Project: NIMR WATER TREATMENT PROJECT
DESIGN, BUILD, OWN, OPERATE & TRANSFER
Nimr
Water Management
&
Energy Efficiency Strategy
(a comprehensive approach)
DESIGN, BUILD, OWN, OPERATE & TRANSFER

Deep wells have been used in the Nimr Oilfield where the water is disposed by booster pumps into aquifers. Disposal into shallow aquifers was phased out in 2005 due to environmental issues leaving PDO with a deep water disposal option only. This activity is causing high energy consumption in an environment with limited power supply. The Nimr oilfield produces between 120,000 to 140,000 barrels of oil per day which translates to an oil water ratio of 1/10.

One of the key design parameters was to ensure gravity flow of the water allowing the system to operate with a minimum external power requirement using the local topography. Secondly compared to the deep disposal wells the Wetland plant uses only 1/50 of the energy consumed including all infrastructure facilities around translating directly to reduction of Carbon Emissions.
Sultanate of Oman

- Area: 309,500 sq km
- Population: 3,418,085
- Income: Oil/Gas, Fishery, Agriculture, Mining & Tourism

Petroleum Development Oman

Oman’s second highest employer with ~ approx. 5,000 permanent & 35,000 contractors employees

owned by Government of Oman 60 % Shell 34 %, Total 4 %, Partex 2%.
Scope of Work

Treatment of Produced Water Quantity 45,000 m³/d

High salinity up to 8,000 ppm Hydrocarbons up to 1,000 ppm

DBOO(T) Project

Design - Build - Own - Operate (Transfer)
NIMR WATER TREATMENT PROJECT

FACILITY PROCESS FLOW

Stage one:
Produced Water Collection in Basin
Followed by Mechanical Pre-treatment-oil removal

Stage two:
Second stage removal of oil through Reed Beds

Third Stage:
Production of Reeds for Bio-Mass /Power Generation

Fourth Stage:
Evaporation Pond:
Production of Industrial Salts
SCOPe OF WOrK

• Treatment of Effluent (Produced Water mixed with Oil & other minerals)
• Project Milestones on PDO:
  - Phase -1 : Delivered 45,000 m³/d by Nov 2010 (Org. Plan : Jan 2011)
  - Phase -2 : Delivery 95,000 m³/d by Sep 2012 (Org. Plan : Oct 2012)
• Quantity
  Phase -1 : 45,000 m³/day
  Phase -2 : 95,000 m³/day
• Challenge
  High salinity up to 8,000 ppm
  High H₂S; up to 1,000 ppm, 280 ppm in average.
• BOOT
  Build – Own – Operate - Transfer
  for Contract period of 20 years (option 5 years) by BAUER
• Mission prediction
  – Potential Salt Production
  - Water reuse (Biosaline Agriculture & Algae Production)
  - Biomass Utilization Yearly Production approx. 3,500 t
    (15,000,000 kWh)
  - Potential Carbon Credits
NIMR WATER TREATMENT PROJECT

FACILITY LAYOUT

Phase-1 (1.8KM)

Phase-2 (1.2KM)

REED BED

EVAPORATION PONDS

SALT PRODUCTION

3.5KM
NIMR WATER TREATMENT PROJECT

GRAVITY FLOW REED BED
TURN-OVER POINT, OIL-SEPARATOR, BUFFER POND AND REED BEDS
Interface – Oil/Water Separator

Equilibration

Oil-Water Separator

Metering Skid

Pumping Station

Oil Storage
NIMR WATER TREATMENT PROJECT

OIL WATER SEPARATOR
NIMR WATER TREATMENT PROJECT

REED BED CONSTRUCTION
Planting of reed Plants
NIMR WATER TREATMENT PROJECT

INTRODUCTION OF WATER TO REED BED (Phase 1)
Introduction of first water to reed bed Track 7 (Phase 2), Apr 2012
NIMR WATER TREATMENT PROJECT

REED BED: Phase 1 (Feb 2011)
NIMR WATER TREATMENT PROJECT

REED BED: Phase 1 (Dec 2011)
NIMR WATER TREATMENT PROJECT

REED BED Phase 1 (Feb 2011)
NIMR WATER TREATMENT PROJECT

EVAPORATION PONDS OF THE SALTWORKS (Dec 2011)
Environmental Footprint and Carbon Emission

- **Oil Recovery**
  An average of about 180 barrels of oil is being recovered in the oil water separator per day.

- **Biomass Production**
  The Wetland as a biological system fixes carbon in the plant structures through photosynthesis. Currently the common Reed Phragmites australis is used, but other potential biomass producers shall be evaluated in the future.

- **Carbon Credits – Energy Balance**
  With the Sultanate of Oman as a signatory of the Kyoto Protocol, future extensions to the treatment system may qualify under the Clean Development Mechanism (CDM) program of the United Nations to generate saleable CER’s (Certified Emission Reductions), commonly known as Carbon Credits.

