# Limited ESIA for Polymer Flooding Enhanced Oil Recovery in the Tambaredjo Oilfield in Saramacca, Suriname

## Limited ESIA Report and EMMP

Report Prepared for

**Staatsolie Maatschappij Suriname N.V.**

SRK Report Number 545842/1

Report Prepared by

srk consulting

August 2019

# Limited ESIA for Polymer Flooding Enhanced Oil Recovery in the Tambaredjo Oilfield in Saramacca, Suriname

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## Staatsolie Maatschappij Suriname N.V.

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**SRK Project Number 545842**

**August 2019**

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# Profile and Expertise of Consultant

SRK Consulting (South Africa) Pty Ltd (SRK) has been appointed by Staatsolie Maatschappij Suriname N.V. (Staatsolie) to undertake a limited Environmental and Social Impact Assessment (ESIA) and compile an Environmental Management and Monitoring Plan (EMMP), required for the proposed polymer flooding Enhanced Oil Recovery process in Saramacca, Suriname.

SRK Consulting was established in 1974 and comprises over 1 400 professional staff worldwide, offering wide-ranging expertise in the natural resources and environmental sectors. SRK's Cape Town environmental department has a proven track record of managing large, complex environmental and engineering projects in the Western Cape, Africa and internationally, including in Suriname, amongst others for the SPCS Power Plant Expansion, EBS Power Plant, Staatsolie Refinery Expansion and Bakhuis Mining and Transportation Projects. SRK has rigorous quality assurance standards and is ISO 9001 certified.

The qualifications and experience of the key independent environmental consultants undertaking the Limited ESIA are detailed below.

Project Director and Reviewer: Christopher Dalgliesh, BBusSc (Hons); MPhil (EnvSci)

Chris Dalgliesh is a Partner and Principal Environmental Consultant with over 25 years' experience, primarily in South Africa, Southern Africa, West Africa and South America (Suriname). Chris has worked on a wide range of projects, notably in the natural resources, Oil & Gas, energy generation, infrastructure and industrial sectors. He has directed and managed numerous Environmental and Social Impact Assessments (ESIAs) and associated management plans, in accordance with international standards. He regularly provides high level review of ESIAs, frequently directs Environmental and Social Due Diligence studies for lenders, and also has a depth of experience in Strategic Environmental Assessment (SEA). He holds a BBusSci (Hons) and MPhil (Environmental Management).

Project Manager: Sue Reuther, BSc Hons (Econ); MPhil (EnvMgt)

Sue Reuther is a Principal Environmental Consultant and Associate Partner with more than 15 years of experience researching and working on issues in the environmental assessment sector. She has been involved in a variety of ESIAs, as well as due diligence reviews against IFC and World Bank Standards.

Sue has managed projects across South Africa and sub-Saharan Africa, in Israel and Suriname for a range of sectors, including mining, infrastructure, industrial and coastal developments, power generation, aquaculture and oil and gas. Sue has two years of previous experience in strategy and financial research and assessment (London). She holds a BSc (Hons) in Economics and MPhil (Environmental Management).

# Statement of SRK Independence

Neither SRK nor any of the authors of this Report have any material present or contingent interest in the outcome of this Report, nor do they have any pecuniary or other interest that could be reasonably regarded as being capable of affecting their independence or that of SRK.

SRK has no beneficial interest in the outcome of the assessment which is capable of affecting its independence.

# Disclaimer

The opinions expressed in this report have been based on the information supplied to SRK by Staatsolie. SRK has exercised all due care in reviewing the supplied information, but conclusions from the review are reliant on the accuracy and completeness of the supplied data. SRK 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 SRK's investigations, and those reasonably foreseeable. These opinions do not necessarily apply to conditions and features that may arise after the date of this Report, about which SRK had no prior knowledge nor had the opportunity to evaluate.

# Limited ESIA for Proposed Tambaredjo Oilfield Polymer Flooding EOR

# Non-Technical Summary: ESIA Report

August 2019 SRK Project Number: 545842

## 1. INTRODUCTION

Staatsolie Maatschappij Suriname N.V. (Staatsolie) operates three oilfields and three oil processing plants in the Saramacca District of Suriname.

Staatsolie aims to improve recovery of remaining oil from the operating Tambaredjo Oilfield by using Enhanced Oil Recovery (EOR) techniques. Following implementation of a polymer flooding (PF) pilot project, Staatsolie proposes to upscale the EOR and implement a commercial scale PF project in the Tambaredjo Oilfield (the project).

SRK Consulting (South Africa) (Pty) Ltd (SRK), a consultancy with extensive experience in Suriname, was appointed to undertake the Limited Environmental and Social Impact Assessment (ESIA) process required for the project.

**See page 6 for details on how you can participate in the process.**

## 2. GOVERNANCE FRAMEWORK

Suriname does not have an approved national environmental policy and there is no promulgated legislation dealing specifically with environmental management. However, environmental legislation is under development and guidelines for environmental assessment have been released. The Limited ESIA process for the proposed PF project complies with the guidelines and other relevant legislation.

In addition to national regulatory requirements, the Limited ESIA process was guided by Good International Industry Practice (GIIP), notably standards and guidelines such as those prescribed by the World Bank Group for Bank-funded private sector development projects.

### 2.1 National Standards

The *Nationaal Instituut voor Milieu en Ontwikkeling in Suriname* (NIMOS) is responsible for the development of national environmental legislation and administers the environmental assessment process in Suriname.

A **draft Environmental Act**, most recently amended in 2016, has been developed as a framework law in response to the 1992 Rio declaration. The draft Act lays down rules for the conservation, management and protection of a sound environment within the framework of sustainable development. The draft Act has been under consideration by the Council of Ministers and The National Assembly (DNA) for some time and has not yet been promulgated. The Act has been submitted to Parliament as an initiative law (*initiatief wet*). Nevertheless, the principles in the draft Act provide guidance for conducting an ESIA in Suriname.

**Draft EIA Regulations**, to be promulgated under the Environmental Act once in force, have also been developed since 2003 and contain requirements for EIA processes and public participation. The draft EIA Regulations are still being amended and are not yet in force.

While there is currently no legislative basis for the assessment of environmental impacts of development proposals in Suriname, NIMOS has published Guidelines for Environmental Assessment (EA) in Suriname. The EA Guidelines will be applied by NIMOS as part of the project permitting process and project developers are expected to comply with the guidelines. NIMOS' *EA Guidelines Volume II: Mining*, also guided the ESIA.

Based on the Screening report compiled by Staatsolie, NIMOS advised that the project should follow a Category B path 2 process in terms of NIMOS's EA Guidelines, and requested that a Limited ESIA process be conducted and an Environmental Management and Monitoring Plan (EMMP), including impact assessment, be produced and submitted to NIMOS.

### 2.2 International Standards

SRK was guided by international standards and Good International Industry Practice (GIIP), notably the Performance Standards (PS) of the International Finance Corporation (IFC), in conducting the ESIA and associated public consultation and information disclosure process.

### 2.3 Corporate Requirements

Staatsolie has adopted procedures for protecting the environment which comply with international standards. An integrated Health, Safety, Environment and Quality (HSEQ) Policy and Management System is implemented across Staatsolie's operations to monitor effects on the health and safety of employees, contractors and affected communities, as well as impacts on the environment.

***Een Nederlandse versie van dit document is beschikbaar.***

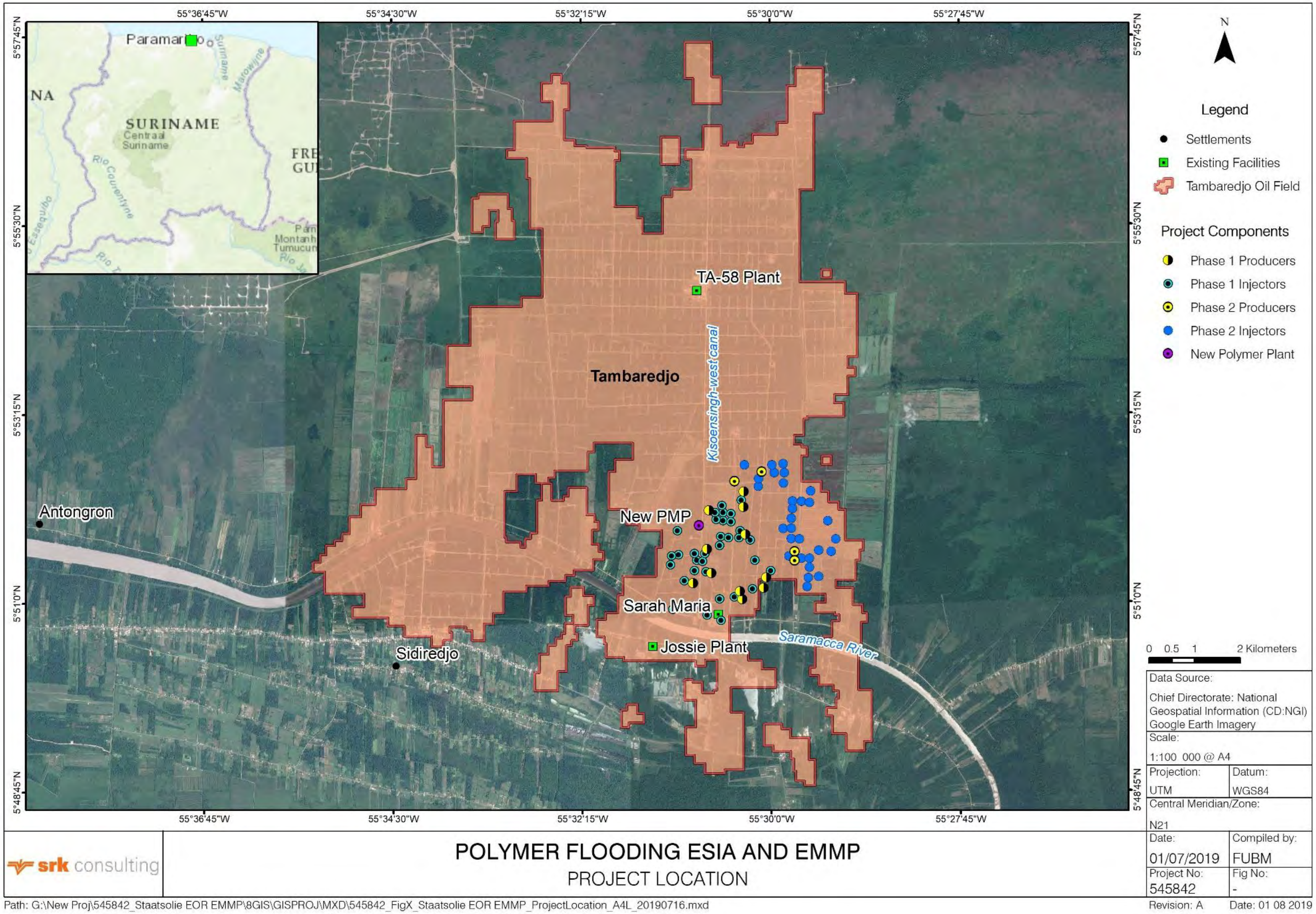



**Figure 1: Location of the PF project**

## 3. THE ESIA PROCESS

The general approach to the Limited ESIA was guided by the requirements of NIMOS, as stipulated in the EA Guidelines (2009) and Guidance Note Environmental Assessment Process (2017), and international best practice.

The objectives of the ESIA are to:

- Document and contextualise the ecological baseline conditions of the study area and the socio-economic conditions of affected communities;
- Assess in detail the environmental and socio-economic impacts that may result from the project;
- Inform and obtain contributions from stakeholders, including relevant authorities and the public, and address their relevant issues and concerns;
- Identify environmental and social mitigation measures to address the impacts assessed; and
- Develop an Environmental and Social Management Plan (ESMP), based in part on the mitigation measures developed in the ESIA Report.

The Limited ESIA process consists of two phases: the Impact Assessment Phase *(current phase)* and the Review Phase. A summary of the ESIA process is shown in Figure 2.

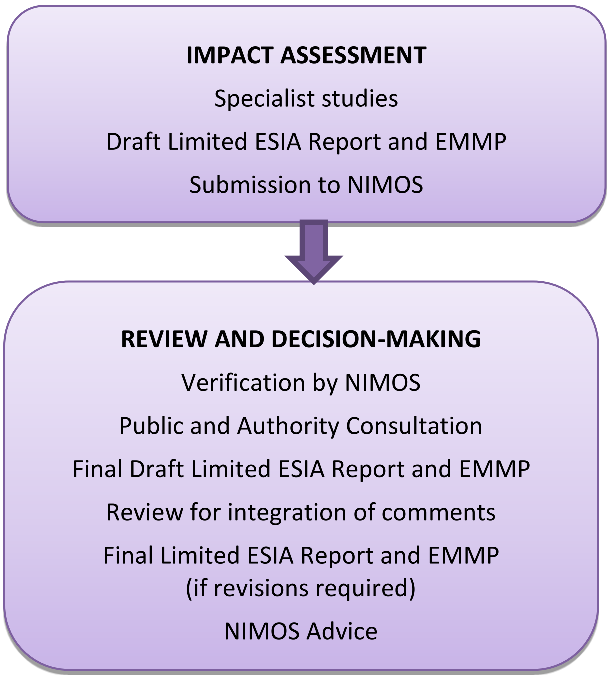



**Figure 2: Schematic of Limited ESIA process**

## 4. DESCRIPTION OF THE SITE AND ENVIRONMENT

The Tambaredjo Oil Field is located between the East-West Connection Road and the coast, and mostly north of the Saramacca River (see Figure 1).

The study area is located in the Young Coastal Plain of the Guiana Basin, on Holocene deposits of the Coronie Formation. The Young Coastal Plain is dominated by flat and low-lying swamps and marshes with clay soils at 1 - 1.5 m above mean sea level (amsl), on which a peat layer has developed.

The project is located in the south-eastern section of the Tambaredjo Oilfield and new wells will be embedded amongst the existing ~1 700 oil wells. A Polymer Mixing Plant (PMP) will be located 1.8 km north of Gangaram Pandayweg along the south-north aligned unpaved (shell sand) road that connects the TA-58 to Gangaram Pandayweg. With the exception of existing oil production infrastructure, the project area is vacant and covered with modified secondary marsh **vegetation** with relatively low **faunal** diversity. The Tambaredjo Polder area has been substantially transformed by human activities (see Figure 3 and Figure 4).

There are few significant sources of **air pollution** in the area. The TA-58 Crude Treatment Facility releases some atmospheric emissions. Other potential sources of air pollution include vehicles on unpaved roads and farming activities in surrounding areas. Air quality measurements taken around the project site showed that all measured pollutants are low and air quality is good.

**Figure 3: Oil well along the road to TA-58**

**Figure 4: Unpaved road and roadside ditches in the Tambaredjo Oilfield**

**Noise** levels are typical of rural areas, with daytime sound at ~46 dBA west of TA-58 (where there is little traffic) and ~66 dBA at Wayamboweg (with public traffic).

The Saramacca District has approximately 3 320 km$^2$ of coastal **wetlands**, of which 370 km$^2$ support mangrove forest. Surface water sampling during the rainy and dry seasons indicated that water quality had not significantly changed from measurements in 1999, and point to the TA-

58, oil drilling and processing and use of insecticide as possible, but limited, sources of contamination.

The northern area supports important ecosystem goods and services, including the Coppename Monding **Nature Reserve** located ~10 km north of the project area, which is listed as a Wetland of International Importance (RAMSAR site).

The coastal plain of Suriname is underlain by three major **aquifers** within the Corantijn Group. Drinking water is abstracted ~12 km east of the project area at Tijgerkreek.

The project area is **not deemed sensitive** with regards to ecosystems and floral and faunal biodiversity.

**Residential** areas nearest to the project area are located along Gangaram Panday Road (~1 km to the south). Most families residing along the Gangaram Panday Road practise horticulture (domestic cultivation). Most farmland in the area lies fallow or has been abandoned, though some fields are located within ~100 m of existing (and ~200 m of new) oil wells. Public piped water infrastructure is being installed, but most households currently depend on rain water for drinking and household purposes.

No records of significant cultural or historical objects / spaces are known in the area.

## 5. PROJECT DESCRIPTION

Enhanced oil recovery (EOR) is the extraction of crude oil that cannot be extracted otherwise (from an oilfield). Three main EOR techniques are:

- *Gas:* Injection of gases into the reservoir to maintain reservoir pressure and displace ("drive") more oil towards producer wells;
- *Thermal:* Injection of steam to heat the oil, effectively making it easier to extract; and
- *Chemical:* Injection of chemicals (including polymer flooding) as dilute solutions to make the oil more mobile and/or increase the viscosity ("thickness") of injected water, to "drive" more oil towards producer wells.

Based on EOR screening and a pilot project, the Tambaredjo Central Area is suited to EOR processes such as PF.

Staatsolie's Tamabaredjo Oilfield PF project entails an initial injection of a small volume of water to condition the reservoir followed by continuous pressurised injection of a viscous polymer solution which will drive more oil towards the producer wells. After about 11 years, once the maximum amount of polymer has been injected, water will be continuously pumped into the reservoir to drive (or "chase") the polymer slug and the oil towards the producer wells.

The project includes the:

- Construction and operation of a PMP to prepare the polymer solution;
- Drilling of 64 new injector wells and 15 new producer wells;
- Construction of 5 km of pipeline and 79 km of injection lines; and
- Construction / extension of access roads within the oilfield.

The PF process requires 21 000 barrels/day of water, abstracted from the Saramacca River and/or groundwater in the S-sand aquifer above the oil reservoir. Power will be obtained from existing sources.

Produced fluid[1] extracted from production wells is conveyed to the Jossie crude treatment plant for separation and treatment. The treated produced water is then discharged into the Saramacca River.

Wells will be drilled in two phases during the first two years of the project. Operations may commence in 2020 and extend to 2044.

It is expected that the project will provide jobs for 20 people during operation.

## 6. ALTERNATIVES

During the planning phases, Staatsolie considered and evaluated a number of alternatives relating to:

- EOR techniques;
- Water supply; and
- Disposal of produced water.

Other EOR techniques and produced water disposal methods, and the suitability of surface and groundwater for water supply, are being assessed by Staatsolie in separate studies.

## 7. STAKEHOLDER ENGAGEMENT

Stakeholder engagement is a key component of the ESIA process and is being undertaken in compliance with GIPP and NIMOS guidelines.

Stakeholder engagement activities during the Limited ESIA process are outlined in Table 1.

**Table 1: Stakeholder engagement activities**

| Activity | Date |
|---|---|
| Release ESIA Report and EMMP for public comment period | August 2019 |
| Public comment period | until 9 September 2019 |
| Public meeting | 21 August 2019 |
| Compile Issues and Responses Summary, finalise ESIA Report | September 2019 |

[1] Mix of oil, water and gas.

## 8. ASSESSMENT OF POTENTIAL IMPACTS

A groundwater and geochemical specialist study, including a surface water component, was undertaken to investigate key potential direct, indirect and cumulative impacts.

The impact assessment is further based on a number of recent specialist studies for the proposed Saramacca Power Plant in the Tambaredjo Oilfield, which provide air quality, noise, surface water quality, terrestrial ecology and social baselines.

For all potentially significant impacts, the significance of the anticipated impact was rated without and with recommended mitigation measures. Impacts are summarised below.

- The predicted *groundwater* impacts due to **abstraction** of groundwater for the PF project are considered to be of *very low* significance. Impacts associated with the possible **contamination** of groundwater resources due to vertical migration of injected polymer is deemed of *low* significance for the deeper brackish groundwater layer and *insignificant* for the shallower freshwater layer. A major **accidental spill** of polymer mix due to a leaking well into a groundwater bearing layer, especially the freshwater layer, is expected to remain localised and extremely unlikely to reach the Tijgerkreek abstraction point before full degradation of the polymer, and is assessed to have an impact of *low* significance.
- The predicted *surface water* impact due to **contamination** during construction is deemed to be of *very low* significance. **Disposal** of produced water containing polymer into the Saramacca River is assessed to have an impact of *low* significance, as the acrylamide (AAM) contained in the produced water will be diluted to acceptable concentrations in the river water. Dilution and degradation of polymer and AAM will occur in the event of an accidental **surface spill** of polymer mix, and is assessed to have a *very low* significance impact on surface water.

Cumulative impacts may derive from existing oil production and groundwater abstraction in the Tambaredjo Oilfield and discharge of produced water to the Saramacca River. Cumulative impacts include a reduction in groundwater quality and quantity and surface water quality, depending on the quality and quantity of abstraction, discharge and unforeseen events, e.g. leaks, from other activities.

Vibration, air quality, noise, ecological, socio-economic, visual and traffic impacts are minor or less significant impacts associated with the PF project. If recommended mitigation measures are adopted, these impacts are not expected to be significant nor long-term.

A number of mitigation and monitoring measures have been identified to avoid, minimise and manage potential environmental impacts associated with the proposed PF project. These are presented in the EMMP.

Table 2 below summarises:

- The impacts assessed in the EIA; and
- Their significance before and following the implementation of essential mitigation measures, on which the significance rating is based.

Potential negative impacts are shaded in reds, benefits are shaded in greens

**Table 2: Summary of impacts**

| Impact | Significance rating | |
|---|---|---|
| | Before mitigation | After mitigation |
| **CONSTRUCTION PHASE IMPACTS** | | |
| **Groundwater Impacts** | | |
| Contamination of groundwater due to spills and well drilling | Very Low | Insignificant |
| **Surface Water Impacts** | | |
| Contamination of surface water, affecting ecosystems | Very Low | Very Low |
| **OPERATION PHASE IMPACTS** | | |
| **Groundwater Impacts** | | |
| Reduction in groundwater level and supply due to groundwater abstraction | Very Low | Very Low |
| Contamination of groundwater in lower brackish aquifer due to intrusion of polymer mix | Low | Low |
| Contamination of groundwater in freshwater aquifer due to intrusion of polymer mix | Insignificant | Insignificant |
| Groundwater contamination due to a leaking well | Medium | Low |
| **Surface Water Impacts** | | |
| Impacts from the disposal of back produced polymer on surface water quality | Medium | Low |
| Risks from chemical spills or leaks to surface water quality | Low | Very low |

Indirect contribution to the emission of greenhouse gases through the subsequent combustion of the extracted fossil fuel will dominate the project's contribution to climate change. However, oil volumes that will be recovered through the PF project, and their ultimate use, are not currently known, and approximate GHG quantities cannot be calculated at this stage. Direct contributions to GHG emissions from electricity and fuel use by the project and possibly methane leaking from wells and pipelines are expected to be comparatively small.

Key essential recommendations / mitigation measures are:

- Implement the EMMP to guide design, construction, operation and decommissioning activities and to provide a framework for the ongoing assessment of environmental performance;
- Ensure that the appropriate personnel and sufficient resources are allocated to expedite implementation of the EMMP;
- Use non-toxic drilling fluids when drilling through freshwater aquifers;
- Ensure that well-casing and cementing meets best practice methods to prevent chemical losses into the upper layers (aquifers) above the oil reservoir;
- Ensure that the polymer used has a residual AAM concentration of <0.1% by weight;
- Monitor polymer mix injection pressure and flow rate, to ensure no polymer mix is unaccounted for;
- Ensure adequate response mechanisms are in place and corrective action is taken to address any instances of non-compliance with standard management measures or procedures;
- Maintain lines of communication with the local communities in the vicinity of the Tambaredjo Oilfield. Ensure that local communities are aware of the Staatsolie grievance mechanism and how to utilise it. Maintain a complaints registry and investigation procedure to ensure that all grievances are adequately addressed;
- Maximise the employment of local (Surinamese) nationals and the procurement of local resources during the construction and operations phases to ensure maximum benefit to the local economy; and
- Compile and implement a detailed Emergency Response Plan prior to commencing with the PF project, setting out roles, responsibilities and procedures to address all potential incidents.

## 9. CONCLUSIONS

This Draft Limited ESIA Report has identified and assessed the potential impacts associated with the proposed Staatsolie PF project at the Tambaredjo Oilfield and shown that potential groundwater and surface water impacts are acceptable.

The project entails trade-offs between social, environmental and economic costs and benefits. The trade-offs are documented in the report, which assesses environmental impacts and benefits and compares these to the No-Go alternative.

There are a number of minor or less significant impacts associated with the project. If recommended mitigation measures are adopted, these impacts are not expected to be significant nor long-term.

## HOW YOU CAN YOU PARTICIPATE IN THE EIA PROCESS

The Limited ESIA Report is not a final report and may be amended based on comments received from stakeholders. As such, stakeholders are invited to participate in the ESIA process by commenting on the ESIA Report, registering on the project database and/or attending a public meeting:

### REVIEW THE REPORT

**Copies of the complete report are available** for public review at the following venues:

- NIMOS;
- Office of the Saramacca District Commissioner at Groningen; and
- SRK's website: www.srk.co.za – click on the 'Recent Publications' and then 'Public Documents' links.

### ATTEND A MEETING

A **Public Meeting** will be held where the information presented in the ESIA Report will be discussed and additional concerns and issues can be raised with the environmental consultants and the project team on **21 August 2019**.

### REGISTER ON THE DATABASE OR PROVIDE YOUR OPINION

Register or send written comment to:

SRK Consulting:
Contact persoon: **Sue Reuther**
**E-mail**: sreuther@srk.co.za
**Tel:** + 27 21 659 3060 **Fax**: +27 21 685 7105

or

Staatsolie:
Contact person: **Farina Ilahibaks**
**E-mail:** FIlahibaks@staatsolie.com
**Tel**: +597 375222 extension 66761

Comments must reach one of the above contact persons **no later than 9 September 2019.**

STAATSOLIE

srk consulting

# Beperkte ESIA voor de voorgestelde 'Polymer Flooding EOR' op het Tambaredjo-olieveld
# Niet-Technische Samenvatting: ESIA-Rapport

August 2019

SRK projectnummer: 545842

## 1. INLEIDING

Staatsolie Maatschappij Suriname N.V. (Staatsolie) beheert drie olievelden en twee olieverwerkingsfaciliteiten in het Saramacca district.

Staatsolie heeft als doel om de winning van de resterende olie op het werkende Tambaredjo-olieveld te optimaliseren door het gebruik van verbeterde oliewintechnieken (EOR – ofwel Enhanced Oil Recovery). Na de implementatie van een 'Polymer Flooding' (PF) proefproject, stelt Staatsolie voor om de EOR op te waarderen en een PF-project op commerciële schaal te starten in het Tambaredjo-olieveld (het Project).

SRK Consulting (Zuid Afrika) (Pty) Ltd (SRK), een advies-bureau met ruime werkervaring in Suriname, werd aangesteld om een beperkte *Milieu en Sociale Effecten Analyse* (ofwel Environmental and Social Impact Assessment [ESIA]) te doen.

**Op pagina 6 vindt u meer informatie over hoe u kunt deelnemen aan dit proces.**

## 2. WETTELIJK EN REGELGEVEND KADER

Principes voor Suriname's milieubeleidsvisie zijn terug te vinden in de Constitutie en in het Nationaal Ontwikkelingsplan. Er wordt gewerkt aan een basis voor milieuwetgeving en er zijn richtlijnen voor milieueffectenanalyse gepubliceerd. Het beperkt ESIA-proces dat bij het voorgestelde projekt gevolgd zal worden, zal gebeuren in overeenstemming met deze richtlijnen en andere relevante wet- en regelgeving.

Bovenop deze nationale regelgevende voorschriften, zal het ESIA-proces zich laten leiden door de "Good International Industry Practice" (GIIP), meer specifiek als die zijn voorgesteld door de Wereldbankgroep voor ontwikkelingsprojecten in de private sector en die door de bank gefinancierd worden.

### 2.1 Nationale normen

Het *Nationaal Instituut voor Milieu en Ontwikkeling in Suriname* (NIMOS) is verantwoordelijk voor de verdere ontwikkeling van de nationale milieuwetgeving en het beheer van het milieueffectenanalyse proces in Suriname.

Naar aanleiding van de Verklaring van Rio uit 1992 werd een **Concept Milieuwet** aangenomen, laatst gewijzigd in 2016. Dit handvest omvat beginselen met betrekking tot de bescherming en het beheer van een gezond milieu binnen het kader van duurzame ontwikkeling. Het wetsontwerp is in behandeling bij de Raad van Ministers en De Nationale Assemblee (DNA), en is dus nog niet uitgevaardigd. De principes van het wetsontwerp bieden begeleiding voor het uitvoeren van een ESIA in Suriname.

**MEA-Uitvoeringsbesluiten,** die zullen worden uitgevaardigd zodra de Milieuwet in werking treedt, worden ook al ontwikkeld sinds 2003 en bevatten vereisten voor ESIA-processen en publieke participatie. De Milieu Uitvoeringsbesluiten worden nog aangepast en zijn nog niet in werking.

Hoewel er momenteel geen wetgevende basis bestaat voor de analyse van milieueffecten van ontwikkelingsvoorstellen in Suriname, heeft het NIMOS Richtlijnen voor Milieuanalyse (EA) gepubliceerd. Deze Richtlijnen worden door het NIMOS gebruikt bij het uitreiken van projectvergunningen en van project-ontwikkelaars wordt verwacht dat ze de richtlijnen volgen. De NIMOS *EA Guidelines Volume II: Mining*, zijn ook gebruikt in het ESIA-proces van dit project.

Op basis van het Screening Rapport van Staatsolie, adviseerde het NIMOS om het project als een Categorie B, optie 2 proces te beschouwen wat betreft de NIMOS EA-Richtlijnen, wat betekent dat een beperkt ESIA-proces, alsook een *Environmental Management and Monitoring Plan* (EMMP - ofwel Milieu Management en Controle Plan), incl. een Effectenanalyse, uitgevoerd en voorgelegd moeten worden aan het NIMOS.

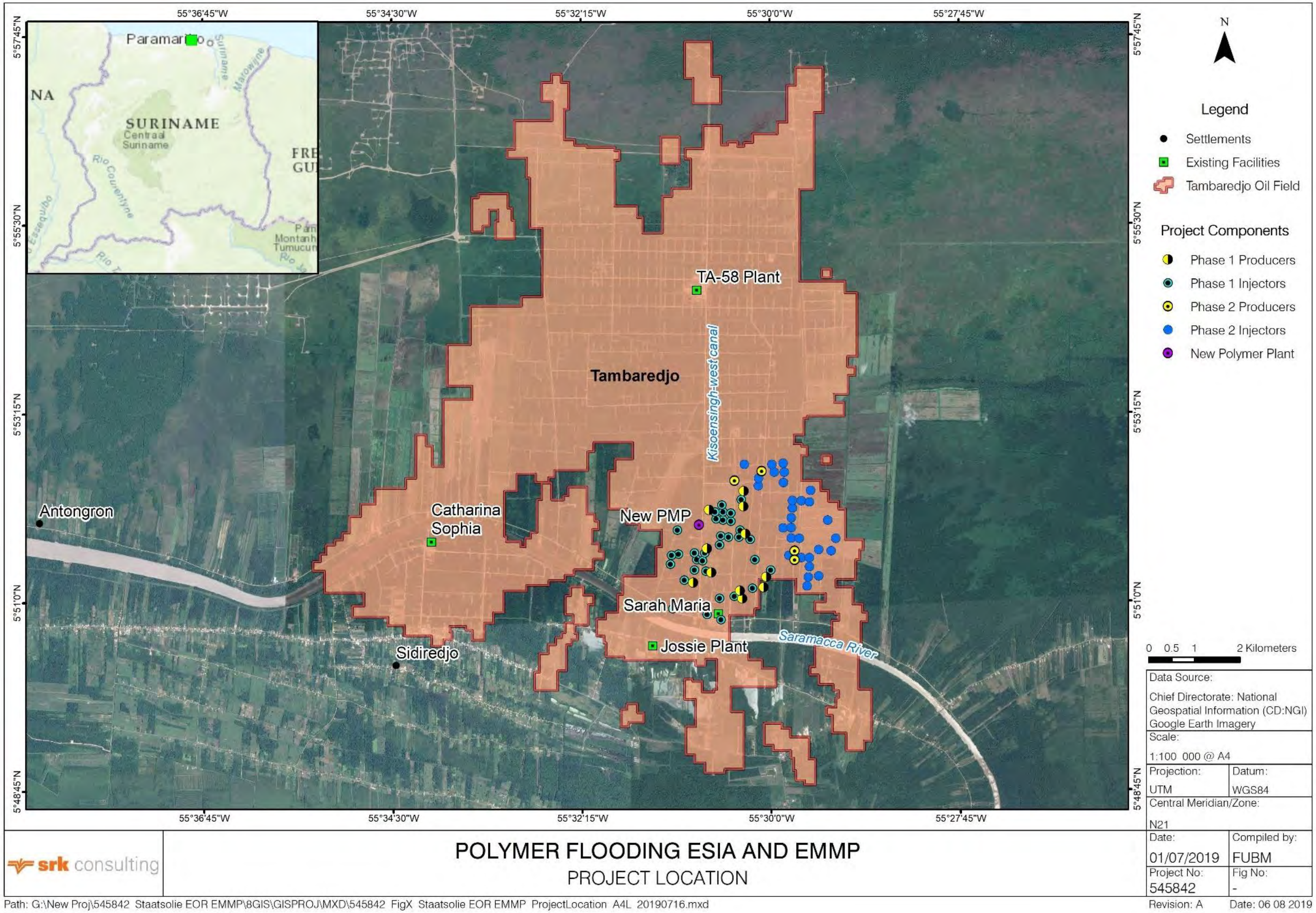
### 2.2 Internationale Normen

SRK laat zich leiden door internationale normen en GIIP bij het uitvoeren van de ESIA, de daarbij horende publieke consultatie en het proces voor het vrijgeven van de informatie, waaronder prestatienormen van de Internationale Financieringsmaatschappij (IFC).

### 2.3 Bedrijfsnormen

Om het milieu te beschermen past Staatsolie procedures toe die voldoen aan internationale standaarden. Staatsolie houdt zich binnen al haar operaties aan een geïntegreerd beleid m.b.t *Health, Safety, Environment and Quality* (HSEQ – ofwel Gezondheid, Veiligheid, Milieu en Kwaliteit) om negatieve effecten op de gezondheid en veiligheid van werknemers, contractors en betrokken gemeenschappen, alsook het milieu, te minimaliseren en beheersen in het kader van continue verbetering.

***An English version of this document is also available.***




**Afbeelding 1: Locatie van het PF-project**

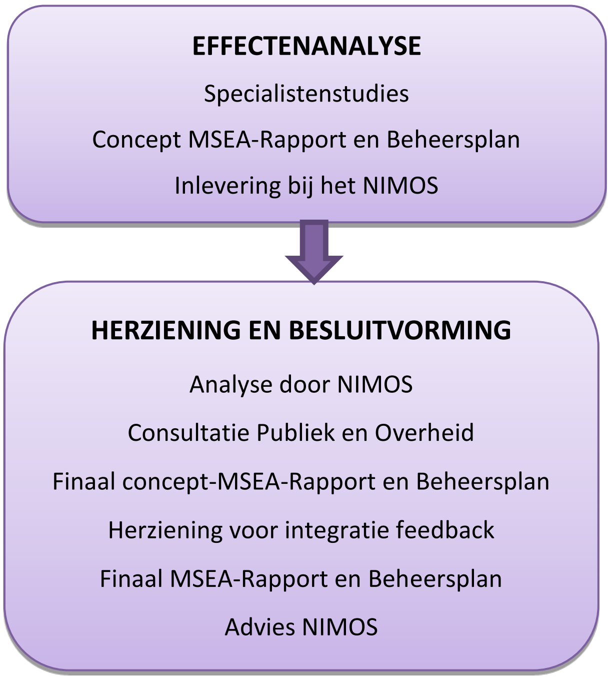
## 3. HET ESIA-PROCES

Bij het uitvoeren van het beperkt ESIA-proces, worden de Richtlijnen van het NIMOS gevolgd, zoals uiteengezet in de Richtlijnen inzake Milieu-analyses van 2009 en de *Guidance Note Environmental Assessment Process* (2017) en GIIP.

De objectieven van de MSEA zijn:

- Het beschrijven en documenteren van de ecologische uitgangssituatie (baseline) van het studiegebied en de socio-economische omstandigheden van de betrokken gemeenschappen;
- Het nauwkeurig analyseren van de potentiële milieu- en socio-economische effecten van het project;
- Het informeren en betrekken van stakeholders, waaronder de relevante overheden en het publiek, om hun bevindingen en bedenkingen te behandelen;
- Het identificeren van mitigerende maatregelen op sociaal en milieu vlak om de vastgestelde effecten te behandelen;
- Het onwikkelen van een *Environmental Management and Monitoring Plan* (EMMP - ofwel Milieu Management en Controle Plan), gedeeltelijk gebaseerd op de mitigerende maatregelen uit het ESIA-Rapport.

Het beperkt ESIA-proces bestaat uit twee fases: de Effectenanalyse *(huidige fase)* en de Herzieningsfase. Afbeelding 2 geeft een overzicht van het ESIA-proces.




**Afbeelding 2: Overzicht van het beperkt ESIA-proces**

## 4. BESCHRIJVING LOCATIE EN MILIEU

Het Tambaredjo-olieveld bevindt zich tussen de Oost-Westverbinding en de oceaan, voornamelijk ten noorden van de Saramaccarivier (afbeelding 1).

Het studiegebied bevindt zich in de Jonge Kustvlakte van het Guyana bassin, op Holocene afzettingen van de Coronie Formatie. De Jonge Kustvlakte bestaat voornamelijk uit vlakke, laaggelegen zwampen en moerassen met kleibodems op 1 – 1.5 meter boven de zeespiegel, waarop zich een veenlaag heeft ontwikkeld.

Het project bevindt zich in het zuidoostelijk gedeelte van het Tambaredjo-olieveld en nieuwe putten zullen ingeplant worden tussen de reeds bestaande 1 700 olieputten. Een *Polymer Mixing Plant* (PMP) zal zich op 1.8 km ten noorden van de Gangaram Pandayweg bevinden, langs de Zuid-Noord onverharde (schelpzand) weg die de TA-58 centrale met de Gangaram Pandayweg verbindt. Met uitzondering van de bestaande olieproducerende centrale, is de projectlocatie verlaten en bedekt met een gewijzigde, secundaire schorre **vegetatie** en er is relatief weinig faunadiversiteit. De Tambaredjo Polder is grotendeels gewijzigd door menselijke activiteiten (afbeelding 3).

Binnen het gebied zijn weinig belangrijke bronnen van **luchtverontreiniging**. De TA-58 Crude Treatment Facility veroorzaakt wat atmosferische emissies. Andere potentiële bronnen van luchtvervuiling zijn de voertuigen op de zandwegen en de agrarische activiteiten in aangrenzende gebieden. Luchtkwaliteitmetingen in de omgeving van de projectlocatie tonen aan dat al de gemeten emissies laag zijn en dat de luchtkwaliteit goed is.

**Afbeelding 2: Olieput langs de weg naar de TA-58**

In rurale gebieden is er typisch een laag **geluidsniveau**, met een dagniveau van 46 dBA ten westen van de TA-58 (waar er weinig verkeer is) en 66 dBA op de Wayamboweg (met openbaar verkeer).

District Saramacca bestaat uit ongeveer 3320 km$^2$ **kustzwampgebied**, waarvan zo'n 370 km$^2$ ingenomen wordt door mangrovebossen. Bij het testen van het oppervlaktewater tijdens het droge- en regenseizoen werd vastgesteld dat de waterkwaliteit niet drastisch gewijzigd was in vergelijking met metingen uit 1999; de TA-58 centrale, het boren naar en het verwerken van olie en het gebruik van pesticiden worden aangewezen als mogelijke, maar beperkte bronnen van vervuiling.

Het noordelijke gebied huisvest belangrijke ecosysteemgoederen- en diensten, waaronder het Coppename Monding **Natuurreservaat**, dat zich op ~10 km ten noorden van de project bevindt en een 'Wetland of International Importance' (RAMSAR gebied) is.

In de kustvlakte van Suriname bevinden zich drie belangrijke **aquifers** van de Corantijn groep. Drinkwater wordt onttrokken op 12 km ten oosten van het projectgebied, namelijk in Tijgerkreek.

Het gebied wordt **niet als sensitief** beschouwd wat betreft ecosystemen en biodiversiteit van flora en fauna.

**Residentiële** gebieden die zich het dichtst bij het project bevinden, zijn die aan de Gangaram Pandayweg (1 km in zuidelijke richting). De meeste families die er wonen, doen aan tuinbouw (voor huishoudelijk gebruik). De meeste agrarische gronden in het gebied liggen er verlaten of braak bij, maar sommige velden bevinden zich binnen 100 meter van de bestaande (en 200 meter van de nieuwe) olieputten. Terwijl er gewerkt wordt aan publieke waterleiding infrastructuur, zijn de meeste huishoudens nog steeds aangewezen op regenwater om in hun drinkwater- en huishoudelijke behoeftes te voorzien.

Er bevinden zich geen belangrijke culturele of historische objecten/plaatsen in het gebied.

## 5. PROJECTBESCHRIJVING

Verbeterde oliewinning (EOR) is de extractie van ruwe olie die op geen andere manier gewonnen kan worden (van een olieveld). De drie belangrijkste EOR-technieken:

- *Gas:* Injectie van gas in het reservoir om de druk in het reservoir te behouden en meer olie te mobiliseren ('drijven') naar de productieputten;
- *Thermisch:* Injectie van stoom om de olie op te warmen, waardoor die meer vloeibaar wordt en aldus makkelijker om naar boven te halen; en
- *Chemisch:* Injectie van chemicaliën (inclusief polymeren) als verdunde oplossing om de olie meer mobiel te maken en/of het geïnjecteerde water te 'verdikken' zodat meer olie naar de productieputten gedreven wordt.

Gebaseerd op de EOR-screening en een proefproject, is het centrale gebied Tambaredjo geschikt voor EOR-processen zoals PF.

Het Tamabaredjo-olieveld PF-project van Staatsolie bestaat uit een initiële injectie van een klein volume water om het reservoir te conditioneren, gevolgd door een continue injectie van een slijmerige polymeeroplossing onder druk waardoor meer olie naar de productieputten gedreven zal worden. Na ongeveer 11 jaar, als het maximaal volume van polymeren geïnjecteerd is, zal constant water in het reservoir gepompt worden, om aldus het polymeerslijm en de olie naar de productieputten te drijven.

Dit project omvat:

- Bouwen en inbedrijfstelling van een PMP om de polymeeroplossing voor te bereiden;
- Boren van 64 nieuwe injectieputten en 15 nieuwe productieputten;
- Aanleggen van 5 km aan pijpleidingen en 79 km aan injectielijnen; en
- Aanleggen / uitbreiden van toegangswegen binnen het olieveld.

Voor het PF-proces zijn 21 000 vaten/dag water nodig, dat uit de Saramaccarivier gepompt zal worden en/of grondwater in de S-zandlaag aquifer boven het oliereservoir. Elektriciteit zal uit bestaande bronnen verkregen worden.

De productievloeistof[1] die uit de productieputten gepompt wordt, zal naar de ruwe oliecentrale Jossie geleid worden voor splitsing en behandeling. Het behandelde, vrijkomend water wordt achteraf in de Saramaccarivier geloosd.

De putten zullen in 2 fases geboord worden tijdens de eerste 2 jaar van het project. De werkzaamheden kunnen aanvangen in 2020 en duren tot 2044.

Naar verwachting zal het project werk 20 jobs creëren tijdens de inbedrijfstelling.

## 6. ANALYSE VAN ALTERNATIEVEN

Tijdens de planningsfase heeft Staatsolie een aantal alternatieven onderzocht:

- EOR technieken;
- Waterbevoorrading; en
- Lozing van het vrijkomend water.

Andere EOR-technieken en manieren om het vrijkomend water te lozen, alsook de geschiktheid van oppervlakte- en grondwater voor waterbevoorrading worden door Staatsolie onderzocht in aparte studies.

## 7. OVERLEG MET STAKEHOLDERS

Volgens GIIP en richtlijnen van het NIMOS is het overleg met stakeholders cruciaal in het ESIA-proces. De activiteiten die uitgevoerd worden tijdens het ESIA-proces worden uiteengezet in tabel 1.

**Tabel 1: Overleg met stakeholders**

| Activiteit | Datum |
|---|---|
| Uitvaardigen ESIA-Rapport en EMMP aan het publiek | Augustus 2019 |
| Periode publieke becommentariëring | tot 9 Sep 2019 |
| Openbare bijeenkomst | 21 Augustus 2019 |
| Documenteren aanbevelingen en feedback, finaliseren MSEA-Rapport | September 2019 |

## 8. EFFECTENANALYSE

Een specialistenstudie van het grondwater en de geochemie, waaronder een oppervlaktewatercomponent, werd reeds ondernomen om de directe, indirecte en cumulatieve effecten te analyseren.

De effectenanalyse is ook gebaseerd op een aantal recente specialistenstudies die uitgevoerd werden voor de

[1] Mengsel van olie, water en gas.

voorgestelde Saramacca krachtcentrale in het Tambaredjo-olieveld; zij vormen de baseline op het gebied van luchtkwaliteit, geluid, waterkwaliteit, terrestrische ecologie en sociaal vlak.

Voor alle potentieel belangrijke effecten werd het belang van het verwachtte effect beoordeeld – met en zonder voorgestelde mitigeringsmaatregelen. De effecten worden hieronder samengevat.

- Het verwachtte effect op het *grondwater* door de **onttrekking** van grondwater voor het PF project wordt als *heel laag* beoordeeld. Het effect van een mogelijke **contaminatie** van het grondwater door de verticale migratie van het geïnjecteerde polymeer wordt als *laag* beoordeeld op de laag van dieper gelegen brak grondwater en *onbelangrijk* op de ondiepe laag van zoetwater. Er wordt verwacht dat een grote, **accidentele lozing** van de polymeeroplossing door een lekke put in de grondwaterlaag, vooral de zoetwaterlaag, lokaal zal blijven en zich niet zal verspreiden naar het Tijgerkreek onttrekkingspunt vooraleer de polymeer volledig is afgebroken; het effect hiervan wordt dus als *laag* beoordeeld.
- Het verwachtte effect van **contaminatie** tijdens de constructie op het *oppervlaktewater* wordt als *heel laag* beoordeeld. Het effect van de **lozing** van het vrijkomend water dat polymeer bevat in de Saramaccarivier wordt als *laag* beoordeeld, daar de acrylamide (AAM) in het vrijkomend water door het rivierwater tot aanvaarde concentraties verdund zal worden. Verdunning en afbraak van polymeer en AAM zullen optreden indien er een accidentele **oppervlaktelozing** van de polymeeroplossing gebeurt, en de invloed hiervan op het oppervlaktewater wordt als *heel laag* beschouwd.

Cumulatieve effecten kunnen voortkomen uit de bestaande olieproductie en het onttrekken van grondwater in het Tambaredjo-olieveld en het lozen van het vrijkomend water in de Saramaccarivier. Cumulatieve effecten omvatten onder meer een verslechtering in de kwaliteit en de hoeveelheid van het grondwater en de kwaliteit van het oppervlaktewater, afhankelijk van de kwaliteit en de hoeveelheid van de extractie, lozing en onvoorziene omstandigheden, e.g. lekkages, van andere activiteiten.

Effecten op trilling, luchtkwaliteit, geluid, ecologie, socio-economisch, visueel en verkeer zijn klein of van minder belang bij het PF project. Indien de voorgestelde mitigeringsmaatregelen toegepast worden, dan wordt verwacht dat de effecten niet ernstig noch van lange duur zullen zijn.

Om de mogelijke effecten van de geplande project op het milieu te vermijden, te verminderen en beheersbaar te maken, werden een aantal maatregelen en controlemechanismen voorgesteld. Deze worden verder uiteengezet in het EMMP.

Tabel 2 beschrijft:

- De effecten die beoordeeld werden in de ESIA; en
- De mate van impact van de effecten voordat en nadat de mitigerende maatregelen zijn toegepast, waarop de classificatie van hun prioriteit gebaseerd is.

Potentieel negatieve effecten zijn in het rood gearceerd, potentiële voordelen in het groen

**Tabel 2: Samenvatting effectenanalyse**

| Impact | Beoordeling | |
|---|---|---|
| | Voor mitigatie | Voor mitigatie |
| **IMPACT TIJDENS CONSTRUCTIEFASE** | | |
| **Impact op grondwater** | | |
| Contaminatie van grondwater door lozingen en boren van putten | Heel laag | Onbelangrijk |
| **Impact op oppervlaktewater** | | |
| Contaminatie van oppervlaktewater, invloed op ecosystemen | Heel laag | Heel laag |
| **IMPACT TIJDENS DE OPERATIONELE FASE** | | |
| **Impact op grondwater** | | |
| Afname grondwaterniveau en voorraad door grondwateronttrekking | Heel laag | Heel laag |
| Contaminatie van grondwater in de lager gelegen brak aquifer door de invloed van de polymeeroplossing | Laag | Laag |
| Contaminatie van grondwater in de zoetwater aquifer door de invloed van de polymeeroplossing | Onbelangrijk | Onbelangrijk |
| Grondwater contaminatie door een lekkende put | Matig | Laag |
| **Impact op oppervlaktewater** | | |
| Impact door lozing van gebruikte polymeer op de kwaliteit van het oppervlaktewater | Matig | Laag |
| Risico van chemische lozingen of lekkages op de kwaliteit van het oppervlaktewater | Laag | Heel laag |

Het grootste effect van het project op de klimaatverandering zal bestaan uit de indirecte bijdrage tot de emissie van broeikasgassen door de daaropvolgende verbranding van de onttrokken fossiele brandstoffen. Op dit moment echter, is het nog niet duidelijk welke hoeveelheid olie door het PF project gewonnen zal worden en hoe die uiteindelijk gebruikt zal worden; dus kunnen exacte BKG hoeveelheden nu nog niet berekend worden. Directe bijdrages tot BKG emissies door het gebruik van elektriciteit en brandstof tijdens het project en mogelijke lekkages van methaan uit putten en pijpleidingen worden als relatief klein beschouwd.

De belangrijkste aanbevelingen/mitigeringsmaatregelen zijn:

- Het EMMP in werking stellen; het zal het ontwerp, de constructie-, operationele- en ontmantelings-activiteiten begeleiden en als kader dienen voor de permanente evaluatie van milieuprestaties;
- Verzekeren dat bevoegd personeel en toereikende middelen voorzien worden zodat de implementatie van het EMMP zo snel mogelijk afgehandeld kan worden;
- Gebruik van niet-giftige boorvloeistoffen bij het boren in zoetwaterlagen;
- Verzekeren dat goede methodes toegepast worden bij het cementeren zodat chemische lekkages in de bovenste lagen (aquifers) boven het oliereservoir voorkomen worden;
- Verzekeren dat het gebruikte polymeer een residuele AAM concentratie heeft van <0.1% in gewicht;
- Controleren van de druk en het debiet van het polymeermengsel, om zeker te zijn dat geen polymeermengsel verloren raakt;
- Verzekeren dat de correcte reactiemechanismen in plaats zijn en dat correctieve actie genomen wordt indien de standaard beheersplannen of procedures niet nageleefd worden;
- Onderhouden van open communicatielijnen met de lokale gemeenschappen in de nabijheid van het Tambaredjo olieveld. Verzekeren dat de lokale gemeenschappen op de hoogte zijn van het Staatsolie klachtenmechanisme en hoe ze het kunnen gebruiken. Ontwikkelen van een klachtenregister en onderzoeksprocedures om te garanderen dat alle klachten degelijk behandeld worden;
- De tewerkstelling van lokale staatsburgers (van Suriname) en de aanbesteding van lokale hulpbronnen tijdens de constructie en inbedrijfstelling te optimaliseren om zo maximaal voordeel te bieden aan de lokale economie; en
- Opstellen en uitvoeren van een Noodplan vooraleer aangevangen wordt met het PF project, definiëren van rollen, verantwoordelijkheden en procedures om al de potentiële incidenten te behandelen.

## 9. CONCLUSIES

Het concept ESIA-Rapport heeft de potentiële effecten van het voorgestelde project geïdentificeerd en geanalyseerd en aangetoond dat de mogelijke effecten op het grond- en oppervlaktewater aanvaardbaar zijn.

Het project is een compromis tussen sociale-, milieu- en economische kosten en voordelen. De voor- en nadelen worden in het rapport afgewogen; de milieueffecten en voordelen worden vergeleken met het ‘No-Go’ alternatief.

Er zijn een paar kleinere of minder belangrijke effecten verbonden aan de project. Indien de voorgestelde mitigeringsmaatregelen gevolgd worden, dan wordt verwacht dat deze effecten niet ernstig, noch van lange duur zullen zijn.

## HOE U KUNT DEELNEMEN IN HET ESIA PROCES

Dit MSEA-Rapport is geen finaal rapport en het kan aangepast worden naargelang de feedback van stakeholders. Daarom worden stakeholders graag uitgenodigd om deel te nemen aan het ESIA-proces door feedback te geven op het ESIA-Rapport, door zich aan te melden op de database van het project en/of een openbare vergadering bij te wonen:

### RAADPLEEG HET RAPPORT

**Een kopie van het volledige rapport is beschikbaar** voor publieke consultatie op:

- NIMOS;
- Kantoor van de Saramacca Districtscommissaris in Groningen; en
- SRK website: www.srk.co.za – druk op de link ‘Recent Publications’ en dan ‘Public Documents’.

### WOON EEN VERGADERING BIJ

Een **Openbare vergadering** zal worden gehouden waarop de informatie uit het MSEA-Rapport besproken zal worden en waar bijkomende aanbevelingen en bedenkingen gedeeld kunnen worden met de milieuconsultants van het project team op **21 August 2019**.

### REGISTREERT U ZICH OP DE DATABASE OF GEEF UW MENING

Registreer/stuur een schriftelijk commentaar aan:

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or

Staatsolie:
Contactpersoon: **Farina Ilahibaks**
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Stuur uw opmerkingen aan één van boven-staande contacten vóór **9 September 2019.**

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# Acronyms and Abbreviations

| | |
|---|---|
| AoI | Area of Influence |
| AQSRs | Air Quality Sensitive Receptors |
| BFPD | Barrels of Fluid Per Day |
| BOD | Biological oxygen demand |
| CIA | Cumulative Impact Assessment |
| CITES | Convention on the International Trade in Endangered Species of Wild Flora and Fauna 1973 |
| $CO_2$-e | $CO_2$-equivalent |
| COD | Chemical Oxygen Demand |
| DC | District Commissioner |
| DO | Dissolved Oxygen |
| EA | Environmental Assessment |
| EBS | N.V. Energiebedrijven Suriname |
| EC | Electrical Conductivity |
| EHS | Environmental, Health and Safety |
| EMMP | Environmental Monitoring and Management Plan |
| EOR | Enhanced Oil Recovery |
| EPC | Engineering, Procurement and Construction |
| ESIA | Environmental and Social Impact Assessment |
| EU | European Union |
| GFI | General Field Instruction |
| GLC | Ground Level Concentration |
| GHG | Greenhouse Gases |
| GIIP | Good International Industry Practice |
| HFO | Heavy Fuel Oil |
| HSEC | Health, Safety, Environment and Community |
| HSEQ | Health, Safety, Environment and Quality |
| HV | High-voltage |
| IFC | International Finance Corporation |
| IUCN | International Union for Conservation of Nature |
| $L_{Aeq}$ | Equivalent A-weighted sound level |
| LFO | Light Fuel Oil |
| MSDS | Material Safety Data Sheet |
| MUMA | Multiple Use Management Area |
| MW | Megawatt |
| NIMOS | Nationaal Instituut voor Milieu en Ontwikkeling in Suriname |
| NTU | Nephelometric Turbidity Unit |
| OECD | Organisation for Economic Co-ordination and Development |
| PF | Polymer Flooding |
| PMP | Polymer Mixing Plant |
| ppm | parts per million |
| PS | Performance Standard |
| QRA | Quantitative Risk Assessment |
| SIA | Social Impact Assessment |

| | |
|---|---|
| SLM | Sound level meter |
| SOM | Staatsolie Maatschappij Suriname N.V. |
| SPCS | Staatsolie Power Company Suriname |
| SRK | SRK Consulting (South Africa) (Pty) Ltd |
| Staatsolie | Staatsolie Maatschappij Suriname N.V. |
| SWM | Suriname Waterleiding Maatschappij |
| TSS | Total Suspended Solids |
| USEPA | United States Environmental Protection Agency |
| VECs | Valued Environmental and Social Components |
| VPR | Vortex Pressure Regulators |
| WHO | World Health Organisation |

**Units:**

| | |
|---|---|
| bbl | Barrels (1 barrel converts to 159 litres) |
| bgl | Below ground level |
| bpd | Barrels per day |
| °C | Degrees Celsius |
| dB(A) | Decibels (weighted) |
| ft | Feet (1 foot converts to 0.3048 m) |
| ha | Hectare |
| km | Kilometre |
| $km^2$ | Square kilometre |
| km/h | Kilometres per hour |
| L | Litres |
| $\mu g/m^3$ | Microgram per cubic metre |
| m | Metre |
| mm | Millimetre |
| m/s | Metres per second |

**Chemical compounds:**

| | |
|---|---|
| AA | Acrylic acid |
| AAM | Acrylamide |
| CO | Carbon monoxide |
| $CO_2$ | Carbon dioxide |
| $FeCl_3$ | Ferric chloride |
| $H_2SO_4$ | Sulfuric acid |
| HCl | Hydrochloric acid |
| N | Nitrogen |
| NaOH | Caustic soda |
| $NH_4^+$ | Ammonium |
| $NO_2$ | Nitrogen dioxide |
| $NO_X$ | Oxides of nitrogen |
| PAM | Polyacrylamide |
| PM | Particulate matter |
| $SO_2$ | Sulphur dioxide |
| VOC | Volatile Organic Compounds |

# Glossary

| | |
|---|---|
| Aquifer | An underground body of permeable rock or unconsolidated materials (gravel, sand or silt) which can contain or transmit groundwater. |
| Avifauna | The collective birds of a given region. |
| Baseline | Information gathered at the beginning of a study which describes the environment prior to development of a project and against which predicted changes (impacts) are measured. |
| Biodiversity | The diversity, or variety, of plants, animals and other living things in a particular area or region. It encompasses habitat diversity, species diversity and genetic diversity. |
| Construction Phase | The stage of project development comprising site preparation as well as all construction activities associated with the development. |
| Consultation | A process for the exchange of views, concerns and proposals about a project through meaningful discussions and the open sharing of information. |
| Cumulative Impacts | Direct and indirect impacts that act together with current or future potential impacts of other activities or proposed activities in the area/region that affect the same resources and/or receptors. |
| dB(A) | A unit of sound level - a weighted sound pressure level with the use of the A metering characteristic and weighting specified in ANSI Specifications for Sound Level Meter. |
| Electrical Conductivity (in water) | Reflects the capacity of water to conduct electrical current and is directly related to the concentration of salts dissolved in water. |
| Ecology | The study of the interrelationships of organisms with and within their physical surroundings. |
| Ecosystem | The interconnected assemblage of all living organisms that occupy a given area and the physical environment with which they interact. |
| Endemic / Endemism | Species unique (native or restricted) to a defined geographic location, i.e. ecological state of a species being unique to a defined geographic location. |
| Environment | The external circumstances, conditions and objects that affect the existence of an individual, organism or group. These circumstances include biophysical, social, economic, historical and cultural aspects. |
| Environmental and Social Impact Assessment | A process of evaluating the environmental and socio-economic consequences of a proposed course of action or project. |
| Environmental Impact Assessment Report | The report produced to relay the information gathered and assessments undertaken during the Environmental Impact Assessment. |
| Environmental and Social Management Plan | A description of the means (the environmental specification) to achieve environmental objectives and targets during all stages of a specific proposed activity. |
| Fauna | The collective animals of a particular region, habitat or geological period. |
| Feasibility study | The determination of the technical and financial viability of a proposed project. |
| Flora | The collective plants of a particular region, habitat or geological period. |
| Geohydrology | The study of the character, source and mode of occurrence of groundwater |

| | |
|---|---|
| Heritage Resources | Refers to something tangible or intangible, e.g. a building, an area, a ritual, etc. that forms part of a community's cultural legacy or tradition and is passed down from preceding generations and has cultural significance. |
| Herpetofauna | Amphibians and reptiles of a particular region, habitat or geological period. |
| Hydrology | (The study of) surface water flow. |
| Impact | A change to the existing environment, either adverse or beneficial, that is directly or indirectly due to the development of the project and its associated activities. |
| Integrated Environmental Management | The practice of incorporating environmental management into all stages of a project's life cycle, namely planning, design, implementation, management and review and closure. |
| Mitigation measures | Design or management measures that are intended to avoid and / or minimise or enhance an impact, depending on the desired effect. These measures are ideally incorporated into a design at an early stage. |
| Operational Phase | The stage of the works following the Construction Phase, during which the development will function or be used as anticipated in the Environmental Authorisation. |
| Polymer Flooding | The mixing of water with long chain polymer molecules to increase the water viscosity, and injection thereof into oil wells to enhance the recovery of oil through improved vertical and areal sweep efficiency. |
| Polder | A low-lying tract of land enclosed by dikes that form an artificial hydrological entity: it has no connection with outside water other than through canals and manually operated devices (e.g. pumps and sluices). |
| Production String | That part of an oil well comprising the production tubing and other completion components and serving as the conduit through which the production fluid flows from the oil reservoir to the surface through the wellhead. |
| Scoping | A procedure to consult with stakeholders to determine issues and concerns and for determining the extent of and approach to an ESIA (one of the phases in an ESIA). This process results in the development of a scope of work (or Plan of Study) for the ESIA and specialist studies. |
| Specialist study | A study into a particular aspect of the environment, undertaken by an expert in that discipline. |
| Stakeholders | All parties affected by and/or able to influence a project, often those in a position of authority and/or representing others. |
| Sustainable development | Sustainable development is generally defined as development that meets the needs of the present generation without compromising the ability of future generations to meet their own needs. |
| Viscosity | Viscosity is a measure of a fluid's resistance to flow. For example, oil has a higher viscosity than water. |

# 1 Introduction

## 1.1 Background and Introduction

Staatsolie Maatschappij Suriname N.V. (Staatsolie) is the Surinamese State oil company founded in 1980 and wholly owned by the Republic of Suriname. The company explores, produces and refines crude oil. Staatsolie operates three oilfields in the Saramacca District of Suriname: Tambaredjo, Tambaredjo North-West and Calcutta, as well as three processing plants: TA-58, Jossie and Catharina Sophia (CS). The Tambaredjo Oilfield is located 40 km west of Paramaribo and 8 km south of the Atlantic coast, north of the East-West Connection Road (*Oost-West Verbinding*) (see Figure 1-1).

Staatsolie aims to improve recovery of remaining oil from the operating Tambaredjo Oilfield by using Enhanced Oil Recovery (EOR) techniques. Following implementation of a polymer flooding (PF) pilot project, Staatsolie proposes to upscale the EOR and implement a commercial scale PF project in the Tambaredjo Oilfield (the project).

Staatsolie has appointed SRK Consulting (South Africa) (Pty) Ltd (SRK), an international consultancy with extensive experience in Suriname, as independent consultants to undertake the Limited Environmental and Social Impact Assessment (ESIA) process and compile the Environmental Management and Monitoring Plan (EMMP) required for the project.

## 1.2 Purpose of the Report

This ESIA Report documents the steps undertaken during the Limited ESIA (also referred to as the "ESIA") process to assess the significance of potential impacts and determine measures to mitigate the negative impacts and enhance the benefits (or positive impacts) of the proposed PF project. The report presents the findings of the Limited ESIA process.

The ESIA Report is accompanied by an EMMP, which documents the management and monitoring measures that need to be implemented during the design, construction and operation phases of the project to ensure that impacts are appropriately mitigated and benefits enhanced.

More specifically, the objectives of this ESIA Report are to:

- Inform the stakeholders about the proposed project and the Limited ESIA process followed;
- Obtain contributions from stakeholders and ensure that all issues, concerns and queries raised are fully documented and addressed;
- Assess in detail the potential environmental and socio-economic impacts of the project; and
- Identify environmental and social mitigation measures to address the impacts assessed.

This report will be submitted to the Nationaal Instituut voor Milieu en Ontwikkeling in Suriname (NIMOS) for their comment and acceptance.

## 1.3 Structure of this Report

This report discusses relevant environmental legislation and its application to this project, outlines the Limited ESIA process, presents a detailed project description and environmental baseline, details the stakeholder engagement process and assesses the potential impacts of the project before concluding the report with a set of pertinent findings and key recommendations, which are reflected in the EMMP. The report consists of the following sections:

**Section 1: Introduction**

Provides an introduction and background to the proposed project and outlines the purpose of this document and the assumptions and limitation applicable to the study.

**Section 2: Governance Framework and Environmental Process**

Provides a brief summary and interpretation of the relevant legislation as well as pertinent strategic planning documents, and outlines the approach to the environmental process.

**Section 3: Project Description**

Describes the location and current status of the site and provides a brief summary of the surrounding land uses as well as background to, motivation, and description of, the proposed project.

**Section 4: Description of the Affected Environment**

Describes the biophysical and socio-economic characteristics of the affected environment against which potential project impacts are assessed.

**Section 5: Stakeholder Engagement**

Details the stakeholder engagement approach and summarises stakeholder comments that informed the impact assessment.

**Section 6: Environmental Impact Assessment**

Describes the specialist studies undertaken and assesses the potential impacts of the project utilising SRK's proven impact assessment methodology.

**Section 7: Conclusions and Recommendations**

Provides the key findings and conclusions of the Limited ESIA Report.

**Section 8: Way Forward**

Concludes the document with an outline of the remaining steps in the Limited ESIA process.

**Appendix C: Environmental Management and Monitoring Plan**

Presents the measures that need to be implemented to ensure that impacts are appropriately mitigated.

## 1.4 Assumptions and Limitations

As is standard practice, the report is based on a number of assumptions and is subject to certain limitations. These are as follows:

- Information provided by Staatsolie, other consultants and specialists is assumed to be accurate and correct. This includes the chemical composition of the injected PF fluid, the proposed locations and pumping rates of all producers, injectors and water supply borehole and the inputs to the geological, groundwater, fate and transport parameters;
- SRK's assessment of the significance of impacts of the proposed development on the affected environment is based on the assumption that the activities will be confined to those described in Section 3. If there are any substantial changes to the project description, impacts may need to be reassessed;
- As per NIMOS' requirements, the report is based on secondary data. Primary fieldwork was not considered necessary for this study, as the existing data was deemed adequate;

- It is assumed that no significant developments or changes will take place in the area of influence in the period between data collection and submission of the report;
- Where detailed design information is not available, the precautionary principle, i.e. a conservative approach that overstates negative impacts and understates benefits, has been adopted;
- Negotiations with landowners on whose property wells may be drilled are excluded from the scope of work; and
- Staatsolie will in good faith implement the agreed mitigation measures identified in this report. To this end it is assumed that Staatsolie will commit sufficient resources and employ suitably qualified personnel.

Additional assumptions and limitations applicable to the numerical groundwater model are provided in Section 6.1.1 of the specialist study in Appendix A.

Notwithstanding the above, SRK is confident that these assumptions and limitations do not compromise the overall findings of the report.

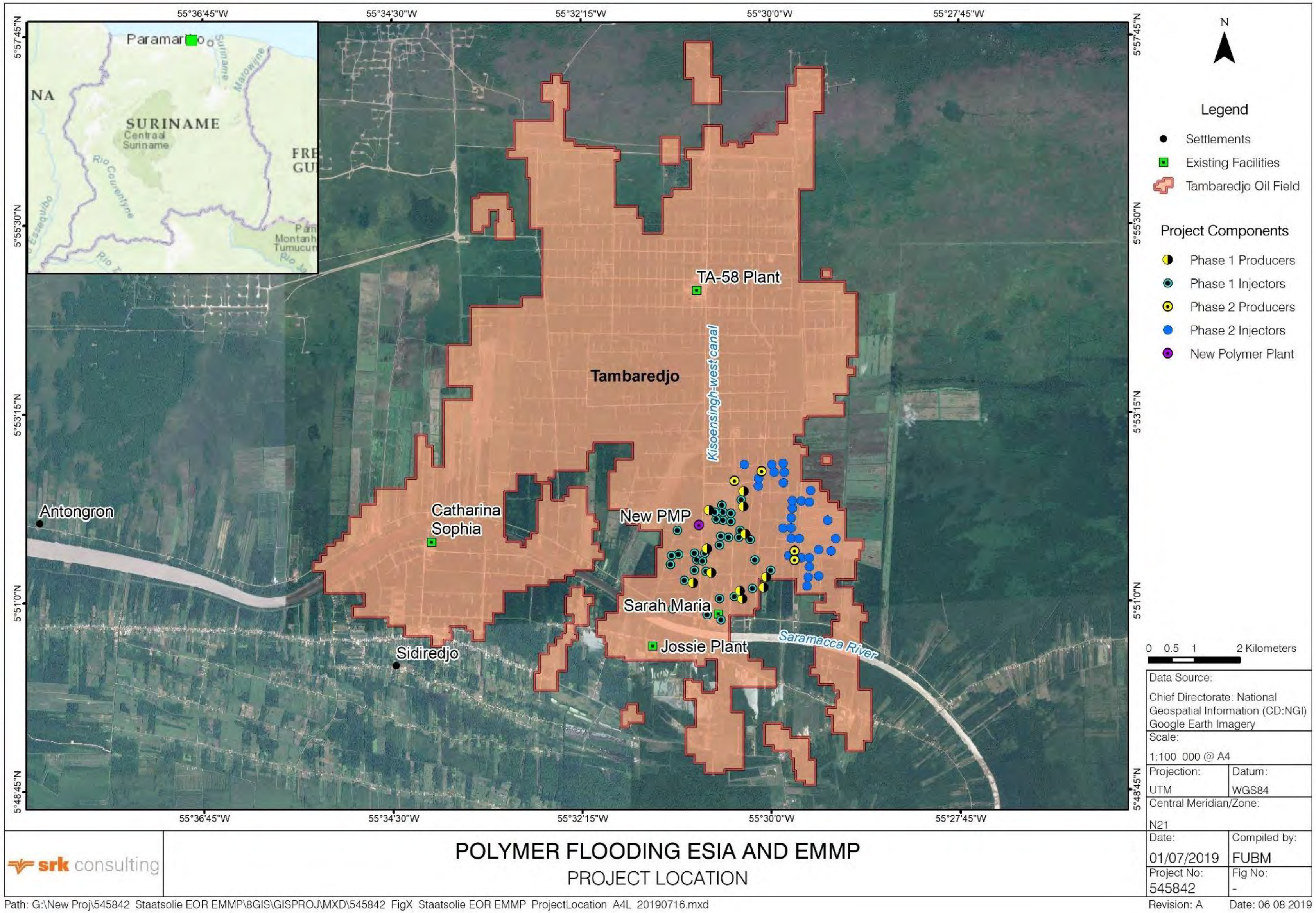



**Figure 1-1: Locality map: Tambaredjo Oilfield**

# 2 Governance Framework and Environmental Process

## 2.1 Introduction

Suriname is governed in terms of the 1987 Constitution of the Republic of Suriname, reformed in 1992, which provides for a legal basis for the country's environmental policies. Article 6g states that "the social objective of the State is directed towards the creation and stimulation of conditions necessary for the protection of nature and the maintenance of ecological balance".

