Chapter 7 – Water Quality

Contents

7 Water Quality

7.1 Introduction

This section of the Environmental and Social Impact Statement deals with the assessment of the potential impacts of the proposed development on surface and groundwater quality and hydrology in the study area. The assessment of effects encompasses surface water and groundwater quality, and surface water and groundwater resources (in terms of water quantity and dynamics).

7.2 Assessment Methodology

7.2.1 Baseline Conditions

This study involved a combination of desk-based studies, consultations with stakeholders, review of previous investigation reports, surface water and groundwater sampling and testing and associated analysis and risk assessment.

EAME undertook a comprehensive desk study[1] of the proposed Terminal site covering a large number of relevant topics (geology, water usage and quality, etc). The information obtained during this study enabled EAME to design a sampling programme to provide additional information on the baseline conditions of the area sufficient to assess the potential impact risks associated with the development.

This assessment has been undertaken in accordance with current guidance on EIA[2] and has involved a review of the following sources of baseline data:

- Site walkovers undertaken in August and September 2014 to provide an assessment of current site activities and the site's environmental setting;
- Desk-based research;
- A environmental site investigation which involved the drilling of the seven boreholes to 6m depth, all of which were be converted to long-term groundwater monitoring wells comprising 50mm standpipes (with geosock) for subsequent monitoring to determine the hydro-geological conditions (such as groundwater flow direction) and to establish baseline groundwater quality conditions;

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[1] WTPS Iraq Oil Terminal Desk Study, Earth & Marine Environmental Consultants, August 2014, REF: 014-1287 REV00

[2] Environmental Impact Assessment – A Guide to Procedures, DETR, November 2000.

Photograph 7.1: *Application of Geotextile screening sock and a completed installation*

- The wells were surveyed in to the Iraqi Geospatial Reference System (IGRS) to allow an accurate representation of the true depth to groundwater and allow the hydraulic gradient (if any) to be determined;

- Prior to groundwater monitoring, the wells were dipped using a groundwater interface probe to ascertain groundwater levels within the wells and the presence (if any) of free-phase product;

Photograph 7.2: *BH03 being dipped using a groundwater interface probe and training Iraqi personnel to purge the monitoring wells*

- The wells were then developed to ensure a good interface within the groundwater bearing strata, by purging and removing standing water amounting to approximately three well volumes. Following this process, a representative groundwater sample from was obtained from each well. Samples collected were visually assessed, particularly for the presence of free-phase product, oil sheens or unusual colouration. Relevant field observations and in-situ measurements were recorded during groundwater monitoring;

- All groundwater samples were analysed, at an appropriately accredited laboratory, for a number of parameters including metals and metalloids, pH, Total Sulphate, Chloride, Phosphate, Monohydric Phenols, Cyanide, Speciated Polycyclic Aromatic Hydrocarbons (PAHs), Total Petroleum Hydrocarbons (C_{10} – C_{40}), Volatile Organic Compounds (VOCs) and Semi-Volatile Organic Compounds (SVOCs);

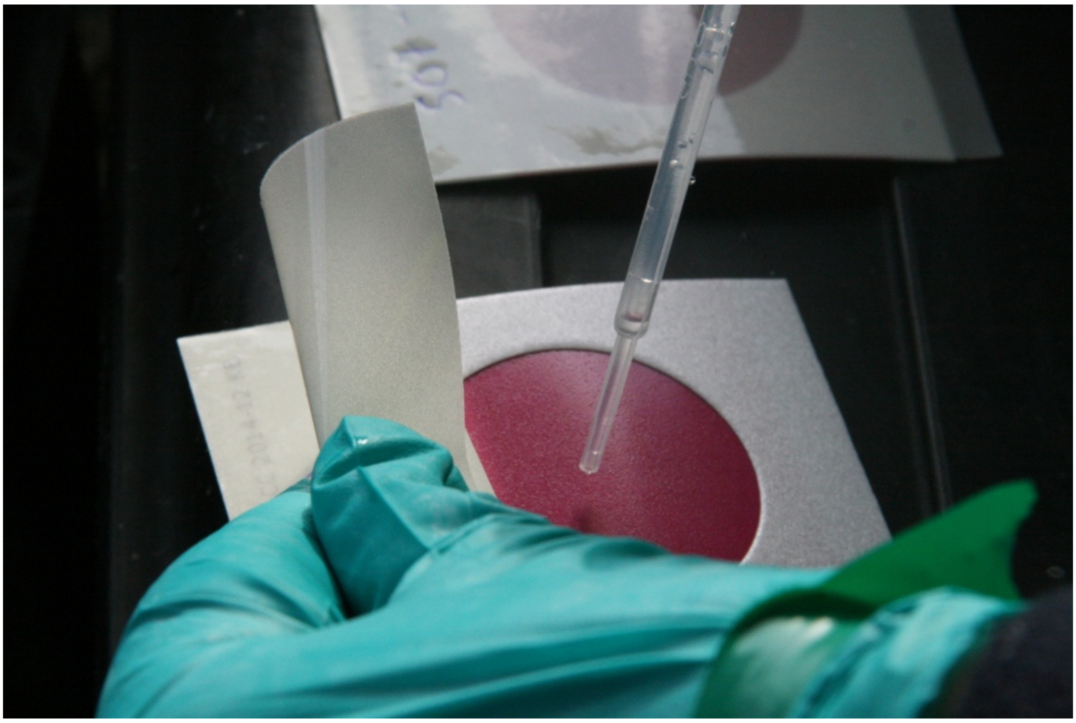
- In addition, automatic level loggers were installed in each borehole so as to assist in the characterisation of the hydrogeological regime and to ascertain whether the groundwater within the site is tidally influenced. The monitoring devices were left in place for at least 72 hours to ensure that several tidal cycles had been observed;

- Ten surface water samples, five from 1.0m below the water surface and five from 1.0m above the river bed, were collected from the Khor Al-Zubair in the Terminal development area using a Niskin Water Sampler. All collected samples were placed in pre-cleaned sample jars of appropriate size and type for each laboratory analysis to be performed. All samples were given a unique reference number, dated and the information recorded on an appropriate Chain of Custody form for dispatch with the samples to an appropriately accredited laboratory;

Photograph 7.3: *Niskin Water Sampler*

- During the surface water sampling events, field water quality data was also obtained for temperature, pH, Oxygen Reduction Potential (ORP), conductivity, turbidity, Total Dissolved Solids (TDS) and DO using a Xylem EXO Sensor. In addition, other relevant observations including the Forel-Ule colour comparator scale, Secchi depth, sea state and meteorological information were recorded; and

- It is not possible to obtain reliable coliform data from a laboratory as the travel time between the field and a suitably accredited laboratory was too great, therefore, field testing was undertaken. A small aliquot of each water sample was obtained, added to individual coliform count plates and placed in an incubator for 24 hours, at the end of which, coliform bacteria, if present, was observed in the count plates.



Photograph 7.4: *Sample being added to a Coliform Counting Plate*

7.2.2 Assessment Criteria

Standard practice for the assessment of contaminated waters follows a risk-based approach and is structured in a tiered manner. As well as having a systematic approach to collecting the data it is also necessary to adopt recognised techniques and standards in assessing them and particularly with regard to environmental risk assessment.

Table 7.1: Tiered Assessment	
Tier 1 Assessment	Comparison of site contaminant concentrations against generic standards and compliance criteria including an assessment of risk using the source pathway target model
Tier 2 Assessment	Derivation of site specific risk assessment criteria and calculation of site specific clean up goals

The groundwater analytical results have been compared to Iraqi Drinking Water Standards (IQS 417/2001) and where Iraqi standards do not exist, World Health Organisation (WHO) Guidelines, has been used. However, it should be noted that the IQS appear to be adapted from WHO guidelines and not from appropriate local epidemiological studies, so in that respect are still generic criteria.

The chemical analysis results for the surface water samples have been compared, where available, to the following standards:

- Iraqi promulgated contamination standards (i.e. *The New Determinants for the Prevention of Pollution of Rivers No. (25), 1967* as amended);
- World Health Organisation (WHO) standards;
- North American (US and Canadian) guideline values;
- European Community (EC) Environmental Quality Standards (EQSs); and
- UK Environment Agency (EA).

Whilst these guidelines are not directly applicable, they do provide a useful indicator value for water quality in the absence of Iraqi promulgated standards.

Identification of Impacts

The effects on water quality likely to arise from the construction and operational phases of the proposed development are principally the following:

- the potential disruption of groundwater flows from piling, in ground structures and the dewatering of excavations;
- mobilisation of contaminants and cross contamination between water bodies by the creation of new pathways;

- spillage and leaks of new potential contaminants either directly into the river or onto exposed soils and thence groundwater;
- effects related to the discharge of routine site runoff on local land drainage and water quality;
- Disruption of tides and currents by in-water structures; and
- potential impacts arising in relation to water demand.

The impact assessment considered the likelihood of each of these scenarios.

Assessment and Evaluation of Effects

The assessment and evaluation of effects considers how those impacts that are likely could change the baseline conditions with respect to water quality and behaviour.

The assessment of effects has involved the following general approach:

- the sensitivity of aquatic receptors has been established on the basis of their use, proximity to the site, existing quality or resource value and consideration of potential pathways;
- evaluation of the significance of the potential changes in water quantity and quality and assessment of the sensitivity of the resource to the predicted changes;
- the potential effects have been classified, prior to mitigation, as minor, moderate or major (either positive or negative); and
- where the predicted effects are considered to be significant, mitigation measures have been incorporated to eliminate or reduce the impacts to an acceptable level. The residual effects (post mitigation) are discussed in the final subsection of this chapter.

7.3 Baseline Conditions – Desk-based Research

7.3.1 Groundwater

This section provides a summary of the relevant desk study information only.

