TARCRETE MANAGEMENT IN KUWAIT'S BURGAN OILFIELD

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ABSTRACT

Tarcrete is crude oil contamination that has formed across 175km^2 of the Kuwait Burgan Oilfield as a result of the damage caused to production wells during the 1990 Gulf War. Remedial action on tarcrete affected areas is now being planned. The aim of this study is to evaluate the current tarcrete management objectives set as part of the UNCC Claim "*Remediation of Areas Damaged by Tarcrete*" by determining its effects on soil properties and vegetation establishment in the Kuwait Burgan Oilfield. A ground survey was undertaken to characterize its physical characteristics and develop a standard guideline for describing tarcrete. An intrusive investigation analysed tarcrete and the underlying soil. Soil temperature, moisture and electrical conductivity was monitored to evaluate the effects of tarcrete on these soil conditions. Vegetation cover was surveyed to evaluate potential effects on re-vegetation. Tarcrete occurred primarily as a "mat-like" continuous layer with an average thickness of 1.10$\pm$0.49cm, it was hardened and friable. A "gravel-like" fine to medium, very sparse, uneven, hardened, very friable to friable tarcrete type was also present. Chemical analysis detected TPH fraction C21-C35 (0.01% to 0.05%) and PHC fraction >C35-C90 (6% to 7%). SARA testing identified the main component to be polar heterocyclic molecules. This composition is representative of weathered crude oil. Metal concentrations were negligible and no PAH was detected. Contamination to the underlying soil was not detected nor were changes to the soil's bulk chemical properties. Mean increase in soil temperatures of 4°C and 3°C was measured in areas of high and low tarcrete cover, respectively. Soil moisture showed a median increase of 62% and 58% at 100mm and 200mm depths in high tarcrete cover areas and 23% and 31% at 100mm and 200mm depths in low tarcrete cover areas. Moisture was retained in tarcrete areas. A mean increase in electrical conductivity occurred at high and low cover sites (68% and 19%) and were detected the longest at high tarcrete cover sites. Mean canopy cover at low tarcrete cover sites was 62% compared to 54% at high and no cover sites. This study illustrates tarcrete creates conditions that promote desert plant establishment depending on the ratio of tarmat cover to the percentage of fragmentation. Based on literature reviews and the Study Area conditions, is unlikely that planned remediation activities involving mechanical fragmentation will increase vegetation establishment. Instead, it will be potentially detrimental to the re-established vegetation so it is argued that the current tarcrete management objectives are unnecessary. The proposal to remove remedial intervention on the basis that tarcrete poses 'no risk' is recommended. No risk shall be verified via detailed quantitative human health and ecological risk assessments. Manual tarcrete fragmentation based on a fractioning index could enhance re-vegetation. Developing the index would require detailed quantitative measurements of the exposed soil vs covered soil, additional soil moisture and temperature monitoring and vegetation surveys and soil erosion studies.

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List of Abbreviations

API gravity	The American Petroleum Institute gravity
Burgan	Burgan Oilfield in Kuwait
C.V.	Coefficient of Variation
CSM	Conceptual Site Model
EC	Electrical conductivity
EOD	Explosive Ordnance Disposal
ID	Identification
IUCN	International Union for Conservation of Nature
KERP	Kuwait Environmental Remediation Projects
KISR	Kuwait Institute of Scientific Research
KNFP	Kuwait National Focal Point
KOC	Kuwait Oil Company
OoM	Order of magnitude
PCoC	Potential contaminants of concern
PHC	Petroleum hydrocarbons
PoPC	Pathways of potential concern
RoPC	Receptors of potential concern
SAR	Sodium Adsorption Ratio
SARA	Saturates, aromatics, resins and asphaltenes (analytical method IP469)
TC-Pr1	Tarcrete Project 1
TC-Pr2	Tarcrete Project 2
TC-Pr3	Tarcrete Project 3
TPH	Total petroleum hydrocarbon
UNCC	United Nations Compensation Committee
UN GC	United Nations Governing Council
US EPA	United States Environmental Protection Agency
UTM	Universal Transverse Mercator
UXO	Unexploded ordinance

1 Glossary

Aliphatic Hydrocarbons: "Hydrocarbons in which the carbon-hydrogen groupings are arranged in open chains which may be branched. Includes paraffins and olefins" (Weisemen (ed.), pp. 89, 1998).

Aromatic (unsaturated) Hydrocarbons: This fraction is comprised of non-polar hydrocarbons consisting of one aromatic ring with or without alkyl chains and cycloalkane rings. Polar, higher molecular weight aromatics may fall in the resin or asphaltene fraction.

Asphaltenes: A constituent of petroleum products with a high molecular mass and dark colour (Weisemen (ed.), pp. 89, 1998). The asphaltene fraction is defined as a solubility class (insoluble and precipitating in pentane, hexane and heptane; precipitate is soluble in aromatic solvents such as toluene or benzene). The asphaltene fraction is comprised of polar polycyclic aromatic hydrocarbon clusters and contains the largest percentage of heteroatoms (Oxygen, Sulfur, Nitrogen) and organometallic constituents (Nickel, Vanadium, Iron) in crude oil.

Camel Pitter: A modified disk plough that breaks up the ground surface whilst applying seed.

Conceptual Site Model: A tool used to identify sources of potential of chemicals of concern, possible transport mechanisms and exposure pathways that could potentially affect receptors (flora, fauna, human, environmental media).

Explosive Ordnance Disposal (EOD): The removal of unexploded explosive ordnance.

F4 Panel: Appointed in 1998 by the Governing Council of the UNCC to process claims and pay compensation for losses and damages suffered as a direct result of Iraq's 1990-1991 invasion and occupation of Kuwait.

Friability: In terms of the *Guideline for Describing Tarcrete*, friability is used to describe how easily tarcrete with a soft or hardened consistency can be broken into pieces. Adapted

from sedimentary rock texture descriptions (Tucker, 2011, pp. 97-98), categories of Friability are: Very Friable, Friable, Hard, Very Hard and Extremely Hard.

Heterocyclic Molecules: Carbon and hydrogen atoms with oxygen, nitrogen or sulphur.

Pathways of Potential Concern (PoPC): Possible routes a contaminant can be transferred to receptors or environmental media (e.g.; inhalation, ingestion and direct contact).

Petroleum Hydrocarbons (PHC): A complex mixture of chemicals that comprise of crude oil and its refined products (e.g.; diesel, gasoline).

Percent Canopy Cover: The proportion of the ground area that is covered by vegetation foliage (canopy) expressed as a percent. Canopy cover can be used as an indicator for soil stability, hydrologic function, biotic integrity and habitat.

Polar I: Part of the SARA analysis, the polar fraction reports hydrocarbon compounds with melting points above 100°C. Polar I are the lower molecular weight compounds within this fraction representing 'resins' or the carbon rage of >C40 to C60. Overlap with the Polar II fraction will occur with the molecules close to the C40 band.

Polar II: Part of the SARA analysis, the polar fraction reports hydrocarbon compounds with melting points above 100°C. Polar II are the higher molecular weight compounds within this fraction representing the 'asphaltene' or the carbon range of >C60 to C100. Overlap with the Polar I fraction will occur with the molecules close to the C40 band.

Potential Contaminants of Concern (PCoC): Any contaminant which may or may not be causing risk or adverse effects to environmental media (including flora, fauna) and/or human health.

Resins: A fraction of petroleum hydrocarbons that is soluble in pentane and hexane but insoluble in liquid propane. The fraction is comprised of polar hydrocarbon molecules often

containing heteroatoms such as nitrogen, oxygen or sulfur. They are structurally similar to asphaltenes, however, the molecular weight is less.

Receptors of Potential Concern (PoPC): Environmental media (including flora, fauna) and/or humans which may or may not be exposed to potential contaminants of concern or contaminants of concern.

SARA Analysis: An analytical method that quantifies the hydrocarbon and non-hydrocarbon composition of crude oil into Saturates, Asphaltenes, Resins and Aromatics (SARA). Using IP 469 (2006) methodology, SARA results are presented as saturates, aromatics, polars (I) and polars (II).

Saturated Hydrocarbons: A fraction of petroleum hydrocarbons comprised of non-polar hydrocarbons which can be straight-chained, cyclical and branched.

Sodium Adsorption Ratio (SAR): Describes the tendency for sodium cations to be adsorbed at cation-exchange sites in soil. SAR is calculated by dividing the amount of sodium by the square root of half the sum of calcium and magnesium concentrations. Concentrations of the ions are in milliequivalents per litre (Allaby and Allaby, 1999).

Tarcrete: Oil contamination consisting of a coherent crust or gravel with no visible contamination of underlying soil. Tarcrete has a [black] hue of 10YR, value of 2 and chroma of 1 (dry and moist colour). The texture is a mix of sand and solidified oil with 0% to 2% coarse fragments, ranging in consistency from a malleable tar mat-like substance to a hardened asphalt-like substance.

Total Petroleum Hydrocarbons (TPH): The total concentration of the hydrocarbons extracted and measured by a particular analytical method (Weisemen (ed.), 1998). TPH provides an indication of the level of oil contamination that is present.

Unexploded ordinance (UXO): Explosive weapons that still have the potential to explode.

Waxes: Non-liquid complex mixtures of n-, iso- and cyclo-alkanes with chain lengths ranging from C18 to C65.

2 Introduction

The Iraqi invasion of Kuwait in 1990 resulted in Kuwait's oil infrastructure, including approximately 800 oil production wells, being damaged and set on fire causing widespread oil contamination in both north and south Kuwait. The oil fires and damaged wells were eventually brought under control after one year (PAAC, 2002a).

Extensive impacts to the environment occurred from oil spreading over the land surface penetrating soil to varying depths and forming oil lakes. In addition, areal fallout from oil spray, together with combustion products from oil fires formed a surface cover of tarcrete (PAAC, 2002b). The most extensive damage occurred within Kuwait Oil Company's Greater Burgan Oilfield in south-east Kuwait (Grealish et al, 2001a), which is the location of this study (Figure A-1, Appendix A).

In 1991 the United Nations Compensation Commission (UNCC) was created as a subsidiary body of the United Nations Security Council. In 1998, the Governing Council (GC) of the UNCC appointed the "F4" Panel whose mandate is to process claims and pay compensation for losses and damages suffered as a direct result of Iraq's 1990-1991 invasion and occupation of Kuwait (UNCC, nd)

Based on the "F4" Panel ('Panel') recommendations, the UNCC has awarded the Government of Kuwait funds under 5 claims for addressing environmental damages throughout Kuwait. The claim that addresses tarcrete within the Burgan Oilfield is referred to as *Claim no. 5000450 "Remediation of Damaged Terrestrial Resources"* (TC-Pr3). This covers an estimated area of 175 km^2, which is 65% of the total area impacted by tarcrete (UNCC, 2014) (Figure A-2, Appendix A).

The focus of this research targets an area heavily impacted by tarcrete, covering approximately 25km^2 in the south-eastern area of the Burgan Oilfield (Figure A-1 and A-2, Appendix A).

2.1 *Remediation/ Restoration Approaches: Tarcrete*

The latest recommendations made by the Panel are covered in the Project Plan for Kuwait Environmental Remediation Program (KERP) (dated 5 March 2013): "Remediation of areas

damaged by tarcrete", Element 3 of Claim No. 5000450. These recommendations are subdivided into 3 projects; TC-Pr1 for areas of south Kuwait beyond the south-eastern oilfield boundary of Burgan; TC-Pr2 for north Kuwait; and TC-Pr3 for areas within the Burgan Oilfield. This study focuses on TC-Pr3, which includes:

- Site characterisation using high resolution satellite images (used to identify areas for tarcrete remediation through mechanical fragmentation and re-seeding)[1];
- UXO survey and clearance prior to mechanical fragmentation;
- Implementation of mechanical fragmentation and seeding; and
- Environmental monitoring.

2.1.1 Request for Modifications

A request for scope modification is currently being considered for TC-Pr3 by KERP stakeholders, based on acquiring a better understanding of the tarcrete as a potential source of contamination, together with consideration given to the most appropriate utilisation of UN funds.

The UNCC Governing Council Decision 258, enables the claimant countries to request for material changes or a modification to the "F4" Panel recommended scheme following appropriate justification for a revised approach which is shown to be cost effective.

The proposed modification would result in limited intervention where minimal remedial activity would be undertaken on tarcrete. A revised evaluation of tarcrete characteristics is required to demonstrate the risk posed to the environment after 24 years of weathering. It has been observed in many areas that natural re-vegetation is taking place with plants exploiting cracks in tarcrete which have resulted largely from weathering, manmade disturbance, burrowing animals and insects.

[1] This is required due to discrepancies between areas mapped as tarcrete (Figures A-2 (TC-Pr3), A-4, A-4-1 to A-4-4 (CIC, 2003) and actual ground coverage (Section 6.2 and Appendix B)

2.1.2 UXO Monitoring

The Kuwait Ministry of Defence conducted a state-wise EOD programme in 1991-1993. UXO clearance certificates were generated for areas which had surface clearance activities completed, which includes the Study Area.

2.2 *Aim and Objectives*

The aim of this thesis is to evaluate the current tarcrete management objectives set as part of the UNCC Claim "*Remediation of Areas Damaged by Tarcrete*" by determining the effects of tarcrete on soil properties and vegetation establishment in the Kuwait Burgan Oilfield.

The objectives are to:

a. Characterize (physical and chemical properties) the tarcrete within the KOC fence in the South Oilfields, Burgan;
b. Determine the effect of weathering on tarcrete composition;
c. Determine the effect that the distance of oil deposition has on tarcrete characteristics;
d. Develop a guideline for describing tarcrete;
e. Develop a tarcrete classification system;
f. Determine the effect of tarcrete on the soil;
g. Determine the effect of tarcrete on natural re-vegetation; and
h. Evaluate the current management plan of mechanical fragmentation and seeding.

2.3 *Structure of the thesis*

This study is divided into nine chapters plus appendices. Chapter 1 is this introduction to the study. Chapter 3 reviews the available literature on tarcrete focussing on its physical and chemical properties including influences of deposition and weathering. Also included in Chapter 3 is background information on the environmental setting of the Study Area and well as the history and current status of the planned management objectives. Chapter 4 presents the information collected in Chapter 3 and an initial analysis of potential risks in a preliminary Conceptual Site Model (CSM). The methodologies and quality assurance/control procedures used to undertake the site investigations required to fill data gaps in the CSM and provide the information required to achieve the objectives of this study are presented in Chapter 5. The resulting raw data is provided in Chapter 6. Chapter 7 evaluates the

characterization data before determining its effects on soil and vegetation establishment. Chapter 8 discusses the findings and updates the preliminary CSM. Conclusions and an appraisal the current management objectives are found in Chapter 9. Also included in Chapter 9 is an analysis of the current study and recommendations for future studies. References are listed in Chapter 0 with Appendices following.

3 Literature Review

A review of the literature was focused on existing studies relating to tarcrete which can assist in understanding its characteristics, potential impacts to soil and vegetation establishment and relevant information that would contribute to the CSM.

From 1991 to 2003[2] the Kuwait Institute for Scientific Research (KISR) and the State of Kuwait were the prominent bodies responsible for studies relating to tarcrete. Many of these studies are only available from KISR. Correspondence requesting such studies has been ongoing since 18 February 2014; however, at the time of writing only a limited number were received. A literature review using peer-reviewed scientific journal databases revealed no studies on tarcrete or tarcrete in Kuwait post 2011. A review of this literature is provided herein.

3.1 *Location*

The Study Area is situated in the Burgan Oilfield within the State of Kuwait ('Kuwait') in the Arabian Peninsula (Grealish et al, 2001a). It is an arid desert between 28°50'N and 29°10'N latitude and 47°50'E and 48°05'E longitude spanning UTM Grid Zones 38 and 39 (Grealish et al, 2001a). The Burgan Oilfield ('Burgan') is one of three operational oilfields within the Greater Burgan Oilfield (Grealish et al, 2001a; USEIA, 2013). It covers 3.3% of Kuwait, an area of approximately 562km^2 (Grealish et al, 2001a). It is located approximately 40km south of Kuwait City (USEIA, 2013) and is bordered by the town of Ahmadi to the north-east, an industrial area to the east (Grealish et al, 2001a), a recently developed residential area to the south-east and more KOC oilfields and the Al-Jaber Air base to the west (Figure A-1, Appendix A).

The area included as part of TC-Pr3 is made up of 423 tarcrete patches totalling approximately 175km^2 within the south-eastern area of Burgan (Figure A-2, Appendix A). Exploration, upstream and midstream production infrastructure such as extraction wells, separation facilities and transportation pipelines scatter the landscape.

[2] Date based on available literature and literature referenced within available studies.

3.2 *Crude Oil*

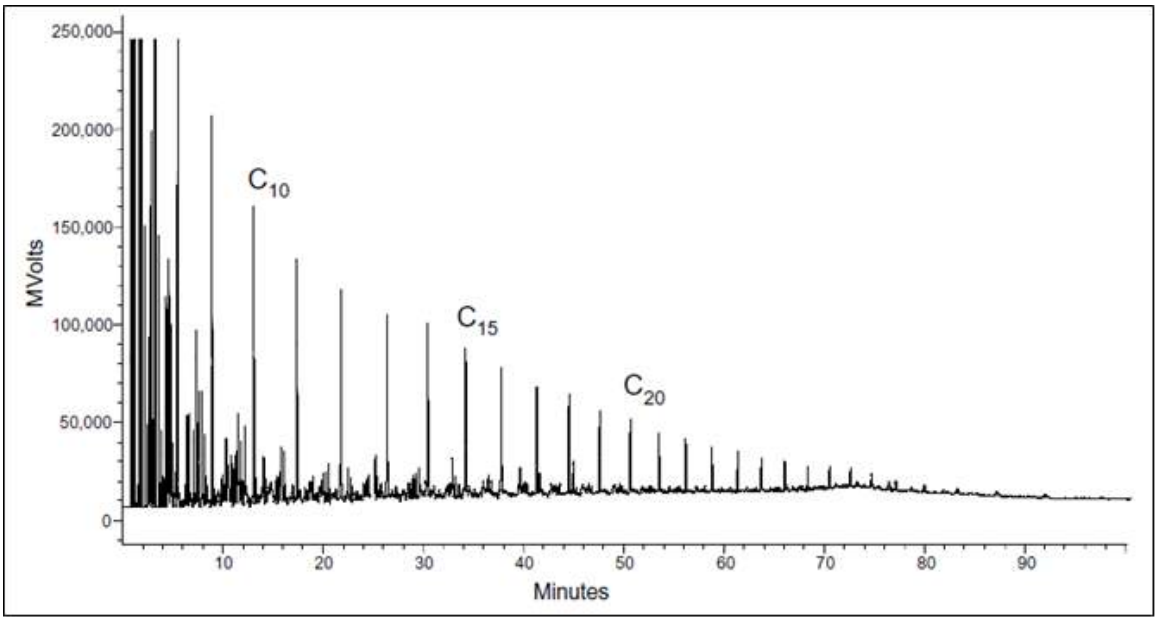
Crude oil (crude or petroleum) naturally occurs within the earth's geological formations in a liquid, gas or solid form (tar or bitumen) and is extracted and refined into a wide range of products from gasoline to motor oil and lubricants (grease) (Overton et al., 1994; Riva, 2013).

Crude oil is comprised of a complex mixture of hydrocarbons, heterocyclic molecules and small amounts of trace metals. Heterocyclic molecules are carbon and hydrogen atoms with oxygen, nitrogen or sulphur (Weisemen (ed.), 1998, Duan, Qian, Wang et. al., 2004). Identifying all components of crude oil is not possible; therefore, it is characterised by the boiling ranges of its constituents and approximate carbon number referred to as 'fractions' (Weisemen (ed.), 1998). The hydrocarbon component of crude oil is divided into saturated and aromatic (unsaturated) hydrocarbons. This division is on based on the bond structure of the molecules which influences the behaviour of the mixture (Weisemen (ed.), 1998). Within each structural group there are further subgroups based on the molecule arrangements which will also have an influence on how the mixture behaves. The amount of heterocyclic compounds within crude are significant. These compounds are concentrated in the heavier fractions and are referred to as asphaltenes (Weisemen (ed.), 1998).

One method to quantify the hydrocarbon and heterocyclic molecule composition of crude is the SARA (Saturates, Asphaltenes, Resins and Aromatics) analysis. Using IP 469 (2006) methodology, SARA results are presented as saturates, aromatics, polar (I) and polar (II). Saturates are non-polar hydrocarbons which can be straight-chained or branched. The aromatic fraction contains slightly polar hydrocarbons consisting of one aromatic ring without or with alkyl chains and cycloalkane rings (mono-aromatics; e.g.; benzene, toluene and phenol) and along with additional aromatic rings (poly-aromatics; e.g.; PAH). Polar, higher molecular weight aromatics may fall in the resin (Polar I) or asphaltene fraction (Polar II). Polar (I) is the resin fraction (soluble in pentane and hexane but insoluble in liquid propane), comprised of polar hydrocarbon molecules often containing heteroatoms such as nitrogen, oxygen or sulphur. They are structurally similar to asphaltenes, however, the molecular weight is less. The melting point of the Polar (1) compounds is above 100°C which means the fractions >C40-C60. Polar (II) are the asphaltene fraction, comprising of polar

polycyclic aromatic hydrocarbon clusters and contains the largest percentage of heteroatoms (oxygen, sulphur, nitrogen) and organometallic constituents (nickel, vanadium, iron) in the crude oil. Polars (II) are insoluble and precipitating in pentane, hexane and heptane. Polar (II) compounds represent the carbon range >C60-C100. Overlap is present between Polar (I) and Polar (II) are a colloid mixture.

The oil from within Burgan is extracted from three cretaceous sandstone reservoirs and has an average API gravity of 32° and a sulphur content of 2.5% (Kaufman et al., 2002) classifying it as a light sour crude. Light crudes have lower concentrations of asphaltenes and resins than heavy crude (<20° API) (McMillen et al., 2001). The "sourness" of a crude is dependent on its sulphur content (Overton et al., 1994). Figure 3-1 is a chromatogram of a typical Burgan Oil that demonstrates the abundance of lighter hydrocarbon fractions up to C20 and the absence of heavier molecular weight hydrocarbons (>C35 which are observed between 70-80 minutes).

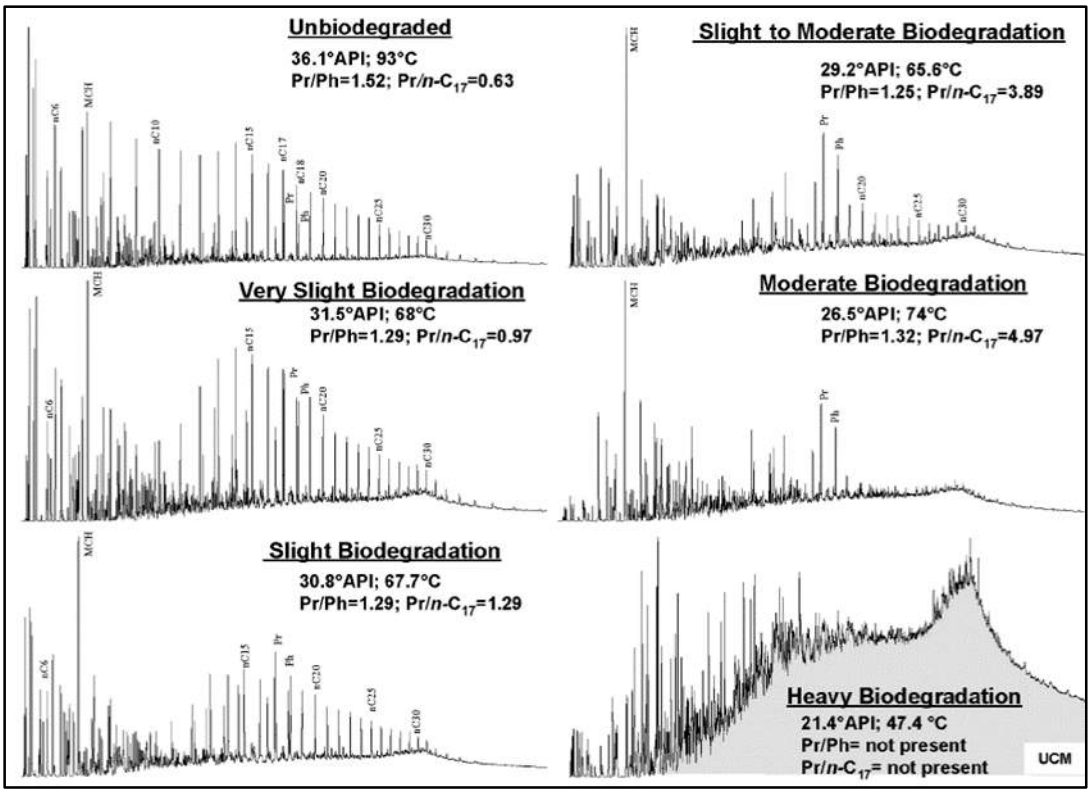


Source: Kaufman et al., 2002

Figure 3-1: Chromatogram of a Typical Burgan Oil

3.2.1 Weathered Crude Oil

Weathering of crude oil is the physical and chemical changes that occur from exposure to the environment (Overton et al., 1994). As crude oil weathers, less low molecular weight hydrocarbons are present in the oil, leaving higher molecular weight hydrocarbons (as demonstrated by Figure 3-2). As the molecular weight increases, solubility and volatility decreases (Weisemen (ed.), 1998; McMillen et al. (e.d.), 2001) thus making it more resistant to physical weathering and chemical degradation (Overton et al., 1994). Initially weathering is dominated by evaporation and later biodegradation (Hyuk et al., 2014). The changes and rates of change that occur are dictated by fraction specific fate and transport properties such as molecular weight, solubility and volatility.



Source: Wenger et al., 2002

Figure 3-2: Changes in Oil Composition with Weathering for a Light Crude (36.1° API)

3.3 *Tarcrete*

The term "tarcrete" originated from Farouk El-Baz in 1991 and related to damage caused from the Gulf War by "*oil sprayed from exploded wells* [that] *soaked into the desert surface*

and hardened, combining with the pebbles to form a new, hard-as-rock substance" (Gulf War Oil Well Fires and Oil Spills, para. 6., The Energy Library). Under the UN Claim 5000450 tarcrete is defined as "*oil contamination consisting of a thin, coherent oil crust with no visible contamination of underlying soil*" and "*ranges in consistency from a malleable tar mat-like substance to a hardened asphalt-like substance*" (Consortium of International Consultants (CIC), 2003b, pp.1, 18-19).

The definition and terminology used to describe of tarcrete vary throughout the literature. Other terms include "tar mat", "oil mist contamination" and "dry oil contamination" (CIC, 2003a). In some instances these terms meet the UN definition criteria e.g.; use of "tar mat" in Grealish et al (2001a, b). In other studies (Kuwait Oil Company, 1993; Al-Ajimi et al., 1994 and El-Baz, 1994 – all cited in CIC, 2003a) the definition of these terms, may include unconsolidated soot material and/or areas with visible oil contamination in the underlying soil (CIC 2003a, b). The focus of this report is on the areas defined within the UN Claim 5000450; therefore, herein the relevant material shall follow the UN definition and shall be referred to as "tarcrete".

Within the literature, damage to terrestrial resources from tarcrete only appears in relation to Kuwait and its formation as a result of the damaged oil wells during the Gulf War. Tarcrete is referenced in relation to the damage of Saudi Arabia's marine and coastal resources (Jones et al., 2008) but is otherwise limited to Kuwait.

3.3.1 Physical Characteristics

The known physical characteristics of tarcrete are limited to the details contained within its definition. The only studies which provide greater details of its physical attributes are CIC (2003b) and Grealish et al. (2001a, b).

CIC (2003b) expands on the continuity of tarcrete, making reference to continuous and fragmented pieces ranging from 0.65-1.25mm up to 2-6mm (Table 3-1). Conversely, Grealish et al. (2001a, b) provide in-depth details by describing tarcrete following a modified soil survey guideline. A summary is provided in Table 3-1. The following is an excerpt from the reports detailing a "typical [tarcrete] pedon"

"The T [tarcrete] *horizon has a* [black] *hue of 10YR, value of 2 and chroma of 1 (dry and moist colour). The texture is a mix of sand and solidified oil, 0 to 2% coarse fragments. Dry consistency is hard or very hard. Moist consistency is firm. Thickness ranges from 1 to 5cm, with a mean of 1cm. The layer can be peeled off the underlying soil like a mat. In some areas, this layer may be thin or broken due to degradation of less oil mist falling on the surface.* Grealish et al. (2001a, pp.148-149; b, pp.95-96).

Table 3-1 Summary of Tarcrete Physical Characteristics

Physical Characteristics	Literature Source		
	CIC, 2003b	**Grealish et al., 2001a**	**Grealish, et al., 2001a 2001b**
Constituents	NA	Soil solidified with oil	Soil solidified with oil with 0-30% gravel content
Thickness	Thin	0.7-1.9cm	0.5-1cm
Colour	Black	Black (10YR, Value of 2, Chroma of 1 (moist)	Black (10YR, Value of 2, Chroma of 1 (moist)
Cohesive/ Non-cohesive	Cohesive	Cohesive, can be peeled off surface like a mat	Cohesive, can be peeled off surface like a mat
Consistency	Malleable to hardened asphalt-like	Very hard dry consistency, non-sticky	Hard dry consistency, non-sticky
Subsurface Soil	Not visually oil-stained	Not visually oil-stained	Clean sandy soil (not visually oil-stained)
Continuity	Continuous or fragmented into coarse-grained sand particles (0.65-1.25 mm) and up to fine-gravel size pieces (2-6 mm)	Continuous or fragmented	Continuous or fragmented
Depth where buried (cm)	1-2	Not defined	Not defined
Occurrence on topography	No defined	All landscape positions	All landscape positions

Tarcrete deposition has been widely studied in order to determine its extent and distribution across the landscape (CIC 2003a, b; PAAC, 2002a, b) but little information is known on the influence of deposition distance on the characteristics of the material.

The deposition of tarcrete within Burgan is described as being "an almost solid sheet" and extends downwind (south-east) up to 13Km (CIC, 2003b). It is a layer with an average thickness of 1cm to 1.5cm (Grealish et al., 2001a, b; PACC, 2002a; CIC, 2003b) increasing up to 10cm near the centre of the deposition (PAAC 2002a, p.68).

3.3.2 Chemical Properties

Chemical properties of tarcrete has been primarily reported as the concentration of Total Petroleum Hydrocarbons (TPH) (Henry and Overton, 1993; Zuman and Al-Sdirawi, 1993; Puskas, Abdullah and Joseph 1995b; Guerinik et al., 2001; cited in CIC2003a; Grealish et al., 2001a, b; CIC, 2003b). However, only the CIC (2003b) and Grealish et al. (2001a, b) studies have sampled material that meets the UN definition of tarcrete. These two studies have used different analytical methods. CIC (2003b) utilised the United States Environmental Protection Agency (USEPA) SW 9071B which uses n-hexane as the extraction solvent (USEPA, 2004). Grealish et al. (2001a b) used USEPA method 418.1 which uses Trichlorotrifluoroethane to extract the hydrocarbons (Nadim et al., 2000). Although the use of two different analytical methods makes the results not directly comparable, CIC (2003b) determined that the methods yielded approximately the same results.

TPH concentrations from tarcrete samples collected within Burgan in 2001 was 29,000mg/kg, samples from the As-Sabryiah and Ar-Rawatayn Oilfields in 2001 was 21,000mg/kg (Grealish et al., 2001a, b) and samples covering all of Kuwait's oilfields and adjacent areas in 2003 was 22,006mg/kg TPH (CIC, 2003b).

TPH provides an indication of the level of oil contamination (Weiseman, 1998) whereas analysis of the hydrocarbon fractions provides information on toxicity and mobility (Weiseman, 1998). Previous studies that have examined the TPH composition include

polycyclic aromatic hydrocarbon[3] (PAH) characterization in CIC (2003b) and PAH and asphaltene concentration analysis in Henry and Overton (1993 cited in CIC, 2003a). The definition of tarcrete used within the latter study is unknown. Fractionated TPH analysis has not been previously tested.

PAHs are persistent and can be toxic and carcinogenic. They have low solubility in water and low vapour pressure (Albers, 2003). In CIC (2003b) a significant presence of PAH concentrations relative to clean soils was found in tarcrete. A mean concentration of 1,799.5mg/kg and 435.6mg/kg was detected in pure tarcrete samples and in soil with tarcrete fragments compared to 19.7mg/kg in the clean samples. Details of the PAHs found in the Henry and Overton, 1993 study (cited in CIC, 2003a) were unavailable. The summary noted that incomplete combustion had occurred with the resulting effect being a limited presence of PAHs in the material (CIC, 2003a). Samples were collected in early August 1991, whilst 300 wells were still burning (CIC, 2003a).

The CIC (2003a) summary of the 1993 Henry and Overton study revealed that mean asphaltene concentrations in the tarcrete samples (62.28%) were significantly higher than the source crude oil (3.5%) and oil lakes. Based on tarcrete and source crude chromatograms it was concluded that tarcrete comprised of few light alkanes and that limited biodegradation, if any, was occurring.

In addition to hydrocarbons, CIC (2003b) and Grealish et al. (2001a; b) analysed for some potentially toxic metals. CIC (2003b) analysed samples for cadmium, lead, nickel, potassium, vanadium and mercury and concluded that concentrations were "very low". A similar conclusion was drawn for lead, nickel and vanadium by Grealish et al. (2001a, b). Table 3-2 provides the mean concentrations of the metals analysed in each study.

[3] acenaphthylene, acenaphthene, anthracene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(a)anthracene, benzo(ghi)perylene, benzo(k)fluoranthene, chrysene, fluoranthene, fluorene, indeno(1,2,3-cd)pyrene, naphthalene, phenanthrene and pyrene.

Table 3-2: Mean Concentrations of Heavy Metals Found in Tarcrete Samples

Sample Location	Nickel (mg/kg)	Vanadium (mg/kg)	Lead (mg/kg)	Cadmium (mg/kg)	Mercury (mg/kg)	Potassium (mg/kg)	Reference
All Kuwait's oilfields and adjacent areas	18.71	16.83	2.179	0.19	0.0153	331	CIC, 2003b
Burgan Oilfield	12.07	9.91	2.93	-	-	-	Grealish et al. 2001a
As-Sabriyah and Ar-Rawdatyn Oilfields	18.71	16.83	2.25	-	-	-	Grealish et al. 2001b

Other chemical properties considered in the available studies include electrical conductance (CIC, 2003b and Grealish et al., 2001a, b), chloride and sulfate (CIC, 2003b). Mean chloride concentrations (1,503mg/kg-dry) and specific conductance (1,167µmhos/cm) were found to be significantly higher in tarcrete compared to clean soil samples (166mg/kg-dry and 132µmhos/cm in the surface layer) (CIC, 2003b). Mean sulfate concentrations (306mg/kg) were similar to clean soil (730mg/kg).

3.3.3 Weathering

As there has been no recent research on Kuwait's tarcrete, any changes to the contaminant that has occurred in the past decade is unknown. From the earlier literature two studies investigated the chemical properties of tarcrete over time: Puskas et al., 1995a (cited in CIC, 2003a) and Guerinik et al., 2001 (cited in CIC 2003a). Changes to the physical characteristics have not been specifically studied but are inferred from the available literature.

The Puskas et al., 1995a (cited in CIC, 2003a) study compared results from samples collected at 6 different times from 1991-1994 from the Greater Burgan and Raudhatain/Sabriyah

Oilfields. Analytical results of shallow depth samples (0cm to 2.54cm) indicated no change in higher molecular weight PAH but a mean decrease of approximately 70% (8.2%-13% to 1%-3.5%) in Total Extractable Matter (TEM) from 1991-1994. Analysis of the deeper samples (2.54cm to 5.08cm) did not show any changes and were comparable to background samples (0.01%-0.10%) (CIC, 2003a).

Guerinik et al., 2001 (cited in CIC 2003a) sampled from the same locations (in addition to others) from 1999-2001. Samples which correspond with the UN definition of tarcrete were those collected from "fallout" sites, areas where unburned petroleum as droplets (along with soot and smoke) covered the soil surface with a sticky crust up to 2.5cm (CIC, 2003a, p.12). Samples were collected from two depths (0cm to 2.54cm and 2.54cm to 5.08cm) and were analysed for TEM. Results were similar to the Puskas et al., 1995a (cited in CIC, 2003a) study indicating no further degradation had occurred (CIC, 2003a).

The physical descriptions of tarcrete remain unchanged throughout the literature (El-Baz, 1994 cited in PAAC, 2002a; Puskas et al., 1995a cited in CIC, 2003a; Grealish et al., 2001a, b; CIC, 2003a, b) suggesting no significant physical changes have occurred over the 11 year study period. The one exception is continuity across the landscape. CIC (2003a) describes tarcrete fragmentation in areas of disturbance (specific locations are not provided) and various remote sensing and ground-truthing studies (PAAC, 2002a; CIC, 2003a) report changes in its visual appearance citing sand encroachment (PAAC, 2002a; CIC, 2003a), changes in vegetation cover, volatilization, infiltration, weathering and natural degradation (PAAC, 2002a) as the cause.

3.3.4 Tarcrete Classification

To date tarcrete studies have been focused on understanding the contaminant as a whole. Its range of characteristics have been grouped together to create one entity, "tarcrete", in order to differentiate it from other oil contamination (soot, dry and wet oil) and provide a field description (Grealish et al., 2001a, b; CIC, 2002; CIC, 2003b). The possibility of classifying tarcrete based on trends corresponding between the chemical composition of tarcrete and its physical characteristics has not yet been explored.

3.4 *Climate*

Kuwait is an arid climate characterized by long dry hot summers and short mild winters. Precipitation is minimal and dust storms are frequent (AL-Awadhi and Al Shuaibi, 2013). During the summer the average ambient temperature is 37°C (Al-Awadhi and Al Shuaibi, 2013) with average daily highs ranging from 42°C to 46°C (Al-Jarallah and Aleisa, 2014). Temperatures over 50°C are not uncommon (Al-Awadhi and Al Shuaibi, 2013). From mid-August to October humidity can exceed 95% (Al-Jarallah and Aleisa, 2014). In the winter, the average air temperature is 17°C (Al-Awadhi and Al Shuaibi, 2013), ranging from 7°C to 21°C (Al-Jarallah and Aleisa, 2014).

The average annual rainfall ranges from 75mm to 150mm (Al-Jarallah and Aleisa, 2014), occurring from late October to early May with the majority falling in January. No precipitation occurs from June to September (World Climate, nd).

North-westerly winds account for 60% of Kuwait's wind direction (KISR, 2012; Al-Awadhi and Al Shuaibi, 2013) but Kuwait's wind pattern is based on the south-easterly winds (KISR, 2012; Al-Awadhi and Al Shuaibi, 2013), which happen predominately in early summer but can occur during winter (KISR, 2012). Kuwait experiences an average of 255.4 dusty days annually with average wind speeds of 4.8m/s (Al-Awadhi and Al Shuaibi, 2013).

3.5 *Geology / Geomorphology*

The geology of Kuwait typically comprises flat lying sedimentary rocks from the Tertiary age which overlay gently folded Cretaceous and Jurassic formations. These are described as the Fars and Ghar formations, which comprise a fluviatile sequence of ungraded often cross bedded sands and gravel, calcareous sandstone, sandy limestone and unconsolidated clay and sand (CIC 2002). The Dibdibba formation overlies the Fars and Ghar formations and is divided into upper and lower members. This formation consists of fluviatile sequence of ungraded cross bedded sands and gravels, or lenticular bodies of sandy clays, sandstones, conglomerate and siltstones.

The surface soils which can extend to 2m depth in Burgan, include a surface layer of 'lag deposits' (Quarternary deposits), which are a thin layer often weakly cemented by lime or

gypsum. The general landscape around Burgan is composed of recent eolian soil deposits that are influenced by sparse vegetation, gravel and gatch ('duricrust' comprising calcrete and silcrete precipitates (CIC 2002, Khalaf and Al-Ajmi 1993).

The surface topography surrounding Burgan is typically a featureless plain covered by sand. The Ahmadi Ridge to the north-east of the Study Area provides the maximum elevation in the area of 125m, whilst the Study Area typically lies at elevation of 70m, with shallow undulations ranging between 68m and 75m.

3.6 *Soils*

The Major Soil Group within the Study Area is Torripsamment (Figure A-3, Appendix A). These soils are typically deep and well drained and occur in central and south-eastern Kuwait (Omar et al., 2001, pp. 347-348).

Typic Torripsamments is the soil sub-group that covers approximately 75% of the Greater Burgan Oilfield which has been impacted by oil contamination resulting from the damaged wells (Grealish et al. 2001a). This sub-group is described as a loose sand between 0.5m and 1.5m depth, which is quartz dominant with minor calcite, microcline and albite. Whilst sand is the predominant component, silt and clay make up 2% to 10%; gravel is typically less than 15% (occasionally 35% in layers). The porosity of the sub-group ranges from 30% to 40% and surface infiltration rate is estimated to be 150mm/h to 300mm/h. Organic matter is low (0% to 0.5%). Calcium carbonate can range from 1% to 10% and gypsum is considered to be negligible. The typical pH for this sub-group is 7.5 to 8.5. (Grealish et al., 2001a).

3.6.1 Soils affected by Oil Contamination

Zaman and Alsdirawi (1993 cited in Grealish et al., 2001a) determined that Kuwait's soils, relative to oil concentrations, are high in potassium, calcium, magnesium, iron, nickel, barium, manganese and strontium. Sodium concentrations, attributed to the use of seawater to extinguish the well fires, were notably elevated in oil mist ("tarcrete") sites. Calcium, cobalt, lead, cadmium and mercury were found in similar concentrations in both oil and soil. Soil vanadium concentrations were less than that found in oil. Details on the type of oil contamination examined and the resulting concentrations were not provided and it is noted

that calcium was reported as having both similar and higher soil concentrations compared to oil.

Investigations into the impacts of tarcrete to the underlying soil are limited to Grealish et al. (2001a, b) and CIC (2003b), in which chemical analysis of the tarcrete is compared to the same analysis of the underlying soil. Grealish et al. (2001a, b) investigated the Greater Burgan and Raudhatin/Sabriyah Oilfields whereas CIC (2003b) investigated all Kuwait's oilfields and adjacent areas. Subsurface sample collection depths in Grealish et al. (2001a, b) were 10cm, 30cm, 50cm, 100cm and periodically 150cm and 200cm; however, the reports do not provide any data or discussion on subsurface sample results. In CIC (2003b) one subsample at a depth of 20cm was collected.

Statistical analysis on surface and subsurface samples of TPH, metals, anions and specific conductance concluded that no impacts to the subsurface soil had occurred as a result of the tarcrete (CIC 2003b). TPH (Table 3-3), anions and specific conductance was generally the same in the subsurface soils as their surface counterpart and metal concentrations were low in both surface and subsurface samples. Limited samples demonstrated elevated chloride, sulfate and specific conductance values in the subsurface soil. This was attributed to the use of seawater in extinguishing fires. The statistical differences between surface and subsurface PAH concentrations were not presented. Other than TPH concentrations, no subsurface analytical data was provided. Given that metal concentrations in tarcrete and subsurface soil samples were similar, it is considered that Table 3-2 in Section 3.3.2 provides an indication of the concentrations of analysed metals detected in the soil.

Table 3-3 TPH Concentrations in Surface and Subsurface Samples

Sample Location	Minimum Concentration (mg/kg)	Maximum Concentration (mg/kg)	Median Concentration (mg/kg)
Clean surface vs	50	2,120	89
subsurface	50	2,150	60
Soil with tarcrete (fragmented) surface vs	50	36,900	976
Subsurface	50	3,990	409
Tarcrete surface vs	79	135,000	19,100
Subsurface	4,220	40,400	14,900

Source: adapted from CIC, 2003b

The literature reports that tarcrete inhibits water infiltration and increase runoff thus affecting soil moisture (Grealish et al., 2001a, b; CIC, 2003c). No soil moisture data was provided or discussion on how this conclusion was determined. A remote sensing analysis study conducted in 2001 comparing pre and post war surface temperatures concluded that tarcrete sites showed higher surface temperatures than sites without tarcrete or with other contamination (e.g.; larger oil lakes) and infers that this temperature increase is occurring to the soil (Kwarteng 2001 cited in PAAC, 2002a, p.60). Colour Landsat Images were unavailable and a request for the full article was unsuccessful. Therefore, background temperatures or the actual temperature increase could not be verified.

3.7 *Water Resources*

There are no aquifers in the Study Area (PAAC, 2002a). Shallow groundwater systems present in the Greater Burgan Oilfield area are 'brackish' (Omar et. al., 1981 cited in PAAC 2002a) with approximately 10,000mg/L Total Dissolved Solids (TDS). To the west of Burgan in the At-Tawil oasis, the typical TDS measurement is 3,000mg/L (Kwarteng 2001 cited in PAAC 2002a).

There is an absence of surface water features within Kuwait (Grealish et al., 2001a) with the exception of standing water in local 'gatch pits'; excavations where natural bedrock material (gatch) has been quarried to the depth of the perched water table. Water often remains at the quarry base creating habitats for flora and fauna. An example of a 'gatch pit' with standing

water present throughout the year is located on the southern side of the Study Area (Figure A-5, Appendix A).

3.8 *Flora*

Desert flora are predominately annual species which exhibit a discontinuous spatial distribution as a mechanism to lessen the competition for water; the main limiting factor of germination and plant growth (Laity, 2008; Li, Li, Jiang et al., 2008). Annuals have shallow root systems which depend on the surface (2cm-10cm depth) soil moisture for germination and the deeper (10cm-30cm) moisture for growth (Laity, 2008).

The Study Area is covered by the Cyperetum vegetation unit (Figure A-4, Appendix A). It is characterized by the dominant occurrence of the perennial sedge *Cyperus conglomeratus* and annual herb species *Astragulas annularis, Brassica tournefortii and Plantago boissieri*. This unit develops in sandy locations with Torripsammet soils. *Cyperus conglomeratus* grows to be approximately 60cm in height and forms a dense cluster at its base. Hummocks of fine sand form at the base of these plants proving it to be an effective sand stabilizer (Omar, Misak, Sabbir et al., 2001, p.349).

Due to the harsh climate natural recovery in desert ecosystems is slow, making them vulnerable to disturbance (Lovich and Bainbridge, 1999; Abella, Chiquoine, Newton, et al., 2015). After a disturbance, annuals tend to recover more rapidly than perennials and an increase in the number of different species and the amount of cover tends to occur prior to the restoration of plant community structure (Abella, 2010).

From 1991-1992 a study on the impacts of “oil mist” (tarcrete) on vegetation within the Greater Burgan reported total vegetation cover being 2.63% compared to 14.02% in the control sites (Al-Ajimi et al., 1994 cited in CIC, 2003a). Conclusions from CIC, 2003c (p. 4) state that the solid oil accumulation (not specifically referring to tarcrete) impedes vegetation growth by burying seed banks, inhibiting germination and preventing seedling root systems to penetrate through the hardened oil. It is further stated that no significant re-vegetation in these areas could occur whilst this contamination is present. However, new plant

establishment and growth was observed occurring within the 1992 growing season (Zarman and Al-Sdirawi, 1993 cited in CIC, 2002).

CIC (2003c) discusses the existence of a progress report for a three-year vegetation and wildlife assessment study within the Greater Burgan undertaken by KISR as well as two other post-war terrestrial assessments; however, despite an online search and a formal request to KISR these reports were never located. More current studies on vegetation cover from within the Burgan Oilfield were not found.

3.9 *Fauna*

Desert fauna are an intrinsic component of vegetation establishment. They aid in seed dispersal, germination and enhance soil fertility by through altering soil properties (Laity, 2008).

The insect, arachnid and reptile communities in Kuwait are highly diverse (Clayton 1983 cited in PAAC, 2003a; Al Houty, 2011; Cox, et. al, 2012) whereas the residential bird community is low. However 300 to 390 avian species migrate through Kuwait annually (Omar, 2007; Omar et al., 2009; Pope and Zogaris, 2012). The mammal population has been reduced to between twenty and twenty-two indigenous species (Omar, 2000, cited in PAAC, 2002a; Cowan, 2013) which no longer includes large carnivores and ungulates (Cowan, 2013).

Impact studies on Kuwait's wildlife from the environmental damage caused by the Gulf War was not found for arachnids and mammal populations. Impacts to birds were identified as damage caused to coastal habitats (Gerges, 1993) and ongoing mortality caused by birds mistaking oil lakes for water (Omar et al., 2009). Studies conducted outside the oilfield concluded insignificant changes had occurred to the insect community (Al Houty, 2009). Not specifically related to impacts from the war, an International Union for Conservation of Nature (IUCN) database search on the conservation status of Kuwait's non-marine reptile population has identified the current community as having only one "vulnerable" species (*Uromastyx aegyptia*) and twenty-one species of "least concern" (IUCN, 2014).

Tarcrete impacts on the fringed-toed lizard *Acanthodactylus scutellatus* (*A. scutellatus*) (an indicator species for PAH accumulation) from within the Greater Burgan Oilfield have been studied by Al-Hashem, Brian and Omar (2007), Al-Hashem and Brian (2009a-c cited in Al-Hashem, 2011) and Al-Hashem (2009a, b, 2011). A summary of the key conclusions are:

- Concentrations of PAHs in the tissues of *A. scutellatus* and its prey was highest from tarcrete sites compared to soot and clear sites but went undetected in control sites. Detected levels may be harmful to their survival. Ingestion of contaminated prey was identified as a PAH source. "Clear [clean] sites" presented higher PAH levels than soot sites.
- Liver damage is occurring to specimens from tarcrete areas.
- Low concentrations of nickel and vanadium were detected in the tissues of *A. scutellatus* but may contribute to impacts on health and survival.
- Compared to soot and clean sites, *A. scutellatus* was least present at tarcrete locations whilst the presence of ant prey was highest. Possible factors affecting the population included control of the habitat by larger lizards and/or impacts from tarcrete (potentially PAHs).
- Adult males from tarcrete and soot sites were larger than those from the clear sites;
- Specimens from dark tarcrete sites were darker in colour and showed a preference towards dark coloured enclosures.
- Potential changes towards aggressive territorial behaviours in tarcrete sites not observed in soot, clean or control sites.

3.10 *Management Objectives*

3.10.1 Original F4 Recommendations

According to the original Panel recommendations the tarcrete covered areas in Burgan should be fragmented manually and treated with organic amendments to encourage recovery of the soil to accelerate and enhance on-going natural recovery. Monitoring UXO during the fragmentation process would be required. Re-vegetation would follow and include a programme of transplanting young plants (KNFP, 2011).

KNFP submitted a request for modification to use mechanical means for fragmenting tarcrete replacing manual fragmentation. Also included was removing the requirement for an organic amendment and transplantations, a re-seeding program was proposed instead (KNFP, 2011). This was not agreed at that time but was raised again as part of the 7th biannual report (KNFP, 2012) which was discussed in Geneva in February 2012 and formally accepted.

3.10.2 Implementation of Recommendations

It is currently proposed that mechanical fragmentation and seeding will be done using a Camel Pitter, a modified disk plough that breaks up the ground surface whilst applying seed (Figure 3-3).



Source: KIMSEED International Pty Ltd. (nd)

Figure 3-3: Camel Pitter on Tarcrete in Kuwait

Pitting has been previously applied to degraded arid lands to improve soil conditions and re-vegetation by increasing water infiltration and retention, reducing evaporation and promoting germination and seedling growth (Bainbridge, 1999, Chanani, Tavan and Hoseini, 2011).

Literature findings indicate that success has been limited in some settings. Those that are applicable to conditions in Burgan include: negligible increasing soil moisture on coarse textured soils (Houston, 1965 cited in Bainbridge, 1999) and in climates with similar precipitation patterns (Oliveria et al., 1987 cited in Bainbridge, 1999). The FAO (nd) review

on this technique has listed underlying hard crust as a constraint and notes that the potential for wind erosion would result following treatment until new plants establish to stabilise the soil. Results from the Kuwait trial (seen in Figure 3-3) are unavailable.

Whilst the majority of the exiting vegetation is retained using this methodology (FAO, nd), the health of its survival after treatment has not been researched. Studies have shown where existing vegetation was retained the success of the treatment was limited (Berlinger and Cammack, 1990 cited in Bainbridge, 1999) or similar to results gained from enclosing the area from disturbance (Chanani, Tavan and Hoseini, 2011).

3.10.3 Current Status of Modification Requests

More recently (June 2014) and after the start of this thesis, further requests for modification have been considered by KNFP. These include removing the requirement for remedial intervention of tarcrete within Burgan. The stakeholders are requesting that tarcrete be re-assessed in line with the site setting; i.e., given that tarcrete is within an industrial area, taking into consideration the level of risk to the environment following 24 years of weathering.

KNFP are currently considering submitting a request for modification to the Claim which includes;

- Undertaking UXO survey; and
- Further characterisation of tarcrete in its current weathered form.

The recommendation requests that following these activities there would be no further requirement for tarcrete remediation, subject to the findings of the characterisation. These discussions are still on-going.

4 Preliminary Conceptual Site Model

A preliminary CSM (Figure 4-1) has been developed as a tool to identify potential chemicals of concern (PCoCs) that may be released from the tarcrete and any possible transport mechanisms and exposure pathways that could potentially affect the soil, environmental media and fauna which may be detrimental to vegetation growth. This CSM is based on available Site information and results of previous investigations (Chapter 3). It is restricted to the objectives of this study and takes into consideration the management objectives (Section 3.10).

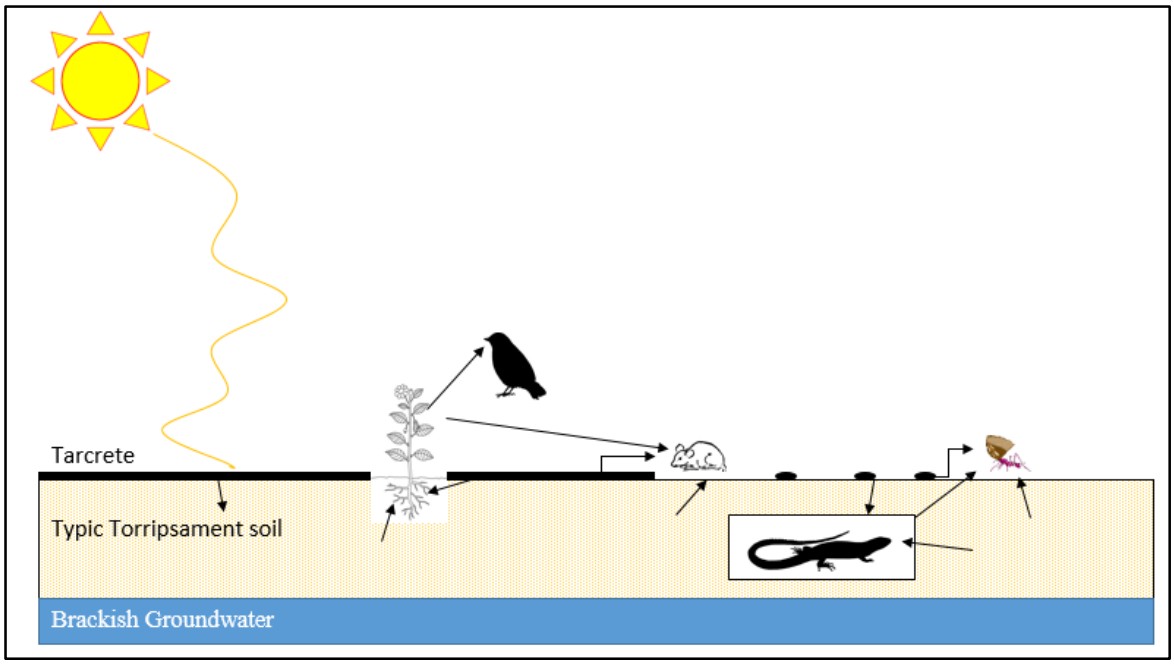


Figure 4-1: Preliminary Conceptual Site Model

4.1 *Source of Contamination and PCOCs*

The scope of this assessment is limited to the tarcrete affected land within TC-Pr3; therefore, tarcrete occurring within the Site was the only source of contamination considered in the CSM.

PCoCs within this CSM are hydrocarbons (all fractions, including heterocyclic hydrocarbons and PAHs) and the metals vanadium, cobalt, lead, cadmium and mercury. These chemicals have been identified as PCoC as they are constituents of tarcrete (Section 3.3) and can be

toxic to plants by impeding germination and growth (Sethy and Ghosh, 2013; Somtrakoon and Chouychai, 2013). In addition, PAH have been identified as bio-accumulating in the fauna as a result of tarcrete (Al-Hashem, Brian and Omar, 2007; Al-Hashem and Brian, 2009a cited in Al-Hashem, 2011).

Whilst previous studies have concluded no significant increases in metal concentrations within the soil resulting from tarcrete (CIC, 2003b), metals are considered within the CSM to provide updated information on tarcrete constituents that can be harmful to the identified receptors.

4.2 *Potential Receptors*

Receptors of potential concern (RoPC) is limited to soil and environmental media which, if impacted, may be detrimental to vegetation growth. Therefore, in addition to soil and vegetation, terrestrial organisms have been identified as RoPC. For analysis within the CSM fauna have been divided into soil invertebrates, reptiles, birds and mammals.

4.3 *Transport and Release Mechanisms and Potentially Affected Media*

Potential transport and release mechanisms that may occur on Site and the media which could be affected include:

- Dermal uptake by direct contact;
- Absorption by plant roots from direct contact;
- Ingestion of flora and fauna tissue which contains bio-accumulated PCoC;
- Leaching and erosion via surface water runoff and infiltration into the soil causing contamination via sorption; and
- Photodegradation of tarcrete causing soil contamination via sorption.

These mechanisms have been determined though consultation with risk assessment guidance (USEPA, 2003; USEPA, 2007a, b; Power et al. 2008; Connell et al. 2009) and literature sources on the characteristics of the individual PCoC (ATSDR, 2004; Venkatarman and Sudha 2005; ATSDR, 2007; ATSDR, 2008; CCME, 2008; CCME, 2010; ATSDR 2012, ATSDR, 2013, Sethy and Ghosh, 2013).

4.4 *Pathways*

Based on the transport and release mechanisms and the potentially affected media (Section 4.3), pathways of potential concern (PoPC) to the identified receptors (Section 4.2) are:

- Incidental ingestion of tarcrete and soil particulate by all mammals, birds and reptiles.
- Ingestion of PCoC by all mammals, birds and reptiles through contaminated food sources; and
- Direct contact (dermal exposure) with tarcrete and PCoC in the soil by invertebrates, reptiles, plants and mammals.

4.5 *Pollutant Linkages*

Each potential pollutant linkage (source, receptor, pathway connection) was evaluated to determine the possibility of occurrence (including via the management activities). Possible linkages considered to be of a likely risk are included within the Pathway-Receptor Diagram; unlikely risks have been excluded (Figure 4-2).

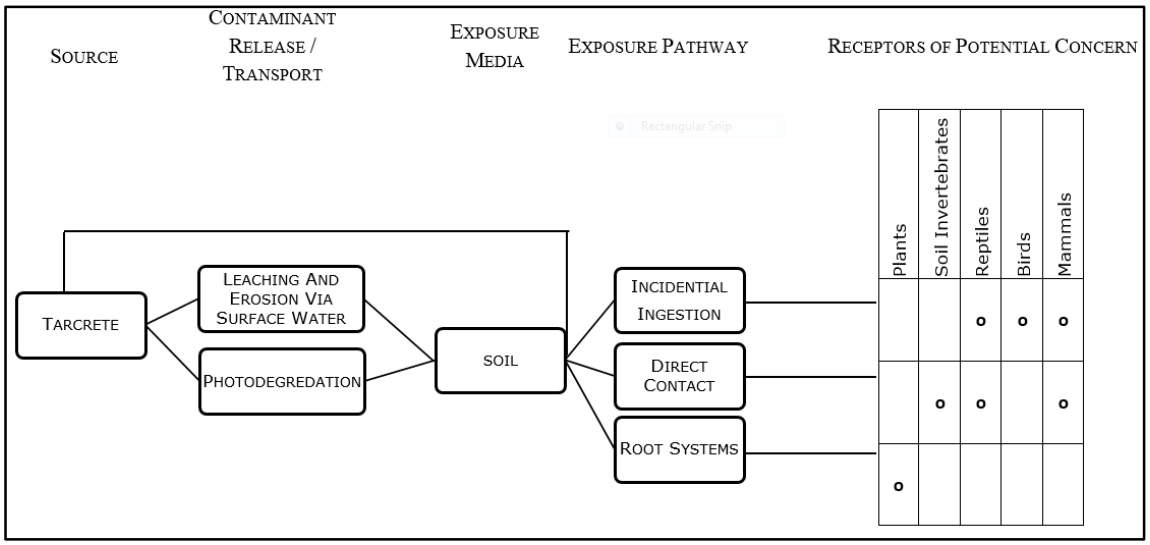


Figure 4-2: Preliminarily CSM Pathway-Receptor Diagram

4.5.1 Incidental Ingestion by Terrestrial Organisms

Incidental ingestion by terrestrial organisms relates to the ingestion of soil and tarcrete particulate and the dietary intake of contaminated food sources by mammals, birds and reptiles. Incidental ingestion by soil invertebrates is not considered here but is evaluated as

part of the dermal contact pollutant linkage by considering potential concentrations within the soil (USEPA 2007a; CCME, 2008).

It is acknowledged that bio-accessibility and bioaccumulation will vary among the PCoC and the receptor groups (USEPA, 2007a; Connell et al., 2009; CCME, 2010) and therefore the potential risk of this pollutant linkage will also vary. Notwithstanding, exposure to the PCoC by incidental ingestion of particulate and dietary exposure is considered a likely risk as this is a common pathway for wildlife (Connell et al., 2009, USEPA, 2003; CCME, 2010), the PCoCs have been identified on the Site (Chapter 3) and have the potential to be bioavailable to receptors (USEPA, 2007a; CCME, 2010). In addition, on-Site studies have demonstrated this pollutant linkage for PAH and *A. scutellatus* (Al-Hashem, Brian and Omar, 2007).

Implementing the management objective to fragment the tarcrete would potentially increase the level of risk associated with these exposure routes by increasing the amount of tarcrete particulate available for ingestion and uptake by prey species.

4.5.2 Direct Contact and Dermal Absorption by Terrestrial Organisms

The pollutant linkage of direct contact and dermal absorption to mammals and reptiles, and direct contact to soil invertebrates is considered a potential on-Site risk on the basis that these receptor groups are known to be on-Site and are in constant contact with the ground surface and therefore the tarcrete. This pollutant linkage also considers the exposure risk from food and incidental ingestion by soil invertebrates which is likely (USEPA, 2007a) and has been confirmed in one ant species (Al-Hashem, Brian and Omar, 2007). This linkage also has the potential to exist for burrowing receptors if the underlying soil has been contaminated.It is recognised that the level of risk is variable and may be negligible depending on the species (Gaines, Chow and Dyer, 2008) and the PCoC as each have varying levels of dermal uptake potential (USEPA, 2007a).

Direct contact with plant roots and uptake into the vegetation is considered under this pollutant linkage. It is considered a potential risk for some of the PCoC (Power et al., 2008) if the underlying soil has been contaminated.

Impacts to this pollutant linkage by fragmenting the tarcrete is anticipated to be negligible as the tarcrete will remain on-Site, creating little difference from the current situation.

4.6 *Assumptions*

The CSM includes the following assumptions:

- Human receptors are not considered within CSM as it is limited in scope to the potential impacts to soil and environmental media which may be detrimental to vegetation growth.
- Fauna were not subdivided into different groups based on feeding habits.
- Dust inhalation was not an identified PoPC as it is generally not a considered pathway for wildlife (Power et al., 2008).
- Influences of specific soil conditions (e.g.; pH) on metals were not considered. The CSM assumes metals in any possible state has the potential to be present.

4.7 *Information Gaps*

Information gaps identified from the CSM have been grouped into absent, deficient and outdated information.

Absent Data

- Bioaccumulation of PCoC in vegetation and bio-accessibility to terrestrial organisms.

Deficient Data

- Information on physical characteristics of tarcrete in relation to deposition from source.
- Status of the fauna community in tarcrete areas and potential impacts caused by tarcrete to these communities.

Outdated Information

- Physical characteristics, chemical properties and temporal changes to tarcrete.
- Physical properties of the soil underlying tarcrete.
- Impacts to the underlying soil as a result of tarcrete.
- Chemical properties of the soil underlying tarcrete.
- Current status of the vegetation community in tarcrete areas.

4.8 *Site Investigation*

Based on the objectives of this study and considering resource limitations (budget, time and labour) the following investigations were undertaken in order to fill information gaps and provide the necessary information required to evaluate the management plans.

Studies to determine the bioaccumulation of PCoC in vegetation and bio-accessibility to terrestrial organisms, as well as the current status of the fauna community in tarcrete areas and potential impacts caused by tarcrete, will not be undertaken due to resource limitations. An assessment on the necessity of these studies will be evaluated based on the current study results and discussed within the updated CSM (Chapter 8).

Field Survey

A ground survey was undertaken to provide information on tarcrete deposition from source wells, update physical characterization data and develop a standard for describing tarcrete.

A survey of the underlying soil was included to expand and update knowledge of the soil properties occurring under the tarcrete.

Soil Monitoring

Regular monitoring of soil temperature, moisture and electrical conductivity (EC) was undertaken to understand the effects tarcrete on these soil conditions and thus the underlying soil and potential vegetation establishment.

Intrusive Ground Investigation

An intrusive ground investigation was completed to augment and update tarcrete and underlying soil chemical data and assess any effects of weathering on tarcrete composition and potential soil impacts resulting from tarcrete.

Vegetation Survey

A vegetation survey to determine percent canopy cover was conducted to assess the current re-vegetation success in tarcrete areas to determine potential effects on vegetation recovery.

5 Methodology

The following sections describe the data collection and analysis process undertaken to carry out the site investigations.

5.1 *Field Survey*

Tarcrete and underlying soil descriptions were recorded along four, south-easterly line-transects that commenced at source wells (Figure 4-1). Transect locations were selected based on a desk review satellite maps (scale 1:24,000) and a ground reconnaissance exercise. Transect location criteria was: accessible source wells within the tarcrete areas that had limited overlap with other contaminated features and oil field operation facilities but included an area that was representative of the tarcrete contamination. The TMA line was selected because ground-truthing revealed the presence of tarcrete was limited in this area and therefore, had the potential to act in a similar manner as a 'control' site. Additionally, where tarcrete was present it occurred as tarcrete gravel, which was different to the continuous mat observed along the other transects. Transects that included the greatest area of UXO clearance were given the highest preference.

The distance of the transect lines are between 1.6km (TMA and TMC) and 2.8km (TMD). Transect line TMB is 1.65km. Transect lines TMA, TMB and TMD are positioned in parallel approximately 2km apart and terminate at the boundary fence, as illustrated in Figure A-5, Appendix A. To allow for variability in positioning, transect line TMC is set further back into the oilfield and terminates 1.65km from the source, with the end of the transect broadly in line with the start points of the three parallel transects. When undertaking early reconnaissance a distance of approximately 1.6km was considered to be the minimum distance required to illustrate changes in tarcrete deposition and characteristics.

In March 2014 the transect lines were demarcated (Figure A-5, Appendix A) and general observations on the presence of tarcrete, continuity, thickness and physical properties were recorded. Based on this initial survey and the available literature a draft *Guideline for Describing Tarcrete* ("Guideline") was developed (Section 5.2).

A second field survey event was undertaken in November and December 2014 during which the tarcrete and underlying soil descriptions was described every 100m along the transect lines (Figure A-5, Appendix A). Every 50m a visual check was completed to detect any changes. Tarcrete was described in accordance with the Guideline. The underlying soil was described in accordance with BS5930 (BSI, 1999). Topside, underside and cross-section photographs of the tarcrete layer and a cross-section of the underlying soil profile were taken to accompany the descriptions. Results of the survey are summarized in Section 6.1.8. Full transect descriptions and photographs are provided in Appendix B.

5.2 *Guideline for Describing Tarcrete*

A draft Guideline was developed. It is based on the UN definition of tarcrete (Section 3.3), Grealish et al. (2001a, b) "typical pedon" description, CIC (2003b) identification criteria (Section 3.3.1), reconnaissance observations recorded in March 2014 and by adapting guidance used to describe soils (FAO, 2006) and other geological features (Tucker, 2011).

The first step in developing the Guideline was a review of the definition to ensure it was representative of the material currently present. The UN definition was considered as the overarching guide but was modified to include elements, making the definition more comprehensive. The basis for the modifications were the Grealish et al. (2001a, b) characterization (Section 3.3.1) and field reconnaissance observations.

Alterations included the removal of the "thin oil crust" to include for gravel-like tarcrete that is not a crust and a more representative texture description, as provided in Grealish et al. (2001a, b) and confirmed during site surveys. "Thin" was removed from the definition as it is unnecessarily subjective; a quantitative measure can be obtained from tarmat and it does not apply to the gravel-like tarcrete. Colour (Grealish et al., 2001a, b) was also added as it was verified in the field to be applicable to all tarcrete samples. Elements of the Grealish et al. (2001a, b) definition that did not apply to both the mat-like and gravel-like tarcrete or was not represented every time tarcrete was encountered was not incorporated.

Preliminary observations identified two distinct categories of tarcrete (mat-like and gravel-like) each with varying individual characteristics that explained how it was encountered. For

mat-like tarcrete this included continuity and thickness, whereas for gravel-like tarcrete this included size, abundance and distribution. Including details of ground cover within the description provides information that can be related to how the tarcrete may be influencing the environment at that location (water infiltration and natural vegetation establishment) and potentially what chemical or fate and behaviour characteristics may be represented.

Grealish et al. (2001a, b) and the UN definition suggested that tarcrete was variable in consistency. Therefore, a consistency category was added. The UN defined consistency range provided the basis for the category. Formal definitions of the terminology used by the UN ("malleable, tar-like" and "hardened, asphalt-like") were developed and additional classes ('slightly malleable' and 'hardened') were established to provide a spectrum of classes across the category.