Suriname does not have an approved national environmental policy and there is no promulgated legislation dealing specifically with environmental management. However, environmental legislation is under development and various guidelines for environmental assessment have been released. The Limited ESIA process for the proposed PF project will comply with relevant guidelines and other relevant legislation.

In addition to national regulatory requirements, the Limited ESIA process will be guided by Good International Industry Practice (in this report generally referred to as [international] best practice), notably standards and guidelines such as those prescribed by the World Bank Group for Bank-funded private sector development projects[1], as well as those of the International Finance Corporation (IFC). The World Bank Group standards and guidelines include environmental and social guidelines and standards that relate to the implementation and scope of the ESIA process. Where applicable, the application of the standards and guidelines will be modified to reflect the scale of the project and other relevant factors.

The key national and international legislative, regulatory and institutional requirements *relevant to and guiding* the proposed ESIA process are discussed in more detail in Sections 2.2 and 2.3 below.

Note that other requirements, e.g. related to occupational health and safety, may pertain to the proposed project, but identification and interpretation of these is beyond the brief of this study. As such, the list provided below is not intended to be definitive or exhaustive and serves to highlight key environmental legislation and obligations only.

## 2.2 Suriname Legal Requirements

### 2.2.1 Legal Requirements Regarding Environmental Assessment

NIMOS was established in 1998 as an autonomous Government Foundation and currently reports on its activities to the Environmental Coordination Department in the Cabinet of the President. The Office of Environmental and Social Assessments, a division of NIMOS, is responsible for the administration of ESIA processes in Suriname.

A **draft Environmental Act**, most recently amended in 2016, has been developed as an environmental framework law in response to the 1992 Rio declaration. The draft Act lays down rules for the conservation, management and protection of a sound environment within the framework of sustainable development. The draft Act has been under consideration by the Council of Ministers for some time and has not yet been promulgated. The Act has been submitted to Parliament as an initiative law (initiatief wet). Nevertheless, the principles in the draft Act provide guidance for EIA in Suriname.

[1] The World Bank Group standards are applied as best practice guidelines and not as an investment requirement.

**Draft EIA Regulations**, to be promulgated under the Environmental Act once in force, have also been developed since 2003 and contain requirements for EIA processes and public participation. The draft EIA Regulations are under review and are not yet in force.

NIMOS has published **Guidelines for Environmental Assessment** (EA) in Suriname. The Guidelines stipulate the EA process that should be undertaken once the environmental framework law and EIA Regulations are in place (NIMOS, 2017). The EA Guidelines are being applied by NIMOS as part of the project assessment process and project developers are expected to comply with the guidelines.

The EA Guidelines series consists of the following volumes:

- **Volume I: Generic (2009)** – This volume contains general guidelines for determining whether an EA is required, the nature and extent of the analysis required and the procedure that should be followed in the conduct of an EA. The guidelines cover aspects such as project screening, classification of projects, scoping guidelines, public consultation, structure of EA reports and the EA report review process, including criteria for review and a compliance checklist. Project screening is required to determine if EA is required and the appropriate level (category) of EA. Projects are classified into one of three categories, namely Category A (EA is mandatory), Category B (some form of EA is required) or Category C (no EA is required).

  Based on screening checklist submitted by Staatsolie, NIMOS confirmed that the PF project is classified as a "Category B path 2 project", for which a Limited ESIA and an EMMP are required.
- **Volume II: Mining (2005)** – These guidelines provide an outline of the requirements for conducting EA for mining (including oil and gas) projects.
- **Volume III: Forestry (2005)** – *These guidelines are not relevant to this project.*
- **Volume IV: Social Impact Assessment (2005)** – These guidelines provide an outline of the requirements for conducting Social Impact Assessment, whether as part of an EA process or required independently for projects that have potential impacts on the social environment.
- **Volume V**: **Power Generation and Transmission Projects (2005)** – *These guidelines are not relevant to this project.*
- **Volume VI: Aquaculture Projects (2011)** – *These guidelines are not relevant to this project.*
- **Volume VII: Agriculture Project (2013)** – *These guidelines are not relevant to this project.*

As a supplement to the more comprehensive Environmental Assessment Guidelines (Volume I), NIMOS released a **Guidance Note NIMOS Environmental Assessment Process (2017)**, which highlights the EA process that is implemented in the current legislative environment (prior to the promulgation of the Environmental Act and EIA Regulations). It defines five EIA process phases, *viz.* Screening, Scoping, Assessment, Review and Decision-making phases, and associated reporting requirements, as well as NIMOS decision-making timeframes. The process flow diagram is shown in Figure 2-2.

At the conclusion of an EA process, NIMOS provides environmental advice regarding approval or denial of the project to the agency authorized to issue a permit to undertake the development or activity.

Staatsolie is following the NIMOS EA Guidelines. Acrylamide (AAM) is listed as a pollutant in the draft State Order for Environmental Pollution. After promulgation of the Environmental Act and the State Order for Environmental Pollution, discharge of produced water into the Saramacca River will have to be registered and Staatsolie must obtain a certificate. Discharge of AAM as a pollutant in the produced water will require a permit from NIMOS.

### 2.2.2 Other Environmental Legal Requirements

Selected legal instruments governing environmental management in Suriname are included in Table 2-1 below. Note the table only lists key instruments and is not necessarily comprehensive, and not all of the listed instruments necessarily apply to this project.

Requirements are tracked by the Staatsolie Corporate Legal Department, where appropriate. Staatsolie complies with and implements these provisions through various internal processes and plans, e.g. Health, Safety, Environment and Quality (HSEQ) Policy, Project Health, Safety, Environment and Community (HSEC) Inductions, General Field Instructions (GFIs), Waste management plan, EMMP and appropriate contractual agreements with Contractors.

**Table 2-1: Selected relevant national environmental legislation**

| Title | Objective | Implementing agency | Relevance |
|---|---|---|---|
| *Prevention of pollution* | | | |
| Hinderwet, G.B. 1930 no. 64 z.l.g. bij S.B. 2001 no. 63<br>(Nuisance Act G.B. 1930 no. 64 as amended by S.B. 2001 no. 63) | Controls industrial pollution (noise, air and waste) | District Commissioners are responsible for enforcement and issue permits in consultation with Ministries of Health, Labour and NIMOS | Permits are required for industrial development projects. |
| Politiestrafwet, G.B. 1915 no. 77, z.l.g. bij S.B. 1990 no. 24.<br>(Police Criminal Act, G.B. 1915 no.77 as amended by S.B. 1990 no. 24 | Contains many general environmental provisions with respect to public places, including waste disposal, noise, control of pests, hunting and fishing, water pollution, etc. | Ministry of Justice and Police<br>Public Prosecution Department (Openbaar Ministerie) | Article 39a penalizes the disposal of waste in public places.<br>Article 51 penalizes the contamination of a water resource. |
| Wet van 30 maart 2015, houdende nadere wijziging van het Wetboek van Strafrecht (G.B. 1911 no. 1, zoals laatstelijk gewijzigd bij S.B. 2012 no. 70)<br>(Act No. 44 of 30 March 2015, amending Criminal Act G.B.1911 no.1, as amended by S.B. 2012 no. 70) | Stipulates penalties for a range of offenses | Ministry of Justice and Police<br>Public Prosecution Department (Openbaar Ministerie) | Articles 225a and 225b stipulates penalties for environmental pollution. |
| Petroleumwet 1990 S.B. 1991 no. 7, z.l.g. bij S.B. 2001 no. 58<br>(Petroleum Act 1990 S.B. 1991 no. 7, as amended by S.B. 2001 no. 58) | Specifies that petroleum activities should be carried out in such a way as to prevent negative environmental impacts and that state land should be returned to its original condition as far as reasonably possible upon termination of activities. | Ministry of Natural Resources | Environmental impacts of oil production must be managed.<br>Provisions should be made for the decommissioning of the Polymer Mixing Plant / oilfield. |
| Decreet E-8B, S.B. 1981 No. 59 houdende machtiging tot verlening aan de Staatsolie Maatschappij Suriname N.V. van een vergunning voor het doen van onderzoek naar en van een concessie voor de | Article 9 specifies that Staatsolie must take all reasonable measures in line with “good oilfield practice” to undertake its activities in a safe manner. Staatsolie is also responsible for the | Ministry of Natural Resources | Environmental impacts of oil production must be managed.<br>Provisions should be made for the decommissioning of the PMP / oilfield. |

| Title | Objective | Implementing agency | Relevance |
|---|---|---|---|
| ontginning van koolwaterstofvoorkomens | management of effluent discharge and oil waste. | | |
| Decreet Mijnbouw S.B. 1986 no. 28, S.B. 1997 no. 44.<br>Decreet van 8 mei 1986, houdende algemene regelen omtrent de opsporing en ontginning van delfstoffen | Artikel 16 states that all measures must be taken to ensure the safety and rehabilitation of a mined-out area.<br>If the rights holder fails in this duty, the State may rehabilitate the area and recover the costs from the rights holder. | Ministry of Natural Resources | Environmental impacts of oil production must be managed.<br>Provisions should be made for the decommissioning of the PMP / oilfield. |
| *Protection of biodiversity resources* | | | |
| Natuurbeschermingswet 1954 G.B. 1954 no.26 z.l.g. S.B. 1992 no. 80<br>(Nature Conservation Act 1954 G.B. 1954 no.26 as amended by S.B. 1992 no. 80) | Establishment and management of conservation areas and wildlife | Ministry of Spatial Planning, Land and Forestry Management | The Coppename Monding Nature Reserve is located along the coast east of the Coppename River mouth, north of the project area. |
| Jachtwet G.B. 1954 no. 25 z.l.g. bij S.B. 1997 no. 33<br>(Game Act G.B. 1954 no. 25 as amended by S.B. 1997 no. 33) | Provides for the protection of game as well as threatened species; game species are categorized and subject to an open and closed hunting season | Ministry of Spatial Planning, Land and Forestry Management | Certain species in Suriname are protected in terms of the Game Act. However, these are not expected to occur in the study area or to be affected by the project. |
| Beheersgebied Noord Saramacca S.B. 2002 no. 88<br>(Ministerial Order to designate North Saramacca as a MUMA S.B. 2002 no. 88) | The area between the Coppename River in the west, the boundary of the Saramacca District in the east and the Wayambo Road and Saramacca River in the south, including the sea to 6 m depth, is designated the<br>North Saramacca Multiple Use Management Area (MUMA) | Ministry of Spatial Planning, Land and Forestry Management | The project is located within the North Saramaca MUMA.<br>A MUMA is designated to maintain biological productivity, ensure the health of globally significant wildlife and protect resources for sustainable livelihoods, but may also be commercially utilised within sustainable limits; permits are required for research and resource extraction. |
| Richtlijnen Gronduitgifte Estuariene Beheersgebieden S.B. 2005 no. 16<br>(Guidelines for land issuance in the estuarine management areas S.B. 2005 no. 16) | Provides guidelines for the issuance and use of domain land within the estuarine zone to maintain natural functions | Ministry of Spatial Planning, Land and Forestry Management | The proposed PF project falls outside (south) of the designated area, but possible impacts must be considered. |
| *Protection of heritage resources* | | | |
| Monumentenwet S.B. 2002 no. 72<br>(Monuments Act 2002, S.B. 2002 no. 72) | Preservation of historical monuments and architecture in Suriname | Ministry of Education and Community Development | Applies to any archaeological items that may be encountered during construction |

A **draft Waste Act** (2004) has been compiled but has not been promulgated. The draft Act sets out regulations for the treatment of waste materials to protect the environment, based on the “polluter pays” principle. Different types of waste materials are identified, and rules prescribed for adequate storage, transportation and treatment (including recycling, composting and disposal) of each waste type. The Act makes provision for the prosecution of transgressors.

A **draft Act** concerning the extraction of **groundwater** prohibits the extraction of groundwater without a license from the Minister of Natural Resources. The permitting procedure is also regulated through this Act. In addition, the Act also provides technical specifications for drilling. Staatsolie has initiated the process to acquire permits for groundwater abstraction for the PF project.

Legislation relating to **Occupational Health and Safety** is given effect through Staatsolie’s General Field Instructions (GFIs), including those listed in Appendix F of the EMMP provided in Appendix C.

Agencies which will or may be involved in various approval or consultation processes applicable to this project are expected to include the:

- Ministry of Labour (*Ministerie van Arbeid)* – which is responsible for the supervision of compliance with employment protection and health and safety inspection regulations;
- *NIMOS* – which is an autonomous Government Foundation. The Office of Environmental and Social Assessments, a division of NIMOS, is responsible for the administration of EIA processes in Suriname;
- Ministry of Natural Resources (*Ministerie van Natuurlijke Hulpbronnen)* – which is responsible for policy and compliance monitoring with regards to the exploitation and management of mineral and energy resources;
- Ministry of Regional Development (*Ministerie van Regionale Ontwikkeling)* – which is responsible for nature conservation and the development of rural areas and the provision of services outside Paramaribo through the District Commissioners;
- Ministry of Public Health (*Ministerie van Volksgezondheid*) – which is responsible for general public health management; and
- Ministry of Spatial Planning, Land and Forest Management (*Ministerie van Ruimtelijke Ordening, Grond- en Bosbeheer)* – which is responsible for city and land use planning and forest, flora and fauna resource management.

### 2.2.3 Planning Framework

According to the Resolution on Land Allocation in Coastal Zone Management Areas (2005), in the area between the Atlantic Ocean and the Saramacca River, land to the north of the red line shown in Figure 2-1 acts as a buffer zone to the Coppename-monding Nature Reserve and is reserved for coastal protection and sustainable production. No land can be allocated for other use in this area.

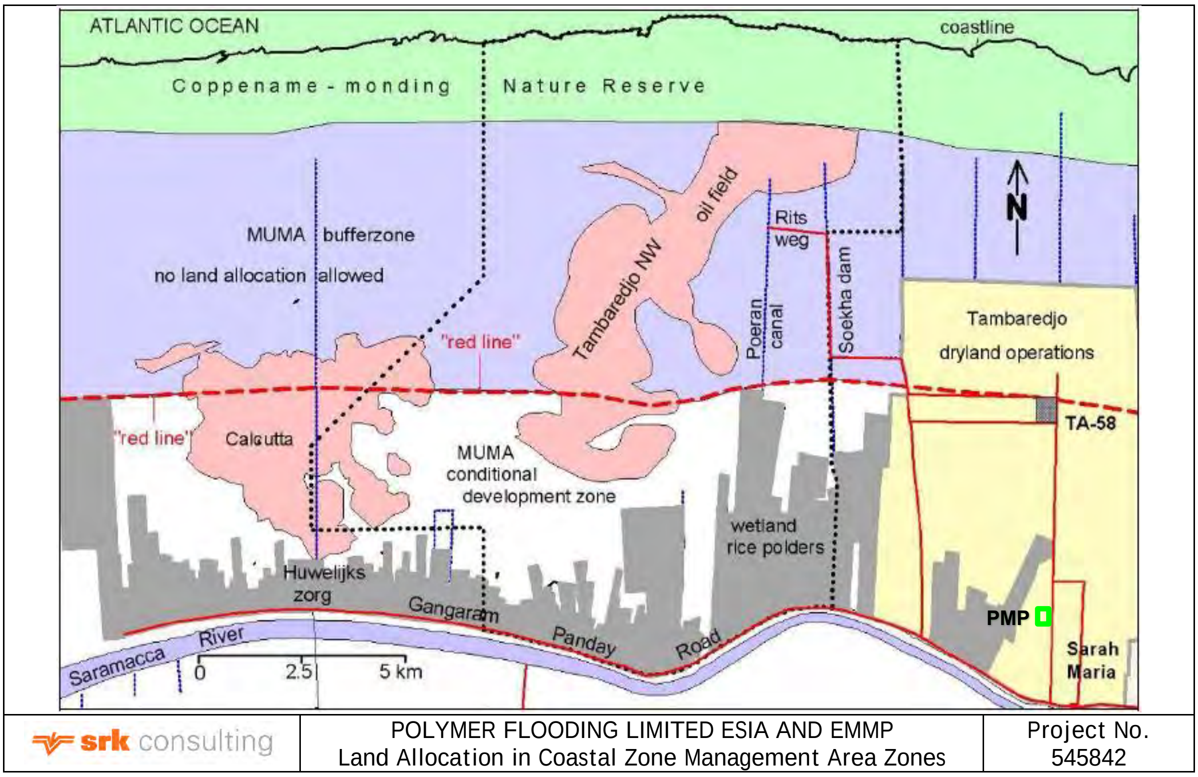



**Figure 2-1: Land Allocation in Coastal Zone Management Area Zones**

Source: Noordam (2014)

Land can be allocated for other uses south of the red line. Restrictions in this area stipulate that no water extraction from the seaside drainage basin is allowed and that excess water should be drained into the Saramacca River.

Staatsolie's proposed PF project lies south of the red line within an operating oilfield, and the project is thus expected to be compatible with the Resolution on Land Allocation in Coastal Zone Management Areas.

## 2.2.4 International Agreements

Suriname is signatory to a number of international agreements and conventions relating to environmental management. The international conventions are not always translated into national legislation. An overview of selected agreements relevant to this project is provided in Table 2-2 below.

**Table 2-2: Overview of international agreements relevant to the project**

| Agreement / Convention | Purpose | Relevance |
|---|---|---|
| *Biodiversity* | | |
| Convention on Wetlands of International Importance (RAMSAR Convention), 1971<br>*Suriname ratified in 1985* | Intergovernmental treaty for the conservation and sustainable use of wetlands. | The Coppename-monding Nature Reserve, located ~10 km north of the project site, is a Ramsar wetland. |
| Convention on Nature Protection and Wildlife Preservation in the Western Hemisphere, 1940 | Provides for the establishment of protected areas, research co-operation between governments, listing of species for special protection and control of trade in protected fauna and flora. | The Coppename-monding Nature Reserve, located ~10 km north of the project site, is a Western Hemisphere Shorebird Reserve. |

| Agreement / Convention | Purpose | Relevance |
|---|---|---|
| Convention on the International Trade in Endangered Species of Wild Flora and Fauna 1973 (CITES)<br>*Suriname ratified in 1980* | International agreement between governments to ensure that international trade in specimens of wild animals and plants does not threaten their survival | Several fauna species found in the greater project region are listed in annexures of CITES. |
| Convention on Biological Diversity, 1992<br>*Suriname ratified in 1996* | Development of national strategies for the conservation and sustainable use of biological diversity | Suriname has a National Biodiversity Strategy that aims to value and protect biological diversity, including natural and cultural resources, through equitable and sustainable use for present and future generations. |
| Air quality and climate change | | |
| Vienna Convention for the Protection of the Ozone Layer, 1985<br>*Suriname acceded in 1997* | Protection of the ozone layer, came into force in 1988. | Oil production may generate ozone-depleting substances. |
| Montreal Protocol on Substances that Deplete the Ozone Layer, 1989<br>*Suriname acceded in 1997 and ratified all amendments in 2006* | Protection of the ozone layer. | Oil production may generate ozone-depleting substances. |
| United Nations Framework Convention on Climate Change (UNFCC), 1994<br>*Suriname ratified in 1997* | Control of and limiting greenhouse gas emissions. | Oil production emits and contributes to greenhouse gases. Suriname has prepared a Climate Change Action Plan 2008-2013. |
| Kyoto Protocol, 1997<br>*Suriname ratified in 2006* | Provides for greenhouse gas emissions targets. | Oil production emits and contributes to greenhouse gases. Suriname has prepared a Climate Change Action Plan 2008-2013. |
| Paris Agreement, 2015<br>*Suriname signed in 2016*<br>*Suriname has not yet ratified* | Limit the global average temperature increase above pre-industrial levels to well below 2°C.<br>The Nationally Determined Contribution (NDC) of Suriname included commitments to improve sustainable forest management to enhance the country's carbon sink potential, but no targets in terms of absolute or relative Greenhouse Gas (GHG) emissions by 2030. | Oil production emits and contributes to greenhouse gases. |

## 2.3 International Standards, Requirements and Guidelines

### 2.3.1 Environmental Assessment

SRK will be *guided* by international standards and best practice in conducting the Limited ESIA and associated public consultation and information disclosure process, primarily the Performance Standards (PS) of the IFC – the private sector arm of the World Bank Group – which contain guidelines on how to undertake ESIAs and various specialist studies (see Table 2-3).

**Table 2-3: IFC Performance Standards**

Note: **Bold text** indicates standards that may be relevant to the Limited ESIA.

| Performance Standard | Aims and objectives | Applicability to this project |
|---|---|---|
| PS 1: Assessment and Management of Environmental and Social Risks and Impacts | Requires the proponent to conduct a process of environmental and social assessment and to establish and maintain an Environmental and Social Management System (ESMS), appropriate to the nature and scale of the project and commensurate with the level of its environmental and social risks and impacts. PS1 aims to:<br>• Identify and evaluate environmental and social risks and impacts of the project;<br>• Adopt a mitigation hierarchy to anticipate and avoid, or where avoidance is not possible, minimize, and, where residual impacts remain, compensate/offset for risks and impacts to workers, affected communities, and the environment;<br>• Promote improved environmental and social performance of clients through the effective use of management systems;<br>• Ensure that grievances from affected communities and external communications from other stakeholders are responded to and managed appropriately;<br>• Promote and provide means for adequate engagement with affected communities throughout the project cycle on issues that could potentially affect them; and<br>• Ensure that relevant environmental and social information is disclosed and disseminated. | PS1 is relevant to the project. PS1 has guided the ESIA process, specifically the:<br>• Engagement of stakeholders during the Limited ESIA process;<br>• Identification and assessment of project impacts, as well as the identification of strategies to avoid, minimise or offset these impacts; and<br>• Development of an EMMP for the construction and operation of the PF project. |
| PS 2: Labor and Working Conditions | Recognizes that the pursuit of economic growth through employment creation and income generation should be accompanied by protection of the fundamental rights of workers. PS2 aims to:<br>• Promote fair treatment, non-discrimination and equal opportunity of workers;<br>• Establish, maintain and improve the worker-management relationship;<br>• Promote compliance with national employment and labour laws;<br>• Protect workers, including vulnerable categories of workers such as children, migrant workers, workers engaged by third parties and workers in the client's supply chain; and<br>• Promote safe and healthy working conditions and the health of workers; and avoid the use of forced labour. | As the project will employ a (limited) number of workers, PS2 is relevant to the project. However, employment will follow established procedures at Staatsolie. |
| PS 3: Resource Efficiency and Pollution Prevention | Recognizes that increased economic activity and urbanization often generate increased levels of pollution to air, water, and land, and consume finite resources in a manner that may threaten people and the environment at the local, regional, and global levels. Thus, PS3 aims to:<br>• Avoid or minimise pollution from project activities;<br>• Promote more sustainable use of resources (including energy and water); and | As oil production utilises and generates polluting substances, contributes to GHG emissions and utilises energy and other resources, PS3 is applicable to the project. PS3 has guided the ESIA process, specifically the:<br>• Identification of potential impacts on human health and the environment, as well as strategies to avoid, minimise or offset these impacts; and |

| Performance Standard | Aims and objectives | Applicability to this project |
|---|---|---|
| | • Reduce project-related Greenhouse Gas (GHG) emissions. | • Compilation of an EMMP which includes strategies to avoid, minimise or offset these impacts. |
| PS 4: Community Health, Safety and Security | Recognizes that project activities, equipment, and infrastructure can increase community exposure to risks and impacts. PS4 aims to:<br>• Anticipate and avoid adverse impacts on the health and safety of affected communities during the project life from both routine and non-routine circumstances; and<br>• Ensure that the safeguarding of personnel and property is carried out in accordance with relevant human rights principles and in a manner that avoids or minimizes risks to the affected communities. | As the project will generate some noise and gaseous emissions (including GHG) in publicly accessible areas (notably roads) during construction, PS4 is applicable to the project. PS4 has guided the ESIA process, specifically the:<br>• Identification of potential impacts on human health and safety;<br>• Engagement of community members about the project; and<br>• Compilation of an EMMP which includes measures to address risks that have been identified. |
| PS 5: Land Acquisition and Involuntary Resettlement | Recognizes that project-related land acquisition and restrictions on land use can have adverse impacts on communities and persons that use this land. PS5 thus aims to:<br>• Avoid, and when avoidance is not possible, minimize displacement by exploring alternative project designs;<br>• Avoid forced eviction;<br>• Anticipate and avoid, or where avoidance is not possible, minimize adverse social and economic impacts from land acquisition or restrictions on land use by (i) providing compensation for loss of assets at replacement cost and (ii) ensuring that resettlement activities are implemented with appropriate disclosure of information, consultation and the informed participation of those affected; and<br>• Improve, or restore, the livelihoods and standards of living of displaced persons. | As the site is not inhabited, is not used for any income generating activities, and is leased by the applicant, PS5 is not applicable to the project. |
| PS 6: Biodiversity Conservation and Sustainable Management of Living Natural Resources | Recognizes that protecting and conserving biodiversity, maintaining ecosystem services, and sustainably managing living natural resources are fundamental to sustainable development. PS6 aims to:<br>• Protect and conserve biodiversity;<br>• Maintain the benefits from ecosystem services; and<br>• Promote the sustainable management of living natural resources through the adoption of practices that integrate conservation needs and development priorities. | Although the project is located in an existing oilfield with more than 1 700 active wells, areas with secondary vegetation, more pristine areas and a nature reserve are located in the vicinity. PS6 is thus applicable to the project. PS6 has guided the ESIA process, specifically the:<br>• Assessment of ecological impacts; and<br>• Compilation of an EMMP which includes measures to address impacts that have been identified. |
| PS 7: Indigenous Peoples | Recognizes that Indigenous Peoples, as social groups with identities that are distinct from mainstream groups in national societies, are often among the most marginalized and vulnerable segments of the population. PS7 thus aims to:<br>• Ensure that the development process fosters full respect for human rights, dignity, | As the site is not inhabited or used by Indigenous People, PS7 is not applicable to the project. |

| Performance Standard | Aims and objectives | Applicability to this project |
|---|---|---|
| | aspirations, culture and natural resource-based livelihoods of Indigenous Peoples;<br>• Anticipate and avoid adverse impacts of projects on communities of Indigenous Peoples, or when avoidance is not possible, to minimize and/or compensate for such impacts;<br>• Promote sustainable development benefits and opportunities for Indigenous Peoples in a culturally appropriate manner;<br>• Establish and maintain an ongoing relationship based on informed consultation and participation with the Indigenous Peoples affected by a project throughout the project's life-cycle;<br>• Ensure the Free, Prior and Informed Consent of the affected communities of Indigenous Peoples when the circumstances described in this Performance Standard are present; and<br>• Respect and preserve the culture, knowledge and practices of Indigenous Peoples. | |
| PS 8: Cultural Heritage | Recognizes the importance of cultural heritage for current and future generations. As such, PS8 aims to:<br>• Protect cultural heritage from the adverse impacts of project activities and support its preservation; and<br>• Promote the equitable sharing of benefits from the use of cultural heritage. | Archaeological sites, such as graves and remnants of previous activities, are distributed throughout Suriname and not well documented. As such, PS8 could be applicable to the project.<br>However, the project is located within an active oilfield, and the polder on which the project is located has significantly transformed the natural swamp and would have impacted on any artefacts.<br>The ESIA process recommends a chance finds procedure for use during construction. |

Where appropriate, application of the standards and guidelines will be customised to reflect the scale of the project and other relevant factors (e.g. time constraints). Other selected relevant international guidelines will be taken into account where appropriate.

## 2.4 Corporate Requirements

Staatsolie has adopted procedures for protecting the environment which comply with international standards. An integrated HSEQ Policy and Management System is implemented across Staatsolie operations to monitor its effects on the health and safety of its employees, contractors and affected communities, as well as impacts on the environment.

**Box 1. Staatsolie HSEQ Policy**

Staatsolie demonstrates a firm commitment to Health, Safety, Environment & Quality (HSEQ) by effectively using an integrated management system, through which we continuously:

- Comply with relevant laws and legislation, and Staatsolie's requirements, while taking the needs of our stakeholders into account;
- Identify risks, determine mitigating measures, and apply these measures to our work in order to prevent incidents and damage to the environment;

- Hold all employees and contractors accountable to follow Staatsolie's HSEQ requirements, in order to achieve excellent performance with zero harm;
- Continually improve our management system by enhancing processes, services, and our product quality through the setting of explicit performance objectives;
- Involve all employees and contractors in the decision-making processes of our HSEQ management system.

## 2.5 Limited ESIA Process

An ESIA is a systematic process to identify, predict and evaluate the environmental[2] effects of a proposed project. The purpose of an ESIA is to:

- Provide information for decision-making on the environmental consequences of proposed actions by identifying the potentially significant environmental effects and risks of a proposed project (i.e. ensure that environmental factors are considered in decision-making processes along with economic and technical factors). This means that the outcome of an ESIA process provides advice to the decision-makers, and is not a final decision in itself; and
- Promote environmentally sound and sustainable development through the identification of appropriate enhancement and mitigation measures.

Sustainable development has been defined in many ways, but the most frequently quoted definition is that of the Brundtland Commission (WCED, 1987): *Sustainable development is 'development that meets the needs of today's generation without compromising those of future generations'.*

It is widely accepted that adverse environmental impacts of projects and development need to be prevented or minimised, and ESIA has become an important tool in achieving this through the integration of environmental considerations into proposed projects. Recommendations made by an ESIA may necessitate the redesign of some project components, require further studies, identify changes which alter the economic viability of the project or cause a delay in project implementation. An ESIA should also lead to a mechanism whereby adequate monitoring is undertaken to achieve effective environmental management of the project during implementation.

The general approach to the Limited ESIA will be guided by the requirements of NIMOS, as stipulated in the EA Guidelines (2009) and Guidance Note Environmental Assessment Process (2017), and international best practice.

2 'Environment' is used in the broadest sense (including social and cultural aspects of the environment).

**Relevant principles underpinning the ESIA are:**

- Assessment based on appropriate information;
- Accountability for information on which decisions are made;
- Broad interpretation of the term "environment" (inclusion of social and biophysical environment);
- An open and transparent participatory approach;
- Consultation with stakeholders;
- Due consideration of alternatives;
- Attempt to mitigate negative impacts and enhance positive impacts;
- Attempt to understand the social costs and benefits of the proposed project;
- Regard for individual and community rights and obligations; and
- Opportunity for public and specialist input in the ESIA process.

**The main objectives of the ESIA are to:**

- Document and contextualise the ecological baseline conditions of the study area and the socio-economic conditions of affected communities;
- Assess in detail the environmental and socio-economic impacts that may result from the project;
- Inform and obtain contributions from stakeholders, including relevant authorities and the public, and address their relevant issues and concerns;
- Identify environmental and social mitigation measures to address the impacts assessed; and
- Develop an Environmental and Social Management Plan (ESMP), based in part on the mitigation measures developed in the ESIA Report.

The EA process as prescribed by NIMOS is shown in Figure 2-2. Staatsolie completed the screening phase of the EA process prior to SRK's appointment. NIMOS advised that the project should follow a Category B path 2 process in terms of NIMOS's EA Guidelines, and requested that a Limited ESIA process be conducted and an EMMP, including impact assessment, be produced and submitted to NIMOS.

The dashed red box in Figure 2-2 indicates the EA aspects covered by SRK in the Limited ESIA process.

A more detailed overview of SRK's proposed Limited ESIA process is provided in Figure 2-3.

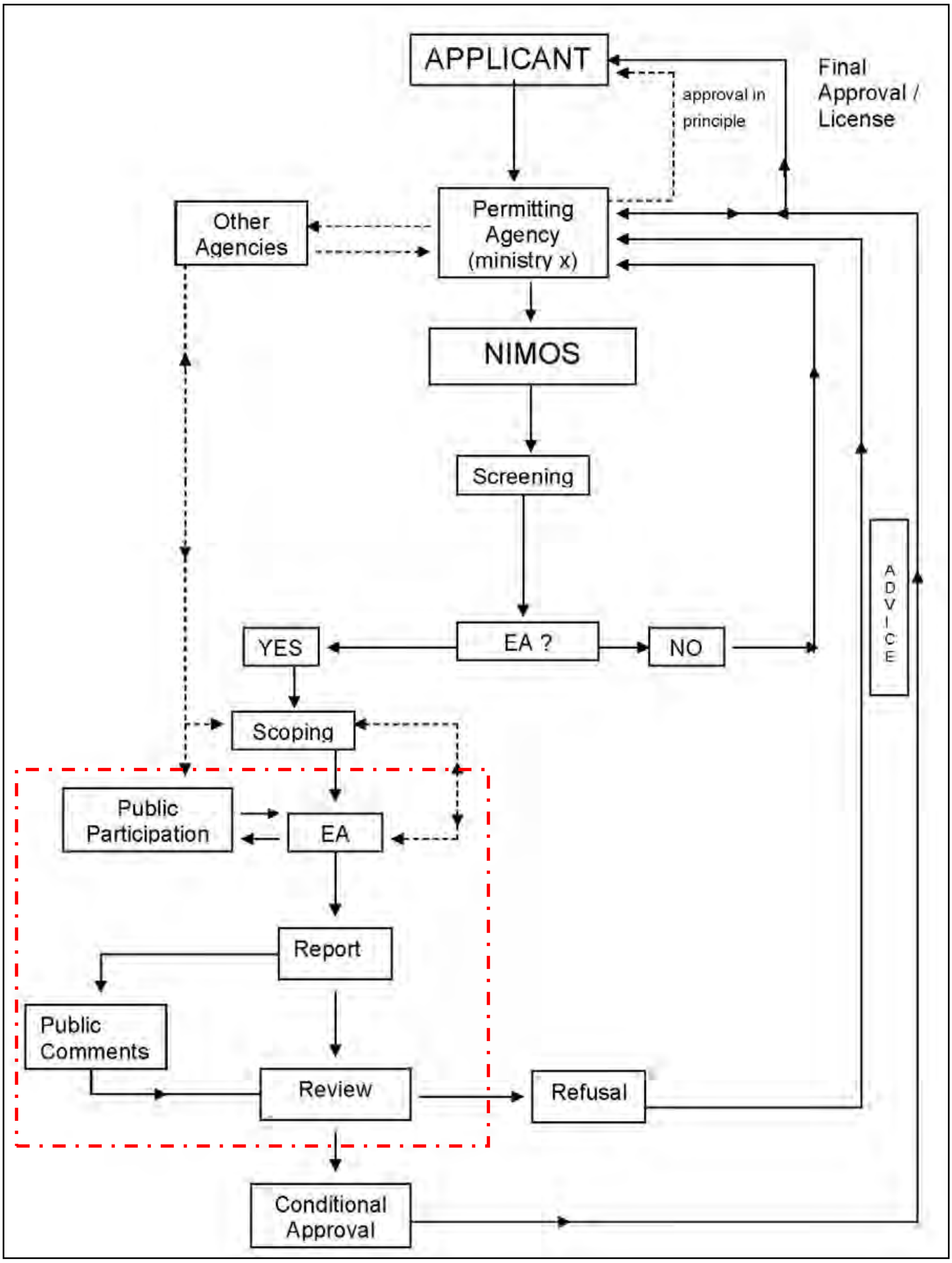



**Figure 2-2: NIMOS Environmental Assessment flow diagram**

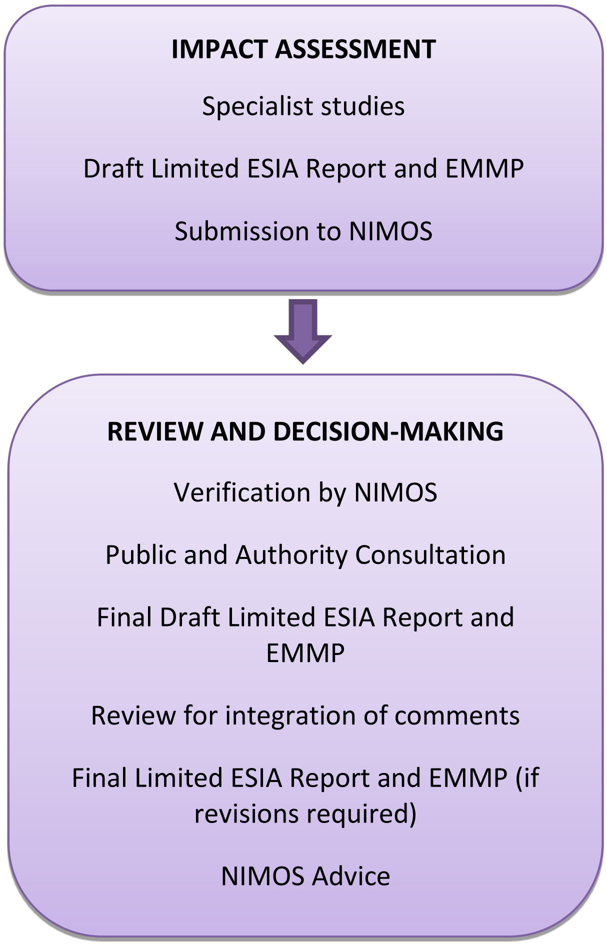



**Figure 2-3: Overview of the Limited ESIA process**

# 3 Project Description

## 3.1 Introduction

Oil production generally occurs in three stages: primary, secondary and tertiary. Enhanced Oil Recovery (EOR) is a tertiary strategy option that is employed when primary (natural flow) and secondary (water and gas injection) techniques are no longer effective.

Three main EOR techniques are:

- *Gas:* Injection of gases into the reservoir to maintain reservoir pressure and displace ("drive") more oil towards producer wells;
- *Thermal:* Injection of steam to heat the oil, effectively making it more permeable and easier to extract; and
- *Chemical:* Injection of chemicals (including *polymer flooding*) as dilute solutions to make the oil more mobile and/or increase the viscosity ("thickness") of injected water, to "drive" more oil towards producer wells.

Normally a PF project entails an initial injection of a small volume of water to condition the reservoir followed by continuous pressurised injection of the viscous polymer solution which will drive more oil towards the producer wells. Once the maximum amount of polymer has been injected, water will be continuously pumped into the reservoir to drive (or "chase") the polymer slug and the oil towards the producer wells.

## 3.2 Description of the Project Area

### 3.2.1 Site Description

The project area is located in the Tambaredjo Oilfield, 40 km west of Paramaribo and 8 km south of the coast, in the Saramacca District of Suriname. The Tambaredjo field is located between the East-West Connection Road and the coast, and mostly north of the Saramacca River (see Figure 1-1).

The oilfield has been operated by Staatsolie since the 1990s. The original swamp habitat has been replaced by secondary marsh vegetation, which is characterised as a modified habitat. The polder is used for oil production from a large number of wells in a 200 x 200 m grid (see Figure 3-1). The polder is traversed by unpaved roads and anthropogenic activity levels are intense. The polder is drained by a system of roadside ditches that are connected to main canals (see Figure 3-2). The north-south trending canals drain into the Saramacca River.

The proposed project is located in the south-eastern section of the Tambaredjo Oilfield. New injector and producer wells will be drilled between existing oil producer wells, in an area where Staatsolie has been producing oil since the 1990s, and where ~1 700 operational wells are located (see Figure 3-5).

The Polymer Mixing Plant (PMP) will be located ~2 km north of the Saramacca River and 1.8 km north of Gangaram Pandayweg, along the south-north aligned unpaved (shell sand) road that connects the TA-58 to Gangaram Pandayweg. This unpaved road is parallel to the Kisoensingh-west Canal, one of the main drainage features of the Tambaredjo Oilfield (see Figure 1-1). Five concrete foundations for storage tanks have already been constructed on the site (see Figure 3-3).

| srk consulting | POLYMER FLOODING LIMITED ESIA AND EMMP<br>Oil well along the road to TA-58 | Project No.<br>545842 |
|---|---|---|

**Figure 3-1: Oil well along the road to TA-58**

Source: R. Bong A Jan (1 August 2018)

| srk consulting | POLYMER FLOODING LIMITED ESIA AND EMMP<br>Unpaved roads and roadside ditches in the Tambaredjo Oilfield | Project No.<br>545842 |
|---|---|---|

**Figure 3-2: Unpaved roads and roadside ditches in the Tambaredjo Oilfield**

Source: S. Reuther (1 August 2018)


| srk consulting | POLYMER FLOODING LIMITED ESIA AND EMMP<br>Proposed site for the polymer mixing plant | Project No.<br>545842 |
|---|---|---|

**Figure 3-3: Proposed site for the polymer mixing plant**

### 3.2.2 Surrounding Land Use

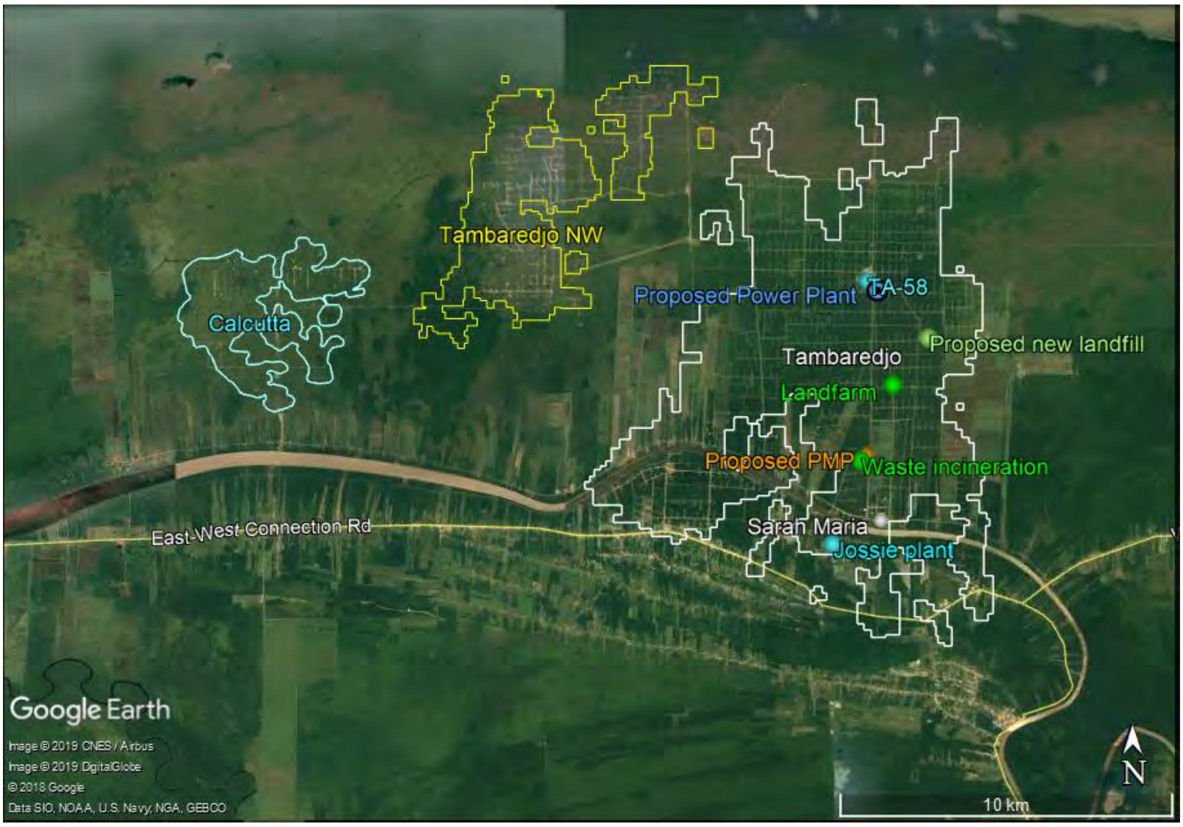
Staatsolie explores, produces and refines crude oil in Suriname. In the Saramacca District, Staatsolie operates three oilfields: Tambaredjo, Tambaredjo North-West and Calcutta. The proposed PF project is located in the Tambaredjo Oilfield (see Figure 1-1).

Staatsolie commenced construction of the Tambaredjo Polder in the 1990s, to facilitate dryland oil production. The polder covers approximately 10 000 ha and is drained by a system of roadside ditches that are connected to north-south aligned canals which drain into the Saramacca River to the south. Oil is extracted from a large number of wells in 200 x 200-metre grids across the polder. The wells are connected by unpaved (shell sand) roads to a series of secondary access roads which ultimately connect to the Gangaram Pandayweg.

Staatsolie has constructed the TA-58 and Jossie crude treatment plants to separate the water and crude oil that are jointly extracted from the well, in the Tambaredjo Polder (see Figure 3-4). The oil-water separation plants comprise pumps, processing facilities and oil storage tanks. Backup generators for the Sarah Maria facility are also located at TA-58.

Waste incineration pits and a landfarm on the Tambaredjo Polder provide for waste disposal. Domestic and industrial waste from upstream operations is disposed at an open dumpsite and incinerated in two open pits. A new ~10 ha landfill and incinerator south-east of the proposed Sarah Maria power plant site are proposed to improve waste management (see Figure 3-4). The 7 ha landfarm is used to bioremediate oil-contaminated soil, sludge from oil spills and waste from cleaned storage tanks. The landfarm is bunded and designed to contain contaminated water, including runoff.

Processed crude oil from the TA-58 and Jossie plants is conveyed by pipeline to the refinery and export terminals at Tout Lui Faut, south of Paramaribo.




| srk consulting | POLYMER FLOODING LIMITED ESIA AND EMMP<br>Location of Staatsolie oilfields in the Saramacca District | Project No.<br>545842 |
|---|---|---|

**Figure 3-4: Location of Staatsolie oilfields and facilities in the Saramacca District**

## 3.3 Proponent's Project Motivation

Staatsolie continuously explores for and develops new oil reserves. However, the implementation of EOR techniques to extract crude oil that cannot be extracted otherwise, offers an opportunity to extend the lifespan of existing oilfields.

Based on EOR screening, the Tambaredjo Central Area qualifies as a reasonable candidate for EOR processes such as chemical and thermal EOR. Extended oil production will be achieved by implementing commercial scale PF within the existing production area of the Tambaredjo Oilfield.

In 2008, a PF pilot Project comprising three injector wells and 33 producing wells over an area of 1.5 km$^2$ was implemented in the Tambaredjo Oilfield. Although no formal environmental impact assessment was done for the pilot, potential environmental and health impacts of polymers were reviewed to determine the selection of a safe alternative. Based on the pilot project, it was concluded that a 12% incremental oil recovery is achievable without incurring prohibitive operational issues, equivalent to an estimated 4 Million Stock Tank Barrels[3].

Given the indicated opportunity for additional oil recovery, Staatsolie aims to expand the PF project to 64 injector wells in order to increase oil recovery and reserves.

## 3.4 Project Alternatives

An ESIA process should identify and describe alternatives to the proposed activity that were considered, or, failing that, provide adequate motivation for not considering alternatives. Different

[3] Volume of oil after production, at surface pressure and temperature (as opposed to reservoir conditions)

types or categories of alternatives can be identified, e.g. location alternatives, type of activity, design or layout alternatives, technology alternatives and operational alternatives.

Not all categories of alternatives are applicable to all projects. However, the consideration of alternatives is inherent in the detailed design and the identification of mitigation measures, and therefore, although not specifically assessed, alternatives have been and will be taken into account in the design and ESIA processes. Staatsolie considered and evaluated a number of alternatives relating to:

- EOR techniques to stimulate the oil;
- Water supply; and
- Disposal of produced water.

An overview of alternatives considered by the Staatsolie project team to date is included as Table 3-1. Alternatives shaded in grey are not further assessed in the Limited ESIA.

**Table 3-1: Alternatives**

| Aspect | Alternatives | Considerations | Finding |
|---|---|---|---|
| EOR techniques | Polymer flooding | Most suitable due to geological and reservoir fluid characteristics, and because PF technique has already proven successful in the Tambaredjo Oilfield. | Assessed in ESIA |
| | Other EOR techniques | Not suitable / considered because other EOR technologies are still being prepared for piloting and are not yet mature / proven technologies in Tambaredjo Oilfield. | Screened out |
| Water supply | Surface water | Surface water is abundant and not the main source of potable water for communities. | Preferred option<br>Assessed in ESIA |
| | Groundwater | This option is suitable, but not preferred, because the water-holding sands (aquifers) are mostly classified as freshwater, making them candidates for potable water sources. It is preferred to not utilise this water for industrial purposes but rather to retain it as a potential potable water source. | Feasible alternative<br>Assessed in ESIA |
| Disposal of back produced polymer | Discharge to Saramacca River | This is the most efficient available option at present. | Assessed in ESIA |
| | Re-injection into well | This is being considered in a separate study.<br>Staatsolie is already re-injecting at Huwelijkszorg, but not in the Tambaredjo Oilfield. | Assessed by Staatsolie in a different study |

# 3.5 Project Description

## 3.5.1 Project Components

### 3.5.1.1 Polymer Mixing Plant

The project includes construction and operation of a PMP to prepare a polymer solution. The PMP will be installed on a 1.7 ha site located ~2 km north of the Saramacca River and 1.8 km north of Gangaram Pandayweg, along the road that connects the TA-58 to Gangaram Pandayweg (see Figure 3-5).

The PMP will comprise (see Figure 3-6):

- Two 10 000 barrels per day (bbl)[4] raw water tanks;
- Two 10 000 bbl treated water tanks;
- One 10 000 bbl backup tank;
- One 55 000 bpd water treatment unit;
- A polymer preparation unit;
- A hopper feed;
- Three polymer mother solution high pressure pumps (one for back up);
- Three water high pressure pumps (one for back up); and
- A mixer for dilution.

Water for the process will be abstracted from the Saramacca River (preferred option) or water supply well(s) (groundwater) and pumped through pipelines to the PMP raw water tanks, from where it is conveyed to the water treatment unit and on to the treated water storage tanks. The water will be used to prepare a 2 350 parts per million (ppm) anionic polyacrylamide polymer solution which will be diluted at the PMP to 1500 ppm (injection viscosity of 85 cP) prior to injection.

### 3.5.1.2 Injector and Producer Wells

Injector and producer wells will be drilled between existing producers (see Figure 3-5):

- 64 injector wells (for injection of water and polymer mixture); and
- 15 (additional) producer wells to extract crude oil.

Wells will be drilled in two phases during the first two years of the project, as shown in Table 3-2.

**Table 3-2: Well drilling programme**

| Year | Number of drilled wells | Type of well |
|---|---|---|
| 1 | 11 | Production / Producer |
| | 33 | Injectors |
| | 2 | Water well (if required) |
| 2 | 4 | Production / Producer |
| | 31 | Injectors |
| | 2 | Water well (if required) |

[4] Complying with convention, this study mostly uses imperial and oil industry units of measurement, rather than metric system units (those some are selectively provided).

The design and specifications of the injector wells were selected based on the following criteria:

- Applicability of wellhead;
- Well integrity;
- Protection of freshwater zones;
- Resistance to corrosion;
- Cost effectiveness; and
- Durability.

Injector wells comprise a 10 3/4” L-80 carbon steel conductor casing to a depth of ~80 ft, with a 7” L-80 injection casing running to the top of the injection reservoir and cemented in place. Injection will be done through a 3 ½” L-80 injection tubing.

The production string for the producer wells will be designed based on an average well initial of 15 bbl/d. For the given oil viscosity, reservoir depth, etc. a small tubing size of 2-3/8” will be adequate at these flow rates. The production string configuration of producer wells comprises a tubing anchor, down hole pump, tubing string (2-3/8” or 2-7/8”) of carbon steel J-55 with sucker rod string grade C (3/4” or 7/8”). Tubing anchors (or No-Turn-tool) are run below the Progressive Cavity pump so that the resistive torque, which develops in the tubing string in response to pump operation in backspin mode, is directly transferred to the casing.

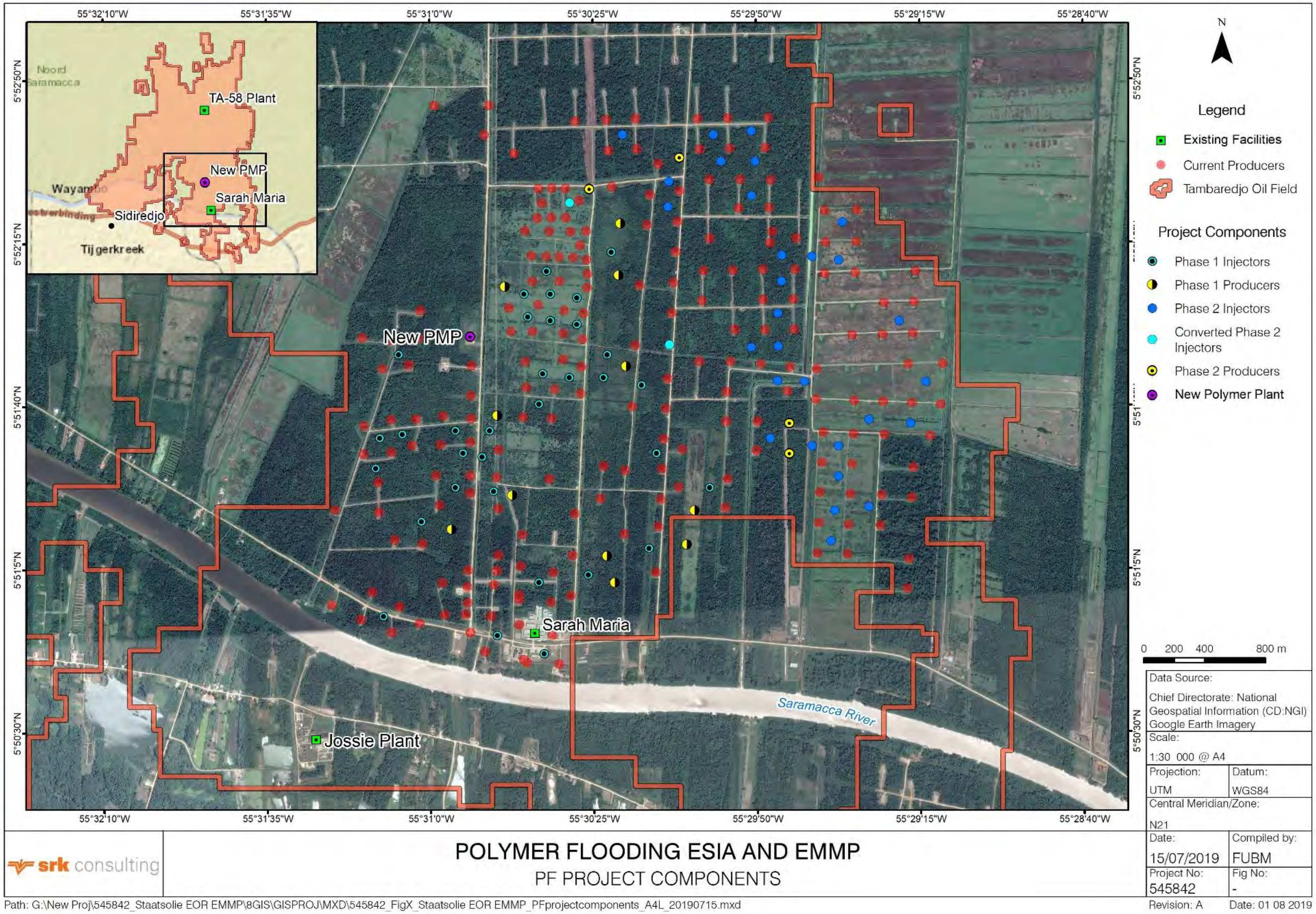



**Figure 3-5: PF project components**

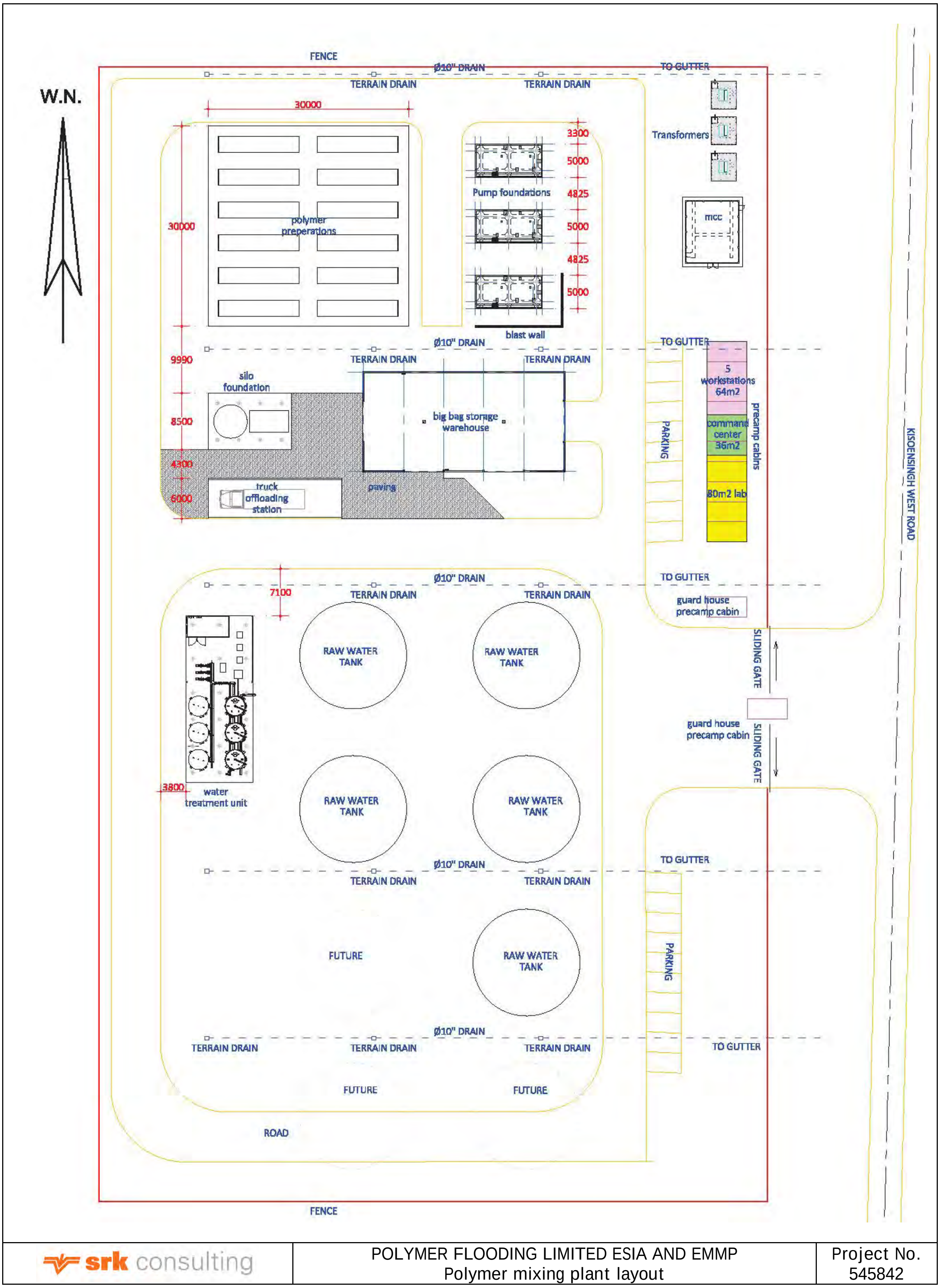



**Figure 3-6: Polymer mixing plant layout**

#### 3.5.1.3 Infrastructure

The project also includes installation of pipelines to convey:

- Water to the PMP;
- Polymer solution from the PMP to the injector wells; and
- Produced fluid from the new production wells to the Jossie crude treatment plant.

The high-pressure pipeline distribution system comprises of a stainless-steel pipeline and manifold system and injection flow lines. The flow and pressure are controlled individually for each well by a set of regulating valves and restriction orifices (referred to as Vortex Pressure Regulators [VPR]) specifically designed to avoid viscosity degradation of the polymer solution due to shear.

The following will be installed for the pipeline distribution system:

- 5 km of 14-inch stainless-steel high pressure pipeline;
- Two EA manifolds for injection lines; and
- 79 km of 4-inch injection lines.

Access roads (e.g. to service pipelines) will also be constructed.

### 3.5.2 Polymer Flooding Process

Key steps in the PF process are briefly described below (see Figure 3-8):

- At start up, water will be injected into the injector wells for up to (less than) 1 month, at a maximum injection rate of 850 bpd per well. This serves to reduce the interfacial tension between the oil and water phases and to alter the wettability of the reservoir rock to improve oil recovery;
- The polymer solution will be injected continuously into an injector well, at an average injection rate of 190 – 315 bpd per well (maximum 550 bpd) to a depth of 900 – 1 100 ft True Vertical Depth (TVD), with a maximum bottom hole injection pressure of 1 060 psi;
- It is expected that incremental oil will be produced within one year of the start of polymer mix injection;
- After ~11 years, no more polymer will be added and drive water will be pumped into the injector well to drive the polymer slug and the oil bank toward the production wells;
- Produced fluid[5] will be extracted from existing and new production wells and conveyed via pipelines to the Jossie crude treatment plant, where the fluid is collected in tanks for treatment;
- At the Jossie plant crude treatment stream, the water and minimum quantities of gas in the produced fluid will be separated from the crude, which will then be stored in tanks prior to transportation to the refinery; and
- At the Jossie plant water treatment stream, the produced water will be treated to remove remaining oil; it is then discharged into the Saramacca River.

In future, produced water may be re-injected. If this is not possible, disposal of produced water to the Saramacca River is proposed.

[5] Mix of oil, water and gas.

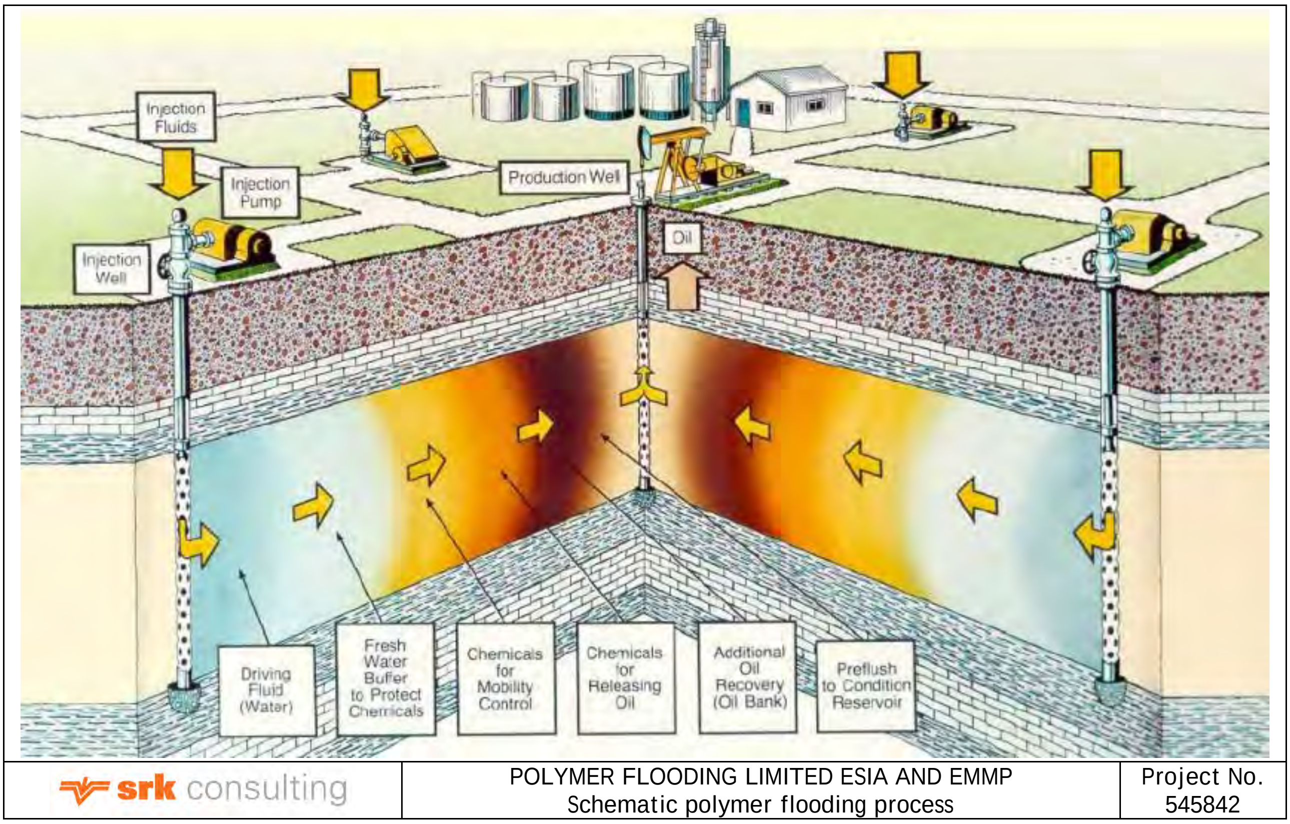



**Figure 3-7: Schematic polymer flooding process**

Source: Al Manahali (n.d.)

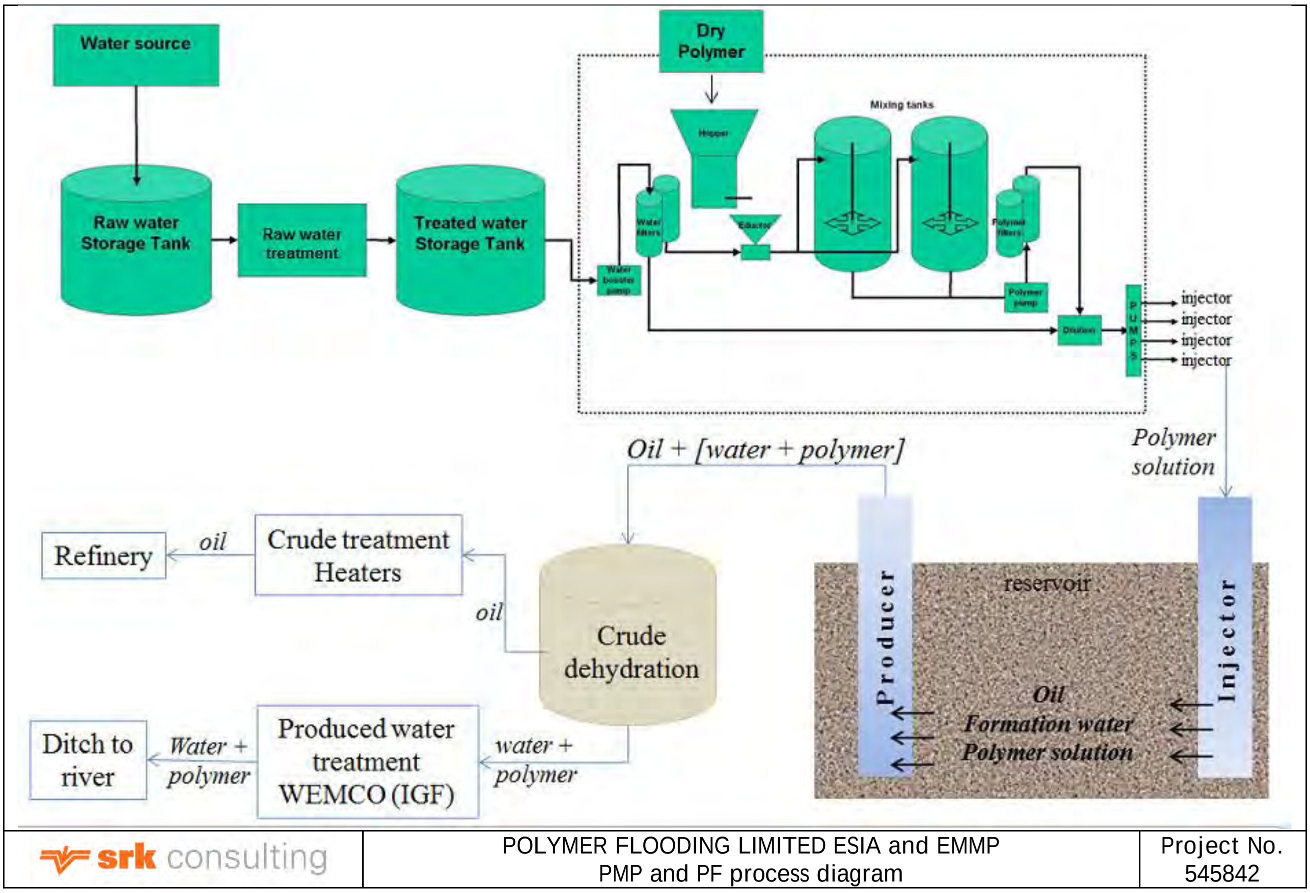



**Figure 3-8: PMP and PF process diagram**

### 3.5.3 Construction

#### 3.5.3.1 Polymer Mixing Plant

Civil and mechanical works will be executed during the construction of the PMP.

