Responsible Groundwater Management in Kuwait's Oil Fields

Lessons Learned from KOC-KISR Joint Projects

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Acknowledgment

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Introduction

- Oil production industry is, without a doubt, the backbone of the Kuwaiti economy. It is not possible to over emphasize the importance of supporting this industry.
- Due to the urgent need of the Kuwait Oil Company （KOC） and based on their future development plans, which propose a an increase in the utilization of groundwater reserve.

Introduction

- In line with KOC's efforts to preserve the natural resources of the country, in realization of the fragileness of the groundwater resources.
- Kuwait Institute for Scientific Research （KISR）has completed several research project requested and funded by KOC.
- In this presentation the outcomes of two completed selected projects are presented.

Selected 2 KISR-KOC Projects

1. Impacts of Effluent Disposal Pit on Groundwater Quality at Sabriya Oil Field

2. Management of Water Table Rise around A Booster Station in Burgan Oil Field

Project 1

IMPACTS OF EFFLUENT DISPOSAL PIT ON GROUNDWATER QUALITY AT SABRIYA OIL FIELD

Introduction

- Based on an earlier surface resistivity survey and KOC recognition of the threat imposed by the discharge pits upon the groundwater quality in the areas of its operation.
- The studied disposal pit is unlined and located in the close proximity of the sensitive fresh groundwater aquifers in Raudhatain and Umm Al-Aish areas.
- These fresh groundwater aquifers are the only source of natural groundwater with potable water quality.

Objectives

- To investigate the potential adverse impacts of effluent disposal pit on the groundwater quality at Sabriya oil fields of northern Kuwait.
- To recommend the necessary measures to prevent and remediate such adverse effects under oil exploration and disposal scenarios.