The inclusion of a consistency class within the Guideline was considered a necessary component as different consistencies may influence fate and transport properties. This attribute was considered only applicable to the mat-like tarcrete. Determination of consistency is based on a dry sample. This attribute was not considered applicable to gravel-like tarcrete. It was assumed the gravel-like tarcrete would be a hard consolidated mass, unaffected by elements that result in changing consistency such as increase in moisture content or exposure to heat (FAO, 2006).

To provide a more robust description of consolidation and the strength of the material, a friability category was added to supplement the 'hardened' consistency classes as these elements may provide an indication on the amount of degradation that is occurring and assist with identifying remedial options.

The draft Guideline was tested and refined during the November/December 2014 field survey (Section 6.2). The resulting final Guideline is presented in Section 6.1. Test results and alterations to the draft are discussed in Section 8.1.2.

5.3 *Selection of Monitoring Sites*

Sites (Figure A-5, Appendix A) were selected at different points along the transect lines at which monitoring, sampling and vegetation surveys were conducted. The sites were selected to represent different tarcrete and vegetation characteristics along the source well gradient. Accessibility and UXO clearance status also formed the basis of the selection criteria. Nine sites were selected on this basis, three along transects TMA and TMD, one along TMB and two along TMC.

5.4 *Soil Monitoring*

Soil temperature, soil moisture and EC were measured at a randomly selected location within a 5m radius of the monitoring site (Section 5.1 and Figure 4-1). Monitoring events were carried out from March 2014 until consistent null readings were being recorded. Soil temperature and EC were measured at a depth of 100mm using a Hanna HI98331 Direct Soil Conductivity and Temperature Meter. Soil moisture was measured at depths of 100mm and 200mm using an Extech M0750 Soil Moisture Meter. During each monitoring event the time, weather and ambient temperature were also recorded.

5.5 *Intrusive Ground Investigation*

On 13 December 2014 discrete samples of tarcrete and the underlying soil (or exposed soil where tarcrete was absent) were collected from random locations within a $5m^2$ radius at each monitoring site. Samples were collected using a stainless steel shovel and placed in laboratory issued 500ml glass jars. Samples were immediately transferred into an icebox where they were stored on ice packs until transferred to the laboratory. Tarcrete samples were collected from the surface and broken into pieces for placement into the collection jars. A 20cm deep trial pit was then dug using the shovel directly under the tarcrete or from the surface (in the absence of tarcrete) in order to collect the soil samples. Soil samples were composed of material spanning the 20cm depth profile. Tarcrete pieces, where present, were removed from the soil samples in order to ensure that only the chemical composition of the soil was analysed. Each sample was photographed and its properties described using the same methodology implemented during the field survey (Section 5.1). During sample collection soil temperature, soil moisture and EC were measured following the same methodology as described in Section 5.4.

The sample identification (ID) assigned corresponded to the name of the monitoring point (Figure A-5, Appendix A) and an assigned prefix based on the material type; "TC" was allocated to tarcrete samples and "SO" for soil samples. Results of the investigation are presented in Section 6.4. Sample descriptions and photographs are provided in Appendix D.

5.5.1 Laboratory Analysis

Samples were submitted to SGS Environmental Services laboratory in Saudi Arabia on 19 December 2014. Due to budgetary constraints not all samples were analysed nor was the full suite of analysis competed on each sample.

All samples were analysed for PAH and fractionated TPH in order to characterize the tarcrete and assess impacts to the underlying soil. TPH (fractionated) analysis was also used to assess effects of weathering. SARA analysis was conducted on three tarcrete samples. Two at similar distances from the well along transects TMB and TMD and a third along transect TMD to provide information on composition changes with distance from the well. One soil sample (from TMD-MP1) was analysed for SARA due to the high cost of the analysis. Metals in tarcrete were analysed from the three monitoring sites along the TMD in order to characterize the tarcrete and show changes with distance. All soil samples were analysed for metals with the exception of two. Soil samples analysed included locations with and without tarcrete, both gravel and tarmat. The soil samples were also analysed for parameters useful in determining soil health for plant growth; pH, nutrients, salinity levels (sodium absorption ratio or SAR) and percent moisture. A particle size analysis was undertaken to provide an indication on soil pathway properties and plant growth in terms of moisture retention. Testing was also selected to allow for an assessment of correlations between different physical and chemical characteristics (Table 5-4) in order to develop a tarcrete classification system.

The sample schedule of analysis for tarcrete and soil is provided in Table 5-1 and Table 5-2, respectively. Laboratory analytical methods for each test are summarized in Table 5-3. A copy of the chain-of-custody is provided in Appendix E.

Table 5-1: Tarcrete Schedule of Analysis

Tarcrete Field Sample ID	Analyte Name			
	Polycyclic Aromatic Hydrocarbons (PAH) (Speciated)	Total Petroleum Hydrocarbons (Fractionated)	TPH (SARA)	Metals (Ca, Cd, Hg, Pb, V, Co)
TC-TMA-MP2	X	X		
TC-TMB-MP1	X	X		
TC-TMC-MP2	X	X		
TC-TMC-MP3	X	X	X	
TC-TMD-MP1	X	X		X
TC-TMD-MP2	X	X	X	X
TC-TMD-MP3	X	X	X	X

Table 5-2: Soil Schedule of Analysis

Analyte Name	Field Sample ID					
	SO-TMA-MP1	**SO-TMA-MP2**	**SO-TMA-MP3**	**SO-TMB-MP1**	**SO-TMD-MP1**	**SO-TMD-MP2**
Polycyclic Aromatic Hydrocarbons (PAH) (Speciated)	x	x	x	x	x	x
Total Petroleum Hydrocarbons (fractionated)	x	x	x	x	x	x
TPH (Saturates, Aromatics, Resins, Asphaltenes)					x	
Electrical Conductivity (EC) (Salinity)	x	x	x	x	x	x
Percent Moisture	x	x	x	x	x	x
pH	x	x	x	x	x	x
Particle-Size Analysis	x	x	x	x	x	x
Sodium Adsorption Ratio (SAR)	x	x	x	x	x	x
Total Organic Carbon (TOC)	x	x	x	x	x	x
Nitrogen (TKN)	x	x	x	x	x	x
Phosphorous (P - Total)	x	x	x	x	x	x
Potassium (K)	x	x	x	x	x	x
Sulphate (SO_4^{2-} - Total)	x	x	x	x	x	x
Chloride (Cl^-)	x	x	x	x	x	x
Total Alkalinity as Calcium Carbonate ($CaCO_3$)	x	x	x	x	x	x
Metals (Cadmium, Cobalt, Mercury, Lead, Vanadium)	x	x			x	x

Table 5-3: Analytical Methods used in Laboratory Analysis

Analyte Name	Analytical Method
Total Petroleum Hydrocarbons (Fractionated)	EPA8015 + 8260
Fractionated Petroleum Hydrocarbons (>C35-C90)	EPA8015_8260_MAMTCA_ECY97_602
Polycyclic Aromatic Hydrocarbons (PAH) (Speciated)	EPA 8270C
SARA (Saturates, Aromatics, Resins, Asphaltenes)	IP 469/01 (2006)
Percent Moisture	ASTM D2216
pH	EPA 9045
Electrical Conductivity (EC) (Salinity)	EPA 120.1
Sodium Adsorption Ratio (SAR)	Calculated
Total Organic Carbon (TOC)	ISO 10964
Nitrogen (TKN)	EPA 351.2 Rev2
Phosphorous (P - Total)	EPA 365.4
Potassium (K)	APHA 3120 B
Sulphate (SO_4^{2-} - Total)	EPA 300.1
Chloride (Cl^-)	EPA 300.1
Calcium (Ca)	USEPA 6010
Total Alkalinity as Calcium Carbonate ($CaCO_3$)	APHA 2320 B
Metals (Cadmium, Cobalt, Mercury, Lead, Vanadium)	EPA6020A
Particle-Size Analysis	ISO 11277: 2009 (E)

5.6 *Tarcrete Classification System*

A Tarcrete Classification System was to be developed based on trends corresponding between the chemical data and described physical characteristics (as per the Guideline, Section 6.1). Sample chemical data to be used to represent the different physical traits are presented in Table 5-4.

Table 5-4: Physical Characteristics with Corresponding Sample ID

Physical Characteristics	Chemical Data Sample ID
Type	
Mat-like	TC-TMB-MP1 TC-TMC-MP2 TC-TMC-MP3 TC-TMD-MP1 TC-TMD-MP2 TC-TMD-MP3
Gravel-like	TC-TMA-MP2[1]
Continuity	
Continuous	TC-TMC-MP3 TC-TMD-MP2 TC-TMD-MP3 TC-TMB-MP1 TC-TMC-MP2
Broken	TC-TMD-MP1
Thickness	
Thickest	TC-TMD-MP1 (15mm)[2]
	TC-TMD-MP2 (15mm)[2]
↓	TC-TMC-MP3 (12mm)
	TC-TMD-MP3 (11mm)[2]
Thinnest	TC-TMB-MP1 (10mm)
	TC-TMC-MP2 (10mm)[2]
Consistency	
Soft	TC-TMD-MP2
Hardened	TC-TMB-MP1 TC-TMC-MP2 TC-TMC-MP3 TC-TMD-MP1 TC-TMD-MP3 TC-TMA-MP2
Friability	
Very Friable	TC-TMB-MP1 (very friable to friable)
Friable	TC-TMC-MP2 TC-TMC-MP3 TC-TMD-MP1 TC-TMD-MP2 TC-TMD-MP3
Hard	TC-TMA-MP2 (friable to hard)
Very Hard[3]	N/A
Extremely Hard[3]	N/A

[1] Only 1 sample analysed due to budgetary constraints. See 5.5.1 for sample selection. [2] Average thickness [3] No representative sample

5.7 *Effects of Weathering on Tarcrete Composition*

To determine the effects of weathering on tarcrete's composition the fractionated hydrocarbon data will be compared to data available via the literature review which describes weathering effects on both crude oil (Section 3.2.1) and tarcrete (Section 3.3.3). The results of this analysis are presented in Section 7.2 and disused in Section 8.2.

5.8 *Vegetation Survey of Canopy Cover*

Percent canopy cover was measured at the nine monitoring locations (Figure A-5, Appendix A) using a line-point intercept method (Herrick et al., 2005a) on 22, 28, 29 March 2014 and 4 and 5 April 2014. Plants were surveyed along three 50m transects set in a spoke design at approximately 120 degree angles. At 10m intervals a pointer rod was dropped vertically from a height of 0.5m, all living plant species that intercepted the pointer rod were recorded, always measuring from the same side of the line. The first species to intercept with the pointer-rod was recorded as the "Top Canopy" subsequent intercepting species were recorded as "Lower Canopy". Each canopy species was only recorded once. The surface soil (or tarcrete) on which the base of the pointer-rod landed was recorded as "Surface Soil".

Percent canopy cover was calculated using automated spreadsheets provided by The Jornada for use with the selected line-point intercept method. This method calculates percent canopy cover by adding up the total number of Top Canopy species (along a 50m transect line) and multiplying it by two (Herrick et al., 2005b). Bare ground, basal cover and litter are other indicators that can be calculated using this method as is an understanding of species composition. These were not included in the scope of this study as percent cover was deemed sufficient to determine vegetation recovery success. Vegetation survey results are presented in Section 6.5. Photographs of the vegetation transect lines are presented in Appendix F.

5.9 *Quality Assurance / Quality Control*

The following describes steps taken during the investigations to provide confidence in the data.

Field Procedures

Prior to soil monitoring events field equipment used to measure soil moisture, temperature and EC were checked and calibrated as necessary.

To minimise the potential for cross contamination during sampling events:

- Disposable gloves were worn and replaced for each sample collection.
- Sampling equipment was decontaminated prior to collection of each sample using a solution of anionic (non-phosphate) soap and potable water followed by a "clean" rinse using potable water.
- Single use sample containers provided by the laboratory was used to transport the samples.
- Sample temperatures in transit to laboratory was controlled by packaging in cool boxes and packing with frozen ice packs. The laboratory recorded sample received temperatures.
- Ordinarily duplicates, rinsate and trip blanks would have been analysed; however, this was not achievable with a small sample numbers and limited budget.

Analytical Results

Analysis was undertaken by SGS Laboratories, an internationally accredited laboratory who were successfully selected using KOC contracting procedures and are part of the list of approved suppliers.

Chain-of-custody documentation was completed to track delivery, possession and handling and ensure the correct parameters were analysed.

Data Review

Upon receiving the analytical data checks made on sample results revealed inconsistencies. The laboratory was requested to re-run a number of analyses to ensure results were compliant with methodologies. The revised results are used within the report.

All automated calculations performed on the vegetation survey data were manually verified.

6 Results

6.1 *Guideline for Describing Tarcrete*

The following Guideline has standardized the definition of tarcrete as well as the procedure and terminology by which tarcrete is described. Comprehensive explanations with supporting pictorial references (where available) and keys of the individual characteristics are provided. When describing tarcrete, characteristics should be referenced in the sequence presented in Figure 6-1.

The guide is structured to first describe tarcrete type (Section 6.1.2) followed by characteristics relating specifically to mat-like tarcrete: continuity (Section 6.1.3) and thickness (Section 6.1.4) followed by characteristics specific to gravel-like tarcrete: size (Section 6.1.5), abundance (6.1.6) and distribution (Section 6.1.7). Characteristics used to describe both types of tarcrete are within Sections 6.1.8 (consistency) and 6.1.9 (friability).

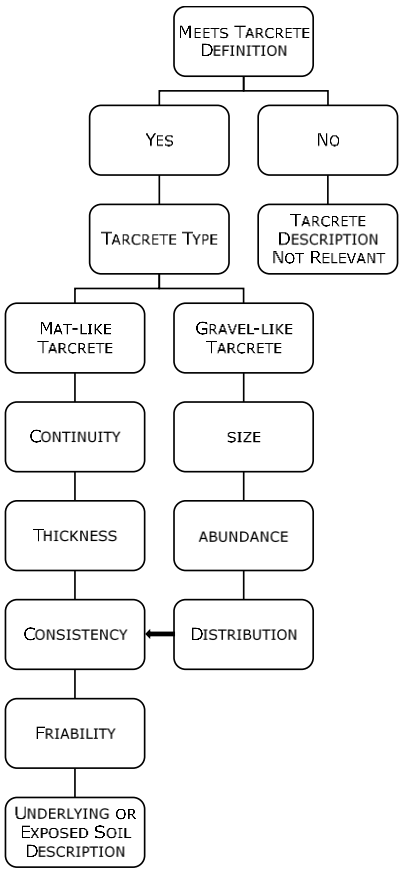


Figure 6-1: Tarcrete Description Process

Additional information that should be recorded includes, but is not limited to, general site information (location, coordinates, etc.), date, time, weather conditions, author, photographic records, distance from well and underlying soil descriptions. Soil should always be described following an applicable national or international standard.

6.1.1 Definition

Material classified as tarcrete must adhere to the following definition, which is an amalgamation of the UN Claim 5000450 definition and aspects of the Grealish et al. (2001a, b) description:

"*Oil contamination consisting of a coherent crust or gravel with no visible contamination of underlying soil. Tarcrete has a [black] hue of 10YR, value of 2 and chroma of 1 (dry and moist colour). The texture is a mix of sand and solidified oil with 0% to 2% coarse fragments, ranging in consistency from a malleable tar mat-like substance to a hardened asphalt-like substance".* Figure 6-2 and Figure *6-5* provides a visual representation of tarcrete, note the underlying soil has not been visually contaminated. Conversely, the material in Figure 6-3 is not tarcrete due to the visually contaminated underlying soil.



Figure 6-2: Tarcrete: No Visible Contamination to Underlying Soil



Figure 6-3: Not Tarcrete: Visible Contamination to Underlying Soil

6.1.2 Type

There are two types of tarcrete: mat-like (Figure 6-4) or gravel-like (Figure 6-5). Mat-like tarcrete can also be referenced as "Tarmat" and is identified as a consolidated layer that can be peeled off the soil like a mat (Grealish et al., 2001a, b). It varies in continuity, thickness, consistency and friability.

The gravel-like type should be referenced as "Tarcrete gravel". Tarcrete gravel is identified as pieces of tarcrete with no existing layer. Gravel-like tarcrete varies in size, abundance and distribution.



Figure 6-4: Mat-like Tarcrete



Figure 6-5: Gravel-like Tarcrete

6.1.3 Continuity

Continuity is used to describe the level of fragmentation occurring across mat-like tarcrete.

Continuity is grouped into three categories:

- Continuous: mat-like layer is more than 80% continuous (Figure 6-6)
- Fragmented: mat-like layer is 50-80% continuous (Figure 6-7)
- Broken: mat-like layer is <50% continuous (*Figure 6-8*)



Figure 6-6: Continuous Mat-like Tarcrete



Figure 6-7: Fragmented Mat-like Tarcrete



Figure 6-8: Broken Mat-like Tarcrete

6.1.4 Thickness

Mat-like tarcrete varies in thickness. Thickness is measured using a ruler (Figure 6-9) at several locations around the tarcrete piece to provide a range or average.



Figure 6-9: Measuring Mat-like Tarcrete

6.1.5 Size

Size is used to describe tarcrete gravel. There are three size categories based on the measured dimensions of the gravel:

- Fine: <10mm (Figure 6-10)
- Medium: 10-50mm (Figure 6-11)
- Coarse: >50mm (photographic example not available)

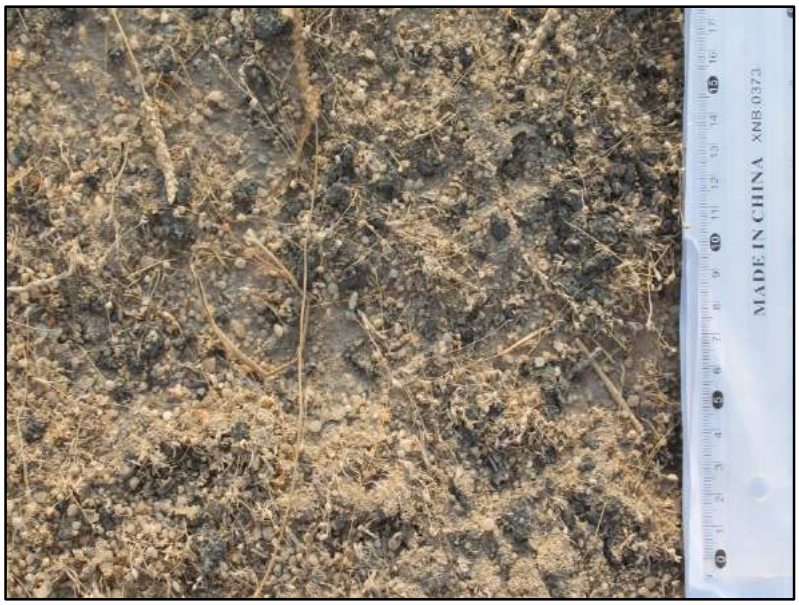


Figure 6-10: Fine Tarcrete Gravel



Figure 6-11: Medium Tarcrete Gravel

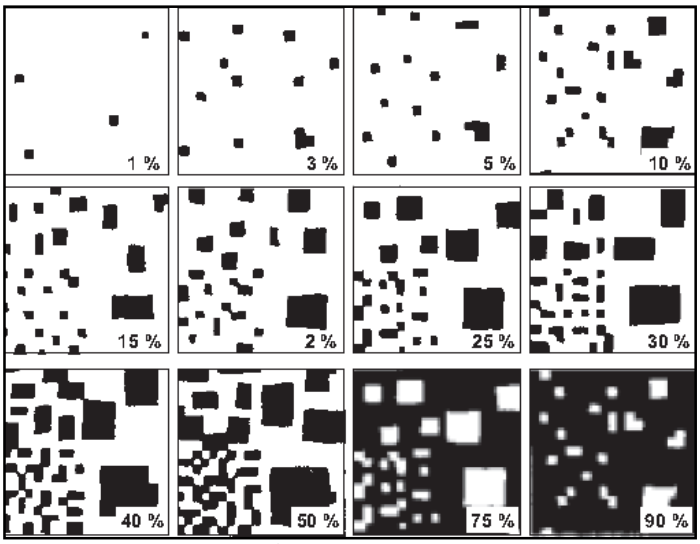
6.1.6 Abundance

Abundance is an estimate of the percentage of tarcrete gravel cover over an area or by volume. Categories of abundance are:

- Abundant: 75-100% (photographic example not available)
- Moderately abundant: 50-75% (photographic example not available)

- Sparse: 25-50% (Figure 6-13)
- Very sparse <25% (Figure 6-14)

Figure 6-12 (FAO, 2006) provides a tool for estimating abundance. When selecting a category, include an estimation of the percentage within the category that is present on-site. For example: "very sparse (approximately 1%)".



Source: Guideline for Soil Descriptions (FAO, 2006, p. 30)

Figure 6-12: Visual Representation of Abundance



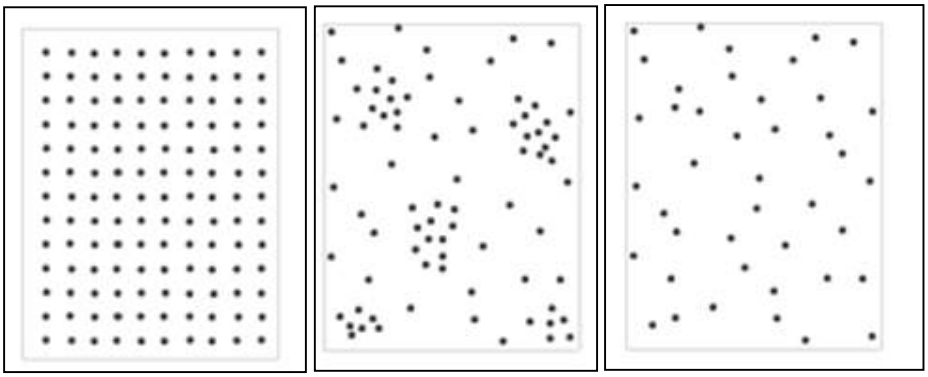
Figure 6-13: Sparse Tarcrete Gravel Abundance



Figure 6-14: Very Sparse Tarcrete Gravel Abundance

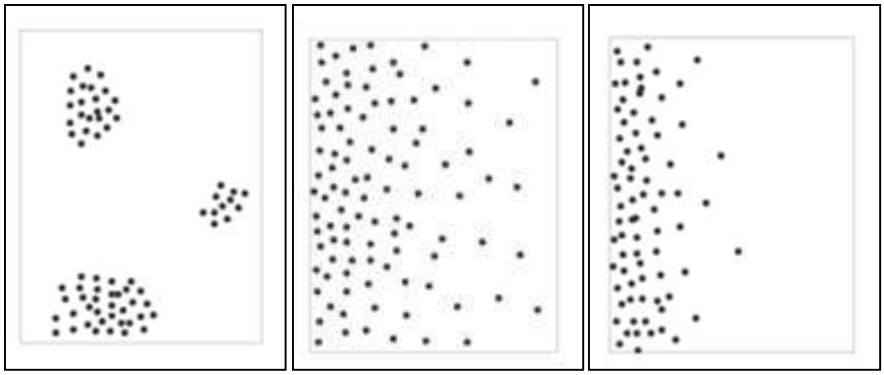
6.1.7 Distribution

Distribution is used to describe the way in which the tarcrete gravel is spread across an area. The categories of distribution are even and uneven. Even and uneven distributions can range in appearance on the ground. Figure 6-15 and Figure 6-16 provides examples of possible arrangements. Photographic examples are seen in Figure 6-13 (even) and Figure 6-17 (uneven).



Adapted from: University of Sydney, 2010

Figure 6-15: Examples of Even Distribution of Tarcrete Gravel



Adapted from: University of Sydney, 2010

Figure 6-16: Examples of Uneven Distribution of Tarcrete Gravel



Figure 6-17: Uneven Distribution of Tarcrete Gravel

6.1.8 Consistency

Tarcrete by definition varies in consistency from a malleable tar-like to hardened asphalt-like material. Based on these descriptions, a consistency gradient was developed:

- Malleable, Tar-like: sticky, easily bent without breaking into pieces
- Slightly Malleable: still tar-like and sticky. Does not break into pieces but is not easily bent.

- Soft: no longer tar-like or sticky. Firm to touch but can be indented with thumb pressure. Cannot be bent without breaking. Generally has firm top crust with bitumen underside which leaves a black to brown residue on fingers.
- Hardened: firm and ridged. Cannot be dented with thumb pressure. Cannot be bent without breaking. Bitumen underside may be present.
- Hardened, Asphalt-like: hard and unyielding to pressure; cannot be broken into pieces with fingers. Bitumen underside generally not present.

6.1.9 Friability

Friability is used to describe how easily tarcrete with a soft or hardened consistency can be broken into pieces. Categories of friability are adapted from sedimentary rock texture descriptions (Tucker, 2011, pp. 97-98):

- Very Friable: Crumbles easily between fingers
- Friable: Easily broken
- Hard: Grains can be separated from sample with penknife. Breaks easily when hit with hammer
- Very Hard: Grains are difficult to separate with a penknife. Difficult to break with hammer
- Extremely Hard: Sharp, hard hammer blow required. Sample breaks across most grains

6.2 *Field Survey*

The following is a summary of the field survey findings. All distances are reported from the source well (measured as 0m). 1:30,000 scale drawings of the transects are provided in Appendix A Figures A-4-1 to A-4-4.Detailed descriptions and photographs of the tarcrete at each 100m point along the transect lines are provided in Appendix B.

6.2.1 Transect TMA

Transect TMA was surveyed on 29 November 2014. The weather was sunny, clear sky, moderate north-westerly wind, with ambient air temperatures ranging from 20°C to 25°C. Heavy rains had occurred throughout the week.

The transect length is 1600m from the source well to the oilfield boundary fence. The first occurrence of tarcrete is at approximately 353m from the source well. Tarcrete is not present from 0m to 353m and from 1500m to 1600m. 0m to 80m is made/disturbed ground for the well pad, 80m to 353m is dry oil lake and from 1500m to 1600m is a gatch road to the boundary fence.

Tarcrete along transect TMA was gravel-like, fine to medium in size, very sparse (<1% to 1%), uneven, hardened, very friable. Deviations included: an increase in abundance to between 5% and 10% from 500m to 900m; even distribution was observed from 600m to 800m and friability changed at 1100m to 1500m becoming 'friable' and at 968m to 1000m turning 'friable to very friable'. From 505m to 600m sporadic mat-like tarcrete (hardened, friable, 10mm) was observed.

The underlying soil (all locations) was yellowish brown fine to medium quartz SAND AND SILT. Occasional organic matter was present in the soil from 1000m to 1500m.

6.2.2 Transect TMB

Transect TMB was surveyed on 6 and 12 December 2014. On 6 December 2014 the weather was sunny, clear sky, no wind with an ambient air temperature of 22°C. Weather throughout the week had been similar. On 12 December 2014 the weather was sunny, clear sky, moderate north-westerly wind with ambient air temperatures ranging from 25°C to 26°C. The weather throughout the week was humid and damp.

The transect length is 1646m. The first occurrence of tarcrete was at approximately 150m from the source well. Tarcrete was absent along several lengths due to the following:

- 0m to 50m and 1022m to 1080m was made/disturbed ground for the drill pad
- 50m to 150m was a contaminated soil pile
- 540 to 595m and 872m to 898m was disturbed ground/gatch road
- 595m to 704m and 1000m to 1022m was a dry oil lake
- 743m to 800m was a pipeline track (disturbed ground)
- 1630m to 1646m was a gatch road to the boundary fence

Tarcrete along TMB was mat-like tarcrete, 4mm to 30mm, continuous, hardened, friable. Deviations of continuity were observed from 500m to 540m where the tarcrete became fragmented. Changes to a soft consistency was noted from 200m to 300m, 1150m to 1300m and 1400m to 1500m. Friability changes were noted from 450m to 500m where the tarcrete became very friable changing to friable to hard from 500m to 540m.

The underlying soil was predominately light yellowish brown fine to medium quartz SAND. Organic matter was present in the soil from 450m to 540m, 1100m to 1150m and 1300m to 1500m.

6.2.3 Transect TMC

Transect TMC was surveyed on 6 and 13 December 2014. On 6 December 2014 the weather was sunny, clear sky, no wind with an ambient air temperature of 22°C. Weather throughout the week had been similar. On 13 December 2014 the weather was sunny, clear sky, light south-easterly wind increasing to moderate throughout the day with an ambient air temperature of 25°C. The weather throughout the week was humid and damp.

The transect length is 1600m. The first occurrence of tarcrete was at approximately 289m from the source well. Tarcrete was absent along several lengths due to the following:

- 0m to 52m was made/disturbed ground for the well pad
- 52m to 289m was a dry oil lake
- 380m to 500m was a disturbed area housing oil field facilities
- 371m to 380m, 780m to 820m, 975m to 1026m, 1193m to 1267m, 1467m to 1481m and 1557m to 1589m were gatch roads

Tarcrete observed along the TMC transect was mat-like, 4-7mm, continuous (>80% ground cover) hardened and friable. Deviations included a soft consistency from 700m to 780m and soft to hard consistency from 1500m to 1600m. The tarcrete became very friable to friable from 1400m to 1600m.

The underlying soil was predominately light yellowish brown fine to medium quartz SAND with trace organic material embedded into the soil. A SILT component was noted from 1500m to 1600m.

6.2.4 Transect TMD

Transect TMD was surveyed on 28 November 2014. Weather was sunny, partly cloudy, slight north-westerly wind, with the ambient temperature ranging from 25°C to 27°C. Heavy rains occurred throughout the week.

The transect length is 2970m. The first occurrence of tarcrete was at approximately 186m from the source well. Tarcrete was absent along several lengths due to the following:

- 0m to 150m was made ground for the well pad
- 150m to 186m and 249m to 300m was a dry oil lake
- 650m to 1050m was gatch road and disturbed area for oil field facilities
- 1795m to 1810m disturbed ground/gatch road
- 1900m to 2350m was a dry oil lake/disturbed ground
- 2900m to 2970m was a gatch road to the boundary fence.

Tarcrete along transect TMD is mat-like tarcrete, continuous (>80% ground cover), 5mm to 25mm, hardened, friable. Exceptions included a change in tarcrete type to gravel-like tarcrete from 2700m, a change to soft consistency from 300m to 400m and 1600m to 1795m and again from 1812m to 1900m where it was soft to hard. The tarcrete changed to very friable from 186m to 249m and 1250m to 1400m and again from 2500m to 2650m where it was very friable.

The underlying soil was predominately pale brown slightly gravely silty SAND. Gravel is quartz rounded to sub-angular, fine. A trace CLAY content was recorded from 1500m to 1812m and again from 2500m onwards. Soil colour changed to light yellowish from 1300m to 1600m and 2700m onwards, to very pale brown from 1700m to 1812m and yellowish brown from 2400m to 2700m.

6.3 *Soil Monitoring*

Measurements of soil temperature, moisture and EC occurred at each monitoring site weekly from March to May, bi-monthly in June and July and once in August 2014. One exception was at TMB-MP1 which was only measured twice in March 2014. The resulting monthly minimum, maximum, average and standard deviation for each monitored parameter has been tabulated and presented in each of the following subsections. Complete data sets are provided in Appendix G.

In addition to a summary of the soil monitoring data, tarcrete and soil descriptions collected during the intrusive investigation are provided.

6.3.1 Monitoring Site TMA-MP1

At monitoring site TMA-MP1 the tarcrete is gravel, fine, very sparse (less than 1%), uneven, hardened, friable to hard. Soil is yellowish brown fine to medium silty SAND.

Table 6-1: TMA-MP1 Monthly Soil Temperature Descriptive Statistics

	Soil Temperature (^{0} C)					
	March	**April**	**May**	**June**	**July**	**August**
Minimum	24.6	29.9	36.8	39.3	44.7	43.2
Mean	28.9	35.1	40.3	42.2	46.1	43.2
Maximum	34.0	41.1	42.5	45.0	47.5	43.2
Standard Deviation	4.2	4.7	2.6	4.0	2.0	NA

Table 6-2: TMA-MP1 Monthly Moisture Descriptive Statistics

	Moisture at 100mm (%)						**Moisture at 200mm (%)**					
	March	**April**	**May**	**June**	**July**	**August**	**March**	**April**	**May**	**June**	**July**	**August**
Minimum	0.2	0.0	0.0	0.0	0.0	0.0	2.7	0.0	0.0	0.0	0.0	0.0
Mean	3.1	0.1	0.0	0.0	0.0	0.0	5.4	1.1	0.3	0.0	0.0	0.0
Maximum	7.7	1.5	0.4	0.0	0.0	0.0	7.2	2.3	1.1	0.0	0.0	0.0
Standard Deviation	3.2	0.9	0.2	0.0	0.0	NA	1.9	1.3	0.6	0.0	0.0	NA

Table 6-3: TMA-MP1 Monthly Electrical Conductivity Descriptive Statistics

Electrical Conductivity at 100mm (mS/cm)						
	March	**April**	**May**	**June**	**July**	**August**
Minimum	0.01	0.00	0.00	0.00	0.00	0.00
Mean	0.03	0.02	0.00	0.00	0.00	0.00
Maximum	0.05	0.03	0.01	0.00	0.00	0.00
Standard Deviation	0.02	0.01	0.01	0.00	0.00	NA

6.3.2 Monitoring Site TMA-MP2

At monitoring site TMA-MP2 tarcrete is gravel, fine to medium, very sparse (approximately 5%) uneven, hardened, very friable. Soil is yellowish brown fine to medium SAND AND SILT. Occasional organic matter.

Table 6-4: TMA-MP2 Monthly Soil Temperature Descriptive Statistics

	Soil Temperature (^{0} C)					
	March	**April**	**May**	**June**	**July**	**August**
Minimum	23.5	31.3	37.7	40.3	45.7	43.5
Mean	29.3	29.3	35.4	40.3	42.2	43.5
Maximum	33.6	38.3	42.7	44.0	45.8	43.5
Standard Deviation	4.2	3.3	2.2	2.6	0.1	NA

Table 6-5: TMA-MP2 Monthly Moisture Descriptive Statistics

Moisture at 100mm (%)							Moisture at 200mm (%)					
	March	**April**	**May**	**June**	**July**	**August**	**March**	**April**	**May**	**June**	**July**	**August**
Minimum	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Mean	1.2	1.2	1.4	0.0	0.0	0.0	3.3	3.3	1.9	0.0	0.0	0.0
Maximum	2.8	3.5	0.0	0.0	0.0	0.0	5.7	3.8	0.0	0.0	0.0	0.0
Standard Deviation	1.4	1.5	0.0	0.0	0.0	NA	2.4	1.6	0.0	0.0	0.0	NA

Table 6-6: TMA-MP2 Monthly Electrical Conductivity Descriptive Statistics

Electrical Conductivity at 100mm (mS/cm)[4]						
	March	**April**	**May**	**June**	**July**	**August**
Minimum	0.00	0.00	0.00	0.00	0.00	0.00
Mean	0.04	0.02	0.00	0.00	0.00	0.00
Maximum	0.02	0.02	0.01	0.00	0.00	0.00
Standard Deviation	0.02	0.01	0.00	0.00	0.00	NA

6.3.3 Monitoring Site TMA-MP3

No tarcrete is present at TMA-MP3. Soil is yellowish brown fine to medium SAND AND SILT. Occasional organic matter.

Table 6-7: TMA-MP3 Monthly Soil Temperature Descriptive Statistics

	Soil Temperature (^{0} C)					
	March	**April**	**May**	**June**	**July**	**August**
Minimum	24.5	29.7	32.4	29.7	41.6	42.5
Mean	28.1	32.9	35.5	38.8	42.2	42.5
Maximum	30.1	35.4	37.9	40.6	42.8	42.5
Standard Deviation	2.7	2.5	2.3	2.5	0.8	NA

Table 6-8: TMA-MP3 Monthly Moisture Descriptive Statistics

	Moisture at 100mm (%)						Moisture at 200mm (%)					
	March	**April**	**May**	**June**	**July**	**August**	**March**	**April**	**May**	**June**	**July**	**August**
Minimum	45.5	21.2	11.2	10.1	0.9	9.3	>50	30.1	12.7	12.7	19.6	17.1
Mean	48.5	35.5	23.5	12.4	5.5	9.3	NA	NA	NA	18.6	19.9	17.1
Maximum	49.9	48.5	44.0	14.6	10.1	9.3	>50	>50	>50	21.8	20.1	17.1
Standard Deviation	2.0	12.8	14.6	3.2	6.5	NA	NA	NA	NA	4.6	0.4	NA

[4] Result of 0.49mS/cm from 4 May 2015 has been excluded. Value has been identified as an outlier (greater than the interquartile range) using a five number summary test. Result attributed to instrument reading error.

Table 6-9: TMA-MP3 Monthly Electrical Conductivity Descriptive Statistics

Electrical Conductivity at 100mm (mS/cm)						
	March	**April**	**May**	**June**	**July**	**August**
Minimum	0.59	0.59	0.28	0.09	0.16	0.04
Mean	1.42	1.07	0.52	0.31	0.17	0.04
Maximum	2.49	1.53	0.85	0.52	0.17	0.04
Standard Deviation	0.79	0.51	0.28	0.30	0.01	NA

6.3.4 Monitoring Site TMB-MP1

Tarcrete at monitoring site TMB-MP1 is tarmat, continuous, 10mm, hardened, very friable to friable. Soil is light yellowish brown fine to coarse silty SAND. Occasional organic matter.

Table 6-10: TMB-MP1 Monthly Soil Temperature Descriptive Statistics

	Soil Temperature (^{0} C)					
	March	**April**	**May**	**June**	**July**	**August**
Minimum	30.0	32.9	34.3	41.4	47.2	44.6
Mean	33.0	36.8	41.7	43.6	47.9	44.6
Maximum	36.0	44.1	47.2	45.7	48.5	44.6
Standard Deviation	4.2	5.0	5.5	3.0	2.0	NA

Table 6-11: TMB-MP1 Monthly Moisture Descriptive Statistics

Moisture at 100mm (%)							**Moisture at 200mm (%)**					
	March	**April**	**May**	**June**	**July**	**August**	**March**	**April**	**May**	**June**	**July**	**August**
Minimum	0.3	0.0	0.0	0.0	0.0	0.0	4.3	0.0	0.0	0.0	0.0	0.0
Mean	1.1	0.2	0.8	0.0	0.0	0.0	5.2	0.8	2.7	0.0	0.0	0.0
Maximum	1.8	0.7	2.3	0.0	0.0	0.0	6.0	1.6	8.1	0.0	0.0	0.0
Standard Deviation	1.1	0.3	1.1	0.0	0.0	NA	1.2	0.9	3.8	0.0	0.0	NA

Table 6-12: TMB-MP1 Monthly Electrical Conductivity Descriptive Statistics

Electrical Conductivity at 100mm (mS/cm)						
	March	**April**	**May**	**June**	**July**	**August**
Minimum	0.00	0.00	0.00	0.00	0.00	0.00
Mean	0.02	0.01	0.02	0.00	0.00	0.00
Maximum	0.03	0.02	0.04	0.00	0.00	0.00
Standard Deviation	0.02	0.01	0.02	0.00	0.00	NA

6.3.5 Monitoring Site TMC-MP2

Tarcrete at monitoring site TMC-MP2 is tarmat, continuous, 8-12mm, hardened, friable. Soil is light yellowish brown fine to medium SAND.

Table 6-13: TMC-MP2 Monthly Soil Temperature Descriptive Statistics

	Soil Temperature (^{0} C)					
	March	**April**	**May**	**June**	**July**	**August**
Minimum	22.5	32.2	36.6	44.0	45.2	42.9
Mean	30.9	36.2	40.4	44.0	45.7	42.9
Maximum	37.4	40.8	43.0	44.0	46.2	42.9
Standard Deviation	6.2	3.5	2.7	0.0	1.7	NA

Table 6-14: TMC-MP2 Monthly Moisture Descriptive Statistics

	Moisture at 100mm (%)						Moisture at 200mm (%)					
	March	**April**	**May**	**June**	**July**	**August**	**March**	**April**	**May**	**June**	**July**	**August**
Minimum	2.2	0.0	0.0	0.0	0.0	0.0	7.1	0.0	0.0	0.0	0.0	0.0
Mean	4.5	1.2	1.3	0.0	0.0	0.0	7.4	3.2	2.6	0.5	0.0	0.0
Maximum	7.3	2.4	5.1	0.0	0.0	0.0	7.8	7.4	8.3	1.0	0.0	0.0
Standard Deviation	2.5	1.0	2.5	0.0	0.0	NA	0.4	3.1	3.8	0.7	0.0	NA

Table 6-15: TMC-MP2 Monthly Electrical Conductivity Descriptive Statistics

Electrical Conductivity at 100mm (mS/cm)						
	March	**April**	**May**	**June**	**July**	**August**
Minimum	0.02	0.00	0.00	0.00	0.00	0.00
Mean	0.03	0.03	0.01	0.00	0.00	0.00
Maximum	0.05	0.04	0.01	0.00	0.00	0.00
Standard Deviation	0.01	0.02	0.01	0.00	0.00	NA

6.3.6 Monitoring Site TMC-MP3

Tarcrete at TMC-MP3 is tarmat, continuous, 12mm, hardened, friable. Soil is yellowish brown fine to medium SAND. Occasional organic matter.

Table 6-16: TMC-MP3 Monthly Soil Temperature Descriptive Statistics

	Soil Temperature (^{0} C)					
	March	**April**	**May**	**June**	**July**	**August**
Minimum	22.4	33.8	39.3	42.6	45.7	44.9
Mean	29.4	37.3	41.1	43.1	46.4	44.9
Maximum	34.7	43.0	42.8	43.5	47.0	44.9
Standard Deviation	5.1	4.0	1.4	0.6	1.1	NA

Table 6-17: TMC-MP3 Monthly Moisture Descriptive Statistics

	Moisture at 100mm (%)						**Moisture at 200mm (%)**					
	March	**April**	**May**	**June**	**July**	**August**	**March**	**April**	**May**	**June**	**July**	**August**
Minimum	1.1	0.0	0.0	0.0	0.0	0.0	4.0	0.0	0.0	0.0	0.0	0.0
Mean	3.5	1.9	2.9	0.0	0.0	0.0	6.2	4.1	3.2	4.7	0.0	0.0
Maximum	3.5	1.9	2.9	0.0	0.0	0.0	8.7	7.5	9.3	9.3	0.0	0.0
Standard Deviation	2.7	2.5	5.9	0.0	0.0	NA	2.2	3.9	4.2	6.6	0.0	NA

Table 6-18: TMC-MP3 Monthly Electrical Conductivity Descriptive Statistics

Electrical Conductivity at 100mm (mS/cm)						
	March	**April**	**May**	**June**	**July**	**August**
Minimum	0.01	0.00	0.00	0.00	0.00	0.00
Mean	0.03	0.01	0.04	0.01	0.00	0.00
Maximum	0.05	0.02	0.13	0.02	0.00	0.00
Standard Deviation	0.02	0.01	0.06	0.01	0.00	NA

6.3.7 Monitoring Site TMD-MP1

Tarcrete at monitoring site TMD-MP1 is tarmat, broken, 8-12mm, hardened, friable to gravel, medium, moderately abundant, uneven. Soil is light yellowish brown fine to silty SAND. Occasional organic matter.

Table 6-19: TMD-MP1 Monthly Soil Temperature Descriptive Statistics

	Soil Temperature (^{0} C)					
	March	**April**	**May**	**June**	**July**	**August**
Minimum	19.3	32.3	32.5	38.5	45.9	45.0
Mean	27.3	34.9	39.2	41.9	46.0	45.0
Maximum	33.3	41.2	43.2	45.3	46.0	45.0
Standard Deviation	6.1	4.2	4.7	4.8	0.6	NA

Table 6-20: TMD-MP1 Monthly Moisture Descriptive Statistics

	Moisture at 100mm (%)						**Moisture at 200mm (%)**					
	March	**April**	**May**	**June**	**July**	**August**	**March**	**April**	**May**	**June**	**July**	**August**
Minimum	0.7	0.0	0.0	0.0	0.0	0.0	2.5	5.3	0.0	0.0	0.0	0.0
Mean	5.4	0.8	3.4	0.0	0.0	0.0	6.5	6.2	2.5	0.0	0.0	0.0
Maximum	7.5	2.6	8.1	0.0	0.0	0.0	8.4	7.1	7.2	0.0	0.0	0.0
Standard Deviation	3.2	1.2	4.0	0.0	0.0	NA	2.7	1.0	3.3	0.0	0.0	NA

Table 6-21: TMD-MP1 Monthly Electrical Conductivity Descriptive Statistics

Electrical Conductivity at 100mm (mS/cm)						
	March	**April**	**May**	**June**	**July**	**August**
Minimum	0.02	0.00	0.00	0.00	0.00	0.00
Mean	0.04	0.02	0.01	0.00	0.00	0.00
Maximum	0.05	0.05	0.04	0.00	0.00	0.00
Standard Deviation	0.01	0.02	0.02	0.00	0.00	NA

6.3.8 Monitoring Site TMD-MP2

Tarcrete at TMD-MP2 is tarmat, continuous, 10-20mm, soft, friable. Soil is light yellowish brown fine to coarse slightly silty SAND. Occasional organic matter.

Table 6-22: TMD-MP2 Monthly Soil Temperature Descriptive Statistics

	Soil Temperature (^{0} C)					
	March	**April**	**May**	**June**	**July**	**August**
Minimum	21.0	35.7	38.4	45.3	45.6	47.3
Mean	29.7	38.5	41.8	45.7	47.2	47.3
Maximum	35.9	41.1	43.3	46.0	48.8	47.3
Standard Deviation	6.3	2.9	2.3	0.5	1.6	NA

Table 6-23: TMD-MP2 Monthly Moisture Descriptive Statistics

	Moisture at 100mm (%)						Moisture at 200mm (%)					
	March	**April**	**May**	**June**	**July**	**August**	**March**	**April**	**May**	**June**	**July**	**August**
Minimum	8.2	0.5	2.5	0.0	0.0	0.0	10.8	8.0	9.3	8.1	0.0	0.0
Mean	9.0	4.6	7.0	0.4	0.0	0.0	12.2	10.2	12.9	10.6	0.0	0.0
Maximum	10.5	8.4	9.4	0.7	0.0	0.0	13.3	11.1	15.4	13.1	0.0	0.0
Standard Deviation	1.1	3.4	3.1	0.5	0.0	NA	1.1	1.5	2.6	3.5	0.0	NA

Table 6-24: TMD-MP2 Monthly Electrical Conductivity Descriptive Statistics

Electrical Conductivity at 100mm (mS/cm)						
	March	**April**	**May**	**June**	**July**	**August**
Minimum	0.04	0.03	0.02	0.01	0.00	0.00
Mean	0.09	0.05	0.07	0.01	0.00	0.00
Maximum	0.12	0.01	0.04	0.03	0.01	0.00
Standard Deviation	0.05	0.02	0.05	0.00	0.00	NA

6.3.9 Monitoring Site TMD-MP3

Tarcrete at TMD-MP3 is tarmat, continuous, 8-14mm, hardened, friable. Soil is pale brown silty slightly gravelly SAND. Gravel is rounded to sub angular, fine.

Table 6-25: TMD-MP3 Monthly Soil Temperature Descriptive Statistics

	Soil Temperature (^{0} C)					
	March	**April**	**May**	**June**	**July**	**August**
Minimum	22.2	31.8	37.8	43.3	44.9	46.0
Mean	29.1	37.7	40.8	44.0	45.9	46.0
Maximum	33.8	40.5	42.9	44.6	46.9	46.0
Standard Deviation	5.1	4.1	2.2	0.9	1.0	NA

Table 6-26: TMD-MP3 Monthly Moisture Descriptive Statistics

Moisture at 100mm (%)							**Moisture at 200mm (%)**					
	March	**April**	**May**	**June**	**July**	**August**	**March**	**April**	**May**	**June**	**July**	**August**
Minimum	5.3	0.0	0.0	0.0	0.0	0.0	7.2	1.6	7.1	0.0	0.0	0.0
Mean	6.3	1.7	5.3	2.6	0.0	0.0	7.7	4.4	8.5	3.8	0.6	0.0
Maximum	7.1	5.7	7.9	5.2	0.0	0.0	8.7	8.1	9.7	7.6	1.2	0.0
Standard Deviation	1.0	2.7	3.7	3.7	0.0	NA	0.7	3.2	1.3	5.4	0.8	NA

Table 6-27: TMD-MP3 Monthly Electrical Conductivity Descriptive Statistics

Electrical Conductivity at 100mm (mS/cm)						
	March	**April**	**May**	**June**	**July**	**August**
Minimum	0.02	0.00	0.02	0.01	0.00	0.00
Mean	0.03	0.02	0.04	0.02	0.01	0.00
Maximum	0.03	0.05	0.06	0.03	0.01	0.00
Standard Deviation	0.01	0.02	0.02	0.01	0.01	NA

6.4 *Intrusive Ground Investigation*

The intrusive ground investigation occurred on 13 December 2014 between 11:50 to 15:25 hours. The weather was 25°C, sunny and clear sky with a light south-easterly wind. Descriptions of the tarcrete and soil samples are provided in Section 6.3 with corresponding photographs provided in Appendix D. The schedule of analysis is presented in Section 5.5.1.

6.4.1 Tarcrete

The followings provides a summary of the tarcrete analytical results. Laboratory Certificates of Analysis are contained in Appendix E.

Fractionated testing of TPH in the tarcrete samples resulted in all hydrocarbon fractions up to C21 being below the limit of reporting (LOR) in all samples. Hydrocarbon fractions C21-C35 aliphatics and aromatic were present in all samples (Table 6-28). Aliphatics ranged from 79mg/kg (TC-TMC-MP2) to 391mg/kg (TC-TMA-MP2) and aromatics ranged from 12mg/kg (TC-TMD-MP2) to 64mg/kg (TC-TMD-MP1). Fractionated petroleum hydrocarbon (PHC) testing detected concentrations of the >C35-C90 fraction in all samples. Results ranged from 34,724.7mg/kg (TC-TMB-MP1) to 106,560.8mg/kg (TC-TMA-MP2) (Table 6-28). PAH testing of the US EPAs priority pollutant PAHs resulted in concentrations below the LOR in all samples (Table 6-29).

A breakdown of the hydrocarbon and heterocyclic molecule composition of tarcrete was undertaken using a SARA test. Concentrations showed saturates ranging from 9,436mg/kg (TC-TMD-MP2) to 17,233.3mg/kg (TC-TMC-MP3), aromatics ranging from 12,663.4mg/kg (TC-TMD-MP3) to 27,671.3mg/kg (TC-TMC-MP3), Polars I ranging from

18,182.8mg/kg to 35,195.2mg/kg and Polars II ranging from 324.9mg/kg to 809.6mg/kg in TC-TMC-MP3 (Table 6-30).

Tarcrete was tested for concentrations of six metals (Table 6-31). Results detected calcium concentrations ranging from 12,835mg/kg (TC-TMD-MP2) to 19,632mg/kg (TC-TMD-MP3), lead ranging from 1.2mg/kg (TC-TMD-MP3) to 1.4mg/kg (TC-TMD-MP1), vanadium ranging from 11.3mg/kg (TC-TMD-MP3) to 18.6mg/kg (TC-TMD-MP1) and Cobalt ranging from 0.6mg/kg (TC-TMD-MP3) to 0.8mg/kg (TC-TMD-MP1). Cadmium and mercury were below the LOR (0.3mg/kg and 1.3mg/kg, respectively) in all samples analysed.

Table 6-28: Tarcrete Fractionated TPH and PHC Analytical Results

Analyte Name	Units	LOR	Sample ID						
			TC-TMA-MP2	TC-TMB-MP1	TC-TMC-MP2	TC-TMC-MP3	TC-TMD-MP1	TC-TMD-MP2	TC-TMD-MP3
Volatile Aliphatics (C5-C6)	mg/kg	20	<20	<20	<20	<20	<20	<20	<20
Volatile Aliphatics (C6-C8)	mg/kg	20	<20	<20	<20	<20	<20	<20	<20
Volatile Aliphatics (C8-C10)	mg/kg	20	<20	<20	<20	<20	<20	<20	<20
Extractable Aliphatics (C10-C12)	mg/kg	5	<5	<5	<5	<5	<5	<5	<5
Extractable Aliphatics (C12-C16)	mg/kg	5	<5	<5	<5	<5	<5	<5	<5
Extractable Aliphatics (C16-C21)	mg/kg	5	<5	<5	<5	<5	<5	<5	<5
Extractable Aliphatics (C21-C35)	mg/kg	5	391	152	79	378	389	211	112
Volatile Aromatics (C5-C6)	mg/kg	0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5

Analyte Name	Units	LOR	Sample ID						
			TC-TMA-MP2	TC-TMB-MP1	TC-TMC-MP2	TC-TMC-MP3	TC-TMD-MP1	TC-TMD-MP2	TC-TMD-MP3
Volatile Aromatics (C6-C8)	mg/kg	0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Volatile Aromatics (C8-C10)	mg/kg	0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Extractable Aromatics (C10-C12)	mg/kg	5	<5	<5	<5	<5	<5	<5	<5
Extractable Aromatics (C12-C16)	mg/kg	5	<5	<5	<5	<5	<5	<5	<5
Extractable Aromatics (C16-C21)	mg/kg	5	<5	<5	<5	<5	<5	<5	<5
Extractable Aromatics (C21-C35)	mg/kg	5	53	55	51	56	64	12	19
Fractionated PHC >C35-C90	mg/kg	0.5	106560.8	34724.7	82801.7	80474.9	58714.5	47920.1	40455.6

Table 6-29: Tarcrete PAH Analytical Results

Analyte Name	Units	LOR	Sample ID						
			TC-TMA-MP2	TC-TMB-MP1	TC-TMC-MP2	TC-TMC-MP3	TC-TMD-MP1	TC-TMD-MP2	TC-TMD-MP3
Naphthalene	mg/kg	0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Acenaphthalene	mg/kg	0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Acenaphthene	mg/kg	0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Fluorene	mg/kg	0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Phenanthrene	mg/kg	0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Anthracene	mg/kg	0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Fluoranthene	mg/kg	0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Pyrene	mg/kg	0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Benzo(a)anthracene	mg/kg	0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Chrysene	mg/kg	0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Benzo(a)pyrene	mg/kg	0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Indeno(1,2,3-cd)pyrene	mg/kg	0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Dibenz(a,h)anthracene	mg/kg	0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5

Analyte Name	Units	LOR	Sample ID						
			TC-TMA-MP2	TC-TMB-MP1	TC-TMC-MP2	TC-TMC-MP3	TC-TMD-MP1	TC-TMD-MP2	TC-TMD-MP3
Benzo(g,h,i)perylene	mg/kg	0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Benzo(b&k)fluoranthene	mg/kg	1	<1	<1	<1	<1	<1	<1	<1

Table 6-30: Tarcrete SARA Analytical Results

			Sample ID		
Analyte Name	Units	LOR	TC-TMC-MP3	TC-TMD-MP2	TC-TMD-MP3
Saturates	mg/kg	10	17233.3	9436.0	9415.6
Aromatics	mg/kg	10	27671.3	17571.9	12663.4
Polars (I)	mg/kg	10	35195.2	20557.1	18182.8
Polars (II)	mg/kg	10	809.6	578.3	324.9

Table 6-31: Tarcrete Metal Analytical Results

			Sample ID		
Analyte Name	Units	LOR	TC-TMD-MP1	TC-TMD-MP2	TC-TMD-MP3
Calcium	mg/kg	0.25	18116	12835	19632
Cadmium	mg/kg	0.3	<0.3	<0.3	<0.3
Mercury	mg/kg	1.3	<1.3	<1.3	<1.3
Lead	mg/kg	0.4	1.4	1.3	1.2
Vanadium	mg/kg	0.4	18.6	11.8	11.3
Cobalt	mg/kg	0.3	0.8	0.7	0.6

6.4.2 Soil

The following is a summary of the soil analytical results. Laboratory Certificates of Analysis are provided in Appendix E. Results of the soil monitoring data measured at the time of sample collection are provided in Appendix D.

Fractionated testing of TPH in the soil samples resulted in all hydrocarbon fractions being below the limit of reporting (LOR) in all samples. Fractionated petroleum hydrocarbon (PHC) testing detected concentrations of the >C35-C90 fraction in all samples. Results ranged from 303.7mg/kg (SO-TMA-MP1) to 787.5mg/kg (SO-TMA-MP3) (Table 6-33). PAH testing resulted in concentrations below the LOR in all samples (Table 6-34).

SARA testing was undertaken on sample SO-TMD-MP1. Concentrations of saturates, aromatics, Polars I and II were 131.2mg/kg, 158.4mg/kg, 160mg/kg and <10mg/kg or LOR, respectively Table 6-35.

Soil samples were tested for concentrations of six metals (Table 6-36). Results detected calcium concentrations ranging from 23,403mg/kg (SO-TMD-MP1) to 42,830mg/kg (SO-TMA-MP2), lead 1.3mg/kg (SO-TMD-MP1 and SO-TMD-MP2) to 1.5mg/kg (SO-TMA-MP1 and SO-TMA-MP2), vanadium 6.0mg/kg (SO-TMD-MP2) to 11.0mg/kg (SO-TMA-MP2) and cobalt 1.6mg/kg (SO-TMD-MP2) to 2.5mg/kg (SO-TMA-MP2). Cadmium and mercury were below the LOR (0.3mg/kg and 1.3mg/kg, respectively) in all samples analysed.

General chemistry testing preformed on the soil samples are presented in Table 6-37: Soil General Chemistry Analytical Results. Given some of the wide ranges within the results descriptive statistics showing the minimum, mean, maximum, standard deviation and the median have been calculated and are presented in Table 6-38.

Results indicated that soil moisture ranged from 1.5% (SO-TMA-MP1) to 3.1% (SO-TMA-MP2) with a mean moisture content of 2.4$\pm$0.5%. Soil pH ranged from 8.1 (SO-TMB-MP1) to 9.0 (SO-TMA-MP1, SO-TMD-MP1 and SO-TMD-MP2) with a mean of 8.8$\pm$0.4.

Chemical analysis on soil plant nutrients Total Kjeldahl Nitrogen (TKN) and total phosphorous ('phosphorous') ranged from 0.9mg/kg (SO-TMA-MP1) to 1.8mg/kg (SO-TMA-MP3) TKN with a mean concentration of 1.2$\pm$0.3 and 69mg/kg (SO-TMA-MP3) to 108mg/kg (SO-TMD-MP2) phosphorous with a mean concentration of 91$\pm$15mg/kg.

Concentrations of potassium, sulfate and chloride were wide ranging. Potassium concentrations ranged from 26.75mg/kg in (SO-TMA-MP1) to 81.4mg/kg (SO-TMD-MP2) and concentrations of sulfate and chloride ranged from 82.4mg/kg and 13.7mg/kg in SO-TMA-MP2 to 527.5mg/kg and 7,740.0mg/kg in SO-TMA-MP3, respectively. The mean and median potassium concentration is 45.91$\pm$20.45mg/kg and 38.81mg/kg. The mean and median concentration of chloride is 1,311.1$\pm$3149.5mg/kg and 20.7mg/kg.

The total organic carbon content in the soil samples ranged from 1,630mg/kg (SO-TMD-MP1) to 2,130mg/kg (SO-TMA-MP3) with a mean concentration of 1,870±212mg/kg.

Results of the soil salinity parameters detected alkalinity as calcium carbonate ranging from 196mg/kg (SO-TMA-MP2) to 662mg/kg (SO-TMA-MP3) with a mean and median concentration of 281±102mg/kg and 252mg/kg, conductivity ranged from 220µS/cm (SO-TMD-MP1) to 5,830µS/cm (SO-TMA-MP3), with a mean and median value of 1,213±2263 µS/cm and 298µS/cm. The sodium absorption ratio (SAR) was below the LOR of 0.25 in all samples with the exception of SO-TMA-MP3, in which SAR was 10.522.

A particle size distribution (PSD) analysis was conducted on six soil samples. The ratio of grain size between TMA-MP1, TMA-MP2, TMB-MP1, TMD-MP1 and TMD-MP2 for coarse sand ranged between 17.1% and 21%; medium sand ranged between 18.9% and 25.6%; fine sand ranged between 40.2% and 45.2%. Silt (<0.063mm) content between these samples ranged between 5.9% and 14.2%. The grain size proportions for TMA-MP3 for coarse sand and medium sand were 26.1% and 37% respectively and fine sand was 26.8%, whilst the silt content was 8%.

Table 6-32: Intrusive Ground Investigation Soil Monitoring Data

Sample Location	Soil Temperature (^{0} C)	Electrical Conductivity (mS/cm)	Moisture at 100mm (%)	Moisture at 200mm (%)
TMA-MP1	20.7	0.03	7.8	8.7
TMA-MP2	20.5	0.11	8.1	8.8
TMA-MP3	20.6	2.08	11.7	off scale
TMB-MP1	20.6	0.05	7.4	7.4
TMC-MP1	22.5	0.02	1.1	1.1
TMC-MP2	23.9	0.06	2.2	4.3
TMD-MP1	17.8	0.05	7.7	11.9
TMD-MP2	26.1	0.12	8.3	8.5
TMD-MP3	24.5	0.04	10.4	11.4

Table 6-33: Soil Fractionated Hydrocarbon Analytical Results

			Sample ID					
Analyte Name	**Units**	**LOR**	**SO-TMA-MP1**	**SO-TMA-MP2**	**SO-TMA-MP3**	**SO-TMB-MP1**	**SO-TMD-MP1**	**SO-TMD-MP2**
Volatile Aliphatics (C5-C6)	mg/kg	20	<20	<20	<20	<20	<20	<20
Volatile Aliphatics (C6-C8)	mg/kg	20	<20	<20	<20	<20	<20	<20
Volatile Aliphatics (C8-C10)	mg/kg	20	<20	<20	<20	<20	<20	<20
Extractable Aliphatics (C10-C12)	mg/kg	5	<5	<5	<5	<5	<5	<5
Extractable Aliphatics (C12-C16)	mg/kg	5	<5	<5	<5	<5	<5	<5
Extractable Aliphatics (C16-C21)	mg/kg	5	<5	<5	<5	<5	<5	<5
Extractable Aliphatics (C21-C35)	mg/kg	5	<5	<5	<5	<5	<5	<5
Volatile Aromatics (C5-C6)	mg/kg	0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Volatile Aromatics (C6-C8)	mg/kg	0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Volatile Aromatics (C8-C10)	mg/kg	0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Extractable Aromatics (C10-C12)	mg/kg	5	<5	<5	<5	<5	<5	<5
Extractable Aromatics (C12-C16)	mg/kg	5	<5	<5	<5	<5	<5	<5
Extractable Aromatics (C16-C21)	mg/kg	5	<5	<5	<5	<5	<5	<5

			Sample ID					
Analyte Name	**Units**	**LOR**	**SO-TMA-MP1**	**SO-TMA-MP2**	**SO-TMA-MP3**	**SO-TMB-MP1**	**SO-TMD-MP1**	**SO-TMD-MP2**
Extractable Aromatics (C21-C35)	mg/kg	5	<5	<5	<5	<5	<5	<5
Fractionated PHC >C35-C90	mg/kg	0.5	303.7	418.9	787.5	487.2	449.6	524.1

Table 6-34: Soil PAH Analytical Results

			Sample ID					
Analyte Name	**Units**	**LOR**	**SO-TMA-MP1**	**SO-TMA-MP2**	**SO-TMA-MP3**	**SO-TMB-MP1**	**SO-TMD-MP1**	**SO-TMD-MP2**
Naphthalene	mg/kg	0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Acenaphthalene	mg/kg	0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Acenaphthene	mg/kg	0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Fluorene	mg/kg	0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Phenanthrene	mg/kg	0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Anthracene	mg/kg	0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Fluoranthene	mg/kg	0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Pyrene	mg/kg	0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Benzo(a)anthracene	mg/kg	0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Chrysene	mg/kg	0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Benzo(a)pyrene	mg/kg	0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Indeno(1,2,3-cd)pyrene	mg/kg	0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Dibenz(a,h)anthracene	mg/kg	0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Benzo(g,h,i)perylene	mg/kg	0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Benzo(b&k)-fluoranthene	mg/kg	1	<1	<1	<1	<1	<1	<1

Table 6-35: Soil SARA Analytical Results

Analyte Name	Units	Reporting Limit	Sample ID
			SO-TMD-MP1
Saturates	mg/kg	10	131.2
Aromatics	mg/kg	10	158.4
Polars (I)	mg/kg	10	160
Polars (II)	mg/kg	10	<10

Table 6-36: Soil Metal Analytical Results

			Sample ID			
Analyte Name	**Units**	**LOR**	**SO-TMA-MP1**	**SO-TMA-MP2**	**SO-TMD-MP1**	**SO-TMD-MP2**
Calcium	mg/kg	0.25	29445	42830	23403	30832
Cadmium	mg/kg	0.3	<0.3	<0.3	<0.3	<0.3
Mercury	mg/kg	1.3	<1.3	<1.3	<1.3	<1.3
Lead	mg/kg	0.4	1.5	1.5	1.3	1.3
Vanadium	mg/kg	0.4	9.2	11.0	9.4	6.0
Cobalt	mg/kg	0.3	2.4	2.5	2.1	1.6

Table 6-37: Soil General Chemistry Analytical Results

Analyte Name	Units	LOR	Sample ID					
			SO-TMA-MP1	**SO-TMA-MP2**	**SO-TMA-MP3**	**SO-TMB-MP1**	**SO-TMD-MP1**	**SO-TMD-MP2**
Moisture	%	0.1	1.5	3.1	2.7	2.5	2.4	2.4
pH	pH	0.1	9.0	8.9	8.9	8.1	9.0	9.0
Total Kjeldahl Nitrogen	mg/kg	0.1	0.9	1.1	1.8	1.2	1.2	1.0
Total Phosphorus	mg/kg	1	81	91	69	92	105	108
Potassium	mg/kg	0.25	26.75	34.73	58.37	33.34	40.89	81.4
Sulphate	mg/kg	0.2	226.7	82.4	527.5	146.9	92.3	116.5
Chloride	mg/kg	0.2	19.4	13.7	7740.0	20.2	21.1	52.4
Alkalinity as Calcium Carbonate	mg/kg	0	465	196	662	319	199	224
Total Organic Carbon	mg/kg	0	2100	1920	2130	1720	1630	1720
Conductivity	µS/cm	1	260	273	5830	369	220	323
Sodium Absorption Ratio (SAR)	-	0.25	<0.25	<0.25	10.52	<0.25	<0.25	<0.25

Table 6-38: Descriptive Statistics for Soil General Chemistry Analytical Results

Analyte Name	Units	LOR	Minimum	Mean	Maximum	Standard Deviation	Median
Moisture	%	0.1	1.5	2.4	3.1	0.53	2.5
pH	pH	0.1	8.1	8.8	9.0	0.4	9.0
Total Kjeldahl Nitrogen	mg/kg	0.1	0.9	1.2	1.8	0.3	1.2
Total Phosphorus	mg/kg	1	69	91	108	15	92
Potassium	mg/kg	0.25	26.75	45.91	81.40	20.45	37.81
Sulphate	mg/kg	0.2	82.4	198.7	527.5	169.2	131.7
Chloride	mg/kg	0.2	13.7	1311.1	7740.0	3149.5	20.7
Alkalinity as Calcium Carbonate	mg/kg	0	196	281	465	102	252
Total Organic Carbon	mg/kg	0	1630	1870	2130	212	1820
Sodium Absorption Ratio	-	0.25	<0.25	NC[1]	10.522	NC[1]	NC[1]
Conductivity	µS/cm	1	220	1213	5830	2263	298

[1]NC: Cannot be calculated. Values below LOR

Table 6-39: Soil Particle Size Distribution (PSD) Results

Particle Size (mm)	Percent	Sample ID					
		SO-TMA-MP1	SO-TMA-MP2	SO-TMA-MP3	SO-TMB-MP1	SO-TMD-MP1	SO-TMD-MP2
50	%	Nil	Nil	Nil	Nil	Nil	Nil
37.5	%	Nil	Nil	Nil	Nil	Nil	Nil
28	%	Nil	Nil	Nil	Nil	Nil	Nil
20	%	Nil	Nil	Nil	Nil	Nil	Nil
14	%	Nil	Nil	Nil	Nil	Nil	Nil
10	%	Nil	Nil	Nil	Nil	Nil	Nil
6.3	%	Nil	Nil	Nil	Nil	Nil	Nil
5	%	Nil	Nil	Nil	Nil	Nil	Nil
3.35	%	Nil	Nil	Nil	Nil	Nil	0.3
2	%	1.5	1.9	3	1.1	4	1.4
1.18	%	3.8	3.8	7	2.4	7.2	7.3
0.6	%	17.2	13.3	19.1	17.2	12.4	12.6
0.425	%	16.3	12.7	16.6	15.3	11.9	10.1
0.3	%	9.2	9.4	19.4	17.5	13.7	8.8
0.212	%	13.6	11.2	13.7	11.9	10.9	13.9
0.15	%	10.2	14.7	6.4	9.4	16.1	12.5
0.063	%	19.7	19.3	6.7	18.9	17.8	18.8
< 0.063	%	8.5	13.5	8	6.3	5.9	14.2

6.5 *Vegetation Survey of Canopy Cover*

Percent canopy cover was measured along three transect lines at each monitoring site. The percent canopy cover along the TMA monitoring sites TMA-MP1, TMA-MP2 and TMA-MP3 ranged from 52-54%, 52-72% and 0-42%, respectively. The percent canopy cover at TMB-MP1 ranged from 42-62%. The TMC monitoring points TMC-MP2 and TMC-MP3 resulted in percent canopy cover that ranged from 56-70% and 56-76%, respectively. The corresponding range in percent canopy cover for monitoring points TMD-MP1, TMD-MP2 and TMD-MP3 along the TMD transect was 62-76%, 40-60% and 38-64%. The resulting percentages for each survey line are presented in Table 6-40 with the minimum, mean, maximum and median for each monitoring point provided in Table 6-41. Data forms are provided in Appendix F.

