The approach to treatment of the unsaturated zone will depend on:

- The presence (or absence) of elevated concentrations of PAHs (above the NEPM HIL F guideline) in soils;
- The results of the proposed quantitative risk assessment (to derive soil guidelines for TPH and BTEX compounds) – that is, whether the concentrations in soil exceed the risk – based guidelines; and
- Determination of the NSW EPA regarding the SRoH, which the site may, or may not pose (this is likely to be primarily related to unacceptable off site groundwater impacts - impact to groundwater will be derived from impacted soil, and therefore, remediation of soils may be driven by the required groundwater remediation end points).

Based on the nature of the soil impacts, and assuming that some form of soil remediation may be required (to meet the yet to be determined remediation end points), the remediation technology considered most appropriate for impacted soils within the unsaturated zone is soil vapour extraction.

A soil vapour extraction system installed at the site may have a relatively large radius of influence (and therefore be efficient with respect to capital and operating costs) due to:

- The (possible) favourable air permeabilities within the impacted unsaturated zone (based on the interpreted geology); and
- The presence of an overlying clay layer and surface seal of concrete, which will aid in concentrating air flow within the impacted zone.

However, the geology encountered across the site suggests that the soil permeabilities within the unsaturated (and saturated) zones are likely to vary. Consequently, soil vapour extraction pilot testing within the various soil types would be required to determine the applicability of this technology to all or portions of the site.

Soil vapour extraction may also be coupled with a pump and treat groundwater system (unsaturated zone treatment), to promote remediation of aquifer soils exposed within the cone(s) of depression during groundwater abstraction.

Remediation by soil vapour extraction would not result in large scale interruption of site operations (which would occur using excavation as the preferred remedial approach). Soil vapour extraction is also likely to remediate the impacted soils more quickly than bioventing or natural attenuation processes, and therefore:

- Form a more effective transport control mechanism to prevent phase transfer of impacts from the adsorbed to dissolved phase; and
- More effectively reduce ongoing impacts to groundwater.

Bioventing was ranked equal first with soil vapour extraction using the Remediation Technology Review Matrix. However, due to the additional benefits provided by soil vapour extraction (volatilsation) when compared with bio-venting, soil vapour extraction is selected as the preferred approach. The next preferred approach is excavation.

3.5.2 Saturated Zone Treatment

Remediation options for the saturated zone treatment comprise:

- Passive Skimming – passive skimming is employed for the recovery of PSH. Rates of PSH recovery are dependent on intrinsic permeability of the formation, groundwater gradients, the number of passive skimmers employed and the frequency at which the skimmers are emptied;
- Active Skimming - active skimming is employed for the recovery of PSH. Active skimmers are powered using compressed air. As with passive skimming, rates of PSH recovery are dependent on intrinsic permeability of the formation, groundwater gradients and the number of skimmers employed. However, active skimmers automatically and continuously (while PSH is present) transfer the recovered PSH into storage containers. Therefore, active skimming potentially requires less maintenance, while recovering greater volumes of PSH when compared with passive skimming;
- Pump and Treat (Single or Multiple Bore Extraction) – pump and treat technologies through groundwater abstraction from recovery wells may be employed to recover both PSH and groundwater (total fluids pumping), or exclusively groundwater. Application of a (bore extraction) pump and treat approach may:
  - Remove PSH and dissolved phase impacts in groundwater;
  - Restrict/reduce continued migration of the dissolved phase impacts off the site; and
  - If required, de-water the aquifer sufficiently to allow soil vapour extraction to be conducted (to address adsorbed phase impacts currently located within the saturated zone.

  Prior to implementation of this technology, a series of pumping tests would be required to assess the aquifer properties and to enable selection of the most suitable recovery well option (locations, pumping rates, etc)
- Pump and Treat (Interception Trench) – interception trenches are typically used in shallow groundwater environments, where active recovery (groundwater abstraction) of PSH and/or dissolved phase impacts via bores is not considered viable/efficient. Trenches are typically employed in low-flow environments to enhance groundwater recovery rates (by exposing large areas of the aquifer). Trenches are (generally) not applied in deeper groundwater environments, particularly those within sandy soil conditions, as considerable shoring (support) works would be required to facilitate their construction and installation;
- Multiphase Extraction – multiphase extraction uses a high vacuum system to recover PSH and dissolved phase impacts, while also extracting vapours and therefore promoting remediation of adsorbed phase hydrocarbon impacts. Multiphase extraction can be conducted through the use of a

vacuum truck or a permanent vacuum well system. Success of multiphase extraction is dependent on favourable aquifer permeabilities, and amenability of the adsorbed phase impacts to soil vapour extraction techniques (see above section on soil vapour extraction). Implementation of a permanent vacuum well system would require a trial to assess the suitability of this technology to the site specific conditions. Results of the trial are also required to enable a detailed design of the system, including the numbers of extraction wells required, and the depth, construction and spacing of the wells;

- Bio-sparging – bio-sparging is used to promote remediation of dissolved phase and adsorbed phase hydrocarbon impacts (particularly those within the saturated zone) through the introduction of air (or pure oxygen) using an air compressor. Successful application of this approach relies on favourable vertical and lateral hydraulic conductivies and the amenability of the contaminant to biodegradation. Inappropriate application can result in the spreading of contamination and generation of vapour phase impacts. Rates of remediation are dependent on contaminant biodegradation rates;

- Air Sparge with SVE – air sparging with soil vapour extraction is used to promote remediation of dissolved phase and adsorbed phase hydrocarbon impacts (within the saturated and unsaturated zone), and more rarely, PSH. Air sparging comprises introduction of air (or pure oxygen) using an air compressor. The introduced air promotes bioremediation, while also stripping volatile components of hydrocarbon impacts from the adsorbed and dissolved phases, and PSH. Stripped volatiles (present as a vapour phase) are collected by the soil vapour extraction system. Success of air sparging with soil vapour extraction is dependent on favourable permeabilities (within the saturated and unsaturated zones), and the amenability of the contaminants to biodegradation and volatilisation. Typically, implementation of an air sparging system would require a series of aquifer and sparge tests;

- Reactive Barrier Wall – a reactive barrier system comprises passive treatment of impacted groundwater as it passes through a medium engineered to remediate the relevant contaminants of concern. The system will not address soil impacts within the saturated zone. Such systems require extensive pilot trials and post installation monitoring to ensure breakthrough of contamination does not occur. Reactive barrier systems are typically installed in shallow, low flow environments;

- Containment – containment comprises construction of barrier system which prevents movement of impacted groundwater (beyond the area identified as requiring containment). Such systems would require construction of cement-bentonite slurry walls (or the like) from the surface to a lower confining layer of the contaminated aquifer. Post installation monitoring would be required to ensure leakage from the containment area was not occurring; and

- Natural and/or Enhanced Attenuation –using natural biodegradation (aerobic and anaerobic) to remediate dissolved and adsorbed phase impacts with or without hydraulic control, depending on regulatory requirements and nearby sensitive receptors. This is unlikely to occur where contaminants are at levels which are toxic to bacteria. Process may be enhanced through the addition of nutrients and oxygen to improve biological activity. Naturally occurring bacteria are stimulated to consume hydrocarbons through the introduction of inorganic nutrients (nitrogen and phosphorous) and oxygen into the groundwater. Oxygen supply to the groundwater is the most important aspect of the system.