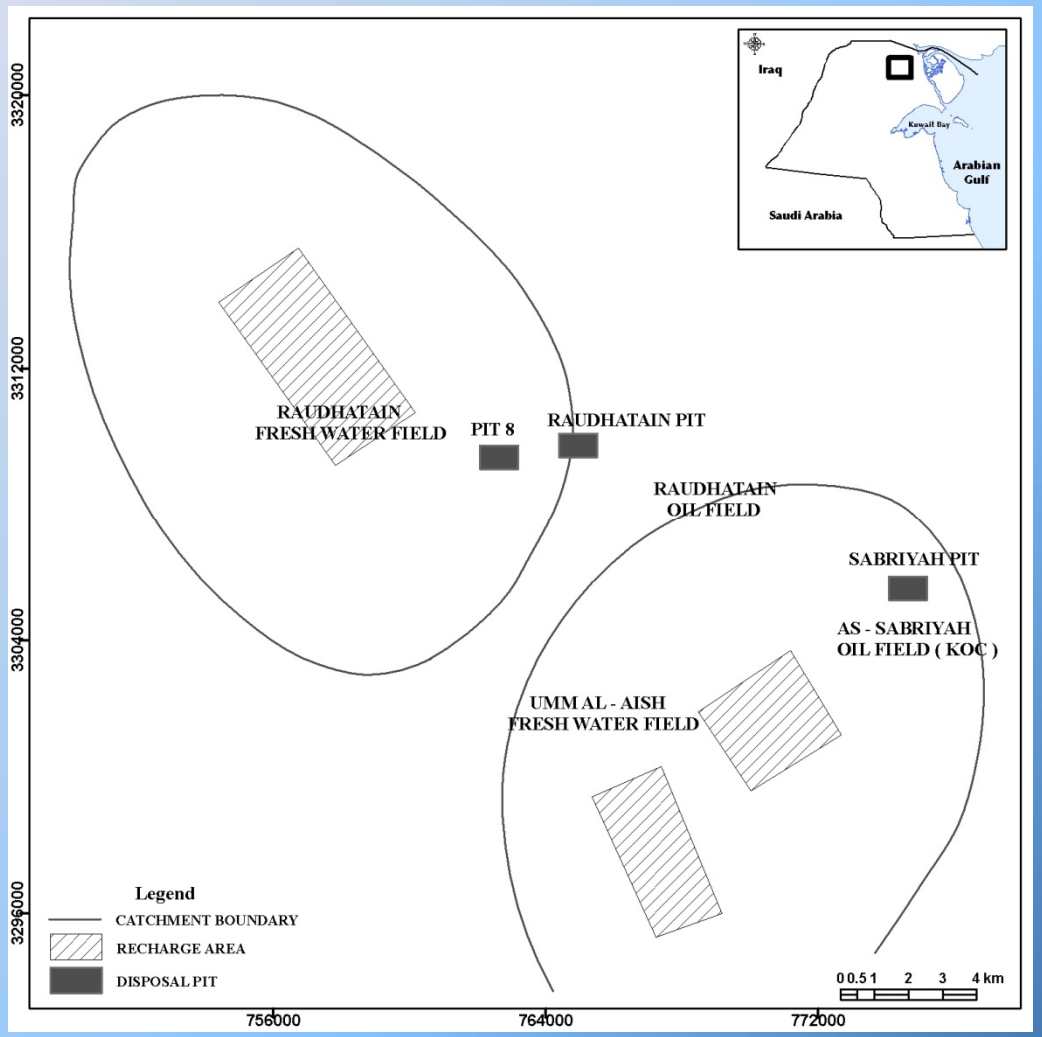
Study Area


Iraq
Saudi Arabia
Kuwait Bay
Arabian Gulf
Abdaly
Mutribah
Ar-Rawdatain
Sabriya
Umm Al-Aish
Al-Seer
Subiya
Rexah
Al-Mutlaa
Kazima
Jahra
Al-Asma
Hawally
Jahra Desert
Farwaniya
Al-Na'yem
Sulaibiya
Mubarak Al-Kabeer
Shradadiya
Kabd
Ahmadi
Al-Salmi
Al-Maqwa
Mangeesh
Ahmadi Desert
Al-Burgan
Umm Gudayr
Araifjan
Shalihat
Al-Khiran
Al-Wafra
Al-Wafra Farms
Nuwaisib
Study Area
km