Alluvium and Aeolian Deposits

The porous nature of the alluvial and Aeolian deposits suggests that any perched groundwater contained within them is likely to be in hydraulic continuity with the adjacent

Khor Al-Zubair, and the groundwater level is likely to rise up and down with the ebb and flow of the tides to a certain extent. As such there is unlikely to be a strong groundwater flow direction. As such, the groundwater contained in these deposits is likely to demonstrate high salinity levels.

Hammar Formation

It should also be noted that the Hammar Formation and the higher horizons of the Dibdibba Formation may also be in continuity with the Khor Al-Zubair channel.

Dibdibba Formation

The Dibdibba Formation comprises gravels and coarse-grained sandstones which is important in supplying water for irrigation purposes. Due to high porosity of the deposits over the site, any rainfall will either evaporate or will percolate into the ground. Water in great quantities can be found stored in this Formation, however, its quality may be highly variable, especially if the Formation is in continuity with the Khor Al-Zubair and saline intrusion is occurring.

This Formation reportedly contains two water layers, an unconfined upper layer containing brackish water and a lower, semi-confined containing saline water. These layers are separated by a hard clay bed locally known as 'Jojeb'. The salinity in the upper layer does not exceed 10,000 mg/l, while the lower layer is characterized by salinity in excess of 10,000 mg/l in most areas.

The lower horizons may not be in continuity and natural slope of the Mesopotamia Plane suggests groundwater flow direction is towards the Arabian Gulf.

7.3.2 Surface Water

This section provides a summary of the relevant desk study information only.

In 2012, EAME undertook an environmental survey of the Khor Al-Zubair, relating to the rehabilitation of KZP, which included the collection of marine water and sediment samples from within the channel. The principal findings of the study were:

- There is generally a lack of evidence of significant pollution in the water, sediment and soils that were tested;
- The concentrations of target analytes, for both the sediment and water samples, were generally less than those observed during a previous study undertaken in 2009. However, this was deemed attributable to different laboratory techniques and large

scale water and sediment transportation creating a different environment over time, rather than a notable improvement in water quality *per se*; and

- The levels of contaminants observed are not a significant cause for concern and should not prove to be an impediment to any dredging and disposal operations.

7.4 Baseline Conditions – Field Data

7.4.1 Groundwater

Borehole Locations

All seven boreholes were drilled, using rotary methods, on the 13th August 2014. All drilling works were conducted using clean drilling methods *i.e.* no oils or other contaminative fluids were used or added during drilling. Each borehole was installed to facilitate follow-on groundwater monitoring.

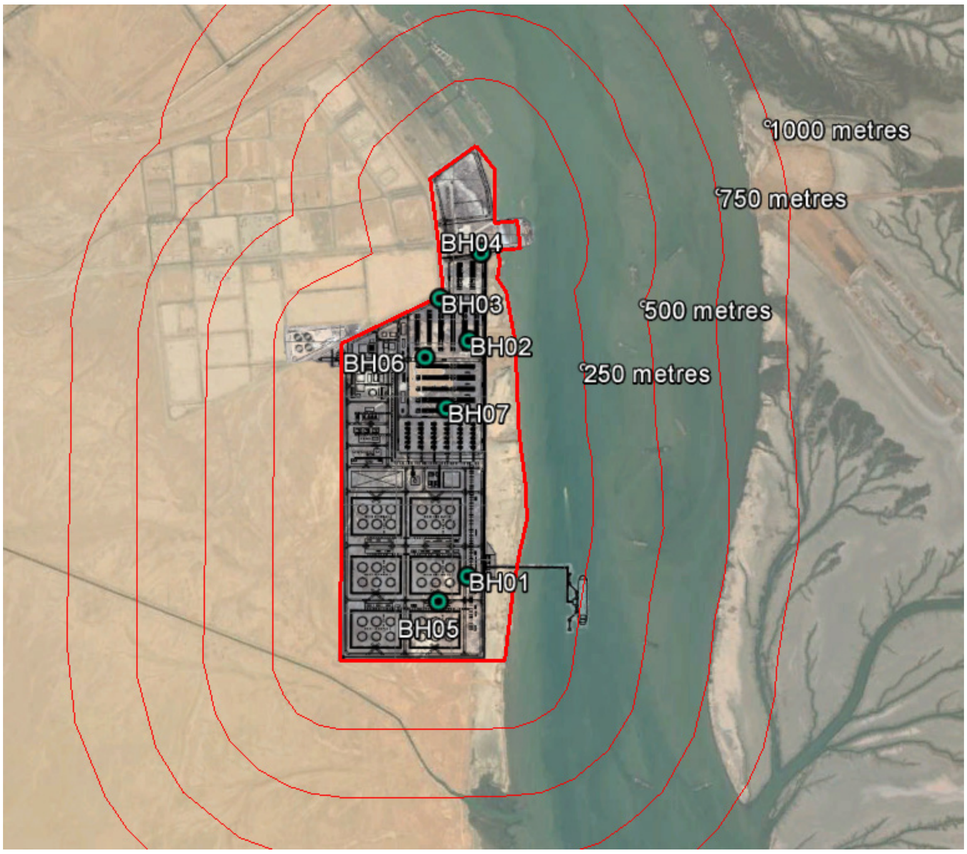


Figure 7.1: *Borehole locations*

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Table 7.2: Borehole Location and Rationale

Location ID	Easting, Northing	Latitude, Longitude	Elevation (m IGRS)	Rationale
BH01	778507.201 3341149.746	30°10'12"N 47°53'33"E	3.709	Close to the Khor Al-Zubair
BH02	778489.365 3342026.42	30°10'40"N 47°53'31"E	4.628	Close to the Khor Al-Zubair
BH03	778405.253 3342177.245	30°10'45"N 47°53'27"E	5.228	Boundary with the Freezone
BH04	778521.197 3342333.51	30°10'38"N 47°53'25"E	4.276	Targeting part of the site currently utilized
BH05	778410.867 3341038.085	30°10'09"N 47°53'27"E	4.09	Spatial coverage
BH06	778349.064 3341969.954	30°10'38"N 47°53'25"E	4.686	Spatial coverage
BH07	778399.976 3341775.446	30°10'32"N 47°53'28"E	4.851	Spatial coverage

Groundwater Survey

It was not possible to ascertain the presence (and depth) of any groundwater strikes during the drilling due to the water which was added to aid the drilling process.

Groundwater samples were obtained from the borehole and window sample locations after completion of the well installations and development of the wells. Prior to sampling the groundwater in each well, the depth to groundwater was first measured and the well developed by the removal of at least three equivalent well volumes using an electric pump. The groundwater levels were then allowed to recover before sampling to ensure that the samples were of “fresh” groundwater, representative of the surrounding water bearing strata. Samples were obtained using disposable HDPE bailers, which were specifically dedicated to each well to avoid cross-contamination between sampling locations. These were disposed of following use. The groundwater samples were assessed in the field for sheens, colour and odours and particularly examined for the presence of free-phase product (*i.e.* a distinct layer of contaminated liquid).

Groundwater Field Monitoring

During the groundwater sampling, the pH, temperature, conductivity (salinity) and ORP were recorded via hand-held field instruments. The results are presented below.

Table 7.3: Groundwater Field Observations and Measurements

BH ID	Description	Electrical Conductivity (µS/m)	pH	Temp (°C)	ORP (mV)
BH01	Brown, sediment-rich	>2,000	7.78	39.4	-40
BH02	Light brown sediment-rich	>2,000	7.13	39.7	-14
BH03	Light brown sediment-rich	>2,000	7.21	36.8	21
BH04	Light brown sediment-rich	>2,000	7.29	31.9	-26
BH05	Light brown sediment-rich	>2,000	7.81	35.8	46
BH06	Light brown sediment-rich	>2,000	7.20	40.5	-16
BH07	Light brown sediment-rich	>2,000	7.76	38.5	-29

The most notable feature of these results is the very high conductivity values (beyond the upper range of the instrument), indicating saline water. The salinity has been imparted from the saline marine soils and associated evaporation and concentration of salts as well as interaction with the tidal waters of the Khor Al-Zubair (which was initially a marine lagoon).

During groundwater sampling and monitoring, no visual or olfactory evidence of hydrocarbon contamination was noted. Following purging, it was noted that a number of the boreholes were very slow to recharge (indicating a relatively inactive groundwater regime).

Groundwater Flow Direction

The surveying of the boreholes to IGRS allows the relative resting groundwater levels to be accurately calculated which permits the determination of hydraulic gradient and hence the flow direction of the groundwater body beneath the site. The resting groundwater elevations for the seven boreholes (m bgl and to IGRS) are presented in *Table 7.4*:

Table 7.4: Resting Groundwater Depths

Location	14th August 2014		28th August 2014	
	m bgl	m IGRS	m bgl	m IGRS
BH01	4.00	7.709	3.45	7.159
BH02	4.20	8.828	3.75	8.378
BH03	4.50	9.128	3.60	8.828
BH04	3.42	7.696	3.00	7.276
BH05	5.00	9.09	5.05	9.14
BH06	5.52	10.206	5.35	10.036
BH07	5.65	10.501	5.00	9.851

Based on the resting groundwater levels, as depicted in *Figures 7.2* and *7.3* overleaf, the gradient and relative elevation of the water table in each borehole does not appear to change between monitoring visits (two weeks apart). The predominant groundwater flow appears to be towards the Khor Al-Zubair (as would be expected). However, the respective elevations show a difference of almost 3m between resting water levels in BH07 and BH01. For a contiguous water body gradient over this distance such a differential would be highly unusual (normally only a few cm difference would be observed all other things being equal). It seems likely, therefore, that the groundwater exists in different perched horizons on the site and may not behave as contiguous water body interacting with the Khor Al-Zubair channel.