Degradation of hydrocarbons usually requires approximately three kilograms of oxygen per one kilogram of hydrocarbon. Oxygen can be supplied using air sparging, addition of hydrogen peroxide slurry, or other oxygen- releasing agents such as calcium or magnesium peroxide slurry. Nutrient and oxygen agents can be added to the sub-surface using well points or infiltration sumps or galleries, or even pressure injected across a grid covering the treatment zone. Alternatively, oxidation agents can be added directly to open excavations. The effectiveness of this approach is dependent on the amenability of the contaminant to bio-degradation, and the rates of biodegradation.

PSH Impacts

PSH was detected in monitoring wells LMW1, LMW2 and LMW4. Baildown tests indicate varying rates of recovery of PSH are possible. The remediation technology considered most appropriate for PSH removal is pump and treat (bore extraction).

Pump and treat (total fluids pumping) is the approach most likely to (rapidly) remove PSH, since it will create a localised cone of depression, encouraging movement of PSH towards the extraction well. Creation of a localised cone of depression will also aid in preventing continued off site migration of impacted groundwater.

A total fluids pumping system would be pneumatically driven by a compressor. The extracted fluids (water and PSH) would be separated prior to treatment and/or disposal.

The PSH remediation approaches ranked 2 and 3 using the Remediation Technology Review Matrix is active skimming and passive skimming, respectively. Active and passive skimming will not co-produce impacted groundwater. However, due to the shallow groundwater gradient present at the site, this approach is unlikely to rapidly remove PSH, since flow of PSH into the recovery wells will be governed by the prevailing groundwater flow conditions (velocities). Furthermore, active and passive skimming are unlikely to effectively capture the PSH plume.

Dissolved and Adsorbed Phase

Elevated concentrations of TPH and BTEX compounds were detected in soil (within the saturated zone) and groundwater in the vicinity of the USTs. Elevated concentrations of C_{10}-C_{36} TPH and PAHs were also detected in groundwater at LMW13. The composition of the TPH impact in groundwater at LMW13 is different to that found near the USTs, indicating a possible second (separate source) of impact.

The elevated concentration of adsorbed phase hydrocarbon impacts within the saturated zone will act as a continuing source of groundwater impact. Therefore, if required, remediation of the saturated zone should address both the dissolved and adsorbed phases of impact.

Recovery tests indicate that the average hydraulic conductivity at the site is approximately 0.48 m/day. Such conductivities are generally conducive to the implementation of air sparging. Air sparging acts by:

- Stripping hydrocarbons from both the adsorbed and dissolved phase; and

- Providing naturally occurring bacteria within the impacted zone with oxygen, promoting bioremediation (also known as bio-sparging) of dissolved and adsorbed phase.

However, since the conductivity values range by almost two orders of magnitude, there may be some areas of the site (where conductivites are low) in which air sparging may not be successful. Alternative schemes to air sparging comprise:

- Pump and treat combined with soil vapour extraction (to address adsorbed phase impacts within the aquifer exposed by groundwater depression during pumping); or
- Multiphase extraction.

However, similar to air sparging, the effectiveness of the soil vapour extraction components of both of the above alternatives is limited in areas of low permeabilities. As discussed in Section 3.5.2, trials tests are required to assess the applicability of these technologies to all, or portions of the site.

Ultimately, the requirement to address the dissolved and adsorbed phase impacts within the saturated zone will depend on the potential risks posed by the remaining impacts (following removal of the PSH), as determined by a quantitative risk assessment, and/or the NSW EPA.

The saturated zone remediation approaches ranked 1, 2 and 3 using the Remediation Technology Review Matrix are:

1) Air sparging;
2) Multi-phase extraction and bio-sparging (equal second); and
3) Pump and Treat – bore extraction.

3.6 Net Present Value Analysis

3.6.1 General

Tables 4 to 6 present a Net Present Value Analyses for the three strategies considered most applicable (based on the rankings derived from the Remediation Technology Review Matrix) to each remediation goal. As detailed in Section 3.3, the remediation goals are:

- Remove all primary sources of potential impact;
- Remove PSH;
- Remediate sub-surface impacted soil to a standard suitable for ongoing commercial/industrial land use;

- Remediate dissolved phase impact to groundwater such that it does not pose an unacceptable risk to human health or the environment (as defined through a quantitative risk assessment or the NSW EPA's SRoH determination);
- Implement a groundwater monitoring program to measure the effectiveness of the remediation activities. The program should be designed to demonstrate that the remediation activities have effectively removed the potential risks which the impacts may pose, based on the achievement of risk based or NSW EPA determined criteria; and
- Demonstrate that the potential impacts from the residual hydrocarbons (following remediation) are suitably limited and appropriate based on the site and surrounding land uses, contaminant concentrations, retardation rates and exposure pathways.

The Remediation Technology Review Matrix provides options for assessment of technologies to address the unsaturated and saturated zones. However, the remediation goal covering remediation of sub-surface impacted soils, involves both the saturated and unsaturated zones. Consequently, the Net Present Value Analysis for remediation of sub-surface impacted soils is divided into:

- Impacted soils within the unsaturated zone; and
- Impacted soils within the saturated zone.

Since the remediation strategies to address impacted soils within the saturated zone are also aimed at remediating dissolved phase groundwater impact, the remediation goals for these media are combined for the purposes of the Net Present Value Analysis.

It is important to note that the Net Present Value Analysis costs are broad estimates and are not intended to be used as precise remediation cost estimates. Rather, the annual costs and net present value estimates have been prepared to compare the projected remediation costs and provide a basis for selection of the preferred remediation strategy.

3.6.2 Primary Sources of Impact

As detailed in Section 3.5, the only practical means available to remove primary sources of impact is to assess all existing potential primary sources, and remove/repair or abandon those found to be contributing to impact at the site. Therefore, a Remediation Technology Review Matrix and Net Present Value Analysis have not been completed for this remediation goal.