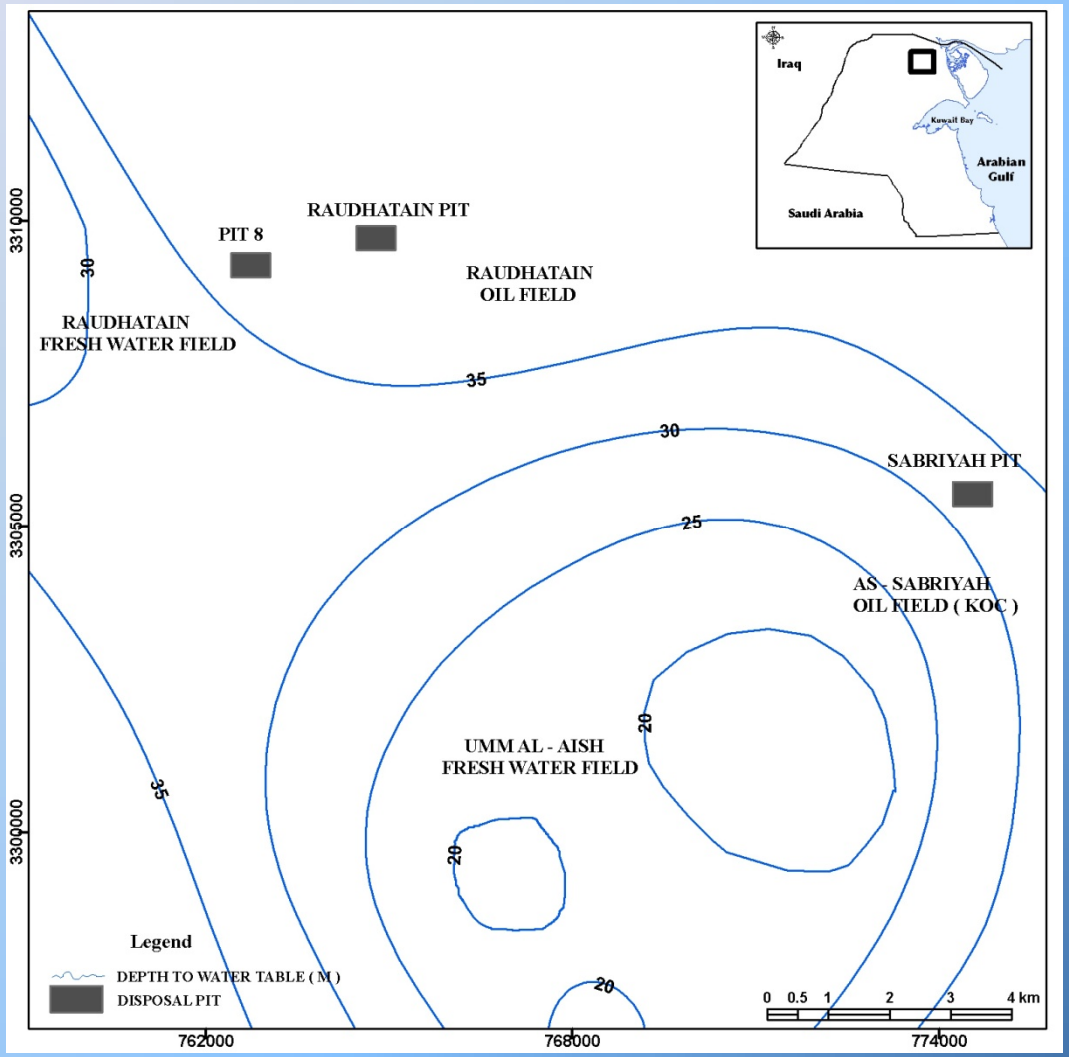
Features of the Studied Disposal Pit

Parameter	Sabriya Pit
Commission Date	No Information
Volume of Disposal (m^3/d)	1900
Present Disposal continuation	yes
Frequency of Disposal	continuous
Nature of Disposed Fluid	Oil and water
Disposed Fluid Oil content (mg/l)	8-10
Disposed Fluid TDS (mg/l)	170000
Lining of Pits	Unlined
Measured Area (m^2)	70000

Catchment Boundaries in Fresh Water Fields



Depth to groundwater



Sabriya pit

Methodology

- Groundwater well installation
- Soil sampling
- Groundwater sampling
- Pumping tests
- Laboratory analyses
- Numerical modelling

Groundwater Well Installation

- One production well and three monitoring wells, 113 mm in diameter and 30-50 m deep, were selected and the wells were drilled, installed and developed.

Well No.	Total Depth (m)	Casing Screen Diameter (mm)	Screen Interval (m)	Groundwater Depth (m)
DP-09	55	200	25 - 50	34.00
DP-10	50	100	25 - 45	18.00
DP-11	50	100	25 - 45	13.90
DP-12	50	100	25 - 45	19.60

Location of Drilled Wells at Sabriya pit

Drilling and Development

Materials Used in Well Construction

Soil Sampling

- A total of about 205 drill cutting samples of 500 g were collected during drilling at 1-m intervals in the 4 drilled wells.
- The samples were examined on-site, and further description was made in the laboratory to construct the conceptual lithological model of the study area.

Groundwater Sampling

Collection of Groundwater Sample from existing operating well

Measuring Groundwater Levels

Sampling Disposal Effluent at Sabriya Pit

Pumping Tests

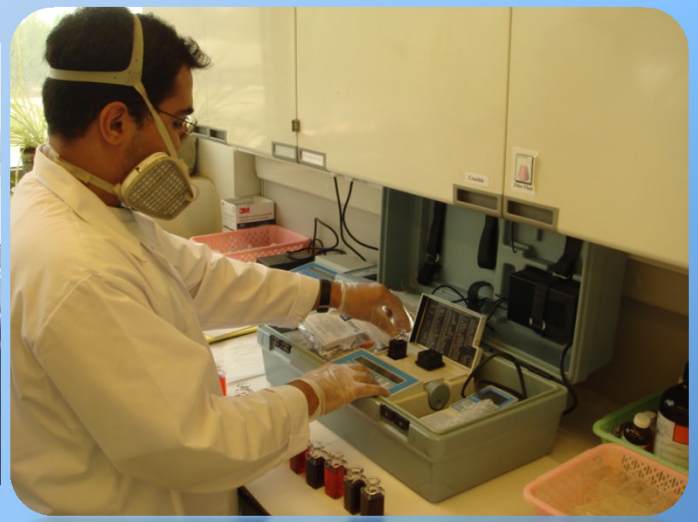
- Well DP-09 was the pumping well and 100 gal/min was the discharge rate for 16 h. Three wells, namely; DP-10, DP-11, and DP-12 were used as observation wells during the pumping and the recovery tests.