Table 6-40: Percent Canopy at Each Survey Line

Monitoring Point	Survey Line	% Canopy Cover
TMA-MP1	1	54
	2	58
	3	52
TMA-MP2	1	60
	2	52
	3	72
TMA-MP3	1	42
	2	38
	3	0
TMB-MP1	1	62
	2	54
	3	42
TMC-MP2	1	66
	2	70
	3	56
TMC-MP3	1	76
	2	56
	3	60
TMD-MP1	1	76
	2	62
	3	68
TMD-MP2	1	54
	2	60
	3	40
TMD-MP3	1	38
	2	40
	3	64

Table 6-41: Summary of Percent Canopy at Each Monitoring Site

Monitoring Point	Minimum % Canopy Cover	Mean % Canopy Cover	Maximum % Canopy Cover	Median % Canopy Cover
TMA-MP1	52	55	58	54
TMA-MP2	52	61	72	60
TMA-MP3	0	27	42	38
TMB-MP1	42	53	62	54
TMC-MP2	56	64	70	66
TMC-MP3	56	64	76	60
TMD-MP1	62	69	76	68
TMD-MP2	40	51	60	54
TMD-MP3	38	47	64	40

7 Data analysis, Interpretation and Classification

The data analysis, classification and interpretation were guided by the study objectives presented in Section 2.2. Details of the analysis approach and results are provided within the following subsections.

The findings of the physical characterization of tarcrete and the resulting Guideline are presented in 6.1 (Guideline) and 6.2 (Field Survey). Discussions on these results are presented in Section 8.1 as no specific analysis was undertaken on the data.

A summary table detailing all sample information including sample ID, material matrix, elevations at monitoring sites and distances from the source well is provided in Appendix D.

7.1 *Chemical Properties of Tarcrete*

Fraction specific fate and transport properties were originally developed by Total Petroleum Hydrocarbon Criteria Working Group (TPHCWG) (Gustafson et al., 1997) for extractable aliphatic and aromatic hydrocarbon fractions up to C35. McMillen et al. (e.d., 2001) has since expanded this work in order to include for more of the heavier hydrocarbon fractions. McMillen et al. (e.d., 2001) changed the TPHCWG aromatic >C21-C35 and aliphatic >C16-C35 fractions by increasing the ranges up to C44 and adding a separate fraction of >C44 which accounts for aromatic and aliphatic fractions that are remaining as the vacuum residuum after the distillation process. Fate and transport properties for the heavy molecular weight fractions developed by both TPHCWG and McMillen et al. (e.d., 2001) are presented in Table 6-1. Properties of a light molecular weight fraction (>C8-C10) is also presented for comparison.

Although there are differences in the tarcrete fractions provided in this study (Table 6-28) and those presented from the literature (Table 6-1) an understanding of the behaviours of the high molecular weight compounds found in tarcrete can be gained. Demonstrated by the properties presented in Table 6-1 tarcrete is deemed to have low solubility and volatility thus making it persistent with limited mobility in the environment (McMillen et al. (e.d.), 2001).

The partition properties such as Henry's Law Constant, Organic Carbon Partition and Leaching Factor can be used to estimate exposure potential. Extrapolating from Table 6-1, tarcrete does not readily partition into the soil, water or air systems (if at all). On this basis the exposure potential to tarcrete is low and thus its toxicity potential is low.

The low toxicity of tarcrete is further demonstrated by the fraction specific references doses (RfDs) and reference concentrations (RfCs) developed by TPHCWG (Edwards et al., 1997) and McMillen et al. (e.d., 2001). RfD and RfCs are intended for use as part of a hazard assessment and are protective of human health (Edwards et al., 1997). The following is a summary of the RfD and RfCs developed for the fractions detected in tarcrete.

An inhalation RfC for the aromatic >C17-C35 fraction was not developed as it is not volatile and therefore does not pose a potential risk by inhalation exposure (Edwards et al., 1997). The oral RfD for this fraction is 0.03mg/kg/day (based on pyrene). The same RfD was used by McMillen et al. (e.d., 2001) for the C35-C44 aromatic fraction.

Table 7-1: Fraction Specific Fate and Transport Properties

Parameter[1]	Boiling Point (°C)	Molecular Weight (g/mol)	Aqueous Solubility (mg/L)	Vapour Pressure (atm)	Henry's Law Constant (cm3/ cm3)	Log of Organic Carbon Partition (unitless)	Leaching Factor from Soil to Water (mg/L)/ (mg/kg)
Symbol	**BP**	**MW**	**S**	**VP**	**H**	**log Koc**	**LFsw**
Aliphatic Fractions							
8-10	1.5E+02	1.3E+02	4.3E-01	6.3E-03	8.0E+01	4.5E+00	2.51E-04
>16-21	3.2E+02	2.7E+02	2.5E-06	1.1E-06	4.9E+03	8.8E+00	8.0E-09
>C16-C44[2]	>6.00E+02	N/A	1.30E-06	7.60E-06	6.40E+03	9.00E+00	8.26E-05
Aromatic Fractions							
8-10	1.5E+02	1.2E+02	6.5E+01	6.3E-03	4.8E-01	3.2E+00	5.16E-03
>16-21	3.2E+02	1.9E+02	6.5E-01	1.1E-06	1.3E-02	4.2E+00	2.21E-04
>C21-35	3.4E+02	2.4E+02	6.6E-03	4.4E-10	6.7E-04	5.1E+00	6.56E-05
>C21-C44[2]	>6.00E+02	N/A	6.60E-03	4.40E-09	6.80E-04	5.10E+00	6.56E-05
Vacuum Residuum							
>C44	>6.00E+02	N/A	1.00E-04	N/A	4.10E-08	5.70E+00	1.65E-05

1 Based on Equivalent Carbon Number
2 Calculated Henry's law constant based on vapour pressure, solubility and molecular weight relationship
Source: adapted from Total Petroleum Hydrocarbon Criteria Working Group Series, Volume 3, Table 8. Pg. 65 & Risk Based Decision Making for Assessing Petroleum Impacts at Exploration and Production Sites, Table 2 (p. 64) Table 4 (p.69)

Hydrocarbons within the C21-C35 fraction are mainly (paraffin and naphthenic) waxes (Thanh et al., 1999). The toxicity criteria recommended by the TPHCWG to develop the RfD for the aliphatic hydrocarbons with fractions >C17 is for white mineral oils which are used as food additives, in cosmetics and pharmaceutical products (Edwards et al., 1997; Stamatas, 2015). The TPHCWG oral RfD for aliphatic hydrocarbons >C17-C34 is 2mg/kg/day and 20mg/kg/day for >C34 (Edwards et al., 1997). McMillen et al. (e.d., 2001) also recommend 20mg/kg/day for the aliphatic fraction range C35-C44.

Toxicity assessments by the TPHCWG state that the oral and dermal bioavailability of compounds >C35 is unlikely (Edwards et al., 1997). McMillen et al. (e.d., 2001) state that

the mobility of fractions >C44 is negligible; however, a dermal RfD of 0.8mg/kg/day was developed for the >C44 range using the vacuum residuum which includes aliphatic, aromatic hydrocarbons as well as the non-hydrocarbon component of resins and asphaltenes (McMillen et al. (e.d.), 2001).

In addition to a PHC component, the metals cobalt, lead and vanadium were also detected within the samples (Table 6-31) in concentrations similar to that of crude oil (IARC, 1989). The toxicity of these metals at the concentrations found is considered to be negligible (when compared to the most stringent concentrations) within recognized soil quality guidelines (CCME, 2015).

The characterization of the tarcrete chemical composition has determined that the tarcrete has a low exposure and toxicity potential to humans and the environment.

7.2 *Effect of Weathering on Tarcrete Composition*

The reason for tarcrete's current composition is due to weathering. Weathering has caused a decrease in the concentrations of lower molecular weight compounds, altering the composition of the tarcrete, once crude oil. The change in the composition of crude oil from weathering is demonstrated by (Figure 3-2). Comparing the Burgan (fresh) crude oil chromatogram in (Figure 3-1), in which no fractions above >C35 are detected to the analytical results of tarcrete and by comparison the weathered crude chromatogram illustrates the change in composition due to weathering.

7.3 *Oil Deposition Distance Effect on Tarcrete Characteristics*

To establish if the distance of oil deposition originating from the damaged source well effects tarcrete characteristics, the physical descriptions collected along each of the four transects together with analytical data, were assessed for trends occurring with distance.

Observations from PAAC (2002a, p.68) stated that the mean tarcrete thickness of 1cm to 1.5cm (Grealish et al., 2001a, b; PAAC, 2002a; CIC, 2003b) increased up to 10cm near the centre of the deposit (PAAC, 2002a). It is considered that this means an increase in the thickness was found from approximately 6m to 7m from the source well, as the tarcrete

deposit in the Burgan Oilfield was described to extend approximately 13km downwind from the damaged wells.

Tarcrete thickness for all tarmat transects (TMB, TMC, TMD) were plotted against increasing distance from the well (Figure 7-1). Along transect TMA tarcrete, where present, was gravel. Thickness is not a characteristic of gravel and therefore a thickness plot for this transect is not shown. Where thickness ranges were recorded the mean value was plotted. Gaps shown in the data plots represent areas where tarcrete was absent, largely as a result of manmade ground disturbance. Refer to Section 6.2 for tarcrete thicknesses and transect descriptions.

Data results show that the mean thickness (1.10$\pm$0.49cm) recorded in this study is the same of that reported in the literature (Grealish et al., 2001a, b; PAAC, 2002a; CIC, 2003b). The maximum thickness encountered was 2.5cm from 900m to 950m along TMB. The maximum expected thickness of 10cm (as reported in the literature) was not encountered within the Study Area.

Using field observations (Appendix B) to analyse the spikes in thickness in Figure 7-1 it is considered that the data spike along TMB from 900m to 950m and 1150m to 1250m is a result of influence from the dry oil lake 1000m to 1100m. Similarly, along TMD it is considered that the increased thickness from 1700m to 1850m is an impact of the dry oil lake encountered at 1900m.

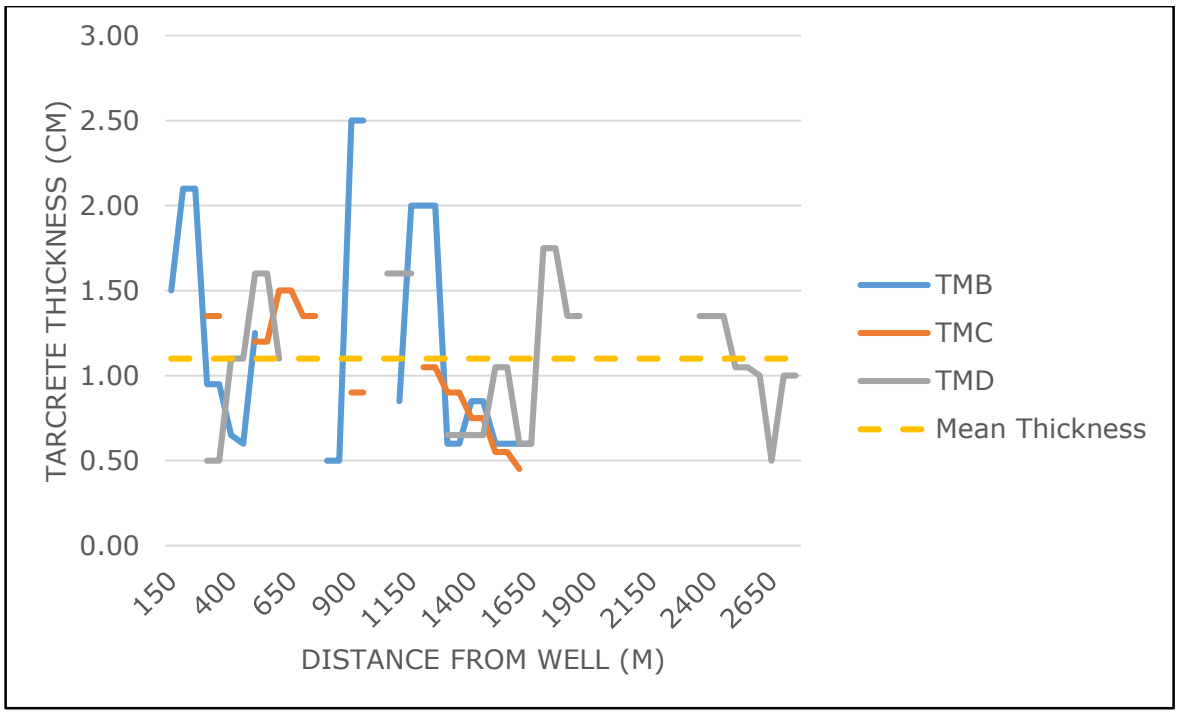


Figure 7-1: Tarcrete Thickness in Relation to Distance from Well

Where deposition thickness is considered to have been influenced, results from these areas are not considered within the following assessment. Transect lines TMB and TMC showed an overall decrease in thickness from the well to the end of the transect line. Tarcrete thickness closest to the TMB source well (at 150m) was between 1.5cm and 2.1cm and thinned to 0.6cm at the end of the transect from 1500m onwards. Tarcrete thickness at the start of the TMC transect is between 1cm and 1.5cm (at 500m) thinning to 0.45cm at 1650m. TMD is different in that it shows tarcrete thinning from 1.1cm at 400m to 0.65cm at 1450m. At 1900m another source well is present (Figure A-5, Appendix A). At the time of the study a new (replacement) well was being drilled (Appendix B). The general trend of decreasing thickness with distance from the source well is illustrated twice along this transect as the tarcrete thins out from 1.35cm to 1.0cm along the remaining portion of the transect (2700m).

In addition to thickness, each of the different aspects of tarcrete's physical characteristics were examined for changes with distance (refer to "Tarmat Physical Changes over Distance", Appendix A). Visual trends along the transect lines indicate that tarcrete type is not influenced by distance. Tarcrete type did not change with distance on any of the transect

lines. All other physical characteristics of the tarmat, with the exception of thickness, showed no consistent changes with distance. Continuity remained relatively unchanged; ‘fragmented continuity’ was the only deviation and was only encountered for 40m along TMB. Properties of consistently and friability varied along the transect length but the changes did not correspond with distance from the well.

The tarcrete gravel transect TMA showed a decreased in size, overall abundance and friability with distance whereas distribution and consistency remained relatively unchanged (Table 7-2). Greater abundance and evenness was observed along TMA approximately between 500m and 750m from the source well.

Table 7-2: Tarcrete Gravel Physical Changes over Distance

Distance from Well (m)	Size	Abundance	Distribution	Consistency	Friability
400	Fine to Medium	1	Uneven	Hardened	Very Friable
450					
500		5			
550		10			
600			Even		
650					
700					Very Friable to Friable
750					
800		5	Uneven		Very Friable
850					
900					
950					Very Friable to Friable
1000		<1%			Very Friable
1050					
1100					Friable
1150					
1200	Fine				
1250					
1300					
1350					
1400					
1450					

The chemical composition of tarcrete was also analysed for trends that occur with distance. Concentrations of available data for transect lines TMC and TMD were plotted. Data from TMA and TMB were not considered as data is only available from one location along these lines. TPH, PHC and metals data is available from three sample locations along transect TMD. SARA data from the TMD transect is available from two locations (Figure 7-2 to Figure 7-7) and TPH and PHC data is available from two sample locations along transect TMC (Figure 7-8 and Figure 7-9).

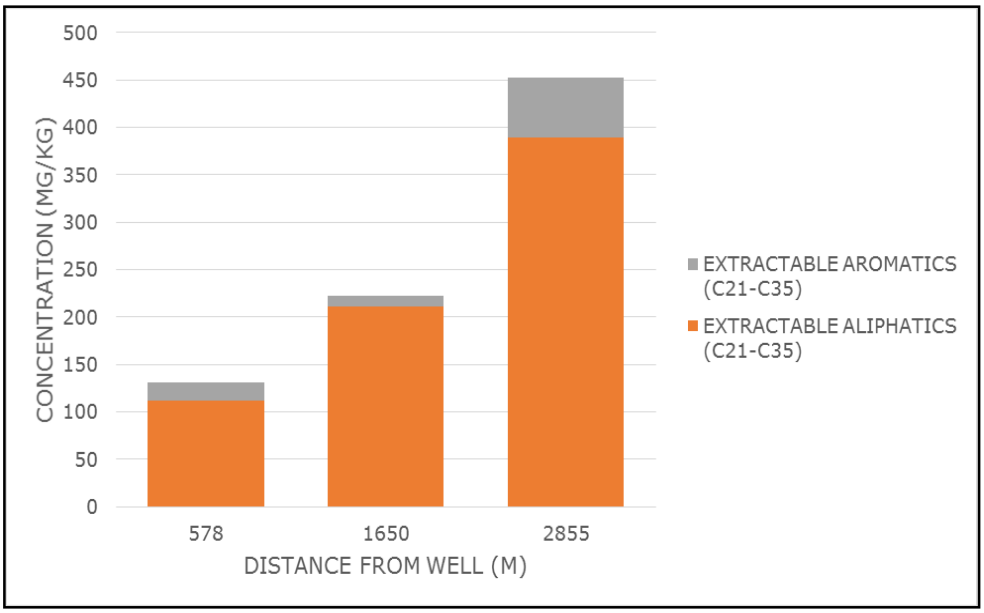


Figure 7-2: Transect TMD: Fractionated TPH Concentrations over Distance from Well

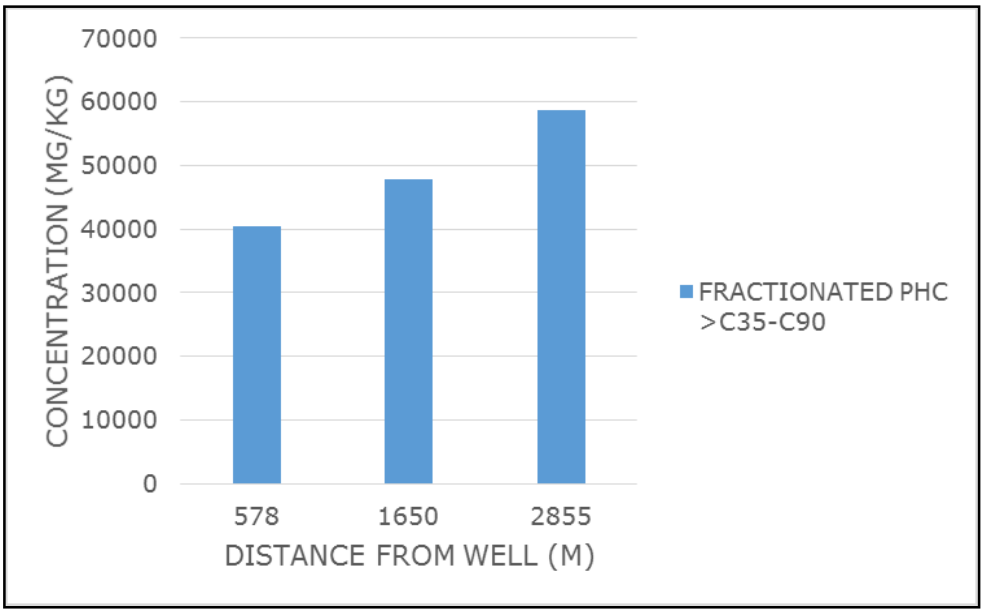


Figure 7-3: Transect TMD: Concentration of PHC >C35-C90 over Distance from Well

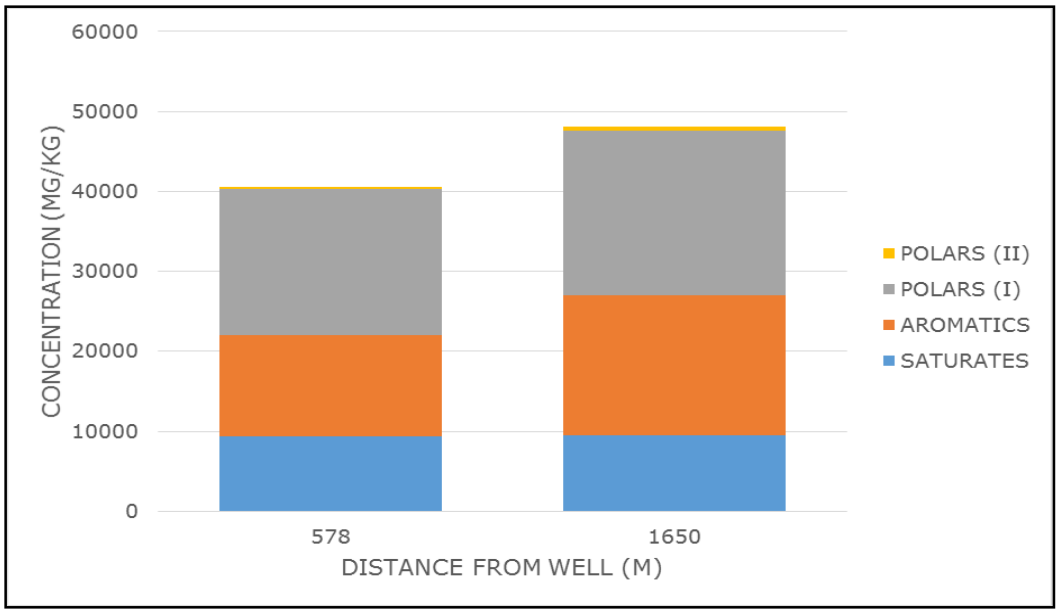


Figure 7-4: Transect TMD: SARA Concentrations over Distance from Well

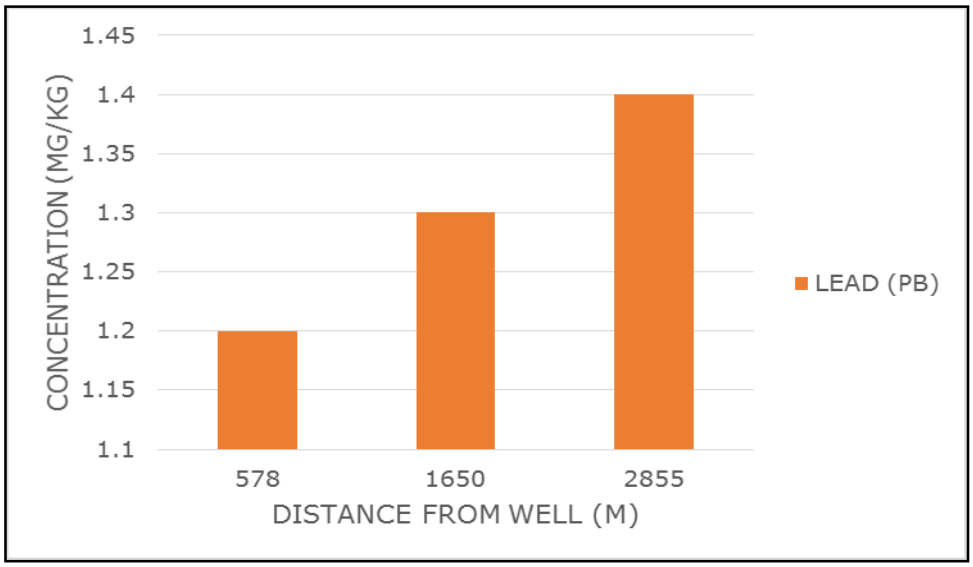


Figure 7-5: Transect TMD: Pb Concentrations over Distance from Well

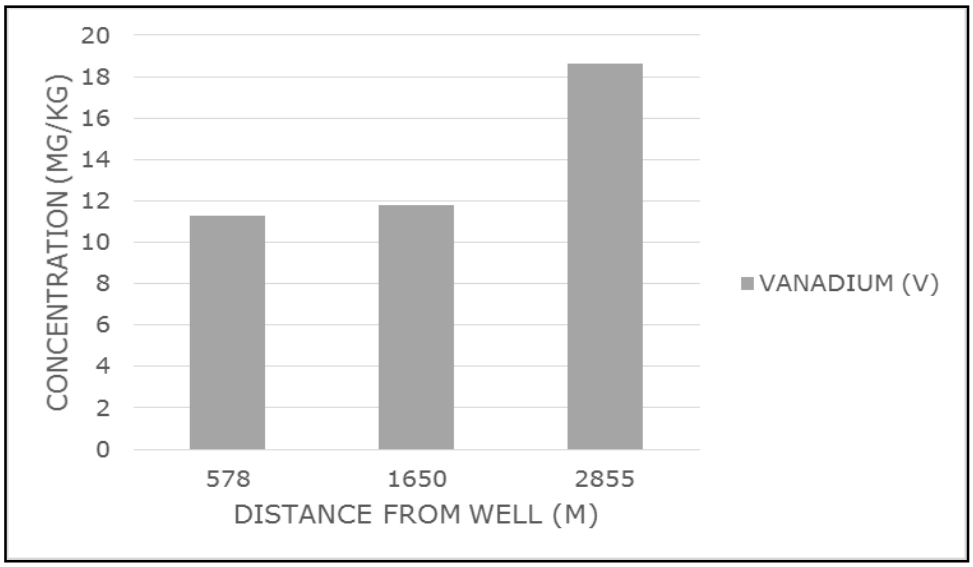


Figure 7-6: Transect TMD: V Concentrations over Distance from Well

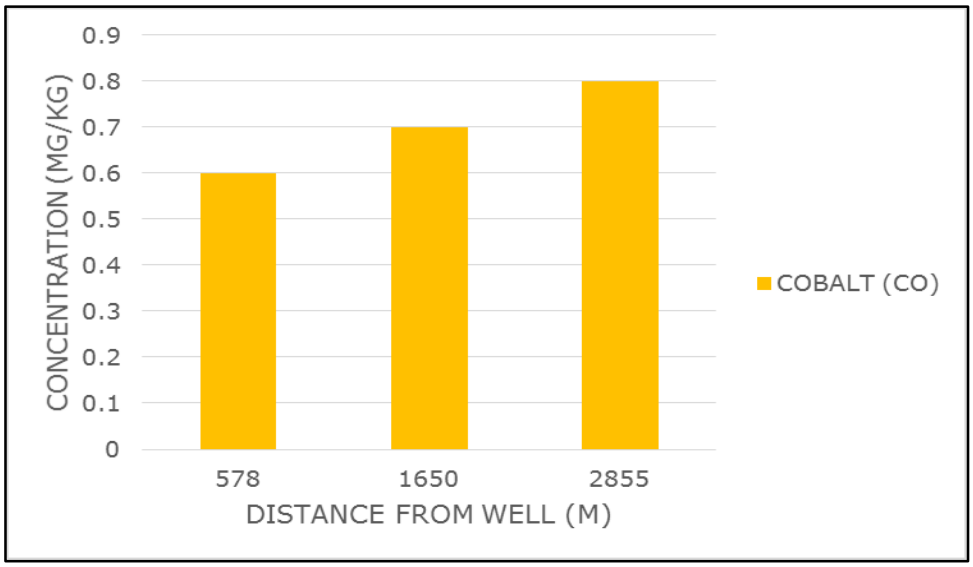


Figure 7-7: Transect TMD: Co Concentrations over Distance from Well

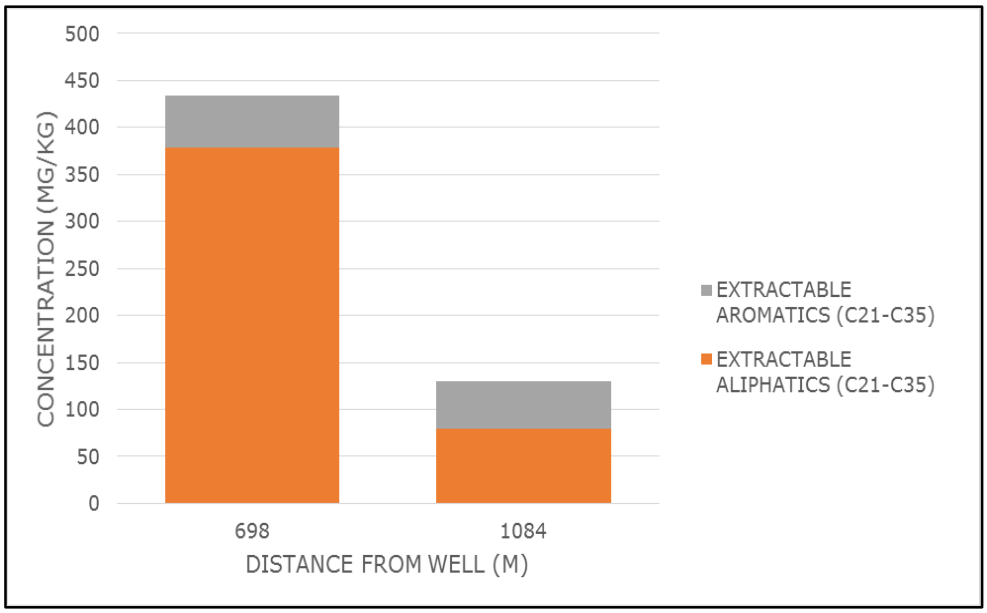


Figure 7-8: Transect TMC: Fractionated TPH Concentrations over Distance from Well

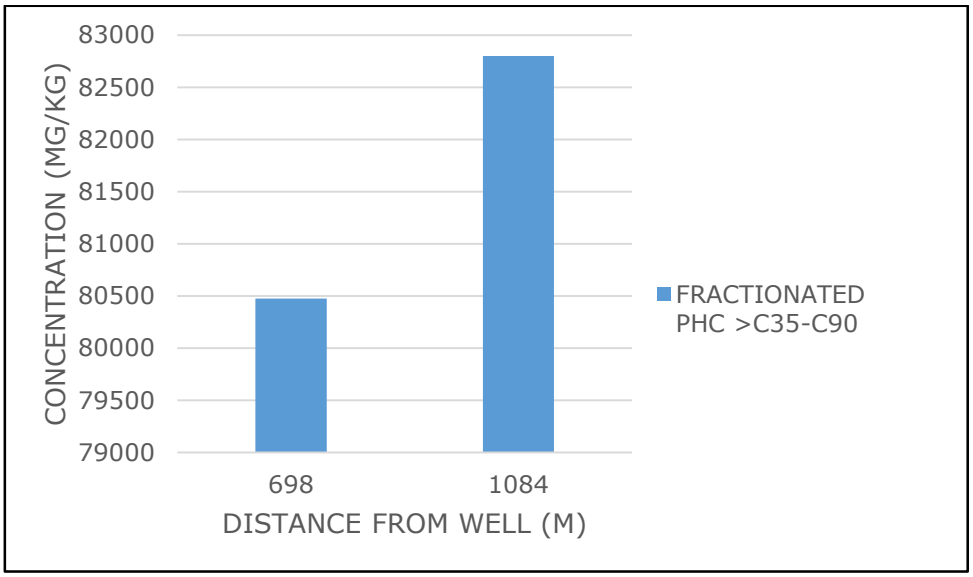


Figure 7-9: Transect TMC: Concentration of PHC >C35-C90 over Distance from Well

Along transect TMD concentrations of all analytes appear to be increasing with distance from the well (Figure 7-2 to Figure 7-7). Similarly, Figure 7-9 illustrates that PHC concentrations from TMC also increase with distance. In contrast TMC shows a general decrease in aliphatics with distance and extractible aromatic concentrations remain much the same (Figure 7-8).

7.4 *Tarcrete Classification System*

It was proposed to develop a classification system by drawing parallels between the different physical characteristics of tarcrete (as per the Guideline, Section 6.1) and the chemical characterization data (Section 6.4.1). It was envisioned that similarities would provide groupings of tarcrete classification types giving information on the nature of the tarcrete toxicity and how it behaves within the environment. However, due to the uniform composition and similar concentrations of the samples the fate and transport properties of each are the same. Therefore a classification system based on this premise would require further ground investigations to determine if there are more diverse chemical compositions of tarcrete in other areas.

7.5 *Effects of Tarcrete on Soil*

Potential effects of tarcrete on soil being investigated are soil contamination and impacts to bulk soil chemical properties and environmental factors (soil moisture and temperature) that relate to soil fertility.

7.5.1 Soil Contamination

To test if tarcrete is causing contamination to the underlying soil the chemical analysis of the soil samples underlying tarcrete was compared to the analysis of the soil samples not covered by tarcrete. Analytical data for these samples are presented in Section 6.4.2. If soil contamination has occurred it is expected that the contaminant concentrations in soil underlying tarcrete would be elevated compared to that found in soil not covered by tarcrete. A one order of magnitude (OoM) cut off was used to define notable differences between the concentrations.

Error! Reference source not found. Table 7-3 draws a comparison between concentrations of the PHC fraction >C35-C90 and **Error! Reference source not found.** Table 7-4 provides a comparison between metal concentrations. PAH, hydrocarbons up to the C35 fraction, cadmium and mercury are excluded from the tables as concentrations were below the LOR and SARA analysis was only undertaken on 1 soil sample (refer to Section 6.4). Therefore, no further analysis of these parameters has been undertaken.

Table 7-3: Comparison of Soil Fractionated Hydrocarbon Concentrations

Soil Samples Underlying Tarcrete						
Analyte Name	**Units**	**LOR**	**SO-TMA-MP2**	**SO-TMB-MP1**	**SO-TMD-MP1**	**SO-TMD-MP2**
Fractionated PHC >C35-C90	mg/kg	0.5	418.9	487.2	449.6	524.1
Soil Samples Not Underlying Tarcrete						
Analyte Name	**Units**	**LOR**	**SO-TMA-MP1**		**SO-TMA-MP3**	
Fractionated PHC >C35-C90	mg/kg	0.5	303.7		787.5	

Table 7-4: Comparison of Soil Metal Concentrations

Analyte Name	**Units**	**LOR**	**Underlying Tarcrete**			**Not Underlying Tarcrete**
			SO-TMA-MP2	**SO-TMD-MP1**	**SO-TMD-MP2**	**SO-TMA-MP1**
Calcium	mg/kg	0.25	42,830	23,403	30,832	29,445
Lead	mg/kg	0.4	1.5	1.3	1.3	1.5
Vanadium	mg/kg	0.4	11.0	9.4	6.0	9.2
Cobalt	mg/kg	0.3	2.5	2.1	1.6	2.4

The concentrations detected in all soil samples for all parameters tested are within the same OoM On this basis tarcrete does not appear to be impacting the underlying soil.

7.5.2 Impacts to Bulk Soil Chemical Properties

Tarcrete impacts to bulk soil chemical properties were assessed by comparing soil chemistry data from sites with tarcrete to sites with little or no tarcrete (Table 7-5). Results of the comparison are presented in Table 7-6**Error! Reference source not found.**. For this analysis sample results from SO-TMA-MP1 are classified as having no tarcrete cover on the basis that the previous analysis has demonstrated that the presence of tarcrete is not causing

contamination to the underlying soil and the tarcrete present at this location was very fine gravel with less than 1% coverage.

The data was first analysed for outliers using a five number summary test. As a result concentrations of TKN, sulphate and chloride and measurements of SAR and conductivity from TMA-MP3 were removed. The data was subsequently evaluated for differences in mean concentrations (Table 7-6) and variability (Table 7-7**Error! Reference source not found.**). One OoM cut off was used to define notable differences between the mean concentrations. Variability was based on the coefficient of variance (CV). CV greater than 1 (>1) is considered to be variable with increasing variability as CV increases. CV less than 1 (<1) is not considered variable.

Soils underlying tarcrete compared to soils without tarcrete cover are all within the same OoM in all parameters tested. Conductivity, pH, potassium and chloride were slightly more variable in soils underlying tarcrete compared to soils without a tarcrete cover but all CV were less than 1; therefore, any variability is considered negligible. It is suggested from these results that the presence of tarcrete is not having an effect on these soil properties.

Table 7-5: Soil Sample IDs for Samples with and without Tarcrete Cover

Underling Tarcrete	SO-TMB-MP1	SO-TMD-MP1	SO-TMD-MP2
Without Tarcrete Cover	SO-TMA-MP1	SO-TMA-MP2	SO-TMA-MP3

Table 7-6: Mean and Standard Deviation of Soil Chemistry Results for Samples with and without Tarcrete Cover

			Underlying Tarcrete		**Without Tarcrete Cover**	
Analyte Name	**Units**	**LOR**	**Mean**	**Standard Deviation**	**Mean**	**Standard Deviation**
Moisture	%	0.1	2.43	0.06	2.43	0.83
pH	pH	0.1	8.7	0.5	8.9	0.1

			Underlying Tarcrete		Without Tarcrete Cover	
Analyte Name	**Units**	**LOR**	**Mean**	**Standard Deviation**	**Mean**	**Standard Deviation**
Total Kjeldahl Nitrogen[1]	mg/kg	0.1	1.1	0.1	1.0	0.1
Total Phosphorus	mg/kg	1	102	9	80	11
Potassium	mg/kg	0.25	51.88	25.85	39.95	16.44
Sulphate[1]	mg/kg	0.2	118.6	27.4	154.6	102.0
Chloride[1]	mg/kg	0.2	31.2	18.3	16.6	4.0
Alkalinity as Calcium Carbonate	mg/kg	-	247.33	63.31	313.87	137.55
Total Organic Carbon	mg/kg	-	1690.00	51.96	2050.00	113.58
Sodium Absorption Ratio[1]	-	0.25	<0.25	NA	<0.25	NA
Conductivity[1]	µS/cm	1	304	76	267	9

[1]TMA-MP3 data excluded

Table 7-7: Coefficient of Variation (CV) of Soil Chemical Properties

Analyte Name	Underlying Tarcrete	Without Tarcrete Cover
Moisture	0.02	0.34
pH	0.06	0.01
Total Kjeldahl Nitrogen[1]	0.10	0.10
Total Phosphorus	0.08	0.14
Potassium	0.50	0.41
Sulphate[1]	0.23	0.66
Chloride[1]	0.59	0.24
Alkalinity as Calcium Carbonate	0.26	0.44
Total Organic Carbon	0.03	0.06
Sodium Absorption Ratio[1]	NC	NC
Conductivity[1]	0.25	0.03

[1]TMA-MP3 data excluded

Concentrations of TKN, sulphate and chloride together with measurements of SAR and conductivity from TMA-MP3 were identified as outliers. TMA-MP3 is a location without tarcrete and has unique localised conditions that make it different from other sites, this is discussed in greater detail in Chapter 8.

It is worth noting that the mean pH (8.8 $\pm$0.35, n=6) in all samples was found to be greater than the typical range for a Typic Torripsament soil (7.5 to 8.5) (Grealish et al., 2001a).

7.5.3 Impacts to Soil Environmental Factors

To establish if tarcrete is impacting the soil environment, soil temperature, moisture and EC were measured from sites with a varying presence of tarcrete (Section 6.3) and compared for differences. Results of the analysis are presented in Sections 7.5.3 to 7.5.6.

Table 7-8 provides the monitoring site groupings that were used to compare differences in monthly soil temperature, moisture and EC across sites with varying tarcrete cover. TMA-MP1 and TMA-MP2 have been categorized as sites without tarcrete cover on the basis that:

- Results illustrate tarcrete is not causing contamination to the underlying soil (Section 7.5.1);
- TMA-MP1 comprises very fine gravel with less than 1% coverage (Section 6.2.1); and
- TMA-MP2 fine to medium gravel with approximately 5% cover (Section 6.2.1).

The continuity of tarcrete at the remaining sites has been described as continuous (more than 80% cover); however, a continuum within this category was observed among the monitoring sites, as presented in Table 7-8 and observed in photographs of the monitoring sites (Appendix C). The thickness of the tarcrete found at each monitoring site has been included in the table for reference as consideration of its potential effects on the results was also reviewed.

Table 7-8: Monitoring Sites Representing Each Tarcrete Continuity Category

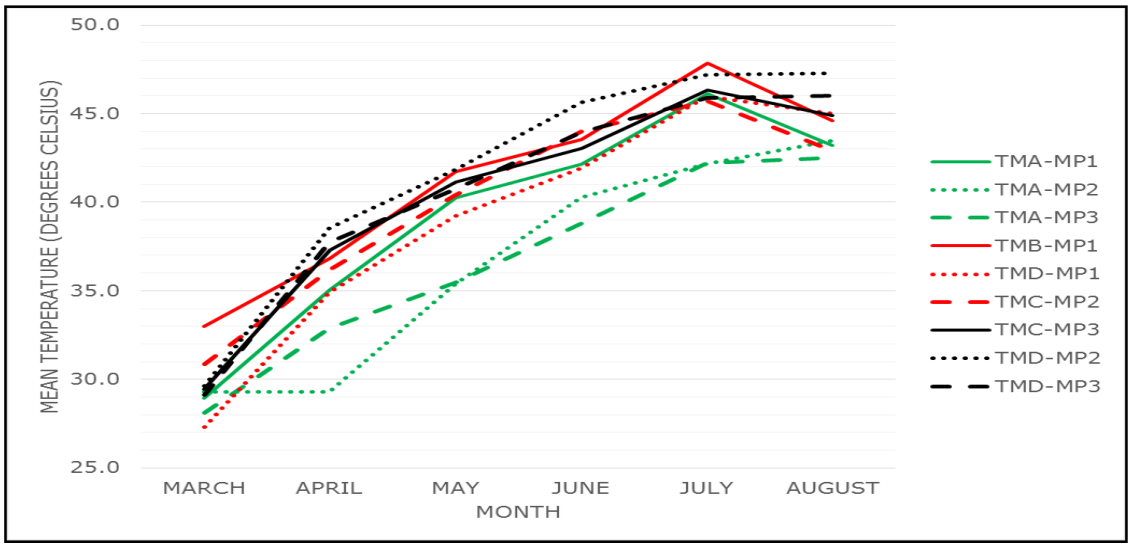
Without Tarcrete Cover	Low Tarcrete Cover	Low Tarcrete Cover Thickness (cm)	High Tarcrete Cover	High Tarcrete Cover Thickness (cm)
TMA-MP1	TMB-MP1	0.5	TMC-MP3	1.2
TMA-MP2	TMD-MP1	1.5	TMD-MP2	1.5
TMA-MP3	TMC-MP2	1.0	TMD-MP3	1.1

7.5.4 Soil Temperature

Mean soil temperature data was evaluated for differences in mean monthly temperatures and variability (CV). CV = >1 is considered to be variable with increasing variability as CV increases. CV = <1 is not considered variable. Mean temperatures were used to reduce variation caused by measurements being collected at varying times throughout the day.

The overall trend of the data is considered normal for Kuwait at the time of year. Ambient temperatures are increasing from March to July and start to reduce in August; therefore, similar trends in soil temperature are expected.

Figure 7-10 and Table 7-9 show that sites with the highest tarcrete cover generally have the highest soil temperatures and the least amount of variability. Sites without tarcrete cover generally have the lowest soil temperatures and the most amount of variability. The CV is <1 for all months in all categories. The small amount of variability that exists is considered negligible.



Green lines = sites without tarcrete, Red lines = sites with low tarcrete cover, Black lines = sites with high tarcrete cover

Figure 7-10: Mean Monthly Soil Temperatures

Analysing the percent differences (Table 7-9), the mean soil temperature differences between high tarcrete cover sites and sites without tarcrete range from 0.6°C in March to 5.4°C in April with a median value of 4.0°C. The mean soil temperature differences between low tarcrete cover sites and sites without tarcrete range from 1.1°C in August to 3.6°C in April with a median value of 3.1°C.

Temperatures recorded at the site with the thinnest tarcrete (0.5cm at TMB-MP1) are generally the highest among the low continuity tarcrete sites. Conversely, temperatures recorded at the site with the thickest tarcrete (1.5cm at TMD-MP1) are generally the lowest (Figure 7-10 and Table 7-8). The same trends are not observed amongst the high continuity tarcrete sites (Figure 7-10 and Table 7-8).

Table 7-9: Soil Temperature Differences Among Tarcrete Continuity Categories

	March	April	May	June	July	August
Without Tarcrete Cover						
Mean	28.8	32.4	37.0	40.4	43.5	43.1
Standard Deviation	0.6	2.9	2.8	1.7	2.3	0.5
CV	0.0	0.1	0.1	0.0	0.1	0.0
Low Tarcrete Cover						
Mean	30.4	36.0	40.4	43.2	46.5	44.2
Standard Deviation	2.9	1.0	1.3	1.1	1.2	1.1
CV	0.1	0.0	0.0	0.0	0.0	0.0
Difference of Without Tarcrete	1.6	3.6	3.4	2.7	3.0	1.1
High Tarcrete Cover						
Mean	29.4	37.8	41.2	44.2	46.5	46.1
Standard Deviation	0.3	0.6	0.5	1.3	0.7	1.2
CV	0.0	0.0	0.0	0.0	0.0	0.0
Difference of Without Tarcrete	0.6	5.4	4.2	3.8	3.0	3.0
Legend:						
Lowest Value						
Middle Value						
Highest Value						
CV = >1						

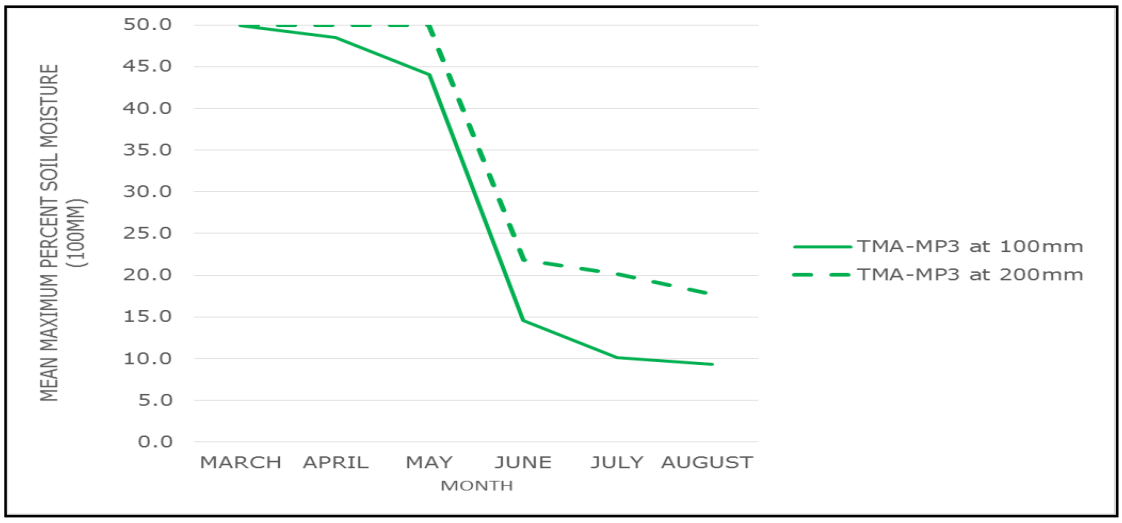
7.5.5 Soil Moisture

Soil moisture data was evaluated for differences in mean monthly percent moisture and variability (CV). CV = >1 is considered to be variable with increasing variability as CV increases. CV = <1 is not considered variable. The percent difference between sites with tarcrete cover and sites without tarcrete was also calculated and compared and any potential influence of tarcrete thickness evaluated.

Maximum monthly soil moisture readings were used to best illustrate the variation that can occur among the sites across the months. Percent moisture at 100mm depth in July and August was 0% at all locations and was thus excluded from Figure 7-12. Data from TMA-MP3 has been plotted separately (Figure 7-11) and excluded from calculations (Table 7-10 and Table 7-11) as soil moisture levels at this location are considerably different from all other locations (Figure 7-12 and Figure 7-13). Rain events were recorded once in March on a monitoring day (heavy rain), twice in April (including one heavy rain and high wind event) and once in May (light rain).

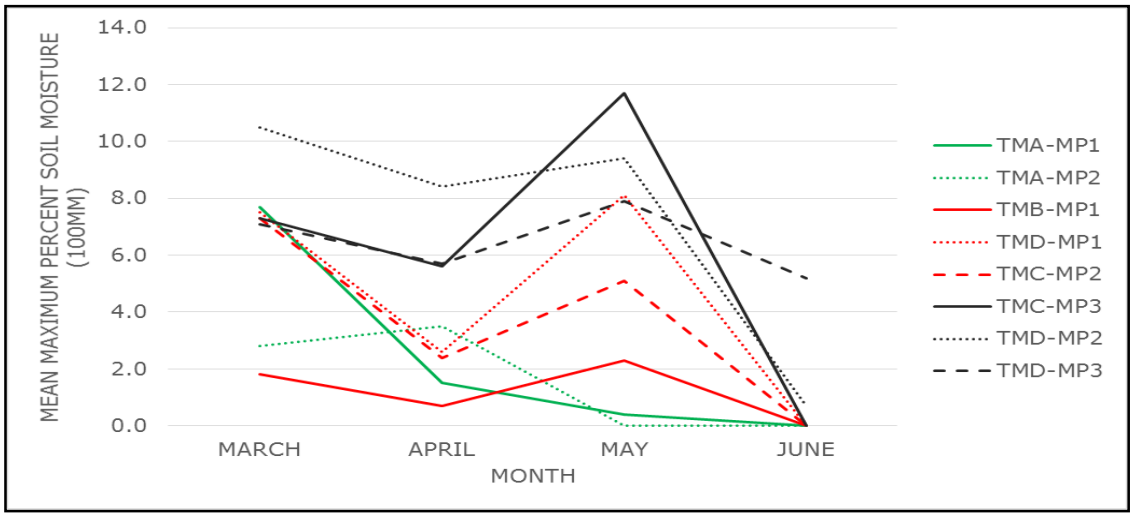
The overall data trend is typical for the time of year in Kuwait. With increasing temperatures a decrease in soil moisture is expected. Moisture spikes in May are attributed to the rain event that occurred the morning of the monitoring. Spikes at TMA-MP2 at 100mm may also be related to the rain events that occurred during April.

Soil moisture at TMA-MP3 consistently and sizeably exceeds monthly moisture levels recorded at all other sites at both depths (Figure 7-11 compared to Figure 7-12 and Figure 7-13). From 8 March 2014 to 17 May 2014, with the exception of 26 April 2015, soil moisture levels at 200mm depth were greater than the scale of the measuring instrument; maximum reading is 50% (Figure 7-11). Data from TMA-MP3 is consistently different from other sites and is discussed in greater detail in Section 8.8. Results of the analysis presented herein exclude TMA-MP3.



Green lines = sites without tarcrete

Figure 7-11: TMA-MP3 Maximum Monthly Percent Soil Moisture at 100mm and 200mm Depths



Green lines = sites without tarcrete, Red lines = sites with low tarcrete cover, Black lines = sites with high tarcrete cover
Percent moisture in July and August was 0% at all locations.

Figure 7-12: Maximum Monthly Percent Soil Moisture at 100mm Depth

At 100mm depth Figure 7-12 and Table 7-10 shows that the sites with the highest tarcrete cover generally have the highest soil moisture and retain moisture the longest. These sites show the lowest variability with the exception of the month of June during which CV >1. This high variability was a result of a high moisture reading at TMD-MP3 (5.2%), compared to TMD-MP2 (0.7%) and TMC-MP3 (0%).

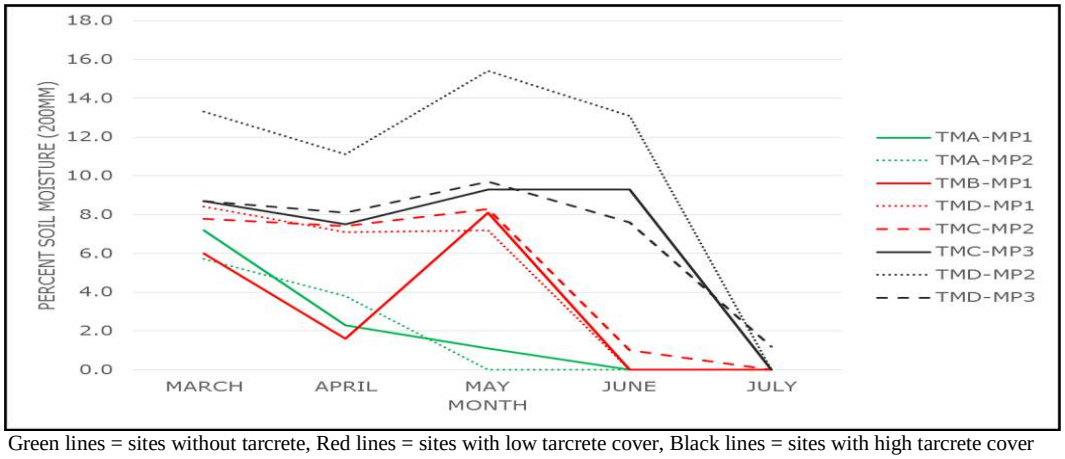
Sites without tarcrete cover generally have the lowest soil moisture at 100mm depth, the only exception being during April when the low tarcrete cover site has the lowest percent moisture (Figure 7-12 and Table 7-10). At this depth these sites have the highest variability from March to May, soil moisture was 0% in June and July. The highest variability at sites without tarcrete occurred in May when CV >1, resulting from high moisture levels at TMD-MP1 (8.1%) compared to TMC-MP2 (5.1%) and TMB-MP1 (2.3%).

Soil moisture levels measured at 100mm depth for areas of low tarcrete cover have moisture readings consistently between sites with high tarcrete cover and those without (Figure 7-12 and Table 7-10). With the exception of April when it was the low cover site that had the lowest moisture reading (1.9%), compared to sites without tarcrete (2.5%) and sites with high tarcrete cover (6.6%). The data variability at low tarcrete sites (readings taken at 100mm), consistently has a CV <1, therefore, overall it is the least variable among the categories across all months at this depth.

Table 7-10: Soil Moisture Differences Among Tarcrete Continuity Categories at 100mm

	March	April	May	June
Without Tarcrete Cover[1]				
Mean	5.3	2.5	0.2	0.0
Standard Deviation	3.5	1.4	0.3	0.0
CV	0.7	0.6	1.4	N/A
Low Tarcrete Cover				
Mean	5.5	1.9	5.2	0.0
Standard Deviation	3.2	1.0	2.9	0.0
CV	0.6	0.5	0.6	N/A
% Difference (Without Tarcrete)	29	17	34	0
High Tarcrete Cover				
Mean	8.3	6.6	9.7	2.0
Standard Deviation	1.9	1.6	1.9	2.8
CV	0.2	0.2	0.2	1.4
% Difference (Without Tarcrete)	43	60	64	100
Legend:				
Lowest Value				
Middle Value				
Highest Value				
CV = >1				

[1]TMA-TM3 data excluded



Green lines = sites without tarcrete, Red lines = sites with low tarcrete cover, Black lines = sites with high tarcrete cover
Percent moisture in July and August was 0% at all locations.

Figure 7-13: Maximum Monthly Percent Soil Moisture at 200mm Depth

Table 7-11: Soil Moisture Differences Among Tarcrete Continuity Categories at 200mm

	March	April	May	June	July
Without Tarcrete Cover[1]					
Mean	6.5	3.1	0.6	0.0	0.0
Standard Deviation	1.1	1.1	0.8	0.0	0.0
CV	0.2	0.3	1.4	N/A	NA
Low Tarcrete Cover					
Mean	7.4	5.4	7.9	0.3	0.0
Standard Deviation	1.2	3.3	0.6	0.6	0.0
CV	0.2	0.6	0.1	1.7	NA
% Difference (Without Tarcrete)	31	31	40	3	0.0
High Tarcrete Cover					
Mean	10.2	8.9	11.5	10.0	0.4
Standard Deviation	2.7	1.9	3.4	2.8	0.7
CV	0.3	0.2	0.3	0.3	1.7
% Difference (Without Tarcrete)	42	51	58	97	100
Legend:					
Lowest Value					
Middle Value					
Highest Value					
CV = >1					

[1]TMA-TM3 data excluded

At 200mm depth locations with highest tarcrete cover generally have the highest soil moisture and the longest moisture retention. Sites without tarcrete cover generally have the lowest soil moisture, leaving sites with low tarcrete cover with moisture levels that fall within this extent (Figure 7-13 and Table 7-11). There is one month in each of the different cover categories where the variability at 200mm depth is greater than 1 (Table 7-11). For sites without tarcrete this was May, for low cover sites it was June and for high cover sites it was July. All are attributed to having one location among the group at which a moisture reading above 0% was obtained. Considering the mean CV across all months for each category, the result is the same (calculated at 0.6), whereas the median CV is 0.3 for sites without tarcrete and sites with high tarcrete cover. The median CV across all sites is marginally higher at 0.4.

The percent difference between sites (Table 7-10) with high tarcrete cover and sites without tarcrete shows that at 100mm depth high tarcrete cover can increase soil moisture from 43% to 100% with a median increase of approximately 62%. Similarly, at 200mm depth this increase can range from 42% to 100% with a median increase of 58%. By comparison sites with low tarcrete cover can cause a soil moisture increase of 0% to 34% with median increases of 23% at 100mm; and from 0% to 40% at 200mm depth with a median increase of 31%, compared to sites without tarcrete (Table 7-11).

To determine if tarcrete thickness was influencing soil moisture, the sum of the soil moisture at each location at each depth was plotted against tarcrete thickness. A linear regression analysis demonstrates that there is not a strong linear relationship between tarcrete thickness and soil moisture at either 100mm ($r^2 = 0.6205$) or 200mm depth ($r^2 = 0.412$).

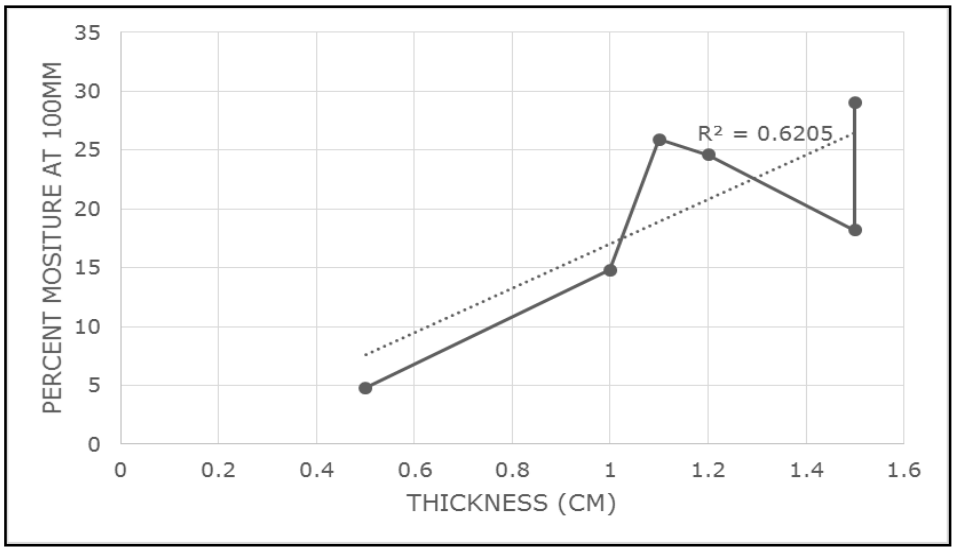


Figure 7-14: Relationship between Soil Moisture at 100mm and Tarcrete Thickness

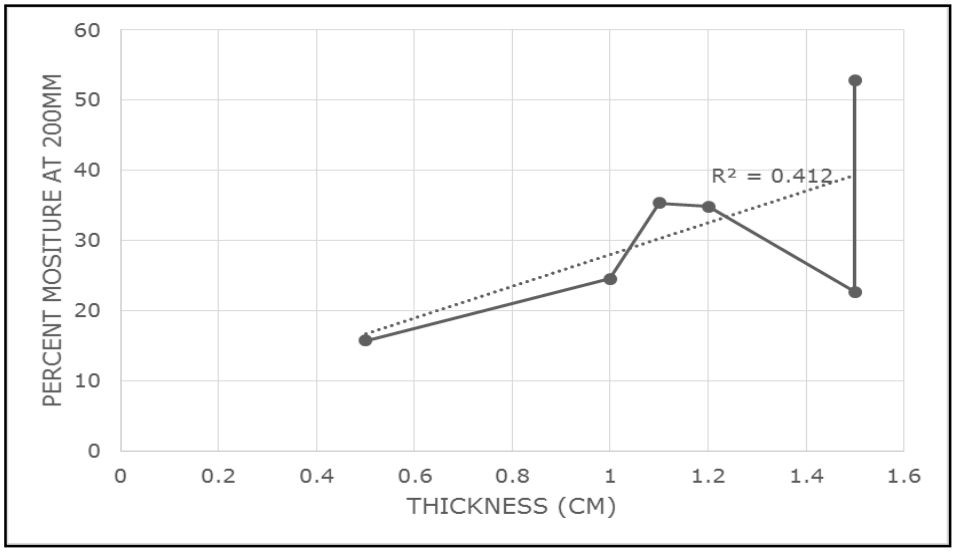


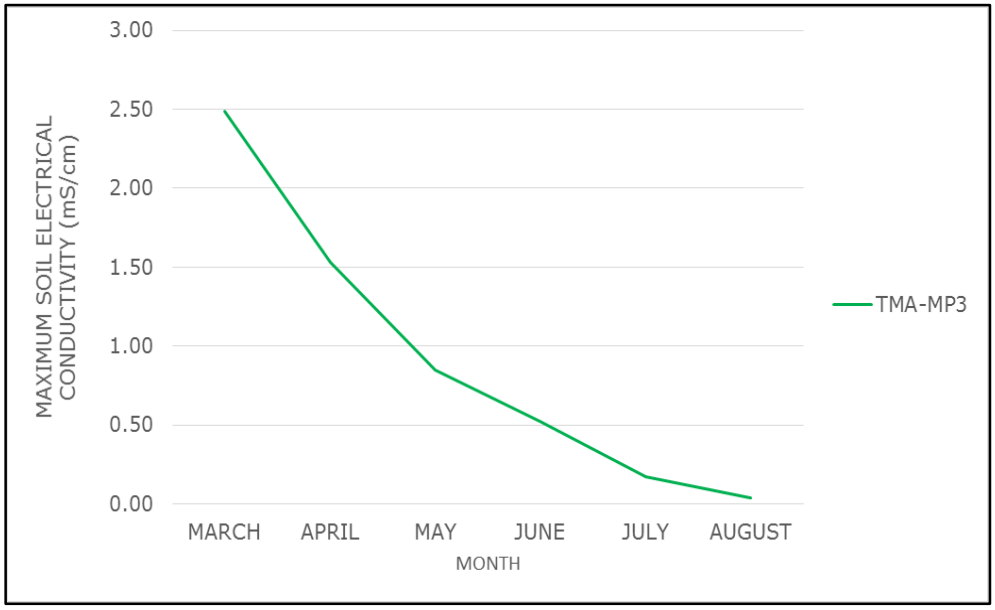
Figure 7-15: Relationship between Soil Moisture at 200mm and Tarcrete Thickness

7.5.6 Soil Electrical Conductivity

EC data was evaluated for differences and variability (CV). CV = >1 is considered to be variable with increasing variability as CV increases. CV = <1 is not considered variable. The percent difference between sites with tarcrete cover and sites without tarcrete was also calculated and compared. Maximum monthly soil EC readings were used as a comparison between the tarcrete coverage categories to illustrate the variation that can occur throughout the year.

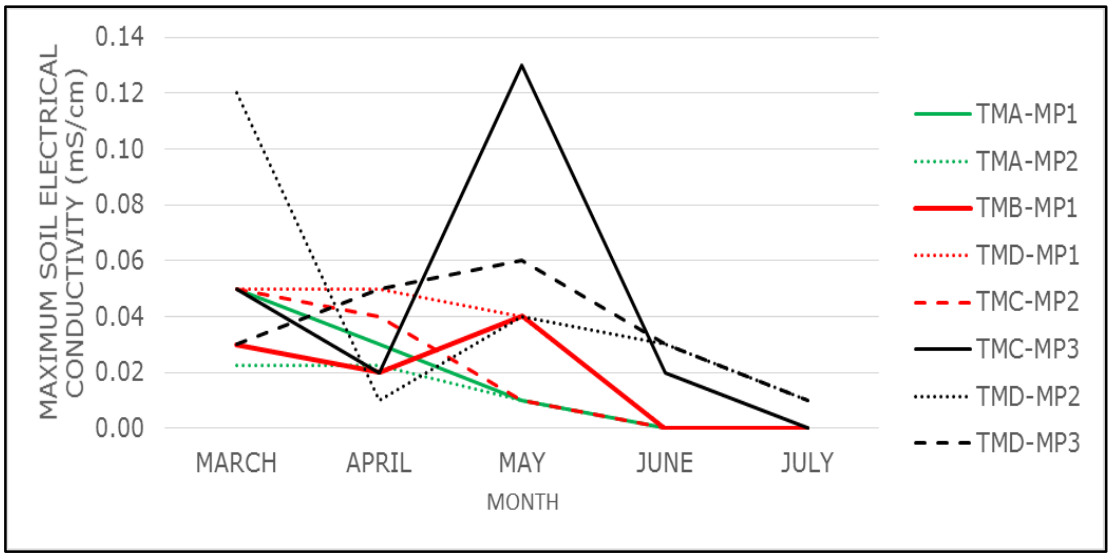
Data from TMA-MP3 has been plotted separately (Figure 7-16) and is excluded from calculations (Table 7-12) and discussion due to EC levels that consistently and sizeably exceed monthly EC levels recorded at all other sites. EC levels are influenced by specific localised characteristics that were encountered only at this site (discussed in Section 8.8). Rain events were recorded once in March on a monitoring day (heavy rain), twice in April (including one heavy rain and high wind event) and once in May (light rain).

The overall data trend is typical for the time of year in Kuwait with increasing temperatures and a decrease in soil moisture (Section 7.5.5), a decrease in soil EC is expected. The data spikes for May are attributed to the rain event that occurred the morning of the monitoring.



Green lines = sites without tarcrete

Figure 7-16: TMA-MP3 Maximum Monthly Soil Electrical Conductivity



Green lines = sites without tarcrete, Red lines = sites with low tarcrete cover, Black lines = sites with high tarcrete cover
EC in August was 0.00mS at all locations.

Figure 7-17: Maximum Monthly Soil Electrical Conductivity

Table 7-12: Soil Electrical Conductivity Differences Among Tarcrete Continuity Categories

	March	April	May	June	July
Without Tarcrete Cover[1]					
Mean	0.04	0.03	0.01	0.00	0.00
Standard Deviation	0.02	0.01	0.00	0.00	0.00
CV	0.54	0.20	0.00	NA	NA
Low Tarcrete Cover					
Mean	0.04	0.04	0.03	0.00	0.00
% Difference (Without Tarcrete)	0.01	0.02	0.02	0.00	0.00
CV	0.27	0.42	0.58	NA	NA
Diff	29.63	40.93	25.71	0.00	0.00
High Tarcrete Cover					
Mean	0.07	0.03	0.08	0.03	0.01
% Difference (Without Tarcrete)	0.05	0.02	0.05	0.01	0.01
CV	0.71	0.78	0.62	0.22	0.87
Diff	45.58	29.77	65.71	100.00	100.00
Legend:					
Lowest Value					
Middle Value					
Highest Value					

[1]TMA-MP3 data excluded Note: EC in August was 0.00mS at all locations.

Figure 7-17 and Table 7-12 show that the sites with the highest tarcrete cover generally have the highest EC and the longest presence of dissolved salts across the months, with measurements above 0.00mS still being recorded in July. April is the only month in which the high tarcrete sites were surpassed by another category. The difference between all sites in April was 0.01mS.

Results from the sites without tarcrete generally have the lowest EC until June when no readings above 0.00mS were detected. EC levels at sites with low tarcrete were not detected after May and had the lowest EC readings in March and the highest in April. EC levels in May were between the two other tarcrete cover categories (Figure 7-17 and Table 7-12).

Table 7-12 shows that the overall percent increase in EC at sites with high tarcrete cover is 30% to 100%, with a mean difference of 68%. At low tarcrete cover sites this difference averages 19% (median difference of 26%) and ranges from 0% to 41%.

The mean CV across all months for each category decreases by 0.2 from the high tarcrete cover sites (CV = 0.6) to the no tarcrete cover sites (CV = 0.2) but never exceeds 1. Any variability that is occurring is considered negligible (Table 7-12).

7.6 *Determine the Effect of Tarcrete on Natural Re-vegetation*

To determine the effect of tarcrete on natural re-vegetation, percent canopy cover from each of the monitoring sites was divided into groups based on presence of tarcrete. Monitoring site groupings remain the same as those used to assess tarcrete impacts to soil environmental factors (Table 7-8). The minimum, mean and maximum percent cover encountered within each tarcrete continuity category has been tabulated (Table 7-13) and compared.

Table 7-13: Percent Canopy Cover Among Tarcrete Continuity Categories

Tarcrete Continuity		Absent[1]	Low Tarcrete Continuity	High Tarcrete Continuity
Percent Canopy Cover	Minimum	38	42	38
	Mean	54	62	54
	Maximum	72	76	76
	Total	428	566	488

[1]Excludes results from TMA-MP3 Line 3 (identified as an outlier[4])

Table 7-13 demonstrates that the mean percent canopy cover is 8% higher at the low tarcrete cover sites (62%) compared to the high cover sites (54%) and sites without tarcrete (54%).

The greatest range in percent canopy cover occurs at the sites without tarcrete, ranging from 0% along line 3 at TMA-MP3 to 72% TMA-MP2, line 3 (Section 6.5, Table 6-40). However, data from TMA-MP3 line 3 has been identified[5] as an outlier and therefore excluded from the analysis discussed herein. Data pertaining to TMA-MP3 is consistently different from other sites (discussed in Section 8.8).

With the outlier removed (Table 7-13), the greatest range in cover occurs at high tarcrete cover sites with a 38% difference between the minimum and maximum percent cover encountered. Sites with low tarcrete cover and where tarcrete is absent, the range is 34% or 4% less than the high tarcrete cover sites.

[5] Value has been identified as an outlier (greater than the interquartile range) using a five number summary test.

8 Discussion

8.1 *Physical Characteristics of Tarcrete*

Physical characteristics of tarcrete were assessed based on tarcrete 'type' which was defined by its presence as a consolidated layer. A "mat-like" tarcrete (tarmat) is present as a layer that can be lifted off the soil. Within the Study Area the tarmat was mainly continuous, with an average thickness of 1.10±0.49cm, hardened and friable (Sections 6.2.2 to 6.2.4).

