GOLDER ASSOCIATES AFRICA (PTY) LTD

REPORT ON:

KINGFISHER SOILS IRRIGATION POTENTIAL ASSESSMENT

Submitted to:

Golder Associates Africa (Pty) Ltd
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REPORT NR: P355

VILJOEN & ASSOCIATES

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February 2018

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EXECUTIVE SUMMARY

Golder Associates Africa (Pty) Ltd requested during October 2017 an update on certain soil aspects related to the Kingfisher Baseline Soil Assessment conducted in 2014. The update includes the soil mapping reflecting the *South African Taxonomical Classification System* that need to be changed to *FAO Classification System*. The pipeline route changed with nominal changes at the northern end of the pipeline route and reasonable deviation from the original base corridor at the southern end of the pipeline and need to be addressed in terms of soils. An assessment of the irrigation suitability of 45m^3/day sewage effluent on soils immediately around the CPF.

From the update it is conclusive the dominant soils on the Buhuka Flats study area according to the FAO Soil Classification System include *Ferrasols*, *Litosols*, *Gleysols* and *Vertisols*. The *Ferrasols* is most suitable for the irrigation of 45m^3/day sewage effluent. CNOOC would not want to irrigate far away due to pumping and piping costs. Irrigation would essentially have to be in close proximity to the permanent accommodation area. *i.e.* the Ferrasols occur near the CPF. A 3 to 5ha area in close proximity to the CPF would enable enough even distribution and rotation of 45m^3/day sewage effluent to maintain plant available water between 33 – 1,500kPa. An indigenous pasture should be identified that would be suitable and sustainable for 45m^3/day sewage effluent irrigation purposes.

The ***45m^3/day sewage effluent*** should be carefully monitored to ensure:

- pH 5,3 and 7,2 (*no acid and/or alkaline anomalies*), EC<250mS/m, SAR<15 – maintain SAR<10 to ensure buffercapacity, assess toxicity of trace elements for specific pasture species utilized for irrigation, prevent eutrophication in soil through excess nitrogen and phosphorus being irrigated, no human and/or plant pathogens become an environmental risk.

The ***3 – 5ha Ferrasols*** should be carefully monitored to ensure:

- pH 5,3 and 7,2 (*1:2.5 soil:water ratio*) in soil solution, EC<250mS/m (*saturated water extract*), ESP<15 (*1N NH4-Ac extract pH7)* – maintain ESP<10 to ensure buffercapacity, Ca: 200 – 4,000mg/kg (*1N NH4-Ac extract pH7*), Mg: 50 – 500mg/kg (*1N NH4-Ac extract pH7*), K: 20 – 300mg/kg (*1N NH4-Ac extract pH7*), Ca:Mg (1,5 – 4,5), Mg:K (3 – 4) and Ca+Mg/K (10 – 20) (*1N NH4-Ac extract pH7*), NO_3: 10-20mg/kg (*saturated water extract*), P: 10-15mg/kg (*Bray 1 extract*), Heavy metals: <0.01mg/kg (*saturated water extract*), SO_4, Cl, B, F: <0,1mg/kg (*saturated water extract*), No human and/or plant pathogens become an environmental risk, Infiltration capacity: 10-15mm/h @ bulk density 1,275kg/m_3 (*no crust formation*)and C:N Ratio: 1:10.

It should be considered to compile a soil water balance with the chosen pasture species under the climatic condition of the Buhuka Flats to optimize irrigation scheduling.

The 3 – 5ha Ferralsol soil system at 1,500kg/m^3/300mm bulk density contains an estimated 13,500,000 to 22,500,000kg soil. The average CEC range between 5 – 15cmol+/kg (*1N NH4-Ac extract pH7*), which is an enormous advantage in terms of buffercapacity to utilize for 45m^3/day sewage effluent irrigation in combination with plant root uptake of nutrients. However, it must be stressed the system should be carefully monitored and maintained to prevent contamination. Soil remediation cost could be as high as $800/m^3 ($12,000,000/15,000,000m^3 soil @ BD1,500kg/m^3/300mm) depending on the severity of remediation required (*e.g. ESP>15% requires leaching Na with Ca*), this excludes site establishment of earth moving equipment (if necessary).

DECLARATION OF INDEPENDENCE

Chris J Viljoen, CEO Viljoen Associates, hereby declare:

- Viljoen Associates act as independent specialist in this investigation.
- The assessment is conducted in a scientific manner and findings will not be manipulated for a favourable outcome.
- Viljoen Associates have no financial, personal or any other interest in this application managed by Golder Associates Africa (Pty).
- All particulars furnished in this declaration are true and correct.

***M.Sc., Pr. Sci. Nat*.**

DISCLAIMER

The opinions expressed in this Report have been based on the information supplied to Viljoen Associates (Pty) Ltd by Golder Associates Africa (Pty) Ltd. Viljoen Associates has exercised all due care in reviewing the supplied information. Whilst Viljoen Associates has compared key supplied data with expected values, the accuracy of the results and conclusions from the review are entirely reliant on the accuracy and completeness of the supplied data. Viljoen Associates does not accept responsibility for any errors or omissions in the supplied information and does not accept any consequential liability arising from commercial decisions or actions resulting from them. Opinions presented in this report apply to the site conditions and features as they existed at the time of the investigation, and those reasonably foreseeable.