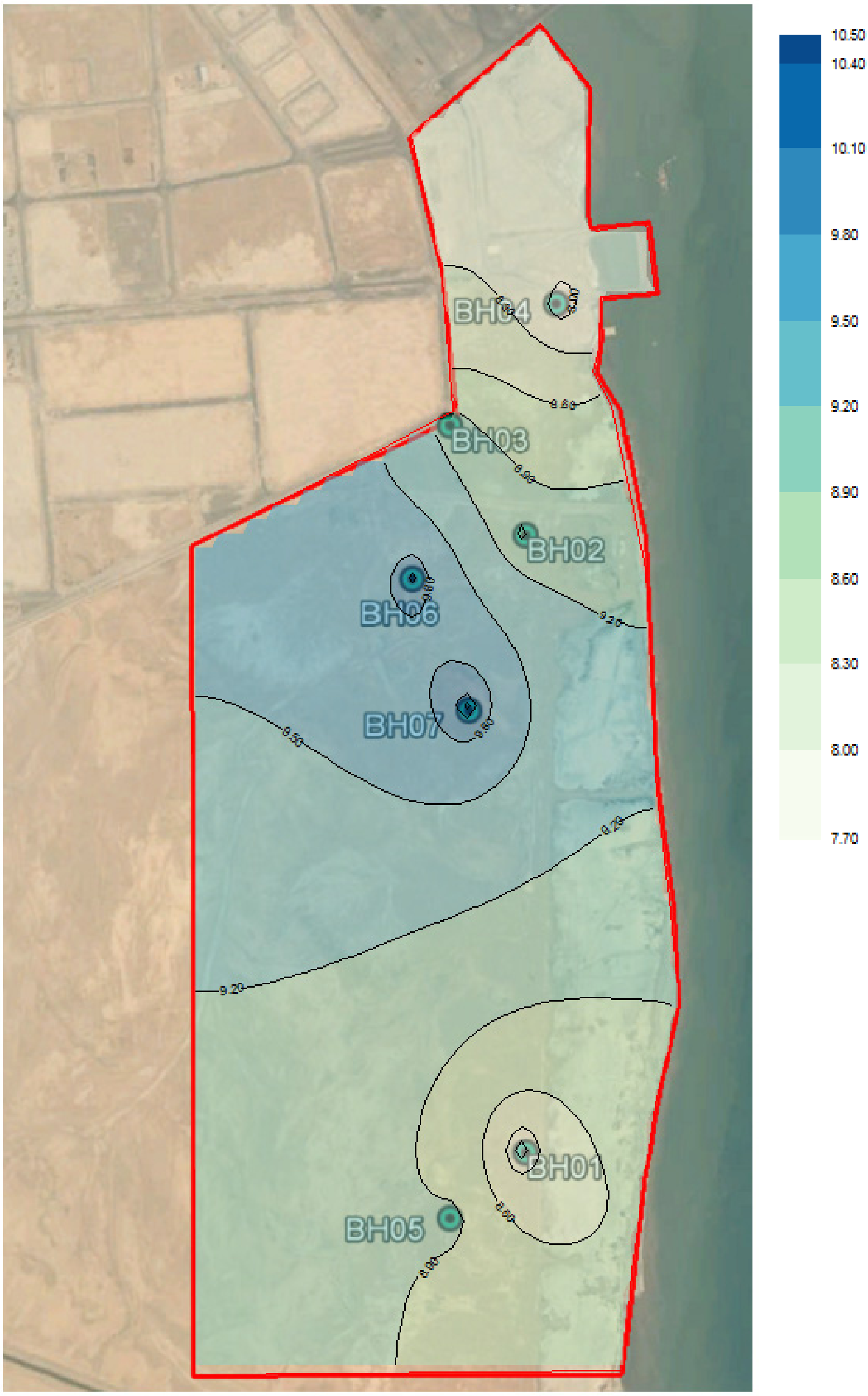

Figure 7.2: *Groundwater regime 14th August 2014*

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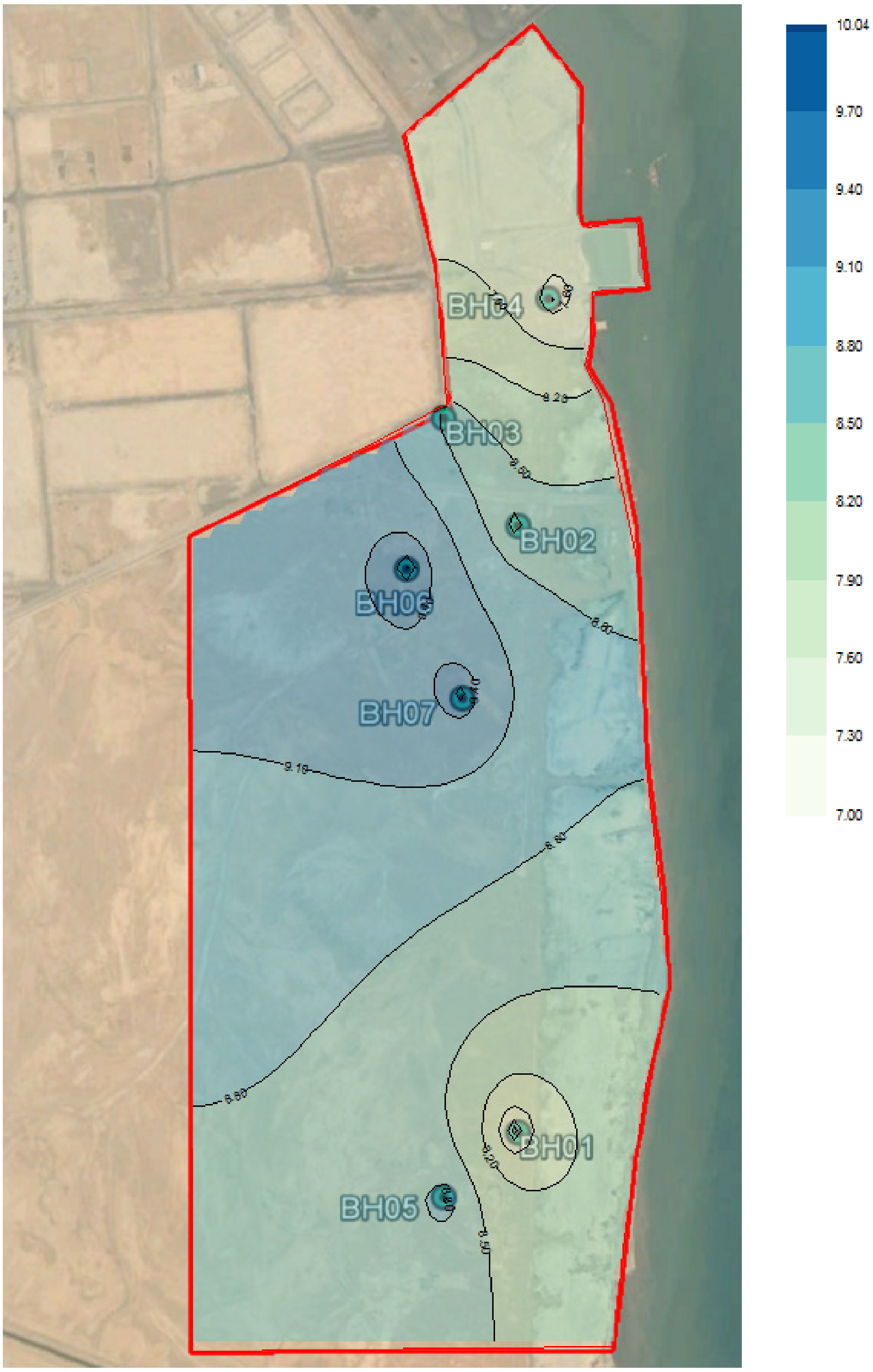

Figure 7.3: *Groundwater regime 28th August 2014*

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Groundwater Level Monitoring

In order to try and understand the relationship between groundwater and the Khor Al-Zubair channel, automatic level loggers were installed in each of boreholes. In particular this was intended to determine if the site's groundwater is tidally influenced. The level loggers were installed and operated from 28th to the 30th August 2014.

The tides in this region are termed 'irregular semi-daily tides' with two high and two low tides per day with markedly differing heights and a maximum tidal range in the order of 5m[4]. If there was a strong tidal influence on the groundwater beneath the Terminal site then a similar daily variation in groundwater level could be expected. This was not strongly observed but ignoring the water level changes at a microlevel (mm) there is an underlying rise and fall of the water level over the monitoring period (albeit only by a few millimetres). This is evident in the groundwater level data from the boreholes closest to the river, BH01 and BH02 (see *Figures 7.1* and *7.2*).

