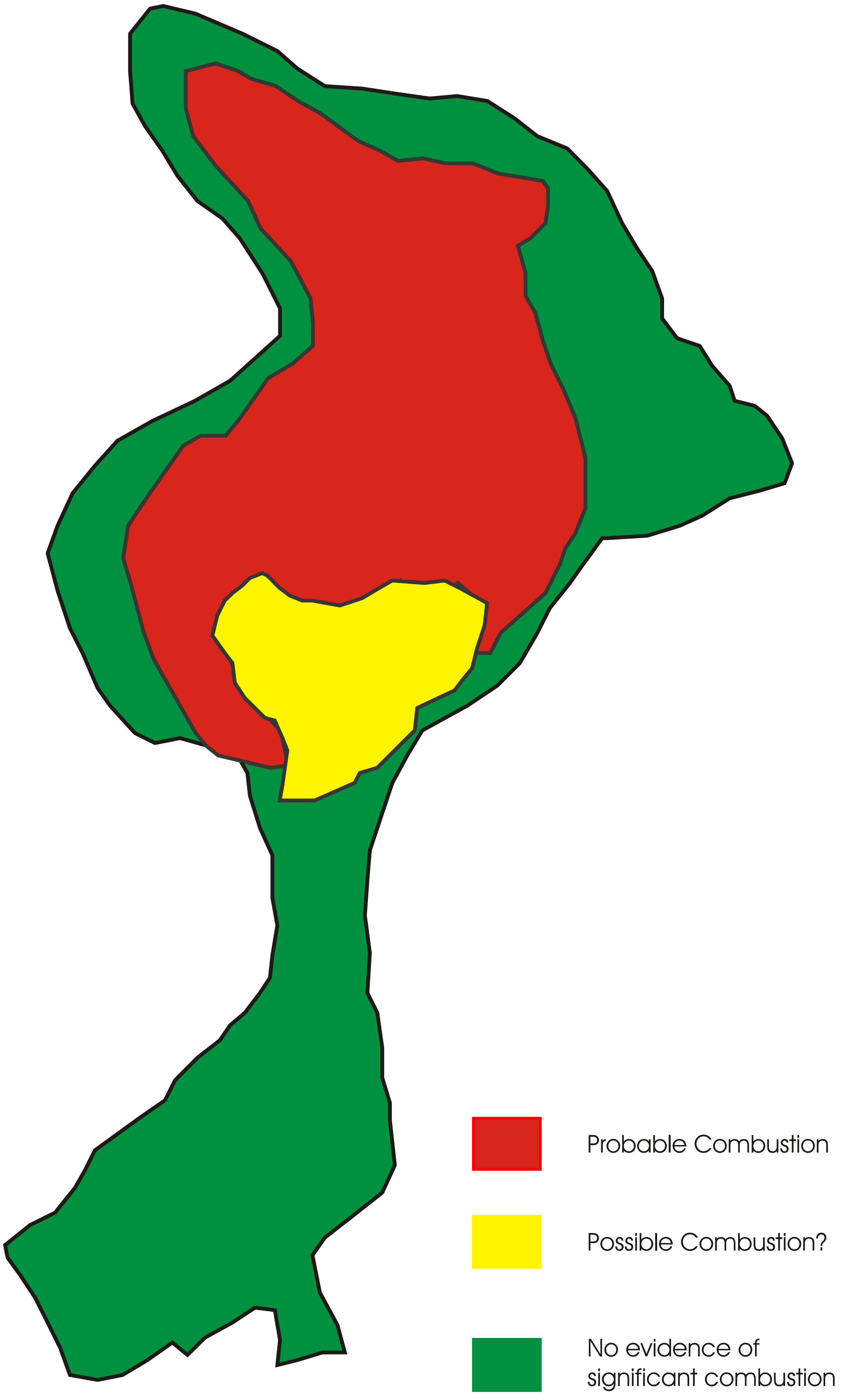


Drawing Title

Maghtab Landfill: Conceptual Site Model Section C

Figure No 3.6c		
Scale at A4 : NTS		
Drawn IMC	Approved	Revised
Checked	Date 18/11/02	Date

Scott Wilson



Drawing Title

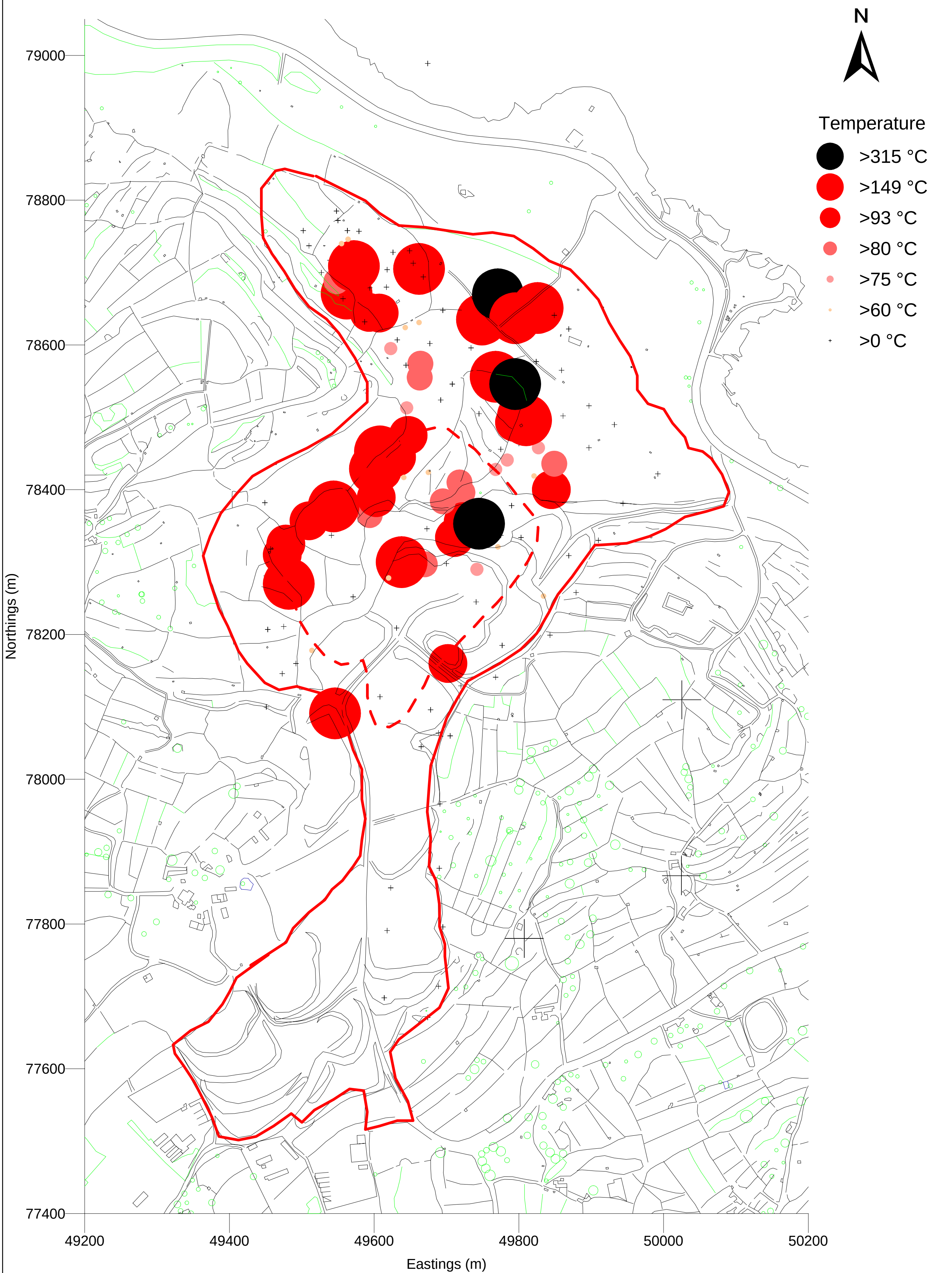
Maghtab Landfill
Assessment of Combustion

Figure No 3.7

Scale at A4 : NTS

Drawn IMC	Approved	Revised
Checked	Date 15/11/02	Date

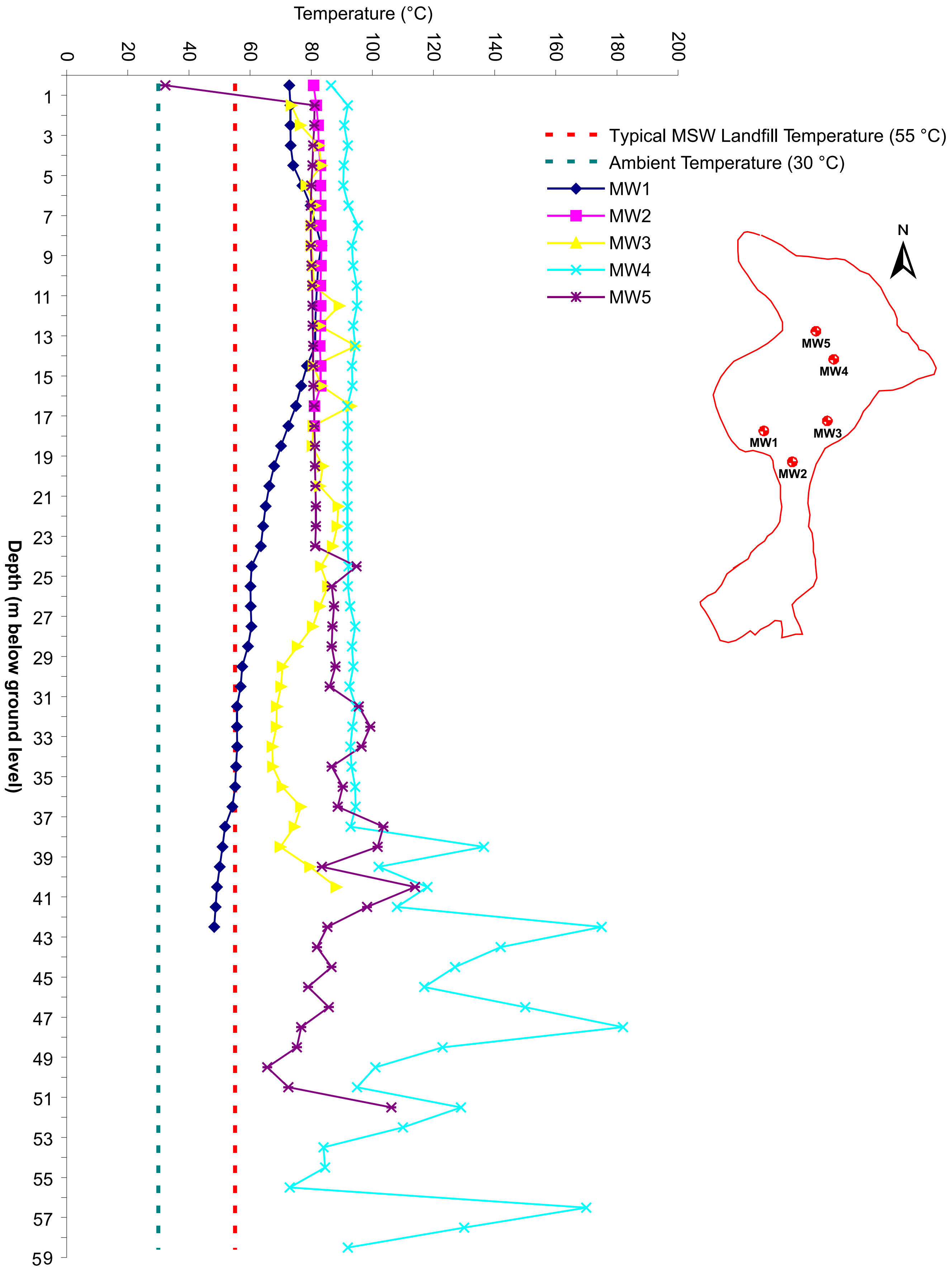
Scott Wilson



Drawing Title	Figure No 3.8	
Maghtab Landfill Surface Temperatures	Scale at A4 : As Shown	

Drawn	Approved	Revised
IMC	_	
Checked	**Date**	**Date**
_	07/10/02	

Scott Wilson



Drawing Title

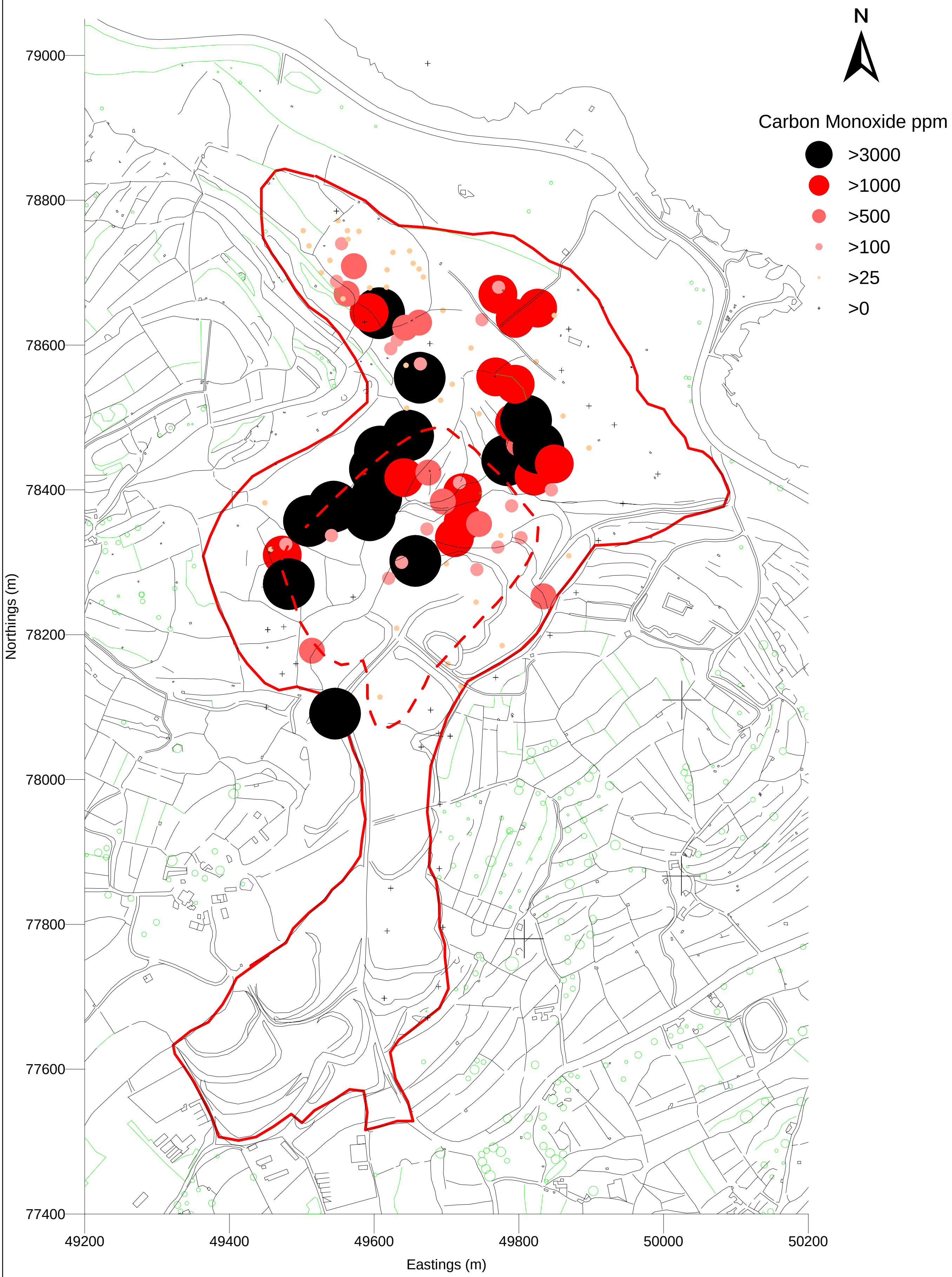
Maghtab Landfill Temperature Profiles

Figure No 3.9

Scale at A4 : As Shown

Drawn IMC	Approved BCG	Revised
Checked -	Date 24/02/03	Date

Scott Wilson



Drawing Title

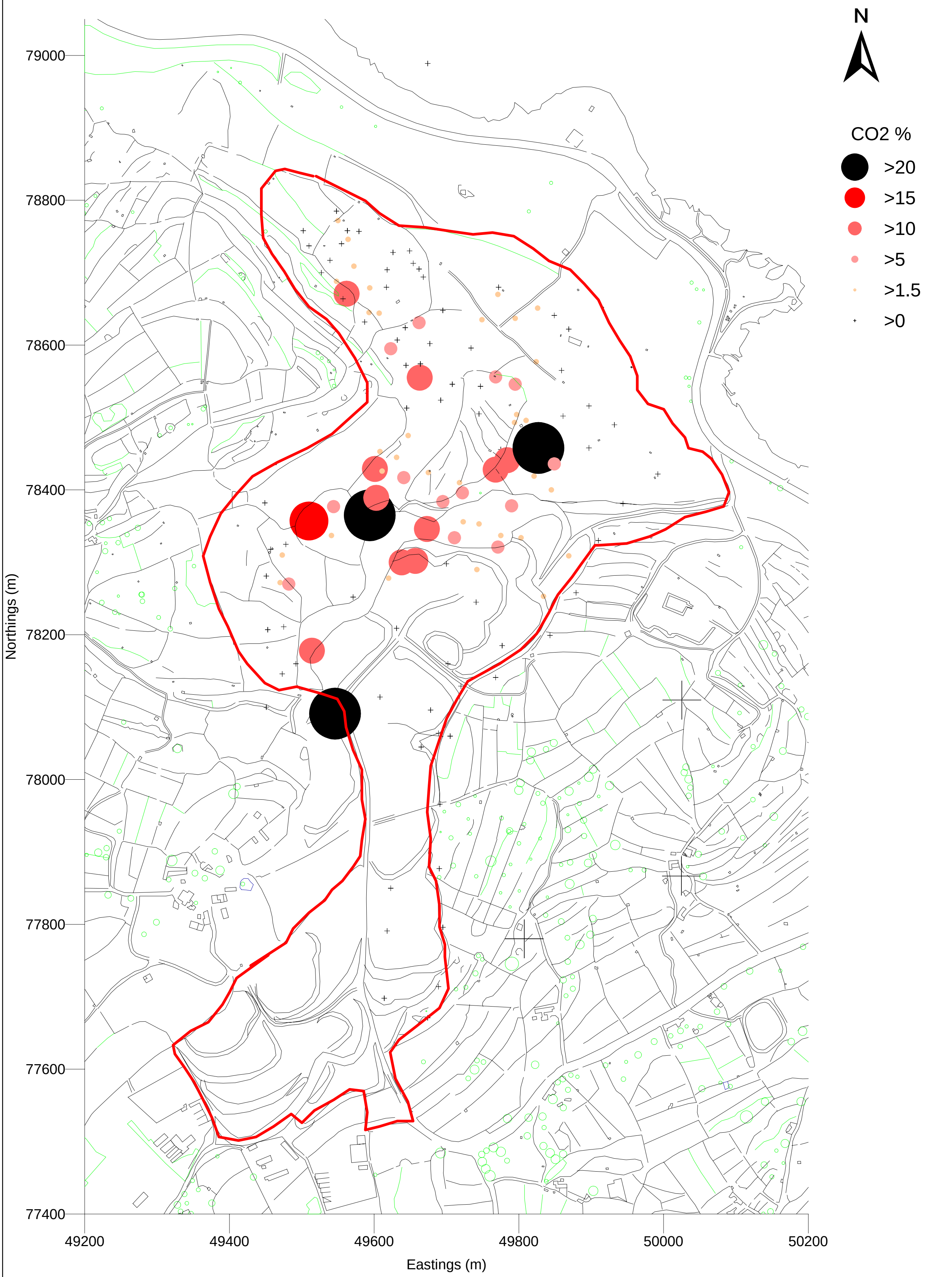
Maghtab Landfill
Surface Gas Concentrations

Figure No 3.10

Scale at A4 : As Shown

Drawn IMC	Approved –	Revised
Checked –	Date 07/10/02	Date

Scott Wilson

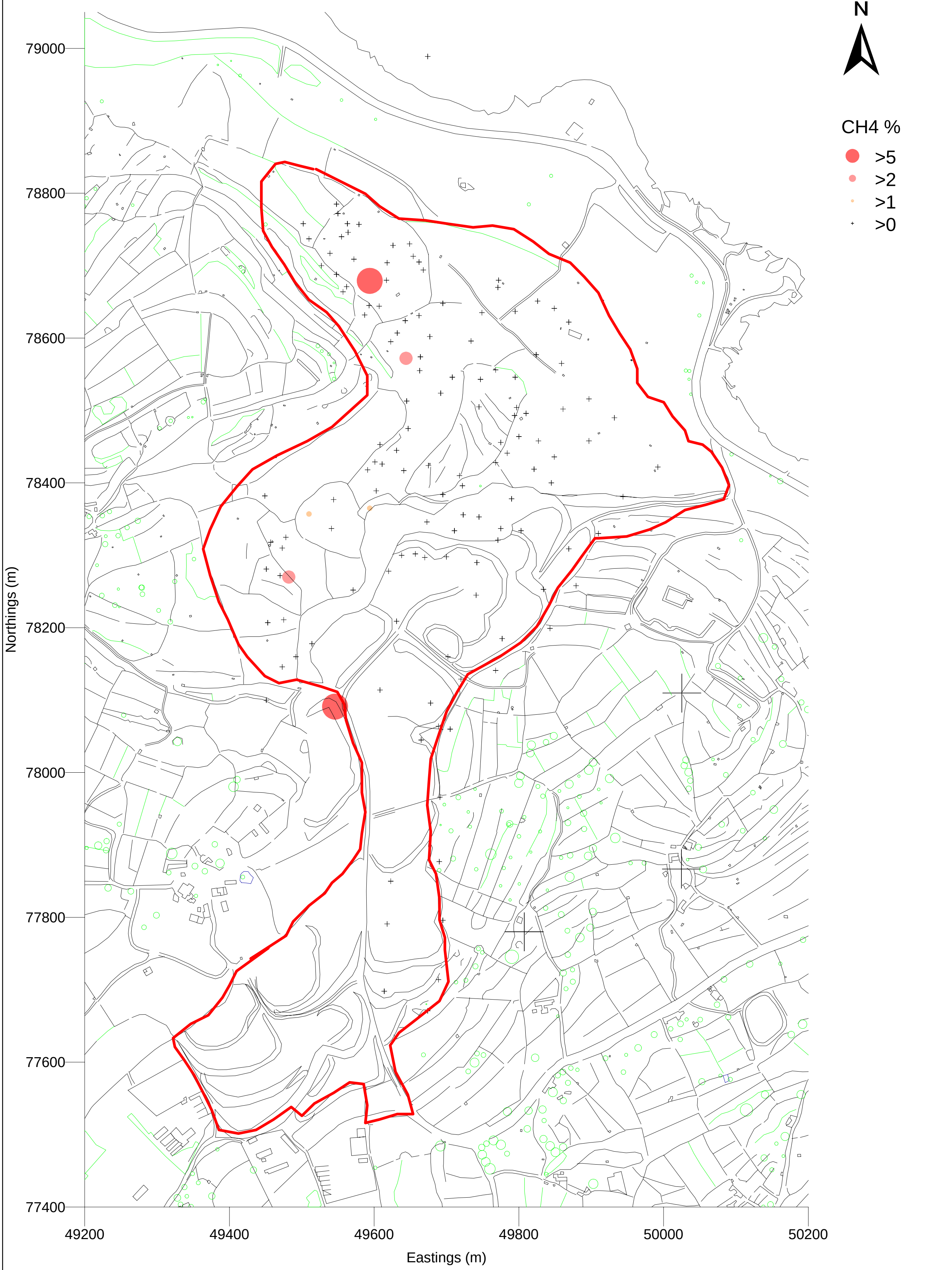


Drawing Title

Maghtab Landfill
Surface Gas Concentrations

Figure No. 3.11		
Scale at A4 : As Shown		
Drawn IMC	Approved _	Revised
Checked _	Date 07/10/02	Date

Scott Wilson

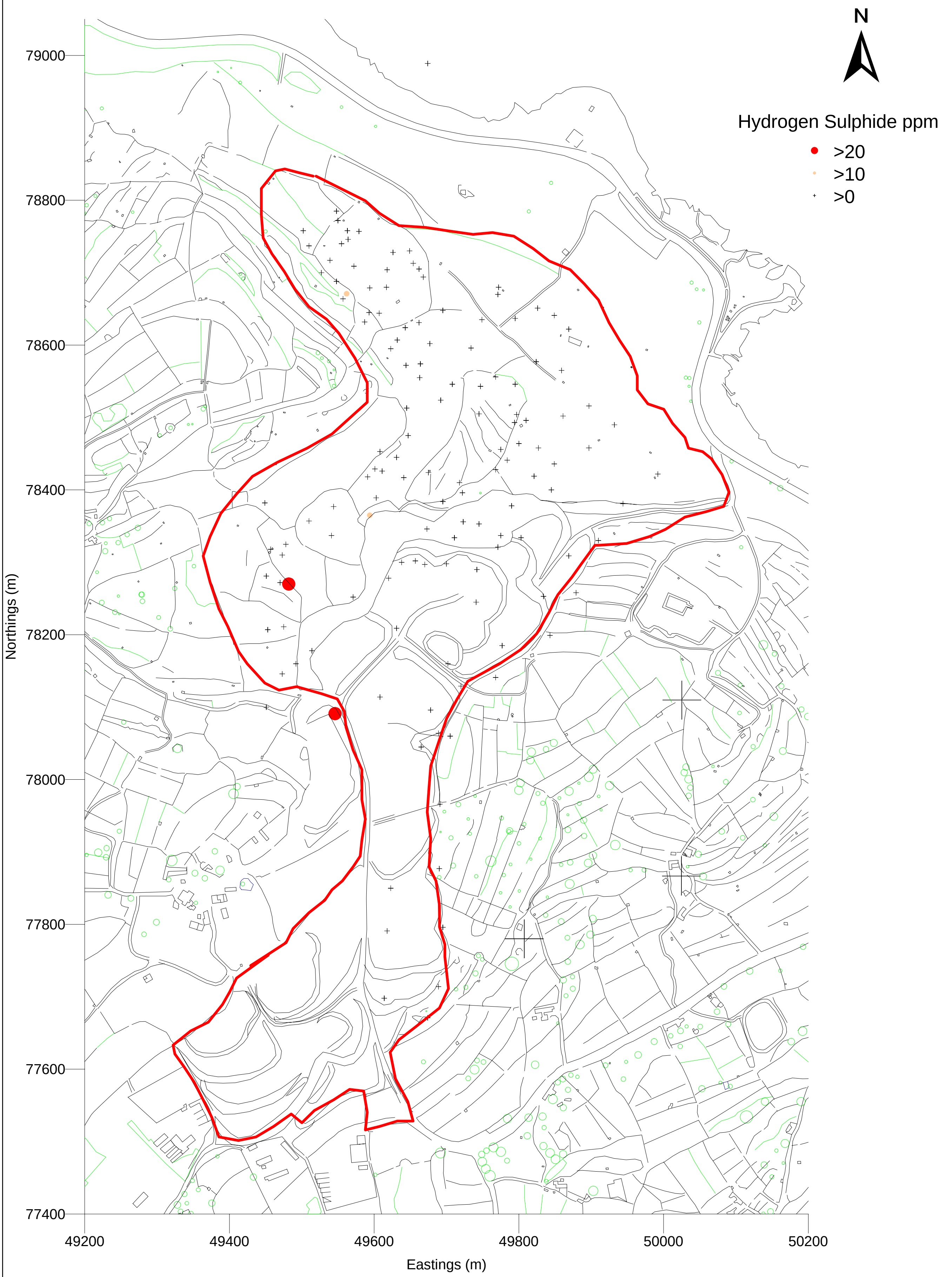


Drawing Title

Maghtab Landfill
Surface Gas Concentrations

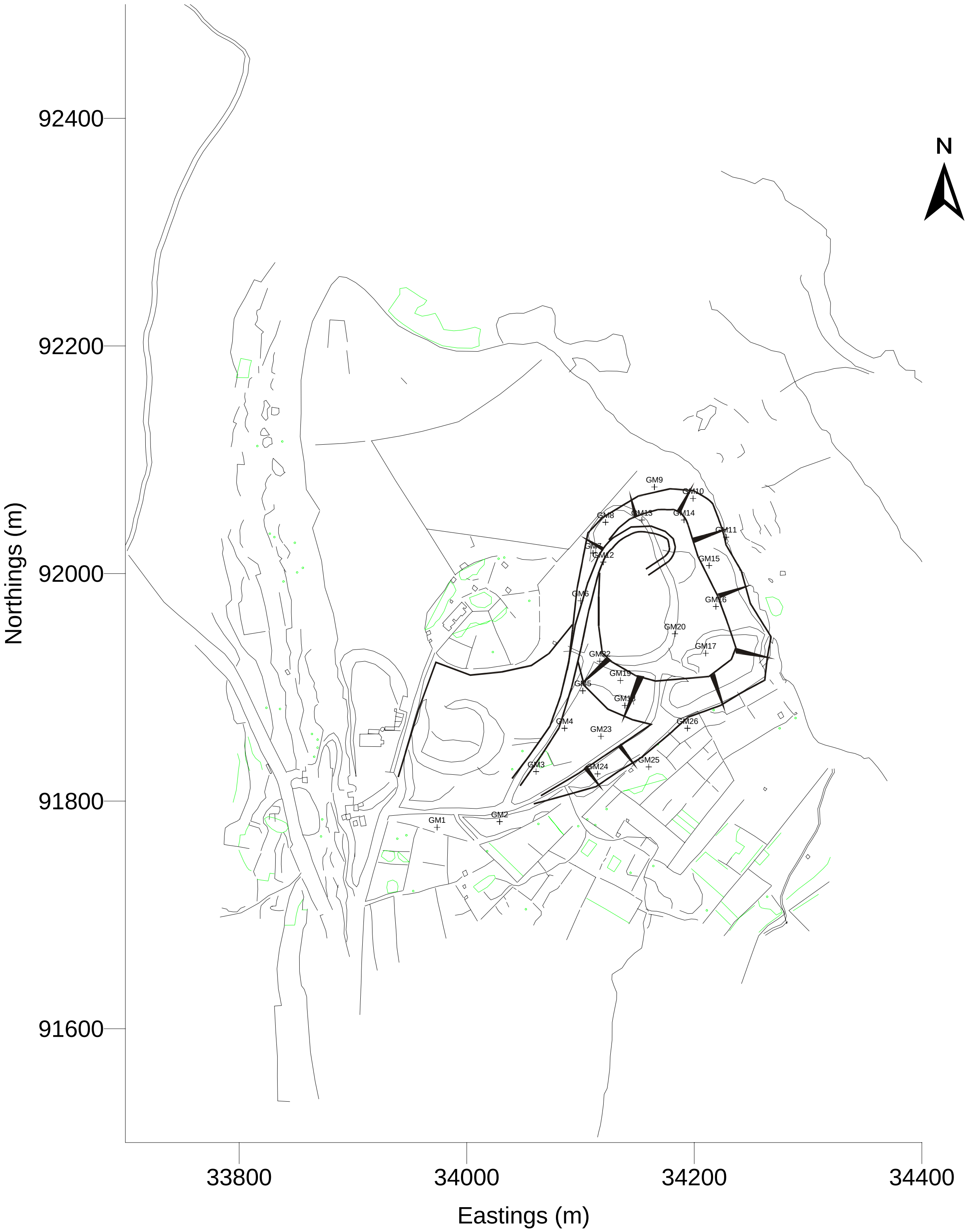
Figure No. 3.12		
Scale at A4 : As Shown		
Drawn IMC	Approved –	Revised
Checked –	Date 07/10/02	Date

Scott Wilson



Drawing Title	Figure No. 3.13		
Maghtab Landfill Surface Gas Concentrations	Scale at A4 : As Shown		
	Drawn IMC	Approved _	Revised
	Checked _	Date 07/10/02	Date

Scott Wilson



Drawing Title

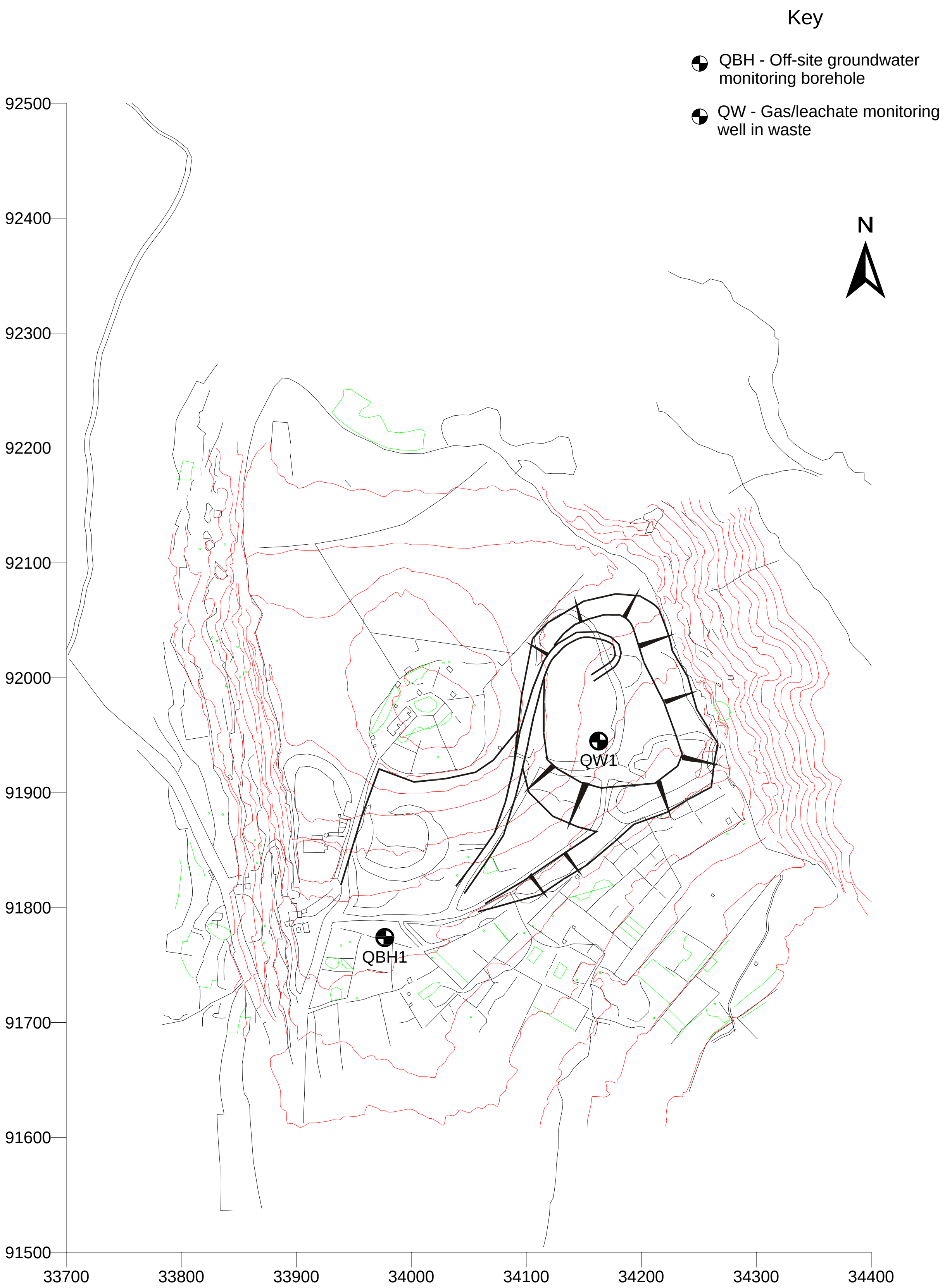
Qortin Landfill
Surface Gas/Temperature Monitoring Locations

Figure No 4.1

Scale at A4 : As Shown

Drawn IMC	Approved –	Revised
Checked –	Date 07/10/02	Date

Scott Wilson



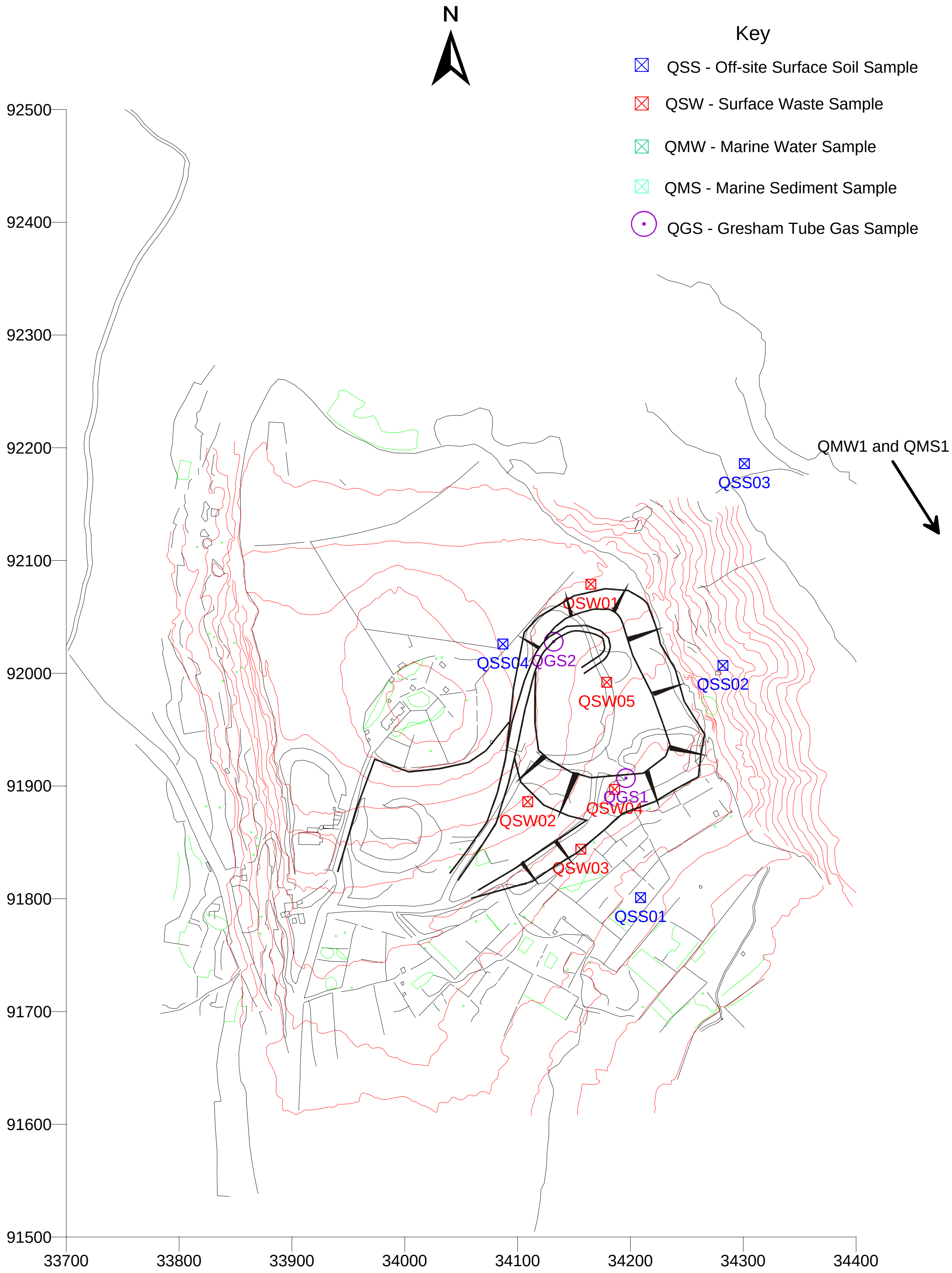
Drawing Title

Qortin Borehole Location Plan

Figure No. 4.2

Scale at A4 : As Shown

Drawn IMC	Approved _	Revised
Checked _	Date 07/10/02	Date

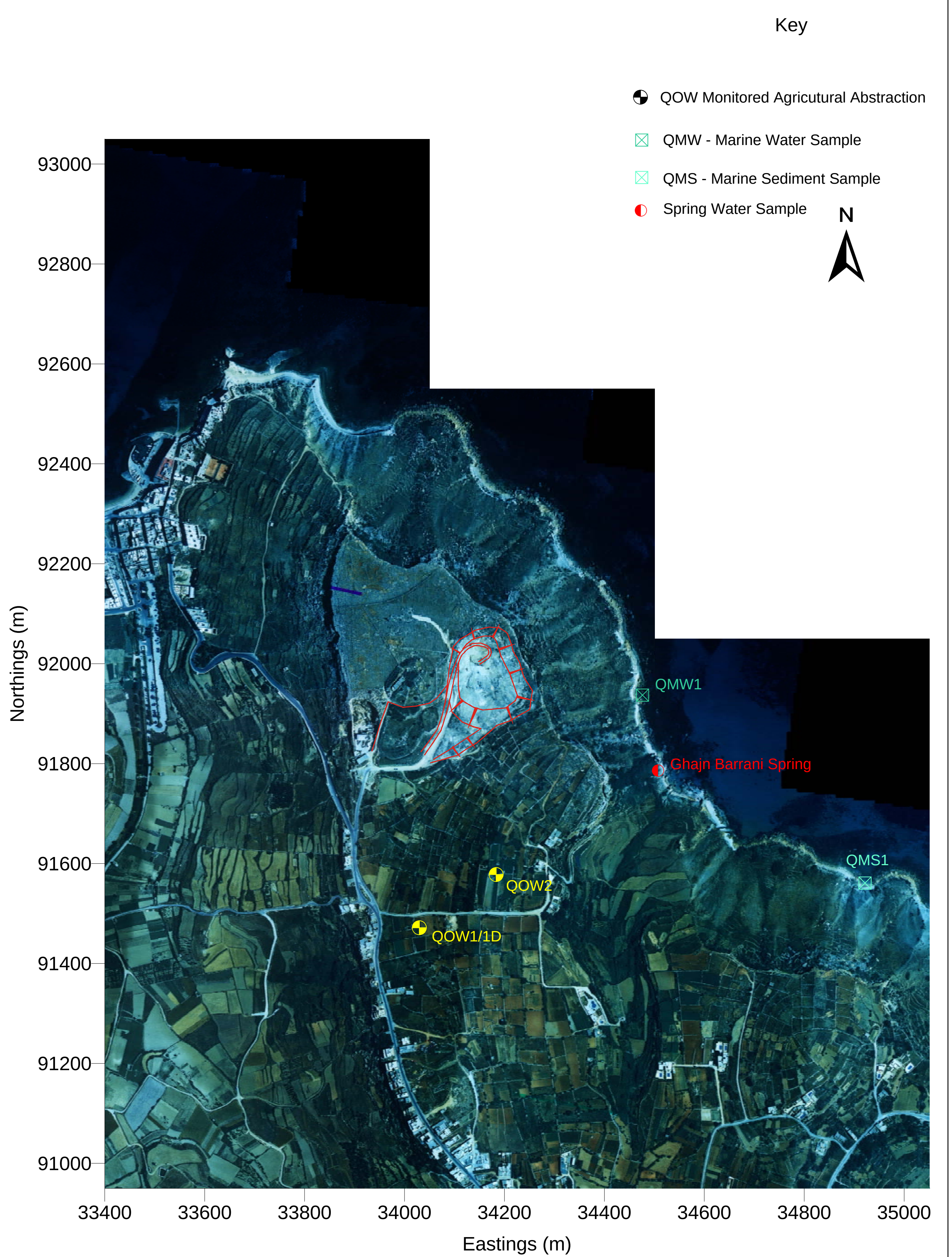


Drawing Title

Qortin Landfil
Surface Sampling Locations

Figure No. 4.3		
Scale at A4 : As Shown		
Drawn IMC	Approved –	Revised
Checked –	Date 07/10/02	Date