EXPERTISE OF COMPILING SPECIALIST

The report was compiled by:

Name	Professional registration and short list of expertise	Signature
Chris J Viljoen	*M.Sc., Pr. Sci. Nat. 400131/96 (Earth Science)* Baseline soil surveys, soil impact assessments, land use assessments, land capability assessments, agricultural potential assessments & wetland delineations for EIA and EMPR. Soil contamination assessments and formulation of cost effective remediation strategies for rehabilitation and closure purposes. Rehabilitation and closure plans. Geotechnical assessments for site selection, *e.g.* tailings dams, residential developments, *etc*. Twenty eight (28) years active in Soil Science	

Full CV's of the specialist is available on request.

1 TERMS OF REFERENCE

Figure 1. Kingfisher Study Area.

During October 2017 *Golder Associates Africa (Pty) Ltd* requested an update on certain soil aspects related to the Kingfisher Baseline Soil Assessment (**Figure 1**) conducted in 2014. It includes:

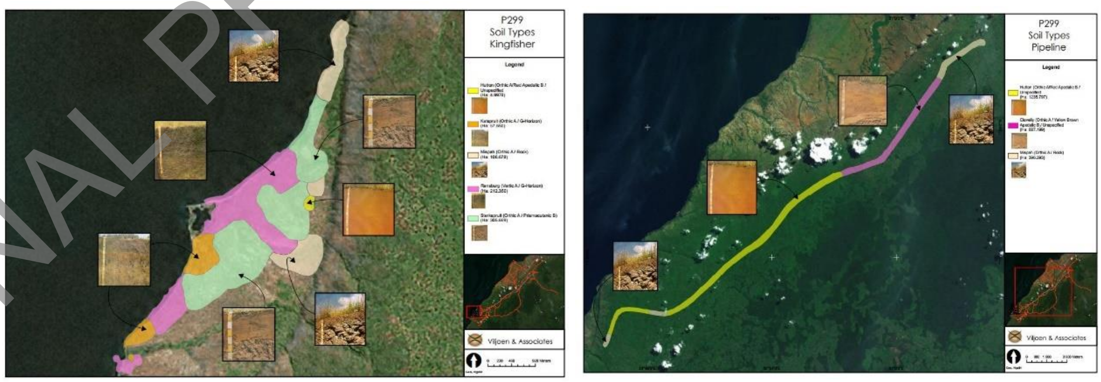

Figure 2. Soils: Taxonomical Classification System.

- The soil mapping (**Figure 2**) reflects *South African Taxonomical Classification System* and needs to be changed to *FAO Classification System*.

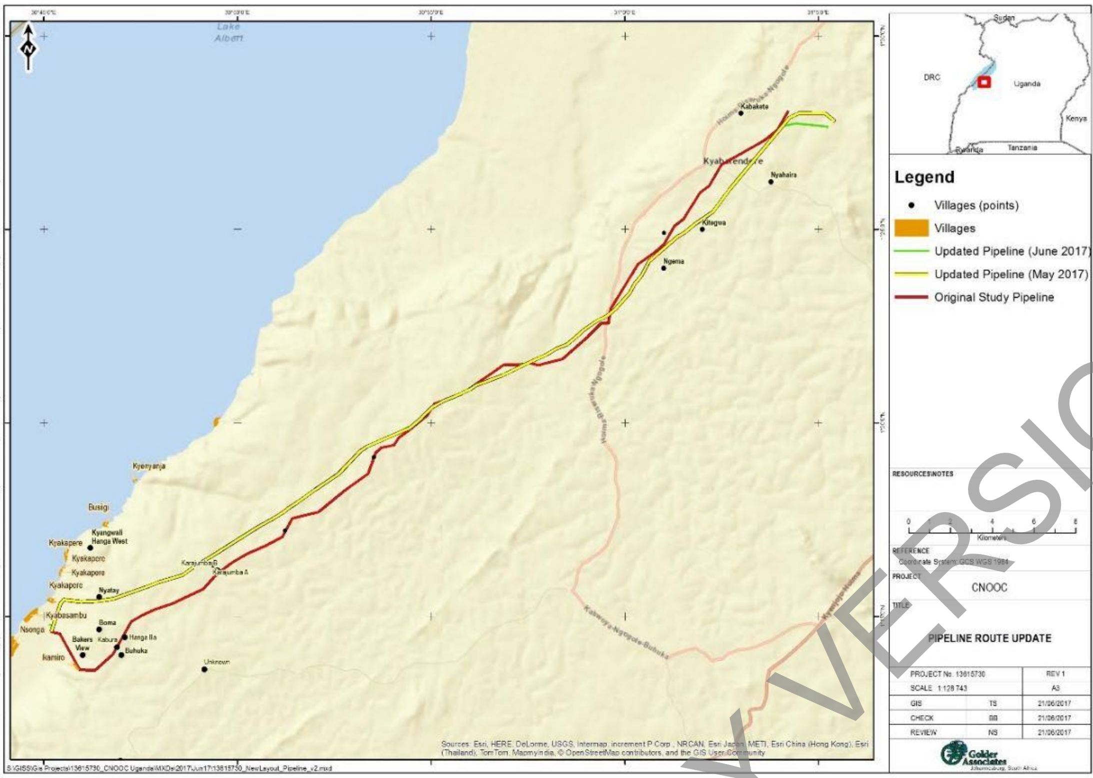

Figure 3. Changes to pipeline route.

- The pipeline route has changed with nominal changes at the northern end of the pipeline route and reasonable deviation from the original base corridor at the southern end of the pipeline.