The second type of tarcrete is "gravel-like". It does not occur as a layer but rather as small fragments. It has likely been formed by manmade ground disturbance in areas of tarmat or as solidified droplets of oil spray. How tarcrete gravel was formed is speculation. Determination of the way in which tarcrete was formed was outside of the scope of this study. Tarcrete gravel in the Study Area was limited to one transect and was described as fine to medium, very sparse, uneven, hardened, very friable to friable (Section 6.2.1).

The resulting physical characterization of tarcrete is similar to previous studies (Grealish et al., 2001a, b; CIC, 2003, b). With the exception that the literature suggests some tarcrete would be more malleable (CIC, 2003b). This was not encountered during this study but may be attributed to the area studied or the time of year. Physical characteristics were assessed during the colder winter months which may decrease malleability. Comparison of results encountered during this study is limited to three studies (Grealish et al., 2001a, b; CIC, 2003, b) due to the varying definitions and terminology used to describe tarcrete. Therefore, with the intention of ensuring data from future research is more comparable a *Guideline for Describing Tarcrete* (Section 6.1) was developed to standardize the way in which tarcrete is described.

8.1.1 The Effect of Depositional Distance from the Source on Tarcrete's Physical Characteristics

The effect of deposition distance from the well on the characteristics of tarcrete was limited (Section 7.3). With respect to tarmat, only a minor decrease in thickness was observed (Figure 7-1). No other physical characteristics were influenced by distance (Figure A-5, Appendix A). For tarcrete gravel the size, abundance and friability slightly reduced with increased distance (Table 7-2). Although tarcrete gravel abundance decreased with distance

the change was minor (5% to <1%) and is within the 'very sparse' or <25% cover category (Section 6.2.1).

In previous studies the influence of depositional distance on tarcrete's physical characteristics has been limited to an assessment on thickness. Observations made in the PAAC report (2002a, p.68), stated that the mean tarcrete thickness of 1cm to 1.5cm (Grealish et al., 2001a, b; PAAC, 2002a; CIC, 2003b) increased up to 10cm near the centre of the deposit (PAAC, 2002a). It was considered that this is to mean the centre of the tarcrete source across the Burgan Oilfield which was described as extending to approximately 13km downwind of the wells. By comparison, data results show that the mean thickness (1.10$\pm$0.49cm) recorded in this study is similar to that reported in the literature (Grealish et al., 2001a, b; PAAC, 2002a; CIC, 2003b). The maximum thickness encountered was 2.5cm from 900m to 950m along transect TMB. The maximum expected thickness of 10cm (as reported in the literature) was not encountered within the Study Area.

8.1.2 Development of a Guideline to Describe Tarcrete

Using the physical characterization information, the Guideline (Section 6.1) was developed. To date the most comprehensive tarcrete field descriptions were produced by KISR, which utilises a modified soil description standard (Grealish et al., 2001a, b).

The Guideline developed as part of this study expanded on KISR's work, adapted guides used to characterize soil, utilized criteria from previous tarcrete studies and current field observations. On this basis gravel-like tarcrete is described in terms of size, abundance and distribution. Tarmat is described in terms of continuity (coverage and fracturing) and thickness. Consistency and friability are described for both tarcrete types.

The Guideline is representative of the physical characteristics of tarcrete. It is based on the available literature (Grealish et al., 2001a, b; CIC, 2003b), the official UN definition (CIC, 2003b) and has been field tested. Some of the classes developed as part of the Guideline within each category were not encountered during the field survey but may still be relevant in other study areas.

Modifications were made to the Guideline (Section 5.1.8) to encompass tarcrete characteristics observed in the field that were not originally anticipated. Modifications included the addition of a 'soft' class within the consistency category and the expansion of the tarcrete gravel description to include the 'consistency' and 'friability' categories.

Testing of the Guideline is considered incomplete as many of the classes within each category were not encountered. The elimination of classes at this time is not recommended as the area tested covered only a small portion of the total tarcrete affected area and was conducted only during the colder winter months (November and December). Future development of the Guideline with further assessment of tarcrete is recommended. This may include elimination of categories where their inclusion provides no further information that can be related to tarcrete's impact to either underlying soil quality or the localised soil environment.

8.2 *Chemical Composition of Tarcrete and Effects of Weathering*

Samples were analysed for fractionated TPH, PAH[6], PHC >C35-C90, SARA and metals (Ca, Cd, Co, Hg and V) (Section 5.5.1). A small concentration (0.01% to 0.05%) of the residual range organic fraction C21-C35 was detected above the LOR (Table 6-28). Analysis of PHC >C35-C90 detected a mean concentration of 6% to 7%. SARA results determined the main component to be polar heterocyclic molecules (Section 7.1). Concentrations of tested PAH were not detected above the LOR (Table 6-29) and metal concentrations were negligible (Section 7.1). The chemical composition was the same for both types of tarcrete and all samples were within the same OoM (Section 7.1).

The analytical results for the tarcrete, which indicate an absence of lower weight hydrocarbons and higher percentage by ratio of the more resistant heavier weight hydrocarbons, can largely be attributed to the weathering process. This change is composition is demonstrated by the weathered crude chromatograms presented in Figure 3-2 in comparison to the Burgan oil chromatogram in Figure 3-1.

[6] US EPA priority pollutant PAHs

Based on fraction specific fate and transport properties (Table 7-1) and reference doses and concentrations (Section 7.1), the exposure and toxicity potential of tarcrete to humans and the environment is low, as it has low solubility and volatility properties. As a result tarcrete is persistent with little potential for degradation and mobility in the environment (Section 7.1).

Tarcrete's persistence and lack of further degradation has been demonstrated by Puskas et al., 1995a (cited in CIC, 2003a) and Guerinik et al., 2001 (cited in CIC 2003a) in which samples spanning from 1991 to 1994 and 1999 to 2001 showed no degradation (Section 3.3.3).

Limited characterization into the fraction specific components of tarcrete has been previously undertaken (Henry and Overton 1993 cited in CIC, 2003a; CIC, 2003b). Henry and Overton 1993 (cited in CIC, 2003a) reported high levels of asphaltenes, low levels of alkanes and limited PAH, which is similar to the findings of the current study. The exception being the detection of PAH.

PAH were not detected above the LOR within this study whereas concentrations of PAH from previous studies ranges from "limited" (Henry and Overton 1993 cited in CIC, 2003a) to significant when compared to "clean soil" (CIC, 2003b). In addition, Puskas et al., 1995a (cited in CIC, 2003a) reported high molecular weight PAH being present in samples tested from 1991 to 1994. The lack of the PAH detected in this study suggest that the tarcrete within the Study Area resulted from damaged wells rather than damaged wells which had been set on fire.

The metals tested as part of this study have also been previously tested by CIC (2003b) and Grealish et al. (2001a; b). Results of this study are comparable to these previous studies which detected "very low" concentrations.

8.2.1 The Effect of Depositional Distance from the Source on Tarcrete

Small changes in concentrations over distance were detected and trends among transects analysed differed (Figure 7-2 to Figure 7-9). However, in all instances the concentration

differences are negligible suggesting that deposition distance does not affect the chemical composition of tarcrete. Given the limited dataset there is a relative amount of uncertainty in this conclusion. Changes in the chemical composition of tarcrete gravel with distance was not analysed because only one sample was collected. The effects of depositional distance has not been previously studied within the available literature.

8.3 *Development of a Classification System for Tarcrete*

It was an objective of this study to develop a classification system by correlating physical characteristics with chemical properties (Section 5.6). However, due to the uniformity of the chemical data (Section 6.4.1) notable differences between the chemical composition and the descriptors used to describe tarmat and tarcrete gravel were not present (Section 7.4). Furthermore, the results of the study demonstrate no contamination resulting from the presence of tarcrete to underlying soils (Section 7.5.1). Therefore, a classification system based on this premise could not be developed.

8.4 *The Effect of Tarcrete on Underlying Soil*

Based on a comparison between the chemical analysis of soil underlying tarcrete and the same analysis of soil not underlying tarcrete (Table 7-3 and Table 7-4) tarcrete is not impacting the soil with respect to increases in hydrocarbons and the analysed metals.

Bulk soil chemical properties from soils underlying tarcrete was compared to soil from sites without tarcrete. Findings from this analysis also demonstrated no effects as a result of the tarcrete (Table 7-6 and Table 7-7).

8.5 *Updated Conceptual Site Model*

Based on the findings of this study the preliminary CSM has been updated (Figure 8-1). The scope of the assessment, planned management objectives, potential receptors remain the same (Chapter 4).

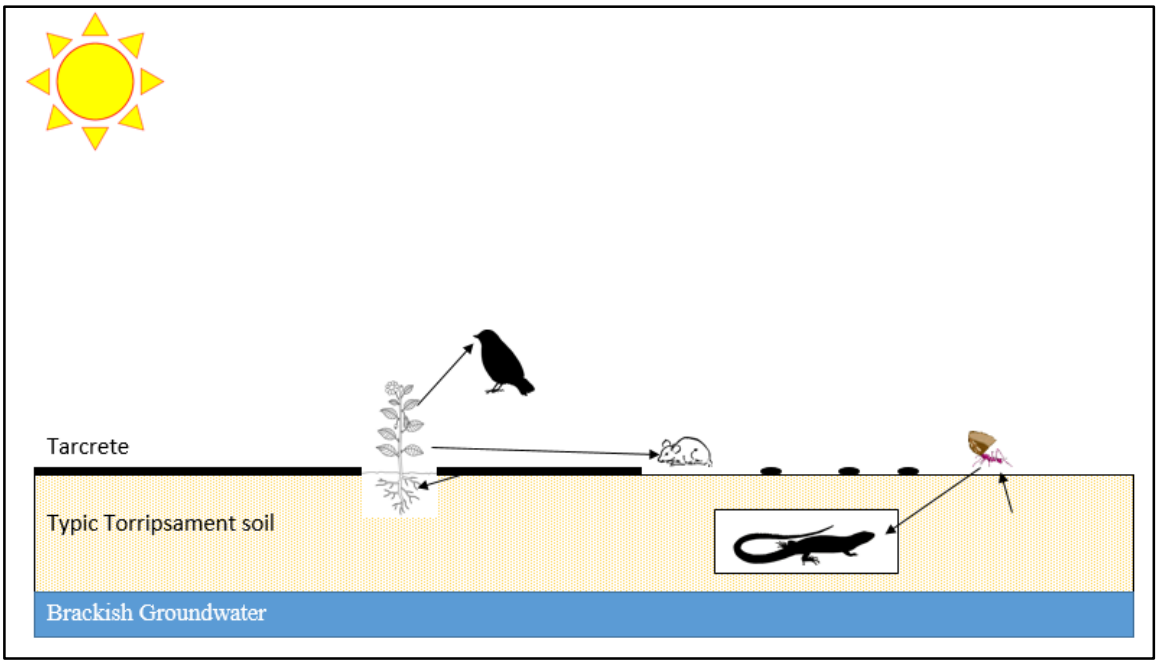


Figure 8-1: Updated Conceptual Site Model

Tarcrete is weathered crude oil contamination therefore the PCoC analysed are deemed to be appropriate and sufficient to characterize its chemical properties.

Using the characterization data (Section 6.4) and analysis of impacts on the underlying soil (Section 7.5.1) to inform the CSM, release and transport mechanisms no longer considered as part of the CSM (with justification) are summarized in Table 8-1.

Table 8-1: Justification for the Removal of Release and Transport Mechanisms from the CSM

Release and Transport Mechanisms and Potentially Affected Media	Justification for Removal from CSM
Dermal uptake by direct contact	• Dermal exposure minimal. • Dermal bioavailability low to none; therefore, low toxicity potential.
Absorption by plant roots from direct contact	• PCoC were not found in soils; therefore, direct contact with plant roots is not occurring. • Metal concentrations were not found in toxic levels.
Leaching and erosion via surface water runoff infiltration into the soil causing contamination via sorption	• Fraction specific fate and transport properties indicate a low leaching and erosion potential. • Metal concentrations were not found in toxic levels. • PCoC were not found in soils
Photodegradation of tarcrete causing soil contamination via sorption	Soil contamination is not evident after two decades of photodegradation.

Previous studies concluded that tarcrete was causing negative impacts to the fringed-toed lizard (Section 3.9). Effects were associated with direct and indirect ingestion of the contaminant (PAH, vanadium and nickel constituents), and behavioural changes resulting from tarcrete's alteration of the physical habitat.

No vegetation or fauna tissue were analysed as part of this study therefore it is unknown if the PCoC are bio-accumulating in tarcrete areas. On this basis this pathway cannot be omitted from the CSM; however, based on the characterization results it is unlikely this mechanism is occurring. No PAH were detected in any of the samples. Low levels of vanadium were detected and no evidence of impacts to underlying soil. Nickel was not analysed; however, it

has been determined within the literature that tarcrete contains "very low" concentrations of nickel (Section 3.3.2) and that Kuwait's soils are found to be relatively high in nickel (compared to concentrations found in crude oil) (Section 3.6.1). Additionally the tissue results from the Al-Hashem and Brian (2009a-c cited in Al-Hashem, 2011) study detected only low concentrations of nickel and conclusions as to the effects were based on plausibility, they were not definitive.

Behavioural effects caused by direct contact / the presence of tarcrete are outside of the scope of this study but based on the literature cannot be determined as no effects.

On this basis PoPC to terrestrial organisms relating to incidental ingestion (including ingestion of contaminated prey), direct contact and dermal exposure to tarcrete are still included within the updated CSM. All PoPC relating to exposure of contaminated soil are no longer included in the CSM as soil contamination was not evident.

Based on the removal of transport and release mechanisms and PoPC, the possibility of occurrence (including planned management activities) of pollutant linkages have been re-evaluated and the Pathway-Receptor Diagram updated (Figure 8-2).

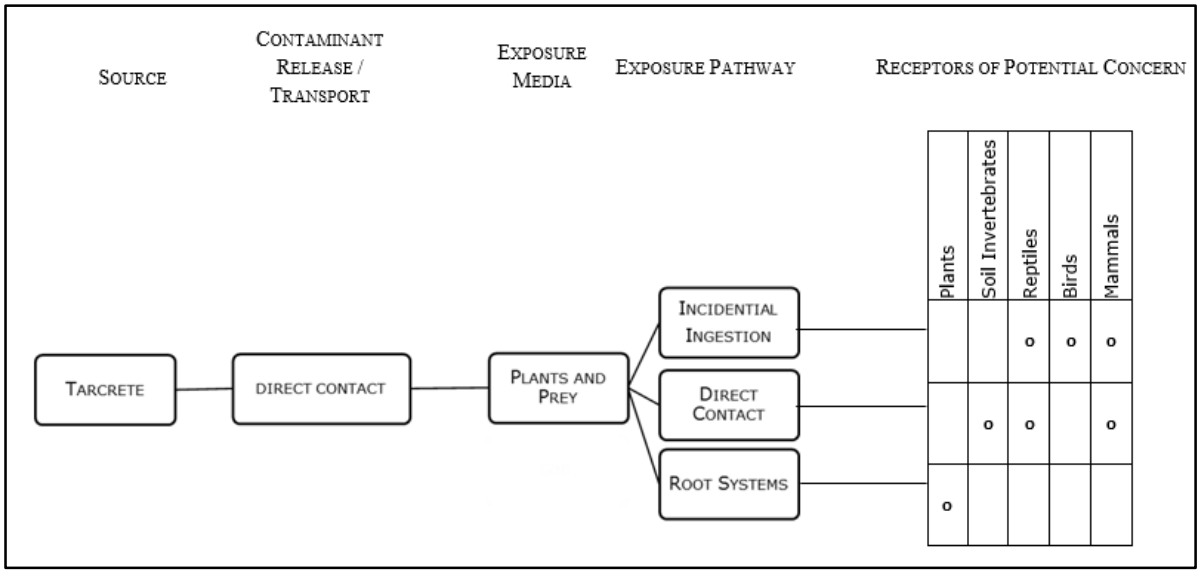


Figure 8-2: Updated CSM Pathway-Receptor Diagram

8.6 *The Physical Effect of Tarcrete on Underlying Soils*

Previous studies have stated that the presence of tarcrete is casing in negative impact to soil moisture (Grealish et al., 2001a, b; CIC, 2003c) and increasing surface temperatures (Kwarteng 2001 cited in PAAC, 2002a, p.60).

Based on data gathered during this study the presence of tarcrete is causing an increase in soil temperature (ranging from 0.6°C to 5.4°C). This increase is amplified in areas where tarcrete cover is highest (up to 4.0°C) (Figure 7-10 and Table 7-9). Results further suggest that an increase in tarcrete thickness limits ambient temperature effecting the soil temperature (Section 7.5.4). Although the same trend is not observed amongst the high continuity tarcrete sites (Figure 7-10 and Table 7-8). This could be a result of the minimal difference in the thicknesses among these sites (the greatest difference being 0.4cm, Table 7-8).

Soil moisture was investigated at two depths (100mm and 200mm). At both depths soil moisture was generally highest in the areas with high tarcrete continuity (Figure 7-12 and Figure 7-13). A median increase of 62% at 100mm depth and 58% at 200mm was detected when compared to sites without tarcrete cover (Table 7-9 and Table 7-10). Soil moisture levels at sites with less continuity (higher fragmentation) are slightly elevated or similar to sites without tarcrete. The median increase at these sites was 23% at 100mm and 31% and 200mm when compared to sites without tarcrete (Table 7-9 and Table 7-10). Areas with tarcrete cover also displayed higher soil moisture retention. At 100mm soil moisture readings were still being detected in high tarcrete cover sites in June whilst no soil moisture was below detectable levels at all other sites (Figure 7-12). At 200mm depth at sites with no tarmat cover soil moisture was no longer detected after May whereas moisture at sites with low and high tarcrete cover was detected into June and July, respectively (Figure 7-13).

Notwithstanding, all sites considered within this analysis are categorized as “Continuous” or >80% cover, in accordance with the Guideline (Section 6.2). The categories of ‘high’ and ‘low’ cover were based on visual differences within the Continuous category to order to determine if the presence of tarcrete was impacting the soil environment (i.e.; soil moisture, temperature and EC) (Section 7.5.3). Based on the division of this already high continuous

category it is demonstrated that even a small amount of fragmentation can have considerable effects on soil moisture.

It has been stated in the literature (Grealish et al., 2001a, b; CIC, 2003c) that the presence of tarcrete is having a negative effect on soil moisture by inhibiting water infiltration and increasing runoff (Grealish et al., 2001a, b; CIC, 2003c). Results from this study demonstrate that soil moisture is being positively affected where high continuity tarcrete exists with some fragmentation. In areas of low continuity tarcrete, soil moisture is either being positively affected or it is similar to areas where tarcrete is absent. The difference in the resulting conclusions between this study and the existing literature may be attributed to a difference in tarcrete cover and fragmentation and soil texture as these are unknown parameters of the previous studies.

Results from this study demonstrate that the measurements for EC are greater where tarcrete exists, particularly in areas of high tarcrete continuity. The EC probe utilized in the study measures the dissolved salts in the soil pore water, therefore, it is expected that there is a direct correlation between the presence of soil moisture and EC. Field measurements of EC have not been undertaken in previous studies.

8.7 *The Effect of Tarcrete on Plant Establishment*

The presence of tarcrete with moderate fracturing and fragmentation has a positive effect on vegetation establishment. Sites with low tarcrete continuity had 8% more vegetation cover compared to sites with high tarcrete continuity or where tarcrete is absent (Table 7-13).

The slight increase in soil moisture at these sites (Section 7.5.5) creates beneficial environmental conditions for desert plant growth by alleviating the main limiting factor affecting desert plant growth (Laity, 2008; Li, Li, Jiang et al., 2008). The fragmentation curtails the higher soil temperatures found in the high tarcrete cover sites (Figure 7-10), which can be detrimental to plant growth (Laity, 2008). Additionally, longer moisture retention at 200mm (Figure 7-13) extends the growing season as desert vegetation uses the moisture at this depth for growth (Laity, 2008).

Previous studies have stated that the presence of tarcrete is hindering vegetation and that no significant re-vegetation in these areas could occur whilst this contamination is present (CIC, 2003c, p. 4). Studies conducted in the 1992 growing season reported the total vegetation percent cover in an oil mist (tarcrete) site was 2.63% compared to 14.02% in a control site (Zaman and Al-Sdirawi, 1993; Al-Ajimi et al., 1994 cited in CIC, 2003a, p.10). Expressed as a ratio, 84% of the total vegetation percent cover measured in the study was in areas without tarcrete and 16% was growing in tarcrete areas.

The results of this study show the total vegetation percent cover in low tarcrete areas to be 566% and 428% in high tarcrete areas compared to 428% in areas without tarcrete (Table 7-13). Expressed as a ratio, 29% of the total vegetation percent cover measured in the 2014 growing season was in areas without tarcrete and 71% was growing in tarcrete areas.

Between these two growing seasons the canopy cover in tarcrete areas increased by 55% and decreased by 13% in areas without tarcrete. There are several reasons that may be attributing to this outcome. The majority of plants in the Kuwait desert are annuals, which have significant annual variations in cover depending on the amount and timing of precipitation within the growing season (Li, Li, Jiang et al., 2008). Therefore, these results may be due to a difference in precipitation that occurred during each of these years and the local conditions at the sites. Other reasons that may be attributing to this change may include, but are not limited to, increased tarcrete fragmentation since 1992 and differences within the two studies such as cover measurement methodologies, differences in the study area with respect to size of the study area, soil texture, percent tarcrete cover and topography.

Although species composition and abundance were outside of the scope of this study, details on the dominant species recorded in the upper and lower canopies are recorded within the field logs (Appendix F). A total of nineteen different plant species were recorded and the dominant species varied along transects and at different monitoring locations.

8.8 *Characteristics of Transect TMA-MP3*

During the long term monitoring and collection of data the study revealed an area which had a different set of characteristics and therefore considered as an anomaly compared with other

monitoring sites. The northern most transect at monitoring point TMA-MP3 demonstrated consistently high moisture readings at both 100mm and 200mm depth, with increased associated EC readings. Within this area tarcrete gravel was sparse.

There was a notable difference in the vegetation community compared to survey lines at other monitoring points. This included the lack of vegetation cover at TMA-MP3 line 3 and the dominance of the salt tolerant plant (*Salsola, imbricata*); a 'low growing halophytic shrub' (KISR 2007) which was in abundance.

Observations made at this location included the presence of thin soil salt crust. The presence of this crust is likely a result of the elevated concentrations of sodium, magnesium, calcium, chloride sulphate in the soil pore water (Table 6-36 and Table 6-37 and Figure 7-16 and Figure 7-17).

This monitoring point was in close proximity to an oil lake feature which suggests a localised topographic low. The adjacent dry oil lake feature, which historically resulted from a nearby damaged well, is broadly orientated in an east-west direction, indicating that there is a gentle gradient from west to east and follows the contours for an area of low elevation.

The topographic setting combined with unusually elevated measurements for moisture and EC suggests the presence of a shallow perched water table, possibly localised and brackish in nature. This has not been proven as part of this study and is speculation based on observations. Additional assessment would be required to investigate these assumptions further.

9 Conclusion

The characterization results of this study indicate that there are some physical variations of tarcrete in the Study Area (Section 6.2). Negligible effects on tarcrete characteristics were caused by the distance of oil deposition from the well (Section 7.3). Physical differences are similar to those described in studies undertaken over a decade ago (Section 8.1).

There were negligible differences in the chemical constituents (Section 7.1) across the Study Area. The characteristics of the hydrocarbons present in tarcrete are representative of the effects of weathering on crude oil (Section 8.2). Changes in chemical characteristics compared to previous studies is not as clear as most studies assessed TPH concentrations whereas this study focused on the fraction specific hydrocarbon concentrations in order to understand its fate and transport properties and its toxicity potential.

Based on the comparison of tarcrete analytical data against the fraction specific fate and transport properties and reference doses and concentrations developed by the TPHCWG, tarcrete is stable and resistant to degradation due to its low solubility and volatility properties. These properties limit the release of its chemicals constituents into the environment and thus tarcrete has a low exposure potential. The high molecular weight fractions dominating the tarcrete composition indicate that it is of low toxicity (Section 7.1).

No faunal or ecotoxicological studies were conducted as part of this research. The literature review revealed that studies conducted on the fringed-toed lizard indicate that tarcrete is toxic to this species and its prey and may also be the cause of behavioural changes due to its physical presence (Section 3.9). Based on the results of the tarcrete and soil analytical data (Section 6.4) and assessments made on tarcrete's impacts to the underlying soil (Section 7.5) impacts due to toxicity are unlikely (Section 8.5). Any impacts resulting from tarcrete's physical presence were not assessed.

Based on the physical and chemical characterisation data a Guideline for Describing Tarcrete was established but a classification system based on correlations between physical and chemical characteristics was not possible due to its uniformity (Section 7.4). Tarcrete's

effects on soil properties includes an increase in soil temperature, moisture and EC. Contamination to the underlying soil was not detected (Section 7.5.1) nor were changes to the bulk soil chemical properties OoM (Section 7.5.2). Effects on soil temperature, moisture and EC were observed to be amplified in high tarcrete continuity areas compared to areas where tarcrete is more fragmented (Chapter 7).

Raised soil temperatures at tarcrete sites were observed from March to August with a mean increase of 4°C in areas of high tarcrete cover and 3°C in areas with slightly more fragmentation (Figure 7-10). Soil moisture was increased (by 62% and 23% at 100mm and by 58% and 31% at 200mm in high and low cover sites, respectively). Areas with tarcrete cover also retained soil moisture the longest (Figure 7-12 and Figure 7-13).

EC was measured at 100mm depth. Sites with higher moisture content exhibited higher levels of EC. A mean increase in EC at sites with high and low tarcrete cover was 68% and 19%, respectively, when compared to sites without tarcrete cover (Table 7-12). At high tarcrete cover sites readings were detected for longer durations in the summer months, for example the month of July compared to May at other sites (Figure 7-17).

The consequence of these effects on natural re-vegetation is positive where continuous (>80% cover) tarmat exists with some fragmentation (Table 7-13). Areas within the continuous tarmat category (>80% cover) with minimal fracturing and areas with an absence of tarcrete, had a reduced canopy cover (by approximately 8%) in comparison to areas with continuous tarmat which have a higher level of fracturing. The mean percent canopy cover at low tarcrete cover sites was 62% compared to 54% at the high cover sites (Table 7-13).

The current tarcrete management objective is to mechanically fragment and seed the area using a Camel Pitter. Based on the available literature (Section 3.10.2) improvements to soil conditions which make the technique successful are comparable to those resulting in areas with continuous tarmat with some fragmentation in that they both increase water infiltration and retention and reduce evaporation.

Although improvements to soil conditions can be achieved by Camel Pitting, limited success has been reported in coarse textured soils and climates with similar precipitation patterns to Kuwait, where an underlying hard crust is present and where existing vegetation was retained (Berlinger and Cammack, 1990 cited in Bainbridge, 1999); all of which are found in the Study Area (the underlying hard crust being the tarcrete). As the results of the Kuwait Camel Pitting trial are unavailable, the limited success of Camel Pitting in environments similar to the Study Area are considered valid and are anticipated if the technique is applied within the Burgan South Oilfield.

Another study (Chanani, Tavan and Hoseini, 2011) has concluded that results gained from Camel Pitting are comparable to those gained by enclosing the area from disturbance. The TC-Pr3 area is essentially within an enclosure created by a security fence that surrounds the oilfield. Access is limited to oilfield workers and equipment; therefore, disturbance from grazing animals is restricted and impacts from vehicle traffic and human activities are minimized. The minimal level of disturbance that is occurring within the "enclosure" may be beneficial as plants are observed to be exploiting cracks in tarcrete which have resulted from manmade disturbance, burrowing animals and insects. Therefore, it is unlikely that significant gains would be achieved by applying Camel Pitting within the oilfield even if the environmental conditions were conducive to its success.

Whilst the health and survival of the vegetation retained after Camel Pitting has not been specifically studied (Section 3.10.2), it is widely recognised that desert ecosystems are vulnerable to disturbance and take a long time to recover (Section 3.8). The vegetation survey undertaken in this study did not assess plant community health or structure but it does demonstrate a level of recovery in tarcrete areas (Section 8.7). Furthermore, visual observations (Appendix B) and species recorded (Appendix F) suggest that the plant communities in the tarcrete areas are more robust and diverse than in areas without tarcrete (Transect TMA, Appendix B).

Results from this study indicate that the effects of tarcrete on natural re-vegetation (in terms of percent canopy cover) is positive where continuous (>80% cover) tarmat exists with some

fragmentation and is neutral in areas with minimal fracturing (Table 7-13). The study also determines that Camel Pitting is unlikely to increase vegetation establishment and is potentially detrimental to the existing natural recovery that has taken place over the past two decades. Therefore, the current tarcrete management objectives for the Remediation of Areas Damaged by Tarcrete are deemed unnecessary. The June 2014 modification request which removes the requirement for remedial intervention of the tarcrete within the Burgan Oilfield on the basis that a revised evaluation of the tarcrete characteristics demonstrates no risk posed to the environment is recommended.

9.1 *Analysis of Current Study*

Whilst the findings from the field works and the subsequent analysis of data have broadly been successful, limitations of the study and lessons to be considered if similar future studies are undertaken are summarized herein.

Limitations of the current study include a relatively small Study Area (25km^2) and small datasets largely resulting from limited resources. The scale of tarcrete contamination covers 175km^2, therefore, to get an overall representation of the tarcrete within the Burgan Oilfield a larger area should be studied. The selection of monitoring sites should include greater variability with respect to tarcrete continuity to better define the point along the continuum where the effects of cover start to change. Rather than visually estimating continuity a more quantitative measure of fragmentation is preferred and should be introduced into the tarcrete description guideline.

Soil monitoring continued into the summer months to assess soil moisture retention and differences in soil temperature; however, a full year of monitoring would provide a more comprehensive dataset by capturing the full growing season (October to May) and changes towards the end of the dormant period (September to October).

The vegetation survey only considered percent canopy cover which is an acceptable and recognized standard for assessing presence of vegetation. It was determined to be of particular relevance as the majority of the vegetation community comprises of annual species. To include basal cover as an indicator would be of added value in determining re-vegetation

success as it is less affected by differences in annual precipitation (Herrick et al., 2005a). In addition, undertaking a vegetation survey at the start of the growing season (October/November) and again at the end of the growing season (March/April) would provide a percentage of new establishment in each of the different sites. Species abundance and health was not assessed in the current study. Collecting this information in future studies would inform on the state of the natural re-generation and can be used to direct management strategies if trying to aid the establishment of specific plant communities.

The impact tarcrete poses on local fauna was unable to be determined by the analysis undertaken as part of this study. Fauna assessments (habitat, tropic structure, ecotoxicology) were outside the scope of this study but is a limitation in its assessment of the current management objectives as current studies suggest that tarcrete is impacting the faunal community. Faunal studies are being recommended (Section 9.2).

9.2 *Recommendations for Future Studies*

The study findings conclude that the current approved management objectives are not recommended (Section 9). Rather it supports the proposed management strategy which requires an updated assessment of tarcrete's characteristics and potential risk to the environment (Section 9). This study has provided the basis of an updated assessment of tarcrete and the risk it poses to the environment but with limitations (Section 9.1). Therefore, increased detailed studies are recommended.

Since the commencement of this research human health and ecological detailed quantitative risk assessments (DQRAs) are being designed for all contamination types requiring clean-up under the UNCC claims for environmental damage in the Kuwait's oilfields (e.g.; wet and dry oil lakes, tarcrete, etc.). Limited scope DQRAs are being designed and enabling works such as UXO clearance is ongoing. It is planned that larger DQRAs are undertaken across KOC impacted oilfields. Implementation of the DQRAs will require the following steps:

- Review all literature and develop separate CSMs (human health and ecology).
- Site characterisation over a large area, including ecological studies (Section 9.2.1).

- Laboratory testing including TPH testing using criterial working group (CWG), SARA, Hexane Extractable Matter (HEM), Diesel Range Organics (DRO) Petrol Range Organics (PRO) and Residual Range Organics (RRO).
- Review and interpret chemical data. Evaluate transport and pathway mechanisms between soil, water, ecology and air. Assess concentrations in relation to hydrocarbon fractions (carbon banding) and use this information to identify hazards (Chemicals of Concern, environmental media type) and update the CSM.
- Use CSMs and conduct an exposure assessment (determine how much and how long are identified receptors subjected to the identified hazards).
- Conduct a toxicity assessment to identify potential health effects from contact with contamination in terms of dosages and toxicity values.
- Combine the results and produce a risk characterisation to determine the probability of an adverse effect, derive remediation clean-up criteria and provide recommendations on risk management, remedial action or further studies.

9.2.1 Ecological Studies

The requirements of the ecological DQRA have been determined and a contract to undertake the works is currently being bid. As described in KOC, 2016, it will include both flora and fauna communities and will be based on community health, structure and ecological function determined by undertaking the following:

- *Literature review to determine floral and faunal species presence and abundance;*
- *Where there is an absence of historical ecological data, a control area shall be established to be representative of Site conditions that have not been impacted by post-war operations.*
- *Identify important ecosystem components through identification of critical habitats and major taxonomic groups to derive valued ecosystem components (VECs);*
- *Ecological field studies that evaluate biodiversity through visual assessment.*
- *For the various trophic levels which acts as a surrogate for demonstrating ecological function, surveys will be conducted to enumerate the species that are present, their relative abundance, and physical health. Trophic levels would be*

associated with the primary producers (i.e., vegetation) and consumers (i.e., soil invertebrates, reptiles, birds, and mammals). The biodiversity of each area will be compared to biodiversity of a control area within the oilfield not impacted by petroleum hydrocarbon release.

- *Development of diversity indices based on historical and current field observations.*

This study has illustrated that where tarcrete is present its continuity appears to be the most important factor in promoting environmental conditions beneficial for desert plant establishment (Section 8.6). In particular the ratio of tarmat cover in relation to the percentage of fragmentation. Therefore, if it is determined that tarcrete has no adverse effects and no remedial action is recommended.

If management to enhance re-vegetation is pursued it is recommended to manually fragment high continuity tarmat areas in a manner that promotes vegetation to establish in a discontinuous spatial distribution, as found in the natural setting (Section 3.8). This would limit soil erosion, promote water infiltration, prevent wholesale destruction of existing vegetation and minimise damage to ecological habitats that have become established over the past twenty years. Implementing this strategy would require the following additional analysis which has considered the current management objectives (Section 2.1) and lessons learned from the current study (Section 9.1):

- Analysis of high resolution satellite images to identify areas of continuous tarcrete.
- UXO survey and clearance.
- Ground truth selected areas (confirm and delineate tarcrete areas). This would include completing field logs describing tarcrete (using the Guideline) and visually inspecting under the tarcrete at set distances along transects to confirm no underlying visual contamination.
- Configure a continuity or fractioning index that prescribes the level of fracturing required to optimise soil conditions for vegetation growth. This would require:
    - **Detailed quantitative measurement of the exposed soil vs covered soil** over a pre-determined area. It is recommended that a large area be considered to account for the large spatial distribution of desert plant communities.

- **Soil moisture and temperature monitoring** across all seasons (minimum one) and at depth intervals that are pertinent to vegetation establishment and growth for the species present within different vegetation communities. Monitoring shall occur across areas with varying coverage and fragmentation of tarcrete.
- **Vegetation surveys** over consecutive years (minimum two) at the start and end of the growing season in the same locations across to determine percent cover, basal cover, species presence and abundance in tarcrete areas over time. Surveys shall occur where soil parameters are being monitored.

Measurements of soil erosion (aeolian and fluvial) across areas with varying tarcrete coverage and fragmentation and the impact of the erosion on soil nutrient retention levels are recommended to augment the index studies. Soil erosion can be measured either by field measurements or models; if model input parameters include soil exposure areas on a small scale. Soil nutrient levels will require analytical testing of eroded area pre and post erosion events (e.g.; wind storms or flash flooding) and against a control site.

The objective of these recommendations would be to determine how to optimise the most effective physical state of tarcrete within the existing environment to minimise disturbance, limit intervention and reduce generation of tarcrete as a waste.

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Appendices

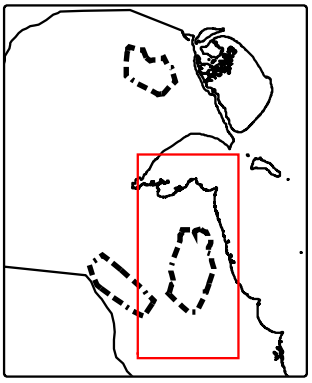
Appendix A

Figures



Legend:

- KOC Oilfield Security Fence
- Study
- Landmarks
- Roads



Orientation N

0 2,500 5,000 10,000

Meters

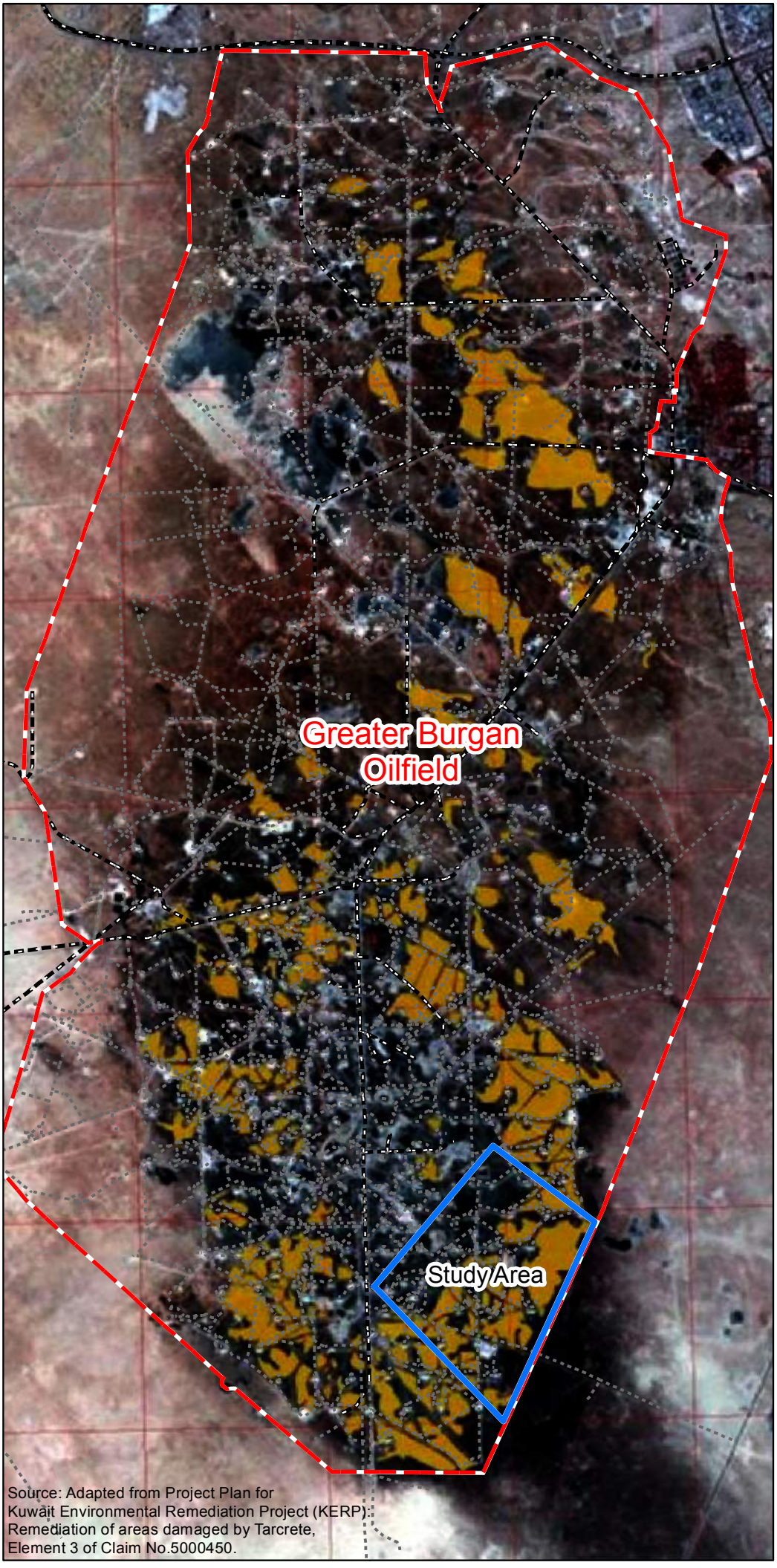
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Figure A-1: Site Location Plan

Kuwait Environmental Remediation Program

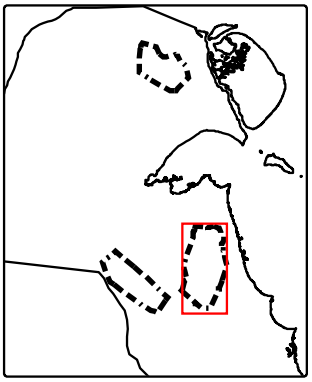
UNCONTROLLED HARD COPY FOR INFORMATION ONLY

Date	Scale
25 March 2015	1:340,000



Legend:

- Study Area
- KOC Security Fence
- Asphalt road
- Unpaved road
- Tarcrete Areas as per TC-Pr3



Orientation N

0 1,250 2,500 5,000

Meters

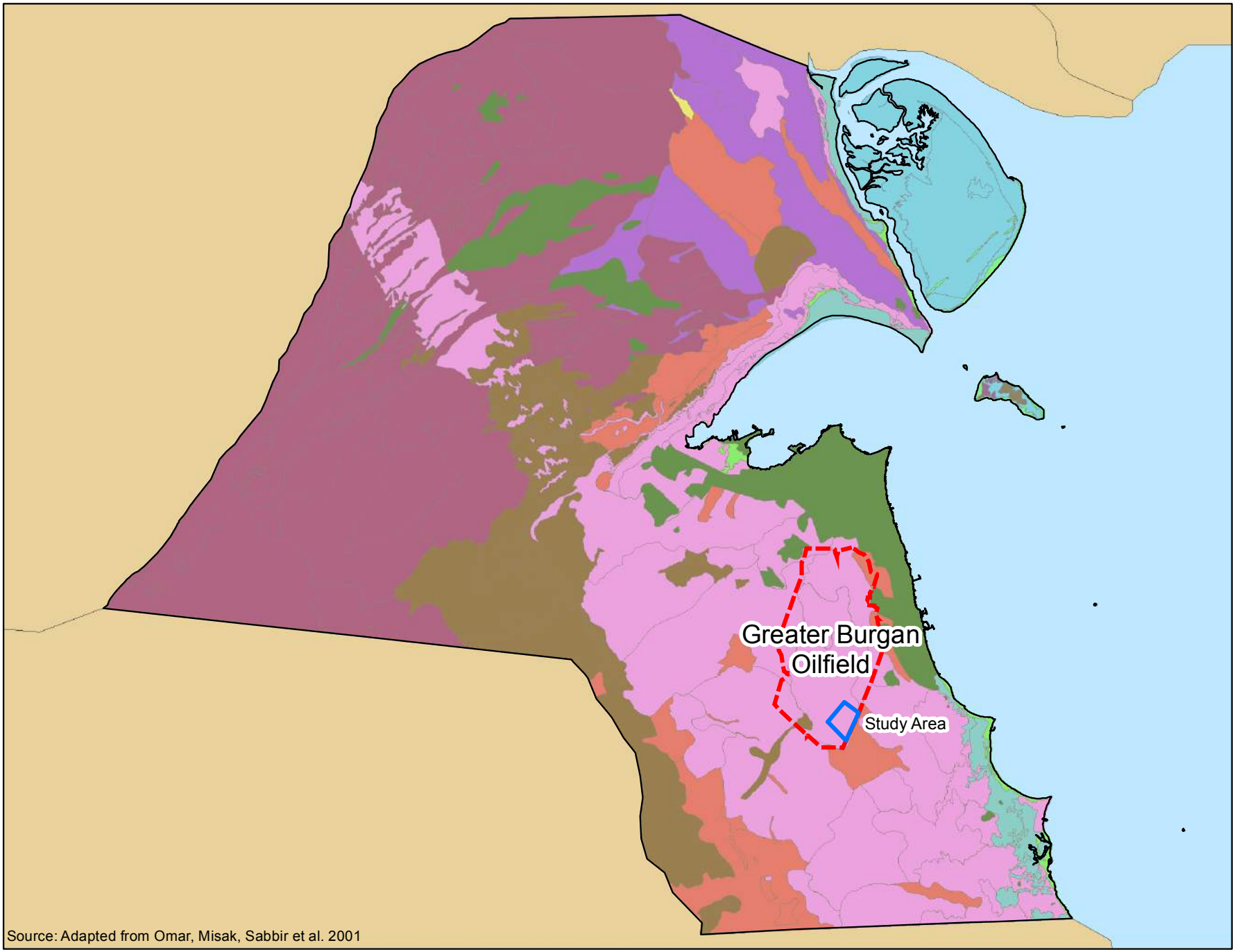
Title Figure A-2: Project TC-Pr3: Tarcrete-Damaged Areas in the Burgan Oilfield

Kuwait Environmental Remediation Program

UNCONTROLLED HARD COPY FOR INFORMATION ONLY

Date	Scale
25 March 2015	1:150,000

Source: Adapted from Project Plan for Kuwait Environmental Remediation Project (KERP): Remediation of areas damaged by Tarcrete, Element 3 of Claim No.5000450.

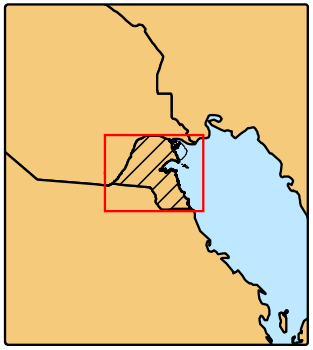


Legend:

- Study Area
- KOC Security Fence

Soil Group

- Aquisalids
- Calcigypsids
- Haplocalcids
- Haplogypsids
- Miscellaneous units
- Missing
- Petrocalcids
- Petrogypsids
- Torriorthents
- Torripsamments



Orientation N

0 7,500 15,000 30,000

Meters

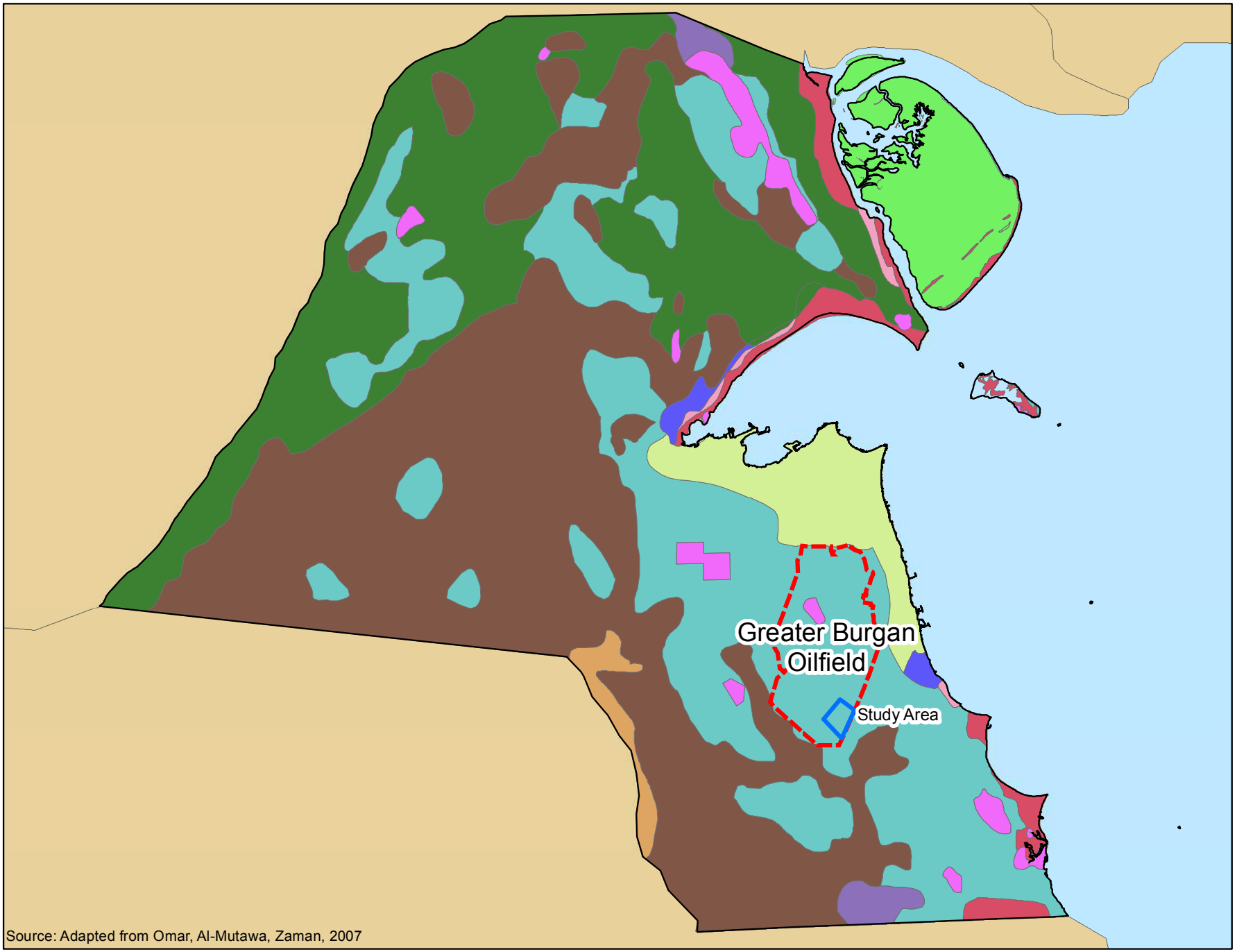
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Figure A-3: Major Groups of Soil in Kuwait

Kuwait Environmental Remediation Program

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Date	Scale
30 March 2015	1:1,000,000

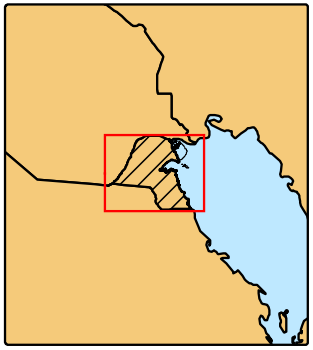


Legend:

- Study Area
- KOC Security Fence

Vegetation Type

- Agricultural Area
- Bare
- Centropodietum
- Cyperetum
- Halophyletum
- Haloxyletum
- Panicetum
- Rhanterietum
- Stipagrostietum
- Urban Area
- Zygophylletum



Orientation N

0 7,500 15,000 30,000

Meters

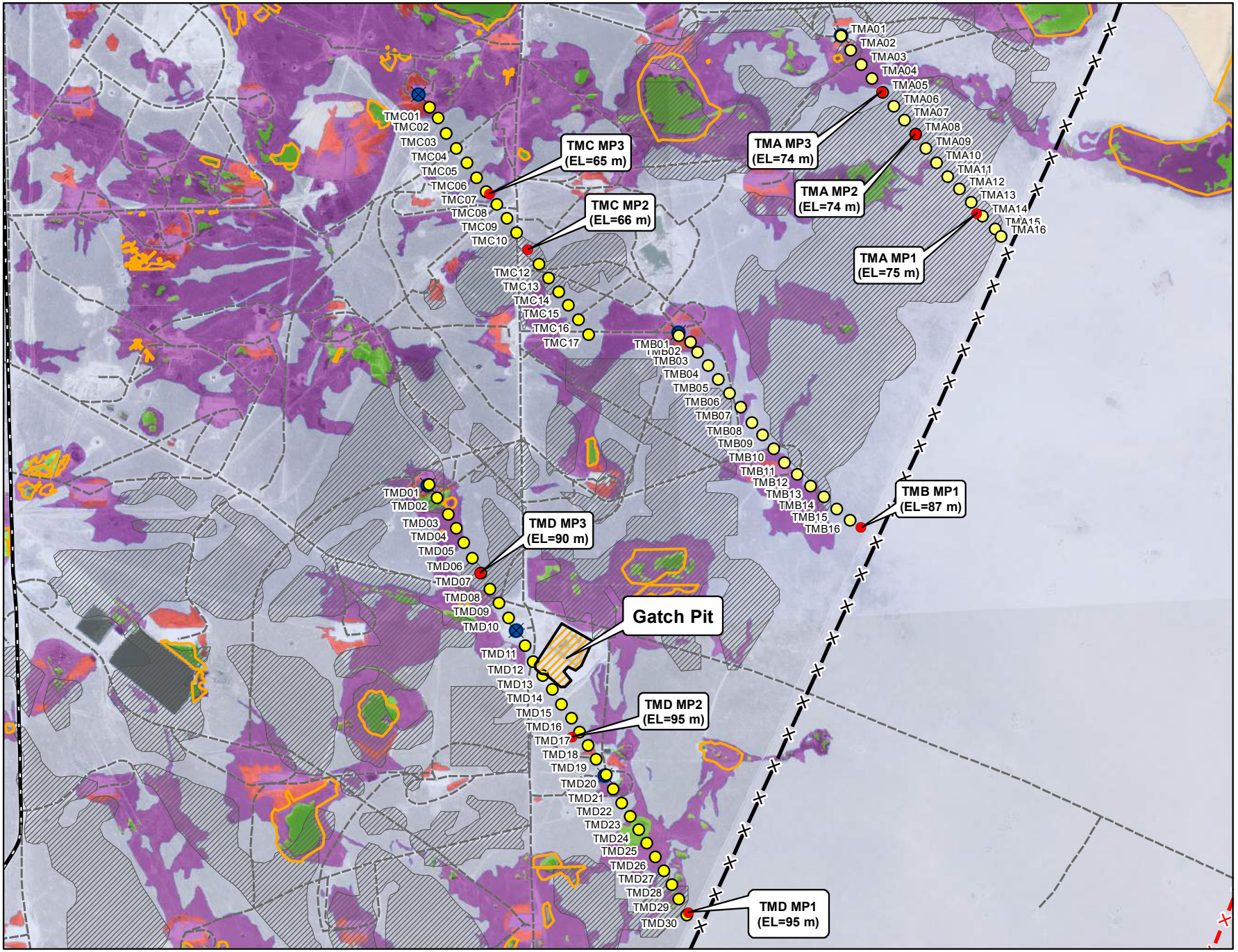
Title

Figure A-4: Vegetation Types in Kuwait

Kuwait Environmental Remediation Program

UNCONTROLLED HARD COPY FOR INFORMATION ONLY

Date	Scale
30 March 2015	1:1,000,000



Legend:

- Existing Security Fence
- Future Security Fence
- Rig/Desert Road
- Asphalt Road
- No EOD Cert.

Feature

- Wet Oil Contamination
- Dry Oil Contamination
- Oil Contaminated Pile
- Tarcrete (CIC Report, 2003)
- Tarcrete Areas as per TC-Pr3

Monitoring Points

Transect Points

Oil Wells

EL = Elevation

*Elevations(meters) are based on the Mina Ahmadi Construction Datum (MACD)

Orientation N

0 250 500 1,000

Meters

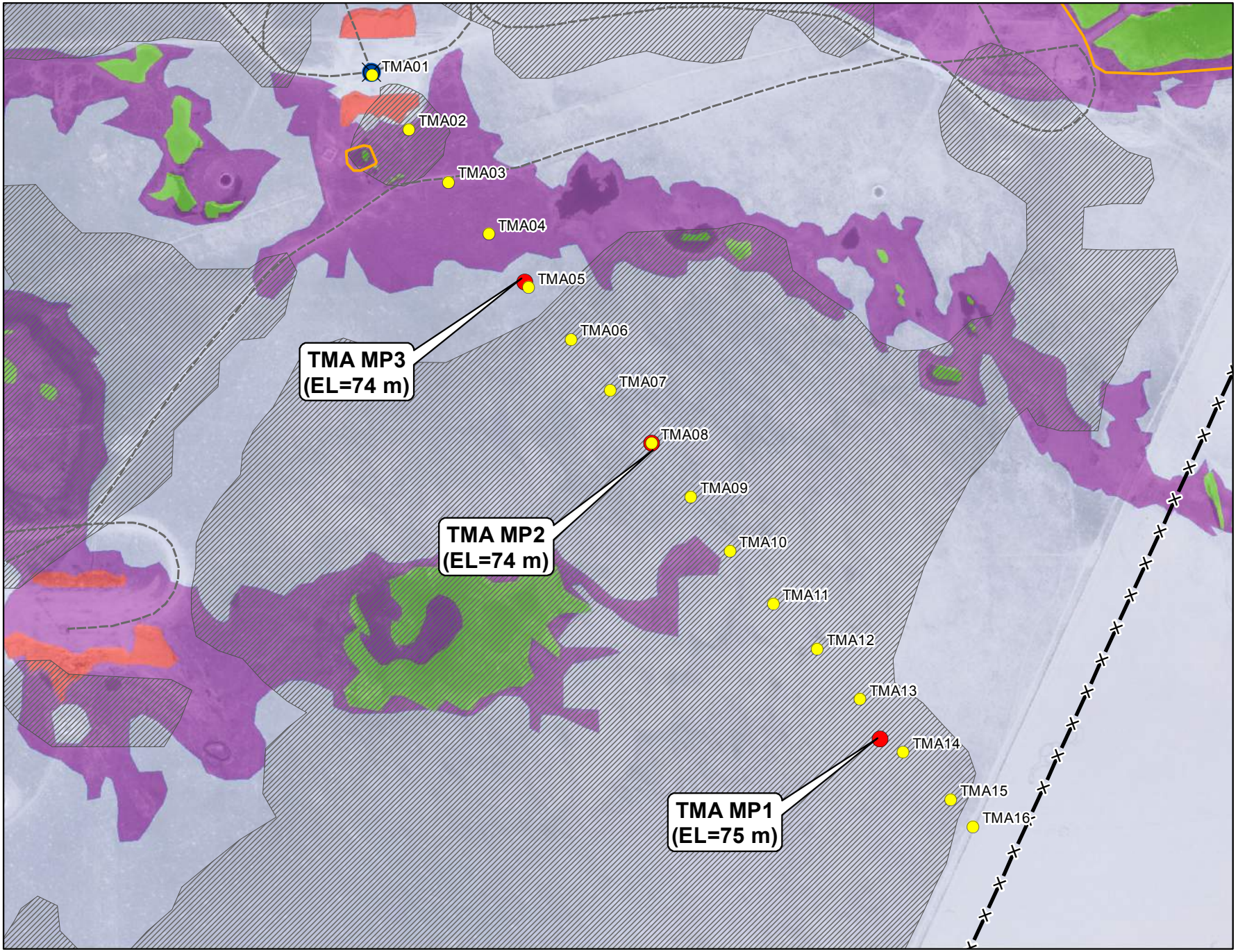
Title

Figure A-5: Study Area Layout
Transect Locations and Monitoring Points

Kuwait Environmental Remediation Program

UNCONTROLLED HARD COPY FOR INFORMATION ONLY

Date	Scale
26 March 2015	1:30,000



Legend:

- Existing Security Fence
- Future Security Fence
- Rig/Desert Road
- Asphalt Road
- No EOD Cert.

Feature

- Wet Oil Contamination
- Dry Oil Contamination
- Oil Contaminated Pile
- Tarcrete (CIC Report, 2003)
- Tarcrete Areas as per TC-Pr3

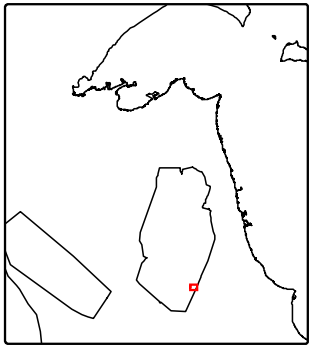
Monitoring Points

Transect Points

Oil Wells

EL = Elevation

*Elevations(meters) are based on the Mina Ahmadi Construction Datum (MACD)



Orientation

N

0 50 100 200

Meters

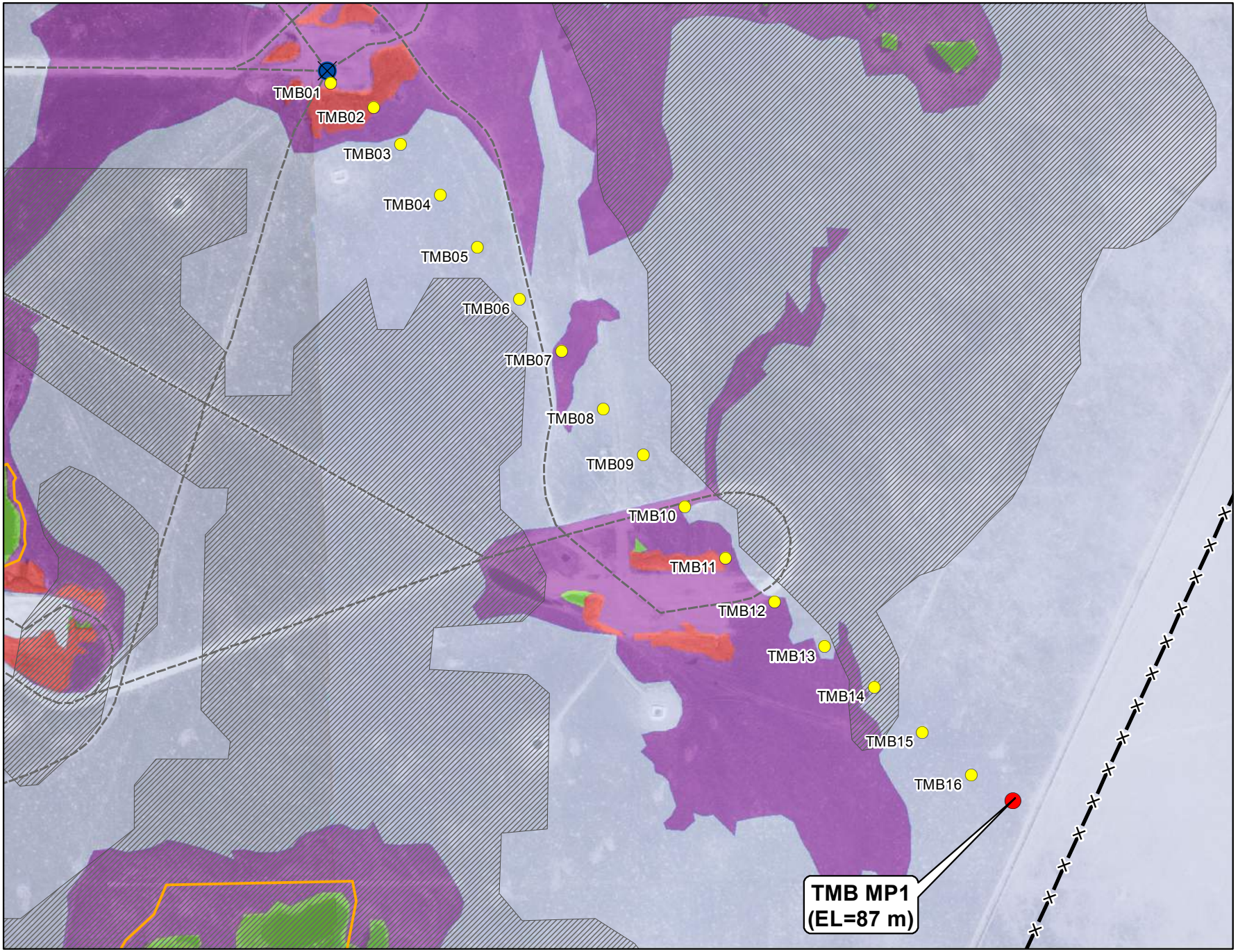
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Figure A-5-1: Study Area Layout
Transect Locations and Monitoring Points

Kuwait Environmental Remediation Program

UNCONTROLLED HARD COPY FOR INFORMATION ONLY

Date	Scale
26 March 2015	1:8,000



Legend:

- Existing Security Fence
- Future Security Fence
- Rig/Desert Road
- Asphalt Road
- No EOD Cert.

Feature

- Wet Oil Contamination
- Dry Oil Contamination
- Oil Contaminated Pile
- Tarcrete (CIC Report, 2003)
- Tarcrete Areas as per TC-Pr3

Monitoring Points

Transect Points

Oil Wells

EL = Elevation

*Elevations(meters) are based on the Mina Ahmadi Construction Datum (MACD)

Orientation N

0 50 100 200

Meters

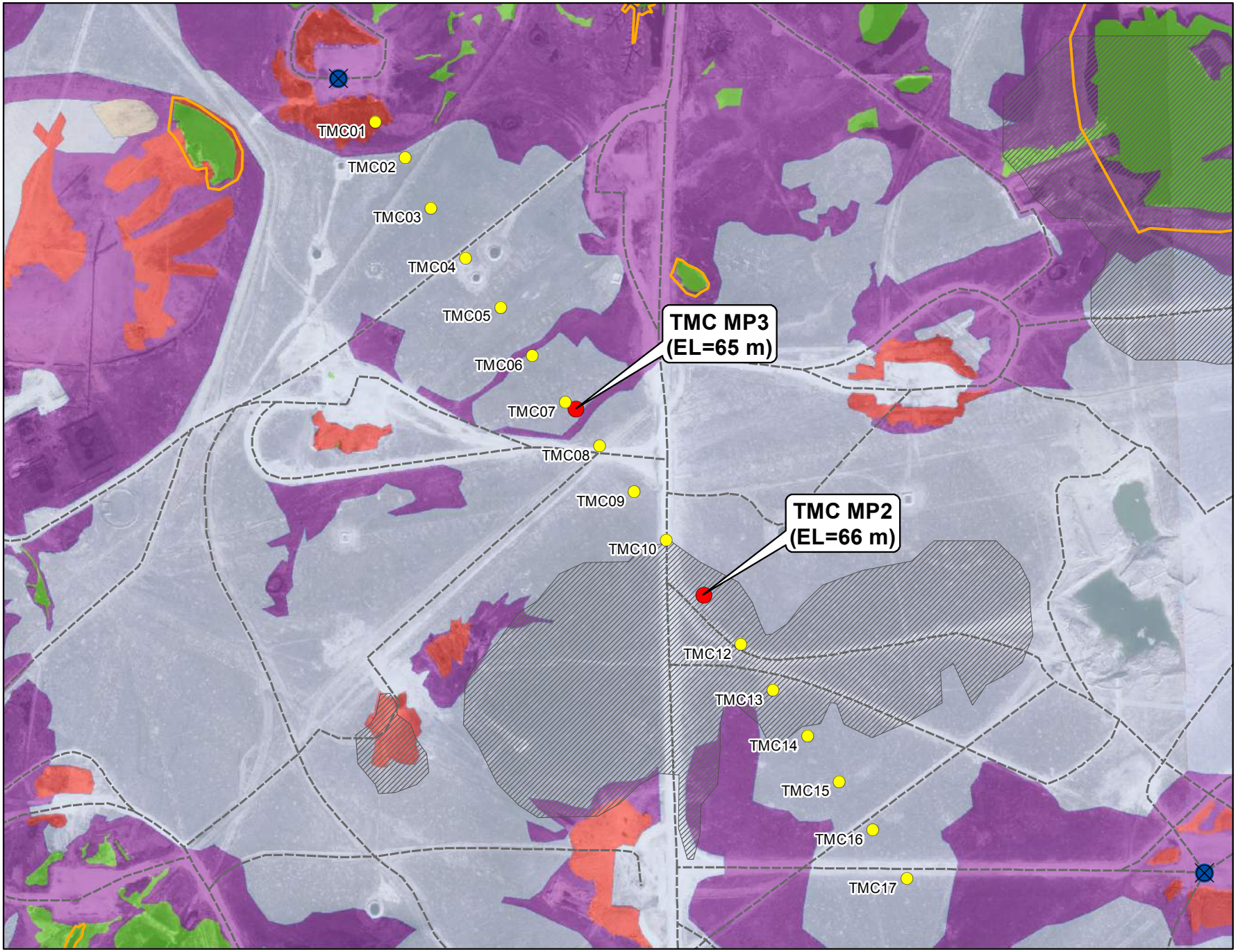
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Figure A-5-2: Study Area Layout
Transect Locations and Monitoring Points

Kuwait Environmental Remediation Program

UNCONTROLLED HARD COPY FOR INFORMATION ONLY

Date	Scale
26 March 2015	1:8,000



Legend:

- Existing Security Fence
- Future Security Fence
- Rig/Desert Road
- Asphalt Road
- No EOD Cert.