3.6.3 Remove PSH

The Net Present Value Analysis (Table 4) indicates that passive skimming is the preferred approach for the removal of PSH at the site. However, as indicted in Table 4, passive (and active) skimming is likely to take far longer to remove the PSH than total fluids pumping. Since PSH forms an ongoing source for dissolved and adsorbed phase impacts, URS recommends total fluids pumping as the preferred remediation approach. Total fluids pumping will also contribute to remove some of the impacted (dissolved phase) groundwater from under the site while in operation, and help to control the continued migration of PSH. It may also facilitate soil vapour extraction of impacted soils within the cone of depression created by the total fluids pumping.

3.6.4 Remediation of Sub-Surface Soil – Unsaturated Zone

The Net Present Value Analysis (see Table 5) indicates that soil vapour extraction is the preferred approach for the removal of adsorbed phase impacts at the site. Soil vapour extraction is likely to achieve the remediation goal quicker than bio-venting, and is likely to be less expensive than excavation (based on the indicative depths required to remove impacted soils). As discussed in Section 3.6.5 (below), soil vapour extraction could also form part of the selected remediation strategy for the adsorbed phase in the saturated zone and dissolved phase hydrocarbon impact. Remediation of the unsaturated zone will be driven by the proposed quantitative risk assessment and/or the NSW EPA.

3.6.5 Remediation of Sub-Surface Soil (Saturated Zone) and Dissolved Phase Groundwater

As previously discussed, remediation of the saturated zone (adsorbed and dissolved phase impacts) will be driven by the results of the proposed additional investigations (to delineate the extent of on site and off site soil and groundwater impacts), quantitative risk assessment, and/or by the NSW EPA's assessment of whether the site poses a SRoH.

The Net Present Value Analysis (see Table 6) indicates that air sparging with soil vapour extraction is the preferred approach for the remediation of adsorbed and dissolved phase impacts at the site. Air sparging with soil vapour extraction is likely to more rapidly achieve the remediation goals than either bio-sparging or multi-phase extraction, while:

- Generating less waste streams than multi-phase extraction; and
- Minimising the potential for migration of vapour phase impacts into site buildings or under adjacent properties, as may occur with bio-sparging (which does not have a soil vapour extraction component to the remediation system).

However, as previously discussed, air sparging may not be suitable for all areas of the site, based on the large variation in hydraulic conductivities across the site. Consequently, a mixed approach, which may employ both air sparging and other alternative remedial options (such as multi-phase extraction or pump and treat) may be required. It is noted that air sparging can cause the lateral spreading of impacted groundwater. Consequently, should air sparging be proposed near to a site boundary, an accompanying form of plume control (pump and treat) may be required.

Final selection of the preferred remediation system will be driven by:

- The results of the proposed additional investigations (further on and off site assessments and a site specific quantitative risk assessment);
- NSW EPA's determination of the site with respect to SRoH issues; and
- Pilot test results.

3.6.6 Groundwater Monitoring Program

A groundwater monitoring event will be conducted immediately prior to the commissioning of the selected remedial system. Following commissioning of the system, quarterly groundwater monitoring events will be conducted to assess the effects, efficacy and progress of remediation works. Quarterly groundwater monitoring events will continue following decommissioning of the system. Hydrocarbon impacts will be considered to have been removed from the dissolved phase when groundwater samples collected from three consecutive (quarterly) groundwater monitoring events meet the remediation end points. Groundwater samples will be collected from all on site and off site monitoring wells.

4.1 Introduction

This section describes the processes involved in the remediation of the site using the approaches detailed in Section 3. Section 4.2 details the general approach to site remediation, while Section 4.3 describes the staging of the remediation program.

4.2 Remediation Preparation

4.2.1 Pilot Studies

The favoured approaches to remediation of the site (comprising total fluids pumping, soil vapour extraction and air sparging) were selected based on:

- Handex description of the site geology;
- Hydrogeological data (hydraulic conductivities);
- Distribution and nature of impacts to soil and groundwater; and
- Probability and efficiency of the approach meeting the remediation goals and end points.

However, to quantify the potential effectiveness of the selected approach, pilot studies are required. These pilot tests will comprise:

- Trials of total fluids pumping for the recovery of PSH; and
- Pilot soil vapour extraction, aquifer pumping and air sparing tests in areas of site identified as having differing geology and hydraulic conductivities.

The results of the pilot tests will be used to design the remediation system(s) required to remove the PSH and, if required, address impacts within the saturated and unsaturated zone.

4.2.2 Council Notification/Approval for Remediation Works

Local council approval may be required for the remediation works. A trade waste agreement from Sydney Water might also be required, should the remediation approach require the disposal of recovered groundwater (after treatment) to sewer.

4.2.3 Environmental Management Plan

The EMP will provide guidance on the following issues associated with the remediation works:

- Environmental – management and monitoring of soil, groundwater, noise, odour and dust generated during the installation and operation of the remediation system;
- Waste management – management of waste materials generated during the installation and operation of the system. This may include impacted soil and groundwater, PSH and spent activated carbon (if required);
- Contingency Planning – approach to encountering unexpected conditions which might occur during remediation;
- Hours of Operation – definition of the hours of operation, as stipulated by Council in its approvals for the remediation works;
- Health and Safety – required personal protective equipment, safe work protocols; and
- Emergency Procedures – protocols in case of failure of the system which may cause harm to human health and the environment. Contact numbers for Mobil, URS and emergency service will also be made available to all personnel.

The EMP will be prepared by an appropriately qualified environmental consultant.

4.2.4 Operation and Maintenance Manual

An operation and maintenance manual will be developed for the selected remediation system to outline:

- Monitoring and maintenance requirements (eg recording of vapour concentrations, vapour pressure, air pressure and servicing of site equipment, water effluent sampling);
- Required frequency of monitoring;
- Emergency and Mobil GRA contact numbers;
- Shutdown procedures (on site and remote); and
- Personal protective equipment requirements.

4.2.5 Site Works

Preparatory remediation works conducted at the site will comprise:

- Implementation of the sections the EMP relevant to installation of the remediation system;
- Conducting pilot studies (as detailed in Section 4.2.1);
- Training of site personnel in emergency procedures; and

- Installation of the remediation system, which may include drilling, monitoring well installation, trenching and connection of air compressors and blowers to the nominated sparge and soil vapour extraction points and PSH recovery wells.

4.2.6 Health & Safety Management

All work conducted at the site as part of the remediation process shall comply at a minimum with:

- ExxonMobil Module 1- General Requirements for Health and Safety Management;
- Requirements of the appropriate regulatory authorities; and
- Site specific health and safety plan (HASP) prepared as part of the EMP.

4.3 Remediation Works

In accordance with the requirements of the NSW EPA, remediation works will be staged to meet the project objectives. This staging will comprise:

- Stage 1 – removal of primary sources of impact and PSH;
- Stage 2 – delineation of site impacts, quantitative risk assessment and development of a remedial strategy for impacts which the risk assessment and/or the NSW EPA determine to pose an unacceptable risk to human health or the environment.