Scott Wilson



Drawing Title

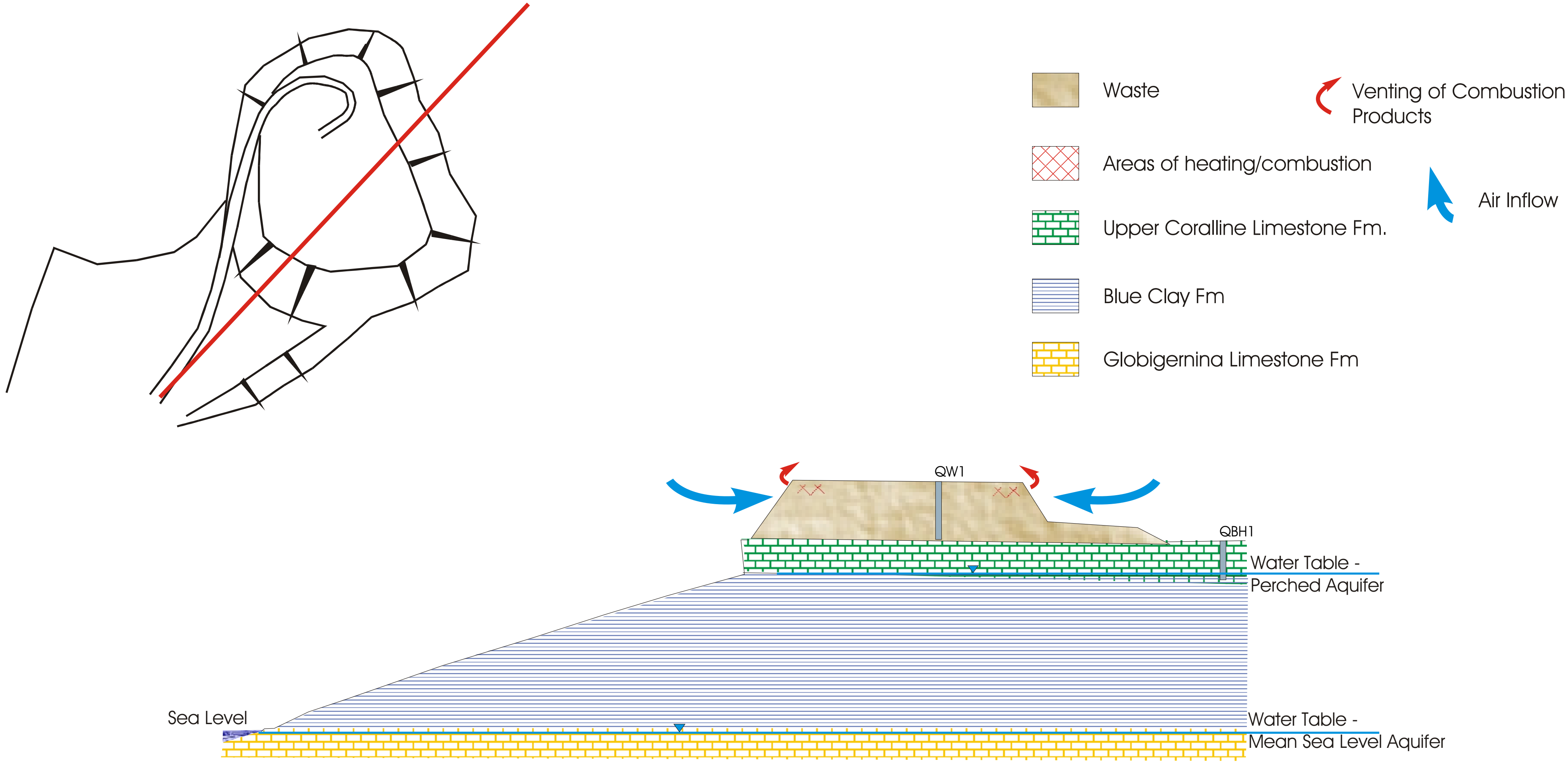
Qortin Off-site
Sampling Locations

Figure No 4.4

Scale at A4 : As Shown

Drawn IMC	Approved _	Revised
Checked _	Date 07/10/02	Date

Scott Wilson

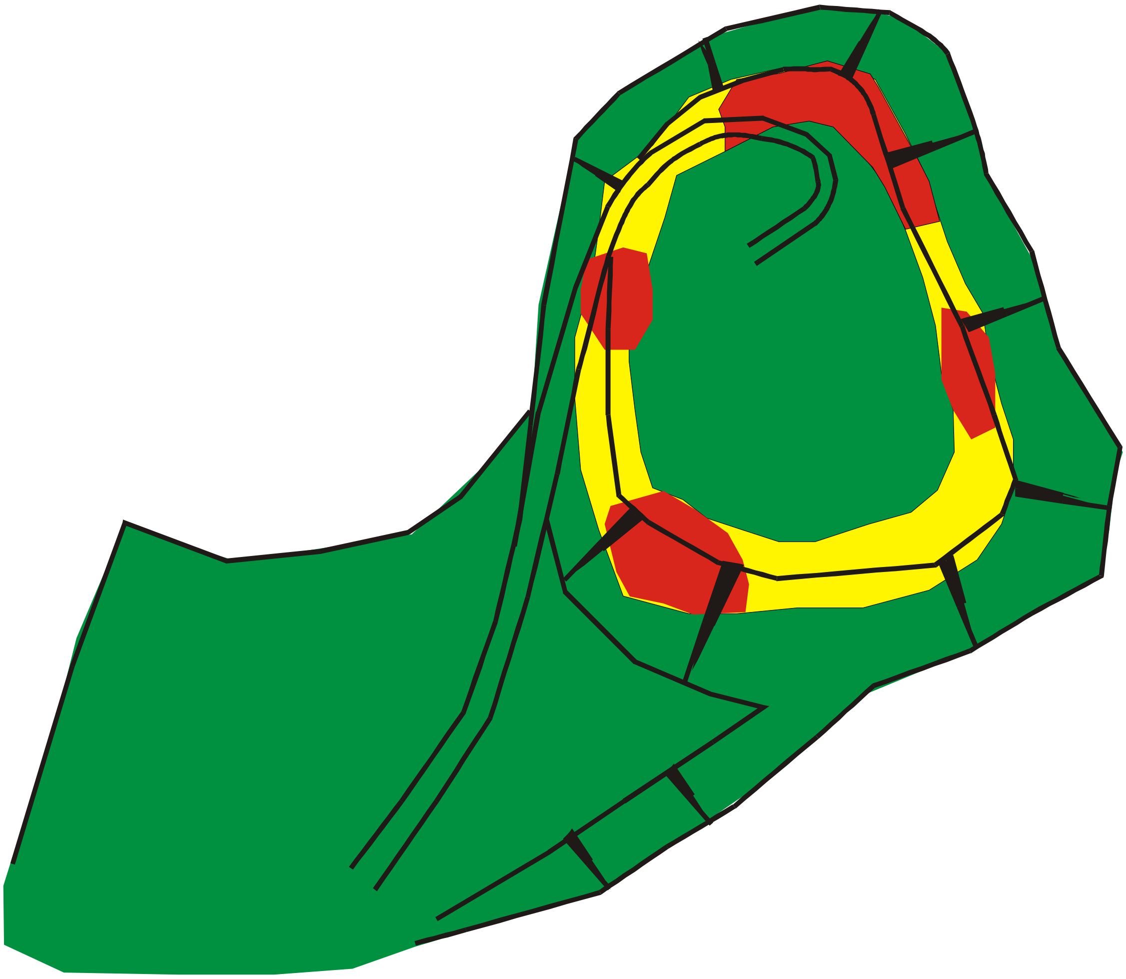


Drawing Title

Qortin Landfill: Conceptual Site Model

Figure No 4.5		
Scale at A4 : NTS		
Drawn IMC	Approved	Revised
Checked	Date 18/11/02	Date

Scott Wilson



Red	Probable Combustion
Yellow	Possible Combustion?
Green	No evidence of significant combustion

Drawing Title

Qortin Landfill
Assessment of Combustion

Figure No 4.6

Scale at A4 : NTS

Drawn IMC	Approved	Revised
Checked	Date 15/11/02	Date

Scott Wilson

Drawing Title

Qortin Landfill
Surface Gas Monitoring

Figure No. 4.7

Scale at A4 : As Shown

Drawn IMC	Approved –	Revised
Checked –	Date 07/10/02	Date

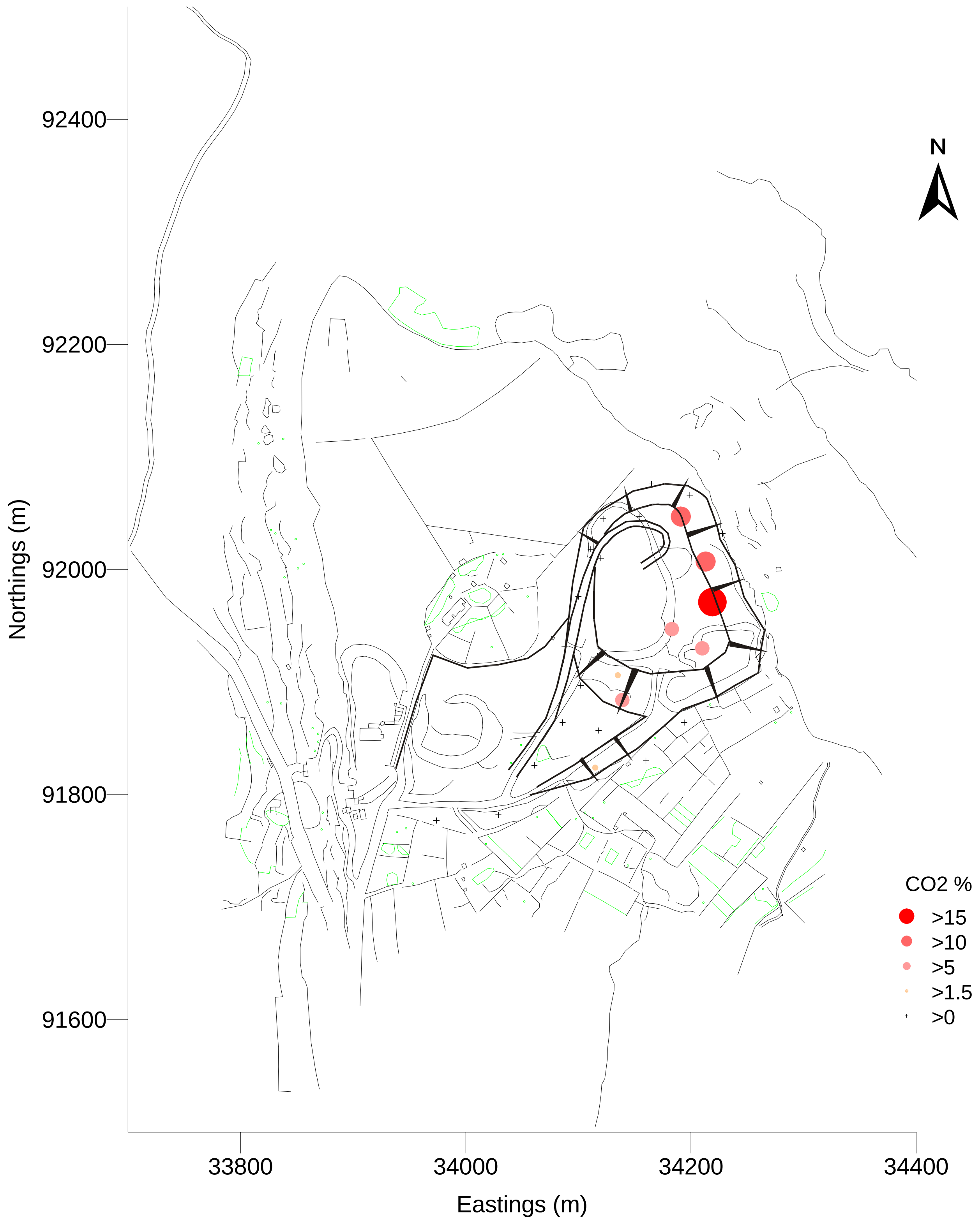
Scott Wilson

Drawing Title

Qortin Landfill
Surface Gas Monitoring

Figure No. 4.8		
Scale at A4 : As Shown		
Drawn IMC	Approved _	Revised
Checked _	Date 07/10/02	Date

Scott Wilson



Drawing Title

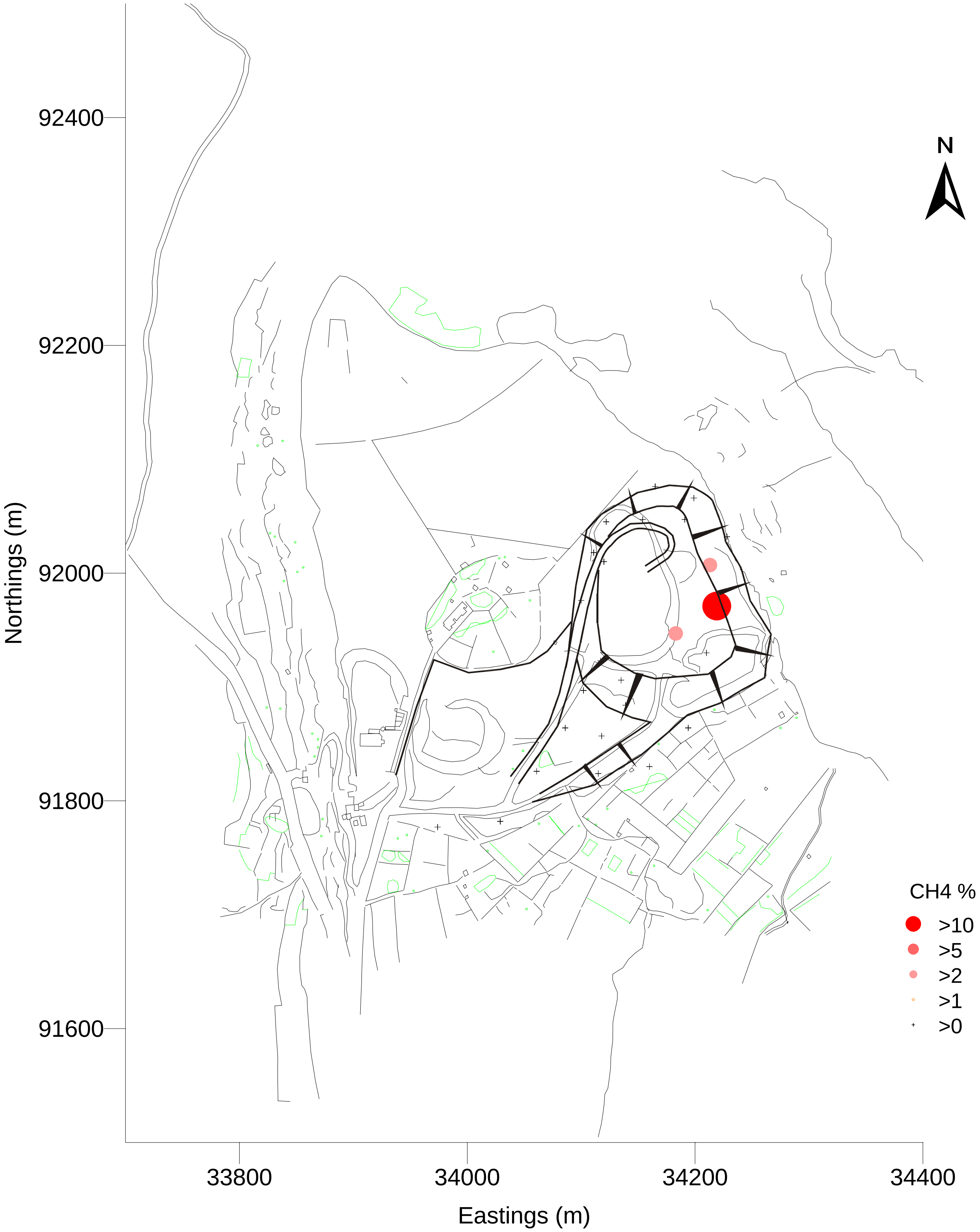
Qortin Landfill
Surface Gas Monitoring

Figure No. 4.9

Scale at A4 : As Shown

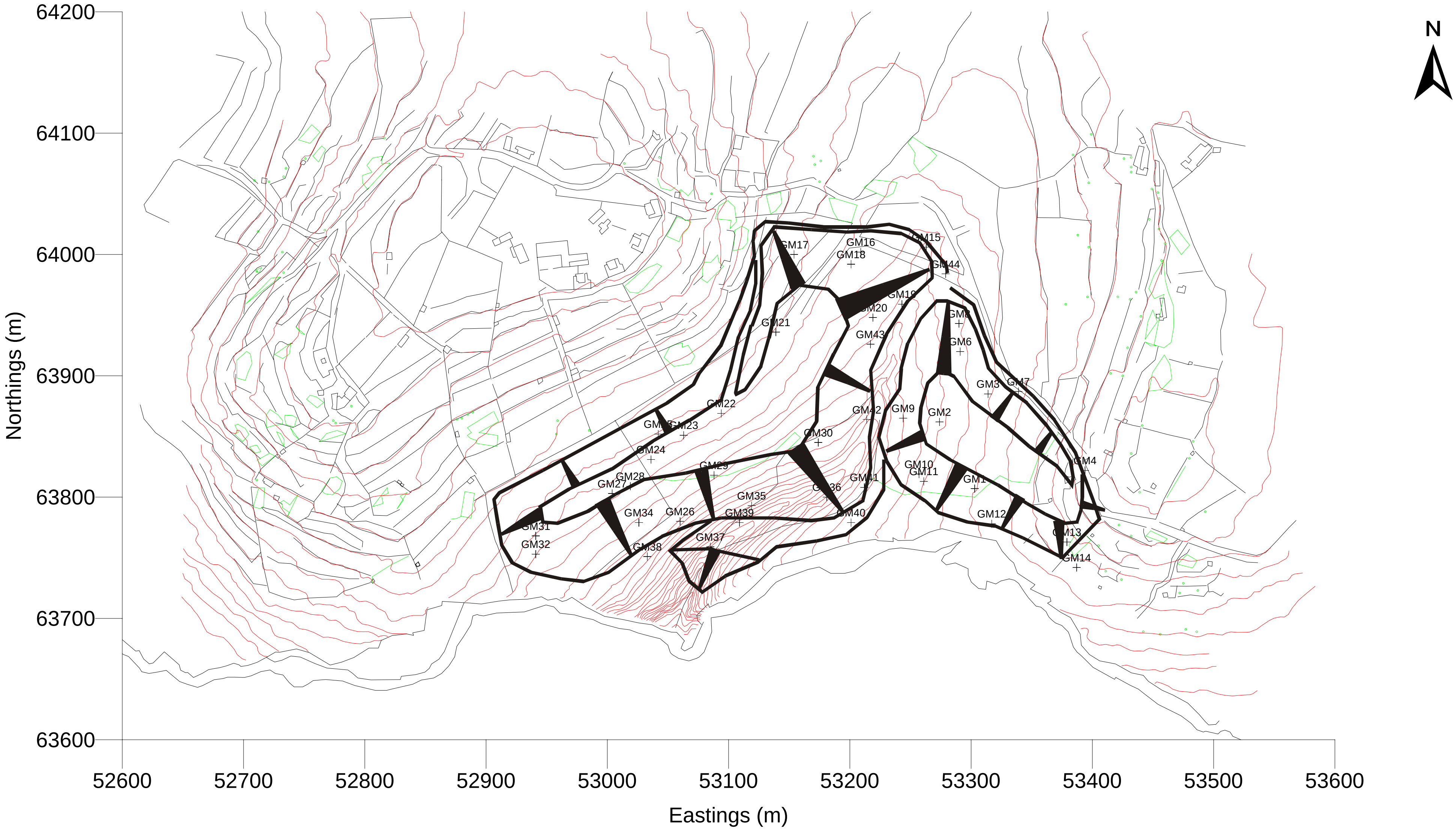
Drawn IMC	Approved _	Revised
Checked _	Date 07/10/02	Date

Scott Wilson



Drawing Title	Figure No. 4.10		
Qortin Landfill Surface Gas Monitoring	Scale at A4 : As Shown		
	Drawn IMC	Approved _	Revised
	Checked _	Date 07/10/02	Date

Scott Wilson

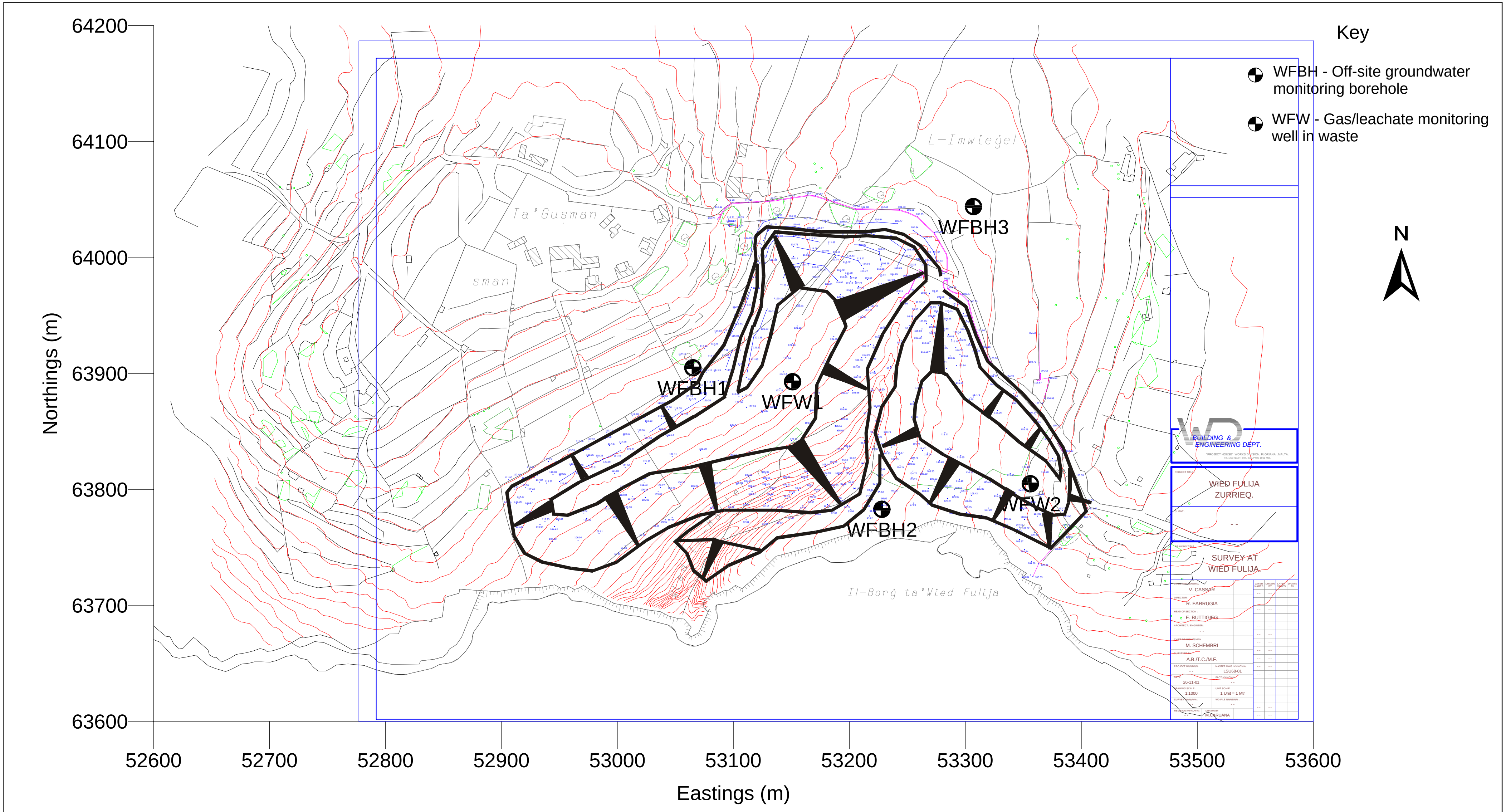


Drawing Title

Wied Fulija
Surface Gas/Temperature
Monitoring Locations

Figure No 5.1		
Scale at A4 : As Shown		
Drawn IMC	Approved	Revised
Checked	Date 07/10/02	Date

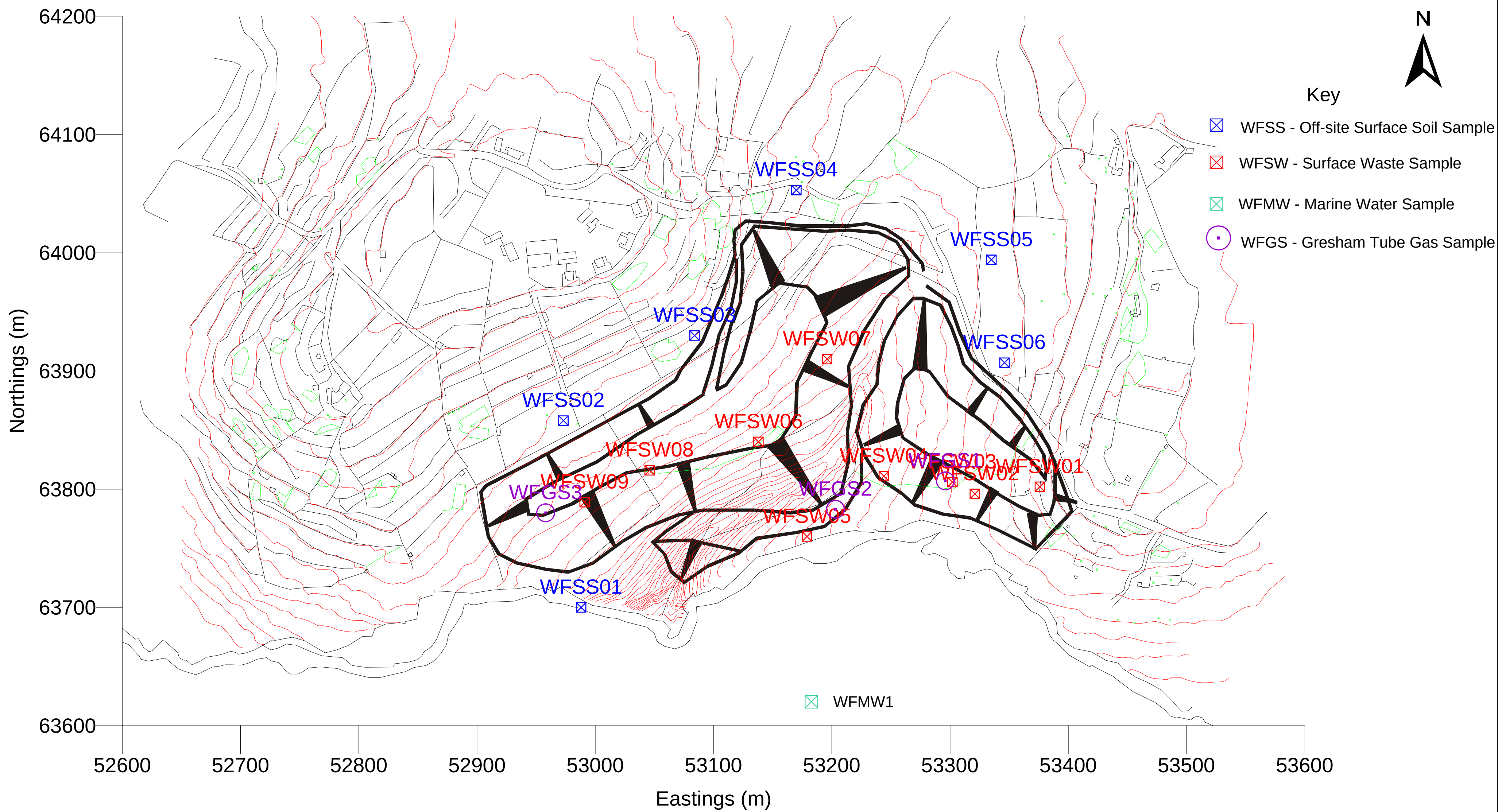
Scott Wilson



Drawing Title

Wied Fulija
Borehole Location Plan

Figure No. 5.2		
Scale at A4 As Shown		
Drawn IMC	Approved	Revised
Checked	Date 07/10/02	Date



Drawing Title

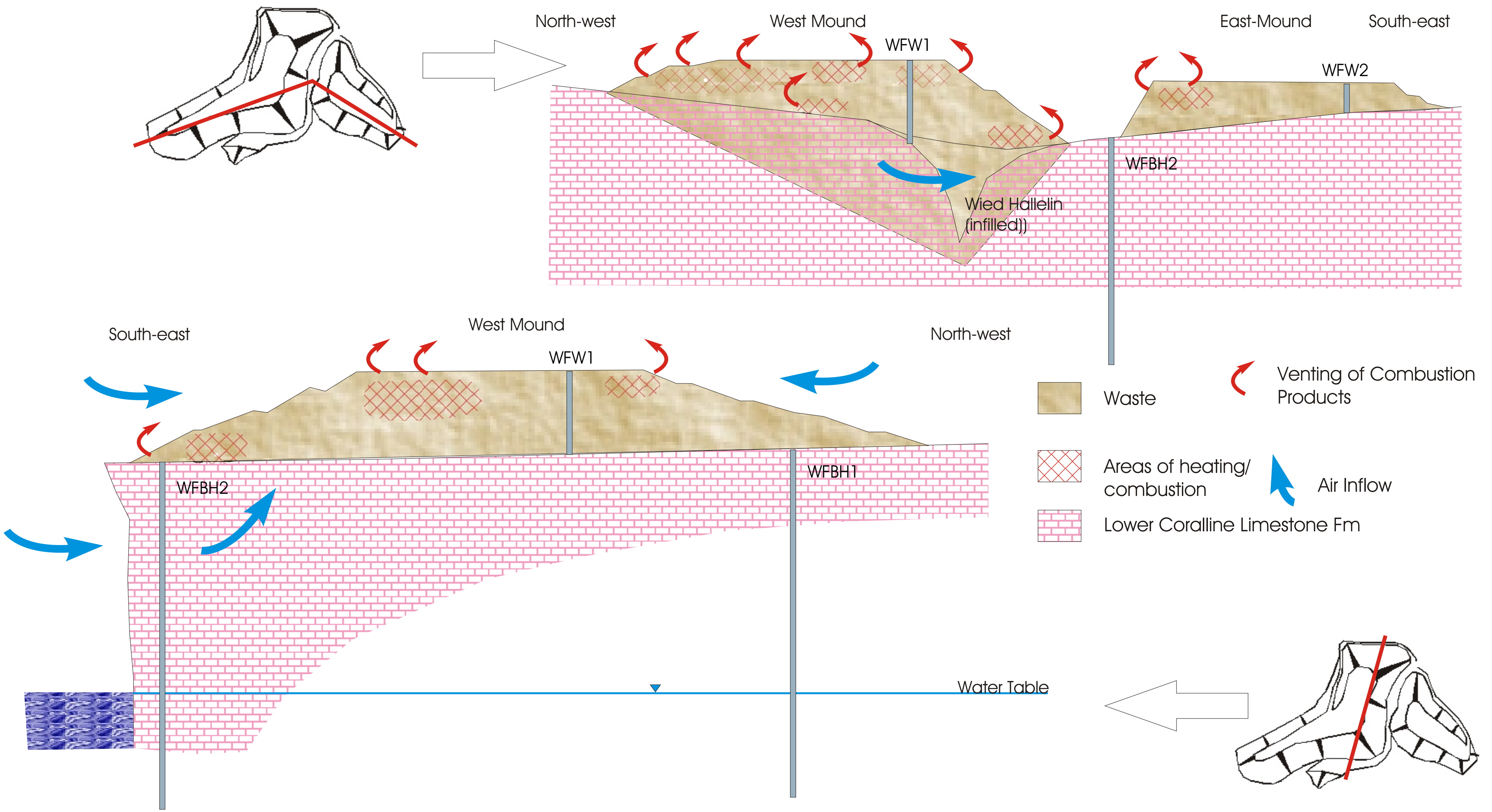
Wied Fulija Landfill
Surface Sampling Locations

Figure No. 5.3

Scale at A4 : As Shown

Drawn	Approved	Revised
IMC	–	
Checked	**Date**	**Date**
–	07/10/02	

Scott Wilson

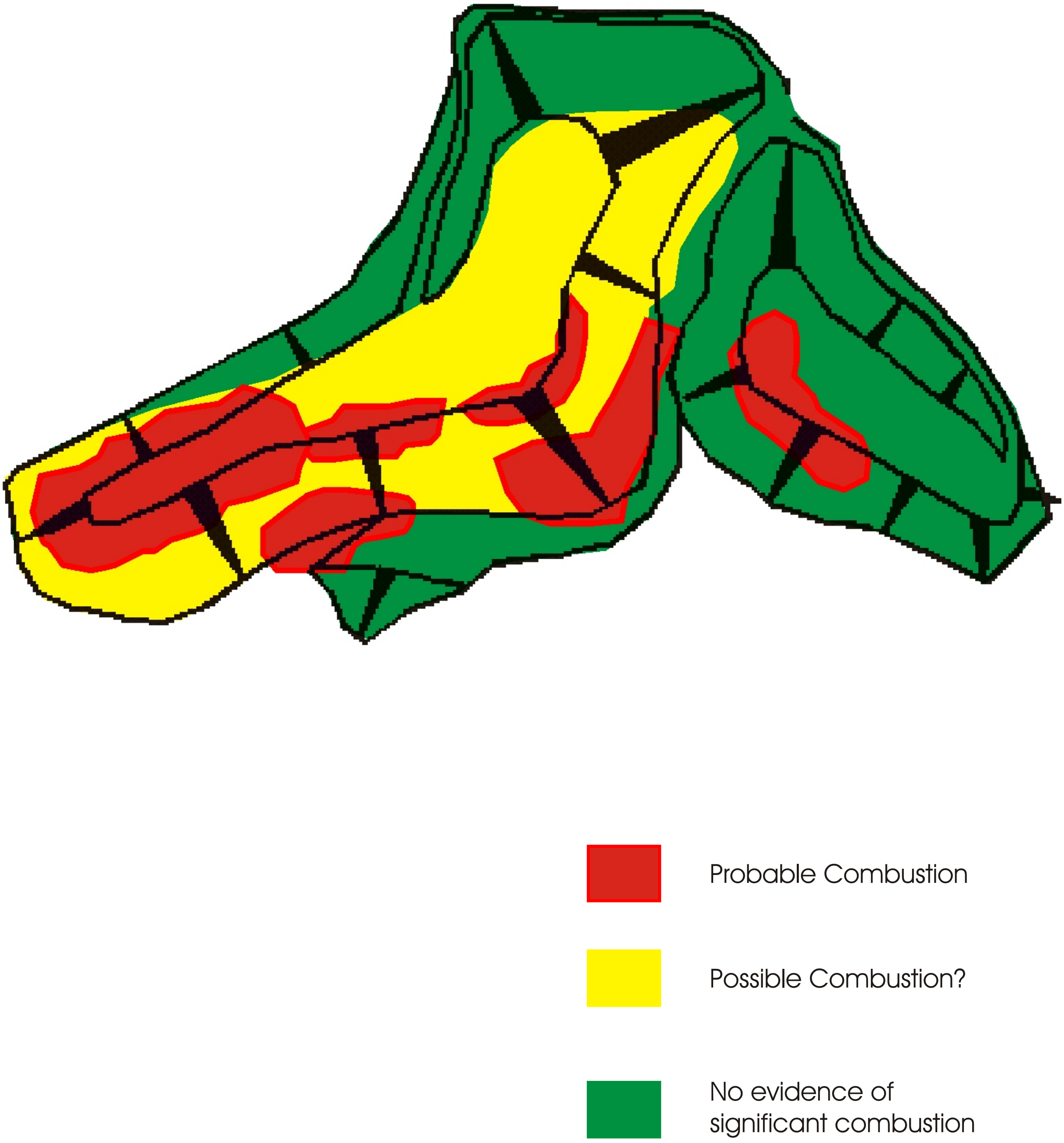


Drawing Title

Wied Fulija Landfill: Conceptual Site Model

Figure No 5.4		
Scale at A4 : NTS		
Drawn IMC	Approved	Revised
Checked	Date 18/11/02	Date

Scott Wilson



Drawing Title

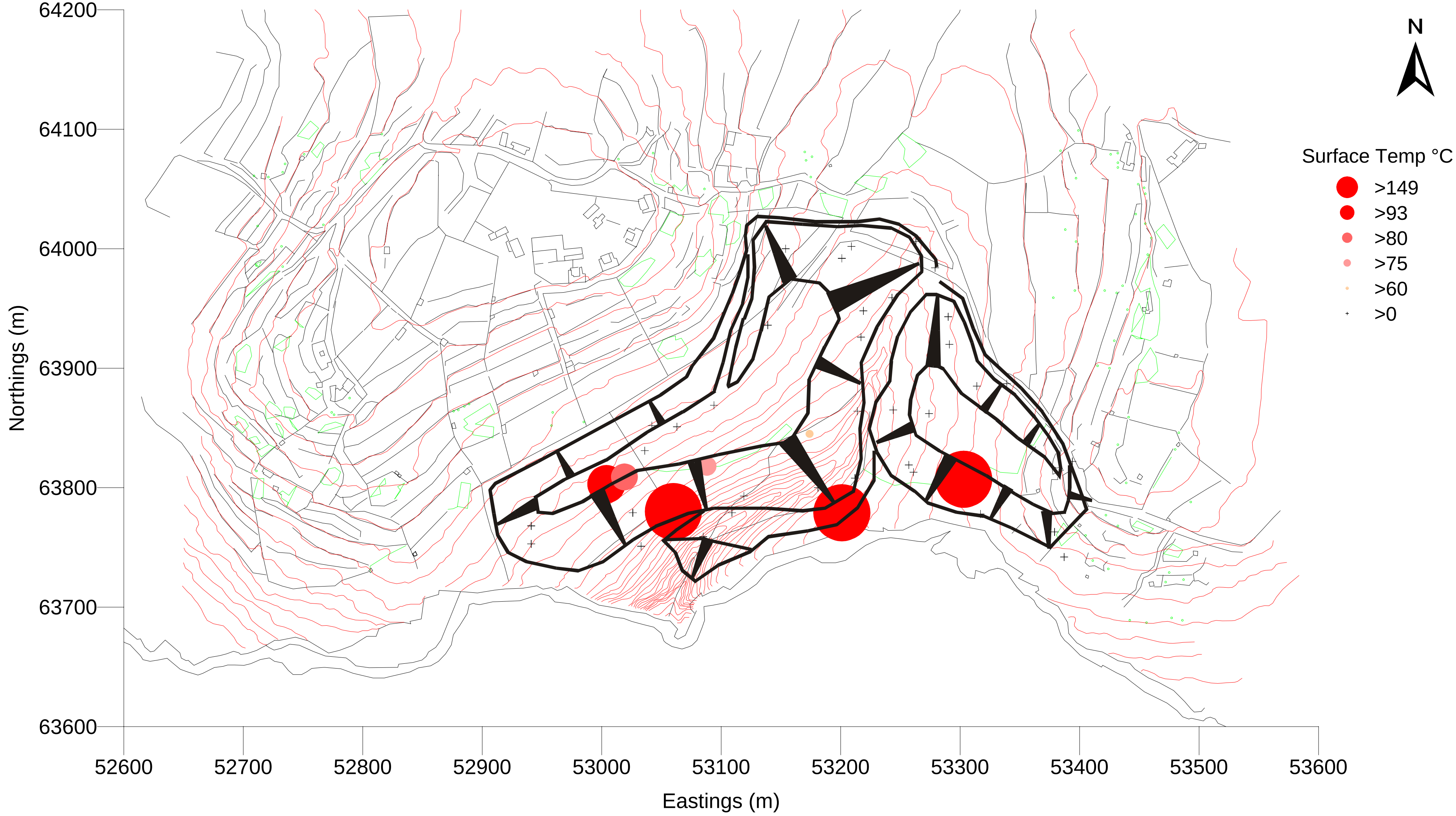
Wied Fulija Landfill
Assessment of Combustion

Figure No 5.5

Scale at A4 : NTS

Drawn IMC	Approved	Revised
Checked	Date 15/11/02	Date

Scott Wilson

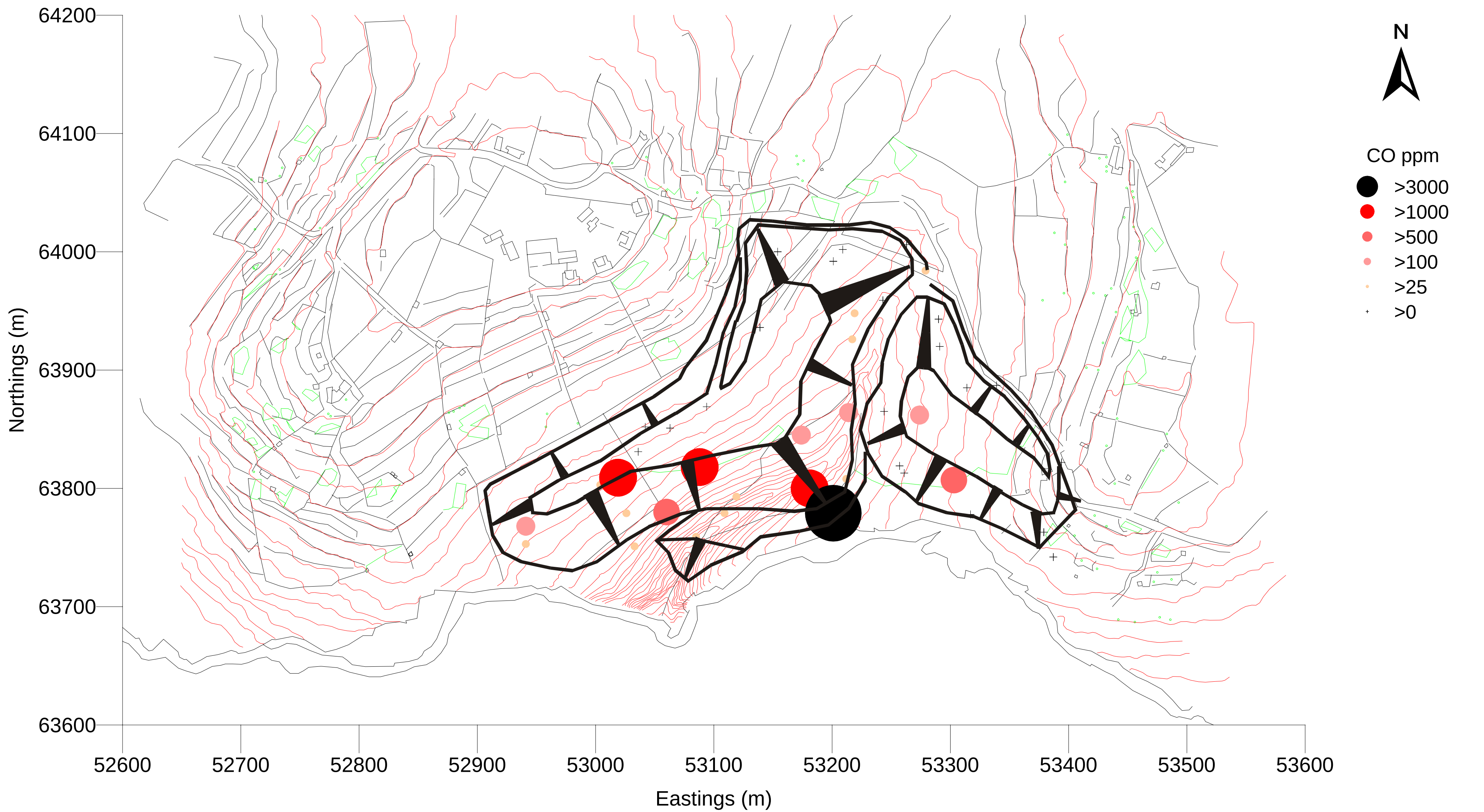


Drawing Title

Wied Fulija
Surface Gas Concentrations

Figure No. 5.6		
Scale at A4 As Shown		
Drawn IMC	Approved	Revised
Checked	Date 07/10/02	Date