Civil works include:

- Site preparation (clearing of existing site, backfill and levelling of the surface);
- Refurbishment (inspection, cleaning, surface prepping) of five existing concrete tank foundations;
- Construction of piled concrete foundation for heavy and vibrating equipment, including:
  - Silo and hopper foundations;
  - Water treatment facility; and
  - Main high pressure water- and polymer- pumps;
- Construction of foundation pads for:
  - Polymer dosing units;
  - Polymer storage warehouse;
  - Transformer foundations;
  - Site offices, control room and laboratory building; and
  - Firefighting;
- Motor Control Centre (MCC) building;
- Internal roads and drainage; and
- Fencing.

Mechanical works include construction and commissioning of:

- A water treatment unit;
- A polymer preparation unit;
- A hopper feed;
- Three polymer high pressure pumps;
- Three water high pressure pumps;
- Two mixers for dilution;
- Two polymer mother solution transfer pumps; and
- 64 VPRs.

#### 3.5.3.2 Injector and Producer Wells

Well bases have a footprint of 75m x 55 m and the procedure to construct them is as follows:

- Verify well coordinates;
- Remove grass to start area preparation;
- Clean up the surrounding ditches;
- Level the area around the well; and

- Place sand and clay to obtain coarse well base layer.

Once locations are prepared, the cellar is installed at the centre point of the well coordinates.

Wells will be constructed using a rig and pulling unit.

#### 3.5.3.3 Infrastructure

Roads for general access to new wells will be rehabilitated or constructed using sand and clay as base layer for a coarse road surface.

### 3.5.4 Operations

#### 3.5.4.1 Polymer Mixing Plant

Polymer mother solution is prepared and diluted to the final concentration by water under high pressure, and then transported through a high-pressure distribution systems to the injector wells. This is effected by high pressure water and polymer mother solution pumps, with one water- and one polymer mother solution- pump is dedicated to each development stage. The high pressure distribution system comprises a stainless steel pipeline and manifold system and fiber spar injection flow lines.

The flow and pressure are controlled for each well by a set of regulating valves and restriction orifices (VPRs) specifically designed to avoid viscosity degradation of the polymer solution due to shear. The polymer mother solution preparation unit, dilution system and water and polymer mother solution pumps are installed at one location while the VPRs are installed in the field.

#### 3.5.4.2 Injector wells

The wells will be monitored through a combination of inspections of operating wells and gathering of process data by means of a smart field data acquisition system.

The average targeted polymer injection viscosity is expected to be 45 cP (1 000 ppm) in an inverted five spot pattern, with an option to inject up to 85 cP (1 500 ppm). Polymer injection will take place for the first ~11 years (1 pore volume) followed by ~13 years of water injection per phase (if applicable). Water injection should be interpreted as the minimum viscosity (1 cP).

The average injection rate is expected to be in the range of 190 - 315 bpd per injector. All injectors will inject a small volume of water injection at start up (prior to polymer injection) (<1 month), which is required for well-conditioning.

#### 3.5.4.3 Producer wells

The wells will be monitored through a combination of inspections of operating wells and gathering of process data by means of a smart field data acquisition system.

Downhole pressure level measurements can be done acoustically and by means of downhole gauges. For this project Surface Read Out gauges are proposed.

#### 3.5.4.4 Jossie Crude Treatment Facility

The process equipment currently used for fluid processing at the Josie Facility utilises conventional technologies, e.g. gravity settling and flotation. These technologies do not meet the polymer flood produced water (PFPW) treatment specifications: Staatsolie's R&D Department is currently studying PFPW treatment methods (Al Kalbani, et al., 2014), including:

- Mechanical: Adding mechanical shear to the produced water-containing polymer will break the polymer, reducing its viscosity;
- Chemical: Adding oxidizers to the polymer solution can break the polymer. These chemicals

generate radicals which can react with the polymer backbone chain and decrease their molecular weight and the viscosity of the solution; and

- Thermal: Adding heat to the polymer solution breaks the polymer.

Staatsolie has initiated a project to design an ancillary treatment facility / process so that the Josie Facility can efficiently process the PFPW to meet Staatsolie';s environmental specifications for produced effluent water discharge or re-injection in a disposal well.

### 3.5.5 Decommissioning

When the economic life of the field is reached, the remaining wells and the supporting facilities will be dismantled.

Two scenarios are possible:

- The area is abandoned, all facilities and plant are demolished and removed, and the area is allowed to revegetate, with or without active rehabilitation / remediation; or
- In the event of an agreed subsequent beneficial land use, part of the infrastructure may be retained for further use.

A Groundwater and Soil Quality Assessment will be conducted for all processing areas. Remediation may include on-site land-farming (bioremediation), but where necessary contaminated soil will be removed from site for treatment or for safe disposal elsewhere.

### 3.5.6 Services

#### 3.5.6.1 Power Supply

Power will be obtained from existing sources. Power supply infrastructure will include the following:

- High-voltage (HV) power connections to existing Josie and Broederschap lines;
- HV power distribution for three streams at 500 KVA;
- Low-voltage (LV) facilities for polymer preparation, maturation tank, polymer high-pressure pumps, storage areas, offices, N2/Air skid and area lighting;
- MCC cabinet, complete with variable-frequency drive (VFD) cabinets, uninterruptible power supply (UPS) and a programmable logic controller (PLC) cabinet. The three-sectioned MCC will be powered through three step down transformers from the Josi and Broederschap lines; and
- Transmitters (flow, pressure, temperature and vibration).

#### 3.5.6.2 Fuel Supply

No fuel is needed during this project.

#### 3.5.6.3 Water Supply

**Potable water**

Potable (drinking) water for personnel, offices and laboratories will be supplied by pipeline from the Sarah Maria water storage tank.

**Process water**

The PF process requires 21 000 bbl/d of water. The water used for polymer mixing and injection must meet specific quality requirements to assure integrity of the injection fluid, the injector well and the near-wellbore region (formation).

Surface water and groundwater are being considered as water sources and discussed below:

- Surface water would be abstracted from the Saramacca River / channel. Staatsolie is conducting tests to ascertain whether the water is suitable. A pump system will have to be installed to pump the water from the channel or the river to the PMP; and
- Groundwater would be abstracted from four new water wells from the S-sand layer just above the oil reservoir. Wells would abstract at 80% of capacity, to provide redundancy if one well is unavailable.

Both options will be further evaluated based on:

- Water quality;
- Cost;
- Water treatment unit design; and
- Chemicals to be used.

### 3.5.7 Employment

While construction phase jobs cannot be estimated at the moment, the operational phase generates employment for ~20 people.

### 3.5.8 Timeline

Construction is expected to take approximately 24 months to completion. Wells will be drilled in two phases during the first two years of the project, as shown in Table 3-2. From Year 3, only polymer injection and oil production will be installed.

The timeline for key project initiation milestones is currently anticipated as shown in Table 3-3.

**Table 3-3: Key project initiation milestones**

| Activity | Start date | Finish date |
|---|---|---|
| Construction of well locations | February 2019 | December 2021 |
| Drilling of injector wells | October 2019 | December 2021 |
| Construction of the PMP | March 2020 | April 2020 |
| Commissioning of PMP | June 2020 | July 2020 |
| Modifications at Jossie Treatment Plant | Studies to determine the type and scale of modifications to the Jossie Treatment Facilities have commenced | |

Operations may commence in 2020 and extend to 2044. The polymer solution will be injected into each injector well for ~11 years. Thereafter, water will be injected into the wells for ~13 years.

Once oil can no longer be extracted, the field will be decommissioned. Decommissioning of the PMP is envisaged between 2045 and 2050.

# 4 Description of the Affected Environment

The following chapter presents an overview of the biophysical and socio-economic environment in which the proposed project is located to:

- Understand the general sensitivity of and pressures on the affected environment;
- Inform the identification of potential issues and impacts associated with the proposed project, which were assessed in the Impact Assessment section; and
- Start conceptualising practical mitigation measures.

The description of the affected environment is based on existing information provided in previous studies by SRK (2019) and specialists for the Proposed Power Plant in the Tambaredjo Oilfield, and Noordam Environmental Consultancy for developments located just west of the project area, notably the Tambaredjo North-West Oilfield Development ESIA (Noordam, 2010), Farmersland Production Development ESIA (Noordam, 2014) and Calcutta-North Appraisal Drilling ESIA (Noordam, 2018). Where information has been obtained from different sources, it is appropriately referenced.

Where appropriate, baseline information has been supplemented or generated by specialists appointed to undertake the Groundwater and Geochemical baseline and impact assessments for the proposed PF project, attached as Appendix A.

## 4.1 Biophysical Environment

### 4.1.1 Geology and Geomorphology

The study area is located in the Young Coastal Plain of the Guiana Basin, on Holocene deposits of the Coronie Formation. The area is situated on predominantly marine clay sediments of the Commewijne Phase, deposited less than 1 000 years ago (Brinkman and Pons, 1968). Considerable accretion has occurred along the coast north of the project area during recent decades. The Young Coastal Plain is dominated by flat and low-lying swamps and marshes with clay soils at 1 - 1.5 m above mean sea level, on which a peat layer has developed.

In the Tambaredjo Oilfield, the swamp has been drained and infilled to facilitate “dryland” oil exploitation (in contrast to the more recently developed Tambaredjo North-West and Calcutta North fields, where “wetland” drilling is practised).

### 4.1.2 Climate

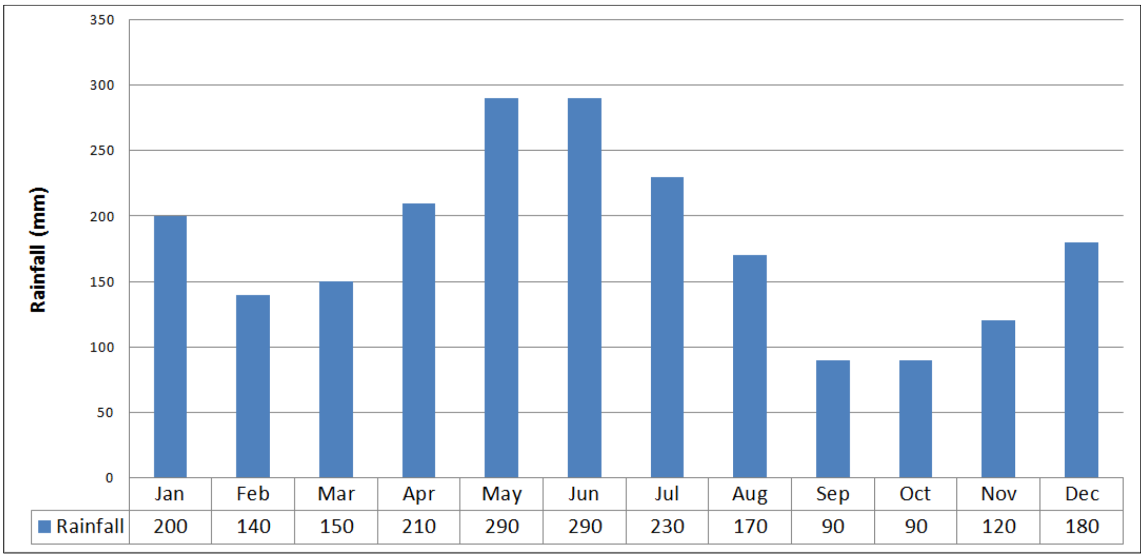
#### 4.1.2.1 General Description of Regional Climate

Suriname has a typical tropical climate with high rainfall and high temperatures. Most rainfall in the region falls in two rainy seasons, interspersed with two ‘dry’ seasons as follows (Webster & Roebuck, 2001):

- Short rainy season – early December until early February;
- Short dry season – early February until mid-April;
- Long rainy season – mid-April until mid-August; and
- Long dry season – mid-August until early December.

#### 4.1.2.2 Rainfall

Rainfall data acquired over a period of 39 years (see Figure 4-1) indicates a long-term average of approximately 2 200 mm per annum in Paramaribo.

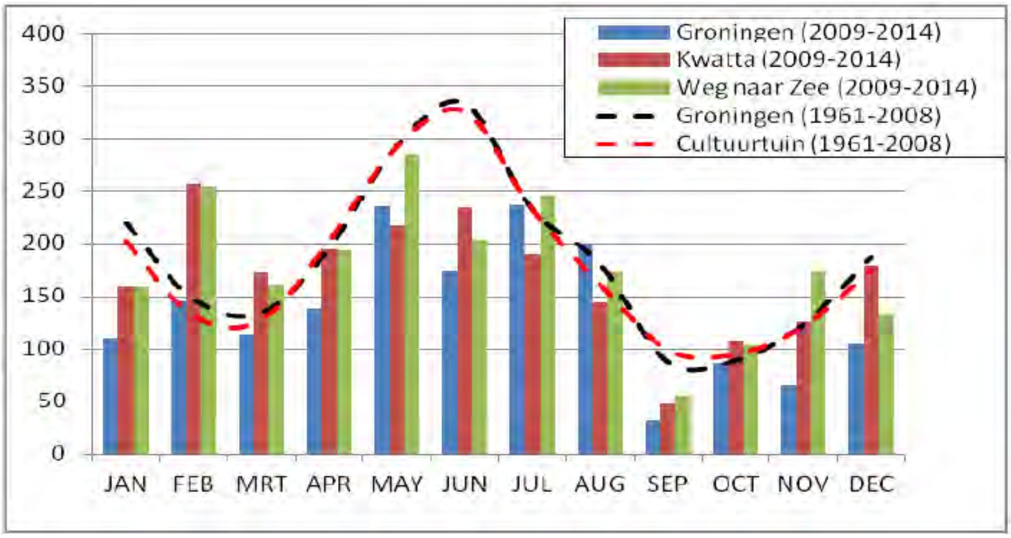



| srk consulting | POLYMER FLOODING LIMITED ESIA AND EMMP<br>Long-term average monthly rainfall recorded in Paramaribo | Project No.<br>545842 |
|---|---|---|

**Figure 4-1: Long-term average monthly rainfall recorded in Paramaribo**

Source: Weatherbase, 2013

Measurements of rainfall in the study area between 2009 and 2014 indicate similar annual rainfall and trends (Noordam, 2014). Average annual rainfall was 2018 mm at Kwatta and 2186 mm at Groningen in the period, compared to a long-term annual average of 2 233 mm at Groningen and 2 248 mm at Cultuurtuin, with a peak in May to July.




| srk consulting | POLYMER FLOODING LIMITED ESIA AND EMMP<br>Average rainfall for 2009 - 2014 (Groningen, Kwatta, Weg naar Zee) and 1961 - 2008 (Groningen, Cultuurtuin) | Project No.<br>545842 |
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**Figure 4-2: Average monthly rainfall for 2009 – 2014 (Groningen, Kwatta, Weg naar Zee) and 1961 – 2008 (Groningen, Cultuurtuin)**

Source: Noordam (2014)

Rainfall is an important parameter with respect to air quality, which deteriorates during dry conditions and improves during the wet season. However, in Suriname even during the dry season(s) rainfall is relatively high. During wet periods, rain suppresses dust particles in the atmosphere and alleviates air pollution. Dust emissions are further reduced by damp soil conditions. During dry periods, dust emissions generally increase as the soils become desiccated.

Humidity is generally high throughout the year, varying between 80% and 90% on the Coastal Plain and 75% in the Interior. The highest humidity values are recorded from May to July and the lowest from September to November.

#### 4.1.2.3 Ambient Temperature

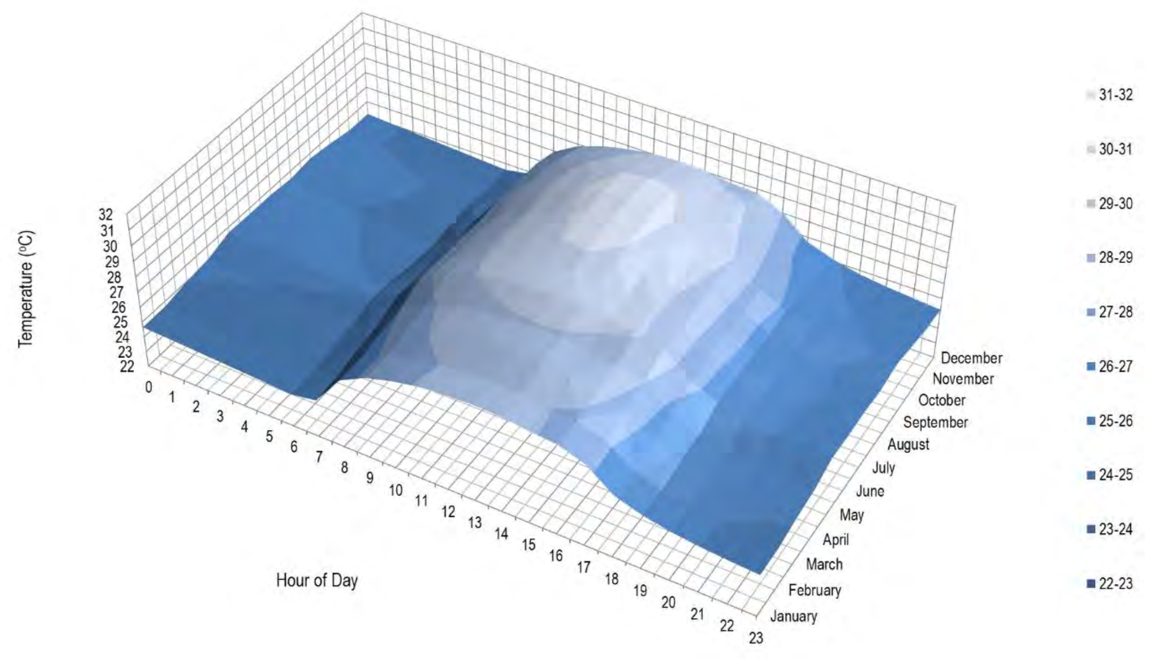
In Suriname, the period between July and October tends to be warmest, with daily temperatures reaching (average) highs of more than 31°C. The period from December to March is coolest, with daily temperatures in the coolest month, January, reaching a high of approximately 30°C. Minimum temperatures throughout the year are between approximately 22°C and 24°C. Monthly average, maximum and minimum temperatures obtained for the period January 2015 to December 2017 are shown in Table 4-1

**Table 4-1: Minimum, maximum and mean temperature 2015 – 2017, Suriname**

| | Jan | Feb | March | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Maximum | 29.5 | 29.7 | 30.4 | 30.8 | 31.7 | 31.1 | 31.5 | 31.7 | 32.3 | 31.7 | 30.9 | 30.7 |
| Minimum | 22.5 | 22.8 | 22.8 | 22.1 | 23.8 | 23.8 | 22.9 | 22.5 | 23.1 | 22.8 | 22.3 | 23.5 |
| Average | 26.0 | 26.0 | 26.4 | 26.6 | 27.1 | 27.1 | 27.2 | 27.1 | 27.3 | 27.1 | 26.8 | 26.6 |

Source: MM5 Data January 2015 – December 2017 (Airshed Planning Professionals, 2018)

Daily and monthly temperature trends are presented in Figure 4-3.




| srk consulting | POLYMER FLOODING LIMITED ESIA AND EMMP<br>Average monthly and daily temperature profile 2015 - 2017 | Project No.<br>545842 |
|---|---|---|

**Figure 4-3: Average monthly and daily temperature profile 2015 – 2017, Saramacca**

Source: MM5 Data January 2015 – December 2017 (Airshed Planning Professionals, 2018)

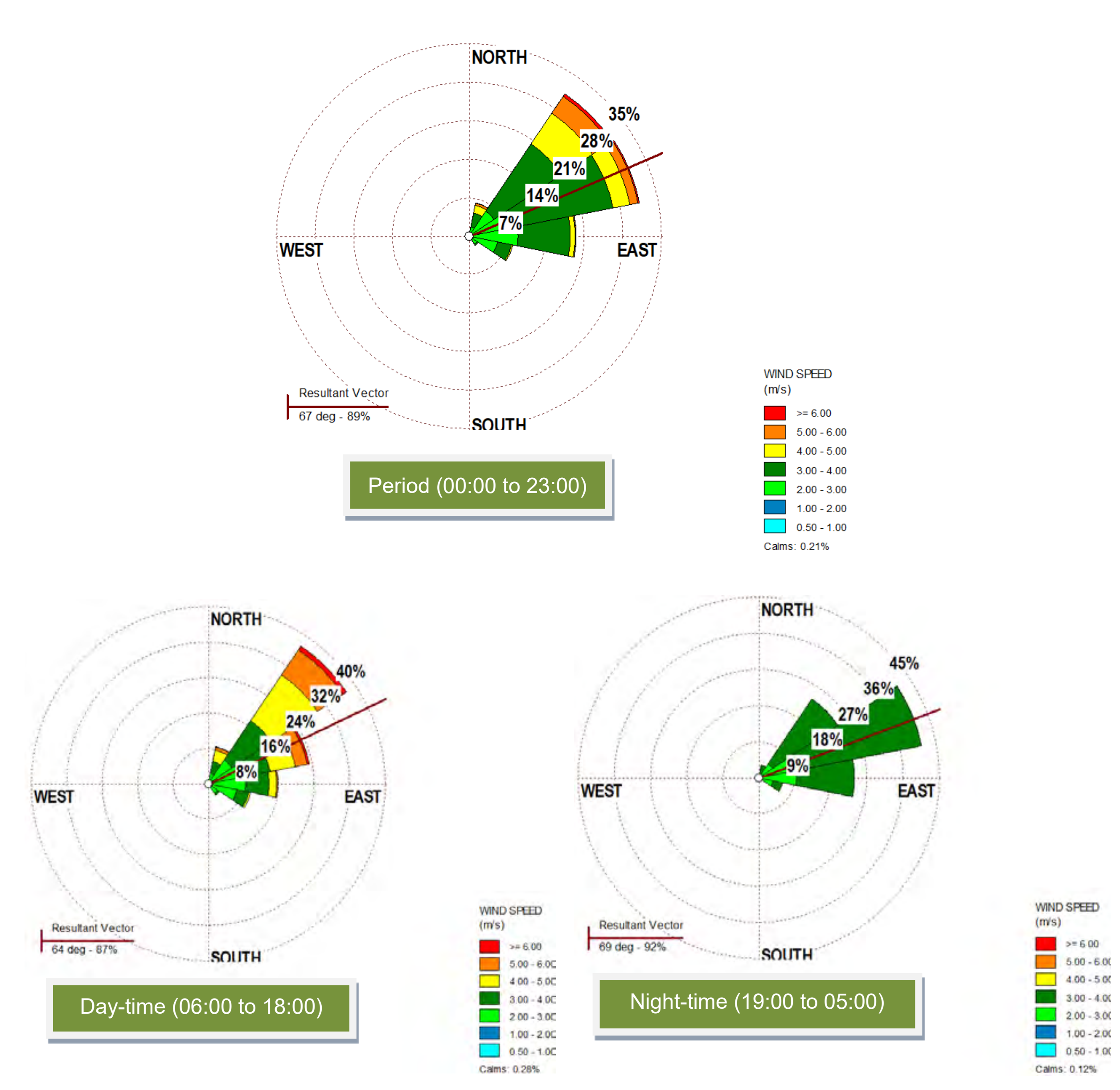
The atmospheric boundary layer is normally unstable during the day as a result of the turbulence due to the sun's heating effect on the earth's surface. The depth of this mixing layer depends predominantly on the extent of solar radiation, growing gradually from sunrise to reach a maximum at about 5-6 hours after sunrise. During night-time conditions a stable layer with limited vertical mixing exists. During windy and/or cloudy conditions the atmosphere is normally neutral (Airshed Planning Professionals, 2012).

### 4.1.2.4 Wind

Suriname does not experience hurricanes like the rest of the Caribbean region, but powerful winds do blow during strong storms. The dominant wind direction is easterly and north-easterly, with little variation between day and night-time wind directions.

Winds speeds are generally lower during the night, with a high frequency of 3 - 4 m/s winds evident at night, with no winds in excess of 5 m/s. During the day, wind speeds tend to be higher and occasionally exceed 6 m/s. Calmer conditions are more frequent at night than during the day (see Figure 4-4). The period average wind speed was calculated as 3.2 m/s (Airshed Planning Professionals, 2018).

Seasonal wind patterns show an increase in the occurrence of high wind speeds from March – May, and to a lesser extent from December – February. From June – August, calm conditions and south-easterly winds increase.




| | | |
|---|---|---|
| srk consulting | POLYMER FLOODING LIMITED ESIA AND EMMP<br>Period, day and night-time wind roses for 2015 - 2017 | Project No.<br>545842 |

**Figure 4-4: Period, day and night-time wind roses for 2015– 2017, Paramaribo**

Source: MM5 Data January 2015 – December 2017 (Airshed Planning Professionals, 2018)

**Note:** Wind roses comprise 16 spokes that represent the directions from which winds blow during a specific period. The colours in the wind roses reflect the different wind speeds. The dotted circles provide information regarding the frequency of occurrence of wind speed and direction. The frequency with which calms occur, i.e. periods during which the wind speed is below 0.5 m/s, is indicated above or next to each wind rose.

### 4.1.3 Air Quality

There are few significant sources of air pollution in the area. The TA-58 plant, located ~7 km north of Gangaram Pandayweg, releases some atmospheric emissions and is the main (continuous) contributor to localised air pollution. Backup generators for the Sarah Maria facility are also located at TA-58 and emit exhaust fumes when operational. Passive air quality sampling was conducted in August 2018 in the vicinity of TA-58, ~5 km north of the proposed PMP. All measured pollutants were low, and well below their respective extrapolated seven-day screening limits, indicating that baseline air quality is good (Airshed Planning Professionals, 2018).

Staatsolie proposes to construct a new power plant ~150 m south-east of the TA-58 plant. Based on modelling, emissions, and ambient pollution levels, are expected to be relatively low and localised (Airshed Planning Professionals, 2018).

Other sources of air pollution include vehicles entraining dust on unpaved roads and farming activities generating mainly airborne particulates during harvesting, burning of surplus biomass and spraying of fields. Public roads, notably Gangaram Pandayweg, and the nearest rice farms are located ~2 km to the south from the proposed PMP and not expected to significantly impact air quality at the project site.

Traffic volume in the Tambaredjo Oilfield is very low, and stringent speed limits apply. Staatsolie vehicles are thus not expected to generate significant dust in the concession area.

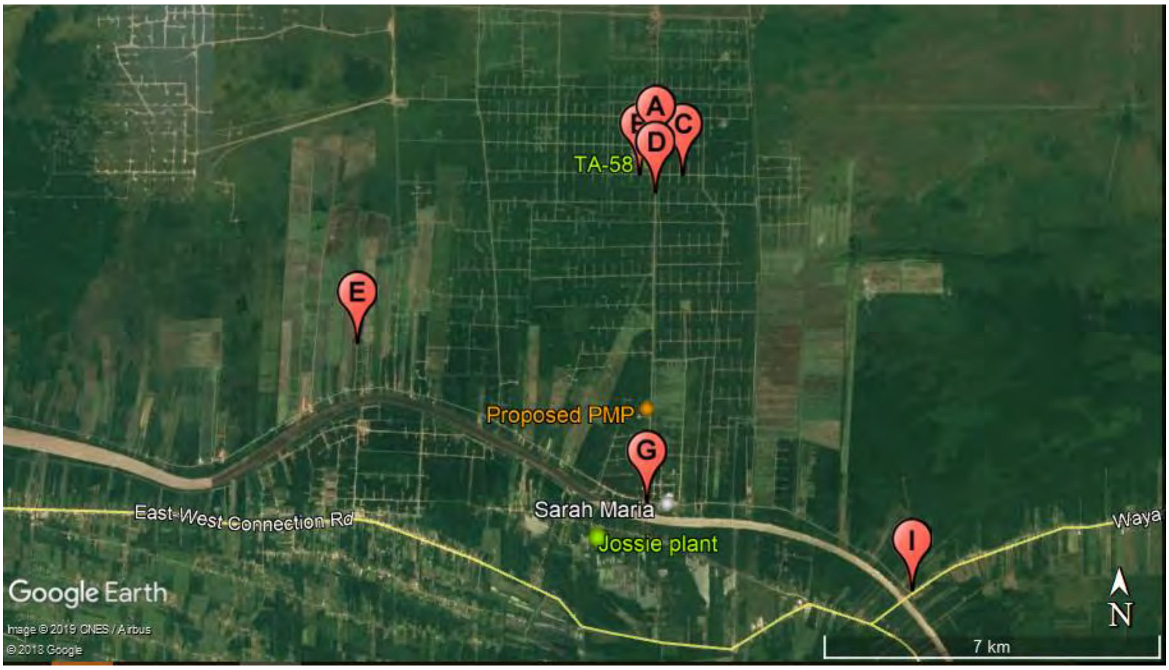
The PMP is located near Staatsolie’s current waste incineration site, where waste burning is undertaken twice per week, which will affect air quality. However, Staatsolie is preparing a new Waste Management Facility, which will include an incinerator and a landfill.

### 4.1.4 Noise

Key sources of environmental noise include the TA-58 plant, which generates a low frequency hum, local fauna, such as birds, insects, primates and dogs, and vehicle traffic within the Sarah Maria facility and on public roads adjacent to the concession.

Noise measurements taken in August 2018 at several locations in and outside of the Tambaredjo Oilfield (see Figure 4-5) indicated that baseline noise levels are typical of rural areas, with daytime sound pressure levels ranging from 46 dBA at location B (in the oilfield west of TA-58, where there is little traffic) to 66 dBA at Location I (outside of the oilfield at the intersection of Wayamboweg and Gangaram Pandayweg, which is characterised by significant light and heavy vehicle traffic) (SRK Consulting, 2019).

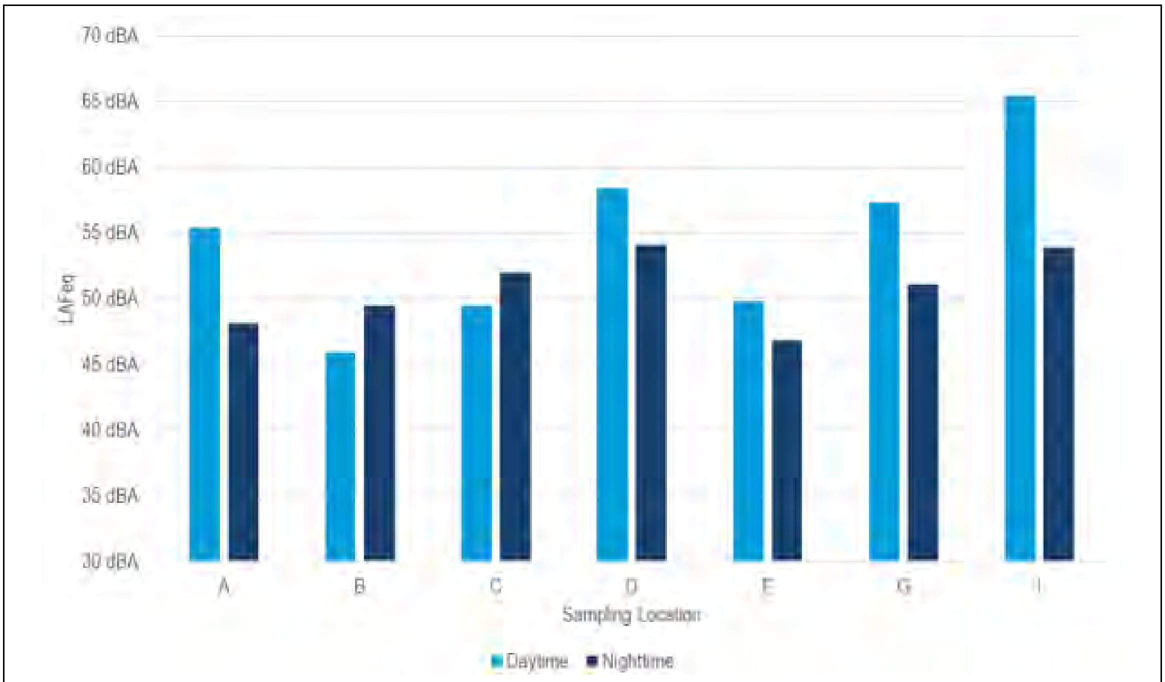
Sampled daytime Equivalent Sound Pressure Levels ($L_{Aeq}$) (Figure 4-6) were highest at sampling locations D, G and I where traffic volumes are highest; however, in the absence of the vehicle traffic, environmental noise at these locations is quite low.




| srk consulting | POLYMER FLOODING LIMITED ESIA AND EMMP<br>Location of August 2018 ambient noise measurement points | Project No.<br>545842 |
|---|---|---|

**Figure 4-5: Location of August 2018 ambient noise measurement points**

Source: SRK Consulting (2019)




| srk consulting | POLYMER FLOODING LIMITED ESIA AND EMMP<br>2018 Day and Night-time $L_{Aeq}$ | Project No.<br>545842 |
|---|---|---|

**Figure 4-6: Sampled 2018 day and night-time Equivalent Sound Pressure Levels $L_{Aeq}$ levels**

Source: SRK Consulting (2019)

### 4.1.5 Hydrology

The Saramacca District has approximately 3 320 km$^2$ of coastal wetlands, of which 370 km$^2$ support mangrove forest. Most wetlands consist of swamplands with poorly to very poorly drained soils, which are inundated either permanently or at least during the greater part of the year. Areas along the coast or tidal river sections are inundated twice a day during high tide. Water quality in the Coastal Plain varies from saline to brackish near the coast to freshwater further south.

Historically, the northern part of the swamp drained north towards the sea, while the southern part drained south towards the Saramacca River. The approximate catchment boundary is indicated by the red line in Figure 4-7. The area draining northwards is considered to support important ecosystem goods and services that are particularly sensitive to the hydrology and water quality, and includes the Coppename Monding Nature Reserve (see Figure 4-8). The PF area lies in the south-draining area of the Reserve.

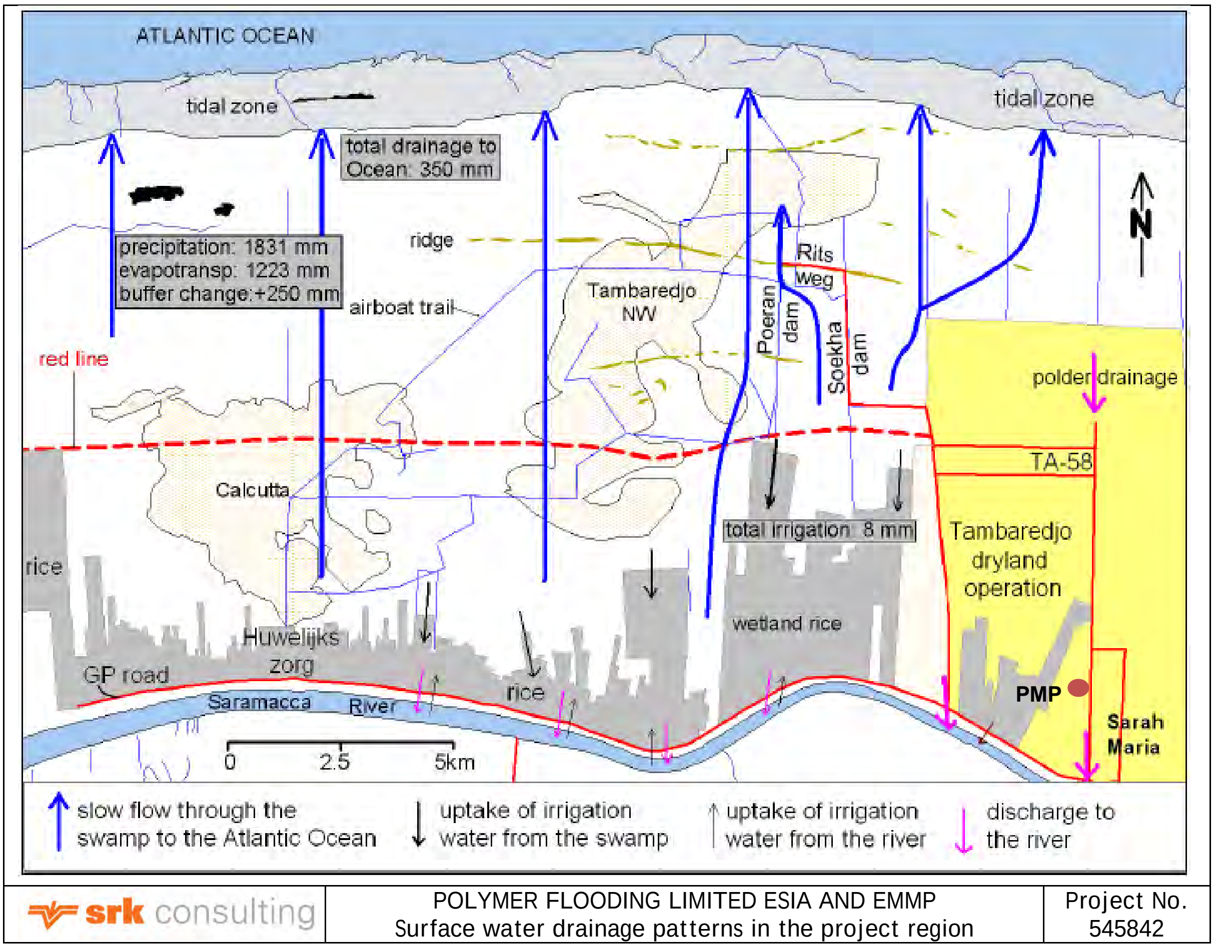



**Figure 4-7: Surface water drainage patterns in the project region**

Source: Noordam (2010)

Volumes refer to the study period from 18 November 2008 to 23 July 2009.

The natural hydrological conditions of the area draining southwards have been affected over time by dryland cropping, road construction, development of rice polders, abstraction and discharge of irrigation water and the development of the Tambaredjo oil polder. As a result, water levels have changed, flow of swamp water to the Saramacca River has been obstructed in certain areas, and drainage patterns have changed as indicated in Figure 4-7, i.e. more water drains northwards than previously, while the entire Tambaredjo Polder drains southwards.

The Tambaredjo Oilfield (outlined in white in Figure 4-8) was developed in a former wetland area located between the Buru and Wayambo Swamps. The polder is characterised by south-north aligned dams and canals that obstruct the natural water flow in the swamp. The entire polder area now drains via two main canals towards the Saramacca River.


| srk consulting | POLYMER FLOODING LIMITED ESIA AND EMMP<br>Location of Tambaredjo oil polder relative to other features | Project No.<br>545842 |
|---|---|---|

**Figure 4-8: Location of Tambaredjo oil polder relative to other hydrological features**

New project components[6] are located on the Tambaredjo Polder, from which excess water is discharged into the Saramacca River by a number of large N-S canals. In addition to these N-S canals there are also a number of E-W canals that connect the N-S canals. The N-S canals drain into the Saramacca River through culverts. The project site drains through the Kisoensingh-west Canal that runs along the main access road of the polder. The culverts along the Saramacca River are operated by Staatsolie, so the company has full control on the water management of the polder (Noordam, 2018a)

Key sources of potential water pollution include the TA-58 plant, the Sarah Maria facility the waste incineration area and the landfarm in the Tambaredjo Polder (see Figure 3-4).

#### 4.1.5.1 Tambaredjo Polder Water Quality

Historic water quality data (1999) for the Tambaredjo polder recorded elevated chloride (salinity) > 250 ppm chloride at the outlet of the TA-58 oil-water separator, where effluent is released into the canal. It is, however, expected that salinity will be considerably reduced downstream at the outfall into the Saramacca River due to dilution of the effluent by stormwater.

Very low pH was measured near TA-58, but in the remainder of the locations pH is much higher. Overall pH during the dry season is higher than during the rainy season. Dissolved oxygen (DO) levels vary from low to medium, with overall higher DO in the dry season.

Very high turbidity was measured at one location, but typically varies between 35 and 66 Nephelometric Turbidity Unit (NTU), consistent with data for a 2016-17 sampling campaign (Staatsolie), for which 90% of the results are between 41 and 114 FTU. These turbidity values

[6] The Jossie plant is located south of the Saramacca River, outside of the Tambaredjo polder, but inside the Tambaredjo Oilfield.

correspond with Total Suspended Solids (TSS) values between 31 and 82 mg/L (Staatsolie data 2015-2016, sampling Kisoensingh-west Canal).

Nitrate and ammonia levels are very low, which is normal for unpolluted natural waters. The phosphate levels are very low to medium. The measured nutrient levels do not point to organic pollution.

In July and October 2018, surface water samples were taken in the Kisoensingh-west Canal at locations SO1-SO3 (and the Saramacca River at location SO4) (see Figure 4-9), during the rainy and dry season, respectively, to determine the baseline water characteristics and concentration of key pollutants. Aside from higher pH, all other parameters are more or less within the same range as in 1999.

A number of metals are found in the water, of which barium, arsenic and zinc are encountered in at least 50% of the samples. Arsenic exceeds the guideline value for consumption of organisms by humans, but it is below the value for aquatic life. The elevated barium levels could be related to spills of barite or spent drilling mud**.** The SO3 dry season sample exceeds the United States Environmental Protection Agency (USEPA) guideline for consumption of organisms.

Furthermore, there are a number of chemical compounds, of which toluene and diazinon are found in all rainy season samples and phenols in both rainy and dry season samples. These findings could possibly be related to release during processing of crude oil (toluene), spills or leakages of certain chemicals like wood preservatives (phenols) and the use of insecticides (diazinon).

Of interest is the presence of PCB's in sample SO2 during the rainy season sampling. The sample is taken near TA-58 and most likely points to pollution from that source. The level is well above the USEPA guideline level for human consumption of 0.000064 µg/L and close to or slightly above the guideline level for aquatic life of 0.014 µg/L. Minor diesel and gasoline spills can be observed in samples SO1 (rainy season) and SO2 (dry season).


| srk consulting | POLYMER FLOODING LIMITED ESIA AND EMMP<br>Location of 2018 surface water sampling points | Project No.<br>545842 |
|---|---|---|

**Figure 4-9: Location of 2018 surface water sampling points**

Source: SRK Consulting (2019)

#### 4.1.5.2 Saramacca River Water Quality

A 2018 study (Noordam, 2018a) found that pH is slightly acidic, while salinity is very low. There is, however, a slight increase in pH and EC for the Long Dry Season, but there is no indication of salt intrusion from the ocean, which would be indicated by EC values > 1 mS. Dissolved Oxygen is moderate with values of 5.5 mg/L.

Total Suspended Solids (TSS) is higher than the TSS in the Kisoensingh-west canal (except for sample SO2), probably under influence of the tidal movement. Phosphorus is lower than in the canal, because the canal water has more exchange with soil and organic debris.

Rainy and dry season samples from the Saramacca River (SO4) adjacent to the Tambaredjo Polder, showed elevated levels for barium, zinc and diazinon in both seasons. Similar levels of barium and diazinon have also been recorded in the Suriname and Coppename Rivers (NEC & Ilaco, 2016), with 6-12 µg/L barium and 0.3-0.7 µg/L diazinon. It should be noted that the Coppename River is considered an unpolluted river. The elevated concentrations of these compounds are thought to be the result of natural processes and therefore represent natural background levels in these rivers.

The diazinon levels in the canal are also considered to represent natural background levels, as they are in the same range as found in the rivers. However, the barium level in the canal is above the natural river levels and points to pollution.

Elevated levels for toluene and Total Petroleum Hydrocarbon were measured in the rainy season sample. These are likely the result of an oil spill or leakage.

Apart from the latter, the Saramacca River water can be characterised as unpolluted.

### 4.1.6 Geohydrology

The following summary of the groundwater and geochemical baseline assessment at the project area was mainly sourced and summarised from Sabajo (2016), except where indicated otherwise.

The flat marine plain of the project area is primarily underlain by clays with elongated East-West running beach barrier deposits “ritsen” as the main morphological features. The plain is an assembly of clay plates (“schollen”) dissected by numerous swamps and creeks filled with Holocene clay and peat. The vegetation originally comprised dry-land forest on the beach barriers and better drained parts of the clayey plain, and by swamp forest on the low-lying parts.

Geologically, Suriname is part of the Precambrian Guiana Shield. In the north, the shield shows a seaward dip and is covered by Late Cretaceous and Cenozoic deposits of the Guiana Basin. The shield consists mainly of granitoid and metamorphic rocks (De Vletter, Aleva, & Kroonenberg, 1998).

The Precambrian Guiana Shield started to receive a wedge of sediments in the Late Jurassic-Early Cretaceous with the opening of the Atlantic. The oldest sediments are of Early Senonian (Late Cretaceous) Age. The youngest sediments cropping out in the young coastal plain are of Holocene age. The surface and subsurface sediments of the Coastal Plain area have been grouped into the Corantijn Group.

The Corantijn Group consist of a monoclinical northern dipping (*c.*1°) section of predominantly clastic sediments. These sediments form a regular alternation of sands, clays, siltstones and minor shales. Occasional marls, lignites and gravel may be intercalated locally. The sediments were deposited under fluvial to marginal conditions. Several regressive and transgressive phases as well as major periods of non-deposition can be recognized. The total thickness of the Group increases from south to north and from east to west.

The coastal plain of Suriname is underlain by three major aquifers within the Corantijn Group (SRK Consulting, 2013):

- The A-sand aquifer (in the Burnside Formation) contains freshwater in many locations, including Paramaribo, where it is found at an approximate depth of 150 m. The aquifer thickness varies from 10-60 m. The A-Sand aquifer is not directly recharged by rainwater, and it is suspected that upward leakage of groundwater from the older, underlying formation is likely;
- The Coesewijne aquifer contains freshwater in many locations of the coastal plain, including Paramaribo. The top of the aquifer is found at a depth of 70 m at Paramaribo. The Coesewijne sands are in hydraulic contact with the overlying Zanderij Formation, with groundwater flow in the southern Young Coastal Plain (Helena Christina road – Lelydorp) and diffusion in the northern Young Coastal Plain; and
- The Zanderij aquifer contains mostly brackish water in the Young Coastal Plain. The Formation crops out in the Savanna Belt and dips to the north. At Paramaribo it is found at depths of about 30-50 m. The Zanderij Formation is in hydraulic contact with the sandy deposits of the Coropina Formation (Lelydorp Deposits) south of Lelydorp. In the study area the aquifer does not have hydraulic contact with surface deposits due to the heavy clay in overlying layers.

The oil-bearing sand is found below these aquifers and forms the basal unit of the Saramacca Formation, which was deposited on top of an erosional surface that marks the transition from the Cretaceous to the Tertiary (Palaeocene).

Rainfall in clayey terrain is mainly discharged via overland flow and interflow to creeks, swamps and man-made drainage channels. Phreatic groundwater flow systems are poorly developed because of the low permeability and flat topography.

Groundwater from aquifers north of the Saramacca River is naturally brackish and/or has an objectionable oily taste, and potable (drinking) water is thus not abstracted in this area (Noordam, 2018a). Drinking water is abstracted from the Coesewijne aquifer south of the Saramacca River, e.g. in Tijgerkreek, Tambaredjo and Groningen (SRK Consulting, 2013). Although the groundwater underlying the site is generally brackish and not potable nor abstracted for domestic use, deeper fresh to slightly saline water is encountered at depth (Sabajo, 2016).

### 4.1.7 Flora

This section also incorporates observations from fieldwork undertaken in October 2018 to groundtruth secondary data (Noordam, 2018b).

The coastal region is characterised by vegetation succession from saline mangroves to freshwater habitats. Along the coast, young Black Mangrove (*Avicennia germinans*) develops where mudflats silt up above mean sea level. With the prevailing net coastal accretion, a closed-to-open Black Mangrove belt has developed. South of the Black Mangrove belt, herbaceous brackish water swamps (with or without scattered Black Mangrove trees) have developed on firmer soils on which a peat layer develops. Further inland, grass swamps become fresh and richer in species. Gradually low-to-high species-rich swamp wood may develop.

Original vegetation in the project area is expected to include Herbaceous brackish water swamp, dominated by Cat tails (*Typha dommingensis*) with or without scattered Black Mangrove trees, High swampwood, dominated by Swamp cork wood (*Pterocarpus officinalis*) and White cedar *(Tababuia insignis),* and Swamp scrub and bushes characterized by Swamp Plumb (*Chrysobalanus icaco*) and Swamp Soursop (*Annona glabra*).

The Tambaredjo Polder area has been substantially transformed by human activities such as dryland cropping, road construction, development of rice polders, abstraction and discharge of irrigation water and the development of the Tambaredjo oil polder. Natural swamp and marsh habitat in most of the study area was cleared and drained / infilled to create polders for agriculture.

Secondary marsh forest, dominated by Mira Udu (*Triplaris surinamensis*), has developed on long-abandoned land, where exotic formerly cultivated trees, such as Almond (*Terminalia catappa*) Coconut palm (*Cocos nucifera*), Guava (*Psidium gujave*) and Royal Palm (*Roystonia regia*), are also encountered, while Pina palm (*Euterpe oleracea*) is also commonly found. In addition, six other tree species were recorded in the marsh forest. Much of the forest edges is covered by Patatatetei (*Ipomoea tiliacea*). Ditches are present along all forest edges, and Mokomoko (*Montrichardia arborescens*) has developed in and along these ditches. On the excavated material, locally Busipapaya (*Cecropia obtusa*) has developed.

The secondary marsh forest has low plant diversity compared to undisturbed similar habitats. Secondary vegetation on land abandoned less than 10 years ago comprises shrubs, bushes and small trees. Temporary fallow land has low vegetation with grasses, rushes and herbs with very low biodiversity. The invasive[7] water hyacinth (*Eichhornia crassipes*) is also present in the area.

The observed low secondary marsh forest contains commonly encountered species, is still in its early stage of development and is relatively low in species diversity. No vulnerable, rare or endangered plant species are present in the study area. The study area is not deemed sensitive with regards to ecosystems and floral biodiversity.

### 4.1.8 Fauna

This section also incorporates observations from fieldwork undertaken in October 2018 to groundtruth secondary data (Noordam, 2018b).

The mudflats and the mangrove zone between the Coppename and the Suriname Rivers are important feeding and nesting areas for residential coastal **birds**, and important feeding and wintering grounds for migratory birds. Breeding colonies of Scarlet ibises and heron species are present in the young Black Mangrove forests along the Saramacca coast from March/April to August/September. The Saramacca coast hosts 13 bird species of international importance. It is expected that the bird species found in the study area also occur in similar (near-) coastal habitats throughout Suriname.

A 1999 survey recorded 41 bird species, noting that the great majority of the bird species observed in the Tambaredjo polder is found in neighbouring swamp habitats, including the coastal strip, while all species are also present elsewhere in the Young Coastal Plain. According to the IUCN Red List, all bird species in the estuarine zone are of Least Concern (IUCN 2018). However, two bird species of the estuarine zone are listed on CITES Appendix I, and therefore should be considered endangered species on a global scale: Jabiru (*Jabiru mycteria)* and Peregrine Falcon (*Falco peregrinus).*

Twenty-four bird species are listed on CITES Appendices II and III, and therefore should be considered vulnerable species on a global scale:

- Scarlet Ibis (*Eudocimus ruber*);
- American Flamingo (*Phoenicopterus ruber*);
- Osprey (*Pandion haliaetus*);
- All parrots (2 species);
- All hummingbirds (4 species in the estuarine zone);
- All hawks, except for the Peregrine Falcon = CITES Appendix I (9 species);
- All New World vultures (3 species); and

[7] Although native to the Amazon Basin, including Suriname, the plant is invasive in the area.

- All owls (3 species).

Some of above species may be present in the Tambaredjo polder periodically or fly over the polder. Apart from the breeding colonies and migrant birds, seasonal patterns in bird distribution are not apparent.

A 1998 study of **fish** communities in the Tambaredjo Oilfield (near the TA-58 plant) identified various Characidae (particularly *Ctenobrycon spilurus*) and Cichlidae species as well as Guyana leaffish *(Polycentrus schomburgkii)* and Guppy *(Poecilia reticulate)*. Fish diversity in the Tambaredjo Oilfield was higher compared to undisturbed *Typha* swamp and high swampwood habitas in adjacent areas. This may indicate that river fish (Warawara [*Hypostomus* sp.]) enter the Tambaredjo oil polder via canals from the Saramacca River and that certain species (e.g. Swamp eel [*Synbranchus marmoratus*], Ston-walapa [*Erythrinus erythrinus*] and Datrafisi [*Crenicichla saxatilis*]) have low abundance or are difficult to catch in their natural swamp(wood) habitat.

**Herpetofauna** diversity in the area is expected to be limited. Reptiles occurring in the study area will include Iguana (*Iguana-iguana*), Spectacled Caiman (*Caiman crocodilus*) and Anaconda (*Eunectes murinus*); these are common in Suriname but diminishing in populated areas. No unique, *Rare, Endangered, Vulnerable* or biogeographically important species were previously found in the Buru Swamp area. The Saramacca coast north of the project area does not provide sand and shell beaches for sea turtle nesting. Most of the snakes and amphibians recorded in the Tambaredjo polder are also known to occur in the neighboring swamp habitats.

A number of **mammals**, including Capybara (*Hydrochoerus hydrochaeris)* and Howler monkey (*Alouatta)*, are known to occur in the region[8]. None of the mammals occurring in the coastal area and listed on the IUCN Red List are confined to the coastal area, and none of them are listed as *Vulnerable* or *Endangered*. All mammals recorded in the Tambaredjo polder are also known to occur in the neighbouring swamp habitats.

The Jaguar (*Panthera onca*), Giant Anteater (*Myrmecophaga tridactyla*) and the Neotropical Otter (*Lontra longicaudis enudris*) are included on the IUCN Red list and CITES appendices. The Brown Capuchin (*Cebus apella*) and the Spectacled Caiman (*Caiman crocodilus*) are included in Appendix II of CITES, indicating a globally vulnerable status. All other species expected to occur on the site and listed in Annexure B, are of Least Concern (IUCN Red list) and not included in the CITES Appendices

Overall, the secondary marsh forest found at the project site is expected to have relatively low fauna diversity compared to undisturbed similar habitats, due to the fragmentation of higher secondary vegetation (which is more likely to harbour animals) and human activity in the area. The study area is not deemed sensitive with regards to ecosystems and fauna.

### 4.1.9 Conservation Areas

The Coppename Monding Nature Reserve was first established as a bird sanctuary in 1953 along the coast east of the Coppename River mouth, and declared a nature reserve in 1966 for the purpose of research, nature education and tourism. It is also listed as a Wetland of International Importance (RAMSAR site).

The southern boundary of the eastern-most portion of the Coppename Monding Nature Reserve is located ~2.5 km north of the Tambaredjo polder and ~10 km north of the proposed PF project area (see Figure 4-8).

[8] See Annexure B of Noordam (2018b) for a more detailed list.

## 4.2 Socio-Economic Environment

This section is largely based on Social Solutions (2018). The project is located in the 872 km$^2$ Wayambo resort, which has the smallest population of the resorts of Saramacca district, with 1 186 residents, less than 10% of the district population of 15 696.

The only inhabited areas on the right (northern) bank of the Lower Saramacca River are located along (parts of) the Gangaram Pandayweg, which branches off Wayambo Road (that leads towards Paramaribo) and extends for 30 km towards the west along the right bank of the Lower Saramacca River. Roughly 345 persons (less than 100 families) live permanently along the Gangaram Pandayweg, in four settlements: Sarah Maria (near the existing Staatsolie facility), La Prevoyance (10-12 residences and local government institutions), Bombay (15-16 residences) and Huwelijkszorg (~30 residences).

Residential areas located nearest to the project area are shown in Figure 4-10. Eight residential clusters comprising three to four households each and one allotment project comprising four houses are located in the 8 km section from the intersection with Wayambo Road that leads past the Sarah Maria facility.

Most families residing along the Gangaram Pandayweg practise horticulture (domestic cultivation). Crops include tomatoes, eggplant, beans and oerdi, the latter for commercial purposes. Farming activities include animal husbandry (cows and chickens) and cultivation of plantains and rice. Most farmland in the area lies fallow or has been abandoned. One sawmill operates along Gangaram Pandayweg; logs are transported by river and processed planks are transported to Paramaribo by pick-up truck on the Gangaram Pandayweg every two weeks. Approximately 20-25 persons living along Gangaram Pandayweg are currently employed by Staatsolie.

Three school buses transport pupils to and from school on the Gangaram Pandayweg. Other traffic on the road is used by commuting residents, Staatsolie personnel driving to and from the Sarah Maria facility, Staatsolie contractors/subcontractors driving to and from Staatsolie facilities and non-residents visiting their weekend/holiday homes and/or outsiders visiting the fishing spots.

Field observations noted frequent truck movements (sand transport). Traffic intensity peaks between 07h00 – 09h00 and 12h00 - 15h00, attributed to commuter traffic to and from the Sarah Maria facility.

Fishing spots are located on the private terrain of land owners living along the Gangaram Pandayweg. During fishing season (usually the dry season), fishing spots or ‘fish holes’ (of which five are well known) are opened to the public. Staatsolie representatives reported that people illegally use Staatsolie’s concession area on the Tambaredjo polder for fishing and hunting.

Some households have access to tap water, but most depend on rain water for drinking water. Water pipelines have been installed along Gangaram Pandayweg from the intersection with Wayambo (km 0) to Km 3 and from Km 7 to Km 11.5, but as of July 2019 none of the households had been connected yet. All household along Gangaram Pandayweg have access to electricity.

While the district of Saramacca accommodates a multicultural society with different ethnic groups, the Hindustani and Javanese ethnic groups dominate the cultural landscape in this part of the country. Population data from 2014 show that 53.3% of the total district population is of Hindustani ethnic descent, while other ethnic groups included Javanese and Creole people (people of African descent).

The Gangaram Pandayweg and its surrounding area is not a traditional residential area of Indigenous Peoples and Maroons, and these tribal communities are not present in the vicinity of the Tambaredjo Oilfield.

The main religion practised in Saramacca district is Hinduism (44.6%). Other religions practised in this district include Christianity (23.5%), Islam (18.8%), and other religions (3%).

Three archaeological sites – all settlements with graves - are located in the area, on the left bank of the Saramacca River: they will not be affected by the project. Two Hindu temples located along the Gangaram Pandayweg, one at Bombay and another one at Huwelijkszorg.


| srk consulting | POLYMER FLOODING LIMITED ESIA AND EMMP<br>Socio-economic features in the study area | Project No.<br>545842 |
|---|---|---|

**Figure 4-10: Socio-economic features in the study area**

Source: adapted from Social Solutions (2018)

# 5 Stakeholder Engagement

Stakeholder engagement forms a key component of the ESIA process. The objectives of stakeholder engagement are outlined in this section, followed by a summary of the approach to be followed, in compliance with best practice and NIMOS guidelines.

## 5.1 Objectives and Approach to Stakeholder Engagement

The overall aim of public consultation is to ensure that all stakeholders have adequate opportunity to provide input into the process and raise their comments and concerns. More specifically, the objectives of public consultation are to:

- Identify stakeholders and inform them about the proposed development and Limited ESIA process;
- Provide stakeholders with the opportunity to participate effectively in the process and identify relevant issues and concerns associated with the proposed project; and
- Provide stakeholders with the opportunity to review documentation and assist in identifying mitigation and management options to address potential environmental issues.

## 5.2 Stakeholder Engagement Activities

The activities undertaken and planned during the Limited ESIA process are outlined in Table 5-1.

**Table 5-1: Stakeholder engagement activities undertaken during the Scoping Phase**

| Task | Objectives | Dates |
|---|---|---|
| Initial landowner meeting | Arranged by Staatsolie to introduce the project to landowners and obtain input at an early stage | 31 May 2019 |
| Identify and compile a stakeholder database | To determine initial key stakeholders | June / July 2019 |
| Release ESIA Report and EMMP, including a Non-Technical Summary, and place on SRK website and at the offices of the DC of Saramacca and NIMOS | To provide stakeholders with access to the ESIA Report. | 8 August 2019 |
| Advertise public stakeholder meeting and notification to key stakeholders | To notify stakeholders of the opportunities to engage the ESIA and Staatsolie project teams and comment on the project | 8 August 2019 |
| Public comment period | To provide stakeholders with the opportunity to review and comment on the findings of the Limited ESIA. | 8 August 2019 to 9 September 2019 |
| Public meeting | To present the findings of the ESIA Report to stakeholders and provide an opportunity for questions and discussion. | 21 August 2019 |
| Compile Issues and Responses Summary and finalise ESIA Report | To record all issues and concerns raised and collate these comments in the final report which provides NIMOS with information to compile their advice. | September 2019 |

The key activities are described in more detail below.

### 5.2.1 Initial Landowner Meeting

Staatsolie convened an initial meeting with landowners on 31 May 2019 to introduce the project and the Limited ESIA process and to obtain landowner input at an early stage of the project.

Meeting notes are provided in Appendix B.

### 5.2.2 Identification of Key Stakeholders

Relevant district and national authorities, organisations and representatives as well as surrounding landowners were identified by Staatsolie and SRK and registered as stakeholders on the initial project database. These stakeholders have been notified of the Limited ESIA and the release of this report for comment.

In accordance with the best practice and NIMOS guidelines, all other persons can request in writing to be placed on the register, submit written comments or attend meetings in order to be registered as stakeholders and included in future communication regarding the project. All persons who do so will be registered as stakeholders, and advertisements advise that stakeholders register as such.

A list of registered stakeholders is provided in Table 5-2.

**Table 5-2: Stakeholder database**

| Name | Organization |
|---|---|
| Woei, L | Kabinet van de President Coordinatie Milieu |
| Abeleven, D | Kabinet van de President Coördinatie Milieu |
| Soman, S | NIMOS |
| Tewarie, A | NIMOS |
| Doebay, L | NIMOS |
| Asmowidjojo, Schubert | Ministerie van Ruimtelike Ordening, Grond-en Bosbeheer |
| Meghoe-Bhairo, L. | Ministerie van Natuurlijke Hulpbronnen |
| Oedai, R. | Ministerie van Openbare Werken, Transport en Communicatie |
| Bakker, J. | Ministerie van Openbare Werken, Transport en Communicatie |
| Esajas, H | DC Saramacca |
| Oosterling, M. | DC Saramacca |
| Valdink, R | DC Commissariaat Saramacca |
| Linger, A | BO Wayambo |
| Kromotani, R | RR Wayambo |
| Karamat, Haroen | Landowner |
| Amirullah | Landowner |
| Missier, R.A. | Landowner |
| Edam | Landowner |
| Tjok - Goerdin, B. | Landowner |
| Mahespalsingh, Johnny | Landowner |
| Harripersad | Landowner |
| Abboud | Landowner |

### 5.2.3 Notification of the Limited ESIA Process and ESIA Report for Public Comment

Newspaper advertisements announcing the availability of the ESIA Report for stakeholder review and inviting stakeholders to register on the project database will be placed in newspapers.

Hard copies of the full report will be available for public viewing at the following venues:

- NIMOS; and
- Office of the Saramacca District Commissioner at Groningen.

An electronic version of the ESIA Report can also be accessed on SRK's website **www.srk.co.za** (via the 'Library' and 'Public Documents' links).

Stakeholders will be provided with a 30-day comment period.

### 5.2.4 Public Meeting

A public meeting is a public forum at which the findings of the ESIA are presented for discussion. A public meeting will be held during the comment period to provide stakeholders with the opportunity to ask questions and discuss any concerns related to the project.

The public meeting will be held on:

- Date: 21 August 2019
- Venue: Staatsolie's Sarah Maria Emplacement (Conference Room 4), Saramacca

Additional meetings may be scheduled with key stakeholders.

### 5.2.5 Issues and Concerns Raised by Stakeholders to Date

Stakeholder comments on the project were received during Staatsolie's initial landowner meeting (see Appendix B). Comments are briefly summarised below:

**Table 5-3: Summary of stakeholder comments at the landowner meeting**

| Comment | Stakeholder | Response |
|---|---|---|
| What is the effect of the polymer in case of a leakage on the vegetation / agriculture? | Mr. Doerga | The risk from accidental surface spills of polymer is addressed in Section 6.4.3.2. The main concern of particularly large spills relates to the polymer mix reaching surface water at higher concentrations. However, it is expected that the polymer concentration in the Saramacca River will dilute to safe levels within a relatively short period of time given the high water volume and flow and natural degradation rate of polymer. It is not expected a spill will move offsite in the soil.<br>Polymer is used as a soil conditioner in agriculture to limit soil erosion and improve irrigation efficiency and dust control and not a concern in small quantities.<br>Measures to deal with a PAM spills are laid out in Section 3.1.6 of the EMMP. Smaller spills will biodegrade naturally on-site. For larger spills or spills in sensitive areas, contaminated soils may have to be removed to a land farm. The EMMP also includes stipulates measures for the prevention, monitoring and immediate containment of spills. |
| In the presentation it has been mentioned that the polymer is degradable. Why is it not mentioned that it is biodegradable? | Mr. Baldew | More information is provided in Section 6.3.2.1 and below:<br>Due to their large size, PAM molecules become physically trapped in blind pores as a function of the physical properties of the reservoir matrix. As PAM molecules are forced through narrow interstitial spaces within the reservoir, the molecules which are sensitive to shearing, are broken into smaller pieces. PAMs are generally very insensitive to bacteria, although sulphate reducing bacteria (as detected in well 1J22 and present in the Tambaredjo oil reservoir) can degrade the polymer.<br>Staatsolie further notes that the polymer (HPAM) is not classified as toxic and does not bio-accumulate. However, it does not pass the standard OECD 306 biodegradation test. Due to this failure, HPAM has a level-4 substitution warning on UKCS while it is classified as a "red" chemical in Norway. |
| How long will be the process of polymer injection? | Mr. Baldew | The anticipated timeline is described in Section 3.5.8. |

| Comment | Stakeholder | Response |
|---|---|---|
| | | After an initial injection of water (less than 1 month), the polymer solution will be injected into each injector well for ~11 years. Thereafter, water will be injected into the wells for ~13 years. |
| Why is Staatsolie not purchasing the land? | Mr. Baldew | Staatsolie: The Government of Suriname has awarded Staatsolie the concession rights. In collaboration with the landowners, the activities are being executed. |

These comments have been considered in the assessment of impacts in Section 6 of this report.

# 6 Environmental Impact Assessment

## 6.1 Introduction

### 6.1.1 Environmental Impacts Identified

Based on the professional experience of the ESIA team, legal requirements (Section 2), the nature of the proposed activity (Section 3), the nature of the receiving environment (Section 4) and issues raised in the stakeholder engagement process (Section 5), the following key environmental issues – potential negative impacts and potential benefits – were identified:

- **Groundwater** – possible impact on groundwater levels from abstraction of groundwater for project use, and possible pollution of mostly brackish groundwater from the proposed injection of a polymer mix into underground oil reservoirs; and
- **Surface water** – possible surface water pollution from the proposed discharge of produced water into the Saramacca River.

### 6.1.2 Specialist Studies Undertaken

A groundwater and geochemical specialist study, including a surface water component, was undertaken to investigate the key potential direct, indirect and cumulative impacts (negative and positive) of the project on groundwater and surface water.

The impact assessment is further based on a number of specialist studies for the proposed Saramacca Power Plant (SRK Consulting, 2019) in the Tambaredjo Oilfield, which provide air quality, noise, surface water quality, terrestrial ecology and social baselines.

### 6.1.3 Alternatives Assessed in the ESIA

During the prefeasibility phase of most projects various development alternatives are investigated. Depending on the specific project circumstances the following alternatives may be considered:

- Site Alternatives;
- Design Alternatives;
- Process Alternatives; and
- The No-Go Alternative.

In the case of the PF project, alternatives were considered during the Concept and Feasibility phases of the project, and feasible and preferred alternatives were identified (refer to Section 3.4). As such, only those alternatives (in addition to the No-Go alternative) will be assessed in Sections 6.2 to 6.4.6.

Alternatives assessed include the following:

- EOR technique: Polymer flooding;
- Water abstraction:
    - Surface water (Saramacca River); and/or
    - Groundwater; and
- Disposal of back produced polymer: Discharge to the Saramacca River.

#### 6.1.3.1 No-Go Alternative

The No-Go alternative entails no change to the status *quo*, in other words no PF is undertaken to extract additional oil, and current oil production continues while economically feasible. This means that the PMP and additional infrastructure is not constructed and production on the Tambaredjo Oilfield will cease as per current production timelines (and earlier than anticipated with the implementation of PF).