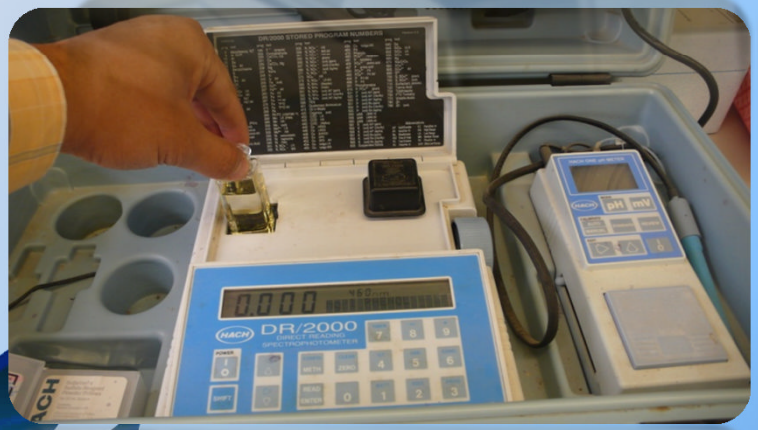
Laboratory Analyses

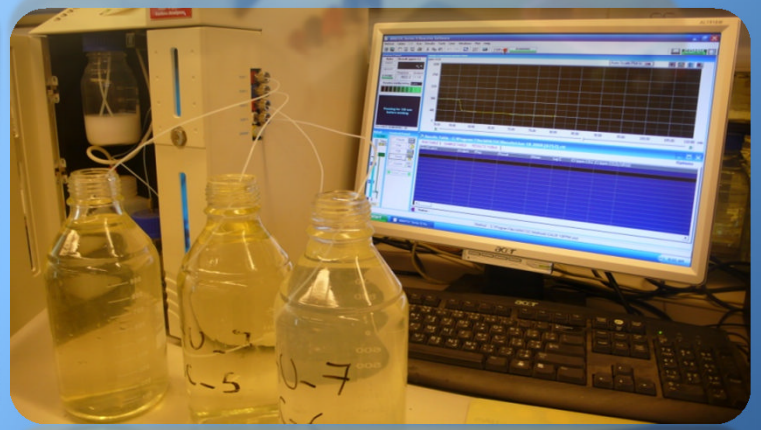
- The collected groundwater samples and the effluent pit samples were analysed for a wide range of parameters.
- The standard USEPA methods were adopted to analyse water parameters in the laboratory.
- Samples were also analysed of stable isotopes which are Oxygen-18 and Deuterium.

Group	Parameters
Major Ions	TDS, Na, Ca, Mg, K, Cl, SO_4 , HCO_3 , CO_3 , Fe, H_2S
Organic	TOC, TPH, BOD, COD, BTEX, PAH's
Nutrients	PO_4 , NO_3 , NH_3
Trace Elements	Al, Ba, Be, Cd, Cu, Cr, Pb, Li, Mn, Ni, V,Zn

Laboratory Analyses







Numerical modelling

- The Visual MODFLOW version 2010.1 software of Schlumberger Water Services was used for the numerical modelling of flow and transport of infiltrated water from the pit within the aquifers of the study area.
- The USGS SEAWAT 2000 engine is included in this software, allowing modelling of variable density flow such as seawater intrusion modelling problems.

Results of Groundwater Quality

- The groundwater in this study area was found to be highly saline (brine).
- The TDS ranged from 88000 to 150000 mg/l indicating brine water quality, whereas pit water salinity found was 165000 mg/l.
- Total petroleum hydrocarbon was detected in high concentrations ranging from 2.0 to 5 mg/l, whereas TPH in pit water found was 6.0 mg/l.
- The laboratory analysis of these groundwater confirmed the groundwater contamination from the disposed pit water.

Conclusions

- The recharge pit is located within two kilometer of the Umm Al-Aish freshwater body (TDS ≤ 2000 mg/l) and rests over an area where groundwater is brackish in nature (TDS 4500 – 6000 mg/l) that can be used for irrigation and other commercial requirements.
- The pit is located on the down gradient side of the freshwater body of Umm Al-Aish depression and because of its location, unless there is a reversal of gradient due to high volume withdrawal from the freshwater body or high rate of recharge from the pit over a long time or both, threat of the freshwater body being contaminated by the leaked fluid from the pit is not high.

Conclusions

- Due to the variations in the conditions of the floor of the pit and possible non-uniform deposition of heavy oil and sludge on the bottom, the leakage rate is non-uniformly distributed over the base of the pit.
- The groundwater mound has reached a height of about 27 m in the vicinity of the pit and its base extends over a radius of about 0.5 - 1 km around the pit.
- During the study TDS of the water body in the mound is 10,000 mg/l to ≥ 150,000 mg/l where the original water quality in the area was in the range of 4500 – 6000 mg/l.

Conclusions

- The mound will dissipate soon once the discharge to the pit, and hence recharge to the groundwater, is discontinued.
- After complete stoppage of disposal of fluids to the pit, the contaminated plume will move to the east with time following the prevailing hydraulic gradient. Concurrently, density stratification will take place within the aquifer, thus improving the water quality close to the water table, though complete restoration of the water quality to its original condition may not be expected in the near future.

Recommendations

- Wells should be drilled between the pit and the Umm Al-Aish freshwater body to monitor any advance of the pollution plume from the pit to the freshwater.
- Regular monitoring of groundwater quality surrounding the pit area.
- It was recommended to stop the discharge of the oil field brines and other methods of disposal (e.g., injection into deeper aquifers, remediation of the liquids through advanced zero-discharge techniques and others) should be considered.

Project 2

MANAGEMENT OF WATER TABLE RISE AROUND A BOOSTER STATION IN BURGAN OIL FIELD

Study Background

- A rise in groundwater level at the Booster Station 140 in Burgan oil field was observed by KOC.
- It is a cause for concern for KOC with regard to the underground facilities and to the field.
- In response to KOC request, a 12 month period project was conducted.