Scott Wilson



Drawing Title

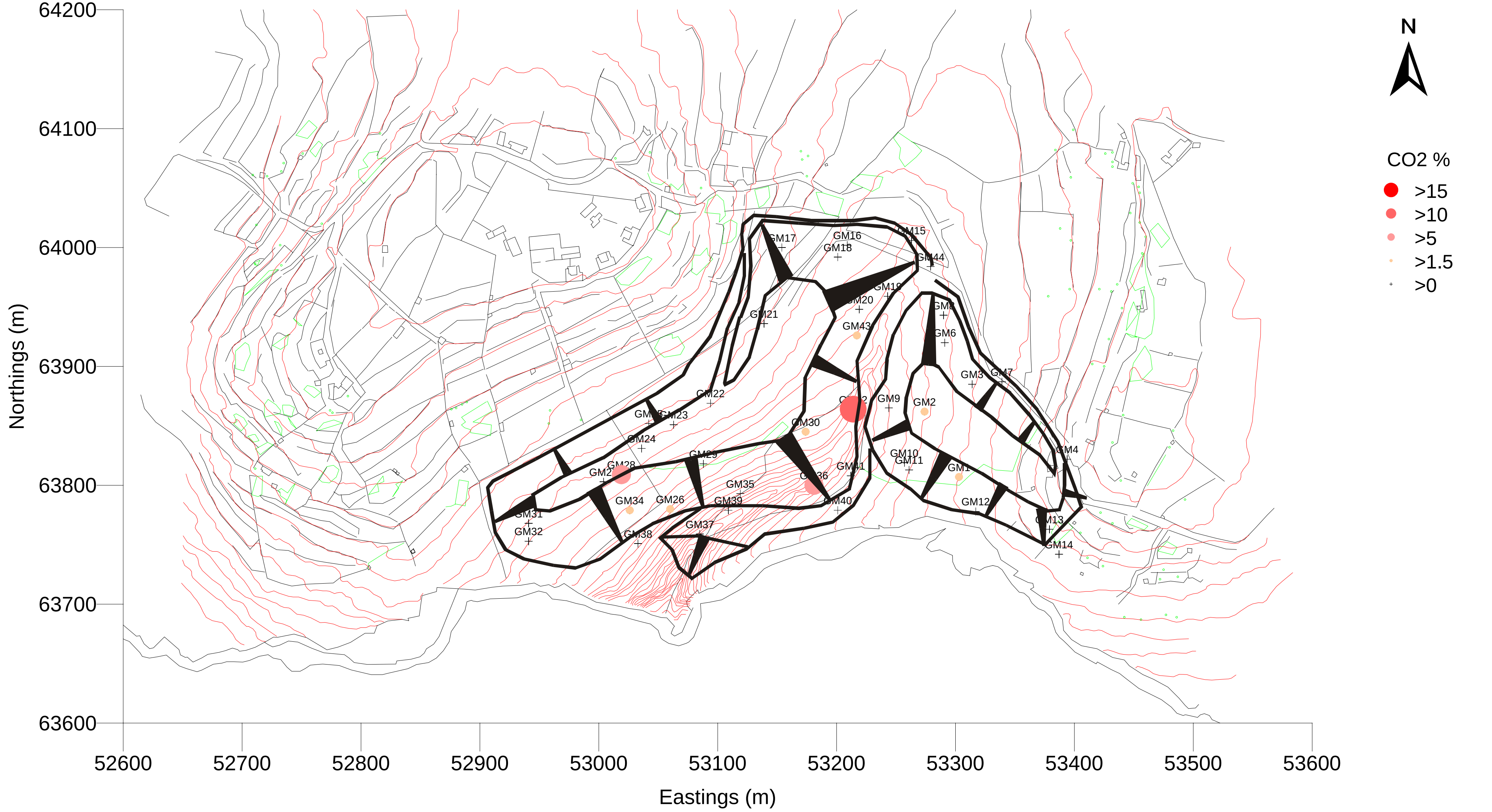
Wied Fulija
Surface Gas Concentrations

Figure No. 5.7

Scale at A4 As Shown

Drawn	Approved	Revised
IMC	_	
Checked	Date	Date
_	07/10/02	

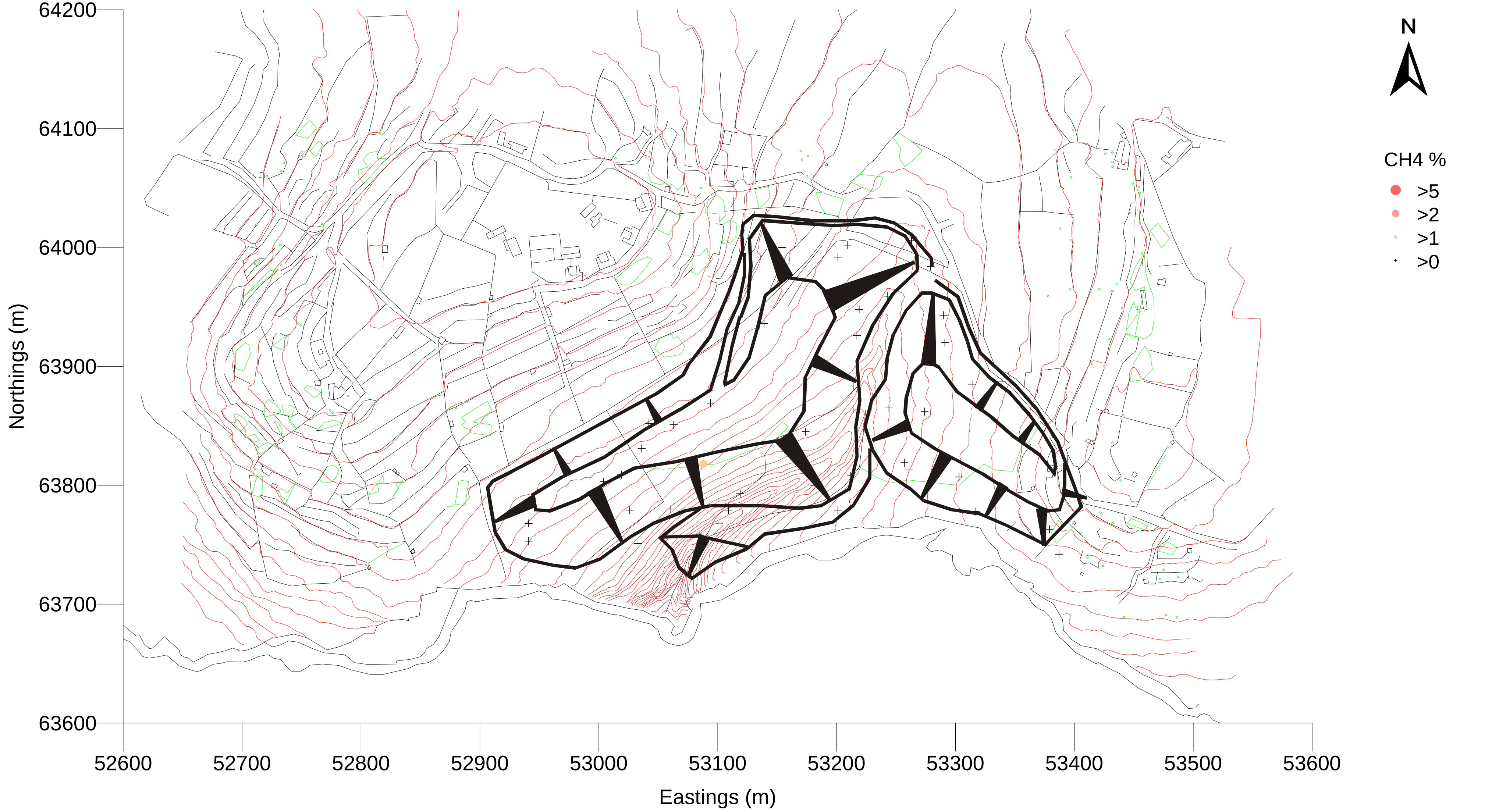
Scott Wilson



Drawing Title

Wied Fulija
Surface Gas Concentrations

Figure No. 5.8		
Scale at A4 : As Shown		
Drawn IMC	Approved	Revised
Checked	Date 07/10/02	Date

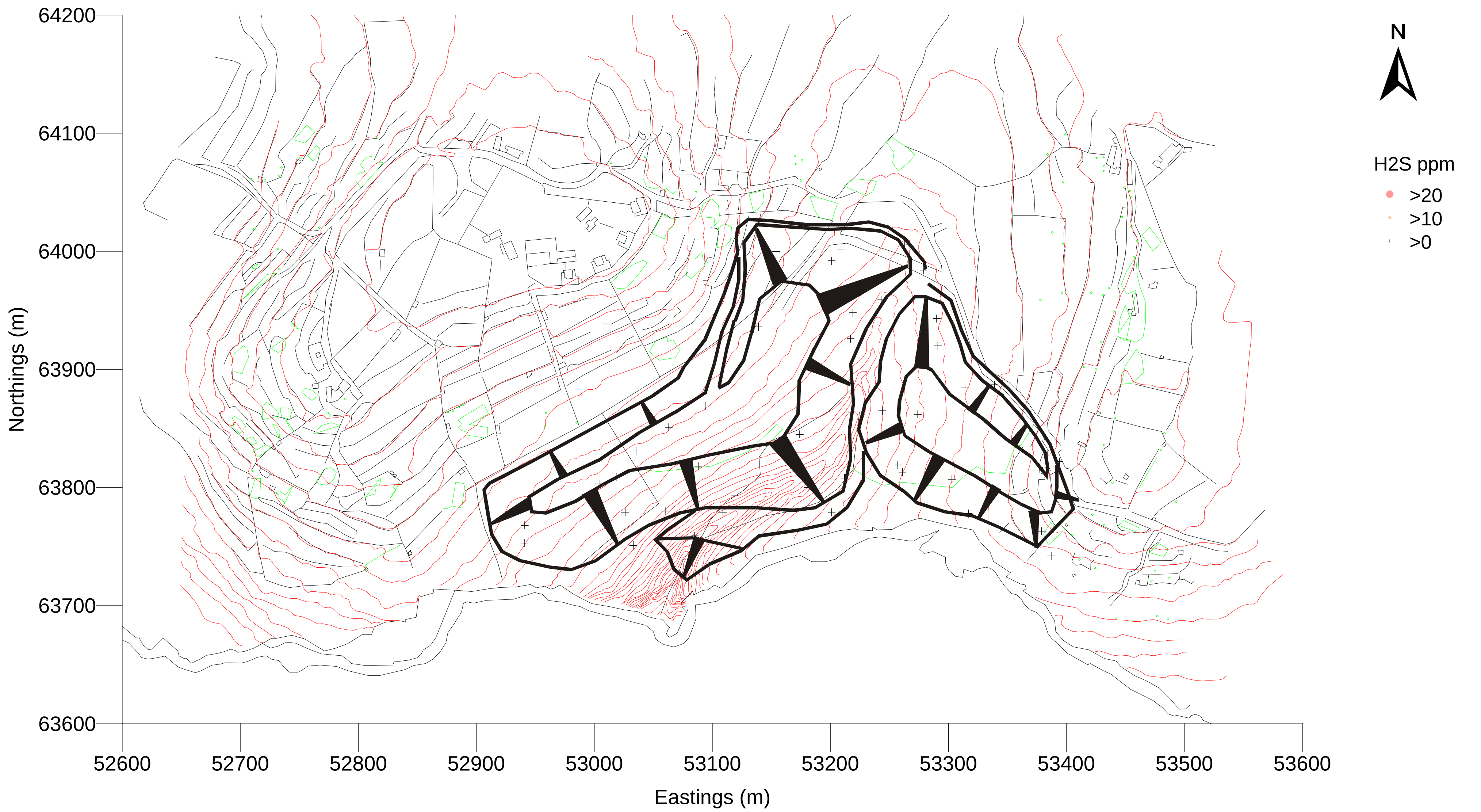


Drawing Title

Wied Fulija
Surface Gas Concentrations

Figure No. 5.9		
Scale at A4 As Shown		
Drawn IMC	Approved	Revised
Checked	Date 07/10/02	Date

Scott Wilson



Drawing Title

Wied Fulija
Surface Gas Concentrations

Figure No. 5.10

Scale at A4	As Shown	
Drawn IMC	Approved _	Revised
Checked _	Date 07/10/02	Date

Scott Wilson

Plates

Plate 2.1: Thermal Surveying with Infrared Camera

Plate 2.2: Drilling Rig on Magħtab

Plate 2.3: Surface Gas Monitoring – Magħtab

Plate 2.4: Off-site Soil Sampling – Magħtab

Plate 2.5: Groundwater Sampling - Qortin

Plate 2.6: Groundwater Sampling from Agricultural Abstraction – Qortin

Plate 2.7: Gresham Sampling – Magħtab

Plate 2.8: High Volume Sampler (MHVS1) - Magħtab

Plate 3.1: Combustion venting and waste settlement – Magħtab north face

Plate 3.2: Condensate around combustion vent – Magħtab west face

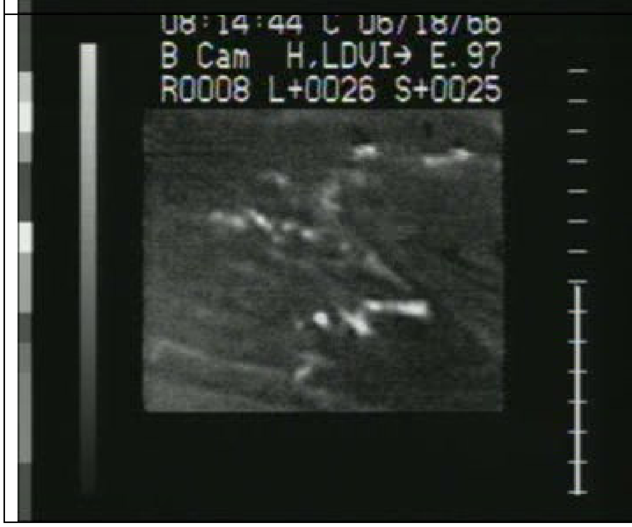
Plate 3.3: Thermal Survey North Face of Magħtab

	a) Aerial view of north face showing locations of photos b) and c)
	b) heating on western side of north face extending to low levels. Note lack of heating in older waste at base.
	c) extension of b) showing heating more restricted to upper layers of waste on eastern side of N face.

Plate 3.4: Thermal Survey West Side of Magħtab

a) Aerial view of west side of Magħtab showing locations of photos b) and c)

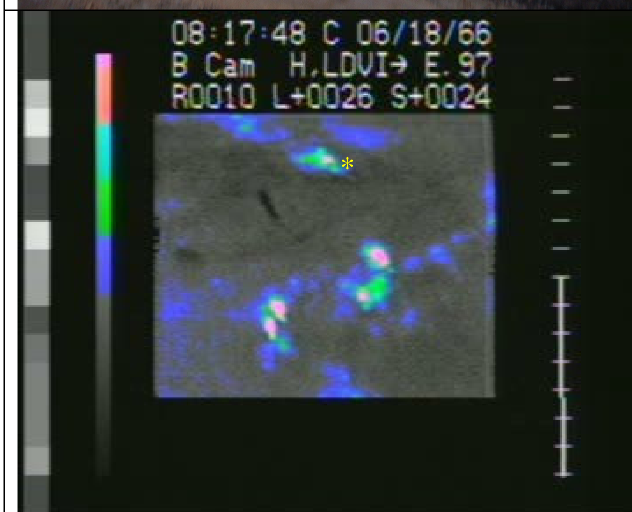
b) heating on upper layers of western side



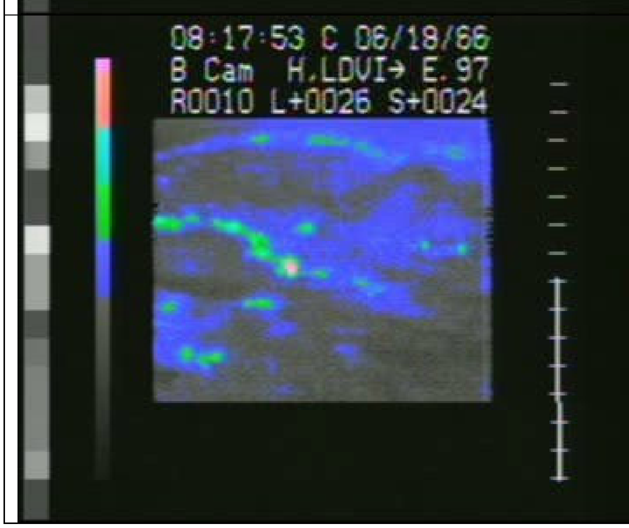
c) heating on upper layers of north-west (Għallis) ridge

Plate 3.5: Thermal Survey Top of Magħtab

a) Aerial view of top of Magħtab showing locations of photos b) and c)



b) heating on upper layers of western side and top of landfill. Area marked (*) was site of major vent in June 2002 and site of large fire in July 2002 when overtipped with fresh waste

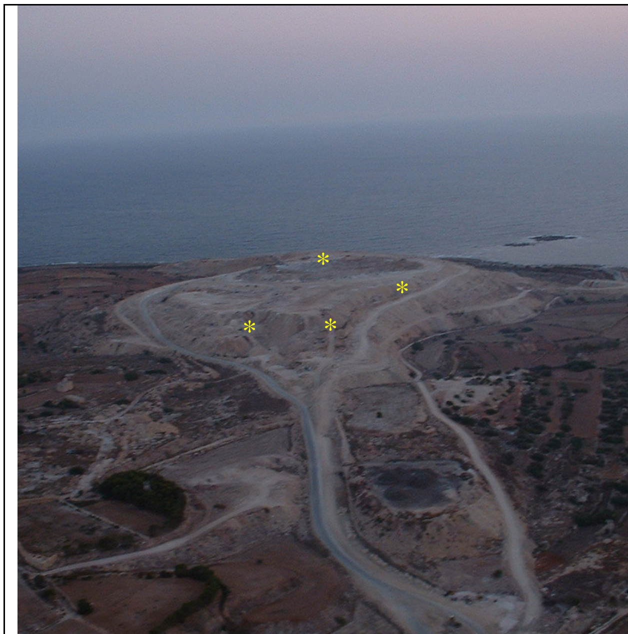


c) heating under area of recent waste deposition on top of Magħtab. Note curved lines of heat corresponding to areas of waste buried as waste deposition front moves.

Plate 3.6: Thermal Survey East Side of Magħtab

	a) Aerial view of eastern side of Magħtab showing locations of photos b) and c)
	b) heating along side of main haul road on eastern side of landfill
	c) heating under area of recent waste deposition on top of Magħtab. Note curved lines of heat corresponding to areas of waste buried as waste deposition front moves.

Plate 3.7: Thermal Survey South Side of Magħtab



a) Aerial view of south side of Magħtab. Asterisks denote areas of heating in photo b)

b) limited heating on southern side and top of landfill

Plate 4.1: Thermal Survey Qortin

a) Aerial view of Qortin showing locations of photos b) and c)

b) very limited heating along north-western crest of Qortin (site of some cracking and minor venting)

c) limited heating under north-eastern crest of Qortin (site of cracking and venting).

Plate 4.2: Qortin from Għajn Barrani showing Upper Coralline Limestone overlying Blue Clay with Globigerina Limestone at sea level.

Plate 4.3: Qortin from base of Upper Coralline Limestone scarp
(Note Tal-Pitkal Member overhanging Mtarfa and Għajn Melel Members and detached blocks of limestone)

Plate 4.4: Qortin from west (Note cambering of Upper Coralline Limestone plateau)

Plate 5.1: Thermal Survey Wied Fulija – East Mound

	a) Aerial view of east mound at Wied Fulija. Asterisks show locations of heating in photo b).
	b) limited heating along south-western crest of east mound (site of some cracking and minor venting)

Plate 5.2: Thermal Survey Wied Fulija - West Mound

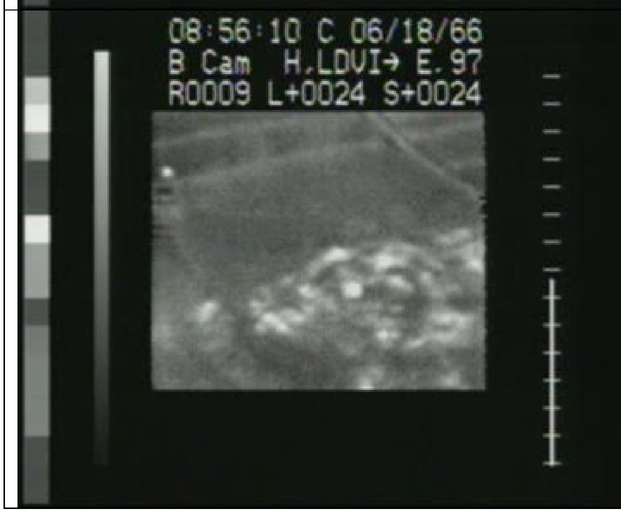
a) Aerial view of Qortin showing locations of photos b) - e). Note cliff overhang and infilled valley of Wied Ħallelin.

b) heating on crest and on base of south-eastern corner of west mound.

c) heating on centre of west mound.

Plate 5.2: Continued

d) Top of western end of west mound



e) western end of west mound

Appendix A
Drilling Records

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Scott Wilson Kirkpatrick & Co. Ltd.
Bayheath House, Rose Hill West, Chesterfield, Derbyshire. S40 1JF England
Tel: +44 (0) 1246 209221 Fax: +44 (0) 1246 209229

Contract:	Contract No:	Date: 22.07.02 / Date Commenced: 22.07.02	Sheet No:	Ground Level (m):
Maghtab Landfill Site	M1022		1 of 4	Not Known

Drilling Method:	Drilling Equipment/Rig No:	Drilling/Casing Diam (mm):	Bit Type:	Flush Type:
Rotary	FLT Rig	150mm to 3mbgl	Tungsten Carbide	Water

Borehole No	Angle of Hole	Strata Thickness (m)		Description of Strata	Depth of Casing (m)	Flush Return (%)	Final Depth Borehole (m)
		From	To				
MBH1	90°	GL	3	Fill/construction material	3	50	3

Comments:
Mobilise rig, set up and install casing to rockhead level at 3mbgl.

Hours Worked on Site			Remarks: Standing Time/Weather Conditions/Groundwater etc:	Signed for Scott Wilson Ltd.
From	To	Total		
0630	1530	9	Sunny and clear with light winds	Signed for by Client:

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Contract: Maghtab Landfill Site	Contract No: M1022	Date: 23.07.02 Date Commenced: 22.07.02	Sheet No: 2 of 4	Ground Level (m): Not Known

Drilling Method: Rotary	Drilling Equipment/Rig No: FLT Rig	Drilling/Casing Diam (mm): 150mm to 3mbgl	Bit Type: Tungsten Carbide	Flush Type: Water

Borehole No	Angle of Hole	Strata Thickness (m)		Description of Strata	Depth of Casing (m)	Flush Return (%)	Final Depth Borehole (m)
		From	To				
MBH1	90^{o}	3	20	Coralline Limestone	3	50	20

Comments:

Hours Worked on Site		
From	To	Total
0630	1530	9

Remarks: Standing Time/Weather Conditions/Groundwater etc:

Sunny and clear with light winds

Signed for Scott Wilson Ltd.

Signed for by Client:

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Contract:	Contract No:	Date:	Sheet No:	Ground Level (m):
Maghtab Landfill Site	M1022	24.07.02 Date Commenced: 22.07.02	3 of 4	Not Known

Drilling Method:	Drilling Equipment/Rig No:	Drilling/Casing Diam (mm):	Bit Type:	Flush Type:
Rotary	FLT Rig	150mm to 3mbgl	Tungsten Carbide	Water

Borehole No	Angle of Hole	Strata Thickness (m) From	Strata Thickness (m) To	Description of Strata	Depth of Casing (m)	Flush Return (%)	Final Depth Borehole (m)
MBH1	90°	20	40	Coralline Limestone	3	60	40

Comments:
(1000 - 1200hrs) FLT Rig Breakdown (MBH1 at 25mbgl). Mechanic called to site.
(1200hrs) Drilling resumed.
(1330hrs) MBH1 terminated at 40mbgl.

Hours Worked on Site From	To	Total	Remarks: Standing Time/Weather Conditions/Groundwater etc:	Signed for Scott Wilson Ltd.
0630	1330	7	Sunny and clear with light winds. Delays: See above Comments.	Signed for by Client:

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Contract:	Contract No:	Date:	Date Commenced:	Sheet No:	Ground Level (m):
Maghtab Landfill Site	M1022	08.08.02	25.07.02	4 of 4	Not Known

Drilling Method:	Drilling Equipment/Rig No:	Drilling/Casing Diam (mm):	Bit Type:	Flush Type:
NA	FLT Rig	NA	NA	NA

Borehole No	Angle of Hole	Strata Thickness (m)		Description of Strata	Depth of Casing (m)	Flush Return (%)	Final Depth Borehole (m)
		From	To				
MBH1	90°	GL	37	Well installation	NA	NA	37

Comments:
Partial deterioration of hole accounting for hole depth of 37mbgl. UPVC well liner installed to 37mbgl (50mm dia. slotted standpipe from 37 to 2mbgl, plain standpipe from 2mbgl to 1magl). Gravel pack placed from 37 to 2mbgl and bentonite from 2mbgl to GL. On completion, place steel protection cover with concrete plinth at base and secure with padlock.
(1220hrs) GWL = 22.07mbgl, GW Temp = 20.2°C, Ambient Air Temp = 30.8°C.

Hours Worked on Site		
From	To	Total
1200	1530	3.5

Remarks: Standing Time/Weather Conditions/Groundwater etc:

Sunny and clear with light to moderate winds.

Signed for Scott Wilson Ltd.

Signed for by Client:

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Contract: Maghtab Landfill Site	Contract No: M1022	Date: 12.08.02 Date Commenced: 12.08.02	Sheet No: 1 of 3	Ground Level (m): Not Known

Drilling Method: Rotary	Drilling Equipment/Rig No: FLT Rig	Drilling/Casing Diam (mm): -	Bit Type: Tungsten Carbide	Flush Type: Water

Borehole No	Angle of Hole	Strata Thickness (m)		Description of Strata	Depth of Casing (m)	Flush Return (%)	Final Depth Borehole (m)
		From	To				
MBH2	90°	GL	38	Coralline Limestone	-	70	38
	90°	38	55	Coralline Limestone	-	0	55

Comments:

Hours Worked on Site			Remarks: Standing Time/Weather Conditions/Groundwater etc:	Signed for Scott Wilson Ltd.
From	To	Total		
1430	1730	3	Sunny and clear with light winds	Signed for by Client:

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Contract:	Contract No:	Date:	Sheet No:	Ground Level (m):
Maghtab Landfill Site	M1022	13.08.02 Date Commenced: 12.08.02	2 of 3	Not Known

Drilling Method:	Drilling Equipment/Rig No:	Drilling/Casing Diam (mm):	Bit Type:	Flush Type:
Rotary	FLT Rig		Tungsten Carbide	Water

Borehole No	Angle of Hole	Strata Thickness (m)		Description of Strata	Depth of Casing (m)	Flush Return (%)	Final Depth Borehole (m)
		From	To				
MBH2	90^{o}	55	71	Coralline Limestone	-	0	71

Comments:
(0800hrs) MBH2 terminated at 71mbgl.
Install UPVC well liner (50mm dia. slotted standpipe from 71 to 2mbgl and plain standpipe from 2mbgl to 1magl.
(0935hrs) GWL = 50.19mbgl, GW Temp = 20.2^{o}C, Ambient Air Temp = 30.1^{o}C.

Hours Worked on Site			Remarks: Standing Time/Weather Conditions/Groundwater etc:	Signed for Scott Wilson Ltd.
From	To	Total	Sunny and clear with light winds	Signed for by Client:
0630	1000	3.5		

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Contract: Maghtab Landfill Site	Contract No: M1022	Date: 20.08.02 Date Commenced: 12.08.02	Sheet No: 3 of 3	Ground Level (m): Not Known

Drilling Method: Rotary	Drilling Equipment/Rig No: FLT Rig	Drilling/Casing Diam (mm):	Bit Type: Tungsten Carbide	Flush Type: Water

Borehole No	Angle of Hole	Strata Thickness (m)		Description of Strata	Depth of Casing (m)	Flush Return (%)	Final Depth Borehole (m)
		From	To				
MBH2	90°	-	-	Well installation	-	NA	71

Comments:
Check hole depth; no deterioration.
Complete well installation: place gravel pack from 71mbgl to 2mbgl and bentonite from 2mbgl to GL. On completion, place steel protection cover with concrete plinth at base and secure with padlock.

Hours Worked on Site			Remarks: Standing Time/Weather Conditions/Groundwater etc:	Signed for Scott Wilson Ltd.
From	To	Total		
0700	0930	2.5	Sunny and clear with light winds.	Signed for by Client:

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Contract: Maghtab Landfill Site	Contract No: M1022	Date: 29.07.02 Date Commenced: 29.07.02	Sheet No: 1 of 4	Ground Level (m): Not Known

Drilling Method: Rotary	Drilling Equipment/Rig No: FLT Rig	Drilling/Casing Diam (mm): 150mm to 5mbgl	Bit Type: Tungsten Carbide	Flush Type: Water

Borehole No	Angle of Hole	Strata Thickness (m)		Description of Strata	Depth of Casing (m)	Flush Return (%)	Final Depth Borehole (m)
		From	To				
MBH3	90^{o}	GL	5	Fill/construction material	6	100	-
		5	6	Coralline Limestone	6	100	6

Comments:
(0900hrs) FLT Rig repaired and on site. Set up and install casing to rockhead level at 6mbgl.
(1400hrs) FLT Rig breakdown (engine). MBH3 at 6mbgl. Work postponed.

Hours Worked on Site		
From	To	Total
0900	1530	6.5

Remarks: Standing Time/Weather Conditions/Groundwater etc:

Sunny and clear with light winds
Delays: See above Comments.

Signed for Scott Wilson Ltd.

Signed for by Client:

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Contract: Maghtab Landfill Site	Contract No: M1022	Date: 12.08.02 Date Commenced: 29.07.02	Sheet No: 2 of 4	Ground Level (m): Not Known

Drilling Method: Rotary	Drilling Equipment/Rig No: FLT Rig	Drilling/Casing Diam (mm): 150mm to 5mbgl.	Bit Type: Tungsten Carbide	Flush Type: Water

Borehole No	Angle of Hole	Strata Thickness (m)		Description of Strata	Depth of Casing (m)	Flush Return (%)	Final Depth Borehole (m)
		From	To				
MBH3	90^o	6	7	Coralline Limestone	6	100	-
		7	8.5	Coralline Limestone	6	100	-
		8.5	10.5	Globigerina Limestone	6	100	-
		10.5	30	Coralline Limestone	6	60	-
		30	50	Coralline Limestone	6	0	50

Comments:
(0800hrs) FLT Rig repaired, set up at MBH3 location and resume open hole drilling operations.
'Very hard' limestone band encountered between 7 and 8mbgl.
(1430hrs) MBH3 terminated at 50mbgl.
(1015hrs) GWL = 36.64mbgl, GW Temp = 23.4^{o}C, Ambient Air Temp = 31.9^{o}C.

Hours Worked on Site			Remarks: Standing Time/Weather Conditions/Groundwater etc:	Signed for Scott Wilson Ltd.
From	To	Total	Sunny and clear with light winds	Signed for by Client:
0800	1430	7		

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Contract:	Contract No:	Date:	Sheet No:	Ground Level (m):
Maghtab Landfill Site	M1022	13.08.02 Date Commenced: 29.07.02	3 of 4	Not Known

Drilling Method:	Drilling Equipment/Rig No:	Drilling/Casing Diam (mm):	Bit Type:	Flush Type:
Rotary	FLT Rig	150mm to 5mbgl	Tungsten Carbide	Water

Borehole No	Angle of Hole	Strata Thickness (m)		Description of Strata	Depth of Casing (m)	Flush Return (%)	Final Depth Borehole (m)
		From	To				
MBH3	90^{o}	-	-	Well installation	6	NA	50

Comments:
Check hole depth; no deterioration.
Install UPVC well liner (50mm dia. slotted standpipe from 50 to 2mbgl and plain standpipe from 2mbgl to 1magl).

Hours Worked on Site			Remarks: Standing Time/Weather Conditions/Groundwater etc:	Signed for Scott Wilson Ltd.
From	To	Total		
0930	1130	2	Sunny and clear with light winds.	Signed for by Client:

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Contract: Maghtab Landfill Site	Contract No: M1022	Date: 19.08.02 Date Commenced: 29.07..02	Sheet No: 4 of 4	Ground Level (m): Not Known

Drilling Method: Rotary	Drilling Equipment/Rig No: FLT Rig	Drilling/Casing Diam (mm):	Bit Type: Tungsten Carbide	Flush Type: Water

Borehole No	Angle of Hole	Strata Thickness (m)		Description of Strata	Depth of Casing (m)	Flush Return (%)	Final Depth Borehole (m)
		From	To				
MBH3	90^{o}	-	-	Well installation	-	NA	50

Comments:
Check hole depth; no deterioration.
Complete well installation: place gravel pack from 50 to 2mbgl and bentonite from 2mbgl to GL. On completion, place steel protection cover with concrete plinth at base and secure with padlock.

Hours Worked on Site			Remarks: Standing Time/Weather Conditions/Groundwater etc:	Signed for Scott Wilson Ltd.
From	To	Total	Sunny and clear with light winds.	
1230	1400	0.5		Signed for by Client:

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Contract:	Contract No:	Date:	Sheet No:	Ground Level (m):
Maghtab Landfill Site	M1022	13.08.02 Date Commenced: 13.08.02	1 of 2	Not Known

Drilling Method:	Drilling Equipment/Rig No:	Drilling/Casing Diam (mm):	Bit Type:	Flush Type:
Rotary	FLT Rig	-	Tungsten Carbide	Water

Borehole No	Angle of Hole	Strata Thickness (m)		Description of Strata	Depth of Casing (m)	Flush Return (%)	Final Depth Borehole (m)
		From	To				
MBH4	90^{o}	GL	1.5	Overburden – Sand	1.5	80	1.5
		1.5	15	Coralline Limestone	1.5	80	50

Comments:
(0800 - 0900) Mobilise, set up rig and install casing to rock head level at 1.5mbgl.
(1015hrs) MBH4 terminated at 15mbgl.
Install UPVC well liner (50mm dia. slotted standpipe from 15 to 2mbgl and plain standpipe from 2mbgl to 1magl).
(1015hrs) GWL = 3.64mbgl, GW Temp = 26.2^{o}C, Ambient Air Temp = 33.6^{o}C.

Hours Worked on Site			Remarks: Standing Time/Weather Conditions/Groundwater etc:	Signed for Scott Wilson Ltd.
From	To	Total		
0800	1100	3	Sunny and clear with light winds.	Signed for by Client:

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Contract:	Contract No:	Date:	Sheet No:	Ground Level (m):
Maghtab Landfill Site	M1022	19.08.02 Date Commenced: 13.08.02	2 of 2	Not Known

Drilling Method:	Drilling Equipment/Rig No:	Drilling/Casing Diam (mm):	Bit Type:	Flush Type:
Rotary	FLT Rig		Tungsten Carbide	Water

Borehole No	Angle of Hole	Strata Thickness (m)		Description of Strata	Depth of Casing (m)	Flush Return (%)	Final Depth Borehole (m)
		From	To				
MBH4	90^o	-	-	Well Installation	-	NA	15

Comments:
Check hole depth; no deterioration.
Complete well installation: place gravel pack from 15 to 2mbgl and bentonite from 2mbgl to GL. On completion, place steel protection cover with concrete plinth at base and secure with padlock.

Hours Worked on Site			Remarks: Standing Time/Weather Conditions/Groundwater etc:	Signed for Scott Wilson Ltd.
From	To	Total	Sunny and clear with light winds.	Signed for by Client:
1400	1430	0.5		

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Contract: Maghtab Landfill Site	Contract No: M1022	Date: 13.08.02 Date Commenced: 13.08.02	Sheet No: 1 of 3	Ground Level (m): Not Known

Drilling Method: Rotary	Drilling Equipment/Rig No: FLT Rig	Drilling/Casing Diam (mm): -	Bit Type: Tungsten Carbide	Flush Type: Water

Borehole No	Angle of Hole	Strata Thickness (m)		Description of Strata	Depth of Casing (m)	Flush Return (%)	Final Depth Borehole (m)
		From	To				
MBH5	90°	GL	0.5	Overburden - Sand	-	100	0.5
		0.5	20	Coralline Limestone	-	100	20

Comments:
(1015 - 1100) Mobilise and set up rig.
(1415hrs) MBH5 terminated at 20mbgl.

Hours Worked on Site		
From	To	Total
1015	1415	4

Remarks: Standing Time/Weather Conditions/Groundwater etc:

Sunny and clear with light winds

Signed for Scott Wilson Ltd.

Signed for by Client:

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Tel: +44 (0) 1246 209221 Fax: +44 (0) 1246 209229

Contract:	Contract No:	Date:	Sheet No:	Ground Level (m):
Maghtab Landfill Site	M1022	14.08.02 Date Commenced: 13.08.02	2 of 3	Not Known

Drilling Method:	Drilling Equipment/Rig No:	Drilling/Casing Diam (mm):	Bit Type:	Flush Type:
Rotary	FLT Rig		Tungsten Carbide	Water

Borehole No	Angle of Hole	Strata Thickness (m) From	Strata Thickness (m) To	Description of Strata	Depth of Casing (m)	Flush Return (%)	Final Depth Borehole (m)
MBH5	90°	-	-	Well Installation	-	NA	20

Comments:
Check hole depth; no deterioration.
Install UPVC well liner (50mm dia. slotted standpipe from 20 to 2mbgl and plain standpipe from 2mbgl to 1magl).
(0740hrs) GWL = 3.04mbgl, GW Temp = 21.3°C, Ambient Air Temp = 29.2°C.

Hours Worked on Site From	To	Total	Remarks: Standing Time/Weather Conditions/Groundwater etc:	Signed for Scott Wilson Ltd.
0700	0800	1	Sunny and clear with light winds.	Signed for by Client:

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Contract: Maghtab Landfill Site	Contract No: M1022	Date: 19.08.02 Date Commenced: 13.08.02	Sheet No: 3 of 3	Ground Level (m): Not Known

Drilling Method: Rotary	Drilling Equipment/Rig No: FLT Rig	Drilling/Casing Diam (mm):	Bit Type: Tungsten Carbide	Flush Type: Water

Borehole No	Angle of Hole	Strata Thickness (m)		Description of Strata	Depth of Casing (m)	Flush Return (%)	Final Depth Borehole (m)
		From	To				
MBH5	90°	-	-	Well Installation	-	NA	20

Comments:
Check hole depth; no deterioration.
Complete well installation: place gravel pack from 20 to 2mbgl and bentonite from 2mbgl to GL. On completion, place steel protection cover with concrete plinth at base and secure with padlock.

Hours Worked on Site		
From	To	Total
1430	1530	1

Remarks: Standing Time/Weather Conditions/Groundwater etc:

Sunny, clear with light winds.

Signed for Scott Wilson Ltd.

Signed for by Client:

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Contract: Maghtab Landfill Site	Contract No: M1022	Date: 13.08.02 Date Commenced: 13.08.02	Sheet No: 1 of 3	Ground Level (m): Not Known

Drilling Method: Rotary	Drilling Equipment/Rig No: FLT Rig	Drilling/Casing Diam (mm): -	Bit Type: Tungsten Carbide	Flush Type: Water

Borehole No	Angle of Hole	Strata Thickness (m)		Description of Strata	Depth of Casing (m)	Flush Return (%)	Final Depth Borehole (m)
		From	To				
MBH6	90^{o}	GL	34	Coralline Limestone	-	75	34

Comments:
(1415 - 1515) Mobilise and set up rig.
(1730hrs) MBH6 at 34mbgl. End of shift.

Hours Worked on Site			Remarks: Standing Time/Weather Conditions/Groundwater etc:	Signed for Scott Wilson Ltd.
From	To	Total		
1415	1730	3.15	Sunny and clear with light winds	Signed for by Client:

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Contract: Maghtab Landfill Site	Contract No: M1022	Date: 14.08.02 Date Commenced: 13.08.02	Sheet No: 2 of 3	Ground Level (m): Not Known

Drilling Method: Rotary	Drilling Equipment/Rig No: FLT Rig	Drilling/Casing Diam (mm):	Bit Type: Tungsten Carbide	Flush Type: Water

Borehole No	Angle of Hole	Strata Thickness (m)		Description of Strata	Depth of Casing (m)	Flush Return (%)	Final Depth Borehole (m)
		From	To				
MBH6	90°	34	57	Coralline Limestone	-	75	57

Comments:
(0850hrs) MBH6 terminated at 57mbgl.
(1630hrs) GWL = 40.89mbgl, GW Temp = 20.2°C, Ambient Air Temp = 30.7°C.

Hours Worked on Site			Remarks: Standing Time/Weather Conditions/Groundwater etc:	Signed for Scott Wilson Ltd.
From	To	Total	Sunny and clear with light winds.	Signed for by Client:
0630	0845	2.15		

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Contract: Maghtab Landfill Site	Contract No: M1022	Date: 19.08.02 Date Commenced: 13.08.02	Sheet No: 3 of 3	Ground Level (m): Not Known

Drilling Method: Rotary	Drilling Equipment/Rig No: FLT Rig	Drilling/Casing Diam (mm):	Bit Type: Tungsten Carbide	Flush Type: Water

Borehole No	Angle of Hole	Strata Thickness (m)		Description of Strata	Depth of Casing (m)	Flush Return (%)	Final Depth Borehole (m)
		From	To				
MBH6	90°	-	-	Well installation	-	NA	57

Comments:
Gravel placed at base of hole from 57 to 50.50mbgl. Install UPVC well liner (50mm dia. slotted standpipe from 50.50 to 2mbgl and plain standpipe from 2mbgl to 1magl). Place gravel pack from 50.50 to 2mbgl and bentonite from 2mbgl to GL. On completion, place steel protection cover with concrete plinth at base and secure with padlock.