### 6.1.4 Impact Rating Methodology

The assessment of impacts was based on specialists' expertise, SRK's professional judgment, field observations and desk-top analysis.

The significance of potential impacts that may result from the proposed project was determined in order to assist decision-makers (typically by a designated competent authority or state agency, but in some instances, the applicant).

The **significance** of an impact is defined as a combination of the **consequence** of the impact occurring and the **probability** that the impact will occur.

The criteria used to determine impact consequence are presented in the table below.

**Table 6-1: Criteria used to determine the consequence of the impact**

| Rating | Definition of Rating | Score |
|---|---|---|
| A. *Extent– the area (distance) over which the impact will be experienced* | | |
| Local | Confined to project or study area or part thereof (e.g. the Tambaredjo Oilfield) | 1 |
| Regional | The region (e.g. Saramacca District, Saramacca River catchment, aquifers north of Saramacca River) | 2 |
| (Inter) national | Nationally or beyond | 3 |
| B. *Intensity– the magnitude of the impact in relation to the extent of the impact and sensitivity of the receiving environment, taking into account the degree to which the impact may cause irreplaceable loss of resources* | | |
| Low | Site-specific and wider natural and/or social functions and processes are negligibly altered | 1 |
| Medium | Site-specific and wider natural and/or social functions and processes continue albeit in a modified way | 2 |
| High | Site-specific and wider natural and/or social functions or processes are severely altered | 3 |
| C. *Duration– the timeframe over which the impact will be experienced and its reversibility* | | |
| Short-term | Up to 2 years and reversible | 1 |
| Medium-term | 2 to 15 years and reversible | 2 |
| Long-term | More than 15 years and irreversible | 3 |

The combined score of these three criteria corresponds to a **Consequence Rating**, as follows:

**Table 6-2: Method used to determine the consequence score**

| *Combined Score* (A+B+C) | 3 – 4 | 5 | 6 | 7 | 8 – 9 |
|---|---|---|---|---|---|
| *Consequence Rating* | Very low | Low | Medium | High | Very high |

Once the consequence was derived, the probability of the impact occurring was considered, using the probability classifications presented in the table below.

**Table 6-3: Probability classification**

| *Probability– the likelihood of the impact occurring* | |
|---|---|
| Improbable | < 40% chance of occurring |
| Possible | 40% - 70% chance of occurring |
| Probable | > 70% - 90% chance of occurring |
| Definite | > 90% chance of occurring |

The overall **significance** of impacts was determined by considering consequence and probability using the rating system prescribed in the table below.

**Table 6-4: Impact significance ratings**

| | | Probability | | | |
|---|---|---|---|---|---|
| | | Improbable | Possible | Probable | Definite |
| Consequence | Very Low | INSIGNIFICANT | INSIGNIFICANT | VERY LOW | VERY LOW |
| | Low | VERY LOW | VERY LOW | LOW | LOW |
| | Medium | LOW | LOW | MEDIUM | MEDIUM |
| | High | MEDIUM | MEDIUM | HIGH | HIGH |
| | Very High | HIGH | HIGH | VERY HIGH | VERY HIGH |

Finally the impacts were also considered in terms of their status (positive or negative impact) and the confidence in the ascribed impact significance rating. The prescribed system for considering impacts status and confidence (in assessment) is laid out in the table below.

**Table 6-5: Impact status and confidence classification**

| *Status of impact* | |
|---|---|
| Indication whether the impact is adverse (negative) or beneficial (positive). | + ve (positive – a 'benefit') |
| | – ve (negative – a 'cost') |
| *Confidence of assessment* | |
| The degree of confidence in predictions based on available information, SRK's judgment and/or specialist knowledge. | Low |
| | Medium |
| | High |

The impact significance rating should be considered by authorities in their decision-making process based on the implications of ratings ascribed below:

- **INSIGNIFICANT**: the potential impact is negligible and **will not** have an influence on the decision regarding the proposed activity/development.
- **VERY LOW**: the potential impact is very small and **should not** have any meaningful influence on the decision regarding the proposed activity/development.
- **LOW**: the potential impact **may not** have any meaningful influence on the decision regarding the proposed activity/development.
- **MEDIUM**: the potential impact **should** influence the decision regarding the proposed activity/development.
- **HIGH**: the potential impact **will** affect the decision regarding the proposed activity/development.
- **VERY HIGH**: The proposed activity should only be approved under special circumstances.

Practicable mitigation and optimisation measures are recommended and impacts are rated in the prescribed way both without and with the assumed effective implementation of mitigation and optimisation measures. Mitigation and optimisation measures are either:

- **Essential**: measures that must be implemented and are non-negotiable; and
- **Best Practice:** recommended to comply with best practice, with adoption dependent on the proponent's risk profile and commitment to adhere to best practice, and which must be shown to have been considered and sound reasons provided by the applicant if not implemented.

In addition to essential and best practice measures, a very extensive suite of Staatsolie standard management measures and procedures will be implemented. These are referred to in the EMMP.

### 6.1.5 Integration of Studies into the ESIA Report and Review

The completed specialist study and their findings have been integrated into the Limited ESIA Report. The key findings of the specialist were evaluated in relation to other observations to provide an overall and integrated assessment of the project impacts.

SRK has considered the suite of potential impacts in a holistic manner and in certain instances, based on independent professional judgment and this integrated approach, may have altered impact significance ratings provided by the specialist. Where this has been done it is indicated in the relevant section of the report.

Specialists have made recommendations for the management of impacts, and the ESIA team has assessed these recommendations. For the sake of brevity, only **key** (i.e. non-standard essential) mitigation measures are presented in impact rating tables (later in this section), with a collective summary of all recommended mitigation measures presented at the end of each discipline.

## 6.2 Less Significant (or Minor) Impacts

More significant impacts are assessed later in this chapter. Certain impacts, while important, are anticipated to be of limited or **low significance** either by virtue of the scale of the impacts, their short duration (e.g. construction phase only) and/or the disturbed nature of the receiving environment. These impacts include:

- Vibration impacts;
- Air quality impacts;
- Noise impacts;
- Visual impacts; and
- Traffic impacts.

If recommended mitigation measures are adopted, these impacts are not expected to be significant nor long term and have therefore not been subjected to detailed impact analysis. However, they have been assessed by the ESIA team and are discussed below.

### 6.2.1 Vibration Impacts

Ground vibration is a natural result of activities such as blasting, drilling and piling. The shockwave energy that travels from source could cause damage and annoyance. Energy is transmitted through the ground, creating vibration waves that propagate through soil and rock strata to the foundations of nearby buildings. Once the vibration reaches a building, it is transferred through the foundations into the structure. Any structural resonances that may be excited will increase the effect of the vibration.

Humans are extremely sensitive to low levels of vibration and can detect levels of ground vibration of less than 0.1 mm/s, less than one hundredth of the levels which could cause even minor cosmetic damage to a normal building. Complaints and annoyance regarding ground vibration are therefore much more likely to be determined by human perception than by noticing minor structural damage. However, these effects, and the startling effect of sudden impulses of both sound and vibration can be a source of nuisance.

During *construction*, potential sources of vibration and associated impacts on nearby structures include construction activities, such as compacting, drilling and/or piling for the PMP and well construction. Typical vibration levels of vibration-generating equipment and activities such as piling and compacting are low.

There are no sensitive structures in the vicinity of the project site. The structures nearest to the proposed PMP are the Staatsolie Sarah Maria facility located 1.7 km away. While some injection Phase 1 injection and producer wells will be located in the vicinity of the Sarah Maria facility, several existing producers are located even closer. It is thus expected that Staatsolie will manage well drilling appropriately to prevent any vibration impacts on nearby structures.

There are no notable sources of vibration during *operation*.

The significance of potential vibration impacts on structures and nearby residents is considered *insignificant*.

The above assessment is based on the assumption that the following measures are implemented during construction:

- Implement standard vibration management and monitoring measures during piling, drilling and compacting.

### 6.2.2 Air Quality

Above certain concentrations, air pollutants may have public health impacts, such as increasing the rate of certain cardiovascular (heart) and pulmonary (lung) diseases, cancers and strokes (AGI, 2018). Common pollutants include sulphur dioxide ($SO_2$), nitrogen dioxide ($NO_2$), particulate matter (PM), carbon monoxide (CO) and volatile organic compounds (VOCs).

The most significant atmospheric emissions during *construction* include:

- Fugitive particulate matter (Total Suspended Particulates, $PM_{10}$ and $PM_{2.5}$[9]) due to bulk earthworks, windblown dust from exposed surfaces, stockpiles and the construction of infrastructure; and
- Particulate matter and gases from combustion of fuels by mobile equipment (CO, $PM_{10}$, $PM_{2.5}$, $SO_2$ and VOCs).

The most significant atmospheric emissions during *operation* include particulate matter and gases from combustion of fuels by mobile equipment and evaporation from the oil and gas being extracted, stored and transported (CO, $PM_{10}$, $PM_{2.5}$, $SO_2$ and VOCs). No other significant sources of emissions from project operation have been identified, as the PMP will obtain power from existing sources.

Air quality measurements undertaken in 2018 showed that baseline air quality is generally good, despite existing operations in the Tambaredjo Oilfield (see Section 4.1.3). The extent of increased ambient pollutant concentrations will depend on the level of additional activity. Traffic and oil production by the PF project will be relatively limited compared to the existing and historic activity in the Tambaredjo Oilfield. As the project area is largely vegetated, and the nearest producer wells are located ~1 km from residences, the ambient concentration of pollutants emitted by oilfield activities is expected to be below guideline values at receptors.

The Gangaram Pandayweg is the only access road leading to the Tambaredjo Oilfield. Any additional vehicles transporting persons, material and equipment for the project will add to dust generated by general and Staatsolie traffic on the road, further affecting air quality which may pose a human health risk. Furthermore, dust settles on the roofs of houses, cars and any other surface within the homes, posing a nuisance to residents living along the road.

The significance of potential air quality impacts on nearby residents is considered *very low*.

The above assessment is based on the assumption that the following measures are implemented:

[9] Particles with an aerodynamic diameter less than 10 micron and less than 2.5 micron, respectively

During construction:

- Limit and phase vegetation clearance and the construction footprint to what is essential;
- Reduce airborne dust through e.g. dampening dust-generating areas, roads and stockpiles with water; and
- Maintain all generators, vehicles, drills and other equipment in good working order to minimise exhaust fumes.

During operation:

- Maintain infrastructure and equipment such as tanks, pipelines, valves and fittings in good working order to prevent leaks and minimise evaporation of oil.
- Maintain vehicles in good working order to minimise atmospheric emissions.

Best practice air quality mitigation measures during construction are as follows:

- Schedule logistics to minimise traffic on the Gangaram Pandayweg;
- Inform nearby residents and businesses in a timely manner of delivery schedules;
- Avoid deliveries at night;
- Publicise delivery schedules on social media;
- Monitor trucks at strategic points along the Gangaram Pandayweg to determine compliance with traffic rules agreed upon between Staatsolie and contractor; and
- Intensify the dust suppression programme on the Gangaram Pandayweg during construction, especially the section from the beginning of the Gangaram Pandayweg (Km 0) to the entrance to the Tambaredjo Oilfield (Km 6).

### 6.2.3 Noise

The most significant sources of noise during *construction* include:

- Transportation of persons, materials and equipment. As the Gangaram Pandayweg is the only road providing access to the Tambaredjo Oilfield, traffic is expected to increase during project implementation and will generate noise. Excessive noise will disturb local area users, including the residents living along the road. At night, noise may disturb residents living further from the road; and
- Construction activities such as piling and drilling. However, the nearest receptors are located more than 1 km from the nearest wells to be drilled and more than 2 km from the PMP, and noise from construction activities is not expected to exceed guidelines and be a concern.

No significant sources of noise from project operation have been identified.

The significance of potential noise impacts on nearby residents is considered *very low*.

Best practice noise mitigation measures during construction are as follows:

- Schedule logistics to minimise traffic on the Gangaram Pandayweg;
- Inform nearby residents and businesses in a timely manner of delivery schedules;
- Avoid deliveries at night;
- Publicise delivery schedules on social media; and

- Monitor trucks at strategic points along the Gangaram Pandayweg to determine compliance with traffic rules agreed upon between Staatsolie and contractor.

### 6.2.4 Ecological Impacts

Secondary marsh forest vegetation dominates the vacant portions of the Tambaredjo Oilfield, including some areas where new project components will be installed. However, all new wells and infrastructure are located between and close to existing producers and infrastructure on the Tambaredjo Oilfield (see Figure 3-5). The PMP site was partially developed in the past (see Figure 3-3). As such, most of the project is located in highly disturbed areas, and vegetation clearing will be minimised. The vegetation is of low sensitivity, does not comprise vulnerable, rare or endangered plant species and occurs commonly in the Young Coastal Plain.

Through vegetation clearance some loss of habitat will occur. However, the project area is only expected to support a few adapted species, because it is close to human activity. Moreover, any wildlife can shift to neighbouring forest areas. Potential disturbances to wildlife will be caused mainly by vehicles, construction machinery, and human presence. However, in general, the species present in the vicinity of the project site are already adapted to a comparable amount of disturbance from oil production activities. Wildlife in the surrounding area may be temporarily disturbed during the construction period. However, there is sufficient opportunity to move to less noisy areas in the surrounding marsh forest.

The significance of potential terrestrial ecology impacts is considered *very low*.

### 6.2.5 Socio-economic Impacts

Eight residential clusters comprising three to four households each and one allotment project comprising four houses are located in the 8 km section from the intersection with Wayambo Road that leads past the Tambaredjo Oilfield (see Figure 4-10).

Potential socio-economic impacts of the construction phase include:

- Compromised drinking water quality from dust generated by project traffic, as households located along the Gangaram Pandayweg are not yet connected to the water distribution network. As such, most families living along the road rely on the collection of rain water for use as drinking water. Traffic on the unpaved Gangaram Pandayweg, generates dust, which settles on roofs and in gutters, contaminating drinking water collected in storage tanks. However, traffic related directly to the PF project is expected to be a minor component of overall traffic on Gangaram Pandayweg;
- Increased safety risk from heavy vehicles during construction, as residents living along the Gangaram Pandayweg complain that the speed limit (40 km/h) is regularly exceeded by heavy vehicles. More traffic (and speeding) increases the risk of accidents;
- Employment opportunities created by the project, as construction activities will provide jobs to local construction firms and workers, including subcontractors. National producers and suppliers of construction materials may experience increased business. However, construction jobs will be relatively short-term and limited, and are likely to be executed largely by specialist suppliers; and
- Damage to archaeological sites due to site clearing and earthworks. However, no known archaeological sites will be affected by the project. Unregistered sites could exist in the project footprint, as few places have been excavated, but the project is located within a dense well field that would have likely affected those sites already.

Most families residing along the Gangaram Pandayweg practise horticulture (domestic cultivation). Some agricultural fields are located in close proximity to the Tambaredjo Oilfield, and concerns have been raised about the effects of PF injection or spills on agricultural production. While some new wells will be drilled in close proximity (~200 m) to agricultural areas, existing producer wells are located even closer (~100 m) (see Figure 6-1). As such, the new wells are not expected to cause a significant impact on existing agricultural activities.

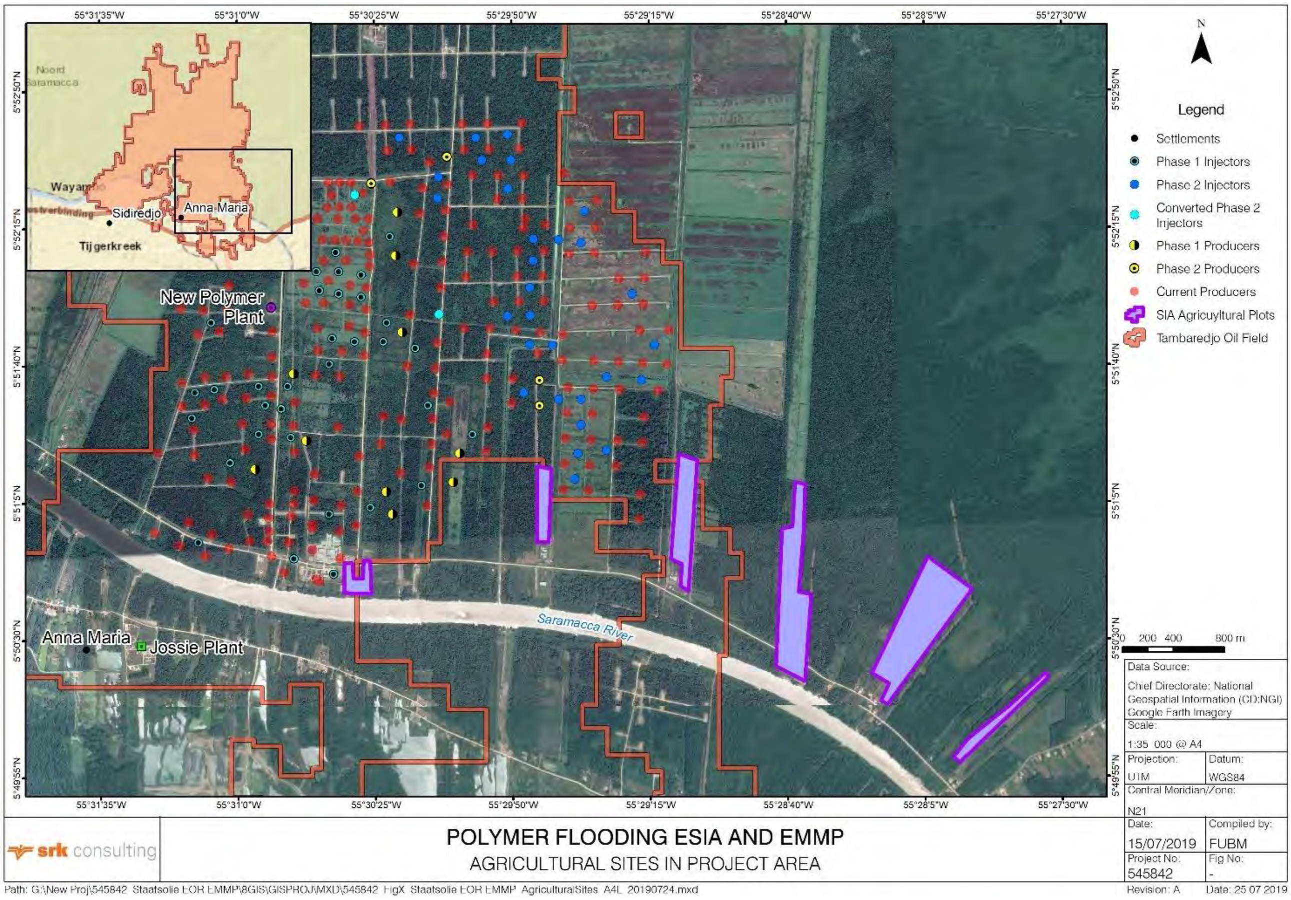



**Figure 6-1: Agricultural sites in the project area**

Source: Agricultural plots from Social Solutions (2018)

Groundwater modelling has shown that injected polymer mix is not expected to infiltrate to groundwater or reach the surface (see Section 6.3.4.2), while surface spills are likely to be localised and unlikely to spread unless they occur near drainage canals discharging into the Saramacca River, away from agricultural areas. Discharge of back produced polymer and any major spills are likely to dilute quickly in the Saramacca River, so that safe levels of potentially harmful substances (such as AAM) are not exceeded (see Sections 6.4.3.1 and 6.4.3.2 respectively).

The significance of potential socio-economic impacts is considered *very low*.

The above assessment is based on the assumption that the following measures are implemented:

- Continue to publicise and implement the existing Staatsolie grievance mechanism;
- Provide compensation in the event that a spill of polymer mix affects agricultural areas;
- Clean up any spills and contaminated soil immediately, and inform potentially affected landowners;
- Procure and utilise local skills and resources wherever possible;
- Train local people to acquire skills required for the project; and
- Compile and implement a chance finds procedure.

### 6.2.6 Visual Impacts

The current visual quality and sense of place of the project site is defined by existing oil production activities on the site.

Potential sources of visual impacts include construction equipment and activities during construction, and the PMP and associated structures and activities during operation. The magnitude of potential visual impacts from the above sources is considered *insignificant*, as:

- No public receptors (communities and commuters) are located near the site, which is located within Staatsolie's concession area and not publicly accessible;
- The activities are visually congruent with existing activities in the area. The PMP site was partially developed in the past (see Figure 3-3);
- The visual screening capacity of the surrounding vegetation is considered to be high, as trees will effectively shield visual impacts; and
- The visual impact from construction activities is relatively short-lived.

The above assessment is based on the assumption that the following measures are implemented in the project design, construction and operation phases:

- Retain screening vegetation around the site (wells) as much as possible; and
- Regularly collect and dispose of redundant equipment, waste and litter.

### 6.2.7 Traffic Impacts

The Sarah Maria facility, and Tambaredjo Oilfield, are serviced by the East-West Road and Gangaram Pandayweg. These roads are also used by many other private and commercial vehicles as well as Staatsolie employees and contractors currently working at Sarah Maria, and are most busy during the morning and afternoon rush hour.

During *construction*, potential sources of traffic impacts include construction vehicles travelling to and from the PMP and well field, to transport workers, execute works or deliver materials. The magnitude of potential traffic impacts from the above sources is considered *very low*, as:

- The construction workforce is not yet known but likely to be relatively small;
- Material will mostly be delivered outside of peak rush hour; and
- The construction period is relatively short.

During *operation*, potential sources of traffic impacts include employees travelling to work at the PMP and wells, and some ongoing commercial deliveries. The magnitude of potential traffic impacts from these sources during the operation of the PF project is considered *insignificant*, as the additional workforce of ~20 will add only a very negligibly to existing traffic volumes.

The above assessment is based on the assumption that the following measures are implemented in the project design, construction and operation phases:

- Schedule delivery of material transported by road to times that fall outside of rush hour;
- Ensure that trucks transporting large equipment or hazardous material are clearly marked and accompanied by safety vehicles; and
- Inform relevant authorities of special loads vehicles.

## 6.3 Potential Groundwater Impacts

### 6.3.1 Introduction, Terms of Reference and Methodology

This assessment is based on the Groundwater and Geochemical Study undertaken by SRK (see Appendix A). The purpose of the study was to assess the potential impacts of the project on groundwater, indicate its environmental acceptability and recommend practicable mitigation measures to minimise potential impacts and maximise potential benefits.

The ToR for the study were to:

- Describe the existing baseline characteristics of the project area / Zone of Influence and place this in a regional context;
- Identify and assess potential impacts resulting from the project (including impacts associated with the construction and, operation phases of the project;
- Indicate the acceptability of alternatives and recommend a preferred alternative;
- Identify and describe potential cumulative impacts resulting from the proposed development in relation to proposed and existing developments in the surrounding area;
- Recommend mitigation measures to avoid or minimise impacts and/or optimise benefits associated with the proposed project; and
- Recommend and draft a monitoring campaign, if applicable.

#### 6.3.1.1 Methodology

The following methodology was applied to the *geochemical* assessment:

- Review the geological conceptual model and incorporate the geochemical characteristics that affect the fate and transport of chemicals injected during PF. Review induced effects caused by the degradation of PF additives on naturally occurring compounds in the host matrix which may be mobilised under changing geochemical conditions. As the geochemical environment plays a critical role in determining the most likely biodegradation pathways for organic compounds in groundwater, the geochemical conceptual model was integrated with the hydrogeological conceptual model and transcribed into the 3-D numerical model to predict the potential risk to the upper groundwater resources;
- Compile a database of physical, chemical and toxicological properties of the known PF additives, based on the Material Safety Data Sheet (MSDS)/Safety Data Sheet (SDS) and available international chemical references;
- Rank parameters affecting the solubility (e.g. pH, Eh), mobility (e.g. partition co-efficient) and persistence (biodegradation) of chemicals;
- Assess the potential effect of biological degradation of the organic compounds and toxicity of the daughter products and intermediaries. Where biodegradation rates are not known, modelled biodegradation rates (e.g. EPISUITE™ BIOWIN™) were used where possible; and
- Include the fate and transport characteristics in the 3-D numerical groundwater model.

The following methodology was applied to the *groundwater* assessment:

- Review and assess available data, designs, as-built drawings, reports and models;
- Develop a conceptual groundwater model, including the description of the processes that control or influence the movement and storage of groundwater and solutes in the geohydrological system;

- Source and pre-process model input data from laboratory and field test results, reports, spreadsheets, engineering designs and outputs of the geochemical study;
- Set up a 3-D numerical seepage model using the FEFLOW 7.1 (DHI-WHASY GmbH) software[10], includes definition of model type, geometry, grid and discretization, hydraulic parameter zoning and properties, boundary conditions, injection site volumes, densities and concentrations, and abstraction volumes and densities;
- Conduct model calibration to estimate parameters and fluxes within the calculated range, so that model results correspond reasonably to a pre-agreed set of outputs at particular locations or across defined sections, based on conceptual and analytical calculations, available monitoring data, as well as any field and laboratory data from comparable sites; and
- Run predictive model scenarios focussing on the potential for impact on the upper, fresher water sections of the aquifer and the local river, from both a flow (volume) and chemical (contamination) perspective. Outputs include changes to groundwater levels, mass balances and potential plume migration distances/areas and sensitivity analyses.

Depths are presented in feet (ft) as provided by Staatsolie, although numerical model output graphs utilise meters (m).

### 6.3.2 Chemicals of Potential Concern

The physical and chemical properties of the PF additives (and degradation products) and chemical hazard based on the solubility, mobility, persistence and toxicity are summarised below.

#### 6.3.2.1 Polyacrylamide

Polyacrylamide (PAM) refers to a group of water-soluble molecules formed by polymerization of acrylamide monomers (AAM). Aside from EOR, PAM is used in a range of other industries, e.g. as a thickener or flocculant in grout, cement, sewage/wastewater treatment, pesticide formulations, cosmetics, sugar manufacturing, food packaging, plastic products and paper production and as a soil conditioner in agriculture, mining and construction to limit soil erosion and improve irrigation efficiency and dust control.

PAM is highly soluble and considered non-toxic, but susceptible to retention and degradation within the reservoir. PAM has a relatively high partition coefficient. The adsorption of PAM onto mineral surfaces has been demonstrated to be rapid and is dependent on the PAM structure, reservoir mineralogy and groundwater characteristics. Due to the long length of the polymer and large number of anionic groups, PAM's adsorption occurs at multiple sites along the polymer length. As such, there is a small probability that all train segments are simultaneously detached from the surface, and adsorption is considered irreversible.

Due to their large size, PAM molecules become physically trapped in blind pores as a function of the physical properties of the reservoir matrix. As PAM molecules are forced through narrow interstitial spaces within the reservoir, the molecules which are sensitive to shearing, are broken into smaller pieces. PAMs are very insensitive to bacteria, although sulphate reducing bacteria (as detected in well 1J22 and widely present in the reservoir) can degrade the polymer.

Biological degradation breaks down the PAM creating smaller lower molecular weight polymers. During this process no AAM monomer is released. The chemical degradation of PAM is more

[10] An axisymmetric radial groundwater flow model was used to evaluate pressure effects and plume migration because the hydrostratigraphy is considered to be relatively horizontal and homogeneous at depth, if anisotropic.

pronounced than the biological degradation and is promoted by free radicals. The PAM solution is susceptible to chemical degradation by dissolved oxygen, $H_2S$, and $Fe^{2+}$.

#### 6.3.2.2 Acrylamide

All PAMs contain some level of residual AAM due to an incomplete polymerization process; the amount varies substantially depending on the manufacturing process.

AAM is a likely human carcinogen and neurotoxin, highly soluble in water, has a low potential to partition to organic matter, and has a low volatilization potential in water; it is therefore considered the key environmental risk associated with the use of PAMs. The residual AAM concentration of the PAM used in Staatsolie's trial is 0.04% (based on the MSDS), within the expected range of residual AAM in high molecular weight PAM.

AAM is highly soluble in water, has a low potential to partition to organic matter, and has a low volatilization potential in water. It is therefore unlikely to adsorb to mineral surfaces in the reservoir.

The maximum permissible concentration in drinking water is 0.5 µg/L (WHO, 2011). No limits have been published for livestock watering. No adverse effects on soil microbial populations have been reported from agricultural application at 3 – 7 kg/ha. Residual AAM concentrations in crops are low, and AAM is not absorbed by plant tissues and apparently breaks down rapidly when exposed to living plant tissue (Sojka, Biorneberg, Entry, Lentzl, & Orts, 2007).

The EU (2002) risk assessment for AAM reviewed available ecotoxicological studies and derived a Predicted No Effects Concentration (PNEC) for aquatic organisms of 33.85 µ/L AAM. *This value was derived from the lowest No Observed Effect Concentration (NOEC) from acute toxicity tests for freshwater species and includes an assessment (safety) factor of 1 000 as no long-term studies on fish or the water flea Daphnia magna* were conducted.

#### 6.3.2.3 Ammonium

Ammonium ($NH_4^+$) is a likely daughter product formed during the degradation of PAM that depends on temperature, pH and concentration of dissolved salts in the water it enters. The ammonium cation is less mobile in soil and water than ammonia and is involved in the biological processes of nitrogen fixation, mineralization and nitrification. $NH_4^+$ impacts on aquatic ecology (particularly fish) and suitability of water as potable water.

#### 6.3.2.4 Acrylic Acid

Acrylic acid (AA) is another likely daughter product formed during the degradation of PAM. AA is very soluble in water and is not generally expected to adsorb to mineral surfaces.

In biological oxygen demand (BOD) studies, AA has been shown to biodegrade rapidly under aerobic conditions. AA is also amenable to anaerobic treatment. Although AA is moderately toxic to aquatic life, it is not persistent in aquatic environments, due to rapid oxidation. Large releases can deplete dissolved oxygen (BAMM, 2013). The half-life for AA degradation under aerobic conditions in sandy soil is estimated to be less than 1 day (INCHEM, 1997).

### 6.3.3 Assessment of Impacts: Construction Phase

The following potential construction phase impact was identified and assessed:

- G1: Contamination of groundwater from accidental to spills and well drilling.

#### 6.3.3.1 Potential Impact G1: Contamination of Groundwater from Accidental Spills and Well Drilling

Leaks and spills of contaminants on exposed surface areas during construction could, in principle, contaminate underlying groundwater. However, there is no shallow (superficial) groundwater, while the aquifers below the project site are deep and have no connectivity to and are isolated from the surface, as they are covered by thick impermeable clay layers. As such, contamination is unlikely to migrate and surface spills are unlikely to result in groundwater contamination.

Injector and producer wells drilled to ~ 990 ft below ground level (bgl) will intersect aquifers, including an aquifer at ~490 ft bgl that is used for freshwater abstraction at Tijgerkreek, some 12 km to the south-west of the closest injector well. Drilling could be a source for pollutants to reach groundwater if e.g. toxic drilling fluid is used. Given low transmissivity, it is unlikely that any contamination would reach the abstraction point at Tijgerkreek in concentrations exceeding guidelines (also see Section 6.3.4.4). Groundwater is not abstracted for drinking purposes in the vicinity of the Tambaredjo Oilfield, but some is abstracted for process water. In the event of contamination reaching groundwater, it is likely to persist for the medium term.

The impact is assessed to be of ***very low*** significance and with the implementation of mitigation is reduced to ***insignificant*** (Table 6-6).

**Table 6-6: Significance of contamination of groundwater due to spills and well drilling**

| | *Extent* | *Intensity* | *Duration* | *Consequence* | *Probability* | *Significance* | *Status* | *Confidence* |
|---|---|---|---|---|---|---|---|---|
| Without mitigation | Local<br>1 | Medium<br>2 | Medium<br>2 | Low<br>5 | Possible | VERY LOW | – ve | Medium |
| Key essential mitigation measures:<br>• Use non-toxic drilling fluids when drilling through freshwater aquifers.<br>• Ensure that well casing and cementing meets best practice methods to prevent chemical losses into the upper layers above the oil reservoir. | | | | | | | | |
| With mitigation | Local<br>1 | Low<br>1 | Short-term<br>1 | Very Low<br>3 | Improbable | INSIGNIFI-CANT | | Medium |

### 6.3.4 Assessment of Impacts: Operation Phase

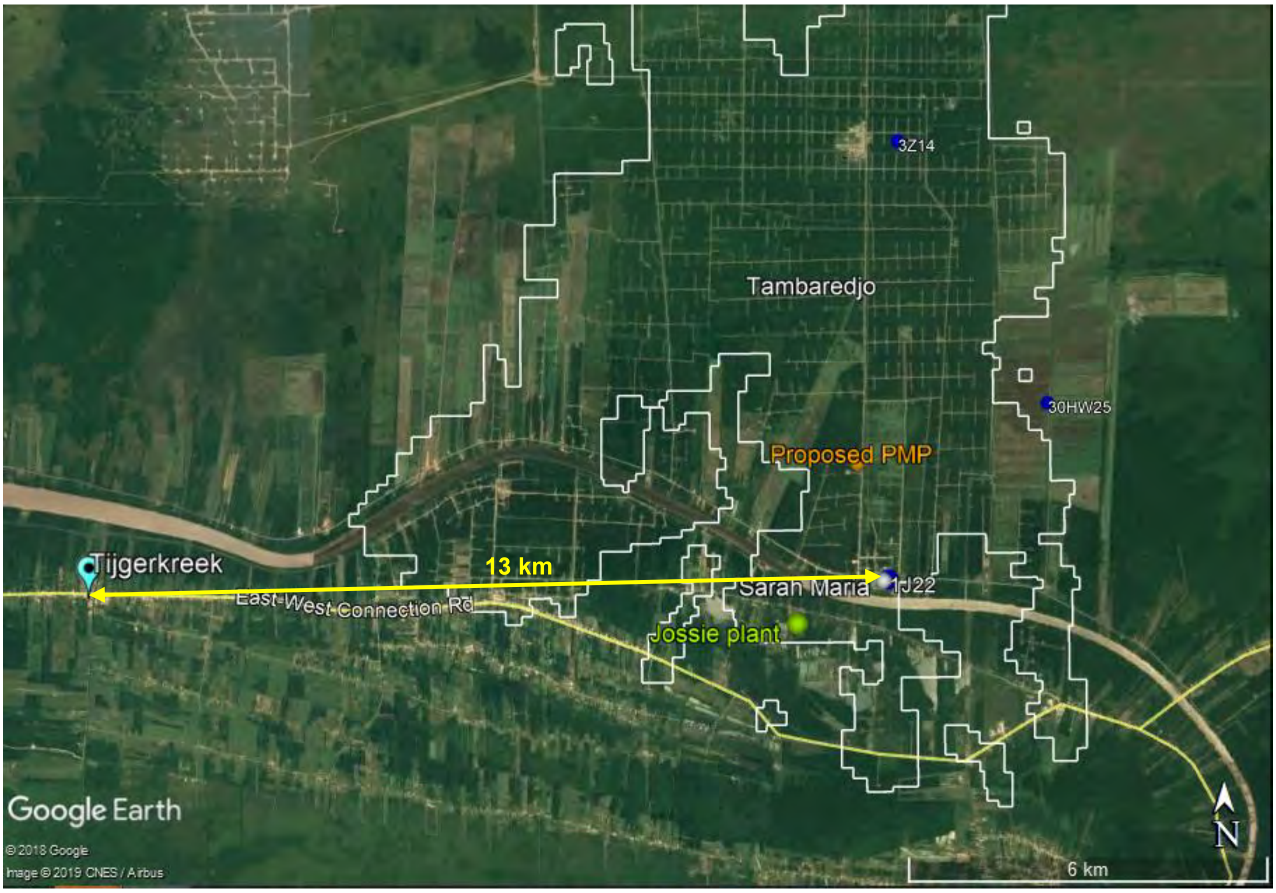
The following potential operation phase impacts and risks were identified and assessed:

- G2: Reduction in groundwater level and supply due to groundwater abstraction;
- G3: Contamination of groundwater in brackish aquifer due to intrusion of polymer mix;
- G4: Contamination of groundwater in freshwater aquifer due to intrusion of polymer mix; and
- G5: Groundwater contamination due to accidental leakage from a well.

#### 6.3.4.1 Potential Impact G2: Reduction in Groundwater Level and Supply due to Groundwater Abstraction

Groundwater abstracted from borehole 1J22 may be used to supply the PF project. Numerical modelling indicates that the maximum horizontal extent of the drawdown zone is ~100 m from the pumping borehole, while the maximum drawdown cone at the borehole is ~4 m.

No other boreholes are being pumped for water supply within 100 m of 1J22, and there is thus no expected effect on other boreholes from abstraction at 1J22. The drawdown from 1J22 will also not affect the Suriname Waterleiding Maatschappij (SWM) abstraction borehole at Tijgerkreek, which is located 13 km from 1J22 (see Figure 6-2) and well beyond the zone of influence of the PF project and the modelled area.




| srk consulting | POLYMER FLOODING LIMITED ESIA AND EMMP<br>Distance between Tijgerkreek and 1J22 abstraction points | Project No.<br>545842 |
|---|---|---|

**Figure 6-2: Distance between Tijgerkreek and 1J22 abstraction points**

The impact is assessed to be of ***low*** significance (Table 6-7).

**Table 6-7: Reduction in groundwater level and supply due to groundwater abstraction**

| | Extent | Intensity | Duration | Consequence | Probability | Significance | Status | Confidence |
|---|---|---|---|---|---|---|---|---|
| Without mitigation | Local<br>1 | Low<br>1 | Long-term<br>3 | Low<br>5 | Improbable | VERY LOW | -ve | High |
| Key essential mitigation measures:<br>• Obtain a license from the Minister of Natural Resources for the extraction of groundwater. | | | | | | | | |
| With mitigation | Regional<br>1 | Low<br>1 | Long-term<br>3 | Low<br>5 | Improbable | VERY LOW | -ve | High |

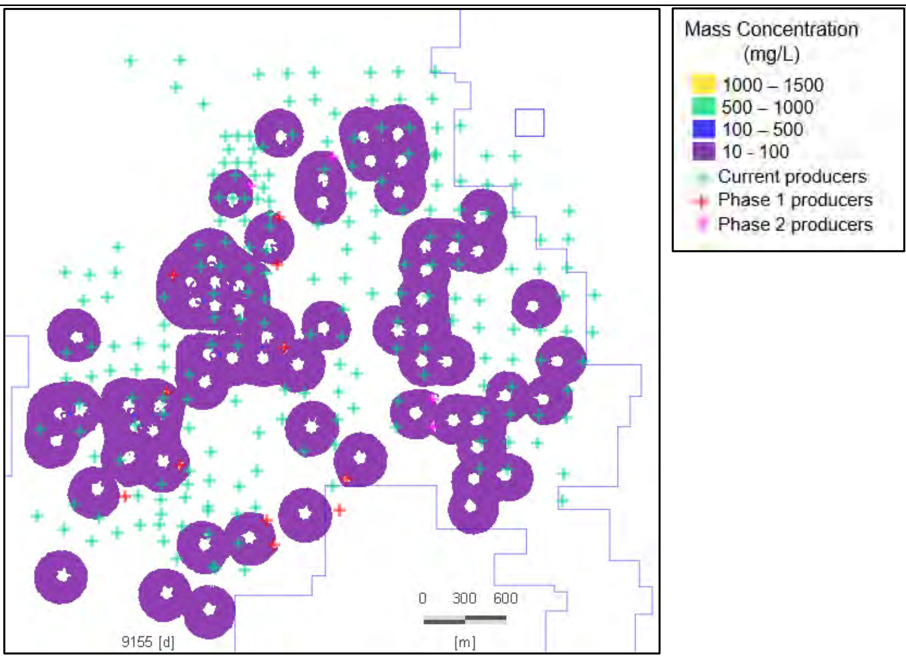
### 6.3.4.2 Potential Impact G3: Contamination of Groundwater in Brackish Aquifer due to Intrusion of Polymer Mix

Over time, some of the polymer mix injected into the oil-bearing layer will migrate horizontally within the layer and vertically into overlying (and underlying) layers, with the bulk either abstracted at producer wells or fully degrading within the oil reservoir layer; it thus has the potential to contaminate groundwater contained in overlying layers. Brackish water is contained in the layer at ~790 ft bgl, i.e. ~200 ft above the oil reservoir.

PAM is considered non-toxic but contains a residual amount of AAM due to an incomplete polymerization process. AAM is considered a likely human carcinogen and neurotoxin with a maximum permissible concentration in drinking water of 0.5 µg/L (WHO, 2011). In the polymer mix, AAM is likely to be present at a concentration of 400 µg/L at the point of injection[11].

After injection into wells, PAM breaks down chemically or biologically to form naturally occurring compounds of low toxicity, such as $NH_4^+$ and AA. These are unlikely to travel as far as PAM, since $NH_4^+$ is readily adsorbed and AA biodegrades rapidly. As such, the residual concentration of AAM is considered the major environmental risk associated with the use of PAMs. No additional AAM is formed during the PAM degradation process. AAM migrates faster than PAM presenting a greater risk of dispersed contamination, but also degrades faster, counteracting this risk.

The numerical model has thus used PAM to represent the maximum fate and transport of all chemicals of potential concern, including AAM. Based on injection and production (abstraction) rates provided by Staatsolie, the model indicates that PAM will spread vertically (upward) by a maximum (worst-case) 328 ft, to a depth of 656 ft bgl. Some PAM will thus migrate up to the brackish groundwater layers ~200 ft above the reservoir (at ~790 ft bgl) (see Figure 6-3). The predicted concentrations of PAM shown in Figure 6-3 do not factor in any degradation of PAM and are thus likely to overestimate residual PAM (and, therefore, AAM) concentrations.




| srk consulting | POLYMER FLOODING LIMITED ESIA AND EMMP<br>Predicted PAM concentration at 784 ft bgl in Year 25 | Project No.<br>545842 |
|---|---|---|

**Figure 6-3: Predicted PAM concentration at 784 ft bgl in Year 25**

As the water from that brackish groundwater layer is not suitable for drinking purposes, the intensity of the impact will be limited. PAM that has migrated into this layer will degrade over time.

The impact is assessed to be of ***low*** significance (Table 6-8).

[11] Expected concentrations based on a PAM concentration of 1 000 mg/L and residual AAM of 0.04% would be 1 000 mg/L * 0.04% = 0.4 mg/L = 400 µg/L The maximum AAM concentration, assuming a maximum PAM concentration of 1 500 mg/L in the polymer mix, and residual AAM concentration of 0.1% in the PAM, the AAM concentration would be 1 500 mg/L * 0.1% = 1.5 mg/L = 1 500 µg/L.

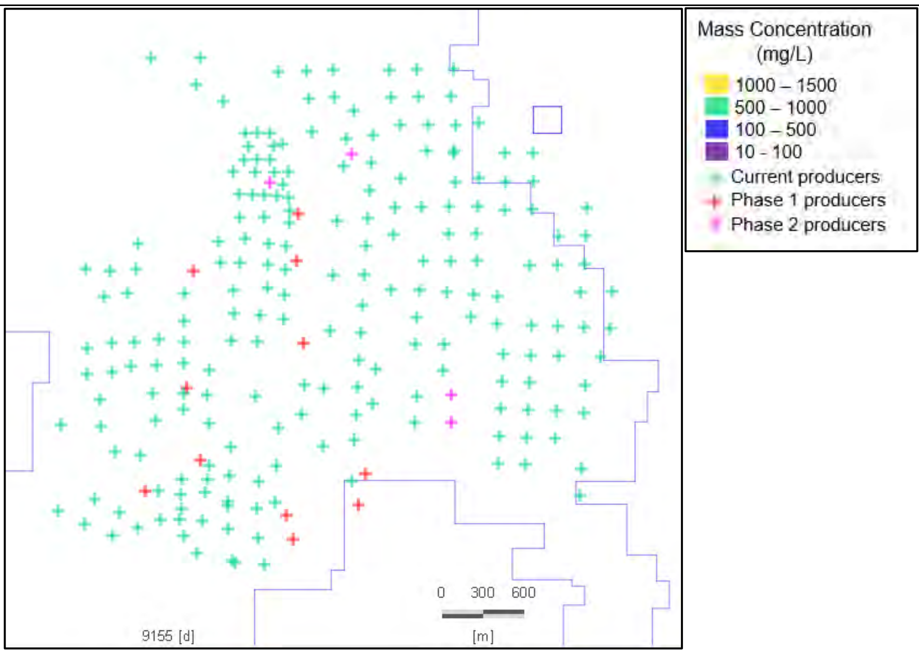
**Table 6-8: Significance of contamination of groundwater in brackish aquifer due to intrusion of polymer mix**

| | Extent | Intensity | Duration | Consequence | Probability | Significance | Status | Confidence |
|---|---|---|---|---|---|---|---|---|
| Without mitigation | Local<br>1 | Low<br>1 | Long-term<br>3 | Low<br>5 | Probable | LOW | -ve | Medium |
| Key essential mitigation measures:<br>• Manage injection pressures to ensure that the PF chemicals are not chased/forced beyond the confines of the oil reservoir. | | | | | | | | |
| With mitigation | Local<br>1 | Low<br>1 | Long-term<br>3 | Low<br>5 | Probable | LOW | -ve | High |

### 6.3.4.3 Potential Impact G4: Contamination of Groundwater in Freshwater Aquifer due to Intrusion of Polymer Mix

The discussion provided in Section 6.3.4.2 refers. Freshwater is contained in the aquifer at ~490 ft bgl (500 ft above the oil reservoir). Water abstracted at the Tijgerkreek well some 12 km from the nearest injector well, and potentially at 1J22 for the PF project, exploit this aquifer.

Based on injection and production (abstraction) rates provided by Staatsolie, the model indicates that PAM will migrate vertically (upwards) by a maximum (worst-case) 328 ft, to a depth of 656 ft bgl. It is thus not expected that PAM will migrate to the freshwater layer at ~490 ft bgl (see Figure 6-4).




| | | |
|---|---|---|
| srk consulting | POLYMER FLOODING LIMITED ESIA AND EMMP<br>Predicted PAM concentration at 490 ft bgl in Year 25 | Project No.<br>545842 |

**Figure 6-4: Predicted PAM concentration at 490 ft bgl in Year 25**

The impact is assessed to be *insignificant*.

### 6.3.4.4 Potential Risk G5: Groundwater Contamination due to Accidental Leaks from a Well

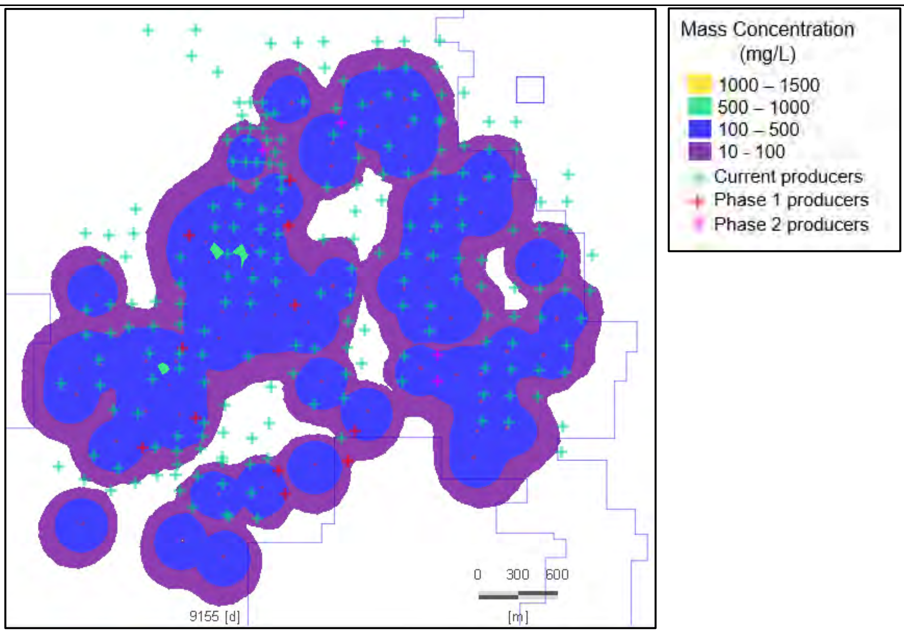
Although not anticipated during routine project operations, and thus not a project impact, this section considers the potential effect of spills from a leaking well. If a well is improperly cased, polymer (and AAM) could enter groundwater layers above the reservoir in high concentrations that far exceed the safe drinking water level of 0.5 µg/L. A key concern regarding leaked polymer relates to the contamination of groundwater that is abstracted for drinking purposes.

If contamination occurs, it is not chemically possible to effectively treat polluted groundwater, both *in situ* and once abstracted. However, AAM (the contaminant of prime concern) will degrade over time.

AAM degradation rates and consequent concentrations depend on the specific circumstances, such as location and volume of the leak, and it could take years for a large leak to fully degrade to drinking water concentrations. Monitoring at the abstraction point and possibly at new sentinel wells would be required if a major leak does occur.

The behaviour of a leaked polymer plume cannot be modelled as it represents a risk (unplanned event) as opposed to an impact (arising from a planned and foreseeable activity), and factors such as leak volume, leak location (depth of leak and distance to nearest abstraction point), site-specific degradation rate, groundwater volume and transmissivity (groundwater flow speed) are unknown.

However, the predicted behaviour of PAM in the reservoir the polymer mix is injected into can provide an indication of the behaviour of a (very large) leak at a different level along the well, as the hydrogeological characteristics are broadly comparable in the oil-bearing and groundwater-bearing layers, comprised of sand. Based on injection and production (abstraction) rates provided by Staatsolie for the project, the model indicates that PAM spreads radially by 100 – 150 m after one year in the reservoir. At its greatest extent, polymer will have spread horizontally by ~250 m from injector wells (see Figure 6-5).



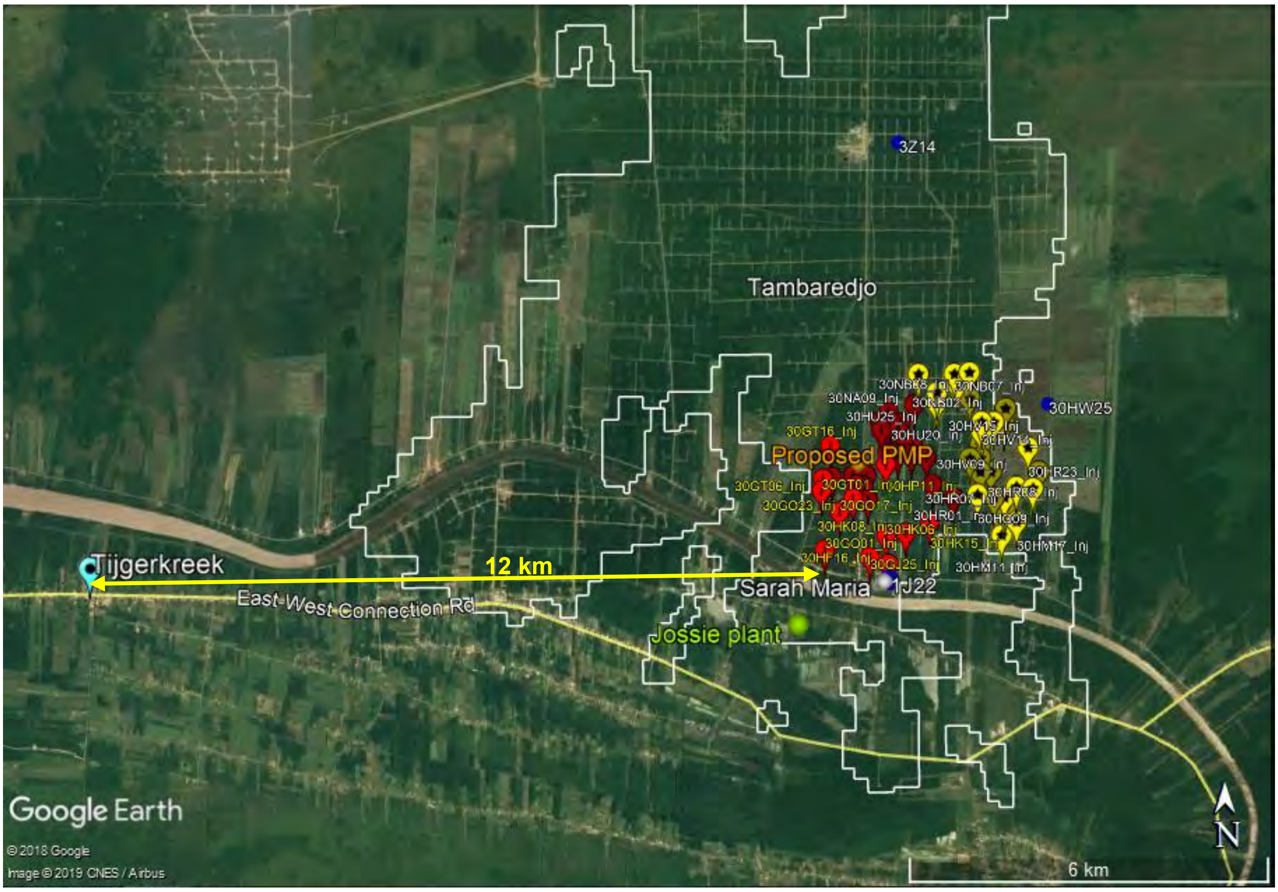

| | | |
|---|---|---|
| srk consulting | POLYMER FLOODING LIMITED ESIA AND EMMP<br>Predicted PAM concentration at 990 ft bgl (oil reservoir) in Year 25 | Project No.<br>545842 |

**Figure 6-5: Predicted PAM concentration at 990 ft bgl (oil reservoir) in Year 25**

As the Tijgerkreek abstraction point is 12 km from the closest injector well (see Figure 6-6), a spill of polymer mix due to a leaking well into a groundwater bearing layer, notably the freshwater layer, is expected to remain localised and extremely unlikely to reach the Tijgerkreek abstraction point before full degradation of the PAM and AAM.

Any future groundwater abstraction close to the Tambaredjo Oilfield may, however, be affected, and water quality would need to be monitored.

The risk of a leak (i.e. unplanned loss of polymer mix in the upper well layers) can be effectively mitigated by installing appropriate casing aligned to best practice principles, which is also critical to the successful execution of the PF project, to maintain pressure and volume of the polymer mix and produced fluid.




| srk consulting | POLYMER FLOODING LIMITED ESIA AND EMMP<br>Distance between Tijgerkreek and closest injector well | Project No.<br>545842 |
|---|---|---|

**Figure 6-6: Distance between Tijgerkreek and closest injector well**

The impact is assessed to be of ***medium*** significance and with the implementation of mitigation is reduced to ***low*** (see Table 6-9).

**Table 6-9: Significance of groundwater contamination due to accidental leaks from a well**

| | Extent | Intensity | Duration | Consequence | Probability | Significance | Status | Confidence |
|---|---|---|---|---|---|---|---|---|
| Without mitigation | Local<br>1 | High<br>3 | Medium<br>2 | Medium<br>6 | Probable | MEDIUM | -ve | Medium |
| Key essential mitigation measures:<br>• Ensure that well casing and cementing meets best practice methods to prevent chemical losses into the upper layers above the oil reservoir.<br>• Monitor polymer mix injection pressure and flow rate, to ensure no polymer mix is unaccounted for.<br>• In the event of a leak, cease injection of polymer mix at the well.<br>• In the event of a major leak, monitoring groundwater quality at the water abstraction point and possibly at new sentinel wells. | | | | | | | | |
| With mitigation | Local<br>1 | High<br>3 | Medium<br>2 | Medium<br>6 | Possible | LOW | -ve | Medium |

## 6.3.5 The No-Go Alternative

The No-Go alternative entails no change to the status *quo*, in other words no PF is undertaken to extract additional oil, while current oil production continues while economically feasible. This means that the PMP and additional infrastructure is not constructed and production on the Tambaredjo Oilfield will cease as per current production timelines (and earlier than anticipated with the implementation of PF).

As such, no polymer mix will be injected into the reservoir, and no additional (ground)water supplies for PF are required. There will be no impacts on or risks to groundwater associated with the PF project.

### 6.3.6 Mitigation Measures: Potential Groundwater Impacts

**Essential** groundwater mitigation measures during **construction** are as follows:

- Use non-toxic drilling fluids when drilling through freshwater aquifers.
- Ensure that well casing and cementing meets best practice methods and Staatsolie standards to prevent chemical losses into the upper layers above the oil reservoir.
- Develop (or maintain and adapt) procedures for the safe transport, handling and storage of potential pollutants;
- Design and construct hazardous material storage facilities with suitable impermeable materials and a minimum 110% containment capacity;
- Ensure all on site staff are trained in the use of spill prevention measures; and
- Clean up any spills immediately, through containment and removal of free product and appropriate rehabilitation or disposal of contaminated soils.

**Essential** groundwater mitigation measures during **operation** are as follows:

- Obtain a license from the Minister of Natural Resources for the extraction of groundwater.
- Manage injection pressures to ensure that the PF chemicals are not chased/forced beyond the confines of the oil reservoir.
- Monitor polymer mix injection pressure and flow rate, to ensure no polymer mix is unaccounted for.
- Develop (or maintain and adapt) procedures for the safe transport, handling and storage of potential pollutants;
- Ensure all on site staff are trained in the use of spill prevention measures;
- Clean up any spills immediately, through containment and removal of free product and appropriate rehabilitation or disposal of contaminated soils;
- Cease injection of polymer mix at the well in the event of a leak; and
- Monitor groundwater quality at the water abstraction point and possibly at new sentinel wells in the event of a leak.

**Essential** groundwater mitigation measures during **decommissioning** are as follows:

- Remove all old surface equipment, contaminated soil from small spills and other waste at the surface.
- Plug the well in accordance with best practice methods to prevent leaks of fluids and methane to the surface and of oil, gas or salty water into freshwater aquifers.

### 6.3.7 Monitoring: Potential Groundwater Impacts

- Monitor groundwater quality before initiation of the PF project and quarterly thereafter.
- Monitor groundwater level quarterly when abstracting groundwater for the PF project.

## 6.4 Potential Surface Water Impacts

### 6.4.1 Introduction, Terms of Reference and Methodology

This assessment was included in the Groundwater and Geochemical Study undertaken by SRK (see Appendix A).

The objectives of the surface water quality assessment is to:

- Describe the hydrological characteristics and surface water chemistry of the study area in general;
- Determine the potential for the project to impact on nearby surface water bodies, notably the Saramacca River;
- Assess the vulnerability of surface water resources, including the identification of potential pollutant linkages; and
- Recommend mitigation measures to reduce the potential for impacts on surface water.

### 6.4.2 Assessment of Impacts: Construction Phase

The following potential direct construction phase impact was identified:

- S1: Contamination of surface water, affecting ecosystems.

#### 6.4.2.1 Potential Impact S1: Contamination of Surface Water, Affecting Ecosystems

Site preparation, excavation and construction of the PMP, wells and associated infrastructure will likely result in some direct impact on the water quality in the Kisoensingh-west Canal and other canals draining the Tambaredjo polder, which discharge into the Saramacca River. These canals are already impacted by Staatsolie activities in the polder. The most likely potential contaminants and their potential effects are:

- Hydrocarbons, such as oil, petrol or diesel from construction equipment and associated fuels, which could impact on water quality of the receiving water body. Small amounts of hydrocarbons readily break down in the soil and aquatic environment, and only larger volumes are of significant concern; and
- Suspended solids, which can also be harmful to biota and the aquatic environment as they affect benthic ecosystems, block respiratory organs of fish, reduce photosynthesis in plants, etc.

Given the artificial and somewhat disturbed characteristics of the receiving canal environment (see Section 4.1.5.1), impacts due to contamination are considered of medium intensity in localised areas close to point source discharges.

The impact is assessed to be of ***very low*** significance (Table 6-10).

**Table 6-10: Significance of contamination of surface water affecting ecosystems**

| | *Extent* | *Intensity* | *Duration* | *Consequence* | *Probability* | *Significance* | *Status* | *Confidence* |
|---|---|---|---|---|---|---|---|---|
| Without mitigation | Local 1 | Medium 2 | Short-term 1 | Very Low 4 | Definite | VERY LOW | – ve | High |
| Key essential mitigation measures:<br>• Implement good housekeeping practices. | | | | | | | | |
| With mitigation | Local 1 | Medium 2 | Short-term 1 | Very Low 4 | Definite | VERY LOW | – ve | High |

### 6.4.3 Assessment of Impacts: Operation Phase

The following potential operation phase impacts and risks were identified:

- S2: Impacts from the disposal of back produced polymer on surface water quality; and
- S3: Risks from chemical spills or leaks to surface water quality.

Required water volumes for the PF process are insignificant compared to water volumes in the Saramacca River; consequently, impacts from abstraction of surface water from the Saramacca River are considered insignificant and are not assessed.

#### 6.4.3.1 Potential Impact S2: Impacts from the Disposal of Back Produced Polymer on Surface Water Quality

From the production well, the produced fluid will be pumped to the Jossie Crude Treatment Facility, where the crude and produced water are separated. The produced water (back-produced polymer) is then treated and disposed of. At present, the treated produced water from the PF trial phase is discharged to the Saramacca River, which is also currently proposed for the PF project.

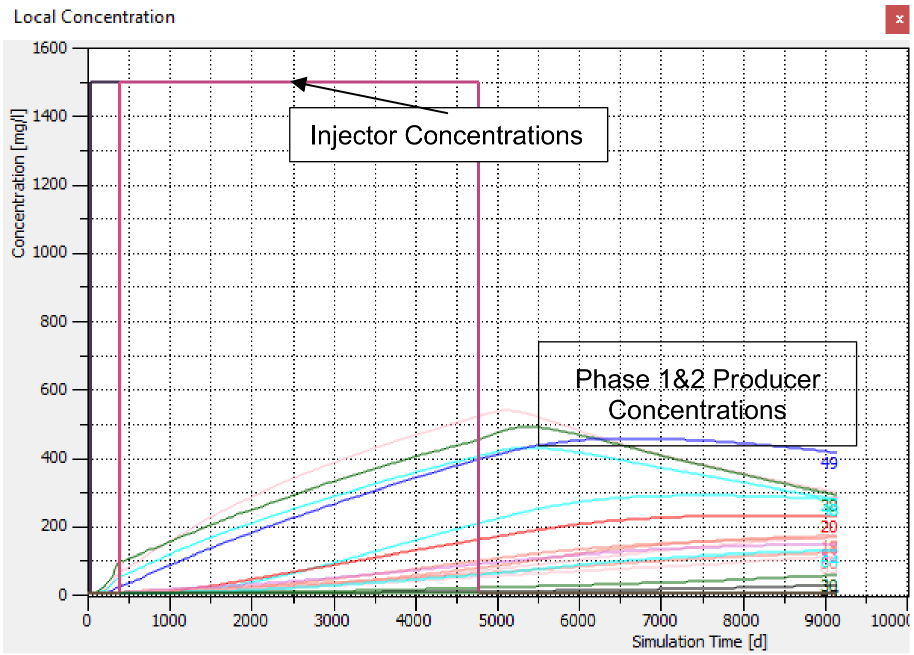
Based on assumptions of river geomorphology, the Saramacca River contains ~1.6 $Mm^3$ of water in the 4 km section adjacent to the Tambaredjo Oilfield[12], into which the treated produced water would be discharged.

The maximum estimated discharge volume is ~1 190 $m^3/d$ (9 925 bbl/d) of produced water, containing a maximum of 833 kg/d of PAM[13] (at 700 mg/L of PAM in the produced water – the peak concentration of PAM predicted by the model to occur in Year 21, see Figure 6-7). This implies an AAM concentration of 700 µg/L (at 0.1% of PAM) in the produced fluid / discharge, or 0.8 kg/d AAM discharge in 1 190 $m^3/d$ produced water. At full dilution in the 4 km Saramacca River section adjacent to the Tambaredjo Oilfield, the average PAM concentration in the river water would be 0.5 mg/L[14] and the average AAM concentration would be 0.5 µg/L[15], well below the EU aquatic threshold of 33.8 µg/L and equivalent to the WHO maximum permissible concentration in drinking water of 0.5 µg/L (WHO, 2011).

Flow in the Saramacca River will transport the water plume and contaminants away from the site, resulting in a potential impact of regional extent. As AAM is considered to be a likely human carcinogen and neurotoxin, and the calculated concentration of AAM in the river water near the Tambaredjo Oilfield could approach the WHO limit, the intensity of the impact is conservatively rated medium. As disposal will take place throughout the 25 years of the PF project, the duration is long-term.

The likelihood of the impact occurring is deemed possible (not probable), as the considered scenario is very conservative; it essentially ignores degradation of AAM and further dilution with other produced water that is generated from oil production at the Tambaredjo oilfield and assumes maximum discharge volume at all times and no.

[12] Assuming a triangular cross-sectional area for the river (160 m x 5 m deep) and a length of 4 000 m (from Jossie Plant to edge of Tambaredjo oil field), this results in a river water volume of 160 m x 2.5 m x 4 000 m x 1 000 $L/m^3$ = 1 600 000 000 L.
[13] Based on the reservoir model concentration of 1 000 mg/L PAM.
[14] 833 000 000 mg/d / 1 600 000 000 L = 0.5 mg/L per day PAM.
[15] Assuming conservatively that AAM is 0.1% of PAM, then the concentration of AAM (µg/L) = 0.5mg/L PAM x 0.1% x 1 000 = 0.5 µg/L.




| Produced Polymer Concentration P10 | |
|---|---|
| Year | mg/L |
| 1 month | |
| 1 | 34 |
| 2 | 49 |
| 3 | 93 |
| 4 | 154 |
| 5 | 217 |
| 6 | 274 |
| 7 | 326 |
| 8 | 374 |
| 9 | 414 |
| 10 | 446 |
| 11 | 468 |
| 12 | 494 |
| 13 | 521 |
| 14 | 547 |
| 15 | 579 |
| 16 | 604 |
| 17 | 631 |
| 18 | 651 |
| 19 | 667 |
| 20 | 681 |
| 21 | 694 |
| 22 | 553 |
| 23 | 389 |
| 24 | 290 |
| 25 | 241 |

srk consulting | POLYMER FLOODING LIMITED ESIA AND EMMP
Model PAM concentrations versus reported produced polymer concentrations | Project No. 545842

**Figure 6-7: Model PAM concentrations versus reported produced polymer concentrations**

The impact is assessed to be of ***medium*** significance and with the implementation of mitigation is reduced to ***low*** (Table 6-11).

**Table 6-11: Significance of disposal of back produced polymer on surface water quality**

| | Extent | Intensity | Duration | Consequence | Probability | Significance | Status | Confidence |
|---|---|---|---|---|---|---|---|---|
| Without mitigation | Regional 2 | Medium 2 | Long-term 3 | High 7 | Possible | MEDIUM | -ve | Medium |
| Key essential mitigation measures:<br>• Ensure total AAM mass disposed remains below 0.8 kg/d (this is equivalent to a concentration of 0.7 mg/L AAM assuming a maximum discharge volume of 1 190 m³/day[16]).<br>• Ensure that the polymer used has a residual AAM concentration of <0.1% by weight.<br>• Ensure the back-produced polymer is free from any other contaminants (through treatment, if required) before disposal.<br>• Ensure that disposal takes place in the fastest flowing part of the Saramacca River and/or is dispersed over an appropriate length such that dilution occur over the 4 km Saramacca River section adjacent to the Tambaredjo Oilfield within a day.<br>• Obtain a permit from NIMOS for the discharge of AAM as a pollutant in the produced water, once relevant laws are promulgated. | | | | | | | | |
| With mitigation | Local 1 | Medium 2 | Long-term 3 | Medium 6 | Improbable | LOW | -ve | Medium |

### 6.4.3.2 Potential Impact S3: Risk from Accidental Chemical Spills or Leaks to Surface Water Quality

Although not anticipated during routine project operations, and thus not a project impact, this section considers the potential effect of accidental spills or leaks of:

- Chemicals used in the produced water treatment plant;
- Small amounts of polymer mix from the PMP or during transfer to the injector well; and

[16] 0.7 mg = 0.0000007 kg x 1 190 000 l/d (equivalent to 1 190 m³/d) = 0.8 kg/d

- Large amount of polymer mix if a pipeline ruptures.

**Produced water treatment plant**

The produced water treatment plant is likely to use a number of chemicals that would contaminate surface water if spilled in sufficient quantities; these could include caustic soda [NaOH], hydrochloric acid [HCl], sulfuric acid [$H_2SO_4$] and ferric chloride [$FeCl_3$]. The potential impacts of such a spill include altering the soil pH, potential accumulation of chemicals at the location of a spill and potential dispersion to surface water.

However, these chemicals are likely to be used in relatively small quantities at the plant (Logisticon Water Treatment, 2017). Good housekeeping practices, such as proper storage of these chemicals in bunded areas, will minimise the risk to surface water in the event of spills, leaks or tank rupture.

**Small spills of polymer mix**

Leaks or spills of PAM and polymer mix could occur at the PMP or from leaks (e.g. drips, sweating flanges etc) in the pipeline conveying the polymer mix to injector wells. Such spills are likely to be relatively small but could occur over a longer period if not quickly repaired. The potential effect of small long-term releases on surface water resources is likely to be low and localised given the rapid biodegradation rate of AAM and strong adsorption of PAM to soil particles.

