Appendix 5: US EPA Ecological Soil Screening Level for Aluminium

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Ecological Soil Screening Level for Aluminum

Interim Final

OSWER Directive 9285.7-60

U.S. Environmental Protection Agency
Office of Solid Waste and Emergency Response
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SUMMARY OF ECO-SSLs FOR ALUMINUM

Aluminum (Al) is the most commonly occurring metallic element, comprising eight percent of the earth's crust (Press and Siever, 1974). It is a major component of almost all common inorganic soil particles, with the exceptions of quartz sand, chert fragments, and ferromanganiferous concretions. The typical range of aluminum in soils is from 1 percent to 30 percent (10,000 to 300,000 mg Al kg-1) (Lindsay, 1979 and Dragun, 1988), with naturally occurring concentrations varying over several orders of magnitude.

EPA recognizes that due to the ubiquitous nature of aluminum, the natural variability of aluminum soil concentrations and the availability of conservative soil screening benchmarks (Efroymson, 1997a; 1997b), aluminum is often identified as a COPC for ecological risk assessments. The commonly used soil screening benchmarks (Efroymson, 1997a; 1997b) are based on laboratory toxicity testing using an aluminum solution that is added to test soils. Comparisons of total aluminum concentrations in soil samples to soluble aluminum-based screening values are deemed by EPA to be inappropriate.

The standard analytical measurement of aluminum in soils under CERCLA contract laboratory procedures (CLP) is total recoverable metal. The available data on the environmental chemistry and toxicity of aluminum in soil to plants, soil invertebrates, mammals and birds as summarized in this document support the following conclusions:

- Total aluminum in soil is not correlated with toxicity to the tested plants and soil invertebrates.
- Aluminum toxicity is associated with soluble aluminum.
- Soluble aluminum and not total aluminum is associated with the uptake and bioaccumulation of aluminum from soils into plants.
- The oral toxicity of aluminum compounds in soil is dependant upon the chemical form (Storer and Nelson, 1968). Insoluble aluminum compounds such as aluminum oxides are considerably less toxic compared to the soluble forms (aluminum chloride, nitrate, acetate, and sulfate). For example, Storer and Nelson (1968) observed no toxicity to the chick at up to 1.6% of the diet as aluminum oxide compared to 80 to 100% mortality in chicks fed soluble forms at 0.5% of the diet.

Because the measurement of total aluminum in soils is not considered suitable or reliable for the prediction of potential toxicity and bioaccumulation, an alternative procedure is recommended for screening aluminum in soils. The procedure is intended as a practical approach for determining if aluminum in site soils could pose a potential risk to ecological receptors. This alternative procedure replaces the derivation of numeric Eco-SSL values for aluminum. Potential ecological risks associated with aluminum are identified based on the measured soil pH. Aluminum is identified as a COPC only at sites where the soil pH is less than 5.5.

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1.0 INTRODUCTION

Aluminum (Al) is the most commonly occurring metallic element, comprising eight percent of the earth's crust. Only oxygen and silicon are more abundant (Press and Siever, 1974). It is a major component of almost all common inorganic soil particles with the exceptions of quartz sand, chert fragments, and ferromanganiferous concretions. The typical range of aluminum in soils is from 1% to 30% (10,000 to 300,000 mg Al kg^{-1}) [compiled by Lindsay (1979) and Dragun (1988)]. In his text book on *Chemical Equilibria in Soils*, Lindsay (1979) used an arbitrary aluminum reference concentration for all soils as averaging 7.1% (71,000 mg Al kg^{-1}).

Aluminosilicates, including the feldspars, micas, and clay minerals, are the most common primary and secondary minerals in soils (McLean, 1965). Aluminum oxide, Al_2O_3, occurs as corundum and emery. The hydroxide, $Al(OH)_3$, occurs as gibbsite. Diaspore (AlOOH) and cryolite are other sources of soil aluminum (Hesse, 1972). Aluminum also occurs in interlayer positions in clays, often forming complete layers to which the term chlorite is sometimes applied.

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2.0 ALUMINUM CHEMISTRY

The aluminum ion bonds through oxygen to form a wide variety of functional groups. In igneous rocks, aluminum is largely bonded to oxygen ions in tetrahedral coordination. As the rocks weather, aluminum progressively acquires more octahedral bonding. The weathering release of aluminum from 2:1 layer silicates in soils is enhanced by inputs of acids from the natural decomposition of organic matter and minerals and from pollution (McBride, 1994). Acids as weak as dilute H_2CO_3 have been shown to decompose the silicate and montmorillonite layers facilitating the release of aluminum (Jackson, 1963).

The hydrated aluminum ion (Al hexahydronium ion) is an acid in the general sense that it contains protons (hydrogen ions) removable from the six water molecules ($-OH_2$) surrounding the aluminum in an octahedral coordination. For simplicity these hydrolysis species are generally written without the hydrated water even though the water is present. This trivalent cation complex occurs in acid solutions of pH 5.0 or 5.2 and below (Jackson, 1963; McLean et al., 1965; Tisdale and Nelson, 1975). As the pH of the soil solution increases, first one and then two of the ($-OH_2$) groups lose a hydrogen ion to form an (-OH) ion, resulting in di- or mono-valent hydroxyaluminum cations. All three of these cation species are adsorbed by negatively charged (cation) exchange sites in the soil. The di- and monovalent forms are adsorbed more strongly than $Al(-OH_2)_6^{3+}$ (McLean et al., 1965; Jackson, 1963). This ion is octahedrally hydrated and therefore less strongly held electrostatically and by hydrogen bonding than are the di- or mono-valent hydroxy-aluminum cations (Jenny, 1961). It is readily displaced from the clay with a neutral salt such as potassium chloride (Jenny, 1961; Jackson, 1963; McLean et al., 1965; Tisdale and Nelson, 1975).

As the pH increases still further, the third ($-OH_2$) group loses a hydrogen ion, and aluminum hydroxide, $Al(OH)_3 \bullet 3H_2O$, is formed. The steps in the dissociation of protons from the hydrated aluminum ion in dilute solution may be represented by the following equations (Jackson, 1963; Black, 1968; Lindsay, 1979; McBride, 1994; Tisdale and Nelson, 1975):

$$Al(H_2O)_6^{3+} + H_2O = Al(H_2O)_5OH^{2+} + H^+ \qquad \log K_1 = -4.97$$

$$Al(H_2O)_5OH^{2+} + H_2O = Al(H_2O)_4(OH)_2^{+} + H^+ \qquad \log K_2 = -4.93$$

$$Al(H_2O)_4(OH)_2^{+} + H_2O = Al(H_2O)_3(OH)_3^{0}\,(aq) + H^+ \qquad \log K_3 = -5.7$$

$$Al(H_2O)_3(OH)_3^{0}\,(aq) + H_2O = Al(H_2O)_2(OH)_4^{-} + H^+ \qquad \log K_4 = -7.4$$

The concentrations of these species as a function of pH are shown in Figure 2.1.

Once soil pH is lowered much below 5.5, aluminosilicate clays and aluminum hydroxide minerals begin to dissolve, releasing aluminum-hydroxy cations and $Al(H_2O)_6^{3+}$ that then exchange with other cations from soil colloids. The fraction of exchange sites occupied by $Al(H_2O)_6^{3+}$ and its hydrolysis products can become large once the soil pH falls below 5.0.

Furthermore, as the pH is lowered, the concentration of soluble aluminum, which is toxic, increases (McBride, 1994).

The chemistry of $Al(H_2O)_6^{3+}$ (normally written without the water molecules as Al^{3+}) in soil solution is complicated by the fact that soluble inorganic and organic ligands form complexes with Al^{3+}. Whether a ligand increases or decrease aluminum solubility depends on the particular aluminum-ligand complex and its tendency to remain in solution or precipitate. Ligands that increase the overall solubility of aluminum include F^-, oxalate^{2-}, citrate^{3-}, fulvic acid, and monomeric silicate. Those that decrease the overall solubility of aluminum include phosphate, sulfate, polymeric silicate, and hydroxyl. It is usually the case that a large fraction of the soluble aluminum is found in the form of organic and fluoride complexes. Some of the aluminum may also be complexed with soluble silicate. There is evidence that these various complexed forms of aluminum are much less phytotoxic than soluble Al^{3+} or Al-hydroxy cations. In fact, the Al^{3+} activity in soil solution is better correlated to diminished root growth in acid soils that is total soluble aluminum or exchangeable aluminum as a fraction of cation exchange sites (McBride, 1994).

There is some evidence to suggest that the $Al_{13}O_4(OH)_{24}(H_2O)_{12}^{7+}$ polymeric cation is highly phytotoxic. This is a metastable species, however, that may not exist in soil solutions. It may be formed by localized and transitory high pH conditions created during the titration of aluminum salt solutions with strong base (McBride, 1994).

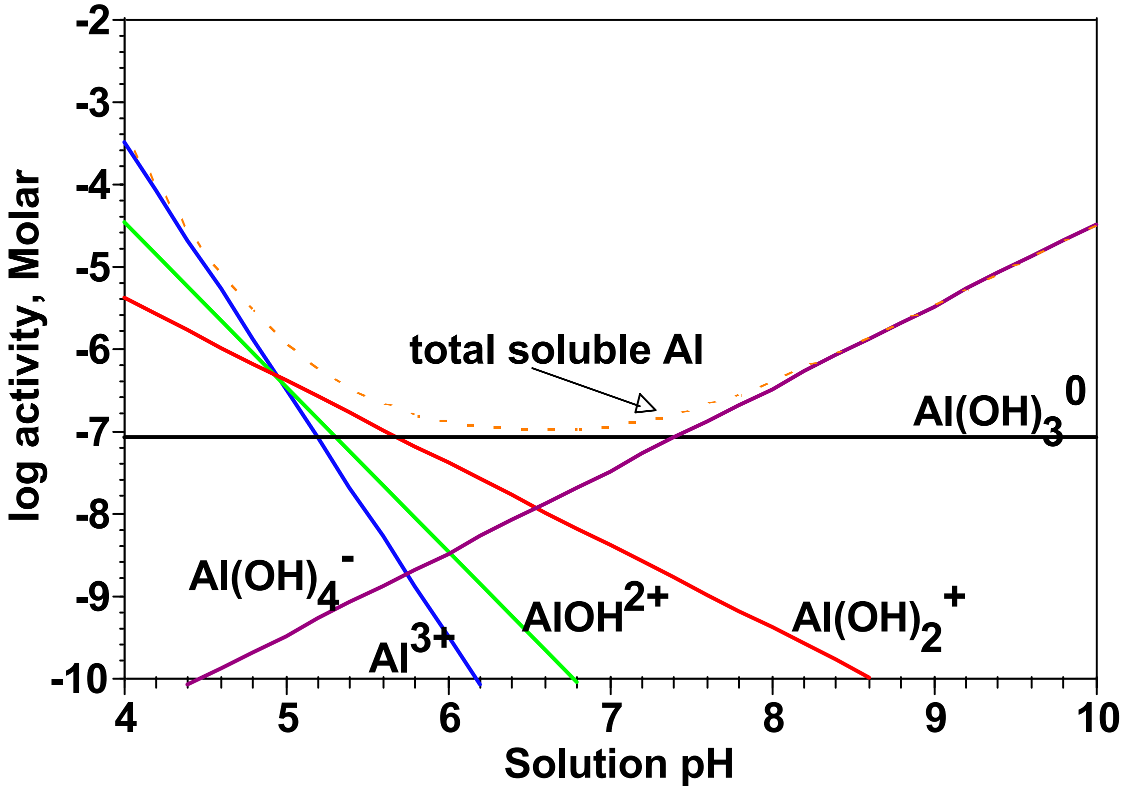

Figure 2.1. Solubility diagram of the most significant species of aluminum in an aqueous solution of $AlCl_3$. Gibbsite ($AlOH_3$) is present as the solid phase at all pH values. The broken line depicts total soluble aluminum (sum of all species concentrations). Polymetric aluminum- hydroxy cations are not significant species under the conditions of this system (from McBride, 1994).

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3.0 EFFECTS OF ALUMINUM ON PLANTS

The extensive research literature in the agricultural sciences on the effects of aluminum on plants dates back nearly a century. There is an ongoing need to identify not only the essential plant nutrients but also factors that limit optimal plant growth and productivity. Once aluminum was found to limit plant growth, efforts were made to discover the modes of action for aluminum toxicity, the ways to predict which soils were aluminum toxic, the methods to amend these problem soils to ameliorate aluminum toxicity, and breeding programs to produce aluminum tolerant plants.

3.1 General Effects

The toxic effects of aluminum on plants has been noted by many workers. Toxic levels of aluminum decrease the height and both the fresh and dry weight yields of plants (Rees and Sidrak, 1961; Munns, 1965; Hortenstine and Fiskell, 1961). The effects on roots occur long before any noticeable effects to the tops (McLean and Gilbert, 1927). The first evidence of injury in the roots is a discolored appearance. Then lateral roots become stunted, or fail to develop, and the whole root system fails to elongate (McLean and Gilbert, 1927; and Rhue and Grogan, 1977). This effect on root elongation has also been reported by Clarkson (1965), Matsumoto et al. (1976), Keser et al. (1975), Lafever et al. (1977), Rees and Sidrak (1961), and Fleming and Foy (1968). Injury to roots is characterized by a disorganization of the root cap, root apex, and vascular elements (Fleming and Foy, 1968). According to a study by McLean and Gilbert (1927), it appeared as if aluminum decreased the permeability of the roots to water and nutrients

The toxic effects of aluminum to plants are observed in association with soluble aluminum (Al^{3+}). For example, Mulder et al. (1989) observed a dose response relationship between 'Tyler' wheat root length versus the concentration of Al^{3+} (see Figure 3.1).

In addition, several studies of conifers grown in Al-enriched solutions at a pH lower than 5.5 resulted in reduced root growth rates (Hutchinson et al. 1986), shorter roots, less root mass, and lower root:shoot ratios than controls (Nosko et al. 1988), and reduced root elongation (Eldhuset et al. 1987). When beech trees were exposed to Al-enriched solutions at a pH range of 4.2 to 5.4, their leaves, roots and stems were 21% to 44% lower than controls (Bengtsson et al. 1988) (Sparling and Lowe, 1996).

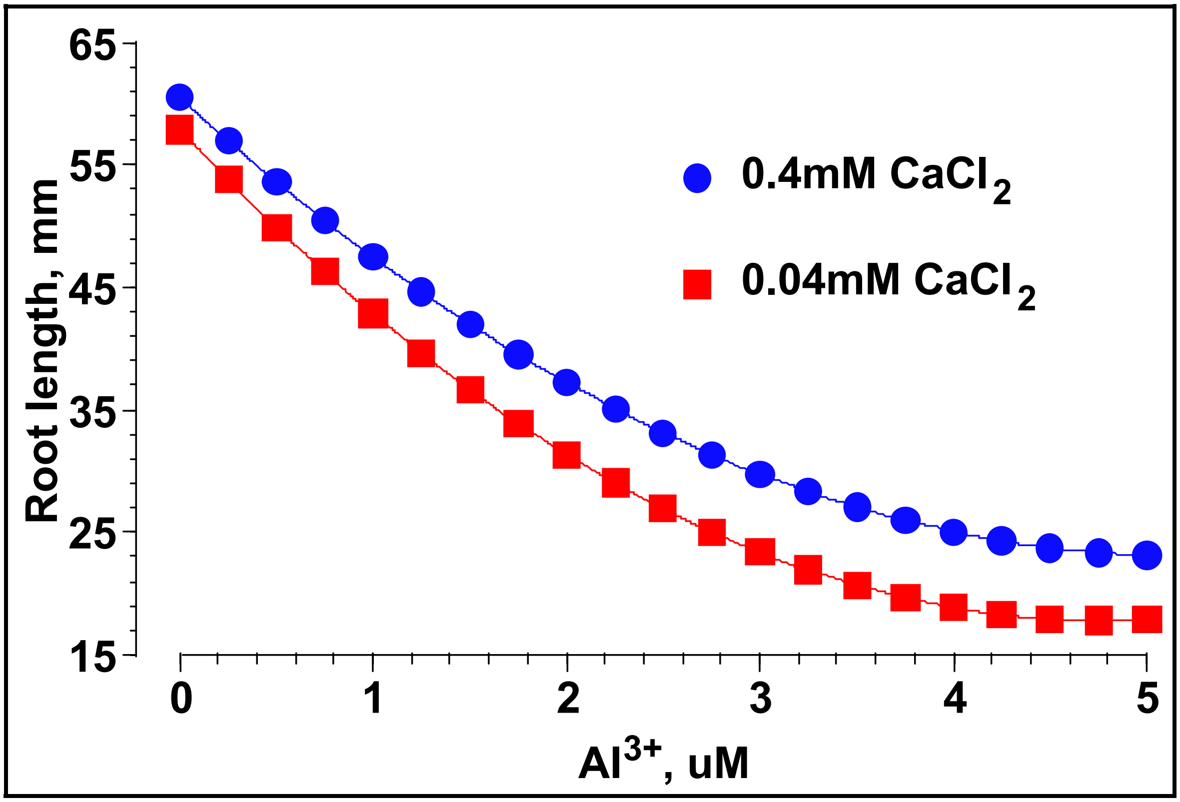

Figure 3.1. 'Tyler' wheat root length versus concentration of Al^{3+} (from Parker et al., 1989).

3.2 Essentiality

Although there is no convincing evidence of its essentiality in plants, aluminum has long been known to be a constituent of a blue pigment in Hydrangea (Chenery, 1948). There also have been many examples reported over the past 50 years in which plant growth has been stimulated by subtoxic concentrations of aluminum (Matsumoto et al., 1976; Bertrand and de Wolf, 1968). The beneficial effects of aluminum may relate to reduction by the aluminum of the uptake of a second element present in the root environment at potentially toxic concentrations (Liebig et al., 1942; Suthipradit, 1988) In most cases in which positive effects of aluminum on plant growth have been reported, there has been insufficient supporting information to establish whether or not they were indirect effects mediated through alleviation of toxicity of another element. Most positive responses to aluminum have been observed at nominal aluminum concentrations of $\leq$ 37 mm*M*. However, because of the ease with which free aluminum ions are lost from solution by complexation, polymerization, and precipitation reactions, the actual aluminum concentrations in solution have probably been much lower (Asher, 1991)

3.3 Effect on Phosphorus and Calcium

In addition to root growth inhibition, a decrease in the uptake and utilization of phosphorus is the primary symptom of aluminum toxicity in some susceptible plant species (MacLean and Chiasson, 1966; Naidoo et al., 1978). Aluminum inactivates phosphorus, primarily within the roots of plants, and thus interferes with the normal phosphate metabolism of plants (Wright, 1943; Wright, 1945; Wright and Donahue, 1953). Naidoo et al. (1978) found that aluminum and phosphorus were mainly concentrated on or in the outer cells of the root caps. Utilizing a scanning electron microscope focused at one point, Naidoo et al. (1978) found that "spot" analysis of the outer cell of snapbean and cotton root caps at high magnification showed that aluminum and phosphorus formed a precipitate at the cell surface when aluminum was present in nutrient solution. Data from Clarkson (1966) indicated that 85 to 95% of the aluminum in the roots was located in the cell wall fraction. This aluminum seemed to fix the phosphorus by an absorption-precipitation reaction, an extension of the reaction found in soils. According to McCormick and Borden (1972 and 1974), the Al-PO_4 precipitate occurred as scattered globules rather than as a continuous layer. The absorption-precipitation phenomenon occurred in the extracellular and intercellular material of the root cap. McCormick and Borden (1972) also concluded that aluminum may not only reduce phosphate availability by preventing the uptake of external sources, but also may be able to "extract" the phosphate from the root tissue and disrupt important metabolic activities.

In addition to the nonmetabolic interaction between aluminum and phosphate at the cell surface or in the free space, a small proportion of the total aluminum found in the root appears to be inside the cell. Internal precipitation of phosphorus cannot explain the rapid cessation of cell division in terms of phosphorus starvation. Any interaction between aluminum and phosphorus must be at a metabolic level rather than a phosphorus deficiency through precipitation in order for cell division to stop suddenly. The results of Clarkson (1965) showing reduction and cessation of root growth might be explained by an effect of aluminum on the turn-over of certain key phosphorylated compounds such as adenosine triphosphate (ATP). Observations suggested aluminum may either inhibit hexokinase or combine with the substrate to make it unavailable (Clarkson, 1966).

Aluminum within root cells probably accumulates by ion exchange onto enteric phosphorus in the nucleic acids and membrane lipids. aluminum in the nuclei may act directly to reduce or inhibit cell division by interference with nucleic acid replication (Clarkson, 1965; Matsumoto et al., 1976; Naidoo et al., 1978). Ragland and Coleman (1962) and Rees and Sidrak (1961) postulated that aluminum may cause a rearrangement of cell constituents and the protoplasm to coagulate.

Researchers have observed that aluminum causes a calcium deficiency in plants (Long and Foy, 1970; Armiger et al., 1968; Vlamis, 1953; Evans and Kamprath, 1970; MacLean and Chiasson, 1966) which was due not to a deficiency of calcium in the growth medium, but to the detrimental effect of aluminum on adsorption and translocation of calcium.

3.4 Differential Tolerance of Plants to Aluminum Toxicity

Species of plants show a considerable difference in the amount of aluminum they are able to tolerate. Susceptible plants can tolerate no more than one or two parts per million (ppm) in nutrient solutions while other plants can tolerate over 100 ppm with little damage (McLean and Gilbert, 1927; Ligon and Pierre, 1932; Peiffer, 1976; Chapman, 1966). Rhue and Grogan (1977) and Reid et al. (1969) theorized that aluminum tolerance is genetically controlled. Vose and Randall (1962) cite the cation exchange capacity of the roots as a possible factor in aluminum resistance. Tolerance to both aluminum and manganese toxicities was associated with a low cation exchange capacity of the plant root, which favors mono- to di-valent uptake in accordance with the Donnan theory. Naidoo et al. (1978), Keser et al. (1975), and Foy et al. (1978) postulated that tolerant plants have a mechanism for preventing aluminum uptake. Foy et al. (1978) found that certain aluminum-tolerant cultivars of wheat, barley, rice, peas, and corn had the ability to increase the pH of the small quantities of nutrient solutions in which they were grown. The increase in pH decreased the solubility and toxicity of aluminum. The exact physiological mechanism of aluminum- tolerance or toxicity, however, was unresolved (Foy et al., 1978).

4.0 UPTAKE AND ACCUMULATION OF ALUMINUM BY PLANTS

4.1 Plant Uptake of Aluminum

According to Rasmussen (1968), the epidermal cells appear to effectively exclude the aluminum from entering the root at the root cap. The mode of aluminum entry begins with the growth of a lateral root from the pericycle. As the lateral root enlarges, the cells of the endodermis divide, and, as the root forces its way through the cortex of the parent root, the lateral root is encased in an endodermal layer. Once the root breaks through the surface, however, the endodermal layer dies and sloughs-off, creating a path by which aluminum and other elements can penetrate into the cortical and vascular tissue of both the lateral and parent roots.

Bioavailability of aluminum for plant uptake and toxicity is associated with pH, since aluminum is soluble and biologically available in acidic (pH <5.5) soils and waters, but is biologically inactive in circumneutral to alkaline (pH 5.5-8.0) conditions. In alkaline soils and solutions (pH >8.0), the solubility of aluminum increases, but its bioavailability is poorly known (Sparling and Lowe, 1996).

Weathering or acidification to pH below 5.5 increases the dissolution kinetics of Al and places some of the metal into solution, where it is readily bioavailable to living organisms (although dissolved organic carbons, such as F, PO_3^{3-} and SO_4^{2-} can ameliorate toxicity by reducing bioavailability) (Sparling and Lowe, 1996). Once in solution, Al may combine with several organic complexes, especially oxalic, humic, and fulvic acids. Aluminum may also combine with inorganic molecules, including sulfate (SO_4^{2-}), fluoride (F^-), phosphate (PO_3^{3-}), biocarbonates (HCO_3^-), or hydroxides (OH^-), depending on the relative concentrations of these anions. Biological activity and toxicity vary with composition. For example, Al sulfates are generally considered less toxic than hydroxide or organically bound Al (Driscoll and Schecher 1988). Aqueous Al (Al^{3+}), however, is more chemically and biologically active than that bound to soil or sediments (Sparling and Lowe, 1996).

Monomeric and hydrolyzed forms of Al [Al^{3+}, $Al(OH)^{2+}$, $Al(OH)_2^+$, $Al(OH)_3$] are typically the most toxic, whereas, polymeric and organically bound forms have slight to no phytotoxicity (Fageria et al. 1988; Taylor, 1988). Often, the sum of the concentrations of monomeric Al is used to estimate the phytotoxicity to a growing medium. Although Parker et al. (1989) contended that polymeric Al can be as toxic as Al^{3+} in nutrient solutions, polymeric Al is generally not soluble in soil and therefore, should not be as toxic. In soil, the concentration of Al^{3+} may suffice to predict toxicity (Sparling and Lowe, 1996).

4.2 Accumulation of Aluminum in Plant Tissue

Root staining techniques have shown that aluminum accumulates principally in the root tips of the main root and lateral root tissue, with small quantities in the cortex and epidermal cells (McLean and Gilbert, 1927; Fleming and Foy, 1968; Matsumoto et al., 1976). Aluminum has a high affinity for pectin so that cell wall surfaces of the Donnan Free Space are the most obvious areas for aluminum to concentrate upon entering the root (Rorison, 1965; Clarkson, 1967).

Data on aluminum uptake by roots suggest that, in the initial stages, most of the aluminum incorporated becomes bound to the adsorption sites in the cell wall, most likely to free carboxyl groups. Aluminum may also be precipitated on the root or cell surfaces as $Al(OH)_3$ by the hydrolysis of $Al(OH)_2$ and Al(OH) by free carboxyl groups (Clarkson, 1967). The positively charged amorphous aluminum hydroxides are known to adsorb and precipitate phosphorus from solution, forming $Al(OH)_2H_2PO_4$. This same thing can happen on cell surfaces effectively reducing the concentration of phosphorus available for metabolic uptake (Clarkson, 1967).

5.0 EFFECTS OF ALUMINUM ON SOIL INVERTEBRATES

A preliminary review of the literature revealed only one study on the toxicity of aluminum to earthworms or other soil invertebrates. Van Gestel and Hoogerwerf (unpublished), as reported by Van Gestel (1992), determined the influence of soil pH on the sublethal toxicity of aluminum for *Eisenia andrei* in artificial soil. Effects on growth and reproduction were studied in worms exposed for 6 weeks (Table 5.1). Results were expressed in terms of a No-Observed-Effect-Concentrations (NOEC). They concluded that low soil pH significantly increased aluminum toxicity. At the highest pH tested (7.3), earthworm growth was significantly increased at high aluminum concentrations in soil. This increased growth was not related, however, to the aluminum dose. The effect of aluminum on cocoon production did not seem to be influenced by soil pH. At pH 3.4 (lowest pH reported), all worms died at 1000 mg Al kg^{1} dry soil. At this pH level cocoon production was almost completely inhibited at 320 mg Al kg^{-1}, whereas at pH 4.3 and 7.3 it was only halved at this concentration. Cocoon production in control groups was significantly reduced at pH 3.4 compared to the two higher pH soils. Aluminum extracted with 1N calcium chloride appeared to decrease with increasing soil pH. The effects on growth and cocoon production could, however, only partially be related to the amount of free aluminum in the soil. They concluded that other factors apparently also played a role.

Table 5.1. Influence of soil pH on the effect of aluminum on *Eisenia andrei* in artificial soil (6 weeks exposure).

Parameter	NOEC (mg Al/kg dry soil) at pH		
	3.4	4.3	7.3
Survival	320	1000[a]	1000[a]
Growth	100	1000[a]	32[b]
Cocoon production	100	100	100
Cocoon fertility	100	1000[a]	1000[a]
Juveniles/fertile cocoons	100[a]	1000[a]	1000[a]

[a] Reliability of this value is low due to a low number of cocoons
[b] Growth was significantly increased at higher concentrations of aluminum

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6.0 UPTAKE AND ACCUMULATION OF ALUMINUM IN SOIL INVERTEBRATES

Data on the uptake and accumulation of aluminum from soil pore water into soil invertebrates could not be located for review.

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7.0 MEASURING ALUMINUM IN SOILS

When researchers, using nutrient solutions, displaced soil solutions, and soils at various pH levels, discovered that conditions toxic to plants in acid soils were due, in many cases, to toxic levels of aluminum, it was apparent that a way of determining the plant available aluminum could be useful for the evaluation of the potential toxicity of a particular soil. Many different methods of measuring aluminum in soils have been used. Displacement of the soil solution, the use of acid solutions, and buffered and unbuffered salt solutions are reported as methods for extracting aluminum.

7.1 Total Aluminum

Total aluminum is often measured in soils because it provides useful information on the characterization of soils with respect to the origin of parent materials and weathering. It also serves as a basis for calculating the mineralogical composition of the sample (Bertsch and Bloom, 1996). Total soil aluminum as a direct measure of aluminum toxicity, however, appears to have little or no value based on the previously presented information. It is not possible to correlate the soil solution concentration of aluminum to the total soil aluminum measurement. Mulder et al. (1989) measured total soil aluminum (%) and soil solution aluminum in samples collected below plant rooting zones and found no relationship between the two concentrations (Figure 7.1).

7.2 Exchangeable and Extractable Aluminum

Exchangeable and extractable aluminum, displaced most commonly with an unbuffered salt solution such as 1*M* KCl, 0.5*M* $CaCl_2$, or 0.5*M* $BaCl_2$, traditionally have had two primary uses. The first is the formulation of lime requirements for acid soils (Kamprath, 1970; Reeve and Sumner, 1970; Amedee and Peech, 1976; Farina et al., 1980; Juo and Kamprath, 1979; Oates and Kamprath, 1983a,b). Second, because of its importance as a predominant cation in acid soils, exchangeable aluminum is a critical variable in establishing effective cation exchange capacity (ECEC) values, which are utilized for soil management and classification purposes, and in evaluating changes in forested soils influenced by acidic deposition and land-use practices (Juo et al., 1976; Pavan et al., 1984; Evans and Zelazny, 1987; Mulder et al., 1987; Lilieholm and Feagley, 1988; Adams et al., 1990; Reuss et al., 1990; Rasmussen et al., 1991). For these applications, investigators are interested in arriving at a reproducible measure of exchangeable Al^{3+} that reflects aluminum exchange equilibria as accurately as possible (Bertsch and Bloom, 1996).

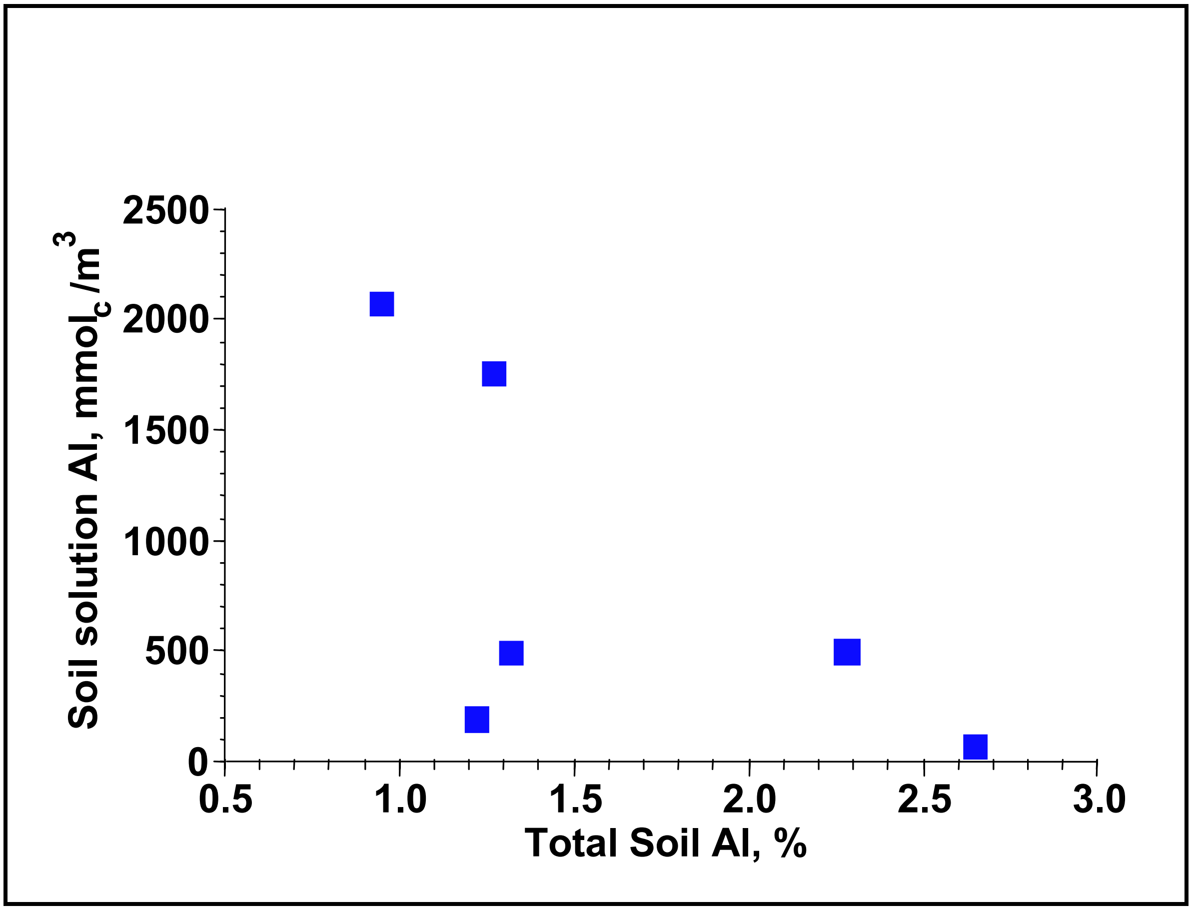

Figure 7.1. Soil solution aluminum collected below plant rooting zones (from Mulder et al., 1989).

7.3 Soluble Aluminum

Soluble aluminum in soil solutions can be an important parameter to study the impact of acidification on forest soils and watershed, the formation (or dissolution) of secondary soil minerals, and to assess aluminum toxicity to plants in acid soils and aquatic organisms in acidified watersheds. Most techniques used to obtain soil solutions for chemical analysis of the typical predominant soil cations (Ca^{2+} , Mg^{2+} , Na^{+}, and K^{+}) also can be used for aluminum. More care is needed, however, since aluminum is typically present in soil solution at much lower concentrations and at much higher concentrations in the whole soil that the other soil cations. Also, the solubility of aluminum is pH dependent and factors that result in change of pH to a value near neutrality can result in loss by precipitation. Many commonly utilized sampling devices can result in either the removal of aluminum through sorption, or contamination of aluminum through dissolution reactions. Collection of samples with low aluminum concentrations require great care to minimize contamination from background sources. Methods of collecting soil solutions in which to measure soluble aluminum include *in situ* sampling with lysimeters, miscible displacement of soils in packed columns, centrifugation with or without a heavy liquid immiscible with water, and filtrations of soil solution samples through a nonreactive membrane filter with pore sizes of 0.45-mmm or less (Bertsch and Bloom, 1996).

Mulder et al. (1989) demonstrated that the relationship between soil solution pH and soluble aluminum concentrations and demonstrated that above a pH of 5.0 soluble aluminum is not measured (Figure 7.2). This data supports the conclusion that at a soil pH of 5.0 and higher, soluble aluminum does not occur and toxicity associated with aluminum in soils is not expected.

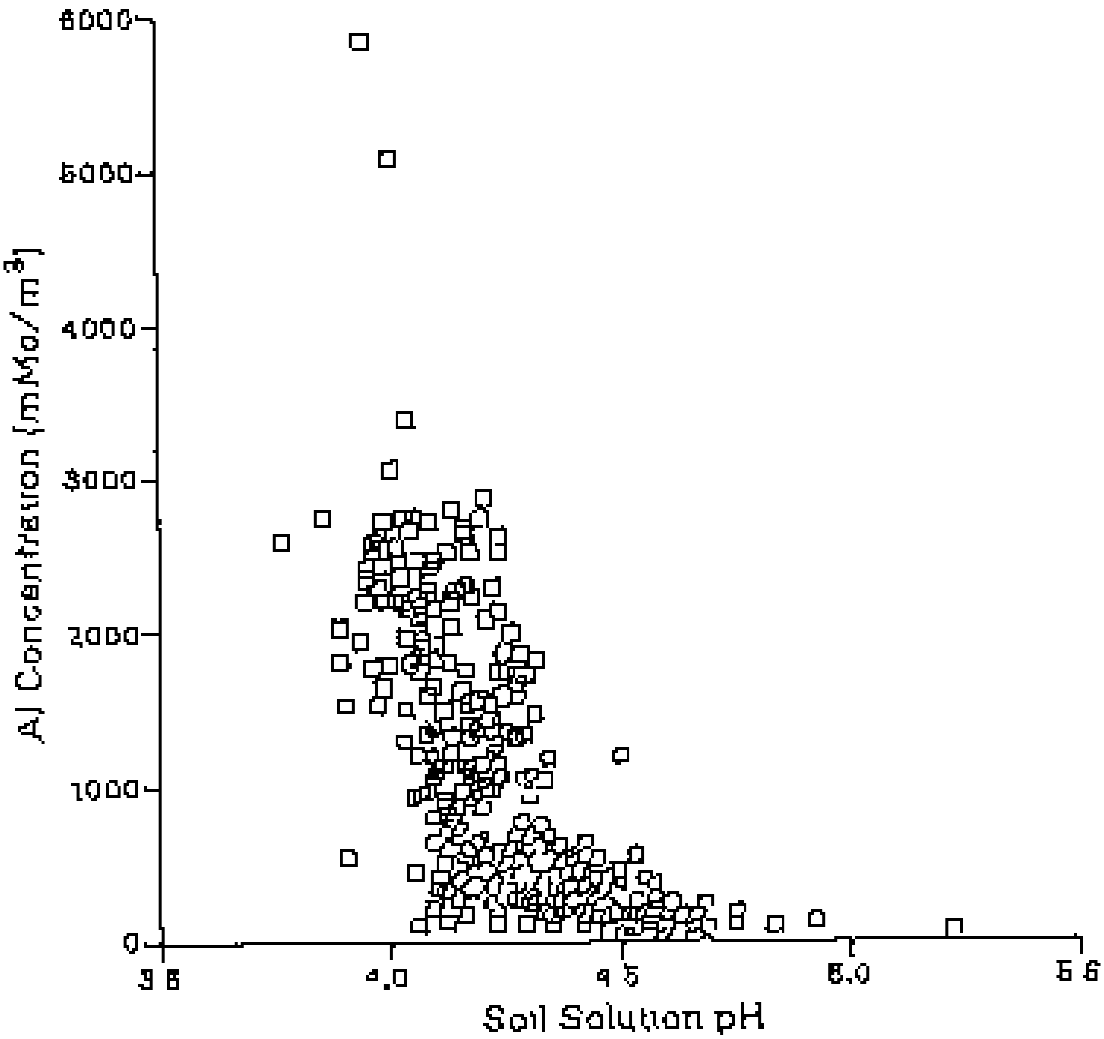

Figure 7.2. Aluminum soil solution concentrations versus soil solution pH in sub-soil solutions (below 50 cm depth) at six study sites (from Mulder et al., 1989).

8.0 CONCLUSIONS ON SCREENING SOILS FOR ALUMINUM TOXICITY

Aluminum (Al) is the most commonly occurring metallic element comprising eight percent of the earth's crust (Press and Siever, 1974). It is a major component of almost all common inorganic soil particles with the exceptions of quartz sand, chert fragments, and ferromanganiferous concretions. The typical range of aluminum in soils is from 1% to 30% (10,000 to 300,000 mg Al kg^{-1}) (Lindsay, 1979 and Dragun, 1988) with naturally occurring concentrations variable over several orders of magnitude.

EPA recognizes that due to the ubiquitous nature of aluminum, the natural variability of aluminum soil concentrations and the availability of conservative soil screening benchmarks (Efroymson, 1997b), aluminum is often identified as a contaminant of potential concern (COPC) for ecological risk assessments. The commonly used soil screening benchmarks (Efroymson, 1997b) are based on laboratory toxicity testing using aluminum solution amendments to test soils. Comparisons of total aluminum soil concentrations to solution based screening values are deemed by EPA to be inappropriate.

The standard analytical measurement of aluminum in soils under CERCLA contract laboratory procedures (CLP) is total recoverable metal. The available data on the environmental chemistry and toxicity of aluminum in soil to plants and soil invertebrates as discussed in the preceding chapters supports the following conclusions:

- Total aluminum in soil is not correlated with toxicity to the tested plants and soil invertebrates.
- Aluminum toxicity is associated with soluble aluminum.
- Soluble aluminum and not total aluminum is associated with the uptake and bioaccumulation of aluminum from soils into plants.

Measurement of Soluble Aluminum in Soils

Chemical and toxicological information suggests that aluminum must be in a soluble form in order to be toxic to biota. It is, however, difficult to measure accurately or with precision the concentration of soluble aluminum in pore water or in soil extracts. The difficulties associated with the measurement of soluble aluminum are discussed in detail in the previous chapters and include the following:

- Contamination problems. Aluminum is ubiquitous and the possibility of contamination of pore water or soil extract samples with aluminum from other sources is high. Sampling requires special handling to minimize background contamination.
- Forms of soluble aluminum which may be toxic are poorly understood

- Techniques for measurement of soluble aluminum are not well developed and would require refinement in order to consistently provide reproducible results that could be used with confidence.

Based on the available information, it is not possible at this time to recommend the direct measurement of soluble aluminum as the method for prediction of toxicity of aluminum in soils. It is possible to recommend as an alternative the measurement of soil pH. The presence of soluble aluminum forms is pH dependent. Thus, the measurement of soil pH provides an indirect but reliable approach for assessing if soluble aluminum could be present. The use of a pH screening level of 5.5 is considered environmentally protective .

Alternative Screening Procedure for Aluminum

Potential ecological risks associated with aluminum in soils is identified based on the measured soil pH. **Aluminum is identified as a COPC only for those soils with a soil pH less than 5.5.** The technical basis for this procedure is that the soluble and toxic forms of aluminum are only present in soil under soil pH values of less than 5.5. Site-specific considerations could, however warrant inclusion of aluminum as a COPC.

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Appendix 6: Results Soil Investigation 2013

Test Report - Chemical Analysis

Customer / Contractor	Tebodin Middle East Ltd.	Report No. / Ref. No.	ILS/12/2013/7751_1_Rev1
Address	ALBA	Report Date	02-01-2014
Project Name	ALBA L5 & PS5 Modelling of Emissions	Date of sample receipt	11-12-2013
Sample description	Soil	Sample Id. No.	Composite Sample-1
Source / Location	ALBA	Date of test	16-12-2013
Condition of sample during receipt	Satisfactory	Consultant	Bechtel

Parameters	Unit	Test method	Result
Boron	mg/kg	USEPA 6010,7000	4.34
Chromium	mg/kg		<0.1
Manganese	mg/kg		<0.1
Iron	mg/kg		<0.1
Nickel	mg/kg		<0.1
Copper	mg/kg		<0.1
Zinc	mg/kg		<0.1
Arsenic	mg/kg		<0.1
Molybdenum	mg/kg		<0.1
Cadmium	mg/kg		<0.1
Barium	mg/kg		<0.1
Lead	mg/kg		<0.1
Mercury	mg/kg		<0.01
Magnesium	mg/kg		358
Calcium	mg/kg		1281
Fluoride	mg/kg		3.6
Aluminum	mg/kg		0.13
Cyanide	mg/kg		<0.01
Phosphate	mg/kg		0.1
Sulphur	mg/kg		1920
pH	-	BS 1377-Part 3	8.77
Acid Soluble Sulphates	%		3.04
Acid Soluble Chloride	%		0.21
Total Organic Carbon	%		0.22
Oil & Grease	%	APHA 5520 E	1.00

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Test Report - Chemical Analysis

Customer / Contractor	Tebodin Middle East Ltd.	Report No. / Ref. No.	ILS/12/2013/7751_1_Rev1
Address	ALBA	Report Date	02-01-2014
Project Name	ALBA L5 & PS5 Modelling of Emissions	Date of sample receipt	11-12-2013
Sample description	Soil	Sample Id. No.	Composite Sample-1
Source / Location	ALBA	Date of test	16-12-2013
Condition of sample during receipt	Satisfactory	Consultant	Bechtel

Parameters	Unit	Test method	Result
Total Petroleum Hydrocarbons			
Volatile Hydrocarbons (C_5-C_{10})	µg/kg	ASTM D 6730	< 50
Extractable Petroleum Hydrocarbons(C_{11}-C_{40})	mg/kg		Not Detected
BTEX			
Benzene	µg/kg	ASTM D 6730	< 50
Ethyl Benzene	µg/kg		< 50
Toluene	µg/kg		< 50
Xylene	µg/kg		< 50
Polyaromatic hydrocarbons			
Naphthalene	µg/kg	EPA 8270	< 50
Acenaphthylene	µg/kg		< 50
Acenaphtene	µg/kg		< 50
Fluorene	µg/kg		< 50
Phenanthrene	µg/kg		< 50
Anthracene	µg/kg		< 50
Fluoranthehe	µg/kg		< 50
Pyrene	µg/kg		< 50
Benzo(a)anthracene	µg/kg		< 50
Chrysene	µg/kg		< 50
Benzo(b)fluoranthene	µg/kg		< 50
Benzo(k)fluoranthene	µg/kg		< 50
Benzo(a)pyrene	µg/kg		< 50
Indeno(1,2,3-cd)pyrene	µg/kg		< 50
Dibenzo(a,h)anthracene	µg/kg		< 50
Dibenzo(ghi)perylene	µg/kg		< 50

Remarks:

1. Test results relate to the sample tested only.
2. Test Report shall not be reproduced except in full, without written approval of the Laboratory.
3.Samples from Trial Pit 1,2,3,4 were collected to form Composie Sample -1

T. Retna Raj	PVH Murali Krishna	Christy Nicholas
General Manager	Technical Incharge	Laboratory Incharge
Approved By	**Reviewed by**	**Verified by**

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Interlab

Geotechnical Engineering Services - Material Testing - Chemical Analysis - NDT - Calibration Services

Test Report - Chemical Analysis

Customer / Contractor	Tebodin Middle East Ltd.	Report No. / Ref. No.	ILS/12/2013/7751_2_Rev1
Address	ALBA	Report Date	02-01-2014
Project Name	ALBA L5 & PS5 Modelling of Emissions	Date of sample receipt	11-12-2013
Sample description	Soil	Sample Id. No.	Composite Sample-2
Source / Location	ALBA	Date of test	16-12-2013
Condition of sample during receipt	Satisfactory	Consultant	Bechtel

Parameters	Unit	Test method	Result
Boron	mg/kg	USEPA 6010,7000	5.1
Chromium	mg/kg		<0.1
Manganese	mg/kg		<0.1
Iron	mg/kg		<0.1
Nickel	mg/kg		<0.1
Copper	mg/kg		<0.1
Zinc	mg/kg		<0.1
Arsenic	mg/kg		<0.1
Molybdenum	mg/kg		<0.1
Cadmium	mg/kg		<0.1
Barium	mg/kg		<0.1
Lead	mg/kg		<0.1
Mercury	mg/kg		<0.01
Magnesium	mg/kg		343
Calcium	mg/kg		1386
Fluoride	mg/kg		3.9
Aluminum	mg/kg		0.12
Cyanide	mg/kg		<0.01
Phosphate	mg/kg		0.1
Sulphur	mg/kg		1896
pH	-	BS 1377-Part 3	8.45
Acid Soluble Sulphates	%		4.48
Acid Soluble Chloride	%		0.13
Total Organic Carbon	%		0.19
Oil & Grease	%	APHA 5520 E	1.10

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Interlab

Geotechnical Engineering Services - Material Testing - Chemical Analysis - NDT - Calibration Services

Test Report - Chemical Analysis

Customer / Contractor	Tebodin Middle East Ltd.	Report No. / Ref. No.	ILS/12/2013/7751_2_Rev1
Address	ALBA	Report Date	02-01-2014
Project Name	ALBA L5 & PS5 Modelling of Emissions	Date of sample receipt	11-12-2013
Sample description	Soil	Sample Id. No.	Composite Sample-2
Source / Location	ALBA	Date of test	16-12-2013
Condition of sample during receipt	Satisfactory	Consultant	Bechtel

Parameters	Unit	Test method	Result
Total Petroleum Hydrocarbons			
Volatile Hydrocarbons (C_5-C_{10})	µg/kg	ASTM D 6730	< 50
Extractable Petroleum Hydrocarbons(C_{11}-C_{40})	mg/kg		Not Detected
BTEX			
Benzene	µg/kg	ASTM D 6730	< 50
Ethyl Benzene	µg/kg		< 50
Toluene	µg/kg		< 50
Xylene	µg/kg		< 50
Polyaromatic hydrocarbons			
Naphthalene	µg/kg	EPA 8270	< 50
Acenaphthylene	µg/kg		< 50
Acenaphtene	µg/kg		< 50
Fluorene	µg/kg		< 50
Phenanthrene	µg/kg		< 50
Anthracene	µg/kg		< 50
Fluoranthehe	µg/kg		< 50
Pyrene	µg/kg		< 50
Benzo(a)anthracene	µg/kg		< 50
Chrysene	µg/kg		< 50
Benzo(b)fluoranthene	µg/kg		< 50
Benzo(k)fluoranthene	µg/kg		< 50
Benzo(a)pyrene	µg/kg		< 50
Indeno(1,2,3-cd)pyrene	µg/kg		< 50
Dibenzo(a,h)anthracene	µg/kg		< 50
Dibenzo(ghi)perylene	µg/kg		< 50

Remarks:
1. Test results relate to the sample tested only.
2. Test Report shall not be reproduced except in full, without written approval of the Laboratory.
3.Samples from Trial Pit 6,7,9,11 were collected to form Composie Sample -2

T. Retna Raj General Manager **Approved By**	PVH Murali Krishna Technical Incharge **Reviewed by**	Christy Nicholas Laboratory Incharge **Verified by**

Test Report - Chemical Analysis			Page No. 1 of 2
Customer / Contractor	Tebodin Middle East Ltd.	Report No. / Ref. No.	ILS/12/2013/7751_3_Rev1
Address	ALBA	Report Date	02-01-2014
Project Name	ALBA L5 & PS5 Modelling of Emissions	Date of sample receipt	11-12-2013
Sample description	Soil	Sample Id. No.	Composite Sample-3
Source / Location	ALBA	Date of test	16-12-2013
Condition of sample during receipt	Satisfactory	Consultant	Bechtel
Parameters	**Unit**	**Test method**	**Result**
Boron	mg/kg	USEPA 6010,7000	5.7
Chromium	mg/kg		<0.1
Manganese	mg/kg		<0.1
Iron	mg/kg		<0.1
Nickel	mg/kg		<0.1
Copper	mg/kg		<0.1
Zinc	mg/kg		<0.1
Arsenic	mg/kg		<0.1
Molybdenum	mg/kg		0.1
Cadmium	mg/kg		<0.1
Barium	mg/kg		<0.1
Lead	mg/kg		<0.1
Mercury	mg/kg		<0.01
Magnesium	mg/kg		349
Calcium	mg/kg		1578
Fluoride	mg/kg		4
Aluminum	mg/kg		0.11
Cyanide	mg/kg		<0.01
Phosphate	mg/kg		0.1
Sulphur	mg/kg		2080
pH	-	BS 1377-Part 3	8.56
Acid Soluble Sulphates	%		5.89
Acid Soluble Chloride	%		0.46
Total Organic Carbon	%		0.28
Oil & Grease	%	APHA 5520 E	0.90

Test Report - Chemical Analysis

Customer / Contractor	Tebodin Middle East Ltd.	Report No. / Ref. No.	ILS/12/2013/7751_3_Rev1
Address	ALBA	Report Date	02-01-2014
Project Name	ALBA L5 & PS5 Modelling of Emissions	Date of sample receipt	11-12-2013
Sample description	Soil	Sample Id. No.	Composite Sample-3
Source / Location	ALBA	Date of test	16-12-2013
Condition of sample during receipt	Satisfactory	Consultant	Bechtel

Parameters	Unit	Test method	Result
Total Petroleum Hydrocarbons			
Volatile Hydrocarbons (C_5-C_{10})	µg/kg	ASTM D 6730	< 50
Extractable Petroleum Hydrocarbons(C_{11}-C_{40})	mg/kg		Not Detected
BTEX			
Benzene	µg/kg	ASTM D 6730	< 50
Ethyl Benzene	µg/kg		< 50
Toluene	µg/kg		< 50
Xylene	µg/kg		< 50
Polyaromatic hydrocarbons			
Naphthalene	µg/kg	EPA 8270	< 50
Acenaphthylene	µg/kg		< 50
Acenaphtene	µg/kg		< 50
Fluorene	µg/kg		< 50
Phenanthrene	µg/kg		< 50
Anthracene	µg/kg		< 50
Fluoranthehe	µg/kg		< 50
Pyrene	µg/kg		< 50
Benzo(a)anthracene	µg/kg		< 50
Chrysene	µg/kg		< 50
Benzo(b)fluoranthene	µg/kg		< 50
Benzo(k)fluoranthene	µg/kg		< 50
Benzo(a)pyrene	µg/kg		< 50
Indeno(1,2,3-cd)pyrene	µg/kg		< 50
Dibenzo(a,h)anthracene	µg/kg		< 50
Dibenzo(ghi)perylene	µg/kg		< 50

Remarks:
1. Test results relate to the sample tested only.
2. Test Report shall not be reproduced except in full, without written approval of the Laboratory.
3.Samples from Trial Pit 5,8,10,12 were collected to form Composie Sample -3

T. Retna Raj	RVH Murali Krishna	Christy Nichola's
General Manager	Technical Incharge	Laboratory Incharge
Approved By	**Reviewed by**	**Verified by**

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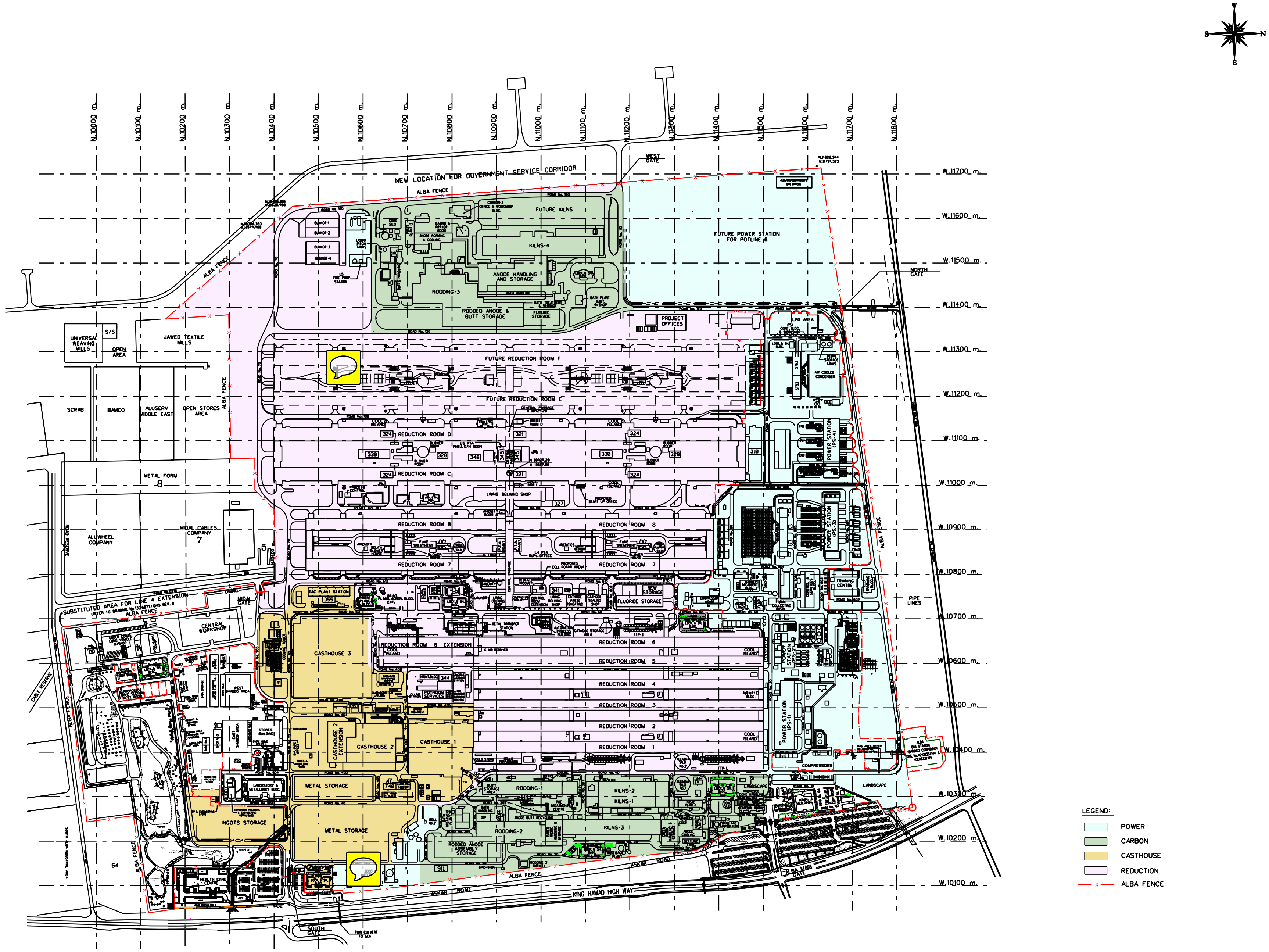
Appendix 7: Groundwater Monitoring Locations



ITEM	DESCRIPTION	QTY.	MATERIAL	DRG. No. OR MANUFACTURER

DRAWN	HASSAN-U11147	29.05.12
CHECKED	DAHER ABEDEEN	
APPROVED	W.P. OTTESON	

LIMITATION OF USE

THIS DRAWING DOCUMENT AND THE INFORMATION THEREON IS THE PROPERTY OF ALUMINIUM BAHRAIN AND SHOULD BE USED ONLY FOR THE PURPOSE FOR WHICH IT WAS EXPRESSLY LOANED AND IS TO BE RETURNED UPON REQUEST OR COMPLETION OF THE WORK FOR WHICH IT WAS ISSUED. IT SHOULD NOT BE COPIED IN ANY MANNER NOR IS ANY INFORMATION TAKEN THEREFROM TO BE TRANSMITTED OR PASSED ON TO A THIRD PARTY.

SUPPLIER CODE: A9900

PROJECTION: FIRST ANGLE

FUNCTIONAL LOCATION No.: 01-09-005-016

EQUIPMENT No.:

SCALE: 1:3000 A0

ALUMINIUM BAHRAIN B.S.C.

SUPPLIER'S NAME: ALBA

PROJECT: ALBA PLANT

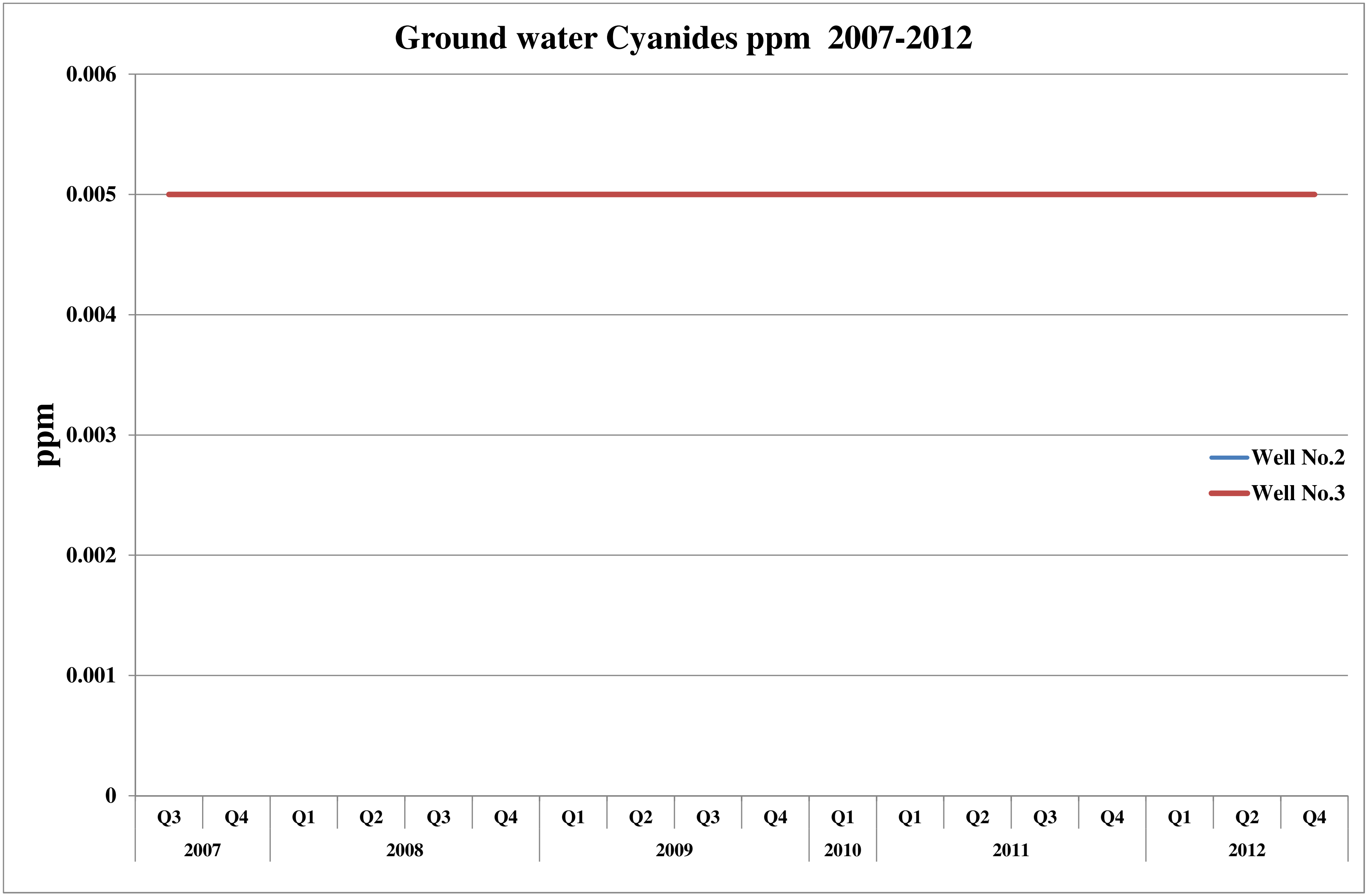
DRAWING TITLE: GENERAL PLANT LAYOUT 2012 (SMELTER)

DRAWING No.: C02.502/090

REV.