Hours Worked on Site			Remarks: Standing Time/Weather Conditions/Groundwater etc:	Signed for Scott Wilson Ltd.
From	To	Total	Sunny and clear with light winds.	Signed for by Client:
0930	1230	3		

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Contract:	Contract No:	Date:	Sheet No:	Ground Level (m):
Maghtab Landfill Site	M1022	25.07.02 Date Commenced: 25.07.02	1 of 11	Not Known

Drilling Method:	Drilling Equipment/Rig No:	Drilling/Casing Diam (mm):	Bit Type:	Flush Type:
Rotary	Diamec	220mm to 12mbgl	Tungsten Carbide	Water

Borehole No	Angle of Hole	Strata Thickness (m)		Description of Strata	Depth of Casing (m)	Flush Return (%)	Final Depth Borehole (m)
		From	To				
MW1	90^{o}	GL	12	Waste & Cover Material	12	0	12

Comments:
Very high torque on bit and no advancement at 12mbgl.

Hours Worked on Site		
From	To	Total
0630	1530	9

Remarks: Standing Time/Weather Conditions/Groundwater etc:

Sunny and clear with light to moderate winds.

Signed for Scott Wilson Ltd.

Signed for by Client:

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Contract:	Contract No:	Date:	Sheet No:	Ground Level (m):
Maghtab Landfill Site	M1022	26.07.02 Date Commenced: 25.07.02	2 of 11	Not Known

Drilling Method:	Drilling Equipment/Rig No:	Drilling/Casing Diam (mm):	Bit Type:	Flush Type:
Rotary	Diamec	220mm to 12mbgl 150mm to 15mbgl	Tungsten Carbide	Water

Borehole No	Angle of Hole	Strata Thickness (m) From	Strata Thickness (m) To	Description of Strata	Depth of Casing (m)	Flush Return (%)	Final Depth Borehole (m)
MW1	90^o	12	15	Waste & Cover Material	15	1	15

Comments:
Very high torque on bit at 12mbgl. Hole advanced through difficult ground conditions / obstructions to 16mbgl. Strong odour (waste) arising with returns from depth of 16m. Hole collapse in uncased section between 15 and 16mbgl while attempting to advance casing.

Hours Worked on Site From	To	Total
0630	1530	9

Remarks: Standing Time/Weather Conditions/Groundwater etc:

Sunny and clear with light winds.

Signed for Scott Wilson Ltd.

Signed for by Client:

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Contract:	Contract No:	Date:	Sheet No:	Ground Level (m):
Maghtab Landfill Site	M1022	29.07.02 Date Commenced: 25.07.02	3 of 11	Not Known

Drilling Method:	Drilling Equipment/Rig No:	Drilling/Casing Diam (mm):	Bit Type:	Flush Type:
Rotary	Diamec	220mm to 12mbgl 150mm to 18mbgl	Tungsten Carbide	Water

Borehole No	Angle of Hole	Strata Thickness (m)		Description of Strata	Depth of Casing (m)	Flush Return (%)	Final Depth Borehole (m)
		From	To				
MW1	90^{o}	15	18	Waste & Cover Material	18	0	18

Comments:
Very high torque on bit and slow progress through difficult ground conditions / obstructions encountered between 16 and 17mbgl.
(1500hrs) Diamec Rig breakdown. Work carried out to repair hydraulic system (seals).

Hours Worked on Site		
From	To	Total
0630	1500	8.5

Remarks: Standing Time/Weather Conditions/Groundwater etc:

Sunny and clear with light winds.
Delays: See above Comments

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Contract:	Contract No:	Date:	Sheet No:	Ground Level (m):
Maghtab Landfill Site	M1022	30.07.02 Date Commenced: 25.07.02	4 of 11	Not Known

Drilling Method:	Drilling Equipment/Rig No:	Drilling/Casing Diam (mm):	Bit Type:	Flush Type:
Rotary	Diamec	220mm to 12mbgl 150mm to 25mbgl	Tungsten Carbide	Water

Borehole No	Angle of Hole	Strata Thickness (m) From	Strata Thickness (m) To	Description of Strata	Depth of Casing (m)	Flush Return (%)	Final Depth Borehole (m)
MW1	90°	18	25	Waste & Cover Material	25	0	25

Comments:
(0630 - 0900hrs) Intermittent delays due elevated gas levels arising from top of casing (H_2S levels fluctuating, max of 148ppm, but dispersing). On occasions, personnel move upwind as precaution.
High torque on bit and slow progress from 18m depth. Bit stuck at 24mbgl. Free string and extract casing to release bit prior to resumption and advance hole to 25mbgl.

Hours Worked on Site From	To	Total	Remarks: Standing Time/Weather Conditions/Groundwater etc:	Signed for Scott Wilson Ltd.
0630	1530	9	Sunny and clear with light winds to moderate winds. Delays : See above Comments.	Signed for by Client:

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Contract:	Contract No:	Date:	Sheet No:	Ground Level (m):
Maghtab Landfill Site	M1022	31.07.02 Date Commenced: 31.07.02	5 of 11	Not Known

Drilling Method:	Drilling Equipment/Rig No:	Drilling/Casing Diam (mm):	Bit Type:	Flush Type:
Rotary	Diamec	220mm to 12mbgl 150mm to 36mbgl	Tungsten Carbide	Water

Borehole No	Angle of Hole	Strata Thickness (m)		Description of Strata	Depth of Casing (m)	Flush Return (%)	Final Depth Borehole (m)
		From	To				
MW1	90^{o}	25	36	Waste & Cover Material	36	0	36

Comments:
Difficult ground conditions / obstruction between 25 and 26mbgl.
Drill bit stuck at 36mbgl at end of shift.

Hours Worked on Site		
From	To	Total
0630	1530	9

Remarks: Standing Time/Weather Conditions/Groundwater etc:

Sunny and clear with light wind to moderate winds.

Signed for Scott Wilson Ltd.

Signed for by Client:

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Contract:	Contract No:	Date: 01.07.02	Sheet No:	Ground Level (m):
Maghtab Landfill Site	M1022	Date Commenced: 25.07.02	6 of 11	Not Known

Drilling Method:	Drilling Equipment/Rig No:	Drilling/Casing Diam (mm):	Bit Type:	Flush Type:
Rotary	Diamec	220mm to 12mbgl 150mm to 42.25mbgl	Tungsten Carbide	Water

Borehole No	Angle of Hole	Strata Thickness (m)		Description of Strata	Depth of Casing (m)	Flush Return (%)	Final Depth Borehole (m)
		From	To				
MW1	90^{o}	36	42.25	Waste & Cover Material	42.25	0	42.25

Comments:
(0615hrs – 1000hrs) Intermittent delays due to fluctuating H_2S emissions recorded at 140ppm (top of casing) and 16ppm (at 0.5m from casing head). Bentonite placed between annulus of 220mm and 150mm casing. Hot emissions from borehole following addition of water in attempt to suppress gas emissions.
(1000hrs) Wind strengthening and H_2S dispersal satisfactory; no further delays.
Drill bit freed at 36mbgl but recurring problems with drill bit stuck at 37.5mbgl. Free string and extract casing to release bit. On completion, drilling resumed and hole advanced to 42.25mbgl. Very high torque on bit between 37.5m and 42.25m.

Hours Worked on Site		
From	To	Total
0615	1530	9.25

Remarks: Standing Time/Weather Conditions/Groundwater etc:

Sunny, clear and calm conditions. Winds strengthening from mid-morning.
Delays: See above Comments.

Signed for Scott Wilson Ltd.

Signed for by Client:

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Contract: Maghtab Landfill Site	Contract No: M1022	Date: 02.08.02 Date Commenced: 25.07.02	Sheet No: 7 of 11	Ground Level (m): Not Known

Drilling Method: Rotary	Drilling Equipment/Rig No: Diamec	Drilling/Casing Diam (mm): 220mm to 12mbgl 150mm to 42.25mbgl	Bit Type: Tungsten Carbide	Flush Type: Water

Borehole No	Angle of Hole	Strata Thickness (m)		Description of Strata	Depth of Casing (m)	Flush Return (%)	Final Depth Borehole (m)
		From	To				
MW1	90°	42.25	45	Waste & Cover Material	42.25	0	42.25
MW1	90°	NA	NA	Well Installation	42.25	NA	42.25

Comments:
(0630 – 0900hrs) Intermittent delays due to fluctuating H_2S emissions, max 165ppm but dispersing. Bentonite placed between annulus of 220mm and 150mm casing to successfully supress H_2S emissions.
Obstruction encountered at 42.25m and 44.5mbgl. At 44.5m, hole depth advanced 0.5m over course of 3hrs drilling in attempt to clear obstruction. MW1 terminated at 45mbgl. Final depth: 42.25mbgl following collapse of hole in uncased section between 42.25m and 45mbgl.
Install galvanised well liner (50mm dia. 'drilled' standpipe from 42.25 to 3mbgl and plain standpipe from 3mbgl to 1magl). Attempt to extract casing – jammed. No further progress.

Hours Worked on Site		
From	To	Total
0630	1530	9

Remarks: Standing Time/Weather Conditions/Groundwater etc:

Sunny and clear with light winds strengthening (to moderate) throughout afternoon.
Delays: See above Comments.

Signed for Scott Wilson Ltd.

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Contract:	Contract No:	Date:	Sheet No:	Ground Level (m):
Maghtab Landfill Site	M1022	05.07.02 Date Commenced: 25.07.02	8 of 11	Not Known

Drilling Method:	Drilling Equipment/Rig No:	Drilling/Casing Diam (mm):	Bit Type:	Flush Type:
Rotary	Diamec	220mm to 12mbgl 150mm (extraction in progress)	Tungsten Carbide	Water

Borehole No	Angle of Hole	Strata Thickness (m) From	Strata Thickness (m) To	Description of Strata	Depth of Casing (m)	Flush Return (%)	Final Depth Borehole (m)
MW1	90°	-	-	Well installation	21	NA	42.25

Comments:
(0630-0730hrs) Demobilise rig and set up at location of MW2.
(0730-1000hrs) Work continued to free casing. On completion, place gravel pack accordingly with displacement of casing. Casing extracted to 21mbgl.
(1230-1530hrs) Work postponed due to fluctuating H_2S levels recorded at top of casing (max >500ppm). Personnel transferred to assist set up of drilling rig at relocated MW2 location. (New location - close to southern limit).

Hours Worked on Site From	To	Total
0630	1530	9

Remarks: Standing Time/Weather Conditions/Groundwater etc:

Sunny and clear with moderate to strong winds.
Delays: See above Comments.

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Contract: Maghtab Landfill Site	Contract No: M1022	Date: 06.07.02 Date Commenced: 25.07.02	Sheet No: 9 of 11	Ground Level (m): Not Known

Drilling Method: Rotary	Drilling Equipment/Rig No: Diamec	Drilling/Casing Diam (mm): 220mm to 12mbgl 150mm (extraction in progress)	Bit Type: Tungsten Carbide	Flush Type: Water

Borehole No	Angle of Hole	Strata Thickness (m)		Description of Strata	Depth of Casing (m)	Flush Return (%)	Final Depth Borehole (m)
		From	To				
MW1	90^o	-	-	Well installation	7.5mbgl	NA	42.25

Comments:
(1100 – 1230hrs) Intermittent delays due to fluctuating H_2S levels, with max of 332ppm (and dispersing). On occasions, all personnel move upwind as precaution.
Temperature of emissions from top of casing recorded at 71.4^{o}C (1250hrs).
Gravel pack placed with displacement of casing. Casing extracted to 7.5mbgl.
N.B. Work carried out concurrently with drilling at MW2.

Hours Worked on Site		
From	To	Total
0630	1530	9

Remarks: Standing Time/Weather Conditions/Groundwater etc:

Sunny and clear with light winds strengthening (to moderate) throughout day.
Delays: See above Comments.

Signed for Scott Wilson Ltd.

Signed for by Client:

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Contract:	Contract No:	Date:	Sheet No:	Ground Level (m):
Maghtab Landfill Site	M1022	07.07.02 Date Commenced: 25.07.02	10 of 11	Not Known

Drilling Method:	Drilling Equipment/Rig No:	Drilling/Casing Diam (mm):	Bit Type:	Flush Type:
Rotary	Diamec	220mm (extraction in progress) 150mm (extraction completed)	Tungsten Carbide	Water

Borehole No	Angle of Hole	Strata Thickness (m) From	Strata Thickness (m) To	Description of Strata	Depth of Casing (m)	Flush Return (%)	Final Depth Borehole (m)
MW1	90°	-	-	Well installation	3.5	NA	42.25

Comments:
Gravel pack placed with displacement of casing. 150mm dia. casing extraction complete. 220mm dia.casing extracted 3.5mbgl.
N.B. Work carried out concurrently with drilling at MW2.

Hours Worked on Site From	To	Total	Remarks: Standing Time/Weather Conditions/Groundwater etc:	Signed for Scott Wilson Ltd.
1030	1215	1.75	Sunny and clear with light to moderate winds.	Signed for by Client:

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Contract: Maghtab Landfill Site	Contract No: M1022	Date: 08.07.02 Date Commenced: 25.07.02	Sheet No: 11 of 11	Ground Level (m): Not Known

Drilling Method: Rotary	Drilling Equipment/Rig No: Diamec	Drilling/Casing Diam (mm): 220mm (extraction completed)	Bit Type: Tungsten Carbide	Flush Type: Water

Borehole No	Angle of Hole	Strata Thickness (m)		Description of Strata	Depth of Casing (m)	Flush Return (%)	Final Depth Borehole (m)
		From	To				
MW1	90^{o}	-	-	Well installation	-	NA	42.25

Comments:
Extract final lengths of 220mm dia. casing and place gravel pack to 3mbgl and bentonite seal from 3mbgl to GL.
On completion place steel protection cover, with concrete plinth at base, and secure with padlock.
MW1 Well installation completed.

Hours Worked on Site			Remarks: Standing Time/Weather Conditions/Groundwater etc:	Signed for Scott Wilson Ltd.
From	To	Total		
0630	1000	3.5	Sunny and clear with light to moderate winds.	Signed for by Client:

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Contract:	Contract No:	Date:	Date Commenced:	Sheet No:	Ground Level (m):
Maghtab Landfill Site	M1022	06.08.02	06.08.02	1 of 8	Not Known

Drilling Method:	Drilling Equipment/Rig No:	Drilling/Casing Diam (mm):	Bit Type:	Flush Type:
Rotary	Diamec	220mm to 5mbgl	Tungsten Carbide	Water

Borehole No	Angle of Hole	Strata Thickness (m) From	Strata Thickness (m) To	Description of Strata	Depth of Casing (m)	Flush Return (%)	Final Depth Borehole (m)
MW2	90°	GL	9	Waste & Cover Material	5	0	5

Comments:
MW2 location relocated to within 10m of southern edge at request of landfill operators.
220mm dia. casing advanced to 5mbgl.
H_2S levels at top of casing recorded at 67ppm but dispersing to safe levels at work station.
MW2 open hole advanced to 9mbgl. Unable to advance casing beyond 5mbgl. Hole collapse in uncased section.
Final hole depth of 5m achieved by end of shift.

Hours Worked on Site From	To	Total
0630	1530	9

Remarks: Standing Time/Weather Conditions/Groundwater etc:

Sunny and clear with light winds strengthening (to moderate) throughout day.

Signed for Scott Wilson Ltd.

Signed for by Client:

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Contract:	Contract No:	Date: 07.08.02 / Date Commenced: 06.08.02	Sheet No:	Ground Level (m):
Maghtab Landfill Site	M1022		2 of 8	Not Known

Drilling Method:	Drilling Equipment/Rig No:	Drilling/Casing Diam (mm):	Bit Type:	Flush Type:
Rotary	Diamec	220mm to 5mbgl 150mm to 9mbgl	Tungsten Carbide	Water

Borehole No	Angle of Hole	Strata Thickness (m)		Description of Strata	Depth of Casing (m)	Flush Return (%)	Final Depth Borehole (m)
		From	To				
MW2	90^{o}	9	14	Waste & Cover Material	9	0	9

Comments:
MW2 open hole advanced to 14mbgl. Unable to advance casing beyond 9mbgl. Hole collapse in uncased section. Final hole depth of 9m achieved by end of shift.

Hours Worked on Site		
From	To	Total
0630	1530	9

Remarks: Standing Time/Weather Conditions/Groundwater etc:

Sunny and clear with light to moderate winds.

Signed for Scott Wilson Ltd.

Signed for by Client:

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Contract:	Contract No:	Date: 08.08.02	Sheet No:	Ground Level (m):
Maghtab Landfill Site	M1022	Date Commenced: 06.08.02	3 of 8	Not Known

Drilling Method:	Drilling Equipment/Rig No:	Drilling/Casing Diam (mm):	Bit Type:	Flush Type:
Rotary	Diamec	220mm to 5mbgl 150mm to 15mbgl	Tungsten Carbide	Water

Borehole No	Angle of Hole	Strata Thickness (m)		Description of Strata	Depth of Casing (m)	Flush Return (%)	Final Depth Borehole (m)
		From	To				
MW2	90^o	9	21	Waste & Cover Material	15	1	15

Comments:
Very slow progress for duration of 3hrs, drilling through difficult ground conditions / obstructions encountered at 15mbgl. Continue drilling to 21mbgl. Black slurry noted in 1% returns at 16m depth.
Unable to advance casing beyond 15mbgl. Collapse in uncased section of hole. Final hole depth of 18m achieved by end of shift.

Hours Worked on Site		
From	To	Total
0630	1530	9

Remarks: Standing Time/Weather Conditions/Groundwater etc:

Sunny and clear with light to moderate winds

Signed for Scott Wilson Ltd.

Signed for by Client:

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Contract:	Contract No:	Date:	Sheet No:	Ground Level (m):
Maghtab Landfill Site	M1022	09.08.02 Date Commenced: 06.08.02	4 of 8	Not Known

Drilling Method:	Drilling Equipment/Rig No:	Drilling/Casing Diam (mm):	Bit Type:	Flush Type:
Rotary	Diamec	220mm to 5mbgl 150mm to 18mbgl	Tungsten Carbide	Water

Borehole No	Angle of Hole	Strata Thickness (m)		Description of Strata	Depth of Casing (m)	Flush Return (%)	Final Depth Borehole (m)
		From	To				
MW2	90^{o}	15	18	Waste & Cover Material	18	0	18

Comments:
Casing advanced to 18mbgl.
(1500) Diamec Rig Breakdown (water pump).
MW2 terminated at 18mbgl.

Hours Worked on Site		
From	To	Total
0630	1530	9

Remarks: Standing Time/Weather Conditions/Groundwater etc:

Sunny & clear with slight winds strengthening (to moderate) throughout day

Signed for Scott Wilson Ltd.

Signed for by Client:

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Contract: Maghtab Landfill Site	Contract No: M1022	Date: 20.08.02 Date Commenced: 06.08.02	Sheet No: 5 of 8	Ground Level (m): Not Known

Drilling Method: Rotary	Drilling Equipment/Rig No: Diamec	Drilling/Casing Diam (mm): 220mm at 5mbgl 150mm extraction in progress.	Bit Type: Tungsten Carbide	Flush Type: Water

Borehole No	Angle of Hole	Strata Thickness (m)		Description of Strata	Depth of Casing (m)	Flush Return (%)	Final Depth Borehole (m)
		From	To				
MW2	90°	-	-	Well Installation	5	NA	17

Comments:
Install galvanised steel well liner. (50mm dia. 'drilled' standpipe from 18 to 2mbgl and plain standpipe from 2mbgl to 1magl). Gravel pack placed with displacement of casing. 150mm casing extracted to 4.5m
N.B. Well liner withdrawn 1m during initial extraction of casing.

Hours Worked on Site			Remarks: Standing Time/Weather Conditions/Groundwater etc:	Signed for Scott Wilson Ltd.
From	To	Total	Sunny & clear with light winds.	
0930	1530	6		Signed for by Client:

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Contract:	Contract No:	Date:	Date Commenced:	Sheet No:	Ground Level (m):
Maghtab Landfill Site	M1022	21.08.02	06.08.02	6 of 8	Not Known

Drilling Method:	Drilling Equipment/Rig No:	Drilling/Casing Diam (mm):	Bit Type:	Flush Type:
Rotary	Diamec	220mm (recovery in progress) 150mm (extraction completed)	Tungsten Carbide	Water

Borehole No	Angle of Hole	Strata Thickness (m) From	Strata Thickness (m) To	Description of Strata	Depth of Casing (m)	Flush Return (%)	Final Depth Borehole (m)
MW2	90^{o}	-	-	Well Installation	-	NA	17

Comments:
Extraction of 150mm dia. casing completed. Top section of 220mm dia. casing removed, lower 3m section and casing shoe 'down hole'. 360^{0} excavator on site and excavate around standpipe in attempt to recover 220mm dia. casing lengths. Excavation advanced to 3mbgl.

Hours Worked on Site From	To	Total
0930	1530	6

Remarks: Standing Time/Weather Conditions/Groundwater etc:

Sunny & clear with light winds.

Signed for Scott Wilson Ltd.

Signed for by Client:

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Tel: +44 (0) 1246 209221 Fax: +44 (0) 1246 209229

Contract: Maghtab Landfill Site	Contract No: M1022	Date: 22.08.02 Date Commenced: 06.08.02	Sheet No: 7 of 8	Ground Level (m): Not Known

Drilling Method: Rotary	Drilling Equipment/Rig No: Diamec	Drilling/Casing Diam (mm): 220mm (recovery abandoned) 150mm (extraction completed)	Bit Type: Tungsten Carbide	Flush Type: Water

Borehole No	Angle of Hole	Strata Thickness (m)		Description of Strata	Depth of Casing (m)	Flush Return (%)	Final Depth Borehole (m)
		From	To				
MW2	90°	-	-	Well Installation	-	NA	17

Comments:
Continue excavation using 360^0 excavator. Excavation around standpipe advanced to 5mbgl. Work to recover casing, abandoned.

Hours Worked on Site			Remarks: Standing Time/Weather Conditions/Groundwater etc:	Signed for Scott Wilson Ltd.
From	To	Total		
1300	1530	2.5	Sunny & clear with light winds.	Signed for by Client:

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Contract:	Contract No:	Date:	Sheet No:	Ground Level (m):
Maghtab Landfill Site	M1022	23.08.02 Date Commenced: 06.07.02	8 of 8	Not Known

Drilling Method:	Drilling Equipment/Rig No:	Drilling/Casing Diam (mm):	Bit Type:	Flush Type:
Rotary	Diamec	220mm (recovery abandoned) 150mm (extraction completed)	Tungsten Carbide	Water

Borehole No	Angle of Hole	Strata Thickness (m) From	Strata Thickness (m) To	Description of Strata	Depth of Casing (m)	Flush Return (%)	Final Depth Borehole (m)
MW2	90^o	-	-	Well Installation	-	NA	17

Comments:
220mm dia. casing placed around exposed well liner. Excavation backfilled and gravel filter reinstated to 2mbgl. Bentonite seal placed from 2mbgl to GL. On completion place steel protection cover, with concrete plinth at base, and secure with padlock.
MW2 Well installation completed.

Hours Worked on Site From	To	Total
1015	1300	2.75

Remarks: Standing Time/Weather Conditions/Groundwater etc:

Sunny and Clear with light to moderate winds

Signed for Scott Wilson Ltd.

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Contract:	Contract No:	Date:	Date Commenced:	Sheet No:	Ground Level (m):
Maghtab Landfill Site	M1022	03.10.02	03.10.02	1 of 6	Not Known

Drilling Method:	Drilling Equipment/Rig No:	Drilling/Casing Diam (mm):	Bit Type:	Flush Type:
Rotary	Yale1	110mm to 40mbgl	Tungsten Carbide	Water

Borehole No	Angle of Hole	Strata Thickness (m) From	Strata Thickness (m) To	Description of Strata	Depth of Casing (m)	Flush Return (%)	Final Depth Borehole (m)
MW3	90	0	15	Waste and cover material	15	0	15

Comments:
Set up rig at location of MW3.

Hours Worked on Site From	To	Total	Remarks: Standing Time/Weather Conditions/Groundwater etc:	Signed for Scott Wilson Ltd.
0700	1500	8		
				Signed for by Client:

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Contract: Maghtab Landfill Site	Contract No: M1022	Date: 04.10.02 Date Commenced: 03.10.02	Sheet No: 2 of 6	Ground Level (m): Not Known

Drilling Method: Rotary	Drilling Equipment/Rig No: Yale1	Drilling/Casing Diam (mm): 110mm to 40mbgl	Bit Type: Tungsten Carbide	Flush Type: Water

Borehole No	Angle of Hole	Strata Thickness (m)		Description of Strata	Depth of Casing (m)	Flush Return (%)	Final Depth Borehole (m)
		From	To				
MW3	90°	15	27	Waste & Cover Material	27	0	27

Comments:

Hours Worked on Site			Remarks: Standing Time/Weather Conditions/Groundwater etc:	Signed for Scott Wilson Ltd.
From	To	Total		
0700	1530	8.5		Signed for by Client:

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Contract: Maghtab Landfill Site	Contract No: M1022	Date: 07.10.02 Date Commenced: 03.10.02	Sheet No: 3 of 6	Ground Level (m): Not Known

Drilling Method: Rotary	Drilling Equipment/Rig No: Yale1	Drilling/Casing Diam (mm): 110mm to 40mbgl	Bit Type: Tungsten Carbide	Flush Type: Water

Borehole No	Angle of Hole	Strata Thickness (m)		Description of Strata	Depth of Casing (m)	Flush Return (%)	Final Depth Borehole (m)
		From	To				
MW3	90^o	27	41	Waste & Cover Material	40	0	41

Comments:
High torque with bit damage occurring. Borehole very hot with evidence of burning

Hours Worked on Site			Remarks: Standing Time/Weather Conditions/Groundwater etc:	Signed for Scott Wilson Ltd.
From	To	Total		
0630	1530	9		Signed for by Client:

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Contract: Maghtab Landfill Site	Contract No: M1022	Date: 08.10.02 Date Commenced: 03.10.02	Sheet No: 4 of 6	Ground Level (m): Not Known

Drilling Method: Rotary	Drilling Equipment/Rig No: Yale1	Drilling/Casing Diam (mm): 110mm to 40mbgl	Bit Type: Tungsten Carbide	Flush Type: Water

Borehole No	Angle of Hole	Strata Thickness (m)		Description of Strata	Depth of Casing (m)	Flush Return (%)	Final Depth Borehole (m)
		From	To				
MW3	-	-	-	Well Installation	40	NA	41.0

Comments:
Install galvanised steel well liner (50mm dia. 'drilled' standpipe from 40.0m to 2mbgl and plain standpipe from 2mbgl to 1magl). Gravel pack placed from 40.0m to 2mbgl. Casing stuck.

Hours Worked on Site			Remarks: Standing Time/Weather Conditions/Groundwater etc:	Signed for Scott Wilson Ltd.
From	To	Total		
0630	1530	9		Signed for by Client:

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Contract: Maghtab Landfill Site	Contract No: M1022	Date: 09.10.02 Date Commenced: 03.10.02	Sheet No: 5 of 6	Ground Level (m): Not Known

Drilling Method: Rotary	Drilling Equipment/Rig No: Yale1	Drilling/Casing Diam (mm): 110mm to 40mbgl	Bit Type: Tungsten Carbide	Flush Type: Water

Borehole No	Angle of Hole	Strata Thickness (m)		Description of Strata	Depth of Casing (m)	Flush Return (%)	Final Depth Borehole (m)
		From	To				
MW3	-	-	-	Well Installation	40	NA	41.0

Comments:
Casing withdrawn and bentonite placed from 2mbgl to GL. On completion, place steel protection cover with concrete plinth at base and secure with padlock.

Hours Worked on Site			Remarks: Standing Time/Weather Conditions/Groundwater etc:	Signed for Scott Wilson Ltd.
From	To	Total		
0630	1530	9		Signed for by Client:

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Contract: Maghtab Landfill Site	Contract No: M1022	Date: 08.10.02 Date Commenced: 10.10.02	Sheet No: 6 of 6	Ground Level (m): Not Known

Drilling Method: Rotary	Drilling Equipment/Rig No: Yale1	Drilling/Casing Diam (mm): 110mm to 40mbgl	Bit Type: Tungsten Carbide	Flush Type: Water

Borehole No	Angle of Hole	Strata Thickness (m) From	Strata Thickness (m) To	Description of Strata	Depth of Casing (m)	Flush Return (%)	Final Depth Borehole (m)
MW3	-	-	-	Demobilise	-	NA	41.0

Comments:
Demobilise rig and equipment

Hours Worked on Site From	To	Total	Remarks: Standing Time/Weather Conditions/Groundwater etc:	Signed for Scott Wilson Ltd. / Signed for by Client:
0630	1530	9		

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Contract:	Contract No:	Date:	Date Commenced:	Sheet No:	Ground Level (m):
Maghtab Landfill Site	M1022	23.09.02	23.09.02	1 of 6	Not Known

Drilling Method:	Drilling Equipment/Rig No:	Drilling/Casing Diam (mm):	Bit Type:	Flush Type:
Rotary	Yale1	110mm to 57mbgl	Tungsten Carbide	Water

Borehole No	Angle of Hole	Strata Thickness (m)		Description of Strata	Depth of Casing (m)	Flush Return (%)	Final Depth Borehole (m)
		From	To				
MW4	90	0	12	Waste and cover material	12	0	12

Comments:
Set up rig at location of MW4.

Hours Worked on Site			Remarks: Standing Time/Weather Conditions/Groundwater etc:	Signed for Scott Wilson Ltd.
From	To	Total		
0700	1500	8		Signed for by Client:

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Contract: Maghtab Landfill Site	Contract No: M1022	Date: 24.09.02 Date Commenced: 23.09.02	Sheet No: 2 of 6	Ground Level (m): Not Known

Drilling Method: Rotary	Drilling Equipment/Rig No: Yale1	Drilling/Casing Diam (mm): 110mm to 57mbgl	Bit Type: Tungsten Carbide	Flush Type: Water

Borehole No	Angle of Hole	Strata Thickness (m)		Description of Strata	Depth of Casing (m)	Flush Return (%)	Final Depth Borehole (m)
		From	To				
MW4	90°	12	29	Waste & Cover Material	29	0	29

Comments:

Hours Worked on Site			Remarks: Standing Time/Weather Conditions/Groundwater etc:	Signed for Scott Wilson Ltd.
From	To	Total		
0700	1530	8.5		Signed for by Client:

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Contract:	Contract No:	Date:	Sheet No:	Ground Level (m):
Maghtab Landfill Site	M1022	30.09.02 Date Commenced: 23.09.02	3 of 6	Not Known

Drilling Method:	Drilling Equipment/Rig No:	Drilling/Casing Diam (mm):	Bit Type:	Flush Type:
Rotary	Yale1	110mm to 57mbgl	Tungsten Carbide	Water

Borehole No	Angle of Hole	Strata Thickness (m) From	Strata Thickness (m) To	Description of Strata	Depth of Casing (m)	Flush Return (%)	Final Depth Borehole (m)
MW4	90^o	29	45	Waste & Cover Material	45	0	45

Comments:
Borehole very hot with evidence of burning

Hours Worked on Site From	To	Total	Remarks: Standing Time/Weather Conditions/Groundwater etc:	Signed for Scott Wilson Ltd. / Signed for by Client:
0630	1530	9		

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Contract:	Contract No:	Date:	Sheet No:	Ground Level (m):
Maghtab Landfill Site	M1022	01.10.02 Date Commenced: 23.09.02	4 of 6	Not Known

Drilling Method:	Drilling Equipment/Rig No:	Drilling/Casing Diam (mm):	Bit Type:	Flush Type:
Rotary	Yale1	110mm to 57mbgl	Tungsten Carbide	Water

Borehole No	Angle of Hole	Strata Thickness (m) From	Strata Thickness (m) To	Description of Strata	Depth of Casing (m)	Flush Return (%)	Final Depth Borehole (m)
MW4	90	45	57	Waste & Cover Material	57	0	57

Comments:

Hours Worked on Site From	To	Total
0630	1530	9

Remarks: Standing Time/Weather Conditions/Groundwater etc:

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Signed for by Client:

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Contract: Maghtab Landfill Site	Contract No: M1022	Date: 02.10.02 / Date Commenced: 23.09.02	Sheet No: 5 of 6	Ground Level (m): Not Known

Drilling Method: Rotary	Drilling Equipment/Rig No: Yale1	Drilling/Casing Diam (mm): 110mm to 57mbgl	Bit Type: Tungsten Carbide	Flush Type: Water

Borehole No	Angle of Hole	Strata Thickness (m) From	Strata Thickness (m) To	Description of Strata	Depth of Casing (m)	Flush Return (%)	Final Depth Borehole (m)
MW4	-	-	-	Well Installation	57	NA	57

Comments:
Install galvanised steel well liner (50mm dia. 'drilled' standpipe from 57.0m to 2mbgl and plain standpipe from 2mbgl to 1magl). Gravel pack placed from 57.0m to 2mbgl. Casing too hot to handle.

Hours Worked on Site From	To	Total	Remarks: Standing Time/Weather Conditions/Groundwater etc:	Signed for Scott Wilson Ltd.
0630	1530	9		
				Signed for by Client:

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Contract:	Contract No:	Date:	Sheet No:	Ground Level (m):
Maghtab Landfill Site	M1022	03.10.02 Date Commenced: 23.09.02	6 of 6	Not Known

Drilling Method:	Drilling Equipment/Rig No:	Drilling/Casing Diam (mm):	Bit Type:	Flush Type:
Rotary	Yale1	110mm to 40mbgl	Tungsten Carbide	Water

Borehole No	Angle of Hole	Strata Thickness (m) From	Strata Thickness (m) To	Description of Strata	Depth of Casing (m)	Flush Return (%)	Final Depth Borehole (m)
MW4	-	-	-	Complete well installation and demobilise	-	NA	57

Comments:
Casing withdrawn and bentonite placed from 2mbgl to GL. On completion, place steel protection cover with concrete plinth at base and secure with padlock. Demobilise rig and equipment

Hours Worked on Site From	To	Total	Remarks: Standing Time/Weather Conditions/Groundwater etc:	Signed for Scott Wilson Ltd.
0630	1530	9		Signed for by Client:

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Contract:	Contract No:	Date:	Date Commenced:	Sheet No:	Ground Level (m):
Maghtab Landfill Site	M1022	09.09.02	09.09.02	1 of 7	Not Known

Drilling Method:	Drilling Equipment/Rig No:	Drilling/Casing Diam (mm):	Bit Type:	Flush Type:
Rotary	AAN1	110mm to 49mbgl	Diamond impreg.	Water

Borehole No	Angle of Hole	Strata Thickness (m)		Description of Strata	Depth of Casing (m)	Flush Return (%)	Final Depth Borehole (m)
		From	To				
MW5	90	0	6	Waste and cover material	6	0	6

Comments:
Set up rig at location of MW5.

Hours Worked on Site		
From	To	Total
0700	1500	8

Remarks: Standing Time/Weather Conditions/Groundwater etc:

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Signed for by Client:

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Contract:	Contract No:	Date:	Date Commenced:	Sheet No:	Ground Level (m):
Maghtab Landfill Site	M1022	10.09.02	09.09.02	2 of 7	Not Known

Drilling Method:	Drilling Equipment/Rig No:	Drilling/Casing Diam (mm):	Bit Type:	Flush Type:
Rotary	AAN1	110mm to 49mbgl	Diamond impreg.	Water

Borehole No	Angle of Hole	Strata Thickness (m)		Description of Strata	Depth of Casing (m)	Flush Return (%)	Final Depth Borehole (m)
		From	To				
MW5	90°	6	17	Waste & Cover Material	17	0	17

Comments:

Hours Worked on Site		
From	To	Total
0700	1530	8.5

Remarks: Standing Time/Weather Conditions/Groundwater etc:

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Contract: Maghtab Landfill Site	Contract No: M1022	Date: 11.09.02 Date Commenced: 09.09.02	Sheet No: 3 of 7	Ground Level (m): Not Known

Drilling Method: Rotary	Drilling Equipment/Rig No: AAN1	Drilling/Casing Diam (mm): 110mm to 49mbgl	Bit Type: Tungsten Carbide.	Flush Type: Water

Borehole No	Angle of Hole	Strata Thickness (m) From	Strata Thickness (m) To	Description of Strata	Depth of Casing (m)	Flush Return (%)	Final Depth Borehole (m)
MW5	90°	17	29	Waste & Cover Material	29	0	29

Comments:
Revert to using tungsten carbide bit

Hours Worked on Site From	To	Total	Remarks: Standing Time/Weather Conditions/Groundwater etc:	Signed for Scott Wilson Ltd.
0630	1530	9		Signed for by Client:

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Contract: Maghtab Landfill Site	Contract No: M1022	Date: 12.09.02 Date Commenced: 09.09.02	Sheet No: 4 of 7	Ground Level (m): Not Known

Drilling Method: Rotary	Drilling Equipment/Rig No: AAN1	Drilling/Casing Diam (mm): 110mm to 49mbgl	Bit Type: Tungsten Carbide	Flush Type: Water

Borehole No	Angle of Hole	Strata Thickness (m)		Description of Strata	Depth of Casing (m)	Flush Return (%)	Final Depth Borehole (m)
		From	To				
MW5	90	29	37	Waste & Cover Material	37	0	37

Comments:
Borehole burning with very hot conditions

Hours Worked on Site			Remarks: Standing Time/Weather Conditions/Groundwater etc:	Signed for Scott Wilson Ltd.
From	To	Total		
0630	1530	9		Signed for by Client:

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Contract: Maghtab Landfill Site	Contract No: M1022	Date: 13.09.02 Date Commenced: 09.09.02	Sheet No: 5 of 7	Ground Level (m): Not Known

Drilling Method: Rotary	Drilling Equipment/Rig No: AAN1	Drilling/Casing Diam (mm): 110mm to 49mbgl	Bit Type: Tungsten Carbide	Flush Type: Water

Borehole No	Angle of Hole	Strata Thickness (m) From	Strata Thickness (m) To	Description of Strata	Depth of Casing (m)	Flush Return (%)	Final Depth Borehole (m)
MW5	90	37	51	Waste & Cover Material	49	0	51

Comments:

Hours Worked on Site From	To	Total	Remarks: Standing Time/Weather Conditions/Groundwater etc:	Signed for Scott Wilson Ltd.
0630	1530	9		Signed for by Client:

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Contract:	Contract No:	Date:	Sheet No:	Ground Level (m):
Maghtab Landfill Site	M1022	16.09.02 Date Commenced: 09.09.02	6 of 7	Not Known

Drilling Method:	Drilling Equipment/Rig No:	Drilling/Casing Diam (mm):	Bit Type:	Flush Type:
Rotary	AAN1	110mm to 49mbgl	Tungsten Carbide	Water

Borehole No	Angle of Hole	Strata Thickness (m)		Description of Strata	Depth of Casing (m)	Flush Return (%)	Final Depth Borehole (m)
		From	To				
MW5	-	-	-	Well installation	49	NA	51

Comments:
Install galvanised steel well liner (50mm dia. 'drilled' standpipe from 51.0m to 2mbgl and plain standpipe from 2mbgl to 1magl). Gravel pack placed from 51.0m to 2mbgl

Hours Worked on Site			Remarks: Standing Time/Weather Conditions/Groundwater etc:	Signed for Scott Wilson Ltd.
From	To	Total		
0630	1530	9		Signed for by Client:

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Contract:	Contract No:	Date:	Sheet No:	Ground Level (m):
Maghtab Landfill Site	M1022	17.09.02 Date Commenced: 09.09.02	7 of 7	Not Known

Drilling Method:	Drilling Equipment/Rig No:	Drilling/Casing Diam (mm):	Bit Type:	Flush Type:
Rotary	AAN1	110mm to 49mbgl	Tungsten Carbide	Water

Borehole No	Angle of Hole	Strata Thickness (m)		Description of Strata	Depth of Casing (m)	Flush Return (%)	Final Depth Borehole (m)
		From	To				
MW5	-	-	-	Complete well installation	-	NA	51
				and demobilise			

Comments:
Casing withdrawn and bentonite placed from 2mbgl to GL. On completion, place steel protection cover with concrete plinth at base and secure with padlock. Demobilise rig and equipment

Hours Worked on Site		
From	To	Total
0630	1530	9

Remarks: Standing Time/Weather Conditions/Groundwater etc:

Signed for Scott Wilson Ltd.

Signed for by Client:

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Contract: Wied Fulija Landfill Site	Contract No: M1022	Date: 23.08.02 Date Commenced: 23.08.02	Sheet No: 1 of 4	Ground Level (m): Not Known

Drilling Method: Rotary	Drilling Equipment/Rig No: AANI	Drilling/Casing Diam (mm): 101mm to 10mbgl	Bit Type: Tungsten Carbide	Flush Type: Water

Borehole No	Angle of Hole	Strata Thickness (m)		Description of Strata	Depth of Casing (m)	Flush Return (%)	Final Depth Borehole (m)
		From	To				
WFW1	-	-	-		-	-	-

Comments:
Mobilise and set up rig at location of WFW1.

Hours Worked on Site			Remarks: Standing Time/Weather Conditions/Groundwater etc:	Signed for Scott Wilson Ltd.
From	To	Total	Sunny and clear with light to moderate winds	Signed for by Client:
0700	1500	8		

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Contract: Wied Fulija Landfill Site	Contract No: M1022	Date: 26.08.02 Date Commenced: 23.08.02	Sheet No: 2 of 4	Ground Level (m): Not Known

Drilling Method: Rotary	Drilling Equipment/Rig No: AANI	Drilling/Casing Diam (mm): 101mm to 10mbgl	Bit Type: Tungsten Carbide	Flush Type: Water

Borehole No	Angle of Hole	Strata Thickness (m)		Description of Strata	Depth of Casing (m)	Flush Return (%)	Final Depth Borehole (m)
		From	To				
WFW1	90^{o}	GL	10	Waste & Cover Material	10	0	10

Comments:

Hours Worked on Site			Remarks: Standing Time/Weather Conditions/Groundwater etc:	Signed for Scott Wilson Ltd.
From	To	Total		
0630	1530	9	Sunny and clear with light to moderate winds	Signed for by Client:

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Contract:	Contract No:	Date:	Sheet No:	Ground Level (m):
Wied Fulija Landfill Site	M1022	27.08.02 Date Commenced: 23.08.02	3 of 4	Not Known

Drilling Method:	Drilling Equipment/Rig No:	Drilling/Casing Diam (mm):	Bit Type:	Flush Type:
Rotary	AANI	101mm to 12mbgl	Tungsten Carbide	Water

Borehole No	Angle of Hole	Strata Thickness (m)		Description of Strata	Depth of Casing (m)	Flush Return (%)	Final Depth Borehole (m)
		From	To				
WFW1	90^{o}	10	20.5	Waste & Cover Material	12	0	20.5

Comments:

Hours Worked on Site		
From	To	Total
0630	1530	9

Remarks: Standing Time/Weather Conditions/Groundwater etc:

Sunny and clear with light to moderate winds

Signed for Scott Wilson Ltd.