- Assessment of the irrigation suitability of 45m^3/day sewage effluent on soils immediately around the CPF. CNOOC would not want to irrigate far away due to pumping and piping costs so the irrigation would essentially have to be in close proximity to the permanent accommodation area.

2 INVESTIGATION OBJECTIVES

The objectives of the investigation were interpreted as:

- Convert soils classified in the Taxonomical Soil Classification System to FAO System.

- Assess the irrigation potential of 45m^3/day sewage effluent on soils immediately around the CPF.

3 METHOD OF INVESTIGATION

To meet the objectives of the investigation the following scope of work was followed:

- Correlating soils classified according to the *Taxonomical Soil Classification System of South Africa* with ***FAO Classification System***.

- Assess ***irrigation potential of soils***.

- Review ***chemical quality of sewage effluent and its effect on soils during irrigation*** at 45m^3/day.

4 PROBLEM ANALYSES

4.1 FAO Classification System

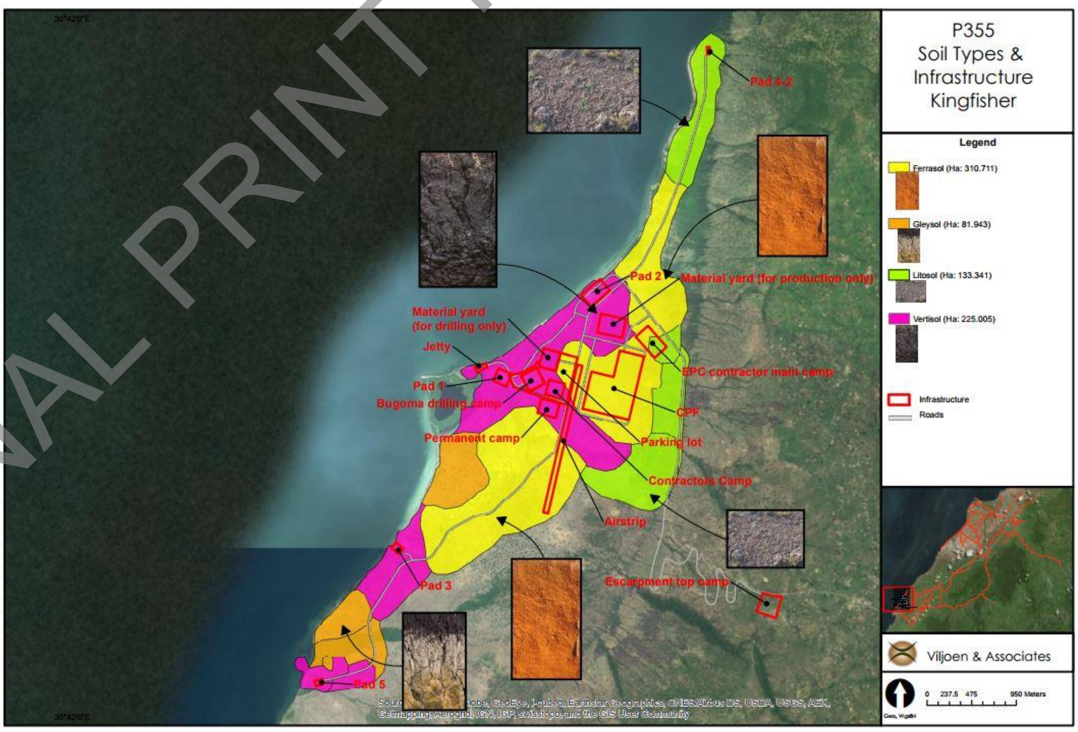

Figure 4. Kingfisher Area FAO Soil Types.

Figure 5. Pipeline FAO Soil Types.

Table 1 summarises the diagnostic criteria of the different soil types:

Table 1. FAO Soils Diagnostic Criteria.

Soil Type	Diagnostic Criteria
Ferrasols 	• Well drained soils. • Red or yellow-brown colour. • Has clay textures. • Ferrosol is usually associated with previous volcanic activity. • Used for intensive crop production.
Gleysols 	• Associated with wetland conditions. • Is usually saturated with groundwater. • Usually covered with swamp vegetation. • In the tropics and subtropics they are cultivated for rice or, after drainage, for field crops and trees. • Characterised by both chemical and visual evidence of iron reduction. • Red, yellow, or brown mottles may be seen.

Table 1. FAO Soils Diagnostic Criteria/continued

Soil Type	Diagnostic Criteria
Litosols 	• Shallow soils on weathered geology. • Lack well defined horisons.
Vertisols 	• High clay content soil, shrinks and swells dramatically under fluctuating soil moisture contents. • When dry form large cracks that may be more than one meter (*three feet*) deep and several centimetres (*inches*) wide. Movement of these soils can crack building foundations and buckle roads. • Highly fertile due to the high clay content. • Depending on the parent material and climate, soils can range from grey or red to the more familiar deep black.