REV.		DATE	BY	CHECKED

Appendix 8: Results Groundwater Monitoring 2007 – 2012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0.004
0.003
0.002
0.001
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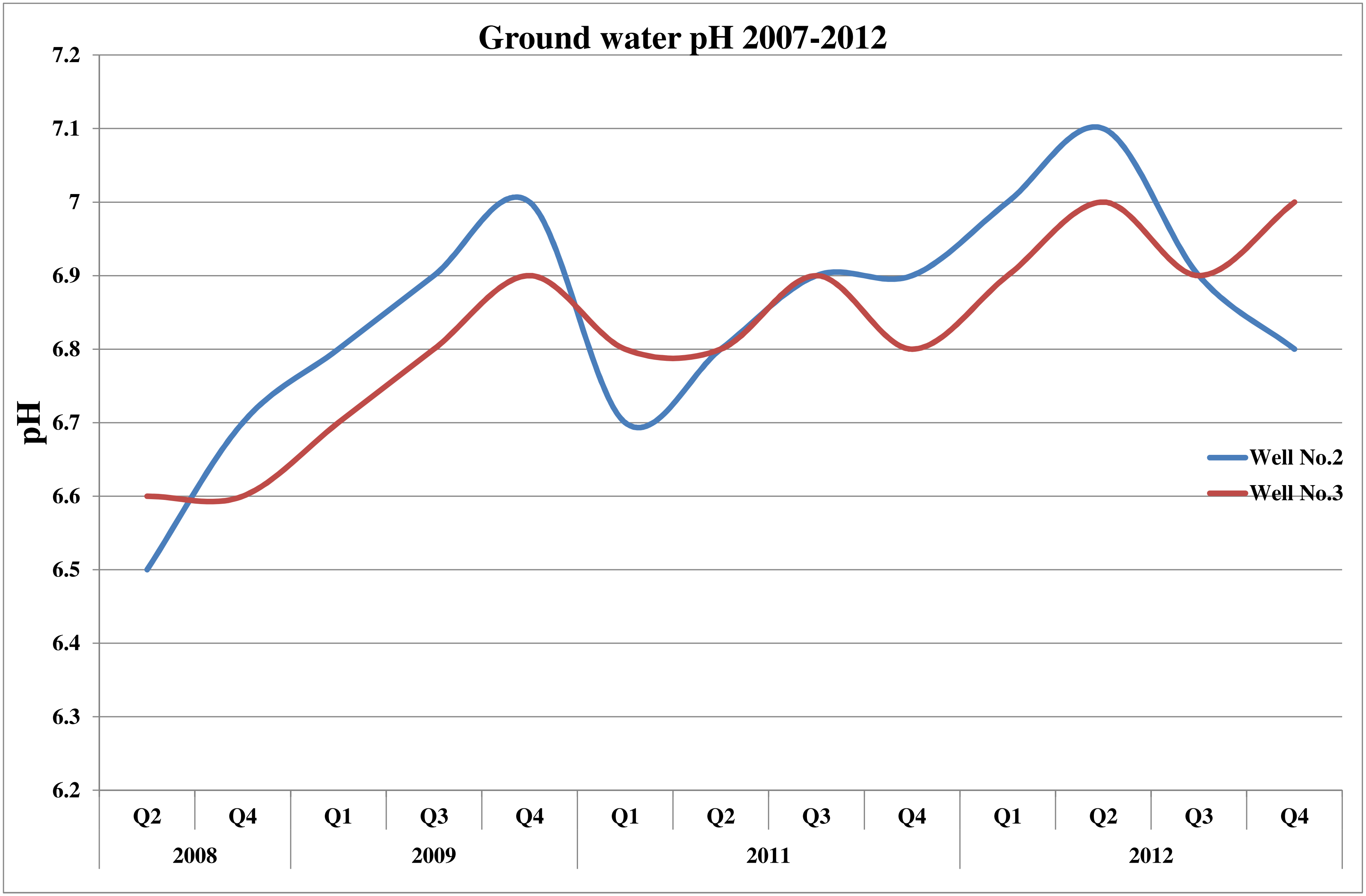
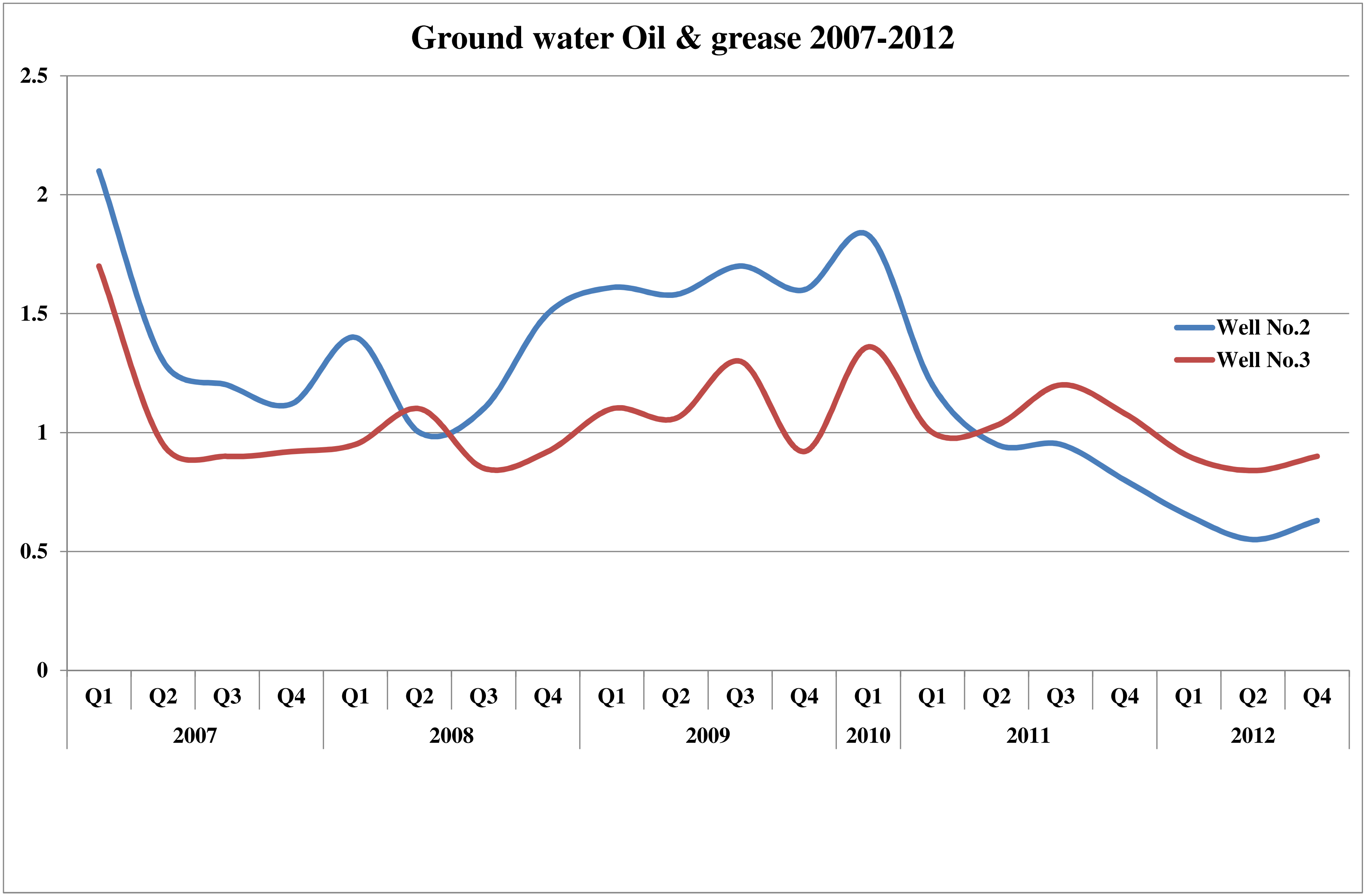
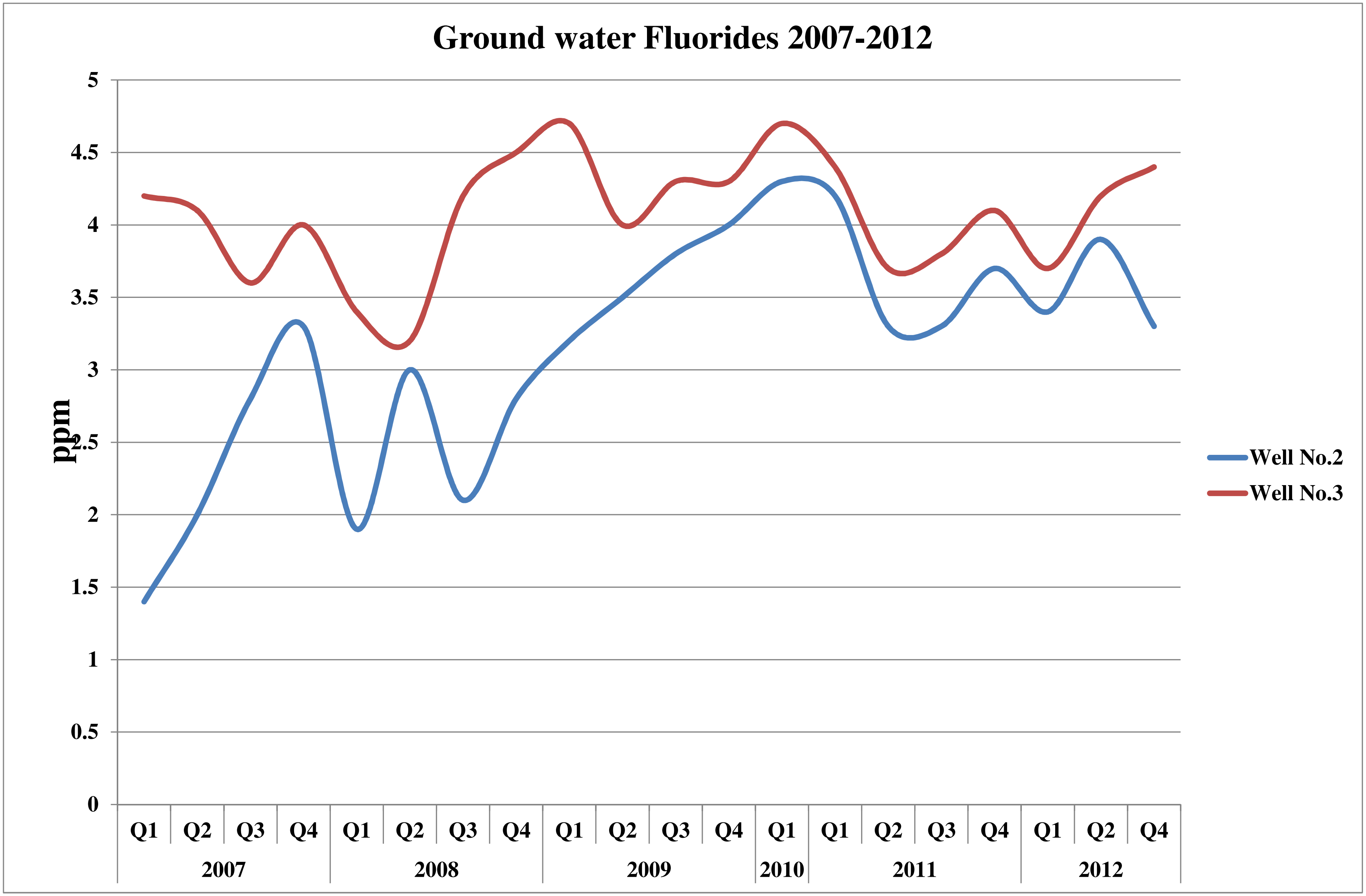
Well No.3
Q3
Q4
2007
Q1
Q2
Q3
Q4
2008
Q1
Q2
Q3
Q4
2009
Q1
2010
Q1
Q2
Q3
Q4
2011
Q1
Q2
Q4
2012


Ground water pH 2007-2012
pH
7.2
7.1
7
6.9
6.8
6.7
6.6
6.5
6.4
6.3
6.2
Q2
Q4
Q1
Q3
Q4
Q1
Q2
Q3
Q4
Q1
Q2
Q3
Q4
2008
2009
2011
2012
Well No.2
Well No.3


Ground water Oil & grease 2007-2012
2.5
2
1.5
1
0.5
0
Well No.2
Well No.3
Q1
Q2
Q3
Q4
2007
Q1
Q2
Q3
Q4
2008
Q1
Q2
Q3
Q4
2009
Q1
2010
Q1
Q2
Q3
Q4
2011
Q1
Q2
Q4
2012


Ground water Fluorides 2007-2012
ppm
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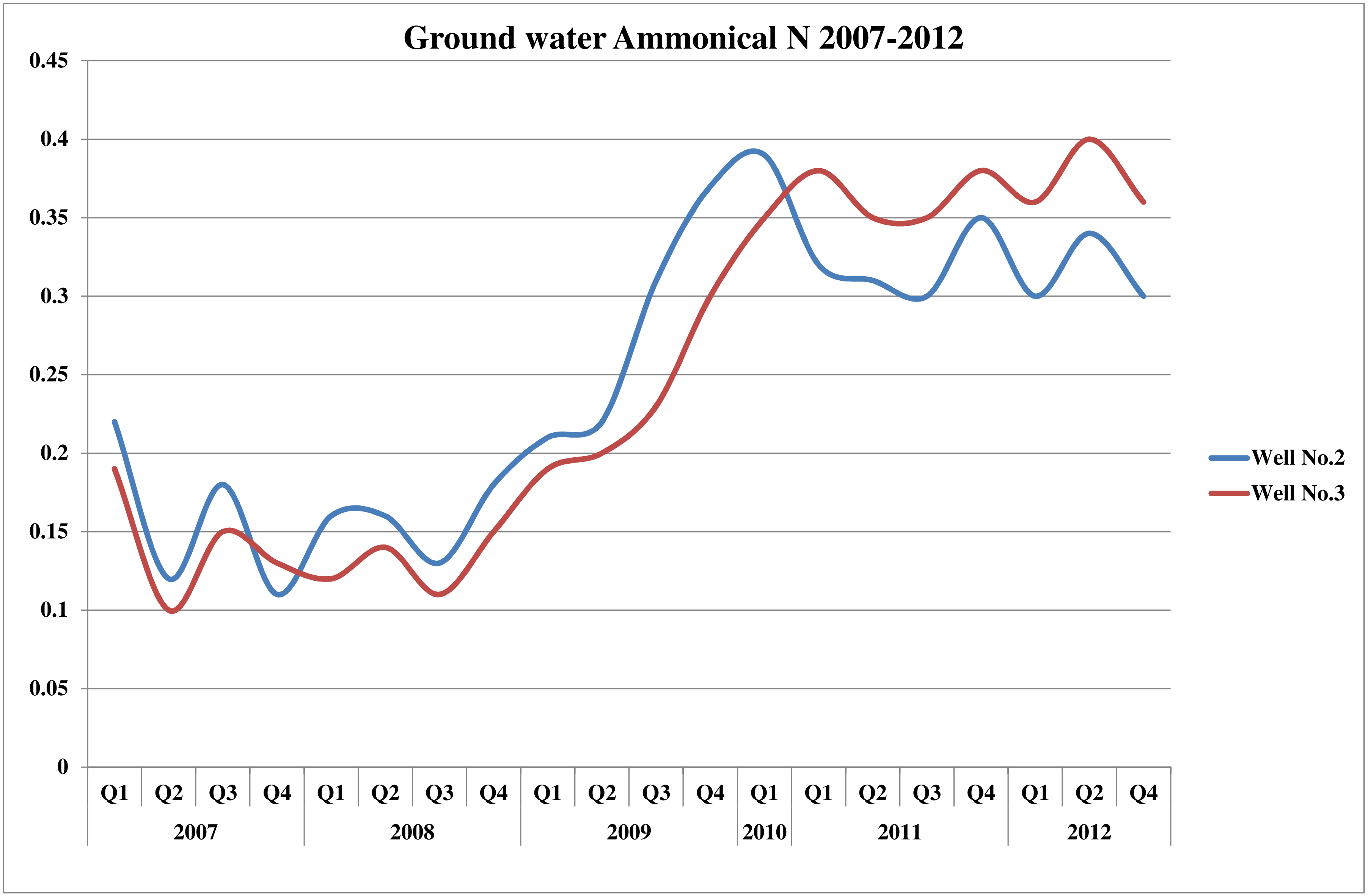
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
Q1 Q2 Q3 Q4 Q1 Q2 Q3 Q4 Q1 Q2 Q3 Q4 Q1 Q1 Q2 Q3 Q4 Q1 Q2 Q4
2007
2008
2009
2010
2011
2012
Well No.2
Well No.3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0.05
0
Q1
Q2
Q3
Q4
Q1
Q2
Q3
Q4
Q1
Q2
Q3
Q4
Q1
Q1
Q2
Q3
Q4
Q1
Q2
Q4
2007
2008
2009
2010
2011
2012
Well No.2
Well No.3

Appendix 9: Noise Monitoring Results 2013

Client: **Bechtel**
Project: ALBA Potline (6) and Power Plant (PS 5) Expansion

Appendix 9:
Noise Monitoring Results

Tebodin

Tebodin Middle East Ltd.
Ahmed Ghanem Mazroui Building
Hamdan Street
Tourist Club Area
P.O. Box 2652
Abu Dhabi
United Arab Emirates

Author: M. van der Vorst
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Revision: 0

BILFINGER

0	24 April 2014	First Issue	KB	MVV
Rev.	Date	Description	Author	Checked by

BILFINGER

Table of contents

BILFINGER

1 Noise Monitoring

1.1 Introduction

In order to assess the noise impact on surrounding land-users and the contribution to ambient noise levels in these areas, noise monitoring was conducted as part of the current ESIA study.

The ambient noise levels were monitored using a Type-2 Integrated and Logging Sound Level Meter for an approximate duration of fifteen (15) minutes per location.

A total of eleven (11) monitoring locations were selected for noise monitoring during the day-time on a weekend day. Noise monitoring on a weekday was performed at fourteen (14) selected locations during day-time and six (6) locations during night-time. Furthermore, an additional six (6) monitoring locations were selected inside the site premises (weekday, day-time).

The monitoring locations are presented in Figure 1 (day-time weekend-day, day-time weekday inside site premises, night-time weekday) and Figure 2 (day-time weekday). The corresponding UTM co-ordinates are listed in Table 1.

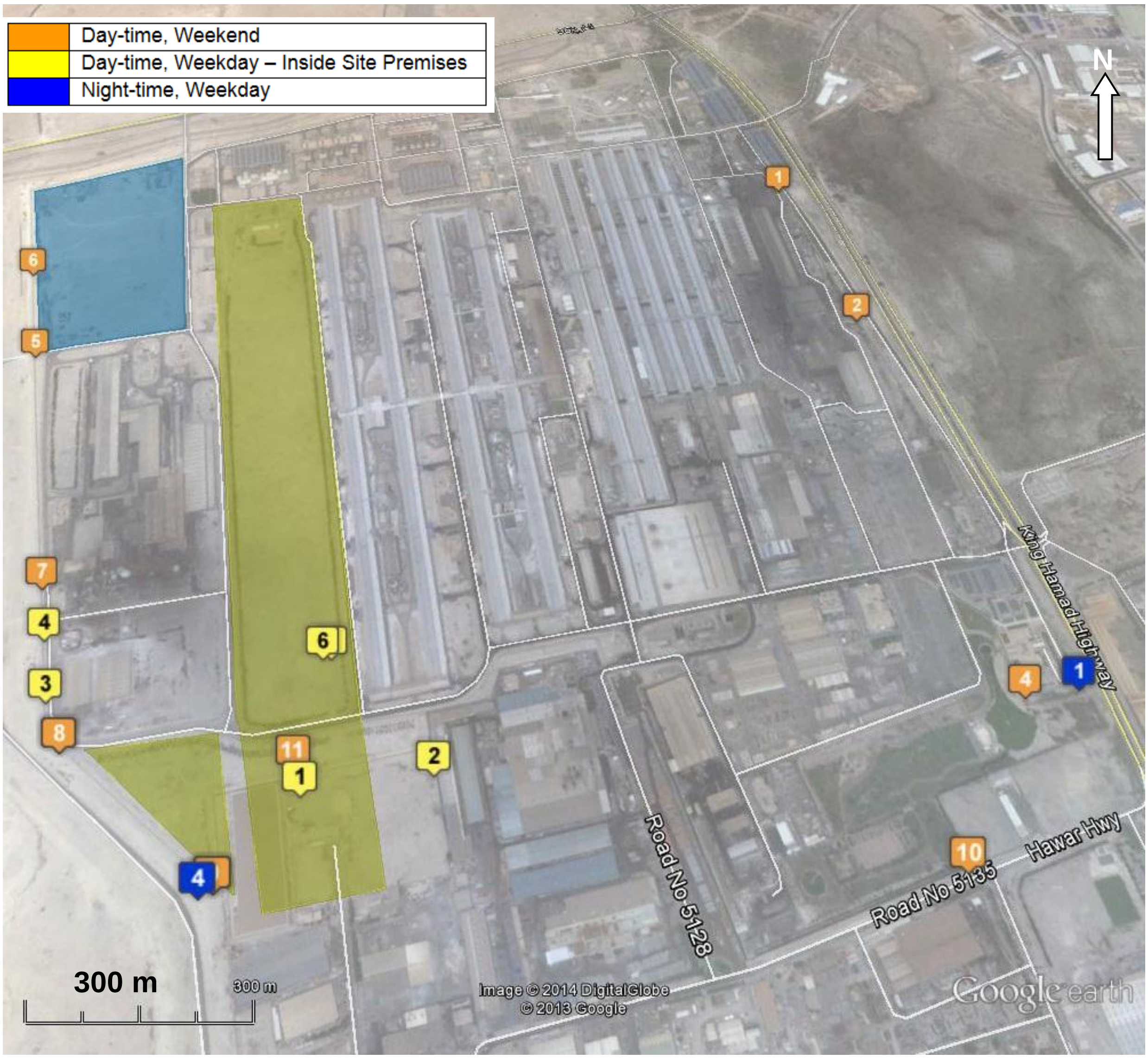

Figure 1 Locations of Noise Monitoring – Fence line and inside Alba's site premises

Figure 2: Locations of Noise Monitoring – Day-time, weekday

Table 1: UTM Co-ordinates of Noise Monitoring

Location Number				UTM Co-ordinates	
Day-time			Night-time		
Weekend Day	Week Day	Inside Site Premises	Weekday	Easting	Northing
1	1	-	5	460862 m E	2886035 m N
2	2	-	6	460977 m E	2885684 m N
3	3	-	1	461219 m E	2884945 m N
4	4	-	-	461131 m E	2884932 m N
5	5	-	-	459418 m E	2885583 m N
6	6	-	-	459358 m E	2885786 m N
7	7	-	-	459555 m E	2885112 m N
8	8	-	2	459651 m E	2884846 m N
9	9	-	3	459916 m E	2884649 m N
10		-	-	460989 m E	2884675 m N
11		-	-	460005 m E	2884821 m N
-	10	-	-	459598 m E	2886130 m N
-	11	-	-	459896 m E	2886420 m N
-	12	-	-	467146 m E	2893181 m N
-	13	-	-	458030 m E	2885724 m N
-	14	-	-	456734 m E	2885769 m N
-	-	-	4	459896 m E	2884642 m N
-	-	1	-	460020 m E	2884782 m N
-	-	2	-	460215 m E	2884812 m N
-	-	3	-	459611 m E	2884922 m N
-	-	4	-	459582 m E	2885023 m N
-	-	5	-	460040 m E	2884994 m N
-	-	6	-	460027 m E	2884994 m N

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1.2 Monitored Noise Levels

Background noise levels in the area were recorded through monitoring. The noise monitoring results are presented in Table A-1 and A-2 respectively.

Table A- 1: Noise Data Inventory GTC and FTC

#	UTM Coordinates		Sound Pressure Levels in dB(A)					Remarks	Time
	Easting	Northing	L_{eq}	L_{max}	L_{min}	L_{10}	L_{90}		
Weekend- 8th February 2014 : Daytime									
1	460862	2886035	69.3	75.8	65.6	70.1	63.6	Close to PL-6 office	12:20
2	460977	2885684	66.5	72.4	60.4	69.1	61.9	Along the eastern fenceline	12:45
3	461219	2884945	71.0	73.7	66.5	71.9	67.0	South Gate- close to emergency clinic- heavy vehicle movements	13:10
4	461131	2884932	64.8	73.2	61.1	68.1	61.9	Fence-line east of ALBA lake	13:30
5	459418	2885583	62.2	64.4	59.8	62.5	61.0	North-west fenceline	13:50
6	459358	2885786	58.3	61.3	56.0	59.4	56.2		14:20
7	459555	2885112	66.5	68.7	65.6	67.2	65.8		14:45
8	459651	2884846	58.5	61.7	51.6	59.7	56.6	South-west corner	15:30
9	459916	2884649	58.5	62.3	56.6	59.7	56.6	Close to Jawad textile mill	15:00
10	460989	2884675	69.1	82.0	49.1	72.5	64.8	Excavation works ongoing close to ALBA lake	15:50
11	460005	2884821	66.0	74.3	60.8	69.5	61.7	South-east fenceline	16:20

Table A- 2: Noise Data Inventory GTC and FTC

#	UTM Coordinates		Sound Pressure Levels in dB(A)					Remarks	Time
	Easting	Northing	L_{eq}	L_{max}	L_{min}	L_{10}	L_{90}		
Weekday- 9thFebruary 2014 : Daytime									
1	460862	2886035	69.4	75.6	65.4	70.0	63.4	Close to PL-6 office	9:30
2	460977	2885684	66.0	72.1	60.2	68.7	61.7	Along the eastern fenceline	10:00
3	461219	2884945	70.5	73.8	66.5	71.4	66.9	South Gate- close to emergency clinic- heavy vehicle movements	10:20
4	461131	2884932	64.0	72.5	60.2	67.2	61.4	Fence-line east of	10:30

#	UTM Coordinates		Sound Pressure Levels in dB(A)					Remarks	Time
	Easting	Northing	L_{eq}	L_{max}	L_{min}	L_{10}	L_{90}		
								ALBA lake	
5	459418	2885583	62.3	64.2	59.6	62.7	61.1	North-western fenceline	10:45
6	459358	2885786	59.0	62.1	56.4	59.7	56.5		11:20
7	459555	2885112	66.8	69.1	65.8	67.4	66.1		11:45
8	459651	2884846	58.6	61.9	51.8	59.9	56.7	South-west corner	12:30
9	459916	2884649	58.7	62.6	56.5	59.9	56.7	Close to Jawad textile mill	13:00
10	459598	2886130	66.0	73.0	64.8	66.5	65.1	North Gate	13:30
11	459896	2886420	67.3	70.2	65.4	68.5	65.9	Outside PS-4	14:20
Weekday- 10thFebruary 2014 : Daytime									
12	467146	2893181	68.6	71.6	67.4	69.4	62.3	Calciner- close to proposed ship loading area	09:00
13	458030	2885724	73.5	80.0	46.1	48.4	75.4	Camps off-plot ALBA facility: heavy traffic	15:25
14	456734	2885769	61.0	67.8	50.8	65.6	52.6	Golf Course	16:00
Weekday- 9th February 2014 : Night time									
1	461219	2884945	65.6	73.0	60.1	70.0	62.5	Near South Gate	00:15
Weekday- 10th February 2014 : Night time									
1	459651	2884846	58.2	61.6	50.4	59.0	56.3	South-west corner	23:40
2	459916	2884649	57.0	62.0	50.1	59.1	56.1	Close to Jawad textile mill	00:10
3	459896	2884642	67.1	70.2	65.0	68.0	65.7	Outside PS-4	01:30
4	460862	2886035	69.0	75.0	65.4	70.1	63.4	Close to PL-6 office	02:10
5	460977	2885684	66.0	71.3	58.4	68.1	61.4	Along the eastern fenceline	03:15

1.3 Conclusions

As can be seen through the results of the monitoring revealed from the above Tables, the ambient noise levels at all areas (Leq 58.3 dB(A) – 73.5 dB(A)) were noted to be within the applicable limits set by the World Bank for industrial and commercial locations (70 dB (A) for both day- and night-time) except for the area close to the clinic where high noise levels were noted from vehicle movements along the nearby highway.

Appendix 10: Waste Water Discharge Quality

Aluminium Bahrain **Date:14.06.11**
Environment&IH Department

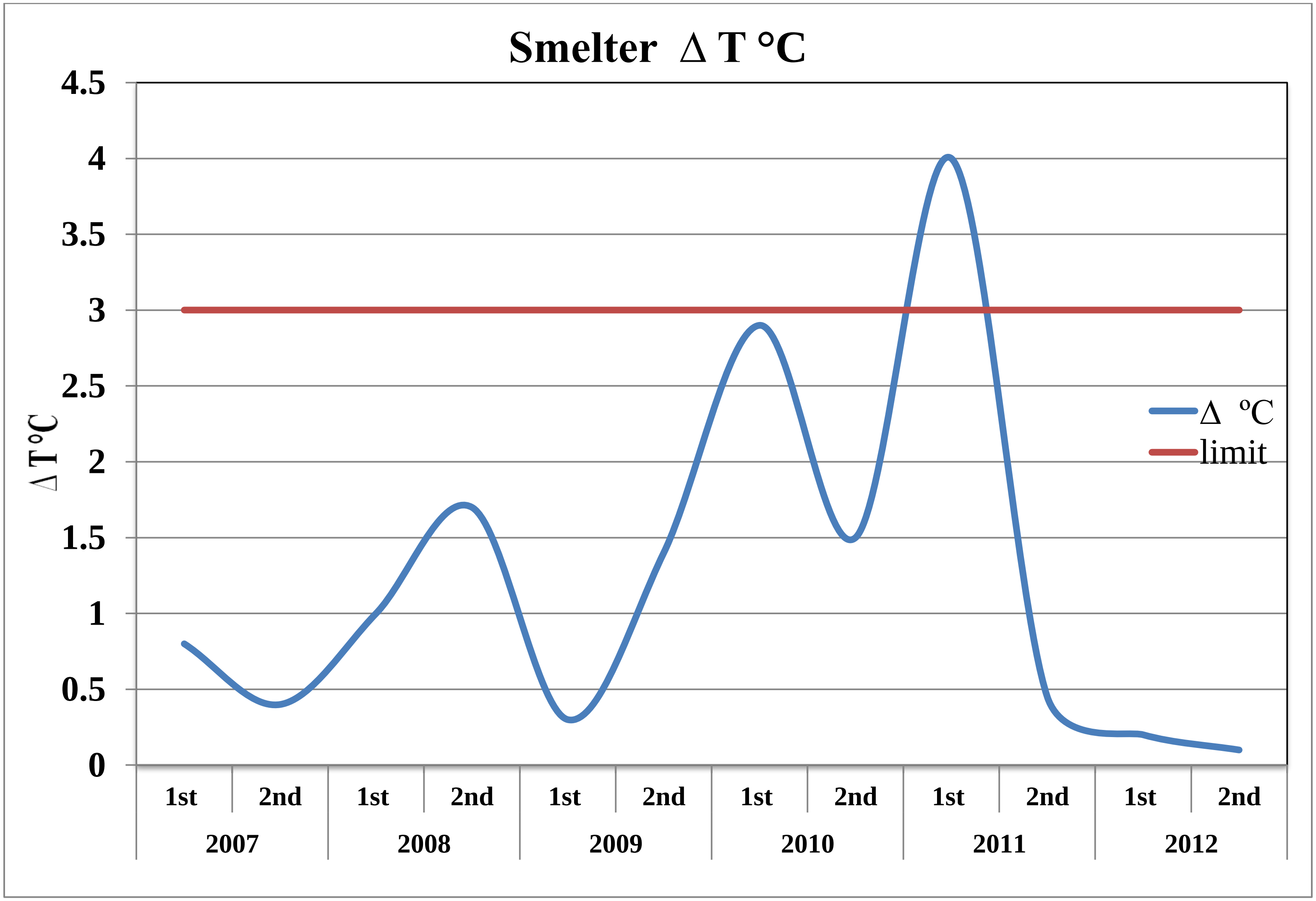
Wastewater Analysis - Half Year 1 of 2011

Sl.No:	Parameter	Unit	Permissible Max.*	Result (Smelter)	Result (Calciner)
1	Temperature Delta T	Dt ºC	± 3	+1	+1
2	pH	pH	6 – 9	7.3	6
3	Total Suspended Solids	mg/1	35	0.85	1.1
4	Oil and Grease	mg/1	15	0.9	0.8
5	Sulphide	mg/1	1	Nil	Nil
6	Residual Chlorine	mg/1	2	Nil	0.02
7	Total Phosphate (P)	mg/1	2	0.33	0.6
8	B.O.D.	mg/1	50	<10	12
9	Iron	mg/1	10	0.4	0.45
10	Turbidity	N.T.U.	75	2.1	1.5
11	Total Cyanide	mg/1	0.1	<0.005	<0.005
12	Ammonia(As Nitrogen)	mg/1	3	0.45	0.55
13	Floating Particles	mg/m²	Nil	Nil	Nil
14	Nitrate (NO_3) as N	mg/1	10	3.77	0.02
15	Nitrite (NO_2) as N	mg/1	1	0.92	0.01
16	Ch. Oxygen Demand	mg/1	350	88	172
17	Total Kjeldahl Nitrogen	mg/1	10	3.1	2.24
18	Total Organic Carbon	mg/1	50	7.1	10
19	Phenols	mg/1	1	0.07	0.01
20	Arsenic	mg/1	0.5	<0.01	<0.01
21	Cadmium	mg/1	0.05	0.04	< 0.02
22	Total Chromium	mg/1	1	0.06	0.01
23	Copper	mg/1	0.5	**0.55**	0.28
24	Lead	mg/1	1	< 0.15	<0.15
25	Mercury	mg/1	0.005	<0.001	<0.001
26	Nickel	mg/1	0.5	0.04	0.075
27	Zinc	mg/1	5	1.27	0.01
28	Total Coliforms	MPN/100	10,000	14	13
29	Aluminium	mg/1	25	0.029	<0.01
30	Fluorescent Petroleum Materials	mg/1	0.1	0.07	<0.001

* Gazette Notification dated 12/12/2001

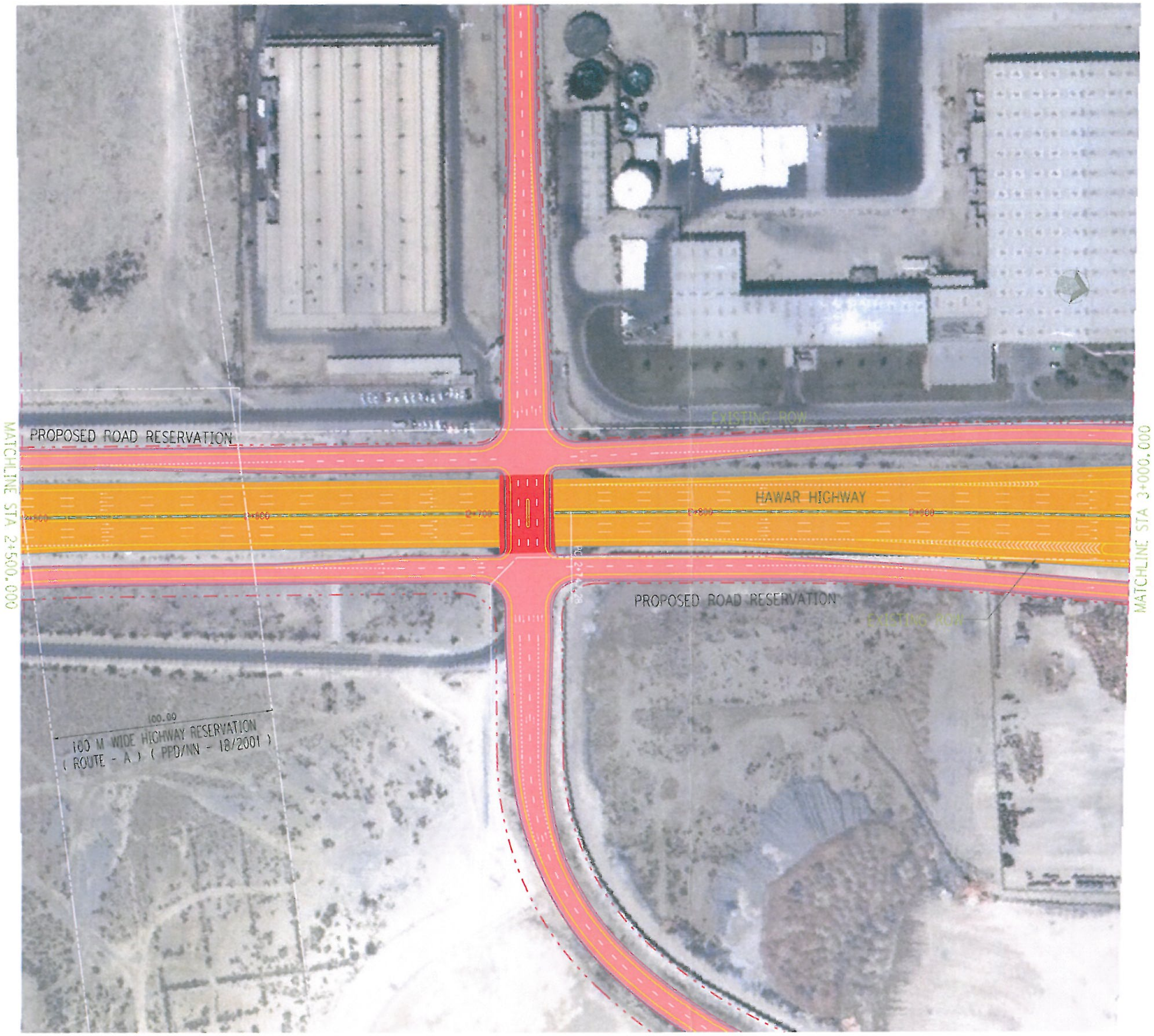
Appendix 11: Marine Ambient Water Temperatures

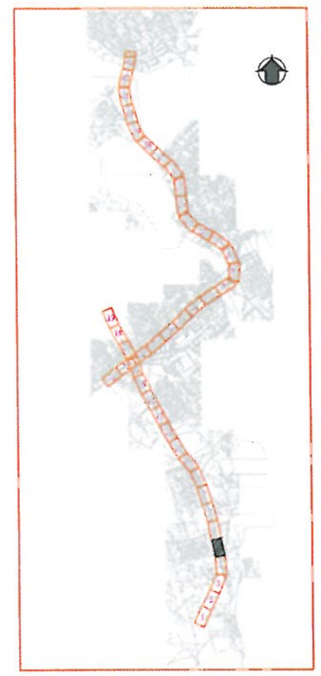
Appendix 11 – Marine water ambient temperatures



Appendix 12: Road Network

Annexure-1





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LEGEND AND ABBREVIATIONS

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- EXISTING RIGHT OF WAY
- EDGE OF ROADWAY

PROPOSED:

- PROPOSED ROAD RESERVATION
- EDGE OF SHOULDER
- EDGE OF CARRIAGEWAY
- EDGE OF MEDIAN
- AT GRADE
- RAMP
- BRIDGE

0 50 100 M

GRAPHIC SCALE: 1:1000 (A1)

F I N A L

REV.	DATE	DESCRIPTION	APPROVED

KINGDOM OF BAHRAIN
MINISTRY OF WORKS AND HOUSING
ROADS PLANNING & DESIGN DIRECTORATE

PARSONS
GLOBAL SERVICES LIMITED
COEPP LICENSE No: FB/102

CONTRACT
BAHRAIN-QATAR CAUSEWAY
TRAFFIC IMPACT STUDY

DRAWING TITLE
ROADWAY LAYOUT
(STA 2+500.000 TO STA 3+000.000)

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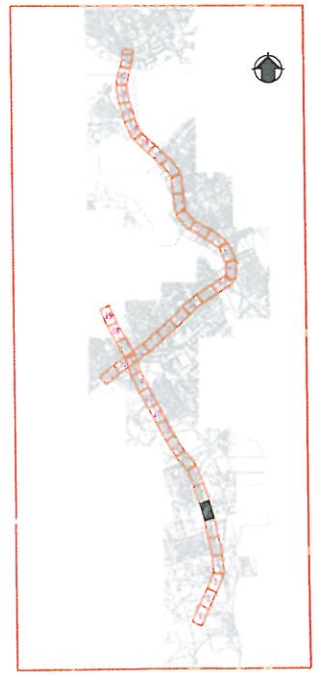

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EDGE OF SHOULDER

EDGE OF CARRIAGEWAY

EDGE OF MEDIAN

AT GRADE

FLYOVER

BRIDGE

0 50 100 M

GRAPHIC SCALE: 1:1000 (A1)

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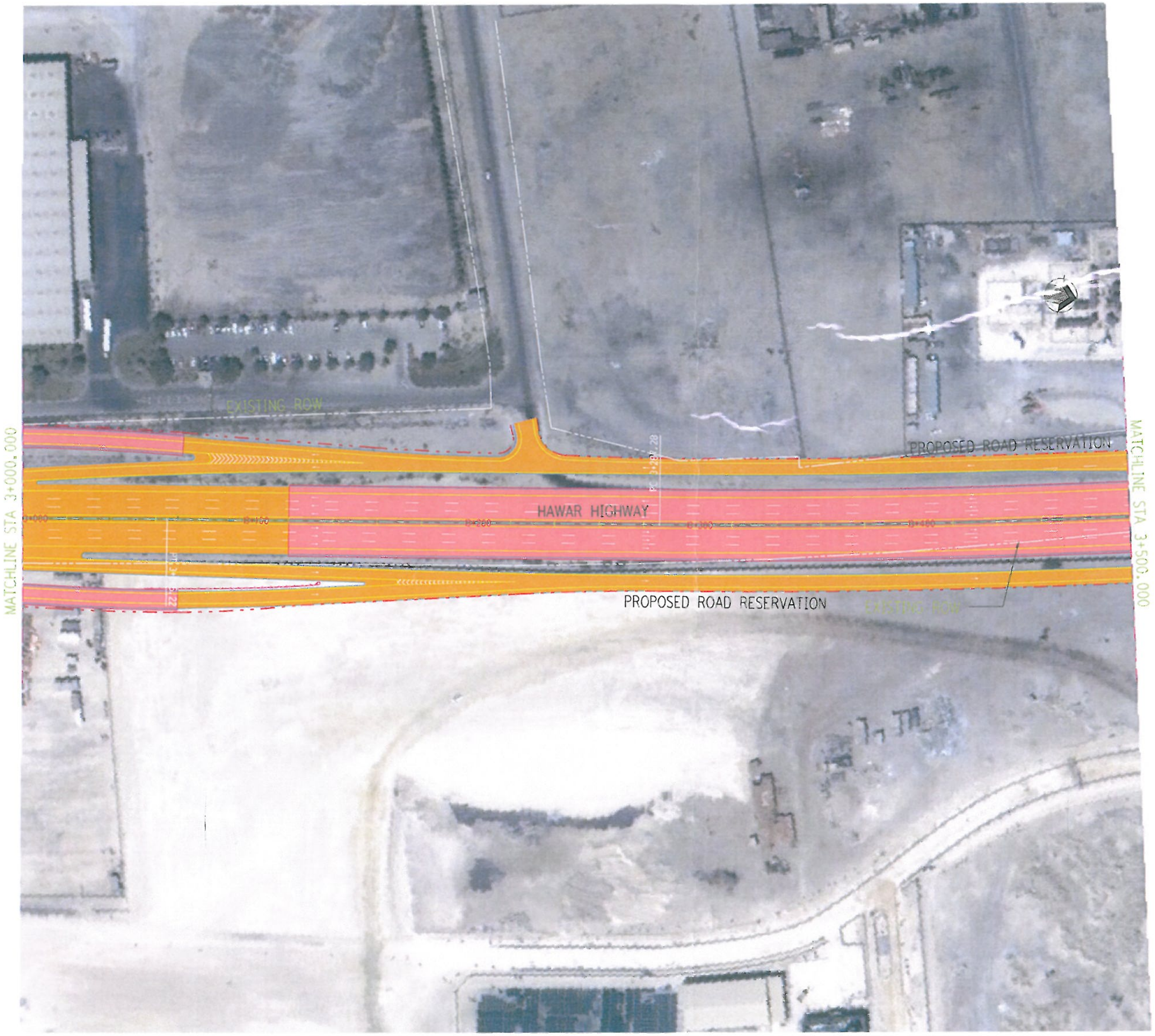

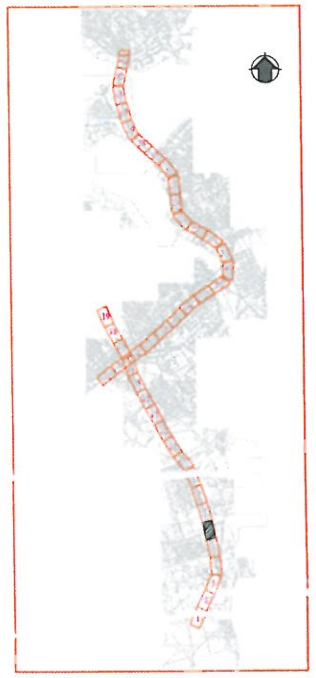

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- EDGE OF MEDIAN
- AT GRADE
- FLYOVER

0 50 100 M

GRAPHIC SCALE: 1:1000 (A1)

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DRAWING TITLE
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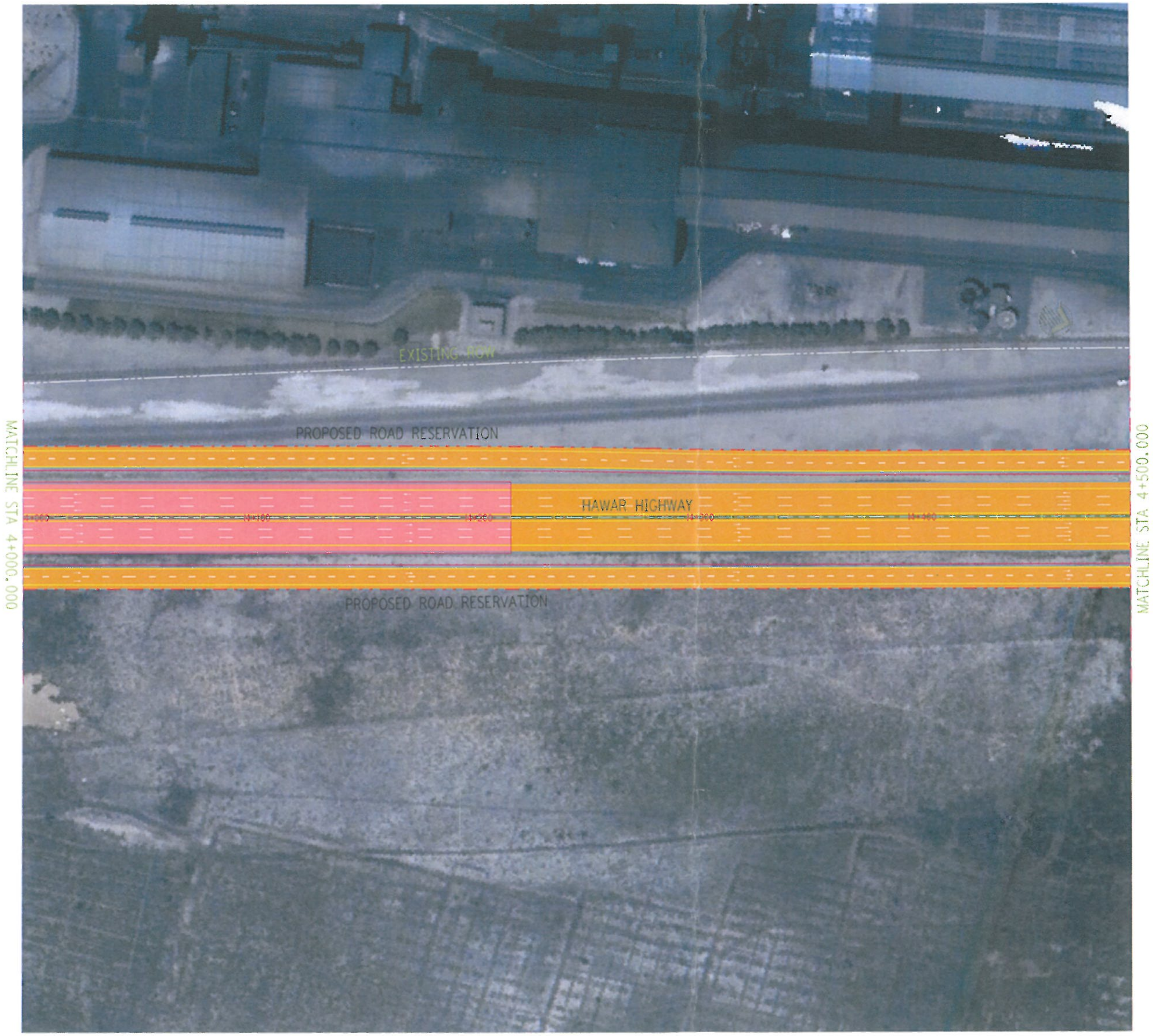

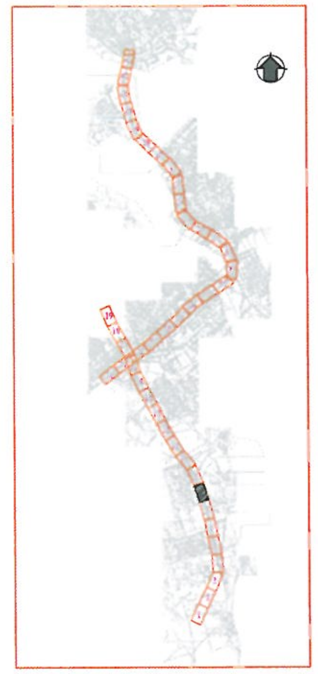

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EDGE OF ROADWAY

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PROPOSED ROAD RESERVATION
EDGE OF SHOULDER
EDGE OF CARRIAGEWAY
EDGE OF MEDIAN
AT GRADE
FLYOVER

0 50 100 M
GRAPHIC SCALE: 1:1000 (A1)

FINAL

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TRAFFIC IMPACT STUDY

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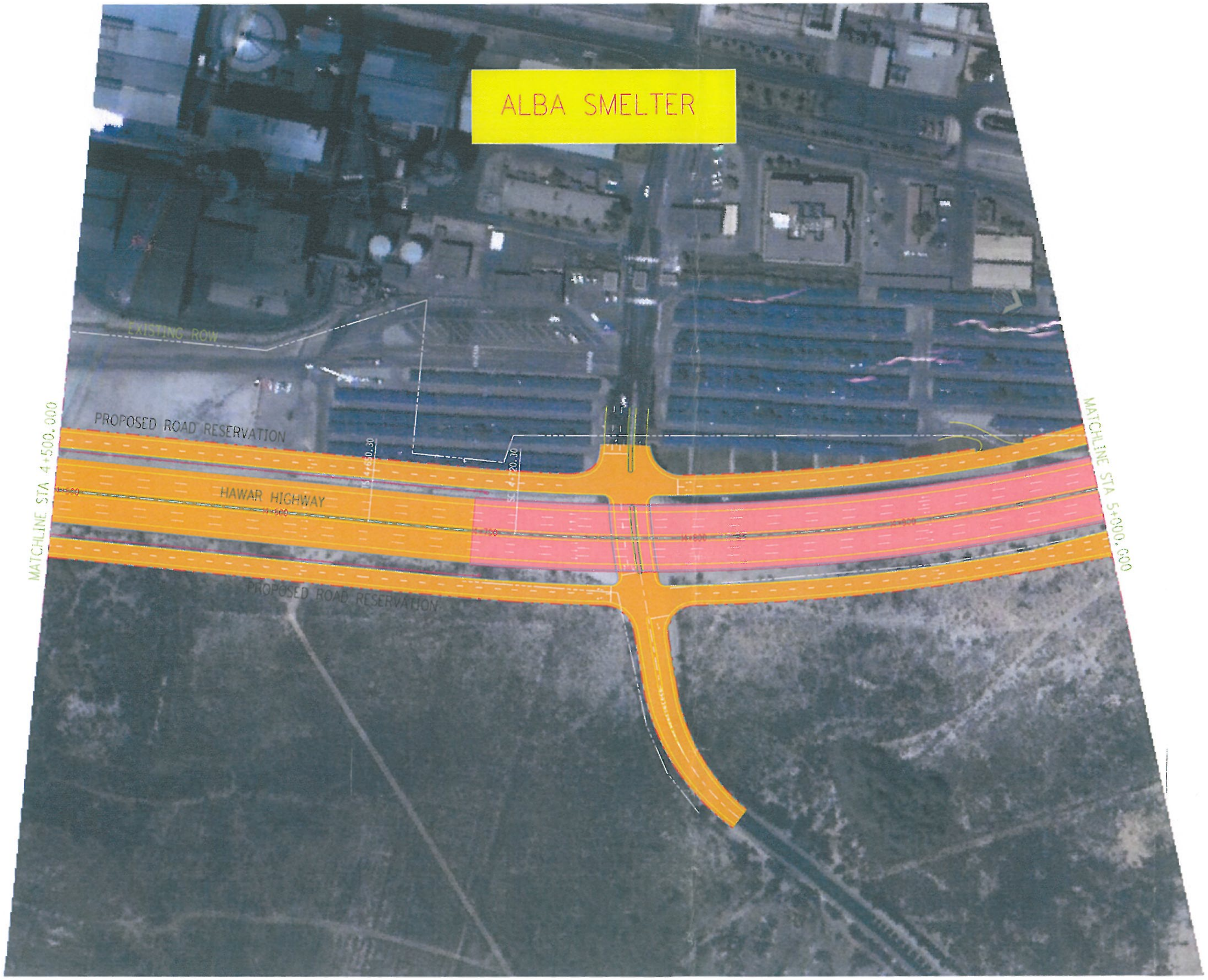

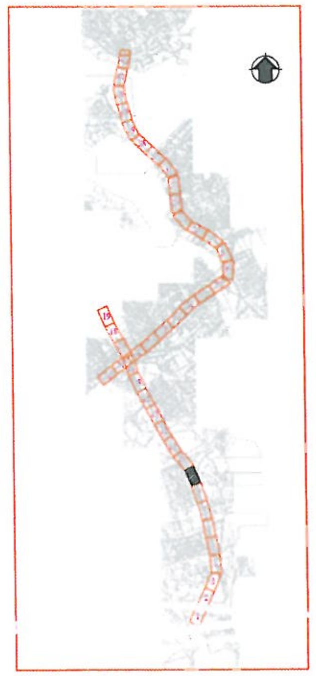

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- EDGE OF MEDIAN
- AT GRADE
- FLYOVER

0 50 100 M

GRAPHIC SCALE: 1:1000 (A1)

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GLOBAL SERVICES LIMITED
COEPP LICENSE No: FB/102

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BAHRAIN-QATAR CAUSEWAY
TRAFFIC IMPACT STUDY

DRAWING TITLE
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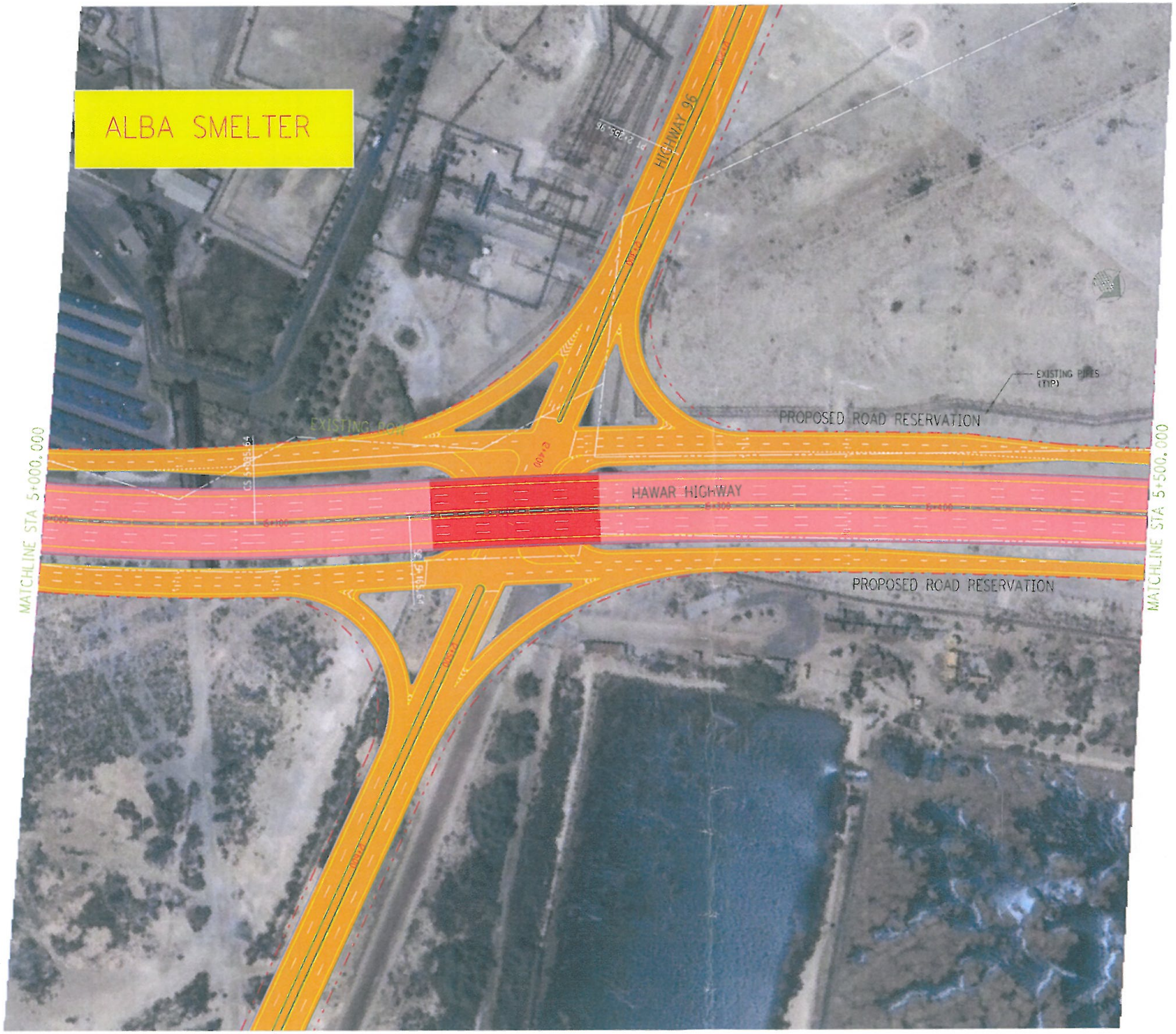

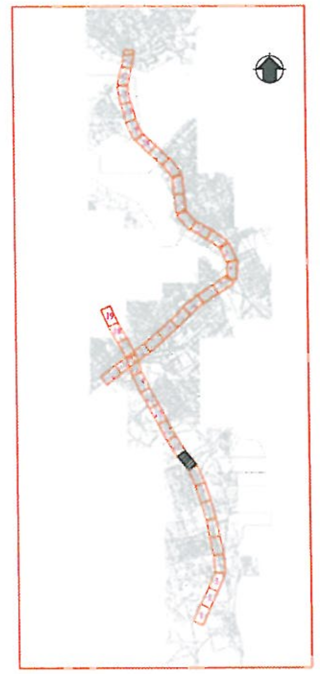

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- BRIDGE

0 50 100 M

GRAPHIC SCALE: 1:1000 (A1)

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DRAWING TITLE
ROADWAY LAYOUT
(STA 5+000.000 TO STA 5+500.000)

DESIGNED: RPJ	DRAWN: JSP	CHECKED: HA
DATE: FEBRUARY 2005		APPROVED: HA
DWG NO.: 645642CRD010		SHT. NO.