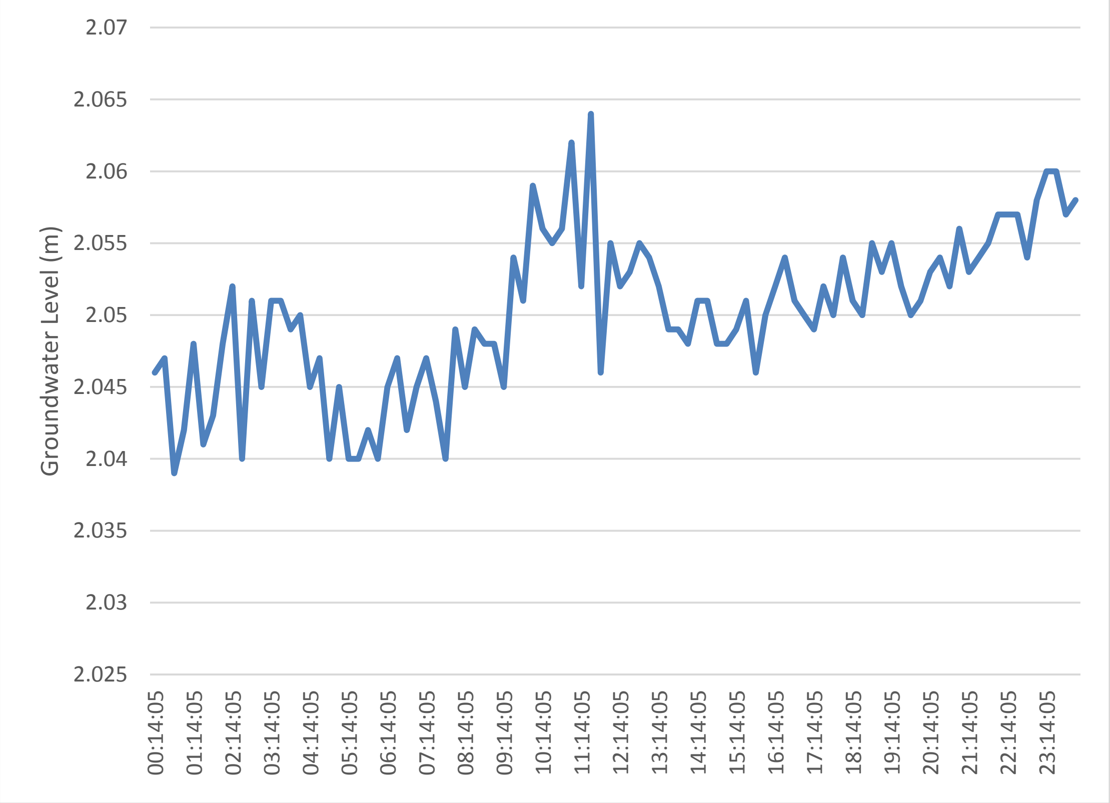

Figure 7.4: *Groundwater level data from BH01 (29th August 2014)*

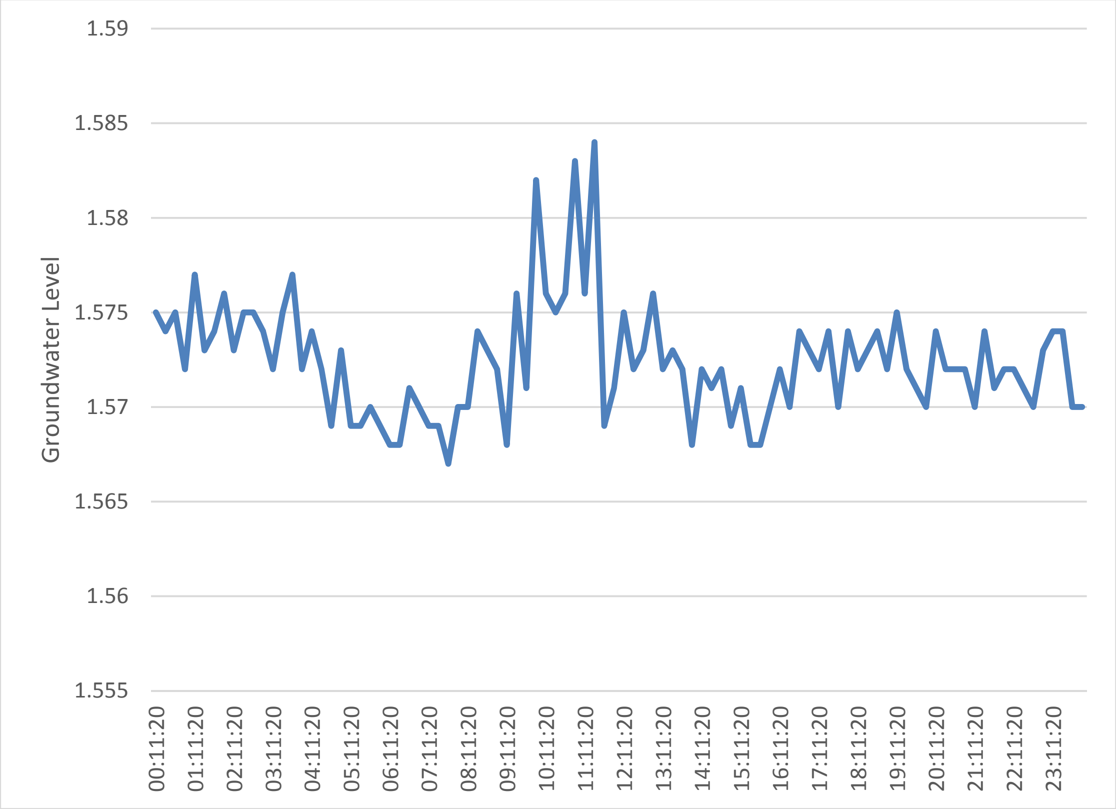

Figure 7.5: *Groundwater level data from BH02 (29th August 2014*)

The small changes in water level observed do not necessarily mean that there is direct daily interaction and transfer of water between the groundwater and Khor Al-Zubair. The small and muted tidal signature that seems to be present may simply be from increases and decreases in pore pressure in the site soils induced by the tidal fluctuations in the Khor Al-Zubair. As such, contamination of groundwater on the site would not necessarily present a migration risk to the Khor Al-Zubair and marine area.

7.4.2 Surface Water

Sampling Locations

The surface water samples were obtained from positions adjacent to the proposed Terminal development area.

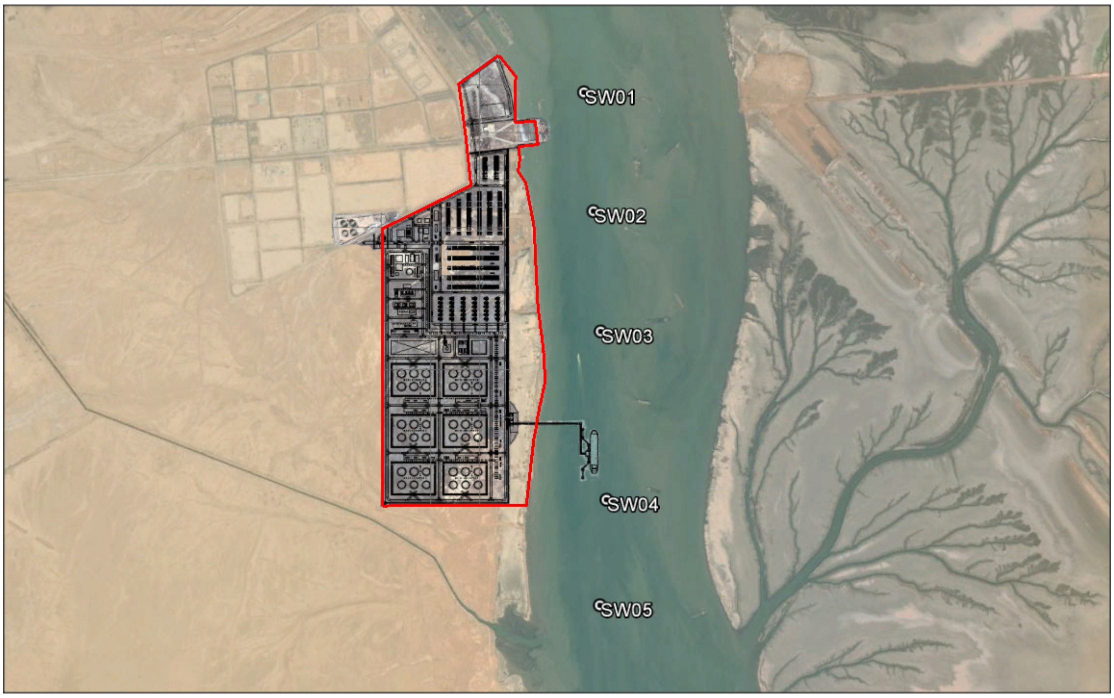

Figure 7.6: *Surface water sampling locations*

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Table 7.5: Surface Water Sampling Locations

Location ID	Grid Reference	Depth to Sea Bed (m)	Meteorological Information	Sea State
SW01	30°10'58.12"N, 47°53'45.18"E	13.7	Sunny, windy	Choppy, 0.5m waves
SW02	30°10'41.95"N, 47°53'46.66"E	14.3	Sunny, windy	Choppy, 0.5m waves
SW03	30°10'25.60"N, 47°53'47.81"E	16.1	Sunny, windy	Choppy, 0.5m waves
SW04	30°10'2.73"N, 47°53'48.72"E	11.00	Sunny, windy	Choppy, 0.5m waves
SW05	30° 9'48.38"N, 47°53'47.68"E	12.00	Sunny, windy	Choppy, 0.5m waves

The river conditions during the sampling was choppy with 0.5m waves as a result of the strong *Shamal* winds which are typical of this time of the year. The water was notably turbid.

Field Observations and Measurements

The surface water samples, obtained from two different depths, were collected using a Niskin Water Sampler on the 13th September 2014. The sampling was undertaken on a suitable vessel which had been audited and pre-approved by EAME.

Table 7.6: Surface Water Sampling - Field Observations and Measurements

Location ID	Depth (m)	Coliform Count (cfu/100ml)	Secchi Depth (m)	Water Colour
SW01	1.0	23,750	0.15	XV 86% Green, 14% Brown
	12.7	23,350		
SW02	1.0	23,300	0.35	XV 86% Green, 14% Brown
	13.3	26,600		
SW03	1.0	24,900	0.15	XV 86% Green, 14% Brown
	15.1	25,300		
SW04	1.0	23,650	0.30	XV 86% Green, 14% Brown
	10.0	22,150		
SW05	1.0	26,650	0.20	XV 86% Green, 14% Brown
	11.0	21,200		

The coliform count plate was prepared in the field and immediately placed in an incubator for 24 hours. This technique gives the total coliforms for a 2ml sample of water.