**Large spill of polymer mix**

A large release of polymer mix (e.g. ruptured bulk containers or pipeline) would occur very rapidly in a once-off event and is likely to reach the Saramacca River given the proximity of the PMP to the Kisoensingh-west Canal, which discharges to the Saramacca River 2 km to the south. A large spill could significantly increase the short-term concentration of AAM in the canal and Saramacca River above safe levels. It is expected that the AAM concentration in the Saramacca River will dilute to safe levels within a relatively short period of time given the high water volume and flow.

The potential impacts from a large-scale release at the polymer plant can be effectively mitigated through standard housekeeping and design measures, such as appropriate bunding of storage areas and installation of low pressure cut-out valves (or similar engineered safety devices) in pipelines.

The impact is assessed to be of ***low*** significance and with the implementation of mitigation is reduced to ***very low*** (Table 6-12).

**Table 6-12: Significance of accidental chemical spills or leaks to surface water quality**

| | Extent | Intensity | Duration | Consequence | Probability | Significance | Status | Confidence |
|---|---|---|---|---|---|---|---|---|
| Without mitigation | Local<br>1 | Medium<br>2 | Long-term<br>3 | Medium<br>6 | Possible | LOW | -ve | Medium |
| • Implement good housekeeping practices. | | | | | | | | |
| With mitigation | Local<br>1 | Low<br>1 | Long-term<br>3 | Low<br>5 | Possible | VERY LOW | -ve | Medium |

## 6.4.4 The No-Go Alternative

The No-Go alternative entails no change to the *status quo,* and the surface water regime will remain unchanged.

## 6.4.5 Mitigation Measures: Potential Surface Water Quality Impacts

**Essential** surface water quality mitigation measures during **construction** are as follows:

- Implement good housekeeping practices to prevent and contain spills.

**Essential** surface water quality mitigation measures during **operation** are as follows:

- Implement good housekeeping practices to prevent and contain spills.
- Treat water before discharge, as required, to ensure AAM mass disposed remains below 0.7 kg/d (this is equivalent to a concentration of 0.7 mg/L AAM assuming a maximum discharge volume of 1 000 $m^3$/day).
- Ensure that the polymer used has a residual AAM concentration of <0.1% by weight.
- Ensure the back-produced polymer is free from any other contaminants (through treatment, if required) before disposal.
- Ensure that disposal takes place in the fastest flowing part of the Saramacca river and/or is dispersed over an appropriate length such that dilution occur over the 4 km Saramacca River section adjacent to the Tambaredjo Oilfield within a day.
- Obtain a permit from NIMOS for the discharge of AAM as a pollutant in the produced water.
- Ensure all chemical storage compounds are installed on hard standing ground with bunding of at least 110% of the largest tank volume to contain any spill. Install collection systems in these areas to manage any spills.
- Construct chemical storage compounds outside of floodplains and further than 100 m from the normal high-water mark of a water body or a water supply borehole.
- Install clean and dirty stormwater management systems.
- Maintain a list of external equipment, personnel, facilities, funding, expert knowledge and materials that may be required to respond to emergencies. The list should include personnel with specialised expertise for spill clean-up, flood control and water treatment.
- Implement maintenance and inspection procedures.
- Install low pressure cut-out valves (or similar engineered safety devices) along the pipeline network.
- Use drip trays when refuelling and servicing vehicles or equipment, where it is not on hardstanding.

### 6.4.6 Monitoring: Potential Surface Water Quality Impacts

- Monitor the surface water quality quarterly, both upstream and downstream of the discharge point, for pH, EC, dissolved oxygen, chemical oxygen demand (COD), AAM, oil and grease, and selected metals. Regarding metals, initially analyse for a comprehensive suite of metals and select parameters for future monitoring based on those results.

## 6.5 Potential Contribution to Climate Change

### 6.5.1 Overview for Suriname

Suriname has a low-lying coastal zone where 80 % of the population lives and most economic activities take place. As such, Suriname is highly susceptible to the effects of sea level rise and is considered one of the so-called small island developing states, a group of developing countries that were recognised as low lying coastal countries that tend to share similar sustainable development challenges including small but growing populations, fragile environments, vulnerability to external shocks and few or no opportunities to create economies of scales (Kromosoeto, 2011).

The 2008 GHG inventory for Suriname (Office of the President of the Republic of Suriname, 2016) found that:

- Total GHG emissions equalled 6.4 million tonnes $CO_2$-equivalent (Mt $CO_2$-e) (versus reported GHG emissions of 8.9 Mt $CO_2$-e in 2003 [NIMOS, 2005]), of which 59% are generated by the energy sector. In 2014 estimated GHG emissions had again risen to 8.04 Mt $CO_2$-e (Climate Watch , 2018);
- Total $CO_2$ removals (GHG sinks) capacity equalled 8.2 Mt $CO_2$-e (versus reported GHG removals of 3.8 Mt $CO_2$-e in 2003 (NIMOS, 2005)), primarily from forestry and agriculture; and
- Suriname acts as a net GHG sink of 1.9 Mt $CO_2$-e annually (versus reported net GHG emissions of 5.0 Mt $CO_2$-e in 2003 (NIMOS, 2005)).

GHG emissions declined sharply in 1999 due to the closure of the Aluminium Smelter but grew again in subsequent years. Energy is derived mainly from hydrocarbons and hydropower. As a result, the energy sector is the largest GHG source, followed by Land-Use Change and Forestry and Agriculture (NIMOS, 2005), (Office of the President of the Republic of Suriname, 2016).

### 6.5.2 Contribution by the Project

The project area itself is located in Suriname's low-lying coastal plain on a polder surrounded by swamp. This area is likely to be vulnerable to possible effects of climate change such as sea level rise and changing rainfall and wind patterns. The burning of fossil fuels is generally accepted to be a factor contributing to climate change. The project is likely to have some impact on climate change and *vice versa*.

Indirect contribution to the emission of GHG through the subsequent burning of the extracted fossil fuel will dominate the project's contribution to climate change. However, oil volumes that will be recovered through the PF project, and their ultimate use, are not currently known, and approximate GHG quantities cannot be calculated at this stage.

Direct contributions to GHG emissions from electricity and fuel use by the project and possibly methane leaking from wells and pipelines are expected to be comparatively small.

The effects of climate change are global, and $CO_2$ is emitted worldwide from a vast number of sources. Seldom is any one source a significant emitter, but combined they emit enormous quantities of $CO_2$. As such, it is difficult to meaningfully rate the contribution of the PF project as a single emission source, and the impact has not been rated formally. The $CO_2$ emissions associated with the project will be largely equivalent to the amount of oil that is produced, which will be very significantly less than has already been produced by the Tambaredjo Oilfield. Oil production rates and volumes in Suriname are very low compared to major global oil producers.

Measures to reduce the $CO_2$ emission volumes associated with the PF project can include operational changes (e.g. increasing energy efficiency), green completions of wells (capturing and using/selling of methane[17]) and use of cleaner electricity (e.g. renewable). However, the implementation of such measures is expected to require operational adjustments that might not be technically or financially feasible.

Offset measures, such as the support of carbon-reducing schemes, can also be considered, but it is noted that the 2008 inventory identifies Suriname as a net GHG sink.

[17] If methane cannot be sold, then flaring is a less attractive alternative but preferable to venting methane into the atmosphere, as the $CO_2$ generated by flaring is a less potent GHG than methane (AGI, 2018).

## 6.6 Cumulative Impacts

### 6.6.1 Introduction

Anthropogenic activities can result in numerous and complex effects on the natural and social environment. While many of these are direct and immediate, the environmental effects of individual activities (or projects) can combine (additive impact) and interact (synergistic impact) with other activities in time and space to cause incremental or aggregate effects. Effects from ongoing but unrelated activities may accumulate or interact to cause additional effects (Canadian Environmental Protection Agency), known as “cumulative” effects or impacts (hereafter cumulative impacts).

Cumulative impacts are defined by the International Finance Corporation (IFC, 2013) as “those that result from the successive, incremental, and / or combined effects of an action, project, or activity when added to other existing (i.e. ongoing), planned, and / or reasonably anticipated future” actions, projects or activities.

Key to the theoretical understanding of cumulative impacts is that the effects of previous and existing actions, projects or activities are already present and assimilated into the biophysical and socio-economic baseline. For the purposes of this report, cumulative impacts are defined as ‘direct and indirect project impacts that act together with external stressors and existing or future potential effects of other activities or proposed activities in the area/region that affect the same resources and/or receptors, also referred to as Valued Environmental and Social Components (VECs)’.

For the most part, cumulative effects or aspects thereof are too uncertain to be quantifiable, due to mainly lack of data availability and accuracy.

### 6.6.2 Methodology

The IFC Good Practice Handbook for Cumulative Impact Assessment (2013), describes five / six key steps and considerations in the assessment of cumulative impacts:

- Definition of the Area of Influence (AoI);
- Identification of VECs, and their baseline condition;
- Identification of activities or stressors that contribute or are anticipated to contribute to cumulative effects in the foreseeable future (i.e. for all phases of the project);
- Implementation of a suitable methodology to assess cumulative impacts and evaluate their significance; and
- Identification of measures to manage and monitor cumulative impacts.

The **Area of Influence** (AoI) can be defined as the area likely to be affected, and the period or duration of occurrence of effects. In practice the AoI is a function of a large number of factors which have changing and varying degrees of influence on the areas surrounding the project throughout the course of the project cycle. The geographical extent of some of these factors can be partially quantified (e.g. air emissions can be defined by a delineated plume under specified meteorological conditions), whilst the extent of others is very difficult to measure (e.g. direct and indirect socio-economic effects).

In CIA it is good practice to focus on **VECs**, which are environmental and social attributes that are considered to be important in assessing risks and can be defined as essential elements of the physical, biological or socio-economic environment that may be affected by a proposed project. Types of VECs include physical features, habitats, wildlife populations (e.g. biodiversity), ecosystem services, natural processes (e.g. water and nutrient cycles, microclimate), social conditions (e.g. health, economics) or cultural aspects (e.g. traditional spiritual ceremonies). VECs should reflect public concern about social, cultural, economic, or aesthetic values, and also the scientific concerns of the professional community (Beanlands & Duinker, 1983).

**Activities** of potential interest include other past, present and future activities that might have caused or may cause impacts on the VECs affected by the project, and / or may interact with impacts caused by the project under review:

- **Cumulative impacts of past and existing activities**: It is reasonably straightforward to identify significant past and present projects and activities that may interact with the project to produce cumulative impacts, and in many respects, these are taken into account in the descriptions of the biophysical and socio-economic baseline (see respective sections in Section 3); and
- **Potential cumulative impacts of planned and foreseen activities**: Relevant future projects that will be included in the assessment are defined as those that are 'reasonably foreseeable', i.e. those that have a high probability of implementation in the foreseeable future; speculation is not sufficient reason for inclusion.

**Stressors** can be defined as natural or anthropogenic aspects which cause a change in, i.e. impact on, the structure or function of the environment. Natural and anthropogenic stressors often have similar effects, e.g. both drought and wood harvesting result in a loss of habitat. Due to rapid increases in human population, anthropogenic stressors on the environment have increased greatly (Cairns, 2013).

### 6.6.3 Cumulative Impact Assessment

Cumulative impacts for this project have been identified based on the extent and nature of the AoI of the projects, status of VECs and understanding of external natural and social stressors. These insights have been informed by engagements with project stakeholders, review of existing documentation, field observations and data collection.

As the cumulative impacts of past and existing projects are incorporated in the baseline, the focus hereafter is on planned and foreseen projects and activities. Given the limited detail available regarding such future developments, the analysis is of a more generic nature and focuses on key issues and sensitivities for the project and how these might be influenced by cumulative impacts with other activities. The future developments that are considered are:

- Those for which approvals have already been granted;
- Those that are currently subject to environmental applications and for which there is currently information available; and
- Those forming part of district or national initiatives.

Where further developments are identified, but are not yet at the stage of planning as detailed above, these are noted in the cumulative impact assessment.

Projects and stressors that have been considered in the cumulative impact analysis are listed in Table 6-13. Cumulative impacts are only assessed for VECs on which the project has a potentially significant impact.

**Table 6-13: Projects / stressors considered in the cumulative impact analysis**

| Project / stressor | Common VECs |
|---|---|
| *Past and present projects / stressors* | |
| Agricultural activities in the resort | Groundwater<br>Surface water |
| Existing oil production on the Tambaredjo, Tambaredjo NW and Calcutta oilfields | Groundwater<br>Surface water |

| Project / stressor | Common VECs |
|---|---|
| *Future projects / stressors* | |
| Possible EOR using similar / other techniques in the Tambaredjo Oilfield and / or adjacent oilfields (Tambaredjo NW and Calcutta) | Groundwater<br>Surface water |

The cumulative impacts considered are:

- Decrease in groundwater quantity and quality; and
- Decrease in surface water quality.

In the sections below, the severity and extent of cumulative impacts is qualitatively rated to derive a high, medium or (very) low significance rating.

#### 6.6.3.1 Cumulative Groundwater Impacts

Staatsolie is abstracting groundwater on the Tambaredjo field for process water. Cumulative impacts on groundwater levels are not expected as boreholes are sufficiently spaced and abstraction from 1J22 would have a small drawdown zone (modelled as ~100 m in radius for abstraction of 480 $m^3$/d).

Existing oil production on the Tambaredjo Oilfield has the potential to affect groundwater, e.g. in the event of leaking wells. Groundwater and well monitoring are recommended as part of the ongoing oil production activities in the area.

A PF pilot project with three injector wells and 33 producing wells has been implemented on 1.5 $km^2$ of the Tambaredjo Oilfield since 2008. As such, some PAM will already be present in the ground and have a cumulative effect with the PAM injected by the commercial-scale PF project. Considering the relatively limited scale of PAM migration and build-up in concentration indicated in the model, the residual PAM from three injector wells is not considered to increase the overall impact significantly.

The cumulative impact on groundwater quantity and quality in the study area is assessed to be of ***very low*** significance.

Possible cumulative impacts of any future PF projects on groundwater should be determined considering actual monitoring data acquired for the current PF project and modelling which takes account of site and project-specific conditions.

Possible cumulative impacts of any future PF projects should be evaluated on the basis of actual monitoring data for the current PF project and modelling, considering site and project-specific conditions.

If additional abstraction of groundwater from the same layer as 1J22 were to take place, and assuming similar impacts (and impact area) to those modelled and described in this report, cumulative impacts on groundwater levels are unlikely if abstraction boreholes are sufficiently spaced due to the small drawdown zones (modelled as ~100 m in radius for abstraction of 480 $m^3$/d). It is noted, however, that the deeper (palaeo)groundwater layers in the area appear to have very limited recharge, and extensive abstraction over sufficiently long time periods is likely to reduce the available groundwater volume and lower the groundwater level.

If PF were to be implemented in other parts of the Tambaredjo Oilfield or nearby Tambaradejo NW or Calcutta oilfields, and assuming similar impacts (and impact area) to those modelled and described in this report, cumulative impacts on groundwater quality from polymer mix migration are possible if the PF takes place within the maximum impact zone of the currently proposed PF project (vertical and horizontal extent as per Figure 6-5 and Section 7 in Appendix A). But PF in the adjacent oilfields is unlikely to result in cumulative impacts on groundwater quality.

#### 6.6.3.2 Cumulative Surface Water Impacts

A PF pilot project with three injector wells and 33 producing wells has been implemented on 1.5 $km^2$ of the Tambaredjo Oilfield since 2008. Produced water from the pilot project, containing some PAM, has been discharged into the Saramacca River. Any contaminants from this discharge will, however, have degraded and/or flowed downstream by the time the full-scale PF project is implemented, and no cumulative effect is expected in this regard. Assuming that the pilot project will now cease, and/or be integrated into the commercial-scale PF project assessed in this study, there will be no cumulative impacts from discharge into the Saramacca River.

Staatsolie also discharges produced water from existing oil production wells and facilities in the Tambaredjo Oilfield via the TA-58, Jossie Crude and CS Treatment Plants, into the Saramacca River. Depending on the quality of the discharged water, cumulative impacts on surface water could arise if different waste streams contain similar contaminants. To mitigate this, all wastewater is required to be suitably treated prior to discharge.

Possible cumulative impacts of discharging produced water from any future PF projects into the Saramacca River should be determined considering actual monitoring data of treated produced water quality acquired for the current PF project.

### 6.6.4 Management of Cumulative Impacts

The management of cumulative impacts will depend on the context in which the development is occurring, i.e. the impacts from other projects and natural drivers that affect the VECs, and the characteristics of the of the PF project impacts. Since cumulative impacts result from the actions of multiple Staatsolie operations / departments, the responsibility for their management is collective.

Additional mitigation measures related to cumulative impacts are as follows:

- Suitably treat all wastewater prior to discharge; and
- Monitor quality and volume of all discharge from Staatsolie activities to the Saramacca River.

## 6.7 Environmental Management and Monitoring Plan

It is critical that mechanisms are in place to ensure that the recommendations and mitigation measures contained in the ESIA Report are fully and effectively implemented. Typically, a customised management plan is the mechanism through which these measures are implemented.

The preparation of management plans is also consistent with the EA Guidelines (Annex 7) published by NIMOS, which require, *inter alia*, that ESIA reports should include:

(8) Proposed Mitigation Measures or an Environmental Management Plan (EMP);

(11) Follow Up & Monitoring Plan[18]; and

(12) Decommissioning Plan.

An EMMP has been developed by SRK as part of the Limited ESIA process, provided in Appendix C. The objective of the EMMP is to set out the management and monitoring measures required to both minimise any potentially adverse environmental impacts and enhance the environmental benefits of the project. A further objective of the EMMP is to ensure that responsibilities and appropriate resources are efficiently allocated to implement the plan.

Management and monitoring measures have been developed from the recommendations and mitigation measures listed in the Limited ESIA Report. By formally documenting environmental

[18] Monitoring measures are recorded in the EMMP.

management measures and commitments, the EMMP serves a vital role in ensuring that potential impacts of the project are minimised, and that the significance of those impacts is as predicted by the Limited ESIA process. The EMMP has been formatted so that it can be developed into a practical document for implementation on site and incorporated into tender documents where appropriate, and also contains environmental management and training requirements to implement the EMMP.

The appended EMMP is released to stakeholders for comment together with the Limited ESIA Report. It is important to recognise that management plans in general are living documents that will need to be periodically reviewed and updated even after their initial completion.

# 7 Conclusions and Recommendations

Staatsolie proposes to implement a commercial-scale PF project in the Tambaredjo Oilfield to increase the extraction of oil that could cannot be otherwise extracted from Staatsolie's existing operations in Saramacca. In accordance with NIMOS's EA guidelines and screening conclusions, a Limited ESIA process has been undertaken for the project, and an EMMP compiled.

The Limited ESIA has examined the available project information and drawn on available (secondary) baseline data to identify and evaluate environmental (biophysical and socio-economic) impacts of the proposed PF project. The Limited ESIA Report aims to inform decision-makers of the key considerations by providing an objective and comprehensive analysis of the potential impacts and benefits of the project and has created a platform for the formulation of mitigation measures to manage these impacts, presented in the appended EMMP, which should be read together with the Limited ESIA Report.

This chapter evaluates the impact of the proposed PF project and presents the principal findings of the Limited ESIA. It further summarises the general conclusions that have been drawn from the Limited ESIA process and which should be considered in evaluating the project. It should be viewed as a supplement to the detailed assessment of individual impacts presented in Chapter 6.

## 7.1 Summarised Evaluation of Impacts

The evaluation is undertaken in the context of:

- The project information provided by the proponent;
- The assumptions made for this ESIA Report;
- The assumption that the recommended (essential) mitigation measures will be effectively implemented; and
- The assessments provided by specialists.

This evaluation aims to provide answers to a series of key questions posed as objectives at the outset of this report, which are repeated here:

- Assess in detail the environmental and socio-economic impacts that may result from the project;
- Identify environmental and social mitigation measures to address the impacts assessed; and
- Produce a Limited ESIA Report that will assist NIMOS's evaluation of the project.

The evaluation and the basis for the subsequent discussion are represented concisely in Table 7-1, which summarises the potentially significant impacts and their significance ratings before and after application of mitigation and/or optimisation measures.

**Table 7-1: Summary of potential impacts of the PF project**

*Potential negative impacts are shaded in reds, benefits are shaded in greens. Insignificant impacts have not been shaded. Only* ***key (non-standard essential)*** *mitigation/optimisation measures are presented. Other management measures are presented in the ESMP.*

| ID # | Impact | Significance rating | | Key mitigation/optimisation measures |
|---|---|---|---|---|
| | | Before mitigation/ optimisation | After mitigation/ optimisation | |
| CONSTRUCTION PHASE IMPACTS | | | | |
| G | Groundwater Impacts | | | |
| G1 | Contamination of groundwater due to spills and well drilling | Very Low | Insignificant | • Use non-toxic drilling fluids when drilling through freshwater aquifers.<br>• Ensure that well casing and cementing meets best practice methods to prevent chemical losses into the upper layers above the oil reservoir. |
| S | Surface Water Impacts | | | |
| S1 | Contamination of surface water, affecting ecosystems | Very Low | Very Low | • Implement good housekeeping practices. |
| OPERATION PHASE IMPACTS | | | | |
| G | Impacts on Groundwater | | | |
| G2 | Reduction in groundwater level and supply due to groundwater abstraction | Very Low | Very Low | • None |
| G3 | Contamination of groundwater in lower brackish aquifer due to intrusion of polymer mix | Low | Low | • Manage injection pressures to ensure that the PF chemicals are not chased/forced beyond the confines of the oil reservoir. |
| G4 | Contamination of groundwater in freshwater aquifer due to intrusion of polymer mix | Insignificant | Insignificant | • Manage injection pressures to ensure that the PF chemicals are not chased/forced beyond the confines of the oil reservoir. |

| ID # | Impact | Significance rating | | Key mitigation/optimisation measures |
|---|---|---|---|---|
| | | Before mitigation/ optimisation | After mitigation/ optimisation | |
| G5 | Groundwater contamination due to a leaking well | Medium | Low | • Ensure that well casing and cementing meets best practice methods to prevent chemical losses into the upper layers above the oil reservoir.<br>• Monitor polymer mix injection pressure and flow rate, to ensure no polymer mix is unaccounted for.<br>• In the event of a leak, cease injection of polymer mix at the well.<br>• In the event of a major leak, monitoring groundwater quality at the water abstraction point and possibly at new sentinel wells. |
| S | Surface Water Impacts | | | |
| S2 | Impacts from the disposal of back produced polymer on surface water quality | Medium | Low | • Treat water before discharge, as required, to ensure AAM mass disposed remains below 0.7 kg/d (this is equivalent to a concentration of 0.7 mg/L AAM assuming a maximum discharge volume of 1000 $m^3$/day).<br>• Ensure that the polymer used has a residual AAM concentration of <0.1% by weight.<br>• Ensure the back-produced polymer is free from any other contaminants (through treatment, if required) before disposal.<br>• Ensure that disposal takes place in the fastest flowing part of the Saramacca river and/or is dispersed over an appropriate length such that dilution occur over the 4 km Saramacca River section adjacent to the Tambaredjo Oilfield within a day |
| S3 | Risks from chemical spills or leaks to surface water quality | Low | Very low | • Implement good housekeeping practices. |

## 7.2 Principal Findings

The proposed PF project will entail so-called triple bottom line costs and/or benefits. The triple bottom line reflects the three pillars of sustainability and concerns itself with environmental (taken to mean biophysical) sustainability, social equity and economic efficiency and is typically employed by companies seeking to report on their performance. The concept serves as a useful construct to frame the evaluation of the effects of the project.

The challenge for NIMOS is to consider a project which should aim to be sustainable in the long term, but which will probably entail trade-offs between social, environmental and economic costs and benefits. The trade-offs are documented in the report, which assesses environmental impacts and benefits and compares these to the No-Go alternative.

There are a number of minor or less significant impacts associated with the PF project. If recommended mitigation measures are adopted, these impacts are not expected to be significant nor long-term. They include vibration, air quality, noise, ecological, socio-economic, visual and traffic impacts.

Relevant observations with regard to potentially significant impact ratings, assuming mitigation measures are effectively implemented, as summarised in Table 7-1, are:

- The predicted **groundwater** impacts due to abstraction of groundwater for the PF project are considered to be of *very low* significance. Impacts associated with the possible contamination of groundwater resources due to vertical migration of injected PAM is deemed of *low* significance for the deeper brackish groundwater layer and *insignificant* for the shallower freshwater layer. A major accidental spill of polymer mix due to a leaking well into a groundwater bearing layer, especially the freshwater layer, is expected to remain localised and extremely unlikely to reach the Tijgerkreek abstraction point before full degradation of the PAM and AAM, and is assessed to have an impact of *low* significance.
- The predicted **surface water** impact due to contamination during construction is deemed to be of *very low* significance. Disposal of produced water containing polymer into the Saramacca River is assessed to have an impact of *low* significance, as the AAM contained in the produced water will be diluted to acceptable concentrations in the river water. Dilution and degradation of PAM and AAM will occur in the event of an accidental surface spill of polymer mix, and is assessed to have a *very low* significance impact on surface water.

Cumulative impacts may derive from existing oil production and groundwater abstraction in the Tambaredjo Oilfield and discharge of produced water to the Saramacca River. Cumulative impacts include a reduction in groundwater quality and quantity and surface water quality, depending on the quality and quantity of abstraction, discharge and unforeseen events, e.g. leaks, from other activities. Possible cumulative impacts of any future PF projects on groundwater and surface water should be determined considering actual monitoring data acquired for the current PF project and modelling which takes account of site and project-specific conditions.

The No-Go alternative entails no change to the status *quo*, in other words no PF is undertaken to extract more oil, and current oil production continues while economically feasible. This means that the PMP and additional infrastructure is not constructed and production on the Tambaredjo Oilfield will cease as per current production timelines (and earlier than anticipated with the implementation of PF). The 12% incremental oil recovery would not be achieved.

A number of mitigation and monitoring measures have been identified to avoid, minimise and manage potential environmental impacts associated with the proposed PF project. These are further laid out in the EMMP.

## 7.3 Recommendations

The specific recommended mitigation and optimisation measures are presented in Chapter 6 and/or the EMMP, and key measures are summarised in Table 7-1 above. Staatsolie would need to implement these mitigation measures to demonstrate compliance and adherence to best practice.

Key recommendations, which are considered essential, are:

1. Implement the EMMP to guide design, construction, operation and decommissioning activities and to provide a framework for the ongoing assessment of environmental performance;
2. Use non-toxic drilling fluids when drilling through freshwater aquifers;
3. Ensure that well casing and cementing meets best practice methods to prevent chemical losses into the upper layers above the oil reservoir;
4. Ensure that the appropriate personnel and sufficient resources are allocated to expedite implementation of the EMMP;
5. Ensure that the polymer used has a residual AAM concentration of <0.1% by weight;
6. Monitor polymer mix injection pressure and flow rate, to ensure no polymer mix is unaccounted for;
7. Ensure adequate response mechanisms are in place and corrective action is taken to address any instances of non-compliance with standard management measures or procedures;
8. Maintain lines of communication with the local communities in the vicinity of the Tambaredjo Oilfield. Ensure that local communities are aware of the Staatsolie grievance mechanism and how to utilise it. Maintain a complaints registry and investigation procedure to ensure that all grievances are adequately addressed;
9. Maximise the employment of local (Surinamese) nationals and the procurement of local resources during the construction and operations phases to ensure maximum benefit to the local economy; and
10. Compile and implement a detailed Emergency Response Plan prior to commencing with the PF project, setting out roles, responsibilities and procedures to address all potential incidents.

# 8 Way Forward

This draft Limited ESIA Report has identified and assessed the potential impacts associated with the proposed Staatsolie PF project at the Tambaredjo Oilfield. The draft Limited ESIA Report and draft EMMP are now available for public comments and we invite stakeholders to review the report and to participate in the stakeholder engagement process.

This draft Limited ESIA Report and draft EMMP are not final reports and may be amended based on comments received from stakeholders. The (English and Dutch) Non-technical Summary (NTS) of the ESIA Report will be sent to all registered stakeholders. Copies of the complete draft Limited ESIA Report and draft EMMP are available for viewing at the following venues:

- NIMOS; and
- Office of the Saramacca District Commissioner at Groningen.

An electronic version of the reports can also be accessed on SRK's website www.srk.co.za (via the 'Library' and 'Public Documents' links) and on Staatsolie's website www.staatsolie.com.

Stakeholders are invited to attend a **Public Meeting** where the information presented in the ESIA Report and EMMP will be discussed and additional concerns and issues can be raised with the environmental consultants and the project team.

The public meeting will be held on Wednesday 21 August 2019.

The public is invited to review the draft Limited ESIA Report and draft EMMP and send written comment to:

| SRK Consulting: | | Staatsolie: |
|---|---|---|
| Contact persoon: **Sue Reuther** | of | Contact persoon: **Farina Ilahibaks** |
| **E-mail**: sreuther@srk.co.za | | **E-mail:** FIlahibaks@staatsolie.com |
| **Tel:** + 27 21 659 3060 **Fax**: +27 21 685 7105 | | **Tel:** +597 375222 toestel 66761 |

Stakeholders will be provided with a 30-day comment period. For comments to be included in the Final Limited ESIA Report and EMMP, they must reach one of the above contact persons **no later than 9 September 2019.**

Once stakeholders have commented on the information presented in the draft Limited ESIA Report and draft EMMP, the Final Limited ESIA Report will be prepared and submitted to NIMOS for consideration. NIMOS will evaluate the environmental and social sustainability of the proposed Project and advise Staatsolie of their decision.

**Prepared by**


Sue Reuther
Principal Environmental Consultant

**Reviewed by**


Chris Dalgliesh
Partner

All data used as source material plus the text, tables, figures, and attachments of this document have been reviewed and prepared in accordance with generally accepted professional engineering and environmental practices.

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# Appendices

# Appendix A: Groundwater and Geochemical Study

# Polymer Flooding Enhanced Oil Recovery in the Tambaredjo Oilfield in Saramacca, Suriname

# Groundwater and Geochemical Specialist Study

**Report Prepared for**

## Staatsolie Maatschappij Suriname N.V.

**Report Number 545842/GW**

**Report Prepared by**

**July 2019**

# Polymer Flooding Enhanced Oil Recovery in the Tambaredjo Oilfield in Saramacca, Suriname

# Groundwater and Geochemical Specialist Study

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# Profile and Expertise of Specialists

SRK Consulting (South Africa) (Pty) Ltd (SRK) has been appointed by Staatsolie Maatschappij Suriname N.V. (Staatsolie) to undertake a Limited Environmental and Social Impact Assessment (ESIA) for the proposed construction and operation of the polymer flooding Enhanced Oil Recovery (EOR) programme in the Tambaredjo Oilfield in the Saramacca District, Suriname. SRK has appointed a team of professionals and specialists to conduct the Groundwater and Geochemical specialist study as part of the ESIA process.

SRK comprises over 1 400 professional staff worldwide, offering expertise in a wide range of environmental and engineering disciplines. SRK's Cape Town environmental department has a distinguished track record of managing large environmental and engineering projects, extending back to 1979. SRK has rigorous quality assurance standards and is ISO 9001 accredited.

The qualifications and experience of the key individual specialists involved in the study are detailed below.

Project Review: Christopher Dalgliesh, BBusSc (Hons); MPhil (EnvSci)
*Certified with the Interim Board for Environmental Assessment Practitioners South Africa (CEAPSA)*
Chris Dalgliesh is a Partner and Principal Environmental Consultant with over 26 years' experience, primarily in South Africa, Southern Africa, West Africa and South America (Suriname). Chris has worked on a wide range of projects, notably in the natural resources, Oil & Gas, waste, infrastructure (including rail and ports) and industrial sectors. He has directed and managed numerous Environmental and Social Impact Assessments (ESIAs) and associated management plans, in accordance with international standards. He regularly provides high level review of ESIAs, frequently directs Environmental and Social Due Diligence studies for lenders, and also has a depth of experience in Strategic Environmental Assessment (SEA), State of Environment Reporting and Resource Economics. He holds a BBusSci (Hons) and M Phil (Env) and is a Certified Environmental Practitioner of South Africa (CEAPSA).

Specialist Consultant: Sheila Imrie, BSc (Hons); MSc (Hydrogeology)
*Registered Professional Scientist with the South African Council for Natural Scientific Professions (SACNASP)*
Sheila is a Principal Hydrogeologist and Numerical Modelling Specialist with 19 years of experience in groundwater resources and IT in South Africa and the UK. She specialises in groundwater modelling and has generated numerous flow and transport models for both industry and government. Sheila holds an MSc (hydrogeology) and is a registered Professional Natural Scientist (Water Science and Mathematical Science) with SACNASP.

Specialist Consultant: Richard O'Brien, BSc (Hons); MSc (Environmental Geochemistry)
*Registered Professional Scientist with with the South African Council for Natural Scientific Professions (SACNASP)*
Richard is a Principal Environmental Geochemist and has over 17 years of experience in the geochemical field. He specialises in the characterisation and management of contaminated land, environmental due diligence assessments, surface and groundwater quality monitoring, environmental risk assessment and remediation. Recent projects have included field trials to successfully motivate geochemical stabilisation of arsenic impacted soil to mitigate leaching to groundwater and is the technical reviewer of an SRK remediation project which is currently injecting emulsified vegetable oil (EVO) to mitigate a dissolved phase chlorinated hydrocarbon plume in an intergranular and fractured rock aquifer system.

# Statement of SRK Independence

Neither SRK nor any of the authors of this Report have any material present or contingent interest in the outcome of this Report, nor do they have any pecuniary or other interest that could be reasonably regarded as being capable of affecting their independence or that of SRK.

SRK has no beneficial interest in the outcome of the assessment which is capable of affecting its independence.

# Disclaimer

The opinions expressed in this Report have been based on the information supplied to SRK by Staatsolie. SRK has exercised all due care in reviewing the supplied information, but conclusions from the review are reliant on the accuracy and completeness of the supplied data. SRK 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 SRK's investigations, and those reasonably foreseeable. These opinions do not necessarily apply to conditions and features that may arise after the date of this Report, about which SRK had no prior knowledge nor had the opportunity to evaluate.

# Table of Contents

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# List of Abbreviations and Units of Measurement

| | |
|---|---|
| 3-D | Three-Dimensional |
| *c.* | *circa* (approximately) |
| AAM | Acrylamide monomer |
| bbl/d | Barrels per day (1 bbl/d converts to 2.38 $m^3$/d) |
| bgl | Below ground level |
| BOD | biochemical oxygen demand |
| EA | Environmental Assessment |
| EOR | Enhanced Oil Recovery |
| EMMP | Environmental Monitoring and Management Plan |
| ESIA | Environmental and Social Impact Assessment |
| ft | Feet (1 foot converts to 0.3048 m) |
| Kd | Soil-Water Partition Coefficient |
| km | Kilometre |
| Koc | Organic Carbon-Water Partition Coefficient |
| Kow | Octanol-Water Partition Coefficient |
| L/s | Litres per second |
| lb | Pounds |
| m | Metres |
| $m^3$/d | Cubic metres per day |
| mg/L | Milligrams per litre |
| mS/m | Milli-Siemens per metre |
| MSDS | Material Safety Data Sheet |
| NAPL | Non-Aqueous Phase Liquid |
| NOEC | No Observed Effect Concentration |
| PAM | Polyacrylamide |
| PCG | Preconditioned Conjugate-Gradient |
| PF | Polymer Flooding |
| PMP | Polymer Mixing Plant |
| PNEC | Predicted No Effects Concentration |
| ppm | Parts per million |
| SDS | Safety Data Sheet |
| SM | Sarah Maria |
| SRK | SRK Consulting (South Africa) (Pty) Ltd |
| Staatsolie | Staatsolie Maatschappij Suriname N.V. |
| ToR | Terms of Reference |

# Glossary

| | |
|---|---|
| Advection | The horizontal movement of some property of a mass of fluid (such as air or water), such as heat, humidity or salinity. |
| Aquifer | A formation, group of formations, or part of a formation that contains sufficient saturated permeable material to store and transmit water; and to yield economical quantities of water to boreholes or springs. An aquifer is the storage medium from which groundwater is abstracted. |
| Biodegradation | The process by which organic substances are decomposed by micro-organisms (mainly aerobic bacteria) into simpler substances such as carbon dioxide, water and ammonia. |
| Carcinogen | A substance or agent that causes the development or increases the incidence of cancer. A carcinogen can also act upon a population to change its total frequency of cancer in terms of numbers of tumours or distribution by site and age. |
| Cumulative Impacts | Direct and indirect impacts that act together with current or future potential impacts of other activities or proposed activities in the area/region that affect the same resources and/or receptors. |
| Daughter Products | An isotope (often one of several) that is the product of the decay of a specific parent isotope. |
| Decay | Change of an element into a different element, usually with some other particle(s) and energy emitted. |
| Dilution | The process of reducing the concentration of a solute in solution, usually simply by mixing with more solvent. |
| Dispersion | A system in which distributed particles of one material are dispersed in a continuous phase of another material. The two phases may be in the same or different states of matter. |
| Fate and Transport | The study of how chemicals degrade and where chemicals travel in the environment when they are released intentionally or unintentionally. |
| Formation | A body of rock identified by lithic characteristics and stratigraphic position. Different formations have different geohydrological properties. |
| Fracture | Any break in a rock including cracks, joints and faults. Fractures can form the main conduits for groundwater flow. They can also form pathways for the movement of contamination. |
| Groundwater | Water found in the subsurface in the saturated zone below the water table. Groundwater is a source of water and is an integral part of the hydrological system. |
| Groundwater Flow Model | The application of a mathematical model to represent a regional or site-specific groundwater flow system |
| Groundwater Mounding | A localised rise in the water table due to infiltration. |
| Hydraulics | (The study of) water flow. |
| Hydrogeology | (The study of) groundwater flow. |
| Hydrology | (The study of) surface water flow. |
| Leaching | The process by which inorganic, organic contaminants or radionuclides are released from the solid phase into the water phase under the influence of mineral dissolution, desorption, complexation processes as affected by pH, redox, dissolved organic matter and (micro)biological activity. |

| | |
|---|---|
| Model Calibration | The adjustment of model parameters in order to achieve or predict real life environmental conditions. |
| Polder | A low-lying tract of land enclosed by dikes that form an artificial hydrological entity: it has no connection with outside water other than through canals and manually operated devices (e.g. pumps and sluices). |
| Sorption | A physical and chemical process by which one substance becomes attached to another. |
| Specialist study | A study into a particular aspect of the environment, undertaken by an expert in that discipline. |
| Storativity | The volume of water released from storage per unit of aquifer storage area per unit change in head. |
| Toxicity | The inherent property of a substance to cause injury or an adverse effect in a living organism. Defined as either cancer slope factor (SF in mg/kg/day-1) for carcinogens and reference dose (Rfd in mg/kg/day) for non-carcinogens. |
| Transmissivity | Transmissivity is the rate at which water is transmitted through a unit width of an aquifer under a unit hydraulic gradient. It is expressed as the product of the average hydraulic conductivity and thickness of the saturated portion of an aquifer. |
| Volatilisation | The chemical process by which chemicals convert from a liquid or solid state into a gas and then disperse into the air above contaminated soil. |

# 1 Introduction

## 1.1 Project Background

The project area is located in the Tambaredjo Oilfield in the Tambaredjo Polder, which has been operated by Staatsolie Maatschappij Suriname N.V. (Staatsolie), the State oil company of Suriname, since the 1990s. The original swamp habitat has been replaced by secondary marsh vegetation, which is characterised as a modified habitat. The polder is used for oil production from a large number of wells in a 200 x 200 m grid. The polder is traversed by unpaved roads and activity level is intense. The polder is drained by a system of roadside ditches that are connected to main canals. The north-south trending canals drain into the Saramacca River.

The Tambaredjo Oilfield (see Figure 1-1)[1] is one of the three oilfields Staatsolie operates in the Saramacca District. The proposed project is located in the dryland portion of the Tambaredjo Oilfield, between existing oil production facilities. The project includes construction and operation of a Polymer Mixing Plant (PMP) to prepare a polymer solution. Water required for the process will be abstracted either from the Saramacca River (preferred option) or extracted from water supply well(s) (alternative option). The water will be pumped through pipelines to the PMP for treatment and use. The project also includes construction of access roads and well locations. Injector and producer wells will be drilled using a rig. Headers and flow lines will be installed to:

- Convey water and polymer solution from the PMP to the injector wells. In the initial stage, treated water will be injected into the targeted oil reservoir for a maximum period of one month, whereafter the injection of polymer will commence; and
- Convey produced fluid[2] from new production wells to the Jossie crude treatment plant.

The project includes:

- Drilling and operating 64 injector wells (for injection of water and polymer), some on private land (where Staatsolie already has installed facilities);
- Drilling and operating 15 (additional) wells to produce crude oil to maximise production as a result of polymer injection; and
- Construction and operation of a PMP.

During the production process, a combination of oil, gas and water is produced and treated at the Crude Treatment Facility. At present, the water phase is treated and afterwards disposed of in the Saramacca River. In future, produced water may be re-injected. If this is not possible, disposal of produced water to the Saramacca River is proposed. SRK anticipates that produced (waste) water will be treated and discharged in compliance with international environmental standards.

Construction will be phased and is expected to take approximately 24 months to completion. Operations may commence in 2020, extending through to 2044 (11 years' polymer injection and 13 years' water injection). Decommissioning of the PMP is envisaged between 2045 and 2050.

[1] The model boundary extends 10 km beyond the proposed PF boundary in all directions and includes the entire Tambaredjo Oilfield (see Figure 6-1).
[2] Mix of oil, water and gas.

## 1.2 Polymer Flooding

Oil production generally occurs in three stages: primary, secondary and tertiary. Enhanced Oil Recovery (EOR) is a tertiary strategy option that is employed when primary (natural flow) and secondary (water and gas injection) techniques are no longer effective.

Secondary recovery includes using water and gas injection to displace the oil and drive it to the surface. When water is injected into an oil reservoir, it follows the path of least resistance, usually the layers with higher permeability, to flow directly to the lower pressure region of the producing wells. If the oil in place has a higher viscosity than the injected water, the water will finger through this oil and bypass it. This results in a low sweep efficiency and a loss in recovery. The goal of polymer injection is to improve the sweep efficiency in the reservoir to increase oil recovery.

Of the chemical EOR methods, polymer flooding (PF) is the most common and straightforward technique. This technology has a long commercial history and proven results, because the risks associated with the application of PF is low. PF utilises high molecular weight polymers to increase the viscosity (thicken) the injected water. PF consists of injecting polymer-augmented water into a subterranean oil formation to improve the sweep efficiency in the reservoir. The increased viscosity of the water causes a better mobility and control between the injected water and the hydrocarbons within the reservoir. Although improved ‘water floods’ do not recover as much of the remaining oil in-place as ‘surfactant floods’, they are cheaper and simpler and are applied more extensively.

Such polymers are susceptible to mechanical breakage and shear degradation and lose their effectiveness in highly saline solutions or solutions with high concentrations of divalent ions. Because dissolved oxygen promotes chemical degradation of both hydrolyzed polyacrylamides (PAM) and polysaccharides, oxygen scavengers such as sodium hydrosulfite or additives such as formaldehyde are often employed.

Reservoirs do not have uniform permeabilities and porosities, and fluid that is injected into a vertical interval will seldom travel through a zone with a uniform flood front. The fluid will preferentially traverse those areas of higher porosity, leaving oil behind in the less permeable lithologies. Polymer injection can redistribute the flow of injected fluids relative to waterflooding by reducing the permeability in areas of more conductive sections and achieving a uniform distribution profile for maximum oil recovery.

## 1.3 Objectives

The primary objective of the groundwater and geochemical study is to assess the fate and transport of the PF additives and return water constituents that could potentially be mobilised during the PF operations, via leakage from the petroleum reservoir to the overlying potable aquifer unit or via surface releases to fresh water resources. The approach (see Section 2) of the groundwater and geochemical study has been to conduct a review of the available literature regarding the fate and transport characteristics of the PF additives (and degradation products) coupled with a conceptual three-dimensional (3-D) hydrogeological model to assess the potential migration routes and impacted areas, in the event of an unintended release of PF fluids.

More specifically, the Terms of Reference (ToR) for this specialist study are as follows:

- Describe the existing baseline characteristics of the project area / Zone of Influence and place this in a regional context;
- Identify and assess potential impacts resulting from the project (including impacts associated with the construction and, operation phases of the project;
- Indicate the acceptability of alternatives and recommend a preferred alternative;

- Identify and describe potential cumulative impacts resulting from the proposed development in relation to proposed and existing developments in the surrounding area;
- Recommend mitigation measures to avoid or minimise impacts and/or optimise benefits associated with the proposed project; and
- Recommend and draft a monitoring campaign, if applicable.

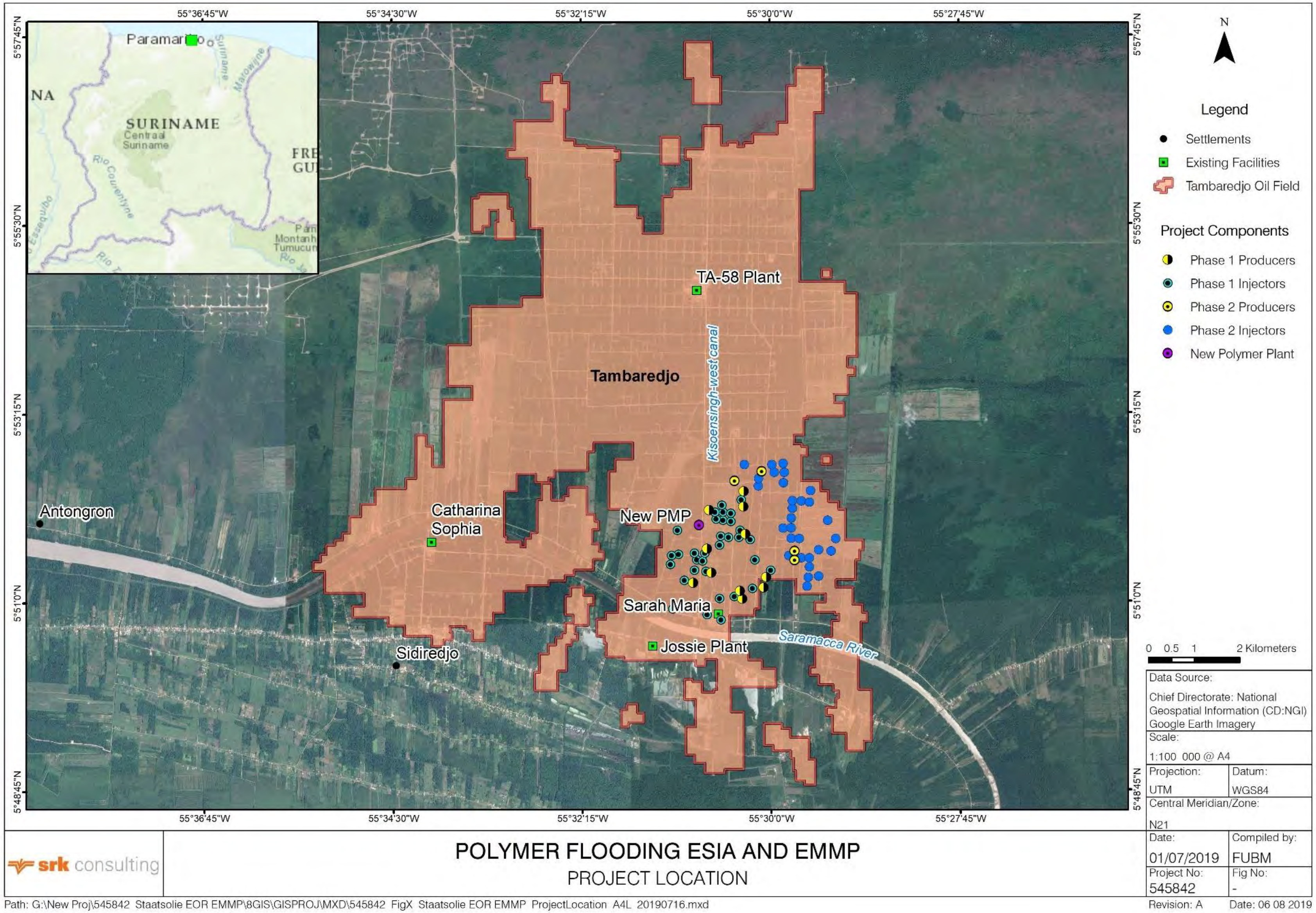



**Figure 1-1: Project location**

# 2 Approach

## 2.1 Methodology – Geochemical Assessment

The following methodology was used to undertake the geochemical assessment.

### 2.1.1 Data Gathering and Analysis

Review the geological conceptual model and incorporate the geochemical characteristics that affect the fate and transport of chemicals that would be injected during the PF. This review included a review of induced affects caused by the degradation of PF additives on naturally occurring compounds in the host matrix which may be mobilised under changing geochemical conditions (e.g. manganese or arsenic). The geochemical environment plays a critical role in determining the most likely biodegradation pathways for organic compounds in groundwater. The geochemical conceptual model was integrated with the hydrogeological conceptual model and transcribed into the 3-D numerical model to predict the potential risk to the upper groundwater resources.

A database of physical, chemical and toxicological properties of the known PF additives, based on the Material Safety Data Sheet (MSDS)/Safety Data Sheet (SDS) and available international chemical references, was compiled (Appendix B). This database served as the primary data for the fate and transport assessment and toxicological data for the impact assessment.

### 2.1.2 Fate and Transport Analysis

The aim of the task is to broadly group the additives based on their environmental behaviour should they be released to the environment. The chemical and physical properties database was interpreted and parameters affecting the solubility (e.g. pH, Eh), mobility (e.g. partition co-efficient) and persistence (biodegradation) were ranked. An overall hazard ranking was calculated as indicative of the primary chemicals of potential concern.

The potential effect of biological degradation of the organic compounds needs to be assessed regarding changes to the above classification, and toxicity of the daughter products and intermediaries. The anaerobic biodegradation pathways and rates were assessed as these are considered more representative of the groundwater/ reservoir environment. Where biodegradation rates are not known, modelled biodegradation rates (e.g. EPISUITE™ BIOWIN™) were used where possible. The slower the biodegradation rate, the longer the residence time of the compound in groundwater or surface water. The contaminant migration rate in groundwater is dependent on both the biodegradation rate and groundwater flow rate which together determine the potential risk to receptors (water supply well or surface water). High biodegradation rates coupled with low groundwater flow rates combine to yield a low risk for potential contaminants to migrate to potential receptors.

The fate and transport characteristics were included in the 3-D numerical groundwater model.

### 2.1.3 Compile Geochemical Report Section

The geochemical section of the report comprises a database of the physical and chemical properties of the PF chemicals which relate to their behaviour in the environment. This data includes a chemical hazard ranking based on the solubility, mobility, persistence and toxicity. The fate and transport behaviour of the PF chemicals was incorporated into the 3-D numerical groundwater model and the potential impacts to the upper aquifer and surface water features assessed.

## 2.2 Methodology – Groundwater Assessment

The following methodology was used to undertake the groundwater assessment (incorporating a hydrological assessment).

### 2.2.1 Data Gathering and Analysis

Available data, designs, as-built drawings, reports and models were reviewed and assessed to determine how to most appropriately process the available data in preparation for the numerical modeling.

### 2.2.2 Develop / Update Conceptual Groundwater Model

The groundwater conceptual model was developed / updated, including the description of the processes that control or influence the movement and storage of groundwater and solutes in the geohydrological system. The conceptual model explains (qualitatively and quantitatively) the observed groundwater behaviour (shallow and deep) in the area and is referenced and discussed / reviewed regularly throughout the remainder of the tasks in the project.

### 2.2.3 Set Up and Calibrate 3-D Density-Dependent Flow Numerical Model

Prior to building the numerical model, input data is required from multiple sources and in pre-defined formats. Sources included laboratory and field test results, reports, spreadsheets, engineering designs, and outputs of the geochemical study. Pre-processing was undertaken using ArcGIS, along with multiple data manipulations using spreadsheet and database queries and macros.

Because the hydrostratigraphy is considered to be relatively horizontal and homogeneous at depth, if anisotropic, and because of the need to model density-driven groundwater flow, an axisymmetric radial groundwater flow model was used to evaluate pressure effects and plume migration.

The 3-D numerical seepage model was implemented using the FEFLOW 7.1 (DHI-WHASY GmbH.) software. The finite element mesh was represented as 3-noded triangles in cross-sectional view. The unsaturated and saturated Preconditioned Conjugate-Gradient (PCG) Solver Method utilises the 3-D forms of Richard’s Equation and Darcy’s Equation. Model setup includes defining the model type, model geometry, grid and discretization, hydraulic parameter zoning and properties, boundary conditions, injection site volumes, densities and concentrations, and abstraction volumes and densities.

Model calibration involves an iterative process to estimate parameters and fluxes within the calculated range, so that model results correspond reasonably to a pre-agreed set of outputs at particular locations or across defined sections. These are based on conceptual and analytical calculations, available monitoring data, as well as any field and laboratory data from comparable sites.

### 2.2.4 Run Model Predictive Scenarios

Predictive scenarios are designed to answer the questions posed in the modelling objectives. In this project, the focus is on the potential for impact of the upper, fresher water sections of the aquifer and the local river, from both a flow (volume) and chemical (contamination) perspective. Outputs include an assessment of changes to groundwater levels, mass balances and potential plume migration distances/areas. In addition, sensitivity analyses were undertaken to help address inherent uncertainty in the knowledge of hydrogeological conditions and the associated possible alterations (ranges) of phreatic surfaces and plume migration that can be expected under varying assumptions.

### 2.2.5 Compile Groundwater Model Report Section

The 3-D numerical groundwater modelling results are summarised in Section 7, including a summary of the input data, pre-processing and usage; model set-up; model calibration; predictive scenario assumptions and set-up; predictive scenario results; and recommendations for future continued use, ongoing calibration and updating of the model.

## 2.3 Methodology - Hydrological Assessment

The Tambaredjo Oilfield is drained by multiple canals towards the Saramacca River. The water quality assessment:

- Describes the hydrological characteristics and surface water chemistry of the study area in general;
- Determines the potential for the project to impact on nearby surface water bodies, notably the Saramacca River;
- Assesses the vulnerability of surface water resources, including the identification of potential pollutant linkages; and
- Recommends mitigation measures to reduce the potential for impacts on surface water.

## 2.4 Assumptions and Limitations

As is standard practice, the study is based on a number of assumptions and is subject to certain limitations, which should be borne in mind when considering information presented in this report. The validity of the findings of the study is not expected to be affected by these assumptions and limitations:

- The assessment is based on technical information supplied to SRK, which is assumed to be accurate. This includes the chemistry of the injected PF fluid, the proposed locations and pumping rates of all producers, injectors and water supply borehole and the inputs to the geological, groundwater, fate and transport parameters;
- The report is based largely on secondary data gathered during a desktop analysis. Primary fieldwork was not conducted for this study, as the existing data was deemed adequate; and
- It is assumed that no significant developments or changes will take place in the area of influence between data collection and submission of the report.

Other assumptions made in the report are explicitly stated in the relevant sections.

# 3 Hydrogeological Baseline

The following summary of the groundwater and geochemical baseline assessment at the project area was mainly sourced and summarised from “Assessment of Groundwater Salinities in the Aquifers of the Coastal Plan in Suriname” Thesis (Sabajo,2016), except where indicated otherwise:

- The flat marine plain of the project area is primarily underlain by clays with elongated East-West running beach barrier deposits “ritsen” as the main morphological features. The plain is an assembly of clay plates “schollen” dissected by numerous swamps and creeks filled with Holocene clay and peat;
- The vegetation was formerly marked by dry-land forest on the beach barriers and better drained parts of the clayey plain, and by swamp forest on the low-lying parts;
- Geologically, Suriname is part of the Precambrian Guiana Shield. In the north, the shield shows a seaward dip and is covered by Late Cretaceous and Cenozoic deposits of the Guiana Basin. The shield consists mainly of granitoid and metamorphic rocks (De Vletter et al, 1998);
- The Precambrian Guiana Shield started to receive a wedge of sediments in the Late Jurassic-Early Cretaceous with the opening of the Atlantic. The oldest sediments are of Early Senonian (Late Cretaceous) Age. The youngest sediments cropping out in the young coastal plain are of Holocene age. The surface and subsurface sediments of the Coastal Plain area have been grouped into the Corantijn Group;
- The Corantijn Group consist of a monoclinical northern dipping (*c.*1°) section of predominantly clastic sediments. These sediments form a regular alternation of sands, clays, siltstones and minor shales. Occasional marls, lignites and gravel may be intercalated locally. The sediments were deposited under fluvial to marginal conditions. Several regressive and transgressive phases as well as major periods of non-deposition can be recognized. The total thickness of the Group increases from south to north and from east to west;
- The coastal plain of Suriname is underlain by three major aquifers within the Corantijn Group (SRK, 2013):
    - The A-sand aquifer (in the Burnside Formation) contains freshwater in many locations, including Paramaribo, where it is found at an approximate depth of 150 m. The aquifer thickness varies from 10-60 m. The A-Sand aquifer is not directly recharged by rainwater, and it is suspected that upward leakage of groundwater from the older, underlying formation is likely;
    - The Coesewijne aquifer contains freshwater in many locations of the coastal plain, including Paramaribo. The top of the aquifer is found at a depth of 70 m at Paramaribo. The Coesewijne sands are in hydraulic contact with the overlying Zanderij Formation, with groundwater flow in the southern Young Coastal Plain (Helena Christina road – Lelydorp) and diffusion in the northern Young Coastal Plain; and
    - The Zanderij aquifer contains mostly brackish water in the Young Coastal Plain. The Formation crops out in the Savanna Belt and dips to the north. At Paramaribo it is found at depths of about 30-50 m. The Zanderij Formation is in hydraulic contact with the sandy deposits of the Coropina Formation (Lelydorp Deposits) south of Lelydorp. In the study area the aquifer does not have hydraulic contact with surface deposits due to the heavy clay in overlying layers.
- Suriname has a humid tropical climate. The average annual temperature is *c.*27°C and the average rainfall is *c.*1 500 mm in the project area;

- Effective rainfall in clayey terrain is mainly discharged via overland flow and interflow to creeks, swamps and man-made drainage channels. Phreatic groundwater flow systems are poorly developed because of the low permeability and flat topography; and
- Groundwater from aquifers north of the Saramacca River is naturally brackish and/or has an objectionable oily taste, and potable (drinking) water is thus not abstracted in this area. Drinking water is abstracted from the Coesewijne aquifer south of the Saramacca River, e.g. in Tijgerkreek, Tambaredjo and Groningen (SRK, 2013). Although the groundwater underlying the site is generally brackish and not potable nor abstracted for domestic use, deeper fresh to slightly saline water is encountered at depth (Sabajo, 2016). Groundwater for the Polymer Flood project will only be extracted from the new wells if the surface water alternative is discarded.
- Although surface water (Saramacca River) is the preferred water source for the project, the water supply wells are the alternative source of water for the PF project. Average water quality data from groundwater samples taken from the 1J22 and 30HW25 raw water tanks are shown in Table 3-2. Average salinity at 1J22 is *c*.487 mS/m whereas in the deeper 30HW25 well is *c*.570 mS/m.

**Table 3-1: Staatsolie potential industrial water supply wells**

| No. | Name | Depth of Water Reservoir (ft) | Drilling Depth | |
|---|---|---|---|---|
| | | | (ft) | (m) |
| 1 | 3Z14 | 343-348 | 352 | 107 |
| 2 | 30HW25 | 1 125-1 142 | 1 051 | 320 |
| 3 | 1J22 | 504-519 | 571 | 174 |

Source – Staatsolie spreadsheet “Info water wells.xlsx”.

**Table 3-2: 1J22 Water quality (average from December 2018 to May 2019)**

| Constituent | Units | 1J22 (raw water tank) Dec 2018 to May 2019 | 30HW25 (water well) May 2014 to Aug 2016 | WHO Drinking-water Guideline Values |
|---|---|---|---|---|
| $HCO_3^-$ | mg/L | 193 | 196 | - |
| $Cl^-$ | mg/L | 295 | 342 | 5 |
| $Ba^{2+}$ | mg/L | 46 | 10 | 1.3 |
| $Ca^{2+}$ | mg/L | 24 | 30 | 100 - 300* |
| $Mg^{2+}$ | mg/L | 31 | 30 | - |
| Fe (total) | mg/L | 0.39 | 0.71 | 0.3* |
| $SO_4^{2-}$ | mg/L | 140 | 2 | 250* |
| pH | - | 6.5 | 6.5 | 6.5 - 8.5* |
| Total Suspended Solids | mg/L | 59 | 33 | - |
| Total Dissolved Salts | mg/L | 436 | 517 | - |
| Salinity | mS/m | 487 | 570 | - |
| Dissolved Oxygen | ppm | 5.35 | 1.80 | - |
| Sulphate-Reducing-Bacterial content 28$^{th}$ day | ppm | 25 | 263 | - |

Source – Staatsolie spreadsheet “Worksheet for water analysis results_1J22.xlsx” and “Water composition 30HW25.xlsx”.

WHO Guidelines for Drinking-water Quality, Fourth Edition, 2017

* non health-based guideline value / - no health-based guideline value is recommended

# 4 Fate and Transport Baseline

The geochemical environment plays a critical role in determining the chemical risk and response of compounds introduced into the groundwater environment. Based on an understanding of the local geological context and the groundwater conditions it is possible to geochemically determine the most likely chemical and biological degradation processes that may take place in groundwater. The geochemical fate and transport baseline was formulated in preparation for quantitative integration into the hydrogeological 3-D numerical model to predict the potential risk to the upper groundwater resources. The geochemical properties of the PF constituents, as well as the physical environment in which they will be transported, are discussed in Section 4.1, and their quantitative interpretation for modelling purposes is given in Section 6.6.

To determine the potential impact of transported constituents, an assessment is required of the potential for chemical or biological degradation and resulting potential daughter products, including their specific fate and transport properties and toxicity. This is summarised in Section 4.2, which leads into the model results discussion of Section 7.3 and impact assessment in Section 8.1.3.

## 4.1 Physical and Chemical Properties

Various processes describe the fate and transport of a constituent (term used in a broad sense here), including volatilisation, leaching, advection, dispersion, sorption, dilution and decay. These processes determine the mobility and distribution of the chemical in air, soil and water. The primary processes governing the fate and transport of chemical constituents, in the context of the PF project, are discussed further below.

### 4.1.1 Water Solubility

The water solubility values determine if the constituent will be present as a separate phase or dissolved phase in water. In the case of organic constituents, the separate phase will be an immiscible liquid or Non-Aqueous Phase Liquid (NAPL). The higher the solubility, the greater the potential for the constituent to migrate with the water and reach potential receptors.

### 4.1.2 Sorption

Sorption causes constituents to migrate slower than the groundwater and describes the partitioning of a compound between the aqueous and solid phase.

#### Organic Carbon-Water Partition Coefficient

The Organic Carbon-Water Partition Coefficient (Koc) is the ratio of the amount of chemical adsorbed per unit weight of organic carbon in the solid phase to the concentration of the chemical in solution at equilibrium. Koc provides an indication of the extent to which a chemical will partition between solid and solution phases in soil. The Koc can be estimated using the solubility of the compound or the Kow (water octanol partition coefficient).

#### Octanol-Water Partition Coefficient

The Octanol-Water Partition Coefficient (Kow) describes a chemical's hydrophobicity and is the ratio of the concentration in the octanol phase to its concentration in the aqueous phase at equilibrium.

#### Soil-Water Partition Coefficient

The Soil-Water Partition Coefficient (Kd) measures the amount of chemical substance adsorbed onto soil per amount of water. The partitioning of most inorganic compounds, which occur as charged dissolved species in groundwater, is not dependant on the organic carbon content of the solid phase.

The soil-water partition coefficient is pH dependant and does not account for any possible precipitation reactions that may occur.

## 4.2 Chemicals of Potential Concern

The PF project proposes to utilise injecting polymer-augmented water into a subterranean oil formation to improve the sweep efficiency in the reservoir. Such polymers are susceptible to mechanical breakage and shear degradation because dissolved oxygen promotes chemical degradation of both PAM and polysaccharides.

This section comprises a database of the physical and chemical properties of the PF additives (and degradation products) which relates to their behaviour in the environment, including a chemical hazard ranking based on the solubility, mobility, persistence and toxicity.

The understanding of the behaviour of the PF chemicals is utilized for refining the chemical input parameters for the 3-D numerical groundwater model to determine the potential impacts to the upper aquifer and surface water features.

### 4.2.1 Polyacrylamide

PAM refers to a group of water-soluble molecules formed by polymerization of acrylamide monomers (AAM). PAM is highly soluble and is considered non-toxic. PAM is however susceptible to retention and degradation within the reservoir.

PAM has a relatively high partition coefficient, and the adsorption of PAM onto mineral surfaces has been demonstrated to be rapid. The degree of adsorption is dependent on the PAM structure, reservoir mineralogy and groundwater characteristics within the local geological formation. Due to the long length of the polymer and large number of anionic groups, PAM’s adsorption occurs at multiple sites along the polymer length. As such, there is a small probability that all train segments are simultaneously detached from the surface, and adsorption is considered irreversible.

Due to their large size, PAM molecules become physically trapped in blind pores as a function of the physical properties of the reservoir matrix. As PAM molecules are forced through narrow interstitial spaces within the reservoir, the molecules which are sensitive to shearing, are broken into smaller pieces.

PAMs are very insensitive to bacteria, although, sulfate reducing bacteria (as detected in 1J22 and reported as 25 ppm in Table 3-2) can degrade the polymer. Biological degradation breaks down the PAM creating smaller lower molecular weight polymers. During this process no AAM monomer is released.

The chemical degradation of PAM is more pronounced than the biological degradation and is promoted by free radicals. The PAM solution is susceptible to chemical degradation by dissolved oxygen, $H_2S$, and $Fe^{2+}$.

### 4.2.2 Acrylamide

AAM is highly soluble in water, has a low potential to partition to organic matter, and has a low volatilization potential in water. It is therefore unlikely to adsorb to mineral surfaces in the reservoir.

All PAMs contain some level of residual AAM, however, the amount varies substantially depending on the manufacturing process. The residual concentration of AAM due to the incomplete polymerization process. AAM is a likely human carcinogen and neurotoxin, highly soluble in water, has a low potential to partition to organic matter, and has a low volatilization potential in water, and is therefore considered the major environmental risk associated with the use of PAMs.

The **maximum** concentration in AAM used in the water purification industry is 0.05% (WHO, 2011) with similar concentrations quoted for agriculture 0.05% (Lentz *et.al*. 2008). Andersen (2005) quoted that typical residual AAM concentrations in the pharmaceutical industry 0.01% to 0.1% with representative concentrations in the range of 0.02% to 0.03% (200 to 300 mg/kg)

Although the residual AAM concertation in the PAM is likely to be similar to that of the trial phase (0.04% as per the MSDS of the trial polymer), for the purposes of this study a higher (and thus mor conservative) residual concentration of 0.1% AAM has been assumed throughout. This concentration is the maximum expected concentration of residual AAM in high molecular weight PAM. Assuming that the maximum PAM concentration of 1 500 mg/L is used for the PF injection, the maximum AAM concentration in the injection fluid would be 1 500 µg/L. (The actual concentrations are reasonably expected to be lower, with a more probable concentration of 400 µg/L AAM based on 0.04% residual AAM and 1 000 mg/L PAM injection concentration.)

AAM is considered to be a likely human carcinogen and neurotoxin with a maximum permissible concentration in drinking water of 0.5 µg/L (WHO, 2017)[3]. No limits have been published for livestock watering. The use of anionic PAM in agriculture to limit soil erosion and improve irrigation efficiency is well established and commercially available since 1995. Although agricultural application rates are lower in the 3 – 7 kg/ha range (Sojka *et.al.*, 2007) no adverse effects on soil microbial populations have been reported. Residual AAM concentrations in crops are low, and it has been shown that AAM is not absorbed by plant tissues and apparently breaks down rapidly when exposed to living plant tissue (Sojka *et.al.*, 2007).

The EU (2002) risk assessment for AAM reviewed available ecotoxicological studies and derived a Predicted No Effects Concentration (PNEC) for aquatic organisms of 33.85 µ/L AAM. This value was derived from the lowest No Observed Effect Concentration (NOEC) from acute toxicity tests for freshwater species. As this data did not include long-term studies for fish or Daphnia an assessment factor (safety factor) of 1 000 is typically and has been applied.

**Aquatic Degradation**

Acrylamide is reported as being hydrolysed to acrylic acid and ammonia with the reaction being catalysed by hydroxyl ions (OH-) and hydrogen ($H^+$) ions (Jung et al., 1980). These values give half-lives of >1 year at 55°C in the pH range 5-9, and so abiotic hydrolysis is considered insignificant as an aquatic degradation process for AAM under natural hydrological conditions.

Acrylamide undergoes biodegradation after a period of acclimation. At a concentration of 2 000 µg/l AAM, 100% degradation was observed after 28 days while 53.3% degradation was observed on a 5 000 µg/L solution after 28 days. At a lower concentration of 1 000 µg/l AAM, a 100% degradation was observed after a 15 day period. Based on the results of these tests AAM was classified as readily biodegradable at lower concentrations (EU, 2002).