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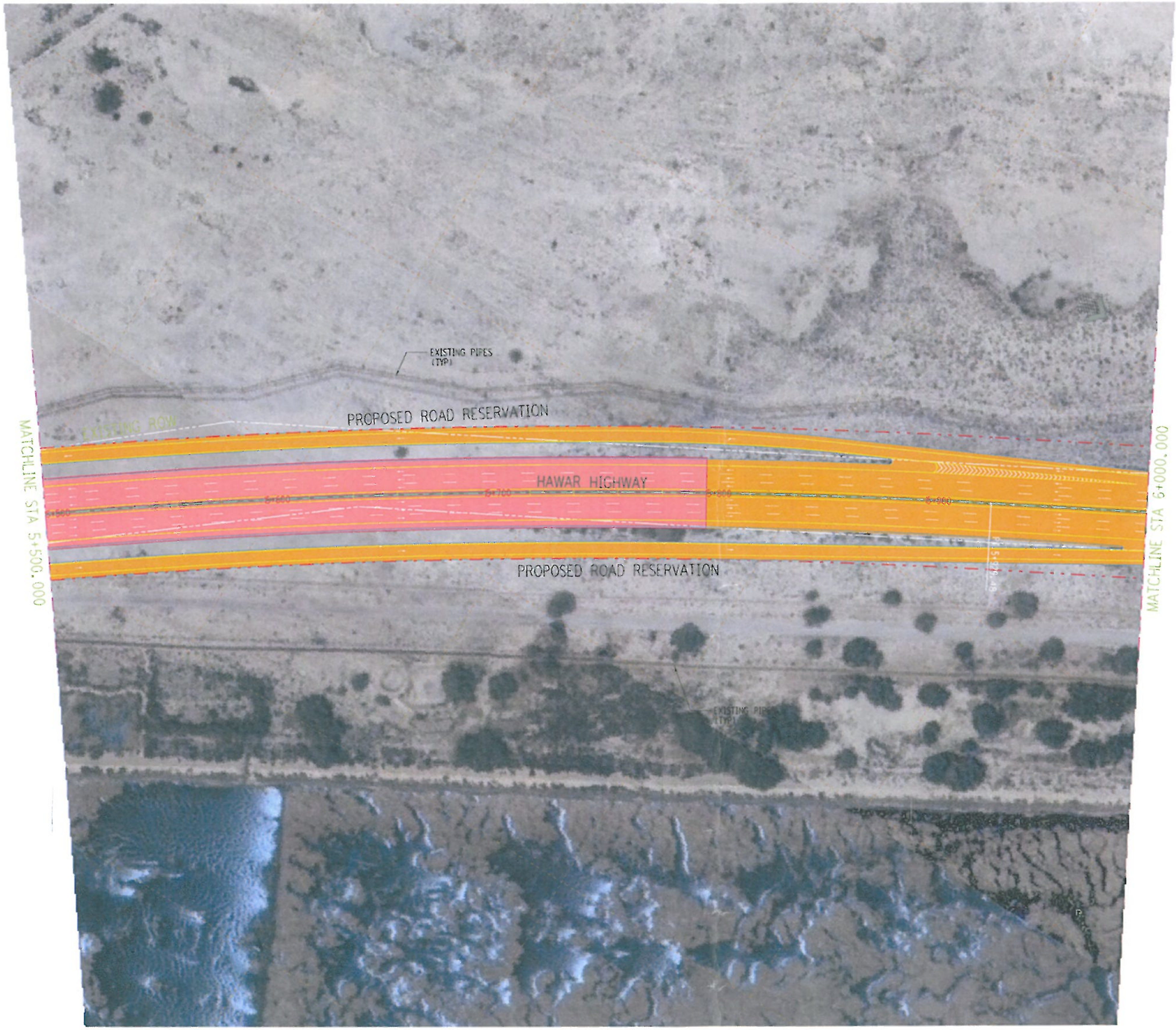

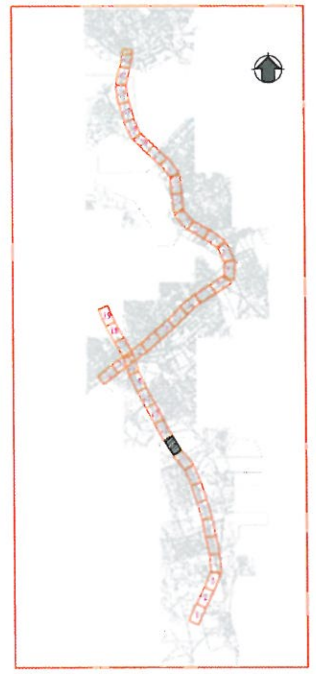

KEYPLAN

LEGEND AND ABBREVIATIONS

EXISTING:

- EXISTING RIGHT OF WAY
- EDGE OF ROADWAY

PROPOSED:

- PROPOSED ROAD RESERVATION
- EDGE OF SHOULDER
- EDGE OF CARRIAGEWAY
- EDGE OF MEDIAN
- AT GRADE
- FLYOVER

0 50 100 M

GRAPHIC SCALE: 1:1000 (A1)

FINAL

REV.	DATE	DESCRIPTION	APPROVED

KINGDOM OF BAHRAIN
MINISTRY OF WORKS AND HOUSING
ROADS PLANNING & DESIGN DIRECTORATE

PARSONS GLOBAL SERVICES LIMITED

COEPP LICENSE No: FB/102

CONTRACT
BAHRAIN-QATAR CAUSEWAY
TRAFFIC IMPACT STUDY

DRAWING TITLE
ROADWAY LAYOUT
(STA 5+500.000 TO STA 6+000.000)

DESIGNED: RPJ	DRAWN: JSP	CHECKED: HA
DATE: FEBRUARY 2005		APPROVED: HA
DWG NO.: 645642CRD011		SHT. NO.

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Appendix 13: One-Day Traffic Survey

Kingdom of Bahrain Ministry of Works Roads Directorate	وزارة الأشغال Ministry of Works Building the Future نبني المستقبل	مملكــة البحرين وزارة الأشغال إدارة الـطرق

MetroCount Traffic Executive | Average Daily Traffic 24 hours

Location: [Hawar Highway] - Near Power Station

Survey Duration: 8:00 Monday, May 20, 2013 => 9:12 Thursday, May 23, 2013 | **Site No. 37**

Direction: Northbound

Hours	0	100	200	300	400	500	600	700	800	900	1000	1100	1200	1300	1400	1500	1600	1700	1800	1900	2000	2100	2200	2300
00:15	42	33	29	23	34	152	233	317	315	333	385	372	349	372	329	541	404	366	284	211	108	71	70	73
00:30	26	19	34	32	68	194	261	382	294	305	395	327	297	357	367	567	351	460	255	179	111	71	83	46
00:45	17	15	27	26	70	261	305	345	257	325	377	332	379	311	467	459	333	356	203	115	92	103	220	45
00:60	26	33	22	34	96	210	356	253	324	304	292	306	339	500	525	431	339	281	171	172	111	79	118	40
Total Hourly	110	99	111	114	267	815	1154	1296	1189	1267	1448	1337	1363	1538	1687	1996	1426	1462	911	676	421	322	490	203

Average Daily Traffic 21702 | AM PEAK (09:45 - 10:45) 1461 | PM PEAK (14:30 - 15:30) 2100

Average Daily Traffic 12hr From 06:00 To 18:00		
	Northbound	18074
	Southbound	17123
	Both Direction	35197

Direction: Southbound

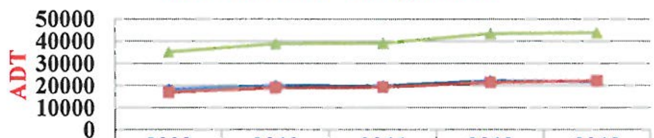
Hours	0	100	200	300	400	500	600	700	800	900	1000	1100	1200	1300	1400	1500	1600	1700	1800	1900	2000	2100	2200	2300
00:15	57	33	24	27	57	231	727	317	445	383	361	311	331	347	366	381	321	260	180	135	114	100	156	39
00:30	42	32	17	25	117	366	653	301	394	351	353	335	305	274	264	347	334	233	176	142	126	106	107	37
00:45	34	28	28	22	144	550	438	339	373	343	309	308	339	266	356	253	235	212	193	153	117	107	94	29
00:60	43	24	30	63	201	762	435	405	427	395	319	316	331	317	309	216	240	225	184	130	94	165	51	25
Total Hourly	175	116	98	136	518	1908	2252	1361	1639	1471	1341	1269	1304	1204	1294	1197	1129	929	733	560	450	477	407	129

Average Daily Traffic 22097 | AM PEAK (05:30 - 06:30) 2692 | PM PEAK (14:30 - 15:30) 1393

[Hawar Highway] - Near Power Station

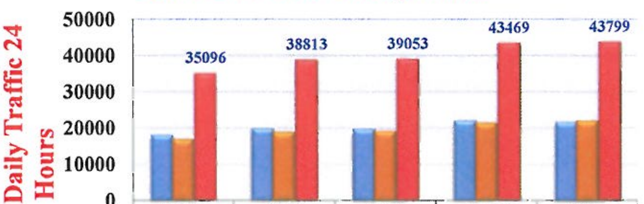
Average Daily Traffic 24 Hours

Last Five Year Comparison



	2009	2010	2011	2012	2013
NB	18159	19897	19803	22054	21702
SB	16937	18916	19250	21415	22097
Total	35096	38813	39053	43469	43799

Last Five Year Comparison



	2009	2010	2011	2012	2013
NB	18159	19897	19803	22054	21702
SB	16937	18916	19250	21415	22097
Total	35096	38813	39053	43469	43799

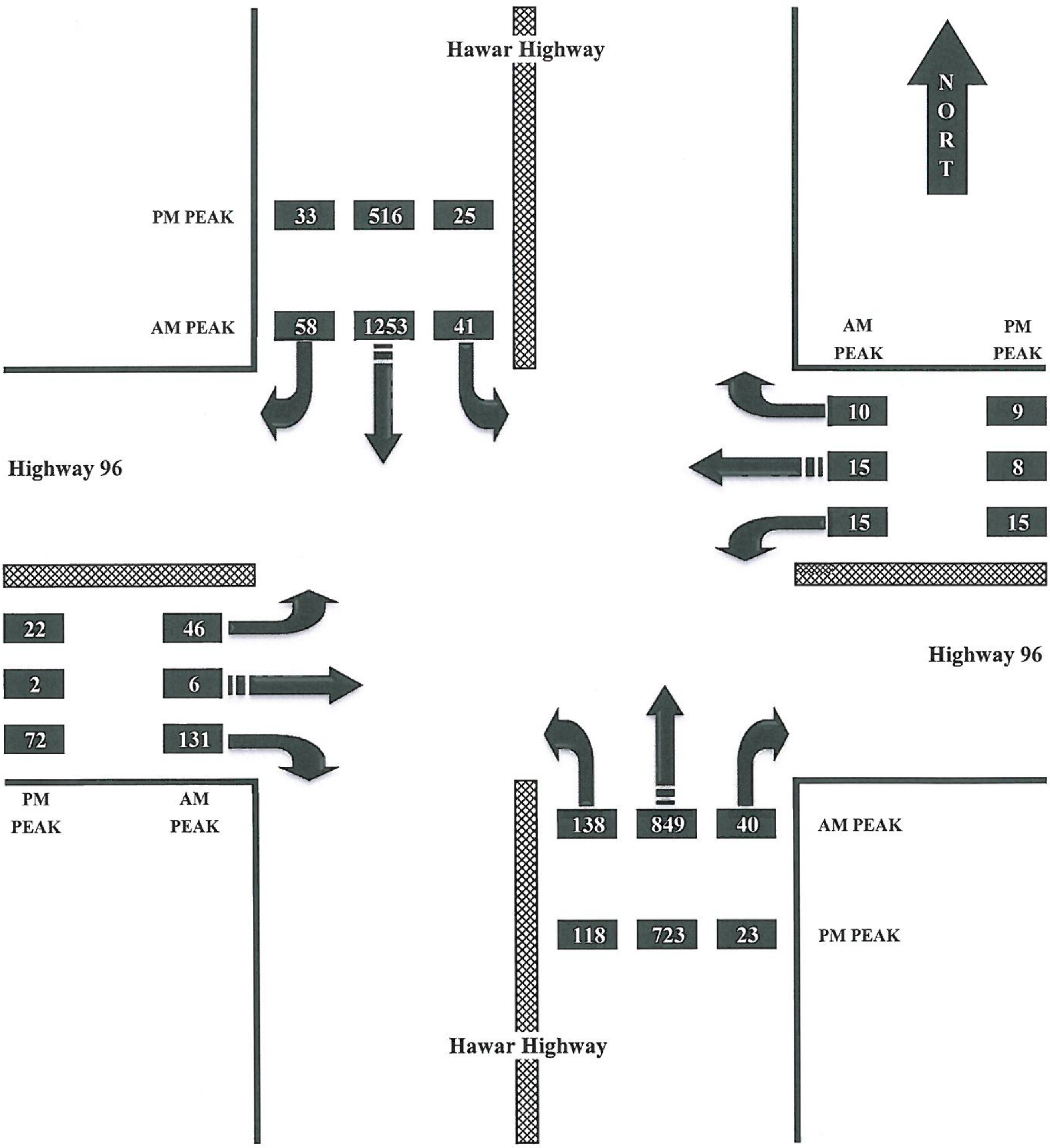
Appendix 14: Four-day Traffic Survey obtained from MoE

Annexure-3

Total

Hawar Highway - Highway 96

AM PEAK : FLOW(6:30-7:30)	MCC2010110
	SITE NO. TSX.067
PM PEAK : FLOW(13:45-14:45)	DATE : Thu. 15/07/2010



TURNING MOVEMENT COUNTS

LOCATION :	Hawar Highway - Highway 96											
DATE :	Thu. 15/07/2010									MCC2010110		
SITE NO.	TSX.067											
	Hawar Highway						Highway 96					
TIME	FROM NORTH			FROM SOUTH			FROM EAST			FROM WEST		
FROM - TO	LT	ST	RT	LT	ST	RT	LT	ST	RT	LT	ST	RT
6:30 - 6:45	11	426	16	36	249	14	6	5	1	16	1	43
6:45 - 7:00	8	387	11	38	228	9	3	2	2	9	4	49
7:00 - 7:15	13	247	17	31	190	7	2	4	3	9	1	22
7:15 - 7:30	9	193	14	33	182	10	4	4	4	12	0	17
7:30 - 7:45	7	160	11	29	169	8	4	2	2	10	2	15
7:45 - 8:00	4	148	9	34	183	6	2	5	3	15	1	16
8:00 - 8:15	5	135	12	29	175	5	3	2	2	9	0	20
8:15 - 8:30	3	109	10	31	178	4	4	3	1	7	0	14
TOTAL	60	1805	100	261	1554	63	28	27	18	87	9	196
AV.HOURLY	30	903	50	131	777	32	14	14	9	44	5	98
FLOW(6:30-7:30)	41	1253	58	138	849	40	15	15	10	46	6	131
12:30 - 12:45	7	80	9	28	168	5	4	3	3	6	0	26
12:45 - 13:00	9	85	11	33	186	7	3	6	0	9	1	25
13:00 - 13:15	5	85	8	26	163	4	5	2	1	8	0	23
13:15 - 13:30	6	97	6	25	155	6	3	3	3	10	3	19
13:30 - 13:45	4	98	9	27	167	8	4	4	0	8	2	22
13:45 - 14:00	8	135	10	30	171	5	6	2	3	5	1	23
14:00 - 14:15	6	138	5	26	185	7	3	3	1	6	0	17
14:15 - 14:30	6	134	7	33	190	6	4	1	4	3	0	19
14:30 - 14:45	5	109	11	29	177	5	2	2	1	8	1	13
14:45 - 15:00	3	99	8	24	168	4	3	4	0	6	0	16
TOTAL	59	1060	84	281	1730	57	37	30	16	69	8	203
AV.HOURLY	24	424	34	112	692	23	15	12	6	28	3	81
FLOW(13:45-14:45)	25	516	33	118	723	23	15	8	9	22	2	72

TOTAL FLOWS FOR 4.5 HOURS 7842

Appendix 15: United Nations Population and Development Statistics

The Demographic Profile of Bahrain

1. Population Trends:

a. Population Size of Bahrain

The population of Bahrain increased from 358 thousand in 1980 to approximately 1.3 million in 2010. It is expected that the population will keep on increasing to reach 1.8 million in 2050.

Table 1: Population Size of Bahrain by Sex, 1980 to 2050

	Population Size (thousands)		
Year	**Males**	**Females**	**Total**
1980	209	149	358
1985	238	179	417
1990	285	208	493
1995	323	236	559
2000	366	272	638
2005	415	310	725
2010	788	474	1,262
2015*	868	536	1,404
2020*	923	585	1,508
2025*	963	625	1,588
2030*	994	660	1,654
2035*	1,017	693	1,711
2040*	1,033	724	1,758
2045*	1,039	751	1,790
2050*	1,031	770	1,801

Source: United Nations, World Population Prospects: The 2010 Revision,
Available on: http://esa.un.org/unpd/wpp/unpp/panel_indicators.htm
* Projections (medium variant)

b. Population Growth in Bahrain

The growth rate of the population in Bahrain decreased from 3.35 percent to 2.55 percent during the period 1985-2005. This was followed by a sharp increase in the growth rate to 11.09 percent in 2005-2010[1]. Projections show that the growth rate of the Bahraini population will decrease to 2.13 percent in 2010-2015 and this downward trend will continue and will reach 0.13 percent in the period 2045-2050.

Table 2: Population Growth in Bahrain, 1980 to 2050

Period	Population growth rate (%)
1980-1985	3.05
1985-1990	3.35
1990-1995	2.52
1995-2000	2.65
2000-2005	2.55
2005-2010	11.09
2010-2015*	2.13
2015-2020*	1.43
2020-2025*	1.04
2025-2030*	0.82
2030-2035*	0.67
2035-2040*	0.54
2040-2045*	0.36
2045-2050*	0.13

Source: United Nations, World Population Prospects: The 2010 Revision
* Projections (medium variant)

[1] The net migration rate for 2005-2010 is 90.2 per 1,000 population - ref. Section 2.c.ii.

2. Indicators of Demographic Transition:

a. Mortality Transition in Bahrain

i. Life Expectancy

Life Expectancy at Birth in Bahrain gained 4.1 years from the period 1980-1985 to the period 2005-2010, increasing from 70.5 years to 74.6 years. It is projected to reach 79.6 years for the period 2045-2050.

Table 3: Life Expectancy at Birth in Bahrain, 1980 to 2050

Year	Life Expectancy at Birth (years)		
	Male	Female	Total
1980-1985	69.3	72.3	70.5
1995-2000	70.8	73.3	71.9
1990-1995	71.7	73.9	72.7
1995-2000	72.6	74.5	73.4
2000-2005	73.3	74.9	74.0
2005-2010	74.0	75.4	74.6
2010-2015*	74.7	76.1	75.3
2015-2020*	75.3	76.7	75.8
2020-2025*	75.9	77.4	76.5
2025-2030*	76.5	78.3	77.2
2030-2035*	77.2	79.0	77.8
2035-2040*	77.7	79.8	78.5
2040-2045*	78.3	80.5	79.1
2045-2050*	78.9	81.1	79.6

Source: United Nations, World Population Prospects: The 2010 Revision
* Projections (medium variant)

ii. Infant mortality

The Infant Mortality Rate of the Bahraini Population was estimated at 21.9 infant deaths per 1,000 live births in 1980-1985 and decreased to 7.2 infant deaths per 1,000 live births in 2005-2010. It is projected to continue this downward trend to reach 4.3 infant deaths per 1,000 live births in 2045-2050.

Table 4: Infant Mortality Rate in Bahrain, 1980 to 2050

Year	Infant mortality Rate (per 1,000 live births)		
	Male	Female	Total
1980-1985	22.7	21.1	21.9
1985-1990	16.6	16.2	16.4
1990-1995	14.0	14.3	14.1
1995-2000	11.1	11.9	11.5
2000-2005	8.6	9.7	9.1
2005-2010	6.6	7.9	7.2
2010-2015*	6.0	7.4	6.7
2015-2020*	5.6	6.9	6.2
2020-2025*	5.3	6.4	5.8
2025-2030*	4.9	6.0	5.4
2030-2035*	4.5	5.6	5.1
2035-2040*	4.3	5.3	4.8
2040-2045*	4.1	5.0	4.5
2045-2050*	3.9	4.8	4.3

Source: United Nations, World Population Prospects: The 2010 Revision
* Projections (medium variant)

iii. Under-five mortality

The under-five mortality rate was estimated at 14 deaths under age five per 1,000 live births in 1995-2000, and has decreased to 9 by 2010. It is projected to continue deceasing to reach 6 deaths per 1,000 live births by 2050.

Table 5: Under-Five Mortality Rate in Bahrain, 1980 to 2050

Year	Under-Five Mortality Rate (per 1,000 live births)		
	Male	Female	Total
1995-2000	14	14	14
2000-2005	11	11	11
2005-2010	9	9	9
2010-2015*	8	9	9
2015-2020*	8	9	8
2020-2025*	7	8	8
2025-2030*	7	8	7
2030-2035*	6	7	7
2035-2040*	6	7	6
2040-2045*	6	7	6
2045-2050*	5	6	6

Source: United Nations, World Population Prospects: The 2010 Revision
* Projections (medium variant)

iv. Maternal mortality

The maternal mortality ratio in Bahrain was estimated at 19 maternal deaths per 100,000 live births in 2008. The presence of a skilled attendant at birth was observed in 97 percent of the deliveries in the period 2000-2010.

Source: World Health Statistics 2011, available on http://www.who.int/whosis/whostat/2011/en/index.html

v. Monitoring Progress in Achieving the ICPD+15 targets

Bahrain is performing very well with regard to meeting the global goals set by ICPD for life expectancy, infant mortality, under-five mortality and maternal mortality.

With a life expectancy of 74.0 years registered for the period 2000-2005, Bahrain has already achieved the ICPD target of greater than 65/70 years set for 2005. Projections show that the country will also meet the global goals of greater than 70/75 years set for 2015 by having a life expectancy of 75.3 years.

The Kindgdom's infant mortality rate for the periods 1995-2000 and 2000-2005 was estimated at 11.5 and 9.1 infant deaths per 1,000 live births indicating that Bahrain has already met the target of 50/70 and of below 50 infant deaths for 2000 and 2005 respectively. The infant mortality rate is projected to continue on decreasing to reach 6.7 infants deaths per 1,000 live births in 2015, which is lower than the target of below 35 deaths per 1,000 live births set for the year 2015.

The same applies for under-five mortality rate, which was estimated at 14 and 11 deaths per 1,000 live births in the periods 1995-2000 and 2000-2005 respectively (ICPD targets are 50/70 per 1,000 live births for 2000 and below 60 per 1,000 live births for 2005), and is projected to continue decreasing to reach 9 deaths per 1,000 live births in 2015 (ICPD target is below 45 per 1,000 live births for 2015).

As to maternal mortality, it stood at 19 maternal deaths per 100,000 live births in 2008, which is already below the goal of 60 to 75 per 100,000 live births set for 2015. The same goes to birth assisted by skilled attendants (quoted as 97 percent of the deliveries for the period 2000-2010), insinuating that Bahrain has exceeded the global target set for 2010 (at least 50 to 85 percent of all births should be assisted by a skilled attendant).

b. Fertility Transition in Bahrain

i. Fertility Rate

The total Fertility Rate in Bahrain declined from 4.63 children per woman in 1980-1985 to 2.63 children per woman in 2005-2010. Projections show that total fertility will decline further to reach 2.13 (Replacement level fertility is 2.1) children per woman in 2020-2025 and will keep on declining to reach 1.76 children per woman in 2045-2050.

Table 6: Total Fertility Rate in Bahrain, 1980 to 2050 (children per woman)

Year	Total Fertility Rate (children per woman)
1980-1985	4.63
1985-1990	4.08
1990-1995	3.35
1995-2000	2.89
2000-2005	2.62
2005-2010	2.63
2010-2015*	2.43
2015-2020*	2.27
2020-2025*	2.13
2025-2030*	2.02
2030-2035*	1.92
2035-2040*	1.85
2040-2045*	1.80
2045-2050*	1.76

Source: United Nations, World Population Prospects: The 2010 Revision
* Projections (medium variant)

ii. Contraceptive prevalence

In 1995, the prevalence of contraceptive use among married Bahraini women was estimated at 61.8 percent. The prevalence of use of modern methods reached 30.6 percent and that of traditional methods 31.2 percent.

Source: United Nations, World Contraceptive Use 2010, POP/DB/CP/Rev2010

c. Migration Transition in Bahrain

i. Internal Migration

The percentage of urban dwellers was estimated at 86.1 percent in 1980. It increased to reach 88.4 percent in 1995 and remained at this level up to 2005. Population projections show that this percentage will continue to increase and will reach 92.3 percent in 2050.

Table 7: Urban and Rural Population in Bahrain, 1980 to 2050

Year	Population (thousands)			Percentage urban	Percentage rural	Year	Annual rate of change of percentage urban (%)	Annual rate of change of percentage rural (%)
	Urban	Rural	Total					
1980	299	48	347	86.1	13.9	1980-1985	0.24	-1.58
1985	360	53	413	87.2	12.8	1985-1990	0.22	-1.60
1990	434	58	493	88.1	11.9	1990-1995	0.06	-0.42
1995	511	67	578	88.4	11.6	1995-2000	-0.00	0.03
2000	574	76	650	88.4	11.6	2000-2005	0.01	-0.08
2005	643	84	728	88.4	11.6	2005-2010*	0.04	-0.34
2010*	701	91	791	88.6	11.4	2010-2015*	0.08	-0.61

Year	Population (thousands)			Percentage urban	Percentage rural	Year	Annual rate of change of percentage urban (%)	Annual rate of change of percentage rural (%)
	Urban	Rural	Total					
2015*	715	92	807	88.6	11.4	2015-2020*	0.11	-0.88
2020*	784	97	882	89.0	11.0	2020-2025*	0.13	-1.15
2025*	852	101	953	89.4	10.6	2025-2030*	0.14	-1.27
2030*	919	102	1,021	90.0	10.0	2030-2035*	0.13	-1.28
2035*	984	102	1,085	90.6	9.4	2035-2040*	0.12	-1.28
2040*	1,045	101	1,145	91.2	8.8	2040-2045*	0.11	-1.29
2045*	1,099	99	1,198	91.8	8.2	2045-2050*	0.10	-1.30
2050*	1,146	96	1,242	92.3	7.7			

Source: United Nations, World Urbanization Prospects: The 2009 Revision Population Database
* Projections (medium variant)

ii. International Migration

Around 315,403 foreign born persons are expected to live in Bahrain in 2010, representing 39.1 percent of the total Bahraini population. Female migrants would represent 32.9 percent of all migrants for that year.

Table 8a: International Migrant (IM) Stock for Bahrain, 1990 to 2010

Indicator	1990	1995	2000	2005	2010*
Estimated number of IMs at mid-year (total)	173,200	205,977	239,366	278,166	315,403
Estimated number of migrants at mid-year (male)	123,851	144,505	165,553	189,533	211,561
Estimated number of migrants at mid-year (female)	49,349	61,472	73,813	88,633	103,842
Estimated number of refugees at mid-year	965	0	1	0	1
IMs as a percentage of the population	35.1	35.7	36.8	38.2	39.1
Female migrants as percentage of all IMs	28.5	29.8	30.8	31.9	32.9
Refugees as a percentage of international migrants	0.6	0.0	0.0	0.0	0.0

Source: United Nations, World Migration Stock: The 2008 Revision
Available on: http://esa.un.org/migration/
* Projections

Table 8b: Annual rate of change of the migrant stock in Bahrain, 1990 to 2010

Year	Annual rate of change of the migrant stock (percent)
1990-1995	3.5
1995-2000	3.0
2000-2005	3.0
2005-2010*	2.5

Source: United Nations, World Migration Stock: The 2008 Revision
* Projections

The annual net migration rate sharply increased from 7.4 migrants per 1,000 population for the period 2000-2005 to 90.2 migrants per 1,000 population for the period 2005-2010.

Table 9: Net Migration in Bahrain, 1980 to 2050

Year	Net Migration (average annual)	
	Rate (per 1,000 population)	Number (thousands)
1980-1985	1.6	1
1985-1990	5.7	3
1990-1995	2.1	1

Year	Net Migration (average annual) Rate (per 1,000 population)	Number (thousands)
1995-2000	6.5	4
2000-2005	7.4	5
2005-2010	90.2	90
2010-2015*	6.2	8
2015-2020*	2.8	4
2020-2025*	1.9	3
2025-2030*	1.9	3
2030-2035*	1.8	3
2035-2040*	1.7	3
2040-2045*	1.7	3
2045-2050*	1.7	3

Source: United Nations, World Population Prospects: The 2010 Revision
* Projections (medium variant)

3. Population Structure:

a. Bahrain's Population Age Composition

The proportion of the population under 15 years of age has been decreasing since 1980 and is projected to continue this downward trend till the year 2050. At the same time, the proportion of the working-age group (15-64) has been increasing since 1980, where it rose from 63.4 percent to reach a peak of 77.9 percent in 2010. It is projected to start declining after this period and will get to 59.1 in 2050. The proportion of the elderly (65+) population fluctuated between 2.1 percent and 2.7 percent during the period 1980-2010. It is projected to start increasing afterwards and will reach 25.4 percent in 2050.

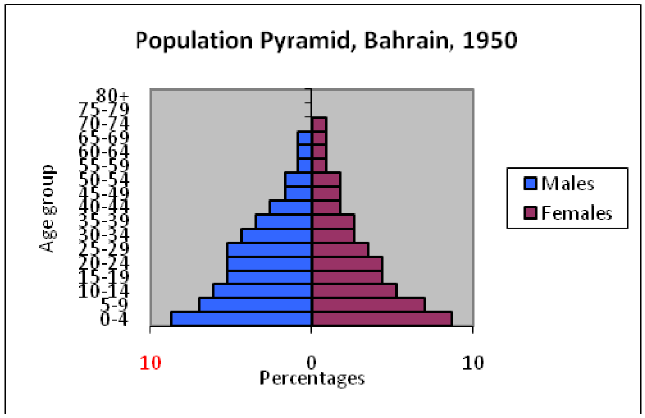
Table 10: Population Distribution by Broad Age Groups in Bahrain, 1980 to 2050 (percent)

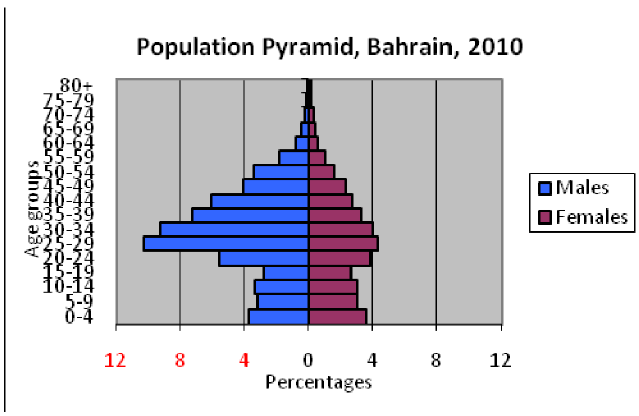
Year	**Age (years)**			
	0-4	**5-14**	**15-64**	**65+**
1980	13.8	20.6	63.4	2.1
1985	13.9	19.5	63.9	2.7
1990	13.3	19.3	65.2	2.2
1995	10.7	19.4	67.5	2.4
2000	9.4	18.7	69.4	2.5
2005	8.6	18.8	70.1	2.6
2010	7.4	12.7	77.9	2.1
2015*	8.3	12.5	76.8	2.4
2020*	6.9	14.1	75.2	3.8
2025*	5.9	13.9	74.0	6.2
2030*	5.3	11.9	73.8	9.0
2035*	5.3	10.5	71.8	12.4
2040*	5.4	10.1	68.4	16.1
2045*	5.4	10.3	63.7	20.6
2050*	5.0	10.5	59.1	25.4

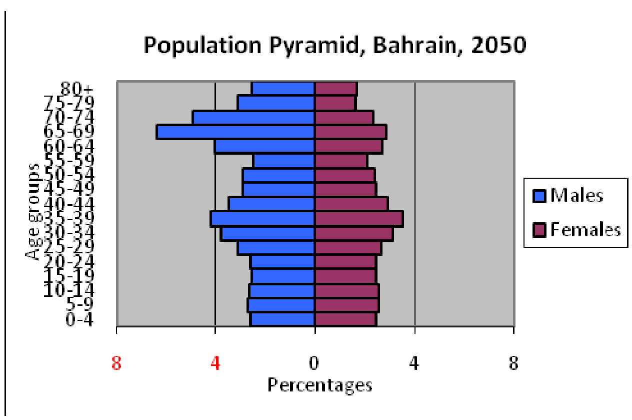
Source: United Nations, World Population Prospects: The 2010 Revision
* Projections (medium variant)

b. Changing Age Structure

The population pyramid in Bahrain shows an unbalanced structure for the working-age groups due to high immigration rates and reliance on foreign labour.







c. Bahrain's Youth

In Bahrain, the percentage of youth (15-24) was estimated at 23.0 percent in 1975 (or 39.6 percent of the working-age group). In 2010, the percentage decreased to reach 14.9 percent (or 19.1 percent of the working-age group). It is projected to continue declining to reach 10.0 percent in 2050 (or 17.0 percent of the working-age group).

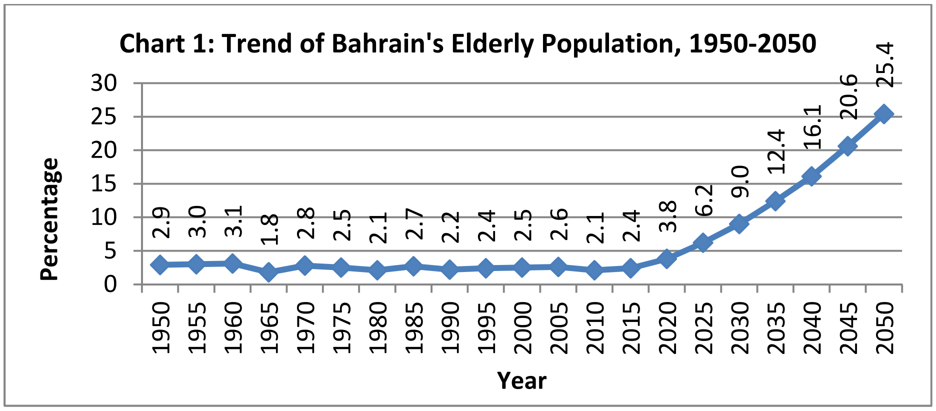
Table 11: Youth (15-24) in relation to total population and to working-age population (15-64), Bahrain, 1950-2050.

Year	Youth (thousands)	Youth (% of total population)	Working-age population (thousands)	Youth (% of working-age group)**
1950	22	19.1	63	34.9%
1955	24	18	74	32.4%
1960	29	17.7	91	31.9%
1965	34	18.3	96	35.4%
1970	37	17.7	112	33.0%
1975	61	23.0	154	39.6%
1980	79	22.0	227	34.8%
1985	67	16.0	266	25.2%
1990	81	16.4	321	25.2%
1995	92	16.5	377	24.4%
2000	107	16.8	443	24.2%
2005	123	17.0	508	24.2%
2010	188	14.9	983	19.1%
2015*	156	11.1	1,078	14.5%
2020*	164	10.9	1,134	14.5%
2025*	180	11.3	1,174	15.3%
2030*	216	13.1	1,221	17.7%
2035*	224	13.1	1,228	18.2%
2040*	200	11.4	1,202	16.6%
2045*	184	10.3	1,141	16.1%
2050*	181	10.0	1,064	17.0%

Source: United Nations, World Population Prospects: The 2010 Revision
* Projections (medium variant)
** ESCWA calculation

d. Bahrain's Elderly

In Bahrain, the percentage of the population aged 65+ increased from 2.9 percent in 1950 to 3.1 percent in 1960, then decreased to reach 1.8 percent in 1965 only to increase again afterwards to 2.8 percent in 1970, fluctuating between 2.7 and 2.1 during the period 1980-2010. It is projected that the percentage of the population aged 65+ will begin to increase starting 2015 and will more than triple (compared to the 2010 rate) by 2025. This upward trend will continue and the percentage of the population aged 65+ to reach 25.4 percent in the year 2050. This rapid demographic change necessitates that policies be put in place to meet the challenges raised by an ageing population.



Source: United Nations, World Population Prospects: The 2010 Revision

e. Bahrain's Dependency Ratios

The total dependency ratio in Bahrain reached its peak in 1965 owing to the high child dependency ratio. It then started decreasing and reached 28 percent in 2010 mainly due to the decrease in the child dependency ratio. It is expected to start increasing again to reach 35 percent in 2025 and 69 percent in 2050 (almost doubling) due to a projected increase in the old-age dependency ratio.

Table 12: Dependency Ratios in Bahrain, 1950-2050 (percent)

Year	Child dependency ratio	Old-age dependency ratio	Total dependency ratio
1950	77	5	82
1955	76	5	81
1960	73	6	79
1965	90	4	94
1970	84	5	90
1975	68	4	72
1980	54	3	58
1985	52	4	57
1990	50	3	53
1995	45	4	48
2000	40	4	44
2005	39	4	43
2010	26	3	28
2015*	27	3	30
2020*	28	5	33
2025*	27	8	35
2030*	23	12	35
2035*	22	17	39
2040*	23	24	46
2045*	25	32	57
2050*	26	43	69

Source: United Nations, World Population Prospects: The 2010 Revision

* Projections (medium variant)

4. Population Policy Profile of Bahrain:

Population policy variable	*1976*	*1986*	*1996*	*2009*
Population size and growth				
View on growth	Satisfactory	Satisfactory	Satisfactory	Too high
Policy on growth	No intervention	No intervention	No intervention	Lower
Population age structure				
Level of concern about				
Size of the working-age population	..	..	..	Minor concern
Ageing of the population	..	..	..	Minor concern
Fertility and family planning				
View on fertility level	Too high	Satisfactory	Satisfactory	Too high
Policy	No intervention	No intervention	Lower	Lower
Access to contraceptive methods	Indirect support	Direct support	Direct support	Direct support
Adolescent fertility				
Level of concern	..	..	Not a concern	Not a concern
Policies and programmes	..	..	No	No
Health and mortality				
View				
Life expectancy at birth	Unacceptable	Acceptable	Acceptable	Acceptable
Under-five mortality	..	..	Unacceptable	Unacceptable
Maternal mortality	..	..	..	Acceptable
Level of concern about HIV/AIDS	..	..	..	Major concern
Measures to respond to HIV/AIDS*	..	..	..	1,2,3
Grounds on which abortion is permitted**	..	..	1,2,3,5	1,2,3,4,5,6,7
Spatial distribution and internal migration				
View on spatial distribution	Satisfactory	Satisfactory	Satisfactory	Satisfactory
Policies on internal migration				
From rural to urban areas	..	..	..	..
From rural to rural areas	..	..	..	..
From urban to rural areas	..	..	..	..
From urban to urban areas	..	..	..	..
Into urban agglomerations	..	Raise	No intervention	..
International migration				
Immigration				
View	Satisfactory	Too high	Satisfactory	Satisfactory
Policy	Maintain	Lower	No intervention	Maintain
Permanent settlement	..	..	No intervention	..
Temporary workers	..	..	No intervention	Lower
Highly skilled workers	..	..	..	..
Family reunification	..	..	No intervention	Maintain
Integration of non-citizens	..	..	..	..
Emigration				
View	Satisfactory	Satisfactory	Satisfactory	Satisfactory
Policy	Maintain	Maintain	No intervention	No intervention
Encouraging the return of citizens	..	..	No	..

* Measures implemented to respond to HIV/AIDS: (1) blood screening; (2) information/education campaigns; (3) antiretroviral treatment; (4) non-discriminatory policies; (5) distribution of condoms.
** Grounds on which abortion is permitted: (1) to save the woman's life; (2) to preserve physical health; (3) to preserve mental health; (4) rape or incest; (5) foetal impairment; (6) economic or social reasons; (7) on request.

Source: United Nations, World Population Policies, 2009

Appendix 16: Ministry of Culture – Letter Regarding Archaeology and Cultural Heritage

قطاع الثقافة والتراث الوطني
Culture & National Heritage

Kingdom of Bahrain مملكة البحرين
Ministry of Culture وزارة الثقافة

30th March 2014

Mehdi Honar,
Director,

Tebodin Middle East Ltd,

P.O.Box 2822, Manama, Bahrain

Tel: 17700544

Dear Sir,

Referring to your letter dated 10th March 2014 for providing you with archaeological and cultural information on the location of ALBA L6 Expansion Project.

We would like to inform you that Ministry of Culture has no archaeological concern in the project area.

Director of Archaeology &

National Heritage

For

ص.ب : 2199 ـ مملكة البحرين ـ هاتف : 17298777 (973 +) ـ 17293300 (973 +) ـ فاكس : 17293820 (973 +)
P. O. BOX : 2199 , Kingdom of Bahrain , Tel. : (+ 973) 17298777, (+ 973) 17293300, Fax: (+ 973) 17293820

Appendix 17: Air Modelling Methodology

Client: **Bechtel**
Project: ALBA Potline (6) and Power Plant (PS 5) Expansion

Appendix 17: Air Modelling Methodology – CALMET and CALPUFF

Tebodin

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Rev.	Date	Description	Author	Checked by

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1 CALMET INTRODUCTION

Meteorology determines the transport and dispersion of industrial emissions, and hence plays a significant role in determining air quality downwind of emission sources. For this assessment, meteorological data for the year 2012 was used to define transport and dispersion parameters. The selection of a 1 year period is consistent with the minimum assessment requirement to perform and predict Air Quality Assessment for the regional study area, when using data from a meteorological model such as MM5 (the Fifth Generation NCAR/Penn State Mesoscale Model).

Meteorological characteristics vary with time (e.g., season and time of day) and location (e.g., height, terrain and land use). The CALMET meteorological pre-processing program was used to provide temporally and spatially varying meteorological parameters for the CALPUFF model. This appendix provides an overview of the meteorology and climate for the region as well as the technical details and options that were used for the application of the CALMET meteorological pre-processor for the Project assessment**.**

1.1 CALMET Domain

The CALMET domain adopted for the Project assessment extends approximately latitude 26.05 in the North 50 km, and longitude 50.61 in the east 50 km. The global study coordinates have been converted to its respective UTM (Universal Transverse Mercator), in km as shown in Figure A- 1. The CALMET domain covers a 2500- km^2 area.

A horizontal grid spacing of 4 km was selected for the CALMET simulation; the study area therefore corresponds to 13 rows by 13 columns. With this grid spacing, it was possible to maximize run time and file size efficiencies while still capturing large-scale terrain feature influences on wind flow patterns.

Table A- 1: CALMET Domain Coordinates

Domain Extent	Northing (^{0})	Easting (^{0})
North East	485322.12	2910507.97
North West	435322.12	2910507.97
South West	435322.12	2860507.97
South East	485322.12	2860507.97

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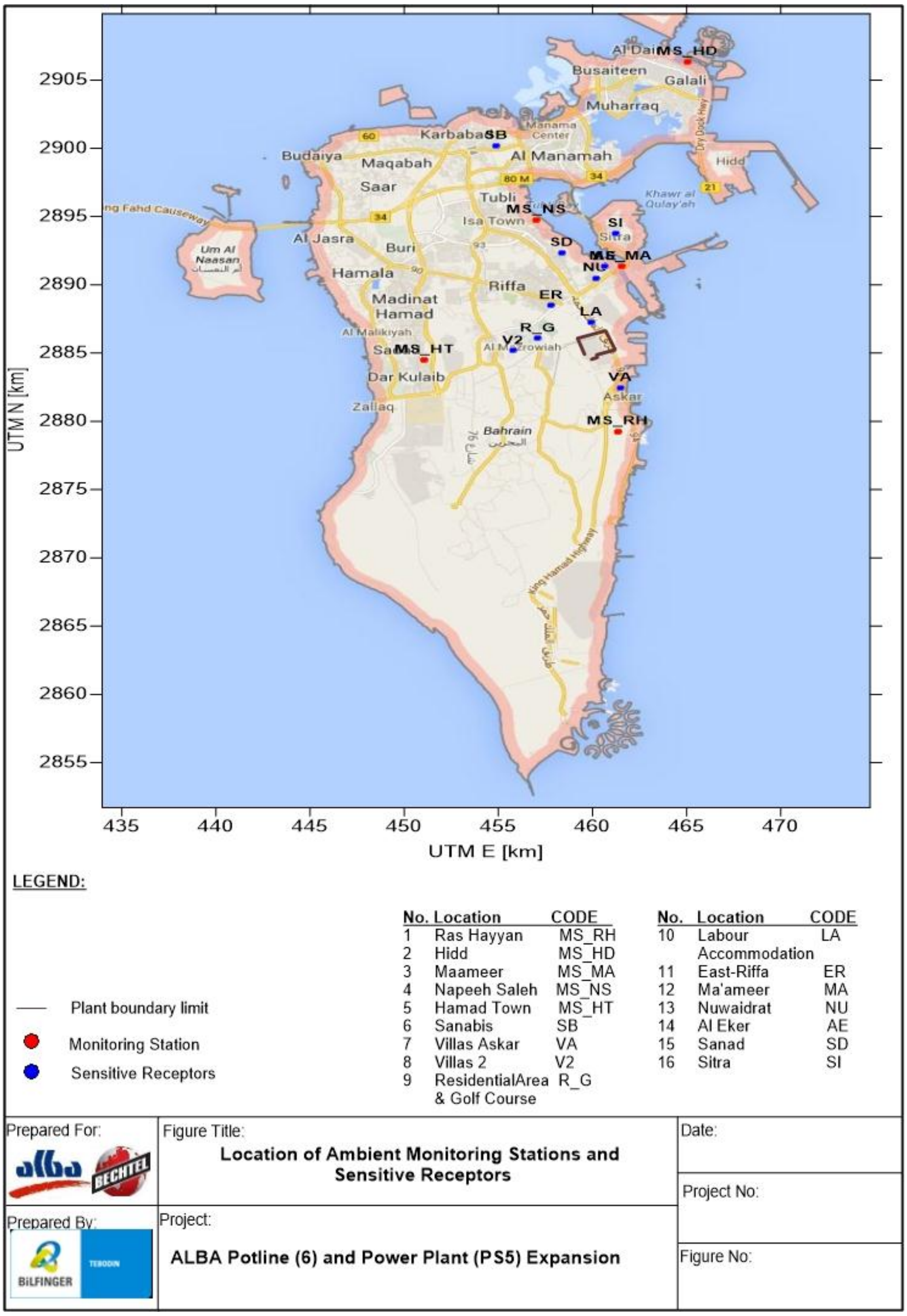

Figure A- 1: **Plant Location with Ambient Monitoring Stations and Sensitive Receptors**

1.2 Meteorological Measurements

Meteorological data collected in the area surrounding the Project have been analysed to characterize the regional and local climate.

1.2.1 Ambient Temperature

Table A- 2: summarises the 2008-2012 historical seasonal and annual mean air temperatures in the CALMET Domain. Annual average ambient temperatures range from 26 and 28 °C for Five years (2008-2012). There is generally little variation in mean daily temperatures between the sites on a seasonal and annual basis. Mean daily temperatures for the period 2008-2012 are presented in below table for the weather monitoring station at Bahrain International Airport.

Table A- 2: Historical Seasonal and Annual Mean Daily Temperatures at Meteorological Stations in the Study Area (2000-2012)

Season	Mean Daily Temperature (°C)				
	2008	2009	2010	2011	2012
Winter	33	33	33	33	33
Summer	20	21	22	20	21
Annual	26	27	28	27	27

Notes :
Winter : May, June, July, August, September and October
Summer : November, December, January, February, March and April
Source: Bahrain Airport weather Data

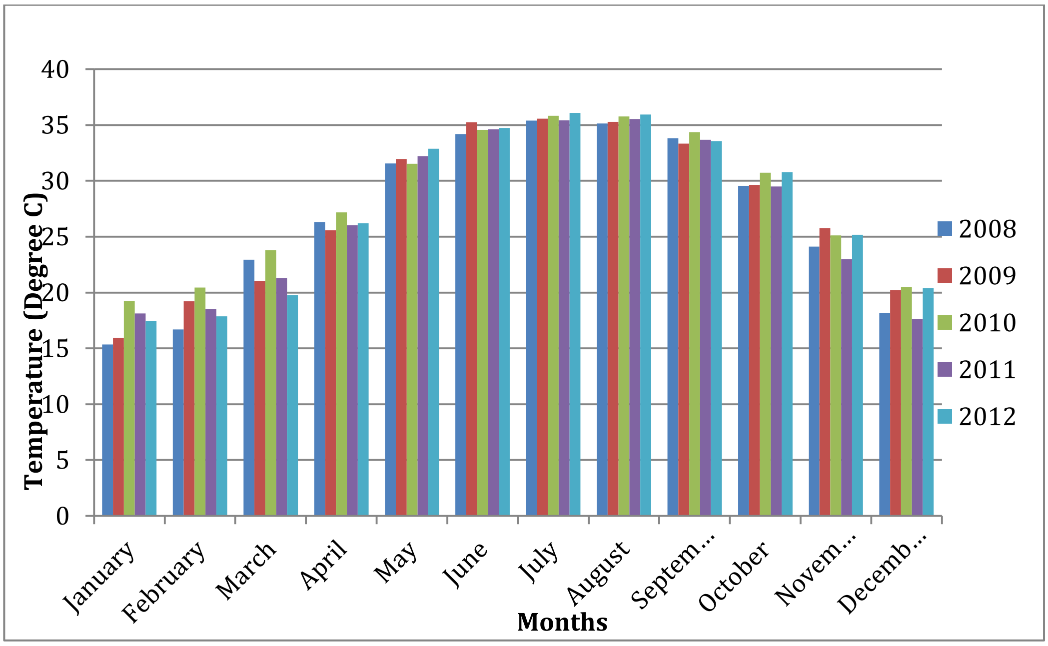

Figure A- 2: Mean Monthly Average Temperatures at Bahrain Airports (2008-2012)

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Table A- 3: Annual Mean Daily Temperatures at Meteorological Stations in the Study Area (2012)

Season	Mean Daily Temperature (^oC) 2012
Winter	21.1
Summer	33.9
Annual	27.5
Notes : Winter : May, June, July, August, September and October Summer : November, December, January, February, March and April	
Source: Bahrain Airport Weather Data (NOAA)	

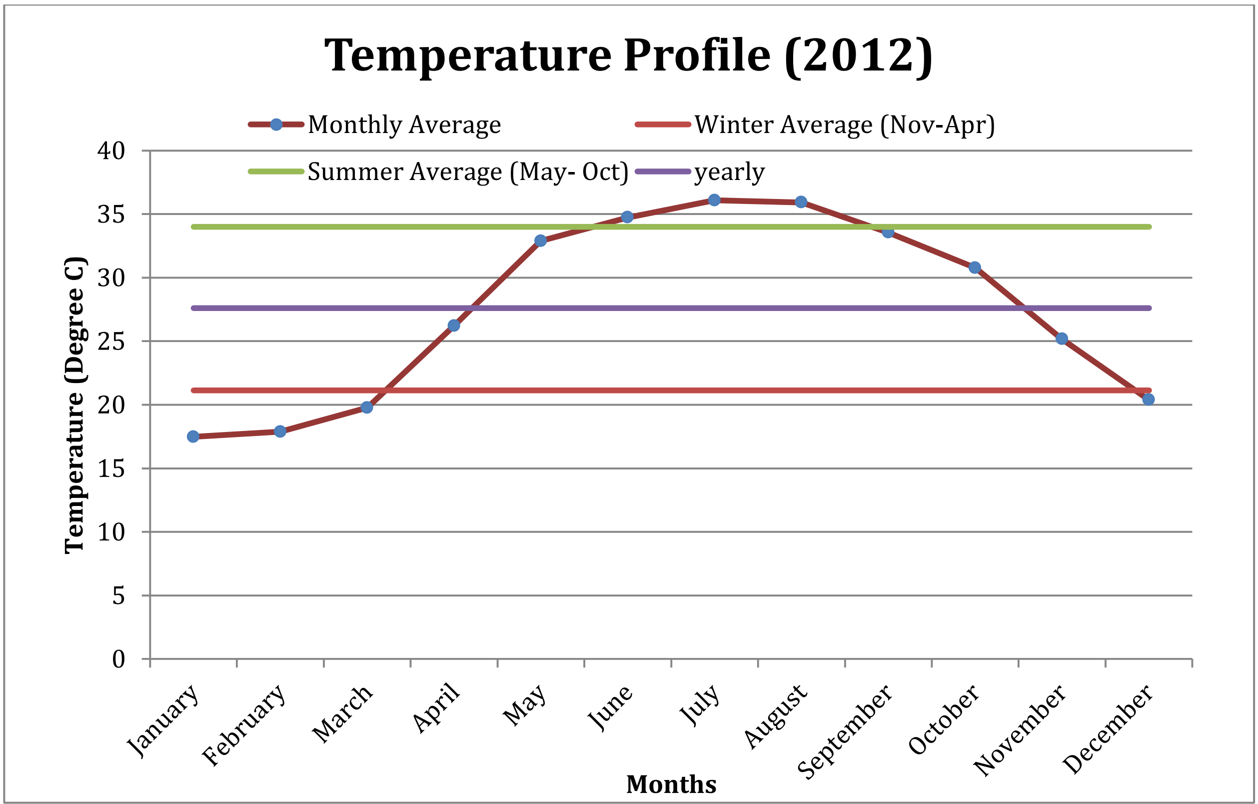


Figure A- 3: Mean Monthly Average Temperatures at Bahrain Airports (2012)

1.2.2 Wind

Wind direction and wind speed are measured at the Environment Bahrain airport locations. A wind rose is a histogram plotted in polar coordinates. The histogram is comprised of 16 bars whose length represents the frequency that the wind blows from one of the 16 cardinal compass points (e.g., N, NNE, NE, and ENE to WNW, NW, and NNW). The bar can be broken down to represent different wind speed classes. Wind roses were prepared from data collected at the continuous monitoring locations in the CALMET Domain. **Figure A- 4**: and **Figure A- 5**: show the wind roses for five years (2008-2012) both individually and combined. The wind class frequency distribution is presented in **Figure A- 6**:

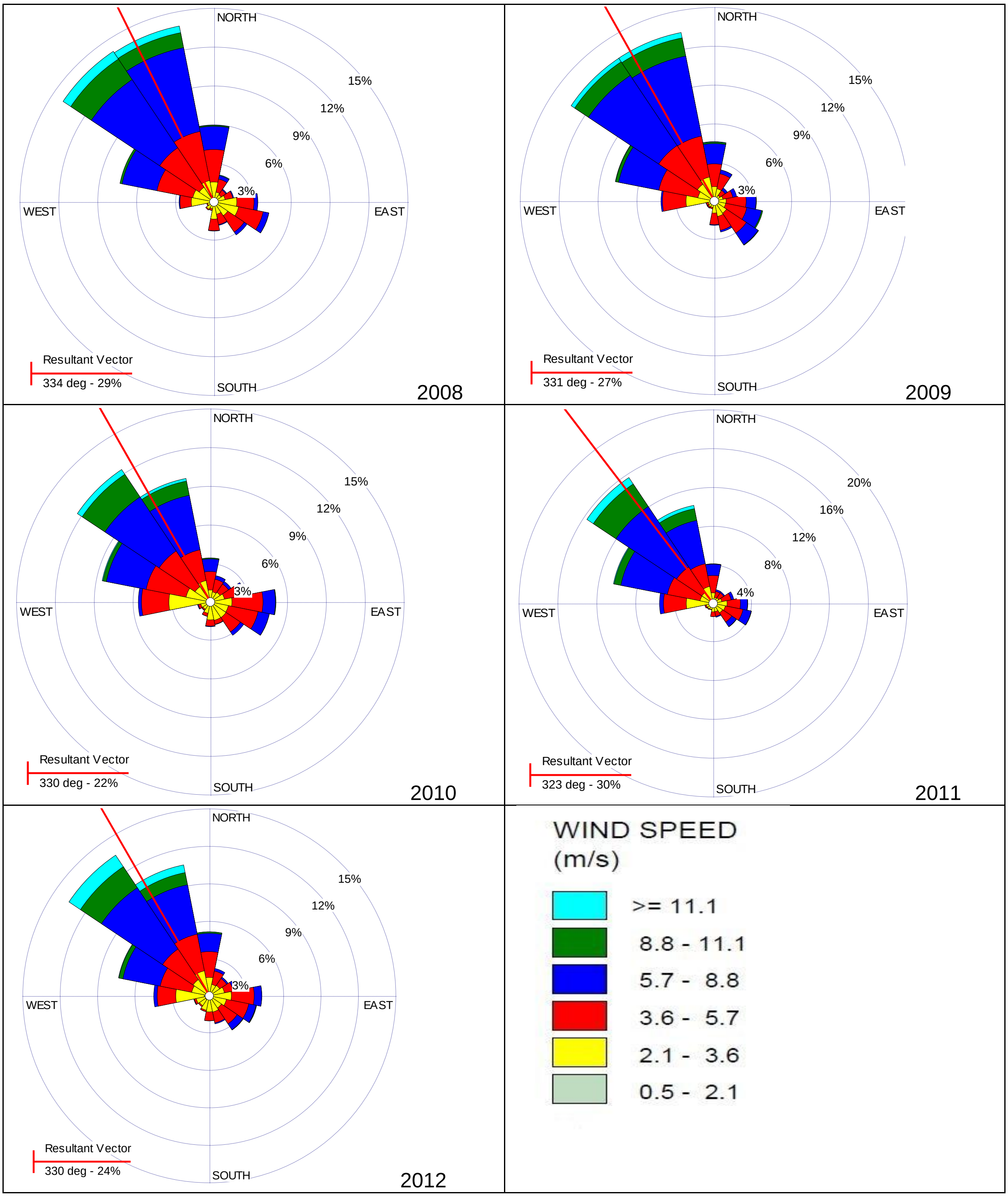
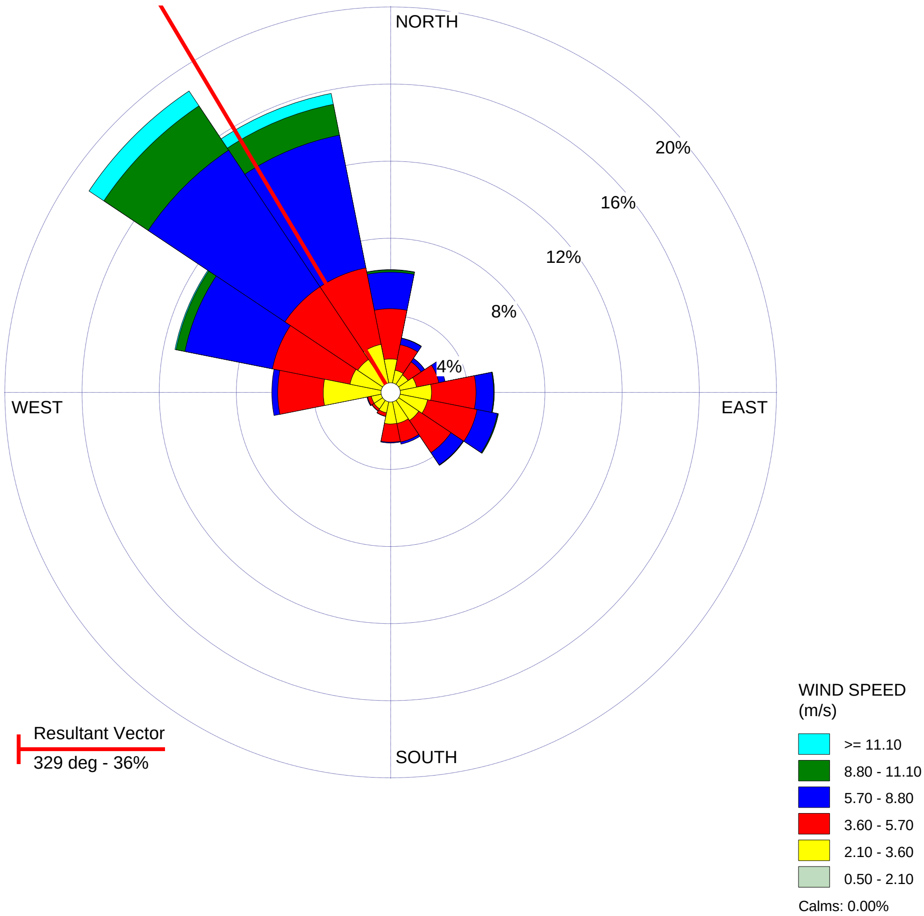


Figure A- 4: Wind Roses 2008, 2009, 2010, 2011 and 2012

WIND ROSE PLOT:
Station #41150 - bahrain international, BH

DISPLAY:
Wind Speed
Direction (blowing from)



COMMENTS:	DATA PERIOD:	COMPANY NAME:	
	Start Date: 1/1/2008 - 00:00 **End Date: 12/31/2012 - 23:00**	MODELER:	
	CALM WINDS: **0.00%**	TOTAL COUNT: **39865 hrs.**	
	AVG. WIND SPEED: **4.95 m/s**	DATE: **4/21/2014**	PROJECT NO.:

Figure A- 5: Wind Rose for five years (2008-2012)

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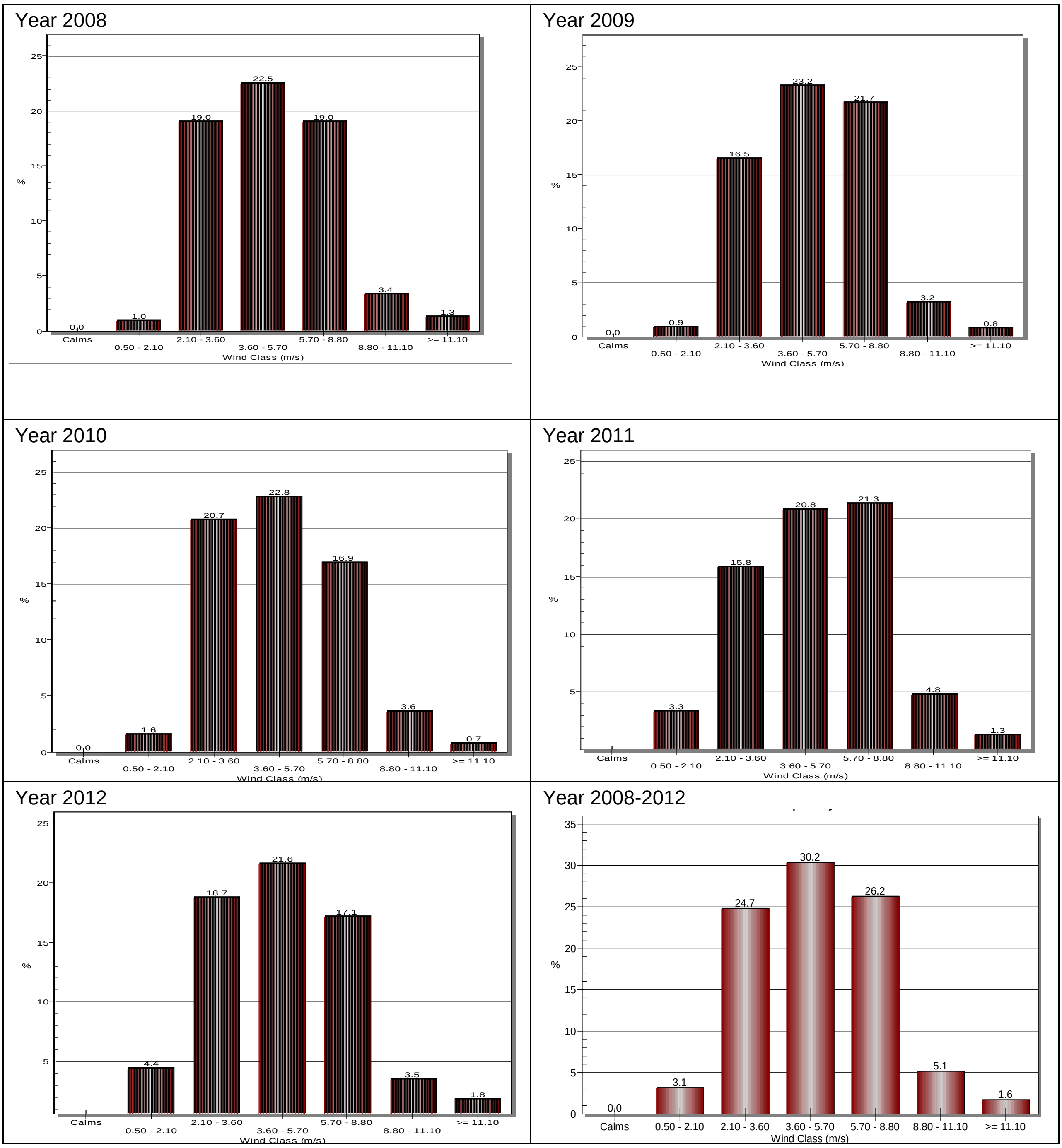

Figure A- 6: Wind class Frequency Distribution for years 2008-2012

1.3 Meteorological Predictions

1.3.1 Meteorological Models

Due to the paucity of meteorological data in the region and the question of the representativeness of measured data at a single site being applied to the region, meteorological models have been used to provide spatially and temporally varying wind and temperature fields across a large region. These models can be categorized as either prognostic or diagnostic models:

Prognostic models use meteorological measurements and fundamental equations of atmospheric motion to determine how meteorological conditions will behave between the observing stations. The MM5 model (a Mesoscale meteorological model assimilation produced by Penn State/NCAR) is an example of a prognostic model that has been applied to entire Bahrain Area for air quality assessment purposes. As a part of the modelling assignment, the MM5 model has been applied on a 4 km grid spacing for year 2012.