Signed for by Client:

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Contract: Wied Fulija Landfill Site	Contract No: M1022	Date: 28.08.02 Date Commenced: 23.08.02	Sheet No: 4 of 4	Ground Level (m): Not Known

Drilling Method: Rotary	Drilling Equipment/Rig No: AANI	Drilling/Casing Diam (mm): 101mm to 20mbgl	Bit Type: Tungsten Carbide	Flush Type: Water

Borehole No	Angle of Hole	Strata Thickness (m)		Description of Strata	Depth of Casing (m)	Flush Return (%)	Final Depth Borehole (m)
		From	To				
WFW1	90°	-	-	Well Installation	20	NA	20.5

Comments:
Run bit to clean hole and advance casing to 20mbgl. Install galvanised steel well liner (50mm dia. 'drilled' standpipe from 20.50 to 2mbgl and plain standpipe from 2mbgl to 1magl). Gravel pack placed from 37 to 2mbgl and bentonite from 2mbgl to GL. On completion, place steel protection cover with concrete plinth at base and secure with padlock.
(1450hrs) Temperature of emissions from top of casing recorded at 73.4°C. Ambient Air Temperature = 32.6 °C.

Hours Worked on Site		
From	To	Total
0630	1530	9

Remarks: Standing Time/Weather Conditions/Groundwater etc:

Sunny with some cloud and light to moderate winds. Mid morning shower.

Signed for Scott Wilson Ltd.

Signed for by Client:

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Contract:	Contract No:	Date:	Sheet No:	Ground Level (m):
Wied Fulija Landfill Site	M1022	29.08.02 Date Commenced: 29.08.02	1 of 2	Not Known

Drilling Method:	Drilling Equipment/Rig No:	Drilling/Casing Diam (mm):	Bit Type:	Flush Type:
Rotary	AANI	101mm to 12mbgl	Tungsten Carbide	Water

Borehole No	Angle of Hole	Strata Thickness (m) From	Strata Thickness (m) To	Description of Strata	Depth of Casing (m)	Flush Return (%)	Final Depth Borehole (m)
WFW2	90^o	GL	12	Waste & Cover Material	12	0	12

Comments:
(0630 – 0845hrs) Mobilise and set up rig.

Hours Worked on Site From	To	Total	Remarks: Standing Time/Weather Conditions/Groundwater etc:	Signed for Scott Wilson Ltd.
0630	1530	9	Overcast with moderate winds. Early afternoon shower.	Signed for by Client:

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Contract: Wied Fulija Landfill Site	Contract No: M1022	Date: 30.08.02 Date Commenced: 29.08.02	Sheet No: 2 of 2	Ground Level (m): Not Known

Drilling Method: Rotary	Drilling Equipment/Rig No: AANI	Drilling/Casing Diam (mm): 101mm to 21.25mbgl	Bit Type: Tungsten Carbide	Flush Type: Water

Borehole No	Angle of Hole	Strata Thickness (m)		Description of Strata	Depth of Casing (m)	Flush Return (%)	Final Depth Borehole (m)
		From	To				
WFW2	90°	12	19.5	Waste & Cover Material	19.5	0	19.5
	90°	19.5	21.25	Lwr Coralline Limestone	19.5	0	21.25

Comments:
Install galvanised well liner (50mm dia. 'drilled' standpipe from 21.25 to 2mbgl and plain standpipe from 2mbgl to 1magl). Gravel pack placed from 21.25 to 2mbgl and bentonite from 2mbgl to GL. On completion, place steel protection cover with concrete plinth at base and secure with padlock.

Hours Worked on Site		
From	To	Total
0630	1545	9.25

Remarks: Standing Time/Weather Conditions/Groundwater etc:

Cloudy with moderate winds.

Signed for Scott Wilson Ltd.

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Contract: Qortin Landfill Site	Contract No: M1022	Date: 02.09.02 Date Commenced: 02.09.02	Sheet No: 1 of 3	Ground Level (m): Not Known

Drilling Method: Rotary	Drilling Equipment/Rig No: AANI	Drilling/Casing Diam (mm): -	Bit Type: Tungsten Carbide	Flush Type: Water

Borehole No	Angle of Hole	Strata Thickness (m)		Description of Strata	Depth of Casing (m)	Flush Return (%)	Final Depth Borehole (m)
		From	To				
QBH1	90^{o}	GL	3	Upr Corraline Limestone	GL	0	3

Comments:
Mobilise and set up rig at location of QBH1.

Hours Worked on Site			Remarks: Standing Time/Weather Conditions/Groundwater etc:	Signed for Scott Wilson Ltd.
From	To	Total		
0630	1530	9	Sunny and clear with light to moderate winds	Signed for by Client:

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Contract: Qortin Landfill Site	Contract No: M1022	Date: 03.09.02 Date Commenced: 02.09.02	Sheet No: 2 of 3	Ground Level (m): Not Known

Drilling Method: Rotary	Drilling Equipment/Rig No: AANI	Drilling/Casing Diam (mm): -	Bit Type: Tungsten Carbide	Flush Type: Water

Borehole No	Angle of Hole	Strata Thickness (m)		Description of Strata	Depth of Casing (m)	Flush Return (%)	Final Depth Borehole (m)
		From	To				
QBH1	90^o	3	12	Upr Coralline Limestone	-	0	-
		12	23	Blue Clay	-		23
					-	0	

Comments:
Foreman reports Blue Clay encountered at an approximate depth of 12mbgl.
(04.09.02) Install UPVC well liner (50mm dia. 'slotted standpipe from 23 to 2mbgl and plain standpipe from 2mbgl to 1magl). Gravel pack placed from 23 to 2mbgl and bentonite from 2mbgl to GL. On completion, place steel protection cover with concrete plinth at base and secure with padlock.

Hours Worked on Site		
From	To	Total
0630	1530	9

Remarks: Standing Time/Weather Conditions/Groundwater etc:

Sunny and clear with light to moderate winds

Signed for Scott Wilson Ltd.

Signed for by Client:

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Contract:	Contract No:	Date:	Sheet No:	Ground Level (m):
Qortin Landfill Site	M1022	03.09.02 Date Commenced: 03.09.02	1 of 3	Not Known

Drilling Method:	Drilling Equipment/Rig No:	Drilling/Casing Diam (mm):	Bit Type:	Flush Type:
Rotary	AANI	101mm to 5mbgl	Tungsten Carbide	Water

Borehole No	Angle of Hole	Strata Thickness (m)		Description of Strata	Depth of Casing (m)	Flush Return (%)	Final Depth Borehole (m)
		From	To				
QW1	90°C	GL	5	Waste & Cover Material	5	0	5

Comments:
(1315 – 1415) Mobilise and set up rig at location of QW1.
N.B. QW1 relocated following obstruction encountered at 0.75mbgl at initial location.

Hours Worked on Site			Remarks: Standing Time/Weather Conditions/Groundwater etc:	Signed for Scott Wilson Ltd.
From	To	Total		
0630	1700	10.5	Sunny with some cloud and light winds	Signed for by Client:

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Contract:	Contract No:	Date: 04.09.02	Sheet No:	Ground Level (m):
Qortin Landfill Site	M1022	Date Commenced: 03.09.02	2 of 3	Not Known

Drilling Method:	Drilling Equipment/Rig No:	Drilling/Casing Diam (mm):	Bit Type:	Flush Type:
Rotary	AANI	101mm to 12mbgl	Tungsten Carbide	Water

Borehole No	Angle of Hole	Strata Thickness (m)		Description of Strata	Depth of Casing (m)	Flush Return (%)	Final Depth Borehole (m)
		From	To				
QW1	90°	5	12	Waste & Cover Material	12	0	12

Comments:
(1310) Foreman reports drilling rig breakdown. No further progress throughout course of day.

Hours Worked on Site			Remarks: Standing Time/Weather Conditions/Groundwater etc:	Signed for Scott Wilson Ltd.
From	To	Total		
0630	1315	6.75	Sunny with some cloud and light winds.	Signed for by Client:

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Contract: Qortin Landfill Site	Contract No: M1022	Date: 05.09.02 Date Commenced: 03.09.02	Sheet No: 3 of 3	Ground Level (m): Not Known

Drilling Method: Rotary	Drilling Equipment/Rig No: Coralias*******	Drilling/Casing Diam (mm): 101mm to 18mbgl	Bit Type: Tungsten Carbide	Flush Type: Water

Borehole No	Angle of Hole	Strata Thickness (m)		Description of Strata	Depth of Casing (m)	Flush Return (%)	Final Depth Borehole (m)
		From	To				
QW1	90^o	12	18	Waste & Cover Material	18	0	18

Comments:
Install galvanised steel well liner (50mm dia. 'drilled' standpipe from 18mbgl to 2mbgl and plain standpipe from 2mbgl to 1magl). Gravel pack placed from 18 to 2mbgl and bentonite from 2mbgl to GL.
(06.09.02) Place steel protection cover with concrete plinth at base and secure with padlock.

Hours Worked on Site		
From	To	Total
0800	1230	4.5

Remarks: Standing Time/Weather Conditions/Groundwater etc:

Sunny and clear with light winds.

Signed for Scott Wilson Ltd.

Signed for by Client:

Appendix B

Testing Schedules

Sample Ref	Description	ICRCL	Asbestos	VOCs	SVOCs	Dioxins	PCBs	Organotin
		40	24	9	9	14	0	4
MSS01	Pale Brown topsoil	●				●		
MSS02	Red silt on Garigue	●						
MSS03	Red silt on Garigue	●						
MSS04	Red silt on Garigue	●						
MSS05	Terracotta Soil	●				●		
MSS06	Red silt on Garigue	●						
MSS07	Red silt/clay from bird trapping area	●				●		
MSS08	Crushed limestone fill	●	●					
MSS09	Crushed limestone fill	●	●					
MSS10	Red silt on Garigue	●				●		
MSS11	Terracotta Soil	●						
MSS12	Terracotta Soil	●						
MSS13	Terracotta Soil	●						
MSS14	Terracotta Soil	●				●		
MSS15	Terracotta Soil	●						
MSW01	Dark grey cover on main tipping area	●	●	●	●	●		
MSW02	Decomposed putrescible wastes	●						
MSW03	Black/grey sludge from slurry lagoon	●		●	●	●		●
MSW04	Black/grey sludge from slurry lagoon	●						●
MSW05	Surface limestone cover from top tipping area	●	●					
MSW06	Vent deposits on top tipping area	●	●	●	●	●		
MSW07	Surface limestone cover from Ghallis extension	●	●					
MSW08	Surface cover/dozer track	●	●					
MSW09	Dried blue slurry/filter cake	●	●					
MSW10	Daily cover/rubbish from level below main tipping area	●	●					
MSW11	Daily cover/rubbish from level below main tipping area	●	●					
MSW12	Daily cover from level below main tipping area	●	●					
MSW13	Silt from north face	●	●					
MSW14	Burnt waste near vent	●	●	●	●	●		
MSW15	Stained (burnt) surface cover	●	●	●	●	●		
MSW16	Dried sludge on north face	●	●					●
MSW17	Dried slurry from lower slurry lagoon	●	●	●	●	●		●
MSW18	Surface cover	●	●					
MSW19	Black soot in drum	●	●	●	●	●		

Sample Ref	Description	ICRCL	Asbestos	VOCs	SVOCs	Dioxins	PCBs	Organotin
		40	24	9	9	14	0	4
MSW20	Old ashy waste and plastic	●	●					
MSW21	Dust from main haul road	●	●					
MSW22	Old waste	●	●					
MSW23	Burnt waste near vent	●	●	●	●	●		
MSW24	Stained (burnt) surface cover	●	●	●	●	●		
MSW25	Burnt domestic waste	●	●					

Sample Ref	Description	ICRCL	Asbestos	VOCs	SVOCs	Dioxins	PCBs	Organotin
		15	**9**	**3**	**3**	**6**	**0**	**0**
WFSS01	Terracotta Soil	●						
WFSS02	Terracotta Soil	●				●		
WFSS03	Terracotta Soil	●				●		
WFSS04	Terracotta Soil	●						
WFSS05	Terracotta Soil	●						
WFSS06	Terracotta Soil	●						
WFSW01	Surface cover on top of eastern waste mound	●	●					
WFSW02	Surface cover on top of eastern waste mound	●	●					
WFSW03	Vent deposits eastern mound	●	●	●	●	●		
WFSW04	Burnt domestic waste on eastern mound	●	●			●		
WFSW05	Waste cover on base of valley	●	●					
WFSW06	Crushed limestone cover on western mound	●	●					
WFSW07	Dark brown waste on top of western mound	●	●					
WFSW08	Discoloured brown crushed limestone cover	●	●	●	●	●		
WFSW09	Vent deposits top of western mound	●	●	●	●	●		

Sample Ref	Description	ICRCL	Asbestos	VOCs	SVOCs	Dioxins	PCBs	Organotin
		9	5	2	2	2	0	1
QSS01	Terracotta Soil	●				●		
QSS02	Pale grey soil on blue clay	●						
QSS03	Blue Clay	●						
QSS04	Red silt on Garigue	●						
QSW01	Dried grey slurry	●	●					●
QSW02	Limestone clay cover on haul road	●	●					
QSW03	Ash associated with burnt DW	●	●	●	●	●		
QSW04	Burnt waste on landfill top	●	●	●	●			
QSW05	Waste and cover mixed on top	●	●					

ID	pH/EC	TDS/TSS	COD	Phenols	TKN/NH4-N	Metals	Major Ions	Sulphide	VOCs	SVOCs
MBH1	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
MBH2	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
MBH3	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
MBH4	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
MBH5	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
MBH6	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
QBH1	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
QOW1	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Q0W1D	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
QOW2	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
2027	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
2028	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
3308	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Ghajn Barrani	✓	✓	✓	✓	✓	✓	✓	✓		
Wied il-Ghasel PS	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
WFBH1	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
WFBH3	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓

	ICRCL	Asbestos	VOCs	SVOCs	Dioxins	PCBs	Organotin		
MMS1	✓			✓	✓	✓	✓		
MMS2	✓			✓	✓	✓	✓		
MMS3	✓			✓	✓	✓	✓	**Broken - in batch 3**	
QMS1	✓								

	pH/EC	TDS/TSS	COD	Phenols	TKN/NH4-N	Metals	Major Ions	Sulphide	VOCs	SVOCs
MMW1	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
QMW1	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
WFMW1	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓

ID	VOCs		
MGS1	✓		
MGS2	✓		
MGS3	✓		
MGS4	✓		
MGS5	✓		
MGS6	✓		
MGS7	✓		
MW1	✓		
MW2	✓		
MW5	✓	Empty - resampled	
QBH1	✓		
QGS1	✓		
QGS2	✓		
WFW1	✓		
WFW2	✓		
WFGS1	✓		
WFGS2	✓		
WFGS3	✓		

	ICRCL	Asbestos	VOCs	SVOCs	Dioxins	PCBs	Organotin
MSS16	✓				✓		
MSS17	✓				✓		
MSS18	✓				✓		
MSS19	✓				✓		
MSS20	✓				✓		
MSS21	✓				✓		
MSS22	✓				✓		
MSS23	✓				✓		
MSS24	✓				✓		
MSS25	✓				✓		
MSS26	✓				✓		
MSS27	✓				✓		
MSS28	✓				✓		

Appendix C
Gas/Temperature Monitoring

ID	Easting	Northing	Temp C	Methane	CO2 %	O2%	CO ppm	H2S ppm	VOCs ppm
MGM1	49451	78100	42.7	0	0	20.7	9	0	48.9
MGM2	49492	78160	51.3	0	0.1	20.8	9	0	0
MGM3	49475	78211	38.9	0	0	20.8	7	0	0
MGM4	49470	78272	64.3	0	2.3	18.3	303	0	59
MGM5	49473	78310	95	0	2.6	17.9	1901	0	221
MGM6	49510	78357	133	1.2	15	8.2	2999	6	90.8
MGM7	49594	78365	81	1.2	22.1	1.7	2999	15	238
MGM8	49544	78377	150	0.6	7.9	12.9	2999	0	160
MGM9	49591	78418	25.1	0.3	0.1	20	67	0	152
MGM10	49601	78429	284	0.7	10.5	10.4	2999	0	876
MGM11	49611	78426	142	0.7	4.7	15.2	2860	0	115
MGM12	49631	78445	101.7	0.4	1.7	18	570	0	99.1
MGM13	49647	78475	110	0.7	3	17	2999	1	89.9
MGM14	49663	78555	83.9	0.7	14.9	3.6	2999	8	1017
MGM15	49664	78574	83.3	0.6	0.3	24	350	0	74.2
MGM16	49644	78572	33.5	4.5	0	20.3	55	0	138
MGM17	49645	78513	75.8	0.3	0	20.7	50	0	68.9
MGM18	49608	78453	239	0.8	3.4	16.2	2999	3	37.2
MGM19	49632	78607	39.1	0.5	0.4	20.3	135	0	18.2
MGM20	49607	78644	118.1	0.4	2.6	18	2999	8	2764
MGM21	49593	78645	124	0.4	3.9	17.5	1500	1	153
MGM22	49562	78671	192.7	0.4	10.3	8.9	999	17	1472
MGM23	49548	78688	92.7	0.4	4.2	18.5	111	0	188
MGM24	49539	78717	56.2	0.3	0.5	21	40	0	17.7
MGM25	49510	78737	34.2	0.3	0.2	21.1	25	0	20.6
MGM26	49527	78700	57.7	0.1	0.1	21.1	40	0	22.4
MGM27	49557	78664	34.3	0.2	0.4	21	40	0	39
MGM28	49587	78632	30.9	0.2	0.1	21.1	21	0	133
MGM29	49623	78595	76.1	0.2	5.3	13.8	145	0	263
MGM30	49478	78325	144.7	0.2	0.6	19.3	140	0	154
MGM31	49473	78146	33.9	0.1	0.2	21	13	0	23.1
MGM32	49453	78207	30.7	0	0.1	21.2	11	0	0
MGM33	49451	78281	32.9	0.1	0.1	21.3	19	0	0
MGM34	49457	78318	50.7	0.2	0	21.1	29	0	12.4
MGM35	49449	78382	40.5	0.2	0	21.1	30	0	0

ID	Easting	Northing	Temp C	Methane	CO2 %	O2%	CO ppm	H2S ppm	VOCs ppm
MGM36	49722	78396	83.3	0.1	9.7	12.2	1212	0	538
MGM37	49718	78410	83.4	0	3.3	17.9	374	0	59.6
MGM38	49775	78337	57	0	1.6	18.3	40	0	0
MGM39	49771	78321	74.9	0	5	13.3	219	0	27.8
MGM40	49742	78290	78.9	0	3.4	15.9	432	0	126
MGM41	49700	78298	39.1	0	0.6	20.5	38	0	0
MGM42	49670	78297	80.9	0	0.2	20.4	298	0	20.4
MGM43	49657	78302	88.2	0.5	12.1	9.1	2999	0	2879
MGM44	49638	78300	194.3	0	10.4	20.1	169	0	254
MGM45	49673	78346	46.3	0.6	10.3	13.4	132	0	631
MGM46	49711	78334	96.6	0.7	8.5	14.1	1537	0	1027
MGM47	49723	78356	141.8	0.2	2.6	19.9	1678	0	958
MGM48	49695	78384	80.1	0.1	6.4	10.1	752	0	241
MGM49	49745	78353	330	0.1	3.7	18.5	617	0	199
MGM50	49741	78245	29.7	0	0	20.9	34	0	0
MGM51	49608	78114	35.4	0	0.1	20.8	35	0	0
MGM52	49571	78252	36.1	0	0	20.9	12	0	0
MGM53	49620	78278	63.4	0.2	3.78	17.9	422	0	32
MGM54	49631	78209	25.9	0	0.5	20.7	26	0	24.4
MGM55	49768	78428	79.9	0.7	12.9	8.4	68	0	0
MGM56	49692	78524	35.5	0	0	20.8	47	0	0
MGM57	49708	78546	26.5	0	0	20.8	30	0	21.9
MGM58	49745	78505	28.5	0	0	20.8	25	0	0
MGM59	49775	78456	31.5	0.8	0.1	20.7	17	0	0
MGM60	49784	78441	79.7	0.4	13.2	5.3	2999	5	33.4
MGM61	49821	78419	73	0.1	2.5	18.7	1034	0	547
MGM62	49800	78464	40.9	0.3	1.3	19.2	585	0	2005
MGM63	49794	78493	95.2	0.3	3	17.3	1505	0	161
MGM64	49747	78543	34.8	0	0	20.8	37	0	0
MGM65	49677	78602	41.8	0.3	0	21.1	19	0	19
MGM66	49643	78624	60.5	0.7	0	19.2	538	0	56.3
MGM67	49662	78705	178	0	0.2	20.9	31	0	0
MGM68	49594	78679	53	6.4	3.2	16.3	42	0	0
MGM69	49662	78631	70.5	0.4	6.5	13.2	907	0	18.7
MGM70	49734	78596	48.7	0.4	1.4	19.7	75	0	0

ID	Easting	Northing	Temp C	Methane	CO2 %	O2%	CO ppm	H2S ppm	VOCs ppm
MGM71	49768	78556	185	0.4	6.3	13.9	1044	0	89.2
MGM72	49797	78504	135.4	0.4	1.8	19.5	457	0	17.6
MGM73	49827	78458	76.5	0.2	21.6	3.3	2999	0	362
MGM74	49845	78400	105.4	0	2.1	19.4	154	0	51.5
MGM75	49849	78436	81.7	0	7.5	12.7	1215	0	87.3
MGM76	49810	78496	298	0.1	2.7	14.3	2999	1	243
MGM77	49795	78546	331	0.2	5.2	14.1	1258	0	124
MGM78	49749	78635	164.5	0.2	3.2	19.3	382	0	54.3
MGM79	49695	78648	29.5	0	1.1	20.4	54	0	21.1
MGM80	49617	78680	26	0	0.5	20.5	39	0	0
MGM81	49572	78709	262	0	2.6	17.8	782	0	1223
MGM82	49502	78758	23.7	0	1.3	20.5	34	0	0
MGM83	49555	78740	71	0	0.8	20.2	496	0	251
MGM84	49618	78704	54.5	0	0.7	20	47	2	2787
MGM85	49668	78694	46.5	0	0.4	14	30	0	341
MGM86	49771	78670	320	0.2	2.2	18.8	2243	0	2511
MGM87	49795	78637	275	0.2	3.2	20.6	1386	0	1140
MGM88	49824	78577	26.3	0.3	1.5	20.8	64	0	0
MGM89	49861	78502	31.2	0.3	0.7	20.8	59	0	0
MGM90	49897	78458	26.2	0	0.5	20.7	54	0	0
MGM91	49897	78458	27.5	0	0.3	20.5	47	0	0
MGM92	49944	78381	30.2	0	0.2	20.8	14	0	0
MGM93	49992	78422	31.9	0	0	16.2	18	0	0
MGM94	49826	78651	194	0.2	4	19.6	1874	0	3604
MGM95	49772	78680	59.5	0.2	0.8	20.8	144	0	211
MGM96	49654	78713	34	0	0.2	20.8	28	0	0
MGM97	49626	78728	39.6	0	0.1	18.3	27	0	42.8
MGM98	49564	78746	62.9	0.1	2	16.7	69	0	128
MGM99	49550	78772	52.8	0.1	3.4	20.4	43	0	0
MGM100	49563	78758	52	0	0.5	19.2	49	0	195
MGM101	49579	78757	53.4	0.1	1	19.2	33	0	5900
MGM102	49649	78730	38.4	0	0.4	19.1	29	0	0
MGM103	49849	78641	49.1	0	0.4	20.6	42	0	270
MGM104	49548	78785	52	0.1	0.1	20.8	21	0	0
MGM105	49869	78622	28.9	0	0.1	20.8	21	0	0

ID	Easting	Northing	Temp C	Methane	CO2 %	O2%	CO ppm	H2S ppm	VOCs ppm
MGM106	49932	78490	30.6	0	0.1	20.9	20	0	0
MGM107	49897	78516	31	0	0	20.8	19	0	0
MGM108	49859	78565	31.7	0	0	20.8	19	0	0
MGM109	49869	78309	54.3	0.1	1.6	18.9	28	0	174
MGM110	49834	78253	66.9	0.1	3.7	15.9	590	0	2146
MGM111	49777	78185	43.5	0	0.6	19.9	44	0	331
MGM112	49720	78129	30.3	0.1	0.2	20.6	26	0	0
MGM113	49689	78064	28.5	0	0.2	20.6	21	0	0
MGM114	49674	78989	28.9	0	0.1	20.2	18	0	0
MGM115	49623	77850	25.4	0	0.1	20.7	17	0	0
MGM116	49618	77791	25.9	0	0.1	20.7	16	0	0
MGM117	49614	77698	26.8	0	0	20.8	17	0	0
MGM118	49674	77671	29.2	0	0	20.9	18	0	0
MGM119	49689	77714	28.7	0	0	20.8	17	0	0
MGM120	49695	77796	31.2	0	0	20.9	16	0	0
MGM121	49690	77877	28.7	0	0	20.8	17	0	0
MGM122	49691	77966	27.7	0	0	20.9	19	0	0
MGM123	49705	78060	29	0	0	20.9	17	0	0
MGM124	49768	78141	27.7	0.3	0	20.9	18	0	0
MGM125	49843	78199	27.5	0	0	20.8	19	0	0
MGM126	49879	78258	28.1	0	0	21	19	0	0
MGM127	49910	78330	28.5	0	0	21	15	0	0
MGM128	49665	78045	36.5	0	0	21	16	0	0
MGM129	49678	78096	47.5	0.1	0	20.9	13	0	0
MGM130	49702	78160	98.7	0.1	0.3	20.4	56	0	41.3
MGM131	49803	78334	58.7	0.2	4.7	15	150	0	349
MGM132	49790	78378	48.8	0.2	8.3	12	105	0	588
MGM133	49546	78091	296	6.8	20.5	2.2	2999	28	1750
MGM134	49514	78178	71.8	0.4	14.9	5.5	946	0	249
MGM135	49541	78337	43.5	0.5	4.4	15.2	104	0	38.2
MGM136	49603	78389	123.2	0.6	13.5	6.2	2999	6	1973
MGM137	49641	78417	67.7	0.7	5.5	13.9	1207	0	203
MGM138	49675	78424	60.7	0.4	3.9	16.3	934	0	547
MGM139	49482	78270	190.3	2.1	9.1	11.9	2999	22	3248

ID	Easting	Northing	Temp C	Methane	CO2 %	O2%	CO ppm	H2S ppm	VOCs ppm
WFGM1	53303	63807	155	0.1	2.9	17.1	881	0	72.5
WFGM2	53274	63862	54.1	0.4	3.5	17.1	216	0	50.1
WFGM3	53314	63885	25.1	0	0.4	20.6	19	0	0.0
WFGM4	53394	63822	26.4	0	0	20.9	20	0	0.0
WFGM5	53340	63386	25.4	0	0	20.9	19	0	0.0
WFGM6	53291	63920	28.5	0	0	21	20	0	0.0
WFGM7	53339	63887	26	0	0	21	18	0	0.0
WFGM8	53290	63943	24.9	0	0	20.8	18	0	0.0
WFGM9	53244	63865	34	0	0	20.9	17	0	0.0
VFGM1	53257	63819	26.2	0	0	20.8	16	0	0.0
VFGM1	53261	63813	28.9	0	0	20.8	16	0	0.0
VFGM1	53317	63778	26.5	0	0	20.8	17	0	0.0
VFGM1	53379	63763	28.1	0	0	20.9	18	0	0.0
VFGM1	53387	63742	26.5	0	0	21	18	0	0.0
VFGM1	53263	64006	34.1	0	0	20.5	15	0	0.0
VFGM1	53209	64002	26	0	0	20.6	19	0	0.0
VFGM1	53154	64000	33.9	0	0	20.8	20	0	0.0
VFGM1	53201	63992	34.2	0	0	20.4	16	0	0.0
VFGM1	53243	63959	40.2	0.2	0	20.8	21	0	0.0
VFGM2	53219	63948	52.3	0.1	0	20.8	49	0	0.0
VFGM2	53139	63936	26.4	0	0	20.9	19	0	0.0
VFGM2	53094	63869	24.1	0	0	21	19	0	0.0
VFGM2	53063	63851	32	0.1	0	21	18	0	0.0
VFGM2	53036	63831	30.1	0	0	21	17	0	0.0
VFGM2	53042	63852	26.3	0	0	21	16	0	0.0
VFGM2	53060	63780	243	0.1	3.3	17	904	0	331
VFGM2	53004	63803	143	0.0	0.5	20.4	44	0	45.2
VFGM2	53019	63809	85.8	0.3	5.1	15.3	1183	0	278
VFGM2	53088	63818	79.8	1.1	1.4	18.7	1857	2	492
VFGM3	53174	63845	70.0	0.3	3.8	15.8	209	0	57.0
VFGM3	52941	63768	46.0	0.1	0.5	20.2	168	0	0.0
VFGM3	52941	63753	43.3	0.1	0.2	20.9	52	0	0.0
VFGM3	53974	63744	38.1	0.0	0.4	20.6	53	0	0.0
VFGM3	53026	63779	41.7	0.1	2.0	18.6	81	0	0.0
VFGM3	53119	63793	32.1	0.1	0.2	20.9	32	0	0.0

ID	Easting	Northing	Temp C	Methane	CO2 %	O2%	CO ppm	H2S ppm	VOCs ppm
VFGM3	53181	63800	55.5	0.6	6.0	14.8	1672	0	485
VFGM3	53085	63759	28.8	0.1	0.5	20.7	58	0	0.0
VFGM3	53033	63751	26.2	0.9	0.2	21.0	35	0	0.0
VFGM3	53109	63779	52.7	0.0	0.0	20.9	32	0	0.0
VFGM4	53201	63779	153	0.9	1.2	16.5	3000	3	1040
VFGM4	53212	63808	39.2	0.4	0.6	20.5	82	0	72.3
VFGM4	53214	63864	51.7	0.4	11.1	8.9	387	0	102
VFGM4	53217	63926	43.9	0.2	2.3	19.3	68	0	0.0
VFGM4	53279	63984	28.5	0.0	0.1	20.7	32	0	0.0

ID	Easting	Northing	Temp C	Methane	CO2 %	O2%	CO ppm	H2S ppm	VOCs ppm
QGM1	33974	91777	28.2	0	0	20.5	6	0	0
QGM2	34029	91782	26.7	0	0	20.6	9	0	0
QGM3	34061	91826	28.9	0	0	20.3	15	0	0
QGM4	34086	91864	29.4	0	0	20.2	16	0	0
QGM5	34102	91897	29.6	0	0	20.6	11	0	0
QGM6	34100	91976	29.2	0	0	20.23	20	0	0
QGM7	34111	92018	26.7	0	0	20.3	21	0	0
QGM8	34122	92045	26.3	0	0	20.4	19	0	0
QGM9	34165	92076	23.9	0	0	20.4	21	0	0
QGM10	34199	92066	26.8	0	0	20.6	21	0	0
QGM11	34228	92032	26.2	0	0	20.7	22	0	0
QGM12	34120	92010	35.4	0.1	0.5	20.2	17	0	0
QGM13	34154	92047	39.4	0.1	0.2	20.6	19	0	0
QGM14	34191	92047	51.5	0.2	14.3	5.3	130	0	14.9
QGM15	34213	92007	58.4	3.8	10.9	9.5	73	0	0
QGM16	34219	91971	67.5	18.5	18.8	5.3	211	0	28.4
QGM17	34210	91930	33.6	0.3	5.1	15.6	34	0	0
QGM18	34139	91884	63.1	0.3	6.8	15.4	34	0	0
QGM19	34135	91906	329	0.1	2.6	17.8	2172	0	448
QGM20	34183	91947	42.3	2.2	5.2	15.9	35	0	0
QGM21	34132	91474	40.7	0	1.6	19.2	23	0	0
QGM22	34117	91923	27.8	0	0.3	20.7	18	0	0
QGM23	34118	91857	27.5	0	0.1	20.9	19	0	0
QGM24	34115	91824	45.3	0.1	3.9	15.2	24	0	0
QGM25	34160	91830	23.9	0	1.4	20.5	18	0	0
QGM26	34194	91864	26.5	0.1	0.3	20.7	18	0	0
QGM27	33004	91887	25.9	0.1	0.1	20.7	19	0	0
QGM28	33019	91925	29.6	0	0.1	20.8	19	0	0
QGM29	33088	91888	27.8	0	0	20.9	17	0	0
QGM30	33174	91876	31.5	0	0	20.6	17	0	0

Appendix D
Soil Analyses

Sample Number	Sample Identity	Type	Depth (m)	Arsenic	Chromium	Copper	Nickel	Lead	Total Sulphate by ICP	Zinc	Acid Soluble Sulphid	Complex Cyanide	Thiocyanate	PAH total 16 GC	Total Phenols HPLC	Cadmium by IRIS	Mercury by IRIS	Selenium by IRIS	Total Organic Matter	pH Value In Soil
		Units		ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	%	
		Method Detection Limit		<1	<1	<1	<1	<1	<50	<1	<10	<2.5	<1	<1.6	<0.01	<0.5	<0.3	<0.5	<0.01	<1.00
	Maximum			**0**	**719**	**252**	**2097**	**563**	**13000**	**727**	**595**	**0**	**21**	**323**	**183.72**	**2.3**	**1.8**	**0**	**70.77**	**12.45**
27	MSW1	Dark grey granular cover materials with waste (ash? and crushed limestone)	0.00-50.00	<1	18	166	38	479	3400	493	<10	<2.5	1	25	<0.01	1.1	<0.3	<0.5	6.32	7.58
30	MSW2	Decomposing domestic waste	0.00-50.00	<1	18	34	21	563	4000	224	<10	<2.5	6	3	1.63	0.7	<0.3	<0.5	2.25	7.79
33	MSW3	Black/grey organic sludge with strong odour	0.00-50.00	<1	64	185	21	76	6900	609	595	<2.5	12	59	0.78	0.8	<0.3	<0.5	11.85	7.58
36	MSW4	grey/dark brown sludge with strong odour	0.00-50.00	<1	13	26	7	6	1100	74	84	<2.5	3	32	1.85	<0.5	<0.3	<0.5	3.83	7.9
39	MSW5	Light grey surface cover material	0.00-50.00	<1	15	8	16	5	1400	34	20	<2.5	1	7	0.11	<0.5	<0.3	<0.5	0.38	7.64
42	MSW6	Dark brown vent exudate	0.00-50.00	<1	12	18	14	32	2700	61	<10	<2.5	2	<1.6	<0.01	<0.5	<0.3	<0.5	0.91	7.53
45	MSW7	Surface cover	0.00-50.00	<1	10	6	11	19	2300	34	<10	<2.5	21	323	183.72	<0.5	1.8	<0.5	4.4	6.87
47	MSW8	Surface cover from bulldozer access track	0.00-50.00	<1	21	20	19	41	2600	89	<10	<2.5	2	3	0.9	<0.5	<0.3	<0.5	0.65	7.73
50	MSW9	Pale blue dried slurry/filter cake	0.00-50.00	<1	6	27	7	2	3800	10	<10	<2.5	6	<1.6	0.19	<0.5	<0.3	<0.5	1	12.45
53	MSW10	Daily cover with domestic waste	0.00-50.00	<1	16	32	16	98	2400	189	<10	<2.5	2	4	0.02	<0.5	0.4	<0.5	1.21	7.37
56	MSW11	Daily cover with domestic waste	0.00-50.00	<1	20	48	18	82	4400	131	<10	<2.5	3	2	0.01	0.5	<0.3	<0.5	2.32	7.36
59	MSW12	Daily cover	0.00-50.00	<1	16	12	17	10	2100	35	<10	<2.5	<1	<1.6	<0.01	<0.5	<0.3	<0.5	0.93	8.43
62	MSW13	Grey silt (dried slurry)	0.00-50.00	<1	15	3	7	2	3600	12	<10	<2.5	<1	2	<0.01	<0.5	<0.3	<0.5	0.23	7.78
65	MSW14	Recently burnt waste	0.00-50.00	<1	18	18	18	121	2500	71	<10	<2.5	12	14	1.29	<0.5	0.4	<0.5	1.21	7.81
68	MSW15	Surface staining of cover associated with burning	0.00-50.00	<1	12	8	12	13	1800	33	<10	<2.5	4	<1.6	11.57	<0.5	<0.3	<0.5	0.52	7.19
71	MSW16	Pale grey dried sludge	0.00-50.00	<1	8	4	8	4	4000	15	<10	<2.5	<1	<1.6	0.86	<0.5	<0.3	<0.5	0.97	8.18
74	MSW17	Pale grey/pink sludge from lower slurry lagoon.	0.00-50.00	<1	719	252	34	205	7100	727	69	<2.5	2	2	0.11	0.7	<0.3	<0.5	3.87	7.47
77	MSW18	Pink ochre silt	0.00-50.00	<1	17	20	18	27	1400	79	<10	<2.5	<1	2	0.03	<0.5	<0.3	<0.5	0.41	8.04
80	MSW19	Black sooty material in crushed drum	0.00-50.00	<1	16	141	21	248	10000	442	12	<2.5	<1	3	0.02	0.7	<0.3	<0.5	2.67	8.06
83	MSW20	Old ashy degraded waste and plastic	0.00-50.00	<1	21	15	2097	32	13000	159	<10	<2.5	2	<1.6	0.03	<0.5	<0.3	<0.5	70.77	9.07
86	MSW21	Crushed limestone dust from main haul road	0.00-50.00	<1	13	10	14	11	1600	31	<10	<2.5	2	<1.6	<0.01	<0.5	<0.3	<0.5	0.29	8.19
89	MSW22	Old degraded waste	0.00-50.00	<1	31	168	35	557	6900	676	15	<2.5	12	3	<0.01	<0.5	<0.3	<0.5	4.34	6.86
92	MSW23	Stained and burnt cover materials	0.00-50.00	<1	17	6	16	5	1400	37	<10	<2.5	2	79	0.2	<0.5	0.5	<0.5	1.81	8.78
95	MSW24	Burnt waste	0.00-50.00	<1	12	221	11	29	1600	44	<10	<2.5	6	<1.6	0.36	<0.5	<0.3	<0.5	0.7	8.4
98	MSW25	Burnt domestic waste	0.00-50.00	<1	25	10	21	42	3600	51	<10	<2.5	12	10	0.58	2.3	<0.3	<0.5	1.9	7.92

Sample Number	Sample Identity	Type	Depth (m)	Total Cyanide	Asbestos Presence	Free Cyanide Soil	Phenol	4-Methylphenol	Naphthalene	Phenanthrene	Anthracene	Fluoranthene	Pyrene	Benzo(a)anthracene	Chrysene	2-Methylnaphthalene
		Units		ppm		ppm										
		Method Detection Limit		<2.5		<2.5										
	Maximum			**0**	**0**	**0**	**982.2616097**	**319.6412803**	**284.8838983**	**2079.279432**	**110.9392915**	**781.5316175**	**2240.920373**	**161.6209345**	**249.1115608**	**111.7461628**
27	MSW1	Dark grey granular cover materials with waste (ash? and crushed limestone)	0.00-50.00	<2.5	NFP	<2.5	<100	<100	<100	204.0367	<100	116.1343	118.5935	<100	<100	<100
30	MSW2	Decomposing domestic waste	0.00-50.00	<2.5	-	<2.5										
33	MSW3	Black/grey organic sludge with strong odour	0.00-50.00	<2.5	-	<2.5	<100	153.9251	<100	<100	<100	<100	<100	<100	<100	<100
36	MSW4	grey/dark brown sludge with strong odour	0.00-50.00	<2.5	-	<2.5										
39	MSW5	Light grey surface cover material	0.00-50.00	<2.5	NFP	<2.5										
42	MSW6	Dark brown vent exudate	0.00-50.00	<2.5	NFP	<2.5	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100
45	MSW7	Surface cover	0.00-50.00	<2.5	NFP	<2.5										
47	MSW8	Surface cover from bulldozer access track	0.00-50.00	<2.5	NFP	<2.5										
50	MSW9	Pale blue dried slurry/filter cake	0.00-50.00	<2.5	NFP	<2.5										
53	MSW10	Daily cover with domestic waste	0.00-50.00	<2.5	NFP	<2.5										
56	MSW11	Daily cover with domestic waste	0.00-50.00	<2.5	NFP	<2.5										
59	MSW12	Daily cover	0.00-50.00	<2.5	NFP	<2.5										
62	MSW13	Grey silt (dried slurry)	0.00-50.00	<2.5	NFP	<2.5										
65	MSW14	Recently burnt waste	0.00-50.00	<2.5	NFP	<2.5	693.7833	<100	284.8839	2079.279	110.9393	317.4752	223.5116	<100	207.3124	111.7462
68	MSW15	Surface staining of cover associated with burning	0.00-50.00	<2.5	NFP	<2.5	982.2616	319.6413	<100	301.8203	<100	<100	<100	<100	<100	<100
71	MSW16	Pale grey dried sludge	0.00-50.00	<2.5	NFP	<2.5										
74	MSW17	Pale grey/pink sludge from lower slurry lagoon.	0.00-50.00	<2.5	NFP	<2.5	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100
77	MSW18	Pink ochre silt	0.00-50.00	<2.5	NFP	<2.5										
80	MSW19	Black sooty material in crushed drum	0.00-50.00	<2.5	NFP	<2.5	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100
83	MSW20	Old ashy degraded waste and plastic	0.00-50.00	<2.5	NFP	<2.5										
86	MSW21	Crushed limestone dust from main haul road	0.00-50.00	<2.5	NFP	<2.5										
89	MSW22	Old degraded waste	0.00-50.00	<2.5	NFP	<2.5										
92	MSW23	Stained and burnt cover materials	0.00-50.00	<2.5	NFP	<2.5	<100	<100	<100	<100	<100	781.5316	2240.92	161.6209	249.1116	<100
95	MSW24	Burnt waste	0.00-50.00	<2.5	NFP	<2.5	256.803	<100	161.602	578.9196	<100	114.7791	<100	<100	149.3155	<100
98	MSW25	Burnt domestic waste	0.00-50.00	<2.5	NFP	<2.5										