The following sections describe the process of the remediation works.

4.3.1 Stage 1

UST, Fuel Line, Dispenser and Interceptor Testing

One of the remediation goals for the site is to remove all primary sources of impact. To determine whether primary sources exist, all USTs, associated fuel and vent lines, fuel dispensers and interceptors will be tested and/or inspected. Should these tests/inspections indicate that a primary source(s) exists, it should be removed or repaired in accordance with the source control approach developed in this report. Supervision and documentation of the removal of USTs, fuel and vent lines, dispensers and interceptors (if required) will be conducted in accordance with the Mobil *Environmental Site Assessment Specification Module 4 – Tank Excavation Assessments*. This includes:

- Inspection of the USTs and fuel lines on removal for rusting, breaches in integrity or evidence of repairs;

- Notation of methodologies employed by contractor in the purging and removal of the tanks (and subsequent impacted soil excavation).

Soil Excavation

Soil which is excavated during the removal of a primary source of hydrocarbon impact (if required) will be sampled to assess the suitability of the material for reuse on site (based on a comparison of the analytical data with the remediation end points). Should the material be unsuitable for on site reuse, it will be either treated on site prior to reuse (on site), or disposed of to an appropriately licenced landfill facility.

Back Filling/Reinstatement

Material will be imported to the site to replace that disposed of off site (if required). The imported back fill material will be selected on the basis of:

- Conformance to the remediation end points;
- Geotechnical suitability; and
- Cost.

The imported fill will be placed and compacted to an appropriate level of compaction.

PSH Removal

Following removal of potential primary sources of impact, the PSH will be removed from site. The pilot studies will aim to establish the best location and method for the recovery of the PSH. Methods to be trialled may include total fluids pumping and groundwater pumping combined with active product skimming.

4.3.2 Stage 2

Delineation of Site Impacts

To delineate the extent of the identified site impacts and to determine the potential for this impact to extend off site, an additional assessment of soil and groundwater conditions on site and to the east and south of the site will be conducted. This assessment will comprise installation of an additional nine groundwater monitoring wells; four on site and five off site (see Figure 3). Soil and groundwater samples will be collected for analysis from each location for the site contaminants of concern (TPH, BTEX and PAHs). This work may be undertaken before or concurrently with the Stage 1 works.

Risk Assessment and NSW EPA Determination

Following completion of the additional assessment works, a quantitative risk assessment will be conducted to determine the potential risks which the soil and groundwater impacts under and beyond the site (if any) pose to the human health and the environment. The quantitative risk assessment will also be used to determine remediation criteria for the site chemicals of concern for which there are no relevant criteria endorsed by the NSW EPA.

The results of the additional investigations and quantitative risk assessment will be provided to the NSW EPA for review. The results of the investigation and risk assessment, and the judgement by the NSW EPA on the level of the risk posed by the identified on site and offsite impacts, will determine whether remediation of the residual dissolved and adsorbed phase impacts is required.

Implementation of Remediation System for Residual Impacts

Should the additional investigation, quantitative risk assessment and NSW EPA determine that remediation of the residual impacts is required, the process described in Section 4.2 will be followed to determine and implement the most appropriate remediation system, and ensure that the system is appropriately managed.

4.3.3 Stage 1 and Stage 2 - Remediation System Monitoring and Maintenance

The remedial approaches selected to remove the PSH and address the dissolved and adsorbed phase impacts (if required) will be regularly monitored to ensure:

- The system is working efficiently,
- The system is not causing a spread in the contaminant plumes; and
- The system is not adversely impacting on the surrounding environmental quality and amendity (noise, air and water).

Data will be collected during monitoring visit to:

- Determine the progress of remedial works;
- Estimate the hydrocarbon mass removal; and
- Improve system operation to maximise efficiencies.

4.3.4 Stage 1 and Post Stage 2 - Environmental Monitoring

Noise

The remediation system will be fitted with appropriate mufflers and be housed within a shed to minimise the amount of noise generated. Should the noise levels produced by the system be considered unacceptable, an upgrade of the system (insulation, installation of additional mufflers) will be made.

Odour

Assessment of odours around the site boundaries will be made during each monitoring visit. A description of the source, intensity and type of odour (if present) will be recorded in the field notebook. Should the odour levels be considered offensive, measures will be implemented to suppress the odours to acceptable levels.

Vapours

The connection points, valves and an air emissions effluent stack (if required) will be monitored for VOCs to determine any leaks in the system and whether breakthrough has occurred in off gas treatment (if required).

4.3.5 Trigger Levels and Responses

In order to mitigate the potential for adverse impacts associated with the remediation works, action levels and associated responses have been developed and are listed in the table below.

Action Level	Associated Response
Elevated vapour concentrations in utility pits	Stop system and reassess system influence and vapour migration – upgrade or alter system operation as required.
Elevated vapour concentrations in effluent stack (if soil vapour extraction involved)	Stop system, replace activated carbon and reassess estimates for breakthrough time.
Leaks in system releasing elevated vapour concentrations	Stop system and repair leakage.
Spreading of dissolved phase plume	Stop system and reassess operation and areas of influence.
System generating excess noise	Stop system and upgrade muffler and insulation.
Vapour concentrations in soil vapour extraction wells low (if operated)	Stop system for period of days, then restart and assess vapour concentrations. If elevated concentrations do not return, consider decommission system (if validation likely to be achieved) or alter sparge and soil vapour extraction schedule.

4.3.6 PSH Remediation Implementation Schedule

URS understand that Mobil wish to commence PSH removal works as soon as possible. On this basis, the following implementation schedule is proposed:

Activity	Implementation Date
Pilot testing	August 2003
System design, drafting of EMP and system monitoring and maintenance manual	September 2003
Equipment procurement and system installation	September – October, 2003
Pre-commissioning groundwater monitoring event	October 2003
System Commissioning	November 2003

Following removal of the PSH plume, a post remediation groundwater sampling round will be conducted in tandem with the additional investigation works. The results of the groundwater sampling and additional investigations will be incorporated into the quantitative risk assessment. The groundwater sampling, additional investigation and risk assessment results will be provided to the NSW EPA for review. The results of these investigations and NSW EPA's judgement of the risk posed by the site will determine whether remediation of the residual adsorbed and dissolved phase impacts is required.

Validation

SECTION 5

5.1 Introduction

Validation is required to ensure that remediation has achieved the objectives of the RAP (by meeting the remediation goals and end points).

5.2 Primary Sources

Validation that the primary sources of hydrocarbon impact will comprise the site fuel storage infrastructure (USTs, fuel and vent lines, dispensers and interceptors) passing the relevant integrity tests and/or inspections.