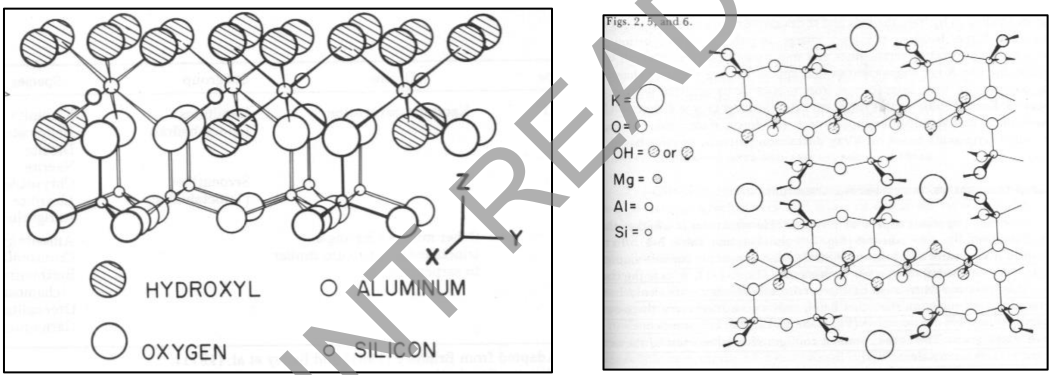

Figure 6. 1:1 and 2:1 clay mineralogy (fraction <0,002mm)

From a particle size distribution perspective, the *fraction smaller than 0,002mm* (**Figure 6**) can be used to separate the Ferrasols, Gleysols Litosols and Vertisols into two distinctive groups in terms of chemical, physical and mechanical behavior:

Group 1: 1:1 clay mineralogy

- Ferrasols, Litosols

Group 2: 2:1 clay mineralogy

- Gleysols, Vertisols

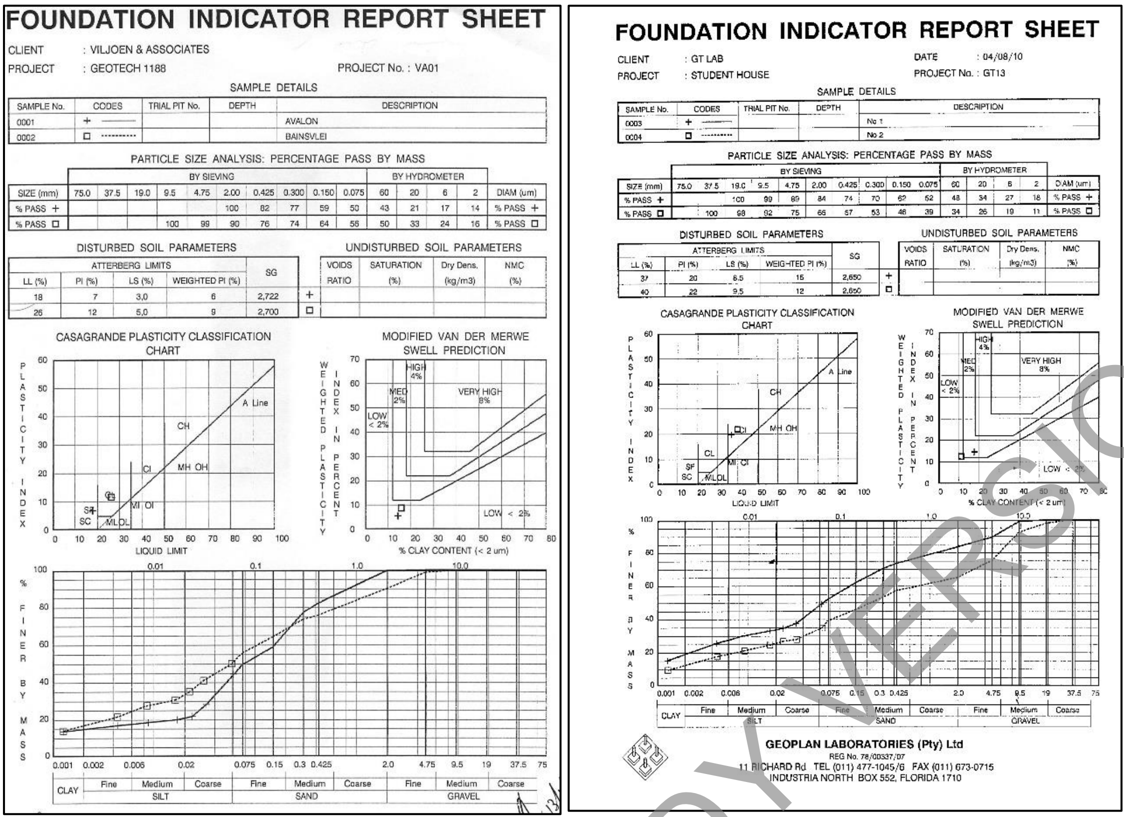

Figure 7. Typical Foundation Indicator Data for soils containing 1:1 (left) and 2:1 (right) clay mineralogy.

Figure 7 illustrates typical foundation indicator data for *Group 1* soils containing 1:1 clay mineralogy (*e.g.* kaolinite) and *Group 2* soils containing 2:1 clay mineralogy (*e.g.* smectite). The plasticity index (PI) represents the different soil's ability to swell and shrink under fluctuating moisture regimes.

4.1.1 Ferrasols

These are soils with an Oxic-B horizon, at least 300 mm thick. Typical properties are the presence of 1:1 clays, hydrated oxides of iron and aluminium, a low cation exchange capacity (<10cmol+/kg clay at pH7). The main processes of soil formation are weathering, humification and pedoturbation due to animals. The soils are characterised by a red (*Fe oxidised*) or yellowish (*Fe reduced*) colour, due to the high concentration of iron(III) and aluminium oxides and hydroxides. If the exchangeable sodium percentage (ESP) exceeds 15% of the cation exchange capacity (CEC @ *pH7 1NH4-Ac Extract*) dispersion in the diffuse double layer around the clay particles will take place and cause soil erosion. The bulk density is on average 1,275kg/m^3 and quantity (15%) of 1:1 clay mineralogy makes handling of the soil easy. The soil is suitable for agricultural production under dryland and irrigation conditions.