Sample Number	Sample Identity	Type	Depth (m)	Dibenzofuran	Dimethyl phthalate	Di-n-butylphthalate	Bis(2-ethylhexyl)pht	tri butyl tin	Trichlorofluorometh	Chloroform	Benzene	Toluene	Tetrachloroethene	Chlorobenzene	Ethylbenzene	p/m-Xylene
		Units														
		Method Detection Limit														
	Maximum			**273.5133576**	**115.6578318**	**452.5033337**	**2968.744794**	**13.62698946**	**3**	**7**	**3728**	**3613**	**1**	**288**	**16785**	**948**
27	MSW1	Dark grey granular cover materials with waste (ash? and crushed limestone)	0.00-50.00	<100	<100	<100	2968.745		<1	<1	13	21	<1	<1	7	22
30	MSW2	Decomposing domestic waste	0.00-50.00													
33	MSW3	Black/grey organic sludge with strong odour	0.00-50.00	<100	<100	<100	1406.666	13.62699	<1	<1	<1	17	<1	<1	<1	2
36	MSW4	grey/dark brown sludge with strong odour	0.00-50.00					<10								
39	MSW5	Light grey surface cover material	0.00-50.00													
42	MSW6	Dark brown vent exudate	0.00-50.00	<100	<100	<100	301.311		3	7	3728	3613	<1	288	16785	948
45	MSW7	Surface cover	0.00-50.00													
47	MSW8	Surface cover from bulldozer access track	0.00-50.00													
50	MSW9	Pale blue dried slurry/filter cake	0.00-50.00													
53	MSW10	Daily cover with domestic waste	0.00-50.00													
56	MSW11	Daily cover with domestic waste	0.00-50.00													
59	MSW12	Daily cover	0.00-50.00													
62	MSW13	Grey silt (dried slurry)	0.00-50.00													
65	MSW14	Recently burnt waste	0.00-50.00	273.5134	<100	116.2464	1746.955		<1	<1	42	16	<1	7	13	9
68	MSW15	Surface staining of cover associated with burning	0.00-50.00	<100	<100	<100	268.3747		<1	<1	17	14	<1	3	27	6
71	MSW16	Pale grey dried sludge	0.00-50.00					<10								
74	MSW17	Pale grey/pink sludge from lower slurry lagoon.	0.00-50.00	<100	115.6578	452.5033	878.4293	<10	<1	<1	<1	<1	<1	<1	<1	<1
77	MSW18	Pink ochre silt	0.00-50.00													
80	MSW19	Black sooty material in crushed drum	0.00-50.00	<100	<100	<100	492.8861		<1	<1	<1	2	<1	<1	1	2
83	MSW20	Old ashy degraded waste and plastic	0.00-50.00													
86	MSW21	Crushed limestone dust from main haul road	0.00-50.00													
89	MSW22	Old degraded waste	0.00-50.00													
92	MSW23	Stained and burnt cover materials	0.00-50.00	<100	<100	<100	371.0882		<1	<1	<1	<1	1	<1	50	25
95	MSW24	Burnt waste	0.00-50.00	<100	<100	158.4755	778.5358		<1	<1	820	57	<1	12	46	10
98	MSW25	Burnt domestic waste	0.00-50.00													

Sample Number	Sample Identity	Type	Depth (m)	Styrene	o-Xylene	Isopropylbenzene	Propylbenzene	1,2,4-Trimethylbenze	1,3,5-Trimethylbenze	1,2-Dichlorobenzene	1,4-Dichlorobenzene	sec-Butylbenzene	tert-Butylbenzene	1,3-Dichlorobenzene	n-Butylbenzene	1,2,4-Trichlorobenze
		Units														
		Method Detection Limit														
	Maximum			**2812**	**1446**	**5583**	**316**	**234**	**355**	**130**	**34**	**93**	**370**	**38**	**421**	**41**
27	MSW1	Dark grey granular cover materials with waste (ash? and crushed limestone)	0.00-50.00	<1	7	<1	<1	1	3	<1	<1	<1	<1	<1	<1	<1
30	MSW2	Decomposing domestic waste	0.00-50.00													
33	MSW3	Black/grey organic sludge with strong odour	0.00-50.00	<1	<1	<1	<1	1	1	<1	<1	<1	5	<1	<1	<1
36	MSW4	grey/dark brown sludge with strong odour	0.00-50.00													
39	MSW5	Light grey surface cover material	0.00-50.00													
42	MSW6	Dark brown vent exudate	0.00-50.00	2812	1446	5583	316	234	355	130	32	93	370	38	421	31
45	MSW7	Surface cover	0.00-50.00													
47	MSW8	Surface cover from bulldozer access track	0.00-50.00													
50	MSW9	Pale blue dried slurry/filter cake	0.00-50.00													
53	MSW10	Daily cover with domestic waste	0.00-50.00													
56	MSW11	Daily cover with domestic waste	0.00-50.00													
59	MSW12	Daily cover	0.00-50.00													
62	MSW13	Grey silt (dried slurry)	0.00-50.00													
65	MSW14	Recently burnt waste	0.00-50.00	3	5	3	<1	3	3	2	<1	<1	<1	2	2	<1
68	MSW15	Surface staining of cover associated with burning	0.00-50.00	25	6	13	2	5	6	4	34	<1	11	<1	6	<1
71	MSW16	Pale grey dried sludge	0.00-50.00													
74	MSW17	Pale grey/pink sludge from lower slurry lagoon.	0.00-50.00	<1	<1	<1	<1	<1	<1	<1	11	<1	<1	<1	<1	<1
77	MSW18	Pink ochre silt	0.00-50.00													
80	MSW19	Black sooty material in crushed drum	0.00-50.00	<1	2	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
83	MSW20	Old ashy degraded waste and plastic	0.00-50.00													
86	MSW21	Crushed limestone dust from main haul road	0.00-50.00													
89	MSW22	Old degraded waste	0.00-50.00													
92	MSW23	Stained and burnt cover materials	0.00-50.00	7	25	17	2	25	14	61	17	2	13	35	10	41
95	MSW24	Burnt waste	0.00-50.00	23	9	6	2	5	4	3	<1	<1	1	2	3	<1
98	MSW25	Burnt domestic waste	0.00-50.00													

Sample Number	Sample Identity	Type	Depth (m)	Naphthalene	1,2,3-Trichlorobenze	Unresolved Complex	C12 Acid	C14 Acid	C14 Acid	C18 Acid	butyl-Benzenesulph	C16-26 Hydrocarbon	C10-30 Hydrocarbon	C6 Acid	C8 Acid	Acetophenone
		Units														
		Method Detection Limit														
	Maximum			8802	74	33260	200	1220	3810	3190	2010	2910	778790	540	570	360
27	MSW1	Dark grey granular cover materials with waste (ash? and crushed limestone)	0.00-50.00	<1	<1	33260										
30	MSW2	Decomposing domestic waste	0.00-50.00													
33	MSW3	Black/grey organic sludge with strong odour	0.00-50.00	<1	<1	12910	200	1220	3810	3190						
36	MSW4	grey/dark brown sludge with strong odour	0.00-50.00													
39	MSW5	Light grey surface cover material	0.00-50.00													
42	MSW6	Dark brown vent exudate	0.00-50.00	8802	74						2010	2910				
45	MSW7	Surface cover	0.00-50.00													
47	MSW8	Surface cover from bulldozer access track	0.00-50.00													
50	MSW9	Pale blue dried slurry/filter cake	0.00-50.00													
53	MSW10	Daily cover with domestic waste	0.00-50.00													
56	MSW11	Daily cover with domestic waste	0.00-50.00													
59	MSW12	Daily cover	0.00-50.00													
62	MSW13	Grey silt (dried slurry)	0.00-50.00													
65	MSW14	Recently burnt waste	0.00-50.00	59	<1								93990			
68	MSW15	Surface staining of cover associated with burning	0.00-50.00	319	<1								36730	540	570	360
71	MSW16	Pale grey dried sludge	0.00-50.00													
74	MSW17	Pale grey/pink sludge from lower slurry lagoon.	0.00-50.00	28	<1								283350			
77	MSW18	Pink ochre silt	0.00-50.00													
80	MSW19	Black sooty material in crushed drum	0.00-50.00	7	<1								11350			
83	MSW20	Old ashy degraded waste and plastic	0.00-50.00													
86	MSW21	Crushed limestone dust from main haul road	0.00-50.00													
89	MSW22	Old degraded waste	0.00-50.00													
92	MSW23	Stained and burnt cover materials	0.00-50.00	80	74								778790			
95	MSW24	Burnt waste	0.00-50.00	111	3								55790			
98	MSW25	Burnt domestic waste	0.00-50.00													

		Units														
		Method Detection Limit														
Sample Number	**Sample Identity**	**Type**	**Depth (m)**	**Unknown (RT 18.49)**	**Unknown (RT 18.55)**	**Unknown (RT 19.06)**	**Unknown (RT 18.30)**	**Unknown (RT 18.35)**	**Unknown (RT 18.78)**	**phenyl-Terphenyl**	**C7 Acid**	**Aminocapric acid**	**Benzamides/Pyridin**	**Limonene**	**Bromofluoromethane**	**Thiobismethane**
	Maximum			**48270**	**7700**	**64990**	**390**	**450**	**1560**	**390**	**1950**	**1690**	**7180**	**25**	**75**	**25**
27	MSW1	Dark grey granular cover materials with waste (ash? and crushed limestone)	0.00-50.00											25		
30	MSW2	Decomposing domestic waste	0.00-50.00													
33	MSW3	Black/grey organic sludge with strong odour	0.00-50.00												75	25
36	MSW4	grey/dark brown sludge with strong odour	0.00-50.00													
39	MSW5	Light grey surface cover material	0.00-50.00													
42	MSW6	Dark brown vent exudate	0.00-50.00													
45	MSW7	Surface cover	0.00-50.00													
47	MSW8	Surface cover from bulldozer access track	0.00-50.00													
50	MSW9	Pale blue dried slurry/filter cake	0.00-50.00													
53	MSW10	Daily cover with domestic waste	0.00-50.00													
56	MSW11	Daily cover with domestic waste	0.00-50.00													
59	MSW12	Daily cover	0.00-50.00													
62	MSW13	Grey silt (dried slurry)	0.00-50.00													
65	MSW14	Recently burnt waste	0.00-50.00													
68	MSW15	Surface staining of cover associated with burning	0.00-50.00													
71	MSW16	Pale grey dried sludge	0.00-50.00													
74	MSW17	Pale grey/pink sludge from lower slurry lagoon.	0.00-50.00	48270	7700	64990										
77	MSW18	Pink ochre silt	0.00-50.00													
80	MSW19	Black sooty material in crushed drum	0.00-50.00				390	450	1560	390						
83	MSW20	Old ashy degraded waste and plastic	0.00-50.00													
86	MSW21	Crushed limestone dust from main haul road	0.00-50.00													
89	MSW22	Old degraded waste	0.00-50.00													
92	MSW23	Stained and burnt cover materials	0.00-50.00													
95	MSW24	Burnt waste	0.00-50.00								1950	1690	7180			
98	MSW25	Burnt domestic waste	0.00-50.00													

Sample Number	Sample Identity	Type	Depth (m)	C9-C13 Hydrocarbon	2-methylfuran	2,5-dimethylfuran	Methylbutyrate	C7-C13 Hydrocarbon	Phenol	Phenylethanone	Biphenyl	Dimethyl disulphide	C10-C13 Hydrocarbo	Benzonitrile	Total Dioxin ng/kg I-
		Units													
		Method Detection Limit													
	Maximum			**1790**	**405**	**195**	**70**	**97200**	**40**	**65**	**15**	**490**	**10**	**40**	**2500**
27	MSW1	Dark grey granular cover materials with waste (ash? and crushed limestone)	0.00-50.00												1.9
30	MSW2	Decomposing domestic waste	0.00-50.00												
33	MSW3	Black/grey organic sludge with strong odour	0.00-50.00	1790											11
36	MSW4	grey/dark brown sludge with strong odour	0.00-50.00												
39	MSW5	Light grey surface cover material	0.00-50.00												
42	MSW6	Dark brown vent exudate	0.00-50.00		405	195	70	97200							2500
45	MSW7	Surface cover	0.00-50.00												
47	MSW8	Surface cover from bulldozer access track	0.00-50.00												
50	MSW9	Pale blue dried slurry/filter cake	0.00-50.00												
53	MSW10	Daily cover with domestic waste	0.00-50.00												
56	MSW11	Daily cover with domestic waste	0.00-50.00												
59	MSW12	Daily cover	0.00-50.00												
62	MSW13	Grey silt (dried slurry)	0.00-50.00												
65	MSW14	Recently burnt waste	0.00-50.00						40	65	15				44
68	MSW15	Surface staining of cover associated with burning	0.00-50.00					5975							2.1
71	MSW16	Pale grey dried sludge	0.00-50.00												
74	MSW17	Pale grey/pink sludge from lower slurry lagoon.	0.00-50.00									490	10		29
77	MSW18	Pink ochre silt	0.00-50.00												6.2
80	MSW19	Black sooty material in crushed drum	0.00-50.00												
83	MSW20	Old ashy degraded waste and plastic	0.00-50.00												
86	MSW21	Crushed limestone dust from main haul road	0.00-50.00												
89	MSW22	Old degraded waste	0.00-50.00												
92	MSW23	Stained and burnt cover materials	0.00-50.00					8850							43
95	MSW24	Burnt waste	0.00-50.00	770							15			40	43
98	MSW25	Burnt domestic waste	0.00-50.00												

Sample Number	Sample Identity	Type	Depth (m)	Arsenic	Chromium	Copper	Nickel	Lead	Total Sulphate by ICP	Zinc	Acid Soluble Sulphide	Complex Cyanide	Thiocyanate	PAH total 16 GC	Naphthalene	Acenaphthylene	Acenaphthene	Fluorene	Phenanthrene	Anthracene	Fluoranthene	Pyrene	Benz(a)anthracene	Chrysene	Benzo(b)fluoranthene	Benzo(k)fluoranthene	Benzo(a)pyrene
		Units		ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm													
		Method Detection Limit		<1	<1	<1	<1	<1	<50	<1	<10	<2.5	<1	<1.6													
	Maximum			**6**	**72**	**18**	**40**	**1448**	**7560**	**78**	**0**	**0**	**6**	**4**													
1	MSS1	Soil on reclaimed area	0.00-50.00	<1	48	14	24	56	1800	78	<10	<2.5	3	3													
3	MSS2	Red clay on Garigue	0.00-50.00	<1	15	18	13	26	1900	65	<10	<2.5	2	<1.6													
5	MSS3	Red clay on Garigue	0.00-50.00	1	70	6	40	370	2000	68	<10	<2.5	3	2													
7	MSS4	Red clay on Garigue	0.00-50.00	6	72	16	34	1448	2200	65	<10	<2.5	5	2													
9	MSS5	Terracotta Soil	0.00-50.00	<1	23	8	23	116	1900	43	<10	<2.5	3	2													
11	MSS6	Red clay on trapping terrace	0.00-50.00	2	60	6	38	35	1700	63	<10	<2.5	<1	<1.6													
13	MSS7	Red clay on Garigue	0.00-50.00	3	56	6	35	46	1400	64	<10	<2.5	2	<1.6													
15	MSS8	Ochre clay and silt	0.00-50.00	<1	13	8	13	29	1800	35	<10	<2.5	1	<1.6													
17	MSS9	Crushed Lst from track	0.00-50.00	<1	13	10	14	10	1700	36	<10	<2.5	4	4													
19	MSS10	Red clay on Garigue	0.00-50.00	<1	51	7	28	1106	1300	61	<10	<2.5	2	2													
21	MSS11	Terracotta Soil	0.00-50.00	<1	40	8	32	486	2400	58	<10	<2.5	4	<1.6													
23	MSS12	Ochre Soil	0.00-50.00	<1	17	6	16	28	2200	42	<10	<2.5	6	<1.6													
25	MSS13	Terracotta Soil	0.00-50.00	<1	24	15	24	27	1800	72	<10	<2.5	2	<1.6													
101	MSS14	Terracotta Soil	0.00-50.00	<1	18	5	15	140	2000	28	<10	<2.5	4	<1.6													
103	MSS15	Terracotta Soil	0.00-50.00	<1	37	7	27	66	1800	52	<10	<2.5	2	2													
191	MSS16	Soil	0.00-50.00	<1	24	14	14	<1	2373	60	<10	<2.5	1	7													
192	MSS17	Soil	0.00-50.00	<1	51	23	26	<1	1518	89	<10	<2.5	2	2													
193	MSS18	Soil	0.00-50.00	7	28	31	17	<1	1779	71	<10	<2.5	5	4													
194	MSS19	Soil	0.00-50.00	6	20	14	12	98	1783	37	<10	<2.5	2	0.82													
195	MSS20	Soil	0.00-50.00	6	22	13	15	<1	1608	36	<10	<2.5	6	4													
196	MSS21	Soil	0.00-50.00	3	85	19	37	<1	1792	71	<10	<2.5	2	6													
197	MSS22	Soil	0.00-50.00	6	25	19	14	106	1577	74	<10	<2.5	2	0.64													
198	MSS23	Soil	0.00-50.00	9	30	27	16	<1	1763	265	<10	<2.5	2	7													
199	MSS24	Soil	0.00-50.00	<1	69	14	28	<1	1496	64	<10	<2.5	2	9													
200	MSS25	Soil	0.00-50.00	6	24	44	14	27	1505	92	<10	<2.5	<1	0.69													
201	MSS26	Soil	0.00-50.00	6	29	27	18	<1	2546	111	<10	<2.5	2	0.62													
202	MSS27	Soil	0.00-50.00	5	16	7	10	<1	1977	52	<10	<2.5	<1	6													
203	MSS28	Soil	0.00-50.00	7	24	19	15	13	1512	58	<10	<2.5	9	1													
116	MMS1	Marine Sediment	UNKNOWN	<1	9	<1	<1	4	5943	25	<10	<2.5	<1	1	< 0.05	< 0.05	0.164	< 0.05	0.101	0.056	0.162	0.160	0.053	0.105	0.133	0.109	0.051
117	MMS2	Marine Sediment	UNKNOWN	<1	5	1	1	9	7560	14	<10	<2.5	1	1	< 0.05	< 0.05	0.080	0.093	0.138	< 0.05	0.193	0.155	0.103	0.174	0.072	0.077	0.068
	MMS3	Marine Sediment	UNKNOWN	<1	5	2	<1	9	4745	9	<10	<2.5	<1	3	0.465	< 0.05	0.131	< 0.05	0.288	< 0.05	0.462	0.380	0.272	0.224	0.145	0.119	0.295

Sample Number	Sample Identity	Type	Depth (m)	Indeno(123cd)pyrene	Dibenzo(ah)anthracene	Benzo(ghi)perylene	Total Phenols HPLC	Cadmium by IRIS	Mercury by IRIS	Selenium by IRIS	Total Organic Matter	pH Value In Soil	Total Cyanide	Asbestos Presence Screen	Free Cyanide Soil	Total Dioxin ng/kg I-TEQ	PCBs µg/kg	TBT	TPT	C18 - 30 hydrocarbons: 70% aromatic (µg/k
		Units					ppm	ppm	ppm	ppm	%		ppm		ppm					
		Method Detection Limit					<0.01	<0.5	<0.3	<0.5	<0.01	<1.00	<2.5		<2.5					
	Maximum						**0.06**	**0.8**	**0.4**	**0**	**4.56**	**8.14**	**0**	**0**	**0**	**61**				
1	MSS1	Soil on reclaimed area	0.00-50.00				<0.01	0.8	<0.3	<0.5	2.99	7.76	<2.5	-	<2.5	1.4				
3	MSS2	Red clay on Garigue	0.00-50.00				0.02	<0.5	<0.3	<0.5	1.72	7.72	<2.5	-	<2.5					
5	MSS3	Red clay on Garigue	0.00-50.00				0.06	0.8	<0.3	<0.5	3.4	7.71	<2.5	-	<2.5					
7	MSS4	Red clay on Garigue	0.00-50.00				0.02	0.8	<0.3	<0.5	4.56	7.81	<2.5	-	<2.5					
9	MSS5	Terracotta Soil	0.00-50.00				0.01	<0.5	<0.3	<0.5	2.18	7.81	<2.5	-	<2.5	61				
11	MSS6	Red clay on trapping terrace	0.00-50.00				0.01	0.7	<0.3	<0.5	2.5	7.95	<2.5	-	<2.5					
13	MSS7	Red clay on Garigue	0.00-50.00				0.02	<0.5	<0.3	<0.5	4.25	7.68	<2.5	-	<2.5	0.91				
15	MSS8	Ochre clay and silt	0.00-50.00				0.02	<0.5	<0.3	<0.5	1.86	7.83	<2.5	NFP	<2.5					
17	MSS9	Crushed Lst from track	0.00-50.00				0.03	<0.5	<0.3	<0.5	1.58	7.63	<2.5	NFP	<2.5					
19	MSS10	Red clay on Garigue	0.00-50.00				0.02	<0.5	<0.3	<0.5	3.34	7.79	<2.5	-	<2.5	0.54				
21	MSS11	Terracotta Soil	0.00-50.00				0.01	0.6	<0.3	<0.5	2.11	7.73	<2.5	-	<2.5					
23	MSS12	Ochre Soil	0.00-50.00				<0.01	<0.5	<0.3	<0.5	1.87	7.64	<2.5	-	<2.5					
25	MSS13	Terracotta Soil	0.00-50.00				<0.01	<0.5	<0.3	<0.5	2.17	7.74	<2.5	-	<2.5					
101	MSS14	Terracotta Soil	0.00-50.00				0.04	<0.5	<0.3	<0.5	1.48	7.79	<2.5	-	<2.5	3.6				
103	MSS15	Terracotta Soil	0.00-50.00				<0.01	<0.5	<0.3	<0.5	1.85	7.91	<2.5	-	<2.5					
191	MSS16	Soil	0.00-50.00				0.01	<0.5	<0.3	<0.5	4.90	7.70	<2.5		<2.5	<0.02				
192	MSS17	Soil	0.00-50.00				<0.01	<0.5	<0.3	<0.5	2.20	7.79	<2.5		<2.5	<0.01				
193	MSS18	Soil	0.00-50.00				0.01	<0.5	<0.3	<0.5	2.66	7.82	<2.5		<2.5	<0.01				
194	MSS19	Soil	0.00-50.00				0.01	<0.5	<0.3	<0.5	1.26	7.71	<2.5		<2.5	<0.01				
195	MSS20	Soil	0.00-50.00				0.02	<0.5	<0.3	<0.5	1.88	7.73	<2.5		<2.5	<0.01				
196	MSS21	Soil	0.00-50.00				<0.01	0.8	<0.3	<0.5	4.43	7.81	<2.5		<2.5	<0.01				
197	MSS22	Soil	0.00-50.00				<0.01	<0.5	<0.3	<0.5	1.77	7.67	<2.5		<2.5	<0.01				
198	MSS23	Soil	0.00-50.00				<0.01	<0.5	<0.3	1.1	3.09	7.68	<2.5		<2.5	<0.01				
199	MSS24	Soil	0.00-50.00				<0.01	0.6	<0.3	30.2	3.72	7.75	<2.5		<2.5	<0.01				
200	MSS25	Soil	0.00-50.00				<0.01	<0.5	<0.3	<0.5	1.35	7.88	<2.5		<2.5	<0.01				
201	MSS26	Soil	0.00-50.00				<0.01	<0.5	<0.3	<0.5	1.50	7.68	<2.5		<2.5	<0.01				
202	MSS27	Soil	0.00-50.00				0.02	<0.5	<0.3	<0.5	0.91	7.86	<2.5		<2.5	<0.01				
203	MSS28	Soil	0.00-50.00				<0.01	<0.5	<0.3	<0.5	2.59	7.74	<2.5		<2.5	<0.01				
116	MMS1	Marine Sediment	UNKNOWN	< 0.05	< 0.05	< 0.05	<0.01	<0.5	0.4	<0.5	0.31	8.07	<2.5		<2.5	<0.014	<1	<10	<10	
117	MMS2	Marine Sediment	UNKNOWN	0.052	< 0.05	< 0.05	0.02	<0.5	<0.3	<0.5	0.54	8.14	<2.5		<2.5	<0.014	<1	<10	<10	
	MMS3	Marine Sediment	UNKNOWN	0.181	0.062	0.216	<0.01	<0.5	<0.3	<0.5	0.43	8.13	<2.5		<2.5		<1	<10	<10	118860

Sample Number	Sample Identity	Type	Depth (m)	Arsenic	Chromium	Copper	Nickel	Lead	Total Sulphate by ICP	Zinc	Acid Soluble Sulphide	Complex Cyanide	Thiocyanate	PAH total 16 GC	Total Phenols HPLC	Cadmium by IRIS	Mercury by IRIS	Selenium by IRIS	Total Organic Matter	pH Value In Soil	Total Cyanide	Asbestos Presence Screen	Free Cyanide Soil
Units				ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	%		ppm		ppm
Method Detection Limit				<1	<1	<1	<1	<1	<50	<1	<10	<2.5	<1	<1.6	<0.01	<0.5	<0.3	<0.5	<0.01	<1.00	<2.5		<2.5
13	WFSW01	Surface cover near compost storage	0.00-50.00	<1	21	43	22	150	2500	185	<10	<2.5	4	15	<0.01	<0.5	<0.3	<0.5	2.81	7.19	<2.5	NFP	<2.5
16	WFSW02	Surface cover on S side of E mound	0.00-50.00	<1	47	490	34	1068	5800	614	<10	<2.5	16	4	<0.01	1.4	<0.3	<0.5	8.24	6.89	<2.5	NFP	<2.5
19	WFSW03	Vent deposits on E mound	0.00-50.00	<1	14	43	10	82	1500	173	<10	<2.5	24	409	6	0.6	19.2	<0.5	5.69	7.28	<2.5	NFP	<2.5
22	WFSW04	Burnt domestic waste at base of E mound	0.00-50.00	<1	191	1301	104	608	7000	1678	24	<2.5	16	6	0.02	8.2	0.6	<0.5	9.72	6.78	<2.5	NFP	<2.5
25	WFSW05	Valley fill	0.00-50.00	<1	126	532	52	278	2100	992	33	<2.5	2	3	<0.01	2.2	<0.3	<0.5	1.29	8.01	<2.5	NFP	<2.5
28	WFSW06	Crushed limestone from W mound top	0.00-50.00	<1	23	5	14	7	1900	32	<10	<2.5	<1	<1.6	<0.01	<0.5	<0.3	<0.5	0.5	7.8	<2.5	NFP	<2.5
31	WFSW07	Dark brown waste	0.00-50.00	<1	30	331	26	859	4900	1693	<10	<2.5	108	3	<0.01	0.9	<0.3	<0.5	8.41	8.41	<2.5	NFP	<2.5
34	WFSW08	Crushed limestone cover	0.00-50.00	<1	32	19	24	71	1900	119	<10	<2.5	2	7	<0.01	0.6	<0.3	<0.5	2.34	7.79	<2.5	NFP	<2.5
37	WFSW09	Dark brown stained crushed lst waste	0.00-50.00	<1	31	262	23	90	3000	503	<10	<2.5	4	186	0.03	1.1	2.9	<0.5	3.57	8.27	<2.5	NFP	<2.5

Sample Number	Sample Identity	Type	Depth (m)	Phenol	2-Chlorophenol	2-Methylphenol	4-Methylphenol	2-Nitrophenol	4-Nitrophenol	2,4-Dichlorophenol	2,4-Dimethylphenol	Naphthalene	Fluorene	Phenanthrene	Anthracene	Fluoranthene	Pyrene	Benzo(a)anthracene	Chrysene	Benzo(a)pyrene
		Units																		
		Method Detection Limit																		
13	WFSW01	Surface cover near compost storage	0.00-50.00																	
16	WFSW02	Surface cover on S side of E mound	0.00-50.00																	
19	WFSW03	Vent deposits on E mound	0.00-50.00	1517.686704	<100	492.8850408	1179.114143	<100	<100	<100	657.2213632	578.0426319	2673.299847	32696.41964	3788.301512	11403.09144	10436.3052	4803.142887	26122.37807	1693.759605
22	WFSW04	Burnt domestic waste at base of E mound	0.00-50.00																	
25	WFSW05	Valley fill	0.00-50.00																	
28	WFSW06	Crushed limestone from W mound top	0.00-50.00																	
31	WFSW07	Dark brown waste	0.00-50.00																	
34	WFSW08	Crushed limestone cover	0.00-50.00	<100	<100	<100	<100	<100	<100	<100	<100	<100	109.6104596	284.8074973	<100	101.5920126	<100	<100	160.7809638	<100
37	WFSW09	Dark brown stained crushed lst waste	0.00-50.00	<100	<100	<100	<100	<100	<100	<100	<100	300.7666756	17245.5566	90033.4856	21131.67029	5230.914424	4750.878766	<100	<100	<100

Sample Number	Sample Identity	Type	Depth (m)	2-Methylnaphthalene	Carbazole	Dibenzofuran	Benzene	Toluene	Chlorobenzene	Ethylbenzene	p/m-Xylene	Styrene	o-Xylene	Isopropylbenzene	1,2,4-Trimethylbenzene	1,3,5-Trimethylbenzene	1,2-Dichlorobenzene	tert-Butylbenzene	1,3-Dichlorobenzene	n-Butylbenzene
		Units																		
		Method Detection Limit																		
13	WFSW01	Surface cover near compost storage	0.00-50.00																	
16	WFSW02	Surface cover on S side of E mound	0.00-50.00																	
19	WFSW03	Vent deposits on E mound	0.00-50.00	590.5742983	3223.329798	1401.264163														
22	WFSW04	Burnt domestic waste at base of E mound	0.00-50.00																	
25	WFSW05	Valley fill	0.00-50.00																	
28	WFSW06	Crushed limestone from W mound top	0.00-50.00																	
31	WFSW07	Dark brown waste	0.00-50.00																	
34	WFSW08	Crushed limestone cover	0.00-50.00	<100	<100	<100	<1	1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
37	WFSW09	Dark brown stained crushed lst waste	0.00-50.00	946.8094987	<100	2833.408155	238	214	17	111	50	29	55	21	21	8	10	7	7	6

Sample Number	Sample Identity	Type	Depth (m)	1,2,4-Trichlorobenzene	Naphthalene	1,2,3-Trichlorobenzene	C12-26 Hydrocarbons	2-methylnaphthalene	1-methylnaphthalene	Biphenyl	C9-C13 Aromatic isomers *	Total Dioxins ng/kg I-TE
		Units										
		Method Detection Limit										
13	WFSW01	Surface cover near compost storage	0.00-50.00									
16	WFSW02	Surface cover on S side of E mound	0.00-50.00									
19	WFSW03	Vent deposits on E mound	0.00-50.00				1585000	115	160	300	1765	3000
22	WFSW04	Burnt domestic waste at base of E mound	0.00-50.00									940
25	WFSW05	Valley fill	0.00-50.00									
28	WFSW06	Crushed limestone from W mound top	0.00-50.00									
31	WFSW07	Dark brown waste	0.00-50.00									
34	WFSW08	Crushed limestone cover	0.00-50.00	<1	<1	<1	14600					6.7
37	WFSW09	Dark brown stained crushed lst waste	0.00-50.00	13	1933	35	3246400				7970	100

Sample Number	Sample Identity	Type	Depth (m)	Arsenic	Chromium	Copper	Nickel	Lead	Total Sulphate by ICP	Zinc	Acid Soluble Sulphide
Units				ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm
Method Detection Limit				<1	<1	<1	<1	<1	<50	<1	<10
1	WFSS01	Terracotta Soil	0.00-50.00	2	66	10	61	1222	2100	80	<10
4	WFSS02	Terracotta Soil	0.00-50.00	<1	47	61	37	106	2000	179	<10
5	WFSS03	Terracotta Soil	0.00-50.00	<1	33	123	27	79	2800	461	<10
7	WFSS04	Terracotta Soil	0.00-50.00	<1	40	15	31	613	2000	88	<10
9	WFSS05	Terracotta Soil	0.00-50.00	<1	60	53	46	1349	2100	151	<10
11	WFSS06	Terracotta Soil	0.00-50.00	1	64	59	45	1516	1600	193	<10

Sample Number	Sample Identity	Type	Depth (m)	Complex Cyanide	Thiocyanate	PAH total 16 GC	Total Phenols HPLC	Cadmium by IRIS	Mercury by IRIS	Selenium by IRIS	Total Organic Matter
Units				ppm	ppm	ppm	ppm	ppm	ppm	ppm	%
Method Detection Limit				<2.5	<1	<1.6	<0.01	<0.5	<0.3	<0.5	<0.01
1	WFSS01	Terracotta Soil	0.00-50.00	<2.5	1	2	0.01	<0.5	<0.3	<0.5	4.9
4	WFSS02	Terracotta Soil	0.00-50.00	<2.5	2	17	<0.01	0.5	<0.3	<0.5	3.65
5	WFSS03	Terracotta Soil	0.00-50.00	<2.5	2	2	<0.01	0.7	<0.3	<0.5	3.34
7	WFSS04	Terracotta Soil	0.00-50.00	<2.5	3	8	0.01	0.6	<0.3	<0.5	3.96
9	WFSS05	Terracotta Soil	0.00-50.00	<2.5	3	11	0.01	0.8	<0.3	<0.5	4.14
11	WFSS06	Terracotta Soil	0.00-50.00	<2.5	<1	8	<0.01	0.9	<0.3	<0.5	2.62

Sample Number	Sample Identity	Type	Depth (m)	pH Value In Soil	Total Cyanide	Asbestos Presence Screen	Free Cyanide Soil	Total Dioxins ng/kg I-TE
Units					ppm		ppm	
Method Detection Limit				<1.00	<2.5		<2.5	
1	WFSS01	Terracotta Soil	0.00-50.00	7.95	<2.5	-	<2.5	
4	WFSS02	Terracotta Soil	0.00-50.00	7.8	<2.5	-	<2.5	2.9
5	WFSS03	Terracotta Soil	0.00-50.00	7.21	<2.5	-	<2.5	5.3
7	WFSS04	Terracotta Soil	0.00-50.00	7.78	<2.5	-	<2.5	
9	WFSS05	Terracotta Soil	0.00-50.00	7.72	<2.5	-	<2.5	
11	WFSS06	Terracotta Soil	0.00-50.00	7.99	<2.5	-	<2.5	

Sample Number	Sample Identity	Type	Depth (m)	Arsenic	Chromium	Copper	Nickel	Lead	Total Sulphate by ICP	Zinc	Acid Soluble Sulphide	Complex Cyanide	Thiocyanate	PAH total 16 GC	Total Phenols HPLC	Cadmium by IRIS	Mercury by IRIS	Selenium by IRIS	Total Organic Matter	pH Value In Soil	Total Cyanide
8	QSW1	Dried grey slurry	0.5	<1	38	12	38	30	2100	59	<10	<2.5	1	<1.6	<0.01	<0.5	<0.3	<0.5	2.11	8.53	<2.5
11	QSW2	Pale brn gry soil adj to haul road	0.5	<1	5	4	8	6	1500	15	<10	<2.5	1	<1.6	0.01	<0.5	<0.3	<0.5	0.38	7.71	<2.5
14	QSW3	Fine grained ash	0.5	<1	23	1469	14	267	9400	474	<10	<2.5	3	<1.6	0.01	0.5	<0.3	<0.5	2.3	7.65	<2.5
17	QSW4	Burnt waste	0.5	<1	227	364	28	239	16000	648	33	<2.5	10	10	3.19	7.1	<0.3	<0.5	5.73	11.33	<2.5
20	QSW5	Dirty cover materials inc. waste	0.5	<1	19	22	17	26	3700	179	<10	<2.5	3	<1.6	0.02	<0.5	<0.3	<0.5	1.31	7.36	<2.5

Sample Number	Sample Identity	Type	Depth (m)	Asbestos Presence Screen	Free Cyanide Soil	Phenanthrene	Anthracene	Fluoranthene	Pyrene	Benzo(a)anthracene	Chrysene
8	QSW1	Dried grey slurry	0.5	NFP	<2.5						
11	QSW2	Pale brn gry soil adj to haul road	0.5	NFP	<2.5						
14	QSW3	Fine grained ash	0.5	NFP	<2.5	146.788376	<100	321.2132263	326.1526353	150.2024251	182.1549771
17	QSW4	Burnt waste	0.5	NFP	<2.5	<100	<100	<100	<100	<100	<100
20	QSW5	Dirty cover materials inc. waste	0.5	NFP	<2.5						

Sample Number	Sample Identity	Type	Depth (m)	Bis(2-ethylhexyl)phthalate	Benzene	Toluene	Ethylbenzene	p/m-Xylene	Styrene	Naphthalene	C16-26 Hydrocarbons	C20-30 Hydrocarbons	Acetone	Unknown (RT 4.86)	Unknown (RT 5.04)	Total Dioxins ng/kg I-TE
8	QSW1	Dried grey slurry	0.5													
11	QSW2	Pale brn gry soil adj to haul road	0.5													
14	QSW3	Fine grained ash	0.5	279.753753	<1	3	<1	<1	<1	<1	19080					
17	QSW4	Burnt waste	0.5	1893.853792	71	16	4	2	5	10		46660	5	3	5	61
20	QSW5	Dirty cover materials inc. waste	0.5													

Sample Number	Sample Identity	Type	Depth (m)	Arsenic	Chromium	Copper	Nickel	Lead	Total Sulphate by ICP	Zinc	Acid Soluble Sulphide	Complex Cyanide	Thiocyanate	PAH total 16 GC	Total Phenols HPLC	Cadmium by IRIS	Mercury by IRIS	Selenium by IRIS	Total Organic Matter	pH Value In Soil	Total Cyanide
1	QSS1	Terracotta Soil	0.5	<1	14	5	11	17	1600	31	<10	<2.5	2	<1.6	<0.01	<0.5	<0.3	<0.5	1.9	7.71	<2.5
2	QSS2	Blue Clay below waste	0.5	<1	11	4	8	378	1800	57	<10	<2.5	7	<1.6	0.01	<0.5	<0.3	<0.5	3.27	7.66	<2.5
4	QSS3	Weathered blue clay	0.5	<1	20	5	30	14	19000	60	<10	<2.5	1	<1.6	<0.01	<0.5	<0.3	<0.5	0.47	7.94	<2.5
6	QSS4	Red Silt on Garige	0.5	3	51	10	35	689	2000	86	<10	<2.5	2	<1.6	0.01	<0.5	<0.3	<0.5	5.31	7.77	<2.5
115	QMS1	Marine sediment	UNKNOWN	15	9	<1	1	3	2806	14	<10	<2.5	1		<0.01	<0.5	<0.3	<0.5	0.08	8.32	<2.5

Appendix E
Water Analyses

		Arsenic Low Level by AA (µg/l)	Calcium (mg/l)	Cadmium by ICP-USN (µg/l)	Chromium by ICP-USN (µg/l)	Copper by ICP-USN (µg/l)	Mercury Low Dutch Target AA (µg/l)	Iron by ICP-USN (µg/l)	Manganese by ICP-USN (µg/l)	Nickel by ICP-USN (µg/l)	Lead (µg/l)	Selenium (µg/l)	Zinc by ICP-USN (µg/l)	Magnesium (mg/l)	Chloride (mg/l)	COD On Unfiltered Sample (mg/l)	Kjeldahl Nitrogen on Water * (mg/l)	Nitrate (mg/l)	Phosphate (mg/l)	Sulphide In Water (mg/l)
	EU DWS	**10**	**-**	**5**	**50**	**2000**	**1**	**200**	**50**	**20**	**10**	**10**	**-**	**-**	**250**	**-**	**-**	**50**	**-**	**-**
Leachate	**MW3**	**431**	348	0.27	**220**	26	0.22	**5000**	**76.3**	**219**	**89.5**	**21.9**	27200	25.9	**5554**	6210	432	12.5	<0.08	<0.1
Peripheral BHs	MBH1	<0.05	200	0.05	0.77	12.7	<0.05	<100	4.9	3.3	1.1	1	47.5	170	**2360**	55	<20	2.8	<0.08	<0.1
	MBH2	<2	118.8	<0.4	11	<5	<0.05	**350**	<1	<10	<50	<50	<5	56.61	**899**	15	<20	7.5	<0.08	<0.1
	MBH3	<0.05	237	<0.05	0.73	25.1	<0.05	<100	6	3.4	1.5	<0.5	42.2	401	**5860**	106	<20	1.1	<0.08	<0.1
	MBH4	<0.05	342	0.07	<0.05	66.9	<0.05	<100	5.9	6.4	1.7	<0.5	25.1	1030	**16235**	214	<20	<0.3	<0.08	<0.1
	MBH5	<0.05	394	<0.05	<0.05	97.1	<0.05	<100	**84.5**	12.5	2.5	<0.5	25.4	1380	**22251**	322	<20	<0.3	<0.08	<0.1
	MBH6	<0.05	132	<0.05	0.16	11.8	<0.05	<100	2.2	1.2	0.6	<0.5	10.8	160	**2713**	48	<20	1.1	<0.08	<0.1
Off-site BHs	2026	<0.05	155	0.16	0.08	8.56	<0.05	<100	0.7	4	1.46	<0.5	60.8	169	**3068**	84	<20	4.3	<0.08	<0.1
	2027	<0.05	116	0.11	<0.05	3.04	<0.05	<100	3.1	1	0.48	<0.5	608	96.6	**1723**	21	<20	7.9	<0.08	<0.1
	3308	<0.05	159	0.06	<0.05	2.94	<0.05	<100	0.5	1.7	0.57	<0.5	20.8	168	**3007**	23	<20	5.1	<0.08	<0.1
PWS	WIED IL-GHASEL PS	<2	84.7	<0.4	12	<5	0.10	<1	<1	<10	<50	<50	160	32.63	**532**	228	<20	22.3	<0.08	<0.1
Sea Water	MMW01	<0.05	329	<0.05	<0.05	97	<0.05	<100	0.7	5.8	0.4	<0.5	24	1480	**22673**	389	<20	<0.3	<0.08	<0.1

		Sulphate (soluble) (mg/l)	Ammoniacal Nitrogen as NH4-N (mg/l)	Potassium (mg/l)	Sodium (mg/l)	Total Suspended Solids (mg/l)	Total Phenols HPLC (mg/l)	Electrical Conductivity (mS/cm)	Dissolved Oxygen (mg/l)	pH Value In Water	Total Dissolved Solids (mg/l)	Alkalinity Total as CaCO3 (mg/l)	Phenol (µg/l)	2-Methylphenol	4-Methylphenol	2,4-dimethyl phenol	1,4-dichlorobenzene	2-Methyl Naphthalene (µg/l)	Diethyl phthalate	Bis(2-ethylhexyl)phthalate (µg/l)	Naphthalene (µg/l)	cis-1,2-Dichloroethene (µg/l)	Chloroform (µg/l)	Trichloroethene (µg/l)	1,1,1-Trichloroethane (µg/l)
	EU DWS	**250**	**0.39**	**-**	**200**	**-**	**-**	**2.5**	**-**	**6.5 - 9.5**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**3**	**100**	**10**	**-**
Leachate	**MW3**	<3	**500**	975	**1590**	88	0.01	**20.1**	-	8.60	10380	4540	281	65	1280	85	3	15	19	707	55				
Peripheral BHs	MBH1	**422**	<0.2	74.3	**1200**	18	<0.01	**8.2**	7.7	8.35	5215	312						2							1
	MBH2	109	<0.2	26.4	**382.5**	<10	<0.01	**2.97**	10.3	8.37	1558	264													
	MBH3	**891**	0.2	148.5	**2400**	156	<0.01	**15.84**	8.5	8.36	10050	244													2
	MBH4	**2227**	0.2	472.5	**6825**	112	<0.01	**38.5**	8.4	8.36	24250	192								9					
	MBH5	**3040**	**0.7**	652.5	**9300**	178	<0.01	**51.4**	6.6	8.22	33175	176								9	3				
	MBH6	**395**	<0.2	76.5	**1200**	22	<0.01	**7.73**	10.3	8.5	4723	176								7					
Off-site BHs	2026	**448**	0.3	81	**1440**	<10	-	**8.39**	4.6	8.42	4550	232													
	2027	245	0.2	51	**870**	<10	-	**5.43**	9.3	8.44	2735	204													
	3308	**452**	0.2	72	**1470**	<10	-	**8.46**	8.6	8.44	3535	224													
PWS	WIED IL-GHASEL PS	95	0.2	12.9	**270**	<10	-	**49.1**	8.9	8.49	1263	168													
Sea Water	MMW01	**3036**	**1.1**	630	**9600**	160	<0.01	**51.3**	9.6	8.23	33725	148								9					