5.3 PSH

PSH recovery will continue until such a time as there is an asymptotic recovery, or until the PSH thickness reduces to less than 5 mm in each affected well over three consecutive groundwater monitoring events.

5.4 Soil

5.4.1 General

Soil validation will comprise an analytical assessment of the following:

- Material used to back fill excavations (if conducted); and
- Soils within the previously identified impacted areas, and across the site area in general.

Validation will comprise collection of soil samples for analysis for the chemicals of concern.

5.4.2 Imported Fill

Fill imported to the site will require validation before being used to back fill validated excavations. Where virgin excavated natural materials (VENM) are imported to site, validation samples will be collected at a rate of one sample per 1 000 m^3 of material. Material that is not classifiable as VENM will be sampled at the rate of 1 sample per 100 m^3 of material.

Field duplicate samples will be collected for intra-laboratory analysis at the rate of one duplicate sample for every 10 original samples. Field triplicate samples will be collected at the rate one triplicate sample for every 20 original samples for inter-laboratory analysis. Rinsate and field blanks will be collected for each day of soil sampling, while trip blanks will be submitted for each esky of samples.

All samples (with the exception of the trip blanks) will be analysed for:

- TPH;
- BTEX;
- PAHs;
- Arsenic, cadmium, chromium, copper, lead, mercury, nickel and zinc;
- Organochlorine pesticides;
- Polychlorinated biphenyls; and
- Other chemicals specific to the source site.

This sampling and analytical approach is consistent with the requirements of the Mobil *Environmental Site Assessment Specification Module 4 – Tank Excavation Assessments* and the Service Station Guidelines.

Trip blanks will only be submitted for TPH (C_6-C_9) and BTEX analysis.

5.4.3 Site Soils

Remediation of the site soils will be required if the quantitative risk assessment and/or NSW EPA determine that the concentrations of the contaminants of concern pose a risk to human health and/or the environment. To ensure the remedial works meet the defined remedial goals, validation of the site soils will be required. Validation will comprise collection of soil samples on a 10 m grid across the site. The size of the grid was calculated using the approach detailed in the *Sampling Design Guidelines (NSW EPA, September, 1995)*. Samples will be collected from the surface at 1 m intervals to 1 m beyond the known depth of soil impact at the site (currently not defined, but greater than 6 m below the ground surface). Two samples from within the (known) impacted soil zone, along with other samples exhibiting indicators of hydrocarbon impact (hydrocarbon odours, elevated VOC readings, colour) will be submitted from each validation location for laboratory analysis.

Field duplicate samples will be collected for intra-laboratory analysis at the rate of one duplicate sample for every 10 original samples. Field triplicate samples will be collected at the rate one triplicate sample for every 20 original samples for inter-laboratory analysis. Rinsate and field blanks will be collected for each day of soil sampling, while trip blanks will be submitted for each esky of samples.

All samples (with the exception of trip blanks) will be analysed for

- TPH;
- BTEX; and
- PAHs.

Trip blanks will only be submitted for TPH (C_6-C_9) and BTEX analysis.

5.5 Groundwater

Quarterly groundwater monitoring events will be conducted throughout the course of, and following the remediation program. Groundwater samples will be collected from all site and off site monitoring wells. Hydrocarbon impacts will be considered to have been removed from the dissolved phase when groundwater samples collected from three consecutive (quarterly) groundwater monitoring events meet the remediation end points.

Field duplicate samples will be collected for intra-laboratory analysis at the rate of one duplicate sample for every 10 original samples. Field triplicate samples will be collected at the rate one triplicate sample for every 20 original samples for inter-laboratory analysis. Rinsate and field blanks will be collected for each day of soil sampling, while trip blanks will be submitted for each esky of samples.

All samples (with the exception of the trip blanks) will be analysed for:

- TPH;
- BTEX; and
- PAHs.

The groundwater samples will also be analysed for arsenic, chromium, copper, lead, nickel and zinc.

Trip blanks will only be submitted for TPH (C_6-C_9) and BTEX analysis.

5.6 Validation Data Quality Assurance

Validation of the field procedures and laboratory analytical results will be conducted to ensure the reliability of the data. This will include:

- Use of experienced personnel to collect samples;
- Use of written protocols to collected samples;
- Preservation and storage of samples upon collection and during transport to the laboratory;
- Sample holding times;
- Use of appropriate analytical and field sampling procedures;
- Required limits of reporting;
- Frequency of conducting quality control measurements;

- Field and trip blank results;
- Laboratory blank results;
- Field duplicate results;
- Laboratory duplicate results, including inter-laboratory duplicate samples;
- Matrix spike/matrix spike duplicate (MS/MSD) results;
- Surrogates spike results; and
- Occurrence of apparently unusual or anomalous results, eg., laboratory results that appear to be inconsistent with field observations or measurements.

In accordance with the *Guidelines for Consultants reporting on Contaminated Sites (NSW EPA, 1997)*, the reliability of the analytical data will be assessed against the data quality objectives, which include discussion of:

- Documentation and data completeness;
- Data comparability;
- Data representativeness; and
- Precision and accuracy for sampling and analysis of each analyte.

5.7 Reporting

Once the remediation goals have been achieved, a validation report will be compiled detailing the remediation and validation approach. This report will be structured in accordance with the requirements of the:

- *Guidelines for Consultants reporting on Contaminated Sites (NSW EPA, 1997);* and
- *Environmental Site Assessment Specification Module 6 – Remediation Action Plans (D.Wright, 3 March, 2002).*

Limitations

URS Australia Pty Ltd (URS) has prepared this report for the use of Mobil Oil Australia Pty Ltd (Mobil) in accordance with the usual care and thoroughness of the consulting profession and the requirements of the Mobil *Environmental Site Assessment Specification Module 6 – Remediation Action Plans*. It is based on generally accepted practices and standards at the time it was prepared. No other warranty, expressed or implied, is made as to the professional advice included in this report. It is prepared in accordance with a signed work request form received from Mobil.

The methodology adopted and sources of information used by URS are outlined in this report. URS has made no independent verification of this information beyond the agreed scope of works and URS assumes no responsibility for any inaccuracies or omissions. No indications were found during our assessments that information contained in this report as provided to URS was false.

This report was prepared between 11 April and 4 July, 2003 and is based on the information available at the time of preparation. URS disclaims responsibility for any changes that may have occurred after this time.

This report should be read in full. No responsibility is accepted for use of any part of this report in any other context or for any other purpose or by third parties. This report does not purport to give legal advice. Legal advice can only be given by qualified legal practitioners.