Diagnostic models use interpolation schemes that rely on empirical relationships to account for topographical or other influences that can occur between the observing sites. The CALMET model is an example of a diagnostic model (Scire et al. 2000). The CALMET model can be applied on a finer scale to the MM5 model output in order to resolve more local-scale terrain influences.

A combination of both models were used for this assessment: the MM5 model output being used to provide an initial guess field with the CALMET model adjusting the initial guess field for the kinematic effects of terrain, slope flows, and terrain blocking effects using the finer scale terrain data to produce a modified wind field. This approach has become the standard for air quality assessments for industrial projects.

While it is clear that the grid points provide a much greater and uniform density across the domain than the locations where meteorological parameters are measured, it must be noted that these are Interpolated / predicted data. Wind, mixing height, and PG stability class data were extracted to show the meteorology specific to the PDA. These are the main parameters that influence transport and dispersion of emissions from the Project.

1.3.2 CALMET Application

The current approved U.S. EPA version of CALMET is Version 5.8, level 070623. For this assessment, a more recent version, Version 6.42 was adopted. A horizontal grid spacing of 4 km was selected for the CALMET simulation; the study area therefore corresponds to 13 rows by 13 columns. With this grid spacing, it was possible to maximize run time and file size efficiencies while still capturing large-scale terrain feature influences on wind flow patterns.

To simulate transport and dispersion processes, it is also important to simulate the representative vertical profiles of wind direction, wind speed, temperature, and turbulence intensity within the atmospheric boundary layer (i.e., the layer within about 2000 metres above the Earth’s surface). To capture this vertical structure, eight vertical layers were selected. CALMET defines a vertical layer as the midpoint between two faces (i.e., nine faces corresponds to eight layers, with the lowest layer always being ground level or 10 m). The vertical faces used in this study are 0, 20, 40, 80, 160, 320, 600, 1400 and 2600 m.

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The CALMET model was applied for 2012 (i.e., for 8,760 hours). The model requires surface and upper air information. The gridded 3-D meteorological data produced by the MM5 model (a Mesoscale meteorological model assimilation produced by Penn State/NCAR) were used as an initial guess field (Scire et al. 2000). The MM5 Mesoscale data were obtained from Lakes Environmental, Canada on a 4 km grid resolution for the years 2012. The MM5 data were supplemented with meteorological data from Bahrain International Airport. The CALMET model adjusted the initial guess field for the kinematic effects of terrain, slope flows, and terrain blocking effects using the finer scaled CALMET terrain data to produce a modified wind field that was used by the CALPUFF model.

The input parameters for the CALMET control file used in for this assessment are provided in **Table A- 4** to **Table A- 11**. The tables indicate "default" values that were identified in the CALPUFF Modelling System Version 6 User Instructions (TRC, 2011). Differences from the default values and the values applied for the assessment of the Sasol Project include:

- **DATUM:** The CALMET default value WGS-84 is the Datum-region for output coordinates were used.
- **NOOBS**: For this assessment, the upper air stations are located outside CALMET domain so option 1 (i.e., surface stations data only) was used to adjust surface field in CALMET model output.
- **BIAS**: These are layer-dependent biases modifying the weights of surface and upper air stations. For this assessment, this parameter is not applicable as only surface station data were used.
- **RMN2**: This is the minimum distance from the nearest upper air station to the surface station for which extrapolation of surface winds at surface station will be allowed. This parameter is not applicable for this assessment as only surface station data were used.
- **IPROG**: The CALMET default value is 0 for not using gridded prognostic model wind data as input and is only applicable for CALMET only using observation data. For this assessment, option 14 was selected as winds from a MM5/3D.DAT file were used as initial guess field.
- **ZUPWND**: used only when parameter IUPWND > 0. This parameter is not applicable for this assessment as IUPWND was set to -1.
- **IRHPROG**: The CALMET default value of 0 is set to use relative humidity data from observations. This default is more appropriate for a model domain that contains a dense surface and upper air station network. For this assessment, a value of 1 was selected to use relative humidity data from the MM5 dataset.
- **ITPROG**: The CALMET default value of 0 is set to use temperature data from observations. This default is more appropriate for a model domain that contains a dense surface and upper air station network. For this assessment, a value of 1 was selected to use temperature data from the MM5 dataset.

Table A- 4: Groups in the CALMET Control File

Input Group	Description	Applicable to Project
0	Input and output file names	Yes
1	General run control parameters	Yes
2	Grid control parameters	Yes
3	Output Options	Yes
4	Meteorological data options	Yes
5	Wind Field Options and Parameters	Yes
6	Mixing Height, Temperature and Precipitation Parameters	Yes
7	Surface meteorological station parameters	Yes
8	Upper air meteorological station parameters	Yes

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Input Group	Description	Applicable to Project
9	Precipitation parameters	Yes

Table A- 5: CALMET Model Options Groups 0 and 1

Parameter	Default	Project	Comment
Input Group 0: Input and Output File Names			
NUSTA	-	0	Number of upper air stations
NOWSTA	-	0	Number of overwater met stations
MM3D	-	6	Number of MM4/MM5/3D.DAT (6 monthly files for the 1-year period
NIGF	-	0	Number of IGF-CALMET.DAT files
Input Group 1: Input and Output File Names			
IBYR	-	2012	Starting year
IBMO	-	1	Starting month
IBDY	-	1	Starting day
IBHR	-	0	Starting hour
IBSEC	-	0	Starting second
IEYR	-	2012	Ending year
IEMO	-	12	Ending month
IEDY	-	31	Ending day
IEHR	-	23	Ending hour
IESEC	-	0	Ending second
ABTZ	-	UTC+3hrs	UTC time zone
NSECDT	3600	3600	Length of modelling time-step (seconds)
IRTYPE	1	1	Run type
LCALGRD	T	T	Special data fields
ITEST	2	2	Flag to stop run after SETUP phase

Table A- 6: CALMET Model Options Group 2: Grid control parameters

Parameter	Default	Project	Comment
PMAP	UTM	UTM	Map projection
IUTMZN	-	39	UTM Zone
UTMHEM	N	N	Hemisphere for UTM projection
DATUM	WGS-84	WGS-84	Datum – region for output coordinate (user defined)
NX	-	13	No. X grid cells
NY	-	13	No. Y grid cells
DGRIDKM	-	4	Grid spacing (km)
XORIGKM	-		Reference coordinate of SW corner of grid cell (1,1) -X coordinate (km)
YORIGKM	-		Reference coordinate of SW corner of grid cell (1,1) -Y coordinate (km)
NZ	-	8	Vertical grid definition: Number of vertical layers
ZFACE	-	0,20,40,80,160,320, 600,1400,2600	Vertical grid definition: Cell face heights in arbitrary vertical grid (m)

Table A- 7: CALMET Model Options Group 3: Output Options

Parameter	Default	Project	Comment
Disk Output:			
LSAVE	T	T	Save met. Fields in the unformatted output files
IFORMO	1	1	Type of unformatted output file
Line Printer Output:			
LPRINT	-	T	Print meteorological fields
IPRINF	-	12	Print intervals (hrs)
IUVOU (NZ)	-	1,0,0,0,0,0,0,0	Specify which layers of U,V wind component to print
IWOUT (NZ)	-	0,0,0,0,0,0,0,0	Specify which level of the W wind component to print
ITOUT (NZ)	-	1,0,0,0,0,0,0,0	Specify which levels of the 3-D temperature field to print
Meteorological fields to print:			
Variable	Print? 0 = no print 1 = print		Comment
STABILITY	1		PGT stability
USTAR	0		Friction velocity
MONIN	0		Monin – Obukhov length
MIXHT	1		Mixing height
WSTAR	0		Convective velocity scale
PRECIP	1		Precipitation rate
SENSHEAT	0		Sensible heat flux
CONVZI	0		Convective mixing height
Testing and debug print options for micrometeorological module:			
LDB	F	F	Print input meteorological data and internal variables
NN1	1	1	First time step for which debug data are printed
NN2	1	1	Last time step for which debug data are printed
LDBCST	F	F	Print distance to land internal variables
Testing and debug print options for wind field module:			
IOUTD	0	0	Control variable for writing the test/debug wind fields to disk files
NZPRN2	1	0	Number of levels, starting at surface, to print
IPR0	0	0	Print the interpolated wind components
IPR1	0	0	Print the terrain adjusted surface wind components
IPR2	0	0	Print the smoothed wind components and the initial divergence fields
IPR3	0	0	Print the final wind speed and direction
IPR4	0	0	Print the final divergence fields
IPR5	0	0	Print the winds after kinematic effects are added
IPR6	0	0	Print the winds after the Froude number adjustment is made
IPR7	0	0	Print the winds after slope flows are added
IPR8	0	0	Print the final wind field components

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Table A- 8: CALMET Model Options Group 4: Meteorological Data Options

Parameter	Default	Project	Comment
NOOBS	0	1	surface station data was used (no upper air observations)
Number of Surface & Precipitation Meteorological Stations:			
NSSTA	-	0	Number of surface stations
NPSTA	-	0	Number of precipitation stations
Cloud Data Options:			
ICLOUD	0	0	Gridded clouds not used (cloud cover data from Bahrain International Airport were used)
File Formats:			
IFORMS	2	2	Surface meteorological data file format
IFORMP	2	2	Precipitation data file format
IFORMC	2	2	Cloud data file format

Table A- 9: CALMET Model Option Group 5: Wind Field Options and Parameters

Parameter	Default	Project	Comment
Wind Field Model Options:			
IWFCOD	1	1	Model selection variables
IFRADJ	1	1	Compute Froude number adjustment
IKINE	0	0	Computer kinematic effects
IOBR	0	0	Use O'Brien procedure for adjustment of the vertical velocity
ISLOPE	1	1	Compute slope flow effects
IEXTRP	-4	-4	Extrapolate surface wind observations to upper layers (similarity theory used with layer 1 data at upper air stations ignored)
ICALM	0	0	Extrapolate surface winds even if calm
BIAS	0	Not Applicable	Layer-dependent biases modifying the weights of surface and upper air stations
RMIN2	4	Not Applicable	Minimum distance from nearest upper air station to surface station for which extrapolation of surface winds at surface station will be allowed Set to -1 for all surface stations should be extrapolated
IPROG	0	14	Use gridded prognostic wind field model output fields as input to the diagnostic wind field model (from MM5.DAT)
ISTEPPG	1	1	Time step (hours) of the prognostic model input data
IGFMET	0	0	Use coarse CALMET fields as initial guess fields
Radius of Influence Parameters:			
LVARY	F	F	Use varying radius of influence
RMAX1	-	12	Maximum radius of influence over land in the surface layer (km)
RMAX2	-	12	Maximum radius of influence over land aloft (km)
RMAX3	-	5	Maximum radius of influence over water
Other Wind Field Input Parameters:			
RMIN	0.1	0.1	Minimum radius of influence used in the wind field interpolation (km)
TERRAD	-	15	Radius of influence of terrain features (km)
R1	-	3	Relative weighting of the first guess field and observations in the surface layer (km)
R2	-	3	Relative weighting of the first guess field and observations in the layers aloft (km)
RPROG	-	0	Relative weighting parameter of the prognostic wind field

Parameter	Default	Project	Comment
			data (km)
DIVLIM	5.0E-6	5.0E-6	Maximum acceptable divergence in the divergence minimization procedure
NITER	50	50	Maximum number of iterations in the divergence minimization procedure
NSMTH (NZ)	2,(mxnz-1)*4	2,4,4,4,4,4,4,4	Number of passes in the smoothing procedure
NINTR2	99	99,99,99,99, 99,99,99,99	Maximum number of stations used in each layer for the interpolation of data to a grid point
CRITFN	1.0	1.0	Critical Froude number
ALPHA	0.1	0.1	Empirical factor controlling the influence of kinematic effects
FEXTR2	NZ*0	0,0,0,0,0,0,0,0	Multiplicative scaling factor for extrapolation of surface observations to upper layers
Barrier Information:			
NBAR	0	0	Number of barriers to interpolation of the wind fields (not applicable, therefore not used)
KBAR	NZ	8	Level (1 to NZ) up to which barriers apply (not applicable, therefore not used)
XBBAR	-	0	X coordinate of beginning of each barrier (not applicable, therefore not used)
YBBAR	-	0	Y coordinate of beginning of each barrier (not applicable, therefore not used)
XEBAR	-	0	X coordinate of ending of each barrier (not applicable, therefore not used)
YEBAR	-	0	Y coordinate of ending of each barrier (not applicable, therefore not used)
Diagnostic Module Data Input Options:			
IDIOPT1	0	0	Surface temperature (0 = compute internally from hourly surface observation)
ISURFT	-	2	Surface meteorological station to use for the surface temperature
IDIOPT2	0	0	Domain-averaged temperature lapse (0 = compute internally from hourly surface observation)
IUPT	-	0	Upper air station to use for the domain-scale lapse rate
ZUPT	200	200	Depth through which the domain-scale lapse rate is computed (m)
IDIOPT3	0	0	Domain-averaged wind components
IUPWND	-1	-1	Upper air station to use for the domain-scale winds
ZUPWND	1, 1000	Not Applicable	Bottom and top of layer through which domain-scale winds are computed (m). Used only IUPWND > 0
IDIOPT4	0	0	Observed surface wind components for wind field module
IDIOPT5	0	0	Observed upper air wind components for wind field module
Lake Breeze Information:			
LLBREZE	F	F	Use lake breeze module *(not applicable therefore not used)*
NBOX	-	0	Number of lake breeze regions
XG1	-	0	X Grid line 1 defining the region of interest
XG2	-	0	X Grid line 2 defining the region of interest
YG1	-	0	Y Grid line 1 defining the region of interest
YG2	-	0	Y Grid line 2 defining the region of interest
XBCST	-	0	X Point defining the coastline in kilometres (Straight line)
YBCST	-	0	Y Point defining the coastline in kilometres (Straight line)
XECST	-	0	X Point defining the coastline in kilometres (Straight line)
YECST	-	0	Y Point defining the coastline in kilometres (Straight line)
NLB	-	0	Number of stations in the region

Parameter	Default	Project	Comment
METBXID	-	0	Station ID's in the region

Table A- 10: CALMET Input Model Option

Group 6: Mixing Height, Temperature and Precipitation Parameters

Parameter	Default	Project	Comment
Empirical Mixing Height Constants:			
CONSTB	1.41	1.41	Neutral, mechanical equation
CONSTE	0.15	0.15	Convective mixing height equation
CONSTN	2400	2400	Stable mixing height equation
CONSTW	0.16	0.16	Over water mixing height equation
FCORIO	1.0E-4	1.0E-4	Absolute value of Coriolis (s-1) (adjusted for project site latitude)
Spatial Averaging of Mixing Heights:			
IAVEZI	1	1	Conduct spatial averaging
MNMDAV	1	10	Maximum search radius in averaging (grid cells)
HAFANG	30	30	Half-angle of upwind looking cone for averaging
ILEVZI	1	1	Layer of winds used in upwind averaging
Convective Mixing Heights Options:			
IMIXH	1	1	Method to compute the convective mixing height (Maul-Carson)
THRESHL	0.05	0.05	Threshold buoyancy flux required to sustain convective mixing height growth overland (W/m3)
THRESHW	0.05	0.05	Threshold buoyancy flux required to sustain convective mixing height growth overwater(W/m3)
ITWPROG	0	0	Option for overwater lapse rates used in convective mixing height growth (1=use prognostic lapse rates)
ILUOC3D	16	16	Land use category ocean in 3D.DAT datasets
Other Mixing Height Variables:			
DPTMIN	0.001	0.001	Minimum potential temperature lapse rate in the stable layer above the current convective mixing height (K/m)
DZZI	200	200	Depth of layer above current convective mixing height through which lapse rate is computed (m)
ZIMIN	50	50	Minimum overland mixing height (m)
ZIMAX	3000	3000	Maximum overland mixing height (m)
ZIMINW	50	50	Minimum overwater mixing height (m)
ZIMAXW	3000	3000	Maximum overwater mixing height (m)
Overwater Surface Fluxes Method and Parameters:			
ICOARE	10	10	COARE with no wave parameterization (not applicable therefore not used)
DSHELF	0	0	Coastal/Shallow water length scale (km)
IWARM	0	0	COARE warm layer computation
ICOOL	0	0	COARE cool skin layer computation
Relative Humidity Parameters:			
IRHPROG	0	1	3D relative humidity from observations or from prognostic data 1 = Use prognostic relative humidity
Temperature Parameters:			
ITPROG	0	1	3D temperature from observations or from prognostic data 1 = Use Surface stations (no upper air observations)
IRAD	1	1	Interpolation type
TRADKM	500	500	Radius of influence for temperature interpolation (km)
NUMTS	5	13	Maximum number of stations to include in temperature interpolation

Parameter	Default	Project	Comment
IAVET	1	1	Conduct spatial averaging of temperatures (1 = yes)
TGDEFB	-0.0098	-0.0098	Default temperature gradient below the mixing height over water (K/m)
TGDEFA	-0.0045	-0.0045	Default temperature gradient above the mixing height over water (K/m)
JWAT1	-	55	Beginning land use categories for temperature interpolation over water
JWAT2	-	55	Ending land use categories for temperature interpolation over water
Precipitation Interpolation Parameters:			
NFLAGP	2	2	Method of interpolation
SIGMAP	100	100	Radius of Influence (km)
CUTP	0.01	0.01	Minimum Precipitation rate cut-off (mm/h)

Table A- 11: CALMET Model Option Group 7: Surface Meteorological Station Parameters

Name	ID	X coordinate (km)	Y coordinate (km)	Time Zone	Anemometer Height
BAH	41150	465.052	2905.300	3	10
Note: BAH-Bahrain International Airport					

2 CALPUFF INTRODUCTION

Ambient air quality models are used to predict air quality changes (i.e., changes to ambient concentrations) associated with future emission scenarios. This section discusses the selection and application of the primary dispersion model that was used for the air quality assessment as part of the Environmental and Social Impact Assessment for the proposed Potline 6 and Power Station 5 expansion project at Aluminium Bahrain (ALBA).

2.1 Model Types

Air quality simulation (or dispersion) models provide a scientific means of relating industrial emissions to air quality changes, by using mathematical equations to simulate transport, dispersion, transformation, and deposition processes in the atmosphere. Dispersion models can address a wide range of distance scales (hundreds of metres to thousands of kilometres) and time scales (minutes to years).

Regulatory agencies have relied on dispersion models as part of their approval process. Numerous models are available to predict ambient air quality changes and the appropriate selection depends on project-specific circumstances. In response to the regulatory use of these models, formal guidelines regarding the selection and application of these models have been developed (e.g., U.S. EPA 2005).

2.2 Model Input/output Files

The application of a dispersion model requires the preparation of input files and the analysis of output files.

The input files include the following:

- Control/option information to identify the model run, to select the available technical features, and to control the output options specific to the selected model;
- Source data that identify the locations, emission characteristics (e.g., stack height), and emission rates (e.g., NOX emission rate) for each source;
- Terrain elevations and surface characteristics to account for terrain influences on airflow and turbulence;
- surface characteristics to provide the deposition properties; and
- Meteorological data on an hourly basis to characterize airflow and turbulence in the region.

The output files include the following:

- A summary file to identify the model run and to provide an overview of the run;
- Hourly concentration files for each receptor and meteorological combination;
- Post analysis software of the concentration file to represent identified scenarios; and
- Presentation software is used to re-format the model predictions and to provide concentrations contour plots that to be superimposed over base maps.

2.3 MODEL SELECTION

2.3.1 Model Requirements

For the ALBA project, the selected model must have the ability to account for:

- Multiple point and area sources
- Flat and elevated terrain features
- Dry deposition of gases and particles and chemical transformation of NO2 and SO2

These features are required to predict ambient concentrations.

2.3.2 Candidate Models

The CALPUFF model was therefore selected as the preferred model for this assessment. CALPUFF has two options with respect to meteorological data:

- The simple mode assumes a uniform meteorological field over the model domain during a given hour. While this approach is consistent with the AERMOD model, CALPUFF has the advantage of allowing the plume trajectories to vary from hour-to-hour in a systematic manner as the wind direction varies from hour-to-hour. This becomes more important to include when the model is applied to larger domains.
- The CALMET model allows for three-dimensionally varying meteorological fields over the model domain during a given hour.

Dispersion Model:

The CALPUFF (Scire et al. 1999) model is a multi-layer, multi-species, non-steady state puff dispersion model that can simulate the effects of time and space-varying meteorological conditions on substance transport, transformation, and removal. CALPUFF can use the three-dimensional meteorological fields developed by the CALMET model or simple, single station, winds in a format consistent with the meteorological files used to drive the ISCST3 or the AERMOD steady-state Gaussian models.

For this assessment, the CALPUFF model with the three-dimensional CALMET wind field was selected. The CALPUFF model performance was gauged by comparing model predictions to selected observations.

2.4 CALPUFF Model

CALPUFF contains algorithms for near-source effects such as building downwash, transitional plume rise, partial plume penetration, as well as longer-range effects such as chemical transformation, and pollutant removal (wet scavenging and dry deposition). It can accommodate arbitrarily varying point source and area source emissions. Most of the algorithms contain options to treat physical processes at differing levels of detail depending on the requirements for the particular model application:

Atmospheric Dispersion:

Several options are provided in CALPUFF for the computation of dispersion coefficients:

- Similarity theory to estimate turbulence measurement (σv and σw) from surface heat and momentum fluxes provided by CALMET
- Pasquill-Gifford (PG) or McElroy-Pooler (MP) dispersion coefficients
- Dispersion equations based on the Complex Terrain Dispersion Model (CTDM)
- Hourly values of direct turbulence measurements (σv and σw)

2.5 MODEL APPLICATION

2.5.1 Model Domain

The CALPUFF model requires the user to define an area where the emissions sources are identified, the meteorological conditions are characterized, and the locations where the air quality changes are to be predicted. The CALPUFF computational domain is selected to represent a 50 km by 50 km area nominally centred over the ALBA Project.

2.5.2 Receptor Locations

Two types of receptors within the Model Domain are defined: nested Cartesian grid points and discrete locations.

2.5.3 Cartesian Grid Receptors

The receptors are based on the following spacing:

- 10 metre receptor spacing along the facility boundary;
- 50 metre receptor spacing within 500 metres from the facility;
- 250 metre receptor spacing from 500 metres to 2 kilometres from the facility;
- 500 metre receptor spacing from 2 kilometres to 5 kilometres from the facility; and,
- 1000 metre receptor spacing beyond 5 kilometres from the facility.

Table A- 12: CALPUFF Study Area Coordinates

Model Domain	Easting (m)	Northing (m)
Northeast Corner	485322.12	2910507.97
Southwest Corner	435322.12	2860507.97
Southeast Corner	485322.12	2860507.97
Northwest Corner	435322.12	2910507.97

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2.5.4 Discrete Receptors

In addition, 10 discrete locations corresponding to specific sites of interest are included. Figure A- 7 shows the locations of the discrete receptors that were included in the assessment. These receptors were broadly grouped as follows:

5 ambient air-quality monitoring sites and 5 - sensitive receptors were chosen. Model predictions are compared to measurements at some monitoring sites to gauge the model performance.

Table A- 13: Sensitive Receptor Locations

No.	Receptor Name	Abbreviation Used	UTM E (km)	UTM N (km)
1	Ras Hayyan	MS_RH	461.356	2879.271
2	Hidd	MS_HD	465.063	2906.347
3	Maameer	MS_MA	461.532	2891.34
4	Napeeh Saleh	MS_NS	457.044	2894.759
5	Hamad Town	MS_HT	451.074	2884.502
6	Sanabis	SB	454.8766	2900.187
7	Villas Askar	VA	461.504	2882.467
8	Villas 2	V2	455.7868	2885.161
9	Residential Area & Golf Course	R_G	457.119	2886.07
10	Labour Accommodation	LA	459.967	2887.245
11	East-Riffa	ER	457.83	2888.485
13	Nuwaidrat	NU	460.1753	2890.493
14	Al Eker	AE	460.6759	2891.332
15	Sanad	SD	458.3597	2892.361
16	Sitra	SI	461.224	2893.765

Note:

MS: Ambient Air Monitoring Station

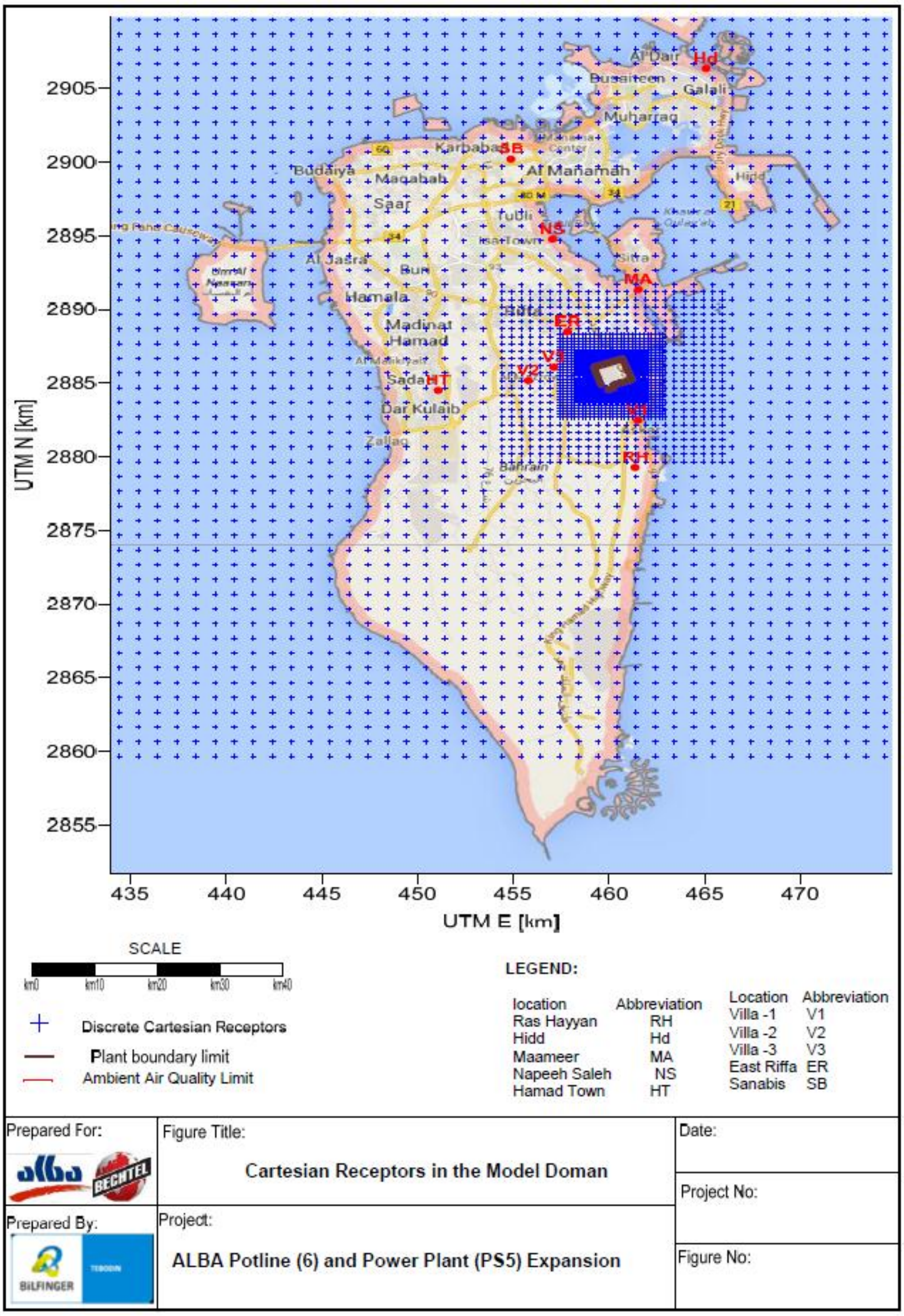

Figure A- 7: **Location of Discrete Monitoring Station Receptors**

2.5.5 Meteorology

The CALMET diagnostic wind field module was used to provide representative wind, temperature, and turbulence fields. One year (2012) of hourly CALMET input files were prepared and used for this assessment. The meteorology inputs for each year account for seasonal variations in the land cover properties.

2.5.6 Dispersion

The CALPUFF model offers a number of dispersion options. The following identifies the dispersion options that were selected for this assessment:

- The similarity scaling approach to estimate σv and σw provides a more up-to-date understanding of dispersion in the boundary layer than the historical discrete PG dispersion approach. The similarity approach treats dispersion as a continuous function, whereas the PG approach considers discrete classes. For this reason, MDISP = 2 (Input group 2) is used to select the similarity to change or move to different area.
- The Probability Distribution Function (PDF) approach accounts for downdrafts and updrafts that occur under convective conditions. The PDF approach increases the predicted concentrations resulting from stacks under convective conditions. For this assessment MPDF = 1 (PDF assumed) is selected.
- The Heffter (σy) adjustment was used. This approach enhances the lateral horizontal dispersion for large distances. This or a similar type of enhancement is recommended for large distances and thus the default Heffter value of 550 m is adopted (Input group 12).
- The default minimum σw values as required as part of Input group 12 were adopted. These values are based on the Briggs (1973) rural dispersion coefficients. These values are consistent with plume behaviour over barren area land use classification.
- The default minimum σv values (0.5 m/s) as required as part of Input group 12 were adopted.

This discussion is provided as the selection of the dispersion algorithms can have an influence on the model predictions. The values that were selected are representing our recent understanding of dispersion processes in the atmosphere and are viewed as appropriate for this assessment.

2.5.7 Building Downwash

Buildings or other solid structures may affect the flow of air near a source and cause building downwash effects (e.g., eddies on the downwind side), which have potential to reduce plume rise and affect dispersion. The Huber-Snyder and Schulman-Scire downwash models are both incorporated into CALPUFF. Schulman-Scire option was used to provide to use either model for all stacks, or make the choice on a stack-by-stack and wind sector-by-wind sector basis. Both algorithms have been implemented in such a way as to allow the use of wind direction specific building dimensions. The more advanced treatment of the PRIME downwash model is also incorporated as an option. This includes treating representative streamline patterns and diffusion rates in both the near and far wakes and recirculation effects in the cavity zone. Building downwash mode was part of the assessment.

2.5.8 Terrain Coefficients

Terrain in the study area is described in the CALMET description. While the terrain near the Project is relatively flat, there are locations where higher terrain occurs. As a plume/puff passes over complex terrain, it has the potential to move closer to the ground. The plume path coefficient (PPC) method can be used to account for this potential decrease in height above the ground. A PPC of 1.0 assumes that the plume trajectory is parallel to the terrain features.

The default CALPUFF values are 0.5, 0.5, 0.5, 0.5, 0.35, and 0.35 for PG stability categories A, B, C, D, E and F, respectively. The selection of these values is not justified in the user guide (Scire et al. 1999). Lott (1984) compared a number of alternate terrain assessment schemes and recommended PPC values of 0.8, 0.7, 0.6, 0.5, 0.4, and 0.3 for Pasquill-Gifford (PG) stability categories A, B, C, D, E and F, respectively. For this assessment, PPC values of 0.8, 0.7, 0.6, 0.5, 0.4, and 0.35 for PG categories A, B, C, D, E and F, respectively, per Davies and Prasad (2005) were adopted.

2.6 Interpretation of Predictions

2.6.1 Comparison to BAAQS

EPA (2010) recommends discarding the eight highest 1-hour predictions at each receptor location during any given year, as these values “are considered outliers and should not be used as the basis for selecting stack height”. This means that the 1-hour Bahrain Ambient Air Quality Standards (BAAQS) values should be compared to the 9th highest prediction, not to the highest prediction. For a one-year period, the 9th highest value corresponds to the 99.9th percentile predicted concentration.

When effecting this comparison, EPA has the expectation that the 9th highest corresponds to a realistic worst-case scenario. Although “realistic” is not defined, one can assume it refers to a normal maximum emissions case that could reasonably be expected during routine operations. Specifically, it does not appear to be associated with maximum emissions due to process upsets or due to pollution-control technology downtime.

EPA also indicates that the second-highest 24-hour average prediction should be compared to the corresponding 24-hour BAAQS (EPA, 2010). The annual average concentration is compared directly to the annual BAAQS. When comparing the 24-hour and annual average concentration to the respective BAAQS, the top eight 1-hour average values are included.

2.6.2 Contour Maps

Predicted concentrations are displayed as contour plots superimposed over a base map of the study areas. The concentration contour plots are based on the maximum values for the one year simulation period. This may result in some “smoothing” of the contours based on tri-angulation statistical method. However, the tabular results are based on direct model output and not on smoothed data.

2.7 CALPUFF Performance

2.7.1 Model Prediction Confidence

Uncertainty associated with dispersion model predictions stems from two main areas (U.S. EPA 2005):

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- **Reducible uncertainty**, which results from uncertainties associated with the input values and with the limitations of the model formulations. Reducible uncertainty can be minimized by better (i.e., more accurate and representative) measurements and improved model formulations.
- **Inherent uncertainty**, which is associated with the stochastic nature of the atmosphere and its representation. Models predict concentrations that represent an ensemble average of numerous repetitions for the same nominal event. An individual observed value can deviate significantly from the ensemble value. This uncertainty may be responsible for a ±50% deviation from the measured values.
- Generally, models are quoted as having a factor-of-two accuracy. Comparison studies indicate that models can predict the magnitude of highest concentration occurring sometime and somewhere within an area to within ±10 to ±40%. Predictions for a specific site and time are often poorly correlated with observed values. This poor correlation can often be related to errors in wind direction. For example, an uncertainty of 5º to 10º in the wind direction can produce a concentration error in the 20 to 70% range (U.S. EPA 2005).

The U.S. EPA (2005) provides guidance to decision makers relative to model uncertainty. Specifically, they recommend that the model predictions be accepted as a "best estimate", until sufficient technical progress has been made to meaningfully implement concepts dealing with uncertainty.

2.7.2 Performance Approach

The performance of the CALPUFF/CALMET model system is determined by comparing model predictions to the Bahrain ambient air quality measurements at the selected monitoring stations. For purpose of gauging model performance, the ambient measurements and predictions are grouped as follows:

Respective to Alba's location, the nearest upwind monitoring station is Maamer sport club station while the nearest downwind monitoring station is indicated at Ras Hayyan.

1. Askar residential area (Ras Hayyan) Monitoring Station - Downwind
2. Residential Area (Villa 3) and Royal Golf Club (Villa 2) - Upwind; and
3. East-Riffa residential area (upwind)

Ambient monitoring data represent contributions from existing ALBA facility and other industrial and anthropogenic sources in the study area. The model predictions, as applied for this comparison assessment, are done for the project alone contributions and do not include the contributions from sources outside the model domain and other project sources.

Model performance is often gauged by comparing the highest predicted values with the highest measured values as the model is often used to determine compliance with BAAQS. However, the meteorological variability and the emission variability can lead to uncertainties with this type of model performance comparison. For this assessment, the Top-25 1-hour predicted and measured concentrations are also calculated and compared. The use of the Top-25 concentrations is viewed as a more robust indicator than the single highest value (U.S. EPA 1992).

The fractional bias (FB) has also been used as a model performance indicator (U.S. EPA 1992) that is defined as:

$$FB = 2 * [\frac{PR - OB}{OB + PR}]$$

always close

Where:

- OB = the average of the Top-25 1-hour concentrations observed at a given site.
- PR = the average of the Top-25 1-hour concentrations predicted at the same site.

The FB has the following properties:

- It is bounded ranging from +2.0 (extreme over-prediction) to -2.0 (extreme under-prediction).
- FB values corresponding to over-predictions and under-predictions by a factor of two ranges from +0.67 to -0.67, respectively.
- A FB value of 0.0 indicates perfect agreement.

The use of the absolute fractional bias (AFB) simplifies the comparison calculations. A model is viewed as acceptable if the AFB is less than 0.67; that is, the model is predicting within a factor of two.

The CALPUFF model comparison is undertaken for the existing emissions scenario and focuses on NO_2, SO_2, and PM_{10} concentration comparisons. Measured and predicted concentrations are compared for the indicated ambient monitoring sites.

2.7.3 Nitrogen Dioxide Comparison

The NO2 concentrations are influenced by NOX emissions from industrial and non-industrial sources.

Table A- 14 compares the maximum 1-hour average concentrations measured and predicted at each monitoring site. The predicted values are based on the maximum contribution for the downwind site (Ras Hayyan Monitoring Station). The table provides the predicted-to-measured concentrations and associated Absolute Fractional Bias value. Values greater than unity indicate over-prediction, while values less than unity indicate under-prediction. The Absolute Fractional Bias (AFB) is also shown. AFB values less than 0.67 indicates the model is predicting within a factor of two.

An examination of the results indicates a slight over-prediction at the monitoring station and is within the limits of prediction analysis as per the USEPA modelling guideline and AFB analysis. The slight over-predictions are likely due to over inherent model limitations of CALPUFF of over-predicting at near field receptors.

The comparison between the measured and predicted values was repeated by comparing the average of the Top-25 measured 1-hour concentrations with the average of the Top-25 predicted 1-hour concentrations.

The maximum-to-minimum ratios are similar to the corresponding values based on the maximum 1-hour predictions. The year-to-year variability between the maximum values that are measured in each year is lower for the Top-25 values.

On comparison of the Top-25 1-hour average concentrations measured and predicted at the selected monitoring site. The predicted values are based on the average Top-25 concentrations for each site and measured values at the Ras Hayyan Monitoring Station for the year 2011.

Table A- 14: Comparison of Maximum Measured and Predicted 1-Hour NO2 Concentrations

Bahrain Air Quality Standard (µg/m3)	Predicted Concentrations (µg/m3)			Contribution of Alba to the Monitoring Station %			AFB		
	NO2			NO2			NO2		
	Annual mean	24 h	1 h	Annual mean	24 h	1 h	Annual mean	24 h	1 h
	40	150	200	40	150	200			
Monitored Background Concentrations	1.2	6.1	15				0.44	0.35	0.27
Scenario-1 Existing	1.8	8.7	20	56%	42%	32%			

2.7.4 Sulphur Dioxide Comparisons

The comparison of measured and predicted SO_2 concentrations often provides the best indication of model performance because:

- The emissions originate from a few, well-documented sources.
- Chemical reactions that affect SO_2 concentrations are not significant for the associated transport times between the sources and the monitoring stations.
- There are a number of locations where ambient measurements are taken.

The model predictions, as previously noted, do not account for upset and abnormal events (e.g., upset scenarios) and hence could appear to under-predict relative to the measurements.

Table A- 15 shows the maximum (first highest) predicted SO_2 concentrations for the simulation year for the indicated monitoring station (Ras Hayyan). The table shows the minimum, the maximum, and the average of the first highest values for the five-year period.

The ratio of the maximum-to-minimum concentration is a measure of the temporal robustness of the average maximum to represent typical peak concentrations. Typically if the ratio is 1.5 or less, indicates that the high concentrations are similar and is acceptable. Below table provides the ratio of the predicted-to-measured concentrations. Values greater than unity indicate over-prediction, while values less than unity indicate under-prediction. The absolute fractional bias (AFB) is also shown; values less than 0.67 indicates the model is predicting within a factor of two.

The under-estimation of the SO_2 concentrations at the Ras Hayyan Industrial monitoring station is likely due to not including short-term peak emissions in the model input. If the facility had been emitting at average emission rate, then the associated predicted 1-hour SO2 concentration would be around 87% of total monitored value at Ras Hayyan. The Top-25 comparison averages out the extreme SO_2 concentrations that are associated with intermittent high SO_2 emission events, providing a more representative indicator of typical peak values. The comparison between the Top-25 average measured and predicted concentrations indicates a general tendency to over predict at most monitoring stations reasonable model performance.

Table A- 15: Comparison of Maximum Measured and Predicted 1-Hour SO_2 Concentrations

Bahrain Air Quality Standard (µg/m3)	Predicted Concentrations (µg/m3)			Contribution of Alba to the Monitoring Station %			AFB		
	SO2			SO2			SO2		
	Annual mean	24 h	1 h	Annual mean	24 h	1 h	Annual mean	24 h	1 h
	50	125	350	50	125	350			
Monitored Background Concentrations	5.60	29.19	71.08				-0.48	-0.30	-0.30
Scenario-1 Existing	3.45	21.58	52.54	62%	74%	74%			

2.8 Summary and Conclusions

2.8.1 Model Application

The CALPUFF dispersion model (Version 6.42, Level 110325) was selected as the primary air quality assessment tool to predict ambient concentrations for the ALBA Project assessment. The following were adopted for the application of the model:

- 8,708 gridded receptor grid points are selected for the 50 km by 50 km Model Domain. An additional 10 ambient monitoring locations were also selected.
- One year meteorological data for the period January 2012 to December 2012 was used. The MM5 data provided by Lakes Environmental, Canada was used by the CALMET model to provide the meteorological data for the CALPUFF model.
- The CALPUFF model is applied to the baseline/existing condition and 2- Future Scenarios (Future Scenario 1- Future Maximum Emissions and Future Scenario -2 Future Mitigated Emissions), using the source and emission inventory information described in the air quality assessment section of the main report.
- The OLM is used to estimate ambient NO_2 concentrations from the predicted NO_X values. Hourly O_3 concentrations from the five monitoring stations are used for this task.
- The approach and input parameters were examined to best represent air quality changes due to the project. These were examined in conjunction with the emission sources.

2.8.2 Model Prediction and Ambient Measurement Comparison

A comparison between the model predictions of the maximum 1-hour, the Top-25 1-hour, and the annual average concentrations and ambient measurements was undertaken. The results of this comparison indicate:

There is a good agreement between predictions and measurements for the Top-25 1- hour NO_2 concentrations, and for the annual average NO_2 concentrations at both the exposed industrial and residential sites. The Top-25 1-hour NO_2 concentrations tend to be over-predicted by 40% at the Industrial sites. The annual average NO_2 concentrations tend to be over-predicted by 56% at the industrial sites. There is closer agreement for the annual averages at the exposed industrial and residential sites. The over-prediction is largely attributed to overestimating industrial emissions.

The model under-predicts the Top-25 1-hour SO_2 concentrations by 30 to 40%, and the annual average SO_2 concentrations by 50%. The under-prediction at one industrial site is due to emission variability for an adjacent industrial source.

The prediction and measurement comparisons of SO_2 and NO_2 concentrations are seen as providing a representative indication of the model performance. The ability of the model to predict concentrations for other emissions depends on the level-of-confidence associated with estimating the other emission rates.

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3 SUPPLEMENTARY - CALPUFF Model Input Options

For the purposes of organization, the CALPUFF control file defines 18 input groups as identified in below table. For many of the options, default values used in the absence of site/project specific data.

Table A- 16 through Table A- 24 indicates the input parameters, the US EPA default options, and the values used for this assessment. For the most part, the US default options are selected to examine transport distances greater than 40 km. For this application, the assessment focusses primarily on transport distances less than this distance. For this reason, non-default parameters are selected, and the following discusses the rational for selecting these options:

- MBDW: The updated PRIME approach (Option 2) is used to simulate building downwash effects associated with the Project structures instead of the default and older ISC (Option 1) approach.
- MSPLIT: Puff splitting is necessary for large model domain.
- MCHEM: The chemical transformation rates are computed internally using (RIVID/ARM3) scheme rather than the older MESOPUFF II scheme.
- MDISP: Dispersion coefficients from internally calculated sigma v, sigma w using micrometeorological variables (u*, w*, L, etc.) (Option 2).
- DATUM: The World Geodetic System 1984 Spheroid coordinates are used as these are consistent with the applied CDED terrain data.
- LSAMP: Sampling grid is not used for this assessment. 8,708 discrete receptors as indicated in Input Group 17 were used.
- ICFRQ: Concentration fields are printed to output list file every 24-hours. This is more a “user defined” rather than “default” parameter.
- IDFRQ: Concentration fields are printed to output list file every 24-hours. This is more a “user defined” rather than “default” parameter.
- BCKO3: Background ozone concentrations (ppb) are based on measurements in the domain rather than a generic default values.
- BCKNH3: Background ammonia concentrations (ppb) are based on measurements in the model domain rather than default values.
- XSAMLEN: Maximum travel distance of slug or puff in meteorological grid units during one sampling unit. A preferred value of 10 has been specified in CALPUFF protocol documents.
- MXNEW: Maximum number of puffs released from one source during one time step. A preferred value of 60 has been specified in CALPUFF protocol documents.
- MXSAM: Maximum number of sampling steps during one time step for a puff. A preferred value of 60 has been specified in CALPUFF protocol documents.
- PPC: The default CALPUFF values are 0.5, 0.5, 0.5, 0.5, 0.35, and 0.35 for PG stability categories A, B, C, D, E and F, respectively

The performance of the CALPUFF/CALMET model system as applied with these respective assumptions has been compared top ambient measurements and has been found to provide representative predictions.

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Table A- 16: Input Groups in the CALPUFF Control File

Input Group	Description	Applicable to Project?
0	Input and output file names	Yes
1	General run control parameters	Yes
2	Technical options	Yes
3	Species list	Yes
4	Grid control parameters	Yes
5	Output options	Yes
6	Sub grid scale complex terrain inputs	No
7	Dry deposition parameters for gases	No
8	Dry deposition parameters for particles	No
9	Miscellaneous dry deposition for parameters	No
10	Wet deposition parameters	No
11	Chemistry parameters	Yes
12	Diffusion and computational parameters	Yes
13	Point source parameters	Yes
14	Area source parameters	Yes
15	Line source parameters	Yes
16	Volume source parameters	No
17	Non-gridded (discrete) receptor information	Yes

Table A- 17: CALPUFF Model Options Groups 1 and 2

Input Group 1: General Run Control Parameters

Parameter	US EPA Default	Project	Comments
METRUN	0	0	All model periods in met file(s) will be run
IBYR	-	2012	Starting year
IBMO	-	1	Starting month
IBDY	-	1	Starting day
IBHR	-	0	Starting hour
XBTZ	-	+3	Base time zone (3 = Eastern Africa)
NSPEC	-	12	Number of chemical species
NSE	-	8	Number of chemical species to be emitted
ITEST	-	2	Program is executed after SETUP phase
MRESTART	-	0	Do not read or write a restart file during run
NRESPD	-	24	File updated every 24 periods
METFM	1	1	CALMET binary file (CALMET.MET)
AVET	60	60	Averaging time in minutes
PGTIME	60	60	PG Averaging time in minutes

Input Group 2: Technical Options

Parameter	US EPA Default	Project	Comments
MGAUSS	1	1	Gaussian distribution used in near field
MCTADJ	3	3	Partial plume path terrain adjustment
MCTSG	0	0	Scale-scale complex terrain not modelled

Parameter	US EPA Default	Project	Comments
MSLUG	0	0	Near-field puffs not modelled as elongated
MTRANS	1	1	Transitional plume rise modelled
MTIP	1	1	Stack tip downwash used (may overestimate flare stack concentrations)
MBDW	1	2	PRIME Method is used to simulate building downwash
MSHEAR	0	0	Vertical wind shear (not used)
MSPLIT	0	1	Puffs are split (necessary for a large domain)
MCHEM	1	3	Transformation rates computed internally using (RIVID/ARM3) scheme
MAQCHEM	0	0	Aqueous phase transformation not modelled
MWET	1	1	Wet removal modelled
MDRY	1	1	Dry deposition modelled
MTILT	0	0	Gravitational settling (plume tilt) is not modelled
MDISP	3	2	Dispersion coefficients from internally calculated sigma v, sigma w using micrometeorological variables (u*, w*, L, etc.)
MTURBVW	3	3	Use both σ_v and σ_w from PROFILE.DAT to compute σ_y and σ_z (n/a)
MDISP2	3	3	PG dispersion coefficients for rural areas (computed using ISCST3 approximation) and MP coefficients in urban areas when measured turbulence data is missing
MTAULY	0	0	Draxler default 617.284 (s)
MTAUADV	0	0	No turbulence advection
MCTURB	1	1	Standard CALPUFF subroutines
MROUGH	0	0	PG σ_y and σ_z is not adjusted for roughness (not applicable)
MPARTLBA	1	1	Partial plume penetration of elevated inversion modelled for the buoyant area sources
MPARTL	1	1	Partial plume penetration of elevated inversion
MTINV	0	0	Strength of temperature inversion computed from default gradients
MPDF	0	1	PDF used for dispersion under convective conditions
MSGTIBL	0	0	Sub-grid TIBL module not used for shoreline
MBCON	0	0	Boundary concentration conditions not modelled
MSOURCE	0	0	Individual source contributions not saved
MFOG	0	0	Do not configure for FOG model output
MREG	1	0	Do not test options specified to see if they conform to regulatory values

Table A- 18: CALPUFF Model Options Groups 3 and 4

Input Group 3: Species List-Chemistry Options

CSPEC	Modelled[1]	Emitted[2]	Dry Deposition[3]	Output Group Number
SO_2	1	1	1	0
SO_4^{2-}	0	0	0	0
NO	0	0	0	0
NO_2	1	1	1	0
HNO_3	0	0	0	0
NO_3^-	0	0	0	0
NO_x	1	1	0	0
PM10	1	1	0	0
HF	1	1	1	0
PF	0	1	0	0

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CO	0	1	0	0
NOTES:				
[1] 0=no, 1=yes				
[2] 0=no, 1=yes				
[3] 0=none, 1=computed-gas, 2=computed particle, 3=user-specified				
Options are shown for the common air contaminants (CACs).				