Although the total coliform count does not differentiate between coliform types, *i.e.* innocuous coliforms and faecal coliforms (such as *E.Coli*), it would be expected that due to the lack of proper sanitation in Iraq, faecal coliforms are likely to represent a significant proportion of the overall coliform count. The EU Directive 2006/7/EC concerning the management of bathing water quality sets the following classification thresholds:

- Inland waters

Intestinal enterococci – Excellent (200 cfu/100ml), Good (400 cfu/100ml), Sufficient (330 cfu/100ml)

Escherichia coli – Excellent (500 cfu/100ml), Good (1000 cfu/100ml), Sufficient (900 cfu/100ml)

- Coastal and transitional waters

Intestinal enterococci – Excellent (100 cfu/100ml), Good (200 cfu/100ml), Sufficient (185 cfu/100ml)

Escherichia coli – Excellent (250 cfu/100ml), Good (500 cfu/100ml), Sufficient (500 cfu/100ml)

The excellent and good classifications are based upon a 95-percentile evaluation whilst the sufficient classification is based upon a 90-percentile evaluation.

Although the EU guideline values have no jurisdiction in Iraq, it is clear to see that the total coliform values observed in the channel hugely exceed by orders of magnitude even the "sufficient" criteria applied in the EU. Consequently, the waters of the Khor Al-Zubair should be regarded as polluted from a coliform perspective. This is not surprising given the discharge of raw or poorly treated sewage and agricultural run-off that occurs into the channels that ultimately flow into the Khor Al Zubair.

Water Quality Field Monitoring Data

In addition, at the same time as the water sampling, EAME also used a Xylem EXO sensor to record in-situ water quality data. This is presented below.

Table 7.7: SW01 Physico-chemical In-situ Water Quality Data

Depth (m)	Temp (°C)	Cond (µS/cm)	TDS (mg/l)	Sal (psu)	ODO (mg/l)	pH	ORP (mV)	Turbidity (FNU)
0.133	28.137	44,172.6	27,089	26.64	5.26	8.09	124.2	226.97
0.165	28.202	45,715.3	28,002	27.64	5.9	8.72	95.5	221.87
1.203	28.167	45,509.1	27,893	27.52	5.68	8.29	128.6	224.68
1.327	28.143	44,217.1	27,113	26.67	5.26	8.1	124.3	227.2
1.742	28.14	44,334.2	27,187	26.75	5.26	8.1	124.7	224.57
2.914	28.145	44,268.7	27,144	26.7	5.27	8.1	124.4	230.31

Table 7.7: SW01 Physico-chemical In-situ Water Quality Data

Depth (m)	Temp (°C)	Cond (µS/cm)	TDS (mg/l)	Sal (psu)	ODO (mg/l)	pH	ORP (mV)	Turbidity (FNU)
3.246	28.141	44,286.9	27,158	26.71	5.26	8.1	124.6	229.87
4.287	28.161	45,359.8	27,805	27.42	5.52	8.17	130.8	225.24
5.529	28.152	45,271.1	27,755	27.37	5.45	8.16	130.8	241.26
6.319	28.165	45,127.3	27,660	27.26	5.36	8.14	129.3	231.15
7.577	28.16	44,505.4	27,282	26.85	5.28	8.11	125.3	227.56
8.145	28.153	44,992.7	27,584	27.18	5.34	8.14	128.6	233.62
9.444	28.159	44,896.4	27,522	27.11	5.3	8.13	127.7	230.61
10.067	28.185	44,704.6	27,391	26.97	5.28	8.11	125.8	255.62
11.235	28.174	44,795.4	27,453	27.04	5.29	8.12	127	236.73
12.39	28.187	44,782.9	27,438	27.02	5.28	8.12	126.6	250.85

Table 7.8: SW02 Physico-chemical In-situ Water Quality Data

Depth (m)	Temp (°C)	Cond (µS/cm)	TDS (mg/l)	Sal (psu)	ODO (mg/l)	pH	ORP (mV)	Turbidity (FNU)
0.127	27.807	42,789.4	26,398	25.89	4.99	8.03	180.3	309.4
1.509	27.924	43,581	26,829	26.36	5.23	8.08	193.9	250.81
2.393	27.924	43,442.8	26,744	26.27	5.13	8.08	190.7	275.99
3.56	27.922	43,399.1	26,718	26.24	5.11	8.07	189.7	280.84
4.54	27.904	43,340.6	26,691	26.21	5.1	8.07	188.9	355.75
5.014	27.818	42,824.2	26,414	25.91	4.97	8.03	180.8	330.51
6.04	27.902	43,198.3	26,604	26.11	5.04	8.06	185.9	339.02
7.439	27.892	43,123.7	26,563	26.07	5.03	8.06	184.8	346.6
8.813	27.884	43,074.9	26,537	26.04	5.01	8.05	183.9	357.23
9.981	27.834	42,885.7	26,443	25.94	4.98	8.04	181.2	348.14

Table 7.8: SW02 Physico-chemical In-situ Water Quality Data

Depth (m)	Temp (°C)	Cond (µS/cm)	TDS (mg/l)	Sal (psu)	ODO (mg/l)	pH	ORP (mV)	Turbidity (FNU)
10.009	27.871	43,028.8	26,515	26.02	5	8.05	183.4	346.67
11.116	27.887	43,023.7	26,503	26	5.01	8.04	182.6	331.54
12.096	27.878	43,005.9	26,496	26	5.01	8.05	181.9	325.31
13.168	27.831	42,889.6	26,448	25.95	5	8.04	181.5	342.79

Table 7.9: SW03 Physico-chemical In-situ Water Quality Data

Depth (m)	Temp (°C)	Cond (µS/cm)	TDS (mg/l)	Sal (psu)	ODO (mg/l)	pH	ORP (mV)	Turbidity (FNU)
0.522	27.346	42,184.1	26,244	25.74	4.98	8.08	19.1	109.1
1.61	27.355	41,858.6	26,037	25.51	4.96	8.06	21.8	110.59
3.829	27.345	42,342.9	26,343	25.84	5	8.09	17.5	108.57
5.905	27.363	41,934.4	26,080	25.56	4.95	8.04	25	110.33
7.199	27.363	41,825.9	26,013	25.48	4.93	8.03	27.8	112.41
9.469	27.362	41,741.3	25,961	25.43	4.92	8.02	30.2	109.92
11.632	27.368	41,656	25,905	25.37	4.93	8.01	34.9	108.44
13.875	27.365	41,691.1	25,928	25.39	4.92	8.01	32.6	110.59
15.224	27.367	41,667.8	25,913	25.37	4.91	8.01	33.9	109.91

A malfunction occurred with the sensor at SW04 (which was the final location surveyed) and no data was recorded.

Table 7.10: SW05 Physico-chemical In-situ Water Quality Data

Depth (m)	Temp (°C)	Cond (µS/cm)	TDS (mg/l)	Sal (psu)	ODO (mg/l)	pH	ORP (mV)	Turbidity (FNU)
0.17	26.962	54,782.2	34,322	34.76	4.91	7.94	196.2	98.53

Table 7.10: SW05 Physico-chemical In-situ Water Quality Data

Depth (m)	Temp (°C)	Cond (µS/cm)	TDS (mg/l)	Sal (psu)	ODO (mg/l)	pH	ORP (mV)	Turbidity (FNU)
0.198	26.942	54,731.7	34,303	34.74	5.12	7.93	200.1	94.31
0.319	26.981	54,830	34,340	34.78	4.81	7.94	193.1	95.07
0.524	26.988	54,852.1	34,350	34.79	4.78	7.94	191.5	95.26
1.232	26.998	54,899.3	34,374	34.81	4.76	7.94	190.1	110.58
1.829	27.000	54,902.4	34,373	34.81	4.73	7.94	185.9	105.61
2.926	27.014	54,964.9	34,404	34.85	4.7	7.94	184.7	105.8
3.992	27.039	55,040.4	34,435	34.88	4.66	7.93	182.4	113.92
4.632	27.035	55,030.6	34,432	34.88	4.64	7.93	181.3	123.87
5.808	27.045	55,070.2	34,450	34.9	4.64	7.93	180.2	141.26
6.118	27.050	55,095.6	34,463	34.91	4.63	7.93	179.7	178.16
6.21	27.034	55,032.4	34,433	34.88	4.61	7.93	177.6	154.08
6.321	27.058	55,121.3	34,474	34.92	4.61	7.93	176.2	217.59
6.515	27.049	55,088.5	34,459	34.91	4.61	7.93	174.7	148.1
7.423	27.059	55,149.8	34,491	34.94	4.58	7.93	174.3	236.93
8.185	27.059	55,164	34,500	34.95	4.57	7.93	173	310.45
9.168	27.060	55,192.1	34,517	34.97	4.56	7.93	172.1	818.38
10.313	27.370	32,186.3	20,028	19.08	3.56	7.61	47.5	262.44

The results from the in-situ measurements appear to be relatively consistent and do not indicate that there is stratification of the water, rather there seems to be a good level of mixing (which again would be expected for a river with two strong tides and a large tidal range where extensive mixing would be promoted).

7.5 Baseline Conditions – Chemical Contamination

7.5.1 Groundwater

Analytical Strategy

A groundwater sample from each borehole was submitted for chemical analysis. The analytical strategy was designed to provide an assessment of the presence of a common range of potential contaminants.