The proposed degradation pathway for AAM is by heterotrophs capable of utilising both the carbon and nitrogen in AAM. The first step in the degradation pathway is the deamination of AAM to acrylic acid, followed by decarboxylation of acrylic acid to ethylene or ethanol.

Degradation of AAM in anaerobic soils is relatively rapid. Under aerobic and waterlogged conditions, AAM is hydrolysed in soils to produce $NH_4^+$. The $NH_4^+$ produced accumulates as $NH_4^+$ under waterlogged conditions or is oxidised to $NO_2^-$ and $NO_3^-$ under aerobic conditions (Abdelmagid et al. 1982). The estimated half-life for biodegradation in soil is estimated at 30 days.

[3] This concentration is derived from the maximum concentration of PAM used in potable water treatment (1 mg/L) and a maximum residual AAM concentration of 0.05%.

**Adsorption**

Adsorption of AAM by natural sediments is considered to be negligible. The following partition coefficients were calculated based on a log Kow of -1.33 by the EU (2002), Kd 0.00976 L/kg for suspended matter and a Kd 0.0039 L/kg for soil. This data shows that the adsorption of AAM to mineral surfaces is insignificant.

### 4.2.3 Ammonium

Ammonium ($NH_4^+$) is a likely daughter product formed during the degradation of PAM. On dissolution in water, ammonia forms the ammonium and hydroxyl ions. The degree of ionization depends on the temperature, the pH, and the concentration of dissolved salts in the water with the ammonium cation (which predominates). The ammonium cation is less mobile in soil and water than ammonia and is involved in the biological processes of nitrogen fixation, mineralization, and nitrification.

The primary driver for limiting $NH_4^+$ discharges to the aquatic environment are its effect on ecology (particularly fish), and potable use of water.

Reactive processes are the determining factors controlling $NH_4$ migration, as a result of cation exchange processes and biological degradation. The $NH_4^+$ ion is readily adsorbed by clay minerals. Sieczka and Koda (2016) found that the adsorption behaviour is best described by the Langmuir equation. However, there is evidence that $NH_4^+$ sorption does not always occur by an exchange mechanism. Sorption of $NH_4^+$ to illite and other 2:1-type clay minerals may be irreversible process because the $NH_4^+$ ion fits into the intra-layer clay lattice (Buss et.al, 2004).

### 4.2.4 Acrylic Acid

Acrylic acid (AA) is another likely daughter product formed during the degradation of PAM. AA is very soluble in water and is not generally expected to adsorb to mineral surfaces.

In biochemical oxygen demand (BOD) studies, AA has been shown to biodegrade rapidly under aerobic conditions. Acrylic acid is also amenable to anaerobic treatment. Although AA is moderately toxic to aquatic life, it is not persistent in aquatic environments, due to rapid oxidation. Large releases can deplete dissolved oxygen (BAMM, 2013). The half-life for AA degradation under aerobic conditions in sandy soil is estimated to be less than 1 day (INCHEM, 1997).

# 5 Hydrological Baseline

The Saramacca District has approximately 3 320 km$^2$ of coastal wetlands, of which 370 km$^2$ support mangrove forest. Most wetlands consist of swamplands with poorly to very poorly drained soils, which are inundated either permanently or at least during the greater part of the year. Areas along the coast or tidal river sections are inundated twice a day during high tide. Water quality in the Coastal Plain varies from saline to brackish near the coast to freshwater further south.

Historically, the northern part of the swamp drained north towards the sea, while the southern part drained south towards the Saramacca River. The approximate catchment boundary is indicated by the red line in Figure 5-1. The area draining northwards is considered to support important ecosystem goods and services that are particularly sensitive to the hydrology and water quality and includes the Coppename Monding Nature Reserve (see Figure 5-2).

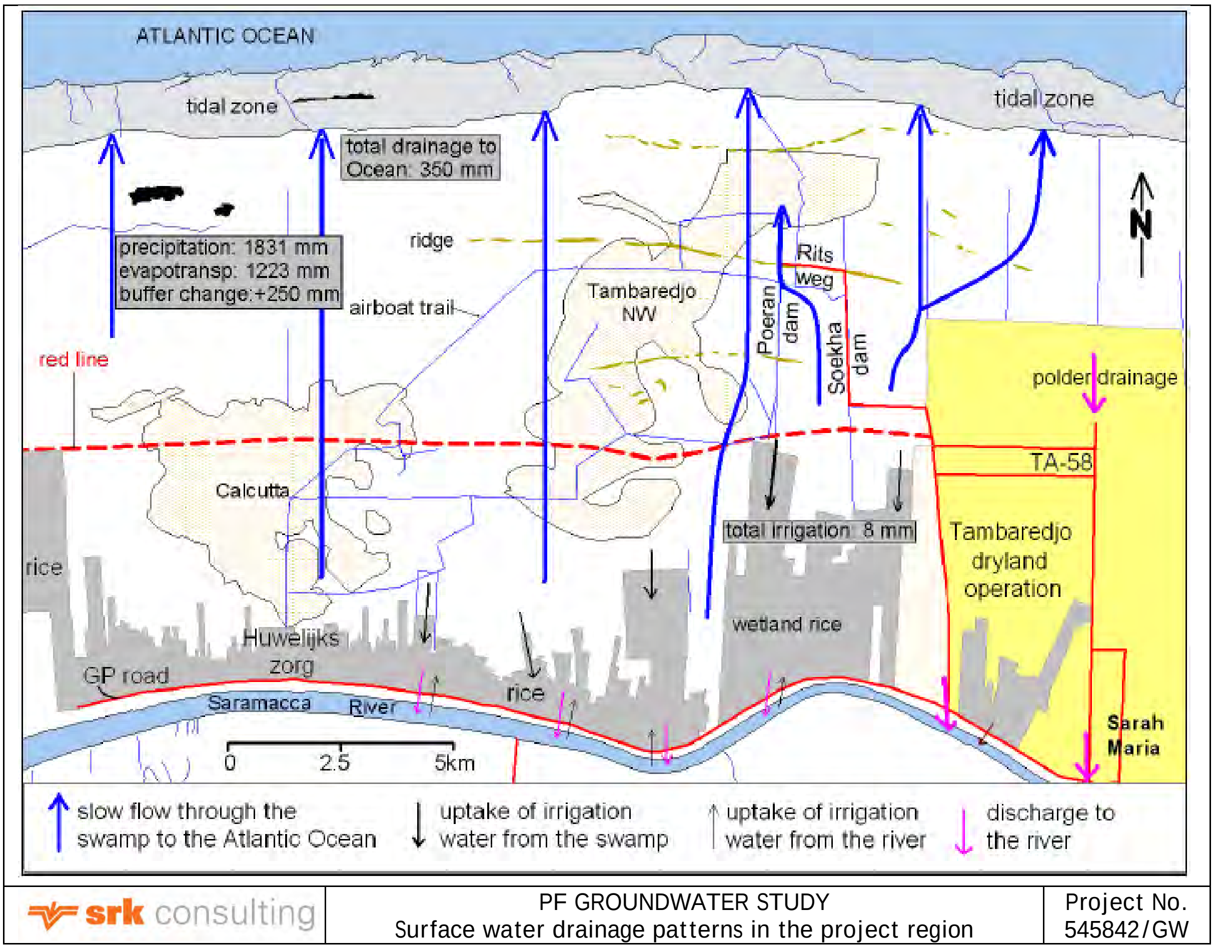



**Figure 5-1: Surface water drainage patterns in the project region**

*Source: Noordam Environmental Consultancy (2010)*

Volumes refer to the study period from 18 November 2008 to 23 July 2009.

The natural hydrological conditions of the area draining southwards have been affected over time by dryland cropping, road construction, development of rice polders, abstraction and discharge of irrigation water and the development of the Tambaredjo oil polder. As a result, water levels have changed, flow of swamp water to the Saramacca River has been obstructed in certain areas, and drainage patterns have changed as indicated in Figure 5-1, i.e. more water drains northwards than previously, while the entire Tambaredjo Polder drains southwards.

The Tambaredjo Oil Field (outlined in white in Figure 5-2) was developed in a former wetland area located between the Buru and Wayambo swamps. The polder is characterised by south-north aligned dams and canals that obstruct the natural water flow in the swamp. The entire polder area now drains via two main canals towards the Saramacca River.


| srk consulting | PF GROUNDWATER STUDY<br>Location of Tambaredjo oil polder relative to other features | Project No.<br>545842/GW |
|---|---|---|

**Figure 5-2: Location of Tambaredjo oil polder relative to other hydrological features**

The project site is located the Tambaredjo Polder, from which excess water is discharged into the Saramacca River by a number of large N-S canals. In addition to these N-S canals there are also a number of E-W canals that connect the N-S canals. The N-S canals drain into the Saramacca River through culverts. The project site drains through the Kisoensingh-west Canal that runs along the main access road of the polder. The culverts along the Saramacca River are operated by Staatsolie, so the company has full control on the water management of the polder.

Key sources of potential water pollution include the TA-58 plant, the Sarah Maria facility the waste incineration area and the landfarm in the Tambaredjo Polder.

## 5.1 Tambaredjo Polder Water Quality

**Historic water quality data** (1999) for the Tambaredjo polder recorded elevated chloride (salinity) > 250 ppm chloride at the outlet of the TA-58 oil-water separator, where effluent is released into the canal. It is, however, expected that salinity will be considerably reduced downstream at the outfall into the Saramacca River due to dilution of the effluent by stormwater.

Very low pH was measured near TA-58, but in the remainder of the locations pH is much higher. Overall pH during the dry season is higher than during the rainy season. Dissolved oxygen (DO) levels vary from low to medium, with overall higher DO in the dry season.

Very high turbidity was measured at one location, but typically varies between 35 and 66 Nephelometric Turbidity Unit (NTU), consistent with data for a 2016-17 sampling campaign (Staatsolie), for which 90% of the results are between 41 and 114 FTU. These turbidity values correspond with Total Suspended Solids (TSS) values between 31 and 82 mg/L (Staatsolie data 2015-16, sampling Kisoensingh-west Canal).

Nitrate and ammonia are very low, which is normal for unpolluted natural waters. The phosphate levels are very low to medium. The measured nutrient levels do not point to organic pollution.

In 2018, surface water samples were taken in the Kisoensingh-west Canal at locations SO1-SO3 (and the Saramacca River at location SO4), upstream and downstream of the proposed new power plant (see Figure 5-3), during the rainy (11 July 2018) and dry seasons (3 October 2018), to determine the baseline water characteristics and concentration of key pollutants. Aside from higher pH, all other parameters are more or less within the same range as in 1999.

A number of metals are found in the water, of which barium, arsenic and zinc are encountered in at least 50% of the samples. Arsenic exceeds the guideline value for consumption of organisms by humans, but it is below the value for aquatic life. The elevated barium levels could be related to spills of barite or disposal of spent drilling mud. The SO3 dry season sample exceeds the USEPA guideline for consumption of organisms.

Furthermore, there are a number of chemical compounds, of which toluene and diazinon are found in all rainy season samples and phenols in both rainy and dry season samples. These findings could possibly be related to release during processing of crude oil (toluene), spills or leakages of certain chemicals like wood preservatives (phenols) and the use of insecticides (diazinon).

Of interest is the presence of PCB's in sample $SO_2$ during the rainy season sampling. The sample is taken near TA-58 and most likely points to pollution from that source. The level is well above the USEPA guideline level for human consumption. Minor diesel and gasoline spills can be observed in samples SO1 (rainy season) and SO2 (dry season).


| srk consulting | PF GROUNDWATER STUDY<br>Location of surface water sampling points | Project No.<br>545842/GW |
|---|---|---|

**Figure 5-3: Location of surface water sampling points**

## 5.2 Saramacca River Water Quality

A 2018 study found that pH is slightly acidic, while salinity is very low. There is, however, a slight increase in pH and EC for the Long Dry Season, but there is no indication of salt intrusion from the ocean, which would be indicated by EC values > 1 mS/m. Dissolved Oxygen is moderate with values of 5.5 mg/L.

Total Suspended Solids (TSS) is higher than the TSS in the Kisoensingh-west canal (except for sample SO2 - LDS), probably under influence of the tidal movement. Phosphorus is lower than in the canal, because the canal water has more exchange with soil and organic debris.

Rainy and dry season samples from the Saramacca River (SO4) adjacent to the Tambaredjo Polder, showed elevated levels for barium, zinc and diazinon in both seasons. Similar levels of barium and diazinon have also been recorded in the Suriname and Coppename Rivers (NEC & ILACO 2016), with 6-12 µg/L barium and 0.3-0.7 µg/L diazinon. It should be noted that the Coppename River is considered an unpolluted river. The elevated concentrations of these compounds are thought to be the result of natural processes and therefore represent natural background levels in these rivers.

The diazinon levels in the canal are also considered to represent natural background levels, as they are in the same range as found in the rivers. However, the barium level in the canal is above the natural river levels and points to pollution.

Elevated levels for toluene and Total Petroleum Hydrocarbon were measured in the rainy season sample. These are likely the result of an oil spill or leakage.

Apart from the latter, the river water can be characterised as unpolluted.

# 6 Numerical Flow and Transport Model Set-Up

## 6.1 Numerical Model Approach

The model was formulated in the 3-D finite element software package *FEFLOW 7.1*, a pre- and post-computer program for the simulation of subsurface flow and transport processes (DHI-WHASY GmbH., October 2017, Diersch, Hans-Jörg G.). The program uses finite element analysis to solve the groundwater flow equation of both saturated and unsaturated conditions as well as mass and heat transport, including fluid density effects and chemical kinetics for multi-component reaction systems. *FEFLOW* allows highly flexible meshes, including structured and fully unstructured meshes. It simulates porous media flow, however, allows for discreet features such as fracture and pipe flow.

This software platform has been chosen considering the following elements:

- Wide use in the groundwater industry, particularly mining;
- Ability to use local mesh refinement, optimizing the number of elements required by the model, and refining the model in areas of interest such as the location of the injectors;
- Ability to incorporate the density and viscosity effects of the PAM into the fate and transport modelling; and
- Extensive pre- and post-processing capabilities, facilitating the interrogation of model inputs and generation of model outputs.

The numerical flow modelling methodology is based on that of Applied Groundwater Modelling by Anderson *et al.* (2015), with the model acceptance criteria and confidence classifications according to the Australian Groundwater Modelling Guidelines by Merz (2012).

### 6.1.1 Assumptions and Limitations

The following simplifying assumptions were taken during the development of the numerical groundwater model:

- For fate and transport modelling, an 'indicator element' is often used to represent the likely contaminant plume footprint and concentration profile. This element does not need to be the chemical of greatest concern: however, from the model results of footprint area and profile, information (and risk) for all associated chemicals that travel with the indicator element (including any elements of concern) can then be deduced. It is thus standard practice to use the indicator element that is likely to travel the greatest distance, thus modeling 'worst case'. Following from the fate and transport review (Section 4 of this report), the agreed and modelled indicator element is PAM. Note that AAM, one of the daughter products of PAM, may be transported beyond the PAM footprint, due to its higher solubility and the effects of biodegredation.
- Based on an overview of the local Tambaredjo geology, the modelled lithological layers are assumed to be flat and homogeneous;
- The total pumping and abstraction rates of the producers and injectors is divided equally between the number of wells active at the time;
- Hydraulic and fate and transport properties are estimated from available literature, as well as data and information provided by Staatsolie, as described in the sections that follow;
- Although there is a lack of data for detailed model calibration, the model can be found 'fit for purpose' by reviewing model inputs, comparing the model output results for injection pressures

and abstracted concentrations to those already determined in other studies and by qualitative comparison between the conceptual and numerical model results; and

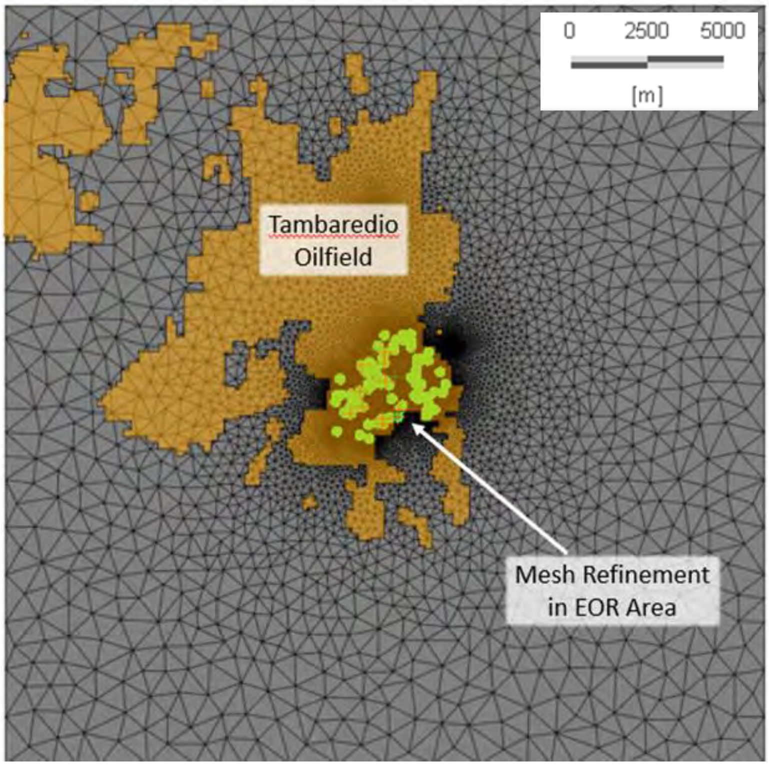
- Re-injection of back produced polymer will be considered by Staatsolie in a separate study and the impact of re-injecting back produced polymer was not modelled.

The following limitations of the model are noted:

- It is possible that contaminant flow could extend further (such as an order of magnitude) along individual preferential pathways (such as fractures or high conductivity zones) than the contaminant footprint area that is calculated in the model which assumes continuous low flow in a matrix; and
- Numerical groundwater models are very useful tools for assisting in the simulation and prediction of groundwater movement under proposed scenarios. They are always theoretical, however, and only based on available data and therefore careful interpretation of the results and regular update of the model is required to draw the most informative conclusions.

## 6.2 Meshing

The numerical flow model boundary is set to be *c.*10 km beyond the proposed PF area in all directions to prevent any boundary effect from influencing model results. The finite element mesh consists of three-noded triangles in plan view, extended with depth to form 3-D triangular prisms. To ensure accurate representation of 3-D flows in the proposed PF area, a fine element size was used with side lengths of *c.*0.2 m around the wells, increasing to *c.*750 m by the *c.*10 km boundary. The model has 16 layers, with 109 384 triangular prism elements per layer and thus there are 1 750 144 elements in total (see Figure 6-1 where the top of the model is shown in plan view).




| srk consulting | PF GROUNDWATER STUDY<br>Model Domain and Finite Element Meshing | Project No.<br>545842/GW |
|---|---|---|

**Figure 6-1: Model domain and finite element meshing**

## 6.3 Layer Geometry

The model comprises 16 layers. The layers are flat / horizontal and are each 30 m in depth, except for the two layers representing the oil reservoir, which are each 3 m in depth. For model representation, each layer is assumed to have homogeneous properties and is assigned a predominant lithology (and thus an associated model 'hydraulic properties zone') based on averages extracted from the exploration well logs (source: Staatsolie Powerpoint file "*Cross sections through PFEA area.pptx*") and personal communications with Staatsolie (*Rakesh Ramdajal, Teamleader Geology & Geophysics*). Model layer geometry and the modelled 3-D representation are shown in Figure 6-2.

**Table 6-1: 3-D Model layer depths and assumed lithology / hydraulic zone**

| Model Layer | Start Depth (ft bgl) | End Depth (ft bgl) | Start Depth (m bgl) | End Depth (m bgl) | Lithology | Model Hydraulic Properties Zone |
|---|---|---|---|---|---|---|
| 1 | 0 | 98 | 0 | 30 | Sand | KZone-Sand |
| 2 | 98 | 196 | 30 | 60 | Clay | KZone-Clay |
| 3 | 196 | 294 | 60 | 90 | Clay | KZone-Clay |
| 4 | 294 | 392 | 90 | 119 | Sand | KZone-Sand |
| 5 | 392 | 490 | 119 | 149 | Sand | KZone-Sand |
| 6 | 490 | 588 | 149 | 179 | Clay | KZone-Clay |
| 7 | 588 | 686 | 179 | 209 | Sand | KZone-Sand |
| 8 | 686 | 784 | 209 | 239 | Clay | KZone-Clay |
| 9 | 784 | 882 | 239 | 269 | Sand | KZone-Sand |
| 10 | 882 | 980 | 269 | 299 | Clay | KZone-Clay |
| 11 | 980 | 990 | 299 | 302 | T-Zone Oil Reservoir | KZone-Reservoir |
| 12 | 990 | 1000 | 302 | 305 | T-Zone Oil Reservoir | KZone-Reservoir |
| 13 | 990 | 1088 | 302 | 332 | Cretaceous Sand | Kzone-CretSand |
| 14 | 1088 | 1186 | 332 | 361 | Cretaceous Clay | Kzone-CretClay |
| 15 | 1186 | 1284 | 361 | 391 | Cretaceous Sand | Kzone-CretSand |
| 16 | 1284 | 1382 | 391 | 421 | Cretaceous Clay | Kzone-CretClay |

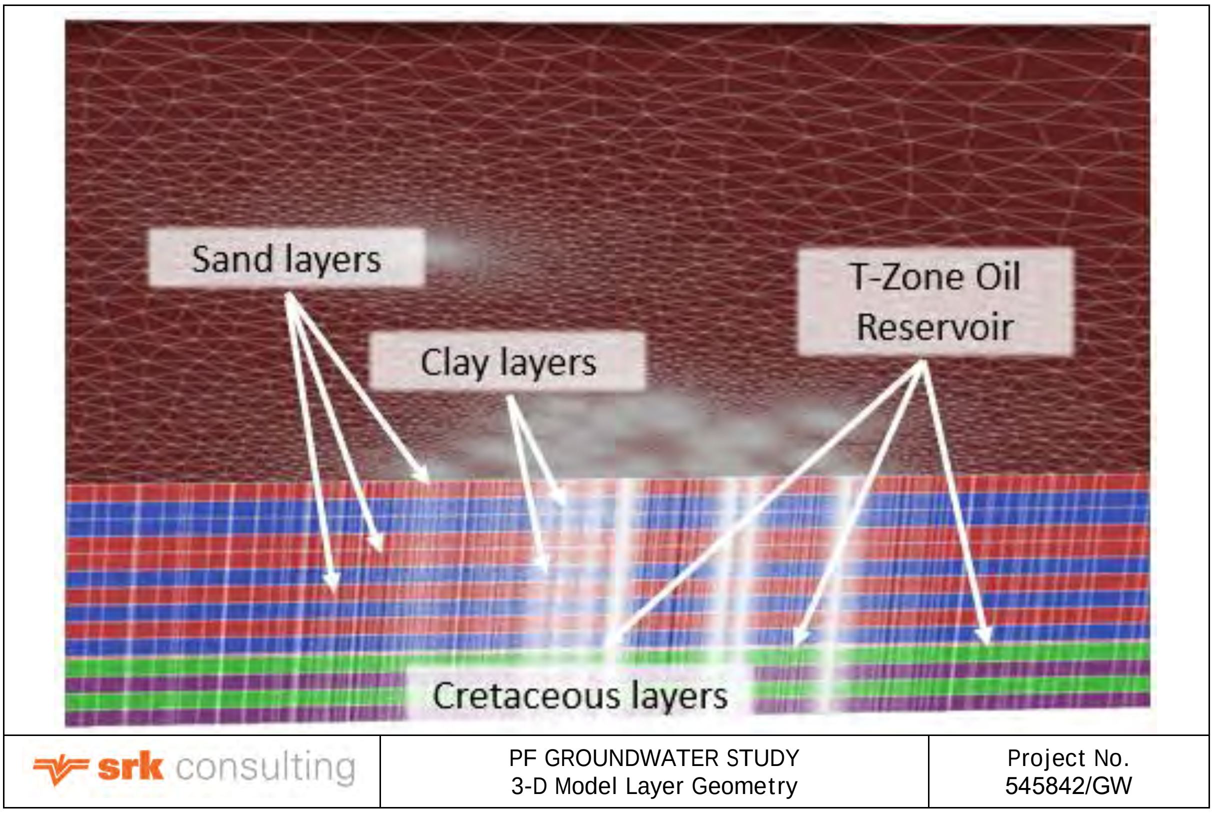



**Figure 6-2: 3-D Model layer Geometry**

## 6.4 Boundary Conditions

A model boundary is the interface between the model domain and the surrounding environment. Boundaries in groundwater models can be specified as:

- Constant head or constant concentration boundary conditions;
- Neuman (or specified flux) boundary conditions; and
- Cauchy (or a combination of Constant and Neuman) boundary conditions.

The following boundary conditions are included in the model:

- All horizontal boundaries in the top model layer are set to a **constant head** of 3.5 m bgl (11.5 ft bgl). The estimation of water level in the top aquifer is based on the well logs (source: Staatsolie Powerpoint file "*Cross sections through PFEA area.pptx*"). It also corresponds to the reported water level for 1J22 (Staatsolie Report B-0479B, 2011). The water level in the top aquifer is assumed to be flat/horizontal, despite there being a slight hydraulic gradient. This assumption is not considered material to the model which require calculation of the vertical flows between pressure differences in the oil reservoir versus the upper aquifer and less so the horizontal flows within the upper aquifer;
- All horizontal boundaries in the top model layer are set to a background **constant concentration** of 0 mg/L of the model scenario indicator element (PAM);
- All remaining boundary cells at the model edge are prescribed as **no flow**; and
- The model base (at a depth of 424 m bgl (*c.*1 391 ft bgl), *c.*300 ft into the Cretaceous) is a **no flow** boundary as it is assumed to be have such a low permeability that it is considered to have little bearing on the model results.

## 6.5 Hydraulic Properties

Hydraulic properties are assigned to each of the modelled 'hydraulic property zones' and are based on the physical properties of each lithology. Permeability, also linked to hydraulic conductivity (K), measures the ease with which groundwater flows in the subsurface. Permeability is a property of the porous medium itself while K is the property of the whole system including both porous medium and the flowing fluid. Storativity (S) is the volume of water per volume of aquifer released as a result of a change in head. For a confined aquifer, the storage coefficient is equal to the product of the specific storage and aquifer thickness of the saturated porous medium. For an unconfined aquifer, the S is the ratio of the volume of water that drains by gravity to that of the total volume and is known as specific yield (or effective porosity). Dispersion is the process by which water, solutes and suspended molecules travel at rates different from the average linear velocity in the direction of the groundwater flow (longitudinal dispersion) or perpendicular to groundwater flow (transverse or vertical dispersion).

Modelled hydraulic properties were obtained from previous studies, literature, analysis of hydraulic test data (for the water supply well), personal communication (pers. comm.) with Staatsolie and model calibration. Modelled values per zone and the associated sources / assumptions on which these values were based are shown in Table 6-2.

**Table 6-2: Model hydraulic properties**

| Property | Unit | KZone-Sand | KZone-Clay | KZone-Reservoir | KZone-Cret.Sand | KZone-Cret.Clay | Source |
|---|---|---|---|---|---|---|---|
| Permeability | Darcy | 20 | 0.012 | 20 | 0.5 | 0.001 | Pers. comm. Rakesh Ramdajal, (Teamleader Geology & Geophysics) and Jasvant Oedietram (Sr. Petrophysicist) |
| K (horizontal) | m/d | 12.79 | 0.01 | 12.79 | 0.32 | 0.001 | Conversion from permeability for average background groundwater concentrations. In addition, analysis of pumping test results at 1J22 (using *Aqtesolv* software) resulted in an estimated 'sand' aquifer horizontal K of *c*.10 m/d. The pumping test was undertaken for a 24 hour period at an abstraction rate of 25 $m^3$/hour. The maximum drawdown was *c*.4.5 m. (Staatsolie Report B-0479B, 2011) |
| Horizontal Anisotropy | - | 1 | 1 | 1 | 1 | 1 | No horizontal anisotropy ($K_x$ versus $K_y$) assumed |
| Vertical Anisotropy (Kh/Kv) | - | 50 | 25 | 10 | 50 | 33 | High vertical anisotropy, particularly in the sand layers, due to the presence of kaolinite horizons within the sand (pers. comm. Rakesh Ramdajal) |
| K (vertical) | m/d | 0.26 | 0.0004 | 1.28 | 0.0064 | 0.00003 | Calculated from vertical anisotropy |
| Porosity | % | 25% | 39% | 30% | 20% | 20% | Above oil reservoir: Sourced from Staatsolie Report B-0479B (2011) and further discussed with Rakesh Ramdajal Reservoir and Cretaceous: Sourced from Staatsolie Report B-01296A (2017) |
| Effective Porosity / Specific Yield | % | 25% | 1% | 30% | 20% | 0.5% | |
| Specific Storage (compressibility) | ($m^{-1}$) | 0.0002 | 0.0030 | 0.0002 | 0.0001 | 0.0010 | Batu (1998) |
| Longitudinal Dispersivity | m | 200 | 100 | 200 | 200 | 100 | Dispersivity in reservoirs is"suggested to be proportional to the distance travelled by the injected bank" (Arya et al. 1988) (quoted and further discussed in SPE164121 (2013)) |
| Transverse Dispersivity | m | 10 | 100 | 10 | 10 | 100 | |

## 6.6 Fate and Transport Properties

Fate and transport properties are assigned to the numerically modelled indicator element, PAM. These processes determine the mobility and distribution of the chemical within the natural flow of the groundwater system. Modelled values for PAM and the associated sources / assumptions on which these values were based are shown in Table 6-3.

**Table 6-3: Model fate and transport properties**

| Property | Unit | Polymer *: (HPAM) | Source |
|---|---|---|---|
| Viscosity (freshwater) | kg/m-d | 86 | Converted from 1 cP.(from Staatsolie, 2018) |
| Viscosity (polymer solution) | kg/m-d | 7 344 | Converted from 85 cP.(from Staatsolie, 2018) |
| Viscosity-Concentration Graph | | See Figure 6-3 | Calculated by extracting data from the viscosity-concentration graph (Figure 1, Staatsolie Report B-0479AA, 2014), and curve matching to define appropriate *FEFLOW* input parameters. |
| Density (polymer solution) | $g/m^3$ | 991 542 | Converted from 61.9 lbs/ft (value from Staatsolie spreadsheet “SNF polymer.xls” provided by Shailesh Kisoensingh, Sr. Reservoir Engineer) |
| Density (fresh water) | $g/m^3$ | 1 000 000 | Standard |
| Density ratio | - | -0.008 | Density ratio in *FEFLOW* is defined as the density difference in the model divided by the freshwater density: $\alpha = (\rho_{max}-\rho_0)/\rho_0$ |
| Retention in Reservoir | µg of polymer / g of sand | 19 | Staatsolie spreadsheet “SNF polymer.xls” provided by Shailesh Kisoensingh |
| Retention in Reservoir at maximum concentration | mg/L | 35 | Concentration retained in the pores = (1-porosity)*(sand density)*(retention factor) |
| Adsorption in Reservoir | µg of polymer / g of sand | 7 | Staatsolie spreadsheet “SNF polymer.xls” provided by Shailesh Kisoensingh |
| Adsorption in Reservoir at maximum concentration | mg/L | 13 | Concentration adsorbed into the solids = (1-porosity)*(sand density)*(adsorption factor) |
| Henry K Ratio in Reservoir (Concentration in solid phase / Concentration in fluid phase) | - | 0.05 | Assuming a reference maximum concentration of 1 000 mg/L (where K= (13+35)/1000)) |
| Henry K Ratio in KZone-Sand | - | 0.05 | Assumed similar mineralogy to that of the reservoir |
| Henry K Ratio in KZone-Clay | - | 0.14 | Clay assumed to be *c*.2.8 times more retentive than sand due to the smaller size of the pores |
| Diffusion co-efficient | $m^2/s$ | $1 \times 10^{-9}$ | Appelo & Postma (2005) |

Notes: *Although SNF Flopaam 6030 was utilised for the purposes of the pilot study, the actual product utilised for the full scale implementation of the PF may differ. The physical characteristics of the polymer are, however expected to be very similar to the polymer formulations utilised in the pilot study, and are quoted here for reference only

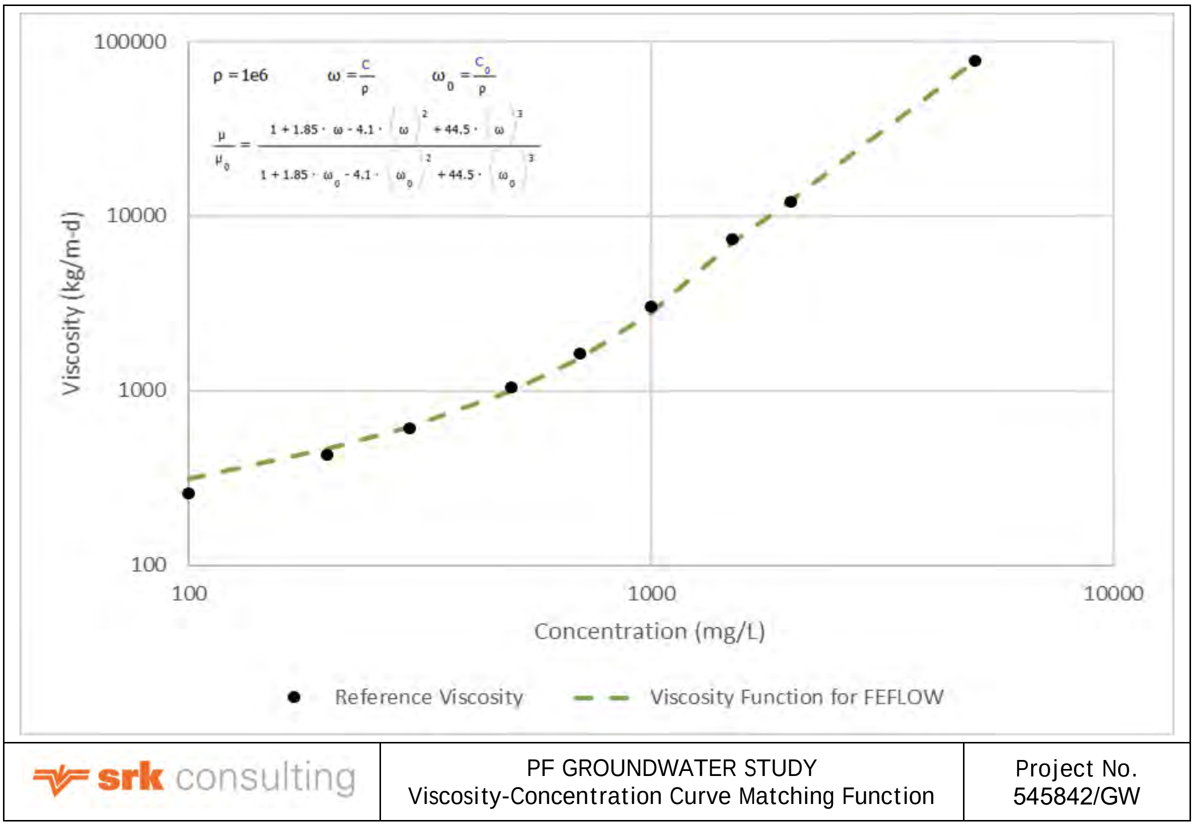



**Figure 6-3: Viscosity-concentration curve matching function**

## 6.7 Supply Boreholes

According to the Staatsolie Report B-0479B (2011), borehole 1J22 is expected to pump groundwater for supply at 2 500 bbl/d (400 $m^3$/d) throughout the PF production time, of which 2 400 bbl/d is for the PF Project at Tambaredjo Oilfield and 100 bbl/d for other uses. Personal communication with Soeraya Mangalsing (Environmental Engineer) confirms that no other boreholes are being pumped for water supply and that the capacity of 1J22 is estimated as 20 $m^3$/hour (480 $m^3$/d) by the borehole owner. The maximum pumping rate of 480 $m^3$/d for 1J22 is therefore assumed in the model.

Pumping is assumed to take place in modelled layer 5 to represent the borehole screen interval of 504 to 519 ft bgl (153 to 158 m bgl).

## 6.8 Injection and Production Schedule

The injection and production schedule (rates and concentrations) per year of production is shown in Table 6-4. The injection rate and PAM concentration are taken for the ‘worst case’ feasible scenario (P10). The total injection and abstraction rates, as well as the PAM concentrations are extracted from the Staatsolie (2018) report. The total pumping and abstraction rates of the producers and injectors is divided equally between the number of wells active at the time. Fresh water is injected for the first month, followed by PAM injection for 13 years, after which fresh water is again injected for 12 years.

The location of the 33 Phase 1 injectors, the 29 Phase 2 injectors (active from year 2), the two converted Phase 2 injectors, the current 200+ producers, the 11 Phase 1 producers and four Phase 2 producers (active from year 2) were provided by Staatsolie in the kmz files at the locations shown in Figure 6-4. Three cross section lines (A-A’, B-B’ and C-C’) are also shown on Figure 6-4. These are used for discussion of model results in Section 7.

In the *FEFLOW* model, injector wells are represented using a time-varying injection rate "well" *fluid flow* boundary condition and a time-varying "mass-concentration" *transport* boundary condition.

Producer wells are represented using a time-varying abstraction rate "well" *fluid flow* boundary condition.

**Table 6-4: Injection and production schedule**

| Injectors | | | | | Producers | | |
|---|---|---|---|---|---|---|---|
| Year | No. of Injectors | Total Injected (bbl/d) (for P10 /worst case) | Injection Per borehole (bbl/d) | PAM Concentration (mg/L) (worst case) | No. of Producers | Total Abstracted (bbl/d) | Abstraction Per borehole (bbl/d) |
| 1 month | 33 | 850 | 25.8 | 0 | 200 (existing) | 5 031 | 25.2 |
| 1 | 33 | 20 317 | 615.7 | 1 500 | 211 | 6 485 | 30.7 |
| 2 | 64 | 18 256 | 285.3 | 1 500 | 215 | 7 093 | 33.0 |
| 3 | 64 | 16 250 | 253.9 | 1 500 | 215 | 7 242 | 33.7 |
| 4 | 64 | 15 377 | 240.3 | 1 500 | 215 | 7 375 | 34.3 |
| 5 | 64 | 14 574 | 227.7 | 1 500 | 215 | 7 458 | 34.7 |
| 6 | 64 | 14 058 | 219.7 | 1 500 | 215 | 7 703 | 35.8 |
| 7 | 64 | 13 656 | 213.4 | 1 500 | 215 | 7 749 | 36.0 |
| 8 | 64 | 13 362 | 208.8 | 1 500 | 215 | 7 802 | 36.3 |
| 9 | 64 | 13 083 | 204.4 | 1 500 | 215 | 7 872 | 36.6 |
| 10 | 64 | 12 886 | 201.3 | 1 500 | 215 | 7 984 | 37.1 |
| 11 | 64 | 12 384 | 193.5 | 1 500 | 215 | 8 076 | 37.6 |
| 12 | 64 | 12 620 | 197.2 | 1 500 | 215 | 8 168 | 38.0 |
| 13 | 64 | 12 391 | 193.6 | 1 500 | 215 | 8 167 | 38.0 |
| 14 | 64 | 14 004 | 218.8 | 0 | 215 | 8 005 | 37.2 |
| 15 | 64 | 14 778 | 230.9 | 0 | 215 | 7 956 | 37.0 |
| 16 | 64 | 15 472 | 241.8 | 0 | 215 | 8 051 | 37.4 |
| 17 | 64 | 15 763 | 246.3 | 0 | 215 | 7 997 | 37.2 |
| 18 | 64 | 15 976 | 249.6 | 0 | 215 | 7 998 | 37.2 |
| 19 | 64 | 16 344 | 255.4 | 0 | 215 | 8 129 | 37.8 |
| 20 | 64 | 16 579 | 259.0 | 0 | 215 | 8 051 | 37.4 |
| 21 | 64 | 16 900 | 264.1 | 0 | 215 | 8 082 | 37.6 |
| 22 | 64 | 17 029 | 266.1 | 0 | 215 | 9 046 | 42.1 |
| 23 | 64 | 16 871 | 263.6 | 0 | 215 | 9 751 | 45.4 |
| 24 | 64 | 16 985 | 265.4 | 0 | 215 | 10 345 | 48.1 |
| 25 | 64 | 16 970 | 265.2 | 0 | 215 | 10 630 | 49.4 |

Source for total injection, abstraction and P10 PAM concentrations – Staatsolie (2018).

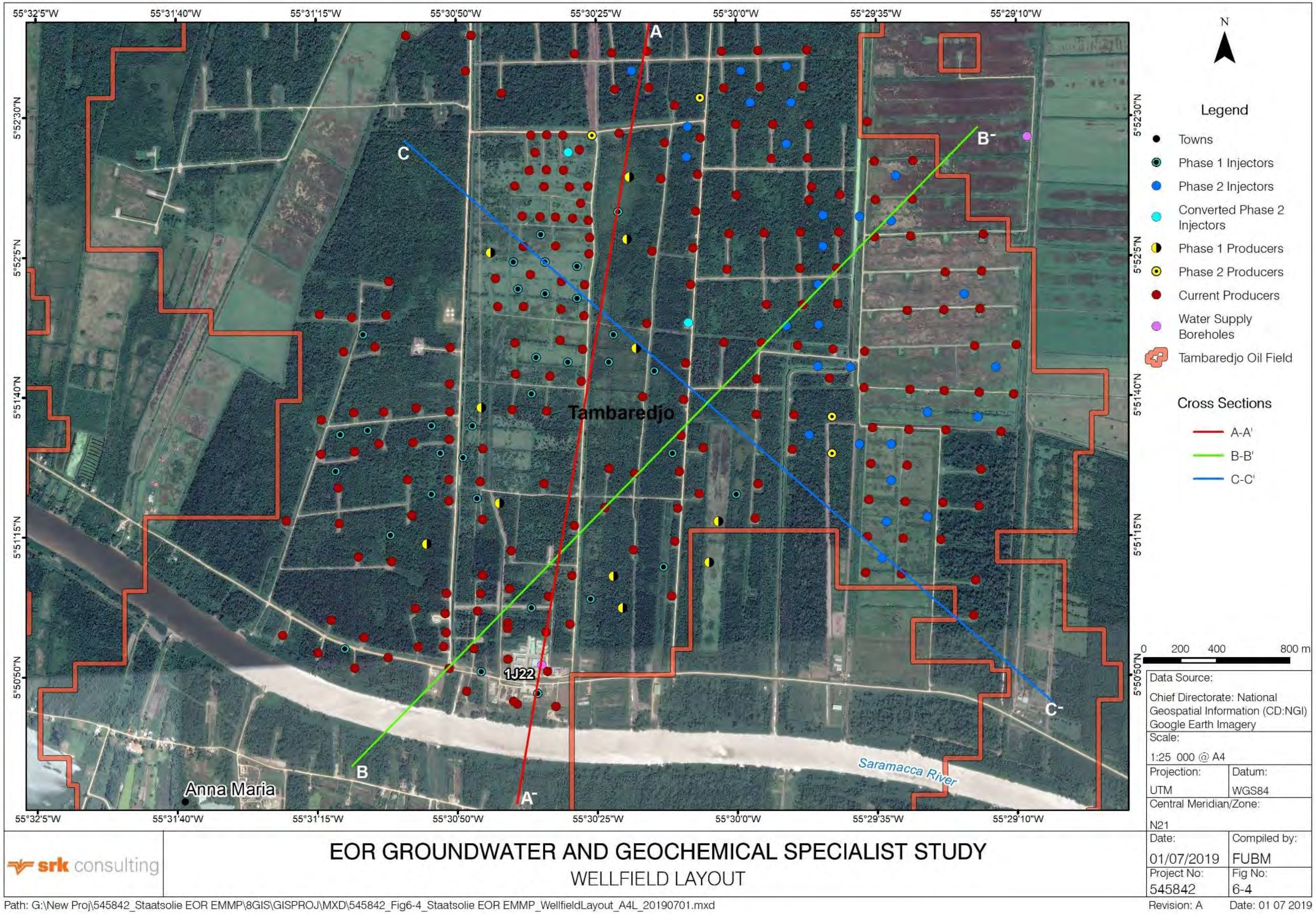



**Figure 6-4: Wellfield layout**

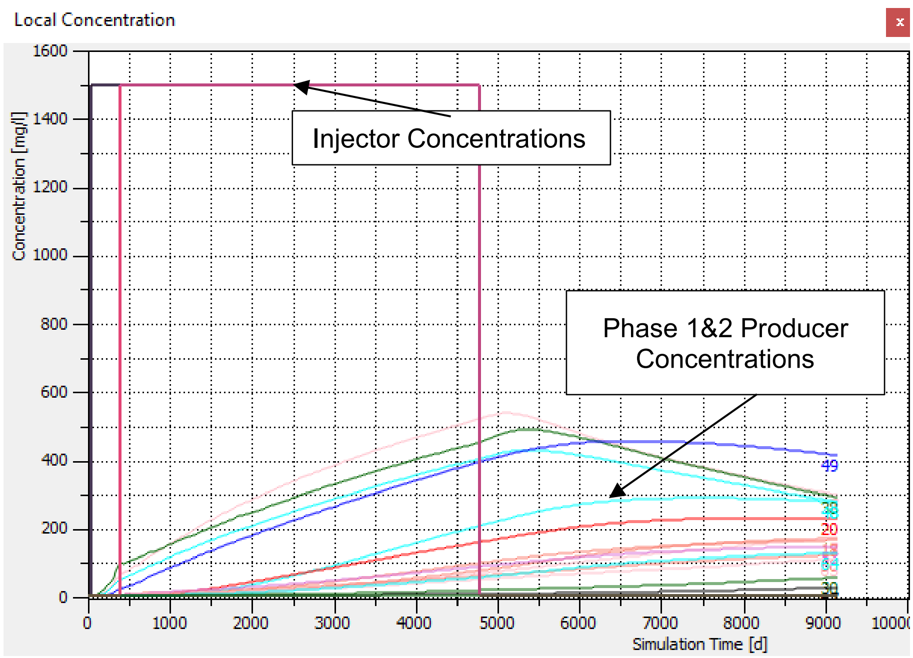
# 7 Model Predictive Scenario Results

## 7.1 Predictive Scenario

The *FEFLOW* model was set up as described in Section 6. The predictive scenario was run for a total simulation time of 9 155 days (25 years and one month). During (and following) the run, all parameters were checked to ensure correspondence to the conceptual model and setup parametisation, including modelled concentrations, viscosity, density, flow directions, rates and model mass balance. Furthermore, the model outputs of injection pressures and abstraction concentrations were checked for correspondence to the range reported for the produced polymer concentrations (see Figure 7-1) from Staatsolie's reservoir model.

Having passed these set-up and calibration checks, the model is considered 'fit for purpose' in assessing risk to groundwater associated with the proposed PF project at the Tambaredjo Oilfield. As the predicted PAM concentrations in the reservoir model are greater than those predicted in SRK's groundwater model, the higher (and thus more conservative) predicted PAM concentrations from the reservoir model have been used to calculate surface water impacts in this study.

Model scenario output results are saved to a recording (.dac) file. Processed model results are discussed in the sub-sections that follow.




| Produced Polymer Concentration P10 | |
|---|---|
| Year | mg/L |
| 1 month | |
| 1 | 34 |
| 2 | 49 |
| 3 | 93 |
| 4 | 154 |
| 5 | 217 |
| 6 | 274 |
| 7 | 326 |
| 8 | 374 |
| 9 | 414 |
| 10 | 446 |
| 11 | 468 |
| 12 | 494 |
| 13 | 521 |
| 14 | 547 |
| 15 | 579 |
| 16 | 604 |
| 17 | 631 |
| 18 | 651 |
| 19 | 667 |
| 20 | 681 |
| 21 | 694 |
| 22 | 553 |
| 23 | 389 |
| 24 | 290 |
| 25 | 241 |

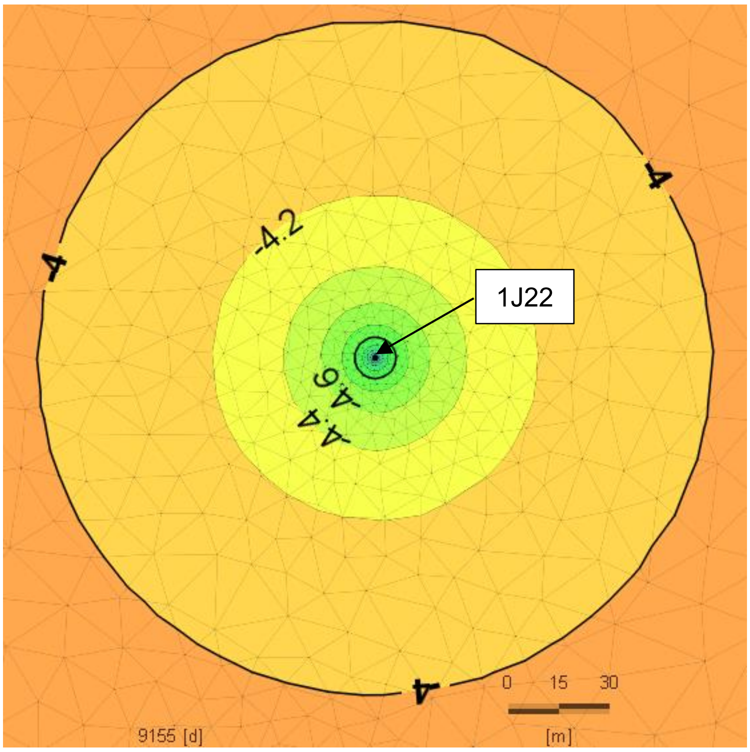
srk consulting | PF GROUNDWATER STUDY Model Concentrations Versus Reported Produced Polymer Concentrations | Project No. 545842/GW

**Figure 7-1: Predicted produced polymer concentrations from the groundwater and reservoir models**

## 7.2 Potential Groundwater Drawdown from Water Supply

Although the preferred source of water supply for the polymer plant is the Saramacca River, the potential use of groundwater has been included in the model should this alternative be implemented. As discussed in Section 6.7, if groundwater is used to supply the polymer plant, then borehole 1J22 would be used. The maximum pumping rate of 480 m$^3$/d (20 m$^3$/hour) was modelled at this borehole over the 25 years period. The extent of the hydraulic drawdown at the pumping depth (504 to 519 ft bgl; 153 to 158 m bgl) after 25 years (9 155 days) of pumping is shown in Figure 7-2. The following key points are noted:

- The original hydraulic head (depth to groundwater) is assumed to be 3.5 m bgl (corresponding to -3.5 m from the reference elevation of 0 m of the model);
- Therefore, after 25 years, the extent of the drawdown zone, as indicated by a 0.5 m decrease from -3.5 m to -4 m, is situated at a radial extent of *c*.100 m from the pumping borehole;
- The maximum drawdown at the pumping borehole is 4 m, where the hydraulic head has been drawn down from the original -3.5 m to *c*.-7.5 m.




srk consulting | PF GROUNDWATER STUDY<br>Hydraulic Head at Water Supply Borehole 1J22 (m bgl) | Project No.<br>545842/GW

**Figure 7-2: Hydraulic head at water supply borehole 1J22 (m bgl)**

## 7.3 Potential for Groundwater Contamination Associated with PF

Modelled concentrations of the 'indicator element' PAM is shown in the figures that follow. As discussed in Section 6.1.2, PAM is modelled to indicate the largest extent to which contaminants (including other chemicals such as any elements of concern) are likely to be transported. The chemicals of potential concern are discussed in Section 4.2. If PAM is shown in the model to not reach an area, then it can be assumed that the contaminants of concern will not reach that area. Where PAM does extend into an area, then the percentage transported concentration (of the maximum PAM concentration modelled as 1 500 mg/L) can be used to indicate the associated maximum concentration of chemical of concern at that location. Thus, the modelling of PAM is used to represent the maximum fate and transport of all chemicals of potential concern.

Figure 7-3 shows a plan view of the oil reservoir at a depth of 990 ft bgl (302 m bgl). Each of the six inserts reflects a different time period being month one, followed by years 1, 2, 13, 15 and 25, respectively. The locations of the producers are shown with a '+'. The concentrations are divided into four classes of 10 – 100 mg/L, 100 – 500 mg/L, 500 – 1 000 mg/L and 1 000 – 1 500 mg/L. The outline of the Tambaredjo Oilfield is also included. The following is noted with respect to the concentration of PAM within the oil reservoir:

- Only fresh water is injected during month one and therefore the concentration of PAM remains at the background concentration of 0 mg/L;
- After one year, PAM has spread radially by 100 – 150 m from the locations of the Phase 1 injectors. Note that there is little movement of the PAM or directional flow due to the very low hydraulic gradient across the site. There may be a slight hydraulic gradient that is not shown in the model, as the modelled water levels are assumed to be exactly horizontal;
- After two years, PAM has spread radially by up to *c.*300 m around the Phase 1 injectors and by 100 – 150 m around the Phase 2 injectors which are only assumed to come online after one year;
- The producers are assumed to be pumping continuously at the rates defined in Section 6.1.9. Over time they are removing higher concentrations of PAM along with the oil recovery, as shown in Figure 7-1;
- The largest total mass of PAM is at the end of Year 13 which is the end of PAM injection. The yellow points in the centre of the concentration circles indicate the highest concentrations. The PAM concentrations continue to spread;
- Fresh water injection is assumed to commence in Year 14, thus at the end of Year 15 it is possible to see the lower concentrations around the injection sites (100 – 500 mg/L as indicated in blue) surrounded by higher concentrations (500 – 1 000 mg/L as indicated in green) before moving out to the lower concentration again. Although the total mass of PAM is less that Year 13, the area of spread is larger; and
- By Year 25, at the end of the proposed PF, the concentrations of PAM are nearly all below 500 mg/L except for a few locations where there is build up in the 'corners' between a number of injectors. The extent of the PAM after 25 years is *c.*3 km by *c.*3 km. Much of the PAM will be retained long term by physical pore retention and adsorption. The rest will likely dilute further over an extended period.

Figure 7-4 shows a plan view of a horizontal 'slice' 200 ft (63 m) above the oil reservoir at 784 ft bgl (239 m bgl). Six time periods are again shown, with the same concentration classes defined, as for Figure 7-3. This depth is still considered to be well below that of likely groundwater abstraction for supply. However, the geophysical borehole logs do seem to indicate that there could be fresh (albeit brackish) water lenses in the sand layers at this depth (as discussed in personal communication with Rakesh Ramdajal). Concentrations of PAM stay well below 100 mg/L (<7% of maximum PAM concentration) throughout the entire 25 years of proposed PF and take a number of years to reach this depth.

Figure 7-5 shows a horizontal 'slice' representing the 'base' / greatest depth of likely groundwater abstraction for supply. This slice is at a depth of 490 ft bgl (149 m bgl) which is 500 ft (153 m) above the oil reservoir. The PAM did not migrate up to this depth at any time during the 25 years of simulation.

Figure 7-6, Figure 7-7 and Figure 7-8 show PAM concentrations for cross sections A, B and C respectively for years 1, 2, 13 and 25. The locations of these cross sections is shown on Figure 6-4. The following is noted:

- The location of cross section A was selected to dissect the water supply borehole 1J22. The lowered hydraulic pressure zone due to water supply pumping, at the modelled depth of abstraction for 1J22 (154 – 158 m bgl) is indicated on the cross section;

- There is also an increased hydraulic pressure in the oil reservoir, due to the injection of PAM at this depth;
- The location of the injectors is apparent from the point sources of higher concentration PAM. Where the point sources have lower concentrations, it is likely that the associated injector is further off the cross section line;
- At the specific cross section depths, the PAM concentrations correspond to the associated plan-view ‘slices’ of that depth in Figure 7-3, Figure 7-4 and Figure 7-5; and
- In all cross sections and time periods, the PAM is shown to spread laterally along the oil reservoir with a maximum (worst-case) vertical extent of 328 ft (100 m) up to a depth of 656 f bgl (200 m bgl).

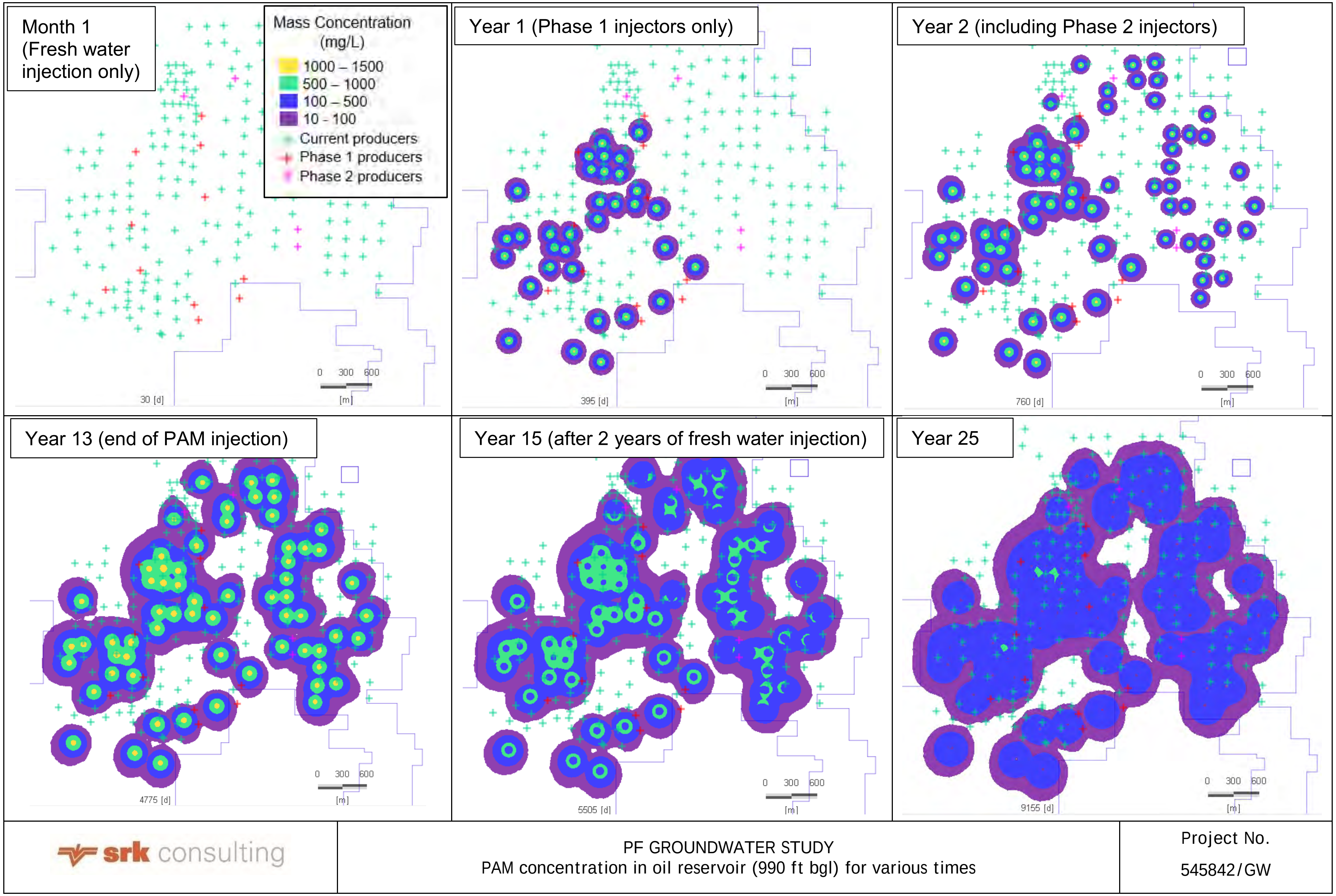



**Figure 7-3: PAM concentration in oil reservoir (990 ft bgl) for various times**

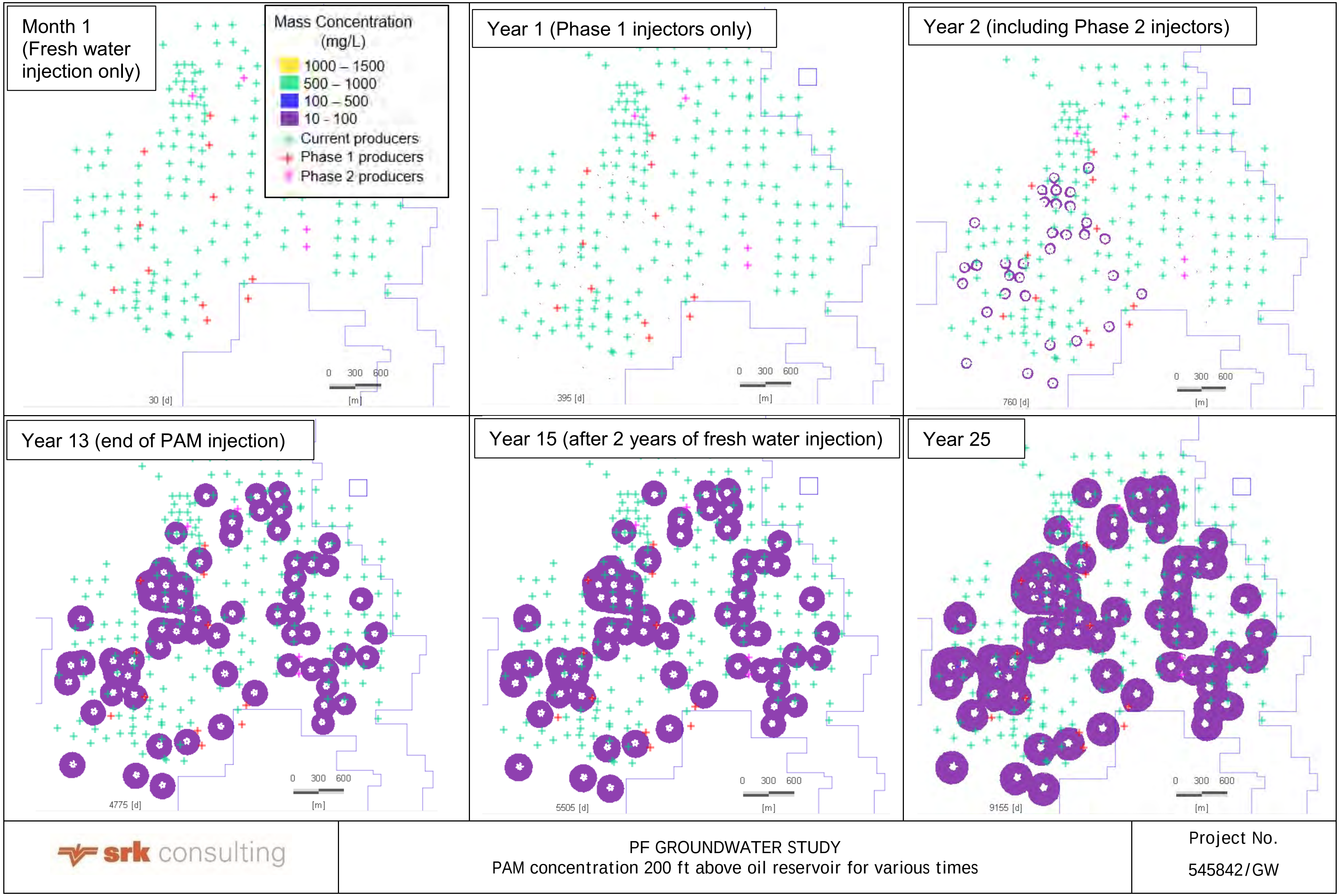
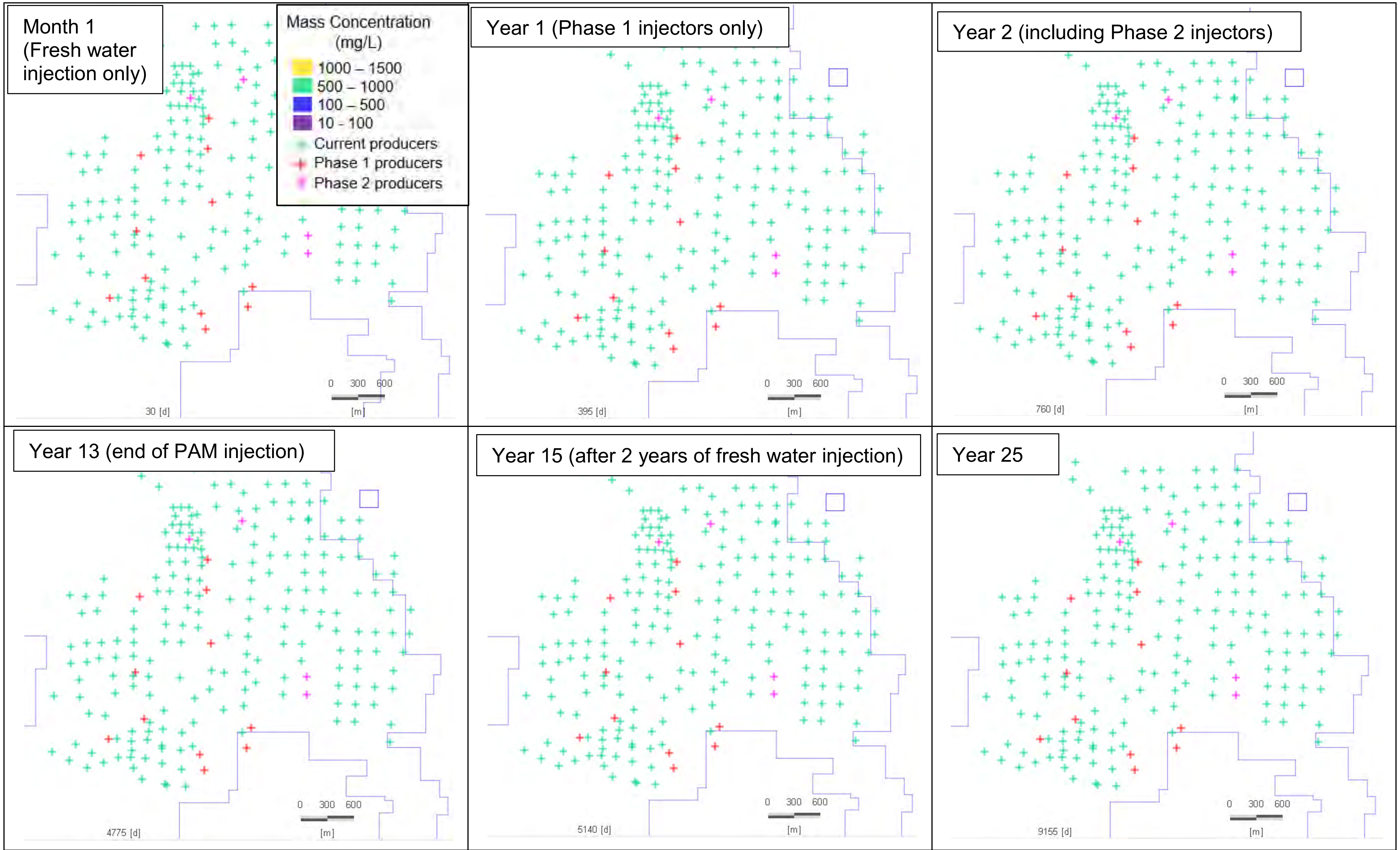



**Figure 7-4: PAM concentration 200 ft above oil reservoir (784 ft bgl) for various times**




| srk consulting | PF GROUNDWATER STUDY<br>PAM concentration at base of groundwater abstraction depth (490 ft bgl) | Project No.<br>545842/GW |
|---|---|---|

**Figure 7-5: PAM concentration at base of groundwater abstraction depth (490 ft bgl) for various times**

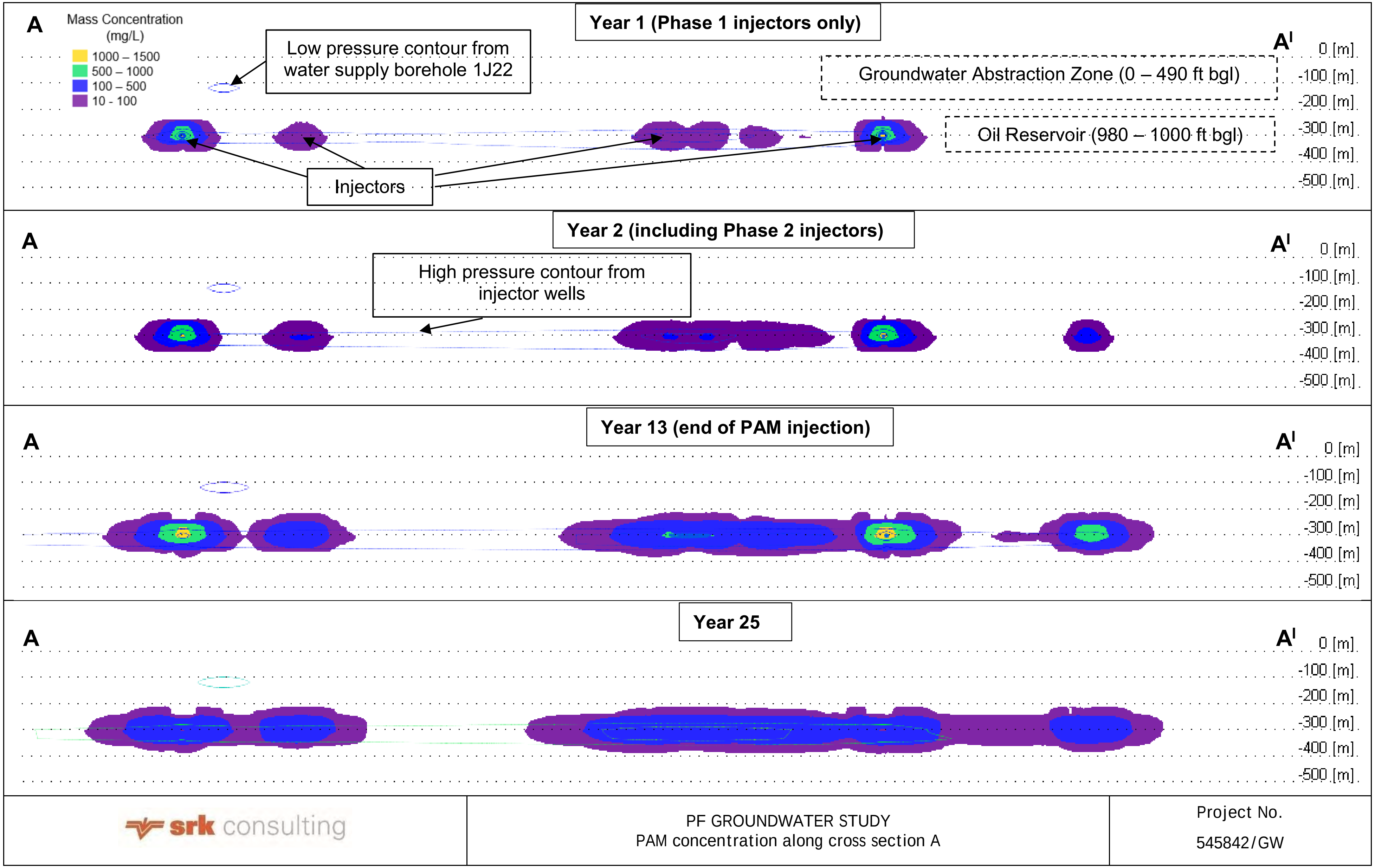



**Figure 7-6: PAM concentration along cross section A**

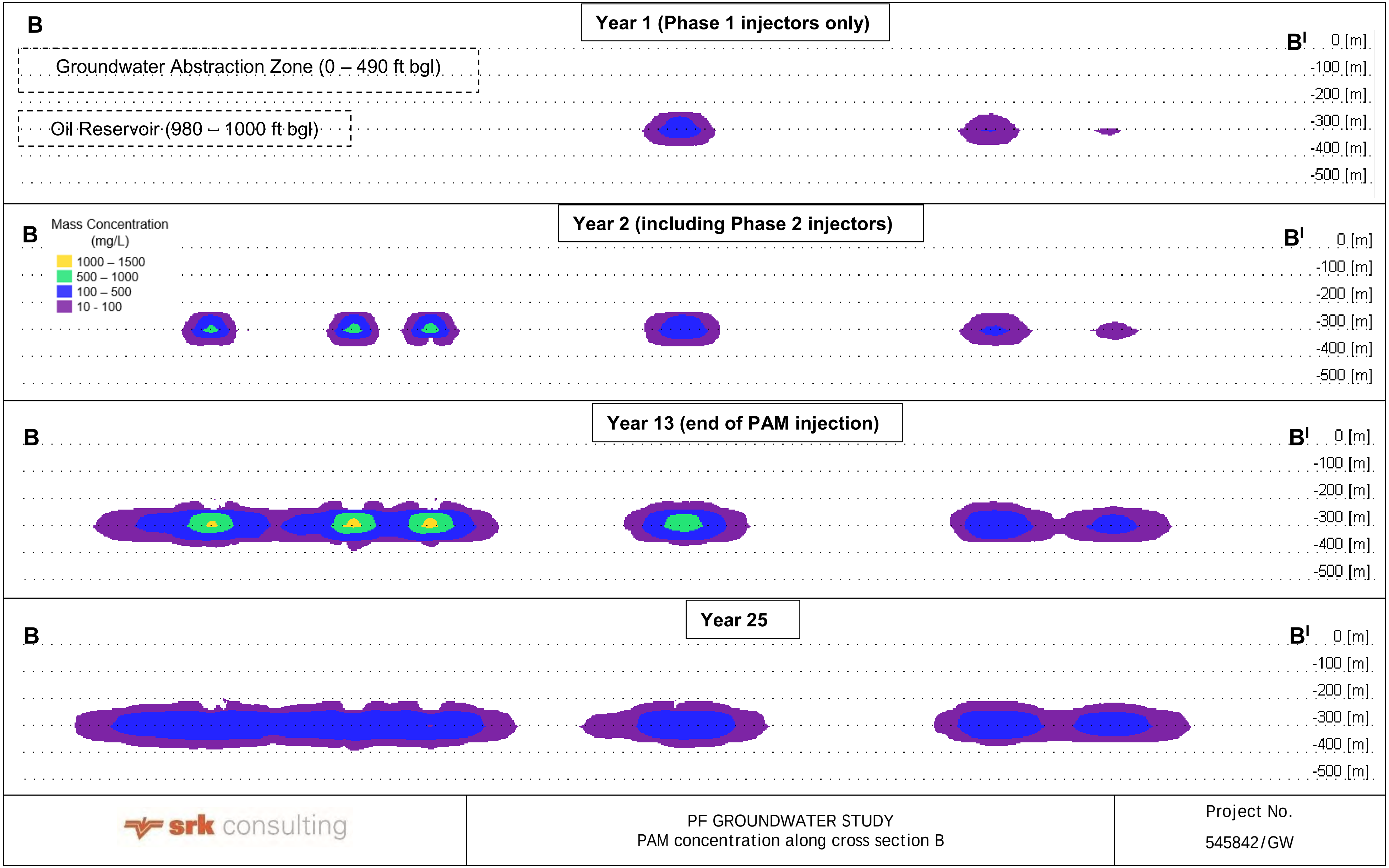
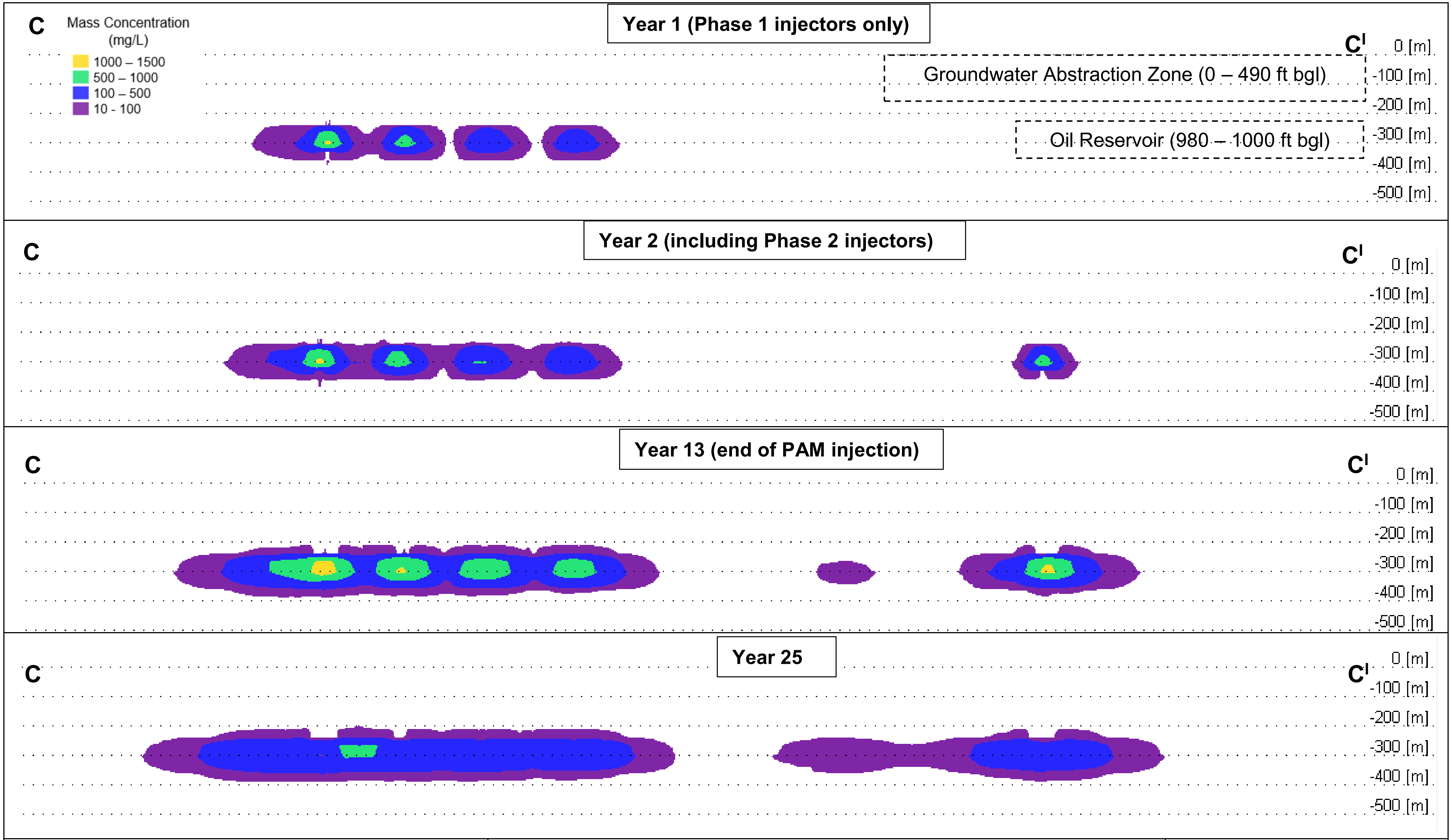



**Figure 7-7: PAM concentration along cross section B**




| srk consulting | PF GROUNDWATER STUDY<br>PAM Concentration along cross section C | Project No.<br>545842/GW |
|---|---|---|

**Figure 7-8: PAM concentration along cross section C**

# 8 Impact Assessment

## 8.1 Potential Groundwater Impacts

### 8.1.1 Assessment of Impacts: Construction Phase

The following potential construction phase impact was identified and assessed:

- G1: Contamination of groundwater from accidental to spills and well drilling.