Feature

- Wet Oil Contamination
- Dry Oil Contamination
- Oil Contaminated Pile
- Tarcrete (CIC Report, 2003)
- Tarcrete Areas as per TC-Pr3

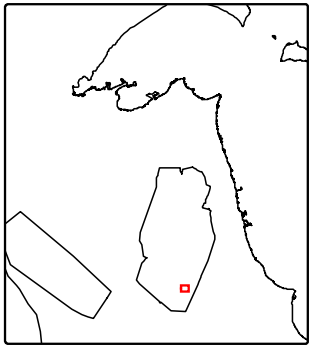
Monitoring Points

Transect Points

Oil Wells

EL = Elevation

*Elevations(meters) are based on the Mina Ahmadi Construction Datum (MACD)



Orientation N

0 50 100 200

Meters

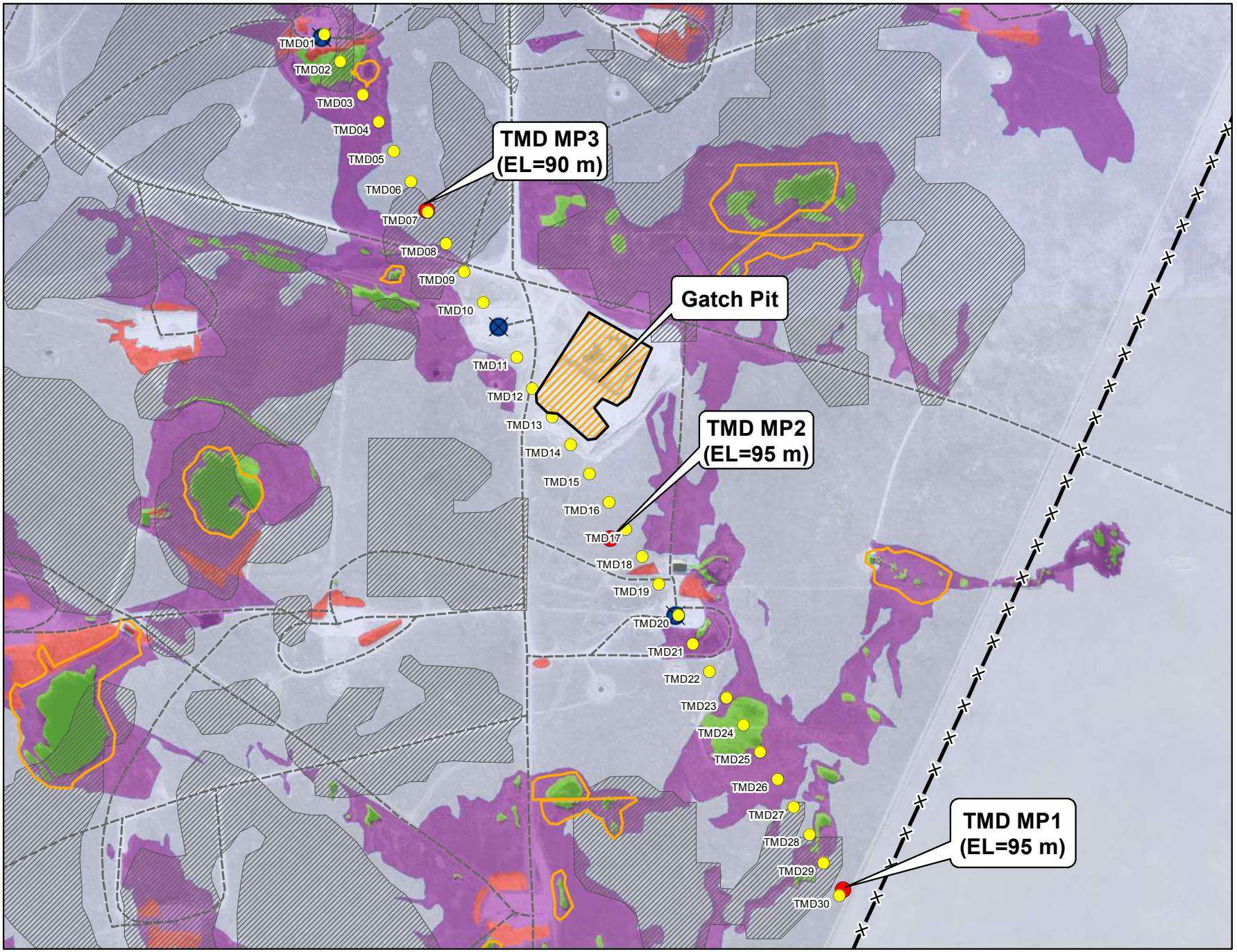
Title

Figure A-5-3: Study Area Layout
Transect Locations and Monitoring Points

Kuwait Environmental Remediation Program

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Date	Scale
26 March 2015	1:9,000



Legend:

- Existing Security Fence
- Future Security Fence
- Rig/Desert Road
- Asphalt Road
- No EOD Cert.

Feature

- Wet Oil Contamination
- Dry Oil Contamination
- Oil Contaminated Pile
- Tarcrete (CIC Report, 2003)
- Tarcrete Areas as per TC-Pr3

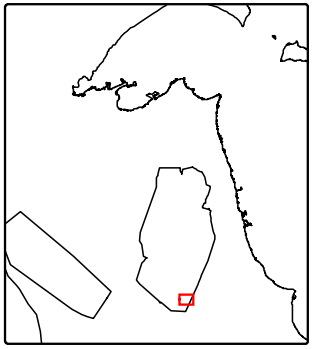
Monitoring Points

Transect Points

Oil Wells

EL = Elevation

*Elevations(meters) are based on the Mina Ahmadi Construction Datum (MACD)



Orientation

N

0 100 200 400

Meters

Title

Figure A-5-4: Study Area Layout
Transect Locations and Monitoring Points

Kuwait Environmental Remediation Program

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Date	Scale
26 March 2015	1:15,000

Appendix B

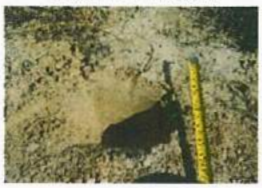
Transect Descriptions and Photographs

Transect TMA

Transect TMA					
Transect Reference	**Survey Point**	**Distance from Well (m)**	**Material**	**Description**	**Comments**
TMA	01	0	Disturbed ground	Well pad/disturbed ground until 80m.	
TMA	01+50m	50			
TMA	02	100	Dry oil lake	80m-353m dry oil lake until 353m	
TMA	02+50m	150	Dry oil lake		
TMA	03	200	Dry oil lake		
TMA	03+50m	250	Dry oil lake		
TMA	04	300	Dry oil lake		
TMA	04+50m	350	Dry oil lake		
TMA	05	400	Tarcrete	Tarcrete gravel, fine to medium, very sparse (approximately 1%), uneven, hardened, very friable	
			Soil	yellowish brown fine to medium slightly clayey SAND AND SILT	
TMA	05+50m	450	Tarcrete/ soil	No change	
TMA	06	500	Tarcrete	Tarcrete gravel, fine to medium, very sparse (approximately 5%), uneven, hardened, very friable	5m SE of TMA06 to TMA07 sporadic presence of tarcrete mat, broken, 5-10mm, hardened, friable
			Soil	yellowish brown fine to medium slightly clayey SAND AND SILT	
TMA	06+50m	550	Tarcrete/soil	Tarcrete gravel abundance increasing to approximately 10%	
TMA	07	600	Tarcrete	Tarcrete gravel, fine to medium, very sparse (approximately 10%), even, hardened, very friable	
			Soil	yellowish brown fine to medium slightly clayey SAND AND SILT	
TMA	07+50m	650	Tarcrete/ soil	No change	
TMA	08	700	Tarcrete	Tarcrete gravel, fine to medium, very sparse (approximately 10%), even, hardened, very friable to friable	
			Soil	yellowish brown fine to medium slightly clayey SAND AND SILT	
TMA	08+50m	750	Tarcrete/ soil	No change	
TMA	09	800	Tarcrete	Tarcrete gravel, fine to medium, very sparse (approximately 5%), uneven, hardened, very friable	
			Soil	yellowish brown fine to medium slightly clayey SAND AND SILT	Soil crust present with fine to medium quartz GRAVEL, rounded to sub-angular on surface.
TMA	09+50m	850	Tarcrete/ soil	No change	No vegetation
TMA	10	900	Tarcrete	Tarcrete gravel, fine to medium, very sparse (approximately 5%), uneven, hardened, very friable	Edge of barren area
			Soil	yellowish brown fine to medium slightly clayey SAND AND SILT	

Transect Reference	Survey Point	Distance from Well (m)	Material	Description	Comments
TMA	10+50m	950	Tarcrete/ soil	No change until TMA-10 +68m: tarcrete gravel, medium, uneven, hardened, friable	Increase in vegetation
TMA	11	1000	Tarcrete	Tarcrete gravel, fine to medium, very sparse (less than 1%), uneven, hardened, very friable	Tarcrete gravel collecting in depressions.
			Soil	yellowish brown fine to medium slightly clayey SAND AND SILT. Occasional organic matter present.	
TMA	11+50m	1050	Tarcrete/ soil	No change	
TMA	12	1100	Tarcrete	Tarcrete gravel, fine to medium, very sparse (less than 1%), uneven, hardened, friable	Soil crust present with fine to medium quartz GRAVEL, rounded to sub-angular on surface.
			Soil	yellowish brown fine to medium slightly clayey SAND AND SILT. Occasional organic matter present.	
TMA	12+50m	1150	Tarcrete/ soil	No change	
TMA	13	1200	Tarcrete	Tarcrete gravel, fine, very sparse (less than 1%), uneven, hardened, friable	Tarcrete gravel collecting in depressions.
			Soil	yellowish brown fine to medium slightly clayey SAND AND SILT. Occasional organic matter present.	Soil crust present with fine to medium quartz GRAVEL, rounded to sub-angular on surface.
TMA	13+50m	1250	Tarcrete/ soil	No change	
TMA	14	1300	Tarcrete	Tarcrete gravel, fine, very sparse (less than 1%), uneven, hardened, friable	Tarcrete gravel collecting in depressions.
			Soil	yellowish brown fine to medium slightly clayey SAND AND SILT. Occasional organic matter present.	Soil crust present with fine to medium quartz GRAVEL, rounded to sub-angular on surface.
TMA	14+50m	1350	Tarcrete/ soil	No change	
TMA	15	1400	Tarcrete	Tarcrete gravel, fine, very sparse (less than 1%), uneven, hardened, friable	Tarcrete gravel collecting in depressions.
			Soil	yellowish brown fine to medium slightly clayey SAND AND SILT. Occasional organic matter present.	Soil crust present with fine to medium quartz GRAVEL, rounded to sub-angular on surface.
TMA	15+50m	1450	Tarcrete/ soil	No change	
TMA	16	1500	Disturbed ground	Gatch road	
TMA	16+50	1550			
TMA	17	1600	Boundary Fence	None	

TMA-05 Profile



TMA-05 Surface



TMA-06 Profile



TMA-06 Surface-Grav



TMA-06 Surface-Soot



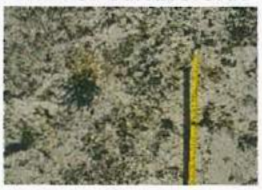
TMA-06 Sporadic Surface-Mat



TMA-07 Profile



TMA-07 Surface-Grav



TMA-08 Profile



TMA-08 Surface



TMA-09 Profile



TMA-09 Surface



TMA-10 Profile



TMA-10 Surface



TMA-11 Profile



TMA-11 Surface



TMA-12 Profile



TMA-12 Surface



TMA-13 Profile



TMA-13 Surface



TMA-14 Profile 1



TMA-14 Surface



TMA-14 Profile 2



TMA-15 Profile 1



TMA-15 Surface



TMA-15 Profile 2



Transect TMB

Transect TMB					
Transect Reference	**Survey Point**	**Distance from Well (m)**	**Material**	**Description**	**Comments**
TMB	01	0	Disturbed ground	Well pad / disturbed ground until 80m	Well BG-248
TMB	01+50m	50	Disturbed ground		
TMB	02	100	Disturbed ground	Contaminated soil pile	
TMB	02+36	136	Disturbed ground		
TMB	02+50m	150	Tarcrete	Tarmat, continuous, 15mm, hardened, friable	
			Soil	Pale brown fine to medium silty SAND	
TMB	03	200	Tarcrete	Tarmat, continuous, 17-25mm, soft, friable	
			Soil	Pale brown fine to medium silty SAND	
TMB	03+50m	250	No change		
TMB	04	300	Tarcrete	Tarmat, continuous, 8-11mm, hardened, friable	
			Soil	yellowish brown fine to coarse SAND	
TMB	04+50m	350	Tarcrete/ soil	No change	Thin silt covering tarcrete (ground)
TMB	05	400	Tarcrete	Tarmat, continuous, 5-8mm, hardened, friable	
			Soil	light yellowish brown fine to medium SAND	
TMB	05+50m	450	Tarcrete/soil	Tarmat, continuous, 5-7mm, hardened, very friable	
			Soil	light yellowish brown fine to medium SAND. Occasional organic matter.	
TMB	06	500	Tarcrete/soil	Tarmat, fragmented, 10-15mm, hardened, friable to hard, into continuous at 574m.	Thin silt coverage overlying tarcrete in area. Tarcrete fragments are odd shaped (no regularity) and range in sizes. Examples measured included (a) 1.2m X 0.8m, (b) 0.7m X 0.35m. At 6 +40m south side of track
			Soil	light yellowish brown fine to medium SAND. Occasional organic matter.	
TMB	06+50m	550	Disturbed ground	At 6+40m north side of track. 6+50m centre of track 6+95 south side of track	
TMB	07	600	Dry oil lake	N/A	
TMB	07+50m	650	Dry oil lake	N/A	
TMB	08	700	Tarcrete	Tarmat, continuous, 6-9mm, hardened, friable	TMB 8+4m margin between dry oil lake and tarcrete
			Soil	light yellowish brown fine to medium SAND.	
TMB	08+50m	750	Disturbed ground	Track for pipeline (8+43m pipeline)	
TMB	09	800	Tarcrete	Tarmat, continuous, 5mm, hardened, friable	
			Soil	light yellowish brown fine to medium SAND.	
TMB	09+50	850	Tarcrete/soil	No change	9+72m north side of track 9 +98m south side of track

Transect TMB					
Transect Reference	**Survey Point**	**Distance from Well (m)**	**Material**	**Description**	**Comments**
TMB	10	900	Tarcrete	Tarmat, continuous, 20-30mm, hardened, friable	
			Soil	light yellowish brown fine to medium SAND.	
TMB	10+50m	950	Tarcrete/soil	No change	
TMB	11	1000	Dry oil lake	N/A	
TMB	11+50m	1050	Disturbed ground	Drill pad / gatch road	TMB 11+22m: interface between tarcrete and disturbed area. TMB 11+80m disturbed ground (new drill pad) imported gatch / gatch road
TMB	12	1100	Tarcrete	Tarmat, continuous, 5-12mm, hardened, friable	
			Soil	light yellowish brown fine to medium silty SAND. Occasional organic matter.	
TMB	12+50m	1150	Tarcrete	Tarmat, continuous, 20mm, soft, friable	
			Soil	yellowish brown fine to medium quartz SAND	
TMB	13	1200	Tarcrete	Tarmat, continuous, 20mm, soft, friable	
			Soil	very pale brown fine to coarse SAND.	
TMB	13+50m	1250	Tarcrete/ soil	No change	
TMB	14	1300	Tarcrete	Tarmat, continuous, 4-8mm, hardened, friable	
			Soil	light yellowish brown fine to medium slightly coarse silty SAND. Occasional organic matter.	
TMB	14+50m	1350	Tarcrete/ soil	No change	
TMB	15	1400	Tarcrete	Tarmat, continuous, 7-10mm, soft, friable	
			Soil	brown fine to medium slightly coarse silty SAND. Occasional organic matter.	
TMB	15+50m	1450	Tarcrete/ soil	No change	
TMB	16	1500	Tarcrete	Tarmat, continuous, 5-7mm, hardened, friable	
			Soil	brown, fine to medium slightly coarse SAND	
TMB	16+50m	1550	Tarcrete/ soil	No change	
TMB	17	1600	Tarcrete	Tarmat, continuous, 5-7mm, hardened, friable	
			Soil	brown, fine to medium slightly coarse SAND	
TMB	71+50m	1630	Disturbed ground	Gatch Road and Boundary Fence	

TMB-03 Profile



TMB-03 Top



TMB-03 Base



TMB-03 Side



TMB-04 Profile



TMB-04 Top



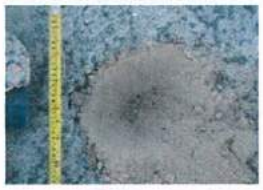
TMB-04 Base



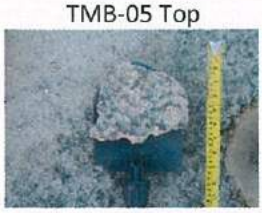
TMB-04 Side



TMB-05 Profile



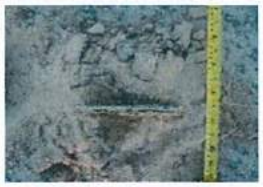
TMB-05 Top



TMB-05 Base



TMB-05 Side



TMB-06 Profile



TMB-06 Top



TMB-06 Base



TMB-06 Side



TMB-08 Profile



TMB-08 Top



TMB-08 Base



TMB-08 Side



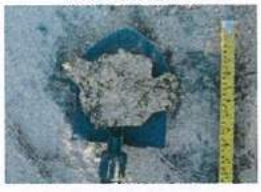
TMB-09 Profile



TMB-09 Top



TMB-09 Base



TMB-09 Side



TMB-10 Profile



TMB-10 Top



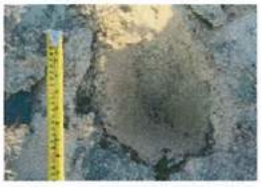
TMB-10 Base



TMB-10 Side



TMB-12 Profile



TMB-12 Top



TMB-12 Base



TMB-12 Side



TMB-13 Profile



TMB-13 Top



TMB-13 Base



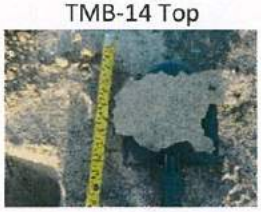
TMB-13 Side



TMB-14 Profile



TMB-14 Top



TMB-14 Base



TMB-14 Side



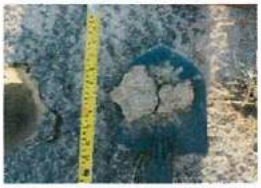
TMB-15 Profile



TMB-15 Top



TMB-15 Base



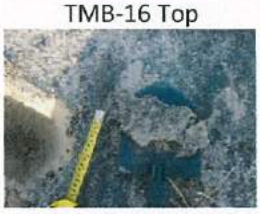
TMB-15 Side



TMB-16 Profile



TMB-16 Top



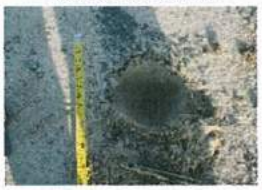
TMB-16 Base



TMB-16 Side



TMB-17 Profile



TMB-17 Top



TMB-17 Base



TMB-17 Side



Transect TMC

Transect TMC					
Transect Reference	**Survey Point**	**Distance from Well (m)**	**Material**	**Description**	**Comments**
TMC	01	0	Disturbed ground	Well	
TMC	01+50	50	Disturbed ground	Well to end of well pad 48m and start of disturbed ground. Disturbed area starts at 48m continues to 52m where dry oil lake starts	
TMC	02	100	Dry oil lake	Dry oil lake starts at 52m from well and ends at 289m from well, replaced by tarmat	
TMC	02+50	150	Dry oil lake		
TMC	03	200	Dry oil lake		
TMC	03+50	250	Dry oil lake		
TMC	04	300	Tarcrete	Tarmat, continuous, 10-17mm, hardened, friable	
			Soil	light yellowish brown fine to medium SAND	
TMC	04+50	350	Tarcrete / soil	No change	
TMC	05	400	Disturbed ground	No tarcrete. Oilfield facilities (burn pits) Ground: gatch 0-0.15m (imported) 2.5YR 7/3.	
TMC	05+50	450	Disturbed ground	Gatch Road	
TMC	06	500	Tarcrete	Tarmat, continuous, 12mm, hardened, friable	
			Soil	yellowish brown fine to medium SAND. Occasional organic matter.	
TMC	06+50	550	Tarcrete / soil	No change	
TMC	07	600	Tarcrete	Tarmat, continuous, 15mm, hardened, friable	
			Soil	yellowish brown fine to medium SAND. Occasional organic matter.	
TMC	07+50	650	Tarcrete / soil	No change	
TMC	08	700	Tarcrete	Tarmat, continuous, 12-15mm, soft, friable	
			Soil	yellowish brown fine to medium SAND. Occasional organic matter.	
TMC	08+50	750	Tarcrete / soil	No change	
TMC	09	800	Disturbed ground	Gatch road / pipeline	
TMC	09+50	850	Tarcrete	Tarmat, continuous, 12-15mm, hardened, friable	
			Soil	yellowish brown fine to medium SAND. Occasional organic matter.	

Transect TMC					
Transect Reference	**Survey Point**	**Distance from Well (m)**	**Material**	**Description**	**Comments**
TMC	10	900	Tarcrete	Tarmat, continuous, 8-10mm, hardened, friable	
			Soil	yellowish brown fine to medium SAND. Occasional organic matter.	
TMC	10+50	950	Tarcrete/ soil	No change	
TMC	11	1000	Disturbed ground	Gatch road	
TMC	11+50	1050	Tarcrete/ soil	No change from TMC9	
TMC	12	1100	Tarcrete	Tarmat, continuous, 8-12mm, hardened, friable	
			Soil	yellowish brown fine to medium SAND. Occasional organic matter.	
TMC	12+50	1150	Tarcrete/ soil	Gatch road	
TMC	13	1200	Tarcrete	Tarmat, continuous, 6-15mm, hardened, friable	
			Soil	yellowish brown fine to medium SAND. Occasional organic matter.	
TMC	13+50	1250	Tarcrete/ soil	No change	
TMC	14	1300	Tarcrete	Tarmat, continuous, 8-10mm, hardened, friable	Just under tarcrete was a layer of fine gravel.
			Soil	yellowish brown fine to medium SAND. Occasional organic matter.	
TMC	14+50	1350	Tarcrete/ soil	No change	
TMC	15	1400	Tarcrete	Tarmat, continuous, 6-9mm, hardened, very friable to friable	
			Soil	yellowish brown fine to medium SAND. Occasional organic matter.	
TMC	15+50	1450	Tarcrete/ soil	No change	
TMC	16	1500	Tarcrete	Tarmat, continuous, 4-7mm, soft to hardened, very friable to friable	
			Soil	yellowish brown fine to medium SAND. Occasional organic matter.	
TMC	16+50	1550	Tarcrete/ soil	No change	
TMC	17	1600	Tarcrete	Tarmat, continuous, 4-5mm, hardened, very friable,	30-40mm of silt overlaying
			Soil	yellowish brown fine to medium SAND. Occasional organic matter.	

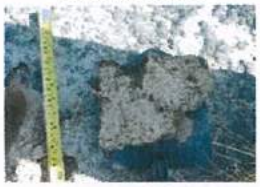
TMC-04 Profile



TMC-04 Top



TMC-04 Base



TMC-04 Side



TMC-06 Profile



TMC-06 Top



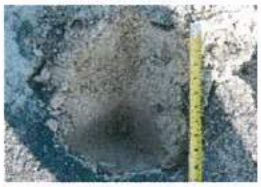
TMC-06 Base



TMC-06 Side



TMC-07 Profile



TMC-07 Top



TMC-07 Base



TMC-07 Side



TMC-08 Profile



TMC-08 Top



TMC-08 Base



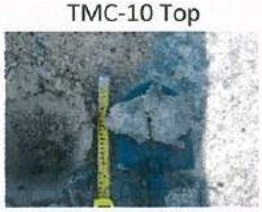
TMC-08 Side



TMC-10 Profile



TMC-10 Top



TMC-10 Base



TMC-10 Side



TMC-12 Profile



TMC-12 Top



TMC-12 Base



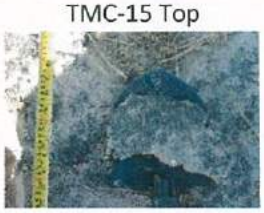
TMC-12 Side



TMC-15 Profile



TMC-15 Top



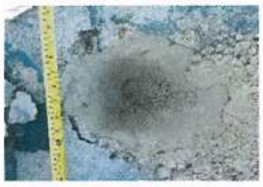
TMC-15 Base



TMC-15 Side



TMC-16 Profile



TMC-16 Top



TMC-16 Base



TMC-16 Side



TMC-17 Profile



TMC-17 Top



TMC-17 Base



TMC-17 Side



Transect TMD

Transect TMD					
Transect Reference	**Survey Point**	**Distance from Well (m)**	**Material**	**Description**	**Comments**
TMD	01	0	Disturbed ground	Well pad / disturbed ground	
TMD	01+50	50			
TMD	02	100	Wet/Dry oil lake	186m dry oil lake ends	
TMD	02+50	150	Wet/Dry oil lake		
TMD	03	200	Tarcrete	Tarmat, continuous, 10-15mm, hardened, very friable	
			Soil	pale brown slightly gravely silty SAND. Gravel is rounded to sub-angular, fine	
TMD	03+50	250	Tarcrete / soil	Dry oil lake present from 249.2m to 300m	
TMD	04	300	Tarcrete	Tarmat, continuous, 10-25mm, soft, friable	
			Soil	pale brown slightly gravely silty SAND. Gravel is rounded to sub-angular, fine	
TMD	04+50	350	Tarcrete / soil	No change	
TMD	05	400	Tarcrete	Tarmat, continuous, 10-12mm, hardened, friable	
			Soil	pale brown slightly gravely silty SAND. Gravel is rounded to sub-angular, fine	
TMD	05+50	450	Tarcrete / soil	No change	
TMD	06	500	Tarcrete	Tarmat, continuous, 10-22mm, hardened, friable	40mm soil covering tarcrete
TMD			Soil	pale brown slightly gravely silty SAND. Gravel is rounded to sub-angular, fine	
TMD	06+50	550	Tarcrete / soil	No change	
TMD	07	600	Tarcrete	Tarmat, continuous, 8-14mm, hardened, friable	
TMD			Soil	pale brown slightly gravely silty SAND. Gravel is rounded to sub-angular, fine	
TMD	07+50	650	Disturbed ground	At TMD 7 +58m Gatch road / disturbed area / oil field facilities (pipelines, etc) until 50m beyond next well	
TMD	08	700			
TMD	08+50	750			
TMD	09	800			
TMD	09+50	850			
TMD	10	900			
TMD	10+50	950			
TMD	11	1000			
TMD	11+50	1050	Tarcrete	Same as 1100m	

Transect TMD					
Transect Reference	**Survey Point**	**Distance from Well (m)**	**Material**	**Description**	**Comments**
TMD	12	1100	Tarcrete	Tarmat, continuous, 10-22mm, hardened, friable	
			Soil	pale brown slightly gravely silty SAND. Gravel is rounded to sub-angular, fine	
TMD	12+50	1150	Tarcrete / soil	no change	
TMD	13	1200	Disturbed ground	Disturbed ground / gatch road 1182m to 1190m	
TMD	13+50	1250	Tarcrete	Same as 1300m	
TMD	14	1300	Tarcrete	Tarmat, continuous, 5-8mm, hardened, very friable	
			Soil	pale brown slightly gravely silty SAND. Gravel is rounded to sub-angular, fine	
TMD	14+50	1350	Tarcrete / soil	no change	
TMD	15	1400	Tarcrete	Tarmat, continuous, 5-8mm, hardened, friable	
			Soil	light yellowish brown slightly gravely silty SAND. Gravel is rounded to sub-angular, fine	
TMD	15+50	1450	Tarcrete / soil	no change	
TMD	16	1500	Tarcrete	Tarmat, continuous, 9-12mm, hardened, friable	
			Soil	light yellowish brown slightly gravely silty SAND. Gravel is rounded to sub-angular, fine	
TMD	16+50	1550	Tarcrete / soil	no change	
TMD	17	1600	Tarcrete	Tarmat, continuous, 5-7mm, soft to hardened, friable	
			Soil	pale brown slightly gravely silty SAND. Gravel is rounded to sub-angular, fine	
TMD	17+50	1650	Tarcrete / soil	no change	
TMD	18	1700	Tarcrete	Tarmat, continuous, 10-25mm, soft to hardened, friable	
			Soil	very pale brown slightly clayey and gravelly silty SAND. Gravel is rounded to sub-angular, fine	
TMD	18+50	1750	Tarcrete / soil	no change	
TMD	19	1800	Tarcrete	Tarmat, continuous, 12-15mm, soft to hardened, friable	
			Soil	very pale brown slightly clayey and gravelly silty SAND. Gravel is rounded to sub-angular, fine	
TMD	19+50	1850	Tarcrete / soil	no change	

Transect TMD					
Transect Reference	**Survey Point**	**Distance from Well (m)**	**Material**	**Description**	**Comments**
TMD	20	1900	Disturbed ground / Dry Oil Lake	Disturbed area. Tarcrete present. Broken, machine dozed to build well pad turning into dry oil lake	
TMD	20+50	1950			
TMD	21	2000			
	21+50	2050			
TMD	22	2100			
	22+50	2150			
TMD	23	2200			
TMD	23+50	2250			
TMD	24	2300			
TMD	24+50	2350	Tarcrete / soil	no change	
TMD	25	2400	Tarcrete	Tarmat, continuous, 12-15mm, hardened, friable	
			Soil	yellowish brown fine to medium silty SAND	
TMD	25+50	2450	Tarcrete / soil	No change	Continuous tarmat, 7mm, area covered with thin silt layer making area appear as broken to fragmented tarcrete; however, digging below surface confirmed continuous tarmat
TMD	26	2500	Tarcrete	Tarmat, continuous, 6-15mm, hardened, very friable	
			Soil	yellowish brown slightly clayey silty coarse SAND	
TMD	26+50	2550	Tarcrete / soil	no change	
TMD	27	2600	Tarcrete	Tarmat, continuous, 6-14mm, hardened, very friable	
			Soil	yellowish brown slightly clayey silty coarse SAND	
TMD	27+50	2650	Tarcrete / soil	Broken, 5mm, hardened, hard	Edge of spill area. No vegetation. Area has oil lake "skin"
TMD	28	2700	Tarcrete	Tarcrete gravel, coarse, very sparse, uneven, 6-14mm, hardened, hard	
			Soil	light yellowish brown slightly clayey silty fine to coarse SAND	
	28+50	2750	Tarcrete / soil	no change	
TMD	29	2800	Tarcrete	Tarcrete gravel, coarse, very sparse, uneven, 6-14mm, hardened, hard	
			Soil	light yellowish brown slightly clayey silty fine to coarse SAND	
TMD	30	2850	Tarcrete / soil	no change	
TMD	30+50	2900	Disturbed ground	Gatch Road	
TMD	31	3000	Boundary Fence	Boundary Fence at 2970m	

TMD-03 Profile



TMD-03 Top



TMD-03 Base



TMD-03 Side



TMD-04 Profile



TMD-04 Top



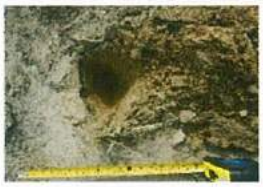
TMD-04 Base



TMD-04 Side



TMD-05 Profile



TMD-05 Top



TMD-05 Base



TMD-05 Side



TMD-06 Profile



TMD-06 Top



TMD-06 Base



TMD-06 Side



TMD-07 Profile



TMD-07 Top



TMD-07 Base



TMD-07 Side



TMD-12 Profile



TMD-12 Top



TMD-12 Base



TMD-12 Side



TMD-14 Profile



TMD-14 Top



TMD-14 Base



TMD-14 Side



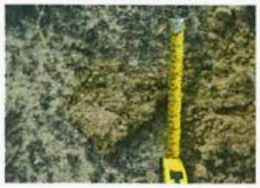
TMD-15 Profile



TMD-15 Top



TMD-15 Base



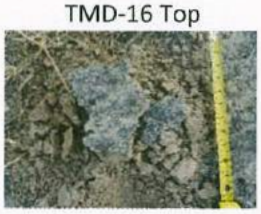
TMD-15 Side



TMD-16 Profile



TMD-16 Top



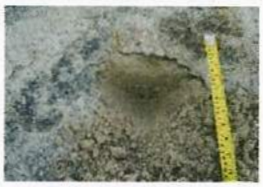
TMD-16 Base



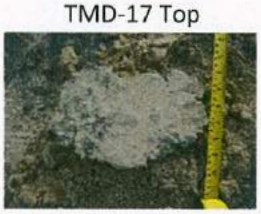
TMD-16 Side



TMD-17 Profile



TMD-17 Top



TMD-17 Base



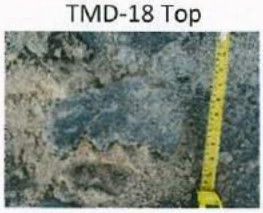
TMD-17 Side



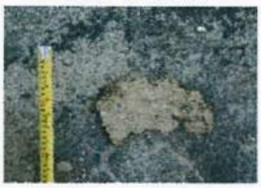
TMD-18 Profile



TMD-18 Top



TMD-18 Base



TMD-18 Side



TMD-19 Profile



TMD-19 Top



TMD-19 Base



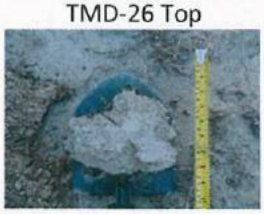
TMD-19 Side



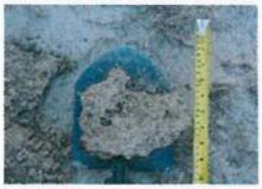
TMD-26 Profile



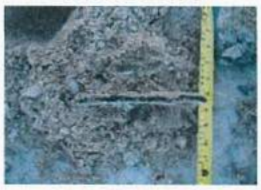
TMD-26 Top



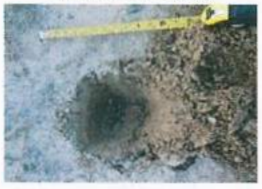
TMD-26 Base



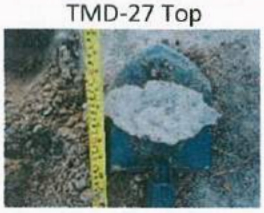
TMD-26 Side



TMD-27 Profile



TMD-27 Top



TMD-27 Base



TMD-27 Side



TMD-28 Profile



TMD-28 Top



TMD-28 Base



TMD-28 Side



Appendix C

Monitoring Site Photographs

TMA-MP1

March 3, 2014

Northwest



Southeast



April 17, 2014

Northwest



Southeast



May 24, 2014

Northwest



Southeast



June 2, 2014

Northwest



Southeast



July 6, 2014

Northwest



Southeast

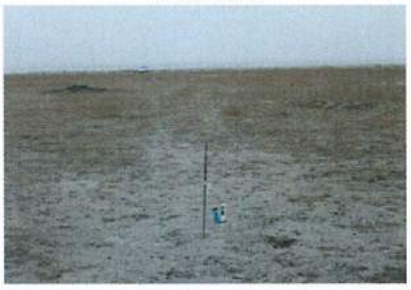


August 18, 2014

Northwest



Southeast



TMA-MP2

March 15, 2014

Northwest



Southeast



April 13, 2014

Northwest



Southeast



May 24, 2014

Northwest



Southeast



June 2, 2014

Northwest



Southeast



July 6, 2014

Northwest



Southeast



August 19, 2014

Northwest



Southeast



TMA-MP3

March 15, 2014

Northwest



Southeast



April 05, 2014

Northwest



Southeast



May 24, 2014

Northwest



Southeast

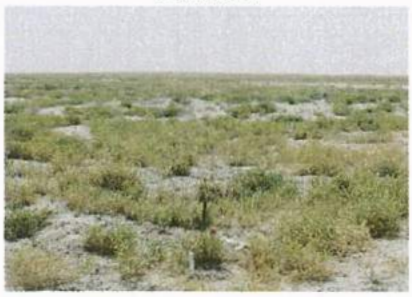


June 2, 2014

Northwest



Southeast



July 6, 2014

Northwest



Southeast



August 19, 2014

Northwest



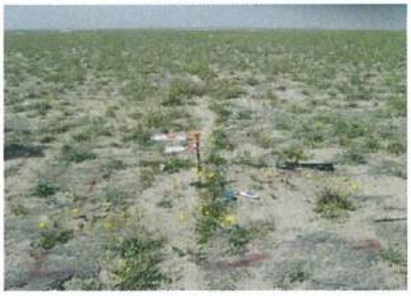
Southeast



TMB-MP1

March 8, 2014

Northwest



Southeast



April 17, 2014

Northwest

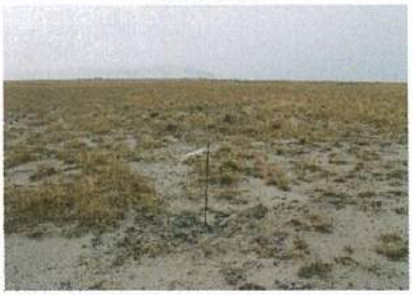


Southeast



May 24, 2014

Northwest



Southeast



June 2, 2014

Northwest



Southeast



July 6, 2014

Northwest



Southeast



August 18, 2014

Northwest



Southeast



TMC-MP2

March 15, 2014

Northwest



Southeast



April 17, 2014

Northwest



Southeast



May 24, 2014

Northwest



Southeast



June 2, 2014

Northwest



Southeast



July 6, 2014

Northwest



Southeast

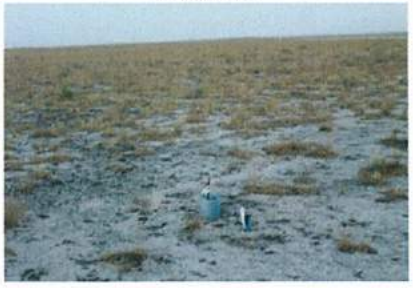


August 19, 2014

Northwest



Southeast



TMC-MP3

March 15, 2014

Northwest



Southeast



April 5, 2014

Northwest



Southeast



May 24, 2014

Northwest



Southeast



June 12, 2014

Northwest



Southeast



July 22, 2014

Northwest



Southeast



August 19, 2014

Northwest



Southeast



TMD-MP1

March 21, 2014

Northwest



Southeast



April 5, 2014

Northwest

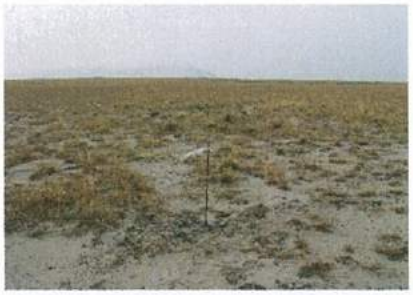


Southeast



May 24, 2014

Northwest



Southeast



June 2, 2014

Northwest

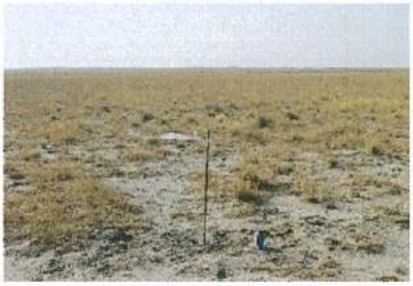


Southeast



July 6, 2014

Northwest

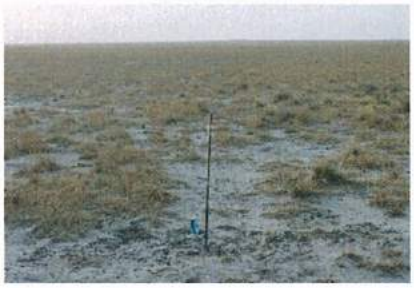


Southeast



August 18, 2014

Northwest



Southeast



TMD-MP2

March 15, 2014

Northwest



Southeast



April 17, 2014

Northwest



Southeast



May 24, 2014

Northwest



Southeast



June 2, 2014

Northwest



Southeast



July 22, 2014

Northwest



Southeast



August 18, 2014

Northwest



Southeast



TMD-MP3

March 15, 2014

Northwest



Southeast



April 17, 2014

Northwest



Southeast



May 24, 2014

Northwest



Southeast



June 12, 2014

Northwest



Southeast



July 22, 2014

Northwest



Southeast



August 18, 2014

Northwest



Southeast



Appendix D

Sample Descriptions and Photographs

Sample Location	Material	Sample ID	Description	Soil Temperature (^{0} C)	Electrical Conductivity (mS)	Moisture @ 100mm (%)	Moisture @ 200mm (%)	Distance from Well (m)	Elevation[1] (m asl)	Time (24 hrs)
TMA-MP1	Tarcrete	-	Tarcrete gravel, fine, very sparse (less than 1%), uneven, hardened, friable to hard	NA	NA	NA	NA	1,276	74.80	1210
	Soil	SO-TMA-MP1	yellowish brown fine to medium silty SAND.	20.7	0.03	7.8	8.7			
TMA-MP2	Tarcrete	TC-TMA-MP2	Tarcrete gravel, fine to medium, very sparse (approximately 5%) uneven, hardened, very friable	NA	NA	NA	NA	707	73.90	1250
	Soil	SO-TMA-MP2	yellowish brown fine to medium SAND AND SILT. Occasional organic matter.	20.5	0.11	8.1	8.8			
TMA-MP3	Tarcrete	-	None present	NA	NA	NA	NA	395	735.53	1225
	Soil	SO-TMA-MP3	yellowish brown fine to medium SAND AND SILT. Occasional organic matter.	20.6	2.08	11.7	off scale			
TMB-MP1	Tarcrete	TC-TMB-MP1	Tarmat, continuous, 10mm, hardened, very friable to friable	NA	NA	NA	NA	1,525	86.80	1150
	Soil	SO-TMB-MP1	light yellowish brown fine to coarse silty SAND. Occasional organic matter.	20.6	0.05	7.4	7.4			
TMC-MP2	Tarcrete	TC-TMC-MP2	Tarmat, continuous, 8-12mm, hardened, friable	NA	NA	NA	NA	1,084	65.54	1330
	Soil	-	light yellowish brown fine to medium SAND	22.5	0.02	1.1	1.1			
TMC-MP3	Tarcrete	TC-TMC-MP3	Tarmat, continuous, 12mm, hardened, friable	NA	NA	NA	NA	698	65.37	1320
	Soil	-	yellowish brown fine to medium SAND. Occasional organic matter.	23.9	0.06	2.2	4.3			

Sample Location	Material	Sample ID	Description	Soil Temperature (^{0}C)	Electrical Conductivity (mS)	Moisture @ 100mm (%)	Moisture @ 200mm (%)	Distance from Well (m)	Elevation[1] (m asl)	Time (24 hrs)
TMD-MP1	Tarcrete	TC-TMD-MP1	Tarmat, broken, 8-22mm, hardened, friable to gravel, medium, moderately abundant, uneven	NA	NA	NA	NA	2,855	95.01	1130
	Soil	SO-TMD-MP1	light yellowish brown fine to coarse silty SAND Occasional organic matter.	17.8	0.05	7.7	11.9			
TMD-MP2	Tarcrete	TC-TMD-MP2	Tarmat, continuous, 10-20mm, soft, friable	NA	NA	NA	NA	1,650	95.00	1505
	Soil	SO-TMD-MP2	light yellowish brown fine to coarse slightly silty SAND. Occasional organic matter.	26.1	0.12	8.3	8.5			
TMD-MP3	Tarcrete	TC-TMD-MP3	Tarmat, continuous, 8-14mm, hardened, friable	NA	NA	NA	NA	578	90.00	1525
	Soil	-	pale brown slight gravely silty SAND. Gravel rounded to sub-angular, fine	24.5	0.04	10.4	11.4			

1 measured from handheld GPS.

Date: 13.12.14
Weather: Sunny, clear sky, light south-easterly wind
Ambient Temperature: 25° C

TMA-MP01 Profile



TMA-MP01 Surface



TMA-MP02 Profile



TMA-MP02 Surface



TMA-MP03 Profile



TMA-MP03 Surface



TMB-MP01 Profile



TMB-MP01 Top



TMB-MP01 Base



TMB-MP01 Side



TMC-MP02 Profile



TMC-MP02 Top



TMC-MP02 Base



TMC-MP02 Side



TMC-MP03 Profile



TMC-MP03 Top



TMC-MP03 Base



TMC-MP03 Side



TMC-03 Profile

TMD-MP01 Profile



TMD-MP01 Top



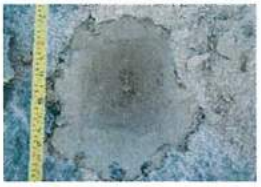
TMD-MP01 Base



TMD-MP01 Side



TMD-MP02 Profile



TMD-MP02 Top



TMD-MP02 Base



TMD-MP02 Side



TMD-MP03 Profile



TMD-MP03 Top



TMD-MP03 Base



TMD-MP03 Side



TMD-03 Profile

TMD-03 Top

TMD-03 Base

TMD-03 Side

Appendix E
Analytical Results

Chain-of-Custody

CoC034.

SGS ENVIRONMENTAL SERVICES

Me.Envilab.jubail@sgs.com
SGS Inspection Services Saudi Arabia LTD
PO Box 725
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Saudi Arabia
Phone: +966 3 362 1266
Mobile: +966 54 120 0399
Fax: +966 3 362 1277
E-mail: abdul.kader@sgs.com

CHAIN-OF CUSTODY RECORD AND ANALYSIS REQUEST

Project Manager:	Daniel Kraft	+965 9752 8722	daniel.kraft@amec.com
Technical Manager:	Simon Martin-Jones	+965 9729 0644	simon.martin-jones@amec.com
Address:	Soil Remediation Office Building, Industrial Area Kuwait Oil Company, Block 8, Al-Ahmadi PO Box 8575, Kuwait 61006	Site Location:	SEK Burgan Oilfield
Project Number: 050669		Project Name:	Limited-Scope Soil Characterization
I attest that the proper field sampling procedures were used during the collection of these samples.		Sampler Name (print):	Elizabeth Kirkham

Field Sample ID	Source of Sample	Lab # (Lab Use Only)	# CONTAINERS	Matrix: WATER	SOIL	AIR	SLUDGE	OTHER	Method Preserved: HCl	HNO_3	H_2SO_4	ICE	NONE	OTHER	Sampling: DATE	TIME	Polycyclic Aromatic Hydrocarbons (PAH)	Total Petroleum Hydrocarbons (fractionated	TPH (fractionated) (SARA)	Electrical Conductivity (Salinity)	Percent Moisture	pH	Particle-Size Analysis	Sodium Adsorption Ratio (SAR)	Total Organic Carbon (TOC)	Nitrogen (TKN)	Phophorous (Total)	Potassium	Sulphate (SO42- - Total)	Chloride	Total Alkalinity as Calcium Carbonate (CaCO	Metals			
SO-TMA-MP1		6127-01	1		x										13.12.14	12:10	x	x		x	x	x	x	x	x	x	x	x	x	x	x			
TC-TMA-MP2		6128-01	1					x							13.12.14	12:50	x	x																	
SO-TMA-MP2		6127-02	1		x										13.12.14	12:50	x	x		x	x	x	x	x	x	x	x	x	x	x	x			
SO-TMA-MP3		6127-03	1		x										13.12.14	12:25	x	x		x	x	x	x	x	x	x	x	x	x	x	x			
TC-TMB-MP1		6128-02	1					x							13.12.14	11:50	x	x																	
SO-TMB-MP1		6127-04	1		x										13.12.14	11:50	x	x		x	x	x	x	x	x	x	x	x	x	x	x			
TC-TMC-MP2		6128-03	1					x							13.12.14	13:30	x	x																	
TC-TMC-MP3		6128-04	1					x							13.12.14	13:20	x	x	x																
TC-TMD-MP1		6128-05	1					x							13.12.14	11:30	x	x																	
SO-TMD-MP1		6127-05	1		x										13.12.14	11:30	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x				
TC-TMD-MP2		6128-06	1					x							13.12.14	15:05	x	x	x																
SO-TMD-MP2		6127-06	1		x										13.12.14	15:05	x	x		x	x	x	x	x	x	x	x	x	x	x	x			
TC-TMD-MP3		6128-07	1					x							13.12.14	15:25	x	x	x																

To be Screened

SPECIAL HANDLING

24 HOURS ☐
EXPEDITED 48 HOURS ☐
SEVEN DAY ☐
OTHER _____ (#) BUSINESS DAYS

SPECIAL DETECTION LIMITS (Specify)

SPECIAL REPORTING REQUIREMENTS (Specify)

REMARKS

Matrix (other) is tarcrete

Lab Use Only Storage Location

Lot #: Work Order #:

CUSTODY RECORD

	Received by:	Time	Date	Relinquished by Sampler:
	Mubeen		15.12.14	E.KARKAM
	Received by:	Time	Date	Relinquished by:
	Hamash			
Way Bill #	Received by Laboratory:	Time	Date	Relinquished by:

SO-TMC-MP2
SO-TMD-MP3
SO-TMC-MP3
TC-TMA-MP3
} place samples on hold.

Tarcrete Analytical Results

ANALYTICAL REPORT

CLIENT DETAILS

Contact	Daniel W. Kraft ,Project Engineer
Client	AMEC
Address	Soil Remediation Office Building, Industrial Area Kuwait Oil Company Block 8, P.O. Box 9575 Al Ahmadi 61006
Telephone	965 97251352
Fax	(Not specified)
Email	daniel.kraft@amecfw.com
Project	Default Project
Samples	(7) Samples
Purchase Order No./Date	COC-34

LABORATORY DETAILS

Manager	Dr. Abdul Kader
Laboratory	SGS Jubail Environmental
Address	P.O. Box: 725, Al Jubail Al Jubail - 31951, Saudi Arabia
Telephone	+966-3-362-1266 ext. 140
Fax	+966-3-362-1277
Email	abdul.kader@sgs.com
SGS Reference	JE14-06128 R0
Report Number	0000009255
Date Reported	24 Feb 2015

COMMENTS

SIGNATORIES

Reviewed & Signed by

Dr. Abdul Kader
Lab Manager

Hanosh Mohanan
Lab Supervisor

Parameter	Units	LOR	Sample Number / Client ID / Sample Matrix / Sampling Date/Time / Sample Receipt Date/Time / Sampled By	JE14-06128.001 TC-TMA-MP2 Sediment 13/12/14 12:50 19/12/14 06:00 SGS Result	JE14-06128.002 TC-TMB-MP1 Sediment 13/12/14 11:50 19/12/14 06:00 SGS Result	JE14-06128.003 TC-TMC-MP2 Sediment 13/12/14 13:30 19/12/14 06:00 SGS Result	JE14-06128.004 TC-TMC-MP3 Sediment 13/12/14 13:20 19/12/14 06:00 SGS Result	JE14-06128.005 TC-TMD-MP1 Sediment 13/12/14 11:30 19/12/14 06:00 SGS Result
Polycyclic Aromatic hydrocarbons EPA 8270								
Naphthalene	mg/kg	0.5		<0.5	<0.5	<0.5	<0.5	<0.5
Acenaphthalene	mg/kg	0.5		<0.5	<0.5	<0.5	<0.5	<0.5
Acenaphthene	mg/kg	0.5		<0.5	<0.5	<0.5	<0.5	<0.5
Fluorene	mg/kg	0.5		<0.5	<0.5	<0.5	<0.5	<0.5
Phenanthrene	mg/kg	0.5		<0.5	<0.5	<0.5	<0.5	<0.5
Anthracene	mg/kg	0.5		<0.5	<0.5	<0.5	<0.5	<0.5
Fluoranthene	mg/kg	0.5		<0.5	<0.5	<0.5	<0.5	<0.5
Pyrene	mg/kg	0.5		<0.5	<0.5	<0.5	<0.5	<0.5
Benzo(a)anthracene	mg/kg	0.5		<0.5	<0.5	<0.5	<0.5	<0.5
Chrysene	mg/kg	0.5		<0.5	<0.5	<0.5	<0.5	<0.5
Benzo(a)pyrene	mg/kg	0.5		<0.5	<0.5	<0.5	<0.5	<0.5
Indeno(1,2,3-cd)pyrene	mg/kg	0.5		<0.5	<0.5	<0.5	<0.5	<0.5
Dibenz(a,h)anthracene	mg/kg	0.5		<0.5	<0.5	<0.5	<0.5	<0.5
Benzo(g,h,i)perylene	mg/kg	0.5		<0.5	<0.5	<0.5	<0.5	<0.5
Benzo(b&k)fluoranthene	mg/kg	1		<1.0	<1.0	<1.0	<1.0	<1.0
Saturated,Aromatic and Polar Compounds by TLC and FID Detection IP 469/01 (2006)								
Saturates	mg/kg	10		N/R	N/R	N/R	17233.3	N/R
Aromatics	mg/kg	10		N/R	N/R	N/R	27671.3	N/R
Polars (I)	mg/kg	10		N/R	N/R	N/R	35195.2	N/R
Polars (II)	mg/kg	10		N/R	N/R	N/R	809.6	N/R
Fractionated PHC EPA8015_8260_MAMTCA_ECY97_602								
Fractionated PHC >C35-C90	mg/kg	0.5		106560.8	34724.7	82801.7	80474.9	56714.5
Total Petroleum Hydrocarbons EPA 8015 & 8260								
Volatile Aliphatics (C5-C6)	mg/kg	20		<20	<20	<20	<20	<20
Volatile Aliphatics (C6-C8)	mg/kg	20		<20	<20	<20	<20	<20
Volatile Aliphatics (C8-C10)	mg/kg	20		<20	<20	<20	<20	<20
Extractable Aliphatics (C10-C12)	mg/kg	5		<5	<5	<5	<5	<5
Extractable Aliphatics (C12-C16)	mg/kg	5		<5	<5	<5	<5	<5
Extractable Aliphatics (C16-C21)	mg/kg	5		<5	<5	<5	<5	<5
Extractable Aliphatics (C21-C35)	mg/kg	5		391	152	79	378	389
Volatile Aromatics (C5-C6)	mg/kg	0.5		<0.5	<0.5	<0.5	<0.5	<0.5
Volatile Aromatics (C6-C8)	mg/kg	0.5		<0.5	<0.5	<0.5	<0.5	<0.5
Volatile Aromatics (C8-C10)	mg/kg	0.5		<0.5	<0.5	<0.5	<0.5	<0.5
Extractable Aromatics (C10-C12)	mg/kg	5		<5	<5	<5	<5	<5
Extractable Aromatics (C12-C16)	mg/kg	5		<5	<5	<5	<5	<5
Extractable Aromatics (C16-C21)	mg/kg	5		<5	<5	<5	<5	<5
Extractable Aromatics (C21-C35)	mg/kg	5		53	55	51	56	64

Parameter	Units	LOR	Sample Number / Client ID / Sample Matrix / Sampling Date/Time / Sample Receipt Date/Time / Sampled By	JE14-06128.001 TC-TMA-MP2 Sediment 13/12/14 12:50 19/12/14 06:00 SGS Result	JE14-06128.002 TC-TMB-MP1 Sediment 13/12/14 11:50 19/12/14 06:00 SGS Result	JE14-06128.003 TC-TMC-MP2 Sediment 13/12/14 13:30 19/12/14 06:00 SGS Result	JE14-06128.004 TC-TMC-MP3 Sediment 13/12/14 13:20 19/12/14 06:00 SGS Result	JE14-06128.005 TC-TMD-MP1 Sediment 13/12/14 11:30 19/12/14 06:00 SGS Result
Metals by ICPMS EPA 6020 A								
Cadmium (Cd)	mg/kg	0.3		N/R	N/R	N/R	N/R	<0.3
Cobalt (Co)	mg/kg	0.3		N/R	N/R	N/R	N/R	0.8
Mercury (Hg)	mg/kg	1.3		N/R	N/R	N/R	N/R	<1.3
Lead (Pb)	mg/kg	0.4		N/R	N/R	N/R	N/R	1.4
Vanadium (V)	mg/kg	0.4		N/R	N/R	N/R	N/R	18.6
Metals by ICP-OES USEPA 6010								
Calcium (Ca)	mg/kg	0.25		N/R	N/R	N/R	N/R	18116.00

Parameter	Units	LOR	Sample Number / Client ID / Sample Matrix / Sampling Date/Time / Sample Receipt Date/Time / Sampled By	JE14-06128.006 TC-TMD-MP2 Sediment 13/12/14 15:05 19/12/14 06:00 SGS Result	JE14-06128.007 TC-TMD-MP3 Sediment 13/12/14 15:25 19/12/14 06:00 SGS Result
Polycyclic Aromatic hydrocarbons EPA 8270					
Naphthalene	mg/kg	0.5		<0.5	<0.5
Acenaphthalene	mg/kg	0.5		<0.5	<0.5
Acenaphthene	mg/kg	0.5		<0.5	<0.5
Fluorene	mg/kg	0.5		<0.5	<0.5
Phenanthrene	mg/kg	0.5		<0.5	<0.5
Anthracene	mg/kg	0.5		<0.5	<0.5
Fluoranthene	mg/kg	0.5		<0.5	<0.5
Pyrene	mg/kg	0.5		<0.5	<0.5
Benzo(a)anthracene	mg/kg	0.5		<0.5	<0.5
Chrysene	mg/kg	0.5		<0.5	<0.5
Benzo(a)pyrene	mg/kg	0.5		<0.5	<0.5
Indeno(1,2,3-cd)pyrene	mg/kg	0.5		<0.5	<0.5
Dibenz(a,h)anthracene	mg/kg	0.5		<0.5	<0.5
Benzo(g,h,i)perylene	mg/kg	0.5		<0.5	<0.5
Benzo(b&k)fluoranthene	mg/kg	1		<1.0	<1.0
Saturated,Aromatic and Polar Compounds by TLC and FID Detection IP 469/01 (2006)					
Saturates	mg/kg	10		9436.0	9415.6
Aromatics	mg/kg	10		17571.9	12663.4
Polars (I)	mg/kg	10		20557.1	18182.8
Polars (II)	mg/kg	10		578.3	324.9
Fractionated PHC EPA8015_8260_MAMTCA_ECY97_602					
Fractionated PHC >C35-C90	mg/kg	0.5		47920.1	40455.6

Parameter	Units	LOR	Sample Number: JE14-06128.006 Client ID: TC-TMD-MP2 Sample Matrix: Sediment Sampling Date/Time: 13/12/14 15:05 Sample Receipt Date/Time: 19/12/14 06:00 Sampled By: SGS Result	Sample Number: JE14-06128.007 Client ID: TC-TMD-MP3 Sample Matrix: Sediment Sampling Date/Time: 13/12/14 15:25 Sample Receipt Date/Time: 19/12/14 06:00 Sampled By: SGS Result
Total Petroleum Hydrocarbons EPA 8015 & 8260				
Volatile Aliphatics (C5-C6)	mg/kg	20	<20	<20
Volatile Aliphatics (C6-C8)	mg/kg	20	<20	<20
Volatile Aliphatics (C8-C10)	mg/kg	20	<20	<20
Extractable Aliphatics (C10-C12)	mg/kg	5	<5	<5
Extractable Aliphatics (C12-C16)	mg/kg	5	<5	<5
Extractable Aliphatics (C16-C21)	mg/kg	5	<5	<5
Extractable Aliphatics (C21-C35)	mg/kg	5	211	112
Volatile Aromatics (C5-C6)	mg/kg	0.5	<0.5	<0.5
Volatile Aromatics (C6-C8)	mg/kg	0.5	<0.5	<0.5
Volatile Aromatics (C8-C10)	mg/kg	0.5	<0.5	<0.5
Extractable Aromatics (C10-C12)	mg/kg	5	<5	<5
Extractable Aromatics (C12-C16)	mg/kg	5	<5	<5
Extractable Aromatics (C16-C21)	mg/kg	5	<5	<5
Extractable Aromatics (C21-C35)	mg/kg	5	12	19
Metals by ICPMS EPA 6020 A				
Cadmium (Cd)	mg/kg	0.3	<0.3	<0.3
Cobalt (Co)	mg/kg	0.3	0.7	0.6
Mercury (Hg)	mg/kg	1.3	<1.3	<1.3
Lead (Pb)	mg/kg	0.4	1.3	1.2
Vanadium (V)	mg/kg	0.4	11.8	11.3
Metals by ICP-OES USEPA 6010				
Calcium (Ca)	mg/kg	0.25	12835.00	19632.00

FOOTNOTES

IS	Insufficient sample for analysis.
LNR	Sample listed, but not received.
*	This analysis is not covered by the scope of accreditation.
^	Subcontracted.
LOR	Limit of Reporting
↑↓	Raised or Lowered Limit of Reporting
N/R	The sample was not analysed for this analyte
QFH	QC result is above the upper tolerance
QFL	QC result is below the lower tolerance

Samples analysed as received.
Solid samples expressed on a dry weight basis.

The QC criteria are subject to internal review according to the SGS QAQC plan and may be provided on request.

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Soil Analytical Results

ANALYTICAL REPORT

CLIENT DETAILS

Contact	Daniel W. Kraft ,Project Engineer
Client	AMEC
Address	Soil Remediation Office Building, Industrial Area Kuwait Oil Company Block 8, P.O. Box 9575 Al Ahmadi 61006
Telephone	965 97251352
Fax	(Not specified)
Email	daniel.kraft@amecfw.com
Project	Default Project
Samples	(6) Samples
Purchase Order No./Date	COC-34

LABORATORY DETAILS

Manager	Dr. Abdul Kader
Laboratory	SGS Jubail Environmental
Address	P.O. Box: 725, Al Jubail Al Jubail - 31951, Saudi Arabia
Telephone	+966-3-362-1266 ext. 140
Fax	+966-3-362-1277
Email	abdul.kader@sgs.com
SGS Reference	JE14-06127 R0
Report Number	0000009256
Date Reported	24 Feb 2015

COMMENTS

SIGNATORIES

Reviewed & Signed by

Dr. Abdul Kader
Lab Manager

Hanosh Mohanan
Lab Supervisor

Parameter	Units	LOR	Sample Number / Client ID	JE14-06127.001 SO-TMA-MP1	JE14-06127.002 SO-TMA-MP2	JE14-06127.003 SO-TMA-MP3	JE14-06127.004 SO-TMB-MP1	JE14-06127.005 SO-TMD-MP1
			Sample Matrix	Soil	Soil	Soil	Soil	Soil
			Sampling Date/Time	13/12/14 12:10	13/12/14 12:50	13/12/14 12:25	13/12/14 11:50	13/12/14 11:30
			Sample Receipt Date/Time	19/12/14 06:00	19/12/14 06:00	19/12/14 06:00	19/12/14 06:00	19/12/14 06:00
			Sampled By	SGS	SGS	SGS	SGS	SGS
				Result	Result	Result	Result	Result
Conductivity EPA 120.1								
Conductivity	µS/cm	1		260	273	5830	369	220
Determination of Moisture ASTM D 2216								
Moisture	%	0.1		1.5	3.1	2.7	2.5	2.4
pH EPA 9045								
pH	pH	0.1		9.0	8.9	8.9	8.1	9.0
Particle size Destribution ISO 11277:2009(E)								
50 mm	%	-		Nil	Nil	Nil	Nil	Nil
37.5 mm	%	-		Nil	Nil	Nil	Nil	Nil
28 mm	%	-		Nil	Nil	Nil	Nil	Nil
20 mm	%	-		Nil	Nil	Nil	Nil	Nil
14 mm	%	-		Nil	Nil	Nil	Nil	Nil
10 mm	%	-		Nil	Nil	Nil	Nil	Nil
6.3 mm	%	-		Nil	Nil	Nil	Nil	Nil
5 mm	%	-		Nil	Nil	Nil	Nil	Nil
3.35 mm	%	-		Nil	Nil	Nil	Nil	Nil
2 mm	%	-		1.50	1.90	3.00	1.10	4.00
1.18 mm	%	-		3.80	3.80	7.00	2.40	7.20
0.6 mm	%	-		17.20	13.30	19.10	17.20	12.40
0.425 mm	%	-		16.30	12.70	16.60	15.30	11.90
0.3 mm	%	-		9.20	9.40	19.40	17.50	13.70
0.212 mm	%	-		13.60	11.20	13.70	11.90	10.90
0.15 mm	%	-		10.20	14.70	6.40	9.40	16.10
0.063 mm	%	-		19.70	19.30	6.70	18.90	17.80
< 0.063 mm	%	-		8.50	13.50	8.00	6.30	5.90
Total Kjeldahl Nitrogen EPA 351.2								
Total Kjeldahl Nitrogen	mg/kg	0.1		0.9	1.1	1.8	1.2	1.2
Total Phosphorus EPA 365.4								
Total Phosphorus	mg/kg	1		81	91	69	92	105
Metals by ICP-OES APHA 3120 B								
Potassium (K)	mg/kg	0.25		26.75	34.73	58.37	33.34	40.89
Anions by Ion Chromatography EPA 300.1								
Sulphate	mg/kg	0.2		226.7	82.4	527.5	146.9	92.3
Chloride	mg/kg	0.2		19.4	13.7	7740.0	20.2	21.1

Parameter	Units	LOR	Sample Number	JE14-06127.001	JE14-06127.002	JE14-06127.003	JE14-06127.004	JE14-06127.005
			Client ID	SO-TMA-MP1	SO-TMA-MP2	SO-TMA-MP3	SO-TMB-MP1	SO-TMD-MP1
			Sample Matrix	Soil	Soil	Soil	Soil	Soil
			Sampling Date/Time	13/12/14 12:10	13/12/14 12:50	13/12/14 12:25	13/12/14 11:50	13/12/14 11:30
			Sample Receipt Date/Time	19/12/14 06:00	19/12/14 06:00	19/12/14 06:00	19/12/14 06:00	19/12/14 06:00
			Sampled By	SGS	SGS	SGS	SGS	SGS
				Result	Result	Result	Result	Result
Alkalinity APHA 2320 B								
Alkalinity as Calcium Carbonate	mg/kg	-		465	196	662	319	199
Organic and Total Carbon ISO 10964								
Total Organic Carbon	mg/kg	-		2100	1920	2130	1720	1630
Polycyclic Aromatic hydrocarbons EPA 8270								
Naphthalene	mg/kg	0.5		<0.5	<0.5	<0.5	<0.5	<0.5
Acenaphthalene	mg/kg	0.5		<0.5	<0.5	<0.5	<0.5	<0.5
Acenaphthene	mg/kg	0.5		<0.5	<0.5	<0.5	<0.5	<0.5
Fluorene	mg/kg	0.5		<0.5	<0.5	<0.5	<0.5	<0.5
Phenanthrene	mg/kg	0.5		<0.5	<0.5	<0.5	<0.5	<0.5
Anthracene	mg/kg	0.5		<0.5	<0.5	<0.5	<0.5	<0.5
Fluoranthene	mg/kg	0.5		<0.5	<0.5	<0.5	<0.5	<0.5
Pyrene	mg/kg	0.5		<0.5	<0.5	<0.5	<0.5	<0.5
Benzo(a)anthracene	mg/kg	0.5		<0.5	<0.5	<0.5	<0.5	<0.5
Chrysene	mg/kg	0.5		<0.5	<0.5	<0.5	<0.5	<0.5
Benzo(a)pyrene	mg/kg	0.5		<0.5	<0.5	<0.5	<0.5	<0.5
Indeno(1,2,3-cd)pyrene	mg/kg	0.5		<0.5	<0.5	<0.5	<0.5	<0.5
Dibenz(a,h)anthracene	mg/kg	0.5		<0.5	<0.5	<0.5	<0.5	<0.5
Benzo(g,h,i)perylene	mg/kg	0.5		<0.5	<0.5	<0.5	<0.5	<0.5
Benzo(b&k)fluoranthene	mg/kg	1		<1.0	<1.0	<1.0	<1.0	<1.0
Sodium Absorption Ratio Calculation								
Sodium Absorption Ratio	-	0.25		<0.250	<0.250	10.522	<0.250	<0.250
Saturated,Aromatic and Polar Compounds by TLC and FID Detection IP 469/01 (2006)								
Saturates	mg/kg	10		N/R	N/R	N/R	N/R	131.2
Aromatics	mg/kg	10		N/R	N/R	N/R	N/R	158.4
Polars (I)	mg/kg	10		N/R	N/R	N/R	N/R	160.0
Polars (II)	mg/kg	10		N/R	N/R	N/R	N/R	<10.0
Fractionated PHC EPA8015_8260_MAMTCA_ECY97_602								
Fractionated PHC >C35-C90	mg/kg	0.5		303.7	418.9	787.5	487.2	449.6
Total Petroleum Hydrocarbons EPA 8015 & 8260								
Volatile Aliphatics (C5-C6)	mg/kg	20		<20	<20	<20	<20	<20
Volatile Aliphatics (C6-C8)	mg/kg	20		<20	<20	<20	<20	<20
Volatile Aliphatics (C8-C10)	mg/kg	20		<20	<20	<20	<20	<20
Extractable Aliphatics (C10-C12)	mg/kg	5		<5	<5	<5	<5	<5
Extractable Aliphatics (C12-C16)	mg/kg	5		<5	<5	<5	<5	<5
Extractable Aliphatics (C16-C21)	mg/kg	5		<5	<5	<5	<5	<5
Extractable Aliphatics (C21-C35)	mg/kg	5		<5	<5	<5	<5	<5
Volatile Aromatics (C5-C6)	mg/kg	0.5		<0.5	<0.5	<0.5	<0.5	<0.5
Volatile Aromatics (C6-C8)	mg/kg	0.5		<0.5	<0.5	<0.5	<0.5	<0.5
Volatile Aromatics (C8-C10)	mg/kg	0.5		<0.5	<0.5	<0.5	<0.5	<0.5
Extractable Aromatics (C10-C12)	mg/kg	5		<5	<5	<5	<5	<5

Parameter	Units	LOR	Sample Number / Client ID	JE14-06127.001 SO-TMA-MP1	JE14-06127.002 SO-TMA-MP2	JE14-06127.003 SO-TMA-MP3	JE14-06127.004 SO-TMB-MP1	JE14-06127.005 SO-TMD-MP1
			Sample Matrix	Soil	Soil	Soil	Soil	Soil
			Sampling Date/Time	13/12/14 12:10	13/12/14 12:50	13/12/14 12:25	13/12/14 11:50	13/12/14 11:30
			Sample Receipt Date/Time	19/12/14 06:00	19/12/14 06:00	19/12/14 06:00	19/12/14 06:00	19/12/14 06:00
			Sampled By	SGS	SGS	SGS	SGS	SGS
				Result	Result	Result	Result	Result
Extractable Aromatics (C12-C16)	mg/kg	5		<5	<5	<5	<5	<5
Extractable Aromatics (C16-C21)	mg/kg	5		<5	<5	<5	<5	<5
Extractable Aromatics (C21-C35)	mg/kg	5		<5	<5	<5	<5	<5

Metals by ICPMS EPA 6020 A

Cadmium (Cd)	mg/kg	0.3	<0.3	<0.3	N/R	N/R	<0.3
Cobalt (Co)	mg/kg	0.3	2.4	2.5	N/R	N/R	2.1
Mercury (Hg)	mg/kg	1.3	<1.3	<1.3	N/R	N/R	<1.3
Lead (Pb)	mg/kg	0.4	1.5	1.5	N/R	N/R	1.3
Vanadium (V)	mg/kg	0.4	9.2	11.0	N/R	N/R	9.4

Metals by ICP-OES USEPA 6010

Calcium (Ca)	mg/kg	0.25	29445.00	42830.00	N/R	N/R	23403.00

Parameter	Units	LOR	Sample Number / Client ID	JE14-06127.006 SO-TMD-MP2
			Sample Matrix	Soil
			Sampling Date/Time	13/12/14 15:05
			Sample Receipt Date/Time	19/12/14 06:00
			Sampled By	SGS
				Result

Conductivity EPA 120.1

Conductivity	µS/cm	1	323

Determination of Moisture ASTM D 2216

Moisture	%	0.1	2.4

pH EPA 9045

pH	pH	0.1	9.0

Parameter	Units	LOR	Result
Sample Number			JE14-06127.006
Client ID			SO-TMD-MP2
Sample Matrix			Soil
Sampling Date/Time			13/12/14 15:05
Sample Receipt Date/Time			19/12/14 06:00
Sampled By			SGS

Particle size Destribution ISO 11277:2009(E)

50 mm	%	-	Nil
37.5 mm	%	-	Nil
28 mm	%	-	Nil
20 mm	%	-	Nil
14 mm	%	-	Nil
10 mm	%	-	Nil
6.3 mm	%	-	Nil
5 mm	%	-	Nil
3.35 mm	%	-	0.30
2 mm	%	-	1.40
1.18 mm	%	-	7.30
0.6 mm	%	-	12.60
0.425 mm	%	-	10.10
0.3 mm	%	-	8.80
0.212 mm	%	-	13.90
0.15 mm	%	-	12.50
0.063 mm	%	-	18.80
< 0.063 mm	%	-	14.20

Total Kjeldahl Nitrogen EPA 351.2

Total Kjeldahl Nitrogen	mg/kg	0.1	1.0

Total Phosphorus EPA 365.4

Total Phosphorus	mg/kg	1	108

Metals by ICP-OES APHA 3120 B

Potassium (K)	mg/kg	0.25	81.40

Anions by Ion Chromatography EPA 300.1

Sulphate	mg/kg	0.2	116.5
Chloride	mg/kg	0.2	52.4

Alkalinity APHA 2320 B

Alkalinity as Calcium Carbonate	mg/kg	-	224

Organic and Total Carbon ISO 10964

Total Organic Carbon	mg/kg	-	1720

Polycyclic Aromatic hydrocarbons EPA 8270

Naphthalene	mg/kg	0.5	<0.5
Acenaphthalene	mg/kg	0.5	<0.5
Acenaphthene	mg/kg	0.5	<0.5
Fluorene	mg/kg	0.5	<0.5
Phenanthrene	mg/kg	0.5	<0.5

Parameter	Units	LOR	Sample Number: JE14-06127.006 Client ID: SO-TMD-MP2 Sample Matrix: Soil Sampling Date/Time: 13/12/14 15:05 Sample Receipt Date/Time: 19/12/14 06:00 Sampled By: SGS Result
Anthracene	mg/kg	0.5	<0.5
Fluoranthene	mg/kg	0.5	<0.5
Pyrene	mg/kg	0.5	<0.5
Benzo(a)anthracene	mg/kg	0.5	<0.5
Chrysene	mg/kg	0.5	<0.5
Benzo(a)pyrene	mg/kg	0.5	<0.5
Indeno(1,2,3-cd)pyrene	mg/kg	0.5	<0.5
Dibenz(a,h)anthracene	mg/kg	0.5	<0.5
Benzo(g,h,i)perylene	mg/kg	0.5	<0.5
Benzo(b&k)fluoranthene	mg/kg	1	<1.0

Sodium Absorption Ratio Calculation

Sodium Absorption Ratio	-	0.25	<0.250

Saturated,Aromatic and Polar Compounds by TLC and FID Detection IP 469/01 (2006)

Saturates	mg/kg	10	N/R
Aromatics	mg/kg	10	N/R
Polars (I)	mg/kg	10	N/R
Polars (II)	mg/kg	10	N/R

Fractionated PHC EPA8015_8260_MAMTCA_ECY97_602

Fractionated PHC >C35-C90	mg/kg	0.5	524.1

Total Petroleum Hydrocarbons EPA 8015 & 8260

Volatile Aliphatics (C5-C6)	mg/kg	20	<20
Volatile Aliphatics (C6-C8)	mg/kg	20	<20
Volatile Aliphatics (C8-C10)	mg/kg	20	<20
Extractable Aliphatics (C10-C12)	mg/kg	5	<5
Extractable Aliphatics (C12-C16)	mg/kg	5	<5
Extractable Aliphatics (C16-C21)	mg/kg	5	<5
Extractable Aliphatics (C21-C35)	mg/kg	5	<5
Volatile Aromatics (C5-C6)	mg/kg	0.5	<0.5
Volatile Aromatics (C6-C8)	mg/kg	0.5	<0.5
Volatile Aromatics (C8-C10)	mg/kg	0.5	<0.5
Extractable Aromatics (C10-C12)	mg/kg	5	<5
Extractable Aromatics (C12-C16)	mg/kg	5	<5
Extractable Aromatics (C16-C21)	mg/kg	5	<5
Extractable Aromatics (C21-C35)	mg/kg	5	<5

	Sample Number		JE14-06127.006
	Client ID		SO-TMD-MP2
	Sample Matrix		Soil
	Sampling Date/Time		13/12/14 15:05
	Sample Receipt Date/Time		19/12/14 06:00
	Sampled By		SGS
Parameter	Units	LOR	Result

Metals by ICPMS EPA 6020 A

Cadmium (Cd)	mg/kg	0.3	<0.3
Cobalt (Co)	mg/kg	0.3	1.6
Mercury (Hg)	mg/kg	1.3	<1.3
Lead (Pb)	mg/kg	0.4	1.3
Vanadium (V)	mg/kg	0.4	6.0

Metals by ICP-OES USEPA 6010

Calcium (Ca)	mg/kg	0.25	30832.00

FOOTNOTES

IS	Insufficient sample for analysis.
LNR	Sample listed, but not received.
*	This analysis is not covered by the scope of accreditation.
^	Subcontracted.
LOR	Limit of Reporting
↑↓	Raised or Lowered Limit of Reporting
N/R	The sample was not analysed for this analyte
QFH	QC result is above the upper tolerance
QFL	QC result is below the lower tolerance

Samples analysed as received.
Solid samples expressed on a dry weight basis.