		Total Coliforms (counts/100 ml)	E.coli (counts/100 ml)	Candida albicans (detection)	Bacillus stearothermophilus (detection)	Listeria monocytogenes (detection)	BOD (mg/l)	TBT (ng/l)	TPT (ng/l)	DBT (ng/l)
	EU DWS	**0**	**0**	**-**	**-**	**-**	**-**			
Leachate	**MW3**							<50	<50	<50
Peripheral BHs	MBH1	**150**	<3	×	×	×	28.2	<50	<50	<50
	MBH2	**23**	<3	×	✓	×	13.6	<50	<50	<50
	MBH3	**23**	<3	×	✓	×	14.7	<50	<50	<50
	MBH4	**240**	**240**	×	×	×	11.3	<50	<50	<50
	MBH5							<50	<50	<50
	MBH6	**64**	<3	×	×	×	13.3	<50	<50	<50
Off-site BHs	2026	>1100	<3	×	✓	×	<1.0	76	<50	<50
	2027	>1100	**23**	×	×	×	<1.0	52	<50	<50
	3308	**15**	<3	×	×	×	3.7	<50	<50	<50
PWS	WIED IL-GHASEL PS	-	-							
Sea Water	MMW01	-	-							

.	Arsenic Low Level by AA (µg/l)	Calcium (mg/l)	Cadmium by ICP-USN (µg/l)	Chromium by ICP-USN (µg/l)	Copper by ICP-USN (µg/l)	Mercury Low Dutch Target AA (µg/l)	Iron by ICP-USN (µg/l)	Manganese by ICP-USN (µg/l)	Nickel by ICP-USN (µg/l)	Lead (µg/l)	Selenium (µg/l)	Zinc by ICP-USN (µg/l)	Magnesium (mg/l)	Chloride (mg/l)	COD On Unfiltered Sample (mg/l)	Kjeldahl Nitrogen on Water * (mg/l)	Nitrate (mg/l)	Phosphate (mg/l)	Sulphide In Water (mg/l)	Sulphate (soluble) (mg/l)	Ammoniacal Nitrogen as NH4-N (mg/l)	Potassium (mg/l)	Sodium (mg/l)
EU DWS	**10**	**-**	**5**	**50**	**2000**	**1**	**200**	**50**	**20**	**10**	**10**	**-**	**-**	**250**	**-**	**-**	**50**	**-**	**-**	**250**	**0.39**	**-**	**200**
WFBH1	<0.05	377	0.09	<0.05	0.85	<0.05	<100	10.6	3.1	0.75	<0.5	13.4	767	**21698**	197	<20	<0.3	<0.08	<0.1	**3042**	**1.3**	600	**10500**
WFBH2	<0.05	356	<0.05	<0.05	85.3	<0.05	**1400**	8	5.1	0.69	<0.5	182	1290	**19984**	242	20.3	<0.3	<0.08	<0.1	**2751**	**1.5**	577.5	**8550**
WFBH3	<0.05	119	<0.05	0.38	1.49	<0.05	<100	0.5	1.5	0.28	<0.5	14	129	**2246**	32	<20	6.9	<0.08	<0.1	**355**	0.2	66	**1110**
WFMW1	<0.05	297	0.17	<0.05	18.6	<0.05	<100	2.4	13.6	8.05	<0.5	55.2	767	**22484**	543	<20	<0.3	<0.08	<0.1	**3026**	**1.2**	607.5	**12150**

.	Total Suspended Solids (mg/l)	Total Phenols HPLC (mg/l)	Electrical Conductivity (mS/cm)	Dissolved Oxygen (mg/l)	pH Value In Water	Total Dissolved Solids (mg/l)	Alkalinity Total as CaCO3 (mg/l)	Phenol (µg/l)	2-Methylphenol	4-Methylphenol	2,4-dimethyl phenol	1,4-dichlorobenzene	2-Methyl Naphthalene (µg/l)	Diethyl phthalate	Bis(2-ethylhexyl)phthalate (µg/l)	Naphthalene (µg/l)	cis-1,2-Dichloroethene (µg/l)	Chloroform (µg/l)	Trichloroethene (µg/l)	1,1,1-Trichloroethane (µg/l)	Total Coliforms (counts/100 ml)	E.coli (counts/100 ml)	Candida albicans (detection)	Bacillus stearothermophilus (detection)	Listeria monocytogenes (detection)	BOD (mg/l)	TBT (ng/l)	TPT (ng/l)	DBT (ng/l)
EU DWS	**-**	**-**	**2.5**	**-**	**6.5 - 9.5**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**3**	**100**	**10**	**-**	**0**	**0**	**-**	**-**	**-**	**-**			
WFBH1	61	-	**50.8**	6.9	8.09	36600	152														<3	<3	×	✓	×	1.8			
WFBH2	102	<0.01	**46.3**	8.1	8.02	31920	132																						
WFBH3	15	-	**6.95**	8.8	8.4	3580	188										**6**	1	**20**		**15**	<3	×	×	×	38			
WFMW1	58	-		8.4	8.11	30300	152														-	-							

	Arsenic Low Level by AA (µg/l)	Calcium (mg/l)	Cadmium by ICP-USN (µg/l)	Chromium by ICP-USN (µg/l)	Copper by ICP-USN (µg/l)	Mercury Low Dutch Target AA (µg/l)	Iron by ICP-USN (µg/l)	Manganese by ICP-USN (µg/l)	Nickel by ICP-USN (µg/l)	Lead (µg/l)	Selenium (µg/l)	Zinc by ICP-USN (µg/l)	Magnesium (mg/l)	Chloride (mg/l)	COD On Unfiltered Sample (mg/l)	Kjeldahl Nitrogen on Water * (mg/l)	Nitrate (mg/l)	Phosphate (mg/l)	Sulphide In Water (mg/l)	Sulphate (soluble) (mg/l)	Ammoniacal Nitrogen as NH4-N (mg/l)	Potassium (mg/l)	Sodium (mg/l)	Total Suspended Solids (mg/l)
EU DWS	**10**	**-**	**5**	**50**	**2000**	**1**	**200**	**50**	**20**	**10**	**10**	**-**	**-**	**250**	**-**	**-**	**50**	**-**	**-**	**250**	**0.39**	**-**	**200**	**-**
QBH1	<2	81.2	<0.4	16	<5	<0.05	**230**	<1	<10	<50	<50	<5	45.31	226	22	<20	3.8	<0.08	<0.1	81	0.2	11.4	108	118
QMW1	<0.05	332	<0.05	<0.05	98.3	<0.05	<100	0.3	5.2	<0.1	<0.5	4.2	1450	**22288**	381	70	<0.3	<0.08	<0.1	**3032**	**1.1**	667.5	**9150**	168
QOW1	<2	174.3	<0.4	15	<5	<0.05	**570**	<1	<10	<50	<50	32	36.41	**376**	16	<20	**185.1**	<0.08	<0.1	**282**	0.2	5.6	144	12
QOW1D	<2	182	<0.4	14	<5	1.56	**610**	<1	<10	<50	<50	79	40.8	**401**	11	<20	**199.2**	<0.08	<0.1	**301**	0.2	8.1	156	<10
QOW2	<2	184.7	<0.4	13	<5	0.64	**620**	<1	<10	<50	<50	<5	53.24	**513**	14	<20	32.7	<0.08	<0.1	**293**	0.2	6.2	**207**	<10
GHAJN SPRING	<2	102.2	-	-	-	<0.05	-	-	-	<50	<50	-	48.76	**501**	45	-	0.5	<0.08	<0.1	71	0.2	1.1	171	NDP

	Total Phenols HPLC (mg/l)	Electrical Conductivity (mS/cm)	Dissolved Oxygen (mg/l)	pH Value In Water	Total Dissolved Solids (mg/l)	Alkalinity Total as CaCO3 (mg/l)	Phenol (µg/l)	2-Methylphenol	4-Methylphenol	2,4-dimethyl phenol	1,4-dichlorobenzene	2-Methyl Naphthalene (µg/l)	Diethyl phthalate	Bis(2-ethylhexyl)phthalate (µg/l)	Naphthalene (µg/l)	cis-1,2-Dichloroethene (µg/l)	Chloroform (µg/l)	Trichloroethene (µg/l)	1,1,1-Trichloroethane (µg/l)	Total Coliforms (counts/100 ml)	E.coli (counts/100 ml)	Candida albicans (detection)	Bacillus stearothermophilus (detection)	Listeria monocytogenes (detection)	BOD (mg/l)	TBT (ng/l)	TPT (ng/l)	DBT (ng/l)
EU DWS	**-**	**2.5**	**-**	**6.5 - 9.5**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**3**	**100**	**10**	**-**	**0**	**0**	**-**	**-**	**-**	**-**			
QBH1	<0.01	1.223	8.8	8.5	0	320								9						**>1100**	**>1100**	×	×	×	7.2			
QMW1	<0.01	**50.7**	9.3	8.23	622	176								9						-	-							
QOW1	<0.01	1.958	11.2	8.31	40225	128						1		9	2					**>1100**	**240**	×	×	×	6.3			
QOW1D	<0.01	2.06	8	8.46	1072	160								8						**11**	**11**	×	×	×	3			
QOW2	<0.01	2.28	10.8	8.29	1214	124								8														
GHAJN SPRING	<0.01	1.894	8.9	8.43	NDP	292														-	-							

Appendix F
Gas Analyses

	Total VOCs (PID)	trans-1,2-Dichloroethene	Carbon Disulphide	1,1,1-Trichloroethane	Benzene	All other VOCs Measured
MW1	0	<10	<10	<10	<10	<10
MW2	0	<10	<10	<10	<10	<10
MW3						
MW4		<10	<10	<10	<10	<10
MW5						
MGS01	369					
MGS02	74					
MGS03	>9999					
MGS04	5772	<10	<10	<10	25	<10
MGS05	8571	<10	<10	<10	40	<10
MGS06	>9999	<10	<10	<10	15	<10
MGS07	8212	45	45	870	15	<10

	Total VOCs (PID)	trans-1,2-Dichloroethene	Carbon Disulphide	1,1,1-Trichloroethane	Benzene	All other VOCs Measured
WFW1	0	<10	<10	<10	80	<10
WFW2	0	<10	<10	<10	15	<10
WFGS1	>9999	<10	<10	10	<10	<10
WFGS2	0	370	<10	6675	20	<10
WFGS3	>9999	20	<10	715	10	<10

		trans-1,2-Dichloroethene	Carbon Disulphide	1,1,1-Trichloroethane	Benzene	All other VOCs Measured
QW1	0	<10	<10	<10	<10	<10
QGS1	2349	<100	<10	275	25	<10
QGS2	621					

Appendix G

Air Monitoring Analyses

Date	Day	Location	Filter No.[1]	PUFF No. [1]	Particulates (mg/kg)		PM10 Air Conc µg/m3
16.10.02	W	1	P14	1	1062.3	Dioxin/PAH 1A Sample	2588
17.10.02	T	1	P13	1	51.7	Metals 1A Sample	126
18.10.02	F	1	P12	1	157		383
19.10.02	S	1	P16	1	74.3		181
20.10.02	S	1	P15	1	958.2		2335
21.10.02	M	1	O42	1	<0.1		<0.2
22.10.02	T	1	P11	1	149.4		364
23.10.02	W	1	P10	1	74.4		181
24.10.02	T	1	P9	2	355.4	Dioxin/PAH 1B Sample	866
25.10.02	F	1	P8	2	48.6	Metals 1B Sample	118
26.10.02	S	1	P7	2	32.5		79
27.10.02	S	1	P6	2	75.2		183
28.10.02	M	1	P5	2	122.3		298
29.10.02	T	1	P4	2	47.2		115
30.10.02	W	1	P3	2	866.6		2112
31.10.02	T	2	P2	3	545.6	Dioxin/PAH 2A Sample	1329
01.11.02	F	2	P1	3	39.3	Metals 2A Sample	96
02.11.02*	S	-	-	-			
03.11.02*	S	-	-	-			
04.11.02	M	2	O50	3	49.3		120
05.11.02	T	2	O49	3	33.9		83
06.11.02	W	2	O48	3	60.2		147
07.11.02	T	2	O47	4	15.3	Dioxin/PAH 2B Sample	37
08.11.02	F	2	O46	4	3.4	Metals 2B Sample	8
09.11.02[#]	S	-	-	-			
10.11.02	S	2	O45	4	16		39
11.11.02	M	2	O44	4	33.5		82
12.11.02	T	2	O43	4	54.7		133
13.11.02	W	2	O41	4	75		183
14.11.02	T	2	O4	4	2.7		7
15.11.02	F	2	O3	4	64.6		157
16.11.02	S	2	O2	4	4		10

	1A	1B	2A	2B
Sample	**P12-P16, O42, 1**	**P5-P9, 2**	**P1-P2, O50, 3**	**O41, O43-47, O4, 4**
No of Days Sampled	**14**	**12**	**8**	**16**
Volume of air Sampled m3	5745.6	4924.8	3283.2	6566.4
Dioxins ng I-TE/sample	8	15	1	1.1
Air Conc. fg/m3	1392.37	3045.809	304.5809	167.5195

	1A	1B	2A	2B
Sample	**P12-P16, O42, 1**	**P5-P9, 2**	**P1-P2, O50, 3**	**O41, O43-47, O4, 4**
No of Days Sampled	**14**	**12**	**8**	**16**
Volume sampled m3	5745.6	4924.8	3283.2	6566.4

Total Conc (µg/sample):

Naphthalene	3.4	1	0.5	0.9
Acenaphthylene	<0.1	0.3	0.4	0.3
Acenaphthene	<0.1	<0.1	<0.1	<0.1
Fluorene	4.7	1.8	2.3	6.3
Phenanthrene	80	49	1.6	27
Anthracene	7.3	6.9	0.6	0.9
Fluoranthene	68	82	4.6	2.8
Pyrene	40	67	<0.1	<0.1
Benz(a)anthracene	12	15	2.2	1.1
Chrysene	46	49	2.3	1.1
Benzo(b/k)fluoranthene	15	13	1.3	<0.1
Benzo(a)pyrene	13	11	<0.1	<0.1
Indeno(123cd)pyrene	1.7	2	0.2	<0.1
Dibenzo(ah)anthracene	1.5	1.5	<0.1	<0.1
Benzo(ghi)perylene	2.6	2.9	0.5	<0.1

Air Conc (fg/m3):

Naphthalene	592	203	152	137
Acenaphthylene	<17	61	122	46
Acenaphthene	<17	<17	<17	<17
Fluorene	818	365	701	959
Phenanthrene	13924	9950	487	4112
Anthracene	1271	1401	183	137
Fluoranthene	11835	16650	1401	426
Pyrene	6962	13605	<17	<17
Benz(a)anthracene	2089	3046	670	168
Chrysene	8006	9950	701	168
Benzo(b/k)fluoranthene	2611	2640	396	<17
Benzo(a)pyrene	2263	2234	<17	<17
Indeno(123cd)pyrene	296	406	61	<17
Dibenzo(ah)anthracene	261	305	<17	<17
Benzo(ghi)perylene	453	589	152	<17

	1A	1B	2A	2B
Sample	**P10 + P11**	**P3 + P4**	**O48 + O49**	**O2 + O3**
No of Days Sampled	**2**	**2**	**2**	**2**
Volume Sampled	820.8	820.8	820.8	820.8

Total Concentration (µg/sample)

Arsenic	1	1	<1	<1
Cadmium	3	1	<1	<1
Cobalt	<1	<1	<1	<1
Chromium	12	22	9	6
Copper	16	21	21	11
Mercury	5	3	<1	<1
Manganese	16	42	3	8
Nickel	8	14	7	8
Lead	41	42	7	3
Antimony	<1	<1	<1	<1
Tin	3	1	<1	<1
Thallium	2	3	<1	<1
Vanadium	5	8	1	2

Air Concentration (ng/m3)

Arsenic	<1	1	<1	<1
Cadmium	4	1	<1	<1
Cobalt	<1	<1	<1	<1
Chromium	15	27	11	7
Copper	19	26	26	13
Mercury	6	4	<1	<1
Manganese	19	51	4	10
Nickel	10	17	9	10
Lead	50	51	9	4
Antimony	<1	<1	<1	<1
Tin	4	1	<1	<1
Thallium	2	4	<1	<1
Vanadium	6	10	1	2

Appendix H
Ecological Surveys

A Description of ecological assets in the vicinity of the public solid waste disposal site at Magħtab, Malta

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Malta University Services

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Introduction
The present consultants have been commissioned by Malta University Services, acting on behalf of Scott Wilson Kirkpatrick & Co Ltd, to undertake a broad-brush ecological survey of the area around the solid waste disposal site at Magħtab, Malta. The scope of the survey is to identify and describe ecological assets present in the vicinity of the site.

Methods
This study is based on a site visits made by the authors during January 2003 and is supplemented by material from the literature. Habitats were characterised on the basis of geomorphological features and plant assemblages as outlined in (Schembri 1991). No attempt was made to provide a complete inventory of the flora and fauna present, as this would have entailed extensive fieldwork during different seasons, however, indicator species were searched for and noted. The designation RDB refers to the Red Data Book status (Schembri and Sultana 1989) of species recorded.

Assessment of the plant communities colonising the area of study was carried out through a straightforward census of species in a vegetative stage. The species inventory comprises remarks on community affiliation and Red Data Book status for each species listed. This inventory obviously omitted all species that were not at the vegetative stage of their life cycle. The presence of a number of species that were not vegetative at the time of survey was inferred through observation of fruits and withered aerial parts. Most sampling effort was directed towards observation of species dominant at the time of survey. Identification of vegetation was carried out in the field by the authors. Forms that were not identified *in situ* were compared with reference material. Freshwater organisms were identified in the laboratory following microscopic examination. Cladocera were identified by comparison with reference material in one of the authors' (SL) collections. Copepods were identified to genus using Wilson & Yeatman (1959) and Harding and Smith (1974). Clam shrimps (Crustacea: Conchostraca) were identified to species by comparison with reference material one of the authors' (SL) collections, in conjunction with the keys of Cottarelli & Mura (1983) and Nourisson & Thiery (1988).

The area under consideration corresponds to portions of four 1:2500 scale survey sheets issued by the Malta Environment and Planning Authority (MEPA). Survey sheets utilised in the present exercise were Sheet No. 4877, Sheet No. 4878, Sheet No. 5077 and Sheet No. 5079. As such the description of ecological assets shall be subdivided into four parts, each part corresponding to a single survey sheet.

Identification of Communities and Assemblages
The term "community", as used in this study has been utilised in the broad sense implied by Barbour et al. (1999). Parts of communities, or habitats of limited spatial extent were classified as "assemblages". The distinction between community and assemblage is subjective, being dependent on the experience and preferences of an observer.

Coding of Grid References
Coordinate systems on the base maps on which field surveys were based conformed to Universal Transverse Mercator grid references. Each base map comprised fifty squares of area 200m by 200m. Ten squares (cumulative length 2 km) oriented in a west-east direction and five squares (cumulative length 1 km) in a North-South direction. In order to facilitate reference, the ten squares in a West-East direction were labelled 1 through 10 while the five squares in a

North-South direction were labelled A through E. Individual squares were therefore labelled utilising binomials (A1, A5) which are referred to throughout this report.

General description of land cover

The waste disposal site at Magħtab is situated along the northern coast of Malta (approximate UTM grid reference of centre of site: 49868378357). The area occupied by the site is bounded by agricultural land to the east, southeast, south, southwest, west and northwest and by karstic terrain to the north and northeast. The parts of the site facing the coast are within a few tens of metres landward of the Salina Coast Road. The area to the northwest, north and northeast of the site is of considerable significance due to the presence of garrigue terrain and a transitional coastal wetland. Much of the footprint of the site is covered by terraced mounds of unconsolidated construction waste. Older portions of the infill were characterised by high coverage of vegetation including trees, at the time of survey. Sediments that were deposited more recently were colonised by an assemblage of *r*-selected opportunistic species tolerant of frequent disturbance. The coastal fringe north of the site outcrops on the Xlendi member of the Lower Coralline Limestone formation. The limestone has eroded to give a typical coastal biokarst terrain dissected into solution hollows (kamenitzas) and fretting with a maximum relief height of approximately 0.5m.

Plant communities

The site of study has been subject to intense anthropogenic influence and, as such, few traces of original vegetational communities (defined as the climax vegetation that would be expected to colonise the area under present tectonic, geomorphological and climatic conditions) persist. Much of the land within the area of study was given over to waste disposal and the vegetation of the site was therefore dominated by opportunistic weed species characteristic of disturbed habitats.

SURVEY SHEET 5077

Land-Cover

The land represented in this survey sheet represents the south-eastern portion of the area under consideration. Much of the land cover is agricultural in function. Several such areas are under active cultivation whilst a number of others are derelict and were characterised by a secondary ecological succession at the time of survey. Patches of natural habitat were mainly represented by a rocky steppe community on karstland and by an extensive, probably monoclonal, stand of Lesser Reed (*Phragmites australis*). Sporadic thickets of Carob (*Ceratonia siliqua*) were associated with development of pseudomaquis. Much of the coastline is rocky although localised accumulations of sand formed a small number of pocket beaches along its length.

Derelict agricultural land (Legend code 8)

Long-derelict agricultural areas characterised by the late-pioneer stages of a xeroseral succession were recorded from sectors A1, A2, A3, B1, B2, B3, B4, B5, C3 and C4. Topsoil cover in these areas was generally shallow and discontinuous. The vegetation recorded from these sites at the time of survey comprised a framework of species characteristic of sustained ecological stability including Spiny Asparagus (*Asparagus aphyllus*) and Caper (*Capparis orientalis*). An assemblage of opportunistic species capable of exploiting transient patches of vacant habitat was superimposed on the underlying framework. Such species included Cape Sorrel (*Oxalis pes-caprae*). Species recorded from these habitats included the following:

Family	**Species**	**Vernacular**	**RDB status**
Apiaceae	*Ferula communis*	Giant Fennel	Not listed
Apiaceae	*Foeniculum vulgare*	Fennel	Not listed
Asparagaceae	*Asparagus aphyllus*	Spiny Asparagus	Not listed
Asteraceae	*Chrysanthemum coronarium*	Crown Daisy	Not listed
Asteraceae	*Dittrichia viscosa*	Sticky Fleabane	Not listed
Asteraceae	*Senecio bicolor*	Silvery Ragwort	Not listed
Brassicaceae	*Capparis orientalis*	Caper	Not listed
Brassicaceae	*Diplotaxis erucoides*	White Mustard	Not listed
Brassicaceae	*Diplotaxis tenuifolia*	Yellow Wall-Rocket	Not listed
Malvaceae	*Malva cretica*	Cretan Mallow	Not listed
Oxalidaceae	*Oxalis pes-caprae*	Cape Sorrel	Not listed
Poaceae	*Avena sterilis*	Wild Oat	Not listed
Poaceae	*Stipa capensis*	Common Awn-Grass	Not listed
Scrophulariaceae	*Antirrhinum siculum*	Sicilian Snapdragon	Not listed
Solanaceae	*Nicotiana glauca*	Shrub Tobacco	Not listed

Beds of Great Reed (Legend code 5) and Lesser Reed (Legend code 3)

A stand of Great reed (*Arundo donax*) and an extensive population of Lesser Reed (*Phragmites australis*) were noted at the mouth of a shallow valley in Sector A3. Previous studies (Zammit, 1999) of the *Phragmites australis* bed suggest that the dominant mode of reproduction is vegetative. This bed may function as a habitat for a number of bird species, including *Acrocephalus* spp warblers.

Rocky steppe (Legend code 6 and Legend code 10)

Communities with structural organisation of rocky steppe/garrigue were recorded from sectors A1, A2, A3, A4, A5, B4 and B5). These communities may represent a localised edaphic disclimax that may have regressed from a structurally uniform maritime garrigue or progressed from communities of derelict agricultural areas. The dominant species in these areas were Hispid Beard-Grass (*Hyparrhenia hirta*) and Mediterranean Steppe-Grass (*Stipa capensis*). The communities in Sectors A4, A5, B4 and B5 (Legend code 6) were characterised by large populations of Century Plant (*Agave americana*) and Sisal (*Agave sisalana*). Species recorded from these communities included the following:

Family	Species	Vernacular	RDB status
Agavaceae	*Agave Americana*	Century Plant	Not listed
Agavaceae	*Agave sisalana*	Sisal	Not listed
Apiaceae	*Daucus carota*	Wild Carrot	Not listed
Apiaceae	*Ferula communis*	Giant Fennel	Not listed
Asparagaceae	*Asparagus aphyllus*	Spiny Asparagus	Not listed
Asphodelaceae	*Asphodelus aestivus*	Branched Asphodel	Not listed
Asteraceae	*Carlina involucrata*	Carline Thistle	Rest (MED)
Asteraceae	*Centauraea nicaensis*	Southern Star Thistle	Not listed
Asteraceae	*Reichardia picroides*	Common Reichardia	Not listed
Asteraceae	*Senecio bicolor*	Silvery Ragwort	Not listed
Convolvulaceae	*Convolvulus oleifolius*	Olive-Leaved Bindweed	Rest (MED)
Hyacinthaceae	*Urginea pancration*	Seaside Squill	Rest (MED)
Iridaceae	*Gladiolus italicus*	Field Gladiolus	Not listed
Lamiaceae	*Prasium majus*	White Hedge-Nettle	Not listed
Lamiaceae	*Teucrium fruticans*	Olive-Leaved Germander	Not listed
Lamiaceae	*Thymbra capitata*	Mediterranean Thyme	GN 85 (1932)
Poaceae	*Avena sterilis*	Wild Oat	Not listed
Poaceae	*Hyparrhenia hirta*	Hispid Beard-Grass	Not listed
Poaceae	*Stipa capensis*	Common Awn-Grass	Not listed
Scrophulariaceae	*Antirrhinum siculum*	Sicilian Snapdragon	Not listed

Remnant drainage channel (Legend code 9)

Remnants of a shallow valley were noted from Sectors B5 and B6. This habitat had probably been reclaimed for agriculture but is now derelict. The bed was colonised by a suite of ruderal species dominated by Yellow Wall-rocket (*Diplotaxis tenuifolia*) within which are interspersed species indicative of a garrigue/steppe community including Caper (*Capparis orientalis*), Hispid Beard-Grass (*Hyparrhenia hirta*) and Great Sage (*Phlomis fruticosa*) [RDB page 30].

Small woodlots and thickets (Legend codes 1, 2, 4)

Small thickets dominated by Carob (*Ceratonia siliqua*) were recorded throughout the area of study. Some thickets comprised secondary dominants including Prickly Pear (*Opuntia ficus-indica*). The refuge and structural diversity provided by the Carobs and sub-dominants generated a microclimate that varied substantially from the surrounding habitat and promoted the development of pseudomaquis. A mixed Tamarisk (*Tamarix* spp.)/Acacia (*Acacia* spp.) woodlot was recorded adjacent to the coastal road in Sector A4.

Rocky shore assemblage

The rocky coast along the western shore of Qala ta' Baħar iċ-Ċagħaq (Sectors A3, A4, A5, B5) was colonised by maritime steppe/garrigue in which Golden Samphire (*Inula crithmoides*) achieved local dominance. Species present recorded from this community included the following:

Family	Species	Vernacular	RDB status
Apiaceae	*Daucus carota*	Wild Carrot	Not listed
Asparagaceae	*Asparagus aphyllus*	Spiny Asparagus	Not listed
Asphodelaceae	*Asphodelus aestivus*	Branched Asphodel	Not listed
Asteraceae	*Carlina involucrata*	Carline Thistle	Rest (MED)
Asteraceae	*Centauraea nicaensis*	Southern Star Thistle	Not listed
Asteraceae	*Inula crithmoides*	Golden Samphire	Not listed
Asteraceae	*Pallenis spinosa*	Ox-Eye Daisy	Not listed
Asteraceae	*Phagnalon graecum*	Eastern Phagnalon	Rest (MED)
Asteraceae	*Reichardia picroides*	Common Reichardia	Not listed
Asteraceae	*Senecio bicolor*	Silvery Ragwort	Not listed
Convolvulaceae	*Cuscuta epithymum*	Dodder	Not listed
Hyacinthaceae	*Urginea pancration*	Seaside Squill	Rest (MED)
Iridaceae	*Romulea ramiflora*	Sand Crocus	Not listed
Lamiaceae	*Prasium majus*	White Hedge-Nettle	Not listed
Lamiaceae	*Thymbra capitata*	Mediterranean Thyme	GN 85 (1932)
Poaceae	*Avena sterilis*	Wild Oat	Not listed
Poaceae	*Hyparrhenia hirta*	Hispid Beard-Grass	Not listed

SURVEY SHEET 5078

Land-Cover

The land represented in this survey sheet represents the north-eastern portion of the area under consideration. Land cover is approximately equally divided between a rocky steppe to the southeast and the footprint of part of the waste disposal site to the north whilst a relatively small area to the south is under active cultivation. A narrow coastal fringe is colonised by vegetation characteristic of gently sloping rocky shores.

Rocky shore assemblage (Legend code 8)

The rocky coast along the western shore of Qalet Marku (Sectors A1, B1, C1, C2, D2) was colonised by maritime steppe/garrigue. The dominant species over the entire coastal fringe was Golden Samphire (*Inula crithmoides*) whilst other species generally considered characteristic of rocky coastal area were present in low abundance. Halophytic species recorded from the coastal fringe included Shrubby Glasswort (*Arthrocnemum macrostachyum*) and Sea-Fennel (*Crithmum maritimum*). The main species recorded from this community included the following:

Family	**Species**	**Vernacular**	**RDB status**
Apiaceae	*Crithmum maritimum*	Sea-Fennel	Not listed
Asteraceae	*Anthemis urvilleana*	Maltese Sea-Chamomile	Endemic
Asteraceae	*Inula crithmoides*	Golden Samphire	Not listed
Asteraceae	*Senecio bicolor*	Silvery Ragwort	Not listed
Chenopodiaceae	*Arthrocnemum macrostachyum*	Shrubby Glasswort	Not listed
Fabaceae	*Lotus ornithopodiodes*	Common Birdsfoot Trefoil	Not listed
Malvaceae	*Lavatera arborea*	Tree Mallow	Not listed
Papaveraceae	*Glaucum flavum*	Yellow-horned Poppy	Not listed

Heterogeneous rocky steppe (Legend code 4)

This group of assemblages occupied the southeastern portion of the site being considered and were continuous with the rocky steppe described under Survey Sheet 5077. The community in this part of the site is characterized by a mosaic of habitat patches, coincident with old field boundaries, in various stages of secondary succession. A number of habitat patches (Sectors C1, D1) were colonised by vegetation generally associated with maquis or high garrigue including Evergreen Honeysuckle (*Lonicera implexa*), Lentisk (*Pistacia lentiscus*) and Common Smilax (*Smilax aspera*). Derelict agricultural areas were colonised by a range of assemblages the structure of which was generally dependent on recency of cultivation. Areas that had been derelict for a longer period than others were colonised by a well established late pioneer stage of succession in Which Great Sage (*Phlomis fruticosa*) was present. Areas that had been cultivated more recently were colonised by species indicative of early secondary succession including Sticky Fleabane (*Dittrichia viscosa*) and Fennel (*Foeniculum vulgare*). The ecotone between the periphery of the dump and the steppic habitat comprised a suite of *r*-selected species characteristic of disturbed habitats including Crown daisy (*Chrysanthemum coronarium*). The main species recorded from these assemblages included the following:

Family	**Species**	**Vernacular**	**RDB status**
Agavaceae	*Agave Americana*	Century Plant	Not listed
Agavaceae	*Agave sisalana*	Sisal	Not listed

Anacardiaceae	*Pistacia lentiscus*	Lentisk	Not listed
Apiaceae	*Daucus carota*	Wild Carrot	Not listed
Apiaceae	*Ferula communis*	Giant Fennel	Not listed
Apiaceae	*Foeniculum vulgare*	Fennel	Not listed
Asparagaceae	*Asparagus aphyllus*	Spiny Asparagus	Not listed
Asphodelaceae	*Asphodelus aestivus*	Branched Asphodel	Not listed
Asteraceae	*Carlina involucrata*	Carline Thistle	Rest (MED)
Asteraceae	*Centauraea nicaensis*	Southern Star Thistle	Not listed
Asteraceae	*Chrysanthemum coronarium*	Crown Daisy	Not listed
Asteraceae	*Dittrichia viscosa*	Sticky Fleabane	Not listed
Asteraceae	*Galactities tomentosa*	Boar Thistle	Not listed
Asteraceae	*Inula crithmoides*	Golden Samphire	Not listed
Asteraceae	*Reichardia picroides*	Common Reichardia	Not listed
Asteraceae	*Senecio bicolor*	Silvery Ragwort	Not listed
Asteraceae	*Sonchus oleraceus*	Smooth Sow Thistle	Not listed
Brassicaceae	*Diplotaxis erucoides*	White Mustard	Not listed
Caesalpinaceae	*Ceratonia siliqua*	Carob	Not listed
Caprifoliaceae	*Lonicera implexa*	Evergreen Honeysuckle	Not listed
Convolvulaceae	*Convolvulus oleifolius*	Olive-Leaved Bindweed	Rest (MED)
Euphorbiaceae	*Euphorbia pinea*	Pine Spurge	Not listed
Fabaceae	*Anthyllis vulneraria* ssp. *maura*	Common Kidney-Vetch	Not listed
Fabaceae	*Astragalus baeticus*	Milk Vetch	Not listed
Fabaceae	*Lotus edulis*	Edible Birdsfoot Trefoil	Not listed
Fabaceae	*Lotus ornithopodiodes*	Common Birdsfoot Trefoil	Not listed
Hyacinthaceae	*Urginea pancration*	Seaside Squill	Rest (MED)
Iridaceae	*Gladiolus italicus*	Field Gladiolus	Not listed
Lamiaceae	*Phlomis fruitcosa*	Great Sage	Special mention p.30
Lamiaceae	*Prasium majus*	White Hedge-Nettle	Not listed
Lamiaceae	*Teucrium fruticans*	Olive-Leaved Germander	Not listed
Lamiaceae	*Thymbra capitata*	Mediterranean Thyme	GN 85 (1932)
Malvaceae	*Lavatera arborea*	Tree Mallow	Not listed
Moraceae	*Ficus carica*	Fig	Not listed
Oxalidaceae	*Oxalis pes-caprae*	Cape Sorrel	Not listed
Poaceae	*Avena sterilis*	Wild Oat	Not listed
Poaceae	*Hyparrhenia hirta*	Hispid Beard-Grass	Not listed
Poaceae	*Piptatherum miliaceum*	Rice-Grass	Not listed
Poaceae	*Stipa capensis*	Common Awn-Grass	Not listed
Scrophulariaceae	*Antirrhinum siculum*	Sicilian Snapdragon	Not listed
Smilacaceae	*Smilax aspera*	Common Smilax	Not listed

Small woodlots and thickets (Legend codes 1, 2, 3)

Small thickets dominated by Carob (*Ceratonia siliqua*) were recorded throughout the area of study. Some thickets comprised secondary dominants including Prickly Pear (*Opuntia ficus-indica*). The refuge and structural diversity provided by the Carobs and sub-dominants generated a microclimate that varied substantially from the surrounding habitat and promoted the development of pseudomaquis. A mixed hedge comprising Tamarisk (*Tamarix* spp.) and Shrubby Orache (*Atriplex halimus*) was recorded adjacent to the coastal road in Sector B1.

SURVEY SHEET 4878

Land-Cover

The land represented in this survey sheet represents the north-western portion of the area under consideration. Land cover is dominated by the footprint of the waste disposal site which is encroaching on the rocky steppe/garrigue at Xagħra tal-Baħar. A narrow coastal fringe is colonised by vegetation characteristic of gently sloping rocky shores. A transitional coastal wetland, Għadira s-Safra, is present within the coastal fringe in Sector A10.

Steppe/garrigue at Xagħra tal-Baħar (Legend code 4)

This habitat was formerly continuous with the rocky steppe described under Survey Sheet 5077 and Survey Sheet 5078 from which it is now isolated by the waste disposal site. Dominant vegetation was characterised by a level of structural organisation consistent with a transition between garrigue and steppe. The present state of the community may indicate a transition between these two levels of organisation although the direction of succession could not be ascertained. The dominant plants were low hemispherical shrubs including Mediterranean Thyme (*Thymbra capitata*) and Olive-leaved Germander (*Teucrium fruticans*). Other species including Sea Squill (*Urginea pancration*) achieved local dominance. Isolated enclaves of maquis vegetation comprised Lentisk (*Pistacia lentiscus*), Evergreen Honeysuckle (*Lonicera implexa*) and Rosemary (*Rosmarinus officinalis*) [RDB: rare, restricted distribution in the Maltese Islands]. A number of freshwater rock pools were also noted from the area. Species recorded from this community included the following:

Family	**Species**	**Vernacular**	**RDB status**
Agavaceae	*Agave Americana*	Century Plant	Not listed
Agavaceae	*Agave sisalana*	Sisal	Not listed
Anacardiaceae	*Pistacia lentiscus*	Lentisk	Not listed
Apiaceae	*Daucus carota*	Wild Carrot	Not listed
Apiaceae	*Foeniculum vulgare*	Fennel	Not listed
Araceae	*Arisarum vulgare*	Friar's Cowl	Not listed
Asparagaceae	*Asparagus aphyllus*	Spiny Asparagus	Not listed
Asphodelaceae	*Asphodelus aestivus*	Branched Asphodel	Not listed
Asteraceae	*Bellis sylvestris*	Southern Daisy	Not listed
Asteraceae	*Carlina involucrata*	Carline Thistle	Rest (MED)
Asteraceae	*Chrysanthemum coronarium*	Crown Daisy	Not listed
Asteraceae	*Galactities tomentosa*	Boar Thistle	Not listed
Asteraceae	*Inula crithmoides*	Golden Samphire	Not listed
Asteraceae	*Phagnalon graecum*	Eastern Phagnalon	Rest (MED)
Asteraceae	*Reichardia picroides*	Common Reichardia	Not listed
Asteraceae	*Senecio bicolor*	Silvery Ragwort	Not listed
Asteraceae	*Sonchus oleraceus*	Smooth Sow Thistle	Not listed
Brassicaceae	*Brassica rapa*	Bargeman's Cabbage	Not listed
Brassicaceae	*Capparis orientalis*	Caper	Not listed
Brassicaceae	*Diplotaxis erucoides*	White Mustard	Not listed
Brassicaceae	*Lobularia maritima*	Sweet Alyssum	Not listed

Cactaceae	*Opuntia ficus-indica*	Prickly Pear	Not listed
Caprifoliaceae	*Lonicera implexa*	Evergreen Honeysuckle	Not listed
Convolvulaceae	*Cuscuta epithymum*	Dodder	Not listed
Cucurbitaceae	*Ecballium elaterium*	Squirting Cucumber	Not listed
Euphorbiaceae	*Euphorbia exigua* var. *pycnophylla*	Maltese Dwarf Spurge	Rest (MED)
Euphorbiaceae	*Euphorbia helioscopa*	Sun Spurge	Not listed
Euphorbiaceae	*Euphorbia pinea*	Pine Spurge	Not listed
Euphorbiaceae	*Mercurialis annua*	Annual Mercury	Not listed
Fabaceae	*Anthyllis hermanniae*	Shrubby Kidney-Vetch	Not listed
Fabaceae	*Anthyllis vulneraria* ssp. *maura*	Common Kidney-Vetch	Not listed
Fabaceae	*Astragalus baeticus*	Milk Vetch	Not listed
Hyacinthaceae	*Urginea pancration*	Seaside Squill	Rest (MED)
Lamiaceae	*Prasium majus*	White Hedge-Nettle	Not listed
Lamiaceae	*Teucrium fruticans*	Olive-Leaved Germander	Not listed
Lamiaceae	*Thymbra capitata*	Mediterranean Thyme	GN 85 (1932)
Malvaceae	*Lavatera arborea*	Tree Mallow	Not listed
Mimosaceae	*Acacia cyanophylla*	Blue-Leaved Acacia	Not listed
Orchidaceae	*Orchis collina*	Fan-Lipped orchid	Not listed
Oxalidaceae	*Oxalis pes-caprae*	Cape Sorrel	Not listed
Pinaceae	*Pinus halepensis*	Aleppo Pine	Not listed
Plantaginaceae	*Plantago coronopus* s.l.	Buck's Horn Plantain	Not listed
Plantaginaceae	*Plantago lagopus*	Hare's-foot Plantain	Not listed
Plantaginaceae	*Plantago serraria*	Toothed Plantain	Not listed
Poaceae	*Hyparrhenia hirta*	Hispid Beard-Grass	Not listed
Poaceae	*Phalaris minor*	Lesser Canary Grass	Not listed
Poaceae	*Piptatherum miliaceum*	Rice-Grass	Not listed
Poaceae	*Stipa capensis*	Common Awn-Grass	Not listed
Tamaricaceae	*Tamarix* sp.	Tamarisk	
Valerianaceae	*Fedia graciliflora*	Horn-of-Plenty	Not listed

Freshwater rock pools

The rainwater pools present in the area represent point repositories for a highly specialised assemblage of species and are therefore of considerable ecological significance. Unpublished studies carried out by one of the authors (SL) indicated that resident fauna of the pools was dominated by microcrustaceans, principally cladocerans, ostracods and copepods. The most abundant species in the water column was C*eriodaphnia quadrangula* (Crustacea: Cladocera). Also present in the water column was the calanoid copepod *Diaptomus* sp. This was a particularly significant find, since the specimens collected from these pools represented the first records of this genus from the Maltese Islands. The bottom sediment of the pools was colonised by ostracods, by the cladoceran *Pleuroxus letourneuxi* and by the conchostracan *Cyzicus tetracerus* [RDB: restricted distribution in the Maltese Islands]. Pool vegetation was characteristic of such habitats in general and comprised obligately aquatic rooted macrophytes and floating algal mats. The species recorded included the following:

Family	Species	Vernacular	RDB status
Alismataceae	*Damasonium bourgaei*	Mediterranean Starfruit	V, Rest (MED+MI)
Callitrichaceae	*Callitriche truncata*	Southern Water-Starwort	R, Rest, (MI)
Ranunculaceae	*Ranunculus saniculaefolius*	Sanicle-Leaved Water Crowfoot	Not listed

Rocky shore assemblage (Legend code 6)

The rocky shore in Sectors A8, A9, A10 and B10 was colonised by maritime steppe/garrigue. The dominant species over the entire coastal fringe was Golden Samphire (*Inula crithmoides*) whilst other species generally considered characteristic of rocky coastal area were present in low abundance. Halophytic species recorded from the coastal fringe included Shrubby Glasswort (*Arthrocnemum macrostachyum*) and Sea-Fennel (*Crithmum maritimum*). The main species recorded from this community included the following:

Family	Species	Vernacular	RDB status
Apiaceae	*Crithmum maritimum*	Sea-Fennel	Not listed
Asparagaceae	*Asparagus aphyllus*	Spiny Asparagus	Not listed
Asteraceae	*Anthemis urvilleana*	Maltese Sea-Chamomile	Endemic
Asteraceae	*Carlina involucrata*	Carline Thistle	Rest (MED)
Asteraceae	*Evax pygmaea*	Pygmy Cudweed	Not listed
Asteraceae	*Galactities tomentosa*	Boar Thistle	Not listed
Asteraceae	*Inula crithmoides*	Golden Samphire	Not listed
Asteraceae	*Reichardia picroides*	Common Reichardia	Not listed
Asteraceae	*Senecio bicolor*	Silvery Ragwort	Not listed
Asteraceae	*Sonchus oleraceus*	Smooth Sow Thistle	Not listed
Asteraceae	*Urospermum picroides*	Prickly Urospermum	Not listed
Brassicaceae	*Capparis orientalis*	Caper	Not listed
Chenopodiaceae	*Arthrocnemum macrostachyum*	Shrubby Glasswort	Not listed
Convolvulaceae	*Convolvulus lineatus*	Narrow-Leaved Bindweed	Not listed
Euphorbiaceae	*Euphorbia pinea*	Pine Spurge	Not listed
Fabaceae	*Anthyllis vulneraria* ssp. *maura*	Common Kidney-Vetch	Not listed
Fabaceae	*Lotus cytisoides*	Grey Birdsfoot Trefoil	Not listed
Fabaceae	*Lotus edulis*	Edible Birdsfoot Trefoil	Not listed
Fabaceae	*Lotus ornithopodiodes*	Common Birdsfoot Trefoil	Not listed
Geraniaceae	*Erodium malcoides*	Glandular Storksbill	Not listed
Geraniaceae	*Erodium moschatum*	Musk Storksbill	Not listed
Hyacinthaceae	*Urginea pancration*	Seaside Squill	Rest (MED)
Iridaceae	*Romulea ramiflora*	Sand Crocus	Not listed
Lamiaceae	*Prasium majus*	White Hedge-Nettle	Not listed
Malvaceae	*Lavatera arborea*	Tree Mallow	Not listed
Oxalidaceae	*Oxalis pes-caprae*	Cape Sorrel	Not listed
Plumbaginaceae	*Limonium virgatum*	Seaside Sea-Lavender	R, Rest(MI)
Poaceae	*Avena* spp.	Wild Oat	Not listed
Poaceae	*Desmazeria pignattii*	Pignatti's Fern-Grass	Rest (MED)
Rubiaceae	*Crucianella rupestris*	Rock Crosswort	Rest (MED)

Rubiaceae	*Valantia muralis*	Wall Valantia	Not listed	
Valerianaceae	*Fedia graciliflora*	Horn-of-Plenty	Not listed	

Transitional coastal wetland at Għadira s-Safra (Sector A10)
Ghadira s-Safra is a seasonally flooded marshland of area 0.8ha, and generally located less than 1m above mean sea level on the northeastern coast of Malta, in the Maghtab-Ghallis area (Fig.1). The site outcrops on the Xlendi Member of the Lower Coralline Limestone Bed and is of Oligocene age. The substratum consists of a fine reddish soil underlain by a thin layer of alluvial clay which enables the marsh to retain water. In most years, the marsh contains water during the wet season (September/October to March/April) and is completely desiccated throughout summer. During the course of a typical wet season, Ghadira s-Safra undergoes several cycles of alternate wetting and drying since the large surface area and shallow depth of the water promote high rates of evapotranspiration which are sufficient to cause drying between successive flooding episodes.