#### Potential Impact G1: Contamination of Groundwater from Accidental Spills and Well Drilling

Leaks and spills of contaminants on exposed surface areas during construction could, in principle, contaminate underlying groundwater. However, there is no shallow (superficial) groundwater, while the aquifers below the project site are deep and have no connectivity to and are isolated from the surface, as they are covered by thick impermeable clay layers. As such, contamination is unlikely to migrate and surface spills are unlikely to result in groundwater contamination.

Injector and producer wells drilled to ~ 990 ft below ground level (bgl) will intersect aquifers, including an aquifer at ~490 ft bgl that is used for freshwater abstraction at Tijgerkreek, some 12 km to the south-west of the closest injector well. Drilling could be a source for pollutants to reach groundwater if e.g. toxic drilling fluid is used. Given low transmissivity, it is unlikely that any contamination would reach the abstraction point at Tijgerkreek in concentrations exceeding guidelines. Groundwater is not abstracted for drinking purposes in the vicinity of the Tambaredjo Oilfield, but some is abstracted for process water. In the event of contamination reaching groundwater, it is likely to persist for the medium term.

The impact is assessed to be of ***very low*** significance and with the implementation of mitigation is reduced to ***insignificant*** (Table 7-1).

**Table 7-1: Significance of contamination of groundwater due to spills and well drilling**

| | *Extent* | *Intensity* | *Duration* | *Consequence* | *Probability* | *Significance* | *Status* | *Confidence* |
|---|---|---|---|---|---|---|---|---|
| Without mitigation | Local 1 | Medium 2 | Medium 2 | Low 5 | Possible | VERY LOW | – ve | Medium |
| Key essential mitigation measures:<br>• Use non-toxic drilling fluids when drilling through freshwater aquifers.<br>• Ensure that well casing and cementing meets best practice methods to prevent chemical losses into the upper layers above the oil reservoir. | | | | | | | | |
| With mitigation | Local 1 | Low 1 | Short-term 1 | Very Low 3 | Improbable | INSIGNIFI-CANT | | Medium |

### 8.1.2 Assessment of Impacts: Operation Phase

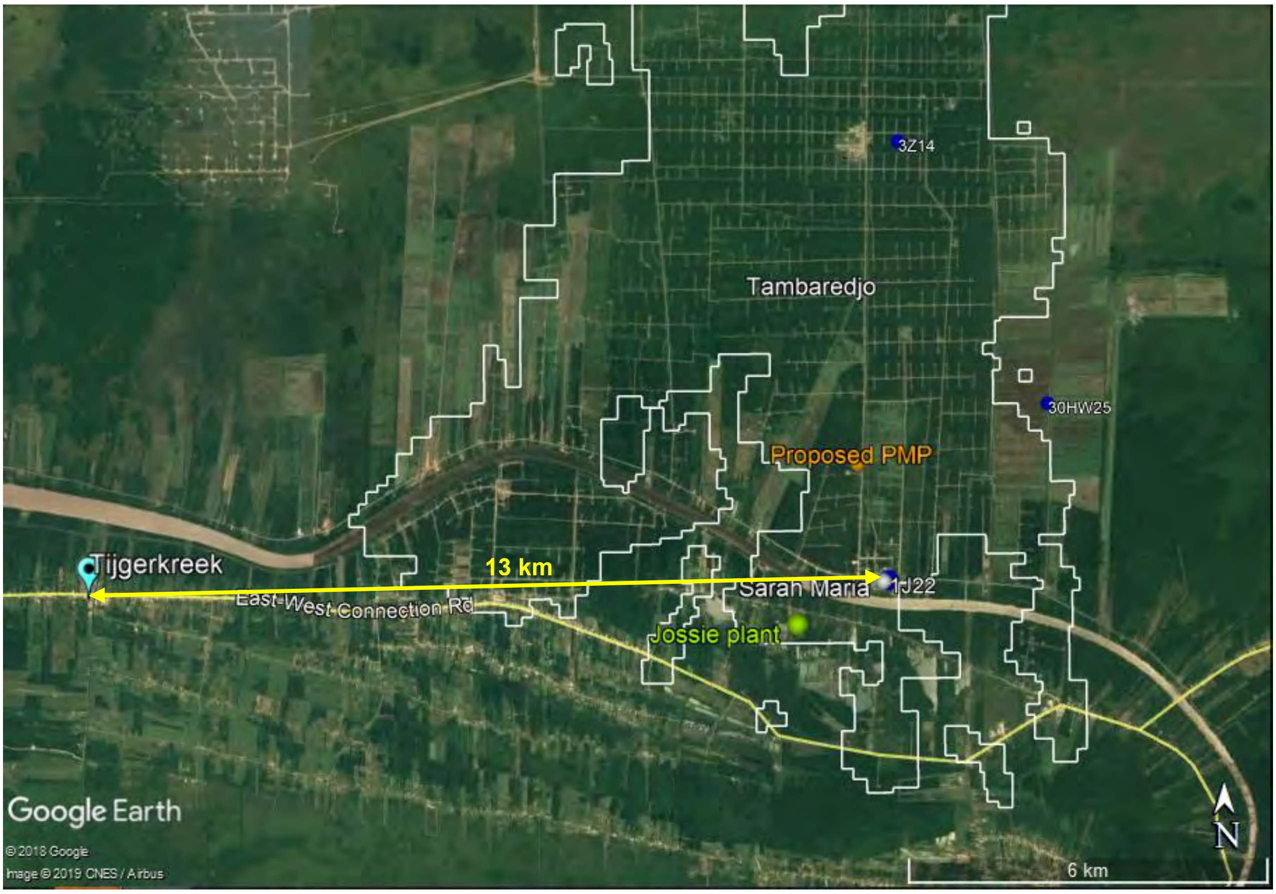
The following potential operation phase impacts and risks were identified and assessed:

- G2: Reduction in groundwater level and supply due to groundwater abstraction;
- G3: Contamination of groundwater in brackish aquifer due to intrusion of polymer mix;
- G4: Contamination of groundwater in freshwater aquifer due to intrusion of polymer mix; and
- G5: Groundwater contamination due to accidental leakage from a well.

## Potential Impact G2: Reduction in Groundwater Level and Supply due to Groundwater Abstraction

Groundwater abstracted from borehole 1J22 may be used to supply the PF project. Numerical modelling indicates that the maximum horizontal extent of the drawdown zone is ~100 m from the pumping borehole, while the maximum drawdown cone at the borehole is ~4 m.

No other boreholes are being pumped for water supply within 100 m of 1J22, and there is thus no expected effect on other boreholes from abstraction at 1J22. The drawdown from 1J22 will also not affect the Suriname Waterleiding Maatschappij (SWM) abstraction borehole at Tijgerkreek, which is located 13 km from 1J22 (see Figure 7-9) and well beyond the zone of influence of the PF project and the modelled area.




| srk consulting | PF GROUNDWATER STUDY<br>Distance between Tijgerkreek and 1J22 abstraction points | Project No.<br>545842/GW |
|---|---|---|

**Figure 7-9: Distance between Tijgerkreek and 1J22 abstraction points**

The impact is assessed to be of ***low*** significance (Table 7-2).

**Table 7-2: Reduction in groundwater level and supply due to groundwater abstraction**

| | Extent | Intensity | Duration | Consequence | Probability | Significance | Status | Confidence |
|---|---|---|---|---|---|---|---|---|
| Without mitigation | Local<br>1 | Low<br>1 | Long-term<br>3 | Low<br>5 | Improbable | VERY LOW | -ve | High |
| Key essential mitigation measures:<br>• Obtain a license from the Minister of Natural Resources for the extraction of groundwater. | | | | | | | | |
| With mitigation | Regional<br>1 | Low<br>1 | Long-term<br>3 | Low<br>5 | Improbable | VERY LOW | -ve | High |

## Potential Impact G3: Contamination of Groundwater in Brackish Aquifer due to Intrusion of Polymer Mix

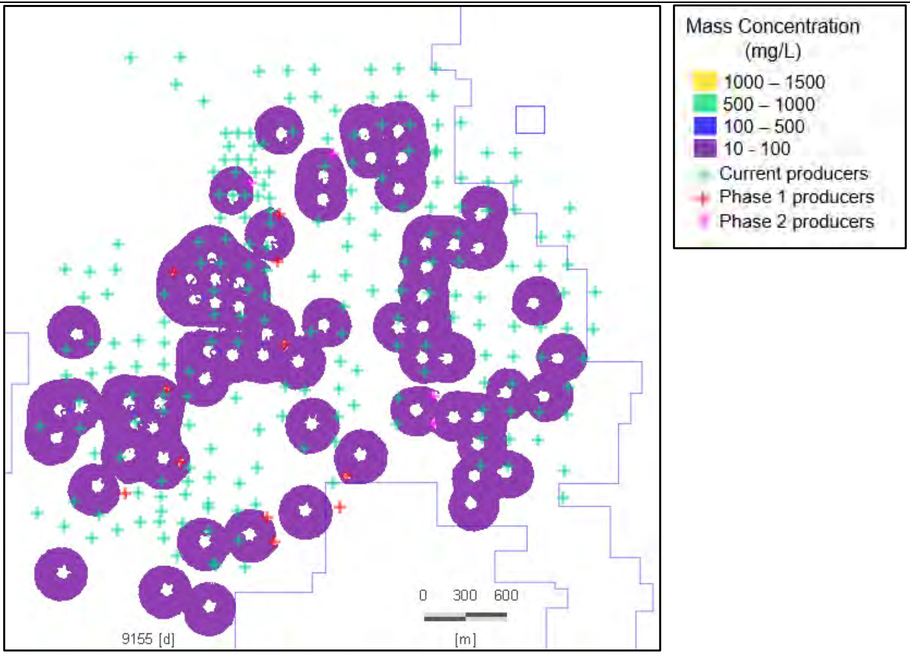
Over time, some of the polymer mix injected into the oil-bearing layer will migrate horizontally within the layer and vertically into overlying (and underlying) layers, with the bulk either abstracted at producer wells or fully degrading within the oil reservoir layer; it thus has the potential to contaminate groundwater contained in overlying layers. Brackish water is contained in the layer at ~790 ft bgl, i.e. ~200 ft above the oil reservoir.

PAM is considered non-toxic but contains a residual amount of AAM due to an incomplete polymerization process. AAM is considered a likely human carcinogen and neurotoxin with a maximum permissible concentration in drinking water of 0.5 µg/L **Invalid source specified.**. In the polymer mix, AAM is likely to be present at a concentration of 400 µg/L at the point of injection[4].

After injection into wells, PAM breaks down chemically or biologically to form naturally occurring compounds of low toxicity, such as $NH_4^+$ and AA. These are unlikely to travel as far as PAM, since $NH_4^+$ is readily adsorbed and AA biodegrades rapidly. As such, the residual concentration of AAM is considered the major environmental risk associated with the use of PAMs. No additional AAM is formed during the PAM degradation process. AAM migrates faster than PAM presenting a greater risk of dispersed contamination, but also degrades faster, counteracting this risk.

The numerical model has thus used PAM to represent the maximum fate and transport of all chemicals of potential concern, including AAM. Based on injection and production (abstraction) rates provided by Staatsolie, the model indicates that PAM will spread vertically (upward) by a maximum (worst-case) 328 ft, to a depth of 656 ft bgl. Some PAM will thus migrate up to the brackish groundwater layers ~200 ft above the reservoir (at ~790 ft bgl) (see Figure 7-10). The predicted concentrations of PAM shown in Figure 7-10 do not factor in any degradation of PAM and are thus likely to overestimate residual PAM (and, therefore, AAM) concentrations.

[4] Expected concentrations based on a PAM concentration of 1 000 mg/L and residual AAM of 0.04% would be 1 000 mg/L * 0.04% = 0.4 mg/L = 400 µg/L The maximum AAM concentration, assuming a maximum PAM concentration of 1 500 mg/L in the polymer mix, and residual AAM concentration of 0.1% in the PAM, the AAM concentration would be 1 500 mg/L * 0.1% = 1.5 mg/L = 1 500 µg/L.




| srk consulting | PF GROUNDWATER STUDY<br>Predicted PAM concentration at 784 ft bgl in Year 25 | Project No.<br>545842/GW |
|---|---|---|

**Figure 7-10: Predicted PAM concentration at 784 ft bgl in Year 25**

As the water from that brackish groundwater layer is not suitable for drinking purposes, the intensity of the impact will be limited. PAM that has migrated into this layer will degrade over time.

The impact is assessed to be of ***low*** significance (Table 7-3).

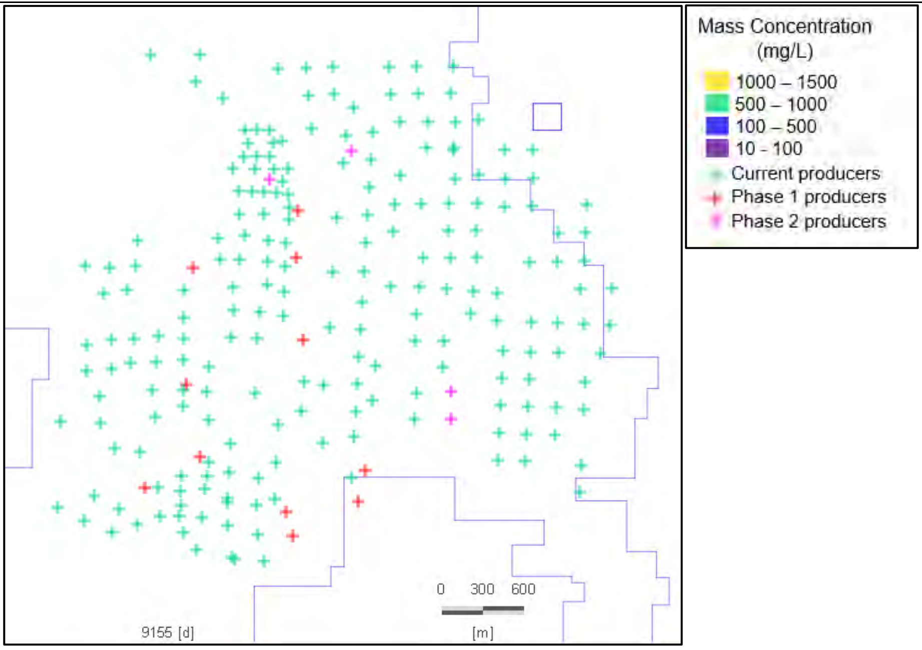
**Table 7-3: Significance of contamination of groundwater in brackish aquifer due to intrusion of polymer mix**

| | Extent | Intensity | Duration | Consequence | Probability | Significance | Status | Confidence |
|---|---|---|---|---|---|---|---|---|
| Without mitigation | Local<br>1 | Low<br>1 | Long-term<br>3 | Low<br>5 | Probable | LOW | -ve | Medium |
| Key essential mitigation measures:<br>• Manage injection pressures to ensure that the PF chemicals are not chased/forced beyond the confines of the oil reservoir. | | | | | | | | |
| With mitigation | Local<br>1 | Low<br>1 | Long-term<br>3 | Low<br>5 | Probable | LOW | -ve | High |

## Potential Impact G4: Contamination of Groundwater in Freshwater Aquifer due to Intrusion of Polymer Mix

The discussion provided for Impact G3 refers. Freshwater is contained in the aquifer at ~490 ft bgl (500 ft above the oil reservoir). Water abstracted at the Tijgerkreek well some 12 km from the nearest injector well, and potentially at 1J22 for the PF project, exploit this aquifer.

Based on injection and production (abstraction) rates provided by Staatsolie, the model indicates that PAM will migrate vertically (upwards) by a maximum (worst-case) 328 ft, to a depth of 656 ft bgl. It is thus not expected that PAM will migrate to the freshwater layer at ~490 ft bgl (see Figure 7-11).




| srk consulting | PF GROUNDWATER STUDY<br>Predicted PAM concentration at 490 ft bgl in Year 25 | Project No.<br>545842/GW |
|---|---|---|

**Figure 7-11: Predicted PAM concentration at 490 ft bgl in Year 25**

The impact is assessed to be *insignificant*.

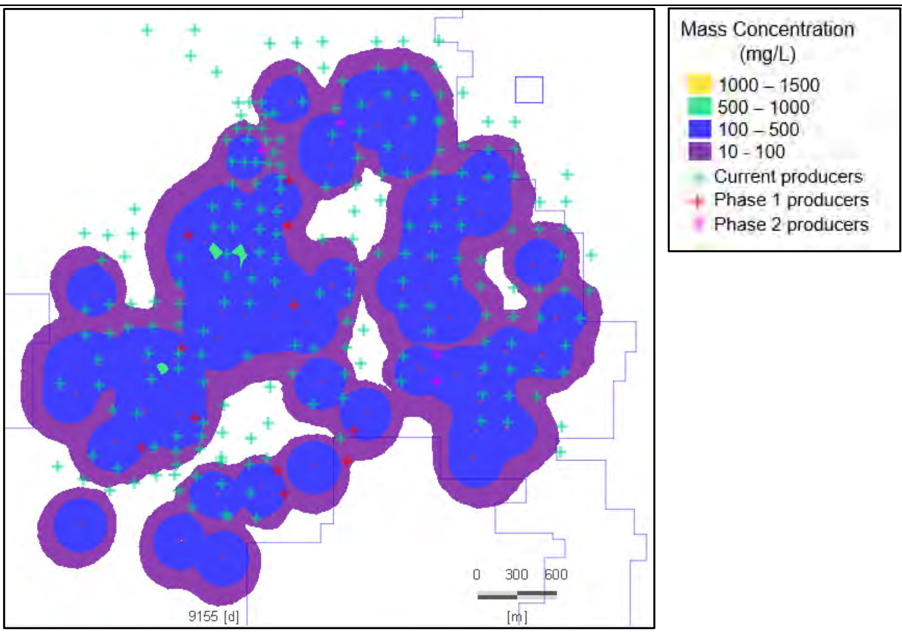
## Potential Risk G5: Groundwater Contamination due to Accidental Leaks from a Well

Although not anticipated during routine project operations, and thus not a project impact, this section considers the potential effect of spills from a leaking well. If a well is improperly cased, polymer (and AAM) could enter groundwater layers above the reservoir in high concentrations that far exceed the safe drinking water level of 0.5 µg/L. A key concern regarding leaked polymer relates to the contamination of groundwater that is abstracted for drinking purposes.

If contamination occurs, it is not chemically possible to effectively treat polluted groundwater, both *in situ* and once abstracted. However, AAM (the contaminant of prime concern) will degrade over time. AAM degradation rates and consequent concentrations depend on the specific circumstances, such as location and volume of the leak, and it could take years for a large leak to fully degrade to drinking water concentrations. Monitoring at the abstraction point and possibly at new sentinel wells would be required if a major leak does occur.

The behaviour of a leaked polymer plume cannot be modelled as it represents a risk (unplanned event) as opposed to an impact (arising from a planned and foreseeable activity), and factors such as leak volume, leak location (depth of leak and distance to nearest abstraction point), site-specific degradation rate, groundwater volume and transmissivity (groundwater flow speed) are unknown.

However, the predicted behaviour of PAM in the reservoir the polymer mix is injected into can provide an indication of the behaviour of a (very large) leak at a different level along the well, as the hydrogeological characteristics are broadly comparable in the oil-bearing and groundwater-bearing layers, comprised of sand. Based on injection and production (abstraction) rates provided by Staatsolie for the project, the model indicates that PAM spreads radially by 100 – 150 m after one year in the reservoir. At its greatest extent, polymer will have spread horizontally by ~250 m from injector wells (see Figure 7-12).



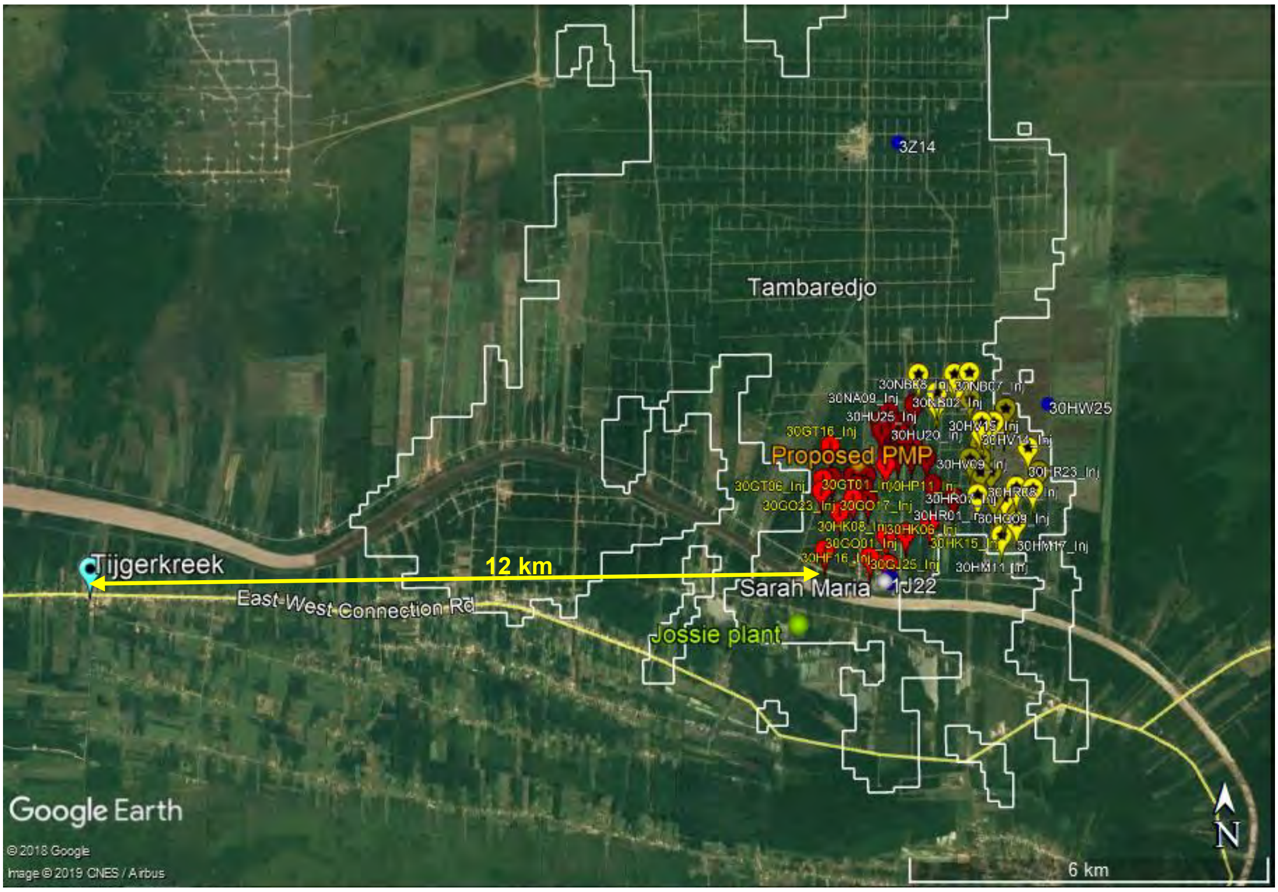

| | | |
|---|---|---|
| srk consulting | PF GROUNDWATER STUDY<br>Predicted PAM concentration at 990 ft bgl (oil reservoir) in Year 25 | Project No.<br>545842/GW |

**Figure 7-12: Predicted PAM concentration at 990 ft bgl (oil reservoir) in Year 25**

As the Tijgerkreek abstraction point is 12 km from the closest injector well (see Figure 7-13), a spill of polymer mix due to a leaking well into a groundwater bearing layer, especially the freshwater layer, is expected to remain localised and extremely unlikely to reach the Tijgerkreek abstraction point before full degradation of the PAM and AAM.

Any future groundwater abstraction close to the Tambaredjo Oilfield may, however, be affected, and water quality would need to be monitored.

The risk of a leak (i.e. unplanned loss of polymer mix in the upper well layers) can be effectively mitigated by installing appropriate casing aligned to best practice principles, which is also critical to the successful execution of the PF project, to maintain pressure and volume of the polymer mix and produced fluid.




| srk consulting | PF GROUNDWATER STUDY<br>Distance between Tijgerkreek and closest injector well | Project No.<br>545842/GW |
|---|---|---|

**Figure 7-13: Distance between Tijgerkreek and closest injector well**

The impact is assessed to be of ***medium*** significance and with the implementation of mitigation is reduced to ***low*** (see Table 7-4).

**Table 7-4: Significance of groundwater contamination due to accidental leaks from a well**

| | Extent | Intensity | Duration | Consequence | Probability | Significance | Status | Confidence |
|---|---|---|---|---|---|---|---|---|
| Without mitigation | Local<br>1 | High<br>3 | Medium<br>2 | Medium<br>6 | Probable | MEDIUM | -ve | Medium |
| Key essential mitigation measures:<br>• Ensure that well casing and cementing meets best practice methods to prevent chemical losses into the upper layers above the oil reservoir.<br>• Monitor polymer mix injection pressure and flow rate, to ensure no polymer mix is unaccounted for.<br>• In the event of a leak, cease injection of polymer mix at the well.<br>• In the event of a major leak, monitoring groundwater quality at the water abstraction point and possibly at new sentinel wells. | | | | | | | | |
| With mitigation | Local<br>1 | High<br>3 | Medium<br>2 | Medium<br>6 | Possible | LOW | -ve | Medium |

### 8.1.3 The No-Go Alternative

The No-Go alternative entails no change to the status *quo*, in other words no PF is undertaken to extract additional oil, while current oil production continues while economically feasible. This means that the PMP and additional infrastructure is not constructed and production on the Tambaredjo Oilfield will cease as per current production timelines (and earlier than anticipated with the implementation of PF).

As such, no polymer mix will be injected into the reservoir, and no additional (ground)water supplies for PF are required. There will be no impacts on or risks to groundwater associated with the PF project.

### 8.1.4 Mitigation Measures: Potential Groundwater Impacts

**Essential** groundwater mitigation measures during **construction** are as follows:

- Use non-toxic drilling fluids when drilling through freshwater aquifers.
- Ensure that well casing and cementing meets best practice methods to prevent chemical losses into the upper layers above the oil reservoir.
- Develop (or maintain and adapt) procedures for the safe transport, handling and storage of potential pollutants;
- Design and construct hazardous material storage facilities with suitable impermeable materials and a minimum 110% containment capacity;
- Ensure all on site staff are trained in the use of spill prevention measures; and
- Clean up any spills immediately, through containment and removal of free product and appropriate rehabilitation or disposal of contaminated soils.

**Essential** groundwater mitigation measures during **operation** are as follows:

- Obtain a license from the Minister of Natural Resources for the extraction of groundwater.
- Manage injection pressures to ensure that the PF chemicals are not chased/forced beyond the confines of the oil reservoir.
- Monitor polymer mix injection pressure and flow rate, to ensure no polymer mix is unaccounted for.
- Develop (or maintain and adapt) procedures for the safe transport, handling and storage of potential pollutants;
- Ensure all on site staff are trained in the use of spill prevention measures;
- Clean up any spills immediately, through containment and removal of free product and appropriate rehabilitation or disposal of contaminated soils;
- Cease injection of polymer mix at the well in the event of a leak; and
- Monitor groundwater quality at the water abstraction point and possibly at new sentinel wells in the event of a leak.

**Essential** groundwater mitigation measures during **decommissioning** are as follows:

- Remove all old surface equipment, contaminated soil from small spills and other waste at the surface.
- Plug the well in accordance with best practice methods to prevent leaks of fluids and methane to the surface and of oil, gas or salty water into freshwater aquifers.

### 8.1.5 Monitoring: Potential Groundwater Impacts

- Monitor groundwater quality before initiation of the PF project and quarterly thereafter.
- Monitor groundwater level quarterly when abstracting groundwater for the PF project.

## 8.2 Potential Surface Water Impacts

### 8.2.1 Assessment of Impacts: Construction Phase

The following potential direct construction phase impact was identified:

- S1: Contamination of surface water, affecting ecosystems.

#### Potential Impact S1: Contamination of Surface Water, Affecting Ecosystems

Site preparation, excavation and construction of the PMP, wells and associated infrastructure will likely result in some direct impact on the water quality in the Kisoensingh-west Canal and other canals draining the Tambaredjo polder, which discharge into the Saramacca River. These canals are already impacted by Staatsolie activities in the polder. The most likely potential contaminants and their potential effects are:

- Hydrocarbons, such as oil, petrol or diesel from construction equipment and associated fuels, which could impact on water quality of the receiving water body. Small amounts of hydrocarbons readily break down in the soil and aquatic environment, and only larger volumes are of significant concern; and
- Suspended solids, which can also be harmful to biota and the aquatic environment as they affect benthic ecosystems, block respiratory organs of fish, reduce photosynthesis in plants, etc.

Given the artificial and somewhat disturbed characteristics of the receiving canal environment, impacts due to contamination are considered of medium intensity in localised areas close to point source discharges.

The impact is assessed to be of ***very low*** significance (Table 7-5).

**Table 7-5: Significance of contamination of surface water affecting ecosystems**

| | *Extent* | *Intensity* | *Duration* | *Consequence* | *Probability* | *Significance* | *Status* | *Confidence* |
|---|---|---|---|---|---|---|---|---|
| Without mitigation | Local<br>1 | Medium<br>2 | Short-term<br>1 | Very Low<br>4 | Definite | VERY LOW | – ve | High |
| Key essential mitigation measures:<br>• Implement good housekeeping practices. | | | | | | | | |
| With mitigation | Local<br>1 | Medium<br>2 | Short-term<br>1 | Very Low<br>4 | Definite | VERY LOW | – ve | High |

### 8.2.2 Assessment of Impacts: Operation Phase

The following potential operation phase impacts and risks were identified:

- S2: Impacts from the disposal of back produced polymer on surface water quality; and
- S3: Risks from chemical spills or leaks to surface water quality.

Required water volumes for the PF process are insignificant compared to water volumes in the Saramacca River; consequently, impacts from abstraction of surface water from the Saramacca River are considered insignificant and are not assessed.

#### Potential Impact S2: Impacts from the Disposal of Back Produced Polymer on Surface Water Quality

From the production well, the produced fluid will be pumped to the Jossie Crude Treatment Facility, where the crude and produced water are separated. The produced water (back-produced polymer) is then treated and disposed of. At present, the treated produced water from the PF trial phase is discharged to the Saramacca River, which is also currently proposed for the PF project.

Based on assumptions of river geomorphology, the Saramacca River contains ~1.6 $Mm^3$ of water in the 4 km section adjacent to the Tambaredjo Oilfield[5], into which the treated produced water would be discharged.

The maximum estimated discharge volume is ~1 190 $m^3$/d (9 925 bbl/d) of produced water, containing a maximum of 833 kg/d of PAM[6] (at 700 mg/L of PAM in the produced water – the peak concentration of PAM predicted by the model to occur in Year 21, see Figure 7-1). This implies an AAM concentration of 700 µg/L (at 0.1% of PAM) in the produced fluid / discharge, or 0.8 kg/d AAM discharge in 1 190 $m^3$/d produced water. At full dilution in the 4 km Saramacca River section adjacent to the Tambaredjo Oilfield, the average PAM concentration in the river water would be 0.5 mg/L[7] and the average AAM concentration would be 0.5 µg/L[8], well below the EU aquatic threshold of 33.8 µg/L and equivalent to the WHO maximum permissible concentration in drinking water of 0.5 µg/L **Invalid source specified.**.

Flow in the Saramacca River will transport the water plume and contaminants away from the site, resulting in a potential impact of regional extent. As AAM is considered to be a likely human carcinogen and neurotoxin, and the calculated concentration of AAM in the river water near the Tambaredjo Oilfield could approach the WHO limit, the intensity of the impact is conservatively rated medium. As disposal will take place throughout the 25 years of the PF project, the duration is long-term.

The likelihood of the impact occurring is deemed possible (not probable), as the considered scenario is very conservative; it essentially ignores degradation of AAM and further dilution with other produced water that is generated from oil production at the Tambaredjo oilfield and assumes maximum discharge volume at all times and no.

The impact is assessed to be of ***medium*** significance and with the implementation of mitigation is reduced to ***low*** (Table 7-6).

**Table 7-6: Significance of disposal of back produced polymer on surface water quality**

| | Extent | Intensity | Duration | Consequence | Probability | Significance | Status | Confidence |
|---|---|---|---|---|---|---|---|---|
| Without mitigation | Regional 2 | Medium 2 | Long-term 3 | High 7 | Possible | MEDIUM | -ve | Medium |
| Key essential mitigation measures:<br>• Ensure total AAM mass disposed remains below 0.8 kg/d (this is equivalent to a concentration of 0.7 mg/L AAM assuming a maximum discharge volume of 1 190 $m^3$/day[9]).<br>• Ensure that the polymer used has a residual AAM concentration of <0.1% by weight.<br>• Ensure the back-produced polymer is free from any other contaminants (through treatment, if required) before disposal.<br>• Ensure that disposal takes place in the fastest flowing part of the Saramacca River and/or is dispersed over an appropriate length such that dilution occur over the 4 km Saramacca River section adjacent to the Tambaredjo Oilfield within a day.<br>• Obtain a permit from NIMOS for the discharge of AAM as a pollutant in the produced water. | | | | | | | | |
| With mitigation | Local 1 | Medium 2 | Long-term 3 | Medium 6 | Improbable | LOW | -ve | Medium |

## Potential Impact S3: Risk from Accidental Chemical Spills or Leaks to Surface Water Quality

Although not anticipated during routine project operations, and thus not a project impact, this section considers the potential effect of accidental spills or leaks of:

[5] Assuming a triangular cross-sectional area for the river (160 m x 5 m deep) and a length of 4 000 m (from Jossie Plant to edge of Tambaredjo oil field), this results in a river water volume of 160 m x 2.5 m x 4 000 m x 1 000 L/$m^3$ = 1 600 000 000 L.
[6] Based on the reservoir model concentration of 1 000 mg/L PAM.
[7] 833 000 000 mg/d / 1 600 000 000 L = 0.5 mg/L per day PAM.
[8] Assuming conservatively that AAM is 0.1% of PAM, then the concentration of AAM (µg/L) = 0.5mg/L PAM x 0.1% x 1 000 = 0.5 µg/L.
[9] 0.7 mg = 0.0000007 kg x 1 190 000 l/d (equivalent to 1 190 $m^3$/d) = 0.8 kg/d

- Chemicals used in the produced water treatment plant;
- Small amounts of polymer mix from the PMP or during transfer to the injection well; and
- Large amount of polymer mix if a pipeline ruptures.

**Produced water treatment plant**

The produced water treatment plant is likely to use a number of chemicals that would contaminate surface water if spilled in sufficient quantities; these could include caustic soda [NaOH], hydrochloric acid [HCl], sulfuric acid [$H_2SO_4$] and ferric chloride [$FeCl_3$]. The potential impacts of such a spill include altering the soil pH, potential accumulation of chemicals at the location of a spill and potential dispersion to surface water.

However, these chemicals are likely to be used in relatively small quantities at the plant **Invalid source specified.**. Good housekeeping practices, such as proper storage of these chemicals in bunded areas, will minimise the risk to surface water in the event of spills, leaks or tank rupture.

**Small spills of polymer mix**

Leaks or spills of PAM and polymer mix could occur at the PMP or from leaks (e.g. drips, sweating flanges etc) in the pipeline conveying the polymer mix to injection wells. Such spills are likely to be relatively small but could occur over a longer period if not quickly repaired. The potential effect of small long-term releases on surface water resources is likely to be low and localised given the rapid biodegradation rate of AAM and strong adsorption of PAM to soil particles.

**Large spill of polymer mix**

A large release of polymer mix (e.g. ruptured bulk containers or pipeline) would occur very rapidly in a once-off event and is likely to reach the Saramacca River given the proximity of the PMP to the Kisoensingh-west Canal, which discharges to the Saramacca River 2 km to the south. A large spill could significantly increase the short-term concentration of AAM in the canal and Saramacca River above safe levels. It is expected that the AAM concentration in the Saramacca River will dilute to safe levels within a relatively short period of time given the high water volume and flow.

The potential impacts from a large-scale release at the polymer plant can be effectively mitigated through standard housekeeping and design measures, such as appropriate bunding of storage areas and installation of low pressure cut-out valves (or similar engineered safety devices) in pipelines.

The impact is assessed to be of ***low*** significance and with the implementation of mitigation is reduced to ***very low*** (Table 7-7).

**Table 7-7: Significance of accidental chemical spills or leaks to surface water quality**

| | Extent | Intensity | Duration | Consequence | Probability | Significance | Status | Confidence |
|---|---|---|---|---|---|---|---|---|
| Without mitigation | Local<br>1 | Medium<br>2 | Long-term<br>3 | Medium<br>6 | Possible | LOW | -ve | Medium |
| • Implement good housekeeping practices. | | | | | | | | |
| With mitigation | Local<br>1 | Low<br>1 | Long-term<br>3 | Low<br>5 | Possible | VERY LOW | -ve | Medium |

### 8.2.3 The No-Go Alternative

The No-Go alternative entails no change to the *status quo,* and the surface water regime will remain unchanged.

### 8.2.4 Mitigation Measures: Potential Surface Water Quality Impacts

**Essential** surface water quality mitigation measures during **construction** are as follows:

- Implement good housekeeping practices to prevent and contain spills.

**Essential** surface water quality mitigation measures during **operation** are as follows:

- Implement good housekeeping practices to prevent and contain spills.
- Ensure AAM mass disposed remains below 0.8 kg/d (this is equivalent to a concentration of 0.7 mg/L AAM assuming a maximum discharge volume of 1 190 $m^3$/day).
- Ensure that the polymer used has a residual AAM concentration of <0.1% by weight.
- Ensure the back-produced polymer is free from any other contaminants (through treatment, if required) before disposal.
- Ensure that disposal takes place in the fastest flowing part of the Saramacca river and/or is dispersed over an appropriate length such that dilution occur over the 4 km Saramacca River section adjacent to the Tambaredjo Oilfield within a day.
- Obtain a permit from NIMOS for the discharge of AAM as a pollutant in the produced water.
- Ensure all chemical storage compounds are installed on hard standing ground with bunding of at least 110% of the largest tank volume to contain any spill. Install collection systems in these areas to manage any spills.
- Construct chemical storage compounds outside of floodplains and further than 100 m from the normal high-water mark of a water body or a water supply borehole.
- Install clean and dirty stormwater management systems.
- Maintain a list of external equipment, personnel, facilities, funding, expert knowledge and materials that may be required to respond to emergencies. The list should include personnel with specialised expertise for spill clean-up, flood control and water treatment.
- Implement maintenance and inspection procedures.
- Install low pressure cut-out valves (or similar engineered safety devices) along the pipeline network.
- Use drip trays when refuelling and servicing vehicles or equipment, where it is not on hardstanding.

### 8.2.5 Monitoring: Potential Surface Water Quality Impacts

Monitor the surface water quality quarterly, both upstream and downstream of the discharge point, for pH, EC, dissolved oxygen, chemical oxygen demand (COD), AAM, oil and grease, and selected metals. Regarding metals, initially analyse for a comprehensive suite of metals and select parameters for future monitoring based on those results.

# 9 Findings and Conclusion

This chapter presents the principal findings and conclusions with regards to the potential groundwater and geochemical impacts of the proposed PF Project at Tambaredjo Oilfield.

## 9.1 Findings

The following findings are pertinent:

- The project area is in the Tambaredjo Oilfield in the Tambaredjo Polder, which has been operated by Staatsolie since the 1990s;
- The original swamp habitat has been replaced by secondary marsh vegetation, which is characterised as modified habitat;
- Geologically, Suriname is part of the Precambrian Guiana Shield. In the north, the shield shows a seaward dip and is covered by Late Cretaceous and Cenozoic deposits of the Guiana Basin. The Cenozoic deposits comprise clay units interspersed with thick sand units;
- The local groundwater is brackish. Groundwater underlying the site is not potable, nor is it currently abstracted for domestic use;
- Only one water supply borehole (1J22) is planned for future use during the PF project, at a maximum abstraction rate of 20 $m^3$/hour (480 $m^3$/d);
- Numerical groundwater modelling results indicate that the maximum horizontal extent of the drawdown zone is c.100 m from the pumping borehole, and that the maximum drawdown at the borehole is c.4 m. Consequently, the borehole will not impact any other groundwater users (as they are outside the drawdown area) and the impact of this water supply borehole on the water resources of the area is assessed to be of low significance;
- PAM refers to a group of water-soluble molecules formed by polymerization of AAM. PAM is highly soluble and is considered non-toxic. The chemical degradation of PAM is more pronounced than the biological degradation and is promoted by free radicals. The PAM solution is susceptible to chemical degradation by dissolved oxygen, $H_2S$, and $Fe^{2+}$;
- The residual concentration of AAM due to the incomplete polymerization process is considered the major environmental risk associated with the use of PAMs. AAM is highly soluble in water, has a low potential to partition to organic matter, and has a low volatilization potential in water. It is therefore unlikely to adsorb to mineral surfaces in the reservoir;
- AAM is a likely human carcinogen and neurotoxin with a maximum permissible concentration in drinking water of 0.5 µg/L (WHO, 2011);
- $NH^{4+}$ and AA are also daughter product formed during the degradation of PAM, however they are unlikely to travel as far as PAM as $NH^{4+}$ is readily adsorbed and AA has been shown to biodegrade rapidly under aerobic conditions;
- The potential impacts from the use of PAM for the PF process on groundwater quality has been numerically modelled. Model scenario results show that the likelihood of chemical injected into the oil reservoir at 990 ft bgl to migrate up to the groundwater aquifer at 490 ft bgl is negligible. Prior to mitigation, the impact from the use of injected chemicals on groundwater quality is of medium significance. After implementation of the proposed mitigation measures, the impact is assessed to be of low significance;

- PF project back-produced polymer may be disposed to surface water. Assuming the high level of dilution expected to occur within the Saramacca River, the expected concentration of PAM (and potential daughter product AAM) is within the WHO maximum permissible concentration in drinking water of 0.5 µg/L (WHO, 2011) for AAM. Consequenlty, the impact is assessed to be of medium significance. With the implementation of the proposed mitigation measures, the impact is assessed to be low; and
- Impacts from spills, leaks and rupture of surface chemicals on water quality is assessed to be of low significance. With mitigation, the impact rating is of very low significance. Installation of appropriate containment measures is essential.

Table 9-1 summarises the potentially significant hydrological, groundwater and geochemical impacts and their significance ratings before and after application of mitigation measures.

**Table 9-1: Summary of impacts and mitigation / optimisation measures**

| ID # | Impact | Significance rating: Before mitigation/ optimisation | Significance rating: After mitigation/ optimisation | Key mitigation/optimisation measures |
|---|---|---|---|---|
| OPERATIONAL PHASE IMPACTS | | | | |
| G1 | Impacts from abstraction of water for supply on groundwater quantity | *Low* | *Low* | • None |
| G2 | Impacts from the use of injected chemicals on groundwater quality | *Medium* | *Low* | • Surface chemical management and handling procedures need to ensure that spills are minimised and rapidly removed<br>• Drilling and construction of the injector wells needs to be done with appropriate rigour to ensure that casing and grouting of the upper layers meets best practice principles to prevent chemical losses above the oil reservoir<br>• Injection pressures need to be appropriately managed to ensure that the PF chemicals are not forced beyond the oil reservoir |
| G3 | Impacts from the disposal of back produced polymer on surface water quality | *Medium* | *Low* | • Ensure AAM mass disposed remains below 833 g/d<br>• Ensure the back-produced polymer is free from any other contaminants (with treating, if required) before disposal<br>• Ensure that disposal takes place in the highest flowing parts of the river and/or is dispersed over an appropriate length such that dilution can occur over a 4 km length within a day<br>• Monitor the surface water quality quarterly, both upstream and downstream of the discharge point<br>• Ensure surface water disposal quality of all contaminants complies with international environmental standards |
| G4 | Impacts from spills, leaks and rupture of surface chemicals on water quality | *Low* | *Very Low* | • Ensure all chemical storage compounds are installed on hard standing ground with bunding (collection system) to prevent seepage of any spillages to ground<br>• Avoid construction of chemical storage compounds in a floodplain and within a distance of 100 m of the normal high-water mark of a water body or a water supply borehole<br>• Implement clean and dirty stormwater management systems<br>• Maintain a list of external equipment, personnel, facilities, funding, expert knowledge, and materials that may be required to respond to emergencies. The list should include personnel with specialised expertise for spill clean-up, flood control and water treatment<br>• Implement maintenance and inspection procedures |

## 9.2 Conclusion

This groundwater and geochemical specialist study assesses the potential impacts Staatsoile's proposed PF project at Tambaredjo Oilfield poses to natural water resources.

Potential impacts identified include impacts from abstraction of water for supply on groundwater quantity; impacts from the use of injected chemicals on groundwater quality; impacts from the disposal of back produced polymer on surface water quality; and impacts from spills, leaks and rupture of surface chemicals on water quality.

To assess these impacts with a high level of confidence, and particularly to understand the potential connection between the oil reservoir and the groundwater aquifer (to the depth of likely abstraction) during the PF injection and production period of 25 years, fate and transport analysis of the injection polymer was undertaken, followed by a 3-D numerical model development to simulate the underground flow and transport conditions over time.

With appropriate mitigation measures, potential impacts to natural water resources from the proposed PF project are assessed to be of low significance.

**Prepared by**

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Principal Hydrogeologist

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Principal Geochemist and Associate Partner

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Chris Dalgliesh

Partner

All data used as source material plus the text, tables, figures, and attachments of this document have been reviewed and prepared in accordance with generally accepted professional engineering and environmental practices.

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# Appendices

# Appendix A: Impact Assessment Methodology

The assessment of impacts was based on specialists' expertise, SRK's professional judgement, field observations and desk-top analysis.

The significance of potential impacts that may result from the proposed project was determined in order to assist decision-makers (typically by a designated competent authority or state agency, but in some instances, the applicant).

The **significance** of an impact is defined as a combination of the **consequence** of the impact occurring and the **probability** that the impact will occur.

The criteria used to determine impact consequence are presented in the table below.

**Table 10-1: Criteria used to determine the consequence of the impact**

| Rating | Definition of Rating | Score |
|---|---|---|
| A. *Extent– the area (distance) over which the impact will be experienced* | | |
| Local | Confined to project or study area or part thereof (e.g. the development site and immediate surrounds) | 1 |
| Regional | The region (e.g. Municipality or Quaternary catchment) | 2 |
| (Inter) national | Nationally or beyond | 3 |
| B. *Intensity– the magnitude of the impact in relation to the extent of the impact and sensitivity of the receiving environment, taking into account the degree to which the impact may cause irreplaceable loss of resources* | | |
| Low | Site-specific and wider natural and/or social functions and processes are negligibly altered | 1 |
| Medium | Site-specific and wider natural and/or social functions and processes continue albeit in a modified way | 2 |
| High | Site-specific and wider natural and/or social functions or processes are severely altered | 3 |
| C. *Duration– the timeframe over which the impact will be experienced and its reversibility* | | |
| Short-term | Up to 2 years and reversible | 1 |
| Medium-term | 2 to 15 years and reversible | 2 |
| Long-term | More than 15 years and irreversible | 3 |

The combined score of these three criteria corresponds to a **Consequence Rating**, as follows:

**Table 10-2: Method used to determine the consequence score**

| *Combined Score* (A+B+C) | 3 – 4 | 5 | 6 | 7 | 8 – 9 |
|---|---|---|---|---|---|
| *Consequence Rating* | Very low | Low | Medium | High | Very high |

Once the consequence was derived, the probability of the impact occurring was considered, using the probability classifications presented in the table below.

**Table 10-3: Probability classification**

| *Probability– the likelihood of the impact occurring* | |
|---|---|
| Improbable | < 40% chance of occurring |
| Possible | 40% - 70% chance of occurring |
| Probable | > 70% - 90% chance of occurring |
| Definite | > 90% chance of occurring |

The overall **significance** of impacts was determined by considering consequence and probability using the rating system prescribed in the table below.

**Table 10-4: Impact significance ratings**

| | | Probability | | | |
|---|---|---|---|---|---|
| | | Improbable | Possible | Probable | Definite |
| Consequence | Very Low | INSIGNIFICANT | INSIGNIFICANT | VERY LOW | VERY LOW |
| | Low | VERY LOW | VERY LOW | LOW | LOW |
| | Medium | LOW | LOW | MEDIUM | MEDIUM |
| | High | MEDIUM | MEDIUM | HIGH | HIGH |
| | Very High | HIGH | HIGH | VERY HIGH | VERY HIGH |

Finally, the impacts were also considered in terms of their status (positive or negative impact) and the confidence in the ascribed impact significance rating. The prescribed system for considering impacts status and confidence (in assessment) is laid out in the table below.

**Table 10-5: Impact status and confidence classification**

| *Status of impact* | |
|---|---|
| Indication whether the impact is adverse (negative) or beneficial (positive). | + ve (positive – a 'benefit') |
| | – ve (negative – a 'cost') |
| *Confidence of assessment* | |
| The degree of confidence in predictions based on available information, SRK's judgment and/or specialist knowledge. | Low |
| | Medium |
| | High |

The impact significance rating should be considered by authorities in their decision-making process based on the implications of ratings ascribed below:

- **INSIGNIFICANT**: the potential impact is negligible and **will not** have an influence on the decision regarding the proposed activity/development.
- **VERY LOW**: the potential impact is very small and **should not** have any meaningful influence on the decision regarding the proposed activity/development.
- **LOW**: the potential impact **may not** have any meaningful influence on the decision regarding the proposed activity/development.
- **MEDIUM**: the potential impact **should** influence the decision regarding the proposed activity/development.
- **HIGH**: the potential impact **will** affect the decision regarding the proposed activity/development.
- **VERY HIGH**: The proposed activity should only be approved under special circumstances.

Practicable mitigation and optimisation measures are recommended, and impacts are rated in the prescribed way both without and with the assumed effective implementation of mitigation and optimisation measures. Mitigation and optimisation measures are either:

- **Essential**: measures that must be implemented and are non-negotiable; and
- **Best Practice:** recommended to comply with best practice, with adoption dependent on the proponent's risk profile and commitment to adhere to best practice, and which must be shown to have been considered and sound reasons provided by the applicant if not implemented.

# Appendix B: Fate and Transport Parameter Summary

Database of Fate and Transport Parameters

| Compound | Kd | Disuvisity in water | Biodegradation rate ($t_{1/2}$) | Drinking water standard | Aquatic Standard |
|---|---|---|---|---|---|
| | (L/kg) | (cm2/sec) | days | µg/L | µg/l |
| PAM | | | 7 (soil) | * | - |
| AAM | 0.039 | 0.00001275 | 15 (surface water) | 0.5 | 33.85 |
| $NH_4$-N | 3 | 0.0000693 | - | 1.5 ** | 1900 |
| Acrylic acid | 0.1 | 0.0000106 | 1 | No value | No value |

Notes: * maximum concentration permissible in potable water treatment is 1 mg/L
** based on aesthetic criteria

# Appendix B: SOM Stakeholder Meeting 31 May 2019

## Meeting Minutes

**Date:** 31 May 2019
**Time:** 10.00 – 10.45
**Participants:** See attendance list
**Subject:** Stakeholder meeting (Information session Polymer Flood Project)

---

**Introduction**

Farina Ilahibaks, Community Relations Officer, opened the meeting with a short introduction on the project. This meeting has been planned to provide information about the project to landowners. Individual sessions will be held with the landowners, to further discuss activities related to the project.

**Presentation**

Shailesh Kisoensingh, Reservoir Engineer, presented on the polymer flood technology (see presentation).

**Questions & Answers**

Q: Mr. Doerga: What is the effect of the polymer in case of a leakage on the vegetation/agriculture?
A: Ms. Mangalsing: Informed the participants that Staatsolie started with the NIMOS permitting process and that SRK Consulting has been hired to prepare and Management and Monitoring Plan for the project. Details on impacts will be specified in the plan and presented to the stakeholders in September 2019.

Q: Mr. Baldew: In the presentation it has been mentioned that the polymer is degradable. Why is it not mentioned that it is biodegradable?
A: Ms. Mangalsing: according to the information of the suppliers the polymer is degradable under certain circumstances. Details on impacts will also be mentioned in the Management and Monitoring Plan.

Q: Mr Baldew: How long will be the process of polymer injection?
A: Mr. Kisoensingh: 10-12 years polymer injection and afterwards water injection.

Mr. Baldew (Info sharing): The family has a plan to execute agricultural activities. And they do want to go through the ISO certification and Global Gap Certification processes. The ISO certification will not be an issue according to Mr. Baldew. But the Global Gap Certification might not be possible for agriculture in an area where polymer is being injected, even if the polymer is injected in an oil reservoir at a depth of more than 100 meters for example. According to Mr. Baldew the land might not be used anymore for agricultural purposes.
In an area where oil production activities are executed Global Gap Certification will not be an issue, if the nearest oil facilities are on a distance of 1km or more.

Q: Mr. Baldew: Why is Staatsolie not purchasing the terrains?
A: Ms. Nahar: That is not done by Staatsolie. Staatsolie has the concession rights and in collaboration with the landowners, the activities are being executed.

**STAATSOLIE** **MAATSCHAPPIJ SURINAME N.V.**
STATE OIL COMPANY SURINAME N.V.

Extern

**Presentielijst Informatiebijeenkomst**
**Polymer Injection Project**

**Datum:** Vrijdag 31 mei 2019
**Tijd:** 10.00u – 12.00u
**Plaats:** Staatsolie Sarah Maria, Conferenceroom 3
**Adres:** Gangaram Pandayweg km. 5½

| Nr. | Naam | Instantie | Telefoon | E-mail | Paraaf |
|---|---|---|---|---|---|
| 1. | Baldew V.S. | Abilakh Missiar | 7546084 | snbiharie@gmail.com | |
| 2. | (Doerga. | (dmahes). | 8517659 | Rb doerga@gmail. | |
| 3. | | | | | |
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**STAATSOLIE** **MAATSCHAPPIJ SURINAME N.V.**
STATE OIL COMPANY SURINAME N.V.

Fonteyn

**Presentielijst Informatiebijeenkomst**
**Polymer Injection Project**

**Datum:** **Vrijdag 31 mei 2019**
**Tijd:** **10.00u – 12.00u**
**Plaats:** **Staatsolie Sarah Maria, Conferenceroom 3**
**Adres:** **Gangaram Pandayweg km. 5½**

| Nr. | Naam | Instantie | Telefoon | E-mail | Paraaf |
|---|---|---|---|---|---|
| 13. | Tahiboks F | Staatsolie | | | [signature] |
| 14. | Mangalsing S. | Staatsolie | | | [signature] |
| 15. | Sanches J. | Staatsolie | | | [signature] |
| 16. | Nahan P. | Staatsolie | | | [signature] |
| 17. | Kisoensingh. S.R. | " | | | [signature] |
| 18. | Dhauri, R. | Staatsolie | | | [signature] |
| 19. | Joesman A | Staatsolie | | | [signature] |
| 20. | A. Schuitemaker | Staatsolie | | | [signature] |
| 21. | | | | | — |
| 22. | | | | | |
| 23. | | | | | |
| 24. | | | | | |

# Overview of Polymer Flooding

**Landowner Presentation**

Shailesh R. Kisoensingh - Reservoir Engineer

IOR/EOR - FSS



## Content

- **Polymer Flooding (PF)**
  - o Principles & process overview of polymer flooding
  - o PF @ Staatsolie
  - o PF elsewhere as proven technology



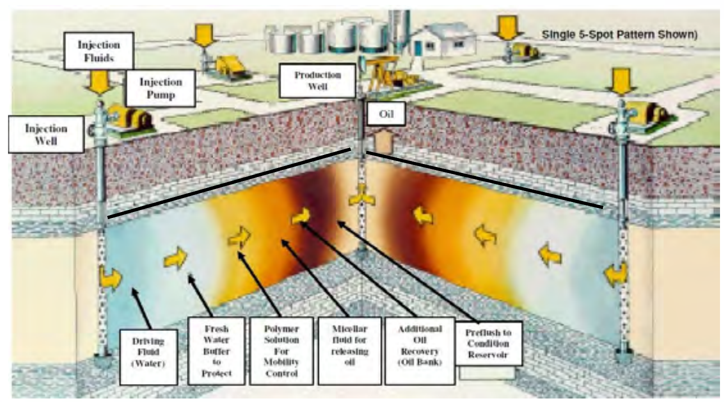
## POLYMER FLOODING

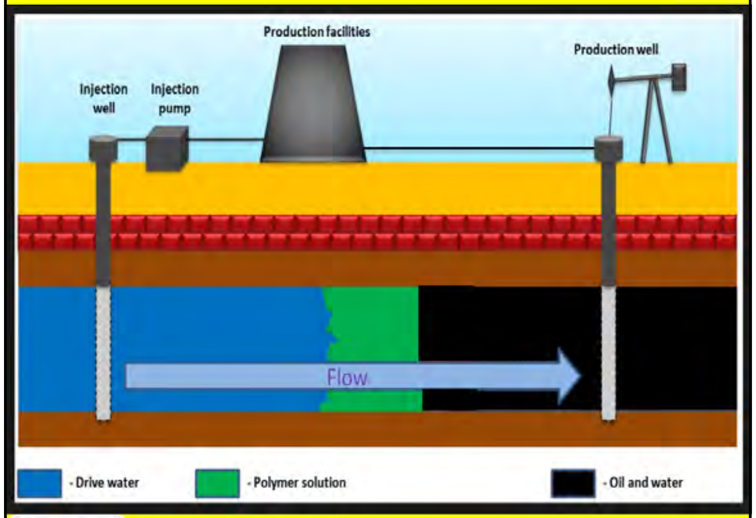
- **Polymer:** molecule with repeated units (monomers)

- **Common use of polymers**:
  - oFood industry: starch, chitosan, xanthan, guar, dextran
  - oNon-food industry: HEC, water shutoff technology, flooding, water clean-up, flocculants, pools
  - oDegrable



## Principle Polymer Flooding








## POLYMER FLOODING VIDEO

- https://www.youtube.com/watch?v=K8cKOQiKm7s
- 0:15-0:35



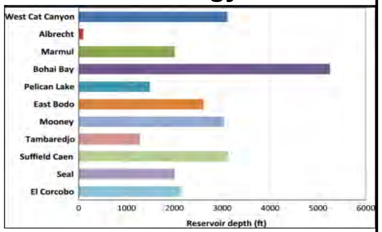
## PF @ Staatsolie (10 Years Ongoing)



## PF @ Staatsolie (10 Years Ongoing)

## PF Elsewhere as Proven Technology

- **Large scale projects:**
  - o China
  - o Oman
  - o Canada
  - o Albania
  - o USA




- **PF projects in South America:**
  - o Brazil (Petrobras)
  - o Argentina (Pluspetrol, YPF)
  - o Venezuela (TBI- Rosneft)

ELSEVIER Journal of Petroleum Science and Engineering
Volume 142, June 2016, Pages 85-100

STAATSOLIE VERTROUWEN IN EIGEN KUNNEN 9

# Appendix C: Environmental Management and Monitoring Plan

# Staatsolie Maatschappij Suriname N.V.

# ENVIRONMENTAL MANAGEMENT AND MONITORING PLAN

# FOR THE PROPOSED POLYMER FLOODING PROJECT IN THE TAMBAREDJO OILFIELD, SARAMACCA

# 2019

**Report prepared by:**

August 2019

**Table of Contents**

## Abbreviations

| | |
|---|---|
| CCU | Corporate Communications Upstream |
| DO | Drilling Operations Division |
| ELT | Ecological Land Type (see review study) |
| EOR | Enhanced Oil Recovery |
| ERP | Emergency Response Plans |
| EMMP | Environmental Management and Monitoring Plan |
| GFI | General Field Instruction |
| HSE | Health, Safety and Environment |
| HSEQU | Health, Safety, Environment and Quality Upstream |
| MUMA | Multiple Use Management Area |
| PF | Polymer Flooding |
| PS & PS | Plant Security and Personnel Services |
| SOM | N.V. Staatsolie Maatschappij Suriname (Staatsolie) |

# 1 INTRODUCTION

Staatsolie Maatschappij Suriname (SOM) intends to extend oil production in the Tambaredjo Oilfield by implementing a commercial scale polymer flooding (PF) project. SRK Consulting (South Africa) (Pty) Ltd (SRK) undertook a Limited Environmental and Social Impact Assessment (ESIA) process and updated SOM's EMMP, as required by the Nationaal Instituut voor Milieu en Ontwikkeling in Suriname (NIMOS).