This report contains information obtained by inspection, sampling, testing or other means of sub-surface assessment. This information is directly relevant only to the points in the ground where they were obtained at the time of the assessment. The borehole logs indicate the inferred ground conditions only at the specific locations tested. The precision with which conditions are indicated depends largely on the frequency and method of sampling, and the uniformity of conditions as constrained by the project budget limitations. The behaviour of groundwater and some aspects of contaminants in soil and groundwater are complex. Our conclusions are based upon the analytical data presented in this report and our experience. Future advances in regard to the understanding of chemicals and their behaviour, and changes in regulations affecting their management, could impact on our conclusions and recommendations regarding their potential presence on this site.

Where conditions encountered at the site are subsequently found to differ significantly from those anticipated in this report, URS must be notified of any such findings and be provided with an opportunity to review the recommendations of this report.

Whilst to the best of our knowledge information contained in this report is accurate at the date of issue, subsurface conditions, including groundwater levels can change in a limited time. Therefore this document and the information contained herein should only be regarded as valid at the time of the assessment unless otherwise explicitly stated in this report.

This remediation action plan addresses the issues in relation to the remediation works at the site.

This assessment addresses the likelihood of hazardous substance contamination resulting from past and current known uses of the subject facility. Given the limited and mutually agreed scope of work, URS does not guarantee that hazardous materials do not exist at the subject property. Similarly, a property which appears to be unaffected by hazardous materials at the time of our assessment may later, due to natural phenomena or human intervention, become contaminated.

As a result, certain conditions such as those listed hereafter may not have been revealed:

- naturally occurring toxins in the sub-surface soils, rocks, water or the toxicity of the on-site flora;
- toxicity of substances common in current habitable environments such as stored household products, building materials and consumables;
- sub-surface contaminant concentrations that do not exceed present regulatory standards but may exceed future standards; and/or
- unknown site contamination such as dumping or accidental spillage which may occur following the site visit by URS.

Subsurface conditions can vary across a particular site and cannot be explicitly defined by these assessments. It is unlikely therefore that the results and estimations expressed in this report will represent the extremes of conditions within the site or the conditions at any location removed from the specific points of sampling. Subsurface conditions including contaminant concentrations can also change in a short time.

The information in this report is considered to be accurate at the date of issue and is in accordance with conditions at the site at the dates sampled.

This document and the information contained herein should only be regarded as validly representing the site conditions at the time of the assessment unless otherwise explicitly stated in a preceding section of this report.

No warranty or guarantee of property conditions is given or intended. URS makes no determination or recommendation regarding a decision to provide or not to provide financing with respect to the site.

References

ANZECC/ARMANC, 2000 *'Australian Water Quality Guidelines for the Protection Of Aquatic Ecosystems'*;

Department of Mineral Resources, 1991 *'1:100 000 Penrith Geological Series Sheet 9030'*;

Handex Australia Pty Ltd, 9 January, 2002 *"Environmental Site Assessment Quix Service Station 161 Hume Highway (Cnr Chadderton Street) Lansvale, NSW (Site No. NJ 3565)"*;

Handex Australia Pty Ltd, 5 September, 2002 *"Additional Well Installation and Groundwater Monitoring Mobil/Quix Service Station 161 Hume Highway (Cnr Chadderton Street) Lansvale, NSW (Site No. NJ 3565)"*;

Handex Australia Pty Ltd, 21 February, 2003 *Multi-Phase Extraction Summary Report Mobil Service Station 161 Hume Highway, Lansvale, NSW (Site No. NJ 3565)"*;

MassTech Australia Pty Limited, 9 April, 2001, *"UPS Precision Test Report Mobil Quix NJ3565 161 Hume Highway Lansvale NSW 2166"*;

MassTech Australia Pty Limited, 6 June 2002 *""UPS Precision Test Report Mobil 161 Hume Highway Lansvale NSW 2166"*;

National Environment Protection Council, 10 December 1999 *'National Environment Protection (Assessment of Site Contamination) Measure 1999'*;

New South Wales Environment Protection Authority, December 1994 *'Guidelines for Assessing Service Station Sites'*;

New South Wales Environment Protection Authority, September 1995 *'Sampling Design Guidelines'*

New South Wales Environment Protection Authority, June 1997 *'Guidelines for Consultants Reporting on Contaminated Sites'*;

New South Wales Environment Protection Authority, May 1999 'Environmental Guidelines: Assessment, Classification and Management of Liquid and Non-Liquid Wastes'; and

URS Australia Pty Ltd, 11 March, 2003 *"Groundwater Monitoring Event Mobil Service Station Site No. NJ 3565 161 Hume Highway, Lansvale, NSW"*.

Tables

TABLE 1: FUEL STORAGE DETAILS

Tank ID	Capacity (KL) (KL)	Contents	Status	Approximate Age (Years)	AST/UST
T1	45	ULP	In use	>10	UST
T2	45	PULP	In use	>10	UST
T3	45	LRP	In use	>10	UST
T4	25	Diesel	In use	>10	UST

Notes:
ULP – unleaded petrol
LRP – lead replacement petrol
PULP - premium unleaded petrol

TABLE 2:NEPM HIL F GUIDELINES

Chemical	Goal (mg/kg)	Goal Source
BENZO(a)PYRENE	5	NEPM HIL F
TOTAL PAHS	100	NEPM HIL F

Notes:
NEPM HIL F- *National Environment Protection (Assessment of Site Contamination) Measure Health Investigation Levels Level F (National Environmental Protection Council, 1999).*

Created By: GDM.
Checked By: CH.

TABLE 3: ANZECC (2000) TRIGGER VALUES AND SERVICE STATION THRESHOLD CONCENTRATIONS

Chemical	GOAL ug/L	GOAL SOURCE
C6-C9	-	-
C10-C36	-	-
BENZENE	950	ANZECC 2000
TOLUENE	300	NSWEPA(1994)
ETHYL BENZENE	140	NSWEPA(1994)
XYLENE	200	ANZECC 2000
PHENOL	320	ANZECC 2000
BENZO(a)PYRENE	0.2	ANZECC 2000
Napthalene	16	ANZECC 2000
Anthracene	0.4	ANZECC 2000
Phenanthracene	2	ANZECC 2000
Flouranthrene	1.4	ANZECC 2000

NOTES:
ANZECC 2000 - *ANZECC/ARMCANZ (2000) Trigger Values for Fresh Waters (95 % Level of Protection)*

TABLE 4: NET PRESENT VALUE PRELIMINARY ESTIMATE - PSH REMOVAL
QUIX Service Station, 116 Hume Highway, Lansvale

COST PROJECTIONS: PUMP AND TREAT (BORE EXTRACTION)