The marsh supports a biota of mixed character. The permanent community mainly comprises terrestrial halophilic macrophytes while the temporary community is typical of ephemeral fresh and brackish water habitats and is only present when the marsh contains water. A number of species inhabiting the marsh are of local or regional ecological significance:

Triops cancriformis (Bosc); (Crustacea: Branchiopoda: Notostraca). Ghadira s-Safra is one of the few localities where this locally rare species has been recorded in recent years (Lanfranco 2001).
Branchipus visnyai Kertesz (Crustacea: Branchiopoda: Anostraca). Ghadira s-Safra is one of two localities in Malta from where this species has been recorded.
Crypsis aculeata (Tracheophyta: Magnoliopsida: Poaceae). Restricted to Ghadira s-Safra.
Riella helicophylla (Bryophyta: Hepaticae); a very rare and endangered liverwort. Listed in Appendix 1 of the Berne Convention as a "Species to be Strictly Protected" (Lanfranco 1999).

Additionally, an unrecorded epizoic association involving *Branchipus schaefferi* Fischer (Anostraca) and *Lyngbya* sp. (Cyanobacteria) has been observed at Ghadira s-Safra (Lanfranco & Schembri, 1995).

This habitat has been scheduled in conformation with Section 46 of the Development Planning Act of 1992 (Legal Notice 288 of 5th May 1995).

SURVEY SHEET 4878

Land-Cover

The land represented in this survey sheet represents the south-western portion of the area under consideration. Land cover is dominated by the footprint of the waste disposal site and by agricultural areas under active cultivation. Natural communities are sparse and mainly persist as seral stages in secondary succession on derelict agricultural areas and as pseudomaquis in Carob thickets.

Derelict agricultural areas (Legend code 7)

These habitats were recorded from Sectors A10, B9, B10, C9 and C10. Species composition varied from one area to another. Dominant species included Fennel (Foeniculum vulgare) interspersed with perennial underscrub comprising Spiny Asparagus (*Asparagus aphyllus*).

Small woodlots and thickets (Legend codes 3, 5, 6)

Small thickets dominated by Carob (*Ceratonia siliqua*) were recorded throughout the area of study. Some thickets comprised secondary dominants including Prickly Pear (*Opuntia ficus-indica*). The refuge and structural diversity provided by the Carobs and sub-dominants generated a microclimate that varied substantially from the surrounding habitat and promoted the development of pseudomaquis. A number of monospecific woodlots composed of *Eucalyptus* spp. were colonising mounds of construction waste. These woodlots have been deliberately introduced for embellishment and bird shooting.

Unconsolidated mounds of rubble (throughout)

Mounds of unconsolidated construction waste were generally colonised by an assemblage of opportunistic *r*-selected species capable of exploiting transient gaps in habitat-space. Vegetation cover on recently-deposited material was dominated by Cape Sorrel (*Oxalis pes-caprae*) and Crown Daisy (*Chrysanthemum coronarium*). Mounds on which no ecologically-recent disturbance was evident were characterised by an incipient secondary succession and were colonised by indicators of relative ecological stability including Shrub Tobacco (*Nicotiana glauca*) and Rice Grass *(Piptatherum miliaceum*).

Figure 1: General view of the waste disposal site at Magħtab

Figure 2: ***Eucalyptus*** **sp. woodlot on mounds on mounds of construction waste**

Figure 3: Transitional coastal wetland at Għadira s-Safra

Figure 4: General aspect of the rocky shore at Għallis

Figure 5: Maritime steppe/garrigue at ix-Xagħra tal-Baħar, Għallis

Figure 6: Incipient secondary succession on mounds of construction waste. The dominant species is Shrub Tobacco (*Nicotiana glauca*)

Figure 7: Accumulations of construction waste encroaching on maritime steppe/garrigue at Għallis

Figure 8: Fan-Lipped Orchid (*Orchis collina*) recorded from ix-Xagħra tal-Baħar, Għallis

General ecological evaluation and policy context

The ecological significance of the site under investigation has been determined in accordance with the policies of the Structure Plan for the Maltese Islands (Malta Structure Plan 1992a), (Malta Structure Plan 1992b):

1. The presence of freshwater rock pools qualifies the maritime steppe/garrigue at ix-Xagħra tal-Baħar, Għallis, as an Area of Ecological Importance in terms of Structure Plan Policy RCO 10(6).

2. The presence of garrigue assemblages qualifies the environs of the site as an Area of Ecological Importance in terms of Structure Plan Policy RCO 10(9).

3. The transitional coastal wetland at Għadira s-Safra qualifies as an Area of Ecological Importance in terms of Structure Plan Policy RCO 10(2).

4. The transitional coastal wetland at Għadira s-Safra qualifies as a Site of Scientific Importance in terms of Structure Plan Policy RCO 11(1) and RCO 11(2).

5. The transitional coastal wetland at Għadira s-Safra is a scheduled site in terms of Section 46 of the Development Planning Act of 1992 (Legal Notice 288, 5th May 1995).

6. The liverwort *Riella helicophylla* listed as a protected species under the Environment Protection Act 1991 in terms of Legal Notice 161 of 1999.

7. The coastal fringe at Għallis is the type locality for the Siculo-Maltese endemic woodlouse *Miktoniscus melitensis* [RDB: R, Rest (MI+MED)] and is therefore considered a Site of Scientific Importance in terms of Structure Plan Policy RCO 11(1) and RCO 11(3).

8. The rubble walls and rural structures present in the vicinity of the site may be subject to the Rubble Walls and Rural Structures (Conservation and Maintenance) Regulations of 1997 (Legal Notice 160 of 1997).

9. The area surrounding the site of study comprises relatively large fields with fertile soil. The cultivated agricultural land therefore probably qualifies as an Area of Agricultural Value (AAV) in terms of Malta Structure Plan policy RCO 1(1), although it is not within the competence of the present authors to assess agricultural value. If the study area does indeed qualify as an AAV, then Malta Structure Plan policies AHF1 to 13 apply, as well as policies RCO2 and RCO7 to RCO9.

10. The waste disposal site would qualify for rehabilitation in terms of Structure Plan policies RCO 19 and RCO 20.

11. Any coniferous trees present in the site or its environs are subject to the Conifer Trees (Preservation) Regulations 1949 (Government Notice 328 of 1949).

12. The Trees and large shrubs within the site of study and the extended area are subject to the Trees and Woodlands (Protection) Regulations of 2001 (Legal Notice 12 of 2001).

13. The following species recorded from the area of study are listed as “Strictly Protected Trees” in terms of Trees and Woodlands (Protection) Regulations, 2001 (Legal Notice 12 of 2001; Schedule I):

Family	**Species**	**Vernacular**	**RDB status**
Anacardiaceae	*Pistacia lentiscus*	Lentisk	Not listed
Pinaceae	*Pinus halepensis*	Aleppo Pine	Not listed

14. The following species recorded from the extended area of study are listed as “Protected Trees” in terms of Trees and Woodlands (Protection) Regulations, 2001 (Legal Notice 12 of 2001; Schedule II):

Family	**Species**	**Vernacular**	**RDB status**
Caesalpinaceae	*Ceratonia siliqua*	Carob	Not listed
Oleaceae	*Olea europea* s.l.	Olive	Rest (MI)?
Moraceae	*Morus* spp.	Mulberry	Not listed

15. Assemblages comprising twenty trees or more qualify as “woodland areas” in terms of the Trees and Woodlands (Protection) Regulations 2001 (Legal Notice 12 of 2001).

16. Any trees of age fifty years or greater are listed as “Protected Trees” in terms of Schedule III of the Trees and Woodlands (Protection) Regulations 2001 (Legal Notice 12 of 2001), provided that they are not listed in Schedule V of the same regulations and provided that they are not causing any damage to the biological identity of any trees listed in Schedules I and II of the same regulations.

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A Description of ecological assets in the vicinity of the public solid waste disposal site at Wied Fulija, limits of Żurrieq, Malta

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Malta University Services

January 2003

Introduction
The present consultants have been commissioned by Malta University Services, acting on behalf of Scott Wilson Kirkpatrick & Co Ltd, to undertake a broad brush ecological survey of the area around the solid waste disposal site at Wied Fulija, limits of Żurrieq, Malta. The scope of the survey is to identify and describe ecological assets present in the vicinity of the site.

Methods
This study is based on a site visits made by the authors during January 2003 and is supplemented by material from the literature. Habitats were characterised on the basis of geomorphological features and plant assemblages as outlined in (Schembri 1991). No attempt was made to provide a complete inventory of the flora and fauna present, as this would have entailed extensive fieldwork during different seasons, however, indicator species were searched for and noted. The designation RDB refers to the Red Data Book status (Schembri and Sultana 1989) of species recorded.

Assessment of the plant communities colonising the area of study was carried out through a straightforward census of species in a vegetative stage. The species inventory comprises remarks on community affiliation and Red Data Book status for each species listed. This inventory obviously omitted all species that were not at the vegetative stage of their life cycle. The presence of a number of species that were not vegetative at the time of survey was inferred through observation of fruits and withered aerial parts. Most sampling effort was directed towards observation of species dominant at the time of survey.

Identification of Communities and Assemblages
The term "community", as used in this study has been utilized in the broad sense implied by Barbour et al. (1999). Parts of communities, or habitats of limited spatial extent were classified as "assemblages". The distinction between community and assemblage is subjective, being dependent on the experience and preferences of an observer.

Coding of Grid References
Coordinate systems on the base maps on which field surveys were based conformed to Universal Transverse Mercator grid references.

General description of land cover
The waste disposal site at Wied Fulija is situated along the southern coast of Malta (approximate UTM grid reference of centre of site: 5321763811). The area occupied by the site is bounded by a perimeter fence on the landward side and by coastal slopes and cliffs on the seaward side. The cliffs are interrupted by the mouth of Wied il-Ħallelin, a narrow ravine that has largely been filled in by waste material. Much of the footprint of the site is covered by terraced mounds of unconsolidated construction waste with which are interspersed localised mounds of fragmented glass and compacted metal containers. Surface outcrops along this band are composed of lower Coralline Limestone that has weathered into a karst landscape characterised by fretting and development of kamenitzas. Soil cover within the site of study was discontinuous and no perennial sources of surface freshwater could be detected

Plant communities

The site of study has been subject to intense anthropogenic influence and, as such, few traces of original vegetational communities (defined as the climax vegetation that would be expected to colonise the area under present tectonic, geomorphological and climatic conditions) persist. Much of the land within the area of study was given over to waste disposal and the vegetation of the site was therefore dominated by opportunistic weed species characteristic of disturbed habitats. A narrow coastal fringe (maximum breadth approximately 25m) was colonised by an assemblage of species generally characteristic of degraded maritime steppe. The plant communities identified in the area of study are described below and represented on a separate vegetation map attached to this document. It should be remarked that there is no clear-cut delineation between adjacent communities or assemblages. The vegetation map, although accurate, should therefore be treated as indicative of the extent of the assemblages identified. In the present study, the breadth of ecotones should be considered as narrow compared to the extent of the assemblage.

Assemblages colonising mounds of rubble **(legend code 1 on accompanying map)**

Mounds of unconsolidated construction waste were generally colonised by an assemblage of opportunistic *r*-selected species capable of exploiting transient gaps in habitat-space. Vegetation cover on recently-deposited material was dominated by Cape Sorrel (*Oxalis pes-caprae*) and Crown Daisy (*Chrysanthemum coronarium*). Mounds on which no ecologically-recent disturbance was evident were characterised by an incipient secondary succession and were colonised by indicators of relative ecological stability including Maltese Salt-Tree (*Darniella melitensis*). Species recorded from these assemblages included the following:

Family	Species	Vernacular	RDB status
Asteraceae	*Chrysanthemum coronarium*	Crown Daisy	Not Listed
Asteraceae	*Galactities tomentosa*	Boar Thistle	Not Listed
Asteraceae	*Senecio bicolor*	Silvery Ragwort	Not Listed
Asteraceae	*Sonchus oleraceus*	Smooth Sow Thistle	Not Listed
Boraginaceae	*Borago officinalis*	Borage	Not Listed
Brassicaceae	*Diplotaxis tenuifolia*	Yellow Wall-Rocket	Not Listed
Brassicaceae	*Lobularia maritima*	Sweet Alyssum	Not Listed
Brassicaceae	*Sisymbrium irio*	London Rocket	Not Listed
Caryophyllaceae	*Silene colorata*	Red Campion	Not Listed
Chenopodiaceae	*Darniella melitensis*	Maltese Salt-Tree	Endemic
Euphorbiaceae	*Mercurialis annua*	Annual Mercury	Not Listed
Geraniaceae	*Erodium malcoides*	Glandular Storksbill	Not Listed
Malvaceae	*Malva sylvestris*	Mallow	Not Listed
Oxalidaceae	*Oxalis pes-caprae*	Cape Sorrel	Not Listed

West Mediterranean clifftop phrygana **(legend code 2 on accompanying map)**

Assemblages characterised by a grade of structural organisation consistent with degraded maritime steppe/garrigue were recorded from a narrow coastal fringe along the southern border of the site of study. Such assemblages were bordering disturbed areas and represented a zone where a flora characteristic of disturbed ground was superimposed on the pre-existing maritime steppe/garrigue. Dominant species in this community included remnants of the original community such as Egyptian St. John's Wort (*Hypericum aegyptiacum*) and Olive-leaved

Germander (*Teucrium fruticans*) interspersed with species indicative of successional regression or recolonisation such as Seaside Squill (*Urginea pancration*) and Branched Asphodel (*Asphodelus aestivuus*). The portions of the community closest to the cliff edge comprised Maltese Rock Centaury (*Palaeocyanus crassifolius*). Species recorded from this community included the following:

Family	Species	Vernacular	RDB status
Aizoaceae	*Mesembryanthemum crystallinum*	Crystal-Plant	RR, Rest (MI)
Anacardiaceae	*Pistacia lentiscus*	Lentisk	Not listed
Apiaceae	*Daucus carota*	Wild Carrot	Not Listed
Araceae	*Arisarum vulgare*	Friar's Cowl	Not Listed
Asclepiadaceae	*Periploca angustifolia*	African Wolfbane	Rest (MED)
Asparagaceae	*Asparagus aphyllus*	Spiny Asparagus	Not Listed
Asphodelaceae	*Asphodelus aestivuus*	Branched Asphodel	Not Listed
Asteraceae	*Carlina involucrata*	Carline Thistle	Rest (MED)
Asteraceae	*Chiliadenus bocconei*	Maltese Fleabane	Endemic
Asteraceae	*Cynara cardunculus*	Wild Artichoke	Not Listed
Asteraceae	*Galactities tomentosa*	Boar Thistle	Not Listed
Asteraceae	*Inula crithmoides*	Golden Samphire	Not Listed
Asteraceae	*Palaeocyanus crassifolius*	Maltese Rock Centaury	Endemic, R, Rest (MI)
Asteraceae	*Senecio bicolor*	Silvery Ragwort	Not Listed
Asteraceae	*Sonchus oleraceus*	Smooth Sow Thistle	Not Listed
Brassicaceae	*Lobularia maritima*	Sweet Alyssum	Not Listed
Brassicaceae	*Sisymbrium irio*	London Rocket	Not Listed
Caryophyllaceae	*Silene colorata*	Red Campion	Not Listed
Chenopodiaceae	*Darniella melitensis*	Maltese Salt-Tree	Endemic
Clusiaceae	*Hypericum aegyptiacum*	Egyptian St. John's Wort	Rest (MED)
Crassulaceae	*Sedum sediforme*	Mediterranean Stonecrop	Not Listed
Ericaceae	*Erica multiflora*	Mediterranean Heath	Not Listed
Euphorbiaceae	*Euphorbia pinea*	Pine Spurge	Not Listed
Fabaceae	*Lotus cytisoides*	Grey Birdsfoot Trefoil	Not Listed
Geraniaceae	*Erodium malcoides*	Glandular Storksbill	Not Listed
Hyacinthaceae	*Urginea pancration*	Seaside Squill	Rest (MED)
Lamiaceae	*Teucrium fruticans*	Olive-Leaved Germander	Not Listed
Plumbaginaceae	*Limonium melitensis*	Maltese Sea-Lavender	Endemic
Poaceae	*Andropogon distachyus*	Purple Beard-Grass	Not Listed
Poaceae	*Hyparrhenia hirta*	Hispid Beard-Grass	Not Listed
Poaceae	*Piptatherum miliaceum*	Rice-Grass	Not Listed
Polygonaceae	*Rumex conglomeratus*	Clustered Dock	Not Listed
Smilacaceae	*Smilax aspera*	Common Smilax	Not Listed

***Periplocion angustifoliae shrub formation* (legend code 2 on accompanying map)**
This assemblage colonised the land on the western side of the mouth of Wied il-Ħallelin. The structural organisation of the community was consistent with that of a maritime steppe/garrigue and species composition was essentially identical to that recorded from the West Mediterranean clifftop phrygana. The principal distinction between the two assemblages was based on relative abundance of the dominant species rather than on their presence or absence. The assemblage in this part of the area of study was characterised by higher relative abundance of African Wolfbane (*Periploca angustifolia*) than in other parts of the site.

Species recorded from this community included the following:

Family	Species	Vernacular	RDB status
Anacardiaceae	*Pistacia lentiscus*	Lentisk	Not listed
Apiaceae	*Daucus carota*	Wild Carrot	Not Listed
Araceae	*Arisarum vulgare*	Friar's Cowl	Not Listed
Asclepiadaceae	*Periploca angustifolia*	African Wolfbane	Rest (MED)
Asparagaceae	*Asparagus aphyllus*	Spiny Asparagus	Not Listed
Asphodelaceae	*Asphodelus aestivuus*	Branched Asphodel	Not Listed
Asteraceae	*Carlina involucrata*	Carline Thistle	Rest (MED)
Asteraceae	*Chiliadenus bocconei*	Maltese Fleabane	Endemic
Asteraceae	*Cynara cardunculus*	Wild Artichoke	Not Listed
Asteraceae	*Galactities tomentosa*	Boar Thistle	Not Listed
Asteraceae	*Inula crithmoides*	Golden Samphire	Not Listed
Asteraceae	*Palaeocyanus crassifolius*	Maltese Rock Centaury	Endemic, R, Rest (MI)
Asteraceae	*Senecio bicolor*	Silvery Ragwort	Not Listed
Asteraceae	*Sonchus oleraceus*	Smooth Sow Thistle	Not Listed
Brassicaceae	*Lobularia maritima*	Sweet Alyssum	Not Listed
Caryophyllaceae	*Silene colorata*	Red Campion	Not Listed
Chenopodiaceae	*Darniella melitensis*	Maltese Salt-Tree	Endemic
Clusiaceae	*Hypericum aegyptiacum*	Egyptian St. John's Wort	Rest (MED)
Crassulaceae	*Sedum sediforme*	Mediterranean Stonecrop	Not Listed
Ericaceae	*Erica multiflora*	Mediterranean Heath	Not Listed
Euphorbiaceae	*Euphorbia pinea*	Pine Spurge	Not Listed
Fabaceae	*Lotus cytisoides*	Grey Birdsfoot Trefoil	Not Listed
Hyacinthaceae	*Urginea pancration*	Seaside Squill	Rest (MED)
Lamiaceae	*Teucrium fruticans*	Olive-Leaved Germander	Not Listed
Plumbaginaceae	*Limonium melitensis*	Maltese Sea-Lavender	Endemic
Poaceae	*Hyparrhenia hirta*	Hispid Beard-Grass	Not Listed
Poaceae	*Piptatherum miliaceum*	Rice-Grass	Not Listed

Temporary freshwater rockpool on karstland
A single temporary freshwater rockpool was noted from the karstified slopes on the coastal fringe. This pool was colonised by vegetation that is generally characteristic of ephemeral lentic habitats including Maltese Waterwort (*Elatine gussonei*) and filamentous algae (*Zygnema* sp., *Spirogyra* sp.). Conspicuous resident fauna included Fairy Shrimp (*Branchipus schaefferi*).

Figure 1: Maltese Salt-Tree (*Darniella melitensis***) colonising mounds of unconsolidated construction debris.**

Figure 2: Mounds of construction debris colonised by Crown daisy (*Chrysanthemum coronarium***)**

Figure 3: Waste material encroaching on the karstified terrain of the coastal fringe

Figure 4: Maltese Rock Centaury (*Palaeocyanus crassifolius*)
[RDB: endemic; rare with a restricted distribution in the Maltese Islands]

Figure 5: Crystal Plant (*Mesembryanthemum crystallinum*)
[RDB: very rare with a restricted distribution in the Maltese Islands]

Figure 6: Mouth of Wied il-Ħallelin, with vertical sides colonised by rupestral vegetation. Much of the mouth has been infilled by construction debris.

General ecological evaluation and policy context
The ecological significance of the site under investigation has been determined in accordance with the policies of the Structure Plan for the Maltese Islands (Malta Structure Plan 1992a), (Malta Structure Plan 1992b):

1. The presence of freshwater rockpools qualifies the coastal fringe as an Area of Ecological Importance in terms of Structure Plan Policy RCO 10(6).

2. The presence of coastal cliffs qualifies the coastal fringe as an Area of Ecological Importance in terms of Structure Plan Policy RCO 10(8).

3. The presence of Maltese Rock Centaury (*Palaeocyanus crassifolius*) [RDB: endemic; rare with a restricted distribution in the Maltese Islands] qualifies the coastal fringe as a Site of Scientific Importance in terms of Structure Plan Policy RCO 11(2).

4. The presence of Crystal Plant (*Mesembryanthemum crystallinum*) [RDB: very rare with a restricted distribution in the Maltese Islands] qualifies the coastal fringe as a Site of Scientific Importance in terms of Structure Plan Policy RCO 11(2).

5. The following species recorded from the area of study are listed as "Strictly Protected Trees" in terms of Trees and Woodlands (Protection) Regulations, 2001 (Legal Notice 12 of 2001; Schedule I):

Family	**Species**	**Vernacular**	**RDB status**
Asclepiadaceae	*Periploca angustifolia*	African Wolfbane	Rest (MED)
Chenopodiaceae	*Darniella melitensis*	Maltese Salt-Tree	Endemic
Anacardiaceae	*Pistacia lentiscus*	Lentisk	Not listed

6. The rubble walls and rural structures present in the vicinity of the site may be subject to the Rubble Walls and Rural Structures (Conservation and Maintenance) Regulations of 1997 (Legal Notice 160 of 1997).

7. The area surrounding the site of study comprises relatively large fields with fertile soil. The cultivated agricultural land therefore probably qualifies as an Area of Agricultural Value (AAV) in terms of Malta Structure Plan policy RCO 1(1), although it is not within the competence of the present authors to assess agricultural value. If the study area does indeed qualify as an AAV, then Malta Structure Plan policies AHF1 to 13 apply, as well as policies RCO2 and RCO7 to RCO9.

8. The site of study would qualify for rehabilitation in terms of Structure Plan policies RCO 19 and RCO 20.

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A Description of ecological assets in the vicinity of the public solid waste disposal site at Xagħra, Gozo.

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Malta University Services

January 2003

Introduction
The present consultants have been commissioned by Malta University Services, acting on behalf of Scott Wilson Kirkpatrick & Co Ltd, to undertake a broad brush ecological survey of the area around the solid waste disposal site in Xagħra, Gozo. The scope of the survey is to identify and describe ecological assets present in the vicinity of the site.

Methods
This study is based on a site visits made by the authors during December 2002 and is supplemented by material from the literature. Habitats were characterised on the basis of geomorphological features and plant assemblages as outlined in (Schembri 1991). No attempt was made to provide a complete inventory of the flora and fauna present, as this would have entailed extensive fieldwork during different seasons, however, indicator species were searched for and noted. The designation RDB refers to the Red Data Book status (Schembri and Sultana 1989) of species recorded.

Assessment of the plant communities colonising the area of study was carried out through a straightforward census of species in a vegetative stage. The species inventory comprises remarks on community affiliation and Red Data Book status for each species listed. This inventory obviously omitted all species that were not at the vegetative stage of their life cycle. The presence of a number of species that were not vegetative at the time of survey was inferred through observation of fruits and withered aerial parts.

The area under consideration corresponds to portions of four 1:2500 scale survey sheets issued by the Malta Environment and Planning Authority (MEPA). Survey sheets utilised in the present exercise were Sheet No. 3291, Sheet No. 3292, Sheet No. 3491 and Sheet No. 3492. As such the description of ecological assets shall be subdivided into four parts, each part corresponding to a single survey sheet.

Identification of Communities and Assemblages
The term "community", as used in this study has been utilized in the broad sense implied by Barbour et al. (1999). Parts of communities, or habitats of limited spatial extent were classified as "assemblages". The distinction between community and assemblage is subjective, being dependent on the experience and preferences of an observer.

Coding of Grid References
Coordinate systems on the base maps on which field surveys were based conformed to Universal Transverse Mercator grid references. Each base map comprised fifty squares of area 200m by 200m. Ten squares (cumulative length 2 km) oriented in a west-east direction and five squares (cumulative length 1 km) in a North-South direction. In order to facilitate reference, the ten squares in a West-East direction were labelled 1 through 10 while the five squares in a North-South direction were labelled A through E. Individual squares were therefore labelled utilising binomials (A1, A5) which are referred to throughout this report.

SURVEY SHEET 3291

Land-Cover

The land represented in this survey sheet represents the south-western extremity of the area under consideration. Much of the land cover is agricultural in function. Ecological communities are mainly restricted to the southernmost portion of the scarp community at il-Milħa and part of area at il-Qortin ta' Għajn Damma. Sporadic thickets of carob (*Ceratonia siliqua*) associated with development of pseudomaquis were recorded from various parts of the area.

Scarp community at il-Milħa [A10, B10]

The west-facing scree at il-Milħa was colonised by Maltese Salt-tree (*Darniella melitensis*) [RDB: Endemic], Caper (*Capparis orientalis*) and Golden Samphire (*Inula crithmoides*) on steep rock faces. The base of the scree was characterised by a dense assemblage comprising Carob (*Ceratonia siliqua*), Almond (*Prunus dulcis*), Fig (*Ficus carica*), Pomegranate (*Punica granatum*) and Great Reed (*Arundo donax*) [A10].

Derelict agricultural areas at il-Milħa [A10]

Long-derelict agricultural areas characterised by the late-pioneer stages of a xeroseral succession. Principal colonists included Fennel (*Foeniculum vulgare*) and Giant Fennel (*Ferula communis*). Escapes or remnants from cultivation, including Sulla (*Hedysarum coronarium*) were present in localised enclaves. Herbaceous cover was almost total, with Cape Sorrel (*Oxalis pes-caprae*) predominant in terms of abundance. Coverage of topsoil was total. The margins of these areas were colonised by species characteristic of sustained ecological stability, including Golden Samphire (*Inula crithmoides*) and Maltese Salt-Tree (*Darniella melitensis*). Species characteristic of this assemblage included the following:

Family	Species	Vernacular	RDB status
Apiaceae	*Ferula communis*	Giant Fennel	Not Listed
Apiaceae	*Foeniculum vulgare*	Fennel	Not Listed
Apiaceae	*Smyrnium olusatrum*	Alexanders	Not Listed
Asparagaceae	*Asparagus aphyllus*	Spiny Asparagus	Not Listed
Asphodelaceae	*Asphodelus aestivus*	Branched Asphodel	Not Listed
Asteraceae	*Carlina involucrata*	Carline Thistle	Rest (MED)
Asteraceae	*Chrysanthemum coronarium*	Crown Daisy	Not Listed
Asteraceae	*Dittrichia viscosa*	Sticky Fleabane	Not Listed
Asteraceae	*Galactities tomentosa*	Boar Thistle	Not Listed
Asteraceae	*Inula crithmoides*	Golden Samphire	Not Listed
Asteraceae	*Reichardia picroides*	Common Reichardia	Not Listed
Asteraceae	*Senecio bicolor*	Silvery Ragwort	Not Listed
Asteraceae	*Sonchus oleraceus*	Smooth Sow Thistle	Not Listed
Asteraceae	*Urospermum picroides*	Prickly Urospermum	Not Listed
Brassicaceae	*Brassica rapa*	Bargeman's Cabbage	Not Listed
Brassicaceae	*Capparis orientalis*	Caper	Not Listed
Brassicaceae	*Diplotaxis erucoides*	White Mustard	Not Listed
Brassicaceae	*Lobularia maritima*	Sweet Alyssum	Not Listed
Brassicaceae	*Matthiola incana* ssp. *melitensis*	Maltese Stocks	Endemic, R
Cactaceae	*Opuntia ficus-indica*	Prickly Pear	Not Listed
Caesalpinaceae	*Ceratonia siliqua*	Carob	Not Listed

Chenopodiaceae	*Beta maritima*	Sea-Beet	Not Listed
Chenopodiaceae	*Darniella melitensis*	Maltese Salt-Tree	Endemic
Euphorbiaceae	*Euphorbia pinea*	Pine Spurge	Not Listed
Euphorbiaceae	*Mercurialis annua*	Annual Mercury	Not Listed
Fabaceae	*Hedysarum coronarium*	Sulla	Not Listed
Hyacinthaceae	*Urginea pancration*	Seaside Squill	Rest (MED)
Lamiaceae	*Teucrium fruticans*	Olive-Leaved Germander	Not Listed
Lamiaceae	*Thymbra capitata*	Mediterranean Thyme	GN 85 (1932)

Garrigue-steppe at Qortin Ta’ Għajn Damma [A10]

The land at il-Qortin ta’ Għajn Damma and the adacent scree were colonised by communities with structure consistent with steppe/garrigue. Dominant plants included Sea Squill (*Urginea pancration*) [RDB: Restricted distribution in the Mediterranean], Pitch Clover (*Psoralea bituminosa*), Branched Asphodel (*Asphodelus aestivus*), Mediterranean Thyme (Thymbra capitata), Olive-leaved Germander (*Teucrium fruticans*), Spiny Asparagus (*Asparagus aphyllus*), Caper (*Capparis orientalis*), Tree Spurge (*Euphorbia dendroides*), Mediterranean Heath (*Erica multiflora*) and Carob (*Ceratonia siliqua*). The garrigue at Għajn Damma is important in terms of conservation potential, and efforts should be made to afford adequate protection to this site.

SURVEY SHEET 3292

Land-Cover

The land represented in this survey sheet represents the north-western portion of the area under consideration. Much of the western portion is taken up by derelict agricultural areas whilst the eastern portion comprises the steppe/garrigue community at il-Qortin. The coastal margin is characterised by a clay-based steppe.

Slope communities at Irdum ta' Kililu [C9, C10, D10, E10]

The steep coastal slopes at Irdum Ta' Kililu were colonised by Maltese Salt-Tree (*Darniella melitensis*) [RDB: Endemic] and Golden Samphire (*Inula crithmoides*). The hillside above the Globigerina was colonised by Wild Artichoke (*Cynara cardunculus*) and Golden Samphire (*Inula crithmoides*). Thickets of Tamarisk (*Tamarix africana*) [RDB: Rare with a restricted distribution in the Maltese Islands and the Mediterranean] were recorded [D10].

Derelcit agricultural areas at il-Mielħa [C9, C10, D9, D10, E9, E10]

The slopes at Il-Mielħa are contiguous with the derelict agricultural areas described for Sheet 3291. Herbaceous cover was total and dominated by Cape Sorrel (*Oxalis pes-caprae*), together with Wild Artichoke (*Cynara cardunculus*), Field Bindweed (*Convolvulus arvensis*), Sulla (*Hedysarum coronarium*), Boar Thistle (*Galactites tomentosa*), Smooth Sow-thistle (*Sonchus oleraceus*), White Mustard (*Diplotaxis erucoides*), Sticky Fleabane (*Dittrichia viscosa*), French Daffodil (*Narcissus tazetta*) and Friar's Cowl (*Arisarum vulgare*). Solitary Tamarisk (*Tamarix africana*) [RDB: Rare with a restricted distribution in the Maltese Islands and the Mediterranean] also occur [E9]. Remnants of cultivated plots, with small stands of Prickly Pear (*Opuntia ficus-indica*), Almond (*Prunus dulcis*) and Fig trees (*Ficus carica*), still occur on the hillside together with Eucalyptus introduced as an attractant for bird-shooting [D9].

Steppe/Garrigue community at il-Qortin ta' Għajn Damma [D10, E10]

This community was generally dominated by an edaphic disclimax of mixed garrigue and steppe character. Enclaves of opportunistic vegetation typical of disturbed ground were superimposed on this community. Such a community results from the interaction of a number of factors. The site would have originally have been colonised by primary maritime garigue dominated by halophytes. This community has been subject to degradation as a consequence of the proximity of the waste disposal site and due to encroachment, resulting in the appearance of steppic character. Regions where disturbance is more severe were characterised by fast-growing opportunists tolerant to such conditions. Dominant plants recorded from this community included Sea Squill (*Urginea pancrationl*), Shrubby Kidney Vetch (*Anthyllis hermanniae*), Olive-leaved Germander (*Teucrium fruticans*) and Mediterranean Thyme (*Thymbra capitata*). The surrounding scarp and boulder scree were colonised by Caper (*Capparis orientalis*), Maltese Salt-Tree (*Darniella melitensis*) [RDB: Endemic], Golden Samphire (*Inula crithmoides*), Mediterranean Thyme (*Thymbra capitata*), Olive-leaved Germander (*Teucrium fruticans*), Branched Asphodel (*Asphodelus aestivuus*), Sea Squill (*Urginea pancration*), [RDB: Restricted distribution in the Mediterranean] and Giant Fennel (*Ferula communis*).

SURVEY SHEET 3491

Land-Cover

The land represented in this survey sheet represents the eastern and north-eastern portions of the area under consideration. Land-cover was dominated by accumulations of solid waste in the north-western sector and a steppe community on a Blue Clay substratum in the north-eastern sector. Much of the remaining area was agricultural in function.

Wied il-Pergla [B2, B3, C2, C3, D2, D3]

Much of the area flanking the bed of Wied il-Pergla is under active cultivation. The valley-bed, parts of the valley sides and part of the valley mouth are colonised by Great Reed (*Arundo donax*) [B2; C2; C3]. The base of the western valley escarpment, which comprises a quasi-vertical rock-face, is colonised by Mediterranean Thyme (*Thymbra capitata*), White Hedge-nettle (*Prasium majus*), Olive-leaved Germander (*Teucrium fruticans*), Branched Asphodel (*Asphodelus aestivuus*), Alexanders (*Smyrnium olusatrum*), Bear's Breeches (*Acanthus mollis*) and Italian Lords-and-Ladies (*Arum italicum*) [B2; C2; D2]. The eastern banks are are coplonised by thickets dominated by Carob (*Ceratonia siliqua*) and comprising Almond (*Prunus dulcis*), Prickly Pear (*Opuntia ficus-indica*), Giant Fennel (*Ferula communis*) with undergrowth dominated by Spiny Asparagus (*Asparagus aphyllus*). [B1, B2, C1, C2, C3; D3;]. The mouth of Wied il-Pergla, was colonised by Great Reed (*Arundo donax*) [B3]. More open parts of the area were colonised by with Golden Samphire (*Inula crithmoides*) [A3, B3] and Chaste Tree (*Vitex agnus-castus*) [RDB: R, Rest(MI)].

Steppe communities at Għajn Barrani [A2, A3, B2, B3]

This community was established on a clay substrate. Herbaceous cover was almost total and dominated by Cape Sorrel (*Oxalis pes-caprae*) interspersed with Wild Artichoke (*Cynara cardunculus*), Clustered Carline-thistle (*Carlina involucrata*), Boar Thistle (*Galactites tomentosa*) and French Daffodil (*Narcissus tazetta*). A number of Tamarisk (*Tamarix africana*) were noted from Sectors A2 and A3 whilst the south-eastern extremity of this community comprised Chaste Tree (*Vitex agnus-castus*) [RDB: R, Rest(MI)] [B3].

Communities of disturbed ground [A1, A2, B1]

The area enclosed by the boundary of the solid waste disposal site was colonised by a plant community comprising species tolerant to severe and frequent disturbance. Vegetation in this part of the site was confined to the borders of the most frequently used dumping areas and to the margins of footpaths. Species present at the time of survey included Crown Daisy (*Chrysanthemum coronarium*), Cape Sorrel (*Oxalis pes-caprae*), Sweet Alyssum (*Lobularia maritima*) and Tree Mallow (*Lavatera arborea*).

SURVEY SHEET 3492

Land-Cover
The land represented in this survey sheet represents the north-eastern portion of the area under consideration. Land-cover was dominated by accumulations of solid waste in the south-western sector and a steppe community along the margins of the waste disposal site.

Steppe/garrigue at il-Qortin ta Għajn Damma [D1]
The portion of the plateau that has not bee covered by waste material is colonised by a community of mixed character. The parts of the community bordering the waste accumulations are characterised by a grade of development consistent with steppe communities whilst further away from the site the community grades into a structure characteristic of garrigue. The steppic elements include species characteristic of areas that have may regressed from garrigue or progressed from an episode of disturbance. Several species recorded from this community are indicative of recent ecological stability including Sea Squill (*Urginea pancration*) [RDB: Restricted distribution in the Mediterranean], Branched Asphodel (*Asphodelus aestivuus*), Pine Spurge (*Euphorbia pinea*) and Crown Daisy (*Chrysanthemum coronarium*) [D1]. The garrigue component is indicated by Shrubby Kidney Vetch (*Anthyllis hermanniae*) and Mediterranean Thyme (*Thymbra capitata*).

Rupestral assemblages [D1]
Vertical scarp faces (D1) were mainly colonised by Caper (*Capparis orientalis*) and Maltese Salt-Tree (*Darniella melitensis*) [RDB: Endemic], forming a community indicative of sustained ecological stability.

Steppe community on clay substrate [C1, C2, D1, D2]
The clay slopes were colonised by herbaceous cover comprising Cape Sorrel (*Oxalis pes-caprae*) within which were interspersed localised populations of Great Reed (*Arundo donax*), Shrubby Orache (*Atriplex halimus*) and Tamarisk (*Tamarix africana*) [RDB: Rare with restricted distribution in the Mediterranean and the Maltese Islands]. Isolated clumps of Maltese Salt-Tree (*Darniella melitensis*) [RDB: Endemic] and Hawthorn (*Crataegeus ?monogyna*) were also recorded.

Shoreline vegetation [B1, C1, C2, D2]
The vegetation along the shoreline comprised Tamarisk (*Tamarix africana*) [RDB: Rare with restricted distribution in the Mediterranean and the Maltese Islands], Golden Samphire (*Inula crithmoides*) and Chaste Tree (*Vitex agnus-castus*) [RDB: Rare with restricted distribution in the Maltese Islands]. The Chaste Tree forms a fairly extensive stand close to the shoreline.

Additional Notes from literature
Numerous small springs, including the one known as Għajn Damma originate from the scarplines in this area [E1]. A small colony of the Levantine Shearwater (*Puffinus yelkouan*) [RDB: Vulnerable with restricted distribution in the Mediterranean] is found here. The last colony of the Jackdaw (*Corvus monedula*) in the Maltese Islands was breeding here. The Barn Owl (*Tyto alba*) [RDB: Endangered] also used to breed here.

Figure 1: Derelict agricultural land at il-Mielħa

Figure 2: Secondary succession on derelict agricultural land at il-Mielħa

Figure 3: steppe community on steep clay slopes in the northern sector of the area of study. Herbaceous cover consists of Cape Sorrel (*Oxalis pes-caprae*).

Figure 4: Stands of Chaste Tree (*Vitex agnus-castus*) in the are of study.

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