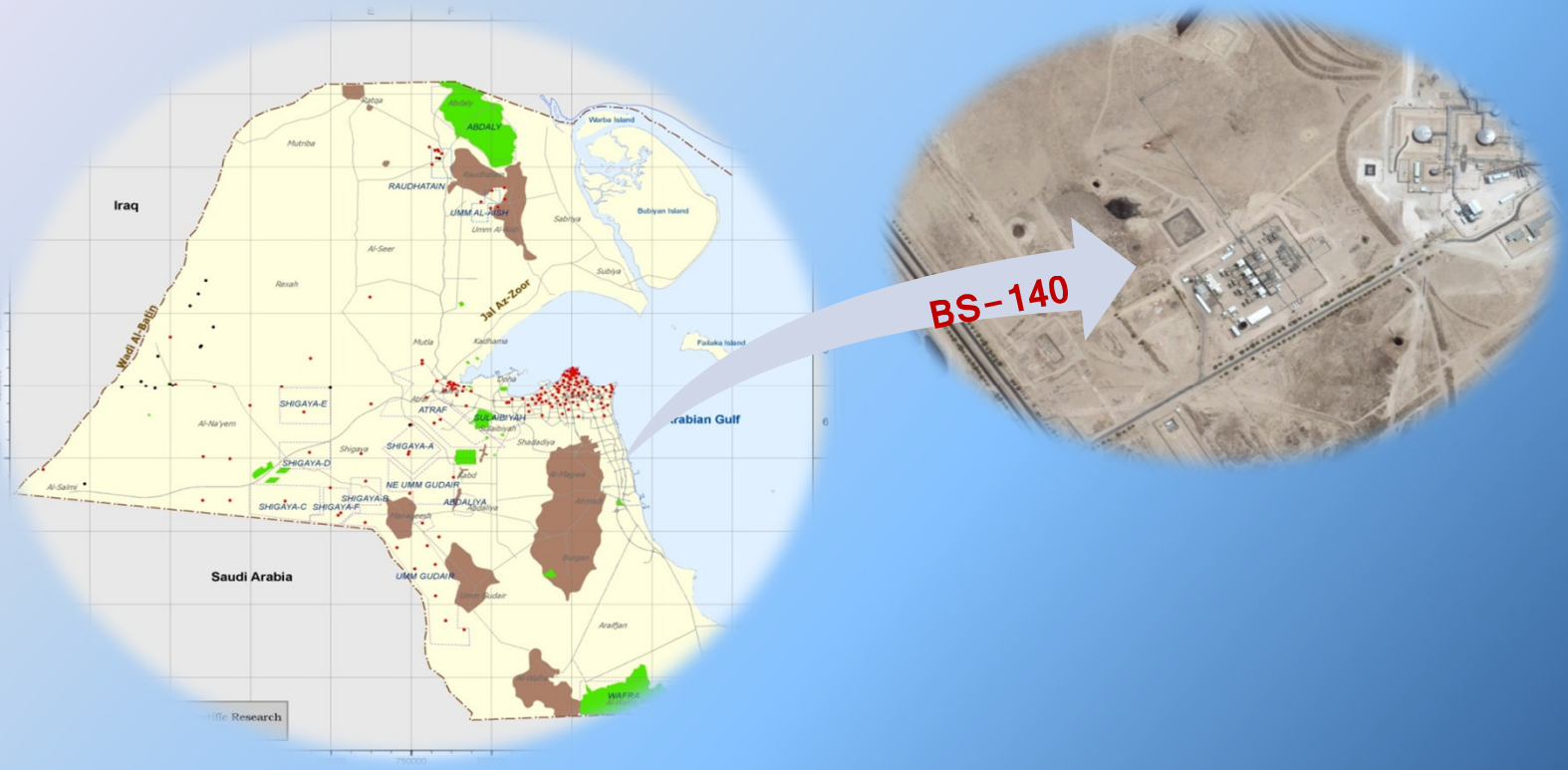
Objectives

- To assess the causes of the water table rise in the study area and to recommend remedial measures
- To develop an implementation and operation plan of the dewatering system

Study Area

- Located in the North eastern part of Burgan oil field (south of the Kuwait City).
- Study area covers an area of 25 km^2 with the BS-140 is situated at the center.
- Geologically, the study area is above the Burgan structure which has numerous radial faults.