The QC criteria are subject to internal review according to the SGS QAQC plan and may be provided on request.

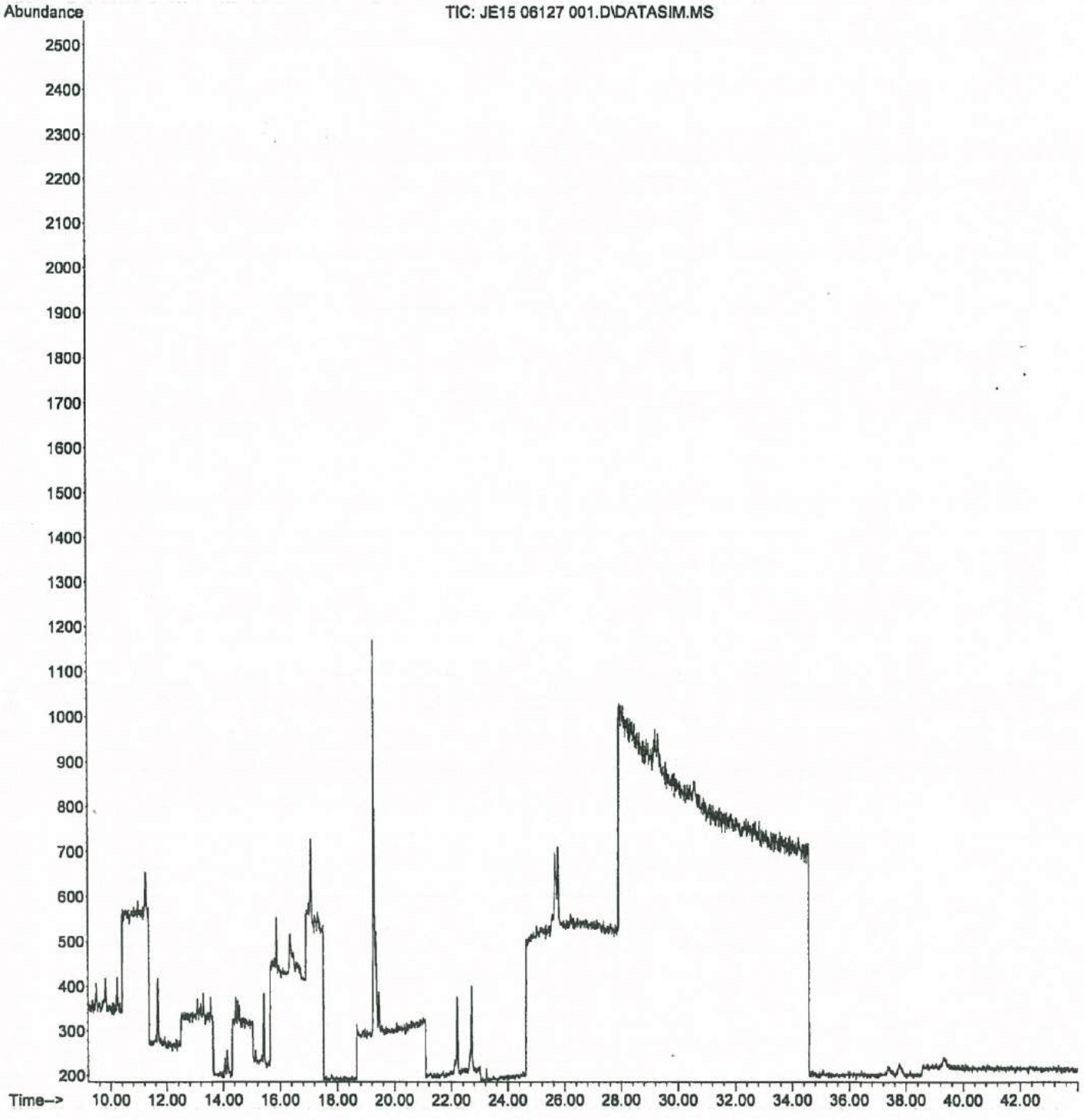
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PAH Chromatograms

File :C:\msdchem\1\data\2015\February\PAH_R SK\JE15 06127 001.D
Operator : Mohammed Haneesh
Acquired : 18 Feb 2015 14:10 using AcqMethod PAH_30M X 250 X 250_FEB.M
Instrument : GC MS
Sample Name: JE15 06127
Misc Info :
Vial Number: 144



Quantitation Report (QT Reviewed)

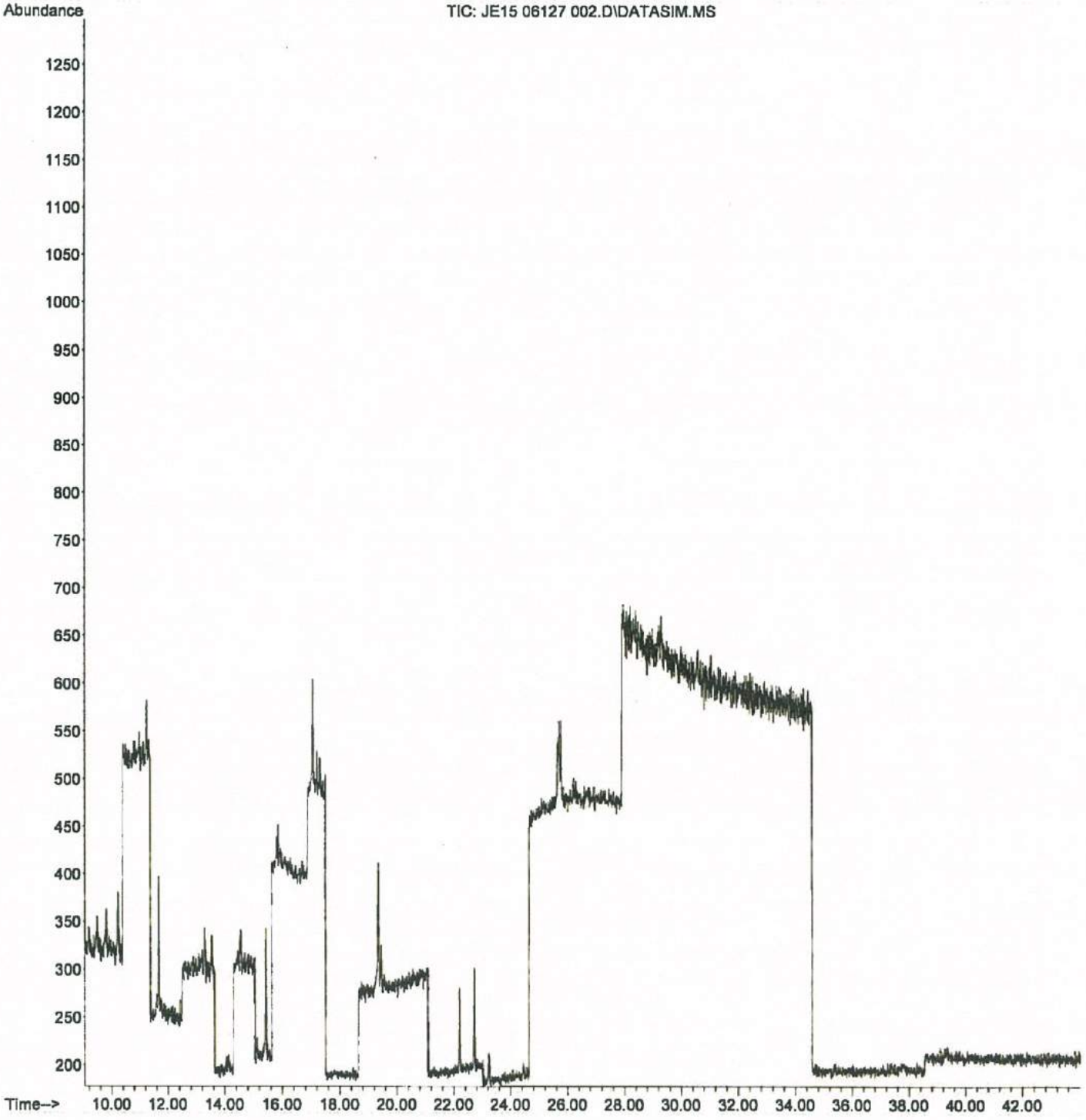
Data Path : C:\msdchem\1\data\2015\February\PAH_R SK\
Data File : JE15 06127 001.D
Acq On : 18 Feb 2015 14:10
Operator : Mohammed Haneesh
Sample : JE15 06127
Misc :
ALS Vial : 144 Sample Multiplier: 1

Quant Time: Feb 22 08:58:16 2015
Quant Method : C:\msdchem\1\methods\PAH_30M X 250 X 250_FEB.M
Quant Title : PAH CAL 30 X 250 X 250 COLUMN
QLast Update : Sat Feb 21 19:24:09 2015
Response via : Initial Calibration

Compound	R.T.	QIon	Response	Conc Units	Dev(Min)
Target Compounds					Qvalue
1] Naphthalene	11.684	128	234	0.59 ppb	# 72
2) 2-Chloronaphthalene	0.000		0	N.D. d	
3) 1-Chloronaphthalene	0.000		0	N.D. d	
4] Acenaphthylene	15.426	152	219	0.38 ppb	# 80
5] Acenaphthene	15.873	153	84	0.23 ppb	# 74
6) 1-Aminonaphthalene	0.000		0	N.D. d	
7) 2-Aminonaphthalene	0.000		0	N.D. d	
8) Fluorene	0.000		0	N.D. d	
9) Phenanthrene	0.000		0	N.D. d	
10) Anthracene	0.000		0	N.D. d	
11) Fluoranthene	0.000		0	N.D. d	
12) Pyrene	0.000		0	N.D. d	
13) Benzo(a)anthracene	0.000		0	N.D. d	
14) Chrysene	0.000		0	N.D. d	
15) Benzo(b)fluoranthene	0.000		0	N.D. d	
16) Benzo(k)fluoranthene	0.000		0	N.D. d	
17) Benzo(a)pyrene	0.000		0	N.D. d	
18) Indeno(1,2,3-cd)pyrene	0.000		0	N.D. d	
19) Dibenzo(a,h)anthracene	0.000		0	N.D. d	
20) Benzo(g,h,i)perylene	0.000		0	N.D. d	

(#) = qualifier out of range (m) = manual integration (+) = signals summed

File :C:\msdchem\1\data\2015\February\PAH_R SK\JE15 06127 002.D
Operator : Mohammed Haneesh
Acquired : 18 Feb 2015 15:01 using AcqMethod PAH_30M X 250 X 250_FEB.M
Instrument : GC MS
Sample Name: JE15 06127
Misc Info :
Vial Number: 145



Quantitation Report (QT Reviewed)

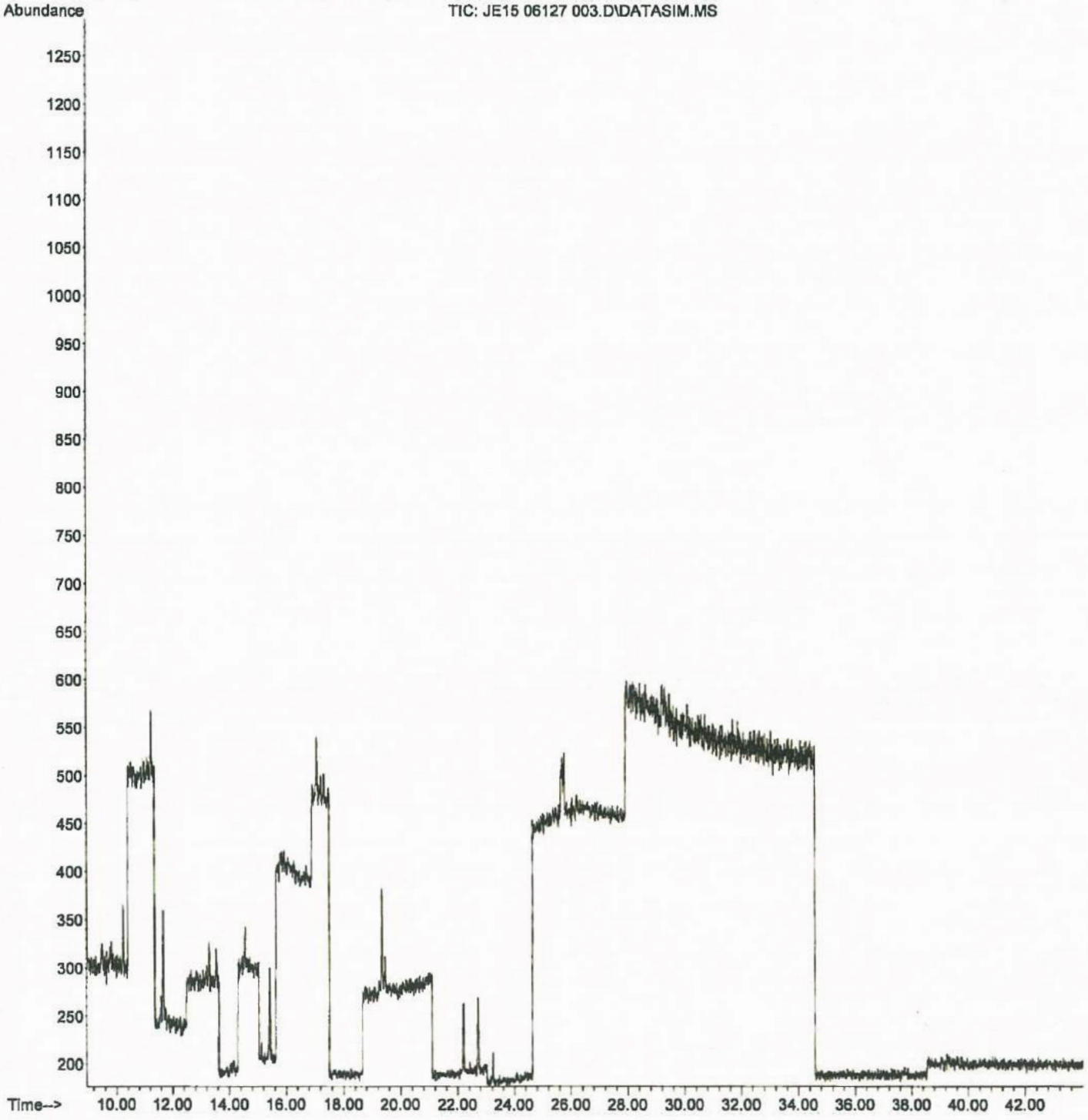
Data Path : C:\msdchem\1\data\2015\February\PAH_R SK\
Data File : JE15 06127 002.D
Acq On : 18 Feb 2015 15:01
Operator : Mohammed Haneesh
Sample : JE15 06127
Misc :
ALS Vial : 145 Sample Multiplier: 1

Quant Time: Feb 22 09:04:12 2015
Quant Method : C:\msdchem\1\methods\PAH_30M X 250 X 250_FEB.M
Quant Title : PAH CAL 30 X 250 X 250 COLUMN
QLast Update : Sat Feb 21 19:24:09 2015
Response via : Initial Calibration

Compound	R.T.	QIon	Response	Conc Units	Dev(Min)
Target Compounds					Qvalue
1] Naphthalene	11.671	128	230	0.58 ppb	# 85
2) 2-Chloronaphthalene	0.000		0	N.D. d	
3) 1-Chloronaphthalene	0.000		0	N.D. d	
4] Acenaphthylene	15.420	152	172	0.30 ppb	# 76
5) Acenaphthene	0.000		0	N.D.	
6) 1-Aminonaphthalene	0.000		0	N.D. d	
7) 2-Aminonaphthalene	0.000		0	N.D. d	
8) Fluorene	0.000		0	N.D. d	
9) Phenanthrene	0.000		0	N.D. d	
10) Anthracene	0.000		0	N.D. d	
11) Fluoranthene	0.000		0	N.D. d	
12) Pyrene	0.000		0	N.D. d	
13) Benzo(a)anthracene	0.000		0	N.D. d	
14) Chrysene	0.000		0	N.D. d	
15) Benzo(b)fluoranthene	0.000		0	N.D. d	
16) Benzo(k)fluoranthene	0.000		0	N.D. d	
17) Benzo(a)pyrene	0.000		0	N.D. d	
18) Indeno(1,2,3-cd)pyrene	0.000		0	N.D. d	
19) Dibenzo(a,h)anthracene	0.000		0	N.D. d	
20) Benzo(g,h,i)perylene	0.000		0	N.D. d	

(#) = qualifier out of range (m) = manual integration (+) = signals summed

File :C:\msdchem\1\data\2015\February\PAH_R SK\JE15 06127 003.D
Operator : Mohammed Haneesh
Acquired : 18 Feb 2015 15:51 using AcqMethod PAH_30M X 250 X 250_FEB.M
Instrument : GC MS
Sample Name: JE15 06127
Misc Info :
Vial Number: 146



Quantitation Report (QT Reviewed)

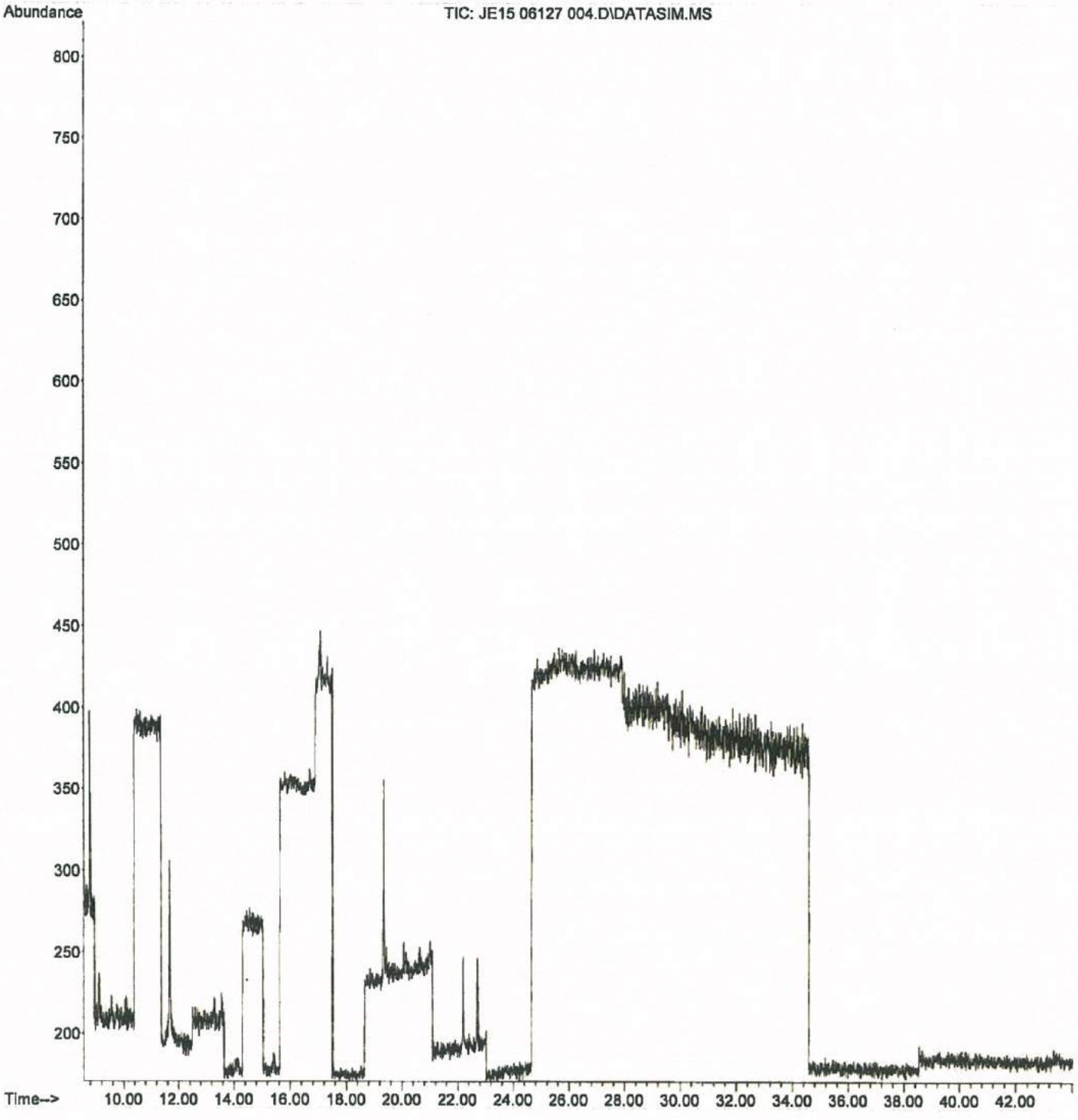
Data Path : C:\msdchem\1\data\2015\February\PAH_R SK\
Data File : JE15 06127 003.D
Acq On : 18 Feb 2015 15:51
Operator : Mohammed Haneesh
Sample : JE15 06127
Misc :
ALS Vial : 146 Sample Multiplier: 1

Quant Time: Feb 22 09:06:44 2015
Quant Method : C:\msdchem\1\methods\PAH_30M X 250 X 250_FEB.M
Quant Title : PAH CAL 30 X 250 X 250 COLUMN
QLast Update : Sat Feb 21 19:24:09 2015
Response via : Initial Calibration

Compound	R.T.	QIon	Response	Conc	Units	Dev(Min)
Target Compounds						Qvalue
1] Naphthalene	11.671	128	210	0.53	ppb	# 72
2) 2-Chloronaphthalene	0.000		0	N.D.		
3) 1-Chloronaphthalene	0.000		0	N.D.		
4) Acenaphthylene	0.000		0	N.D.	d	
5) Acenaphthene	0.000		0	N.D.		
6) 1-Aminonaphthalene	0.000		0	N.D.	d	
7) 2-Aminonaphthalene	0.000		0	N.D.	d	
8) Fluorene	0.000		0	N.D.	d	
9) Phenanthrene	0.000		0	N.D.	d	
10) Anthracene	0.000		0	N.D.	d	
11) Fluoranthene	0.000		0	N.D.	d	
12) Pyrene	0.000		0	N.D.	d	
13) Benzo(a)anthracene	0.000		0	N.D.	d	
14) Chrysene	0.000		0	N.D.	d	
15) Benzo(b)fluoranthene	0.000		0	N.D.	d	
16) Benzo(k)fluoranthene	0.000		0	N.D.	d	
17) Benzo(a)pyrene	0.000		0	N.D.	d	
18) Indeno(1,2,3-cd)pyrene	0.000		0	N.D.	d	
19) Dibenzo(a,h)anthracene	0.000		0	N.D.	d	
20) Benzo(g,h,i)perylene	0.000		0	N.D.	d	

(#) = qualifier out of range (m) = manual integration (+) = signals summed

File :C:\msdchem\1\data\2015\February\JE15 06271\JE15 06127 004.D
Operator : Mohammed Haneesh
Acquired : 22 Feb 2015 2:00 using AcqMethod PAH_30M X 250 X 250_FEB.M
Instrument : GC MS
Sample Name: JE15 06127
Misc Info :
Vial Number: 1



Quantitation Report (QT Reviewed)

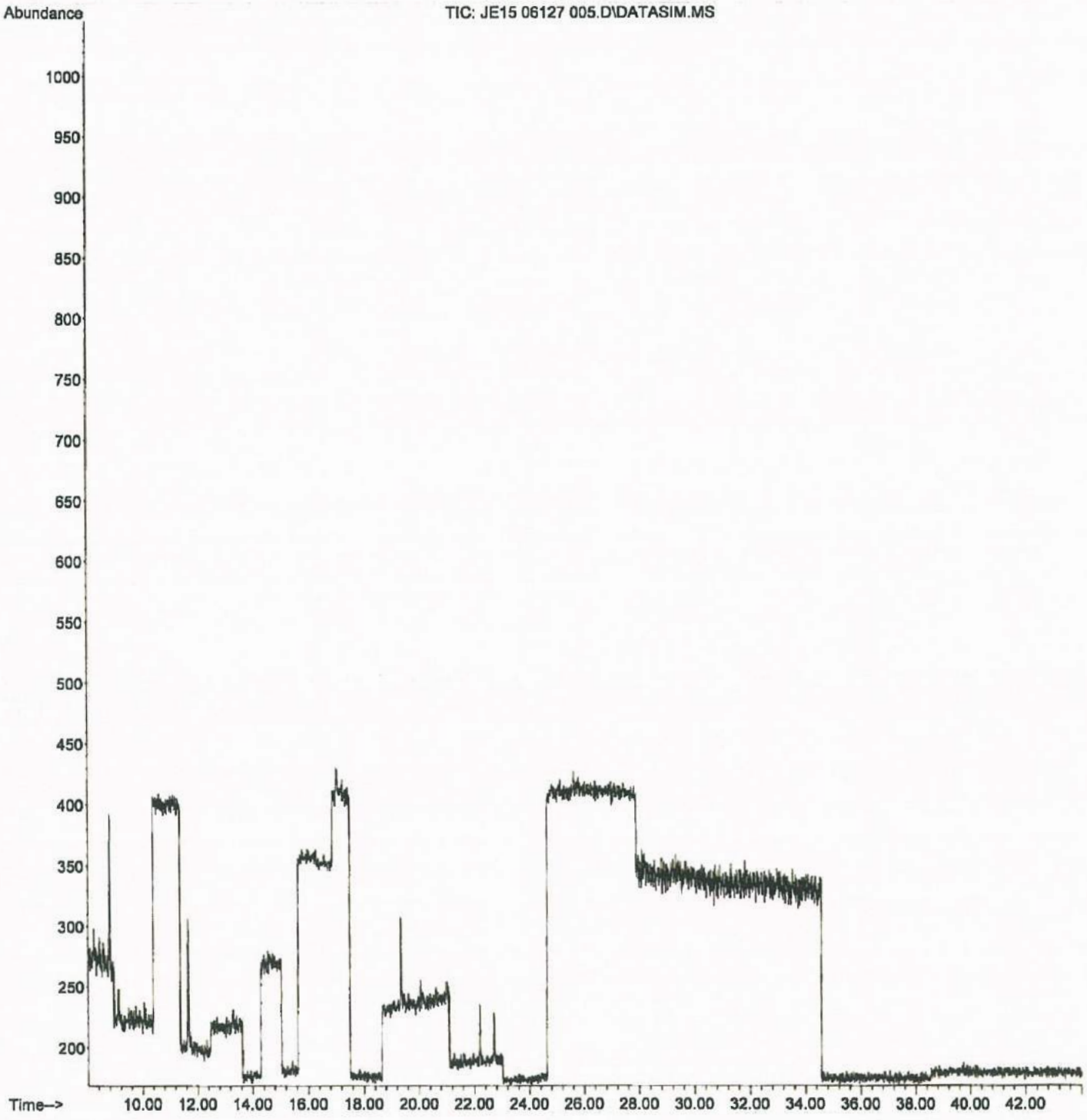
Data Path : C:\msdchem\1\data\2015\February\JE15 06271\
Data File : JE15 06127 004.D
Acq On : 22 Feb 2015 2:00
Operator : Mohammed Haneesh
Sample : JE15 06127
Misc :
ALS Vial : 1 Sample Multiplier: 1

Quant Time: Feb 22 09:10:00 2015
Quant Method : C:\msdchem\1\methods\PAH_30M X 250 X 250_FEB.M
Quant Title : PAH CAL 30 X 250 X 250 COLUMN
QLast Update : Sat Feb 21 19:24:09 2015
Response via : Initial Calibration

Compound	R.T.	QIon	Response	Conc Units	Dev(Min)
Target Compounds					Qvalue
1] Naphthalene	11.671	128	219	0.55 ppb	# 72
2) 2-Chloronaphthalene	0.000		0	N.D. d	
3) 1-Chloronaphthalene	0.000		0	N.D. d	
4) Acenaphthylene	0.000		0	N.D.	
5) Acenaphthene	0.000		0	N.D.	
6) 1-Aminonaphthalene	0.000		0	N.D. d	
7) 2-Aminonaphthalene	0.000		0	N.D. d	
8) Fluorene	0.000		0	N.D.	
9) Phenanthrene	0.000		0	N.D. d	
10) Anthracene	0.000		0	N.D. d	
11) Fluoranthene	0.000		0	N.D. d	
12) Pyrene	0.000		0	N.D. d	
13) Benzo(a)anthracene	0.000		0	N.D. d	
14) Chrysene	0.000		0	N.D. d	
15) Benzo(b)fluoranthene	0.000		0	N.D. d	
16) Benzo(k)fluoranthene	0.000		0	N.D. d	
17) Benzo(a)pyrene	0.000		0	N.D. d	
18) Indeno(1,2,3-cd)pyrene	0.000		0	N.D. d	
19) Dibenzo(a,h)anthracene	0.000		0	N.D. d	
20) Benzo(g,h,i)perylene	0.000		0	N.D. d	

(#) = qualifier out of range (m) = manual integration (+) = signals summed

File :C:\msdchem\1\data\2015\February\JE15 06271\JE15 06127 005.D
Operator : Mohammed Haneesh
Acquired : 22 Feb 2015 2:51 using AcqMethod PAH_30M X 250 X 250_FEB.M
Instrument : GC MS
Sample Name: JE15 06127
Misc Info :
Vial Number: 2



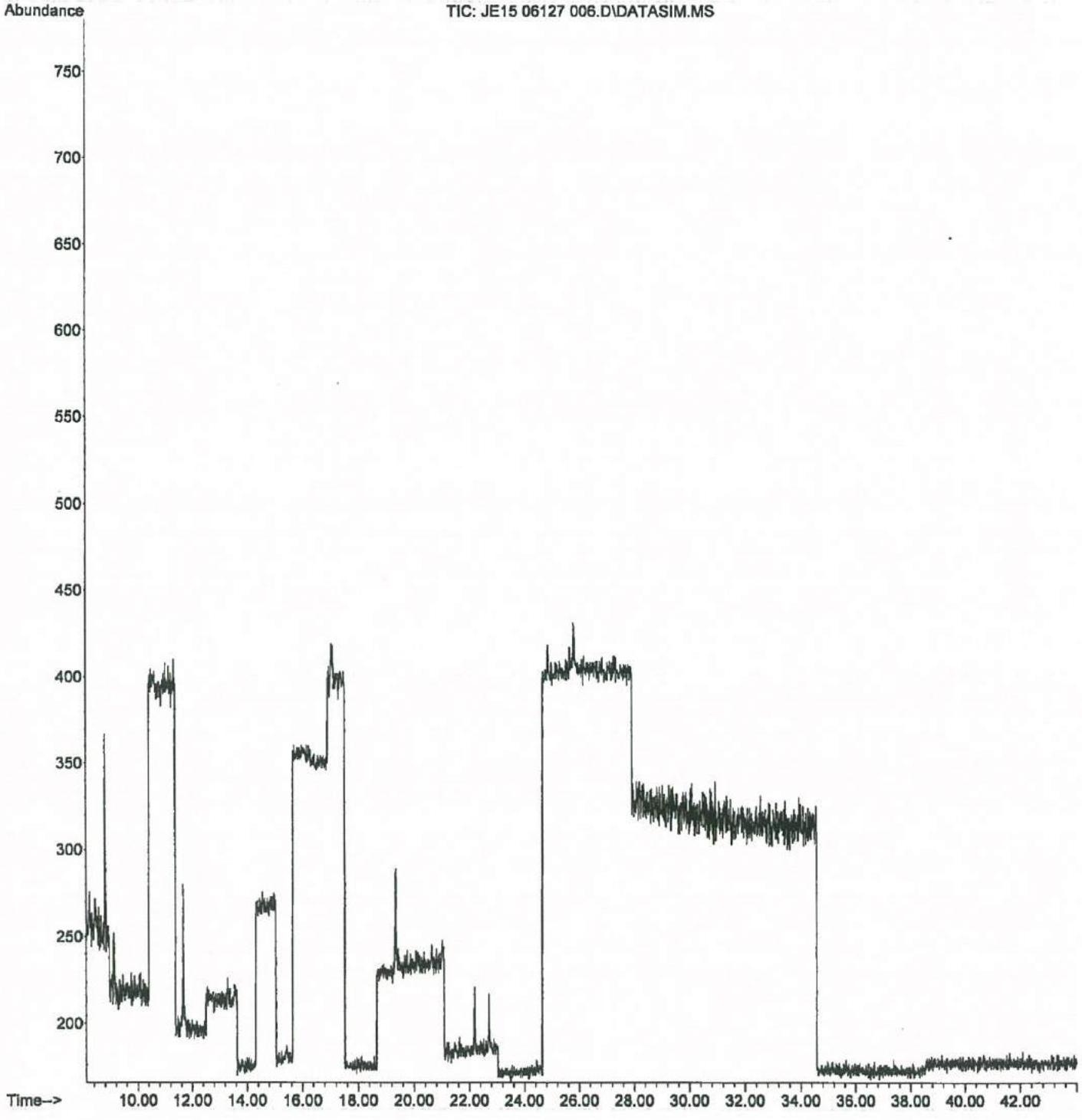
Data Path : C:\msdchem\1\data\2015\February\JE15 06271\
Data File : JE15 06127 005.D
Acq On : 22 Feb 2015 2:51
Operator : Mohammed Haneesh
Sample : JE15 06127
Misc :
ALS Vial : 2 Sample Multiplier: 1

Quant Time: Feb 22 09:11:46 2015
Quant Method : C:\msdchem\1\methods\PAH_30M X 250 X 250_FEB.M
Quant Title : PAH CAL 30 X 250 X 250 COLUMN
QLast Update : Sat Feb 21 19:24:09 2015
Response via : Initial Calibration

Compound	R.T.	QIon	Response	Conc	Units	Dev(Min)
Target Compounds						Qvalue
1] Naphthalene	11.671	128	195	0.49	ppb	# 72
2) 2-Chloronaphthalene	0.000		0	N.D.	d	
3) 1-Chloronaphthalene	0.000		0	N.D.	d	
4) Acenaphthylene	0.000		0	N.D.	d	
5) Acenaphthene	0.000		0	N.D.		
6) 1-Aminonaphthalene	0.000		0	N.D.		
7) 2-Aminonaphthalene	0.000		0	N.D.		
8) Fluorene	0.000		0	N.D.		
9) Phenanthrene	0.000		0	N.D.	d	
10) Anthracene	0.000		0	N.D.	d	
11) Fluoranthene	0.000		0	N.D.	d	
12) Pyrene	0.000		0	N.D.	d	
13) Benzo(a)anthracene	0.000		0	N.D.	d	
14) Chrysene	0.000		0	N.D.	d	
15) Benzo(b)fluoranthene	0.000		0	N.D.	d	
16) Benzo(k)fluoranthene	0.000		0	N.D.	d	
17) Benzo(a)pyrene	0.000		0	N.D.	d	
18) Indeno(1,2,3-cd)pyrene	0.000		0	N.D.	d	
19) Dibenzo(a,h)anthracene	0.000		0	N.D.		
20) Benzo(g,h,i)perylene	0.000		0	N.D.	d	

(#) = qualifier out of range (m) = manual integration (+) = signals summed

File :C:\msdchem\1\data\2015\February\JE15 06271\JE15 06127 006.D
Operator : Mohammed Haneesh
Acquired : 22 Feb 2015 3:41 using AcqMethod PAH_30M X 250 X 250_FEB.M
Instrument : GC MS
Sample Name: JE15 06127
Misc Info :
Vial Number: 3



Quantitation Report (QT Reviewed)

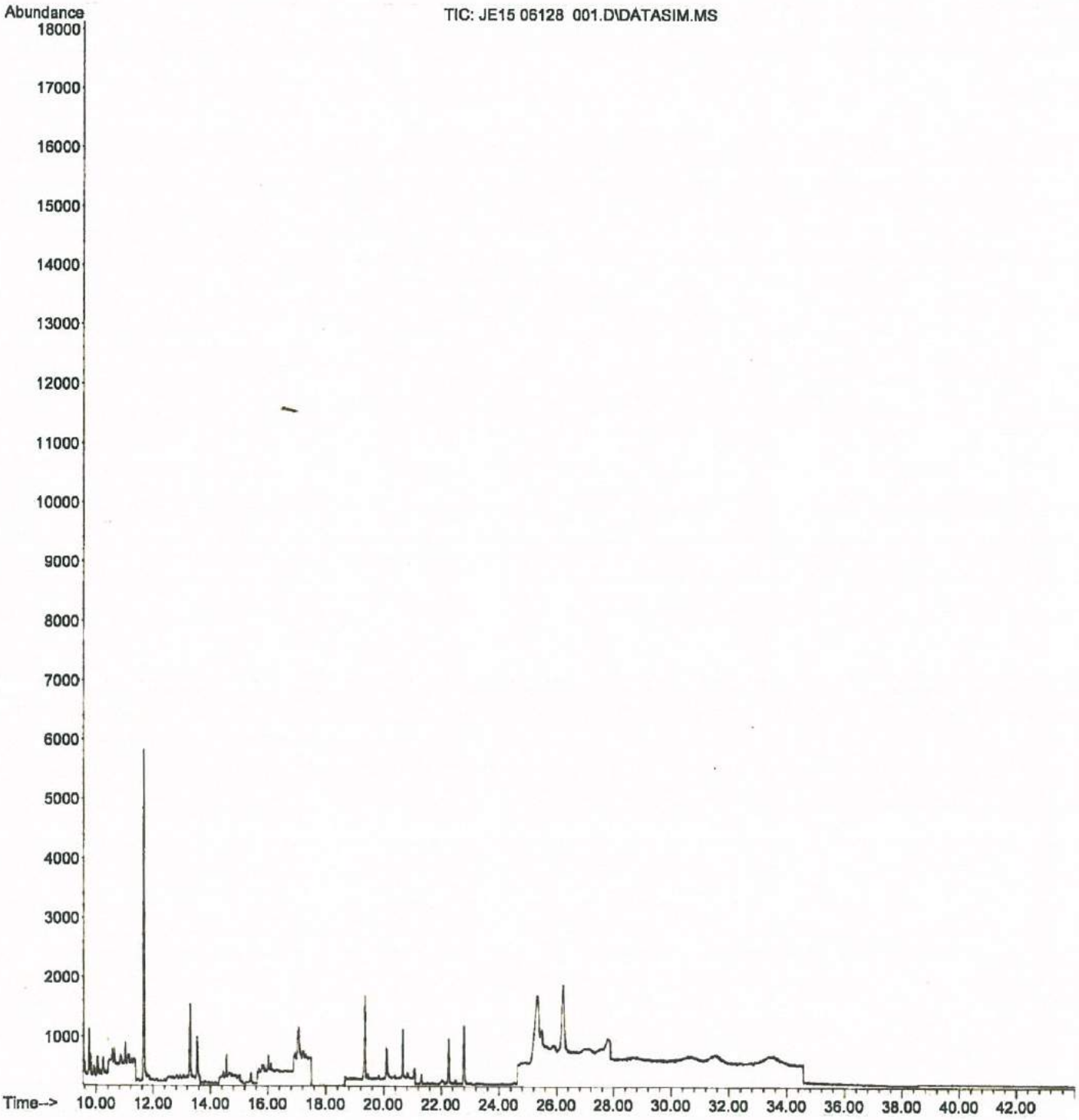
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Data File : JE15 06127 006.D
Acq On : 22 Feb 2015 3:41
Operator : Mohammed Haneesh
Sample : JE15 06127
Misc :
ALS Vial : 3 Sample Multiplier: 1

Quant Time: Feb 22 09:14:32 2015
Quant Method : C:\msdchem\1\methods\PAH_30M X 250 X 250_FEB.M
Quant Title : PAH CAL 30 X 250 X 250 COLUMN
QLast Update : Sat Feb 21 19:24:09 2015
Response via : Initial Calibration

Compound	R.T.	QIon	Response	Conc Units	Dev(Min)
Target Compounds					Qvalue
1] Naphthalene	11.669	128	152	0.38 ppb	# 72
2) 2-Chloronaphthalene	0.000		0	N.D. d	
3) 1-Chloronaphthalene	0.000		0	N.D. d	
4) Acenaphthylene	0.000		0	N.D.	
5) Acenaphthene	0.000		0	N.D.	
6) 1-Aminonaphthalene	0.000		0	N.D. d	
7) 2-Aminonaphthalene	0.000		0	N.D. d	
8) Fluorene	0.000		0	N.D.	
9) Phenanthrene	0.000		0	N.D. d	
10) Anthracene	0.000		0	N.D. d	
11) Fluoranthene	0.000		0	N.D. d	
12) Pyrene	0.000		0	N.D. d	
13) Benzo(a)anthracene	0.000		0	N.D. d	
14) Chrysene	0.000		0	N.D. d	
15) Benzo(b)fluoranthene	0.000		0	N.D. d	
16) Benzo(k)fluoranthene	0.000		0	N.D. d	
17) Benzo(a)pyrene	0.000		0	N.D. d	
18) Indeno(1,2,3-cd)pyrene	0.000		0	N.D. d	
19) Dibenzo(a,h)anthracene	0.000		0	N.D.	
20) Benzo(g,h,i)perylene	0.000		0	N.D. d	

(#) = qualifier out of range (m) = manual integration (+) = signals summed

File :C:\msdchem\1\data\2015\February\PAH_R SK\JE15 06128 001.D
Operator : Mohammed Haneesh
Acquired : 17 Feb 2015 20:18 using AcqMethod 8270_30M X 250 X 250.M
Instrument : GC MS
Sample Name: JE15 06128
Misc Info :
Vial Number: 112



Quantitation Report (QT Reviewed)

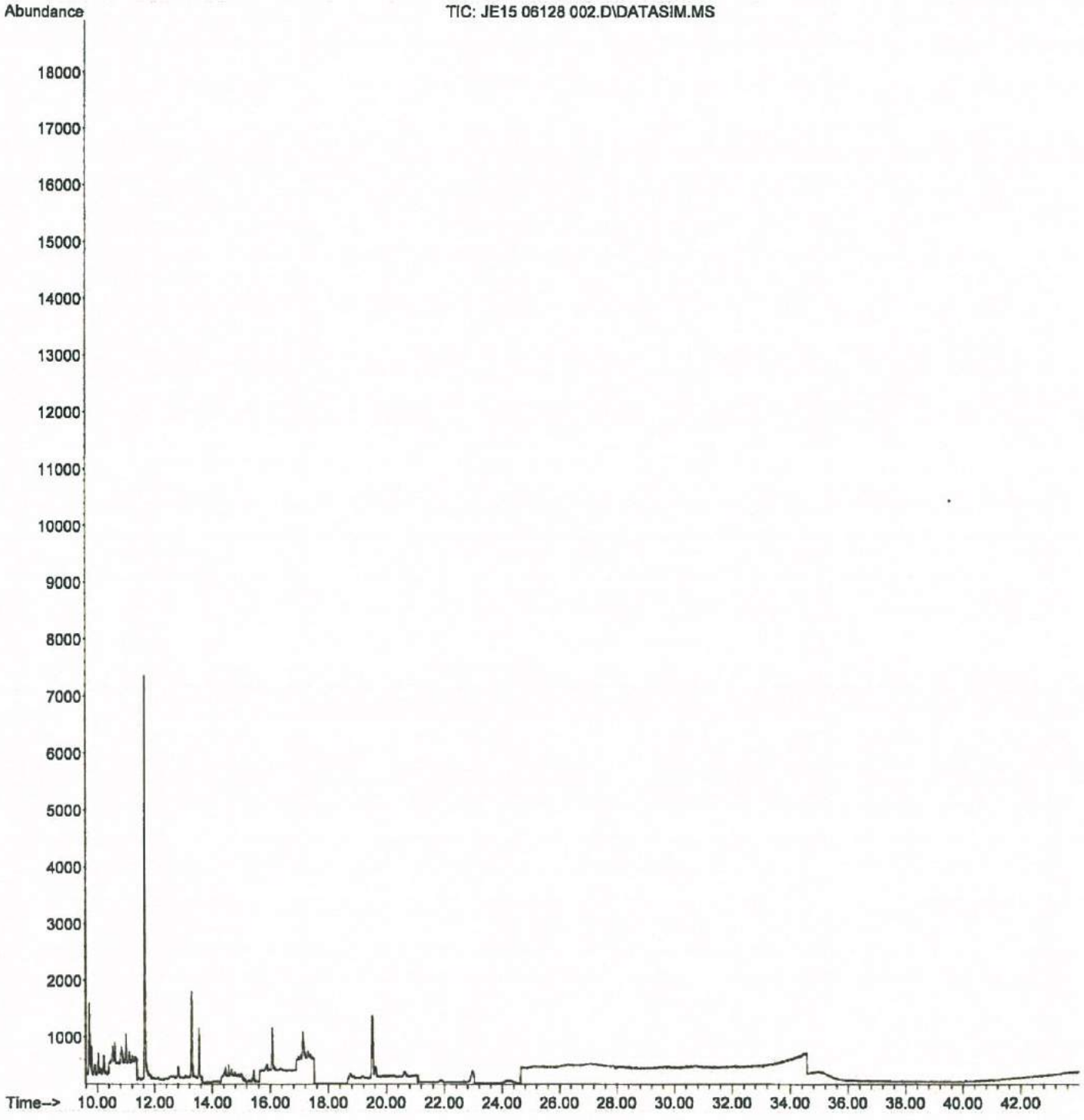
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Data File : JE15 06128 001.D
Acq On : 17 Feb 2015 20:18
Operator : Mohammed Haneesh
Sample : JE15 06128
Misc :
ALS Vial : 112 Sample Multiplier: 1

Quant Time: Feb 21 19:27:14 2015
Quant Method : C:\msdchem\1\methods\PAH_30M X 250 X 250_FEB.M
Quant Title : PAH CAL 30 X 250 X 250 COLUMN
QLast Update : Sat Feb 21 19:24:09 2015
Response via : Initial Calibration

Compound	R.T.	QIon	Response	Conc Units		Dev(Min)
Target Compounds						Qvalue
1] Naphthalene	11.669	128	8389	21.01 ppb		100
2) 2-Chloronaphthalene	0.000		0	N.D. d		
3) 1-Chloronaphthalene	0.000		0	N.D. d		
4] Acenaphthylene	15.419	152	286	0.49 ppb	#	79
5) Acenaphthene	0.000		0	N.D. d		
6) 1-Aminonaphthalene	0.000		0	N.D. d		
7) 2-Aminonaphthalene	0.000		0	N.D. d		
8) Fluorene	0.000		0	N.D. d		
9] Phenanthrene	19.346	178	1861	4.47 ppb		96
10] Anthracene	19.453	178	87	0.22 ppb	#	25
11] Fluoranthene	22.257	202	1109	2.65 ppb		97
12] Pyrene	22.790	202	1415	3.51 ppb		97
13) Benzo(a)anthracene	0.000		0	N.D. d		
14) Chrysene	0.000		0	N.D. d		
15) Benzo(b)fluoranthene	0.000		0	N.D. d		
16) Benzo(k)fluoranthene	0.000		0	N.D. d		
17) Benzo(a)pyrene	0.000		0	N.D. d		
18) Indeno(1,2,3-cd)pyrene	0.000		0	N.D. d		
19) Dibenzo(a,h)anthracene	0.000		0	N.D. d		
20) Benzo(g,h,i)perylene	0.000		0	N.D. d		

(#) = qualifier out of range (m) = manual integration (+) = signals summed

File :C:\msdchem\1\data\2015\February\PAH_R SK\JE15 06128 002.D
Operator : Mohammed Haneesh
Acquired : 17 Feb 2015 21:09 using AcqMethod 8270_30M X 250 X 250.M
Instrument : GC MS
Sample Name: JE15 06128
Misc Info :
Vial Number: 113



Quantitation Report (QT Reviewed)

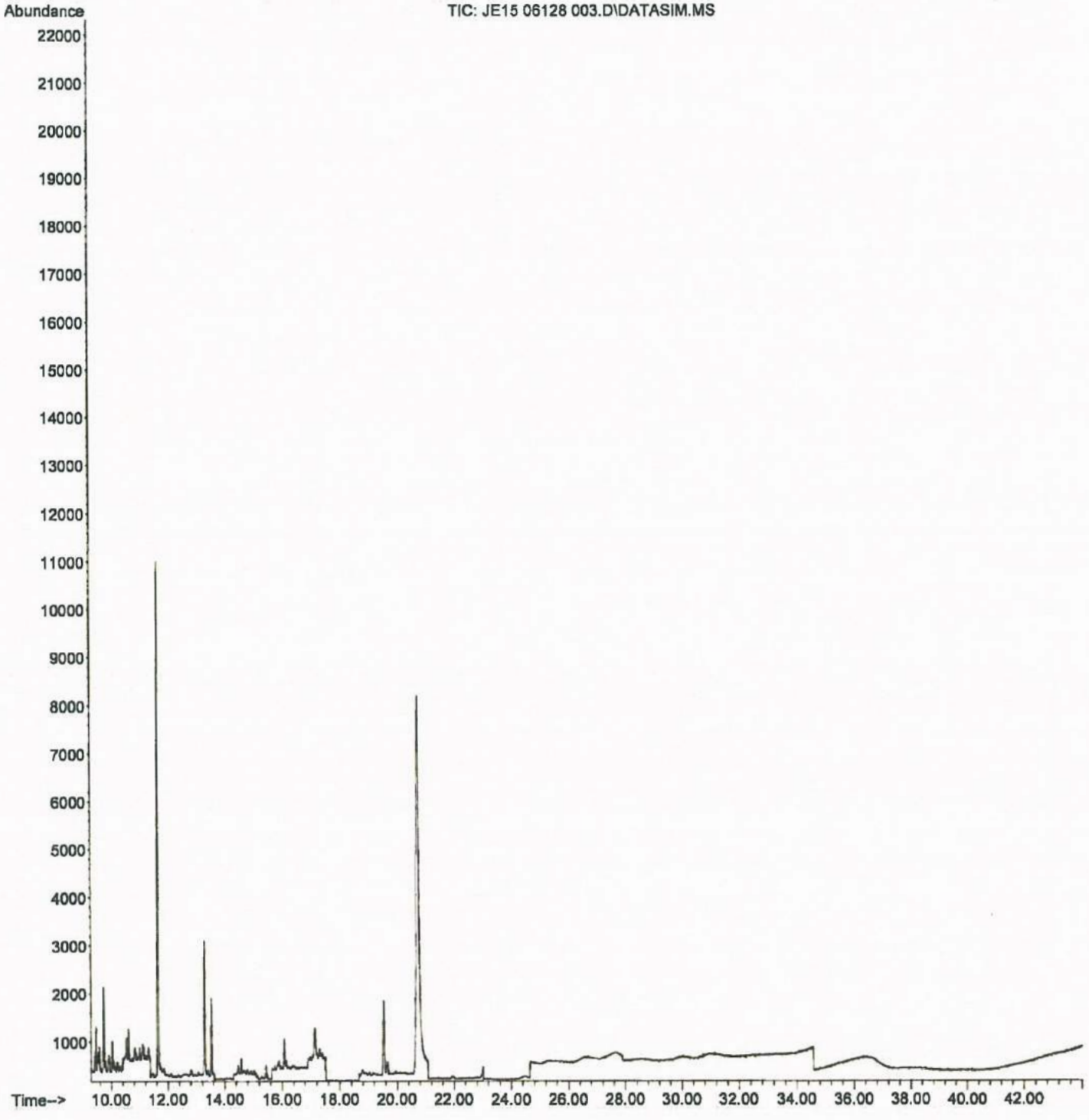
Data Path : C:\msdchem\1\data\2015\February\PAH_R SK\
Data File : JE15 06128 002.D
Acq On : 17 Feb 2015 21:09
Operator : Mohammed Haneesh
Sample : JE15 06128
Misc :
ALS Vial : 113 Sample Multiplier: 1

Quant Time: Feb 21 19:31:09 2015
Quant Method : C:\msdchem\1\methods\PAH_30M X 250 X 250_FEB.M
Quant Title : PAH CAL 30 X 250 X 250 COLUMN
QLast Update : Sat Feb 21 19:24:09 2015
Response via : Initial Calibration

Compound	R.T.	QIon	Response	Conc Units		Dev(Min)
Target Compounds						Qvalue
1] Naphthalene	11.649	128	10596	26.54 ppb		99
2) 2-Chloronaphthalene	0.000		0	N.D.		
3) 1-Chloronaphthalene	0.000		0	N.D. d		
4] Acenaphthylene	15.428	152	258	0.44 ppb	#	70
5] Acenaphthene	15.885	153	56	0.15 ppb	#	20
6) 1-Aminonaphthalene	0.000		0	N.D.		
7) 2-Aminonaphthalene	0.000		0	N.D.		
8] Fluorene	17.119	166	363	0.85 ppb	#	87
9] Phenanthrene	19.516	178	1890	4.54 ppb		98
10] Anthracene	19.516	178	1890	4.72 ppb	#	96
11] Fluoranthene	22.244	202	7	0.02 ppb	#	8
12] Pyrene	22.965	202	1185	2.94 ppb	#	59
13] Benzo(a)anthracene	25.653	228	5	0.02 ppb	#	1
14] Chrysene	25.728	228	5	0.01 ppb	#	1
15] Benzo(b)fluoranthene	29.205	252	6	0.04 ppb	#	21
16] Benzo(k)fluoranthene	29.321	252	13	0.08 ppb	#	1
17] Benzo(a)pyrene	30.521	252	5	0.04 ppb	#	1
18] Indeno(1,2,3-cd)pyrene	37.422	276	4	0.07 ppb	#	56
19] Dibenzo(a,h)anthracene	37.516	278	6	0.10 ppb	#	1
20] Benzo(g,h,i)perylene	39.318	276	9	0.14 ppb	#	1

(#) = qualifier out of range (m) = manual integration (+) = signals summed

File :C:\msdchem\1\data\2015\February\PAH_R SK\JE15 06128 003.D
Operator : Mohammed Haneesh
Acquired : 17 Feb 2015 21:59 using AcqMethod 8270_30M X 250 X 250.M
Instrument : GC MS
Sample Name: JE15 06128
Misc Info :
Vial Number: 114



Quantitation Report (QT Reviewed)

Data Path : C:\msdchem\1\data\2015\February\PAH_R SK\
Data File : JE15 06128 003.D
Acq On : 17 Feb 2015 21:59
Operator : Mohammed Haneesh
Sample : JE15 06128
Misc :
ALS Vial : 114 Sample Multiplier: 1

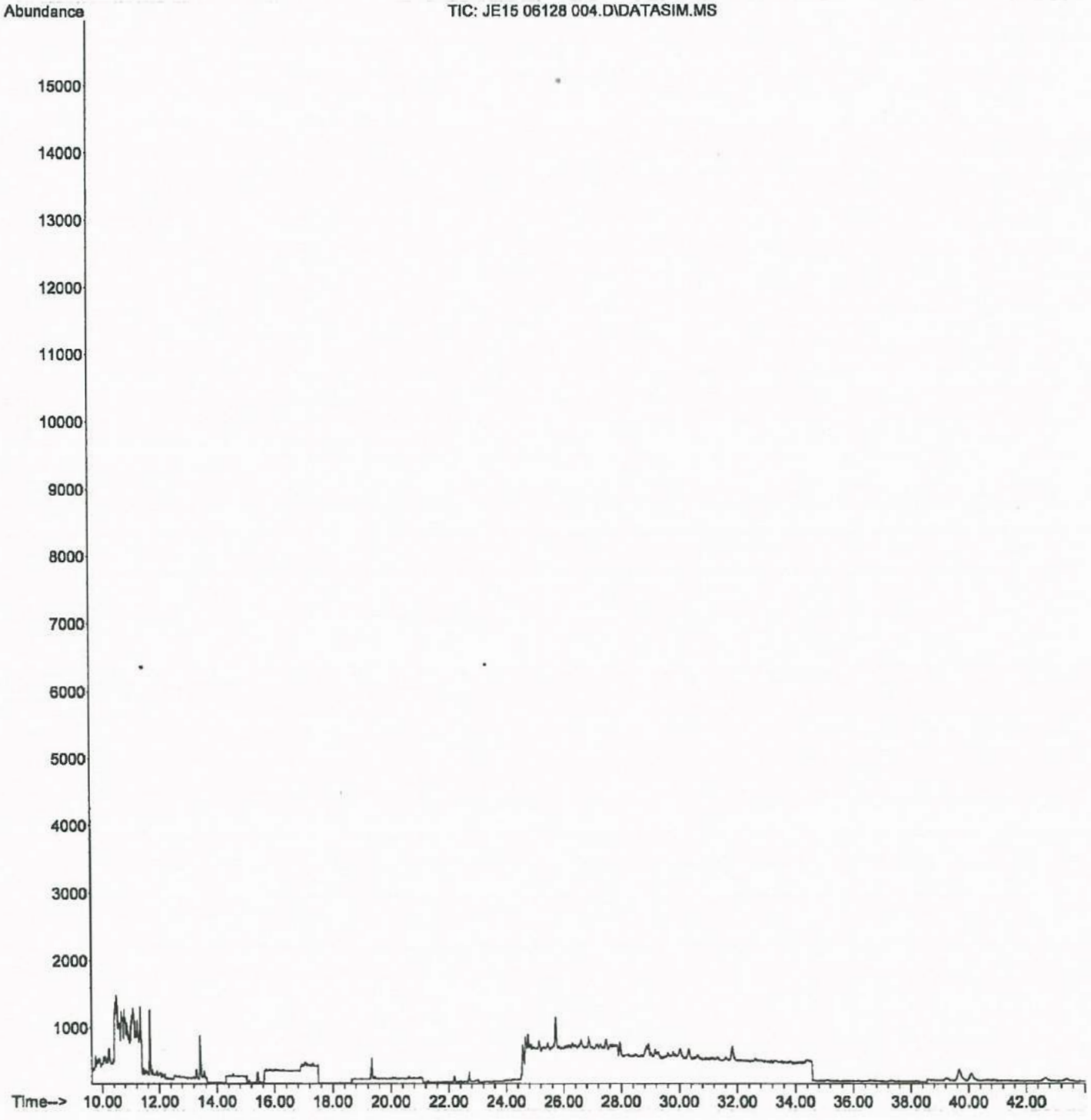
Quant Time: Feb 21 19:39:32 2015
Quant Method : C:\msdchem\1\methods\PAH_30M X 250 X 250_FEB.M
Quant Title : PAH CAL 30 X 250 X 250 COLUMN
QLast Update : Sat Feb 21 19:24:09 2015
Response via : Initial Calibration

Compound	R.T.	QIon	Response	Conc Units		Dev(Min)
Target Compounds						Qvalue
1] Naphthalene	11.655	128	16330	40.90 ppb		99
2) 2-Chloronaphthalene	0.000		0	N.D. d		
3) 1-Chloronaphthalene	0.000		0	N.D. d		
4] Acenaphthylene	15.433	152	366	0.63 ppb		97
5] Acenaphthene	15.890	153	111	0.30 ppb	#	46
6) 1-Aminonaphthalene	0.000		0	N.D. d		
7) 2-Aminonaphthalene	0.000		0	N.D. d		
8] Fluorene	17.133	166	519	1.22 ppb	#	79
9] Phenanthrene	19.545	178	2914	6.99 ppb		98
10] Anthracene	19.545	178	2914	7.28 ppb		98
11) Fluoranthene	0.000		0	N.D. d		
12] Pyrene	23.013	202	681	1.69 ppb	#	59
13) Benzo(a)anthracene	0.000		0	N.D. d		
14) Chrysene	0.000		0	N.D. d		
15) Benzo(b)fluoranthene	0.000		0	N.D. d		
16) Benzo(k)fluoranthene	0.000		0	N.D. d		
17) Benzo(a)pyrene	0.000		0	N.D. d		
18) Indeno(1,2,3-cd)pyrene	0.000		0	N.D. d		
19) Dibenzo(a,h)anthracene	0.000		0	N.D.		
20) Benzo(g,h,i)perylene	0.000		0	N.D. d		

(#) = qualifier out of range (m) = manual integration (+) = signals summed

H_30M X 250 X 250_FEB.M Sat Feb 21 19:39:54 2015

File :C:\msdchem\1\data\2015\February\JE15 06271\JE15 06128 004.D
Operator : Mohammed Haneesh
Acquired : 22 Feb 2015 4:32 using AcqMethod PAH_30M X 250 X 250_FEB.M
Instrument : GC MS
Sample Name: JE15 06128
Misc Info :
Vial Number: 4



Quantitation Report (QT Reviewed)

Data Path : C:\msdchem\1\data\2015\February\JE15 06271\
Data File : JE15 06128 004.D
Acq On : 22 Feb 2015 4:32
Operator : Mohammed Haneesh
Sample : JE15 06128
Misc :
ALS Vial : 4 Sample Multiplier: 1

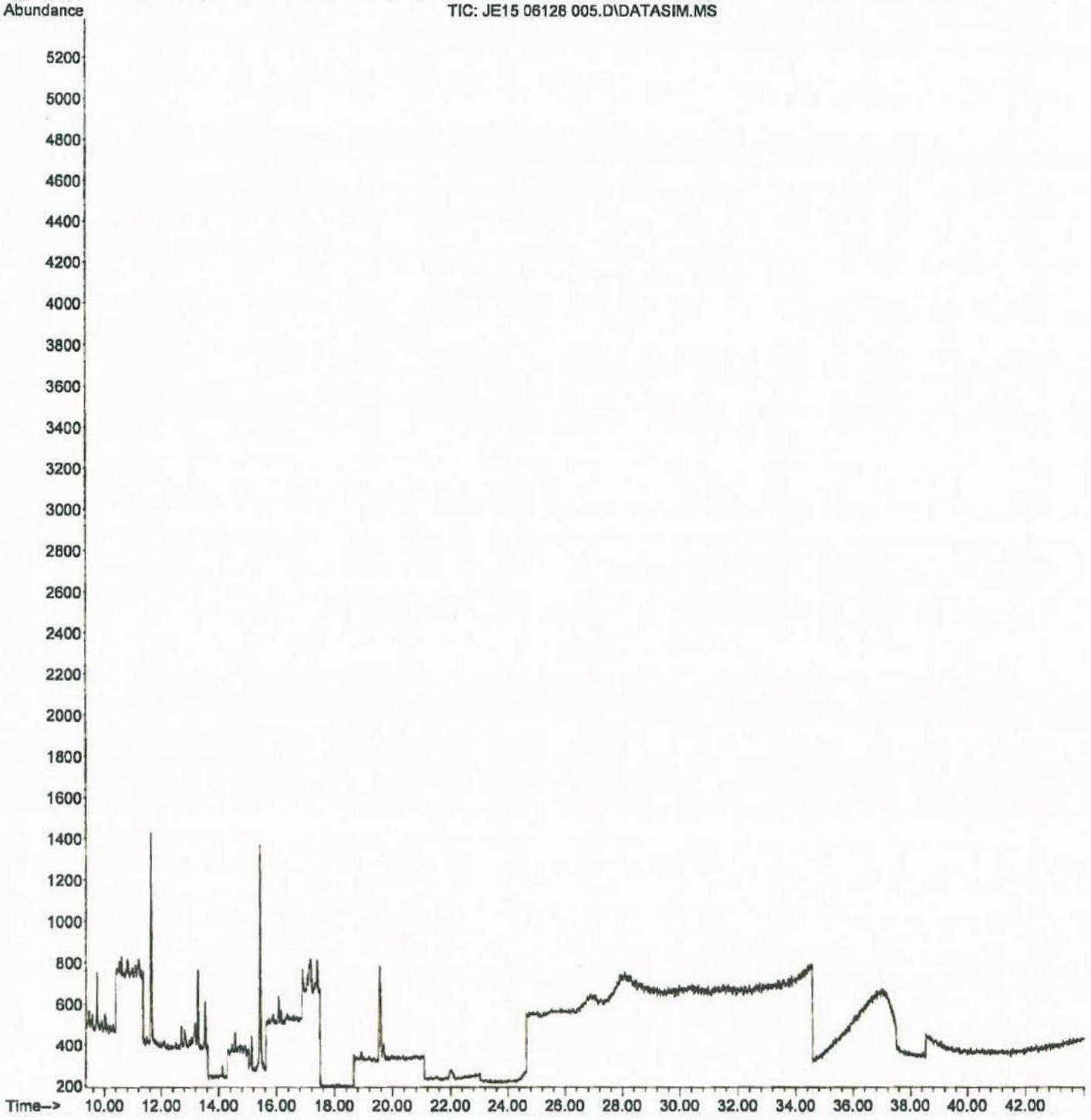
Quant Time: Feb 22 08:40:51 2015
Quant Method : C:\msdchem\1\methods\PAH_30M X 250 X 250_FEB.M
Quant Title : PAH CAL 30 X 250 X 250 COLUMN
QLast Update : Sat Feb 21 19:24:09 2015
Response via : Initial Calibration