Table 7.11: Groundwater Analytical Strategy

Parameter	Rationale
General Inorganics pH, Electrical Conductivity, Salinity, Total Cyanide, Complex Cyanide, Free Cyanide, Sulphate as SO_4, Chloride, Phosphate as PO_4, Phosphate as P, Ammonia as NH_3, Total Nitrogen (Kjeldahl), Nitrate as N, Nitrate as NO_3, Nitrite as N, Nitrite as NO_2,	Commonly associated with industrial sites
Total Phenols (Monohydric)	Commonly associated with industrial sites
Heavy Metals and Metalloids	Commonly associated with industrial sites.
Monoaromatics	
TPH (C_{10} – C_{40})	Targeted analysis for fuels and oils
VOCs	Targeted analysis for fuels and oils
SVOCs	Targeted analysis for PAH compounds and phenols
Radiation Screening	Targeted analysis for NORMs

Assessment of Analytical Results

The first stage of assessment was to screen out those compounds that were not present above the MDL of the laboratory. These are provided in the list below, and have thus not been considered further within the assessment.

- Cyanide (Total, Complex and Free);

- Phosphate as PO_4;
- Phosphate as P;
- Total Phenols (monohydric);
- Hexavalent Chromium; and
- Monoaromatics.

The remaining results are presented in *Appendix H1* and summarised in *Table 7.12*.

Table 7.12: Summary of Groundwater Analytical Results

Parameter	Concentration Range (µg/l)	Guideline Value	No. of Exceedances Above Guideline Value
General Inorganics			
pH	7.5 – 8.5	6.5 – 8.5*^{1}	0
Electrical Conductivity	17,000 – 120,000 µS/cm	NG	-
Salinity	11.2 - >42 ppt	NG	-
Sulphate as SO_4	722,000 – 2,470,000	250,000*^{1}	**All**
Chloride	4,100 – 45,000 mg/l	250 mg/l*^{1}	**All**
Ammonia as NH_3	780 – 6,000	NG	-
Total Nitrogen (Kjeldahl)	3.2 – 5.4	NG	**-**
Nitrate as N	<MDL – 1.2 mg/l	11mg/l*^{2}	0
Nitrate as NO_3	<MDL – 5.4 mg/l	50 mg/l*^{1}	0
Nitrite as N	<MDL – 970	900*^{2}	**2 – BH04 and BH06**
Nitrite as NO_2	<MDL – 3,200	3,000*^{1}	**2 – BH04 and BH06**
Heavy Metals / Metalloids			
Arsenic (dissolved)	1.05 – 3.57	10*^{1}	0
Cadmium (dissolved)	<MDL – 0.23	300*^{1}	0
Iron (dissolved)	5 – 67 mg/l	300*^{1}	0
Lead (dissolved)	0.4 – 1.5	10*^{1}	0

Table 7.12: Summary of Groundwater Analytical Results

Parameter	Concentration Range (µg/l)	Guideline Value	No. of Exceedances Above Guideline Value
Manganese (dissolved)	68 - 710	400 *[2]	**2 – BH02 and BH07**
Mercury (dissolved)	<MDL – 1.32	1*[1]	**2 – BH03 and BH05**
Nickel (dissolved)	9 – 23	20*[1]	**1 - BH07**
Tin (dissolved)	<MDL – 1.2	NG	-
Zinc (dissolved)	1.6 – 5.7	3,000*[1]	0
Petroleum Hydrocarbons			
TPH $C_{10} – C_{40}$	<MDL – 1,120	NG	-
VOCs			
1,2-dichloroethane	638 – 990	NG	-
SVOCs			
2-Methylnaphthalene	<MDL – 0.84	NG	-
Dimethylphthalate	<MDL – 2.0	NG	-
Diethyl phthalate	<MDL – 0.13	NG	-

Notes:

All results expressed in µg/l except for pH and where indicated

<MDL = Below the Method Detection Limit

NG = No guideline value calculated

- = Not relevant

*[1] = Iraqi Drinking Water Standards (2001)

*[2] = World Health Organisation (WHO) Guidelines for Drinking Water Quality

Summary of Groundwater Quality Baseline Conditions

A number of contaminants were found to be elevated when compared to relevant guideline values including sulphate, chloride, nitrate, manganese, mercury and nickel.

The elevated sulphate, chloride and manganese concentrations were not unexpected due to the hypersaline marine environment of the site and such levels are considered natural in this environment.

The elevated mercury may be a result of its natural occurrence in the environment, significant mercury deposits exist in the Alpine – Himalayan orogenic belt[3] but there could also be an anthropogenic contribution from nearby industrial emissions. Similarly Nickel could be both natural and anthropogenic in origin.

TPH was noted, above laboratory's level of detection, in three boreholes, BH01, BH05 and BH06. No hydrocarbon contamination was noted in the soil samples or observed on-site, which suggests that the hydrocarbons observed may the remnants of historic contamination that may have occurred on the site. The levels are not considered to be problematic.

One VOC, 1,2-dichloroethane, was detected in all seven groundwater samples and the highest concentration was detected in BH02. This compound is added to leaded gasoline as a lead scavenger.   This implies a generally low level of contamination throughout the groundwater body.

In total, three SVOCs were detected in the groundwater samples:

- 2-Methylnaphthalene, a natural component of crude oil and coal and is found in pyrolysis,combustion products such as used oils and emissions from combustion engines, was detected in BH05, BH06 and BH07;
- Diethyl phthalate (DEP) was detected in the sample obtained from BH07 only. This compound is a solvent most commonly used to make plastics more flexible; and
- Dimethyl phthalate (DMP) was detected in BH01, BH02, BH04, BH05 and BH07. DMP has many uses including in solid rocket propellants, lacquers, plastics, safety glasses, rubber coating agents, molding powders, insect repellents and pesticides.

Again the presence of these substances at these levels are not considered to be problematic but it is indicative of low levels of contamination.

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[3] GESAMP: Arsenic, Mercury and Selenium in the Marine Environment, UNEP Regional Seas Reports and Studies No 92, UNEP, 1988

7.5.2 Surface Water

Analytical Strategy

The analytical strategy was designed by EAME to provide an assessment of the presence of a common range of potential contaminants.

Table 7.13: Surface Water Analytical Strategy

Parameter	Rationale
General Inorganics pH, Electrical Conductivity, Salinity, Total Cyanide, Complex Cyanide, Free Cyanide, Sulphate as SO_4, Chloride, Phosphate as PO_4, Phosphate as P, Total Nitrogen (Kjedahl), Nitrate as N, Nitrate as NO_3, Nitrite as N, Nitrite as NO_2	General indicators of water quality
Total Phenols (Monohydric)	General indicator of water quality
Speciated Total PAHs	Speciated suite to determine the presence of fuel derivatives and associated compounds
Heavy Metals and Metalloids	General indicator of water quality
TPH ($C_{10} – C_{40}$)	Targeted analysis for fuels and oils

Assessment of Analytical Results

EAME has undertaken a tiered approach in order to provide a preliminary qualitative assessment of the sediment and surface water analytical results.

The first stage of assessment was to screen out those compounds that were not present above the method detection limit (MDL) of the laboratory. These are provided in the list below, and have thus not been considered further within the assessment:

- Cyanide (total, complex and free);
- Nitrite as N;
- Nitrite as NO_2;

- Total phenols (monohydric);
- Total EPA-16 PAHs;
- Chromium (hexavalent); and
- TPH ($C_{10} – C_{40}$).

The remaining results are presented in *Appendix H2* and summarised in *Table 7.14*.

Table 7.14: Summary of Surface Water Analytical Results

Parameter	Concentration Range (µg/l)	Guideline Value	No. of Exceedances Above Guideline Value
General Inorganics			
pH	7.8 – 7.9	6.5 – 8.5^{*1}	0
Electrical Conductivity	50,000 – 74,000 µS/cm	NG	-
Salinity	36.7 - >42 ppt	NG	-
Sulphate as SO_4	3,810,000 – 5,020,000	200,000^{*1}	**All**
Chloride	11,000 – 17,000 mg/l	200 mg/l^{*1}	**All**
Phosphate as PO_4	<MDL - 62	NG	**-**
Phosphate as P	<MDL - 20	NG	**-**
Total Nitrogen (Kjeldahl)	1.4 – 7.3	10^{*2}	0
Nitrate as N	<MDL – 0.4 mg/l	15 mg/l^{*1}	0
Nitrate as NO_3	<MDL – 1.9 mg/l	15 mg/l^{*1}	0
Heavy Metals / Metalloids			
Arsenic (dissolved)	342 – 5.04	50^{*1}	0
Cadmium (dissolved)	<MDL – 0.05	5^{*1}	0
Copper (dissolved)	11 - 19	50^{*1}	0
Iron (dissolved)	0.015 – 0.026 mg/l	0.3 mg/l^{*1}	0
Lead (dissolved)	0.5 – 5.9	50^{*1}	0
Manganese (dissolved)	0.31 - 1.3	10^{*1}	0

Table 7.14: Summary of Surface Water Analytical Results

Parameter	Concentration Range (µg/l)	Guideline Value	No. of Exceedances Above Guideline Value
Mercury (dissolved)	1.02 – 1.45	1*[1]	**All**
Nickel (dissolved)	2.9 – 4.9	10*[1]	0
Tin (dissolved)	<MDL – 0.6	NG	-
Zinc (dissolved)	3.1 - 13	50*[1]	0

Notes:

All results expressed in µg/l except for pH and where indicated

<MDL = Below the Method Detection Limit

NG = No guideline value calculated

- = Not relevant

*[1] = The New Determinants for the Prevention of Pollution of Rivers (No. 25, 1967)

*[2] = US EPA Drinking Water Guideline

Based on the above factors, an initial qualitative assessment of the presence of potential pollutant linkages can be undertaken.

Conceptual Site Model

The ground and surface water conditions, as determined through the site investigation process, have been summarised into a Conceptual Site Model (CSM), which defines the key sources, pathways and receptors that have been identified as being relevant to this site. The CSM within this chapter summarises the following:

- **SOURCES** - the identification of contaminants within the ground and surface water that represent potential pollution sources;
- **PATHWAYS** - the identification of the potential exposure pathways between the potential sources;
- **RECEPTORS** - the identification of the potential receptors for the contamination; and
- **LINKAGES** - the identification of potential pollutant linkages.