	ANNUAL EXPENSES										
REMEDIATION ACTIVITY	*2003*	*2004*	*2005*	*2006*	*2007*	*2008*	*2009*	*2010*	*2011*	*2012*	*TOTAL*
Engineering Design Cost	$35,000										$35,000
Equipment Purchase Cost	$35,000										$35,000
Installation Cost	$45,000										$45,000
Annual Operating Cost	$10,000	$50,000									$60,000
Annual Waste Disposal Cost	$25,000	$5,000									$30,000
Annual Monitoring Cost	$50,000	$50,000									$100,000
TOTAL EXPENSE	$200,000	$105,000	$0	$0	$0	$0	$0	$0	$0	$0	$305,000

DISCOUNT RATE 8%
NET PRESENT VALUE $297,222.22

COST PROJECTIONS: PASSIVE SKIMMING

	ANNUAL EXPENSES										
REMEDIATION ACTIVITY	*2003*	*2004*	*2005*	*2006*	*2007*	*2008*	*2009*	*2010*	*2011*	*2012*	*TOTAL*
Engineering Design Cost	$5,000										$5,000
Equipment Purchase Cost	$15,000										$15,000
Installation Cost	$5,000										$5,000
Annual Operating Cost											$0
Annual Waste Disposal Cost	$10,000	$4,000	$3,000	$3,000	$3,000						$23,000
Annual Monitoring Cost	$50,000	$30,000	$30,000	$30,000	$30,000						$170,000
TOTAL EXPENSE	$85,000	$34,000	$33,000	$33,000	$33,000	$0	$0	$0	$0	$0	$218,000

DISCOUNT RATE 8%
NET PRESENT VALUE $195,226.11

COST PROJECTIONS: ACTIVE SKIMMING

	ANNUAL EXPENSES										
REMEDIATION ACTIVITY	*2003*	*2004*	*2005*	*2006*	*2007*	*2008*	*2009*	*2010*	*2011*	*2012*	*TOTAL*
Engineering Design Cost	$15,000										$15,000
Equipment Purchase Cost											
Installation Cost	$60,000										$60,000
Annual Operating Cost	$10,000	$10,000	$10,000	$10,000							$40,000
Annual Waste Disposal Cost	$15,000	$2,000	$2,000	$1,000							$20,000
Annual Monitoring Cost	$50,000	$50,000	$50,000	$50,000							$200,000
TOTAL EXPENSE	$150,000	$62,000	$62,000	$61,000	$0	$0	$0	$0	$0	$0	$335,000

DISCOUNT RATE 8%
NET PRESENT VALUE $308,986.18

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Checked By: MH.

TABLE 5: NET PRESENT VALUE PRELIMINARY ESTIMATE - SUBSURFACE SOILS - UNSATURATED ZONE
QUIX Service Station, 116 Hume Highway, Lansvale

COST PROJECTIONS: SOIL VAPOUR EXTRACTION (SVE)

	ANNUAL EXPENSES										
REMEDIATION ACTIVITY	*2003*	*2004*	*2005*	*2006*	*2007*	*2008*	*2009*	*2010*	*2011*	*2012*	*TOTAL*
Engineering Design Cost	$30,000										$30,000
Equipment Purchase Cost	$35,000										$35,000
Installation Cost	$60,000										$60,000
Annual Operating Cost	$15,000	$15,000	$15,000	$15,000							$60,000
Annual Waste Disposal Cost	$15,000	$15,000	$15,000	$7,000							$52,000
Annual Monitoring Cost	$75,000	$50,000	$50,000	$30,000							$205,000
TOTAL EXPENSE	$230,000	$80,000	$80,000	$52,000	$0	$0	$0	$0	$0	$0	$442,000

DISCOUNT RATE 8%
NET PRESENT VALUE $413,940.46

COST PROJECTIONS: EXCAVATION

	ANNUAL EXPENSES										
REMEDIATION ACTIVITY	*2003*	*2004*	*2005*	*2006*	*2007*	*2008*	*2009*	*2010*	*2011*	*2012*	*TOTAL*
Engineering Design Cost	$50,000										$50,000
Equipment Purchase Cost											$0
Demolition/Excavation Cost	$650,000										$650,000
Annual Operating Cost											$0
Annual Waste Disposal Cost	$150,000										$150,000
Annual Monitoring Cost	$50,000										$50,000
TOTAL EXPENSE	$900,000	$0	$0	$0	$0	$0	$0	$0	$0	$0	$900,000

DISCOUNT RATE 8%
NET PRESENT VALUE $900,000

COST PROJECTIONS: BIO-VENTING

	ANNUAL EXPENSES										
REMEDIATION ACTIVITY	*2003*	*2004*	*2005*	*2006*	*2007*	*2008*	*2009*	*2010*	*2011*	*2012*	*TOTAL*
Engineering Design Cost											
Equipment Purchase Cost	$30,000										$30,000
Installation Cost	$60,000										$60,000
Annual Operating Cost	$10,000	$10,000	$10,000	$10,000	$10,000	$10,000	$10,000				$70,000
Annual Waste Disposal Cost	$5,000										$5,000
Annual Monitoring Cost	$50,000	$50,000	$50,000	$50,000	$50,000	$50,000	$30,000				$330,000
TOTAL EXPENSE	$155,000	$60,000	$60,000	$60,000	$60,000	$60,000	$40,000	$0	$0	$0	$495,000

DISCOUNT RATE 8%
NET PRESENT VALUE $419,769.39

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Checked By: MH.

TABLE 6: NET PRESENT VALUE PRELIMINARY ESTIMATE - SUB-SURFACE SOILS (SATURATED ZONE) AND DISSOLVED-PHASE PLUME
Former Solchem Site, 49-51 Riverside Road, Chipping Norton, NSW

COST PROJECTIONS: AIR SPARGE WITH SVE

	ANNUAL EXPENSES										
REMEDIATION ACTIVITY	*2003*	*2004*	*2005*	*2006*	*2007*	*2008*	*2009*	*2010*	*2011*	*2012*	*TOTAL*
Engineering Design Cost	$75,000										$75,000
Equipment Purchase Cost	$45,000										$45,000
Installation Cost	$60,000										$60,000
Annual Operating Cost	$15,000	$15,000	$15,000	$5,000							$50,000
Annual Waste Disposal Cost	$10,000	$10,000	$10,000	$5,000							$35,000
Annual Monitoring Cost	$75,000	$75,000	$75,000	$40,000							$265,000
TOTAL EXPENSE	$280,000	$100,000	$100,000	$50,000	$0	$0	$0	$0	$0	$0	$530,000

DISCOUNT RATE 8%
NET PRESENT VALUE $498,018.09

COST PROJECTIONS: MULTI-PHASE EXTRACTION (MPE)