- **Salt Production**
  An engineered salt evaporation area to reduce outflow water volumes to zero, to minimize waste disposal and to be able to set up salt crystallizers to produce technical grade Sodium Chloride finishes the technical status to the facility at the current development stage. Commercial feasibility analysis currently being finalised and potential markets for salt explored.
NIMR WATER TREATMENT PROJECT

Reduction of Environmental Footprint

- **Oil Recovery** - currently up to 56 barrels per day, reduction of disposed quantities

- **Gravity Flow** - Oil Water Separator, Wetland and Evaporation Facility operate without intermediate pumping

- **Construction Measures** - replacing HDPE liner with a mineral sealing

- **Biomass Production** – CO₂ Fixture

![Oil Separation](image)
Reduction of Environmental Footprint

- **Oil Recovery**
  Currently up to 250 barrels per day (average 168 bbl/d) which is otherwise lost via DWD

- **Gravity Flow**
  System operates without intermediate pumping

- **Construction Measures**
  HDPE liner replaced with a mineral sealing

- **Biomass Production**
  CO$_2$ Fixture – Potential energy source or soil ammender
Environmental Values

3) Power Consumption

Calculation of energy used for different types of produced water disposal

<table>
<thead>
<tr>
<th>Disposal Options</th>
<th>Power required</th>
<th>Total Power Used in Project</th>
<th>CO₂</th>
</tr>
</thead>
<tbody>
<tr>
<td>Deep Well Disposal</td>
<td>up to 5.5 kWh/m³</td>
<td>~ 1,800,000 MWh</td>
<td>972,000 t CO₂</td>
</tr>
<tr>
<td>Technical Treatment Plant</td>
<td>0.8 kWh/m³</td>
<td>~ 255,000 MWh</td>
<td>137,700 t CO₂</td>
</tr>
<tr>
<td>Reed Bed</td>
<td>0.1 kWh/m³</td>
<td>~ 32,850 MWh</td>
<td>17,700 t CO₂</td>
</tr>
</tbody>
</table>

0.54 kg CO₂/kWh
Due to the installation of a mineral sealing layer the impact during construction is reduced by up to 80% for this element compared to the installation of an artificial sealing.

Replacing HDPE Lining with a mineral sealing layer

<table>
<thead>
<tr>
<th>kWh/m²</th>
<th>HDPE Liner [6]</th>
<th>Mineral Sealing Layer</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>40.95 (100 %)</td>
<td>8.71 (21 %)</td>
</tr>
</tbody>
</table>

May 1, 2012
Nimr Water System Layout

Current Status

Wells

Water Potential
Total =256 K m3/d minus
Deferred = 15k m3/d
*excludes wells closed-in > 6 months

241k m3/d

Nimr C WI
20K m3/d

ABJ WI
4K m3/d

217k m3/d

NRPS Water Handling

Design Capacity:
* CPI Banks =238k m3/d
* Booster Pumps = 300 k m3/d

Actual Based on Performance Date:
* NRPS Throughput = 230k m3/d

Bank-B CPI By-Pass:
Est'd water capacity gains = 20k i.e. 100-150 net m3/d

Water Disposal Streams

127

80

5

Nimr DWD

Site #1: (Two DWD Pumps, YTD Avg. = 23k, Capacity =40k m3/d)
*Issue: wells acceptance because of increasing reservoir pressure.
Site #2: (Two DWD Pumps, YTD Avg. =33k, Capacity=40k m3/d)
* Pumps and wells performance is acceptable.
Site #3: (Two DWD Pumps, YTD Avg. =49k, Capacity=80k m3/d)
*Two Pumps P9510 and P9530 out of service.
*DWD Well NM411 having integrity issue.
Site #4: (Four DWD Pumps, YTD Avg. = 76K, Capacity 80k m3/d)
* Pumps and wells performance acceptable.

Nimr Bauer

Phase #1:
Stable at 46k m3/d

Phase #2:
Can take up 90-120k m3/d

Nimr SWD

YTD Average 5.5k m3/d
NIMR WATER TREATMENT PROJECT

Benefits to P.D.O & Oman

- Two D.W.D Pumps require Approximately 10 M.W for Disposal of 45K m$^3$/d
- BAUER NWTP uses approximately 4500 KW For Treating and re-use of 45K m$^3$/d
- Abolishing future phases of DWD projects which involves a Capex savings of approx 50 mln USD per phase.
- Offloading noncore activities of Water Treatment and Handling to Contractor, thereby releasing PDO resources and project teams.
- Less unit cost (per cubic meter) of handling water as compared to current DWD cost; Gas savings of 1 BCF per year now and 5 BCF by expanding capacity in Nimr alone.
- Reduction of 300,000 tonnes of CO$_2$ per annum due to energy saving by removal of DWD pumps;

May 1, 2012
Think Green & Conserve Energy.
Thank You