All discussions in this section have been made in relation to the site's proposed industrial/commercial setting.

Identification of Potential Sources

Based on the information gained during the desk study and field work, a summary of the contaminant sources is outlined below:

- **Surface Water:** All ten samples were found to have elevated concentrations, above the relevant guideline values of sulphate, chloride and mercury; and
- **Groundwater:** A number of contaminants were found to be elevated under relevant guideline values including sulphate, chloride, nitrate, manganese, mercury and nickel. In addition, TPH was noted, above laboratory's level of detection, in three boreholes. One VOC, 1,2-dichloroethane, was detected in all seven groundwater samples and the highest concentration was detected in BH02. In total, three SVOCs were detected in the groundwater samples; 2-Methylnaphthalene, Diethyl phthalate (DEP) and Dimethyl phthalate (DMP).

In addition to the limited potential pollution sources that already exist on and around the site, the following potential sources of pollution that may arise as a result of the construction and operational phases of the proposed development have been identified.

Table 7.15: Potential Future Sources of Water Pollution

Construction Phase	Operational Phase
Spillages of polluting materials during construction activities (e.g. fuel spills during plant refuelling)	Increased surface water run-off (which although should be clean rainwater, could pick up contaminants if housekeeping on the site is poor or spillages have occurred, such as fuel and oil leaks from parked vehicles)
Dewatering of contaminated groundwater from excavations and the associated generation of large volumes of potentially contaminated water	Increased wastewater from sanitary usage. In addition, there is the potential for vehicle washing to be undertaken on site
	Storage of refined petroleum products
	Transfer of refined petroleum products

Potential Receptors

Accepting that the potential pollution sources are well understood, the following project related receptors, with regards to water quality, have been identified:

- groundwater underlying the site;
- surface water *(i.e*. Khor Al-Zubair);
- ecological diversity in the receiving waters could also be impacted by certain contaminants that could render the water quality incapable of supporting pollution intolerant species;
- river users (current and future);
- construction workers (when construction commences);
- on-site buildings and services (when construction commences); and
- third party land (*i.e.* the possibility of contamination migrating off-site onto third adjacent land *via* contaminated surface water and groundwater or run-off).

Identification of Potential Exposure Pathways

Exposure pathways are the potential routes and mechanisms by which potential on-site sources could be linked to the identified potential receptors and thereby expose them to potential harm. **Only plausible pathways need be considered**. The following potential pollutant pathways, with regards to water quality, have been identified at the site:

- Dermal;
- Ingestion;
- Migration of contaminants to shallow groundwater bodies and aquifer and to surface water *via* leaching and run-off, or transmission along conduits;
- Spillages and infrastructure failure; and
- Cross contamination of water bodies and soil contaminants through piling activities.

Potential Pollutant Linkages

In order for there to be a plausible pollutant linkage there must be a source, receptor and pathway and a feasible linkage between them (a so called pollutant linkage). Consequently, even where a contaminant is identified, if there is no pathway for the contamination to reach a receptor, or no receptor then there can be no significant risk and remedial actions are not required. Furthermore, even if there is a complete pollutant linkage, it is possible that the contaminant concentration that can pass along the linkage does not represent a significant risk to human health or the environment. Central to this risk assessment process is the development of a 'conceptual model'. This is a descriptive and/or pictorial representation of the area of potential contamination, the surrounding environment and the processes acting on the contaminants by which they can move and come into contact with receptors (*e.g.* by leaching and migration into groundwater).

Production of a conceptual model requires an assessment of risk to be made. Risk is a combination of the likelihood of an event occurring and the magnitude of its consequences. Therefore, in order to assess risk both the likelihood and the consequences of an event must be taken into account. This report adopts the methodology for risk evaluation presented in CIRIA report C552[4]. The method is qualitative and involves the classification of the following:

- the magnitude of the potential severity or consequence of the risk occurring (*Table 7.16*);
- the magnitude of the likelihood or probability of the risk occurring (*Table 7.17*); and
- once the likelihood of an event occurring and its severity have been classified, a risk category can be assigned using *Table 7.18*.

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[4] Contaminated Land Risk Assessment – A Guide to Good Practice, CIRIA report C552 2001

Table 7.16: Classification of Consequence

Consequence	Definition
Severe	Short term (acute) risk to human health likely to result in 'significant harm' as defined by the Environment Protection Act 1990, Part IIA. Short term risk of (significant) pollution of sensitive water resource. Catastrophic damage to building/property. A short term risk to a particular ecosystem, or organism forming part of such ecosystem.
Medium	Chronic damage to human health (significant harm). Pollution of sensitive water resources. A significant change in a particular ecosystem, or an organism forming part of such an ecosystem.
Mild	Pollution of non-sensitive water resources. Significant damage to crops, buildings, structures and services. Damage to sensitive buildings/structures/services or the environment.
Minor	Harm, although not necessarily significant harm, which may results in a financial loss, or expenditure to resolve. Non-permanent health effects to human health (easily prevented by means such as personal protective clothing etc.). Easily repairable effects of damage to buildings, structures and services.

Table 7.17: Classification of Probability

Likelihood	Definition
High	There is a pollution linkage and an event that either appears very likely in the short term and almost inevitable over the long term or there is evidence at the receptor of harm or pollution.
Likely	There is a pollutant linkage and all the elements are present and in the right place, which means that it is probable that an event will occur. Circumstances are such that an event is not inevitable, but possible in the short term and likely over the long term.
Low	There is a pollution linkage and circumstances are possible under which an event could occur. However, it is by no means certain that even over a longer period that such an event would take place and is even less likely in the shorter term.
Unlikely	There is a pollution linkage but circumstances are such that it is improbable that an event would occur even in the very long term.

Table 7.18: Risk Assessment Matrix

		Consequence			
		Severe	**Medium**	**Mild**	**Minor**
Likelihood of Occurrence	**High**	Very High	High	Moderate	Moderate/Low
	Likely	High	Moderate	Moderate/Low	Low
	Low	Moderate	Moderate/Low	Low	Very Low
	Unlikely	Moderate/Low	Low	Very Low	Very Low

EAME has devised a conceptual model based on the information obtained through the site investigation and is based on future commercial/industrial redevelopment. This is detailed in tabular format in *Table 7.19*.

Table 7.19: Conceptual Site Model

Source

(A) **Groundwater:** Elevated concentrations of sulphate, chloride, nitrate, manganese, mercury and nickel. In addition, TPH was noted, above laboratory's level of detection, in three boreholes. One VOC, 1,2-dichloroethane, was detected in all seven groundwater samples. In total, three SVOCs were detected in the groundwater samples; 2-Methylnaphthalene, DEP and DMP.

(B) **Surface Water:** Samples were found to have elevated concentrations of sulphate, chloride and mercury.

Source	Pathway	Receptor	Potential Pollutant Linkage and Significance

Table 7.19: Conceptual Site Model

(A)	Cross contamination between groundwater bodies due to the piling exercise Direct leaching into groundwater from contaminated soils	**Controlled Waters (CWR)** On-site groundwater bodies	**CWR – Low Risk** Limited contamination noted
(A)	Direct contact with building materials	**Built Environment (BER)** On-site buildings and services	**BER – Low Risk** Limited contamination noted although the high sulphate and chloride content of this saline/marine environment may be aggressive towards building materials.
(B)	Cross contamination between groundwater and surface water	**Ecosystems (ESR)** Ecology of Khor Al-Zubair	**ESR – Low Risk** Groundwater and surface water do not appear to be in dynamic hydraulic conductivity and transfer of pollutants between them is unlikely.
(B)	Direct leaching into Khor Al-Zubair from contaminated soils Contaminated water run-off during construction and operational phases Increased waste water consumption	**Controlled Waters (CWR)** Surface water bodies (i.e. Khor Al-Zubair)	**CWR - Low risk** No significant soil contamination was noted.

Table 7.19: Conceptual Site Model

(A) (B)	Spillages during operational phase	**Built Environment (BER)** On-site buildings and services **Human Health (HHR)** Future site users **Controlled Waters (CWR)** Surface water bodies (i.e. Khor Al-Zubair)	**BER – Low Risk** Appropriate industry standard pollution prevention and housekeeping protocols to be implemented **HHR – Low Risk** Appropriate industry standard pollution prevention and housekeeping protocols to be implemented **CWR – Low Risk** Appropriate industry standard pollution prevention and housekeeping protocols to be implemented
(A) (B)	Dermal, Ingestion	**Human Health (HHR)** River users (current and future) Construction workers	**HHR – Low Risk** Limited contamination noted Appropriate PPE to be utilised by construction workers

Summary of Chemical Surface Water Baseline Conditions

In summary, all ten samples were found to have elevated concentrations of sulphate and chloride, above the relevant guideline values, but this is effectively a marine environment so such high levels are natural and to be expected.

In terms of potential contamination, elevated concentrations of mercury were noted in all ten samples. These concentrations could be the result of natural accumulations in the environment (of geological origin) but may also be related to anthropogenic sources given the proximity of a port, heavy industry and major city, with limited pollution control measures employed.

Overall, whilst some elevated concentrations of certain species have been observed and the water quality of the Khor Al-Zubair channel is clearly impacted by coliforms, the site is not regarded as a contaminated and the levels of contaminants observed are not considered to be significant. Other than the potential for the high sulphate and chloride levels in the soils and groundwater (and of course river water) to be aggressive towards construction materials (concrete), the chemical conditions of the groundwater and river water are not considered to be problematic from a development perspective

7.6 Impact Assessment

The impact assessment in the context of an ESIA, considers the potential for the development proposals to impact on the baseline conditions. The groundwater and surface water within the development area can be regarded as uncontaminated on the whole.