4.1.2 Litosols

Shallow soils with continuous hard rock within 100mm of soil surface. Soils that do not show any profile development other than an A horizon, has no diagnostic horizons, and most are basically unaltered from their parent material, which can be unconsolidated sediment or rock. Soil erosion will take place if the exchangeable sodium percentage (ESP) exceeds 15% of the cation exchange capacity (CEC @ *pH7 1NH4-Ac Extract*). The bulk density of the topsoil layer is on average 1,275kg/m^3 and quantity (15%) of 1:1 clay mineralogy makes handling of the soil easy. The soil is not suitable for agricultural production under dryland and irrigation conditions.

4.1.3 Gleysols

Wet soils formed in unconsolidated materials developed to 450 – 600mm deep. These soils are wetland soils (hydric soil) that, unless drained, is saturated with groundwater for long enough periods to develop a characteristic gleyic colour pattern. This pattern is essentially made up of reddish, brownish or yellowish colours at surfaces of soil particles (peds) and/or in the upper soil horizons mixed with greyish/blueish colours inside the peds and/or deeper in the soil. Soil erosion occurs when the exchangeable sodium percentage (ESP) exceeds 15% of the cation exchange capacity (CEC @ *pH7 1NH4-Ac Extract*). The bulk density is on average 1,800kg/m^3 and quantity (>25%) of 2:1 clay mineralogy makes handling of the soil difficult. The soil is not suitable for agricultural production under dryland conditions.

4.1.4 Vertisols

Dark coloured soils with high clay content, cracks wider than 100mm in dry state, gilgai micro-relief, slickensides, wedge-shaped peds. A high content of expansive clay known as montmorillonite that forms deep cracks in drier seasons or years. Alternate shrinking and swelling causes self-mulching, where the soil material consistently mixes itself, causing vertisols to have an extremely deep A horizon (300 – 900mm) and no B horizon. Vertisols typically form from highly basic rocks, such as basalt, in climates that are seasonally humid or subject to erratic droughts and floods, or to impeded drainage. Depending on the parent material and the climate, they can range from grey or red to the more familiar deep black. The shrinking and swelling of vertisols can damage buildings and roads, leading to extensive subsidence. When the exchangeable sodium percentage (ESP) exceeds 15% of the cation exchange capacity (CEC @ *pH7 1NH4-Ac Extract*) dispersion in the diffuse double layer around the clay particles takes place and result in soil erosion. The bulk density is on average 1,800kg/m^3 and quantity (>25%) of 2:1 clay mineralogy makes handling of the soil difficult. The soil is suitable for agricultural production under dryland conditions, however careful planning is required for irrigation scheduling of high clay content vertisols.

4.2 Irrigation Potential Of Soils

4.2.1 Infiltration and Surface Runoff

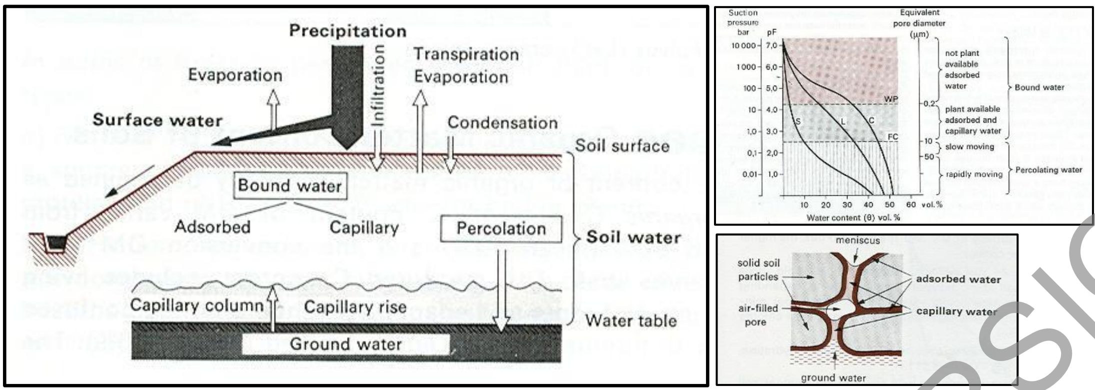

Figure 8. Typical Water Balance.

When water is supplied to soil surface (*precipitation & irrigation*) (**Figure 8**), some of the arriving water penetrates the surface and is absorbed into the soil, while some may fail to penetrate but instead accrue at the surface or flow over it. The water which does penetrate is itself later partitioned between the amount which returns to the atmosphere by evapotranspiration and the portion which seeps downward, with some of the latter re-emerging as streamflow while the remainder recharges the ground water reservoir.

Infiltration is the term applied to the process of water entry into the soil, generally by downward flow through all or part of the soil surface. Water may enter the soil through the entire surface uniformly as under ponding or rain or may enter the soil through furrows or crevices. It may also move up into the soil from a source below (*e.g.* high water table). The rate of this relative to the rate of water supply determines how much water will enter the root zone and how much if any will run off. The rate of infiltration affects not only water economy of plant communities, but also the amount of surface runoff and its attendant danger of soil erosion.