Location

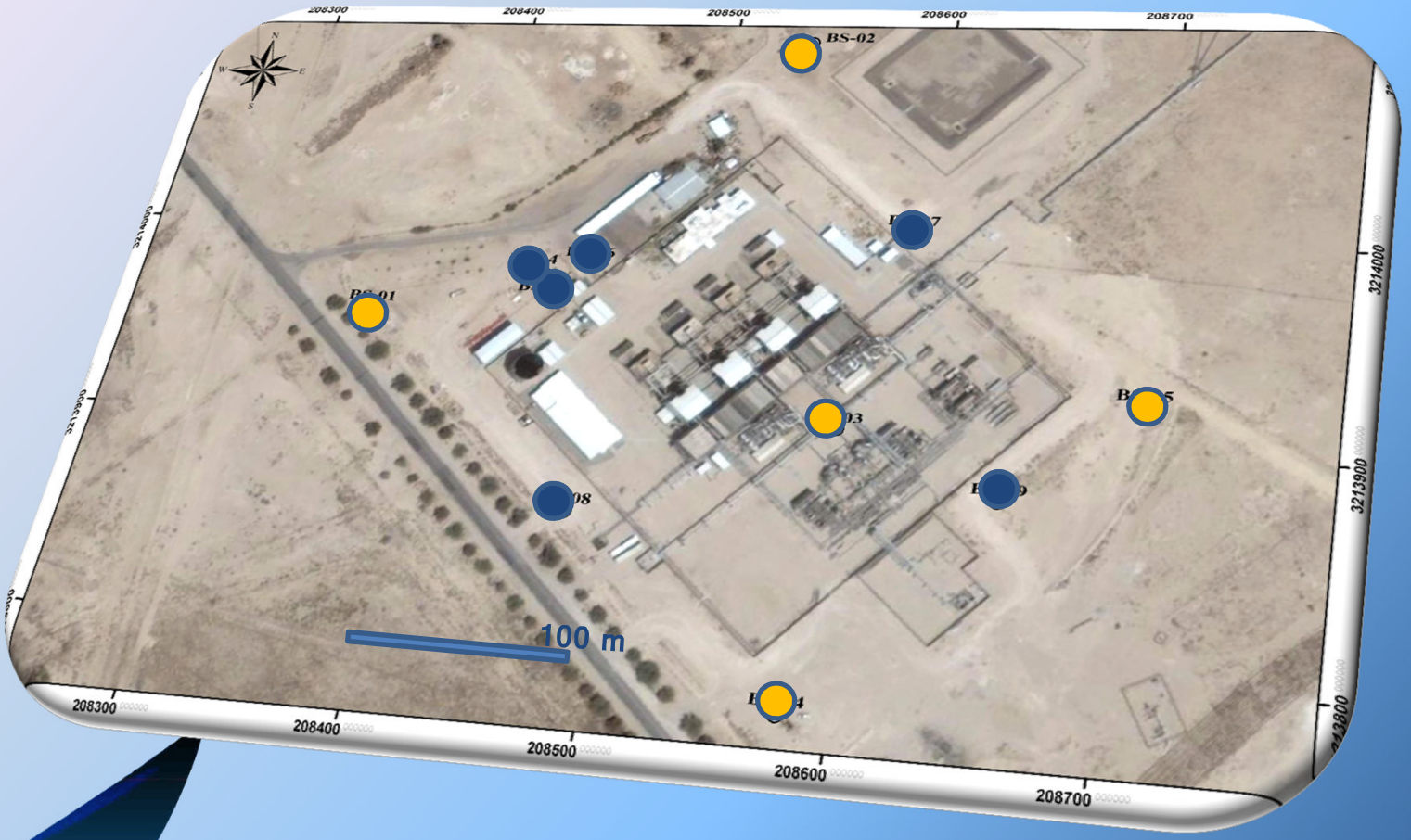

Iraq
Saudi Arabia
Arabian Gulf
Warba Island
Bubiyan Island
Failaka Island
ABDALI
RAUDHATAIN
UMM AL-AISH
Jal Az-Zoor
Wadi Al-Batin
SHIGAYA-E
SHIGAYA-A
SHIGAYA-D
SHIGAYA-B
SHIGAYA-C
SHIGAYA-F
NE UMM GUDAIR
ABDALIYA
UMM GUDAIR
ATRAF
SULAIBIYAH
WAFRA
BS-140

Methodology

- Task 1: Topographic Survey and Data Collection
- Task 2: Designing and Construction Groundwater Monitoring Well Network
- Task 3: Pumping Test and Determination of Aquifer Characteristics
- Task 4: Analysis of Soil and Water Samples
- Task 5: Designing of a Dewatering System and Recommendations
- Task 6: Reporting