Input Group 4: Map Projection and Grid Control Parameters

Parameter	US EPA Default	Project	Comments
PMAP	UTM	UTM	Universal Transverse Mercator
FEAST	0	0	False Easting (km) at the projection origin
FNORTH	0	0	False Northing (km) at the projection origin
IUTMZN	-	39	UTM zone
UTMHEM	N	N	Northern Hemisphere for UTM projection
DATUM	WGS-84	NAR-C	NAS-C used for output coordinates
NX	-	50	Number of X grid cells in meteorological grid
NY	-	50	Number of Y grid cells in meteorological grid
NZ	-	11	Number of vertical layers in meteorological grid
DGRIDKM	-	1	Grid spacing (km) to match CALMET
ZFACE	-	0, 20, 40, 80, 160, 320, 600, 1400, 2600	ZFACE
XORIGKM	-	434.42	Reference X coordinate for SW corner of grid cell (1,1) of meteorological grid (km)
YORIGKM	-	2559.665	Reference Y coordinate for SW corner of grid cell (1,1) of meteorological grid (km)
IBCOMP	-	1	X index of lower left corner of the computational grid
JBCOMP	-	1	Y index of lower left corner of the computational grid
IECOMP	-	50	X index of the upper right corner of the computational grid
JECOMP	-	50	Y index of the upper right corner of the computational grid
LSAMP	T	F	Sampling grid is not used
IBSAMP	-	1	X index of lower left corner of the sampling grid
JBSAMP	-	1	Y index of lower left corner of the sampling grid
IESAMP	-	50	X index of upper right corner of the sampling grid
JESAMP	-	50	Y index of upper right corner of the sampling grid
MESHDN	1	1	Nesting factor of the sampling grid

Table A- 19: CALPUFF Model Option Group 5

Input Group 5: Output Option

Parameter	US EPA Default	Project	Comments
ICON	1	1	Output file CONC.DAT containing concentrations is created
IDRY	1	1	Output file DFLX.DAT containing dry fluxes is created
IWET	1	1	Output file WFLX.DAT containing wet fluxes is created
IT2D	0	0	2D Temperature
IRHO	0	0	Density
IVIS	1	0	Output file containing relative humidity data is not created

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Parameter	US EPA Default	Project	Comments
LCOMPRS	T	T	Do not perform data compression in output file
IQAPLOT	1	1	Create a standard series of output files (e.g., locations of sources, receptors, grids ...) suitable for plotting
IMFLX	0	0	Do not calculate mass fluxes across specific boundaries
IMBAL	0	0	Mass balances for each species are not reported hourly
ICPRT	0	0	Do not print concentration fields to the output list file
IDPRT	0	0	Do not print dry flux fields to the output list file
IWPRT	0	0	Do not print wet flux fields to the output list file
ICFRQ	1	24	Concentration fields are printed to output list file every 24-hour
IIDFRQ	1	24	Dry flux fields are printed to output list file every 24-hour
IWFRQ	1	24	Wet flux fields are printed to output list file every 24-hour
IPRTU	1	3	Units for line printer output are in µg/m3 for concentration and µg/m2/s for deposition
IMESG	2	2	Messages tracking the progress of run are written on screen
LDEBUG	F	F	Logical value for debug output
IPFDEB	1	1	First puff to track
NPFDEB	1	1	Number of puffs to track
NN1	1	1	Meteorological period to start output
NN2	10	10	Meteorological period to end output

Input Group 5: Output Option

Species	Concentrations Printed (0= no, 1 = yes)		Dry Fluxes Printed (0 = no, 1 = yes)		Wet Fluxes Printed (0 = no, 1 = yes)		Mass Flux	
	Printed	Saved to Disk	Printed	Saved to Disk	Printed	Saved to Disk	Printed	Saved to Disk
SO2	0	1	0	1	0	1	0	1
$SO4^{2-}$	0	1	0	1	0	1	0	1
NO	0	1	0	1	0	1	0	1
NO_2	0	1	0	1	0	1	0	1
HNO_3	0	1	0	1	0	1	0	1
NO_3^-	0	1	0	1	0	1	0	1
NO_x	0	1	0	1	0	1	0	1
CO	0	1	0	1	0	1	0	1
PM10	0	1	0	1	0	1	0	1
HF	0	1	0	1	0	1	0	1
PF	0	1	0	1	0	1	0	1
RSC	0	1	0	1	0	1	0	1

Table A- 20: CALPUFF Model Option Groups 6 and 7

Input Group 6: Sub-Grid Scale Complex Terrain Inputs

Parameter	US EPA Default	Project	Comments
NHILL	0	0	Number of terrain features (not applicable)
NCTREC	0	0	Number of special complex terrain receptors (not applicable)

Parameter	US EPA Default	Project	Comments
MHILL	-	2	Hill data created by OPTHILL & input below in Subgroup (6b); Receptor data in Subgroup (6c) (not applicable)
XHILL2M	1	1	Conversion factor for changing horizontal dimensions to metres (not applicable)
ZHILL2M	1	1	Conversion factor for changing vertical dimensions to metres (not applicable)
XCTDMKM	-	0	X origin of CTDM system relative to CALPUFF coordinate system (km) (not applicable)
YCTDMKM	-	0	Y origin of CTDM system relative to CALPUFF coordinate system (km) (not applicable)

Input Group 7: Dry Deposition Parameters for Gases

Species	US EPA Default	Project	Comments
SO_2	0.1509	0.1372	Diffusivity
	1000	1000	Alpha star
	8	8	Reactivity
	0	0	Mesophyll resistance
	0.4	0.03311	Henry's Law coefficient
NO	-	0.2203	Diffusivity
	-	1	Alpha star
	-	2	Reactivity
	-	94	Mesophyll resistance
	-	18	Henry's Law coefficient
NO_2	0.1656	0.1585	Diffusivity
	1	1	Alpha star
	8	8	Reactivity
	5	5	Mesophyll resistance
	3.5	3.5	Henry's Law coefficient
HNO_3	0.1628	0.1041	Diffusivity
	1	1	Alpha star
	18	18	Reactivity
	0	0	Mesophyll resistance
	8E-08	1E-07	Henry's Law coefficient

Table A- 21: CALPUFF Model Option Groups 8, 9, 10, and 11

Input Group 8: Dry Deposition Parameters for Particles

Species	US EPA Default	Project	Comments
SO_4^{2-}	0.48	0.48	Geometric mass mean diameter of SO_4^{2-} [μm]
SO_4^{2-}	2	2	Geometric standard deviation of SO_4^{2-} [μm]
NO_3^-	0.48	0.48	Geometric mass mean diameter of NO_3^-[μm]
NO_3^-	2	2	Geometric standard deviation of NO_3^- [μm]
NO_3^-	2	2	Geometric standard deviation of NO_3^- [μm]

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Input Group 9: Miscellaneous Dry Deposition Parameters

Parameters	US EPA Default	Project	Comments
RCUTR	30	30	Reference cuticle resistance (s/cm)
RGR	10	10	Reference ground resistance (s/cm)
REACTR	8	8	Reference pollutant reactivity
NINT	9	9	Number of particle size intervals for effective particle deposition velocity
IVEG	1	1	Vegetation in non-irrigated areas is active and unstressed

Input Group 10: Wet Deposition Parameters

Species	US EPA Default	Project	Comments
SO_2	3.21E-05	3.21E-05	Scavenging coefficient for liquid precipitation [s^{-1}]
	0	0	Scavenging coefficient for frozen precipitation [s^{-1}]
SO_4^{2-}	1.00E-04	1.00E-04	Scavenging coefficient for liquid precipitation [s^{-1}]
	3.00E-05	3.00E-05	Scavenging coefficient for frozen precipitation [s^{-1}]
NO	2.85E-05	2.90E-05	Scavenging coefficient for liquid precipitation [s^{-1}]
	0	0	Scavenging coefficient for frozen precipitation [s^{-1}]
NO_2	5.13E-05	5.10E-05	Scavenging coefficient for liquid precipitation [s^{-1}]
	0	0	Scavenging coefficient for frozen precipitation [s^{-1}]
HNO_3	6.00E-05	6.00E-05	Scavenging coefficient for liquid precipitation [s^{-1}]
	0	0	Scavenging coefficient for frozen precipitation [s^{-1}]
NO_3^-	1.00E-04	1.00E-04	Scavenging coefficient for liquid precipitation [s^{-1}]
	3.00E-05	3.00E-05	Scavenging coefficient for frozen precipitation [s^{-1}]

Input Group 11: Chemistry Parameters

parameters	US EPA Default	Project	Comments
MOZ	1	1	
BCKO3	12*80	12*30	Background ozone concentration (ppb)
BCKNH3	12*10	3.99, 4.36, 5.72, 5.20, 5.19, 5.89, 6.07, 7.12, 5.59, 4.72, 3.79, 5.35	Background ammonia concentration (ppb)
RNITE1	0.2	0.2	Night-time NO_2 loss rate in percent/hour
RNITE2	2	2	Night-time NO_x loss rate in percent/hour
RNITE3	2	2	Night-time HNO_3 loss rate in percent/hour
MH202	1	1	Read hourly H2O2 concentrations from the H2O2.DAT file (not applicable)
BCKH202	12*1	12*1	Monthly background H_2O_2 concentrations (used for aqueous phase transformations, not applicable)
BCKPMF	-	Not used	Fine particulate concentration for secondary organic aerosol option, used only for MESOPUFF II scheme for OH
OFRAC	-	Not used	Organic fraction of fine particulate for secondary organic aerosol option, used only for MESOPUFF II scheme for OH
VCNX	-	Not used	VOC/NO_x ratio for secondary organic aerosol option, used only for MESOPUFF II scheme for OH

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Table A- 22: CALPUFF Model Option Group 12

Input Group 12: Diffusion/Computational Parameters

parameters	US EPA Default	Project	Comments
SYTDEP	550	550	Horizontal size of a puff in metres beyond which the time dependant dispersion equation of Heffter (1965) is used
MHFTSZ	0	0	Do not use Heffter formulas for sigma z
JSUP	5	5	Stability class used to determine dispersion rates for puffs above boundary layer
CONK1	0.01	0.01	Vertical dispersion constant for stable conditions
CONK2	0.1	0.1	Vertical dispersion constant for neutral/stable conditions
TBD	0.5	0.5	Use ISC transition point for determining the transition point between the Schulman-Scire (Schulman et al., 1998) to Huber-Snyder Building Downwash scheme
ISIGMAV	1	1	Sigma-v is read for lateral turbulence data
IMIXCTDM	0	0	Predicted mixing heights are used
XMXLEN	1	1	Maximum length of emitted slug in meteorological grid Units
XSAMLEN	1	10	Maximum travel distance of slug or puff in meteorological grid units during one sampling unit
MXNEW	99	60	Maximum number of puffs or slugs released from one source during one time step
MXSAM	99	60	Maximum number of sampling steps during one time step for a puff or slug
NCOUNT	2	2	Number of iterations used when computing the transport wind for a sampling step that includes transitional plume rise
SYMIN	1	1	Minimum sigma y in metres for a new puff or slug
SZMIN	1	1	Minimum sigma Z in metres for a new puff or slug
SZCAP_M	5.00E+06		Maximum sigma z in metres to avoid numerical problem in calculating time or distance

Stability class	Parameter			
	Minimum turbulence velocities sigma-v (SVMIN)		Minimum turbulence velocities sigma-w (SWMIN)	
	Minimum turbulence (σ_v) (m/s)		Minimum turbulence (σ_v) (m/s)	
	Land	Water	Land	Water
A	0.5	0.37	0.2	0.2
B	0.5	0.37	0.12	0.12
C	0.5	0.37	0.08	0.08
D	0.5	0.37	0.06	0.06
E	0.5	0.37	0.03	0.03
F	0.5	0.37	0.016	0.016

parameters	US EPA Default	Project	Comments
CDIV	0.0, 0.0	0.0, 0.0	Divergence criteria for dw/dz in met cells
NLUTBIL	4	4	Search radius for nearest land and water cells used in the subgrid TIBL module
WSCALM	0.5	0.5	Minimum wind speed allowed for non-calm conditions (m/s)

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parameters	US EPA Default	Project	Comments
XMAXZI	3000	3000	Maximum mixing height in metres
XMINZI	50	50	Minimum mixing height in metres
WSCAT	1.54	1.54	Wind speed category 1 [m/s]
	3.09	3.09	Wind speed category 2 [m/s]
	5.14	5.14	Wind speed category 3 [m/s]
	8.23	8.23	Wind speed category 4 [m/s]
	10.8	10.8	Wind speed category 5 [m/s]
PLX0	0.07	0.07	Wind Speed Power Law Exponent (Stability class A)
	0.07	0.07	Wind Speed Power Law Exponent (Stability class B)
	0.1	0.1	Wind Speed Power Law Exponent (Stability class C)
	0.15	0.15	Wind Speed Power Law Exponent (Stability class D)
	0.35	0.35	Wind Speed Power Law Exponent (Stability class E)
	0.55	0.55	Wind Speed Power Law Exponent (Stability class 5)
PTG0	0.02	0.02	Potential temperature gradient for E stability [K/m]
	0.035	0.035	Potential temperature gradient for F stability [K/m]
PPC	0.5	0.8	Plume Path Coefficient (Stability class A)
	0.5	0.7	Plume Path Coefficient (Stability class B)
	0.5	0.6	Plume Path Coefficient (Stability class C)
	0.5	0.5	Plume Path Coefficient (Stability class D)
	0.35	0.4	Plume Path Coefficient (Stability class E)
	0.35	0.3	Plume Path Coefficient (Stability class 5)
SL2PF	10	10	Slug-to-puff transition criterion factor equal to sigma y/length of slug
NSPLIT	3	3	Number of puffs that result every time a puff is split
IRESPLIT	0, 0, 0, 0,0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 1, 0, 0, 0, 0, 0,0	0, 0, 0, 0,0,0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 1, 0, 0, 0, 0, 0,0	Time(s) of day when split puffs are eligible to be split once Again
ZISPLIT	100	100	Minimum allowable last hour’s mixing height for puff Splitting
ROLDMAX	0.25	0.25	Maximum allowable ratio of last hour’s mixing height and maximum mixing height experienced by the puff for puff splitting
NSPLITH	5	5	Number of puffs that result every time a puff is horizontally split
SYSPLITH	1	1	Minimum sigma-y of puff before it may be horizontally split
SHSPLITH	2	2	Minimum puff elongation rate due to wind shear before it may be horizontally split
CNSPLITH	1.00E-07	1.00E-07	Minimum concentration of each species in puff before it may be horizontally split
EPSSLUG	1.00E-04	1.00E-04	Fractional convergence criterion for numerical SLUG sampling iteration
EPSAREA	1.00E-06	1.00E-06	Fractional convergence criterion for numerical AREA sampling iteration
DRISE	1	1	Trajectory step length for numerical rise
HTMINBC	500	500	Minimum height (m) to which BC puffs are mixed as they are emitted (MBCON=2 ONLY)

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parameters	US EPA Default	Project	Comments
RSAMPBC	10	10	Search radius (km) about a receptor for sampling nearest BC puff.
MDEPBC	1	1	Concentration is NOT adjusted for depletion

Table A- 23: CALPUFF Model Option Groups 13, 14, and 15

Input Group 13: Point Source Parameters

Parameters	US EPA Default	Project	Comments
NPT1	-	Varies by scenario	Number of point sources with constant stack parameters or variable emission rate scale factors
IPTU	1	1	Units for point source emission rates are g/s
NSPT1	0	Varies by Scenario	Number of source-species combinations with variable emissions scaling factors
NPT2	-	0	Number of point sources with variable emission parameters provided in external file
NOTES:			
'-' symbol indicates that the parameter was not applicable to the Project assessment			

Input Group 14: Area Source Parameters

Parameters	US EPA Default	Project	Comments
NAR1	-	Varies by Scenario	Number of polygon area sources
IARU	1	1	Units for area source emission rates are $g/m_2/s$
NSAR1	0	Varies by Scenario	Number of source species combinations with variable emissions scaling factors
NAR2	-	0	Number of buoyant polygon area sources with variable location and emission parameters
NOTES:			
'-' symbol indicates that the parameter was not applicable to the Project assessment			

Input Group 15: Line Source Parameters

Parameters	US EPA Default	Project	Comments
NLN2	-	Varies by scenario	
NLINES	-	0	
ILNU	1	1	
NSLN1	0	0	
MXNSEG	7	7	
NLRISE	6	6	
NOTES:			
'-' symbol indicates that the parameter was not applicable to the Project assessment			

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Table A- 24: CALPUFF Model Option Groups 16 and 17

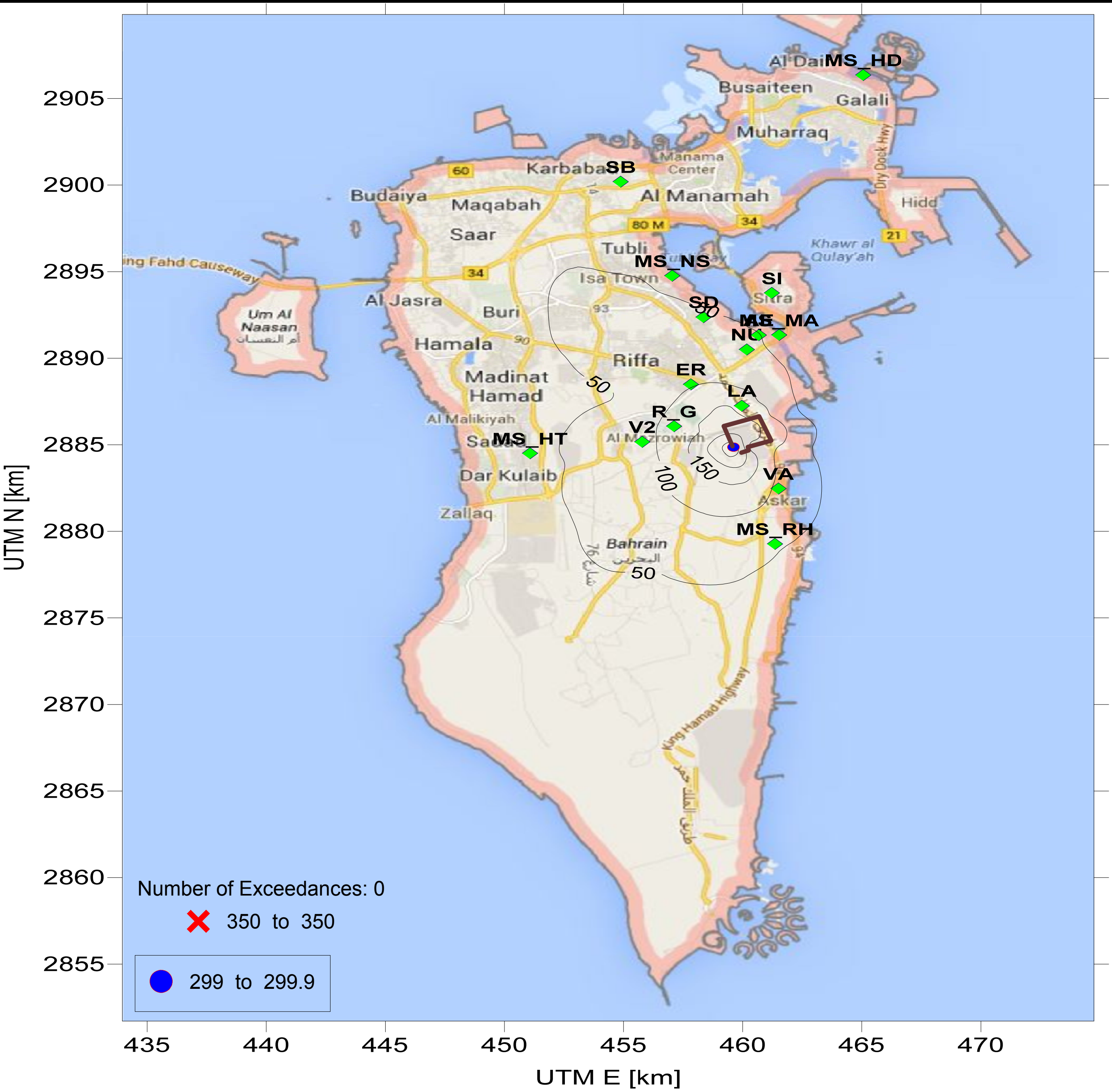
Input Group 16: Volume Source Parameters

Parameters	US EPA Default	Project	Comments
NVL1	-	Varies by scenario	
IVLU	1	1	
NSVL1	0	0	
NVL2	0	0	
NOTES:			
'-' symbol indicates that the parameter was not applicable to the Project assessment			

Input Group 17: Discrete Receptor Information

Parameters	US EPA Default	Project	Comments
NREC	-	17828	Number of non-gridded receptors
NOTES:			
'-' symbol indicates that the parameter was not applicable to the Project assessment			

Appendix 18: Air Dispersion Isopleths



LEGEND:

Ambient Air Quality Standards

Time Weighted Average - Hourly: 350 ug/m3
Maximum Predicted Concentration: 300 ug/m3

- Plant boundary limit
- Ambient Air Quality Limit
- Receptor Locations
- Maximum Concentration

No.	Location	CODE
1	Ras Hayyan	MS_RH
2	Hidd	MS_HD
3	Maameer	MS_MA
4	Napeeh Saleh	MS_NS
5	Hamad Town	MS_HT
6	Sanabis	SB
7	Villas Askar	VA
8	Villas 2	V2
9	ResidentialArea & Golf Course	R_G

No.	Location	CODE
10	Labour Accommodation	LA
11	East-Riffa	ER
12	Ma'ameer	MA
13	Nuwaidrat	NU
14	Al Eker	AE
15	Sanad	SD
16	Sitra	SI

Prepared For:

Figure Title: **Hourly Average Concentration - SO_2**
Baseline Scenario - 1
Existing Emission Sources

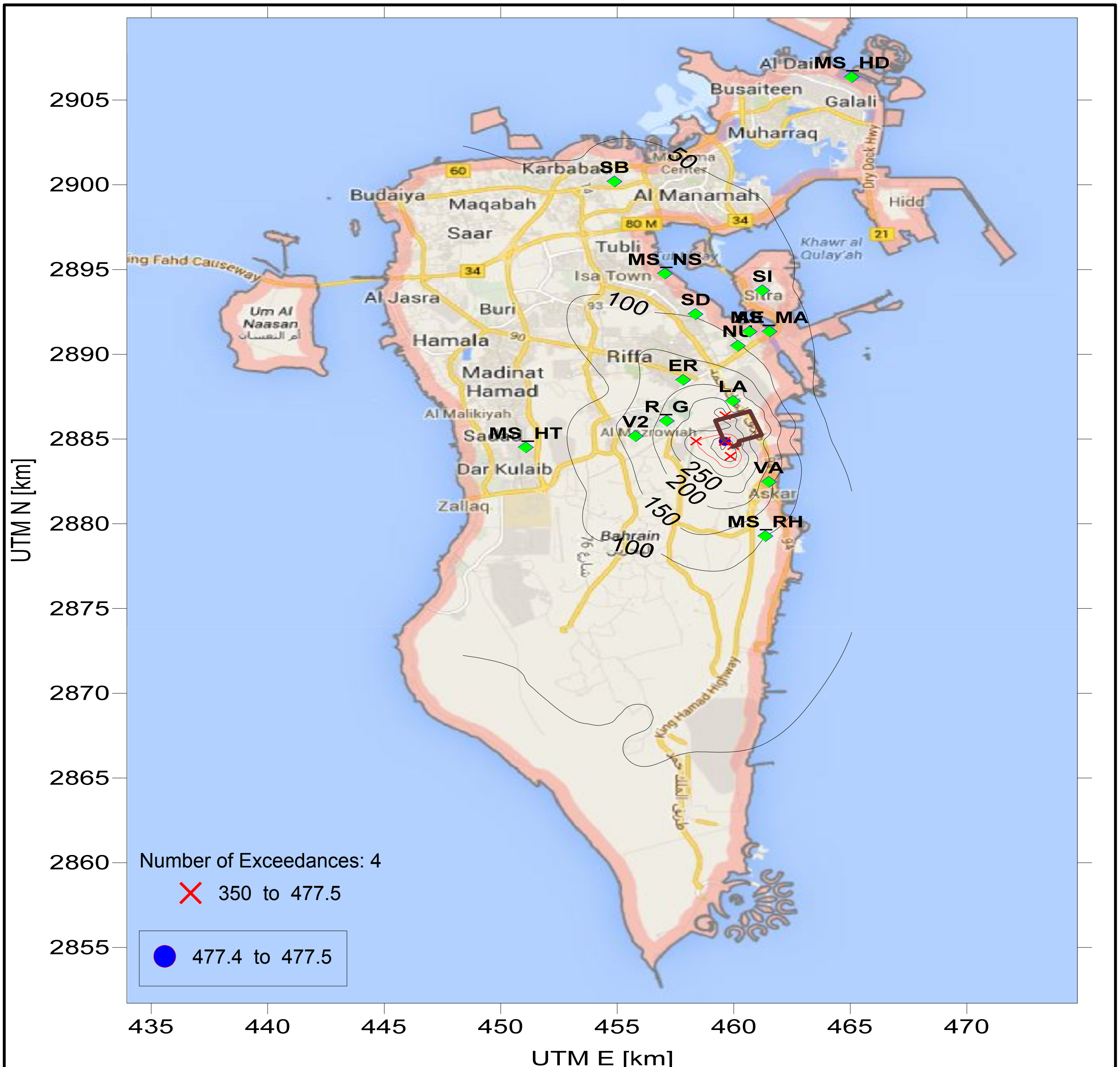
Date: March, 2014

Prepared By:

Project: **ALBA Potline (6) and Power Plant (PS5) Expansion**

Project No: 10921.00

Figure No: 2



LEGEND:

Ambient Air Quality Standards

Time Weighted Average - Hourly: 350 ug/m3
Maximum Predicted Concentration: 477 ug/m3

- Plant boundary limit
- Ambient Air Quality Limit
- Receptor Locations
- Maximum Concentration

No.	Location	CODE
1	Ras Hayyan	MS_RH
2	Hidd	MS_HD
3	Maameer	MS_MA
4	Napeeh Saleh	MS_NS
5	Hamad Town	MS_HT
6	Sanabis	SB
7	Villas Askar	VA
8	Villas 2	V2
9	ResidentialArea & Golf Course	R_G

No.	Location	CODE
10	Labour Accommodation	LA
11	East-Riffa	ER
12	Ma'ameer	MA
13	Nuwaidrat	NU
14	Al Eker	AE
15	Sanad	SD
16	Sitra	SI

Prepared For:

Figure Title:

Hourly Average Concentration - SO_2
Future Scenario -2

Date:

March, 2014

Prepared By:

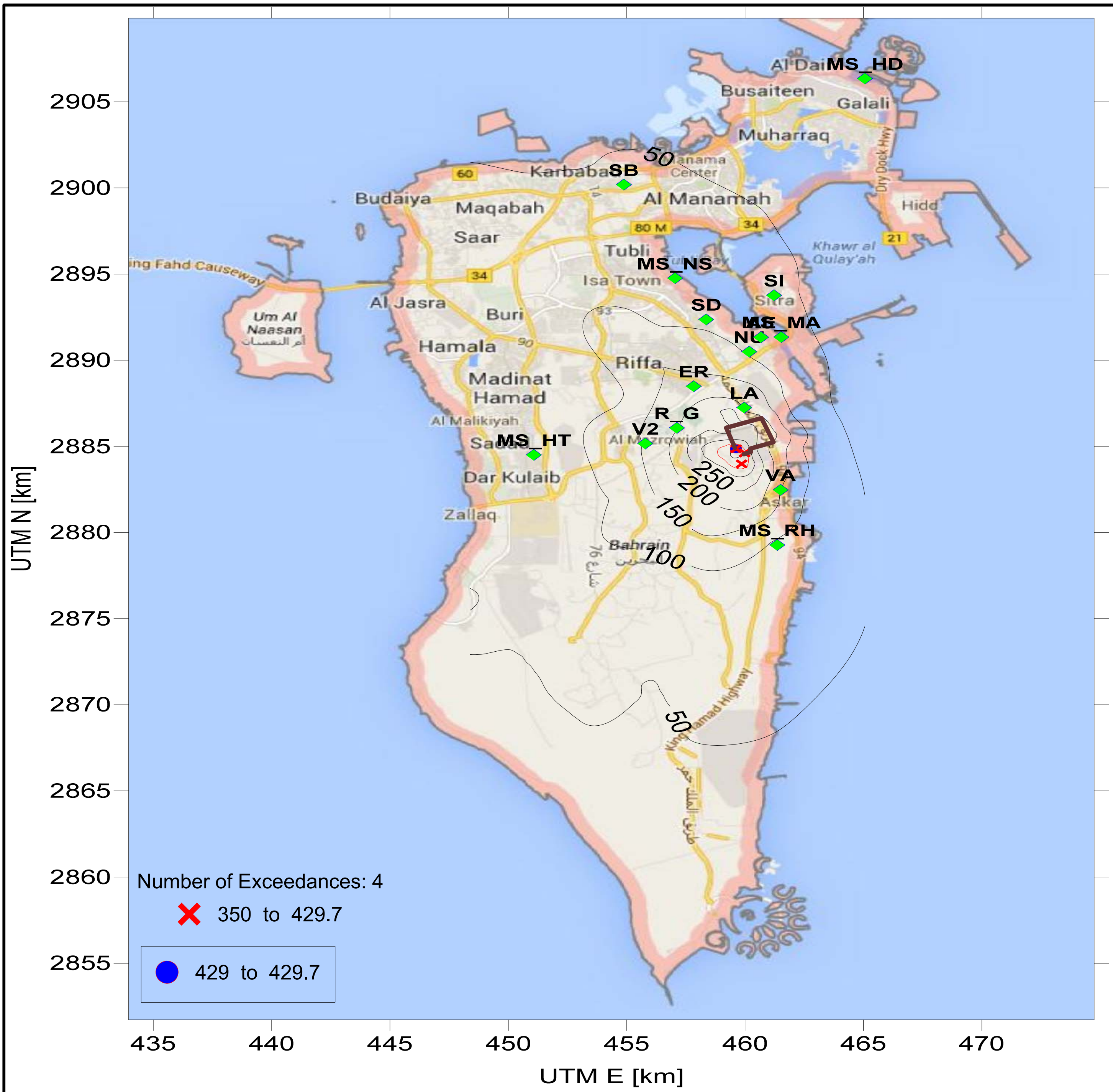
Project:

ALBA Potline (6) and Power Plant (PS5) Expansion

Project No:

10921.00

Figure No: 3



LEGEND:

Ambient Air Quality Standards

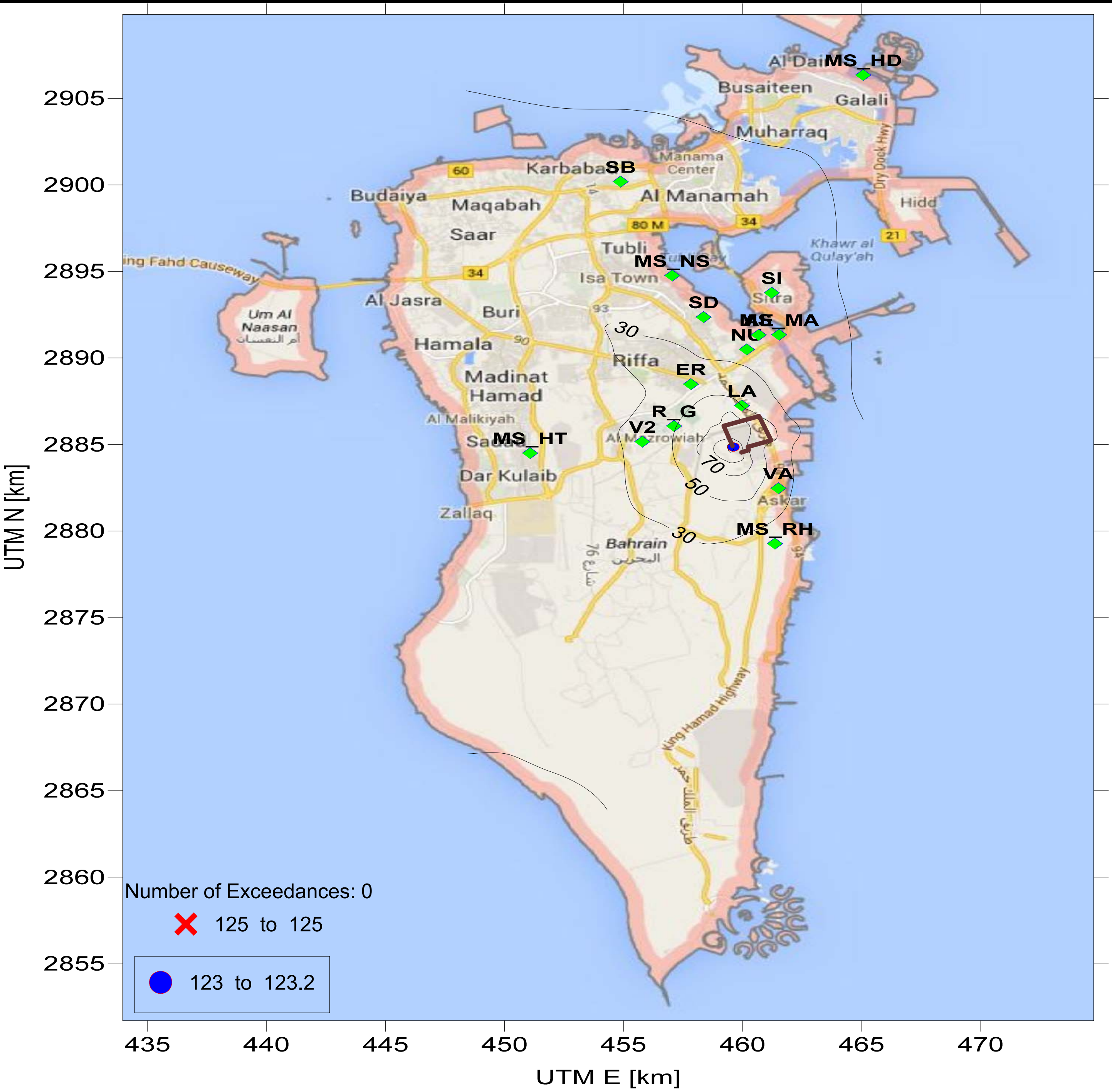
Time Weighted Average - Hourly: 350 ug/m3
Maximum Predicted Concentration: 430 ug/m3

- Plant boundary limit
- Ambient Air Quality Limit
- Receptor Locations
- Maximum Concentration

No.	Location	CODE
1	Ras Hayyan	MS_RH
2	Hidd	MS_HD
3	Maameer	MS_MA
4	Napeeh Saleh	MS_NS
5	Hamad Town	MS_HT
6	Sanabis	SB
7	Villas Askar	VA
8	Villas 2	V2
9	ResidentialArea & Golf Course	R_G

No.	Location	CODE
10	Labour Accommodation	LA
11	East-Riffa	ER
12	Ma'ameer	MA
13	Nuwaidrat	NU
14	Al Eker	AE
15	Sanad	SD
16	Sitra	SI

Prepared For: alba BECHTEL	Figure Title: **Hourly Average Concentration - SO_2 Future Scenario-3**	Date: March, 2014
		Project No: 10921.00
Prepared By: BILFINGER TEBODIN	Project: **ALBA Potline (6) and Power Plant (PS5) Expansion**	Figure No: 4



LEGEND:

Ambient Air Quality Standards

Time Weighted Average - Daily: 125 ug/m3
Maximum Predicted Concentration: 123 ug/m3

Plant boundary limit

Ambient Air Quality Limit

Receptor Locations

Maximum Concentration

No.	Location	CODE
1	Ras Hayyan	MS_RH
2	Hidd	MS_HD
3	Maameer	MS_MA
4	Napeeh Saleh	MS_NS
5	Hamad Town	MS_HT
6	Sanabis	SB
7	Villas Askar	VA
8	Villas 2	V2
9	ResidentialArea & Golf Course	R_G

No.	Location	CODE
10	Labour Accommodation	LA
11	East-Riffa	ER
12	Ma'ameer	MA
13	Nuwaidrat	NU
14	Al Eker	AE
15	Sanad	SD
16	Sitra	SI

Prepared For:

Figure Title:

Daily Average Concentration - SO2
Baseline Scenario - 1
Existing Emission Sources

Date:

March, 2014

Prepared By:

Project:

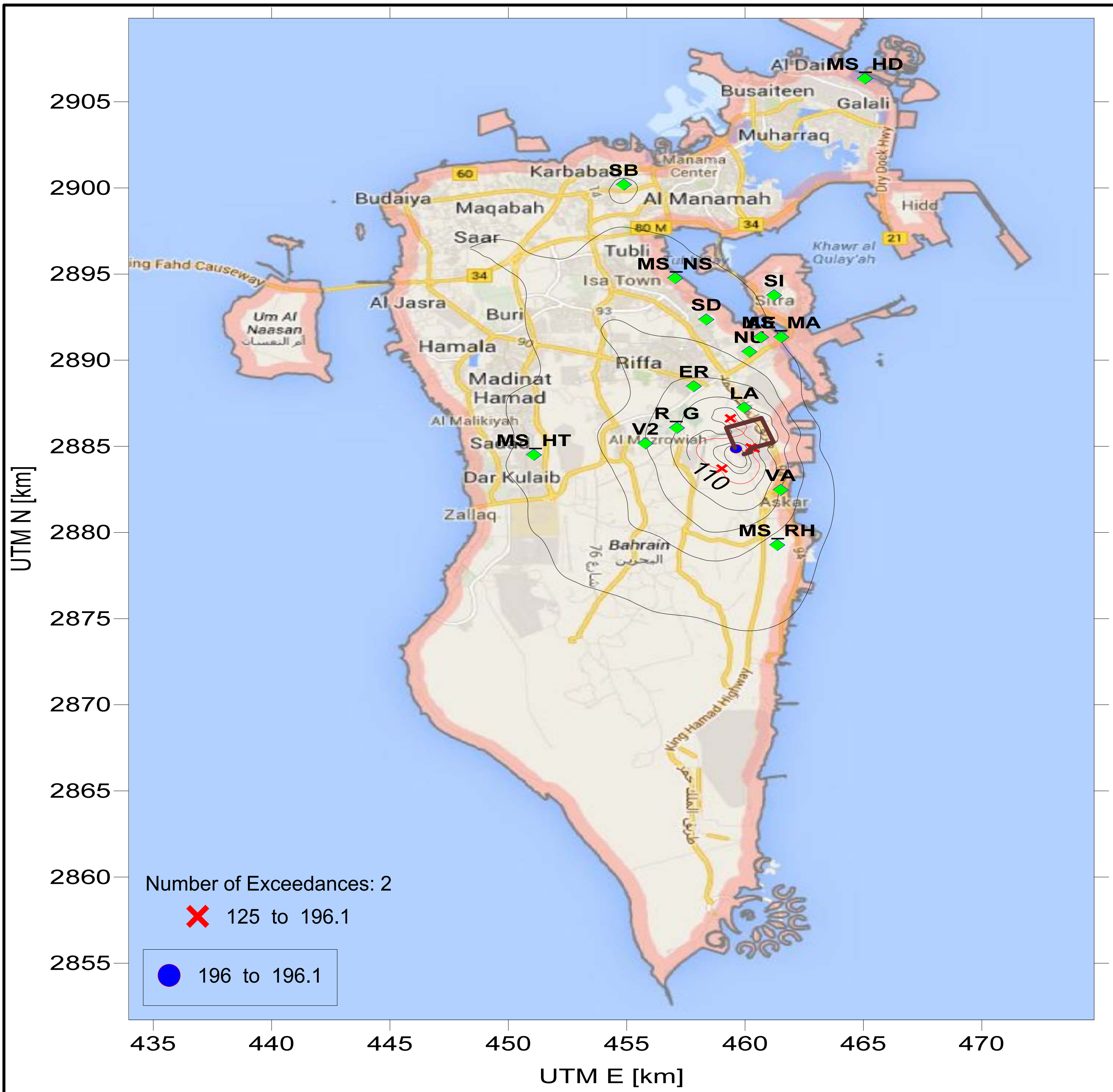
ALBA Potline (6) and Power Plant (PS5) Expansion

Project No:

10921.00

Figure No:

5



LEGEND:

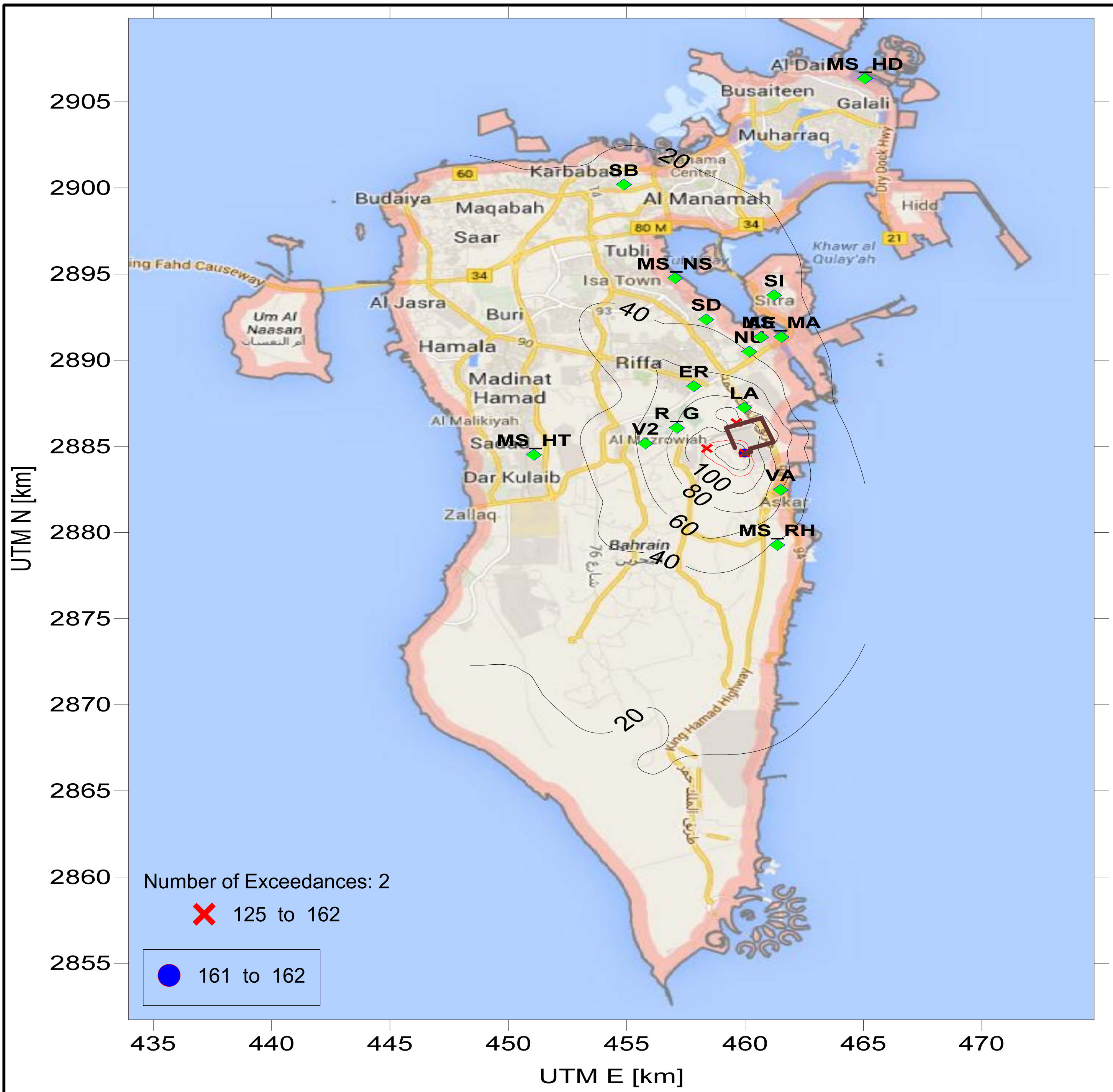
Ambient Air Quality Standards

Time Weighted Average - Daily: 125 ug/m3
Maximum Predicted Concentration: 196 ug/m3

- Plant boundary limit
- Ambient Air Quality Limit
- Receptor Locations
- Maximum Concentration

No.	Location	CODE
1	Ras Hayyan	MS_RH
2	Hidd	MS_HD
3	Maameer	MS_MA
4	Napeeh Saleh	MS_NS
5	Hamad Town	MS_HT
6	Sanabis	SB
7	Villas Askar	VA
8	Villas 2	V2
9	ResidentialArea & Golf Course	R_G
10	Labour Accommodation	LA
11	East-Riffa	ER
12	Ma'ameer	MA
13	Nuwaidrat	NU
14	Al Eker	AE
15	Sanad	SD
16	Sitra	SI

Prepared For:	Figure Title: **Daily Average Concentration - SO_2 Future Scenario-2**	Date: March, 2014
Prepared By:	Project: **ALBA Potline (6) and Power Plant (PS5) Expansion**	Project No: 10921.00
		Figure No: 6



LEGEND:

Ambient Air Quality Standards

Time Weighted Average - Daily: 125 ug/m3
Maximum Predicted Concentration: 162 ug/m3

Plant boundary limit
Ambient Air Quality Limit
Receptor Locations
Maximum Concentration

No.	Location	CODE
1	Ras Hayyan	MS_RH
2	Hidd	MS_HD
3	Maameer	MS_MA
4	Napeeh Saleh	MS_NS
5	Hamad Town	MS_HT
6	Sanabis	SB
7	Villas Askar	VA
8	Villas 2	V2
9	ResidentialArea & Golf Course	R_G

No.	Location	CODE
10	Labour Accommodation	LA
11	East-Riffa	ER
12	Ma'ameer	MA
13	Nuwaidrat	NU
14	Al Eker	AE
15	Sanad	SD
16	Sitra	SI

Prepared For: alba BECHTEL

Figure Title:

Daily Average Concentration - SO_2
Future Scenario-3

Date: March, 2014

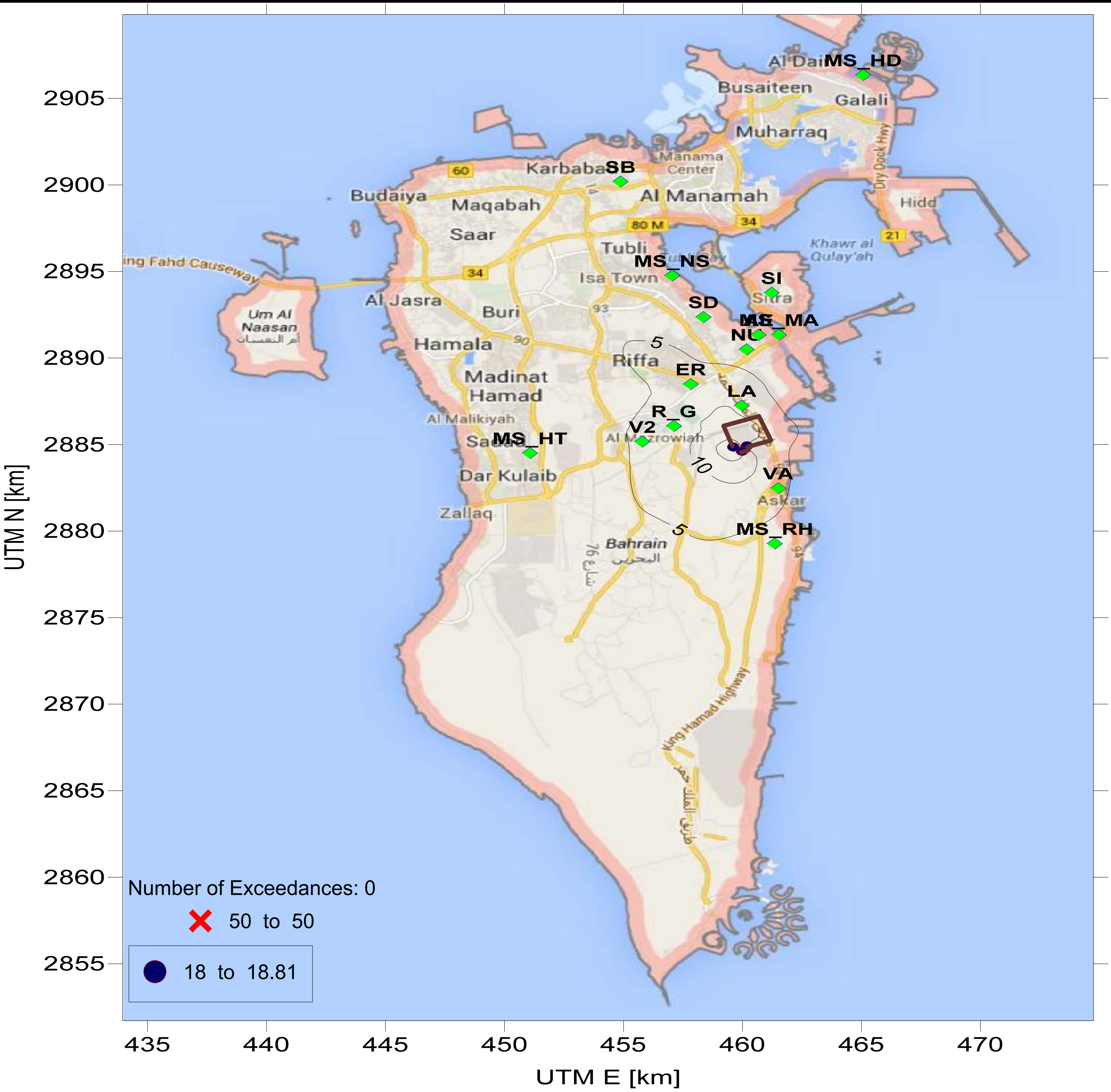
Prepared By: BILFINGER TEBODIN

Project:

ALBA Potline (6) and Power Plant (PS5) Expansion

Project No: 10921.00

Figure No: 7



LEGEND:

Ambient Air Quality Standards

Time Weighted Average - Annual: 50 ug/m3
Maximum Predicted Concentration: 19 ug/m3

Plant boundary limit

Ambient Air Quality Limit

Receptor Locations

Maximum Concentration

No.	Location	CODE
1	Ras Hayyan	MS_RH
2	Hidd	MS_HD
3	Maameer	MS_MA
4	Napeeh Saleh	MS_NS
5	Hamad Town	MS_HT
6	Sanabis	SB
7	Villas Askar	VA
8	Villas 2	V2
9	ResidentialArea & Golf Course	R_G
10	Labour Accommodation	LA
11	East-Riffa	ER
12	Ma'ameer	MA
13	Nuwaidrat	NU
14	Al Eker	AE
15	Sanad	SD
16	Sitra	SI

Prepared For:

Figure Title:

Annual Average Concentration - SO2
Baseline Scenario - 1
Existing Emission Sources

Date:
March, 2014

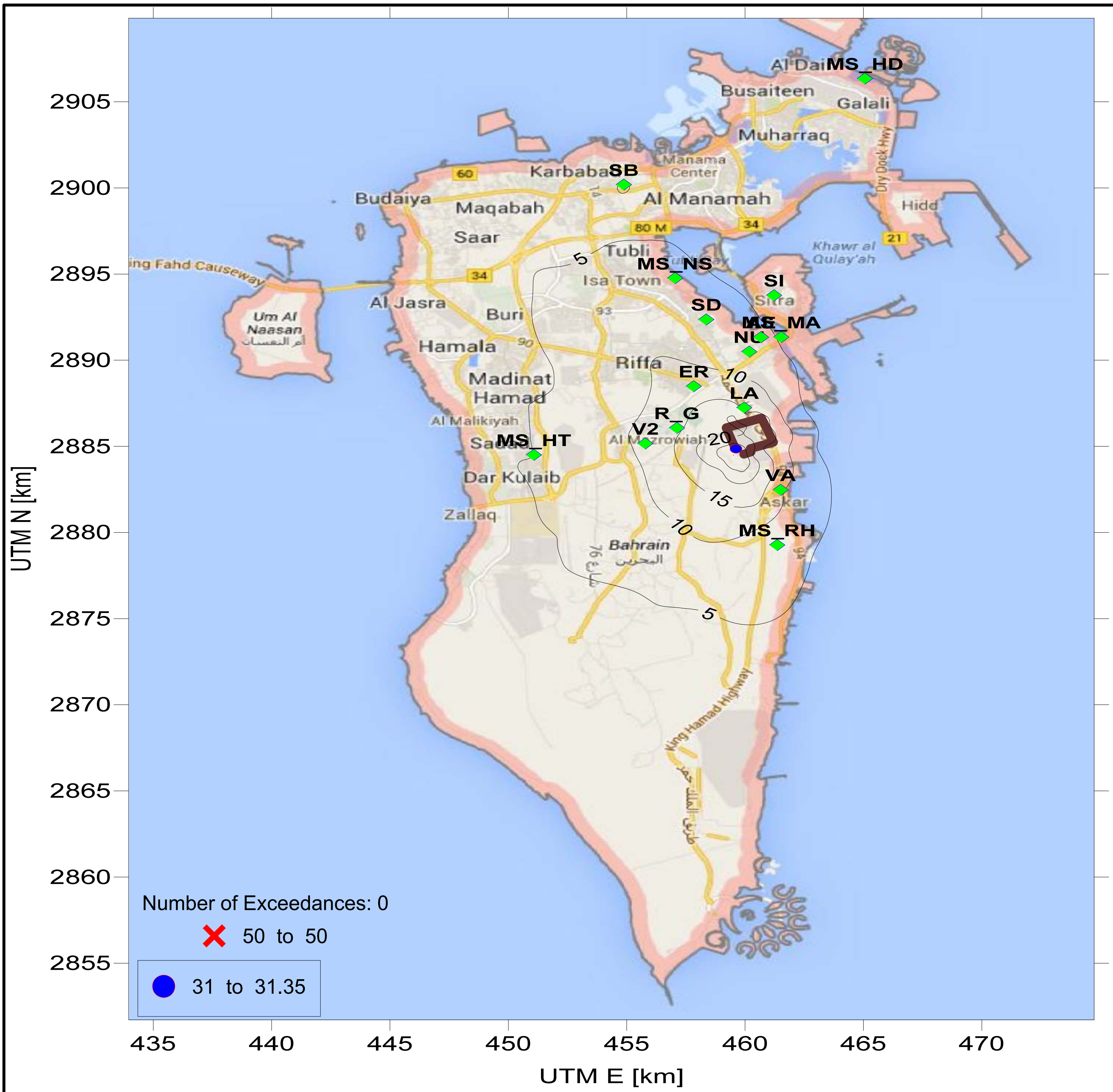
Prepared By:

Project:

ALBA Potline (6) and Power Plant (PS5) Expansion

Project No:
10921.00

Figure No:
8



LEGEND:

Ambient Air Quality Standards

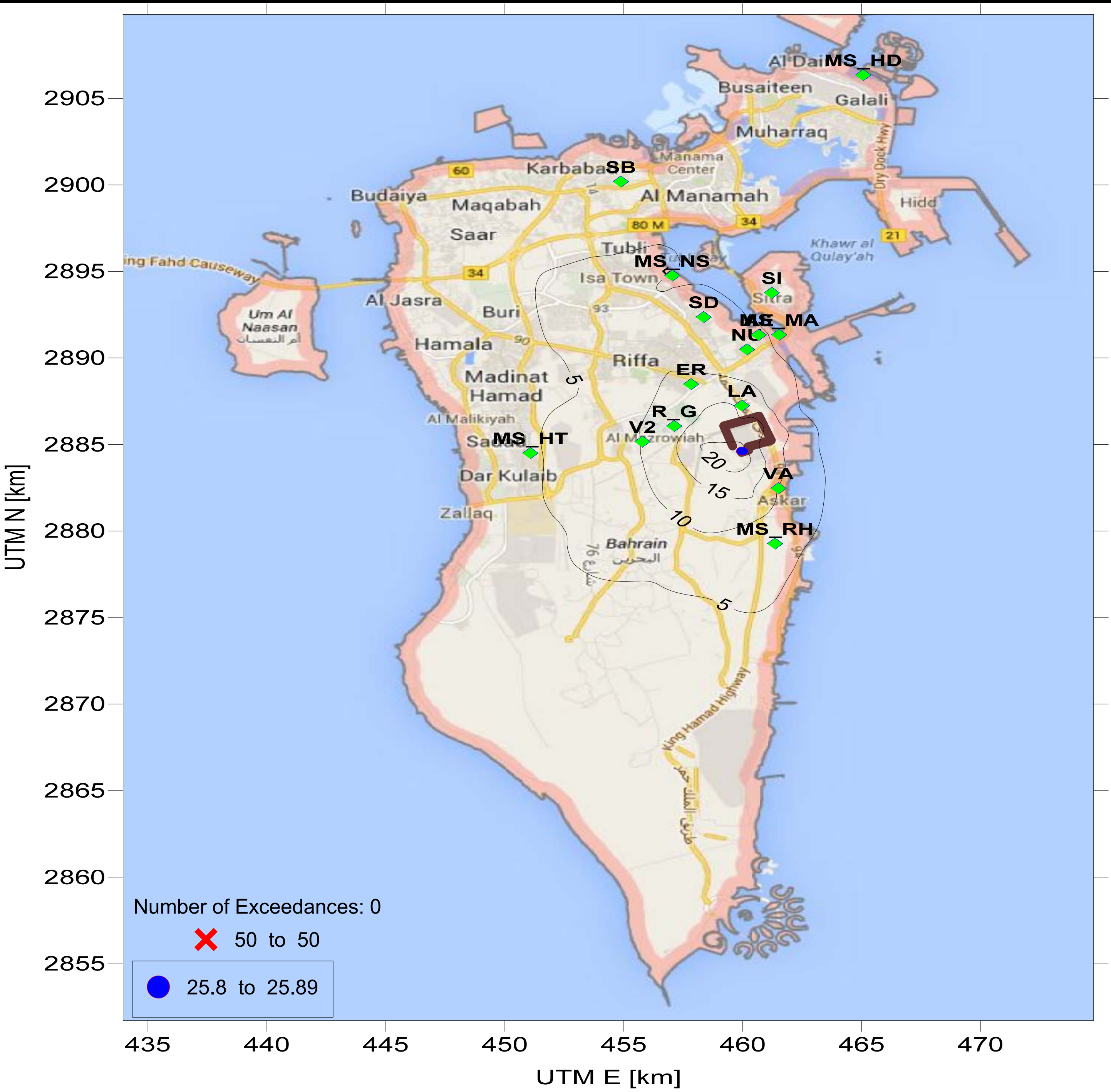
Time Weighted Average - Annual: 50 ug/m3
Maximum Predicted Concentration: 31 ug/m3

- Plant boundary limit
- Ambient Air Quality Limit
- Receptor Locations
- Maximum Concentration

No.	Location	CODE
1	Ras Hayyan	MS_RH
2	Hidd	MS_HD
3	Maameer	MS_MA
4	Napeeh Saleh	MS_NS
5	Hamad Town	MS_HT
6	Sanabis	SB
7	Villas Askar	VA
8	Villas 2	V2
9	ResidentialArea & Golf Course	R_G

No.	Location	CODE
10	Labour Accommodation	LA
11	East-Riffa	ER
12	Ma'ameer	MA
13	Nuwaidrat	NU
14	Al Eker	AE
15	Sanad	SD
16	Sitra	SI

Prepared For:	Figure Title:	Date:
alba BECHTEL	**Annual Average Concentration - SO_2 Future Scenario -2**	March, 2014
		Project No: 10921.00
Prepared By: BILFINGER TEBODIN	Project: **ALBA Potline (6) and Power Plant (PS5) Expansion**	Figure No: 9



LEGEND:

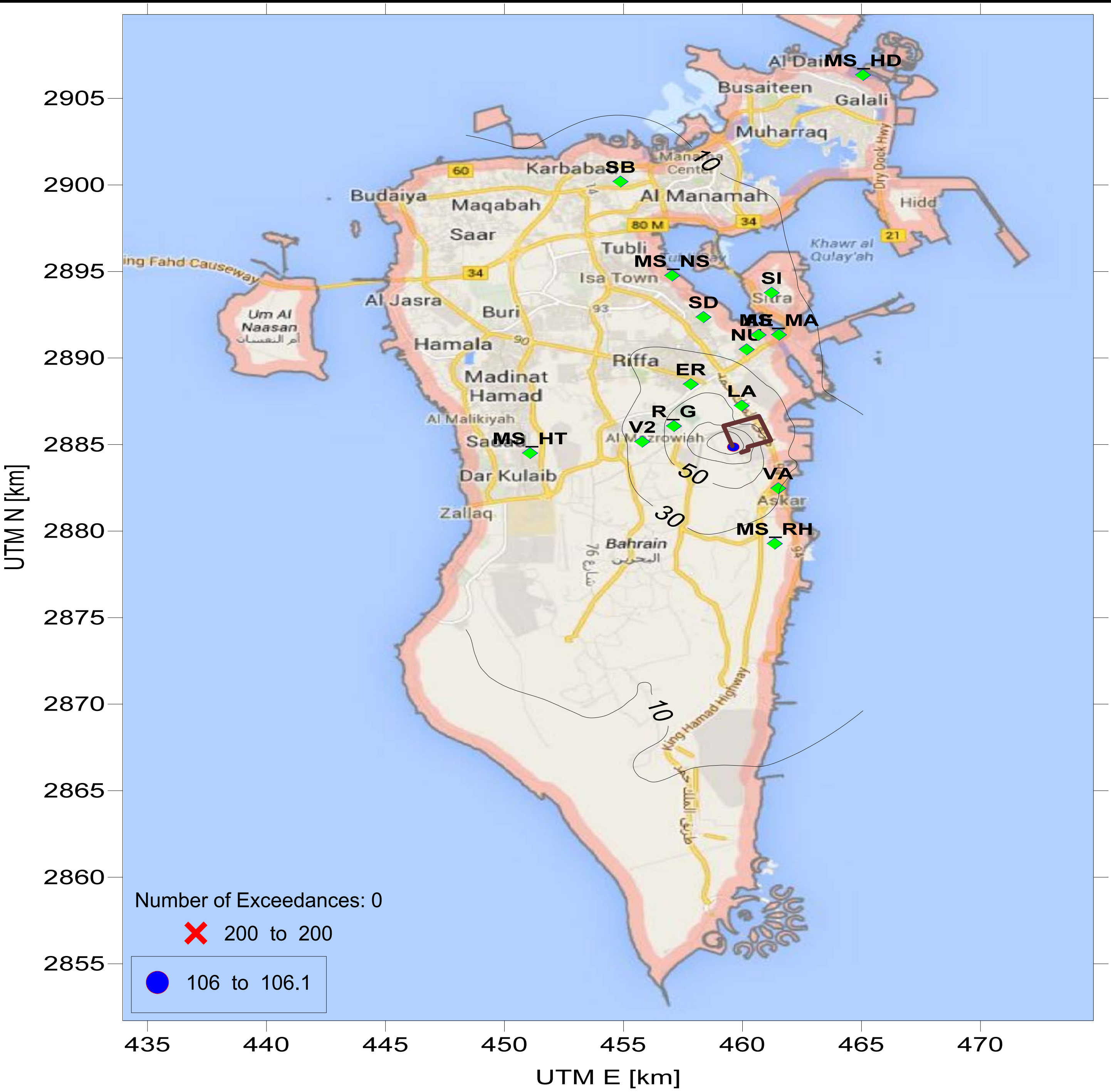
Ambient Air Quality Standards

Time Weighted Average - Yearly: 50 ug/m3
Maximum Predicted Concentration: 28 ug/m3

Plant boundary limit
Ambient Air Quality Limit
Receptor Locations
Maximum Concentration

No.	Location	CODE	No.	Location	CODE
1	Ras Hayyan	MS_RH	10	Labour Accommodation	LA
2	Hidd	MS_HD	11	East-Riffa	ER
3	Maameer	MS_MA	12	Ma'ameer	MA
4	Napeeh Saleh	MS_NS	13	Nuwaidrat	NU
5	Hamad Town	MS_HT	14	Al Eker	AE
6	Sanabis	SB	15	Sanad	SD
7	Villas Askar	VA	16	Sitra	SI
8	Villas 2	V2			
9	ResidentialArea & Golf Course	R_G			

Prepared For:	Figure Title: Annual Average Concentration - SO_2 Future Scenario-3	Date: March, 2014
Prepared By:	Project: ALBA Potline (6) and Power Plant (PS5) Expansion	Project No: 10921.00
		Figure No: 10



LEGEND:

Ambient Air Quality Standards

Time Weighted Average - Hourly: 200 ug/m3
Maximum Predicted Concentration: 106 ug/m3

Plant boundary limit

Ambient Air Quality Limit

Receptor Locations

Maximum Concentration

No.	Location	CODE
1	Ras Hayyan	MS_RH
2	Hidd	MS_HD
3	Maameer	MS_MA
4	Napeeh Saleh	MS_NS
5	Hamad Town	MS_HT
6	Sanabis	SB
7	Villas Askar	VA
8	Villas 2	V2
9	ResidentialArea & Golf Course	R_G

No.	Location	CODE
10	Labour Accommodation	LA
11	East-Riffa	ER
12	Ma'ameer	MA
13	Nuwaidrat	NU
14	Al Eker	AE
15	Sanad	SD
16	Sitra	SI

Prepared For:

Figure Title:

Hourly Average Concentration - NO2
Baseline Scenario - 1
Existing Emission Sources

Date:
March, 2014

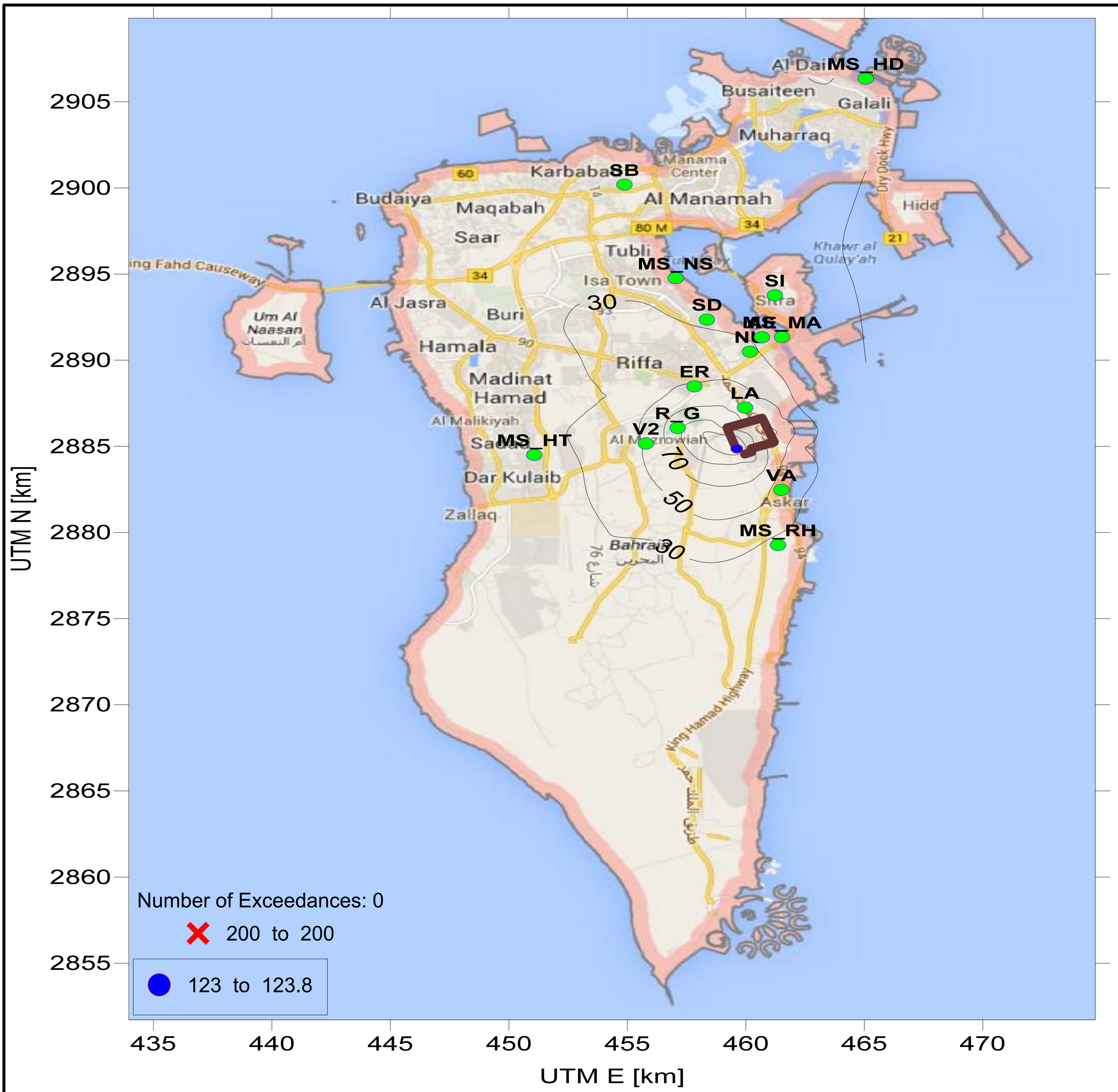
Prepared By:

Project:

ALBA Potline (6) and Power Plant (PS5) Expansion

Project No:
10921.00

Figure No:
11



LEGEND:

Ambient Air Quality Standards

Time Weighted Average - Hourly: 200 ug/m3
Maximum Predicted Concentration: 124 ug/m3

- Plant boundary limit
- Ambient Air Quality Limit
- Receptor Locations
- Maximum Concentration

No.	Location	CODE
1	Ras Hayyan	MS_RH
2	Hidd	MS_HD
3	Maameer	MS_MA
4	Napeeh Saleh	MS_NS
5	Hamad Town	MS_HT
6	Sanabis	SB
7	Villas Askar	VA
8	Villas 2	V2
9	ResidentialArea & Golf Course	R_G

No.	Location	CODE
10	Labour Accommodation	LA
11	East-Riffa	ER
12	Ma'ameer	MA
13	Nuwaidrat	NU
14	Al Eker	AE
15	Sanad	SD
16	Sitra	SI

Prepared For:

Figure Title:

Hourly Average Concentration - NO_2
Future Scenario -2

Date: March, 2014

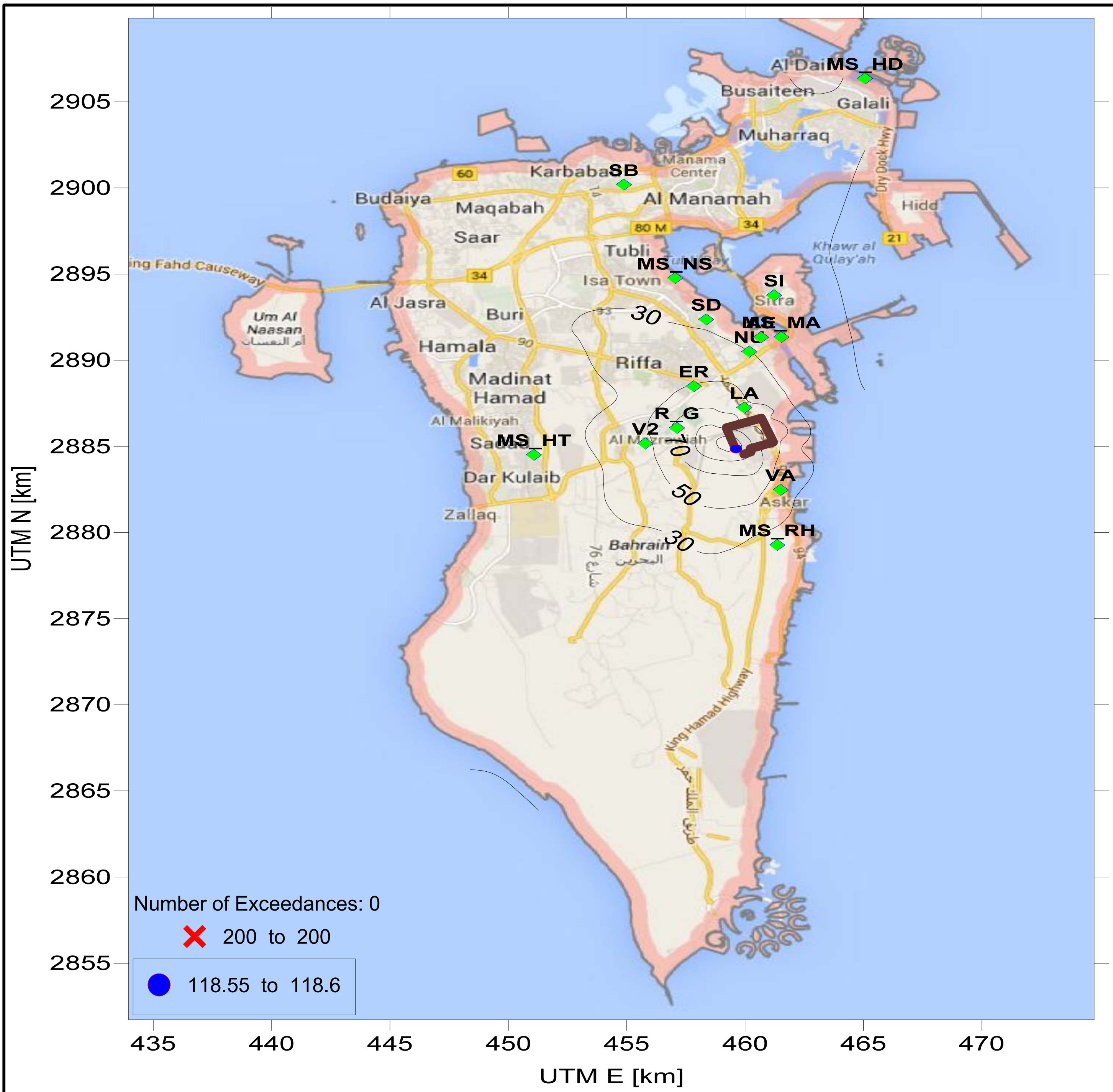
Prepared By:

Project:

ALBA Potline (6) and Power Plant (PS5) Expansion

Project No: 10921.00

Figure No: 12



LEGEND:

Ambient Air Quality Standards

Time Weighted Average - Hourly: 200 ug/m3
Maximum Predicted Concentration: 119 ug/m3

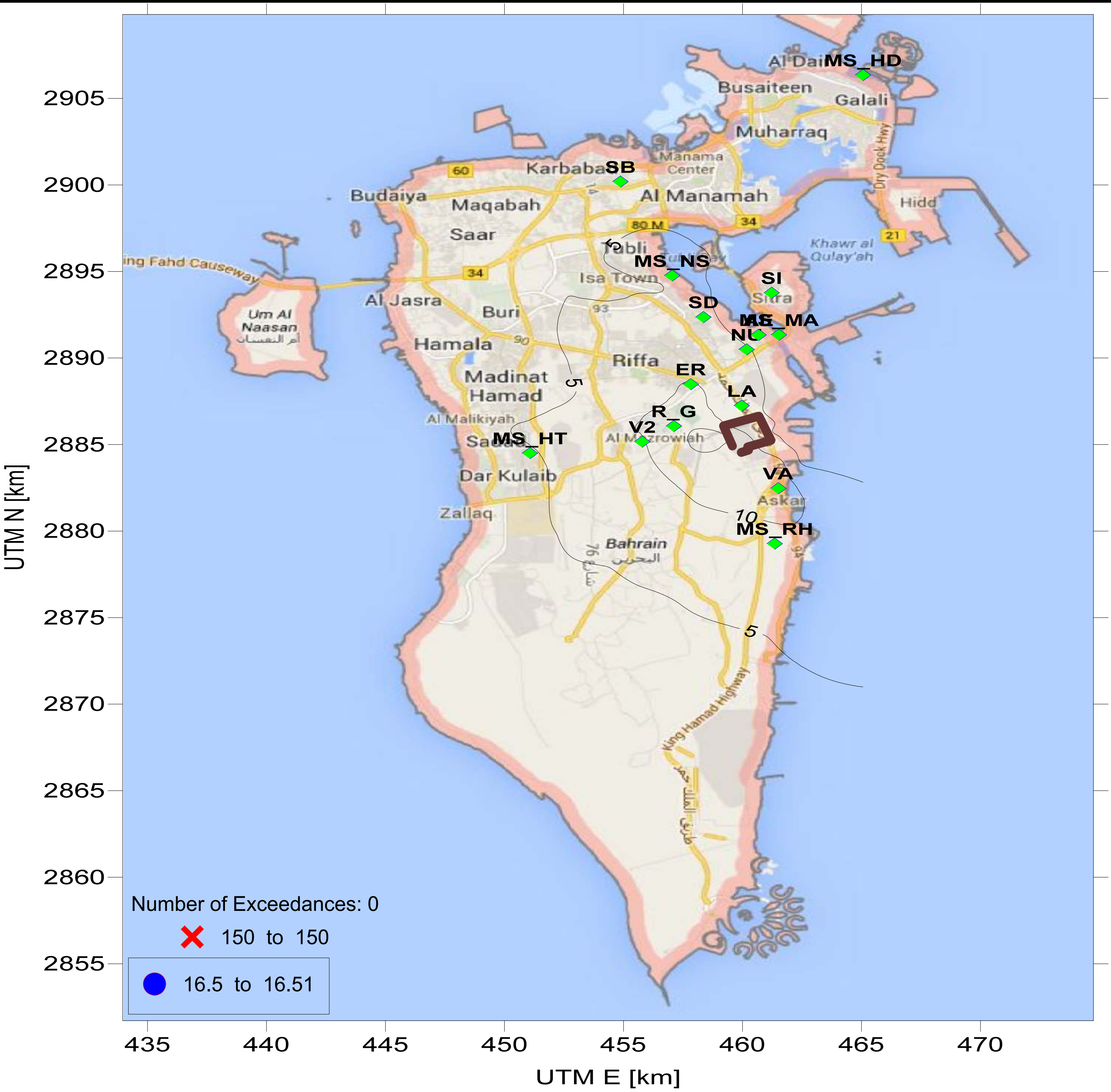
- Plant boundary limit
- Ambient Air Quality Limit
- Receptor Locations
- Maximum Concentration

Number of Exccedances : 0

No.	Location	CODE
1	Ras Hayyan	MS_RH
2	Hidd	MS_HD
3	Maameer	MS_MA
4	Napeeh Saleh	MS_NS
5	Hamad Town	MS_HT
6	Sanabis	SB
7	Villas Askar	VA
8	Villas 2	V2
9	ResidentialArea & Golf Course	R_G

No.	Location	CODE
10	Labour Accommodation	LA
11	East-Riffa	ER
12	Ma'ameer	MA
13	Nuwaidrat	NU
14	Al Eker	AE
15	Sanad	SD
16	Sitra	SI

Prepared For:	Figure Title: **Hourly Average Concentration - NO_2 Future Scenario-3**	Date: March, 2014
Prepared By:	Project: **ALBA Potline (6) and Power Plant (PS5) Expansion**	Project No: 10921.00
		Figure No: 13



LEGEND:

Ambient Air Quality Standards

Time Weighted Average - Daily: 150 ug/m3
Maximum Predicted Concentration: 17 ug/m3

Plant boundary limit

Ambient Air Quality Limit

Receptor Locations

Maximum Concentration

No.	Location	CODE
1	Ras Hayyan	MS_RH
2	Hidd	MS_HD
3	Maameer	MS_MA
4	Napeeh Saleh	MS_NS
5	Hamad Town	MS_HT
6	Sanabis	SB
7	Villas Askar	VA
8	Villas 2	V2
9	ResidentialArea & Golf Course	R_G

No.	Location	CODE
10	Labour Accommodation	LA
11	East-Riffa	ER
12	Ma'ameer	MA
13	Nuwaidrat	NU
14	Al Eker	AE
15	Sanad	SD
16	Sitra	SI

Prepared For:

Figure Title:

Daily Average Concentration - NO_2
Baseline Scenario - 1
Existing Emission Sources

Date:
March, 2014

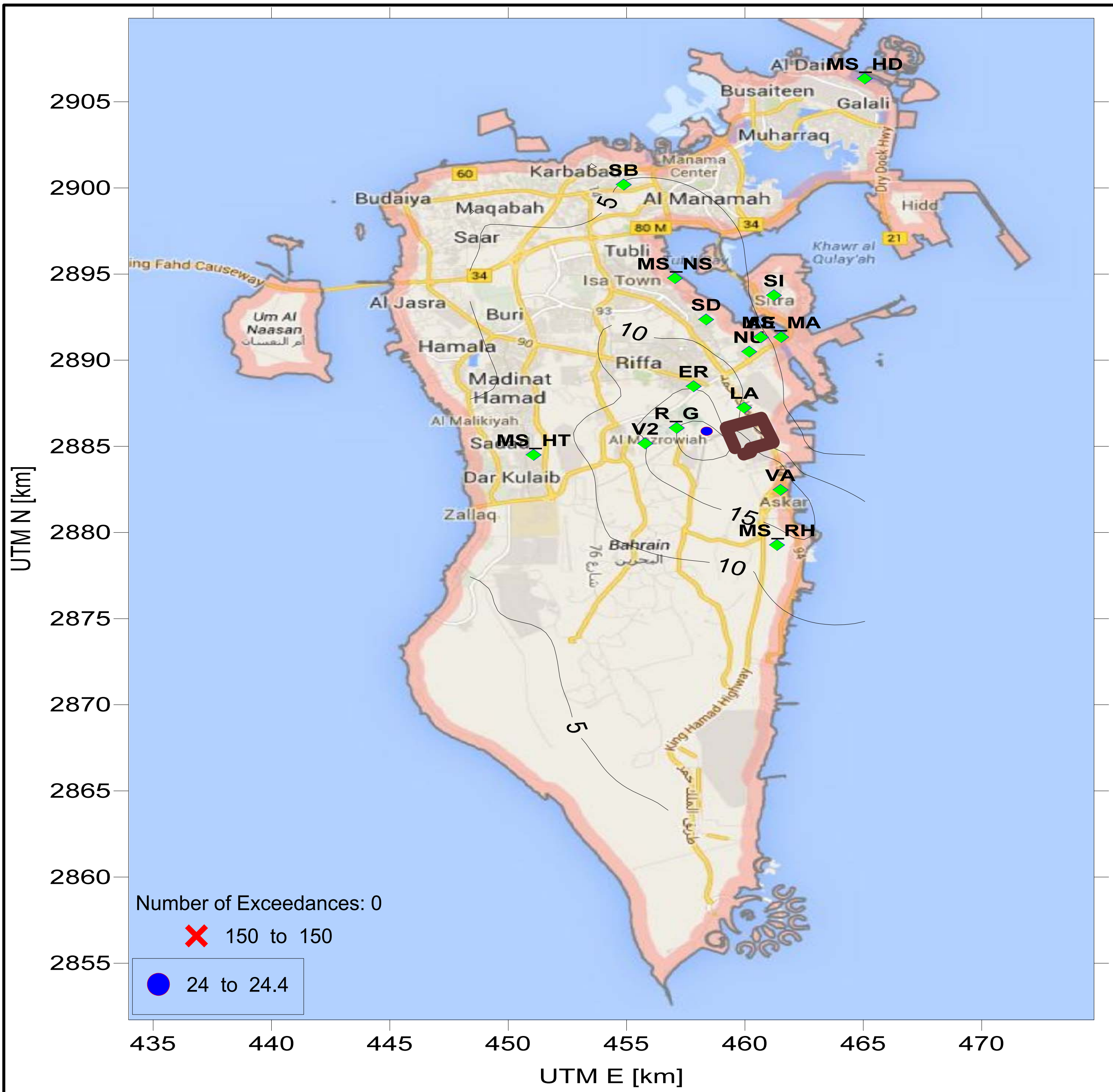
Prepared By:

Project:

ALBA Potline (6) and Power Plant (PS5) Expansion

Project No:
10921.00

Figure No:
14



LEGEND:

Ambient Air Quality Standards

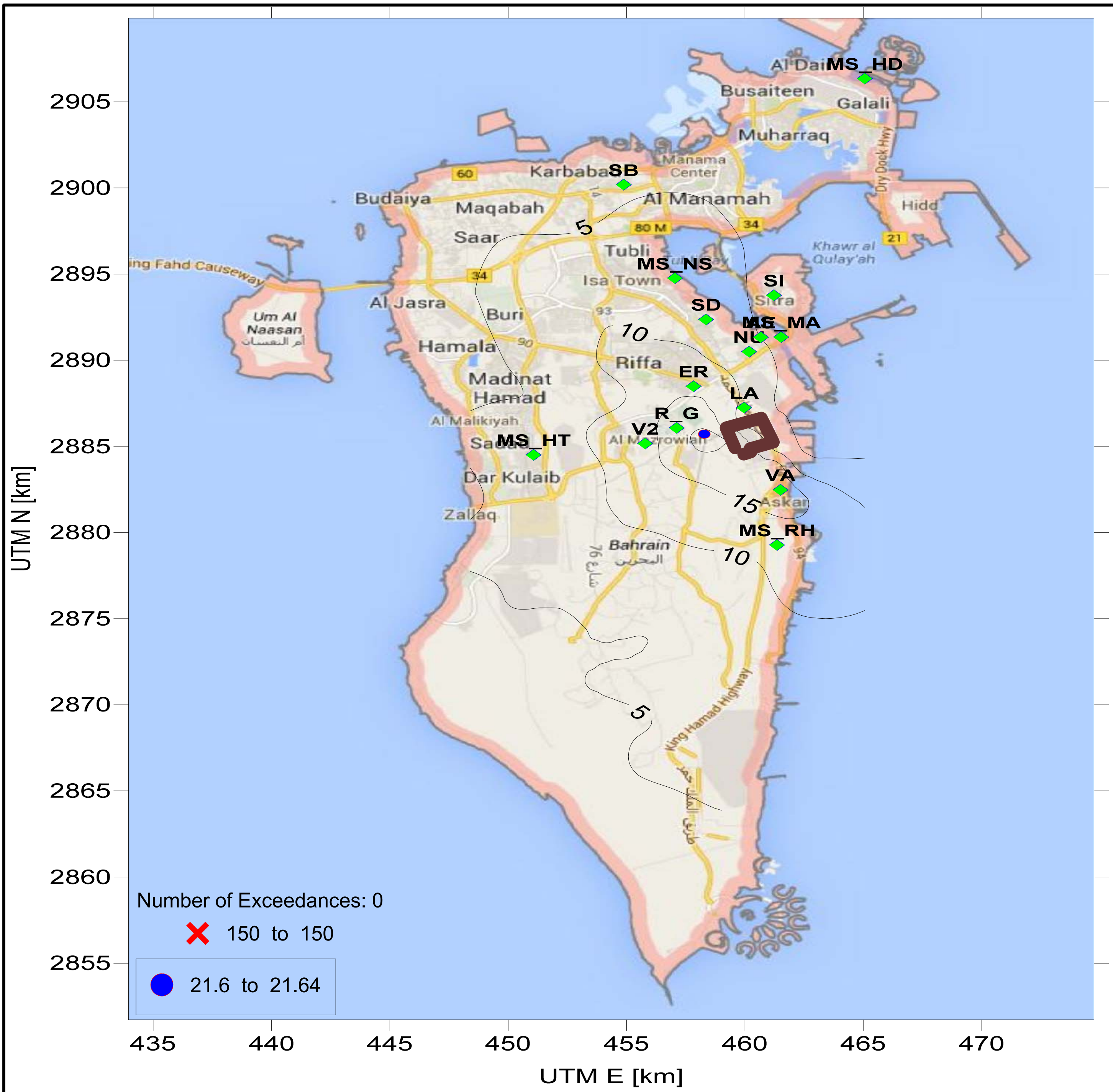
Time Weighted Average - Daily: 150 ug/m3
Maximum Predicted Concentration: 24 ug/m3

- Plant boundary limit
- Ambient Air Quality Limit
- Receptor Locations
- Maximum Concentration

No.	Location	CODE
1	Ras Hayyan	MS_RH
2	Hidd	MS_HD
3	Maameer	MS_MA
4	Napeeh Saleh	MS_NS
5	Hamad Town	MS_HT
6	Sanabis	SB
7	Villas Askar	VA
8	Villas 2	V2
9	ResidentialArea & Golf Course	R_G

No.	Location	CODE
10	Labour Accommodation	LA
11	East-Riffa	ER
12	Ma'ameer	MA
13	Nuwaidrat	NU
14	Al Eker	AE
15	Sanad	SD
16	Sitra	SI

Prepared For:	Figure Title: **Daily Average Concentration - NO_2 Future Scenario -2**	Date: March, 2014
Prepared By:	Project: **ALBA Potline (6) and Power Plant (PS5) Expansion**	Project No: 10921.00
		Figure No: 15



LEGEND:

Ambient Air Quality Standards

Time Weighted Average - Daily: 150 ug/m3
Maximum Predicted Concentration: 22 ug/m3

- Plant boundary limit
- Ambient Air Quality Limit
- Receptor Locations
- Maximum Concentration

No.	Location	CODE
1	Ras Hayyan	MS_RH
2	Hidd	MS_HD
3	Maameer	MS_MA
4	Napeeh Saleh	MS_NS
5	Hamad Town	MS_HT
6	Sanabis	SB
7	Villas Askar	VA
8	Villas 2	V2
9	ResidentialArea & Golf Course	R_G

No.	Location	CODE
10	Labour Accommodation	LA
11	East-Riffa	ER
12	Ma'ameer	MA
13	Nuwaidrat	NU
14	Al Eker	AE
15	Sanad	SD
16	Sitra	SI

Prepared For: alba BECHTEL

Figure Title:

Daily Average Concentration - NO_2
Future Scenario-3

Date: March, 2014

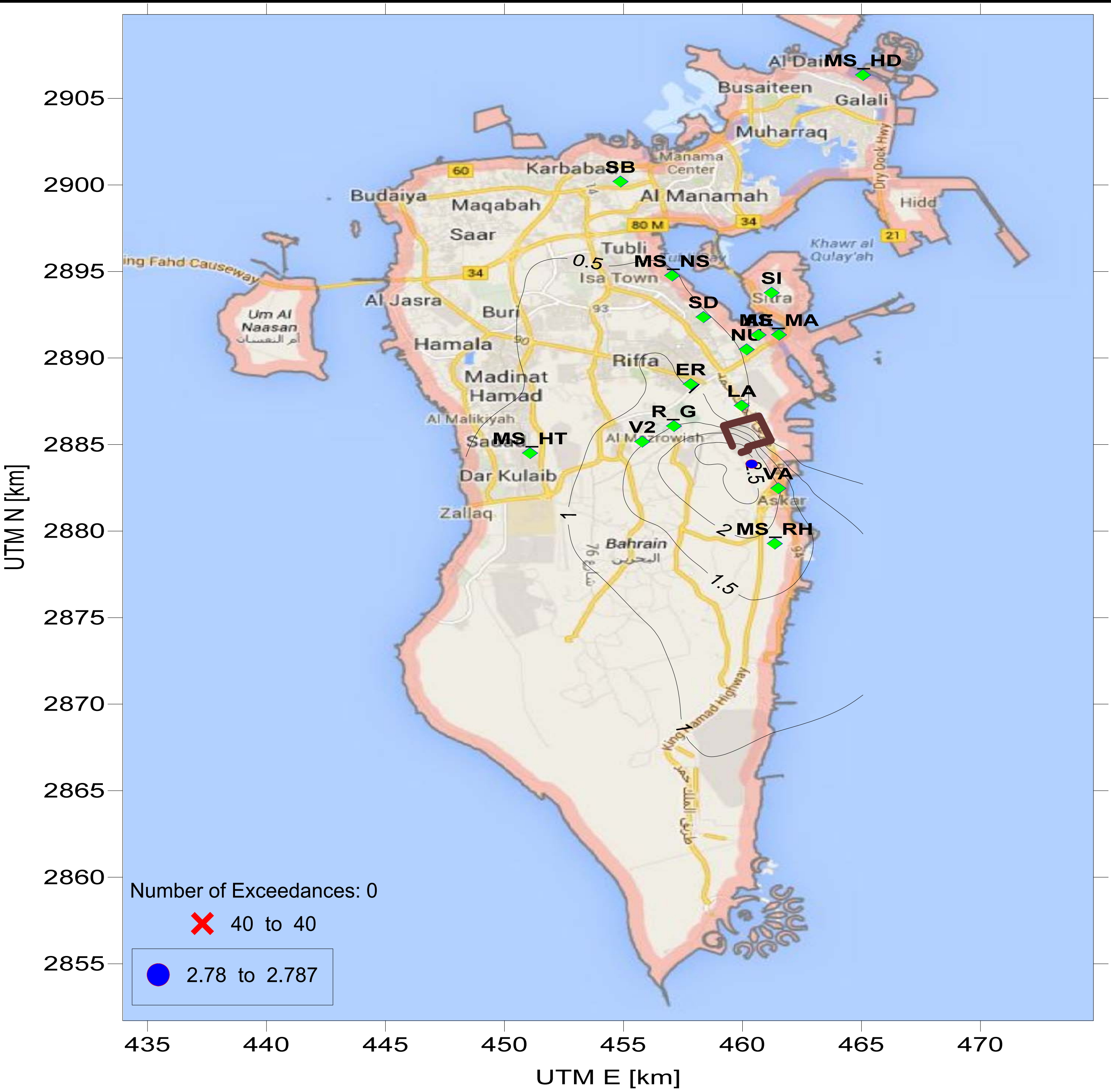
Project No: 10921.00

Prepared By: BILFINGER TEBODIN

Project:

ALBA Potline (6) and Power Plant (PS5) Expansion

Figure No: 16



LEGEND:

Ambient Air Quality Standards

Time Weighted Average - Annual : 40 ug/m3
Maximum Predicted Concentration: 3 ug/m3

Plant boundary limit

Ambient Air Quality Limit

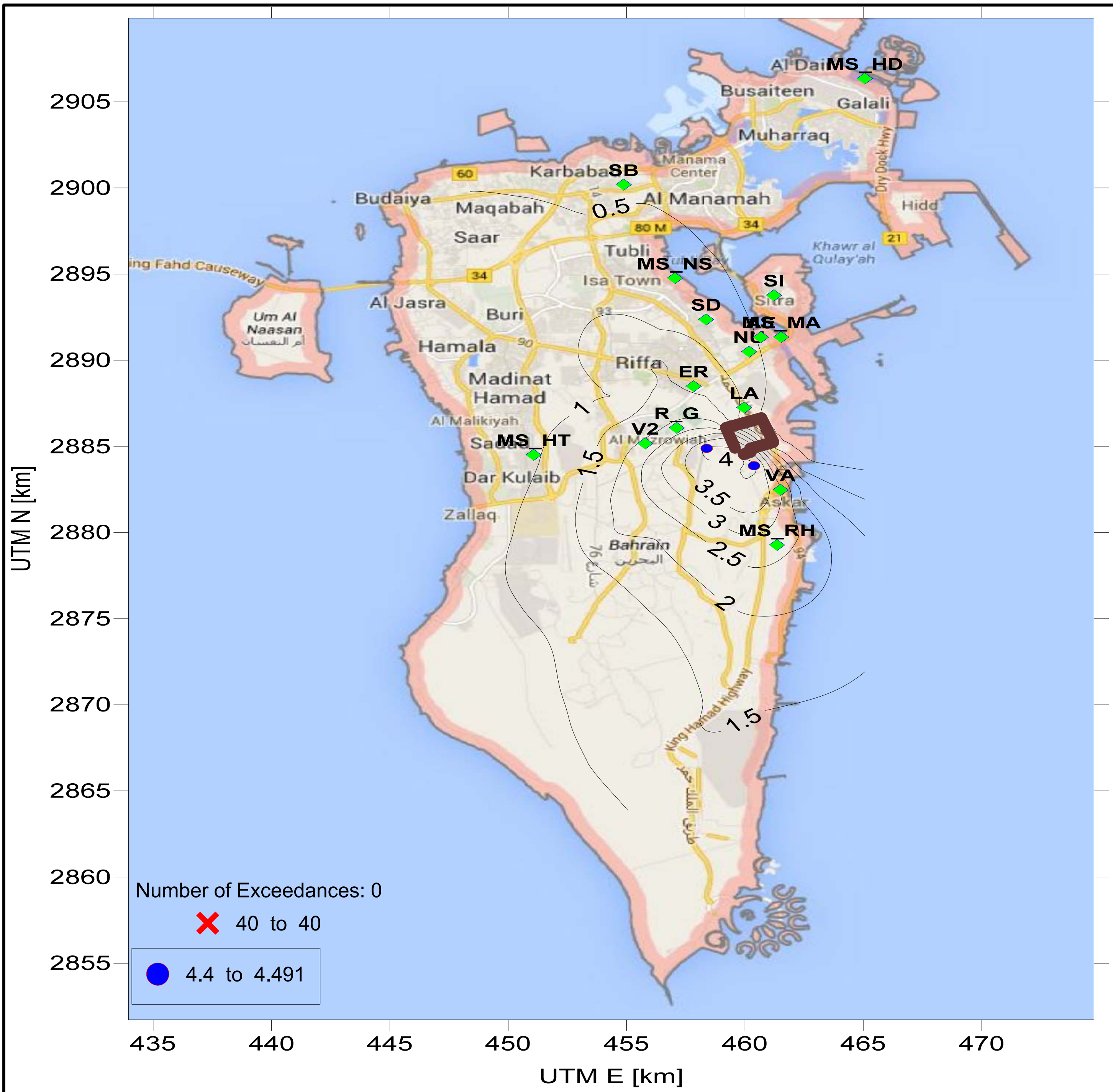
Receptor Locations

Maximum Concentration

No.	Location	CODE
1	Ras Hayyan	MS_RH
2	Hidd	MS_HD
3	Maameer	MS_MA
4	Napeeh Saleh	MS_NS
5	Hamad Town	MS_HT
6	Sanabis	SB
7	Villas Askar	VA
8	Villas 2	V2
9	ResidentialArea & Golf Course	R_G

No.	Location	CODE
10	Labour Accommodation	LA
11	East-Riffa	ER
12	Ma'ameer	MA
13	Nuwaidrat	NU
14	Al Eker	AE
15	Sanad	SD
16	Sitra	SI

Prepared For:	Figure Title: **Annual Average Concentration - NO_2 Baseline Scenario - 1 Existing Emission Sources**	Date: March, 2014
		Project No: 10921.00
Prepared By:	Project: **ALBA Potline (6) and Power Plant (PS5) Expansion**	Figure No: 17



LEGEND:

Ambient Air Quality Standards

Time Weighted Average - Annual: 40 ug/m3
Maximum Predicted Concentration: 4 ug/m3

- Plant boundary limit
- Ambient Air Quality Limit
- Receptor Locations
- Maximum Concentration

No.	Location	CODE
1	Ras Hayyan	MS_RH
2	Hidd	MS_HD
3	Maameer	MS_MA
4	Napeeh Saleh	MS_NS
5	Hamad Town	MS_HT
6	Sanabis	SB
7	Villas Askar	VA
8	Villas 2	V2
9	ResidentialArea & Golf Course	R_G

No.	Location	CODE
10	Labour Accommodation	LA
11	East-Riffa	ER
12	Ma'ameer	MA
13	Nuwaidrat	NU
14	Al Eker	AE
15	Sanad	SD
16	Sitra	SI

Prepared For:

Figure Title:

Annual Average Concentration - NO_2
Future Scenario-2

Date: March, 2014

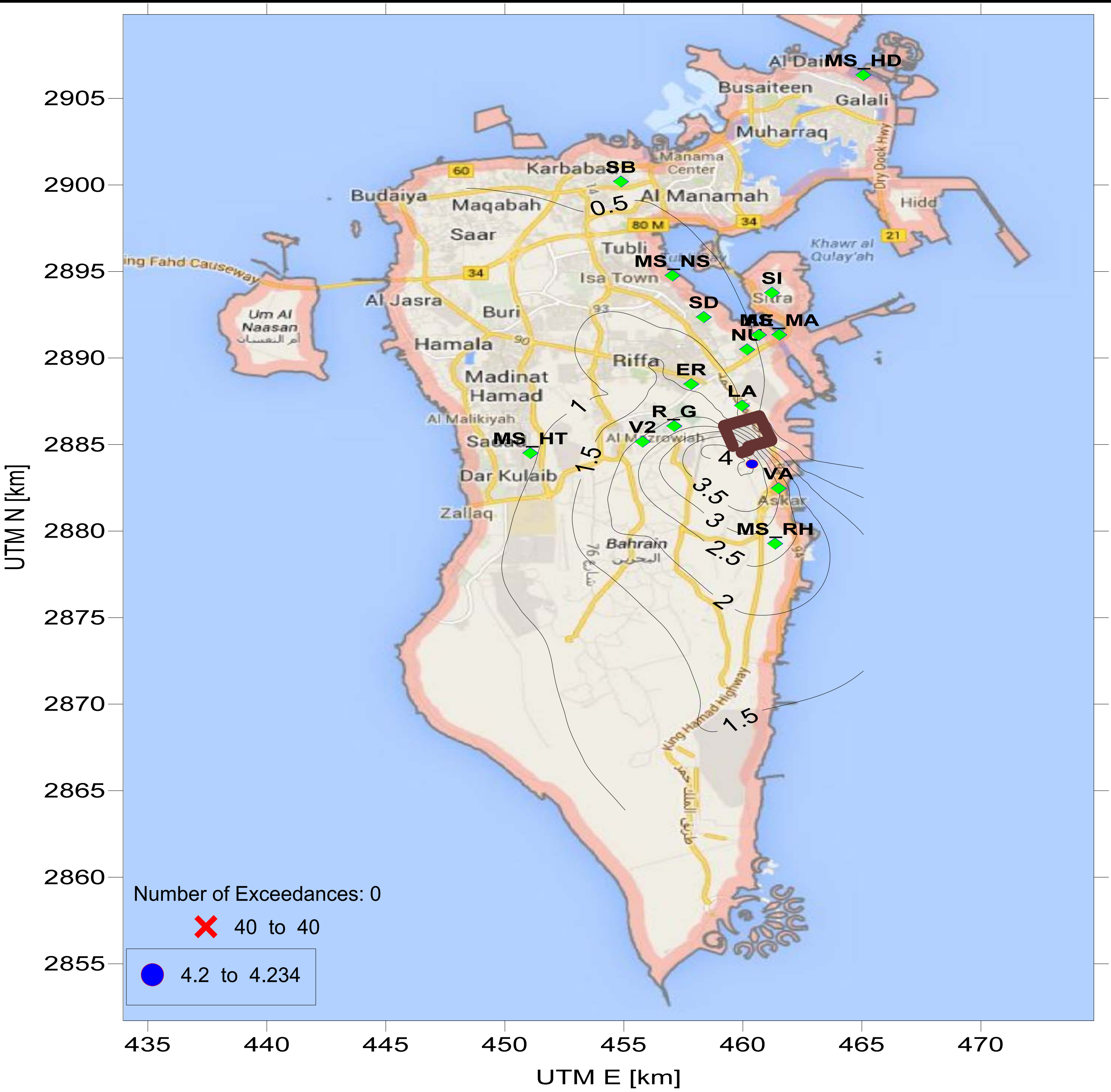
Prepared By:

Project:

ALBA Potline (6) and Power Plant (PS5) Expansion

Project No: 10921.00

Figure No: 18



LEGEND:

Ambient Air Quality Standards

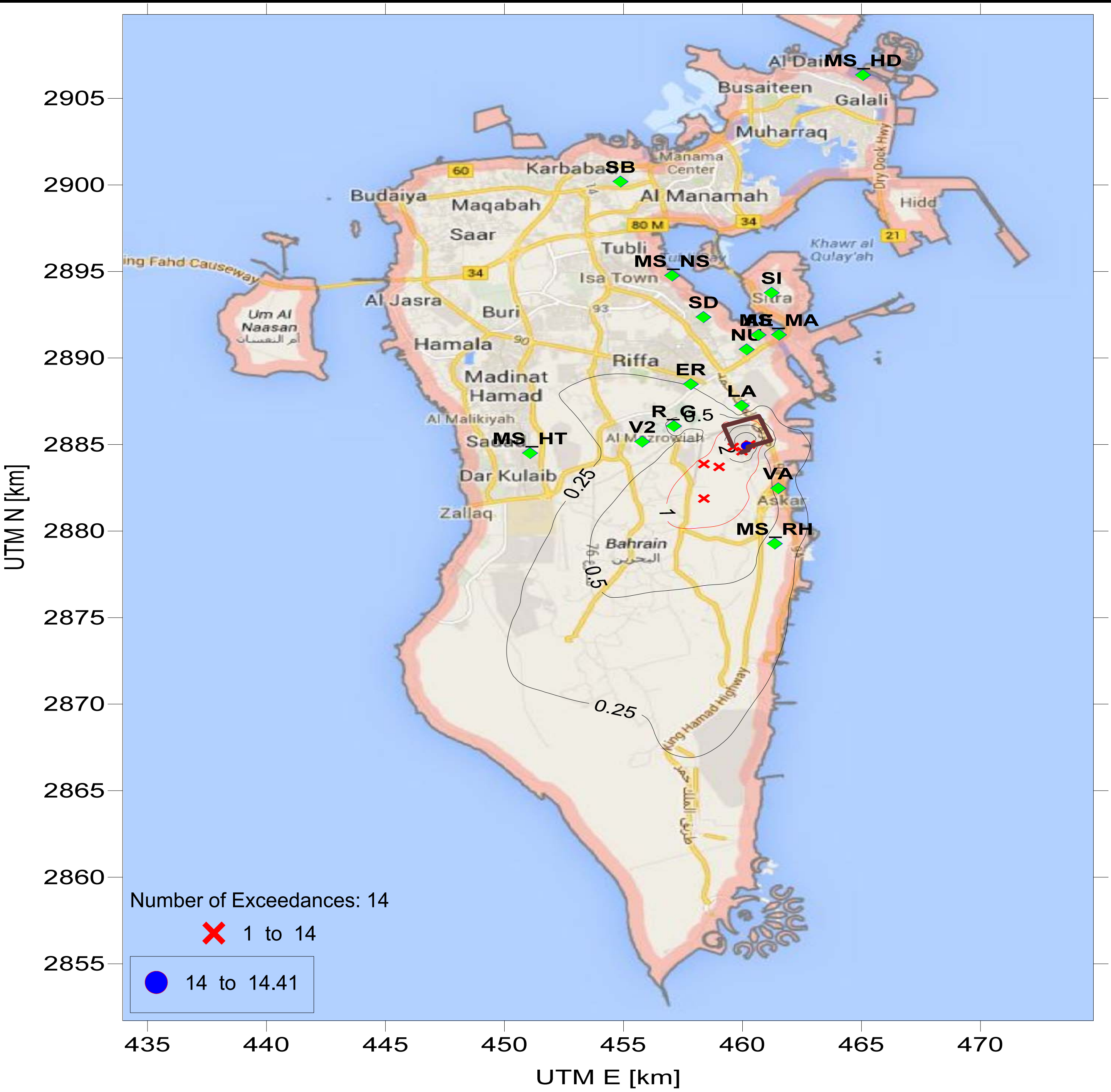
Time Weighted Average - Annual: 40 ug/m3
Maximum Predicted Concentration: 4 ug/m3

- Plant boundary limit
- Ambient Air Quality Limit
- Receptor Locations
- Maximum Concentration

No.	Location	CODE
1	Ras Hayyan	MS_RH
2	Hidd	MS_HD
3	Maameer	MS_MA
4	Napeeh Saleh	MS_NS
5	Hamad Town	MS_HT
6	Sanabis	SB
7	Villas Askar	VA
8	Villas 2	V2
9	ResidentialArea & Golf Course	R_G

No.	Location	CODE
10	Labour Accommodation	LA
11	East-Riffa	ER
12	Ma'ameer	MA
13	Nuwaidrat	NU
14	Al Eker	AE
15	Sanad	SD
16	Sitra	SI

Prepared For:	Figure Title: **Annual Average Concentration - NO_2 Future Scenario-3**	Date: March, 2014
Prepared By:	Project: **ALBA Potline (6) and Power Plant (PS5) Expansion**	Project No: 10921.00
		Figure No: 19



LEGEND:

Ambient Air Quality Standards

Time Weighted Average - Annual : 1 ug/m3
Maximum Predicted Concentration: 14 ug/m3

Plant boundary limit

Ambient Air Quality Limit

Receptor Locations

Maximum Concentration

No.	Location	CODE
1	Ras Hayyan	MS_RH
2	Hidd	MS_HD
3	Maameer	MS_MA
4	Napeeh Saleh	MS_NS
5	Hamad Town	MS_HT
6	Sanabis	SB
7	Villas Askar	VA
8	Villas 2	V2
9	ResidentialArea & Golf Course	R_G

No.	Location	CODE
10	Labour Accommodation	LA
11	East-Riffa	ER
12	Ma'ameer	MA
13	Nuwaidrat	NU
14	Al Eker	AE
15	Sanad	SD
16	Sitra	SI

Prepared For:

Figure Title:

Annual Average Concentration - Gaseous Fluoride (HF)
Baseline Scenario - 1
Existing Sources

Date:

March, 2014

Project No:

10921.00

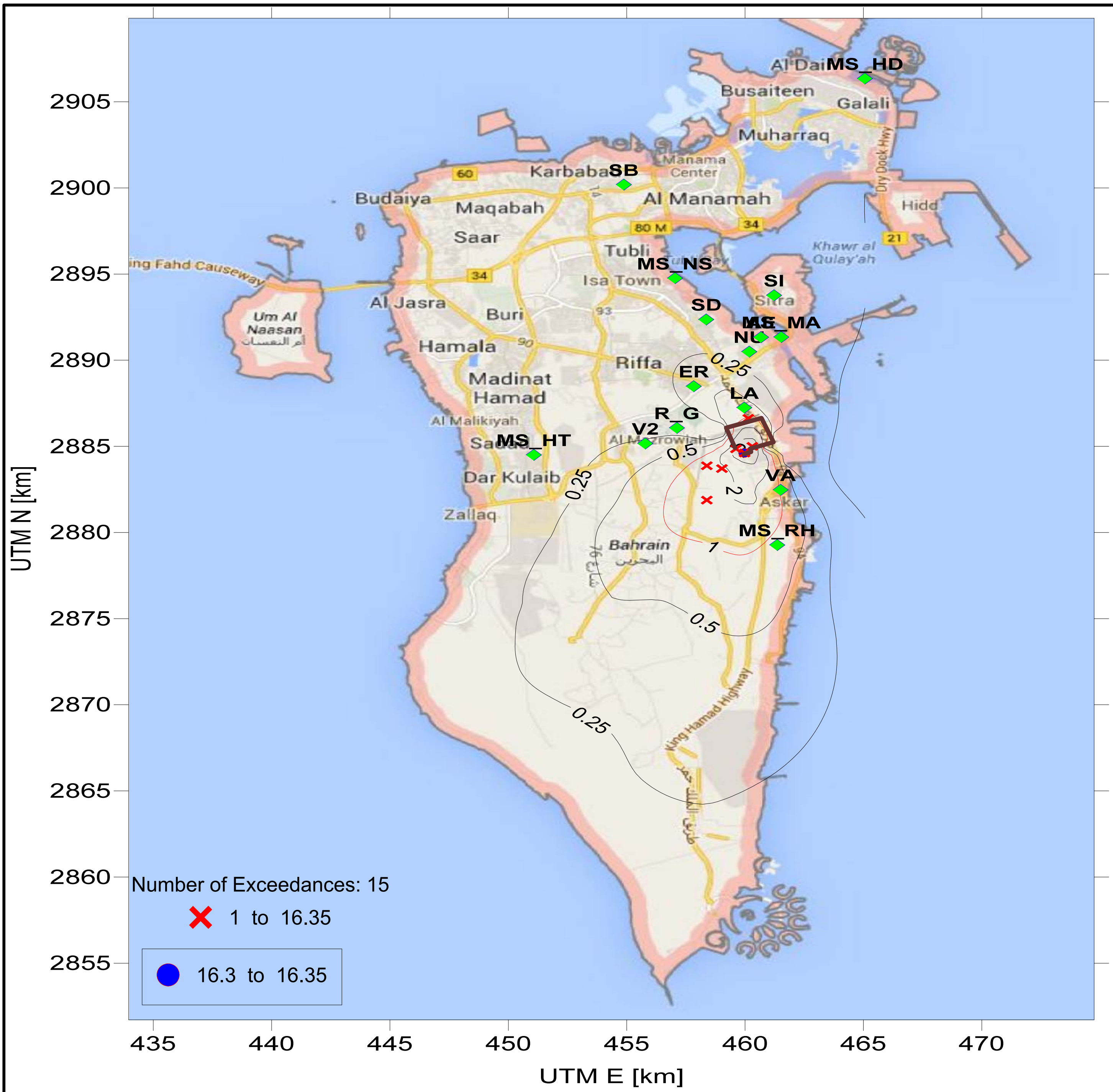
Prepared By:

Project:

ALBA Potline (6) and Power Plant (PS5) Expansion

Figure No:

20



LEGEND:

Ambient Air Quality Standards

Time Weighted Average - Annual: 1ug/m3
Maximum Predicted Concentration: 16 ug/m3

- Plant boundary limit
- Ambient Air Quality Limit
- Receptor Locations
- Maximum Concentration

Number of Exccedances : 0

No.	Location	CODE
1	Ras Hayyan	MS_RH
2	Hidd	MS_HD
3	Maameer	MS_MA
4	Napeeh Saleh	MS_NS
5	Hamad Town	MS_HT
6	Sanabis	SB
7	Villas Askar	VA
8	Villas 2	V2
9	ResidentialArea & Golf Course	R_G

No.	Location	CODE
10	Labour Accommodation	LA
11	East-Riffa	ER
12	Ma'ameer	MA
13	Nuwaidrat	NU
14	Al Eker	AE
15	Sanad	SD
16	Sitra	SI

Prepared For: alba BECHTEL

Figure Title:
Annual Average Concentration - Gaseous Fluoride (HF) Future Scenario-1

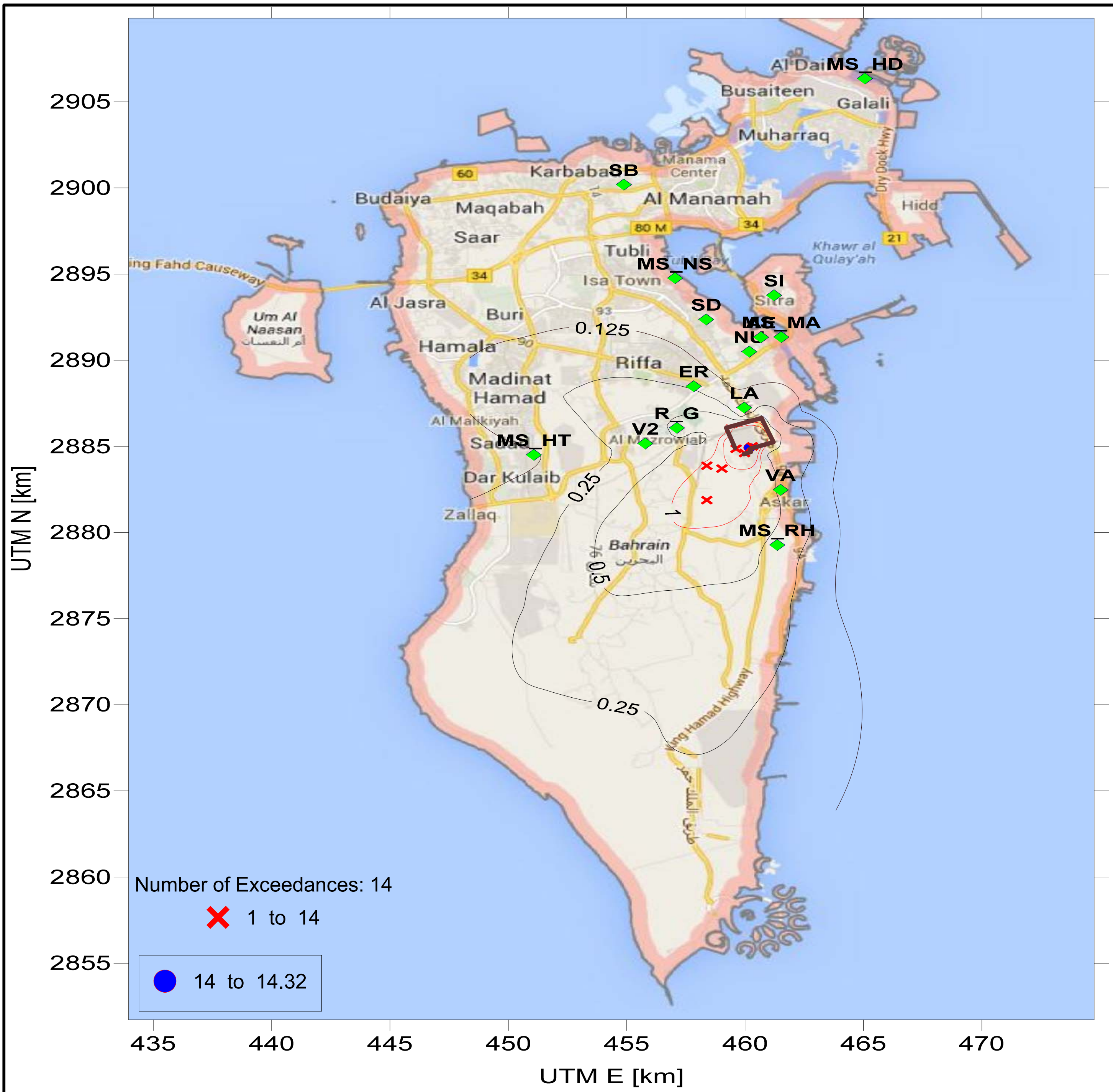
Date: March, 2014

Prepared By: BILFINGER TEBODIN

Project:
ALBA Potline (6) and Power Plant (PS5) Expansion

Project No: 10921.00

Figure No: 21



LEGEND:

Ambient Air Quality Standards

Time Weighted Average - Annual: 1 ug/m3
Maximum Predicted Concentration: 14 ug/m3

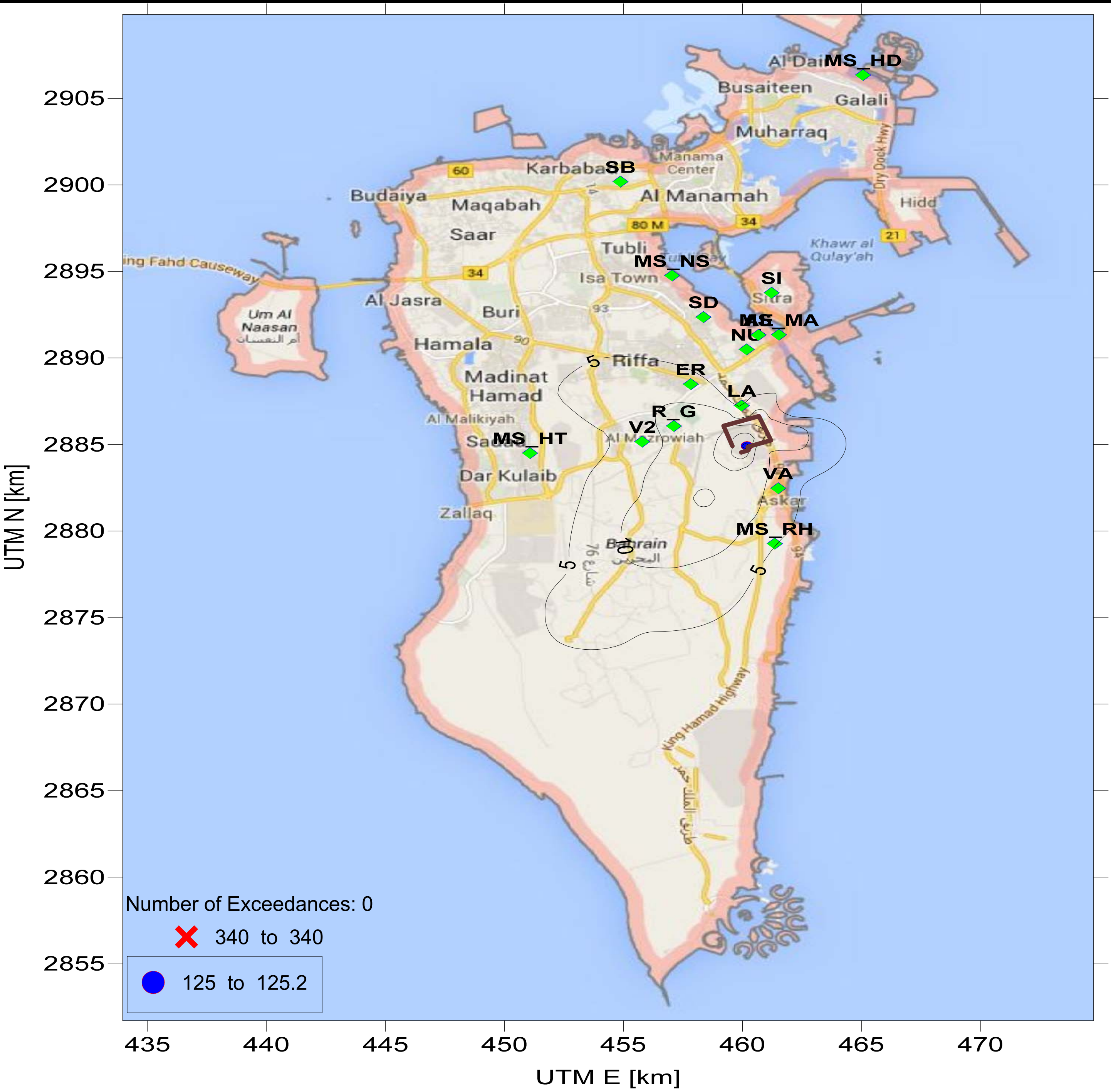
- Plant boundary limit
- Ambient Air Quality Limit
- Receptor Locations
- Maximum Concentration

Number of Exccedances : 0

No.	Location	CODE
1	Ras Hayyan	MS_RH
2	Hidd	MS_HD
3	Maameer	MS_MA
4	Napeeh Saleh	MS_NS
5	Hamad Town	MS_HT
6	Sanabis	SB
7	Villas Askar	VA
8	Villas 2	V2
9	ResidentialArea & Golf Course	R_G

No.	Location	CODE
10	Labour Accommodation	LA
11	East-Riffa	ER
12	Ma'ameer	MA
13	Nuwaidrat	NU
14	Al Eker	AE
15	Sanad	SD
16	Sitra	SI

Prepared For:	Figure Title: **Annual Average Concentration - Gaseous Fluoride (HF) Future Scenario-2**	Date: March, 2014
Prepared By:	Project: **ALBA Potline (6) and Power Plant (PS5) Expansion**	Project No: 10921.00
		Figure No: 22



LEGEND:

Ambient Air Quality Standards

Time Weighted Average - Daily : 340 ug/m3
Maximum Predicted Concentration: 125 ug/m3

Plant boundary limit

Ambient Air Quality Limit

Receptor Locations

Maximum Concentration

No.	Location	CODE
1	Ras Hayyan	MS_RH
2	Hidd	MS_HD
3	Maameer	MS_MA
4	Napeeh Saleh	MS_NS
5	Hamad Town	MS_HT
6	Sanabis	SB
7	Villas Askar	VA
8	Villas 2	V2
9	ResidentialArea & Golf Course	R_G

No.	Location	CODE
10	Labour Accommodation	LA
11	East-Riffa	ER
12	Ma'ameer	MA
13	Nuwaidrat	NU
14	Al Eker	AE
15	Sanad	SD
16	Sitra	SI

Prepared For:

Figure Title:

Daily Average Concentration - PM_{10}
Baseline Scenario - 1
Existing Sources

Date: March, 2014

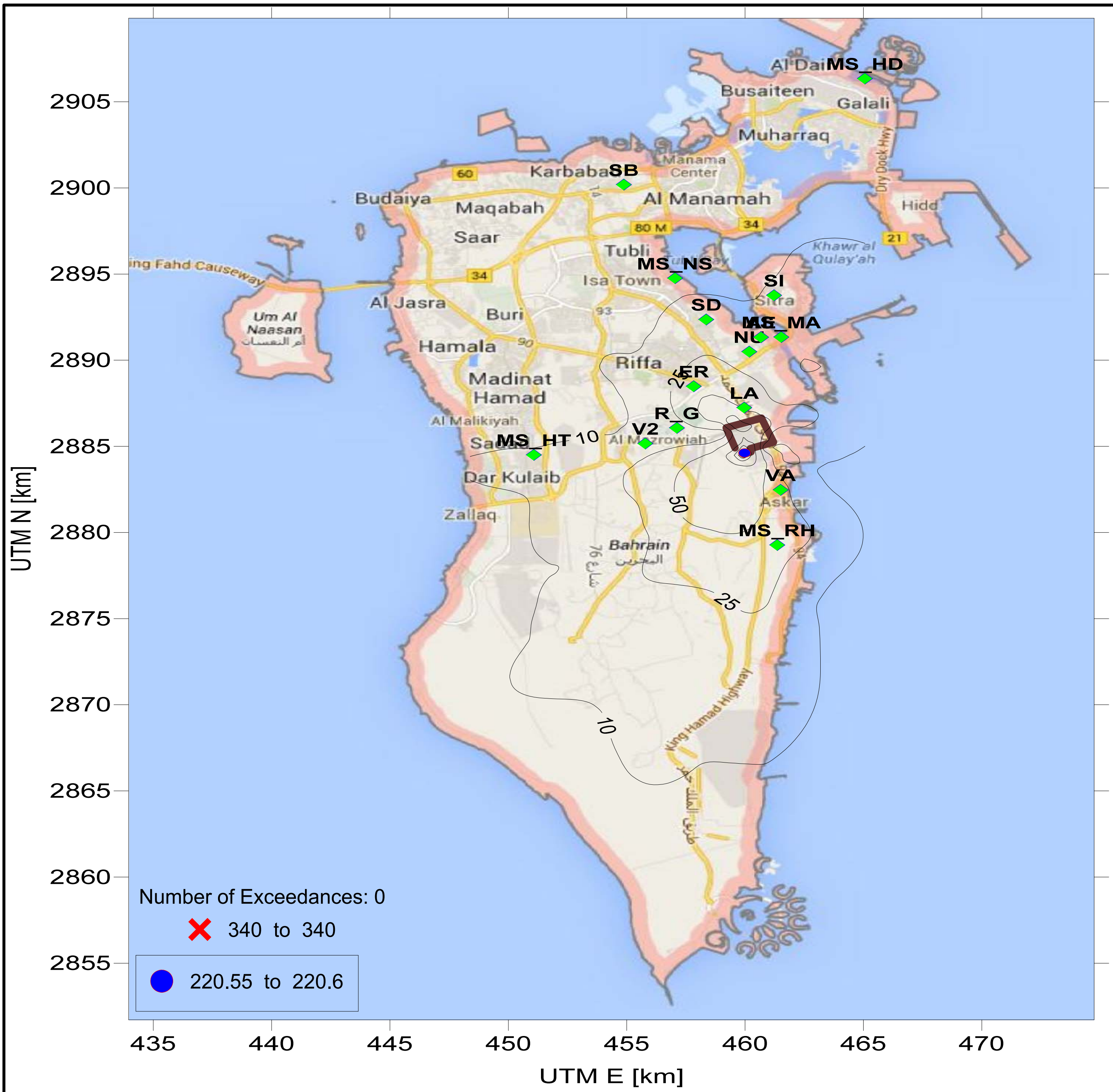
Project No: 10921.00

Prepared By:

Project:

ALBA Potline (6) and Power Plant (PS5) Expansion

Figure No: 23



LEGEND:

Ambient Air Quality Standards

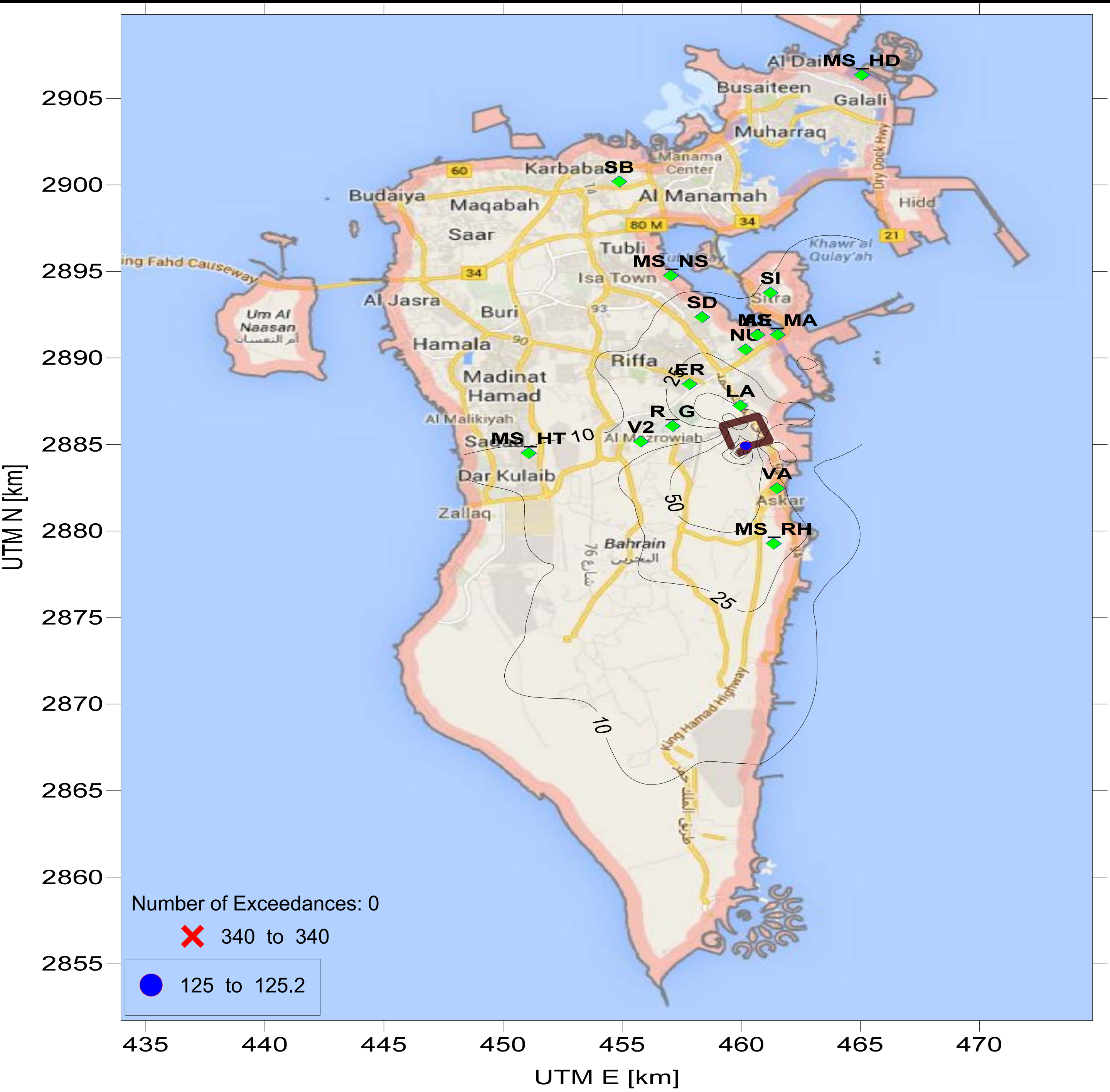
Time Weighted Average - Daily: 340 ug/m3
Maximum Predicted Concentration: 221 ug/m3

- Plant boundary limit
- Ambient Air Quality Limit
- Receptor Locations
- Maximum Concentration

No.	Location	CODE
1	Ras Hayyan	MS_RH
2	Hidd	MS_HD
3	Maameer	MS_MA
4	Napeeh Saleh	MS_NS
5	Hamad Town	MS_HT
6	Sanabis	SB
7	Villas Askar	VA
8	Villas 2	V2
9	ResidentialArea & Golf Course	R_G

No.	Location	CODE
10	Labour Accommodation	LA
11	East-Riffa	ER
12	Ma'ameer	MA
13	Nuwaidrat	NU
14	Al Eker	AE
15	Sanad	SD
16	Sitra	SI

Prepared For:	Figure Title: **Daily Average Concentration - PM_{10} Future Scenario-2**	Date: March, 2014
Prepared By:	Project: **ALBA Potline (6) and Power Plant (PS5) Expansion**	Project No: 10921.00 Figure No: 24



LEGEND:

Ambient Air Quality Standards

Time Weighted Average - Daily: 340 ug/m3
Maximum Predicted Concentration: 221 ug/m3

- Plant boundary limit
- Ambient Air Quality Limit
- Receptor Locations
- Maximum Concentration

No.	Location	CODE
1	Ras Hayyan	MS_RH
2	Hidd	MS_HD
3	Maameer	MS_MA
4	Napeeh Saleh	MS_NS
5	Hamad Town	MS_HT
6	Sanabis	SB
7	Villas Askar	VA
8	Villas 2	V2
9	ResidentialArea & Golf Course	R_G

No.	Location	CODE
10	Labour Accommodation	LA
11	East-Riffa	ER
12	Ma'ameer	MA
13	Nuwaidrat	NU
14	Al Eker	AE
15	Sanad	SD
16	Sitra	SI

Prepared For:	Figure Title: **Daily Average Concentration - PM_{10} Future Scenario-3**	Date: March, 2014
Prepared By:	Project: **ALBA Potline (6) and Power Plant (PS5) Expansion**	Project No: 10921.00 Figure No: 25

Appendix 19: SPL Treatment

Client: **Bechtel**
Project: ALBA Potline (6) and Power Plant (PS 5) Expansion

Appendix 19:
Options for the treatment of Spent Pot Liners

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1 Options for the treatment of SPL

Due to its toxicity Spent Pot Liner (SPL) has been identified in the ESIA as the most significant waste stream that is generated by Alba. For Potline 6, SPL generation would start approximately four (4) years after starting up on the Potline when the pot relining sequence is initiated. From that time, SPL will be generated on a steady basis.