Where the rate of infiltration is restricted, plants may be denied sufficient moisture while the amount of erosion increases. Knowledge of the infiltration process as it is affected by the soil's properties and transient conditions and mode of water supply is therefore a prerequisite for efficient soil and water management.

If water is sprinkled over the soil surface at a steady increasing rate, sooner or later the rising supply rate will exceed the soil's limited rate of adsorption, and the excess will accrue over the soil surface or run of it. The *infiltration rate* is defined as the volume flux of water flowing into the profile per unit of soil surface area. This flux is referred to *infiltration velocity*.

Infiltration depends on the following factors:

- **Time from the onset of rain or irrigation**. The infiltration rate is apt to be relatively high at first, then to decrease and eventually to approach a constant rate that is characteristic for the soil profile.

- **Initial water content**. The wetter the soil is initially, the lower will be the infiltrability (smaller suction gradients) and quicker will be the attainment of the final (constant) rate, which itself is generally independent of the initial water content.

- **Hydraulic conductivity**. The higher the saturated hydraulic conductivity of the soil is, the higher its infiltrability tends to be.

- **Soil surface conditions**. When the soil surface is highly porous and open structure the initial infiltrability is greater than that of a uniform soil, but the final infiltrability remains unchanged, as it is limited by the lower conductivity of the transmission zone beneath. When the soil surface is compacted and the and the profile covered by a surface crust of lower conductivity the infiltration rate is lower that that of the uncrusted (uniform) soil. The surface crust acts as a hydraulic barrier impeding infiltration. This effect, which becomes more pronounced with a thicker and denser crust, reduces both the initial infiltrability and eventually attained steady infiltrability. A soil of unstable structure tends to form such a crust during infiltration, especially as the result of the slacking action of beating raindrops. In such a soil, a plant cover or a surface mulch of plant residues can serve to intercept and break the impact of the raindrops and help to prevent sealing.

- **The presence of impeding layers inside the profile**. Layers which differ in texture or structure from the overlaying soil may retard water movement during infiltration. Clay layers and sand layers can have a similar effect, although for opposite reasons. The clay layer impedes flow owing to its lower saturated conductivity, while a sand layer retards the wetting front where unsaturated conditions prevail owing to the lower unsaturated conductivity of the sand at equal matric suction. Flow into a dry sand layer can take place only after the pressure head has build up sufficiently for water to move into and fill the large pores of the sand.

4.2.2 Irrigation Management For Salt Control

The primary parameters that needs to be considered to ensure effective irrigation management for salt control are the water requirement of the crop and the quality of the irrigation water. Correct irrigation should restore any soil water deficit, while avoiding the application of a wasteful and potentially harmful excess water. An excess may be deliberately applied to control salt levels.

Plant growth is a function of the salinity and matric potential of soil water. Salinity is controlled by leaching, matrix potential is controlled by adequate and timely water application. Soluble salts contained in irrigation water are concentrated in the sol solution by soil evaporation and plant transpiration. Soluble salts are transported by water and salinity control depends on the quality of the irrigation water and on the amount and direction of the water flow. Plant water uptake and surface evaporation may cause an upward flow, a process by which many soils become salinized, especially when the water table is near the soil surface. The net water movement is downward and salts are leached from the root zone when more water is applied than is used during a crop season.

Over time the amount of salt removed by leaching must suffice to prevent the build-up of salinity beyond the level the crop can tolerate. It was once thought to amount removed had to be equal to the amount applied in the irrigation water. However, research have shown the amount of leached salt can be modified by chemical reactions, such as dissolution of soil minerals and salt precipitation. Mineral dissolution decreases and salt precipitation increases with reduction in the leaching fraction. Under steady-state conditions, the amount of salt leached in drainage water may be greater than, equal to, or less than the amount of salt added from the irrigation water.

Chemical reactions also take place between the cations on the exchange complex on the soil and those in solution. Since the salt concentration in the soil solution increases with depth, there is a corresponding increase in the *Sodium Adsorption Ratio (SAR)* of the soil solution in the same direction. The Exchangeable Sodium Percentage (ESP) also increases in the lower part of the root zone and may attain levels detrimental to soil structure. Excessive levels of sodium in the soil solution may be toxic to plant growth. Chemicals such as gypsum can be used to counteract these effects.

4.2.3 Irrigation Methods In Relation To Salinity Control

The usability of poor quality water for irrigation is conditioned to a great extent by the irrigation method employed.

Surface Irrigation

Efficient surface irrigation depends on an even distribution of water. Salinity control procedures include careful land levelling and controlled water application to ensure adequate and rapid watering of the border strip, basin or furrow with a minimum runoff. Inadequate salinity control is mostly due to inherent variability of intake rate and unsatisfactory land levelling. High spots or areas of low intake rates receive inadequate water, whereas excess leaching occurs in areas of high soil permeability or at low spots. The application of additional water to ensure adequate watering everywhere can result in an excessively high water table.

Artificial drainage is often required to control water table levels. The water table should be sufficiently low to prevent the rise of ground water into the root zone. The desirable water table level is dependant on the unsaturated conductivity of the soils. A relatively high water table (100cm) can be tolerated in coarse textured sols. A water table depth of about 180cm is generally recommended for soils of medium texture. A lower table is required for perennial crops than for annuals.