Based upon this conceptual model, the following discussion addresses the impact assessment for the site, based on the current understanding and whether plausible pollutant linkages are likely to be created by the proposed development and lead to significant impacts.

Potential Risks to the Groundwater and Surface Water – Construction Phase

The proposed development is unlikely to significantly impact on the baseline groundwater environment under normal operating conditions (abnormal conditions are dealt with in *Chapter 10*). The risk of accidental spillage of pollutants to ground during the construction phase will be controlled by the implementation of a Construction Environmental Management Plan (CEMP). Any uncontrolled releases of potential contaminants to ground will be managed through the pollution response plan in the CEMP and any impacted area will be remediated. Furthermore, no significant mobile contamination source was observed on the site that could be mobilised by earthworks or piling works. It is recognised, however, that any site investigation is a limited sampling exercise and that there is a possibility of pockets of contamination existing in parts of the site that have not been investigated. Consequently there is a small potential for piling and earthworks impacts if such areas exist and are disturbed.

Environmental Implications of Piling

In impact terms, the principal concerns with piling are:

- piling equipment can generate both noise and vibration that could be evident off-site (this is dealt with in the air quality chapter);
- certain piling methods can bring spoil (some of which may be contaminated) to the surface and other methods may drive contaminated soil down into deeper horizons where it would not have previously existed and those expose groundwater to it; and
- any piling method that passes through contaminated ground or groundwater into underlying uncontaminated strata creates a potential pathway for downward migration of contaminants (i.e. can cross-contaminate previously uncontaminated ground or

groundwater) by allowing contaminated water to drain along the sides of the pile into deeper strata.

It is understood that KZP used 24m deep piles for the berth construction and a similar depth of pile can be anticipated here. The evidence of the site investigation would suggest that the site is not particularly contaminated and there is a low likelihood of contamination been dragged into the deeper groundwater horizons. If any contamination does exist on the site it is likely to be in the near surface zone. If the piling is achieved by pre-cast driven piles, the potential for cross contamination is further reduced. If augered piles are used, these bring material to the surface and thus would also convey contamination to the surface rather than down into deeper groundwater bodies, but the open pile hole does provide a temporary (albeit limited) conduit for cross contamination temporarily (if mobile contamination existed).

The potential for impact from the construction activities does exist but the works will be undertaken under a CEMP and the likelihood of significant impact on groundwater and surface water quality is **Low**.

Potential Risks to the Groundwater and Surface Water – Operational Phase

The developed and operational site will involve the storage and transfer of large volumes of potentially polluting hydrocarbon products across the marine, inter-tidal and land zones. This means there is the potential for substantial releases of these substances from the site. This could have a major impact on soil, groundwater and surface water quality if it occurs. Large scale accidents and incidents and their associated impacts are addressed in *Chapter 10*. Under normal operating conditions, the storage areas will be bunded (secondary containment), the pipelines and transfer systems will be monitored and surveyed regularly and will be operated by trained personnel and all of the equipment will be designed and built to international standards. The operators will also have a comprehensive preventive maintenance programme for all critical infrastructure, plant and equipment. Bearing all of this in mind, the potential impact on groundwater and surface water quality during normal operating conditions is **low**.

The remaining impact consideration is physical disturbance of the groundwater and surface water regimes by the built development.

The surfacing of the site and installation of surface water drainage systems will effectively prevent future percolation and infiltration of rainwater into the ground and thus may limit groundwater recharge where the site has been hard surfaced. This area, however, is very small in surface area and rainfall in this region is very low. Compared to the surrounding unsurfaced land limiting effect on groundwater re-charge will be **negligible**.

The other main area of interaction between the operational development and the water environment will be the placement of piles and the jetty structures in the river channel itself. These could potentially interrupt currents and tidal flows but the relative cross sectional area of these structures compared to the river flow will be very low. The main impact will be localised transient eddy currents and vortices around the legs of the jetty. The overall impact on the tidal currents and flows will be **negligible** as the water will be able to pass around the structures and will not be impeded by them.

Closure and Decommissioning

When the proposed Terminal is closed and decommissioned (and possibly demolished), there may be impacts associated with this. The activities that would typically be involved in the closure and decommissioning of such a facility would be similar to those during construction, involving plant and machinery, earthworks, materials movement and management. Likewise, therefore, the impacts would be similar. It is unlikely that a site such as this would be returned to the status of the present undeveloped site. Whilst potentially polluting materials and valuable or recyclable infrastructure (for example, tanks, pipes, scrap metal, machinery, plant) will be removed, the major structures (concrete, berths, drainage systems, walls, fences, etc) would be unlikely to be removed. In all likelihood, the site would probably be re-used for alternative uses or redeveloped. As such the extent of the works and associated traffic and construction type activities (machinery, earthworks, etc) associated with closure of the facility, whilst similar in nature to the construction activities, are expected to be lesser in scale and duration, as would be the associated impact. It is considered, therefore, that the impact of closure and decommissioning activities upon the water environment will be negligible.

7.7 Mitigation

Control of Surface Water Drainage during Construction

The operation of construction vehicles and general construction activities give rise to the potential for surface runoff to become contaminated with hydrocarbons, silt or other construction materials. This may in turn lead to a contamination event should site drainage be allowed to enter surface watercourses or the ground untreated. These and other pollution risks will be mitigated by the use of a Construction Environmental Management Plan (CEMP) which will require specific pollution prevention and environmental protection techniques to be employed. This may include:

- The use of settlement ponds ponds to aid the removal of any potentially contaminated suspended material that might be derived from construction materials;

- Construction vehicles will be properly maintained to reduce the risk of hydrocarbon contamination and will only be active when required; and
- Construction materials that could spill and cause pollution will be stored, handled and managed with due regard to the sensitivity of the local aquatic environment and provided with secondary containment such that the risk of accidental spillage or release will be minimised.

Residual impact after mitigation: Minor Positive

Wastewater Generation

It is also necessary to consider the potential wastewater generation associated with the new development. The main wastewater stream generated once the site is operational will be sanitary waste water from the toilet blocks, washrooms and catering facilities associated with the site tenants.

Once the site is operational, given the absence of access to a foul sewer, it will be necessary for Terminal to either discharge to a bespoke sewage treatment plant (package plant) that will treat the sanitary waste to a sufficient standard to allow discharge of the treated wastewater to a watercourse or to collect and store sewage to facilitate transport to an offsite treatment facility. The project is not yet at a stage where the detailed design or capacity of these systems can be established, but either option will meet relevant discharge criteria.

Residual impact after mitigation: Minor Negative

Potential Groundwater Interruption during Construction

During construction, dewatering of excavations may be required. Waters generated in this manner will be controlled, treated and discharged appropriately.

Residual impact after mitigation: Neutral

Control of Surface Water or Groundwater by Routine (Operational) Drainage

The principal source of contamination from routine operation of the site is hydrocarbon contamination from the transfer and storage of petroleum products. As such, the management and housekeeping protocols must meet industry standards. Once constructed, the Terminal will allow for the poorly maintained and inefficient infrastructure at KZP to be abandoned and the berths returned to their original design purpose. This will help to reduce the likelihood of pollution incidents of the Khor Al-Zubair.

Residual impact after mitigation: Moderate Positive

Increased Water Consumption

Water efficiency measures can reduce consumption. Therefore, water minimisation and conservation measures are important considerations for the proposed development, to minimise the increase in water demand. Water demand will be reduced as far as possible, by the incorporation of appropriate water saving devices, wherever practicable.

Residual impact after mitigation: Minor Negative

Mitigation of Piling Impacts

A detailed Method Statement will be then agreed setting out the piling technique and protection methods that will be employed. It is likely that this will include:

- augered Piling to bring the contaminated material up to the surface where it can be managed and controlled;
- pre-emptive or simultaneous advancement of solid casing, which will isolate the material being excavated from the surrounding material and prevent groundwater seepages into the borehole, and
- in-situ casting of the Piles with secondary sealing of the made-ground/natural ground interface so that groundwater cannot be transmitted downwards along the outside edge of the formed pile.

The rotary auger piling will bring materials to the surface from each horizon that it passes through. It is proposed that these pile horizons are monitored and periodically sampled to enable them to be characterised and, where possible, segregated. This will enable contaminated material (if any) and uncontaminated material to be defined and segregated for management and handling.

In conclusion, given the location and nature of the nearest sensitive receptors, the overall environmental impact of the proposed development in relation to water quality and hydrology is considered to be Minor Positive.

7.8 Residual Impacts

7.8.1 Residual Effects – Operational Phase

The effects arising from the construction phase are transient in nature.

Residual impact after mitigation; Neutral

7.8.2 Residual Effects – Operational Phase

Once operational, the main waste water stream once the site is operational will be sanitary wastewater from the toilet blocks, washrooms and catering facilities associated with the plant.

Residual impact after mitigation; Neutral

7.9 Flood Risk

A final environmental consideration is flood risk to the development site. EAME has been provided with a standalone preliminary Flood Risk Assessment (FRA) relating to the site. The FRA was undertaken to quantify the risk of flooding, identify potential flooding mechanisms and appropriate mitigation measures (if required).

The site was identified as potentially being at risk from tidal ingress, fluvial flooding from wadis to the west of the site and pluvial flooding. Proposed flood mitigation measures include the construction of a flood bund along the bank of the Khor Al-Zubair, ensuring that the western perimeter wall is water tight and the implementation of an approximately designed site drainage system. It was recommended that a detailed FRA be undertaken prior to moving into the Front End Engineering Design (FEED) phase of the project following the collection of additional data (meteorological, geotechnical, topographic, hydrological and infrastructure).

Residual impact after mitigation: Neutral