Alba's current disposal practice is in line with that stipulated by the authorities. However it is recommended that Alba continues to pursue options for improved disposal. Therefore, different options for SPL disposal are detailed in this Annexure.

1.1 Introduction

As indicated in the Environmental and Social Impact Assessment (ESIA), SPL is generally comprised of a hazardous carbon fraction containing cyanide and fluoride (referred to as "first cut") and the refractory containing portion (referred to as the "second cut"). A schematic overview of a pot is presented in **Figure A1**.

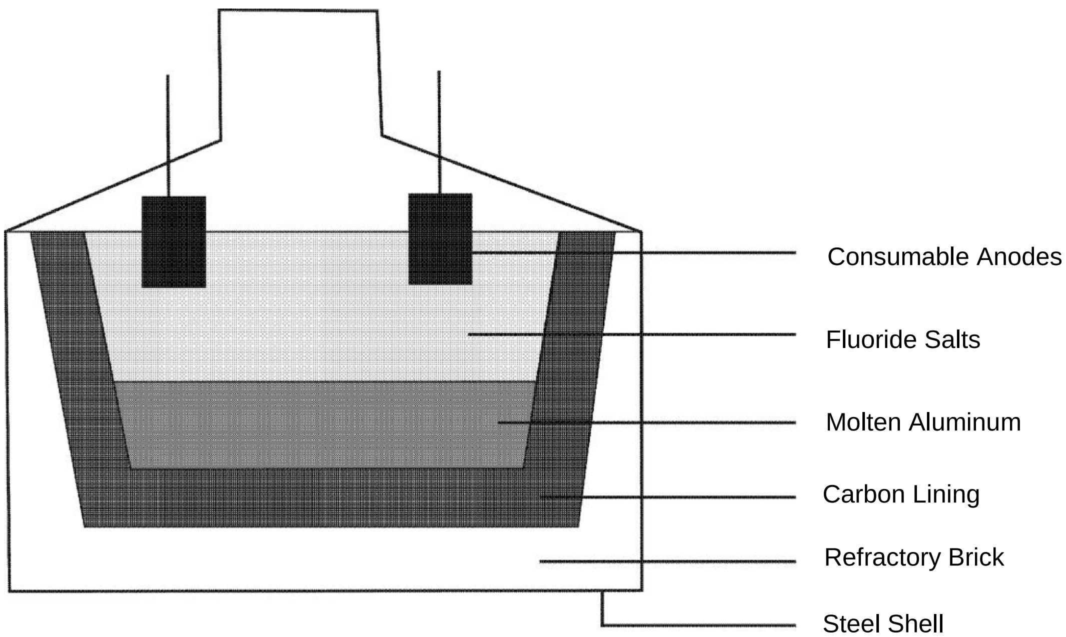

Figure A1: Simplified Diagram of a Typical Electrolysis Pot[1]

[1] Adapted from US EPA - Best Demonstrated Available Technology (BDAT) Background Document For Spent Aluminum Potliners – K088

First of all it is to be noted that safe disposal of SPL is an issue that challenges the global primary aluminium production sector. Currently, SPL (EWC Number 161101) is an absolute hazardous waste material, as defined in the European Waste Catalogue (EWC). In addition, the United States Environmental Protection Agency (US EPA) has categorized SPL under number K088 (primary aluminium smelter waste).

The US EPA has identified management techniques for K088 waste, such as recycling, reclamation, reuse, stabilization, chemical precipitation, and treatment. In May 2000, the Agency has identified a “best” demonstrated technology (BDAT) for SPL treatment (Reynolds Process and the Ormet/Vortec Process). In addition, the US EPA conducted an economic assessment of Land Disposal Restrictions (LDR) Treatment in the same year. It needs to be taken into consideration that the above mentioned documents were established more than a decade ago. However, the US EPA does not have more recent publications regarding SPL.

1.2 Overview

Over the years, many studies focused on disposal options for SPL. In general, however, most of these studies have focused on the "first cut” as the "second cut" is not currently regulated as a hazardous waste (and is generally disposed of in landfills).

Disposal options for this first cut include straight disposal to landfill, macro encapsulation and landfilling, mixing with "anti-agglomeration" agents incinerated and then landfilled (the Reynolds Process) and high temperature oxidation and then landfilling the resulting slag (the Ausmelt Process).

In addition to disposal options, recycling options include vitrification (the Ormet/Vortec Process) and use as a supplemental fuel in an industrial furnace. The only option which has the technical possibility to recycle or reuse both cuts, is the use in a cement kiln. Thereby, the carbon fraction may be used as a fuel and the refractory portion can be used as a raw materials substitute.

In line with Best Available Technology, the available recovery routes are:

- Re-use in cement manufacturing; ceramics or brick industries;
- Re-use as a secondary raw material (rock wool, salt slags recovery, etc.);
- Re-use as a fuel;
- Re-use as a carburiser (steel industry).

Seven options for SPL treatments and their respective advantages and disadvantages are presented in **Table A1.** Based on the (dis)advantages the applicability of each option was assessed. Subsequent sections provide details on the selected options for SPL treatment in the Kingdom of Bahrain.

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Table A1: Options for SPL treatment

#	Method		Advantages	Disadvantages	Option
1	Non-Treatment	**Recycling in cement kilns** Introduction of spent pot lining into a cement kiln destroys the contaminants (cyanides, PAH's) and bounds fluorides with calcium present in the cement or lime, rendering the substance non-hazardous.	• No previous treatment required, full recycling of refractory and carbon sections • Neutralisation of hazardous compounds	• Logistic difficulties (transport)	**Yes**
2	Non-Treatment	**Recycling as road foundation** Refractory of spent pot lining is used as road foundation material. The risk of leaching is reduced, especially in areas with low precipitation, however the chance of leaching remains.	• No prior treatment required, only recycling of refractory material ('second cut").	• Risk of leaching of cyanides remains, due to the remaining hazardous material ("first cut" this method it is not preferred.	**No**
3	Treatment	***Alcoa Portland SPL process*** In a process containing two main stages, SPL is processed in an Ausmelt furnace, where the cyanide is destroyed, and HF is produced. The HF gas is then put through a gas conversion process, where it is converted into aluminium fluoride and recycled back into the Aluminium process.	• Destruction of cyanide, recycling of fluoride • Production of safe slag that can be used as a raw material in other activities.	• Logistics of utilizing slag related to the quantity of the SPL waste.	**Yes**

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#		Method	Advantages	Disadvantages	Option
4	Treatment	***Alcan Low-Caustic Leach and Lime Process (LCLL)*** In the Alcan Low-Caustic Leach and Lime Process (LCLL) finely ground SPL is leached with caustic to remove the fluorine, free and complexed cyanide, alumina, and some silica into the leach liquor. Cyanide is then destroyed by hydrolysis in a high pressure autoclave. The remaining liquor is evaporated to a 50% caustic solution and separated by filtration from sodium fluoride crystals through a difficult filtration process. This sodium fluoride can be converted into aluminium fluoride or calcium fluoride by aqueous processes	• Several elements are recycled for reuse	• Difficult process to implement • The second stage of process is difficult (specialised expertise, and there are some other difficulties with the process).* • Due to the complexity and accompanying problems it is not considered	**No**
5	Treatment	***Comalco Comtor process*** The Comtor process consists of two main stages. After suitable preparation, the spent pot lining is fed into a calcining stage. In this stage the leachable cyanides are destroyed and generated gases are controlled through a filtration system. The released fluorine can be recovered or stabilised. The residue consists mainly of refractory materials, which is no longer considered hazardous waste	• Destruction of cyanide and treatment of fluoride. • Existing and new calcining facilities.	• Not known if it is feasible in Alba's facilities	**Yes**

* The placement of the lower valued caustic product and carbon product in many localities will be challenging;
The caustic liquor is extensively recycled in the process leading to the possibility of impurity build-up in the circuit; The Alcan process will also require more sophisticated technical management (hydrometallurgists) to operate effectively.

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#		Method	Advantages	Disadvantages	Option
6	Treatment	***Reynolds Metals rotary kiln process*** The Reynolds treatment process entails the crushing and sizing of spent pot liner materials, the addition of roughly equal portions of limestone and brown sand as flux, and the feeding of the combined mixture to a rotary kiln, heated to 650°C, for thermal destruction of cyanide and PAH's and binding or fluoride into calcium fluoride.	• Destruction of Cyanide and neutralisation of fluoride.	• The addition of brown sand prevents the mixture from clogging in the kiln but creates approximately 2.5 times the amount of waste (although non-hazardous).	**No**
7	Treatment	***Ormet Process using a Combustion Melting System*** The SPL is fed with sand and limestone to a CMS™ process to melt, or vitrify, the raw materials at high temperatures. Products and residuals of the process include the vitrified material (or glass frit) and air pollution control wastes consisting of bag house dust and dry scrubber residue.	• Destruction of Cyanide and fluoride volatilizes and is removed in air pollution control wastes.	• The process generates non-hazardous glass frit that contains the hazardous constituents which will pose pressure on landfill.	**No**
8	Treatment	***Befesa Integral Waste Recovery Method*** Befesa, an international company specializing in the integral management of Industrial wastes, established five SPL recovery plants in Europe. New technologies for integral waste recovery are emerging in Europe providing major Aluminium producers with a definitive solution.	• Befesa aims to be established in the Gulf Region by 2017 • Integrated Approach whereby all cyanides and soluble fluoride salts are removed. All of the solid metals obtained are reused, closing the cycle for aluminium waste recycling and using every part of the aluminium-containing waste.	• Technical details on removal method not available at this stage.	**Yes**

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1.3 Cement Industry

Two options are possible for waste management of SPL's in the cement industry. The carbon fraction can be used for its calorific value and the refractory can be used as a raw material substitute.

1.3.1 First Cut - Carbon Fraction

Tests have shown that well sorted carbon fractions of the carbon fractions could be used blended with coal (2% of the SPL mixture) without causing any negative effect on the production process. Stack emissions and quality of the clinker produced during the process were not affected as a result of the presence of SPL.

1.3.2 Second Cut - Refractory Fraction

The presence of alumina and silica in SPL allow it to be used as cement raw material. These elements are present in the quarry materials, and in some cases may not be present in sufficient levels. In certain cases addition of these materials may even be necessary.

1.3.3 Application to Alba

From the perspective of feasibility, cement industry management of SPL depends mostly on whether the local cement industry is willing or can absorb the material, and if it is feasible to transport the material. It will be up to Alba to negotiate with cement companies, the following section will examine the other factors.

In both cases (fuel and refractory) careful attention has to be paid to the balances of fluoride and calcium where the SPL will be recycled. The amount that can be introduced will depend on the ratio of these elements that already present in the natural raw materials.

Generally, the SPL content in cement is less than 1% by weight. Considering the amount of future SPL waste production (7,961 tonnes of hazardous SPL for future L6 and crept L1-5), a significant amount of cement production is required (over 7.96 million tonnes cement). Assuming a truck load of 35 tonnes (Dutch Load Standard), 228 truckloads per year are required to transport the material. The amount of truckloads needed to transport the material suggests that transport of the material is an impediment of the technology / method.

On the one side transportation is a disadvantage of the SPL treatment / disposal method, however on the other side all parts of the SPL can be used in the cement industry. With other management techniques, the hazardous materials are destroyed in the treatment process, but slag remains. Thus leaving the task of finding a way of properly disposing and/or using the slag.

As previous mentioned, the environmental benefits of using the cement industry to recycle SPL are that the Hazardous elements in the SPL are destroyed or neutralised. Cyanides are combusted and fluorides are bound in the cement mix. Research has shown that residual impacts from this process are minimal. It should be noted that the transport needed might cause other environmental impacts.

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1.4 Alcoa Portland SPL process

The process was developed at Alcoa's Portland aluminium smelter in conjunction with Ausmelt Ltd and Australia's Commonwealth Scientific Industrial Research Organisation (CSIRO) to render harmless spent pot linings, produced by aluminium smelters.

The Alcoa Portland SPL Process consists of two main stages. In the first, after suitable preparation (crushing, making briquettes, and screening), the spent pot lining is fed into an Ausmelt designed top submerged-lance furnace, where the cyanide-forming chemicals are destroyed at temperatures of 1,250 °C and the contained fluoride is driven off as hydrogen fluoride. The residue (material remaining in the furnace or slag) is a granulated vitreous material known as 'synthetic sand' (slag). In the second stage, a gas-conversion process, developed by Portland Aluminium, converts the hydrogen fluoride off-gases, which have cooled and filtered, into aluminium fluoride in a multistage fluidised bed reactor. The aluminium fluoride is recycled into the aluminium smelting process as a replacement for imported aluminium fluoride.

The synthetic sand produced in the first stage of the process has been cleared by the Victoria EPA for unrestricted use in applications such as road building and concrete, providing that it continues to have a fluoride leachability measure of less than 15 ppm. According to Alcoa, the process achieves this standard.

The plant has been commissioned in 2001 with a capacity of 12,000 tonnes per year.

1.4.1 Application to Alba

At the practical level, the Alcoa Portland Process appears to have several advantages. For example it is sufficiently developed to be commercialised[2] with acceptable levels of risks and it also has the additional value of producing a high value aluminium fluoride product that can be recycled back into the aluminium production process. In addition to this, and as a result of the raw material recycling, it is also claimed to be economically viable.

From an environmental perspective and in considering needed mitigation, the process has several benefits, such as

- The destruction of cyanide component of the SPL;
- The recovery of the fluoride components as aluminium fluoride for re-use in the aluminium smelting process; and
- Generation of a slag output product that is not harmful to the environment and can be safely used as safe road surfaces, foundations or in the cement industry.

[2] The process has been patented (approved or file) through international patent Application WO 94/22604, 6 April 1993: "Combustion of SPL via Top Submerged Lance Smelting" and through Provisional Patent application Number PR 5194 "Process for the Production of the Aluminium Fluoride".

The Alcoa Portland Process eliminates the environmental impacts that result from cyanide and fluoride contamination. The remaining slag could also be used as a raw material in road construction or in the cement industry. Using this as a mitigation measure would greatly reduce the impacts of additional waste production in the proposed expansion.

Unfortunately, a negative practical issue that remains for this method of SPL management is finding an environmentally (avoiding excessive transport) and logistically feasible way for use remaining slag material. Tebodin believes that this issue could be solved in cooperation with local road contractors or government officials.

1.5 Comalco Comtor process

The Comtor process was developed by Comalco at Boyne Island smelters in Australia. Research has revealed very little detail on the method. As already mentioned the Comtor process consists of two main stages. After suitable preparation of the SPL, crushing the spent pot lining to usable feed size, the spent pot lining is fed into calcining stage where the leachable cyanides are destroyed and generated gases are controlled through a filtration system. The released fluorine can be recovered or stabilised. The residue consists mainly of refractory materials, which are no longer considered hazardous waste.

1.5.1 Application to Alba

When viewing the Comtor SPL process with the perspective of practical application, it seems to offer an interesting option. The Comtor relies on the high temperatures generated in the calcining process and advance fluoride fume treatment to reduce the hazardous components of SPL. Alba already possesses advanced fume treatment knowledge (GTC and FTC) and has just constructed a new calcining facility. Little information is available on the details of the method. Thus further research and engineering would be needed to assess the technically feasibility. One possible disadvantage of this method results because of the impure composition of SPL. SPL can become ‘sticky’ when heated at high temperatures leaving residue in furnaces. This would cause additional difficulties for calcining and may affect the effectiveness of the calcining process.

From an environmental perspective and in considering needed mitigation, the process eliminates the environmental dangers from cyanide, and fluoride. Actual reduction of environmental damage caused by fluoride would depend on the effectiveness of the fluoride scrubbing. A danger exists of transferring environmental impact from the ground to the air. As with the slag that remains in the Alcoa process, a suitable logistical and environmental manner would have to found for its’ recycling.

1.6 Other Options

In addition to the options discussed above, the following information can be useful to get an overview of the possibilities for treatment of SPL.

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1.6.1 Alcoa Quebec SPL process

Lacking options in the Quebec region to recycle spent pot lining, Alcoa's three Canadian smelters sourced alternatives in the United States and Germany that increased the amount of SPL they recycled to 90% in 2010 while saving US$2 million in costs.

Government regulations for recycling SPL and an insufficient customer base in the Quebec region where the smelters are located stymied efforts to find a local economically viable recycling solution. As a result, the Canadian smelters sent a portion[3] of their SPL to Alcoa's Gum Springs, Arkansas, facility in the United States for processing.

As part of a recycling program, a large portion of the first cut (carbon fraction) is send to Germany where it is used as an alternative fuel source. In addition, the refractory waste and remaining carbon material is sent to U.S.-based cement manufacturers were the waste is used as a mineraliser. This strategy resulted in recycling of over 90% of the total SPL waste.

1.6.2 Tetronics' technology

Tetronics Ltd is specialized in of Waste Recovery Plants. The company patented a Direct Current (DC) Plasma Arc plant technology, which can be seen as a sustainable alternative for waste management using ultra-high temperatures to melt, gasify or vaporise any waste material, in order to treat, recover or generate commercial products.

Tetronics has experience and know how in the characterisation and treatment of SPL and worked in close collaboration with one of the world's largest aluminium producers, with an annual output of 4 million tonnes of aluminium.

1.6.3 Befesa Integral Waste Recovery Method

Since 2011 Befesa, an international company specializing in the integral management of industrial wastes, established five SPL recovery plants in Europe (three in Germany, one in Spain and one in the UK).

Befesa approach seeks to remove the cyanides and soluble fluoride salts. All of the solid metals obtained are reused, closing the cycle for aluminium waste recycling and using every part of the aluminium-containing waste. However, technical details on the specific approach are not available at this stage.

Recently, a memorandum of understanding was signed between Befesa and Senaat (an Abu Dhabi based industrial investment and holding company) to jointly develop a slags and SPL recycling plant in Abu Dhabi Emirate, United Arab Emirates to treat SPL waste from GCC countries. As Befesa aims to be established in the Gulf Region by 2017, Alba might be one of their future clients.

[3] 11% in 2008

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1.7 Mitigation of Spent Pot Lines

Table A3 summarizes the reduction of SPL waste and environmental impacts.

In general, all methods could lead to the reduction of 2,848 tonnes of SPL waste and the reduction of approximately 50% of un-recycled or treated solid waste. Each method also destroys cyanide and deals with fluoride. The environmental threat of these compounds is therefore also mitigated to different extents. These methods have another positive environmental side effect, in that the use of raw material used in for road construction and/or cement industry can be reduced by use of the inert slag.

Table A3: Reduction of SPL waste and environmental impacts

	Reduction of non-recycled Wastes	Environmental benefits /drawbacks
Cement industry	SPL is 100% recycled Cyanide destroyed Fluoride neutralised	Impacts mitigated Air quality impacts result from transport
Alcoa Portland spent pot lining process	100% of SPL can be recycled Cyanide destroyed Fluoride recycled	Impacts mitigated if slag can be utilised Fluoride is recycled
Comalco Comtor process	100% of SPL can be recycled Cyanide destroyed Fluoride neutralised	Impacts mitigated if slag can be utilised

It is suggested that Alba applies one of these methods to their waste management plan to mitigate the environmental impact of SPL in the proposed expanded operations. Furthermore, possible implementation of the Befesa technology in the gulf region provides future options to fully recycle Alba's SPL waste.

2 References

1. US EPA - Best Demonstrated Available Technology (BDAT) Background Document For Spent Aluminum Potliners – K088 (31 May 2000)

2. US EPA - Economic Assessment of the Revised LDR Treatment Standards for Spent Aluminum Potliner (K088) (23 May 2000)

3. Managing Wastes from Aluminium Smelter Plants. B. Mazumder and B.K. Mishra. Published by Woodhead Publishing India Pvt. 2011

4. Alcoa Inc. - Fluoride-containing hydraulic cements and methods of making the same (2008)

Appendix 20: Noise Modelling

Client: **Bechtel**
Project: ALBA Potline (6) and Power Plant (PS 5) Expansion

Appendix 20: Noise Modelling

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1 Noise Modelling

1.1 Introduction

A quantitative assessment through noise modelling was conducted as part of the present ESIA study to determine the additional contributions to the ambient noise levels from the proposed PL-6 project.

The noise modelling for evaluation of noise contributions was conducted using SoundPLAN developed by Braunstein & Berndt GmbH, Germany. The model is based on sound pressure wave divergence. SoundPLAN is a Microsoft Windows based software tool, which can accept multiple stationary noise sources.

The propagation methodology adopted within the SoundPLAN model was the ISO 9613 'Acoustics – Attenuation of Sound during Propagation Outdoors' This methodology takes account of the following physical effects:

- Geometrical divergence;
- Atmospheric absorption;
- Ground effect;
- Reflection from surfaces; and
- Screening by obstacles.

This method is applicable in practice to a great variety of noise sources and environments. It is applicable, directly or indirectly, to most situations concerning: industrial noise sources, road or rail traffic, construction activities, and many other ground-based noise sources.

1.2 Background Noise Levels

Prior to modelling, background noise levels in the area were recorded through monitoring. The noise monitoring results are presented in Table A-1 and A-2 respectively. The results of the monitoring were used as input to the noise model to evaluate the overall contributions from PL-6 operations.

Table A- 1: Noise Data Inventory GTC and FTC

#	UTM Coordinates		Sound Pressure Levels in dB(A)					Remarks	Time
	Easting	Northing	L_{eq}	L_{max}	L_{min}	L_{10}	L_{90}		
Weekend- 8th February 2014:Daytime									
1	460862	2886035	69.3	75.8	65.6	70.1	63.6	Close to PL-6 office	12:20
2	460977	2885684	66.5	72.4	60.4	69.1	61.9	Along the eastern fenceline	12:45
3	461219	2884945	71.0	73.7	66.5	71.9	67.0	South Gate- close to emergency clinic- heavy vehicle movements	13:10

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#	UTM Coordinates		Sound Pressure Levels in dB(A)					Remarks	Time
	Easting	Northing	L_{eq}	L_{max}	L_{min}	L_{10}	L_{90}		
4	461131	2884932	64.8	73.2	61.1	68.1	61.9	Fence-line east of ALBA lake	13:30
5	459418	2885583	62.2	64.4	59.8	62.5	61.0	North-west fenceline	13:50
6	459358	2885786	58.3	61.3	56.0	59.4	56.2		14:20
7	459555	2885112	66.5	68.7	65.6	67.2	65.8		14:45
8	459651	2884846	58.5	61.7	51.6	59.7	56.6	South-west corner	15:30
9	459916	2884649	58.5	62.3	56.6	59.7	56.6	Close to Jawad textile mill	15:00
10	460989	2884675	69.1	82.0	49.1	72.5	64.8	Excavation works ongoing close to ALBA lake	15:50
11	460005	2884821	66.0	74.3	60.8	69.5	61.7	South-east fenceline	16:20

Table A- 2: Noise Data Inventory GTC and FTC

#	UTM Coordinates		Sound Pressure Levels in dB(A)					Remarks	Time
	Easting	Northing	L_{eq}	L_{max}	L_{min}	L_{10}	L_{90}		
Weekday- 9th February 2014:Daytime									
1	460862	2886035	69.4	75.6	65.4	70.0	63.4	Close to PL-6 office	9:30
2	460977	2885684	66.0	72.1	60.2	68.7	61.7	Along the eastern fenceline	10:00
3	461219	2884945	70.5	73.8	66.5	71.4	66.9	South Gate- close to emergency clinic- heavy vehicle movements	10:20
4	461131	2884932	64.0	72.5	60.2	67.2	61.4	Fence-line east of ALBA lake	10:30
5	459418	2885583	62.3	64.2	59.6	62.7	61.1	North-western fenceline	10:45
6	459358	2885786	59.0	62.1	56.4	59.7	56.5		11:20
7	459555	2885112	66.8	69.1	65.8	67.4	66.1		11:45
8	459651	2884846	58.6	61.9	51.8	59.9	56.7	South-west corner	12:30
9	459916	2884649	58.7	62.6	56.5	59.9	56.7	Close to Jawad textile mill	13:00
10	459598	2886130	66.0	73.0	64.8	66.5	65.1	North Gate	13:30
11	459896	2886420	67.3	70.2	65.4	68.5	65.9	Outside PS-4	14:20
Weekday- 10thFebruary 2014:Daytime									
12	467146	2893181	68.6	71.6	67.4	69.4	62.3	Calciner- close to proposed ship loading area	09:00
13	458030	2885724	73.5	80.0	46.1	48.4	75.4	Camps off-plot ALBA facility: heavy traffic	15:25
14	456734	2885769	61.0	67.8	50.8	65.6	52.6	Golf Course	16:00
Weekday- 9th February 2014:Night time									
1	461219	2884945	65.6	73.0	60.1	70.0	62.5	Near South Gate	00:15

#	UTM Coordinates		Sound Pressure Levels in dB(A)					Remarks	Time
	Easting	Northing	L_{eq}	L_{max}	L_{min}	L_{10}	L_{90}		
Weekday- 10th February 2014:Night time									
1	459651	2884846	58.2	61.6	50.4	59.0	56.3	South-west corner	23:40
2	459916	2884649	57.0	62.0	50.1	59.1	56.1	Close to Jawad textile mill	00:10
3	459896	2884642	67.1	70.2	65.0	68.0	65.7	Outside PS-4	01:30
4	460862	2886035	69.0	75.0	65.4	70.1	63.4	Close to PL-6 office	02:10
5	460977	2885684	66.0	71.3	58.4	68.1	61.4	Along the eastern fenceline	03:15

As can be seen through the results of the monitoring revealed from the above Tables, the ambient noise levels at all areas were noted to (Leq 58.3 dB(A) – 73.5 dB(A)) be within the applicable limits set by the World Bank for industrial and commercial locations (70 dB (A) for both day- and night-time) except for the area close to the clinic where high noise levels were noted from vehicle movements along the nearby highway.

1.3 Emissions Inventory

Subsequent to noise monitoring, a noise emissions inventory was developed using the details of the various noise generating sources added to the facility from PL-6 operations. The details of the same including the sources identified and their duration of operation as well as their respective sound power levels are as presented in Table A-3 and Table A-4 respectively. It has to be stated that below sound pressure levels are estimations based on current information.

Table A- 3: Noise Data Inventory GTC and FTC

#	Generation Source	No. of Sources	Source Location		Nature of Noise Generation	Noise Level Sound Pressure Level
			Easting	Northing	(Continuous / Intermittent)	
1.0	North GTC - Main ID Fans	Total 6				
a)	North GTC- Fan No 1	1	459867	2885557	Continuous	Fan casing - 77 dB(A) @ 1m Motor - 81 dB(A) @ 1m
b)	North GTC- Fan No 2	1	459869	2885546	Continuous	
c)	North GTC, Fan No 3	1	459872	2885532	Continuous	
d)	North GTC- Fan No 4	1	459874	2885521	Continuous	
e)	North GTC, Fan No 5	1	459876	2885510	Continuous	
f)	North GTC, Fan No 6	1	459878	2885500	Intermittent	
2.0	North GTC - Stack	1	459903	2885468	Continuous	Sound Power Level at discharge: 103 dB(A)
3.0	South GTC - Main ID Fans	Total of 6				
3.1	South GTC, Fan No1	1	460001	2884917	Continuous	Fan casing - 77

#	Generation Source	No. of Sources	Source Location		Nature of Noise Generation	Noise Level Sound Pressure Level
			Easting	Northing	(Continuous / Intermittent)	
3.2	South GTC, Fan No 2	1	460004	2884905	Continuous	dB(A) @ 1m Motor - 81 dB(A) @ 1m
3.3	South GTC, Fan No 3	1	460006	2884893	Continuous	
3.4	South GTC, Fan No 4	1	460008	2884881	Continuous	
3.5	South GTC, Fan No 5	1	460011	2884869	Continuous	
3.6	South GTC, Fan No 6	1	460013	2884858	Intermittent	
4.0	South GTC - Stack	1	460037	2884823	Continuous	Sound Power Level at discharge: 103 dB(A)
5.0	L6 FTC - Main ID Fans	Total of 4				
5.1	Fan No 1	1	459554	2885587	Continuous	Fan casing - 77 dB(A) @ 1m Motor - 81 dB(A) @ 1m
5.2	Fan No 2	1	459548	2885586	Continuous	Same as above
5.3	Fan No 3	1	459542	2885585	Continuous	Same as above
5.4	Fan No 4	1	459537	2885584		Same as above
6.0	FTC - Stack	1	459524	2885579	Continuous	Sound Power Level at discharge: 103 dB (A)
7.0	Rectifiers	Total of 6				
7.1	Rectifier No 1	1	459685	2885857	Continuous	83 dB(A) @ 1m
7.2	Rectifier No 2	1	459688	2885832	Continuous	83 dB(A) @ 1m
7.3	Rectifier No 3	1	459693	2885807	Continuous	83 dB(A) @ 1m
7.4	Rectifier No 4	1	459697	2885782	Continuous	83 dB(A) @ 1m
7.5	Rectifier No 5	1	459702	2885758	Intermittent	83 dB(A) @ 1m
7.6	Rectifier No 6	1	459707	2885733	Intermittent	83 dB(A) @ 1m

Table A- 4: Noise Data Inventory Power Station 5

Source	No. of Sources	LwA per 1/3 octave band (centre frequency)										Building Height
	Total	31.5	63	125	250	500	1000	2000	4000	8000	LwA	
CT package												
Inlet	Total of 2	120	113	110	100	88	86	76	87	91	98	18.0
Inlet Plenum	Total of 2	120	114	111	102	87	89	97	90	86	102	3.5
Turbine compartment vent	Total of 2	108	110	105	103	100	98	104	99	94	108	6.0

Source	No. of Sources	LwA per 1/3 octave band (centre frequency)									Building Height
	Total	31.5	63	125	250	500	1000	2000	4000	8000	LwA	
fan (inside bld)												
Exhaust Diffuser (inside building)	Total of 2	133	125	114	112	110	104	103	102	97	112	5.0
Load compartment (inside bld)	Total of 2	105	105	105	100	97	94	97	93	92	102	5.0
Accessory compartment (inside bld)	Total of 2	105	106	103	101	98	95	98	95	91	103	3.5
Generator (inside bld)	Total of 2	112	116	112	98	100	102	101	96	93	107	5.0
Turbine compartment vent fan	Total of 2	104	102	107	102	98	98	94	95	92	103	8.5
Exhaust compartment vent fans	Total of 2	102	101	107	99	96	95	92	92	91	101	8.5
Bypass stack (~35m)	Total of 2	129	127	123	121	118	117	112	102	100	121	35.0
CT Fin Fans	Total of 36	104	108	108	105	102	100	97	95	90	105	4.0
STG package (inside metal siding bld)	Total of 2	118	125	121	114	112	110	110	108	104	117	15.0
ST Fin Fans	Total of 36	104	108	108	105	102	100	97	95	90	105	4.0
HRSG Package												
HRSG inlet	Total of 2	123	122	115	112	108	101	98	92	88	109	15.0
HRSG body	Total of 2	122	118	111	106	100	93	88	86	80	103	27.0
HRSG stack exit (~50m)	Total of 2	120	122	122	120	113	100	80	74	73	115	50.0
HRSG stack breakout	Total of 2	97	99	101	100	90	89	64	54	60	95	0-50
BFW pumps	Total of 4	103	108	115	110	105	105	107	104	95	112	2.0
ACC tower fan noise (per fan) 15cells per tower	Total of 30	107	110	109	106	100	100	95	92	85	105	20.0
CCW pumps (inside STG building)	Total of 4	90	90	89	90	88	90	91	82	76	95	2.0
STG transformer	Total of 2	110	112	110	108	104	102	100	98	94	108	5.5
CTG transformer	Total of 2	110	112	110	108	104	102	100	98	94	108	5.5
Fuel Gas Compressors	Total of 2	112	114	114	113	112	110	107	106	105	115	3.5

Appendix 21: SCE Guideline for CEMP

EIA- 12
Construction Environmental Management Plan (CEMP) Guidelines

Objective: To provide a transparent framework with clear accountabilities for managing the preparation of the Construction Environmental Management Plan (CEMP) in order to manage the environmental effects associated with the project in order to achieve acceptable environmental outcomes.

Required CEMP Content and Recommended Format:

The content of a CEMP may vary by project as the size and scope of a construction project. To promote familiarity and ease of use, a recommended format for the CEMP is provided in the following table, and an overview of the individual CEMP sections is described below. Where other formats are used, the content of each CEMP must include, at a minimum, all of the sections listed in the table. The CEMP also should include a list of acronyms and abbreviations, a glossary of terms, and full references to sources of information.

Recommended Format for the CEMP		
Section 1	Project Title	**Cover Page** Table of content List of Tables List of Figures List of Abbreviations Definition of Terms
Section 2	Project Team Identification (Stackolder)	
Section 3	Introduction	
Section 4	Project Description	4.1 Location 4.2 Planned Construction Activities
Section 5	Environmental Management	5.1 Policy Statement 5.2 Environmental Management Systems 5.3 Roles and Responsibilities 5.4 Regulations and Requirements 5.5 Environmental Awareness and Training

		5.6 Document Review and Updates 5.7 Environmental Commitments 5.8 Coordination with External Entities and Addressing Complaints
Section 6	Environmental Impacts	6.1 Air Emissions Impacts 6.1.1 Dust 6.1.2 Gaseous Pollutants and Particulate Matter Impacts 6.1.3 Odour 6.2 Surface Water Impacts 6.3 Soil and Groundwater Impacts 6.4 Terrestrial Ecology Impacts 6.4.1 Discharges to Land 6.4.2 Ecosystem (Fauna) 6.4.3 Ecosystem (Flora) 6.5 Marine Ecology Impacts 6.5.1 Discharges to Marine Waters 6.5.2 Ecosystem (Fauna) 6.5.3 Ecosystem (Flora) 6.6 Noise and Vibration Impacts 6.7 Traffic Impacts 6.8 Waste Management Impacts 6.8.1 Solid Waste 6.8.2 Liquid Waste (Effluent) 6.8.3 Hazardous Waste 6.9 Other Environmental Impacts
Section 7	Environmental Mitigation Measures	7.1 Air Quality Control Plan 7.1.1 Dust Management 7.1.2 Gaseous Pollutants Management 7.1.3 Odour Management 7.2 Erosion and Sediment Control Plan 7.3 Soil and Groundwater Contamination Control Plan 7.4 Terrestrial Ecology Control Plan 7.4.1 Terrestrial Ecological Management 7.5 Water Quality and Marine Ecology Control Plan 7.5.1 Wastewater Management 7.5.2 Marine Ecological Management

		7.6 Noise and Vibration Control Plan 7.7 Traffic Control Plan 7.8 Waste Management Control Plan 7.8.1 Minimization, Reuse, and Recycling 7.8.2 Solid Waste Management 7.8.3 Liquid Waste (Effluent) Management 7.8.4 Hazardous Waste Management 7.8.5 PCBs, Asbestos, and Ozon-Depleting Substance Management 7.8.6 Use of Environmental Service Providers for Waste Management 7.9 Chemical and Hazardous Materials Management 7.10 Contingency Plan 7.11 Emergency Management Plan 7.11.1 List of Emergency Coordinators 7.11.2 Emergency Procedures 7.12 Security Plan 7.13 Infrastructure Plan
Section 8	Monitoring and Auditing	8.1 Environmental Performance Monitoring 8.2 Reporting Requirements 8.2.1 Incident Reports 8.2.2 Periodic or Quarterly Performance Reports 8.2.3 Monitoring Compliance Reports 8.2.4 Environmental Checklists
Section 9	Documentation	
Section 10	Annexes	

1. Section One: Project Title

- At a minimum, the cover page of the CEMP should include the following:

✓ Project title;
✓ The proponent's name, address, and contact information;
✓ The consultant's name, contact information;
✓ The contractor's name and contact information

After cover page following to be included:

- Table of content
- List of Tables
- List of Figures
- List of Abbreviations
- Definition of Terms

2. Section Two: Project Team Identification (Stakeholder)

The purpose of the stakeholder list is to establish communication channels that will enable more effective control of environmental-related issues. The stakeholder list should identify relevant government agencies, potentially affected parties and the community. A public information and stakeholder consultation program is to be prepared and implemented by the proponent to ensure that the public is familiar with the issues related to the project and that stakeholders are consulted on pertinent issues. Stakeholder list could include the proponent, the environmental consultant, lead contractors, subcontractors and any appointed environmental managers (or other identifiable titles for the persons in charge of implementing the contents of the CEMP).

This section should outline a program for community consultation and communications during the construction.

3. Section Three: Introduction

The introduction should provide a discussion on the reasons or necessity of the project, nature of the project, steps led to the selected project, and if the project is part of a larger proposal.
The project developer must be clearly identified, the consulting team who carried out the assessment;

This section should:

✓ Describe consultation activities undertaken during the preparation of the CEMP;
✓ Outline the outcomes of consultation undertaken during the CEMP preparation process, the issues and suggestions raised by stakeholders or members of the public;

This section should include the environmental permit given for the project. This section should include information about the status of approval for any additional licenses or permits required to perform construction activities.

4. Section Four: Project Description

The Project Description section should include information on the location, overall project planned construction activities, project schedule and milestones, as discussed below.

4.1 Location

The Location section should include a general description of the location.

This section should include details regarding the current condition of the environment at areas potentially impacted by construction activities at the site and surrounding area, and should accomplish the following:

- ✓ Briefly describe the existing environment for each environmental component at the site and surrounding areas. Relevant information may include previous or current land use, monitored noise levels, the presence of soil or groundwater contamination, air quality or water quality measurements, the presence of wildlife, marine resources, or vegetation;
- ✓ Reference baseline data taken from the EIA performed for the project or other studies where baseline data adequately represent the condition of the environment on the proposed project site and adjacent surroundings;
- ✓ Identify sensitive receptors located in the vicinity of the proposed project site, including justification for how the sensitive receptors were determined.

Provide maps that show the geographic location of the project area and surroundings, the maps should show the relative location of sensitive receptors to the project site, including the distance, It should provide maps that. Maps should include all necessary information, such as key, scale, north arrow, legend, location of sensitive receptors, and distance to sensitive receptors

4.2 Planned Construction Activities

This section should cover project construction phases "if any". For example, if activities will be conducted in separate phases, and the CEMP is being submitted only for one particular phase of the development, then this section should describe those activities.

This section should include:

- ✓ Method statement describing the planned construction activities, the discussion may include but are not limited to excavation, demolition, works related to earthworks, infrastructure, dewatering, piling, enabling works, rerouting of pipes, and site remediation, along with typical construction activities;

- ✓ Commencement and completion dates (if the project to be completed in phases, then separate dates for each phase to be provided);
- ✓ Working hours, including the activities required to be undertaken outside these hours;
- ✓ Employees number;
- ✓ Plant and equipment to be used;
- ✓ Location of the site facilities

The CEMP should provide sufficient technical detail to allow for DEAP reviewers to determine the potential impacts.

5. Section Five: Environmental Management

This section should include information regarding the policy statement, Environmental Management Systems, project personnel roles and responsibilities, Environmental Health and Safety EHS regulations and requirements, environmental awareness training, CEMP review and updates, and environmental commitments. The following subsections provide instructions as to the required information that proponents should include for this section of the CEMP.

5.1 Policy Statement

The Policy Statement section should describe the proponent's commitment to environmental protection, health, and safety management and compliance with applicable regulations.

5.2 Environmental Management Systems

The Environmental Management Systems section should discuss the way in which the plan corresponds to the proponent's and/or the main contractor's Environmental Management Systems or the Construction Environment, Health and Safety Plan (EHSMS) Regulatory Framework.

5.3 Roles and Responsibilities

Roles and Responsibilities section should include the roles and responsibilities of personnel in relation to implementation, management, and review. It is the responsibility of all contractors and subcontractors to adhere to requirements contained in the approved EIA, CEMP and all applicable environmental regulations. CEMP adherence to regulations should be contained in any contractual documents between the entities. CEMP should accomplish the following:

- ✓ Provide the names, positions, and contact information of personnel involved with ensuring the proper implementation of the CEMP. For those positions for which personnel have not yet been assigned, the proponent should note this information within the CEMP;

- ✓ Clearly discuss the roles and responsibilities of the proponent, contractors, and subcontractors identified and the interrelationships between these entities "Clearly defined roles and responsibilities will help to ensure that the CEMP is an effective document that will be properly implemented by all personnel involved during the construction process";
- ✓ Provide organizational flowcharts or other diagrams of key personnel "For the better understanding of the relationships between the key individuals among each of the entities"

5.4 Regulations and Requirements

The Regulations and Requirements section should detail the legal framework and requirements to be adhered to during construction and should include the following information:

- ✓ A listing of the applicable environment regulations with which the proponent will comply; this list should include local, national, and international rules and standards or agreements;
- ✓ A listing of any applicable environmental standards, such as air quality or water quality concentrations…etc. The CEMP should also provide sufficient information to clearly define these standards;
- ✓ Information about the conditions contained in any additional licenses required to perform construction activities;
- ✓ A listing of any voluntary agreements, stakeholder agreements, or procedural requirements that must be adhered to during construction

5.5 Environmental Awareness and Training

The Environmental Awareness and Training section should include and overview of the proponent's systematic program to ensure that employees are aware of the CEMP and other environmental requirements. The CEMP should define the competency of the training provider, the frequency of training, and the levels of training for personnel. This information should include, but not be limited to, the following:

- ✓ A description of the environmental awareness and training program for personnel, contractors, and subcontractors needed to comply with measures contained within the CEMP;
- ✓ Identification of training needs, including general knowledge of the CEMP and activity specific guidance for different activities (e.g., the handling of hazardous waste, operation of certain equipment);

- ✓ Established procedures for maintaining records of all training to be performed, including the name of the person trained, the date of training, the name of the trainer, and a description of the training content

5.6 Document Review and Updates

The Document Review and Updates section should establish procedures for the periodic review of the CEMP to ensure that the plan's contents are correct and that it is being properly implemented. These reviews will ensure that—"should conditions arise that alter the plan's contents or requirements—the CEMP remains updated to reflect these changes".

In this section, the project proponent should accomplish the following:

- ✓ Demonstrate how the proponent intends to keep the CEMP as a "live" document, capable of modification during the project's life cycle and as circumstances dictate;
- ✓ Indicate who will regularly review, update the CEMP as construction progresses;
- ✓ Outline procedures for the periodic review of the CEMP to ensure that its contents are correct and that it is being properly implemented

5.7 Environmental Commitments

The Environmental Commitments section should include a summary of the environmental commitments that will be made to manage potential environmental effects. The CEMP environmental commitments statement should describe the following:

- ✓ Adherence to all outcomes and obligations of this CEMP;
- ✓ Proposed mitigation measures and monitoring activities against all residual impacts, unexpected releases, and anything that compromises worker safety;
- ✓ The nature of the work to be undertaken;
- ✓ The objectives to be met;
- ✓ Responsible body for the CEMP environmental commitments;
- ✓ Who is responsible for monitoring and recording that the CEMP environmental commitments are properly fulfilled;

Each CEMP environmental commitment containing the information in the above list should be numbered and indexed in the body of the CEMP to allow for quick reference. The CEMP should also be designed to allow interested parties to determine whether relevant issues have been addressed.

5.8 Coordination with External Entities and Addressing Complaints

The Coordination with External Entities and Addressing Complaints section should provide a management system to receive and address complaints, manage correspondence with any parties that may be affected by the construction activities (e.g., local communities that may be affected by noise or vibration …etc.), document the complaints, and address the corrective actions to be implemented to rectify any deviation from performance standards.

6. Section Six: Environmental Impacts

The Environmental Impacts section of the CEMP should outline the specific construction activities at the project site and on the surrounding environment and note any significant impacts. The plan should also explain the methodology used for determining significant impacts and reference any previously performed environmental studies that provide more extensive assessment of these impacts (e.g., EIA, EHIA). If an environmental study was performed, the proponent should ensure that the impacts discussed in the study are included in the CEMP. If no prior environmental study was performed, the CEMP should include in-depth analysis of the identification of potential impacts and how significant impacts were chosen. The environmental impacts that must be assessed in this section are, at a minimum, air emissions, surface water, soil and groundwater, terrestrial ecology, marine ecology, noise and vibration, traffic, and waste management, as discussed below.

6.1 Air Emissions Impacts

The Air Emissions Impacts section should include, but not be limited to, information regarding dust, gaseous pollutants and particulate matter (PM), and odor. The following subsections provide further information on these components.

6.1.1 Dust

Dust or PM may be emitted from various construction activities, including demolition, traffic along unpaved roads, wind from soil stockpiles, and graded or desert soil. Therefore, this section should accomplish the following:

- ✓Identify all types of dust emissions and sources present during different phases of construction, as well as other pertinent information related to these components;
- ✓List Kingdom of Bahrain emission standard limits and other known international standards if needed

6.1.2 Gaseous Pollutants

Gaseous pollutants, such as Nitrogen oxides (NOx), sulphur oxides (SOx), and volatile organic compounds (VOCs) …etc may be emitted from various construction activities, including the burning of fossil fuel from vehicles and equipment. Therefore, this section should include, but not be limited to, the following information:

- ✓ Identification of all types of gaseous emissions, sources, and flow rates present during different phases of construction, as well as other pertinent information related to these components;
- ✓ A detailed table that shows the fuel consumed for all construction equipment, including fuel type (e.g., diesel, gas), consumption rates, source(s), the units that are operated, and the estimated quantity to be stored on site;
- ✓ A listing of applicable emission standard as per the Ministerial Order No. 10 of 1999 and relevant amendment and other known international standards if required.

6.1.3 Odor

Construction activities have the potential to cause odor problems, which can be a nuisance and cause negative health impacts. Therefore, the CEMP should take into account the presence of compounds that cause odors and must, at a minimum, accomplish the following:

- ✓ Identify and describe the likely source(s) of odor;
- ✓ Specify the qualities or characteristics of any odors (e.g., fishy, almond …etc.);
- ✓ Determine the concentration by measuring the amount of odor-causing chemicals in an air sample;
- ✓ Discuss the anticipated odor intensity;
- ✓ Identify the relevant maximum allowable limits from international standards

6.2 Surface Water Impacts

The Surface Water Impacts section should provide detailed surface water impacts related to storm water. This information should include, but not be limited to, the following:

- ✓ A base map that contains boundary lines of the projected industry site and the nearest storm drain;
- ✓ An analysis of site limitations and development constraints that includes factors such as slope, soil erodibility, depth to bedrock, depth to seasonal high water, and soil percolation to facilitate the evaluation of site suitability for proposed storm water and erosion-control facilities in relation to the overall development proposal

6.3 Soil and Groundwater Impacts

The Soil and Groundwater Impacts section should include, but not be limited to, the following information:

- ✓ A summary of the site's geology;
- ✓ Soil and groundwater characteristics (e.g., chemical and physical analyses, ground stability);
- ✓ A description of the site hydrogeology, including a description of aquifers, groundwater availability and use, and groundwater flow;

- ✓ Potential impacts from construction activities to the soil and ground water

6.4 Terrestrial Ecology Impacts

The Terrestrial Ecology Impacts section should include information on discharges to land and impacts on wildlife and vegetation, as discussed below:

6.4.1 Discharges to Land

This section should describe potential impacts to land on site and in surrounding areas from construction activities including, but not limited to the following:

- ✓A description of discharge point(s) and disposal method(s);
- ✓Information on volumes of discharge;
- ✓The proximity of the event;
- ✓Chemical and physical properties of any discharges;
- ✓A description of any flora or fauna in the terrestrial environment—specifically endangered or sensitive species—that are likely to be impacted;
- ✓The relevant allowable limits from DEAP, or other international standards

6.4.2 Ecosystem (Fauna)

This section should describe potential impacts to habitats of terrestrial ecosystem (Fauna) from construction activities, including habitats located on site and off site

6.4.3 Ecosystem (Flora)

This section should detail potential impacts to ecosystem (Flora)from construction activities, including ecological areas located on site and off site

6.5 Marine Ecology Impacts

The Marine Ecology section should include information on discharges to marine waters; ecosystem, as discussed below:

6.5.1 Discharges to Marine Waters

This section should describe potential impacts to marine waters from construction, excavation, and dewatering activities including, but not limited to, the following information:

- ✓A description of discharge point(s) and disposal method(s);
- ✓Information on volumes of discharge;
- ✓The proximity of the event, process, or activity to the marine environment;
- ✓A list of chemical and physical properties of any marine discharges, including thermal and toxic characteristics;
- ✓A description of any flora or fauna in the marine environment—specifically endangered or sensitive species—that are likely to be impacted;
- ✓The relevant maximum allowable Marine discharge limits as stated by Kingdom of Bahrain Environmental Standards, or international standards should be referenced

6.5.2 Ecosystem (Fauna)

This section should describe potential impacts to habitats of marine life from construction activities, including marine life located on site and off site

6.5.3 Ecosystem (Flora)

This section should describe potential impacts to marine vegetation from construction activities, including ecological areas located on site and off site

6.6 Noise and Vibration Impacts

The Noise and Vibration Impacts section should provide an overview of the noise and vibration produced from the construction activities that includes the following information:

- ✓ Noise and vibration sources from construction equipment and activities;
- ✓ Expected noise and vibration levels under different scenarios, including both individual and cumulative sources;
- ✓ Applicable allowable limits;
- ✓ Noise level at the site boundary;
- ✓ Noise level at identified sensitive areas near the project site;
- ✓ List of the acoustic performances of machines and equipment, including occupational noise classifications provided with an accompanying noise contour map;
- ✓ Modelling or monitoring, if deemed necessary, to demonstrate the noise impact in the surrounding environment, including sensitive areas.

6.7 Traffic Impacts

The Traffic Impacts section should provide a description of the traffic impacts produced from the construction activities. This information should include, but not be limited to, the following:

- ✓ A description of the potential impacts to traffic from construction related activities, including those from the closing of streets and those from increased vehicle usage for construction equipment, supplies, and disposal activities

6.8 Waste Management Impacts

The Waste Management Impacts section should provide information on activities to be conducted during construction, including, but not limited to, activities to manage solid waste, liquid waste, and hazardous waste, as described below:

6.8.1 Solid Waste

This section should provide a detailed description of the anticipated solid and semi-solid wastes that will be generated during the construction processes. This information should include, but not be limited to, the following:

- ✓ The sources of solid waste and maximum generation rates;

- ✓The type of solid waste (e.g., industrial) and its nature (i.e., hazardous, non-hazardous);
- ✓Physical, chemical, and biological properties of the solid wastes before and after treatment and a comparison with the concerned party's solid and semi-solid waste disposal limits
- ✓Identification of materials to be recycled and methods to do so;

6.8.2 Liquid Waste (Effluent)

This section should provide detailed information about anticipated wastewater generated during the construction process. This information should include, but not be limited to, the following:

- ✓Identification of all liquid effluents source(s) (e.g., cooling, cleaning), type (hazardous, non-hazardous), and the discharges rate;
- ✓Method of treatment (if present), treatment capacity, treatment efficiency, , chemical(s) used, , and type and quantities of liquid and solid wastes generated;
- ✓Methods of liquid waste storage before and after treatment;
- ✓Specification regarding the point of discharge, the final discharge (e.g., sea, sewer network, storm water network), and transportation (if present);
- ✓A no-objection letter from the concerned parties if the effluent is to be discharged to the sewer or storm water network;
- ✓DEAP, concerned parties (e.g. Ministry of Works) discharge limits

6.8.3 Hazardous Waste

This section should provide detailed information about anticipated hazardous waste generation during the construction process. This information should include, but not be limited to, the following:

- ✓Identification of all hazardous waste streams and include the type(s), quantities, and source(s);
- ✓Information on the storage locations of hazardous wastes and associated potential impacts to the environment from spills

6.9 Other Environmental Impacts

The Other Environmental Impacts section should include information regarding health and safety impacts, as well as other impacts deemed as important to the project.

7. Section Seven: Environmental Mitigation Measures

As part of the CEMP procedures for managing and mitigating impacts of the project, the proponent should prepare and implement control plans, which should include, but not be limited to, the elements described in the following subsections. The proponent should thoroughly address site-specific mitigation measures for the applicable environmental components discussed in Sections 7.1 through 7.14 of this guidance.

Mitigation strategies should be based on the best available management practices and technologies that will eliminate or minimize adverse impacts to health, safety, and environment in the project site and the surrounding area.

Considerations for providing environmental mitigation measures include the following:

- ✓ Thoroughly address site-specific mitigation measures for the applicable environmental components that are discussed below;
- ✓ Incorporate mitigation measures identified in any previously performed EIA studies for the identified impacts;

The proponent should provide the following control plans in the CEMP:

- ✓ Air Quality Control Plan;
- ✓ Erosion and Sediment Control Plan
- ✓ Soil and Groundwater Contamination Control Plan;
- ✓ Terrestrial Ecology Control Plan;
- ✓ Water Quality and Marine Ecology Control Plan;
- ✓ Noise and Vibration Control Plan;
- ✓ Traffic Control Plan;
- ✓ Waste Management Control Plan;
- ✓ Chemical and Hazardous Materials Control Plan;
- ✓ Contingency Plan;
- ✓ Emergency Management Plan;
- ✓ Infrastructure Plan

An overview of the mitigation measures included in these control plans is provided below. Where generalized mitigation measures are provided in the sections below "note that these are provided only for clarification and are not to be taken as the only measures to be considered".

A sample list of mitigation measures for typical construction activities is provided in Annex 1 of this document. This list does not represent all mitigation options, and proponents should choose best available practices and technologies specific to their construction activities and the project site. A table listing all mitigation measures to be implemented for the project (listed by environmental aspect and including those intended to address cumulative impacts) should be included in the main CEMP document.

7.1 Air Quality Control Plan

The Air Quality Control Plan should provide the control measures to be used to minimize air emissions from all construction activities. In each specific control identified below (i.e., dust management, gaseous pollutants management, and odor management), the plan should discuss procedures for the periodic inspection and routine maintenance of equipment in accordance with the manufacturer's instructions. These procedures should also include documentation requirements for all inspections and maintenance activities.

7.1.1 Dust Management

The section on dust management should provide mitigation measures used to address dust issues arising from sources such as demolition, eroded soil, cleared lands, stockpiles, transportation of materials, machinery, and dirt roads. Mitigation measures for dust management also may include those measures taken to prevent erosion and sediment runoff.

7.1.2 Gaseous Pollutants Management

The section on gaseous pollutants management should provide mitigation measures used to minimize gaseous pollutant air emissions from all construction activities. Control measures may include, but are not limited to, the use of low-sulphur or alternative fuels, the application of emissions-control equipment, or the selection of materials that minimize the emission of gaseous pollutants.

7.1.3 Odor Management

The control plan section on odor management should provide mitigation measures used to minimize odor from all construction activities.

7.2 Erosion and Sediment Control Plan

Large projects usually involve extensive land disturbance, such as removing vegetation and reshaping topography, which make the soil vulnerable to erosion. Soil removed by erosion may become airborne, thereby creating a dust problem, or the soil may be carried by rain water into marine environments, thereby causing physical, chemical, biological, and economic impacts to the waters. To address these issues, the Erosion and Sediment Control Plan should include, but is not limited to, the following information:

- ✓ When considering land disturbance and its potential impacts, the CEMP should give priority to preventative rather than treatment measures. When developing erosion control options, proponents should obtain information about the erosion potential of the site where soil disturbance is planned (erosion potential is determined by the soil type and structure, vegetative cover, topography, and climate) and the nature of the land-clearing to be performed. Erosion will also be affected by the type, nature, and intensity of the earthworks

7.3 Soil and Ground Water Contamination Control Plan

The Soil and Groundwater Contamination Control Plan should outline measures to manage and minimize the impact of the project on soil and groundwater. This plan should include, but not be limited to, the following information:

- ✓ Documentation of the measures used to ensure that oil and hazardous materials are properly contained to prevent contamination of soil and groundwater;
- ✓ As necessary, a listing of the measures needed to remove or remediate previously identified contaminated soil onsite from prior industrial activities

7.4 Terrestrial Ecology Control Plan

The Terrestrial Ecology Control Plan should provide information that accomplishes those aspects outlined below.

7.4.1 Terrestrial Ecological Management

The section on terrestrial ecological management should provide information that accomplishes the following:

- ✓ Describes the procedures used to control and prevent releases to on-site and surrounding terrestrial ecological systems;
- ✓ Discusses procedures to help protect terrestrial ecology, including endangered species;
- ✓ References any prior studies performed that address terrestrial ecology in the vicinity of the project area;
- ✓ Discusses the procedures for clearing activities at the construction site and surrounding area;
- ✓ Identifies buffer zones to be created to protect undisturbed areas;
- ✓ Describes the measures to be taken to re-plant or compensate for any removed vegetation

7.5 Water Quality and Marine Ecology Control Plan

The Water Quality and Marine Ecology Control Plan should include, but is not limited to, information regarding wastewater management and marine ecological management, as discussed below:

7.5.1 Wastewater Management

The section on wastewater management should include, but not be limited to, the following information:

- ✓ A description of the measures to be taken for the control, collection, treatment, or removal of wastewater produced during the construction phase;
- ✓ Where applicable, a description of the systems and procedures established for wastewater produced at housing camps for construction labour

7.5.2 Marine Ecological Management

The control plan section on marine ecological management should include, but not be limited to, information regarding the following:

- ✓The procedures and mitigation measures to be used to prevent contamination or damage to storm water drains and waterways;
- ✓A discussion of the measures taken to protect marine ecology, which could be impacted by construction activities

7.6 Noise and Vibration Control Plan

The Noise and Vibration Control Plan should outline measures to minimize the impacts on local noise levels and vibrations from the construction activities and should accomplish the following:

- ✓Identify the suitable noise suppression or abatement measures required to ensure that ambient noise level concentrations do not exceed limits for both workers on site and for nearby receptors;
- ✓Discuss the measures that will be employed to minimize vibration and the procedures that will be used to notify potentially impacted receptors about these operations

7.7 Traffic Control Plan

The Traffic Control Plan should outline measures to minimize the impacts on local traffic from the construction activities and should accomplish the following:

- ✓Discuss the measures to minimize traffic disturbances and associated impacts from noise;
- ✓Describe the procedures for public notification of any anticipated traffic-related concerns, such as street closings;
- ✓Identify access roads for construction vehicles and safety measures used for pedestrian access and crossings

7.8 Waste Management Control Plan

The Waste Management Control Plan should outline the management of wastes during the construction phase, including the classification of liquid and non-liquid wastes and a description of how these wastes will be managed. As described below, the Waste Management Control Plan should include information on methods for minimizing or recycling wastes, with specific procedures for solid waste management, liquid waste management, hazardous waste management, and the handling or removal of polychlorinated biphenyls (PCBs), asbestos, and ozone-depleting substances. This plan also should include information about the selected waste management service provider.

7.8.1 Minimization, Reuse, and Recycling

The section on minimization, reuse, and recycling should discuss the measures that will be used to avoid/minimize, reuse, and recycle wastes generated at the construction site. Measures may include technological applications, segregation of waste streams, purchasing decisions, the selection of construction materials.

7.8.2 Solid Waste Management

The section on solid waste management should include, but not be limited to, the following information:

- ✓The procedures for solid waste management, including on-site activities related to collection, storage, transportation, processing, and disposal;
- ✓If necessary, a description that differentiates between the procedures used for different waste streams

7.8.3 Liquid Wastes (Effluent) Management

The section on liquid waste management should provide on-site mitigation measures for the reduction, collection, and disposal or treatment of liquid wastes from construction activities.

7.8.4 Hazardous Waste Management

The section on hazardous waste management should include, but not be limited to, the following information:

- ✓The procedures to be used for the reduction, collection, handling, and storage of hazardous wastes from construction activities;
- ✓Information on hazardous waste identification processes, along with labeling and documentation requirements for waste-transfer notes.

7.8.5 PCBs, Asbestos, and ozone-depleting substances Management

The section on PCBs, asbestos, and ODS management should establish procedures for the proper identification, handling, and removal of these materials, as encountered during the removal, renovation, or demolition of any buildings on site.