Inadequate watering and salinisation may occur on fine-textured soils because of insufficient infiltration rates. This is particularly true of crops of high water requirements. If soil permeability is insufficient to meet the leaching requirement a crop with lower water requirement or salt tolerance should b grown. Another possibility is to grow crops with high water requirements in rotation with crops with lower water requirements.

Furrow irrigation is commonly used for row crops. Since salts accumulate at the wetting front as water advances through the soil, salts tend to accumulate between the furrows.

Planting location on the ridge should be governed by the pattern of salt accumulation. The sloping bed system prevents salt accumulation at the location of seed placement. Rain during the growing season may cause damage by leaching salt into the root zone. The risk of damage can be greatly reduced by immediate irrigation. The salts which accumulate in the ridges during the cropping season will tend to become mixed through the surface soil when the field is prepared for the next season. The initial irrigation of the next crop will often provide adequate leaching for seed germination.

Sprinkler Irrigation

Sprinkler irrigation is becoming increasing popular for a number of reasons. In countries with limited supply, water can be saved because with sprinkler irrigation higher efficiencies are easier to obtain than with flood irrigation. Land levelling is not necessary, and the need for artificial drainage is reduced – often natural drainage is sufficient.

Sprinkler irrigation provides an effective means of reducing the salt concentration on the surface, it is therefore increasingly used to start salt-sensitive row crops. Furrow irrigation can then be used for the remainder of the growing season.

For irrigation if woody species, special low angle sprinkler heads can be used to minimise leaf burn due to wetting of the foliage.

Trickle Irrigation

In this method water is applied at low rates through emitters located near the base of the plant. Water deficits resulting from evapotranspiration can be replaced on a daily basis. Trickle irrigation has been successfully used with highly saline waters. With this method high levels of salinity can be tolerated by plants than with other irrigation methods. It is believed that the increased tolerance is due to the steady supply of irrigation water which results in low salinity and high water content of the emitters. Under these conditions the uptake weighted mean salinity of the root zone is relatively constant and for a leaching fraction of 0,1 to 2,5 times that of the irrigation water. Under flood irrigation the uptake weighted mean salinity fluctuates from a minimum which about equal to the salinity of the irrigation water to ten times this value prior to the next water application.

With trickle irrigation zones of high salt concentration develop at the wetting front during the growing season and may have to be leached before a new crop is planted, except when row crops are planted in the old row location.

4.2.4 Properties of Irrigation Water

The quality of irrigation water is determined by:

pH

The pH of irrigation water should fall within 5,3 and 7,2.

Salinity

- The effect of salt on crop growth is osmotic and related to total salt concentration. On average salinity should be <250mS/m.

<u>Sodicity</u>

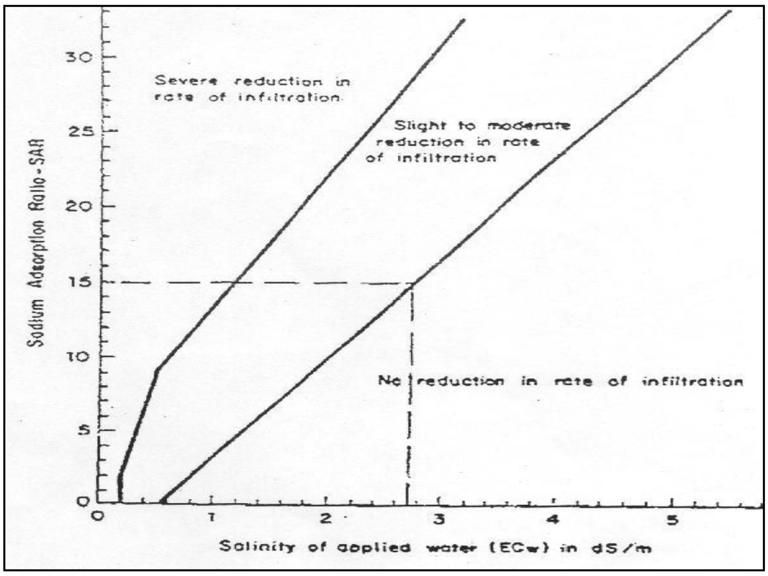

Figure 9. SAR relative to EC.

- The sodium adsorption ratio (SAR) of the effluent should be maintained below 15 and electrical conductivity (EC) should be <250mS/m.