Compound	R.T.	QIon	Response	Conc Units		Dev(Min)
Target Compounds						Qvalue
1] Naphthalene	11.671	128	1432	3.59 ppb	#	90
2) 2-Chloronaphthalene	0.000		0	N.D.		
3) 1-Chloronaphthalene	0.000		0	N.D.		
4] Acenaphthylene	15.420	152	229	0.39 ppb	#	89
5) Acenaphthene	0.000		0	N.D.		
6) 1-Aminonaphthalene	0.000		0	N.D.		
7) 2-Aminonaphthalene	0.000		0	N.D.		
8) Fluorene	0.000		0	N.D. d		
9] Phenanthrene	19.333	178	420	1.01 ppb		98
10] Anthracene	19.440	178	58	0.14 ppb	#	71
11) Fluoranthene	0.000		0	N.D. d		
12] Pyrene	22.705	202	196	0.49 ppb	#	74
13] Benzo(a)anthracene	25.653	228	82	0.29 ppb	#	43
14] Chrysene	25.728	228	736	2.08 ppb	#	94
15) Benzo(b)fluoranthene	0.000		0	N.D. d		
16) Benzo(k)fluoranthene	0.000		0	N.D. d		
17) Benzo(a)pyrene	0.000		0	N.D. d		
18) Indeno(1,2,3-cd)pyrene	0.000		0	N.D. d		
19) Dibenzo(a,h)anthracene	0.000		0	N.D.		
20) Benzo(g,h,i)perylene	0.000		0	N.D. d		

(#) = qualifier out of range (m) = manual integration (+) = signals summed

H_30M X 250 X 250_FEB.M Sun Feb 22 08:41:49 2015

File :C:\msdchem\1\data\2015\February\PAH_R SK\JE15 06128 005.D
Operator : Mohammed Haneesh
Acquired : 17 Feb 2015 23:40 using AcqMethod 8270_30M X 250 X 250.M
Instrument : GC MS
Sample Name: JE15 06128
Misc Info :
Vial Number: 116



Quantitation Report (QT Reviewed)

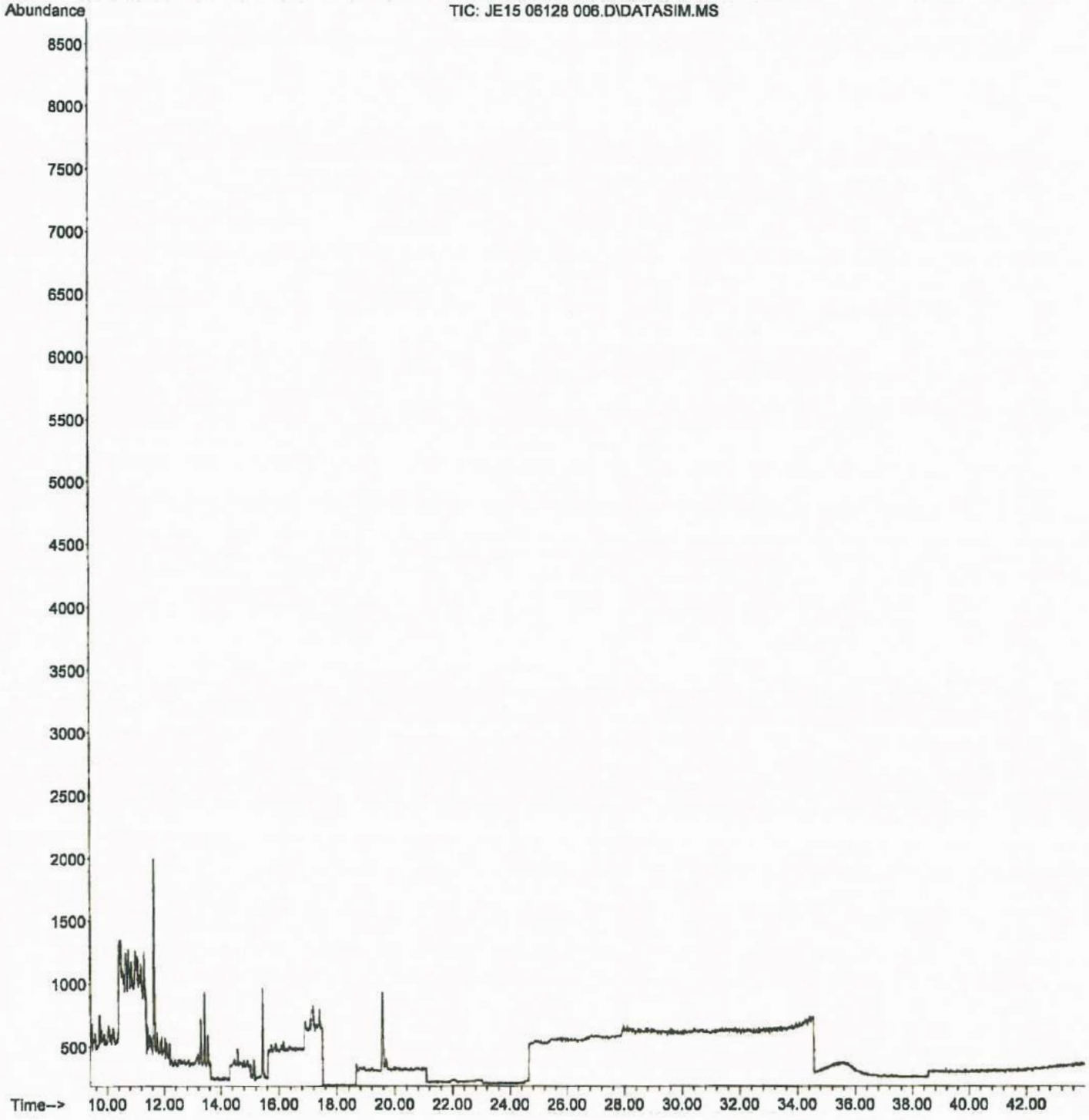
Data Path : C:\msdchem\1\data\2015\February\PAH_R SK\
Data File : JE15 06128 005.D
Acq On : 17 Feb 2015 23:40
Operator : Mohammed Haneesh
Sample : JE15 06128
Misc :
ALS Vial : 116 Sample Multiplier: 1

Quant Time: Feb 21 19:49:08 2015
Quant Method : C:\msdchem\1\methods\PAH_30M X 250 X 250_FEB.M
Quant Title : PAH CAL 30 X 250 X 250 COLUMN
QLast Update : Wed Feb 18 13:08:40 2015
Response via : Initial Calibration

Compound	R.T.	QIon	Response	Conc Units		Dev(Min)
Target Compounds						Qvalue
1] Naphthalene	11.655	128	1568	3.93 ppb	#	97
2] 2-Chloronaphthalene	14.343	162	140	0.34 ppb	#	1
3] 1-Chloronaphthalene	14.343	162	140	0.43 ppb	#	1
4] Acenaphthylene	15.440	152	1733	2.99 ppb		97
5) Acenaphthene	0.000		0	N.D.		
6) 1-Aminonaphthalene	0.000		0	N.D.		
7) 2-Aminonaphthalene	0.000		0	N.D.		
8] Fluorene	17.080	166	64	0.15 ppb	#	67
9) Phenanthrene	0.000		0	N.D. d		
10) Anthracene	0.000		0	N.D. d		
11) Fluoranthene	0.000		0	N.D. d		
12) Pyrene	0.000		0	N.D.		
13) Benzo(a)anthracene	0.000		0	N.D. d		
14) Chrysene	0.000		0	N.D. d		
15) Benzo(b)fluoranthene	0.000		0	N.D. d		
16) Benzo(k)fluoranthene	0.000		0	N.D. d		
17) Benzo(a)pyrene	0.000		0	N.D. d		
18) Indeno(1,2,3-cd)pyrene	0.000		0	N.D. d		
19) Dibenzo(a,h)anthracene	0.000		0	N.D. d		
20) Benzo(g,h,i)perylene	0.000		0	N.D. d		

(#) = qualifier out of range (m) = manual integration (+) = signals summed

File :C:\msdchem\1\data\2015\February\PAH_R SK\JE15 06128 006.D
Operator : Mohammed Haneesh
Acquired : 18 Feb 2015 00:31 using AcqMethod 8270_30M X 250 X 250.M
Instrument : GC MS
Sample Name: JE15 06128
Misc Info :
Vial Number: 117



Quantitation Report (QT Reviewed)

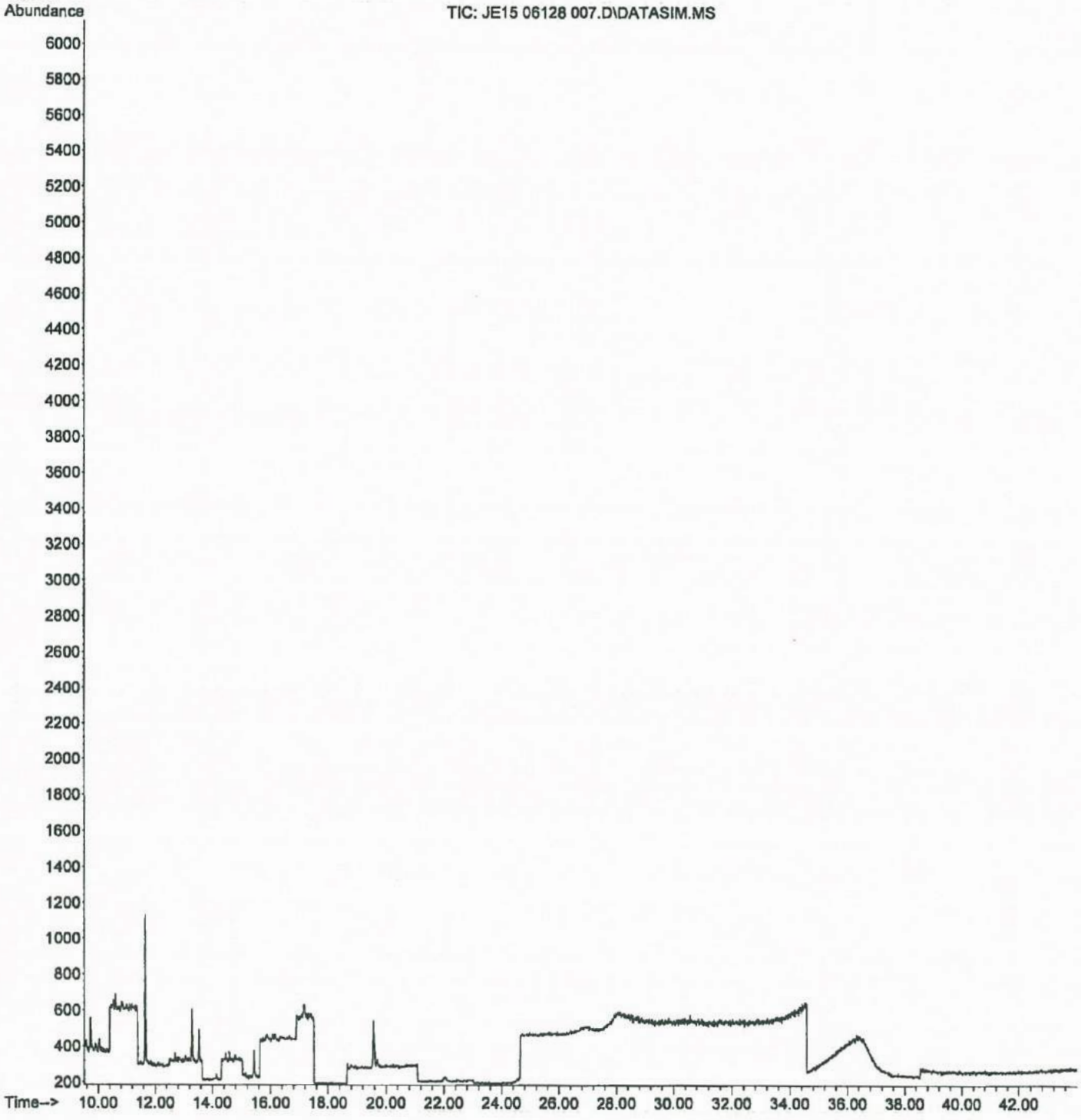
Data Path : C:\msdchem\1\data\2015\February\PAH_R SK\
Data File : JE15 06128 006.D
Acq On : 18 Feb 2015 00:31
Operator : Mohammed Haneesh
Sample : JE15 06128
Misc :
ALS Vial : 117 Sample Multiplier: 1

Quant Time: Feb 21 19:52:07 2015
Quant Method : C:\msdchem\1\methods\PAH_30M X 250 X 250_FEB.M
Quant Title : PAH CAL 30 X 250 X 250 COLUMN
QLast Update : Sat Feb 21 19:24:09 2015
Response via : Initial Calibration

Compound	R.T.	QIon	Response	Conc Units	Dev(Min)
Target Compounds					Qvalue
1] Naphthalene	11.649	128	2359	5.91 ppb #	94
2) 2-Chloronaphthalene	0.000		0	N.D. d	
3) 1-Chloronaphthalene	0.000		0	N.D. d	
4] Acenaphthylene	15.435	152	1066	1.84 ppb #	97
5) Acenaphthene	0.000		0	N.D.	
6) 1-Aminonaphthalene	0.000		0	N.D. d	
7) 2-Aminonaphthalene	0.000		0	N.D. d	
8) Fluorene	0.000		0	N.D. d	
9) Phenanthrene	0.000		0	N.D. d	
10) Anthracene	0.000		0	N.D. d	
11) Fluoranthene	0.000		0	N.D. d	
12) Pyrene	0.000		0	N.D.	
13) Benzo(a)anthracene	0.000		0	N.D. d	
14) Chrysene	0.000		0	N.D. d	
15) Benzo(b)fluoranthene	0.000		0	N.D. d	
16) Benzo(k)fluoranthene	0.000		0	N.D. d	
17) Benzo(a)pyrene	0.000		0	N.D. d	
18) Indeno(1,2,3-cd)pyrene	0.000		0	N.D. d	
19) Dibenzo(a,h)anthracene	0.000		0	N.D. d	
20) Benzo(g,h,i)perylene	0.000		0	N.D. d	

(#) = qualifier out of range (m) = manual integration (+) = signals summed

File :C:\msdchem\1\data\2015\February\PAH_R SK\JE15 06128 007.D
Operator : Mohammed Haneesh
Acquired : 18 Feb 2015 1:22 using AcqMethod 8270_30M X 250 X 250.M
Instrument : GC MS
Sample Name: JE15 06128
Misc Info :
Vial Number: 118



Quantitation Report (QT Reviewed)

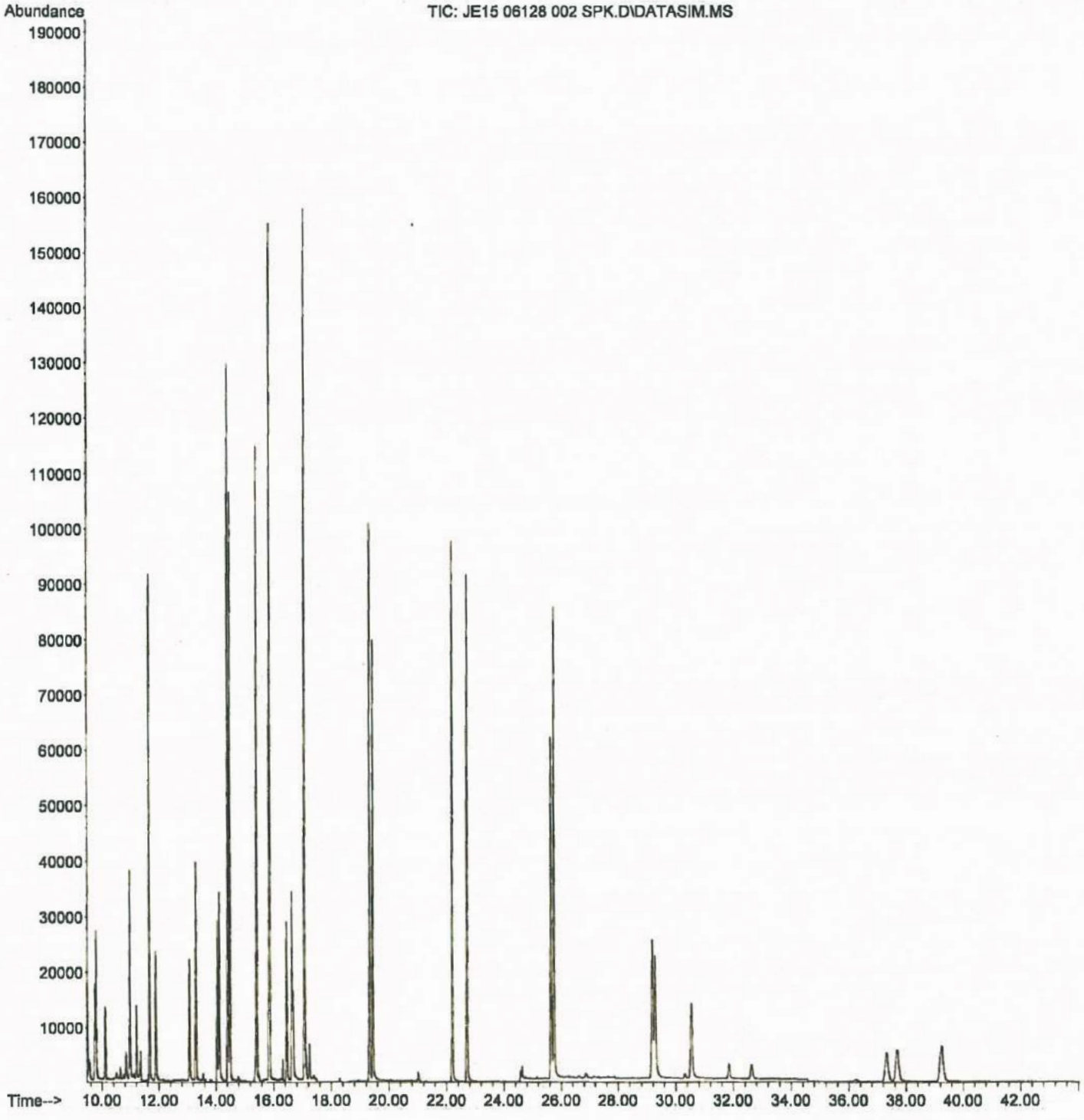
Data Path : C:\msdchem\1\data\2015\February\PAH_R SK\
Data File : JE15 06128 007.D
Acq On : 18 Feb 2015 1:22
Operator : Mohammed Haneesh
Sample : JE15 06128
Misc :
ALS Vial : 118 Sample Multiplier: 1

Quant Time: Feb 21 19:56:38 2015
Quant Method : C:\msdchem\1\methods\PAH_30M X 250 X 250_FEB.M
Quant Title : PAH CAL 30 X 250 X 250 COLUMN
QLast Update : Wed Feb 18 13:08:40 2015
Response via : Initial Calibration

Compound	R.T.	QIon	Response	Conc Units	Dev(Min)
Target Compounds					Qvalue
1] Naphthalene	11.657	128	1267	3.17 ppb	98
2) 2-Chloronaphthalene	0.000		0	N.D. d	
3) 1-Chloronaphthalene	0.000		0	N.D. d	
4] Acenaphthylene	15.435	152	213	0.37 ppb #	79
5) Acenaphthene	0.000		0	N.D.	
6) 1-Aminonaphthalene	0.000		0	N.D. d	
7) 2-Aminonaphthalene	0.000		0	N.D. d	
8) Fluorene	0.000		0	N.D. d	
9) Phenanthrene	0.000		0	N.D. d	
10) Anthracene	0.000		0	N.D. d	
11) Fluoranthene	0.000		0	N.D. d	
12) Pyrene	0.000		0	N.D.	
13) Benzo(a)anthracene	0.000		0	N.D. d	
14) Chrysene	0.000		0	N.D. d	
15) Benzo(b)fluoranthene	0.000		0	N.D. d	
16) Benzo(k)fluoranthene	0.000		0	N.D. d	
17) Benzo(a)pyrene	0.000		0	N.D. d	
18) Indeno(1,2,3-cd)pyrene	0.000		0	N.D. d	
19) Dibenzo(a,h)anthracene	0.000		0	N.D. d	
20) Benzo(g,h,i)perylene	0.000		0	N.D. d	

(#) = qualifier out of range (m) = manual integration (+) = signals summed

File :C:\msdchem\1\data\2015\February\PAH_R SK\JE15 06128 002 SPK.D\
Operator : Mohammed Haneesh
Acquired : 21 Feb 2015 20:04 using AcqMethod PAH_30M X 250 X 250_FEB.M
Instrument : GC MS
Sample Name: SPK
Misc Info :
Vial Number: 149



Quantitation Report (Not Reviewed)

Data Path : C:\msdchem\1\data\2015\February\PAH_R SK\
Data File : JE15 06128 002 SPK.D
Acq On : 21 Feb 2015 20:04
Operator : Mohammed Haneesh
Sample : SPK
Misc :
ALS Vial : 149 Sample Multiplier: 1

Quant Time: Feb 22 08:43:08 2015
Quant Method : C:\msdchem\1\methods\PAH_30M X 250 X 250_FEB.M
Quant Title : PAH CAL 30 X 250 X 250 COLUMN
QLast Update : Sat Feb 21 19:24:09 2015
Response via : Initial Calibration

Compound	R.T.	QIon	Response	Conc	Units		Dev(Min)
Target Compounds							Qvalue
1] Naphthalene	11.671	128	133384	334.08	ppb		99
2] 2-Chloronaphthalene	14.430	162	128137	311.15	ppb		95
3] 1-Chloronaphthalene	14.501	162	103145	314.26	ppb		94
4] Acenaphthylene	15.420	152	159236	274.43	ppb	#	97
5] Acenaphthene	15.867	153	110113	296.78	ppb		96
6] 1-Aminonaphthalene	16.457	143	35002	288.44	ppb	#	92
7] 2-Aminonaphthalene	16.636	143	46777	280.20	ppb	#	93
8] Fluorene	17.074	166	127295	298.71	ppb		97
9] Phenanthrene	19.332	178	128900	309.32	ppb	#	98
10] Anthracene	19.440	178	106772	266.72	ppb		99
11] Fluoranthene	22.194	202	128388	306.67	ppb		99
12] Pyrene	22.712	202	119640	296.82	ppb		99
13] Benzo(a)anthracene	25.634	228	85858	304.22	ppb		98
14] Chrysene	25.746	228	118958	336.23	ppb		99
15] Benzo(b)fluoranthene	29.275	252	54935	319.84	ppb		97
16] Benzo(k)fluoranthene	29.275	252	54935	317.25	ppb	#	95
17] Benzo(a)pyrene	30.541	252	39686	336.50	ppb		98
18] Indeno(1,2,3-cd)pyrene	37.318	276	29062	314.33	ppb	#	77
19] Dibenzo(a,h)anthracene	37.688	278	28530	298.61	ppb		97
20] Benzo(g,h,i)perylene	39.243	276	34873	285.34	ppb		95

(#) = qualifier out of range (m) = manual integration (+) = signals summed

Appendix F

Vegetation Survey Data Forms and Photographs

Vegetation Species By Field Code		
Survey Field Code	**Genus Name**	**Scientific Name**
168	*Plantago spp.*	*Plantago ciliciata*
104	*Gymnarrbena*	*Gymnarrbena micrantha*
122	*Brassica*	*Brassica Tournefortii*
223	*Stipa*	*Stipa Capensis*
G01/G-01	*Schimus*	*Schimus Barbatus*
FISH	*Salsola*	*Salsola imbricata*
SLD	unknown[1]	unknown[1]
G02/G-02	*Cyperus*	*Cyperus conglomeratus*
SB01	*Stipagrostis*	*stipagrostis plumosa*
LYD	*Rhanterium*	*Rhanterium epapposum*
YF1	*Aaronsobnia*	*Aaronsobnia factorvskyi*
WSP	*Fagonia*	*Fagonia glutinosa*
SPS	*Savignya*	*Savignya parviflora*
CP1	*Anisosciadium*	*Anisosciadium lanatum*
BUD1	*Plantago*	*Plantago ovata*
STH	*Carduus*	*Carduus pycnocephalus*
FT	*Atractylis*	*Atractylis carduus*
TH2	unknown[1]	unknown[1]
TH1	*Cathamus*	*Cathamus Oxyacantha*
1 = Annual Forb		

TMA-MP1

TMA-MP01 LINE01 300Deg



TMA-MP01 LINE01 120Deg



TMA-MP01 LINE02 60Deg



TMA-MP01 LINE02 220Deg



TMA-MP01 LINE03 180Deg



TMA-MP01 LINE03 360Deg



Refer to "Monitoring Quick Links" at http://usda-ars.nmsu.edu/Monit_Assess/monitoring.htm for updates.

Line-Point Intercept Indicator Calculations

You must fill in all applicable yellow cells. Fill in Lower Canopy Layer cells where appropriate.

Page 1 of 1 Observer EK/SMJ *Gray cells for indicator calculations*

Plot TMA-MP1 Line 1 Recorder EK Line Length 50 m or ft? m

Direction 300° Date 04/04/14 (mm/dd/yyyy) Intercept (Point) Spacing Interval 100 cm or in? cm

Pt.	Top Canopy	Lower Canopy Layers Code1	Code2	Code3	Soil Surface	Pt.	Top Canopy	Lower Canopy Layers Code1	Code2	Code3	Soil Surface
1	None	None	None	None	S	26	None	None	None	None	S
2	None	None	None	None	S	27	None	None	None	None	S
3	None	None	None	None	S	28	168	None	None	None	S
4	None	None	None	None	S	29	168	None	None	None	S
5	None	None	None	None	S	30	G-01	None	None	None	S
6	None	None	None	None	S	31	168	None	None	None	S
7	168	None	None	None	S	32	168	None	None	None	S
8	168	None	None	None	S	33	168	None	None	None	S
9	168	None	None	None	S	34	168	None	None	None	S
10	None	None	None	None	S	35	104	None	None	None	S
11	None	None	None	None	S	36	168	None	None	None	S
12	None	None	None	None	S	37	G-01	None	None	None	S
13	168	None	None	None	S	38	None	None	None	None	S
14	None	None	None	None	S	39	168	None	None	None	S
15	None	None	None	None	S	40	None	None	None	None	S
16	None	None	None	None	S	41	None	None	None	None	S
17	168	None	None	None	S	42	None	None	None	None	S
18	168	None	None	None	S	43	None	None	None	None	S
19	168	None	None	None	S	44	168	None	None	None	S
20	168	None	None	None	S	45	None	None	None	None	S
21	None	None	None	None	S	46	None	None	None	None	S
22	104	None	None	None	S	47	168	None	None	None	S
23	168	None	None	None	S	48	168	None	None	None	S
24	None	None	None	None	S	49	168	None	None	None	S
25	G-01	168	None	None	S	50	168	None	None	None	S

% canopy cover = 54

% bare ground = 0

% basal cover = 0

% litter = 0

Notes: Only percent canopy cover has been calculated

Top canopy codes: Species code, common name, or NONE (no canopy).

Lower canopy layers codes: Species code, common name, L (herbaceous litter), WL (woody litter, >5 mm (~1/4 in) diameter).

Unknown Species Codes:
AF# = annual forb
PF# = perennial forb
AG# = annual graminoid
PG# = perennial graminoid
SH# = shrub
TR# = tree

Soil Surface (do not use litter): Species Code (for basal intercept)
R = rock fragment (>5 mm (~1/4 in) diameter)
BR = bedrock, M = moss
LC = visible lichen crust on soil
S = soil without any other soil surface code
EL = embedded litter (see page 10)
D = duff

**Bare ground occurs ONLY when Top canopy = NONE, Lower canopy layers are empty (no L), and Soil surface = S.*

Refer to "Monitoring Quick Links" at http://usda-ars.nmsu.edu/Monit_Assess/monitoring.htm for updates.

Line-Point Intercept Indicator Calculations

You must fill in all applicable yellow cells. Fill in Lower Canopy Layer cells where appropriate.

Page 1 of 1 Observer EKSMJ *Gray cells for indicator calculations*

Plot TMA-MP1 Line 2 Recorder EK Line Length 50 m or ft? m

Direction 60 Date 04/04/14 (mm/dd/yyyy) Intercept (Point) Spacing Interval 100 cm or in? cm

Pt.	Top Canopy	Lower Canopy Layers Code1	Code2	Code3	Soil Surface	Pt.	Top Canopy	Lower Canopy Layers Code1	Code2	Code3	Soil Surface
1	None	None	None	None	S	26	168	None	None	None	S
2	168	None	None	None	S	27	None	None	None	None	S
3	None	None	None	None	S	28	None	None	None	None	S
4	None	None	None	None	S	29	168	None	None	None	S
5	168	None	None	None	S	30	None	None	None	None	S
6	None	None	None	None	S	31	168	None	None	None	S
7	None	None	None	None	S	32	168	None	None	None	S
8	168	None	None	None	S	33	168	None	None	None	S
9	168	None	None	None	S	34	168	None	None	None	S
10	168	None	None	None	S	35	168	None	None	None	S
11	168	None	None	None	S	36	168	None	None	None	S
12	None	None	None	None	S	37	168	None	None	None	S
13	None	None	None	None	S	38	None	None	None	None	S
14	168	None	None	None	S	39	168	None	None	None	S
15	None	None	None	None	S	40	168	None	None	None	S
16	168	None	None	None	S	41	None	None	None	None	S
17	None	None	None	None	S	42	None	None	None	None	S
18	168	None	None	None	S	43	None	None	None	None	S
19	G-01	None	None	None	S	44	168	None	None	None	S
20	None	None	None	None	S	45	168	None	None	None	S
21	168	None	None	None	S	46	168	None	None	None	S
22	None	None	None	None	S	47	None	None	None	None	S
23	None	None	None	None	S	48	168	None	None	None	S
24	None	None	None	None	S	49	168	None	None	None	S
25	168	None	None	None	S	50	168	None	None	None	S

% canopy cover = 58

% bare ground = 0

% basal cover = 0

% litter = 0

Notes: Only percent canopy cover has been calculated.

Top canopy codes: Species code, common name, or NONE (no canopy).

Lower canopy layers codes: Species code, common name, L (herbaceous litter), WL (woody litter, >5 mm (~1/4 in) diameter).

Unknown Species Codes:
AF# = annual forb
PF# = perennial forb
AG# = annual graminoid
PG# = perennial graminoid
SH# = shrub
TR# = tree

Soil Surface (do not use litter):
Species Code (for basal intercept)
R = rock fragment (>5 mm (~1/4 in) diameter)
BR = bedrock, M = moss
LC = visible lichen crust on soil
S = soil without any other soil surface code
EL = embedded litter (see page 10)
D = duff

**Bare ground occurs ONLY when Top canopy = NONE, Lower canopy layers are empty (no L), and Soil surface = S.*

Refer to "Monitoring Quick Links" at http://usda-ars.nmsu.edu/Monit_Assess/monitoring.htm for updates.

Line-Point Intercept Indicator Calculations

You must fill in all applicable yellow cells. Fill in Lower Canopy Layer cells where appropriate.

Page 1 of 1 Observer EK/SMJ *Gray cells for indicator calculations*

Plot TMA MP1 Line 3 Recorder EK Line Length 50 m or ft? m

Direction 120 Date 04/04/14 (mm/dd/yyyy) Intercept (Point) Spacing Interval 100 cm or in? cm

Pt.	Top Canopy	Lower Canopy Layers Code1	Code2	Code3	Soil Surface	Pt.	Top Canopy	Lower Canopy Layers Code1	Code2	Code3	Soil Surface
1	None	None	None	None	S	26	None	None	None	None	S
2	None	None	None	None	S	27	168	None	None	None	S
3	168	None	None	None	S	28	168	None	None	None	S
4	168	None	None	None	S	29	168	None	None	None	S
5	None	None	None	None	S	30	168	None	None	None	S
6	None	None	None	None	S	31	None	None	None	None	S
7	168	None	None	None	S	32	None	None	None	None	S
8	None	None	None	None	S	33	None	None	None	None	S
9	168	None	None	None	TCG/S	34	None	None	None	None	S
10	104	168	None	None	S	35	168	None	None	None	TCG/S
11	None	None	None	None	TCG/S	36	None	None	None	None	TCG/S
12	168	None	None	None	S	37	None	None	None	None	S
13	168	None	None	None	S	38	None	None	None	None	S
14	DSP	None	None	None	S	39	None	None	None	None	S
15	None	None	None	None	S	40	168	None	None	None	S
16	G-01	168	None	None	S	41	None	None	None	None	S
17	168	None	None	None	S	42	None	None	None	None	S
18	None	None	None	None	S	43	168	None	None	None	TCG/S
19	168	None	None	None	S	44	168	None	None	None	S
20	None	None	None	None	S	45	168	None	None	None	S
21	None	None	None	None	S	46	168	None	None	None	S
22	None	None	None	None	S	47	WSP	None	None	None	S
23	104	None	None	None	S	48	None	None	None	None	TC
24	168	None	None	None	S	49	None	None	None	None	S
25	168	None	None	None	TCG/S	50	168	None	None	None	S

% canopy cover = 52

% bare ground = 0

% basal cover = 0

% litter = 0

Notes: TCG = Tarcrete gravel
Only percent canopy cover has been calculated.

Top canopy codes: Species code, common name, or NONE (no canopy).

Lower canopy layers codes: Species code, common name, L (herbaceous litter), WL (woody litter, >5 mm (~1/4 in) diameter).

Unknown Species Codes:
AF# = annual forb
PF# = perennial forb
AG# = annual graminoid
PG# = perennial graminoid
SH# = shrub
TR# = tree

Soil Surface (do not use litter):
Species Code (for basal intercept)
R = rock fragment (>5 mm (~1/4 in) diameter)
BR = bedrock, M = moss
LC = visible lichen crust on soil
S = soil without any other soil surface code
EL = embedded litter (see page 10)
D = duff

**Bare ground occurs ONLY when Top canopy = NONE, Lower canopy layers are empty (no L), and Soil surface = S.*

TMA-MP2

Refer to "Monitoring Quick Links" at http://usda-ars.nmsu.edu/Monit_Assess/monitoring.htm for updates.

Line-Point Intercept Indicator Calculations

You must fill in all applicable yellow cells. Fill in Lower Canopy Layer cells where appropriate.

Page 1 of 1 Observer EK/SMJ *Gray cells for indicator calculations*

Plot TMA MP2 Line 1 Recorder EK Line Length 50 m or ft? m

Direction 80 Date 03/28/14 (mm/dd/yyyy) Intercept (Point) Spacing Interval 100 cm or in? cm

Pt.	Top Canopy	Lower Canopy Layers Code1	Code2	Code3	Soil Surface	Pt.	Top Canopy	Lower Canopy Layers Code1	Code2	Code3	Soil Surface
1	None	None	None	None	S	26	None	None	None	None	TCG/S
2	None	None	None	None	S	27	168	None	None	None	TCG/S
3	223	G-01	168	None	S	28	168	None	None	None	TCG/S
4	223	G-01	168	None	S	29	168	None	None	None	TCG/S
5	G-01	None	None	None	S	30	None	None	None	None	TCG/S
6	122	168	None	None	TCG/S	31	G-01	None	None	None	S
7	168	None	None	None	TCG/S	32	104	LYD	None	None	TCG/S
8	168	None	None	None	S	33	168	None	None	None	TCG/S
9	SB-01	168	None	None	S	34	None	None	None	None	S
10	G-01	None	None	None	TCG/S	35	None	None	None	L	TCG/S
11	168	None	None	None	TCG/S	36	168	None	None	None	TCG/S
12	223	None	None	L	TCG/S	37	G-01	168	None	None	TCG/S
13	None	None	None	None	TCG/S	38	None	None	None	None	S
14	None	None	None	None	TCG	39	168	None	None	None	S
15	None	None	None	None	TCG	40	None	None	None	None	TCG/S
16	None	None	None	None	TCG	41	LYD	None	None	None	TCG/S
17	None	None	None	None	TCG/S	42	168	None	None	None	TCG/S
18	G-1	None	None	None	TCG/S	43	None	None	None	None	TCG/S
19	None	None	None	None	TCG/S	44	None	None	None	None	TCG/S
20	None	None	None	None	TCG/S	45	None	None	None	None	S
21	G-01	None	None	None	TCG/S	46	None	None	None	None	S
22	G-01	None	None	None	TCG/S	47	None	None	None	None	S
23	168	None	None	None	TCG/S	48	122	168	None	L	S
24	G-01	None	None	None	TCG/S	49	104	None	None	None	S
25	168	None	None	None	TCG/S	50	SB-01	None	None	None	S

% canopy cover = 60

% bare ground = 0

% basal cover = 0

% litter = 0

Notes: TCG = Tarcrete gravel
Only percent canopy cover has been calculated.

Top canopy codes: Species code, common name, or NONE (no canopy).

Lower canopy layers codes: Species code, common name, L (herbaceous litter), WL (woody litter, >5 mm (~1/4 in) diameter).

Unknown Species Codes:
AF# = annual forb
PF# = perennial forb
AG# = annual graminoid
PG# = perennial graminoid
SH# = shrub
TR# = tree

Soil Surface (do not use litter): Species Code (for basal intercept)
R = rock fragment (>5 mm (~1/4 in) diameter)
BR = bedrock, M = moss
LC = visible lichen crust on soil
S = soil without any other soil surface code
EL = embedded litter (see page 10)
D = duff

**Bare ground occurs ONLY when Top canopy = NONE, Lower canopy layers are empty (no L), and Soil surface = S.*

Refer to "Monitoring Quick Links" at http://usda-ars.nmsu.edu/Monit_Assess/monitoring.htm for updates.

Line-Point Intercept Indicator Calculations

You must fill in all applicable yellow cells. Fill in Lower Canopy Layer cells where appropriate.

Page 1 of 1 Observer EK/SMJ *Gray cells for indicator calculations*

Plot TMA MP2 Line 2 Recorder EK Line Length 50 m or ft? m

Direction 200 Date 03/28/14 (mm/dd/yyyy) Intercept (Point) Spacing Interval 100 cm or in? cm

Pt.	Top Canopy	Lower Canopy Layers Code1	Code2	Code3	Soil Surface	Pt.	Top Canopy	Lower Canopy Layers Code1	Code2	Code3	Soil Surface
1	G-01	None	None	None	TCG/S	26	None	None	None	L	TCG/S
2	None	None	None	None	TCG/S	27	168	None	None	None	TCG/S
3	WSP	None	None	None	TCG/S	28	122	223	None	None	S
4	SB-01	None	None	None	TCG/S	29	104	168	None	None	TCG/S
5	None	None	None	None	TCG/S	30	168	None	None	None	TCG/S
6	168	None	None	None	TCG/S	31	None	None	None	None	TCG/S
7	None	None	None	None	TCG/S	32	168	None	None	None	TCG/S
8	G-01	None	None	None	TCG/S	33	None	None	None	None	TCG/S
9	None	None	None	None	TCG/S	34	168	None	None	None	TCG/S
10	None	None	None	None	TCG/S	35	None	None	None	None	TCG/S
11	None	None	None	None	TCG/S	36	None	None	None	None	TCG/S
12	104	None	None	None	TCG/S	37	None	None	None	None	TCG/S
13	None	None	None	None	TCG/S	38	None	None	None	None	TCG/S
14	168	None	None	None	TCG/S	39	168	None	None	None	TCG/S
15	None	None	None	None	TCG/S	40	None	None	None	None	TCG/S
16	None	None	None	None	TCG/S	41	None	None	None	None	TCG/S
17	168	None	None	None	TCG/S	42	None	None	None	None	TCG/S
18	G-01	None	None	None	TCG/S	43	168	None	None	None	TCG/S
19	None	None	None	None	TCG/S	44	FT	None	None	None	TCG/S
20	None	None	None	None	TCG/S	45	168	None	None	None	TCG/S
21	None	None	None	None	TCG/S	46	168	None	None	None	TCG/S
22	G-01	None	None	None	TCG/S	47	FT	None	None	None	TCG/S
23	None	None	None	None	TCG/S	48	G-01	None	None	None	TCG/S
24	None	None	None	None	TCG/S	49	168	None	None	None	TCG/S
25	168	None	None	None	TCG/S	50	168	None	None	None	TCG/S

% canopy cover = 52

% bare ground = 0

% basal cover = 0

% litter = 0

Notes: TCG = Tarcrete gravel
Only percent canopy cover was calculated.

Top canopy codes: Species code, common name, or NONE (no canopy).

Lower canopy layers codes: Species code, common name, L (herbaceous litter), WL (woody litter, >5 mm (~1/4 in) diameter).

Unknown Species Codes:
AF# = annual forb
PF# = perennial forb
AG# = annual graminoid
PG# = perennial graminoid
SH# = shrub
TR# = tree

Soil Surface (do not use litter):
Species Code (for basal intercept)
R = rock fragment (>5 mm (~1/4 in) diameter)
BR = bedrock, M = moss
LC = visible lichen crust on soil
S = soil without any other soil surface code
EL = embedded litter (see page 10)
D = duff

**Bare ground occurs ONLY when Top canopy = NONE, Lower canopy layers are empty (no L), and Soil surface = S.*

Refer to "Monitoring Quick Links" at http://usda-ars.nmsu.edu/Monit_Assess/monitoring.htm for updates.

Line-Point Intercept Indicator Calculations

You must fill in all applicable yellow cells. Fill in Lower Canopy Layer cells where appropriate.

Page 1 of 1 Observer EK/SMJ *Gray cells for indicator calculations*

Plot TMA MP2 Line 3 Recorder EK Line Length 50 m or ft? m

Direction 320 Date 03/28/14 (mm/dd/yyyy) Intercept (Point) Spacing Interval 100 cm or in? cm

Pt.	Top Canopy	Lower Canopy Layers Code1	Code2	Code3	Soil Surface	Pt.	Top Canopy	Lower Canopy Layers Code1	Code2	Code3	Soil Surface
1	168	None	None	None	TCG/S	26	SB-01	168	None	None	TCG/S
2	None	None	None	None	TCG/S	27	168	104	None	None	TCG/S
3	168	None	None	None	TCG/S	28	None	None	None	None	TCG/S
4	122	168	None	None	TCG/S	29	168	None	None	None	TCG/S
5	None	None	None	None	TCG/S	30	LYD	168	None	None	TCG/S
6	104	None	None	None	TCG/S	31	None	None	None	None	TCG/S
7	None	None	None	None	TCG/S	32	168	None	None	None	TCG/S
8	168	None	None	None	TCG/S	33	168	None	None	None	TCG/S
9	168	None	None	None	TCG/S	34	FISH	None	None	None	TCG/S
10	None	None	None	None	TCG/S	35	168	None	None	None	TCG/S
11	None	None	None	None	TCG/S	36	None	None	None	None	TCG/S
12	None	None	None	None	TCG/S	37	G-01	None	None	None	TCG/S
13	LYD	168	None	None	TCG/S	38	None	None	None	None	TCG/S
14	122	None	None	None	TCG/S	39	122	168	None	None	TCG/S
15	122	168	None	None	TCG/S	40	168	None	None	None	TCG/S
16	FISH	None	None	None	TCG/S	41	None	None	None	None	TCG/S
17	None	None	None	None	TCG/S	42	None	None	None	None	TCG/S
18	168	None	None	None	TCG/S	43	104	168	None	None	TCG/S
19	168	None	None	None	TCG/S	44	168	None	None	None	TCG/S
20	122	None	None	None	TCG/S	45	122	168	None	None	TCG/S
21	168	None	None	None	TCG/S	46	168	None	None	None	TCG/S
22	G-01	None	None	None	TCG/S	47	168	None	None	None	TCG/S
23	104	168	None	None	TCG/S	48	168	G-01	None	None	TCG/S
24	168	None	None	None	TCG/S	49	None	None	None	None	TCG/S
25	SLD	LYD	168	None	TCG/S	50	SLD	168	None	L	TCG/S

% canopy cover = 72

% bare ground = 0

% basal cover = 0

% litter = 0

Notes: TCG = Tarcrete gravel
Only percent canopy cover has been calculated.

Top canopy codes: Species code, common name, or NONE (no canopy).

Lower canopy layers codes: Species code, common name, L (herbaceous litter), WL (woody litter, >5 mm (~1/4 in) diameter).

Unknown Species Codes:
AF# = annual forb
PF# = perennial forb
AG# = annual graminoid
PG# = perennial graminoid
SH# = shrub
TR# = tree

Soil Surface (do not use litter):
Species Code (for basal intercept)
R = rock fragment (>5 mm (~1/4 in) diameter)
BR = bedrock, M = moss
LC = visible lichen crust on soil
S = soil without any other soil surface code
EL = embedded litter (see page 10)
D = duff

**Bare ground occurs ONLY when Top canopy = NONE, Lower canopy layers are empty (no L), and Soil surface = S.*

TMA-MP3

Refer to "Monitoring Quick Links" at http://usda-ars.nmsu.edu/Monit_Assess/monitoring.htm for updates.

Line-Point Intercept Indicator Calculations

You must fill in all applicable yellow cells. Fill in Lower Canopy Layer cells where appropriate.

Page 1 of 1 Observer EK/SMJ *Gray cells for indicator calculations*

Plot TMA MP3 Line 1 Recorder EK Line Length 50 m or ft? m

Direction 280 Date 03/29/14 (mm/dd/yyyy) Intercept (Point) Spacing Interval 100 cm or in? cm

Pt.	Top Canopy	Lower Canopy Layers Code1	Code2	Code3	Soil Surface	Pt.	Top Canopy	Lower Canopy Layers Code1	Code2	Code3	Soil Surface
1	168	None	None	None	S	26	None	None	None	None	S
2	FISH	None	None	None	S	27	None	None	None	None	S
3	FISH	None	None	None	S	28	None	None	None	None	S
4	223	LYD	168	None	S	29	None	None	None	None	TCG/S
5	FISH	104	None	None	S	30	None	None	None	None	TCG/S
6	104	FISH	LYD	L	S	31	None	None	None	None	TCG/S
7	104	FISH	None	L	S	32	None	None	None	None	S
8	104	None	None	None	S	33	None	None	None	None	S
9	G-01	None	None	None	S	34	None	None	None	None	S
10	SLD	None	None	None	S	35	None	None	None	None	S
11	104	SLD	LYD	None	S	36	None	None	None	None	S
12	G-02	None	None	None	S	37	None	None	None	None	TCG/S
13	None	None	None	None	TCG/S	38	None	None	None	None	TCG/S
14	SLD	None	None	None	TC	39	None	None	None	None	S
15	FISH	None	None	None	TC	40	None	None	None	None	S
16	G-01	None	None	None	TCG/S	41	None	None	None	None	S
17	LYD	None	None	None	S	42	FISH	None	None	None	S
18	FISH	None	None	None	S	43	None	None	None	None	TCG/S
19	FISH	LYD	None	None	TCG/S	44	None	None	None	None	S
20	None	None	None	None	S	45	None	None	None	None	S
21	None	None	None	None	TCG/S	46	None	None	None	None	S
22	None	None	None	None	TCG/S	47	None	None	None	None	S
23	FISH	None	None	None	TC	48	None	None	None	None	S
24	None	None	None	None	S	49	None	None	None	None	S
25	G-02	None	None	None	S	50	None	None	None	None	S

% canopy cover = 42

% bare ground = 0

% basal cover = 0

% litter = 0

Notes: TCG = Tarcrete gravel.
TC = Tarcrete
Only percent cover has been calculated.

Top canopy codes: Species code, common name, or NONE (no canopy).

Lower canopy layers codes: Species code, common name, L (herbaceous litter), WL (woody litter, >5 mm (~1/4 in) diameter).

Unknown Species Codes:
AF# = annual forb
PF# = perennial forb
AG# = annual graminoid
PG# = perennial graminoid
SH# = shrub
TR# = tree

Soil Surface (do not use litter):
Species Code (for basal intercept)
R = rock fragment (>5 mm (~1/4 in) diameter)
BR = bedrock, M = moss
LC = visible lichen crust on soil
S = soil without any other soil surface code
EL = embedded litter (see page 10)
D = duff

**Bare ground occurs ONLY when Top canopy = NONE, Lower canopy layers are empty (no L), and Soil surface = S.*

Refer to "Monitoring Quick Links" at http://usda-ars.nmsu.edu/Monit_Assess/monitoring.htm for updates.

Line-Point Intercept Indicator Calculations

You must fill in all applicable yellow cells. Fill in Lower Canopy Layer cells where appropriate.

Page 1 of 1 Observer EK/SMJ *Gray cells for indicator calculations*

Plot TMA MP3 Line 2 Recorder EK Line Length 50 m or ft? m

Direction 160 Date 03/29/14 (mm/dd/yyyy) Intercept (Point) Spacing Interval 100 cm or in? cm

Pt.	Top Canopy	Lower Canopy Layers Code1	Code2	Code3	Soil Surface	Pt.	Top Canopy	Lower Canopy Layers Code1	Code2	Code3	Soil Surface
1	None	None	None	None	S	26	None	None	None	None	S
2	None	None	None	WL	S	27	None	None	None	WL	S
3	None	None	None	None	S	28	None	None	None	None	S
4	None	None	None	None	S	29	None	None	None	None	S
5	G-01	None	None	None	S	30	None	None	None	None	S
6	FISH	None	None	None	S	31	None	None	None	None	S
7	FISH	None	None	None	S	32	None	None	None	None	S
8	FISH	None	None	None	S	33	None	None	None	None	S
9	None	None	None	None	S	34	None	None	None	WL	S
10	None	None	None	None	S	35	None	None	None	WL	S
11	FISH	LYD	None	None	S	36	None	None	None	None	S
12	None	None	None	None	S	37	None	None	None	None	S
13	FISH	None	None	None	S	38	None	None	None	None	S
14	LYD	None	None	WL	S	39	None	None	None	WL	S
15	None	None	None	None	S	40	None	None	None	None	S
16	None	None	None	None	S	41	None	None	None	WL	S
17	None	None	None	None	S	42	FISH	None	None	None	S
18	None	None	None	WL	S	43	FISH	None	None	None	S
19	FISH	None	None	None	S	44	FISH	None	None	None	S
20	LYD	FISH	None	None	S	45	FISH	None	None	None	S
21	FISH	None	None	None	S	46	FISH	G-01	None	None	S
22	FISH	None	None	None	S	47	None	None	None	None	S
23	FISH	None	None	None	S	48	FISH	None	None	None	S
24	None	None	None	None	S	49	None	None	None	None	S
25	None	None	None	WL	S	50	FISH	None	None	None	S

% canopy cover = 38

% bare ground = 0

% basal cover = 0

% litter = 0

Notes: Only percent canopy cover has been calculated.

Top canopy codes: Species code, common name, or NONE (no canopy).

Lower canopy layers codes: Species code, common name, L (herbaceous litter), WL (woody litter, >5 mm (~1/4 in) diameter).

Unknown Species Codes:
AF# = annual forb
PF# = perennial forb
AG# = annual graminoid
PG# = perennial graminoid
SH# = shrub
TR# = tree

Soil Surface (do not use litter):
Species Code (for basal intercept)
R = rock fragment (>5 mm (~1/4 in) diameter)
BR = bedrock, M = moss
LC = visible lichen crust on soil
S = soil without any other soil surface code
EL = embedded litter (see page 10)
D = duff

**Bare ground occurs ONLY when Top canopy = NONE, Lower canopy layers are empty (no L), and Soil surface = S.*

Refer to "Monitoring Quick Links" at http://usda-ars.nmsu.edu/Monit_Assess/monitoring.htm for updates.

Line-Point Intercept Indicator Calculations

You must fill in all applicable yellow cells. Fill in Lower Canopy Layer cells where appropriate.

Page 1 of 1 Observer EK/SMJ *Gray cells for indicator calculations*

Plot TMA MP3 Line 3 Recorder EK Line Length 50 m or ft? m

Direction 40 Date 03/29/14 (mm/dd/yyyy) Intercept (Point) Spacing Interval 100 cm or in? cm

Pt.	Top Canopy	Lower Canopy Layers Code1	Code2	Code3	Soil Surface	Pt.	Top Canopy	Lower Canopy Layers Code1	Code2	Code3	Soil Surface
1	None	None	None	None	S	26	None	None	None	None	TCG/S
2	None	None	None	None	S	27	None	None	None	None	S
3	None	None	None	None	S	28	None	None	None	None	S
4	None	None	None	None	TCG/S	29	None	None	None	None	S
5	None	None	None	None	TCG/S	30	None	None	None	None	S
6	None	None	None	None	S	31	None	None	None	None	S
7	None	None	None	None	S/DOL	32	None	None	None	WL	S
8	None	None	None	None	S/DOL	33	None	None	None	None	S
9	None	None	None	None	S	34	None	None	None	None	S
10	None	None	None	None	S/DOL	35	None	None	None	None	S
11	None	None	None	None	S/DOL	36	None	None	None	None	S
12	None	None	None	None	S	37	None	None	None	None	S
13	None	None	None	None	S	38	None	None	None	None	S
14	None	None	None	None	S	39	None	None	None	None	S
15	None	None	None	None	S	40	None	None	None	None	S
16	None	None	None	None	S	41	None	None	None	None	S
17	None	None	None	None	S	42	None	None	None	None	S
18	None	None	None	None	S	43	None	None	None	None	S
19	None	None	None	None	S	44	None	None	None	None	S
20	None	None	None	None	S	45	None	None	None	None	S
21	None	None	None	None	S	46	None	None	None	None	S
22	None	None	None	None	S	47	None	None	None	None	S
23	None	None	None	None	S	48	None	None	None	None	S
24	None	None	None	None	S	49	None	None	None	None	S
25	None	None	None	None	TCG/S	50	None	None	None	WL	S

% canopy cover = 0

% bare ground = 0

% basal cover = 0

% litter = 0

Notes:
TCG = Tarcrete gravel
DOL = Dry oil lake
Only percent canopy cover has been calculated.

Top canopy codes: Species code, common name, or NONE (no canopy).

Lower canopy layers codes: Species code, common name, L (herbaceous litter), WL (woody litter, >5 mm (~1/4 in) diameter).

Unknown Species Codes:
AF# = annual forb
PF# = perennial forb
AG# = annual graminoid
PG# = perennial graminoid
SH# = shrub
TR# = tree

Soil Surface (do not use litter):
Species Code (for basal intercept)
R = rock fragment (>5 mm (~1/4 in) diameter)
BR = bedrock, M = moss
LC = visible lichen crust on soil
S = soil without any other soil surface code
EL = embedded litter (see page 10)
D = duff

**Bare ground occurs ONLY when Top canopy = NONE, Lower canopy layers are empty (no L), and Soil surface = S.*

TMB-MP1

TMB-MP01 LINE01 55Deg



TMB-MP01 LINE02 180Deg



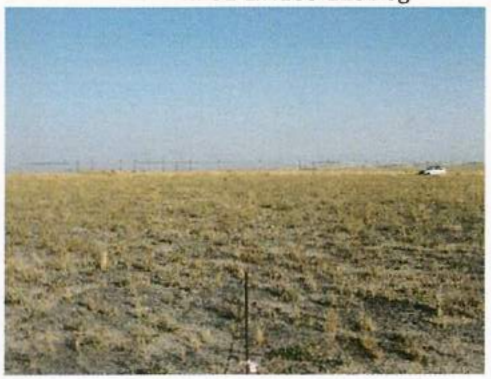
TMB-MP01 LINE01 215Deg



TMB-MP01 LINE02 360Deg



TMB-MP01 LINE03 125Deg



TMB-MP01 LINE03 305Deg



Refer to "Monitoring Quick Links" at http://usda-ars.nmsu.edu/Monit_Assess/monitoring.htm for updates.

Line-Point Intercept Indicator Calculations

You must fill in all applicable yellow cells. Fill in Lower Canopy Layer cells where appropriate.

Page 1 of 1 Observer EK/SMJ *Gray cells for indicator calculations*

Plot TMB MP1 Line 1 Recorder EK Line Length 50 m or ft? m

Direction 55 Date 04/05/2014 (mm/dd/yyyy) Intercept (Point) Spacing Interval 100 cm or in? cm

Pt.	Top Canopy	Lower Canopy Layers Code1	Code2	Code3	Soil Surface	Pt.	Top Canopy	Lower Canopy Layers Code1	Code2	Code3	Soil Surface
1	104	None	None	None	S	26	SLD	None	None	None	TC
2	104	None	None	L	S	27	None	None	None	None	TC
3	SB-1	None	None	None	S	28	104	None	None	None	TC
4	G-01	None	None	None	S	29	None	None	None	None	TC
5	G-01	None	None	None	S	30	None	None	None	None	TC
6	SB-1	None	None	None	S	31	104	None	None	None	TC
7	104	None	None	None	S	32	104	None	None	L	TC
8	None	None	None	None	TC	33	None	None	None	None	TC
9	104	None	None	None	TC	34	104	None	None	L	TC
10	104	None	None	None	TC	35	None	None	None	None	TC
11	104	None	None	None	TC	36	122	None	None	None	TC
12	122	None	None	None	TC	37	None	None	None	None	TC
13	104	None	None	None	TC	38	None	None	None	None	S
14	None	None	None	None	TC	39	G-01	None	None	None	TC
15	104	None	None	None	TC	40	122	None	None	None	TC
16	None	None	None	None	S	41	None	None	None	None	TC
17	104	None	None	None	TC	42	None	None	None	None	TC
18	None	None	None	None	S	43	G-01	None	None	None	TC
19	None	None	None	None	TC	44	104	None	None	None	TC
20	G-01	None	None	None	TC	45	None	None	None	None	TC
21	104	None	None	L	TC	46	None	None	None	None	TC
22	None	None	None	None	TC	47	None	None	None	None	TC
23	None	None	None	None	S	48	104	None	None	L	TC
24	104	None	None	None	TC	49	104	None	None	None	TC
25	104	None	None	None	TC	50	104	None	None	None	TC

% canopy cover = 62

% bare ground = 0

% basal cover = 0

% litter = 0

Notes: TC = Tarcrete
Only percent canopy has been calculated

Top canopy codes: Species code, common name, or NONE (no canopy).

Lower canopy layers codes: Species code, common name, L (herbaceous litter), WL (woody litter, >5 mm (~1/4 in) diameter).

Unknown Species Codes:
AF# = annual forb
PF# = perennial forb
AG# = annual graminoid
PG# = perennial graminoid
SH# = shrub
TR# = tree

Soil Surface (do not use litter): Species Code (for basal intercept)
R = rock fragment (>5 mm (~1/4 in) diameter)
BR = bedrock, M = moss
LC = visible lichen crust on soil
S = soil without any other soil surface code
EL = embedded litter (see page 10)
D = duff

**Bare ground occurs ONLY when Top canopy = NONE, Lower canopy layers are empty (no L), and Soil surface = S.*

Refer to "Monitoring Quick Links" at http://usda-ars.nmsu.edu/Monit_Assess/monitoring.htm for updates.

Line-Point Intercept Indicator Calculations

You must fill in all applicable yellow cells. Fill in Lower Canopy Layer cells where appropriate.

Page 1 of 1 Observer EK/SMJ *Gray cells for indicator calculations*

Plot TMB MP1 Line 2 Recorder EK Line Length 50 m or ft? m

Direction 180 Date 05/04/14 (mm/dd/yyyy) Intercept (Point) Spacing Interval 100 cm or in? cm

Pt.	Top Canopy	Lower Canopy Layers Code1	Code2	Code3	Soil Surface	Pt.	Top Canopy	Lower Canopy Layers Code1	Code2	Code3	Soil Surface
1	None	None	None	None	TC/S	26	104	None	None	None	TC/S
2	None	None	None	None	TC	27	104	None	None	None	TC/S
3	None	None	None	None	TC/S	28	104	None	None	L	TC/S
4	104	G-01	None	None	S	29	104	None	None	None	TC
5	104	G-01	None	None	S	30	223	None	None	None	TC
6	104	None	None	None	S	31	None	None	None	None	TC
7	None	None	None	None	TC	32	None	None	None	L	S
8	104	None	None	None	TC/S	33	104	None	None	None	TC
9	104	G-01	None	None	TC/S	34	104	None	None	None	TC
10	None	None	None	None	TC/S	35	SPS	None	None	L	S
11	104	None	None	None	S	36	None	None	None	None	S
12	None	None	None	None	TC	37	None	None	None	None	TC
13	G-01	None	None	None	TC	38	104	None	None	None	TC
14	None	None	None	None	TC	39	104	None	None	None	TC
15	None	None	None	None	TC	40	104	None	None	L	TC/S
16	G-01	None	None	None	TC	41	104	None	None	None	TC
17	None	None	None	None	TC/S	42	None	None	None	None	TC
18	None	None	None	None	TC	43	G-01	None	None	None	TC
19	SLD	None	None	None	TC	44	None	None	None	None	TC
20	104	None	None	None	TC	45	104	None	None	None	S
21	None	None	None	None	TC	46	104	None	None	None	S
22	223	104	G-01	None	TC/S	47	G-01	None	None	None	TC/S
23	None	None	None	None	TC	48	None	None	None	None	S
24	None	None	None	None	TC	49	None	None	None	None	TC/S
25	None	None	None	None	TC	50	None	None	None	None	TC

% canopy cover = 54

% bare ground = 0

% basal cover = 0

% litter = 0

Notes: TC = Tarcrete
Only percent canopy cover has been calculated

Top canopy codes: Species code, common name, or NONE (no canopy).

Lower canopy layers codes: Species code, common name, L (herbaceous litter), WL (woody litter, >5 mm (~1/4 in) diameter).

Unknown Species Codes:
AF# = annual forb
PF# = perennial forb
AG# = annual graminoid
PG# = perennial graminoid
SH# = shrub
TR# = tree

Soil Surface (do not use litter):
Species Code (for basal intercept)
R = rock fragment (>5 mm (~1/4 in) diameter)
BR = bedrock, M = moss
LC = visible lichen crust on soil
S = soil without any other soil surface code
EL = embedded litter (see page 10)
D = duff

**Bare ground occurs ONLY when Top canopy = NONE, Lower canopy layers are empty (no L), and Soil surface = S.*

Refer to "Monitoring Quick Links" at http://usda-ars.nmsu.edu/Monit_Assess/monitoring.htm for updates.

Line-Point Intercept Indicator Calculations

You must fill in all applicable yellow cells. Fill in Lower Canopy Layer cells where appropriate.

Page 1 of 1 Observer EK/SMJ *Gray cells for indicator calculations*

Plot TMB MP1 Line 3 Recorder SMJ Line Length 50 m or ft? m

Direction 300 Date 04/05/2014 (mm/dd/yyyy) Intercept (Point) Spacing Interval 100 cm or in? cm

Pt.	Top Canopy	Lower Canopy Layers Code1	Code2	Code3	Soil Surface	Pt.	Top Canopy	Lower Canopy Layers Code1	Code2	Code3	Soil Surface
1	None	None	None	None	TC	26	None	None	None	None	TC
2	None	None	None	None	TC	27	None	None	None	None	TC
3	G-01	None	None	None	TC	28	122	104	None	None	TC
4	None	None	None	None	TC	29	122	104	None	None	TC
5	None	None	None	None	TC	30	None	None	None	None	TC
6	None	None	None	None	TC	31	168	None	None	None	TC
7	None	None	None	None	TC	32	None	None	None	None	TC
8	None	None	None	None	TC	33	None	None	None	None	TC
9	None	None	None	None	TC	34	122	None	None	None	TC
10	104	None	None	None	TC	35	None	None	None	None	TC
11	None	None	None	None	TC	36	None	None	None	None	TC
12	None	None	None	None	TC	37	None	None	None	None	TC
13	G-01	None	None	None	TC	38	104	None	None	None	TC
14	104	G-01	None	None	TC	39	104	None	None	None	TC
15	104	None	None	L	TC	40	None	None	None	None	TC
16	None	None	None	None	TC	41	SLD	None	None	None	TC
17	None	None	None	None	TC	42	104	None	None	None	TC
18	104	None	None	None	TC	43	None	None	None	None	TC
19	None	None	None	None	TC	44	223	None	None	None	TC
20	104	None	None	None	TC	45	104	SLD	None	L	TC
21	104	G-01	None	None	TC	46	None	None	None	None	TC
22	None	None	None	L	TC	47	G-01	104	None	None	TC
23	104	G-01	None	None	TC	48	104	None	None	None	TC
24	None	None	None	None	TC	49	None	None	None	None	TC
25	None	None	None	None	TC	50	None	None	None	None	TC

% canopy cover = 42

% bare ground = 0

% basal cover = 0

% litter = 0

Notes: TC = Tarcrete
Only percent canopy cover has been calculated.

Top canopy codes: Species code, common name, or NONE (no canopy).

Lower canopy layers codes: Species code, common name, L (herbaceous litter), WL (woody litter, >5 mm (~1/4 in) diameter).

Unknown Species Codes:
AF# = annual forb
PF# = perennial forb
AG# = annual graminoid
PG# = perennial graminoid
SH# = shrub
TR# = tree

Soil Surface (do not use litter): Species Code (for basal intercept)
R = rock fragment (>5 mm (~1/4 in) diameter)
BR = bedrock, M = moss
LC = visible lichen crust on soil
S = soil without any other soil surface code
EL = embedded litter (see page 10)
D = duff

**Bare ground occurs ONLY when Top canopy = NONE, Lower canopy layers are empty (no L), and Soil surface = S.*

TMC-MP2

TMC-MP02 LINE01 135Deg



TMC-MP02 LINE01 315Deg



TMC-MP02 LINE02 235Deg



TMC-MP02 LINE02 55Deg



TMC-MP02 LINE03 130Deg



TMC-MP02 LINE03 310Deg



Refer to "Monitoring Quick Links" at http://usda-ars.nmsu.edu/Monit_Assess/monitoring.htm for updates.

Line-Point Intercept Indicator Calculations

You must fill in all applicable yellow cells. Fill in Lower Canopy Layer cells where appropriate.

Page 1 of 1 Observer EK/SMJ *Gray cells for indicator calculations*

Plot TMC MP2 Line 1 Recorder SMJ Line Length 50 m or ft? m

Direction 315 Date 03/28/14 (mm/dd/yyyy) Intercept (Point) Spacing Interval 100 cm or in? cm

Pt.	Top Canopy	Lower Canopy Layers Code1	Code2	Code3	Soil Surface	Pt.	Top Canopy	Lower Canopy Layers Code1	Code2	Code3	Soil Surface
1	None	None	None	None	S	26	G-02	None	None	None	TC
2	104	None	None	None	TC	27	223	None	None	None	TC
3	None	None	None	None	S	28	223	None	None	None	TC
4	223	None	None	None	TC	29	None	None	None	None	TC
5	None	None	None	None	S	30	FT	None	None	None	TC
6	122	223	168	None	S	31	122	223	104	None	TC
7	None	None	None	None	S	32	104	223	None	L	S
8	104	None	None	None	TC	33	None	None	None	None	TC
9	None	None	None	None	TC	34	None	None	None	None	TC
10	168	None	None	None	S	35	104	223	None	None	TC
11	223	None	None	L	S	36	None	None	None	None	TC
12	122	104	FT	None	S	37	None	None	None	None	TC
13	104	None	None	None	S	38	168	104	223	None	TC
14	None	None	None	None	S	39	TH-1	None	None	None	S
15	223	None	None	None	S	40	122	None	None	L	TC
16	SLD	None	None	None	S	41	None	None	None	None	TC
17	223	None	None	None	TC	42	None	None	None	None	S
18	CP-1	G-01	None	None	TC	43	122	None	None	None	TC
19	223	104	None	None	S	44	122	None	None	None	TC
20	G-02	G-01	None	L	S	45	223	104	None	None	TC
21	223	104	None	None	S	46	223	104	None	None	TC
22	223	None	None	None	S	47	223	None	None	None	TC
23	None	None	None	None	TC	48	None	None	None	None	TC
24	223	None	None	None	TC	49	None	None	None	None	TC
25	223	None	None	None	TC	50	None	None	None	None	TC

% canopy cover = 66

% bare ground = 0

% basal cover = 0

% litter = 0

Notes: TC = Tarcerte
Only percent canopy cover has been calculated.

Top canopy codes: Species code, common name, or NONE (no canopy).

Lower canopy layers codes: Species code, common name, L (herbaceous litter), WL (woody litter, >5 mm (~1/4 in) diameter).

Unknown Species Codes:
AF# = annual forb
PF# = perennial forb
AG# = annual graminoid
PG# = perennial graminoid
SH# = shrub
TR# = tree

Soil Surface (do not use litter): Species Code (for basal intercept)
R = rock fragment (>5 mm (~1/4 in) diameter)
BR = bedrock, M = moss
LC = visible lichen crust on soil
S = soil without any other soil surface code
EL = embedded litter (see page 10)
D = duff

**Bare ground occurs ONLY when Top canopy = NONE, Lower canopy layers are empty (no L), and Soil surface = S.*

Refer to "Monitoring Quick Links" at http://usda-ars.nmsu.edu/Monit_Assess/monitoring.htm for updates.

Line-Point Intercept Indicator Calculations

You must fill in all applicable yellow cells. Fill in Lower Canopy Layer cells where appropriate.