7.8.6 Use of Environmental Service Providers for Waste Management

For the identified wastes, the control plan should provide information about the registered environmental service provider that will be used to handle the collection, transportation, and disposal of wastes. It is important to note that only these providers are authorized entities to receive waste. A list of environmental service providers can be obtained from the Waste Control Section of GDEWP.

7.9 Chemical and Hazardous Materials Control Plan

The Chemical and Hazardous Materials Control Plan should provide information that, at a minimum, accomplishes the following:

- ✓Discusses the measures that will be taken to minimize the risks associated with chemical, fuel, and oil spills and accidents; these measures can include, but are not limited to, monitoring purchasing requirements, product substitutions, design features for containment, operational controls, work practices, labeling, and storage requirements;
- ✓Specifies the document-control procedures for maintaining material inventories and Material Safety Data Sheets

7.10 Contingency Plan

The Contingency Plan should outline the procedures established and equipment available to respond to spills during construction activities and should, at a minimum, achieve the following:

- ✓Identify potential sources of spills and the measures in place to control them, Include maps showing the presence of chemical, oil, and hazardous waste storage locations, structures and equipment for diversion and containment of spills, and the location of spill response equipment;
- ✓Establish procedures for responding to spills of oil and hazardous materials;
- ✓Provide information about the presence of spill-response equipment throughout the construction site;
- ✓Define the roles & responsibilities of all personnel involved in responding to spills;
- ✓Clearly define immediate actions to be taken to address spills;
- ✓Discuss the measures for containment, cleanup, and disposal of contaminated materials and soil;
- ✓Describe notification requirements for both internal and outside spill-response teams, and provide contact information for these individuals along with local emergency agencies (in close coordination with GDEWP);
- ✓Establish documentation procedures for identifying the root causes, corrective and preventative actions, and setting time lines for their implementation

7.11 Emergency Management Plan

The Emergency Management Plan should outline the procedures established to respond to emergencies during construction activities. This plan should include, but not be limited to, a list of emergency coordinators and emergency procedures, as discussed below.

7.11.1 List of Emergency Coordinators

The Emergency Management Plan should include an up-to-date list of names, addresses, and telephone numbers for emergency coordinators.

7.11.2 Emergency Procedures

The Emergency Management Plan should provide the following information regarding emergency procedures:

- ✓Describe the actions to be taken in response to emergency situations, such as fires, explosions, or the unplanned releases of hazardous materials where hazards exist;
- ✓Provide evacuation plans for the site, including procedures and routes;
- ✓Describe any arrangements agreed to with Ministry of Interior, hospitals, contractors, …etc., and emergency response teams to coordinate emergency response services

7.12 Security Plan

The Security Plan should discuss the control measures to contain and secure the site.

7.13 Infrastructure Plan

The Infrastructure Plan should describe the measures taken to ensure protection of infrastructure (e.g. water systems, transmission lines) during the construction phase.

8. <u>Section Eight:</u> Monitoring and Auditing

The Monitoring and Auditing section of the CEMP should include, but not be limited to, information regarding the monitoring and auditing of environmental performance, as well as information on reporting requirements, environmental checklists, and monitoring review, as discussed below:

8.1 Environmental Performance Monitoring

The CEMP should include information about monitoring requirements for environmental performance. At a minimum, this section should accomplish the following:

- ✓Discuss how identified impacts will be monitored, including the indicators to be measured, the methods and sampling locations, frequency of measurements, detection limits, corrective actions, and the party who will conduct monitoring;
- ✓Provide corrective actions procedures for non-compliance with monitoring;
- ✓Specify notification requirements to responsible personnel and the time frames for notification for corrective actions to be performed;
- ✓Identify the frequency and content of monitoring reports for internal use and those required to be submitted to DEAP for review;

8.2 Reporting Requirements

The CEMP should outline procedures for reporting requirements, including the frequency and content of required reports (it should be noted that some of the below mentioned report could be included in one report), such as the following:

- ✓Pre-operation compliance reports;
- ✓Incident reports;
- ✓Periodic or annual environmental progress reports;

- ✓Non-compliance reports;
- ✓Corrective action reports;
- ✓Complaints reports;
- ✓Any special reports required by government agencies.

The following subsections provide further detail on the types of reporting-requirements information that should be included in the CEMP.

8.2.1 Incident Reports

A proponent must notify DEAP and other relevant authorities as soon as practicable about any environmental incident with actual or potential significance for impacts on the environment. The CEMP should state that, should an incident occur, the proponent must inform DEAP and other relevant authorities immediately and provide an incident report to DEAP outlining the details of the incident within 3 days of the incident. Incidents reports could include the following:

- ✓Fuel or chemical spills;
- ✓System failures or malfunctions;
- ✓Other emergencies (e.g., natural disasters);
- ✓Other events that led to non-compliance with environmental standards/requirements

8.2.2 Periodic or Quarterly Performance Reporting

The CEMP should submit within 3 months of the date of approval of the CEMP and monthly thereafter environmental progress reports for the construction project. This report should accomplish the following:

- ✓Identify the standards, performance measures, and legal requirements that apply to the project construction;
- ✓Assess the environmental performance of the project construction to determine whether it is complying with these standards, performance measures, and legal requirements;
- ✓Identify any non-compliance with the conditions of this CEMP or any standards, performance measures, or legal requirements that apply to the project and occurred during the reporting period;
- ✓If any non-compliance is identified, describe the actions and measures that will be performed to ensure compliance, clearly indicate who is or will be performing these actions and measures, when they will be conducted, and how the effectiveness of these measures will be monitored over time;
- ✓Include a copy of complaints for the quarter and a description of actions taken or being taken to address registered complaints;

- ✓ Provide the results of all environmental monitoring required by the environmental permits, including interpretations and trends or exceptions in these results

8.2.3 Monitoring Compliance Reports

The Monitoring Compliance Reports section of the CEMP should include information regarding the following:

- ✓ Establish a program to monitor environmental compliance of construction activities in accordance with the established procedures defined in the CEMP. These activities may include daily, weekly, or periodic inspections;
- ✓ Provide procedures that establish corrective actions for non-compliance with established CEMP procedures and identify the root causes for the issue. These corrective actions should not only provide an immediate but also help ensure that similar non-compliance will not be repeated;

8.2.4 Environmental Checklists

The CEMP should include checklists to be used during site inspections. These checklists must be specific to the mitigation measures that will be used e and allow for clear distinction about whether the measures are being implemented effectively.

9. Section Nine: Documentation

The CEMP should include requirements to maintain copies of the CEMP, the plans contained within the CEMP, changes to any of these plans, and training records or rosters, audits, monitoring data, and reports submitted to DEAP, other agencies, or local authorities. These documents should be easily accessible for inspection.

10. Section Ten: Annexes

The CEMP should include annexes detailing the information described in the previous sections.

Required annexes of the CEMP should include, but not be limited to, the following information:

- ✓ References and sources of information that were used to prepare the CEMP (e.g., previous environmental studies for the project, best international practices used);
- ✓ Material Safety Data Sheets;
- ✓ Environment policy;
- ✓ Environment manuals;

- ✓ Large-scale drawings and diagrams (e.g., site layout, machinery and equipment layout, process flow diagrams, piping and instrumentation diagrams, emissions points, sewer and storm water systems);
- ✓ Records, checklists, and log templates for inspections, monitoring, maintenance;
- ✓ Complaint procedures;
- ✓ training activities

Appendix 22: Mitigation Measures for EPC Contractor

Client: **Bechtel**
Project: ALBA Potline (6) and Power Plant (PS 5) Expansion

Appendix 22 - General Mitigation Measures to be implemented by the EPC Contractor

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Abbreviations

Alba	Aluminium Bahrain
AST	Above-ground Storage Tanks
BAT	Best Available Technology
CEMP	Construction Environmental Management Plan
dB(A)	A-weighted decibels
DG	Diesel Generator
EMEP	Emergency Management and Evacuation Plan
EPC	Engineering, Procurement and Construction
ESIA	Environmental and Social Impact Assessment
EWA	Electricity and Water Authority
HSE	Health, Safety and Environment
MSDS	Material Safety Datasheet
MTPA	Metric Tonnes per Annum
NOC	No Objection Certificates
PPE	Personal Protective Equipment
PS	Power Station
SO_2	Sulphur Dioxide
TME	Tebodin Middle East Ltd.
UST	Underground Storage Tanks
STP	Sewage Treatment Plant

1 Introduction

As part of the ESIA study, impacts with regards to the construction phase of the expansion project were assessed to the extent possible. As only limited information with regards to the construction phase is available at this stage of the project, the ESIA recommended and the Supreme Council for Environment requested for the preparation of a Construction Environmental Management Plan (CEMP) in order to further detail the environmental impacts related to construction phase.

The current document presents general minimisation measures that shall be implemented by the concerned Engineering, Procurement and Construction (EPC) contractor. These minimisation measures are presented in the form of control plans for the affected environmental components. It is to be noted that the control plans are generic and more specific control plans need to be developed as part of the CEMP.

2 Environmental Control Plans

This section present the construction environmental management plans which contain general minimisation and mitigation measures to be implemented during the construction phase of the expansion project.

The various environmental control plans portray control procedures and preventive measures which are devised to be implemented by the EPC contraction during the construction works in an attempt to minimise or alleviate the associated environmental impacts.

The following control plans are included in subsequent sections:

- Air Quality Control Plan;
- Erosion and Sediment Control Plan;
- Soil and Groundwater Contamination Control Plan;
- Water Quality Control Plan;
- Noise and Vibrations Control Plan;
- Traffic Control Plan;
- Waste Management Control Plan;
- Chemical and Hazardous Materials Control Plan;
- Contingency Plan;
- Emergency Control Plan; and
- Security Plan

2.1 Air Quality Control Plan

Based on the Best Available Technology (BAT), the following control measures have been devised to reduce the impact on the ambient air quality of the project area and the occupational health of workers.

2.1.1 Dust Management

The most prevalent construction emission is fugitive dust. Therefore the following control measures are devised to reduce fugitive dust to As Low As Reasonably Practicable (ALARP) and are expected to be implemented on site by the EPC contractor where applicable.

#	Control Measures – Dust
1	Daily dust suppression through periodic water sprinkling by tankers storing water retained from dewatering activities. The reuse of retained water reduces the consumption of fresh water but also, the saline properties of brackish waters have better dust suppression properties than fresh water.
2	The speed of all vehicles traveling onsite shall be limited to 20 km/hr and unpaved hauled roads should be sprinkled with water to suppress dust generated from vehicle movement.
3	Open-bodies trucks hauling sand, gravel, or soil between on-site and off-site areas are to be fully covered by a Tarpaulin and sprayed with water to avoid loss of materials in transport and generation of dust.
4	Minimum drop heights shall be used during material transfer.
5	Stockpiles should be placed in a sheltered area and away from site boundaries as to contain dust travelling.
6	Limit the area subject to excavation, grading and other construction activity at any one time.
7	Train all site personnel to be fully understands activities that generate dust and measures that should be undertaken to reduce dust emissions.
8	Stockpiles onsite shall be minimised to the extent feasible. Stockpiles should have a maximum height of about 2 m, or equal to or lower than the average height of surrounding structures.
9	Particulate dust masks and safety eye goggles are to be worn as Personal Protective Equipment (PPE) as instructed by the site supervisor.

2.1.2 Gaseous Pollutants Management

The following control measures shall be implemented in order to minimise the combustion and vehicle exhaust emissions generated from the construction activities.

#	Control Measures – Gaseous Pollutants
1	Periodic maintenance such as engine maintenance, lubrication, filter cleaning / replacement, oil changes, replacement of required spares etc., of construction equipment and mobile generators are conducted so as to reduce emissions.
2	Switch off or throttle down the construction equipment and vehicles, when not in use, in order to minimize emissions.
3	Do not overload trucks.
4	Cleaner fuel alternatives such as low sulphur diesel shall be considered if accessible. Fuel with only 0.5% sulphur content shall be used which in turn will reduce SO_2 emissions.
5	Periodic visual checks of all vehicles and machinery on site shall be conducted to detect any black smoke emitted from combustion engines.
6	All welding operations shall be carried out in enclosed areas in order to limit impacts from welding fumes.

2.1.3 Odour Management

The following control measures shall be implemented in order to minimise the occurrence of foul odour generated from the construction activities or facilities made available for workers on site.

#	Control Measures - Odour
1	Food waste from the site office and accommodation camps shall be stored in designated food waste skips which shall be securely sealed shut with their respective lids to prevent secondary ecological impact and odour, and to ensure feral animals and vermin cannot feed on the debris.
2	All holding tanks/ drains shall be adequately closed/sealed (as applicable) to minimize odour emissions.
3	Any spillages onto land shall be immediately cleaned and disposed of as hazardous waste by an approved environmental service provider.
4	Strict prohibition of any open fire and incineration of any type of materials.

2.2 Erosion and Sediment Control Plan

The main objective of the erosion and run-off environmental control plan is to implement procedures that will avoid or minimise soil erosion from disturbance of land caused by construction activities. Erosion and subsequent run-off can occur as a result of construction activities such has removal of the sand dune, traffic and equipment movement on site, and lack of vegetation and dryness of soil. This enhances the potential for the movement of pollutants entering the soil through spills and leakages. Soil removed by erosion may also become airborne and create a dust problem. In the event of heavy rainfall, storm water may lead to the increased flow of contaminated soils and waters and as result contaminate the groundwater. The likelihood of rainfall is very low and thus the impact of storm water is significantly reduced. However, control measures to reduce abnormal flow and erosion are provided below.

#	Control Measures – Erosion and Sediment
1	Permits/ No Objection Certificates (NOC) should be obtained from the Concerned Authorities prior to start of activities related to the construction of the roads and utilities infrastructure.
2	Keep land clearance to a minimum.
3	Wherever possible, avoid clearing areas of highly erodible soils and steep slopes, which are prone to water and wind erosion.
4	Dry stockpiled material shall be stored at a minimum distance of 10m from the nearest water source.
5	Surface runoff from the disturbed soils on the construction area shall be constantly controlled and minimized.
6	Site staff shall visually monitor storm water contamination.
7	Off road travel shall be restricted (where possible) to minimize land disturbance.
8	Appropriate spill control measures and handling procedures to be provided at lay down areas and storage areas to prevent runoffs.

2.3 Soil and Groundwater Contamination Plan

To avoid or reduce the potential risk of contamination to the soil and groundwater, the measures in this control plan can be categorized into three (3) sections based on best practice techniques:

- Fuel and Chemical Handling and Storage
- Erosion and Run-off Management
- Leaks and spills direct into the soil

Impact to soil and groundwater is probable through oil spill and leakages. Therefore, great efforts shall be made and appropriate mitigations measures shall be implemented to avoid seepage and spills of oil and other hazardous substances into the soil.

To protect the project site soil and groundwater mediums from oil and hazardous material spills, refer to Section 2.8; Chemical and Hazardous Materials Control Plan.

Based on BAT the following control measures have been devised to reduce the impact on soil and groundwater of the project area.

#	Control Measures – Soil and Groundwater
1	All hazardous construction materials like fuel, oils and paint shall be stored and handled in leak-tight, bunded containers and placed in dedicated locations with impervious flooring with adequate bund to prevent leakage or spills to the ground/groundwater.
2	All hazardous materials stored on site shall be properly labelled and segregated according to their chemical properties in order to avoid any adverse chemical reactions.
3	During fuelling of equipment and machinery, including the Diesel Generator (DG) sets, drip trays shall be placed to prevent leakage of fuel to the ground/groundwater.
4	Operators have to be instructed to notify their supervisors in the event of a spill/leak is identified, in order to immediately apply the emergency response procedures (clean up, etc.) followed by the necessary corrective action (maintenance, replacement of machinery) to avoid re-occurrence.
5	Regular inspection and maintenance of the construction machinery and vehicles to confirm they are not leaking. All static equipment shall be provided with drip trays.

2.4 Water Quality Control Plan

Wastewater will be generated due to construction, including sanitary wastewater from project site office, labour shed toilets etc. The following control measures shall be implemented in order to ensure that wastewater is properly handled and disposed-off site.

#	Control Measures – Wastewater Management
1	Adequately sized holding tanks shall be used for the collection of sanitary wastewater and the same shall be transferred to the nearest Sewage Treatment Plant (STP) on a daily basis.
2	Hazardous waste and hazardous chemicals (raw materials) shall be segregated and stored in appropriate protected and enclosed areas.
3	The storage skips / areas for each type of waste shall be clearly identified and marked.

#	Control Measures – Wastewater Management
4	Storm water shall be ensured to be clear of any contamination and drained onto land.
5	Water from dewatering activities shall be collected in storage tanks and subsequently pumped to the nearby evaporation lagoon.
6	Regularly service and maintain sanitary system (such as portable toilets, septic tanks, sewage network etc.) in site.

2.5 Noise and Vibration Control Plan

Control measures to minimise the noise impacts during the construction works are provided in this Noise and Vibration Environmental Control Plan.

The most important control measure to ensure compliance of Bahrain's noise limits and to reduce the impact of construction noise on nearby residents is to preferably carry out all activities with high noise impacts during the day rather than at night, and to locate these activities as far away as possible from the site boundary and from any sensitive receptors.

The following control measures based on best practice techniques shall also be strictly implemented on site where applicable.

#	Control Measures – Noise and Vibrations
1	Construction equipment to be oriented away from sensitive receptors as feasible.
2	Noise levels of 70 dB (A) shall be maintained at the fence lines of the construction site.
3	Workers on site shall be provided with adequate PPE so as to alleviate noise levels to below 85 dB (A).
4	All significant noise generating equipment shall be provided with dampeners
5	Appropriate signboards indicating high noise areas shall be displayed at the construction site
6	Periodic maintenance such as engine tuning, lubrication, filter cleaning / replacement, oil changes, replacement of required spares etc., of noise generating equipment such as DG units, air compressors and other construction equipment to be conducted so as to reduce the equipment noise levels, emissions and maintain efficiencies.
7	Simultaneous operation of multiple high noise sources to be minimized to reduce cumulative noise level impacts.

#	Control Measures – Noise and Vibrations
8	Equipment and vehicles that may be in use only intermittently to be shut down during idling periods, or throttled down to a minimum.

2.6 Traffic Control Plan

Improperly managed traffic and extended congestions shall cause noise and emissions of various air pollutants such as carbon monoxide, oxides of nitrogen, sulphur dioxide, and particulate matter along the traffic routes.

Control measures to reduce the anticipated impacts of increased traffic levels to and from the site during construction are provided below.

#	Control Measures – Traffic
1	Vehicles speed shall be limited to 20 km/hr close to community sensitive areas (schools, nearby residential areas).
2	Trucks shall be covered with tarpaulin while transporting materials.
3	Certified drivers shall be used for transportation of men and materials.
4	Periodic maintenance of all the vehicles shall be conducted.
5	Carrying out the works with special attention, where restrictions are imposed by physical obstructions, i.e. Overhead power lines, slip roads, etc.
6	A safe zone has to be provided between live traffic lanes and the working area (this includes equipment, plant, tools, excavated materials, etc.)
7	Adequate barriers are provided to protect the workforce, portable vertical barriers shall be considered.
8	Where half constructed or constructed but not opened to traffic shall be covered with Jersey barriers on both the ends of the road.
9	Access / egress locations for site transport shall be kept to a minimum, preferably one at every work area.
10	Adequate measures shall be implemented to prevent traffic coming into contact with temporary / permanent structures, i.e. by using temporary barriers.
11	Adequate temporary lighting shall be provided wherever it is required.
12	All access routes shall be clearly signed and maintained

13	Arrangements shall be made to reduce the need to reverse vehicles. Where this is not possible, a trained banksman must be provided.
14	All appropriate personnel shall wear high visibility clothing.
15	Precautions like goal post are to be in place for overhead cables.
16	Underground cable and pipes shall be protected with adequate covering and markings.
17	Working area shall be defined in the live road/footway using cautionary boards and flag men which includes the areas for storage of tools and equipment and space to move around the job.
18	The equipment shall not be left on roadway overnight.
19	Not close any lanes of road without approval from Client's representative, suitable signage and devices shall be erected in accordance with instructions from Client.
20	A minimum of seven meter wide temporary roadway for traffic in two-way sections and 5 meter for one way work shall be provided.

2.7 Waste Management Control Plan

This control plan provides control measures to minimise waste and to ensure that proper management and disposal of all wastes (solid and liquid) generated is considered. It is important to note that all waste shall be collected and disposed of by a CWM approved environmental service provider.

The following hierarchy for waste management is always preferred:

- Waste avoidance and/or reduction;
- Reuse; and
- Recycle

Diverting the waste stream in these ways means that waste storage, treatment and disposal options can be reduced. Minimizing the amount of waste on site not only does it protect the environment, but also cut down costs that may be incurred by the EPC contractor or the proponent for handling and disposing of the waste. Construction sites should pursue this hierarchy and seek out waste minimisation opportunities first and foremost, followed by proper waste storage and disposal.

2.7.1 Minimisation, Reuse and Recycling

The EPC contractors waste management plan shall promote the minimisation, reuse, and recycling of wastes generated at the project site through the re-use of materials such as; timber, metals, paper, etc.

Accordingly, wastes deemed recyclable shall be segregated and stored in a separate, designated skips and placed in an accessible location. The stored recyclables shall be utilized in any foreseen potential of re-use otherwise, the materials shall be sent to an appropriate recycling facility via an approved environmental service provider.

The control measures to further minimise the quantity of hazardous and non-hazardous wastes generated on-site are outlined as below.

#	Control Measures – Waste Minimization
1	For overall waste minimization during construction, reduction, reuse and recycling options must be implemented wherever possible.
2	As part of waste minimization, only required material shall be purchased. In case small amount of material are required, this shall be borrowed from other sites.
3	Materials shall be stored as advised by the manufacturer.
4	Good housekeeping shall be ensured throughout the site.
5	Non-recyclable materials shall be substituted by recyclable materials where possible.
6	Hazardous material shall be replaced by non-hazardous material where possible.
7	Material suppliers shall be insisted on packing the material with recyclable material such as cardboard.
8	An inventory shall be maintained to prevent from ordering excess material.
9	Unused surplus material which is sealed shall be exchanged for the required material where possible.
10	Wastes such as spent oil, water based paints, asphalt waste etc. shall be recycled for re-use.

The two main categories of waste which are expected to be generated during construction works include:

- Non-hazardous waste such as paper, packaging and boxes, kitchen and office waste, cardboard, etc.
- Hazardous waste such as oil and lubricants, batteries, cans and small drums, filters, possible asbestos used in isolation materials, ducting, flooring, tube lights etc.

The following section provides specific control measures for waste handling of the non-hazardous and hazardous waste generated during construction.

2.7.2 Non-Hazardous Waste Management

In order to ensure proper management of non-hazardous waste the below control measures shall be implemented. In addition, training and education shall be provided to employees and waste manifest shall be established to keep track of the quantity and quality of wastes produced during construction. Records shall be maintained on regular basis and periodically the information shall be forwarded to the concerned parties and to the Health, Safety and Environment (HSE) department.

#	Control Measures – Non-Hazardous Waste
1	Recyclable and non-recyclable waste shall be stored separately.
2	Different waste types shall not be mixed as this can cause chemical reactions and making recycling impossible.
3	Different colours of closed containers or different sizes shall be used to identify different types of wastes.
4	Regular waste collection shall be insured to prevent overflow.
5	Waste shall not be buried, used as backfill or for landscaping purposes.
6	To the greatest extent possible, excavated materials shall be reused in filling operations or in other processes.
7	All food waste shall be properly stored in sealed tops to minimize the possibility of vermin manifestation.
8	Domestic waste shall be disposed via an approved service provider.
9	Waste storage areas shall be kept clean, well-organized, and equipped with ample clean-up supplies as appropriate for the materials being stored.

2.7.3 Hazardous Waste Management

It is of vital importance to manage the hazardous waste generated throughout the project construction activities. To minimise the risk of pollution from the handling and storage of hazardous substances the following management practices shall be adopted to reduce the possibility of spills, to prevent incorrect waste disposal and to prevent the lack of arrangement in waste management resources.

#	Control Measures – Hazardous Waste
1	All hazardous waste produced shall be collected separately, in polyethene bags and brought to a dedicated storage area away from drainage systems.
2	A temporary area shall be designated until the hazardous waste is collected by an approved service provider.
3	Temporary storage bins shall be lined with trash cover and shall always be available in the site where

#	Control Measures – Hazardous Waste
	hazardous substances are in use.
4	Temporary storage bins shall be cleared at regular frequency to avoid overflow or spills from waste containers.
5	Handling of hazardous substances shall be in accordance with the manufacturer's specifications and legal requirements.
6	Hazardous wastes shall be stored in enclosed and secured storage areas.
7	Supervisors shall ensure that employees who might be exposed to hazardous substances are adequately protected and informed about the safe and proper methods for handling.
8	No dumping, discharge and spillage of hazardous waste shall be allowed.
9	Separate containers, bins or skips shall be provided for hazardous waste.
10	All hazardous materials are to be stored in minimum quantities and in a manner that prevents any potential contamination/ safety risk as per their respective MSDS.

2.7.4 Use of Environmental Service Providers for Waste Management

As previously mentioned, the EPC contractor shall use the services of an approved company for the handling, transport and disposal of the various waste streams.

2.8 Chemical and Hazardous Materials Control Plan

The EPC contractor shall established work instructions for hazardous materials required for the construction project. A copy of the Material Safety Datasheet (MSDS) of all chemicals and solvents planned utilised in the construction activities such as; cement, thinner and epoxy paint should be maintained and made available upon request with the concerned HSE manager. The additional control measures for the control of hazardous chemicals on-site are detailed below.

#	Control Measures – Chemicals and Hazardous Materials
1	Materials to be stored as per MSDS provided.
2	Staff shall be educated on the storage requirements.
3	Workmen shall be trained in usage, supervision and observation to reduce the risk from incorrect usage of hazardous materials.
4	Materials storage containers shall be labelled according to their content.

#	Control Measures – Chemicals and Hazardous Materials
5	Appropriate handling methods are established for diesel and aforementioned chemicals. Any spills/leaks shall be immediately remediated in accordance with contingency plan to reduce contamination of soil and groundwater.
6	Containers shall be regularly checked for damage and leakages.
7	Chemical hazard information (material safety data sheets/labelling) shall be used to define which chemicals have the potential to cause an emergency, in order to target its chemical response planning.

2.9 Contingency Plan

An accidental spillage can mainly occur from chemical, hazardous and oil handling and storage activities on site. To minimise the risk associated with leakage and spills of hazardous materials on to the surrounding environment, the below listed mitigation measures are expected to be considered by the EPC contractor.

#	Control Measures – Accidental Releases
1	Enclosed and secluded storage areas (adequately designed to protect from rains and to prevent any run off) with impervious flooring, bunds, covers/roof and with spill collection and safety facilities to be provided for storage of hazardous materials such as lube oils, toxic and flammable chemicals, cleaning solvents, paints, fuels, etc., according to applicable regulations and MSDS.
2	Onsite fuel storage tanks, if any, to be provided with secondary containment and spill collection facilities. Properly lined areas with spill collection facilities to be provided for loading/unloading of hazardous materials.
3	Roofed and ventilated area with adequate safety protection to be provided for storage of gas cylinders.
4	Onsite and offsite emergency response plans to be established for handling any potential emergency situations due to accidental release of hazardous materials
5	Appropriate handling methods and facilities to be established for hazardous materials. Any spills/leaks to be immediately remediated to minimize contamination of soil and groundwater.
6	Provide secondary containment when hazardous materials are stored in bulk quantities (~55 grams per litre).
7	Routine/Daily checks in the hazardous material storage area to be performed by store keeper and weekly by HSE staff.
8	Maintain good housekeeping practices for all chemical materials. Chemicals should be arranged as per the chemical compatibility chart.

#	Control Measures – Accidental Releases
9	Monthly inspections of the hazardous material storage area, secondary containment, and concrete bunds of 110% surrounding any present Above-ground Storage Tanks (AST) or Underground Storage Tanks (UST) need to be logged.

The prevention of spills and leaks shall be the primary measure taken by the EPC contractor during the construction activities. However, in the unforeseen event of accidental spills and leaks of chemicals and hazardous materials and the potentially significant impact that can occur on the environment, spill response procedures have been developed in this section. The purpose of these procedures is to allow an immediate and effective response that shall limit the environmental impact as much as possible. The magnitude of the spill shall determine the extent of the actions that have to be taken. Therefore a spill clean-up procedure shall be established.

2.9.1 Spill Clean-up Procedure

An incidental spill is defined as either an incident, which can be absorbed or controlled by personnel working in the immediate area, or releases, which do not present any health or safety hazards.

Response actions and procedures shall be contingent upon the nature and quantity of the materials that are released. Therefore, to determine the level of spill response capabilities required, it shall be determined what chemicals are present at the site and in what quantities. In subsequent sections, the different steps to be taken in case of a spill are detailed.

2.9.1.1 Early Detection

Regular inspections of the construction site shall carried out to enable early detection. Awareness sessions of potential pollution risks should be conducted onsite to ensure personnel are familiar with the procedures to follow during the advent of a spill occurrence. To be noted, it is the responsibility of all employees to be familiar with procedures relevant to early detection.

2.9.1.2 Notify the HSE Manager

Each member of the construction staff shall be introduced to the designated site HSE manager during their HSE introduction and associated trainings. Awareness sessions on emergency services and response procedures shall be provided to all onsite personnel.

2.9.1.3 Assess the Risk

Before attempting to clean up a spill, make sure to take into account everything that might be affected by that spill. Look at the risks to human health, the environment and property. If possible, identify the spilled material and determine how much has spilled. Use the container’s label or the MSDS to identify the liquid and the primary dangers posed to spill responders and the environment.

2.9.1.4 Confine the Spill

The spill area shall be limited by blocking, diverting or confining the spill. Next, the spread of the liquid shall be stopped before it has a chance to contaminate a water source. Spill kits containing absorbents are designed to facilitate a quick, effective response. Non-absorbent barriers such as containment boom are available to confine liquids, minimise the spill area, and protect drains.

2.9.1.5 Stop the Source

After the spill is confined, stop the source of the spill. This may simply involve turning a container upright, closing a valve, or plugging a leak from a damaged drum or container. Be sure to transfer liquids from the damaged container to a new one.

2.9.1.6 Evaluate Incident/ Implement Clean-up

Once the spill is confined and the source has been stopped, a plan of action for implementing the spill clean-up is developed. Absorbents that are chemically compatible with the liquid spilled shall be used throughout the spill area. Once the absorbents are saturated, they should be properly disposed. Sorbents do not render liquids non-flammable, neutral or less-hazardous and shall take on the characteristics/properties of whatever liquid is absorbed. Therefore, all measures must be taken as if you were handling the liquid itself. Sorbents do not make the liquid less hazardous. Always refer to the MSDS for the chemical absorbed before proceeding.

2.9.1.7 Decontaminate

Decontaminate the site, personnel and equipment by removing or neutralizing the hazardous materials that have accumulated during the spill. This may involve removing and disposing of contaminated media, such as earth, that were exposed during the spill incident.

Contaminated soils and used clean-up materials (if any) shall be treated as hazardous waste and stored in containers within a designated and earth-bunded storage area. The approved service provider shall collect and consequently dispose of the waste. To be noted, site HSE manager shall retain waste manifest and waste logs/consignment notes of the same.

2.9.1.8 Spill Response Materials

Spill response/pollution control materials, such as sand/adsorbents, sand bags, buckets and shovels, storage containers, and foam fire extinguisher, shall be stored in a safe location on site in close proximity to the waste storage and vehicle re-fuelling areas. These materials are to be used to contain and clean up accidental spills with special care taken in its disposal. The concerned HSE Manager shall keep stocks of spill response materials well maintained and replenished.

2.9.2 Documentation of Incident

It is the responsibility of all personnel to report accidents, incidents, near misses and dangerous occurrences occurred at work site. EPC Contractor shall prepare an Incident procedure. This procedure should include topics such as:

- Tasks and responsibilities
- Seriousness of the incident
- Investigation methodology to identify the root causes of accidents, incidents, dangerous occurrence and non-conformances.
- Routing of incident reports, time frame and close-out.

2.10 Emergency Management Plan

The EPC contractor shall develop an Emergency Management and Evacuation Plan (EMEP) for the proposed construction works. The EMEP describes the actions to be taken in response to emergency situations for all site personnel including employees, first aider, engineers/foremen, project manager and safety engineers.

Project personnel shall be familiar with the requirements of this plan. The procedures and measures included in this Plan shall be explained to all the workers involved during toolbox and kick-off meetings and/or during induction training. As proof of attendance, the HSE Manager shall maintain the toolbox, induction and training attendance form.

2.11 Security Plan

In order to carry out the security of the construction site, the EPC contractor shall establish a security team, led by the Security Inspector, to cordon off the site and control the persons and vehicles. The team members shall help the fire fighting team and guide external agencies like the Fire Brigade to the place of emergency.

During the construction project it shall be ensured that only authorised personnel and vehicles are allowed to enter the Site. Furthermore, a register of all personnel on the Site at any time shall be recorded. In addition, safety barriers shall be provided at the perimeter of the Site. This safety barrier shall be sufficient to prevent unauthorized entry to the Site.

All access points shall have vehicle barriers or gates. All access points shall be secured when not supervised by security staff, and safety barriers shall be installed around any works in public areas. Moreover, access into hazardous areas shall be controlled.

Security staff shall receive the appropriate training and shall be issued with mobile phones, or other suitable means of communication.

Appendix 23: Approved Waste Transporters

SUPREME COUNCIL FOR ENVIRONMENT
DIRECTORATE OF ENVIRONMENTAL ASSESSMENT & CONTROL

LIST OF APPROVED HAZARDOUS & OILY WASTE TRANSPORTERS-2014

#	Organization	Contact Name	Job Title	Work Tel.	Mobile	Fax No.	P. O. Box	Approved Vehicle Nos.	E-mail
1	**AGAS Lubes**	Mr. K. A. Padmanabhan	Vice President	17822240	39607324 39125520	17822241	15360	BRN- 8301 and 14256	agas@batelco.com.bh tampis@batelco.com.bh
2	**Al Buraq**	**CANCELLED**							
3	**SPHINX SERVICES**	Hussain Kamal Moh'd Rafie	M. D T. Foreman	17700222	39456224 39622517	17700443	1940	BRN- 13837, 10434, 11564, 12252, 14116, 10952, 11481, 1131, 11990, 12044, 12034, 11011 & 13276	sphinx@batelco.com.bh
4	**AL-TAWFEEK**	Mr. JayaRajan Padiyath	Senior Manager	17786368	36040802	17786869	24349	BRN- 14491, 13964, 14133, 14117, 10190, 11025, 11285, 11988, 12441, 12258, 13404, 13237 & 11640.	Tawfeek@batelco.com.bh
5	**Al Faisal Clearing & Transport Agency Co.**	Mr. Faisal Hasan Rahma Tahir	General Manager	17737585	39458854 36533502	17737678	32230	BRN-31541, 31928, 35748, 37865, 40734, 41116, 41661, 42537, 42697, 43185, 43186, 43896, 43377, 43396, 44930, 46927, 46940, 46993, 33100, 49191, 37254, 49676, 33235, 40495, 31806, 31811, 33055, 40823, 30553, 32034, 70584, 70585, 73810, 73902, 5595, 30892, 34799 & 36760	tahir@alfaisal-logistics.com

6	**REDMACK**	Mr. Fawaz Al Manai Mr. Suri cam	G. M E.	17700370	39418814 39647775	17700376	29040	BRN- 1984, 12522, 13154, 1507 & 11783	redmack@batelco.com.bh
7	**ASCON**	Mr. A. Aziz Moh'd Al Sayed Mr. Kabindra	G. M Sales Engineer	17343953	39653113 39817028	17343738	24565	BRN- 12873, 10663, 15433 & 15750, 16261, 16477, 17651, 17507, 17506, 18019, 18018, 18388, 15917, 16402, 15472 & 15846.	ascon_bh@hotmail.com
8	**ABU OBAID CONTRACTING EST**	Mr. Abdul Al Ameer Essa	General Manger	17700204	39444689	17702314	26437	BRN-38722	Abuobaid@batelco.com.bh
9	**BRAMCO**	Mr. Ashok Kumar Mr. Raspal Singh	Vice President Asst. Manager	17270439	39662348 39657293	17230614	20260	BRN- 47260, 78092 & 8203	rashpal@bramcogroup.com
10	**Gulf City Cleaning Company**	Mr. James Adrian Cockrem	Operations Manager	17729151	39402485	17825278	669	BRN- 19521, 18764, 47234, 12904, 18766 and 12453	nasswmgt@batelco.com.bh
11	**General Cleaning Maintenance Services**	Mr. Ravi Moorthy	General Manager	17754909	39644168	17754727	20117	BRN- 18249, 18248, 18444, 16449, 16786, 13170, 13994, 13703, 11589, 10793, 10649, 10856, 13834, 13973, 15440, 15513, 13104, 13675, 1589, 15592, 16563, 16780, 45506, 32347, 42327, 45288, 71901 & 71207	gcms@batelco.com.bh
12	**Naval Support Activity**	Mr. Awni Al Masri	Regional Environmental Coordinator	17854603	39463697	17853028	116	45087,52829	awni.almasri@me.navy.mil
13	**Nidukki Trading Company**	Mr. Nasser Mattar	Operatioins Manager	17731648	39645649	17456217	1382	BRN- 16596, 15791, 16035, 16812, 14358, 12544, 10922, 17477, 18160, 19224, 19225, 19523, 18113, 15807, 1764, 10178, 15375, 15641, 15648, 14637, 15376, 11137, 11702, 51293, 77508, 78654, 8192 7 46854	operations@nidukki.bh Nasser@nidukki.bh

14	**Mechanical Contracting Services Company (MCSC)**	Mr. Wassim Abu Hamad	General Manager (Projects)	17623723	39208104	17624082	5238	BRN- 48582, 44485, 47983, 47984, 47985, 47986, 47490, 47491, 47492 and 47493.	Kl_wilson@mcscbahrain.com
15	**Qatar Factory**	Mr. Abdul Nabi Al Saffar	Managing Director	17877447	39458737	17786929	3233	BRN-30059,44273,42790	Saffar01@batelco.com.bh
16	**Mayoof Sanitary Cleaning Services**	Mr. Ebrahim Abdul Karim		17643664	39449009	17644626	33878	BRN-149 &13447	
17	**Contractor Recycling Company**	Mr. Ghulam Bahadur Khan	Director	17232740	39792221	17232760	2304	BRN- 33782, 44456 and 44408.	ctckhan@hotmail.com cte@emirates.net.ae
18	**Osrex International**	Mr. Kaythar Ramzi	General Manager	17702399	36767617	17702858	70108	BRN-60731,15479,39331,10747 & 10746	reemco2006@yahoo.com
19	**Crown industries**	Mr. Thiyaga Rajan	Operations Manager	17830038	39653700	17830379	11101	BRN-44766, 72280 &3337	crownmet@batelco.com.bh
20	**Al Dewaniyah Metal Scrap**	Mr. Mohammad Abdull Al Shiwy	Manager	17225999	39063853	17211599	24500	BRN-75881 & 75882	
21	**Senior Oil Traders**	Mr. Periyasamy P.	Manager	17211099	39901848	17213181	2596	BRN-32964 and 46219	oilstar@batelco.com.bh
22	**Europe Scandinavian Trading WLL**	Mr. Ibrahim Abdulla Shaikh	Chairman	17715775	39411127	17742979	26600	BRN-79288	euroscand@gmail.com
23	**Al Amal Petrochemicals**	Mr. Abdul KHakim Al Shimmiri	Director	17292565	39661998	17290818	5067	BRN-35786	hakeem@alamaltravel.com
24	**Ahmed Mansoor Al Ali**	Mr. Ali Abdulla Al Aali	Director			17262323	778	BRN- 49041, 7308, 7309, 7585, 7586, 7629, 7831, 70124, 70233, 73849, 73850, 73907, 73919, 78338, 78339 & 79250	

25	**Al Faraj Trading & Services**	Mr. Yaqoob Ali Faraj Hussain Alshalaan	Manager/HSE Manager	17700130	39456656 36044573	17700230	2663	BRN- 78608, 78609, 30722, 79266, 41756, 8271, 43798, 73163, 33403, 33938, 34813, 80871,47311, 47312, 72514, 47858, 75300, 77502, 75302, 75079, 43983, 75081, 77069, 34354, 77881, 35039, 40560, 8552, 8551, 8553, 39003, 75080, 75750, 75751, 75078, 78600 & 32202.	Alihojja99@hotmail.com
26	**Skyline Trading Corporation WLL** .	Mr. Wasim ul Haq	Manager	17598008	39472725	17590338	3207	77131& 77132	Stc3207@batelco.com.bh
27	**Bahrain Environment al Protection SPC**	Mr. Abdul Aziz	GM	17211099	-	17213181	2596	43874	bahrainenvprotection@batelco.com.bh
28	**Al Arayyed Transport**	Mr. Shukri Abdulamer Ali Salem al Arayyed	Manager	17732013	36333512	17736836	70097	8767, 76287, 10972 & 17551	alarrayd@batelco.com.bh
29	**Al Alawaji Al Saudia Holding Company**	Mr. Hasan Saleh Al Ebrahim	Technical manager	17741691	39923636	17741695	3045	71806, 71807, 71959,71960, 71961, 71962, 71963, 71964, 71965, 76566	
30	**Union Logistic Company**	Mr. Mohammed Jaffer Durazi	Manager	17402848					

31	**Buchem Industries Services Middle East**	Mr. Markus Waldherr	Managing Director	17875254		17878530	33668	14779, 18878, 1353,36313 &66886	bahrain@buchen.net
32	**Pars Palace Lubricants Co.**	Mr. Khalil Shareef	Manager			17910885	1164	80846 &73349	Pars.co@hotmail.com
33	**Al Haram Metals Co. WLL**	Mr. Umair Ahmed	Supervisor	17704470	39326578	17704104	38175	079968 & 079969	syedzas@batelco.com.bh
34	**Bahrain Medical & Industrial Gas Company**	Mr. Ali Ameer	Manager	17400469	39659295	17400391	778	15059	bmigp@batelco.com.bh
35	**Las vegas cargo & Cleaning Services**	Mr. Ahmed Yousuf Ghuloom Ebrahim	Director	17703290	36751119	17703291	22667	8703	lasvegas@batelco.com.bh
36	**Joz construction**	Mr. Mohammad Joz	Director	17223423	39602650	17213015	283	76432	jozgroup@batelco.com.bh
37	**SPECTRUM Cleaning Company**	Hisham Kooheji	General Manager	77122441	36668664	17700969	756	BRN 19674- 4631- 8272- 43265- 39052- 17037	ABDULRAZAK@MMKOOHJIGROUP.COM.BH
38	**NASSER ABD MOHMMAD COMPANY**	Nasser Abd Mohmmad Mr. Shehab		17700888	39886367	17700488		BRN 72935- 72936	namcosafety@gmail.com
39	**Desert Eagles Services**	Abdulla Habib Almughni/ Hassan Al Mughni	Director	77063838	33922345 & 39787804	77063839	75236	BRN- 19501, 1386, 19021, 11078, 12098, 11456, 18568, 16228, 16229 and 16316	d.e.cargo.s@gmail.com

40	**Sun Gulf Gate Commercial Trading**	Mr. Nixon Lewis	Director	39147515	39455811 & 39108565		13256	BRN 48673, 48674 & 37283	Sungulfgate@gmail.com Sungulfgate@hotmail.com
41	**RB Hilton**	Mr. Ebrahim Zajki	Maintenance Operations Manager	17700380	39695737	17700833	26208	BRN- 81292, 32331 & 77499	Ebrahim.zaki@capeplc.me
42	**Bahrain Maitenance and Diving Services WLL**	Mr. Mohammed Musayeb	Director	17700731	39660173	**17701473**	26195	BRN- 32109, 79505, 3104, 48481 and 12427	bmds@batelco.com.bh
43	**Ebrahim Hasan Mahdi Contracting Est.**					**17703141**	29022		
44	**Gulf Acid Industries**	Ms. Nawal Mohammed Nass			39450917			BRN-8538	
45	**Al Door Excavation & Building Contractor**			17877246		**17877249**	32187	BRN-85698,78988,78986,85713	aldoorexcavations@gmail.com
46	**Tareq Mohammed Al Areeky & Bros. Co.**	Mr. Tareq			33299666 /966-505806845		1233, Al-Khobar		
47	**Anbar Trading Est.**	Mr. Anbar Mubarak				**17764931**		BRN-14183,11999,56172	
48	**Middle East Recycling Co.WLL**	Mr. Ashik Ali Kutay	Director	77052250	39478439	**17910039**	-	BRN-75881, 13022	Ashik@recycleagewll.com

49	**Al Khabbaz Collection of Cooking Oil**	Mr. Abdul Hussain Abdulla Naser Al Khabbaz	Director	33032283	39299322	-	**Flat 21, Building 754, Road 2131 Block 421 Jidhafs**	BRN 37283 & 43190	Ahussain.alkabaz@hotmail.com

Appendix 24: Approved Oily Waste Transporters

Supreme Council for Environment
Directorate of Environmental Assessment & Control

LIST OF OILY WASTE TRANSPORTERS -2014

#	Organization	Contact Name	Job Title	Work Tel.	Mobile	Fax No.	P. O. Box	Approved Vehicle Nos.	E-mail
1	AGAS Lubes WLL	KA Padmanbhan	Vice President	17822240	39607324	17822241	15360	8301,14256	agas@batelco.com.bh
2	Qatar Factory	Abdul Nabi Al Saffar/ Harbinder Singh	Managing Director	17877447	39458737 39195585	17786929	3233	30059,44273,42790	Saffar01@batelco.com.bh
3	Mayoof Sanitary Cleaning Services	Ebrahim Abdul Karim		17643664	39449009	17644626	33878	149 &13447	
4	Contractor Recycling Company	Mr. Akram	Director	17232740	39792221 39527330	17232760	2304	33782,44456,44408 & 73007	cte@emirates.net.ae
5	Osrex International	Kaythar Ramzi	General Manager	17702399	36767617	17702858	70108	60731,15479,39331,10747 & 10746	reemco2006@yahoo.com
6	Al Dewaniyah Metal Scrap	Mr. Mohammad Abdull Al Shiwy	Manager	17225999	17211599	39063853	24500	75881 & 75882	
7	Senior Oil Traders	Mr. Periyasamy P.	Manager	17211099	17213181	39901848	2596	32964	oilstar@batelco.com.bh
8	Europe Scandinavian Trading WLL	Mr. Ibrahim Abdulla Shaikh	Chairman	17715775	17742979	39411127	26600	79288	euroscand@gmail.com
9	Al Amal Petrochemicals	Mr. Abdul KHakim Al Shimmiri	Director	17292565	17290818	39661998	5067	35786	hakeem@alamaltravel.com
10	Nidukki Trading Company	Nasser Mattar	Director	17731648	39645649	17456217	1382	16596, 15791, 16035, 12544,	operations@nidukki.bh Nasser@nidukki.bh
11	Al Haram Metals Co. WLL	Mr. Umair Ahmed	Supervisor	17701470	39414185	17704104	38175		syedzas@batelco.com.bh

12	Pars Palace Lubricants Co.	Mr. Khalil Shareef	Manager			17910885	1164	80846 &73349	Pars.co@hotmail.com
13	Sun Gulf Gate Commercial Trading	Mr. Nixon Lewis	Director	39147515	39455811 & 39108565		13256	BRN 48673, 48674 & 37283	Sungulfgate@gmail.com Sungulfgate@hotmail.com
14	Middle East Recycling Co. WLL	Ashik Ali Kutay	Director	77052250	39478439 , 39947333	17910039	-	75881. 13022	Ashik@recycleagewll.com
15	**Al Khabbaz Collection of Cooking Oil**	Mr. Abdul Hussain Abdulla Naser Al habbazK	Director	33032283	39299322	-	**Flat 21, Building 754, Road 2131 Block 421 Jidhafs**	BRN 37283 & 43190	Ahussain.alkabaz@hotmail.com

Appendix 25: Equator Principles

Client: **Bechtel**
Project: ALBA Potline (6) and Power Plant (PS 5) Expansion

Appendix 25 - Equator Principles

Tebodin

Tebodin Middle East Ltd.
Ahmed Ghanem Mazroui Building
Hamdan Street
Tourist Club Area
P.O. Box 2652
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Rev.	Date	Description	Author	Checked by

Table of contents

Abbreviations

Alba	Aluminium Bahrain
AP	Action Plan
CO_2	Carbon Dioxide
EHS	Environment, Health and Safety
EIA	Environmental Impact Assessment
EPFI	Equator Principles Financial Institutions
ESIA	Environmental and Social Impact Assessment
ESMP	Environmental and Social Management Plan
ESMS	Environmental and Social Management System
GHG	Green House Gas
IFC	International Finance Corporation
ISO	International Organization for Standardization

1 Introduction

1.1 Equator Principles

Industrial Projects can have adverse impacts on people and on the environment. The Equator Principles Financial Institutions (EPFIs) have adopted the Equator Principles (June 2013) in order to ensure that the Projects EPFI finance and advice on are developed in a manner that is socially responsible and reflects sound environmental management practices. Negative impacts on project-affected ecosystems, communities, and the climate should be avoided where possible. If these impacts are unavoidable they should be minimised, mitigated, and/or offset.

The Equator Principles are intended to serve as a common baseline and framework. The EPFI will not provide Project Finance or Project-Related Corporate Loans to Projects where the client will not, or is unable to, comply with the Equator Principles.

1.2 Background

Aluminium Bahrain (Alba) commenced its operations in 1971 and has operated with increasing success and growing production over 30 years, is planning a further expansion from its current level of production of approximately 884,000 tonnes per annum of Primary Aluminium, to a nominal production capacity of 1,446,321 tonnes of aluminium per annum via an additional Potline and Power Station (the Line 6 (L6) & Power Station 5 (PS5) Project).

Tebodin was commissioned to undertake an Environmental and Social Impact Assessment (ESIA) of the Proposed Line 6 Expansion Plan in accordance with Ministerial Order number 1 of 1998, to determine whether this project should be allowed to proceed from an Environmental and Social perspective.

An EIA was prepared by Tebodin in 2003 for the proposed expansion of Potline 5 and Potline 6. However, Potline 6 was never constructed nor commissioned. Alba received approval for the EIA in 2003 from the regulatory authorities.

As part of the financing process for the expansion project, the project will have to comply with the Equator Principles.

2 Applicable Equator Principles and local standards

The Equator Principles, World Bank guidelines and IFC Performance standards were compared with local laws, regulations and guidelines with regard to Social and Environmental topics.

Table 1 presents the summary of the analysis. It can be concluded that the majority of the Standards and Principles are present in both international and local standards and legislation.

The main gap that exists between Equator Principles and local requirements is that IFC and Equator Principles have detailed regulations addressing potential social impacts of a project. Detailed requirements for a social impact assessment are not present in local legislation.

When Equator Principles and IFC standards are not applicable, this is indicated in table 1 as “N.A.”

Table 1: Equator Principles applicability to project

Equator Principles	Local HSE Laws, Guidelines and Procedures
Principle 1: Review and Categorization	Yes, as per Ministerial Order No. (1) of 1998
Principle 2: Environmental and Social Assessment, possible contents	Bahrain is a Non-Designated Country and does not have specific guidelines for content of ESIA report.
Principle 3: Applicable Environmental and Social Standards [1]	
- **Performance Standard 1: Assessment and Management of Environmental and Social Risks and Impacts**	Yes
- **Performance Standard 2: Labor and Working Conditions**	As per Bahrain Labour Law
- **Performance Standard 3: Resource efficiency and Pollution Prevention**	Yes
- **Performance Standard 4: Community Health, Safety and Security**	Yes
- **Performance Standard 5: Land Acquisition and Involuntary Resettlement**	N.A.
- **Performance Standard 6: Biodiversity Conservation and Sustainable Management of Living Natural Resources**	Yes
- **Performance Standard 7: Indigenous Peoples**	N.A.
- **Performance Standard 8: Cultural Heritage**	Project will have no impact
Principle 4: Environmental and Social Management System and Equator Principles Action Plan	Yes
Principle 5: Stakeholder Engagement	Yes
Principle 6: Grievance Mechanism	Yes
Principle 7: Independent Review	N.A. for Alba directly
Principle 8: Covenants	Applicable
Principle 9: Independent Monitoring and Reporting	Depending on EPFI
Principle 10: Reporting and Transparency	Applicable

Note 1: Principle 3 of the Equator Principles states the following: “For projects located in non-designated countries, the Assessment process evaluates compliance with the then applicable IFC Performance Standards on Environmental and Social Sustainability (Performance Standards) and the World Bank Group Environmental, Health and Safety Guidelines (EHS Guidelines)” (Exhibit III).

3 Detailed Review Equator Principles

3.1 Equator Principle 1 - Review and Categorization

3.1.1 Introduction

The Equator Principles use a system of social and environmental categorisation, based on IFC's environmental and social screening criteria, to reflect the magnitude of impacts understood as a result of assessment. These categories are:

- Category A – Projects with potential significant adverse social or environmental impacts that are diverse, irreversible or unprecedented;
- Category B - Projects with potential limited adverse social or environmental impacts that are few in number, generally site-specific, largely reversible and readily addressed through mitigation measures; and
- Category C – Projects with minimal or no social or environmental impacts.

The ALBA line 6 expansion project will be located in Bahrain. According to the World Bank, Bahrain is identified as a High income – non-OECD country (country not a member of the Organisation for Economic Co-operation and Development). Furthermore, Bahrain is considered a 'Non-Designated Country' as Bahrain is not found on the list of Designated Countries on the Equator Principles Association website.

3.1.2 Social and Environmental Impacts

The ALBA line 6 expansion project will be situated on a developed industrial site with an area of approximately 2 km^2. The proposed site is property of ALBA and is considered as a brownfield development.

An ESIA had been prepared previously for the project in 2003. The ESIA identified the environmental and social impacts of the project. In addition, impacts are identified in the present (2014) ESIA.

3.1.3 Categorisation of the Project

Based upon the present 2014 ESIA, the ALBA line 6 expansion project will have potential limited adverse social or environmental impacts and is therefore considered a Category B project.

3.2 Principle 2 - Environmental and Social Assessment

The present ESIA was prepared in line with Bahraini requirements, starting with the preparation of an Environmental Scoping Report and subsequently the ESIA report. Bahrain does not have detailed guidance documents for contents of an ESIA report. Below table indicates if the topics have been addressed in the present ESIA study.

Table 2 Principle 2 requirements

Principle 2: Environmental and Social Assessment, possible contents		Local HSE Laws, Guidelines and Procedures
a)	Assessment of the baseline environmental and social conditions	Yes
b)	Consideration of feasible environmentally and socially preferable alternatives	Yes
c)	Requirements under host country laws and regulations, applicable international treaties and agreements	Yes
d)	Protection and conservation of biodiversity (including endangered species	Yes

	Principle 2: Environmental and Social Assessment, possible contents	Local HSE Laws, Guidelines and Procedures
	and sensitive ecosystems in modified, natural and critical habitats) and identification of legally protected areas	
e)	Sustainable management and use of renewable natural resources (including sustainable resource management through appropriate independent certification systems)	Not specifically. Included in alternatives section
f)	Use and management of dangerous substances	Yes
g)	Major hazards assessment and management	No major hazards envisaged
h)	Efficient production, delivery and use of energy	Yes
i)	Pollution prevention and waste minimization, pollution controls (liquid effluents and air emissions), and solid and chemical waste management	Yes
j)	Viability of Project operations in view of reasonably foreseeable changing weather patterns/climatic conditions, together with adaptation opportunities	Included in CALPUFF air dispersion model, inclusive of meteorological data
k)	Cumulative impacts of existing projects, the proposed project, and anticipated future projects	Yes; however, limited information available regarding future projects
l)	Respect of human rights by acting with due diligence to prevent, mitigate and manage adverse human rights impacts	Not included in ESIA; however Bahraini labour Law No. 36 of 2012
m)	Labour issues (including the four core labour standards), and occupational health and safety	Yes
n)	Consultation and participation of affected parties in the design, review and implementation of the project	Bahrain does not have specific public consultation requirements. Ministry of Environment distributes ESIA report to other Government and private agencies with a vested interest in the project
o)	Socio-economic impacts	Yes
p)	Impacts on affected communities, and disadvantaged or vulnerable groups	Yes
q)	Gender and disproportionate gender impacts	N.A.
r)	Land acquisition and involuntary resettlement	N.A.
s)	Impacts on indigenous peoples, and their unique cultural systems and values	N.A.
t)	Protection of cultural property and heritage	Yes
u)	Protection of community health, safety and security (including risks, impacts and management of project's use of security personnel)	Not included; however, project will take place in secured facility.
v)	Fire prevention and life safety	No

3.3 Principle 3 - Applicable Environmental and Social Standards

For Projects located in Non-Designated Countries, such as Bahrain, the Assessment process evaluates compliance with the applicable IFC Performance Standards on Environmental and Social Sustainability (Performance Standards) and the World Bank Group Environmental, Health and Safety Guidelines (EHS Guidelines) (Exhibit III).

The guidelines are indicated in section 3.4 of the ESIA report and are considered throughout the study.

3.4 Principle 4 Environmental and Social Management System and Equator Principles Action Plan

For all Category A and Category B Projects, the EPFI will require Alba to develop or maintain an Environmental and Social Management System (ESMS).

Principle 4 requires Alba to prepare an Environmental and Social Management Plan (ESMP) to address issues raised in the Assessment process and to incorporate actions required to comply with the applicable standards.

Alba has an ISO 14001 accredited Environmental Management System. The ESIA provides mitigation measures, recommendations, management plan and monitoring plan to ensure environmental and social impacts are avoided or minimized.

3.5 Principle 5 Stakeholder Engagement

For all Category A and Category B Projects, the EPFI will require Alba to demonstrate effective Stakeholder Engagement as an ongoing process in a structured and culturally appropriate manner with Affected Communities and, where relevant, Other Stakeholders.

The ESIA report will be issued to the Bahrain Ministry of Environment, who will subsequently distribute the ESIA report to other Government and private agencies with a vested interest in the project.

ALBA will be requested to make the appropriate Assessment Documentation readily available to the Affected Communities, and where relevant to Other Stakeholders, in the local language and in a culturally appropriate manner.

A minimum requirement, as per Principle 10, is to have a summary of the ESIA report available on Alba's web site.

3.6 Principle 6 Grievance Mechanism

Providing a mechanism for individuals to register any written grievances relating to the Potline 6 Expansion project is an important part of fulfilling the social commitments to the communities within which Alba operates and ensuring effective management of the project.

The grievance mechanism will have to fulfil the following key objectives:

- Provide a clear and accessible avenue for affected people to raise an issue or a dispute during the course of the project;
- Enable people to register a written grievance/complaint without fear of intimidation, persecution or adverse consequence, including the ability to remain anonymous if the person so wishes;
- Provide a mechanism to ensure that a written grievance receive an appropriate level of management enabling appropriate and mutually acceptable corrective actions to be identified and summarily implemented, where required;
- Ensure that complainants receive clear and direct communication on the result of an investigation of their written grievance and the outcomes of any corrective actions in a designated timescale (where complainants do not retain anonymity);
- Verify whether complainants are satisfied with the receipt and resolution of their written grievance/complaint (where complainants do not retain anonymity);

- Promote the relationship and reputation of Alba in the local community; and
- Provide a useful indicator of project and contractor performance.

High numbers of written grievances may point to a need to adjust work practices or procedures in order to reduce adverse effects or conflicts with affected households and communities.

A selection of mechanisms will need to be established (e.g. web-based interface, postal address, email mailbox) that will enable grievances to be received and responded to as appropriate to the concern raised.

3.7 Principle 7 Independent Review

EPFI will determine if an independent review of the ESIA will be required. The Independent Review would be carried out by an Independent Environmental and Social Consultant in order to assist the EPFI's due diligence, and assess Equator Principles compliance.

3.8 Principle 8 Covenants

Alba will have to covenant in the financing documentation to comply with all relevant host country environmental and social laws, regulations and permits in all material respects.

Furthermore, Alba will have to covenant the financial documentation:

a) to comply with the Environmental Social Management Plans (ESMPs) and Equator Principles Action Plan (AP) (where applicable) during the construction and operation of the Project in all material respects; and

b) to provide periodic reports in a format agreed with the EPFI (with the frequency of these reports proportionate to the severity of impacts, or as required by law, but not less than annually), prepared by in-house staff or third party experts, that

   I. document compliance with the ESMPs and Equator Principles AP (where applicable), and

   II. provide representation of compliance with relevant local, state and host country environmental and social laws, regulations and permits; and

c) to decommission the facilities, where applicable and appropriate, in accordance with an agreed decommissioning plan.

3.9 Principle 9 - Independent Monitoring and Reporting

Project Finance

To assess Project compliance with the Equator Principles and ensure ongoing monitoring and reporting after Financial Close and over the life of the loan, the EPFI will, for all Category A and, as appropriate, Category B Projects, require the appointment of an Independent Environmental and Social Consultant, or require that Alba retain qualified and experienced external experts to verify its monitoring information which would be shared with the EPFI.

Project-Related Corporate Loans

For Projects where an Independent Review is required under Principle 7, the EPFI will require the appointment of an Independent Environmental and Social Consultant after Financial Close, or require that Alba retain qualified and experienced external experts to verify its monitoring information which would be shared with the EPFI.

3.10 Principle 10 – Reporting and Transparency

The following client reporting requirements are in addition to the disclosure requirements in Principle 5:

- Alba will have to ensure that, at a minimum, a summary of the ESIA is accessible and available online.
- Alba will have to publicly report GHG emission levels (combined Scope 1 and Scope 2 Emissions) during the operational phase for Projects emitting over 100,000 tonnes of CO_2 equivalent annually (in line with Annex A of the Equator Principles).