Drilling and Installations of Water Wells

Location of 6 New Wells



New Wells

Existing Wells

Location of 3 New Wells

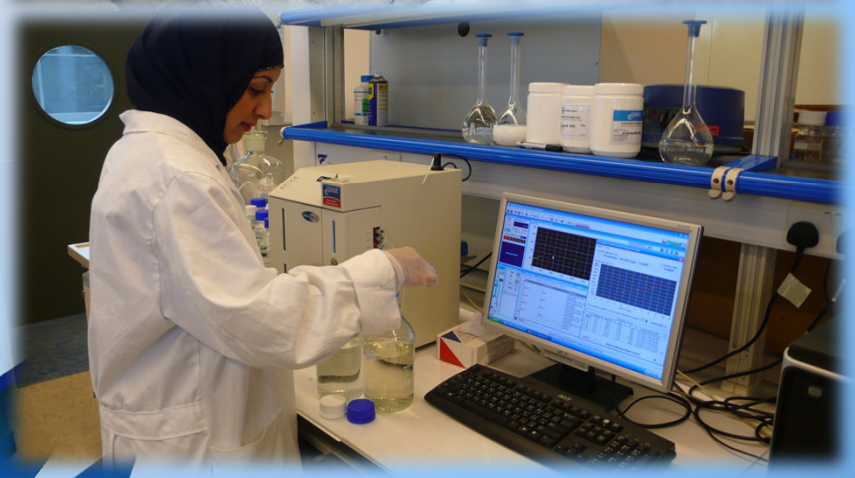
Design of the Installed Wells

Well No.	Total Depth (m)	Casing-Screen Diameter (mm)	Screen Interval (m)
BS-06	43	200	16 - 40
BS-07	40	200	14 -37
BS-08	41	200	14 - 38
BS-09	40	200	14 - 37
BS-10	35	100	06 - 32
BS-11	42	100	12 - 39
BS-12	39	100	06 - 38
BS-13	45	100	15 - 42
BS-14	120	150	93 - 116

Depth to Groundwater level

Well No.	Depth to Groundwater (m)
BS-01	1.86
BS-02	3.09
BS-03	1.82
BS-04	3.75
BS-05	3.79
BS-06	2.99
BS-07	3.43
BS-08	2.63
BS-09	3.66
BS-10	2.30
BS-11	11.75
BS-12	6.15
BS-13	29.15
BS-14	4.62