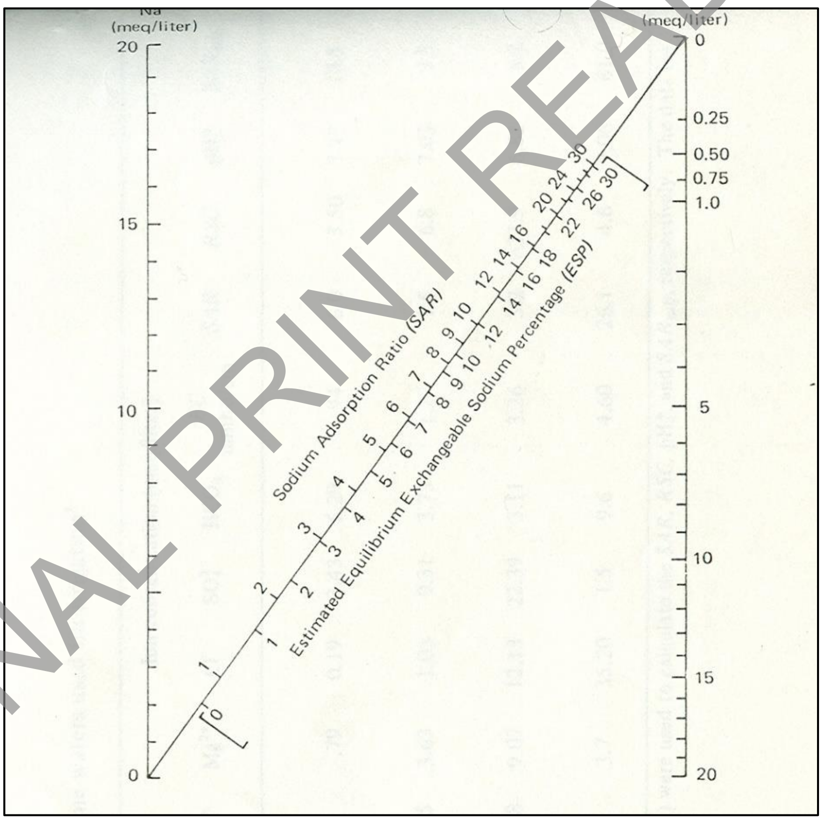

Figure 10. SAR relative to ESP.

- If the SAR is maintained <15 the resulting ESP (*exchangeable sodium percentage 1 N NH4-Ac pH7*) is also <15.

Bicarbonate and carbonate ions

- The principle cations and anions in irrigation water are calcium, magnesium, sodium, bicarbonate, sulphate, chloride and nitrate. If the pH exceeds 8,3 carbonate concentrations can become significant. Potassium concentrations are usually less than 1meq/l.

Trace elements

- Some soluble trace elements may have an inhibitory effect on plant growth. Elements in this category include boron, lithium, selenium and some heavy metals. The effluent water should be constantly be analysed for contamination anomalies.

5 CONCLUSIONS

- The dominant soils on the Buhuka Flats study area according to the FAO Soil Classification System include *Ferrasols*, *Litosols*, *Gleysols* and *Vertisols*.

- The *Ferrasols* is most suitable for the irrigation of 45m^3/day sewage effluent.

- CNOOC would not want to irrigate far away due to pumping and piping costs. Irrigation would essentially have to be in close proximity to the permanent accommodation area. *i.e.* the Ferrasols occur near the CPF.

- A 3 to 5ha area in close proximity to the CPF would enable enough even distribution and rotation of 45m^3/day sewage effluent to maintain plant available water between 33 – 1,500kPa.

- An indigenous pasture should be identified that would be suitable and sustainable for 45m^3/day sewage effluent irrigation purposes.

- The ***45m^3/day sewage effluent*** should be carefully monitored to ensure:

    - pH 5,3 and 7,2 (*no acid and/or alkaline anomalies*).

    - EC<250mS/m.

    - SAR<15 – maintain SAR<10 to ensure buffercapacity.

    - Assess toxicity of trace elements for specific pasture species utilized for irrigation.

    - Prevent eutrophication in soil through excess nitrogen and phosphorus being irrigated.

- No human and/or plant pathogens become an environmental risk.

- The ***<u>3 – 5ha Ferrasols</u>*** should be carefully monitored to ensure:

  - pH 5,3 and 7,2 (*1:2.5 soil:water ratio*) in soil solution.
  - EC<250mS/m (*saturated water extract*).
  - ESP<15 (*1N NH4-Ac extract pH7)* – maintain ESP<10 to ensure buffercapacity.
  - Ca: 200 – 4,000mg/kg (*1N NH4-Ac extract pH7*).
  - Mg: 50 – 500mg/kg (*1N NH4-Ac extract pH7*).
  - K: 20 – 300mg/kg (*1N NH4-Ac extract pH7*).
  - Ca:Mg (1,5 – 4,5), Mg:K (3 – 4) and Ca+Mg/K (10 – 20) (*1N NH4-Ac extract pH7*).
  - NO_3: 10-20mg/kg (*saturated water extract*).
  - P: 10-15mg/kg (*Bray 1 extract*).
  - Heavy metals: <0.01mg/kg (*saturated water extract*).
  - SO_4, Cl, B, F: <0,1mg/kg (*saturated water extract*).
  - No human and/or plant pathogens become an environmental risk.
  - Infiltration capacity: 10-15mm/h @ bulk density 1,275kg/m_3 (*no crust formation*).
  - C:N Ratio: 1:10.

- It should be considered to compile a soil water balance with the chosen pasture species under the climatic condition of the Buhuka Flats to optimize irrigation scheduling.

- The 3 – 5ha Ferralsol soil system at 1,500kg/m^3/300mm bulk density contains an estimated 13,500,000 to 22,500,000kg soil. The average CEC range between 5 – 15cmol+/kg (*1N NH4-Ac extract pH7*), which is an enormous advantage in terms of buffercapacity to utilize for 45m^3/day sewage effluent irrigation in combination with plant root uptake of nutrients. However, it must be stressed the system should be carefully monitored and maintained to prevent contamination. Soil remediation cost could be as high as \$800/m^3 (\$12,000,000/15,000,000m^3 soil @ BD1,500kg/m^3/300mm) depending on the severity of remediation required (*e.g. ESP>15% requires leaching Na with Ca*), this excludes site establishment of earth moving equipment (if necessary).

This investigation was done on available information and subsequent interpretation of data to reveal the properties on site with the techniques described.

M.Sc., Pr. Sci. Nat., SACNSP: 400131/96,

Professional Indemnity Insurance: CFP Brokers Hollard Insurance: SPL/SLFG/000009469