	ANNUAL EXPENSES										
REMEDIATION ACTIVITY	*2003*	*2004*	*2005*	*2006*	*2007*	*2008*	*2009*	*2010*	*2011*	*2012*	*TOTAL*
Engineering Design Cost	$75,000										$75,000
Equipment Purchase Cost	$60,000										$60,000
Installation Cost	$60,000										$60,000
Annual Operating Cost	$15,000	$100,000	$100,000	$100,000	$50,000						$365,000
Annual Waste Disposal Cost	$25,000	$25,000	$25,000	$25,000	$10,000						$110,000
Annual Monitoring Cost	$75,000	$75,000	$75,000	$75,000	$40,000						$340,000
TOTAL EXPENSE	$310,000	$200,000	$200,000	$200,000	$100,000	$0	$0	$0	$0	$0	$1,010,000

DISCOUNT RATE 8%
NET PRESENT VALUE $898,922.38

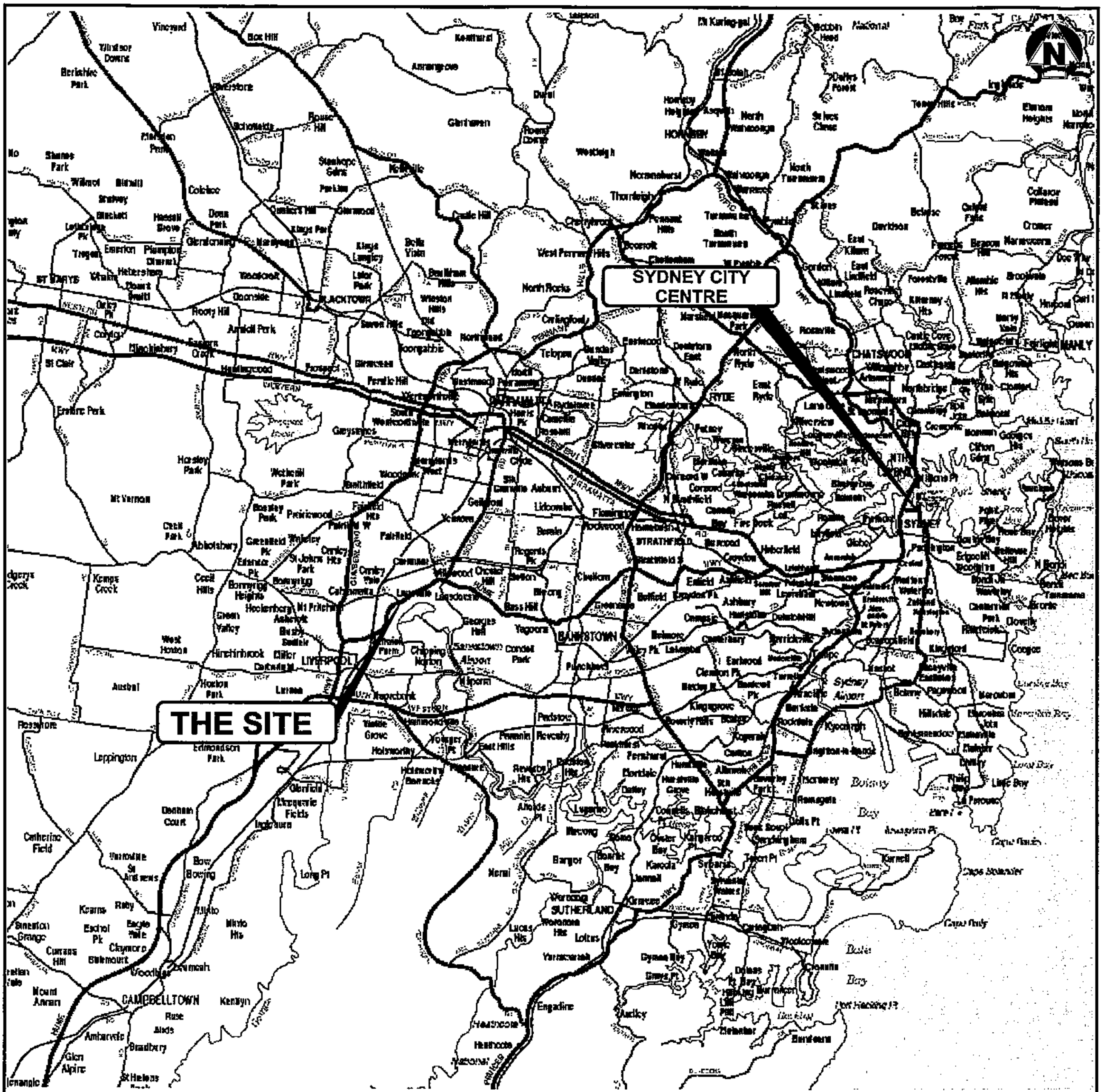
COST PROJECTIONS: BIO-SPARGING

	ANNUAL EXPENSES										
REMEDIATION ACTIVITY	*2003*	*2004*	*2005*	*2006*	*2007*	*2008*	*2009*	*2010*	*2011*	*2012*	*TOTAL*
Engineering Design Cost	$45,000										$45,000
Equipment Purchase Cost	$35,000										$35,000
Installation Cost	$50,000										$50,000
Annual Operating Cost	$15,000	$15,000	$15,000	$15,000	$15,000	$10,000					$85,000
Annual Waste Disposal Cost											$0
Annual Monitoring Cost	$75,000	$75,000	$75,000	$75,000	$75,000	$50,000					$425,000
TOTAL EXPENSE	$220,000	$90,000	$90,000	$90,000	$90,000	$60,000	$0	$0	$0	$0	$640,000

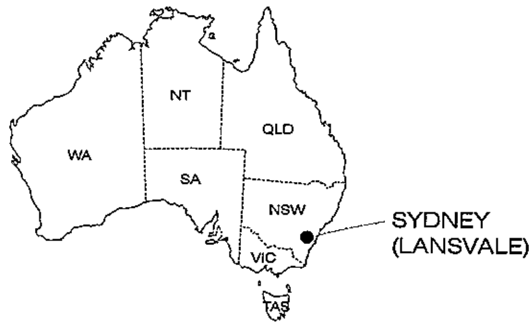
DISCOUNT RATE 8%
NET PRESENT VALUE $558,926.41

Created By: GDM.
Checked By: MH.

Figures



SITE ADDRESS:
MOBIL SERVICE STATION
161 HUME HIGHWAY, LANSVALE, N.S.W.



CLIENT:
MOBIL OIL AUSTRALIA PTY LIMITED

PROJECT:
MOBIL SERVICE STATION, LANSVALE, NSW

TITLE:
LOCAL AREA MAP

DESIGNED: GDM DRAWN: RR DATE: 10/06/03	APPROVED: DATE: STATUS: FINAL	PROJECT: 51556-144 CAD FILE: 002.CDR REVISION: A	URS	FIGURE: 1