Site & Laboratory Analysis

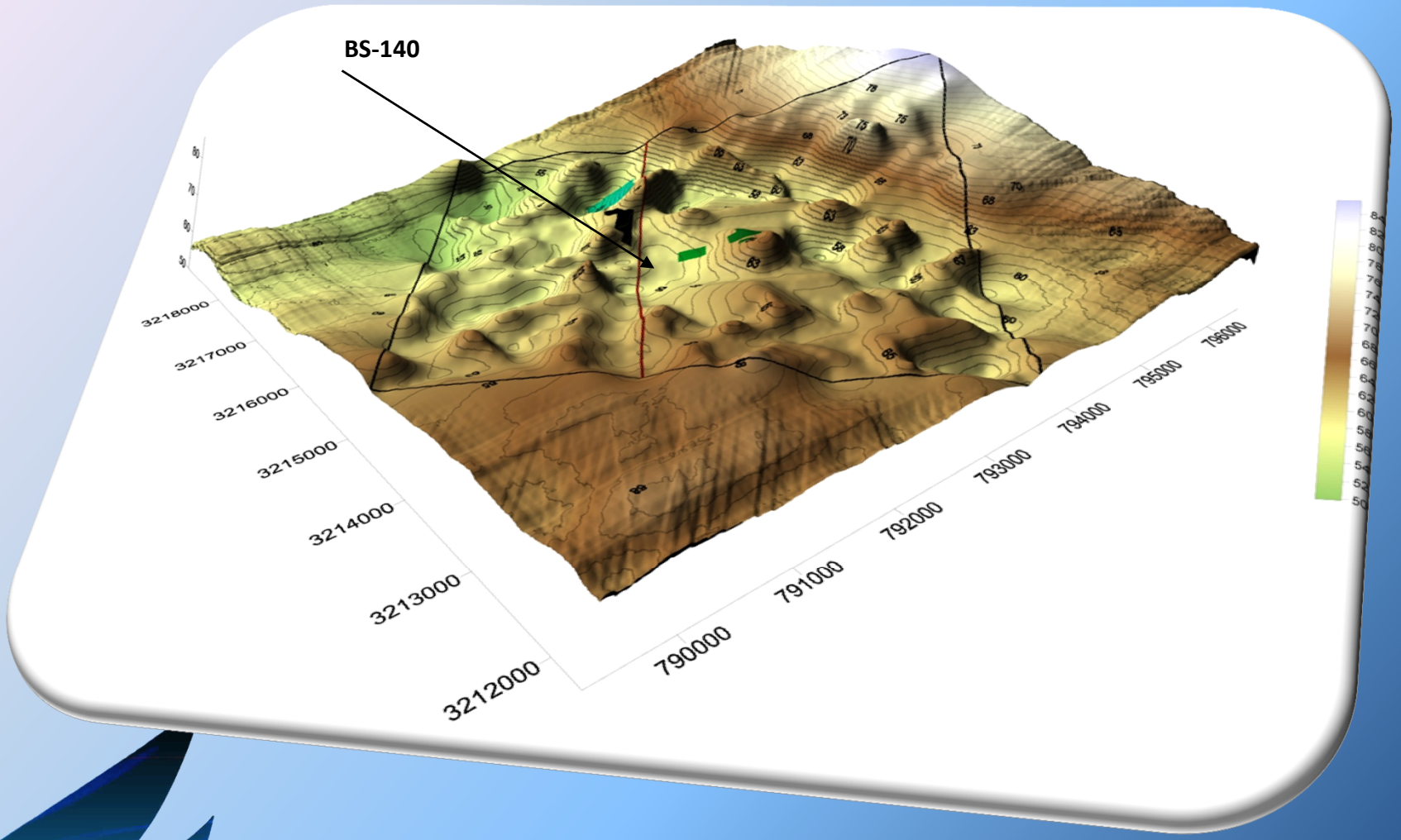


Collection of Water Samples

Overall Observations, Results, Conclusions & Recommendations

Observations

- The study area contains about 135 oil production wells and two abandoned quarries which were previously used as landfills and are having free water presently at the bottom.
- Topographically, the Booster Station BS-140 campus is located in a lowland of about 57 m height in the average surrounded by relatively high hills of about 65 m height.
- The main depressions in the study area usually get filled with water when heavy rain occurs, forming large ponds.


BS-140
3218000
3217000
3216000
3215000
3214000
3213000
3212000
790000
791000
792000
793000
794000
795000
796000

Pond due to Rainfall

Results

- Geologically, the study area is above the Burgan structure which is an anticlinal dome with numerous radial faults.
- In the study area, the upper aquifer belongs to the Kuwait Group of sediments and is composed of unconsolidated sand and gravel, occasionally calcretized with clay intercalations that get thicker toward the bottom.
- The monitoring of water level in the observation wells available within the study area has indicated the recharge of the near surface aquifer from infiltrating rainwater after heavy rain falls, especially in the areas where topographic depressions are present.

Results

- Water quality of the uppermost zone of the Kuwait Group aquifer in the study area is of Na_2SO_4 type
- Samples collected from this water by bailing, showed lower salinity than those of the pumped samples from the same wells, indicating a recharge from rainfall, especially in the areas of topographic depressions
- Pumped water quality of both Kuwait Group and the Dammam Formation aquifers in the study area is very similar and of NaCl type suggesting upward seepage of the Dammam water

Results

- Isotopic analyses of groundwater samples had provided support to the aforementioned conclusions
- The results of 14C and tritium analyses have indicated that the sampled groundwater at the study area had experienced limited recharge from recent rainfall events
- Isotopic data also demonstrated clear difference between the ages of the water from the Dammam Formation and that from the Kuwait Group, the former being older.
- Isotopic fingerprints and the quality of the water from the water network markedly different from ground-water, indicating no recharge from these sources

Conclusions

- The rise of the groundwater in the vicinity of the study area can be attributed to a combination of the reasons as follows:
  - The relatively shallow depth (within 2 – 3 m from the ground surface) of water table in the booster station area under natural conditions
  - Slow but continuous upward seepage of groundwater from the Dammam Formation aquifer
  - Location of the study area in a relatively low land surrounded by hilly areas leading to ponding of water after rainfalls and its infiltration to the groundwater table

Recommendations

- The calibrated and validate three-dimensional, groundwater flow numerical model was used to predict the dewatering requirements for managing the water table rise around BS-140 and the potential drawdown in the water table induced by this dewatering.
- The scenario includes pumping from the four production wells (BS-06, BS-07, BS-08, and BS-09) at a rate of approx 40 gpm) per well, a total of approx 160 gpm to draw the water table down to an average depth of 4.5 m under BS-140.

Recommendations

- Waste disposal pits within the perimeter of the depressions in the study area should be closed immediately
- New lined and large capacity disposal pits （no over flow）, if absolutely necessary, should be constructed in relatively higher lands where the water table is deep and no facilities exist at the immediate neighborhood
- The pumped water can be utilized by KOC for several purposes （irrigation, processing, domestic, recreation lake, fire fighting, injection, etc,） depending on the level of treatment

THANK YOU