Page 1 of 1 Observer EK/SMJ *Gray cells for indicator calculations*

Plot TMC MP2 Line 2 Recorder EK Line Length 50 m or ft? m

Direction 55 Date 03/28/14 (mm/dd/yyyy) Intercept (Point) Spacing Interval 100 cm or in? cm

Pt.	Top Canopy	Lower Canopy Layers Code1	Code2	Code3	Code4	Soil Surface	Pt.	Top Canopy	Lower Canopy Layers Code1	Code2	Code3	Soil Surface
1	None	None	None	None	None	R	26	223	G-02	None	L	S
2	None	None	None	None	None	S	27	None	None	None	None	TC
3	122	168	None	None	None	TC	28	None	None	None	None	TC
4	104	G-01	None	None	None	TC	29	223	104	None	L	TC
5	None	None	None	None	None	S	30	None	None	None	None	TC
6	122	104	SLD	168	L	S	31	FT	104	None	None	S
7	223	CP-1	122	None	None	S	32	223	104	None	None	TC
8	122	223	None	None	None	TC	33	104	None	None	None	TC
9	BUD-1	None	None	None	None	S	34	223	104	None	None	TC
10	122	223	None	None	L	S	35	104	G-02	None	None	TC
11	104	TH-1	None	None	None	S	36	None	None	None	None	TC
12	122	G-02	None	None	None	S	37	122	None	None	None	TC
13	SLD	223	None	None	None	S	38	SLD	223	None	L	S
14	223	None	None	None	None	S	39	223	None	None	None	TC
15	223	104	None	None	L	S	40	None	None	None	None	TC
16	None	None	None	None	None	S	41	None	None	None	None	TC
17	None	None	None	None	None	S	42	None	None	None	None	TC
18	G-02	None	None	None	None	TC	43	None	None	None	None	TC
19	223	None	None	None	None	S	44	SLD	223	None	None	S
20	G-02	None	None	None	None	TC	45	223	None	None	None	TC
21	122	104	FISH	G-02	223	S	46	SLD	None	None	None	TC
22	122	104	223	None	L	S	47	223	104	None	None	TC
23	122	None	None	None	None	S	48	223	None	None	None	TC
24	122	104	G-01	None	L	S	49	104	None	None	None	TC
25	None	None	None	None	None	S	50	None	None	None	None	TC

% canopy cover = 70

% bare ground = 0

% basal cover = 0

% litter = 0

Notes:

TC = Tarcrete
Only percent canopy cover has been calculated.

Top canopy codes: Species code, common name, or NONE (no canopy).

Lower canopy layers codes: Species code, common name, L (herbaceous litter), WL (woody litter, >5 mm (~1/4 in) diameter).

Unknown Species Codes:
AF# = annual forb
PF# = perennial forb
AG# = annual graminoid
PG# = perennial graminoid
SH# = shrub
TR# = tree

Soil Surface (do not use litter):
Species Code (for basal intercept)
R = rock fragment (>5 mm (~1/4 in) diameter)
BR = bedrock, M = moss
LC = visible lichen crust on soil
S = soil without any other soil surface code
EL = embedded litter (see page 10)
D = duff

**Bare ground occurs ONLY when Top canopy = NONE, Lower canopy layers are empty (no L), and Soil surface = S.*

Refer to "Monitoring Quick Links" at http://usda-ars.nmsu.edu/Monit_Assess/monitoring.htm for updates.

Line-Point Intercept Indicator Calculations

You must fill in all applicable yellow cells. Fill in Lower Canopy Layer cells where appropriate.

Page 1 of 1 Observer EK/SMJ *Gray cells for indicator calculations*

Plot TMC MP2 Line 3 Recorder EK Line Length 50 m or ft? m

Direction 165 Date 03/28/14 (mm/dd/yyyy) Intercept (Point) Spacing Interval 100 cm or in? cm

Pt.	Top Canopy	Lower Canopy Layers Code1	Code2	Code3	Soil Surface	Pt.	Top Canopy	Lower Canopy Layers Code1	Code2	Code3	Soil Surface
1	223	None	None	None	S	26	None	None	None	None	S
2	223	FT	None	None	TC	27	None	None	None	None	S
3	None	None	None	None	S	28	122	G-02	None	L	S
4	None	None	None	None	TC	29	122	G-01	None	None	S
5	223	104	None	None	S	30	G-02	None	None	None	S
6	223	G-02	None	None	S	31	None	None	None	None	S
7	223	None	None	None	S	32	G-02	None	None	None	S
8	223	104	None	None	TC	33	None	None	None	None	TC
9	None	None	None	None	S	34	None	None	None	None	S
10	None	None	None	None	TC	35	G-01	None	None	None	TC
11	223	104	None	None	TC	36	223	None	None	None	S
12	223	None	None	None	TC	37	SB-01	None	None	None	S
13	223	G-02	None	None	TC	38	None	None	None	None	S
14	223	None	None	None	TC	39	None	None	None	None	TC
15	None	None	None	None	TC	40	None	None	None	None	TC
16	None	None	None	None	TC	41	None	None	None	None	TC
17	223	104	None	L	S	42	None	None	None	None	TC
18	G-02	None	None	None	TC	43	LYD	None	None	None	S
19	G-02	104	None	WL	S	44	None	None	None	None	TC
20	G-02	104	223	WL	S	45	None	None	None	None	TC
21	None	None	None	None	S	46	104	G-01	None	L	S
22	None	None	None	None	TC	47	223	104	None	None	S
23	168	None	None	None	S	48	None	None	None	None	S
24	104	None	None	None	S	49	None	None	None	None	TC
25	SLD	122	223	BUD	S	50	G-01	None	None	None	TC

% canopy cover = 56

% bare ground = 0

% basal cover = 0

% litter = 0

Notes: TC = Tarcrete
Only percent canopy cover has been calculated.

Top canopy codes: Species code, common name, or NONE (no canopy).

Lower canopy layers codes: Species code, common name, L (herbaceous litter), WL (woody litter, >5 mm (~1/4 in) diameter).

Unknown Species Codes:
AF# = annual forb
PF# = perennial forb
AG# = annual graminoid
PG# = perennial graminoid
SH# = shrub
TR# = tree

Soil Surface (do not use litter):
Species Code (for basal intercept)
R = rock fragment (>5 mm (~1/4 in) diameter)
BR = bedrock, M = moss
LC = visible lichen crust on soil
S = soil without any other soil surface code
EL = embedded litter (see page 10)
D = duff

**Bare ground occurs ONLY when Top canopy = NONE, Lower canopy layers are empty (no L), and Soil surface = S.*

TMC-MP3

TMC-MP03 LINE01 265Deg



TMC-MP03 LINE01 85Deg



TMC-MP03 LINE02 145Deg



TMC-MP03 LINE02 325Deg



TMC-MP03 LINE03 25Deg



TMC-MP03 LINE03 205Deg



Refer to "Monitoring Quick Links" at http://usda-ars.nmsu.edu/Monit_Assess/monitoring.htm for updates.

Line-Point Intercept Indicator Calculations

You must fill in all applicable yellow cells. Fill in Lower Canopy Layer cells where appropriate.

Page 1 of 1 Observer EK/SMJ *Gray cells for indicator calculations*

Plot TMC MP3 Line 1 Recorder EK Line Length 50 m or ft? m

Direction 265 Date 03/28/14 (mm/dd/yyyy) Intercept (Point) Spacing Interval 100 cm or in? cm

Pt.	Top Canopy	Lower Canopy Layers Code1	Code2	Code3	Soil Surface	Pt.	Top Canopy	Lower Canopy Layers Code1	Code2	Code3	Soil Surface
1	104	NONE	NONE	NONE	S	26	NONE	NONE	NONE	NONE	TC
2	NONE	NONE	NONE	NONE	TC	27	168	104	NONE	NONE	TC
3	G-01	122	168	NONE	TC	28	G-02	SLD	223	NONE	S
4	NONE	NONE	NONE	NONE	TC	29	122	104	NONE	L	S
5	104	NONE	NONE	NONE	TC	30	104	168	G-01	L	S
6	NONE	NONE	NONE	NONE	TC	31	168	104	223	NONE	S
7	122	104	NONE	NONE	TC	32	G-01	168	NONE	NONE	S
8	104	223	NONE	NONE	TC	33	104	G-02	NONE	NONE	S
9	104	NONE	NONE	NONE	TC	34	G-01	G-02	NONE	NONE	S
10	NONE	NONE	NONE	NONE	TC	35	223	NONE	NONE	NONE	TC
11	122	104	NONE	NONE	TC	36	NONE	NONE	NONE	NONE	TC
12	122	104	NONE	NONE	TC	37	104	G-01	NONE	L	S
13	104	NONE	NONE	NONE	TC	38	223	104	NONE	WL	S
14	122	104	NONE	NONE	S	39	G-02	223	NONE	NONE	TC
15	223	NONE	NONE	NONE	S	40	223	104	NONE	NONE	TC
16	NONE	NONE	NONE	NONE	TC	41	223	NONE	NONE	NONE	TC
17	168	G-01	104	NONE	TC	42	G-02	NONE	NONE	NONE	TC
18	NONE	NONE	NONE	NONE	TC	43	223	G-02	NONE	NONE	TC
19	NONE	NONE	NONE	NONE	TC	44	122	G-01	NONE	NONE	TC
20	NONE	NONE	NONE	NONE	TC	45	223	104	NONE	NONE	TC
21	104	NONE	NONE	NONE	TC	46	G-02	NONE	NONE	NONE	TC
22	104	NONE	NONE	NONE	TC	47	NONE	NONE	NONE	NONE	TC
23	SLD	NONE	NONE	NONE	TC	48	NONE	NONE	NONE	NONE	TC
24	G-02	104	NONE	NONE	TC	49	223	104	NONE	NONE	TC
25	G-02	G-01	104	TH-2	TC	50	223	G-02	104	NONE	S

% canopy cover = 76

% bare ground = 0

% basal cover = 0

% litter = 0

Notes: TC = Tarcrete
Only percent canopy cover has been calculated.

Top canopy codes: Species code, common name, or NONE (no canopy).

Lower canopy layers codes: Species code, common name, L (herbaceous litter), WL (woody litter, >5 mm (~1/4 in) diameter).

Unknown Species Codes:
AF# = annual forb
PF# = perennial forb
AG# = annual graminoid
PG# = perennial graminoid
SH# = shrub
TR# = tree

Soil Surface (do not use litter):
Species Code (for basal intercept)
R = rock fragment (>5 mm (~1/4 in) diameter)
BR = bedrock, M = moss
LC = visible lichen crust on soil
S = soil without any other soil surface code
EL = embedded litter (see page 10)
D = duff

**Bare ground occurs ONLY when Top canopy = NONE, Lower canopy layers are empty (no L), and Soil surface = S.*

Refer to "Monitoring Quick Links" at http://usda-ars.nmsu.edu/Monit_Assess/monitoring.htm for updates.

Line-Point Intercept Indicator Calculations

You must fill in all applicable yellow cells. Fill in Lower Canopy Layer cells where appropriate.

Page 1 of 1 Observer EK/SMJ *Gray cells for indicator calculations*

Plot TMC MP3 Line 2 Recorder EK Line Length 50 m or ft? m

Direction 145 Date 03/28/14 (mm/dd/yyyy) Intercept (Point) Spacing Interval 100 cm or in? cm

Pt.	Top Canopy	Lower Canopy Layers Code1	Code2	Code3	Soil Surface	Pt.	Top Canopy	Lower Canopy Layers Code1	Code2	Code3	Soil Surface
1	122	None	None	None	TC	26	104	None	None	None	TC
2	122	104	None	None	S	27	104	None	None	None	TC
3	104	None	None	None	S	28	None	None	None	None	TC
4	None	None	None	None	S	29	None	None	None	None	TC
5	168	None	None	None	S	30	None	None	None	L	TC
6	None	None	None	None	S	31	122	None	None	None	S
7	104	None	None	None	S	32	None	None	None	None	S
8	104	None	None	None	S	33	168	None	None	None	S
9	None	None	None	None	S	34	104	168	G-01	L	S
10	None	None	None	None	S	35	104	None	None	None	TC
11	223	104	None	None	S	36	None	None	None	None	TC
12	G-01	None	None	None	TC	37	122	G-02	None	None	TC
13	G-01	104	None	None	TC	38	None	None	None	None	TC
14	104	None	None	None	S	39	104	None	None	None	TC
15	122	SLD	104	L	S	40	None	None	None	None	TC
16	104	None	None	None	S	41	223	104	None	None	TC
17	None	None	None	None	TC	42	None	None	None	None	TC
18	None	None	None	None	TC	43	None	None	None	None	TC
19	None	None	None	None	TC	44	223	104	None	None	TC
20	None	None	None	None	TC	45	G-01	None	None	None	TC
21	104	None	None	None	TC	46	223	None	None	None	TC
22	None	None	None	None	TC	47	223	None	None	None	TC
23	None	None	None	None	S	48	None	None	None	None	TC
24	SLD	104	None	None	S	49	None	None	None	None	TC
25	None	None	None	None	S	50	223	None	None	None	TC

% canopy cover = 56

% bare ground = 0

% basal cover = 0

% litter = 0

Notes: TC = Tarcrete
Only percent canopy cover has been calculated.

Top canopy codes: Species code, common name, or NONE (no canopy).

Lower canopy layers codes: Species code, common name, L (herbaceous litter), WL (woody litter, >5 mm (~1/4 in) diameter).

Unknown Species Codes:
AF# = annual forb
PF# = perennial forb
AG# = annual graminoid
PG# = perennial graminoid
SH# = shrub
TR# = tree

Soil Surface (do not use litter):
Species Code (for basal intercept)
R = rock fragment (>5 mm (~1/4 in) diameter)
BR = bedrock, M = moss
LC = visible lichen crust on soil
S = soil without any other soil surface code
EL = embedded litter (see page 10)
D = duff

**Bare ground occurs ONLY when Top canopy = NONE, Lower canopy layers are empty (no L), and Soil surface = S.*

Refer to "Monitoring Quick Links" at http://usda-ars.nmsu.edu/Monit_Assess/monitoring.htm for updates.

Line-Point Intercept Indicator Calculations

You must fill in all applicable yellow cells. Fill in Lower Canopy Layer cells where appropriate.

Page 1 of 1 Observer EK/SMJ *Gray cells for indicator calculations*

Plot TMC MP3 Line 3 Recorder EK Line Length 50 m or ft? m

Direction 25 Date 03/28/14 (mm/dd/yyyy) Intercept (Point) Spacing Interval 100 cm or in? cm

Pt.	Top Canopy	Lower Canopy Layers Code1	Code2	Code3	Soil Surface	Pt.	Top Canopy	Lower Canopy Layers Code1	Code2	Code3	Soil Surface
1	None	None	None	None	S	26	None	None	None	None	TC
2	None	None	None	None	S	27	104	None	None	None	TC
3	None	None	None	None	S	28	223	None	None	None	TC
4	None	None	None	None	S	29	None	None	None	None	TC
5	None	None	None	None	S	30	None	None	None	None	TC
6	None	None	None	None	S	31	None	None	None	None	TC
7	None	None	None	None	S	32	104	None	None	None	TC
8	None	None	None	None	S	33	None	None	None	None	TC
9	None	None	None	None	S	34	104	None	None	None	TC
10	None	None	None	None	S	35	104	None	None	None	TC
11	None	None	None	None	S	36	168	None	None	None	TC
12	104	None	None	None	TC	37	104	None	None	None	TC
13	104	None	None	None	TC	38	SLD	None	None	None	TC
14	122	104	None	L	TC	39	104	None	None	W	S
15	G-02	None	None	None	TC	40	None	None	None	None	TC
16	122	None	None	None	TC	41	None	None	None	None	TC
17	104	G-01	None	None	TC	42	122	104	G-01	None	TC
18	G-01	None	None	None	TC	43	104	None	None	None	S
19	122	104	None	L	S	44	None	None	None	None	TC
20	104	None	None	None	TC	45	104	TH-2	None	L	S
21	168	None	None	None	TC	46	G-02	SLD	None	L	S
22	104	None	None	None	TC	47	104	None	None	None	TC
23	None	None	None	None	TC	48	104	223	None	None	TC
24	104	None	None	None	TC	49	223	None	None	None	TC
25	104	None	None	L	TC	50	104	G-01	None	None	TC

% canopy cover = 60

% bare ground = 0

% basal cover = 0

% litter = 0

Notes: TC = Tarcrete
Only percent canopy cover has been calculated.

Top canopy codes: Species code, common name, or NONE (no canopy).

Lower canopy layers codes: Species code, common name, L (herbaceous litter), WL (woody litter, >5 mm (~1/4 in) diameter).

Unknown Species Codes:
AF# = annual forb
PF# = perennial forb
AG# = annual graminoid
PG# = perennial graminoid
SH# = shrub
TR# = tree

Soil Surface (do not use litter):
Species Code (for basal intercept)
R = rock fragment (>5 mm (~1/4 in) diameter)
BR = bedrock, M = moss
LC = visible lichen crust on soil
S = soil without any other soil surface code
EL = embedded litter (see page 10)
D = duff

**Bare ground occurs ONLY when Top canopy = NONE, Lower canopy layers are empty (no L), and Soil surface = S.*

TMD-MP1

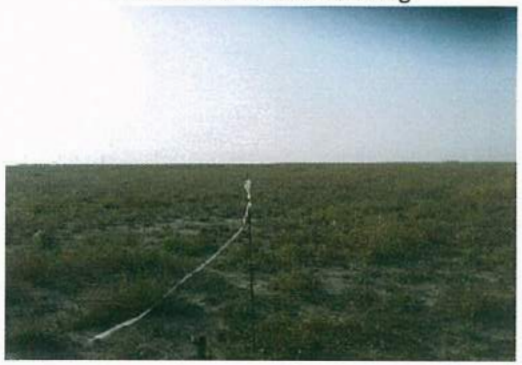
TMD-MP01 LINE01 120Deg



TMD-MP01 LINE01 300Deg



TMD-MP01 LINE01 300Deg



TMD-MP01 LINE02 42Deg



TMD-MP01 LINE02 222Deg



TMD-MP01 LINE03 120Deg



TMD-MP01 LINE03 002Deg



TMD-MP01 LINE03 182Deg



Refer to "Monitoring Quick Links" at http://usda-ars.nmsu.edu/Monit_Assess/monitoring.htm for updates.

Line-Point Intercept Indicator Calculations

You must fill in all applicable yellow cells. Fill in Lower Canopy Layer cells where appropriate.

Page 1 of 1 Observer EK/SMJ *Gray cells for indicator calculations*

Plot TMD MP1 Line 1 Recorder EK Line Length 50 m or ft? m

Direction 300 Date 03/22/14 (mm/dd/yyyy) Intercept (Point) Spacing Interval 100 cm or in? cm

Pt.	Top Canopy	Lower Canopy Layers Code1	Code2	Code3	Soil Surface	Pt.	Top Canopy	Lower Canopy Layers Code1	Code2	Code3	Soil Surface
1	None	None	None	None	S	26	104	168	None	L	S
2	104	168	None	None	S	27	122	168	None	L	S
3	None	None	None	None	S	28	104	None	None	None	S
4	None	None	None	None	S	29	168	104	None	None	S
5	168	168	None	None	S	30	168	None	None	L	S
6	168	168	None	None	S	31	168	TH-1	None	None	S
7	168	104	None	L	S	32	168	104	None	L	S
8	None	None	None	None	TC	33	104	168	None	L	S
9	168	None	None	None	S	34	SLD	168	104	None	S
10	168	168	None	L	S	35	168	223	None	None	S
11	None	None	None	L	S	36	None	None	None	None	S
12	None	None	None	L	S	37	168	104	None	None	S
13	104	None	None	L	S	38	168	G-01	None	None	S
14	None	None	None	L	S	39	168	168	None	None	S
15	104	None	None	None	S	40	None	None	None	None	TC
16	104	None	None	None	TC	41	None	None	None	None	TC
17	None	None	None	None	S	42	G-01	None	None	None	TC
18	168	None	None	L	S	43	168	None	None	None	S
19	104	None	None	None	S	44	168	None	None	None	S
20	168	None	None	None	S	45	104	168	G-01	None	S
21	104	G-01	None	L	S	46	104	168	None	None	S
22	122	168	None	None	TC	47	168	BUD-1	None	None	S
23	122	None	None	None	S	48	G-02	G-01	104	L	S
24	168	None	None	None	S	49	122	168	104	None	TC
25	168	None	None	None	S	50	None	None	None	None	S

% canopy cover = 76

% bare ground = 0

% basal cover = 0

% litter = 0

Notes: TC = Tarcrete
Only percent canopy cover has been calculated

Top canopy codes: Species code, common name, or NONE (no canopy).

Lower canopy layers codes: Species code, common name, L (herbaceous litter), WL (woody litter, >5 mm (~1/4 in) diameter).

Unknown Species Codes:
AF# = annual forb
PF# = perennial forb
AG# = annual graminoid
PG# = perennial graminoid
SH# = shrub
TR# = tree

Soil Surface (do not use litter):
Species Code (for basal intercept)
R = rock fragment (>5 mm (~1/4 in) diameter)
BR = bedrock, M = moss
LC = visible lichen crust on soil
S = soil without any other soil surface code
EL = embedded litter (see page 10)
D = duff

**Bare ground occurs ONLY when Top canopy = NONE, Lower canopy layers are empty (no L), and Soil surface = S.*

Refer to "Monitoring Quick Links" at http://usda-ars.nmsu.edu/Monit_Assess/monitoring.htm for updates.

Line-Point Intercept Indicator Calculations

You must fill in all applicable yellow cells. Fill in Lower Canopy Layer cells where appropriate.

Page 1 of 1 Observer EKSMJ *Gray cells for indicator calculations*

Plot TMD MP1 Line 2 Recorder EK Line Length 50 m or ft? m

Direction 42 Date 03/28/14 (mm/dd/yyyy) Intercept (Point) Spacing Interval 100 cm or in? cm

Pt.	Top Canopy	Lower Canopy Layers Code1	Code2	Code3	Soil Surface	Pt.	Top Canopy	Lower Canopy Layers Code1	Code2	Code3	Code4	Soil Surface
1	TH-2	None	None	None	TC	26	168	None	None	None	None	S
2	None	None	None	None	S	27	104	168	None	L	None	S
3	None	None	None	None	S	28	None	None	None	None	None	S
4	None	None	None	None	S	29	122	168	G-01	104	L	S
5	YF1	None	None	None	S	30	168	LYP	None	L	None	S
6	None	None	None	None	S	31	None	None	None	L	None	S
7	SLD	223	168	None	S	32	None	None	None	None	None	S
8	G-01	None	None	None	S	33	122	168	None	L	None	S
9	104	168	None	None	S	34	SLD	None	None	None	None	S
10	None	None	None	None	S	35	None	None	None	None	None	S
11	168	None	None	None	S	36	122	104	None	L	None	S
12	104	168	None	None	S	37	168	None	None	L	None	S
13	SLD	168	None	None	S	38	168	G-01	104	L	None	S
14	122	168	104	None	S	39	104	168	G-01	None	None	S
15	YF1	None	None	None	S	40	None	None	None	L	None	S
16	122	SLD	168	None	S	41	None	None	None	None	None	S
17	122	223	G-01	168	L	42	168	None	None	None	None	S
18	122	None	None	None	S	43	None	None	None	None	None	TC
19	122	None	None	None	S	44	None	None	None	None	None	TC
20	None	None	None	None	S	45	168	None	None	L	None	S
21	None	None	None	None	S	46	104	168	None	None	None	S
22	SLD	None	None	None	S	47	None	None	None	None	None	TC
23	122	104	None	L	S	48	None	None	None	None	None	TC
24	122	None	None	L	S	49	None	None	None	None	None	S
25	SLD	None	None	L	S	50	None	None	None	None	None	S

% canopy cover = 62

% bare ground = 0

% basal cover = 0

% litter = 0

Notes: TC = Tarcrete
Only percent canopy cover has been calculated.

Top canopy codes: Species code, common name, or NONE (no canopy).

Lower canopy layers codes: Species code, common name, L (herbaceous litter), WL (woody litter, >5 mm (~1/4 in) diameter).

Unknown Species Codes:
AF# = annual forb
PF# = perennial forb
AG# = annual graminoid
PG# = perennial graminoid
SH# = shrub
TR# = tree

Soil Surface (do not use litter):
Species Code (for basal intercept)
R = rock fragment (>5 mm (~1/4 in) diameter)
BR = bedrock, M = moss
LC = visible lichen crust on soil
S = soil without any other soil surface code
EL = embedded litter (see page 10)
D = duff

**Bare ground occurs ONLY when Top canopy = NONE, Lower canopy layers are empty (no L), and Soil surface = S.*

Refer to "Monitoring Quick Links" at http://usda-ars.nmsu.edu/Monit_Assess/monitoring.htm for updates.

Line-Point Intercept Indicator Calculations

You must fill in all applicable yellow cells. Fill in Lower Canopy Layer cells where appropriate.

Page 1 of 1 Observer EK/SMJ *Gray cells for indicator calculations*

Plot TMD MP1 Line 3 Recorder EK Line Length 50 m or ft? m

Direction 182 Date 03/28/14 (mm/dd/yyyy) Intercept (Point) Spacing Interval 100 cm or in? cm

Pt.	Top Canopy	Lower Canopy Layers Code1	Code2	Code3	Soil Surface	Pt.	Top Canopy	Lower Canopy Layers Code1	Code2	Code3	Soil Surface
1	None	None	None	None	S	26	168	G-01	None	None	TC
2	104	None	None	None	S	27	G-01	None	None	None	TC
3	None	None	None	None	S	28	168	None	None	None	TC
4	None	None	None	L	S	29	None	None	None	None	TC
5	G-01	None	None	None	S	30	None	None	None	None	S
6	122	None	None	None	S	31	None	None	None	None	TC
7	104	None	None	None	TC	32	None	None	None	None	S
8	SLD	None	None	None	S	33	None	None	None	None	S
9	None	None	None	None	S	34	122	104	G-01	L	S
10	None	None	None	None	S	35	122	None	None	None	S
11	None	None	None	None	S	36	122	104	G-01	L	S
12	104	None	None	L	S	37	122	None	None	L	S
13	G-01	None	None	L	S	38	122	None	None	L	S
14	168	None	None	None	S	39	122	None	None	L	S
15	122	None	None	None	S	40	None	None	None	L	S
16	SLD	None	None	L	S	41	122	None	None	L	S
17	223	G-01	104	L	S	42	G-01	None	None	L	S
18	SLD	None	None	L	S	43	122	168	None	L	S
19	168	G-01	None	L	S	44	104	168	None	L	S
20	None	None	None	L	S	45	122	None	None	None	S
21	122	168	None	None	S	46	None	None	None	None	TC
22	122	104	168	SLD	S	47	168	None	None	None	S
23	None	None	None	None	TC	48	122	168	G-01	L	S
24	104	G-01	None	None	TC	49	None	None	None	None	TC
25	122	104	G-01	None	S	50	G-01	None	None	None	S

% canopy cover = 68

% bare ground = 0

% basal cover = 0

% litter = 0

Notes: TC = Tarcrete
Only percent canopy cover has been calculated.

Top canopy codes: Species code, common name, or NONE (no canopy).

Lower canopy layers codes: Species code, common name, L (herbaceous litter), WL (woody litter, >5 mm (~1/4 in) diameter).

Unknown Species Codes:
AF# = annual forb
PF# = perennial forb
AG# = annual graminoid
PG# = perennial graminoid
SH# = shrub
TR# = tree

Soil Surface (do not use litter):
Species Code (for basal intercept)
R = rock fragment (>5 mm (~1/4 in) diameter)
BR = bedrock, M = moss
LC = visible lichen crust on soil
S = soil without any other soil surface code
EL = embedded litter (see page 10)
D = duff

**Bare ground occurs ONLY when Top canopy = NONE, Lower canopy layers are empty (no L), and Soil surface = S.*

TMD-MP2

TMD-MP02 LINE01 340Deg



TMD-MP02 LINE01 160Deg



TMD-MP02 LINE02 020Deg



TMD-MP02 LINE02 200Deg



TMD-MP02 LINE03 040Deg



TMD-MP02 LINE03 220Deg



Refer to "Monitoring Quick Links" at http://usda-ars.nmsu.edu/Monit_Assess/monitoring.htm for updates.

Line-Point Intercept Indicator Calculations

You must fill in all applicable yellow cells. Fill in Lower Canopy Layer cells where appropriate.

Page 1 of 1 Observer EK/SMJ *Gray cells for indicator calculations*

Plot TMD MP2 Line 1 Recorder EK Line Length 50 m or ft? m

Direction 340 Date 04/04/2014 (mm/dd/yyyy) Intercept (Point) Spacing Interval 100 cm or in? cm

Pt.	Top Canopy	Lower Canopy Layers Code1	Code2	Code3	Soil Surface	Pt.	Top Canopy	Lower Canopy Layers Code1	Code2	Code3	Soil Surface
1	104	223	None	None	TC	26	223	None	None	None	TC
2	223	SPS	None	None	TC	27	G-02	None	None	None	TC
3	None	None	None	None	TC	28	SPS	223	None	None	TC
4	SB-01	104	None	None	TC	29	None	None	None	None	TC
5	None	None	None	None	TC	30	None	None	None	None	TC
6	G-02	None	None	None	TC	31	None	None	None	None	TC
7	TH-1	None	None	None	TC	32	G-02	None	None	None	TC
8	104	None	None	None	TC	33	104	LYD	None	None	TC
9	None	None	None	None	TC	34	None	None	None	None	TC
10	104	G-01	None	None	TC	35	LYD	None	None	None	TC
11	G-01	None	None	None	TC	36	None	None	None	None	TC
12	G-02	SPS	104	None	TC	37	G-02	None	None	None	TC
13	None	None	None	None	TC	38	104	None	None	None	S
14	SLD	None	None	None	TC	39	223	G-01	None	None	TC
15	None	None	None	None	TC	40	None	None	None	None	TC
16	None	None	None	None	TC	41	223	None	None	None	TC
17	None	None	None	None	TC	42	223	None	None	None	TC
18	G-02	None	None	None	TC	43	None	None	None	None	TC
19	223	104	SPS	None	TC	44	G-01	None	None	None	TC
20	None	None	None	None	TC	45	None	None	None	None	TC
21	None	None	None	None	TC	46	None	None	None	None	TC
22	SLD	FISH	G-01	None	TC	47	None	None	None	None	TC
23	104	None	None	None	TC	48	None	None	None	None	TC
24	G-02	None	None	WL	TC	49	None	None	None	None	TC
25	None	None	None	None	TC	50	None	None	None	None	TC

% canopy cover = 54

% bare ground = 0

% basal cover = 0

% litter = 0

Notes: TC = Tarcrete
Only percent canopy has been calculated

Top canopy codes: Species code, common name, or NONE (no canopy).

Lower canopy layers codes: Species code, common name, L (herbaceous litter), WL (woody litter, >5 mm (~1/4 in) diameter).

Unknown Species Codes:
AF# = annual forb
PF# = perennial forb
AG# = annual graminoid
PG# = perennial graminoid
SH# = shrub
TR# = tree

Soil Surface (do not use litter):
Species Code (for basal intercept)
R = rock fragment (>5 mm (~1/4 in) diameter)
BR = bedrock, M = moss
LC = visible lichen crust on soil
S = soil without any other soil surface code
EL = embedded litter (see page 10)
D = duff

**Bare ground occurs ONLY when Top canopy = NONE, Lower canopy layers are empty (no L), and Soil surface = S.*

Refer to "Monitoring Quick Links" at http://usda-ars.nmsu.edu/Monit_Assess/monitoring.htm for updates.

Line-Point Intercept Indicator Calculations

You must fill in all applicable yellow cells. Fill in Lower Canopy Layer cells where appropriate.

Page 1 of 1 Observer EK/SMJ *Gray cells for indicator calculations*

Plot TMD MP2 Line 2 Recorder EK Line Length 50 m or ft? m

Direction 220 Date 04/04/2014 (mm/dd/yyyy) Intercept (Point) Spacing Interval 100 cm or in? cm

Pt.	Top Canopy	Lower Canopy Layers Code1	Code2	Code3	Soil Surface	Pt.	Top Canopy	Lower Canopy Layers Code1	Code2	Code3	Soil Surface
1	None	None	None	None	TC	26	SB-01	None	None	None	TC
2	None	None	None	None	TC	27	SPS	223	104	None	S
3	None	None	None	None	TC	28	SPS	223	None	L	S
4	None	None	None	None	TC	29	223	None	None	None	S
5	223	LYD	None	L	TC	30	G-01	None	None	None	TC
6	223	SPS	None	None	TC	31	G-01	None	None	None	TC
7	None	None	None	None	TC	32	None	None	None	None	TC
8	None	None	None	None	TC	33	104	223	None	None	TC
9	None	None	None	None	TC	34	223	SPS	104	None	TC
10	223	104	G-01	L	TC	35	G-02	122	None	None	TC
11	223	None	None	None	TC	36	223	104	None	None	TC
12	G-01	None	None	None	TC	37	104	None	None	None	TC
13	G-01	None	None	None	TC	38	223	104	None	None	TC
14	G-01	None	None	None	TC	39	104	None	None	None	TC
15	None	None	None	None	TC	40	None	None	None	None	TC
16	None	None	None	None	TC	41	G-01	None	None	None	TC
17	G-01	None	None	None	TC	42	None	None	None	None	TC
18	None	None	None	None	TC	43	None	None	None	None	TC
19	223	None	None	None	TC	44	104	G-01	None	None	TC
20	223	None	None	None	TC	45	None	None	None	None	TC
21	None	None	None	None	TC	46	223	None	None	None	TC
22	G-01	None	None	None	TC	47	None	None	None	None	TC
23	None	None	None	None	TC	48	G-01	None	None	None	TC
24	G-01	None	None	None	TC	49	None	None	None	None	TC
25	None	None	None	None	TC	50	223	None	None	None	TC

% canopy cover = 60

% bare ground = 0

% basal cover = 0

% litter = 0

Notes: TC = Tarcrete
Only percent canopy has been calculated

Top canopy codes: Species code, common name, or NONE (no canopy).

Lower canopy layers codes: Species code, common name, L (herbaceous litter), WL (woody litter, >5 mm (~1/4 in) diameter).

Unknown Species Codes:
AF# = annual forb
PF# = perennial forb
AG# = annual graminoid
PG# = perennial graminoid
SH# = shrub
TR# = tree

Soil Surface (do not use litter):
Species Code (for basal intercept)
R = rock fragment (>5 mm (~1/4 in) diameter)
BR = bedrock, M = moss
LC = visible lichen crust on soil
S = soil without any other soil surface code
EL = embedded litter (see page 10)
D = duff

**Bare ground occurs ONLY when Top canopy = NONE, Lower canopy layers are empty (no L), and Soil surface = S.*

Refer to "Monitoring Quick Links" at http://usda-ars.nmsu.edu/Monit_Assess/monitoring.htm for updates.

Line-Point Intercept Indicator Calculations

You must fill in all applicable yellow cells. Fill in Lower Canopy Layer cells where appropriate.

Page 1 of 1 Observer EK/SMJ *Gray cells for indicator calculations*

Plot TMD MP2 Line 3 Recorder EK Line Length 50 m or ft? m

Direction 40 Date 04/04/2014 (mm/dd/yyyy) Intercept (Point) Spacing Interval 100 cm or in? cm

Pt.	Top Canopy	Lower Canopy Layers Code1	Code2	Code3	Soil Surface	Pt.	Top Canopy	Lower Canopy Layers Code1	Code2	Code3	Soil Surface
1	223	104	None	None	TC	26	223	None	None	None	TC
2	None	None	None	None	TC	27	223	None	None	None	TC
3	None	None	None	None	TC	28	None	None	None	None	TC
4	None	None	None	None	TC	29	None	None	None	None	TC
5	None	None	None	None	TC	30	223	None	None	None	TC
6	G-02	SPS	CP1	None	TC	31	None	None	None	None	TC
7	G-01	None	None	None	TC	32	None	None	None	None	TC
8	223	G-2	None	None	TC	33	G-02	TH1	None	None	TC
9	None	None	None	None	TC	34	G-02	None	None	None	TC
10	G-02	None	None	None	TC	35	104	None	None	None	TC
11	223	None	None	None	TC	36	None	None	None	None	TC
12	G-02	None	None	None	TC	37	None	None	None	None	TC
13	None	None	None	None	TC	38	None	None	None	None	TC
14	None	None	None	None	TC	39	223	None	None	None	TC
15	Fish	None	None	None	TC	40	None	None	None	None	TC
16	None	None	None	None	TC	41	None	None	None	None	TC
17	None	None	None	None	TC	42	223	None	None	None	TC
18	None	None	None	None	TC	43	None	None	None	None	TC
19	None	None	None	None	TC	44	None	None	None	None	TC
20	None	None	None	None	TC	45	SLD	None	None	None	TC
21	None	None	None	None	TC	46	None	None	None	None	TC
22	None	None	None	None	TC	47	None	None	None	None	TC
23	None	None	None	None	TC	48	223	None	None	None	TC
24	None	None	None	None	TC	49	223	None	None	None	TC
25	None	None	None	None	TC	50	223	104	None	None	TC

% canopy cover = 40

% bare ground = 0

% basal cover = 0

% litter = 0

Notes: TC = Tarcrete
Only percent canopy has been calculated

Top canopy codes: Species code, common name, or NONE (no canopy).

Lower canopy layers codes: Species code, common name, L (herbaceous litter), WL (woody litter, >5 mm (~1/4 in) diameter).

Unknown Species Codes:
AF# = annual forb
PF# = perennial forb
AG# = annual graminoid
PG# = perennial graminoid
SH# = shrub
TR# = tree

Soil Surface (do not use litter):
Species Code (for basal intercept)
R = rock fragment (>5 mm (~1/4 in) diameter)
BR = bedrock, M = moss
LC = visible lichen crust on soil
S = soil without any other soil surface code
EL = embedded litter (see page 10)
D = duff

**Bare ground occurs ONLY when Top canopy = NONE, Lower canopy layers are empty (no L), and Soil surface = S.*

TMD-MP3

TMD-MP03 LINE01 120Deg



TMD-MP03 LINE01 300Deg



TMD-MP03 LINE02 00Deg



TMD-MP03 LINE02 180Deg



TMD-MP03 LINE03 40Deg



TMD-MP03 LINE03 220Deg



Refer to "Monitoring Quick Links" at http://usda-ars.nmsu.edu/Monit_Assess/monitoring.htm for updates.

Line-Point Intercept Indicator Calculations

You must fill in all applicable yellow cells. Fill in Lower Canopy Layer cells where appropriate.

Page 1 of 1 Observer EK/SMJ *Gray cells for indicator calculations*

Plot TMD MP3 Line 1 Recorder EK Line Length 50 m or ft? m

Direction 300 Date 04/04/2014 (mm/dd/yyyy) Intercept (Point) Spacing Interval 100 cm or in? cm

Pt.	Top Canopy	Lower Canopy Layers Code1	Code2	Code3	Soil Surface	Pt.	Top Canopy	Lower Canopy Layers Code1	Code2	Code3	Code4	Soil Surface
1	None	None	None	None	TC	26	None	None	None	None	None	TC
2	None	None	None	None	TC	27	104	None	None	None	None	TC
3	None	None	None	None	TC	28	104	G-01	None	None	None	TC
4	None	None	None	None	TC	29	104	None	None	None	None	TC
5	G-01	None	None	None	TC	30	None	None	None	None	None	TC
6	104	None	None	None	TC	31	SLD	G-02	None	None	None	TC
7	None	None	None	None	TC	32	None	None	None	None	None	TC
8	None	None	None	None	TC	33	None	None	None	None	None	TC
9	104	None	None	None	TC	34	None	None	None	None	None	TC
10	None	None	None	None	TC	35	None	None	None	None	None	TC
11	None	None	None	None	TC	36	122	104	None	None	None	TC
12	None	None	None	None	TC	37	SLD	None	None	None	None	TC
13	168	None	None	None	TC	38	104	None	None	None	None	TC
14	SPS	SLD	104	None	S	39	G-01	None	None	None	None	TC
15	104	SLD	G-01	168	S	40	None	None	None	None	None	TC
16	104	None	None	None	S	41	None	None	None	None	None	TC
17	122	104	None	L	S	42	None	None	None	None	None	TC
18	None	None	None	WL	S	43	SPS	104	G-02	STH	L	TC
19	None	None	None	L	S	44	None	None	None	None	None	TC
20	None	None	None	None	TC	45	None	None	None	None	None	TC
21	G-01	None	None	None	TC	46	None	None	None	None	None	TC
22	None	None	None	None	TC	47	None	None	None	None	None	TC
23	None	None	None	None	TC	48	None	None	None	None	None	TC
24	None	None	None	None	TC	49	None	None	None	None	None	TC
25	None	None	None	None	TC	50	SLD	None	None	None	None	TC

% canopy cover = 38

% bare ground = 0

% basal cover = 0

% litter = 0

Notes: TC = Tarcrete
Only percent canopy has been calculated

Top canopy codes: Species code, common name, or NONE (no canopy).

Lower canopy layers codes: Species code, common name, L (herbaceous litter), WL (woody litter, >5 mm (~1/4 in) diameter).

Unknown Species Codes:
AF# = annual forb
PF# = perennial forb
AG# = annual graminoid
PG# = perennial graminoid
SH# = shrub
TR# = tree

Soil Surface (do not use litter):
Species Code (for basal intercept)
R = rock fragment (>5 mm (~1/4 in) diameter)
BR = bedrock, M = moss
LC = visible lichen crust on soil
S = soil without any other soil surface code
EL = embedded litter (see page 10)
D = duff

**Bare ground occurs ONLY when Top canopy = NONE, Lower canopy layers are empty (no L), and Soil surface = S.*

Refer to "Monitoring Quick Links" at http://usda-ars.nmsu.edu/Monit_Assess/monitoring.htm for updates.

Line-Point Intercept Indicator Calculations

You must fill in all applicable yellow cells. Fill in Lower Canopy Layer cells where appropriate.

Page 1 of 1 Observer EK/SMJ *Gray cells for indicator calculations*

Plot TMD MP3 Line 2 Recorder EK Line Length 50 m or ft? m

Direction 180 Date 04/04/2014 (mm/dd/yyyy) Intercept (Point) Spacing Interval 100 cm or in? cm

Pt.	Top Canopy	Lower Canopy Layers Code1	Code2	Code3	Soil Surface	Pt.	Top Canopy	Lower Canopy Layers Code1	Code2	Code3	Soil Surface
1	223	None	None	None	TC	26	None	None	None	None	TC
2	None	None	None	None	TC	27	None	None	None	None	TC
3	104	None	None	None	TC	28	SLD	None	None	L	TC
4	104	None	None	None	TC	29	G-01	None	None	None	TC
5	None	None	None	None	TC	30	122	SLD	104	None	TC
6	None	None	None	None	TC	31	None	None	None	None	TC
7	None	None	None	None	TC	32	None	None	None	None	TC
8	104	None	None	None	TC	33	SLD	None	None	None	TC
9	None	None	None	None	S	34	SLD	None	None	L	TC
10	104	None	None	None	TC	35	None	None	None	None	TC
11	104	None	None	None	TC	36	None	None	None	None	TC
12	None	None	None	None	TC	37	SLD	168	104	L	TC
13	None	None	None	None	TC	38	168	G-02	None	None	TC
14	104	None	None	L	TC	39	104	G-01	None	None	TC
15	None	None	None	L	S	40	None	None	None	None	TC
16	G-01	None	None	None	TC	41	None	None	None	None	TC
17	None	None	None	None	TC	42	104	None	None	None	TC
18	None	None	None	None	TC	43	None	None	None	None	TC
19	223	None	None	None	TC	44	None	None	None	None	TC
20	None	None	None	None	TC	45	None	None	None	None	TC
21	None	None	None	None	TC	46	None	None	None	None	TC
22	122	168	None	None	TC	47	None	None	None	None	TC
23	None	None	None	None	TC	48	None	None	None	WL	S
24	104	None	None	None	TC	49	None	None	None	None	S
25	None	None	None	None	TC	50	None	None	None	None	S

% canopy cover = 40

% bare ground = 0

% basal cover = 0

% litter = 0

Notes: TC = Tarcrete
Only percent canopy has been calculated

Top canopy codes: Species code, common name, or NONE (no canopy).

Lower canopy layers codes: Species code, common name, L (herbaceous litter), WL (woody litter, >5 mm (~1/4 in) diameter).

Unknown Species Codes:
AF# = annual forb
PF# = perennial forb
AG# = annual graminoid
PG# = perennial graminoid
SH# = shrub
TR# = tree

Soil Surface (do not use litter):
Species Code (for basal intercept)
R = rock fragment (>5 mm (~1/4 in) diameter)
BR = bedrock, M = moss
LC = visible lichen crust on soil
S = soil without any other soil surface code
EL = embedded litter (see page 10)
D = duff

**Bare ground occurs ONLY when Top canopy = NONE, Lower canopy layers are empty (no L), and Soil surface = S.*

Refer to "Monitoring Quick Links" at http://usda-ars.nmsu.edu/Monit_Assess/monitoring.htm for updates.

Line-Point Intercept Indicator Calculations

You must fill in all applicable yellow cells. Fill in Lower Canopy Layer cells where appropriate.

Page 1 of 1 Observer EK/SMJ *Gray cells for indicator calculations*

Plot TMD MP3 Line 3 Recorder EK Line Length 50 m or ft? m

Direction 40 Date 04/04/2014 (mm/dd/yyyy) Intercept (Point) Spacing Interval 100 cm or in? cm

Pt.	Top Canopy	Lower Canopy Layers Code1	Code2	Code3	Soil Surface	Pt.	Top Canopy	Lower Canopy Layers Code1	Code2	Code3	Soil Surface
1	104	None	None	None	S	26	104	None	None	None	TC
2	None	None	None	None	S	27	None	None	None	None	TC
3	None	None	None	None	S	28	122	None	None	None	TC
4	168	None	None	None	TC	29	104	None	None	None	TC
5	None	None	None	None	TC	30	122	104	None	None	TC
6	104	G-01	None	None	TC	31	None	None	None	None	TC
7	SLD	None	None	None	TC	32	G-01	None	None	None	TC
8	None	None	None	None	TC	33	104	None	None	None	TC
9	None	None	None	None	TC	34	None	None	None	None	TC
10	TH-1	168	None	None	TC	35	104	None	None	None	TC
11	None	None	None	None	TC	36	SLD	None	None	None	TC
12	None	None	None	None	TC	37	G-01	None	None	None	TC
13	104	None	None	None	TC	38	G-01	None	None	None	TC
14	SLD	None	None	None	TC	39	SLD	None	None	None	TC
15	SLD	None	None	None	TC	40	None	None	None	None	TC
16	None	None	None	None	TC	41	None	None	None	None	TC
17	168	None	None	None	TC	42	104	None	None	None	TC
18	168	G-01	None	L	TC	43	None	None	None	None	TC
19	None	None	None	None	TC	44	G-02	None	None	None	TC
20	168	G-01	None	L	TC	45	122	G-02	None	None	S
21	SLD	None	None	None	TC	46	G-02	None	None	None	S
22	None	None	None	None	TC	47	122	G-02	None	None	S
23	G-01	None	None	None	TC	48	104	None	None	None	S
24	SLD	None	None	None	TC	49	None	None	None	L	S
25	None	None	None	None	S	50	SLD	SPS	104	L	S

% canopy cover = 64

% bare ground = 0

% basal cover = 0

% litter = 0

Notes: TC = Tarcrete
Only percent canopy has been calculated

Top canopy codes: Species code, common name, or NONE (no canopy).

Lower canopy layers codes: Species code, common name, L (herbaceous litter), WL (woody litter, >5 mm (~1/4 in) diameter).

Unknown Species Codes:
AF# = annual forb
PF# = perennial forb
AG# = annual graminoid
PG# = perennial graminoid
SH# = shrub
TR# = tree

Soil Surface (do not use litter):
Species Code (for basal intercept)
R = rock fragment (>5 mm (~1/4 in) diameter)
BR = bedrock, M = moss
LC = visible lichen crust on soil
S = soil without any other soil surface code
EL = embedded litter (see page 10)
D = duff

**Bare ground occurs ONLY when Top canopy = NONE, Lower canopy layers are empty (no L), and Soil surface = S.*

Appendix G

Soil Monitoring Data

TMA-MP1

Monitoring Site TMA-MP1						
Date (DD.MM.YY)	Weather	Ambient Temperature (^{0}C)	Soil Temperature (^{0}C)	Electrical Conductivity (mS)	Moisture @ 100mm (%)	Moisture @ 200mm (%)
8.03.14	Sunny clear sky, <1% cloud	29	30.5	0.03	2.1	5.6
15.03.14	Low cumulus nimbus, 85%. Heavy rain 5am to 7am, dry at 1040am. 10 to 15 knot westerly breeze.	21	24.6	0.05	7.7	7.2
21.03.14	Overcast. 100% cloud. North-westerly wind approximately 8-10 knots.	23	26.6	0.01	0.2	6
29.03.14	Overcast. Cool. Approx. 8 knot wind from east.	28	34	0.03	2.2	2.7
04.04.14	Sunset. Light breeze from north east	28	29.9	0.02	1.5	2.3
12.04.14	Overcast. Light north-westerly wind	35	35.6	0.03	0.0	0.0
17.04.14	Hot, sunny, come cloud, slight haze, very slight wind	37	33.6	0.02	1.5	2.2
26.04.14	Strong wind from SE 15 to 20 knots. Dust in air making haze. High alt. cloud cover at 80%	36	41.1	0.00	0.0	0.0
4.05.14	Moderate wind, slight haze, clear sky, hot, sunny	34	36.8	0.01	0.4	1.1
8.05.14	Slight haze, light north breeze	35	39.8	0.00	0.0	0.0

Monitoring Site TMA-MP1						
Date (DD.MM.YY)	Weather	Ambient Temperature (^{0}C)	Soil Temperature (^{0}C)	Electrical Conductivity (mS)	Moisture @ 100mm (%)	Moisture @ 200mm (%)
17.05.14	Light to moderate northerly wind. Hot, sunny, no cloud.	41	41.9	0.00	0.0	0.0
25.05.14	Humid, hazy, overcast, strong to moderate westerly wind	40	42.5	0.00	0.0	0.0
2.06.14	Hot , hazy, overcast. Light north-westerly wind	42	39.3	0.00	0.0	0.0
12.06.14	Strong breeze from northwest approximately 20 knots, hot and hazy	42	45	0.00	0.0	0.0
6.07.14	Hot, sunny, humid, hazy, moderate easterly wind	43	47.5	0.00	0.0	0.0
22.07.14	Hot sunny, slightly overcast, moderate north-westerly wind	45	44.7	0.00	0.0	0.0
18.08.14	Overcast, humid, moderate south-easterly wind	39	43.2	0.00	0.0	0.0

TMA-MP2

Monitoring Site TMA-MP2						
Date (DD.MM.YY)	Weather	Ambient Temperature (^{0}C)	Soil Temperature (^{0}C)	Electrical Conductivity (mS)	Moisture @ 100mm (%)	Moisture @ 200mm (%)
8.03.14	Sunny clear sky, <1% cloud	26	30.50	0.04	1.90	3.90
15.03.14	Low cumulus nimbus, 85%. Heavy rain 5am to 7am, dry at 1040am. 10 to 15 knot westerly breeze.	21	23.50	0.01	2.80	5.70
21.03.14	Overcast. 100% cloud. North-westerly wind approximately 8-10 knots.	23	29.50	0.04	0.00	3.70
28.03.14	No cloud. Dry breeze from north.	28	33.6	0.00	0.0	0.0
5.04.14	Sunny. No clouds. Light to moderate westerly wind approx. 8 knots.	29	31.3	0.01	3.5	1.4
13.04.14	Overcast. Light south-easterly breeze	30	34.2	0.02	0.6	2.3
17.04.14	Hot, sunny, come cloud, slight haze, very slight wind	37	37.7	0.01	1.4	3.8
26.04.14	Strong wind from SE 15 to 20 knots. Dust in air making haze. High alt. cloud cover at 80%	36	38.3	0.00	0.0	0.0
4.05.14	Moderate wind, slight haze, clear sky, hot, sunny	34	39.4	0.49	0.0	0.0
8.05.14	Slight haze, light north breeze	32	37.7	0.00	0.0	0.0

Monitoring Site TMA-MP2						
Date (DD.MM.YY)	**Weather**	**Ambient Temperature (^{0}C)**	**Soil Temperature (^{0}C)**	**Electrical Conductivity (mS)**	**Moisture @ 100mm (%)**	**Moisture @ 200mm (%)**
17.05.14	Light to moderate northerly wind. Hot, sunny, no cloud.	39	41.3	0.00	0.0	0.0
25.05.14	Humid, hazy, overcast, strong to moderate westerly wind	40	42.7	0.00	0.0	0.0
2.06.14	Hot , hazy, overcast. Light north-westerly wind	46	40.3	0.00	0.0	0.0
12.06.14	Strong breeze from northwest approximately 20 knots, hot and hazy	40	44.0	0.00	0.0	0.0
6.07.14	Hot, sunny, humid, hazy, moderate easterly wind	43	45.7	0.00	0.0	0.0
22.07.14	Hot sunny, slightly overcast, moderate north-westerly wind	45	45.8	0.00	0.0	0.0
18.08.14	Overcast, humid, hazy, light south-easterly wind	38	43.5	0.00	0.0	0.0

TMA-MP3

Monitoring Site TMA-MP3						
Date (DD.MM.YY)	Weather	Ambient Temperature (^{0}C)	Soil Temperature (^{0}C)	Electrical Conductivity (mS)	Moisture @ 100mm (%)	Moisture @ 200mm (%)
8.03.14	Sunny clear sky, <1% cloud	27.00	27.70	1.26	49.40	>50
15.03.14	Low cumulus nimbus, 85%. Heavy rain 5am to 7am, dry at 1040am. 10 to 15 knot westerly breeze.	20.00	24.50	0.59	49.90	>50
21.03.14	Overcast. 100% cloud. North-westerly wind approximately 8-10 knots.	23.00	30.10	2.49	45.50	>50
29.03.14	Slight breeze. No clouds. Light north-westerly wind.	34.00	30.10	1.34	49.00	>50
5.04.14	Sunny. No clouds. Light to moderate westerly wind approximately 8 knots.	29.00	29.70	1.53	48.50	>50
13.04.14	Overcast. Light south-easterly breeze	30.00	32.10	1.49	43.80	>50
17.04.14	Hot, sunny, some cloud, slight haze, very slight wind	38	34.30	0.59	28.60	>50
26.04.14	Strong wind from SE 15 to 20 knots. Dust in air making haze. High altitude cloud cover at 80%	36.00	35.40	0.66	21.20	30.10

Monitoring Site TMA-MP3						
Date (DD.MM.YY)	**Weather**	**Ambient Temperature (^{0}C)**	**Soil Temperature (^{0}C)**	**Electrical Conductivity (mS)**	**Moisture @ 100mm (%)**	**Moisture @ 200mm (%)**
4.05.14	Moderate wind, slight haze, clear sky, hot, sunny	34.00	32.40	0.85	23.30	>50
8.05.14	Slight haze, light north breeze	33.00	35.70	0.30	44.00	>50
17.05.14	Light northerly wind. Hot, sunny, no cloud.	39.00	35.90	0.66	15.30	14.80
25.05.14	Humid, hazy, overcast, strong to moderate westerly wind	40.00	37.90	0.28	11.20	12.70
2.06.14	Hot , hazy, overcast. Light north-westerly wind	46.00	37.00	0.52	14.60	21.80
12.06.14	Strong breeze from northwest approximately 20 knots, hot and hazy	39.00	40.60	0.09	10.10	15.30
6.07.14	Hot, sunny, humid, hazy, moderate easterly wind	43.00	41.60	0.17	10.10	19.60
22.07.14	Hot sunny, slightly overcast, moderate north-westerly wind	44.00	42.80	0.16	0.90	20.10
18.08.14	Overcast, humid, hazy, light south-easterly wind	38.00	42.50	0.04	9.30	17.10

TMB-MP1

Monitoring Site TMB-MP1						
Date (DD.MM.YY)	Weather	Ambient Temperature (^{0}C)	Soil Temperature (^{0}C)	Electrical Conductivity (mS)	Moisture @ 100mm (%)	Moisture @ 200mm (%)
8.03.14	Sunny clear sky, <1% cloud	30	30	0.03	1.8	4.3
15.03.14	Low cumulus nimbus, 85%. Heavy rain 5am to 7am, dry at 1040am. 10 to 15 knot westerly breeze.	NA	NA	NA	NA	NA
21.03.14	N/A	NA	NA	NA	NA	NA
29.03.14	Overcast. Cool. Approx. 8 knot wind from east.	28	36	0	0.3	6
5.04.14	Sunny. No clouds. Light to moderate westerly wind approximately 8 knots.	30	34.2	0.02	0.2	1.6
12.04.14	Overcast. Light north-westerly wind	36	36.1	0.01	0.7	1.4
17.04.14	Hot, sunny, come cloud, slight haze, very slight wind	37	32.9	0.02	0	0
26.04.14	Strong wind from SE 15 to 20 knots. Dust in air making haze. High altitude cloud cover at 80%	37	44.1	0	0	0
4.05.14	Moderate wind, slight haze, clear sky, hot, sunny	34	34.3	0.01	2.3	2.7
8.05.14	Slight haze, light north breeze	35	41.6	0.01	0	0

Monitoring Site TMB-MP1						
Date (DD.MM.YY)	**Weather**	**Ambient Temperature (^{0}C)**	**Soil Temperature (^{0}C)**	**Electrical Conductivity (mS)**	**Moisture @ 100mm (%)**	**Moisture @ 200mm (%)**
17.05.14	Light to moderate northerly wind. Hot, sunny, no cloud.	41	47.2	0.04	0.9	8.1
25.05.14	Humid, hazy, overcast, strong to moderate westerly wind	40	43.8	0	0	0
2.06.14	Hot , hazy, overcast. Light north-westerly wind	42	41.4	0	0	0
12.06.14	Strong breeze from northwest approximately 20 knots, hot and hazy	42	45.7	0	0	0
6.07.14	Hot, sunny, humid, hazy, moderate easterly wind	43	48.5	0	0	0
22.07.14	Hot sunny, slightly overcast, moderate north-westerly wind	45	47.2	0	0	0
18.08.14	Overcast, humid, moderate south-easterly wind	39	44.6	0	0	0

NA: No readings available

TMC-MP2

Monitoring Site TMC-MP2						
Date (DD.MM.YY)	Weather	Ambient Temperature (^{0}C)	Soil Temperature (^{0}C)	Electrical Conductivity (mS)	Moisture @ 100mm (%)	Moisture @ 200mm (%)
8.03.14	Sunny clear sky, <1% cloud	30	32.6	0.02	5.8	7.8
15.03.14	Low cumulus nimbus, 85%. Heavy rain 5am to 7am, dry at 1040am. 10 to 15 knot westerly breeze.	19	22.5	0.03	2.7	7.1
21.03.14	Overcast. Northerly breeze approximately 5-10 knots	26	30.9	0.05	7.3	7.6
28.03.14	Very light north-westerly wind. Hot and sunny. No cloud	34	37.4	0.02	2.2	7.1
5.04.14	Sunny. No clouds. Light to moderate westerly wind approximately 8 knots.	29	32.2	0.04	2.4	7.4
12.04.14	Overcast. Light north-westerly wind	35	35.6	0.03	1.5	3.1
17.04.14	Hazy, partly cloudy, light SE wind	38	36.1	0.03	0.9	2.1
26.04.14	Strong wind from SE 15 to 20 knots. Dust in air making haze. High altitude cloud cover at 80%	35	40.8	0	0	0
4.05.14	Moderate wind, slight haze, clear sky, hot, sunny	37	36.6	0.01	0.2	0.7
11.05.14	Slight haze, light north breeze	35	40.5	0	0	0

Monitoring Site TMC-MP2						
Date (DD.MM.YY)	**Weather**	**Ambient Temperature (^{0}C)**	**Soil Temperature (^{0}C)**	**Electrical Conductivity (mS)**	**Moisture @ 100mm (%)**	**Moisture @ 200mm (%)**
17.05.14	Light to moderate northerly wind. Hot, sunny, no cloud.	40	41.5	0.01	5.1	8.3
25.05.14	Humid, hazy, overcast, strong to moderate westerly wind	40	43	0	0	1.5
2.06.14	Overcast, hot, hazy, light south-easterly wind	42	44	0	0	1
12.06.14	Strong breeze from northwest approximately 20 knots, hot and hazy	38	44	0	0	0
6.07.14	Hot, sunny, humid, hazy, moderate easterly wind	36	45.2	0	0	0
22.07.14	Hot sunny, slightly overcast, moderate north-westerly wind	44	46.2	0	0	0
18.08.14	Overcast, humid, hazy, light south-easterly wind	38	42.9	0	0	0

TMC-MP3

Monitoring Site TMC-MP3						
Date (DD.MM.YY)	Weather	Ambient Temperature (^{0}C)	Soil Temperature (^{0}C)	Electrical Conductivity (mS)	Moisture @ 100mm (%)	Moisture @ 200mm (%)
8.03.14	Sunny clear sky, <1% cloud	30	30.7	0.05	1.1	7.2
15.03.14	Low cumulus nimbus, 85%. Heavy rain 5am to 7am, dry at 1040am. 10 to 15 knot westerly breeze.	19	22.4	0.02	2.5	4
21.03.14	Overcast. Northerly breeze approximately 5-10 knots	27	29.9	0.05	7.3	8.7
28.03.14	Moderate westerly breeze. No clouds. Hot and sunny.	32	34.7	0.01	3	4.7
5.04.14	Sunny. No clouds. Light to moderate westerly wind approximately 8 knots.	29	33.8	0.02	5.6	7.5
12.04.14	Overcast. Light north-westerly wind	35	35.3	0.02	1.1	1.5
17.04.14	Hazy, partly cloudy, light SE wind	38	37	0.01	0.8	7.2
26.04.14	Strong wind from SE 15 to 20 knots. Dust in air making haze. High altitude cloud cover at 80%	36	43	0	0	0
4.05.14	Warm NS breeze (15 knots), slight haze, clear sky, hot, sunny	37	39.3	0.13	11.7	9.3
11.05.14	Slight haze, light north breeze	35	41.1	0.01	0	2.6

Monitoring Site TMC-MP3						
Date (DD.MM.YY)	**Weather**	**Ambient Temperature (^{0}C)**	**Soil Temperature (^{0}C)**	**Electrical Conductivity (mS)**	**Moisture @ 100mm (%)**	**Moisture @ 200mm (%)**
17.05.14	Light to moderate northerly wind. Hot, sunny, no cloud.	39	41.3	0	0	0.7
25.05.14	Humid, hazy, overcast, strong to moderate westerly wind	40	42.8	0	0	0
2.06.14	Overcast, hot, hazy, light south-easterly wind	42	42.6	0.02	0	9.3
12.06.14	Strong breeze from northwest approximately 20 knots, hot and hazy	38	43.5	0	0	0
6.07.14	Hot, sunny, humid, hazy, moderate easterly wind	36	45.7	0	0	0
22.07.14	Hot sunny, slightly overcast, moderate north-westerly wind	44	47	0	0	0
18.08.14	Overcast, humid, hazy, light south-easterly wind	38	44.9	0	0	0

TMD-MP1

Monitoring Site TMD-MP1						
Date (DD.MM.YY)	Weather	Ambient Temperature (^{0}C)	Soil Temperature (^{0}C)	Electrical Conductivity (mS)	Moisture @ 100mm (%)	Moisture @ 200mm (%)
08.03.14	Sunny. Clear sky. <1 cloud cover	28	26.4	0.03	0.7	7.3
15.03.14	Low cumulus nimbus, 85%. Heavy rain 5am to 7am, dry at 1040am. 10 to 15 knot westerly breeze.	16.6	19.3	0.02	6.3	2.5
21.03.14	Overcast. Northerly breeze approximately 5-10 knots	27	30.3	0.04	7.2	8.4
29.03.14	Overcast. Cool. Approx. 8 knot wind from east.	28	33.3	0.05	7.5	7.9
5.04.14	Sunny. No clouds. Light to moderate westerly wind approximately 8 knots.	29	32.3	0.01	2.6	7.1
12.04.14	Overcast. Light north-westerly wind	36	33.6	0.01	0	5.3
17.0414	Hot, sunny, some cloud, slight haze, very slight wind	38	32.5	0.05	0.6	5.5
26.04.14	Strong wind from SE 15 to 20 knots. Dust in air making haze. High altitude cloud cover at 80%	37	41.2	0	0	7
4.05.14	Moderate wind, slight haze, clear sky, hot, sunny	34	32.5	0.01	5.3	2.3
8.05.14	Slight haze, light north breeze	35.6	39.5	0.04	8.1	7.2

Monitoring Site TMD-MP1						
Date (DD.MM.YY)	**Weather**	**Ambient Temperature (^{0}C)**	**Soil Temperature (^{0}C)**	**Electrical Conductivity (mS)**	**Moisture @ 100mm (%)**	**Moisture @ 200mm (%)**
17.05.14	Light to moderate northerly wind. Hot, sunny, no cloud.	41	43.2	0	0	0.6
25.05.14	Humid, hazy, overcast, strong to moderate westerly wind	40	41.6	0	0	0
2.06.14	Hot , hazy, overcast. Light north-westerly wind	42	38.5	0	0	0
12.06.14	Strong breeze from northwest approximately 20 knots, hot and hazy	42	45.3	0	0	0
6.07.14	Hot, sunny, humid, hazy, moderate easterly wind	43	46	0	0	0
22.07.14	Hot sunny, slightly overcast, moderate north-westerly wind	45	45.9	0	0	0
18.08.14	Overcast, humid, moderate south-easterly wind	39	45	0	0	0

TMD-MP2

Monitoring Site TMD-MP2						
Date (DD.MM.YY)	Weather	Ambient Temperature (^{0}C)	Soil Temperature (^{0}C)	Electrical Conductivity (mS)	Moisture @ 100mm (%)	Moisture @ 200mm (%)
8.03.14	Sunny clear sky, <1% cloud	29	29.7	0.07	8.3	12.8
15.03.14	Low cumulus nimbus, 85%. Heavy rain 5am to 7am, dry at 1040am. 10 to 15 knot westerly breeze.	16	21	0.04	8.9	10.8
21.03.14	Overcast. Northerly breeze approximately 5-10 knots	27	32	0.15	10.5	11.7
29.03.14	Overcast. Cool. Approx. 8 knot wind from east.	28	35.9	0.1	8.2	13.3
4.04.14	Sunny. No clouds. Light to moderate westerly wind approximately 8 knots.	28	36.4	0.05	8.4	11.1
12.04.14	Overcast. Light north-westerly wind	37	35.7	0.03	0.5	8
17.04.14	Hot, sunny, come cloud, slight haze, very slight wind	38	41.1	0.07	5.9	11
26.04.14	Strong wind from SE 15 to 20 knots. Dust in air making haze. High altitude cloud cover at 80%	34	40.9	0.03	3.4	10.7
4.05.14	Moderate wind, slight haze, clear sky, hot, sunny	39	38.4	0.04	8.4	15.4
11.05.14	Slight haze, light north breeze	36	43.2	0.12	9.4	9.3

Monitoring Site TMD-MP2						
Date (DD.MM.YY)	**Weather**	**Ambient Temperature (^{0}C)**	**Soil Temperature (^{0}C)**	**Electrical Conductivity (mS)**	**Moisture @ 100mm (%)**	**Moisture @ 200mm (%)**
17.05.14	Light to moderate northerly wind. Hot, sunny, no cloud.	40	43.3	0.02	7.6	13
25.05.14	Humid, hazy, overcast, strong to moderate westerly wind	39	42.4	0.09	2.5	13.9
2.06.14	Overcast, hot, hazy, light south-easterly wind	42	46	0.01	0.7	13.1
12.06.14	Strong breeze from northwest approximately 20 knots, hot and hazy	37	45.3	0.01	0	8.1
6.07.14	Hot, sunny, humid, hazy, moderate easterly wind	38	45.6	0	0	0
22.07.14	Hot sunny, slightly overcast, moderate north-westerly wind	45	48.8	0	0	0
18.08.14	Overcast, humid, moderate south-easterly wind	39	47.3	0	0	0

TMD-MP3

Monitoring Site TMD-MP3						
Date (DD.MM.YY)	Weather	Ambient Temperature (^{0}C)	Soil Temperature (^{0}C)	Electrical Conductivity (mS)	Moisture @ 100mm (%)	Moisture @ 200mm (%)
8.03.14	Sunny. Clear sky. <1 cloud cover	29	28.5	0.02	7.1	8.7
15.03.14	Low cumulus nimbus, 85%. Heavy rain 5am to 7am, dry at 1040am. 10 to 15 knot westerly breeze.	17.6	22.2	0.03	5.3	7.5
21.03.14	Overcast. Northerly breeze approximately 5-10 knots	27	32	0.03	7.1	7.5
29.03.14	Overcast. Cool. Approx. 8 knot wind from east.	28	33.8	0.03	5.6	7.2
4.04.14	Sunny. No clouds. Light to moderate westerly wind approximately 8 knots.	28	31.8	0.05	5.7	8.1
12.04.14	Overcast. Light north-westerly wind	37	40.5	0.01	0	1.6
17.04.14	Hot, sunny, come cloud, slight haze, very slight wind	37	38.2	0.03	0.9	1.9
26.04.14	Strong wind from SE 15 to 20 knots. Dust in air making haze. High altitude cloud cover at 80%	34	40.4	0	0	5.9
4.05.14	Moderate wind, slight haze, clear sky, hot, sunny	40	37.8	0.06	5.5	7.7
11.05.14	Slight haze, no wind	36	40.3	0.06	7.9	9.7

Monitoring Site TMD-MP3						
Date (DD.MM.YY)	Weather	Ambient Temperature (^{0}C)	Soil Temperature (^{0}C)	Electrical Conductivity (mS)	Moisture @ 100mm (%)	Moisture @ 200mm (%)
17.05.14	Light to moderate northerly wind. Hot, sunny, no cloud.	41	42.9	0.03	0	7.1
25.05.14	Humid, hazy, overcast, strong to moderate westerly wind	39	42	0.02	7.9	9.5
2.06.14	Overcast, hot, hazy, light south-easterly wind	42	44.6	0.03	5.2	7.6
12.06.14	Strong breeze from northwest approximately 20 knots, hot and hazy	37	43.3	0.01	0	0
6.07.14	Hot, sunny, humid, hazy, moderate easterly wind	38	46.9	0.01	0	1.2
22.07.14	Hot sunny, slightly overcast, moderate north-westerly wind	45	44.9	0	0	0
18.08.14	Overcast, humid, moderate south-easterly wind	39	46	0	0	0