This EMMP aims to demonstrate how environmental management and mitigation measures identified in the Limited ESIA Report will be implemented. The mitigation measures apply to the following phases of the development process:

- Design Phase: These measures relate to the detailed layout, planning and design of the project (including associated infrastructure), and will largely be implemented by the planning and development team, prior to the commencement of any physical on-site activities. These mitigation measures are presented in Section 3.1.1;
- Construction Phase: These mitigation measures are applicable during site preparation and construction on the site of the project (including associated infrastructure) and must be implemented by the relevant contractors and sub-contractors. These mitigation measures are presented in Section 3.1.2;
- Operational Phase: These mitigation measures are applicable during the long-term operation and maintenance of the project (including associated infrastructure) and must be implemented by SOM. These mitigation measures are presented in Section 3.1.3; and
- Decommissioning Phase: These mitigation measures are applicable during the decommissioning phase of the project (including associated infrastructure) and must be implemented by the SOM. These mitigation measures are presented in Section 3.1.4.

Monitoring measures are provided in Section 3.2.

## 1.1 SITE AND PROJECT DESCRIPTION

*A more detailed description is provided in the Limited ESIA Report.*

The project area is located in the Tambaredjo Oilfield, 40 km west of Paramaribo and 8 km south of the coast, in the Saramacca District of Suriname. The Tambaredjo field is located between the East-West Connection Road and the coast, and mostly north of the Saramacca River (see Figure 1-1).

The oilfield has been operated by Staatsolie since the 1990s. The original swamp habitat has been replaced by secondary marsh vegetation, which is characterised as a modified habitat. The polder is used for oil production from a large number of wells in a 200 x 200 m grid. The polder is traversed by unpaved roads and activity level is intense. The polder is drained by a system of roadside ditches that are connected to main canals. The north-south trending canals drain into the Saramacca River.

The proposed project is located in the south-eastern portion of the Tambaredjo Oilfield. Sixty-four new injector and 15 new producer wells will be drilled in two phases between existing oil producer wells, in an area where Staatsolie has been producing oil for extended periods of time and where ~1 700 operational wells are located.

The project includes construction and operation of a Polymer Mixing Plant (PMP) to prepare a polymer solution. The PMP will have a footprint of 1.7 ha and will be located ~2 km north of the Saramacca River and 1.8 km north of Gangaram Pandayweg, along the south-north aligned unpaved (shell sand) road that connects the TA-58 to Gangaram Pandayweg and runs parallel to the Kisoensingh-west Canal, one of the main drainage features of the Tambaredjo Oilfield.

The project also includes construction / extension of access roads, 5 km of pipelines and 79 km of injection lines.

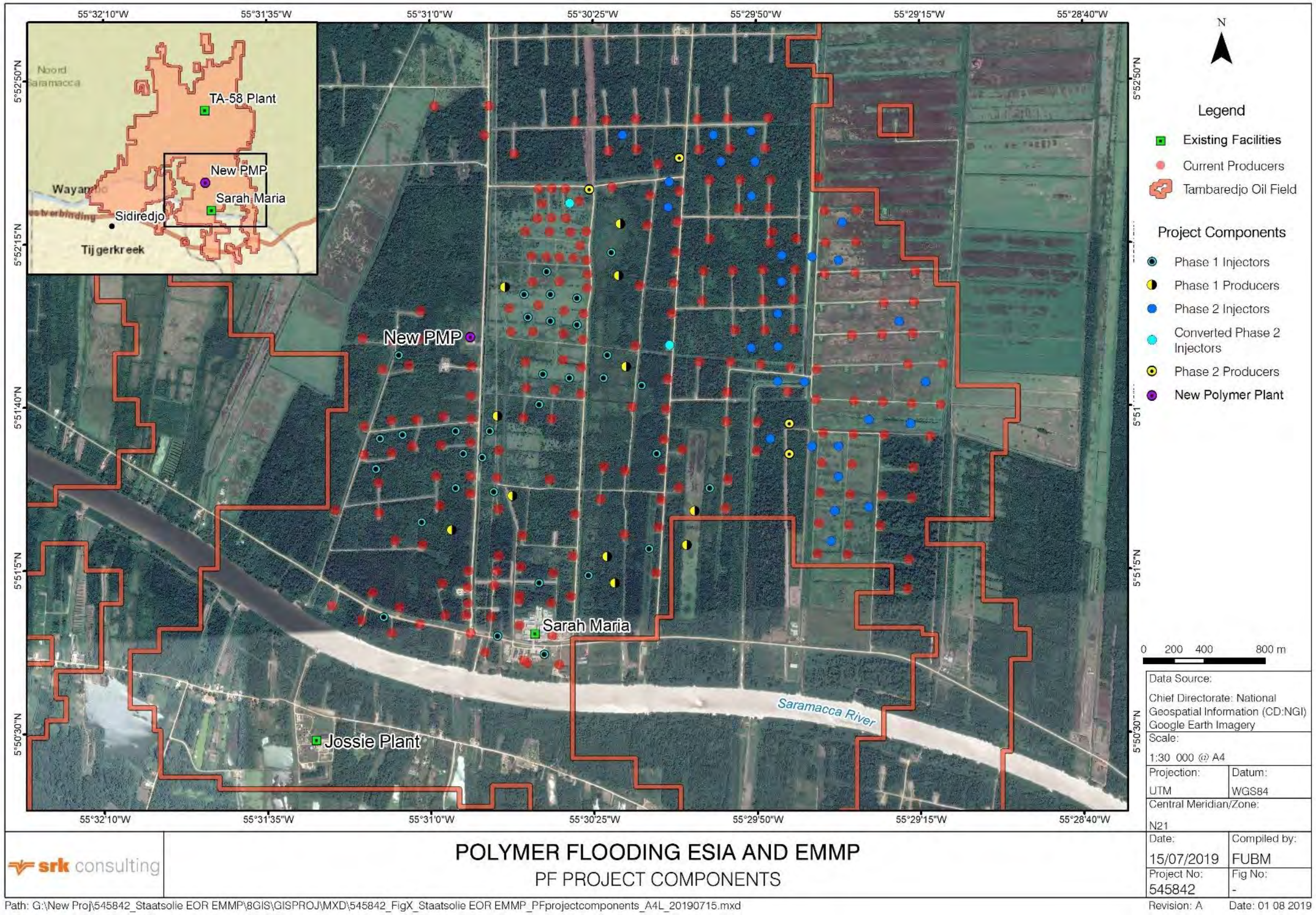



**Figure 1-1: Project components**

Key steps in the PF process are briefly described below:

- At start up, water will be injected into the injector wells for up to (less than) 1 month, at a maximum injection rate of 850 bpd per well. This serves to reduce the interfacial tension between the oil and water phases and to alter the wettability of the reservoir rock to improve oil recovery;
- The polymer solution will be injected continuously into an injector well, at an average injection rate of 190 – 315 bpd per well (maximum 550 bpd) to a depth of 900 – 1 100 ft True Vertical Depth (TVD), with a maximum bottom hole injection pressure of 1 060 psi;
- It is expected that incremental oil will be produced within one year of the start of polymer mix injection;
- After ~11 years, no more polymer will be added and drive water will be pumped into the injector well to drive the polymer slug and the oil bank toward the production wells;
- Produced fluid1 will be extracted from existing and new production wells and conveyed via pipelines to the Jossie crude treatment plant, where the fluid is collected in tanks for treatment;
- At the Jossie plant crude treatment stream, the water and minimum quantities of gas in the produced fluid will be separated from the crude, which will then be stored in tanks prior to transportation to the refinery; and
- At the Jossie plant water treatment stream, the produced water will be treated to remove remaining oil; it is then discharged into the Saramacca River.

When the economic life of the field is reached, the remaining wells and the supporting facilities will be dismantled.

Two decommissioning scenarios are being considered by SOM:

- The area is abandoned, all facilities are removed and the area is allowed to revegetate, with or without active rehabilitation / remediation; or
- In the event of a follow-up land use, part of the infrastructure may be maintained for further use.

## 1.2 ENVIRONMENTAL MANAGEMENT

Compliance with the provisions of a number of Staatsolie documents that address Health, Safety, and Environmental (HSE) issues are mandatory, principally:

- **Health, Safety & Environmental and Quality Policy**: is aimed at continually improving performance and aspires to prevent harm to the safety and health of its Employees, contractors, neighbors, and the environment.
- **GFI's**: general procedures to guide Staatsolie's operations so that it complies with the HSE policy. GFI's applicable to this project are listed in Appendix E.
- **Community Relation Policy**: is aimed at performing business activities in such a way that communities' interest and expectations with regard to socio-environmental aspects are properly considered.

[1] Mix of oil, water and gas.

## 1.3 DESCRIPTION OF THE EMMP

### 1.3.1 Purpose and Scope of the EMMP

The purpose of this EMMP is to set out the management and monitoring measures required to minimize the environmental impacts of design, construction, operations and decommissioning of the PF project, and to ensure that responsibilities and appropriate resources are efficiently allocated to the project.

### 1.3.2 Structure of the EMMP

This EMMP is made up of three parts:

**Part 1: Introduction**

Provides brief background to the project and sets out corporate environmental management requirements as well as a brief description of the purpose, scope and structure of the EMMP.

**Part 2: Environmental Management Procedures**

Sets out the roles and responsibilities for implementation of the EMMP, environmental training requirements, emergency response planning, and monitoring requirements.

**Part 3: Environmental Specifications**

Explains the approach adopted to develop the environmental specifications and sets out the actual specifications in tabular form.

# 2 ENVIRONMENTAL PROCEDURES

## 2.1 PROCESS OWNERS

All processes within Staatsolie are owned by a Process Owner. The following table provides an overview of the different processes of the PF project and the responsible Process Owner.

**Table 2-1: Process Owners**

| Process | Process Owner |
|---|---|
| Construction of infrastructure and drilling locations | Manager Drilling Operations |
| Drilling and completion of injector, oil and water wells | |
| Well plug and abandonment | |
| Decommissioning of wells | |
| Construction and commissioning of Polymer Mixing Plant and required pipeline infrastructure | Project Manager |
| Operations of the Polymer Mixing Facility and required pipeline infrastructure | Manager Treatment & Delivery |
| Monitoring and maintenance of the injector wells | |
| Decommissioning of the Polymer Mixing Facility and required pipeline infrastructure | |
| Operation of Jossie Crude Treatment Facility | |
| Completion and services polymer injectors and oil wells | Manager Lifting & Gathering |
| Monitoring and maintenance of the oil wells | |

## 2.2 ROLES AND RESPONSIBILITIES

This section is intended to ensure that an accountability process is defined and implemented to make certain that responsibilities are performed effectively. The general roles and responsibilities of various parties are outlined in the section below.

| Position | HSE responsibility |
|---|---|
| Upstream Director | Overall accountability for HSE matters for all upstream operations. |
| Project Manager | Overall responsibility for HSE matters with regards to activities during the construction and commissioning of the Polymer Mixing Facility and injector, producer and pipeline facilities |
| Drilling Operations | Responsibility for HSE matters related to site preparation, construction of roads, drilling, plug and abandonment and decommissioning in compliance with international best practices as specified in ESIA/EMMP |
| Production Asset Manager | Overall responsibility for HSE matters with regards to activities during the operational and decommissioning phase of the project. |
| Manager Treatment & Delivery | Responsibility for HSE matters related to the Polymer Mixing Facility, injector wells and Crude Treatment Facility |
| Corporate Communication Upstream Head | Overall accountability of Corporate Communication support for all activities within the Upstream Operations. |
| Manager Lifting & Gathering | Responsibility for HSE matters related to the operations, maintenance and decommissioning of the oil wells within the oilfield |
| HSEQ Upstream Manager | Responsibility to support the operations and monitor the performance with regards to HSE matters. |

| Position | HSE responsibility |
|---|---|
| SOM Employees and contractors | Shall be aware of the EMMP requirements and adhere to the relevant mitigation measures. |

### 2.2.1 Operations Manager

The Project Manager, Drilling Operations (DO) Manager, Lifting and Gathering Manager and Treatment and Delivery Manager shall all within their departments:

- Ensure that the key on-site staff (contractor-supervisors) are duly informed of the EMMP and associated responsibilities and implications of this EMMP prior to commencement of construction (in order to minimize undue delays);
- Inform key on-site staff through initial environmental awareness training of their roles and responsibilities in terms of the EMMP;
- Ensure that a copy of the EMMP shall be available to all on site Construction and Drilling Contractor Field Supervisors;
- Inform the environmental engineer **one week** before the date of the commencement of the project (this date being the day on which preparations activities will start);
- Perform weekly HSE inspections based on the EMMP checklist (Appendix B) and submit weekly HSE reports to the HSEQ Upstream Manager (based on reporting scheme in Table 2-2 in Section 2.5.4);
- Undertakes a post-decommissioning inspection upon completion of each location, which may result in recommendations for additional clean-up and rehabilitation measures;
- Ensure that method statements are submitted to the Environmental Engineer for tasks requiring such; and
- Ensure that action items to rectify non-compliance are closed out in a timely and satisfactory manner.

### 2.2.2 HSEQ Upstream Manager

The HSEQ Upstream Manager shall:

- Identify areas of non-compliance and propose action items to rectify them in consultation with the Project Manager/Project Leader;
- Undertake spot inspections to determine compliance with the EMMP and monitor the activities of the contractor on site with regard to the requirements outlined in this EMMP;
- Alert when action items intended to remedy non-compliance are not closed out in a timely and satisfactory manner;
- Compile compliance reports;
- Submit reports on the implementation of the EMMP and non-compliance to the NIMOS; and
- Undertake a post-decommissioning inspection upon completion of the project area, which may result in recommendations for additional clean-up and rehabilitation measures.

### 2.2.3 SOM Divisions/ Process Owner -representatives and Contractors

The Process Owner-representatives and Contractors delivering services to the project have a duty to demonstrate respect and care for the environment in which they are operating. The Process Owner-representatives and Contractors shall comply with the specifications of the ESIA and EMMP and abide by the instructions of the relevant Process Owner and the HSEQ Upstream Manager and its delegates regarding the implementation of the EMMP. The Process Owner-representatives and Contractors shall report to the relevant Process Owner or the HSEQ Upstream Manager on all matters pertaining to the EMMP.

The Process Owner-representatives shall:

- Ensure that copies of the EMMP shall be available at their offices, and shall also ensure that all personnel on site (including Sub-Contractors and their staff, and suppliers) are familiar with and understand the requirements of the EMMP;
- Ensure that all activities under the control of their department are undertaken in accordance with the following:
    - HSEQ Policy,
    - Community Relations Policy,
    - All applicable Staatsolie GFIs,
    - The EMMP;
- Ensure that all employees and sub-contractors comply with this ESMMP;
- Compile Method Statements as listed hereunder;
- Ensure that any problems and non-conformances are remedied in a timely manner, to the satisfaction of the responsible Process Owner;
- Ensure that all personnel are aware of the Emergency Response Plan and are adequately trained therein;
- Compile the required reports (see table 2-2, to be submitted to the HSEQ Upstream Manager).

## 2.3 ENVIRONMENTAL TRAINING

Environmental awareness training courses shall be run for all personnel on site. It is incumbent upon the Project Manager to convey the objectives of the EMMP and the specific provisions of the EMMP to all personnel involved in the design, construction, operation and decommissioning of the PF project.

Environmental training must cover the specific environmental management requirements as set out in the EMMP, but must also ensure that all on-site staff are aware of and familiar with the relevant requirements and principles/objectives of the HSEQ Policy, emergency response plans, applicable procedures (GFIs) and the EMMP.

The HSE Site Manager will initiate the training sessions for all new or additional staff, and the HSE department shall support with Environmental Awareness Courses (Integrated Health, Safety and Environmental Inductions). Contractors shall ensure that all staff attend the awareness courses to be held not less than one week before the Commencement Date. Where applicable, Contractors shall provide job-specific training on an ad hoc basis when workers are engaged in activities that require Method Statements.

A copy of the EMMP shall be available on site, and the Contractors shall ensure that all the personnel on site (including Sub-Contractors and their staff) as well as suppliers are familiar with and understand the specifications contained in the EMMP.

Operation training will include information on:

- Current land and water use;
- Clearing, access and transportation;
- Waste minimization, handling and disposal methods;
- Fire and spill prevention and control;
- Emergency response procedure (Health, Safety and Environmental issues);
- Handling and storage of hazardous materials, fuels and oils; and
- Reclamation measures.

## 2.4 COMMUNITY ENGAGEMENT

### 2.4.1 Introduction

Community or stakeholder engagement describes the ongoing, interactive relationship between Staatsolie and the community. It is about building and maintaining constructive relationships over time. It is an ongoing process between the company and its project stakeholders that extends throughout the life of the project and encompasses a range of activities and approaches, from information sharing and consultation, to participation, negotiation, and partnerships. It enables people to be informed about local issues related to Staatsolie activities and to contribute ideas and help identify solutions. It strengthens community cooperation and builds the people's trust. Staatsolie recognizes the value of involving the community in its HSEQ policy which includes as one of the key-elements: *"Communication of the Health, Safety and Environmental policy, objectives and targets, and other relevant matters to all employees, contractors and stakeholders"*.

The nature and frequency of community engagement should reflect the level of project risks and impacts.

Within Staatsolie, community engagement is in effect the responsibility of the Corporate Communication Upstream (CCU) department of Staatsolie. This engagement also includes access to private land and land leased from the government. The involved land owners have been (or will be) contacted and the project activities on their land have been (or will be) discussed.

A statement of approval and an agreement have to be agreed on. Furthermore, the Community Relations Officer has organized meetings with the district government, other government organizations, farmers and residents in order to inform them on the coming activities and to discuss.

### 2.4.2 Purpose

Community engagement in the current context is seen as the way of interacting with residents / stakeholders. It is an ongoing process which allows a two-way communication. Stakeholders / residents and Staatsolie will both benefit from community engagement. The purpose is to help outline how Staatsolie will obtain a better understanding of the public's interest and perspective regarding their activities in the Saramacca area. It also helps people within the community feel involved in and be heard in the project.

In order for Staatsolie to understand the concerns, needs and aspirations of the community, Staatsolie needs to create this two-way communication. This can be achieved through:

- Keeping the community informed about issues that affect, or are important to the community; and
- Creating avenues for Staatsolie to listen to issues that affect, or are important to, the community

Meaningful community engagement usually results in minimization of vagueness, conflict and delays, and the establishment of relationships in the local community that can benefit current and future projects. It can limit the number of surprises that occur during a project because all parties share information openly and consistently.

## 2.5 IMPLEMENTATION OF EMMP

This section provides a description of the methods that will be used to implement the EMMP and monitor performance against EMMP commitments.

### 2.5.1 Method Statements

Method statements are to be compiled by Process Owner-representatives for approval by their Process Owner, who reviews and endorses them. The HSEQ Upstream Manager must receive a copy of the method statement for review 2 weeks before commencement of the activity and if there are any issues regarding the environmental specifications he/ she shall make these known to the Process Owner within a week. The method statement typically shall cover applicable details including, but not limited to:

- A reference to the environmental specifications;
- Description of the activities to be undertaken;
- Location where activities will be undertaken, and if on privately owned land the name of the land owner;
- Map of the location;
- Construction drawings;
- Materials and equipment requirements;
- How and where material will be stored;
- The containment (or action to be taken if containment is not possible) of leaks or spills of any liquid or material that may occur;
- Timing of activities (start and end dates); and
- Assurance that the landowner/user is aware of the planned activity.

The following method statements for construction shall be submitted to the Process Owner not less than 14 days prior to the intended date of commencement of the activity:

- Site camp;
- Site preparation;
- Construction activities;
- Setting up or changing of access routes;
- Construction of dams and water management structures;
- Changes of dams and water management structures;
- Movement of rig; and
- Large transports along clay dams.

Contractors / Process Owner Representatives shall abide by these approved method statements.

Appendix A provides a pro forma method statement sheet that must be completed by the process owner for each activity requiring a method statement as specified above.

### 2.5.2 Monitoring

Respective Process Owners together with the HSEQ Upstream Division are responsible for monitoring the performance of on-site personnel against the commitments of the EMMP. Overall control for this function will lie with the HSEQ Upstream Manager, and responsibility for day-to-day monitoring will lie with the Process Owner representatives. The Process Owner is obliged to, and will have the power to, suspend activities if they do not comply with the performance standards specified in the EMMP.

The following principal items will be monitored:

- Correct implementation of EMMP; and
- Compliance with Method Statements.

Monitoring of specific environmental parameters is addressed separately in Section 3.1.5.

Weekly HSE inspections are required during construction, using the checklist provided in Appendix B. These completed checklists must be submitted to the HSEQ Upstream Manager at the end of each week.

### 2.5.3 Data and Information Management

Quantitative data should be stored in the Staatsolie Environmental Statistics database, which will allow systematic storage and manipulation of data, and will permit rapid retrieval for the purposes of internal and external reporting. The representatives of the HSEQ Upstream Manager will administer this database.

In order to ensure a consistent and coherent system for documenting the implementation of the EMMP, all written records and other information will be stored in a filing system that is compatible with the requirements of the existing HSE Management System. This will comprise standardized forms, documents and reporting procedures.

### 2.5.4 Reporting

The frequency and nature of reporting of environmental management performance will depend on the nature of the activity and aspect that is being managed. Reporting will primarily consist of reports to the Project Manager, on critical issues, as required. Table 2-2 below gives an overview of the other obligatory reporting lines.

**Table 2-2: Regular reports and report lines**

| Report Name | Description | Frequency | Responsible | Recipient |
|---|---|---|---|---|
| Water quality monitoring reports | Reports of water quality monitoring done for the project<br>(Staatsolie Environmental Statistics Database) | Quarterly | Treatment & Delivery Manager | HSEQ Upstream Manager |
| Weekly report of safety talks | Reports of talks<br>(Safety Talk Database) | Weekly | All Process Owners | HSEQ Upstream Manager |

| Report Name | Description | Frequency | Responsible | Recipient |
|---|---|---|---|---|
| Weekly HSE Inspection | Compliance with EMMP | Weekly during construction | All Process Owners | HSEQ Upstream Manager |
| Incidents | Report type and consequences for loss of days (Achiever plus Database) | When accident occurs | All Process Owners | HSEQ Upstream Manager |
| Reports of drills held | Drills as emergency response etc. | Yearly | All Process Owners | HSEQ Upstream Manager |
| Method statement | Method statements | Two weeks before commencement of activity | All Process Owners | HSEQ Upstream Manager |
| Compliance Reports | Report with specification on the compliance with the EMMP | At the end of construction of the PMP<br>Thereafter Quarterly | HSEQ Upstream Manager (with input of process owners) | NIMOS |

### 2.5.5 Feedback

Feedback on performance will be communicated to the appropriate parties concerned. Any substandard performance will trigger a process that notifies the responsible party of the nature of the issue and indicates the actions that are required to rectify the situation. This will be followed up by further monitoring to ensure that the sub-standard performance has been corrected.

### 2.5.6 Corrective Action

Corrective action is a critical component of the implementation–review–corrective action–implementation (or plan-do-check-act) cycle and it is through corrective action that continuous improvement can be achieved. Where repeated non-compliance is recorded, procedures may need to be altered accordingly to avoid the need for repeated corrective action.

If environmental compliance monitoring indicates non-conformance with the EMMP or accepted Method Statements, the HSEQ Upstream Manager will formally notify the Process Owner through a Corrective Action Request. The Corrective Action Request documents:

- The nature of the non-conformance/environmental damage;
- The actions or outcomes required to correct the situation; and
- The date by which each corrective or preventive action must be completed.

Upon receipt of the Corrective Action Request, the Process Owner will be required to produce a Corrective Action Plan (or similar plan), which will detail how the required actions will be implemented. The Corrective Action Plan must be submitted to the HSEQ Upstream Manager for acceptance prior to implementation. Once it has been accepted, the corrective action must be carried out within the time limits stipulated in the Corrective Action Request. Additional monitoring by the HSEQ Upstream Manager, or his/her delegate, will then be required to confirm the success or failure of the corrective action.

# 3 ENVIRONMENTAL SPECIFICATIONS

## 3.1 APPROACH TO THE EMMP AND ENVIRONMENTAL MANAGEMENT MEASURES

The general principles contained within this section shall apply to all activities for the duration of the design, construction, operation and decommissioning phases of the PF project. An environmental impact is defined as any change to the existing environment, either adverse or beneficial, that is directly or indirectly the result of the project and its associated activities. Impacts are generated by certain aspects of those activities. In the context of this document, an aspect is defined as *"an action, event, product or service, occurring as a component or result of an activity, which interacts with the existing environment"*.

The fundamental approach adopted in the compilation of this EMMP is that management effort should be focused on environmental aspects to prevent impacts from occurring, i.e. a proactive approach. Proactive measures are then backed up with reactive measures, which serve to minimize the severity or significance of the impact, if it cannot be prevented at source. A series of tables incorporating management measures has been developed and grouped to cover the main activities that give rise to potential impacts during the design, construction, operation and decommissioning phases. Each table provides further detail on the following:

- Prescribed mitigation measure(s);
- Implementation timeframe;
- Monitoring and performance evaluation, including performance indicators and monitoring methods; and
- Identification of the person(s) responsible for implementation of the mitigation measure(s).

Management measures specific to the individual project phases are presented in Section 3.1.1 (Design Phase), 3.1.2 (Construction Phase), 3.1.3 (Operation Phase) and 3.1.4 (Decommissioning Phase).

General environmental management measures applicable to all phases of the project are presented in Section 3.1.5, addressing hazardous materials, repair and maintenance, stormwater management, noise and emissions management, dust management, concrete / cement work, fire management, traffic management, transportation and refueling, employment, environmental awareness training and complaints and grievances.

Section 3.1.6 provides measures that must be taken in response to environmental pollution events.

Appendix F provides waste management measures in the Waste Management Plan.

### 3.1.1 Design Phase

The environmental management and mitigation measures that must be implemented during the design phase, as well as responsibilities and timelines for the implementation of these measures and monitoring thereof, are laid out in Table 3-1.

**Table 3-1: Environmental management and mitigation measures that must be implemented during the *Design* Phase**

| Design Phase Measures | | | | | | |
|---|---|---|---|---|---|---|
| **Aspect** | **ID** | **Mitigation measure / Procedure** | **Responsible** | **Implementation Timeframe** | **Monitoring Methods** | **Performance Indicators** |
| **Authorisations** | 1. | Ensure that all required licences and permits have been obtained before the start of construction / operation, including:<br>• Licence from the Minister of Natural Resources for the extraction of groundwater; and<br>• Obtain a permit from NIMOS for the discharge of AAM as a pollutant in the produced water, once relevant laws are promulgated. | • Staatsolie Project Manager | • Before construction commences | • Keep record of all permits, licences and authorisations | • Required licences/permits on file |
| **Tenders** | 2. | Include the EMMP in all tender documents to ensure that sufficient resources are allocated to environmental management by the Contractor. | • Staatsolie Project Manager | • When issuing tenders | • Keep record of tender documentation | • Ensure EMMP requirements are addressed in bids |
| **PMP design** | 3. | Design hazardous material storage facilities, especially fuel and polymer mix storage, with suitable impermeable materials and a minimum bund containment capacity equal to 110% of the largest container. | • Staatsolie Project Manager | • During design phase | • Review detailed layout plans | • Approval of final design |
| | 4. | Design plant to allow for containment of any contaminated stormwater runoff and polymer spill, to prevent this from reaching canals draining to the Saramacca River. | | | | |
| | 5. | Route stormwater around the plant as much as possible to minimize the potential for contaminating runoff. | | | | |
| | 6. | Place fuel, hazardous material and polymer storage tanks / containers on an impermeable surface and within an appropriate bund (at least 110% of the largest tank) from which any spills / leaks can be collected and pumped into a backup tank. Install a roof if possible to prevent stormwater contamination from these areas. | | | | |
| **Infrastructure** | 7. | Design pipelines with low pressure cut-out valves (or similar engineered safety devices) along the pipeline network, to prevent leakages. | • Staatsolie Project Manager | • During design phase | • Review design | • Inclusion of cut-off valves |
| **Josie treatment plant** | 8. | Complete studies to determine the type of modifications required to be made to the Jossie Treatment Facilities to treat PF project produced water. | • D&TS Manager | • During design phase | • Regular progress reporting | • Appropriate modifications identified |

| Design Phase Measures | | | | | | |
|---|---|---|---|---|---|---|
| **Aspect** | **ID** | **Mitigation measure / Procedure** | **Responsible** | **Implementation Timeframe** | **Monitoring Methods** | **Performance Indicators** |
| **Production facilities** | 9. | Re-design existing production test facilities as required to ensure that no back produced polymer is drained to the environment without treatment | | | | • Facilities checked |

### 3.1.2 Construction Phase

The environmental management and mitigation measures that must be implemented during the construction phase, as well as responsibilities and timelines for the implementation of these measures and monitoring thereof, are laid out in Table 3-2.

**Table 3-2: Environmental management and mitigation measures that must be implemented during the *Construction* Phase**

| Construction Phase Measures | | | | | | |
|---|---|---|---|---|---|---|
| **Aspect** | **ID** | **Mitigation measure / Procedure** | **Responsible** | **Implementation Timeframe** | **Monitoring Methods** | **Performance Indicators** |
| **Site camp** | 1. | Submit a Method Statement for Site Camp establishment for acceptance by Staatsolie at least two weeks prior to the start of construction activities. | • Project Manager / Contractor | • Start of construction | • Visual inspections<br>• Method Statement | • Accepted Method Statement<br>• Site boundaries demarcated<br>• Signage in place |
| | 2. | Establish a suitably fenced Site Camp at the start of the contract, which will allow for site offices, vehicle, equipment, material and waste storage areas to be consolidated as much as possible. Provide water and / or sanitary facilities at the Site Camp for personnel. | | | | |
| | 3. | Demarcate construction site boundaries upon establishment. Control access to the site. Fence off site boundaries and ensure that plant, labour and materials remain within site boundaries. | | | | |
| | 4. | Designate the area beyond the boundary of the site as No Go areas for all personnel on site. No vehicles, machinery, materials or people shall be permitted in the No Go area. | | | | |
| **Safety and Security** | 5. | Ensure that emergency procedures (in relation to fire, spills, contamination of the ground, accidents to employees, use of hazardous substances, etc.) are established prior to commencing construction. | • Staatsolie Project Manager<br>• Staatsolie Manager Drilling Operations | • Throughout construction | • Visual inspection and approval by HSE Site Manager | • Number of safety/emergency incidents. |
| | 6. | Make all emergency procedures, including responsible personnel, contact details of emergency services, etc. available to all the relevant personnel. Clearly display emergency procedures at the relevant locations around the site. | | | | |
| | 7. | Secure the Site Camp, particularly to restrict unauthorized access to fuels and any other hazardous substances. | | | | |
| | 8. | Provide suitable emergency and safety signage on site, and demarcate any areas which may pose a safety risk (including hazardous substances, deep excavations etc.). | | | | |
| | 9. | Advise NIMOS of any environmental emergencies (e.g. major spill of a hazardous substance) on site within 24 hours, together with a record of action taken. | | | | |
| **Vegetation clearing** | 10. | Limit the footprint area of the construction activity to what is essential. | • Drilling Operations | • Throughout construction | • Visual inspection | • Size of area cleared relative to development |

| Construction Phase Measures | | | | | | |
|---|---|---|---|---|---|---|
| **Aspect** | **ID** | **Mitigation measure / Procedure** | **Responsible** | **Implementation Timeframe** | **Monitoring Methods** | **Performance Indicators** |
| | 11. | Designate areas outside the development footprint as No Go areas. | Manager | | | footprint<br>• Size of area disturbed outside of construction site boundary |
| | 12. | Ensure that no vegetation is removed or disturbed outside the delineated construction site boundary. | | | | |
| | 13. | Do not harm, catch or kill animals by any means, including poisoning, trapping, shooting or setting of snares. | | | | |
| | 14. | Safely remove and relocate any fauna that may be physically harmed by construction activities. | | | | |
| **Fauna Management** | 15. | Do not harm, catch or kill birds or animals by any means, including poisoning, trapping, shooting or setting of snares. | • Project Manager / Contractor | • Duration of construction activities | • Visual Inspection | • Number of animals harmed / trapped<br>• Number of animals relocated |
| | 16. | Backfill trenches as soon as pipes have been laid to ensure that the time the trench is exposed is kept to a minimum. | | | | |
| | 17. | Inspect open trenches daily for animals which may have fallen or become trapped. | | | | |
| | 18. | Safely remove and relocate any fauna that may be physically harmed by construction activities. | | | | |
| **Erosion management** | 19. | Ensure that all roads and tracks used for construction have the appropriate water diversion / erosion control structures. | • Project Manager / Contractor | • Throughout construction | • Visual inspection | • Presence of surface erosion |
| **Vibration** | 20. | Implement standard vibration management and monitoring measures during piling, drilling and compacting. | • Project Manager / Contractor | • Throughout construction | • Visual inspection | |
| **Protection of archaeological and paleontological resources** | 21. | Compile and implement a chance (archaeological) finds procedure. | • Project Manager / Contractor | • Throughout construction | • Chance finds procedure compiled and implemented | • Number of chance finds |
| **Well drilling** | 22. | Use non-toxic drilling fluids when drilling through freshwater aquifers. | • Drilling Operations Manager | • During well drilling and construction | • Review design<br>• Supervise works | • Compliance with requirements |
| | 23. | Ensure that well casing and cementing meets best practice methods and Staatsolie standards to prevent chemical losses into the upper layers above the oil reservoir. | | | | |
| **Visual impacts** | 24. | Retain screening vegetation around the site (wells) as much as possible. | • Project Manager / Contractor | • Throughout construction | • Visual inspections | • Visibility of project activities from publicly accessible areas |
| | 25. | Regularly collect and dispose of redundant equipment, waste and litter. | | | | |
| **Ablution facilities** | 26. | Provide ablution facilities (i.e. chemical toilets) for all site staff at a ratio of 1 toilet per 15 workers (absolute minimum 1:25). | | • Throughout construction | • Visual inspections | |

| Construction Phase Measures | | | | | | |
|---|---|---|---|---|---|---|
| **Aspect** | **ID** | **Mitigation measure / Procedure** | **Responsible** | **Implementation Timeframe** | **Monitoring Methods** | **Performance Indicators** |
| | 27. | Secure all temporary / portable toilets to the ground to prevent them toppling due to wind or any other cause. | • Project Manager / Contractor | | • Records of waste disposal | • Number of incidents of staff not using facilities<br>• Number of pollution incidents |
| | 28. | Maintain toilets in a hygienic state. | | | | |
| | 29. | Dispose of chemicals and treated sewage at an approved waste disposal site or sewage plant. | | | | |
| **Construction site rehabilitation and closure** | 30. | Remove all construction equipment, vehicles, equipment, waste and surplus materials, including site offices, temporary fencing and other facilities, from the site. | • Project Manager /Contractor | • Once construction is complete; or<br>• Throughout construction if it takes place in phases / different areas sequentially | • Visual inspection of site<br>• Keep record of rehabilitation measures | • Rehabilitation forms an integral part of operations from start-up<br>• Construction sites fully rehabilitated within five years |
| | 31. | Clean up and remove any spills and contaminated soil in the appropriate manner. | | | | |
| | 32. | Ensure that no discarded materials are buried on site or on any other land not designated for this purpose. | | | | |
| | 33. | Ensure that affected areas are rehabilitated following construction. | | | | |
| | 34. | Rehabilitate areas adjacent to the site (if disturbance is unavoidable) to at least the same condition as was present prior to construction. | | | | |
| | 35. | Rehabilitate any disturbed areas as soon as construction in the area is complete. | | | | |
| | 36. | Rehabilitate all project areas as soon as possible after completion of activities in each area, including removing and/or remediating any contaminated soils. | | | | |

### 3.1.3 Operation Phase

The environmental management and mitigation measures that must be implemented during the operation phase, as well as responsibilities and timelines for the implementation of these measures and monitoring thereof, are laid out in Table 3-3.

**Table 3-3: Environmental management and mitigation measures that must be implemented during the *Operation* Phase**

| Operation Phase Measures | | | | | | |
|---|---|---|---|---|---|---|
| **Aspect** | **ID** | **Mitigation measure / Procedure** | **Responsible** | **Implementation Timeframe** | **Monitoring Methods** | **Performance Indicators** |
| **PMP** | 1. | Ensure that the polymer used has a residual AAM concentration of less than 0.1% by weight. | • Project Manager | • Throughout operations | • Regularly audit programmes | • Compliance with relevant programmes<br>• Regular audits |
| | 2. | Implement a PMP maintenance programme in line with international standards and Staatsolie guidelines. | | | | |
| | 3. | Regularly inspect all machinery and polymer holding tanks for leaks or damages. | • Staatsolie Manager Treatment & Delivery | | | |
| | 4. | Repair any defects as soon as possible. In the case of leaks, ensure that any leaking polymer is captured and not released into the environment. | | | • Visually inspect areas inside and outside the plant for pollution | • Number of contaminations noted on site |
| **Polymer mix and water injection** | 5. | Manage injection pressures to ensure that the PF chemicals are not chased/forced beyond the confines of the oil reservoir. | • Staatsolie Manager Treatment & Delivery | • Throughout operations | • Record calculations of appropriate injection pressure<br>• Monitor groundwater for evidence of contamination with polymer mix | • Evidence of contamination with polymer mix |
| **Produced water (containing back produced polymer) and effluent** | 6. | Treat produced water before discharge. | • Staatsolie Manager Treatment & Delivery | • Throughout operations | • Sample treated water before discharge | • Compliance with guidelines |
| | 7. | Ensure the back-produced polymer quality is suitable for disposal. | | | | |
| | 8. | Dispose effluent from the PF project in the fastest flowing part of the Saramacca river and/or disperse it over an appropriate length such that dilution occur over the 4 km Saramacca River section adjacent to the Tambaredjo Oilfield within a day. | | | | |

### 3.1.4 Decommissioning Phase

The environmental management and mitigation measures that must be implemented during the design phase, as well as responsibilities and timelines for the implementation of these measures and monitoring thereof, are laid out in Table 3-1.

**Table 3-4: Environmental management and mitigation measures that must be implemented during the *Decommissioning* Phase**

| Decommissioning Phase Measures | | | | | | |
|---|---|---|---|---|---|---|
| **Aspect** | **ID** | **Mitigation measure / Procedure** | **Responsible** | **Implementation Timeframe** | **Monitoring Methods** | **Performance Indicators** |
| **Decommissioning planning** | 1. | Plan and make adequate financial provision for rehabilitation and restoration activities. | • Staatsolie | • Initiate at least 1 year before planned decommissioning | • Regular progress reporting | • Determination of closure objectives and requirements |
| | 2. | Initiate consultation with key stakeholders (e.g. private land owner, Department of Public Works, community) before any planned decommissioning to discuss potential decommissioning options, methods and requirements.<br>Two decommissioning scenarios are currently being considered by SOM:<br>• The area is abandoned, all facilities and plant are demolished and removed, and the area is allowed to revegetate, with or without active rehabilitation / remediation; or<br>• In the event of an agreed subsequent beneficial land use, part of the infrastructure may be retained for further use. | | | | |
| | 3. | Determine other potential commercial/beneficial uses for the equipment, infrastructure and land to be decommissioned. | | | | |
| | 4. | Conduct Groundwater and Soil Quality Assessments for all processing areas. | | | | |
| | 5. | Consider best remediation practice for contaminated areas, including on-site land-farming and, where necessary, removal of contaminated soil from site for treatment or for safe disposal elsewhere. | | | | |
| | 6. | Identify and assess any potential environmental and societal risks associated with the preferred method of decommissioning. | | | | |
| | 7. | Address potentially significant environmental and societal risks by amending the proposed method of decommissioning to prevent any significant adverse impacts. | | | | |

| Decommissioning Phase Measures | | | | | | |
|---|---|---|---|---|---|---|
| **Aspect** | **ID** | **Mitigation measure / Procedure** | **Responsible** | **Implementation Timeframe** | **Monitoring Methods** | **Performance Indicators** |
| | 8. | Prepare a detailed Decommissioning Plan, laying out the:<br>• Decommissioning objectives;<br>• Decommissioning procedures;<br>• Environmental and social implications of decommissioning;<br>• Implementation strategy, including stakeholder engagement;<br>• Waste management, including opportunities to reuse or recycle material. | | | | |
| **Plant cleaning** | 9. | Notify relevant authorities and stakeholders before decommissioning activities commence. | • Staatsolie | • Before decommissioning activities start | • Review notifications sent | • Number of stakeholders notified |
| | 10. | Remove all remaining water, sludge, polymer, oil etc from plant and infrastructure. | | • At the start of decommissioning | • Regular review of progress<br>• Review disposal procedures | • Condition of equipment<br>• Insidents of contamination<br>• Cost of clean up |
| | 11. | Clean all equipment before disconnecting or removing it. | | | | |
| | 12. | Ensure that substances, for example process water, sludge, polymer, oil and grease etc, are properly disposed of and not discharged to canals. | | | | |
| | 13. | Ensure that water (or any other substance used to clean plant and infrastructure) is treated and tested for hydrocarbons before being discharged or disposed of. | | | | |
| **Well abandonment** | 14. | Plug wells in accordance with best practice methods to prevent leaks of fluids and methane to the surface and of oil, gas or salty water into freshwater aquifers. | • Staatsolie | • During decommissioning | • Review of proposed methods<br>• (Independent) inspection of activities | • Compliance with best practice |
| **Rehabilitation** | 15. | Rehabilitate areas as required in terms of the agreement with the land owner, intended future land use and the decommissioning plan. | • Staatsolie | • After decommissioning | • Visual inspection of rehabilitation areas, if any | • Success of rehabilitation |
| | 16. | Notify relevant authorities and key stakeholders when decommissioning and rehabilitation are completed. | | | • Proof of notification | |
| **General** | 17. | Provide adjacent landowners with contact details to register any observations and complaints following decommissioning. | • Staatsolie CCU | • Before end of decommissioning | • Proof of notification | |
| | 18. | Clarify issues of residual liability before relinquishment. | | | | |

### 3.1.5 General Environmental Management Measures

This section lists general, typically routine environmental management measures applicable to all phases of the project. Responsibility of implementation will depend on the project phase and component and will be allocated by the HSEQ Upstream Manager.

*Best practice measures are shown in italics.*

#### *3.1.5.1 Hazardous Materials*

- Place fuel, hazardous material and polymer storage tanks / containers on an impermeable surface and within an appropriate bund (at least 110% of the largest tank) from which any spills / leaks can be collected and pumped into a backup tank. Install a roof if possible to prevent stormwater contamination from these areas.
- Construct chemical storage compounds outside of floodplains and further than 100 m from the normal high-water mark of a water body or a water supply borehole.
- Develop (or adapt and implement) procedures for the safe transport, handling and storage of potential pollutants.
- Avoid unnecessary use and transport of hazardous substances.
- Keep Material Safety Data Sheets (MSDS) for all hazardous materials on site and ensure that they are available for reference by staff responsible for handling and storage of materials.

#### *3.1.5.2 Repair and Maintenance*

- Implement maintenance and inspection procedures.
- Regularly perform maintenance of all plant, equipment and infrastructure in line with manufacturer's and Staatsolie's specification.
- Maintain infrastructure and equipment such as tanks, pipelines, valves and fittings in good working order to prevent leaks and minimise evaporation of oil.
- Maintain vehicles in good working order to minimise atmospheric emissions.
- Regularly inspect all equipment, infrastructure (including pipelines) and holding tanks for leaks or damages.
- Repair any defects as soon as possible. In the case of leaks, ensure that the leaking water or effluent is captured and not released to surface water.

#### *3.1.5.3 Stormwater Management*

- Install clean and dirty stormwater management systems.
- Capture stormwater that might be contaminated separately and route to a settling pond where suspended matter can settle out. Dispose of such matter appropriately, e.g. to an approved landfill, and not into the environment.
- Keep outdoor areas clean to minimise the potential of polluting stormwater.
- Collect stormwater from bunded areas and treat or separate waste before disposing into surrounding drainage system.
- Use berms and stormwater drainage systems to prevent surface run-off from entering site excavations.

- Implement measures to maximise the infiltration of stormwater on site.

#### *3.1.5.4 Noise and Emissions Management*

- Maintain all generators, vehicles and other equipment in good working order to minimise exhaust fumes and excess noise.
- Enclose diesel generators used to supply on site power to reduce excess noise, if necessary.

#### *3.1.5.5 Dust Management*

- Limit vegetation clearance and the construction footprint to what is essential.
- Stabilise exposed surfaces as soon as practically possible.
- Minimise dust generated on gravel sections of the Gangaram Pandayweg by:
  - Dampening dust-generating sections of the road;
  - Adhering to speed limits; and
  - Responding to complaints.
- Limit vehicle speeds to 40 km/h on unconsolidated and non-vegetated areas.
- Cover trucks transporting loose material to or from site with tarpaulins, plastic or canvas if necessary, to avoid dust.
- Reduce airborne dust at construction sites through dampening dust-generating areas, roads and stockpiles with water if required.
- Regularly evaluate the effectiveness of all dust management measures. Amend how or which measures are used if necessary.

#### *3.1.5.6 Concrete/Cement Work*

- Use pre-mixed concrete rather than batching on-site where possible.
- Ensure that no cement truck delivery chutes are cleaned on site. Cleaning operations are to take place off site at a location where wastewater can be disposed of in the correct manner. If this is not possible a suitable washing facility is to be developed on site.
- Batch cement in a bunded area within the boundaries of the development footprint only (where unavoidable).
- Ensure that cement is mixed on mortar boards and not directly on the ground (where unavoidable).
- Physically remove any remains of concrete, either solid, or liquid, immediately and dispose of as waste.
- Place cement bags in bins and dispose of bags as waste to a licensed waste disposal facility.
- Sweep / rake / stack excess aggregate / stone chip / gravel / pavers into piles and dispose at a licensed waste disposal facility.

#### *3.1.5.7 Fire Management*

- Ensure that no fires are permitted on or adjacent to site except in areas designated for this purpose. Any such designated areas should be situated as far as possible from flammable material stores and any other high fire risk, or environmentally sensitive areas.

- Ensure that no smoking is permitted on the site except within designated areas.
- Ensure that sufficient fire-fighting equipment is available on site.
- Equip all fuel stores and waste storage areas with fire extinguishers.
- Ensure that all personnel on site are aware of the location of firefighting equipment on the site and how the equipment is operated.
- Suitably maintain firefighting equipment.

#### *3.1.5.8 Traffic Management*

- Manage activities so as to minimise impacts on road traffic as far as possible, e.g.:
    - Attempt to arrange delivery of materials when it will least disrupt traffic; and
    - Stagger deliveries rather than concentrating them during "rush" hours.
- Ensure that all safety measures are observed and that drivers comply with the rules of the road.
- Ensure that vehicle axle loads do not exceed the technical design capacity of roads utilised by the project.
- Ensure that trucks transporting large equipment or hazardous material are clearly marked and accompanied by safety vehicles.
- Investigate and respond to complaints about traffic.
- Inform nearby residents and businesses in a timely manner of delivery schedules;
- Avoid deliveries at night;
- Publicise delivery schedules on social media;
- Monitor trucks at strategic points along the Gangaram Pandayweg to determine compliance with traffic rules agreed upon between Staatsolie and contractor; and
- Intensify the dust suppression programme on the Gangaram Pandayweg during construction, especially the section from the beginning of the Gangaram Pandayweg (Km 0) to the entrance to the Tambaredjo Oilfield (Km 6).

#### *3.1.5.9 Transportation and Refueling*

- Undertake regular maintenance of vehicles and machinery to identify and repair minor leaks and prevent equipment failures.
- Undertake any on-site refuelling and maintenance of vehicles/machinery in designated areas. Line these areas with an impermeable surface and install oil traps.
- Use appropriately sized drip trays for all refuelling and/or repairs done on machinery – ensure these are strategically placed to capture any spillage of fuel, oil, etc.
- Clean up any spills immediately, through containment and removal of free product and appropriate disposal of contaminated soils
- Keep spill containment and clean-up equipment at all work sites and for all polluting materials used at the site.

#### *3.1.5.10 Employment*

- Consider maximising the employment of local workers.
- Work closely with local institutions to identify and communicate required skills and resources that the nationals could provide.
- Consider purchasing resources from Surinamese sources wherever feasible.

#### *3.1.5.11 Environmental Awareness Training*

- Provide environmental awareness training to all personnel on site at the start of their employment. Training should include discussion of:
    - Potential impact of activities on the environment;
    - Suitable disposal of waste and litter;
    - Response to an environmental incident;
    - Key measures in the EMMP relevant to worker's activities; and
    - How incidents and suggestions for improvement can be reported.
- Ensure that all attendees remain for the duration of the training and on completion sign an attendance register that clearly indicates participants' names.

#### *3.1.5.12 Complaints and Grievances*

- Continue to publicise and implement the existing Staatsolie grievance mechanism.
- Provide compensation in the event that a spill of polymer mix affects agricultural areas.
- Inform landowners potentially affected by a spill.

### 3.1.6 Response to Environmental Pollution

This section lists key measures that must be taken in response to environmental pollution during any phases of the project. Responsibility of implementation will depend on the project phase and component and will be allocated by the HSEQ Upstream Manager.

- Maintain a list of external equipment, personnel, facilities, funding, expert knowledge and materials that may be required to respond to emergencies. The list should include personnel with specialised expertise for spill clean-up, flood control and water treatment.
- Immediately stop the activity causing pollution in the event of environmental pollution (e.g. spillage).
- Contain the spill at source or as close to source as possible if a PAM / polymer mix spill occurs, using e.g. booms, soil berms etc. to prevent spread of liquid.
- Remove as much polymer spill liquid as possible, using e.g. absorbent peats etc.
- Allow for natural biodegradation at the release site is possible if a small scale polymer spills (affecting up to 50 $m^2$) occurs, provided the site is not at risk of directly impacting surface water.
- Remove soil to a safe landfarming area if polymer spills in areas with potential for direct migration of polymer mix to surface water.

- Adopt a site-specific in-situ remedial plan if very large releases of polymer, away from surface water receptors, occurs.
- Cease injection of polymer mix at the well in the event of a leak in the well.
- Monitor groundwater quality at the water abstraction point (1J22) and, depending on the location of the leak, possibly at new sentinel wells in the event of a leak.
- Resume activity only once the pollution has been halted or (in the case of spillages) contained without reaching the environment.
- Repair faulty equipment as soon as possible.
- Install additional bunding / containment structures around the equipment that was the source of the leak / spillage to prevent pollution.
- Treat hydrocarbon spills, e.g. during refuelling, with adequate absorbent material, which then needs to be disposed of at a suitable landfill.
- Notify NIMOS of a significant environmental pollution event as soon as possible, latest within 24 hours.

## 3.2 MONITORING FRAMEWORK

The key focus of the monitoring program will be the impacts from the various project activities on the environment at representative sites and at any sites where problems have arisen or are suspected. This will provide information on the accuracy of the impact predictions that were made and on the effectiveness of the EMMP. It will also provide important input information for any future development activities in similar areas.

The primary variables to be addressed in the monitoring program are groundwater level and quality and surface water quality. The monitoring framework program is presented in Table 3-5. Based on this framework the HSEQ Upstream Manager must set up a documented sampling program and allocate responsibilities.

Monitoring results should be provided to NIMOS biannually while monitoring takes place.

**Table 3-5: Monitoring framework programme for the PF Project**

| Aspect | Parameters | Frequency | Monitoring locations | Reference values |
|---|---|---|---|---|
| Groundwater Quality | - pH<br>- EC<br>- Na<br>- K<br>- Mg<br>- $NH_4$<br>- Ca<br>- Cl<br>- $SO_4$<br>- F<br>- $NO_3$<br>- Alkalinity<br>- Selected metals, based on available produced water and background water sampling data, but as a minimum As, Se and Ba<br>- Dissolved organic carbon (bulk indicator of PAM<br>- Other organic compounds (hydrocarbons, humics)<br>Monitor AAM only in response to leaks in an injection well[2] | Before initiation of PF project<br>Quarterly during operation | Routine monitoring at 1J22 | Compare results to baseline measurements taken before initiation of the PF project, to identify any possible impacts of the polymer injection |
| Groundwater level | Measure groundwater level | Quarterly when abstracting groundwater for the PF project | Routine monitoring at 1J22 | Compare results to baseline measurements taken before abstraction for the PF project, to identify any possible impacts of abstraction for the project |

[2] As the model shows AAM is unlikely to reach any shallower water wells; tracking other chemical compounds is likely to be a more robust indicator of water quality changes

| Aspect | Parameters | Frequency | Monitoring locations | Reference values |
|---|---|---|---|---|
| Surface water quality | - pH<br>- EC<br>- Dissolved oxygen<br>- Chemical oxygen demand<br>- AAM<br>- Oil and grease<br>- Selected metals: initially analyse for a comprehensive suite of metals and select parameters for future monitoring based on those results. | Quarterly | Upstream of the discharge point(s) in the Saramacca River, beyond the reach of the tidal push from discharge point, for baseline value<br>Downstream of the discharge point(s) in the Saramacca River, ~at the western boundary of the Tambaredjo Oilfield | Compare results to baseline measurements taken before abstraction for the PF project, to identify any possible impacts of abstraction for the project |
| Effluent | - AAM in treated effluent prior to discharge<br>- Total PF-related effluent volume discharged per day<br>Use of a test kit (rather than remote laboratory) analysis for AAM is preferred, as it allows for faster response times.<br>Other parameters should be presently monitored as part of discharge from existing operations. | Daily while commissioning the PF project / Jossie treatment plant<br>Weekly once regular operations are established. This can be done as part of a composite sample (of effluent) shipped to the lab. | After treatment, prior to discharge | Ensure that no more than 0.8 kg/day of AAM is discharged (this is equivalent to a concentration of 0.7 mg/L AAM in the treated effluent, assuming a maximum discharge volume of 1 190 $m^3$/day)<br>Also comply with the relevant IFC guidelines for effluent discharge |
| Polymer injection | - Polymer mix injection pressure<br>- Polymer mix flow rate | Continuously | Injection wells | Ensure that no polymer mix is unaccounted for after injecting into wells, which would indicate a leaking well |
| Pipeline integrity | - Quantity of polymer mix entering and exiting pipeline | Continuously | Pipeline inlet and outlet and / or visual inspection along the pipeline | Ensure that no polymer mix is unaccounted for in the pipeline system, which would indicate a leaking pipeline |

# Appendices

# Appendix A: Method Statement

**METHOD STATEMENT**

**SOM DEPARTMENT:**……………………….……. **DATE:**……………………………

**PROPOSED ACTIVITY** (give title of Method Statement and reference to Environmental specification):

| |
|---|
| |

**WHAT WORK IS TO BE UNDERTAKEN** (give a brief description of the works):

| |
|---|
| |

**WHERE ARE THE WORKS TO BE UNDERTAKEN** (where possible, provide an annotated plan and a full description of the extent of the works):

| |
|---|
| |

**START AND END DATE OF WORKS FOR WHICH METHOD STATEMENT IS REQUIRED:**

| | |
|---|---|
| Start Date: | End Date: |

**HOW ARE THE WORKS TO BE UNDERTAKEN** (provide as much detail as possible, including annotated maps and plans where possible):

| |
|---|
| |

In case on private land: include signature of owner/user to show that he/she is aware

***Please attach extra pages if more space is required***

# Appendix B: EMMP Checklist

# Weekly Site Checklist

*To be submitted to the HSEQ Upstream Division*

*Location:*

| **Mitigation measure** | **Yes/No** | **Comments** |
|---|---|---|
| All personnel on site are aware of the contents of the EMMP and were made aware of environmental issues. | | |
| All personnel on site are aware of the ERPs | | |
| All personnel on site are aware of the drugs and alcohol policy | | |
| MSDS's are available for all hazardous substances on site. | | |
| Hazardous materials storage area is uncompromised and the hazardous materials register is current and visible. | | |
| Fuel is stored in a bunded area (with 110% of the stored fuel volume) and no leaks are visible. | | |
| Refuelling of vehicles occurs within the designated refuelling area, with adequate pollution prevention measures in place. | | |
| Drip trays are being used where there is a risk of spillage (i.e. fuelling of equipment). | | |
| All containers and storage tanks are leak proof. | | |
| There are no spills and leakages. | | |
| Concrete is not being batched on soil. | | |
| Spill response equipment and materials is functional and accessible. | | |
| No animal kills have been reported. | | |
| Waste is separated and collected in appropriate bins/areas and removed to a suitable landfill regularly. | | |
| Firefighting equipment is functional and accessible. | | |
| Vehicles are roadworthy and in good working order. | | |

| Mitigation measure | Yes/No | Comments |
|---|---|---|
| Deliveries are scheduled during low-traffic hours. | | |
| Erosion control measures are in place and are effective in controlling erosion. | | |
| Dust suppression is implemented if dust is generated. | | |
| There is no trespassing by project personnel. | | |
| There is no trespassing by unauthorized persons. | | |
| There is adequate provision of toilets and toilets are satisfactorily maintained. | | |
| There are no complaints from the community. | | |
| Areas where construction is complete have been cleared and rehabilitated. | | |
| Any other observations or comments. | | |

**<u>Department delegate</u>**

Completed by: ……………………………

Date: ………………………….

Sign: …………………………..

**<u>Environmental Engineer</u>**

Received and checked by:

……………………………

Date: ………………………….

Sign: …………………………..

# Appendix C: Weekly Waste Report

**Contractor's name** :

**Project** :

**Location** :

**Period** :

**Reported by** :

| Waste type | Quantity | Unit: $m^3$ / kg / bbl | Disposal destination |
|---|---|---|---|
| Paper | | | |
| Plastic bottles | | | |
| Rubber gloves | | | |
| Glass | | | |
| Food waste | | | |
| Water filters bags | | | |
| Polymer filter bags | | | |
| Flopaam bags | | | |
| Wooden pallets | | | |
| Metal | | | |
| Drilling waste | | | |
| Cement | | | |
| Package | | | |
| Coating cans | | | |
| Batteries | | | |
| Expired Chemicals | | | |
| Waste of the Jossie Treatment plant | | | |
| Contaminated soil | | | |
| Oil waste | | | |
| Other: | | | |

# Appendix D: Overeenkomst inzake mijnbouwwerkzaamheden

# OVEREENKOMST

TOEGANG TERREINEN VOOR HET VERRICHTEN VAN MIJNBOUWWERKZAAMHEDEN

**De ondergetekenden:**

Staatsolie Maatschappij Suriname N.V., gevestigd aan de Dr. Ir. H.S. Adhinstraat 21 te Paramaribo, ten deze vertegenwoordigd door haar Algemeen Directeur dhr. M.C.H. Waaldijk, hierna te noemen **"Staatsolie"**

en

, houder van ID kaart nummer en wonende aan de te , hierna te noemen **"Gerechtigde"**

**In overweging nemende:**

- dat bij Decreet E-8B (S.B. 1980 nr. 128) aan Staatsolie concessie is verleend tot het verrichten van werkzaamheden verbandhoudende met de opsporing en ontginning van koolwaterstoffen,

- dat in gevolge het Decreet Mijnbouw (S.B. 1986 no. 28), Gerechtigde en derdebelanghebbenden werkzaamheden die hiermee verband houden moeten gedogen,

**Verklaren het volgende overeen te komen:**

**Artikel 1**

Gerechtigde is de ............................................van het perceelland, gelegen in het district .......................... en nader omschreven op de kaart van landmeter d.d. (bijlage 1). Bijlage 1 maakt integraal deel uit van de overeenkomst. Gerechtigde zal een deel van dit perceelland, groot ...........................ter beschikking stellen aan Staatsolie voor het verrichten of doen verrichten van werkzaamheden voortvloeiende uit het recht verkregen door Staatsolie vanwege Decreet E-8B, gedurende de periode ........................................ tot ..........................................................

**Artikel 2**

Staatsolie zal Gerechtigde vergoeden de schade onmiddellijk veroorzaakt door de bovengenoemde werkzaamheden. Deze vergoeding is, afhankelijk van het geval, gebaseerd op taxatie van LVV of andersoortige uit te voeren taxaties, en zal indien van toepassing in een nadere overeenkomst vastgelegd worden.

**Artikel 3**

Partijen zullen indien nodig tijdens de uitvoering van de werkzaamheden met elkaar in overleg treden voor nadere afspraken met betrekking tot de utvoering van bovengenoemde werkzaamheden

**Artikel 4**

Visuele oriëntatie van de staat van bovengenoemd perceelland vóór de aanvang van de werkzaamheden heeft het navolgende doen constateren:

-
-
-

**Artikel 5**

Staatsolie zal ten behoeve van de mijnbouwwerkzaamheden de volgende aanpassingen plegen op bovengenoemd perceelland:

-
-
-

**Artikel 6**

Deze overeenkomst is van kracht jegens Gerechtigde, zijn rechtsverkrijgers en rechtsopvolgers. Gerechtigde is gehouden bij de verkoop en overdracht in eigendom van het geheel of een gedeelte van het in de considerans omschreven perceel, alsmede bij verlening daarop van enig zakelijk genotsrecht, aan de nieuwe eigenaar of zakelijk gerechtigde ten behoeve van Staatsolie, alle de in deze overeenkomst opgenomen verplichtingen, over te dragen.

**Artikel 7**

Staatsolie is gehouden om conform het door het Nationaal Instituut voor Milieu en Ontwikkeling in Suriname (NIMOS) goedgekeurde Environmental Management Plan bij beëindiging van de mijnbouwwerkzaamheden het perceelland te rehabiliteren, zulks in overleg met Gerechtigde.

**Artikel 8**

Na het verrichten van de mijnbouwwerkzaamheden door Staatsolie zal het perceel als volgt worden overgedragen:

-

-

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Aldus overeengekomen en in tweevoud opgemaakt en ondertekend te Paramaribo op …… ................................

Staatsolie Maatschappij Suriname N.V. Gerechtigde

__________________________ _______________________

**R. Elias**
**Managing Director**

# Appendix E: List of applicable GFIs

| GFI no | Subject | Scope |
|---|---|---|
| **Section 1**<br>**ADMINISTRATIVE** | | |
| **104N** | **Security Rules for Saramacca Operations**<br>Dutch | This instruction outlines the security rules and regulations applicable to the Saramacca Operations for the different groups concerned. |
| **105(N)** | **Routine Safety Talks.**<br>English/Dutch | This instruction formalizes the dissemination of information through regular meetings, approximately ten minutes long, commonly called "Toolbox Meetings" or "Safety Talks". |
| **106** | **HSE and Security Induction for New Arrivals.**<br>English | This instruction describes the management of the system that controls HSE and Security Induction through which every new arrival is made familiar with the company's health, safety, environmental and security requirements as they relate to the activity that they are about to undertake. |
| **109(N)** | **Code of dress for industrial areas.**<br>English/Dutch | This General Field Instruction outlines the type of clothing and minimum personal protective equipment (PPE) for the Employees and visitors present at Staatsolie industrial workplaces. |
| **110** | **Incident Reporting.**<br>English | This instruction details the process for the reporting of incidents, which initiate the investigation of these incidents. Incidents are reported and recorded for, Mitigating of consequences; Preventing recurrence; Monitoring performance; Satisfying statutory requirements and for Insurance claims. |
| **119C** | **Personal Protective Equipment and Dress Code.**<br>English/Dutch | This GFI identifies the most common types of personal protective equipment for the various locations on the Saramacca Field. |

| GFI no | Subject | Scope |
| --- | --- | --- |
| **120C** | **General traffic rules.**<br>English/Dutch | This GFI defines the general traffic rules to guide the performance of company Employees, contractor's Employees and visitors while on company roads. It also defines rules for the behavior of drivers of company owned and rented vehicles on public roads. |
| **126** | **Safe Use of Mobile Communication Devices.**<br>English | This instruction provides guidance to the safe use of mobile Communication Devices in order to minimize hazards that are introduced with it. |
| **130(N)** | **Formatting of Work instructions.**<br>English/Dutch | This GFI guides the process of selecting activities for which Work Instructions must be written and the formatting of the instructions. |
| **131** | **Guidelines for Departmental HSE Teams.**<br>English | This GFI outlines the terms of reference and composition of the Departmental HSE Teams which are intended to assist the departmental head in the execution of the departmental HSE program and to achieve workers participation. |
| **132** | **Contractor Health, Safety and Environmental Management**<br>English | This GFI provides guidance to Staatsolie staff in promoting and managing HSE performance of Contractors. |
| **Section 2**<br>**JOB SAFETY INSTRUCTIONS** | | |
| **200(N)** | **Permit to work system - General.**<br>English/Dutch | This GFI provide guidelines to the process of "the Permit to Work system" that is in force at the Saramacca Operations, so designed: |

| GFI no | Subject | Scope |
|---|---|---|
| | | That one central authority knows all activities that are intended to take place at any location and,<br>To ensure that adequate precaution is taken and that the condition of the equipment on which the work was done is safe for returning it to service. |
| **201(N)** | **Permit to work system - Hot work.**<br>English/Dutch | This GFI covers the aspect of the Permit to Work System that deals with the permitting of Hot Work. |
| **202(N)** | **Permit to work system - Confined space entry.**<br>English/Dutch | This GFI covers the aspect of the Permit to Work that covers the special precautions that must be taken to protect workers, required to enter vessels and other confined spaces, from the risks associated with this type of work. |
| **203(N)** | **Permit to work system - Excavation.**<br>English/Dutch | The Excavation Certificate controls the special precautions that must be taken when excavating is requested. |
| **210(N)** | **Handling of Hazardous Chemicals.**<br>English/Dutch | This instruction describes the management system for the selection, handling and disposal of all hazardous chemicals used by Staatsolie. |
| **214(N)** | **Isolation, Lockout and Warning Tags.**<br>English/Dutch | This procedure establishes guidelines to prevent personal injury and property damage due to an unexpected release of energy or hazardous materials. |
| **215** | **Management of Change Procedure**<br>English | This General Field Instruction provides guidelines in how to manage division cross-bordering changes at the Saramacca Operations that might create safety hazards for others than the originating division of the intended change. |

| GFI no | Subject | Scope |
|---|---|---|
| 225(N) | **Storage, Transportation and handling of Compressed, liquefied and pressurized gasses.** English/Dutch | This GFI handles the general guidelines for safe storage, transportation and the handling of gas bottles. The most common industrial gasses, which are used by Staatsolie, are oxygen, acetylene, nitrogen, propane (LPG), butane and carbon dioxide. |
| 228(N) | **Abrasive Blasting.** English/Dutch | This instruction provides guidelines for the protection of personnel engaged in abrasive blasting and others who may be in the surrounding areas where abrasive blasting is conducted. |
| 229(N) | **Spray painting.** English/Dutch | This instruction provides guidance for the safe use of spray painting whereby care must be taken to protect the workers involved, other personnel in the vicinity, nearby equipment and the environment. |
| 230 | **Housekeeping** English | This document provides guidance to Employee's to ensure that proper housekeeping is maintained. |
| 232 | **Job Safety Analysis** English | Job Safety Analysis is a proven method that evaluates a sequence of job steps or tasks to identify and document potential hazards and to take countermeasures to protect workers' health and safety against those hazards. This instruction provides guidance for conducting a Job Safety Analysis. |
| 233 | **Safety Color Codes** | This instruction establishes the requirements for a uniform visual system for marking potential hazards, and provides an effective means of communicating hazard information to the Employees & contractors, in order to reduce the likelihood of injury from potential hazards in the work environment. It defines the color codes of signs, tags and barricades to be used in controlling exposure to potential hazards, and specifies requirements |

| GFI no | Subject | Scope |
|---|---|---|
| | | for design uniformity to promote Employee recognition and avoidance of hazards. |
| | **Section 3**<br>**EMERGENCY RESPONSE** | |
| **305(N)** | **Emergency Response - Injury / Illness**.<br>English/Dutch | This instruction describes the procedure that needs to be followed when an emergency situation at the Staatsolie Saramacca Location turns up. |
| | **Section 4**<br>**EQUIPMENT STANDARDS AND SPECIFICATIONS** | |
| **400** | **Inspection of Fire Protection and Emergency Equipment.**<br>English | This GFI provides departments and divisions of the Saramacca Operations with procedures for the inspection of Fire protection and Emergency Equipment, which must be in good condition at all time. |
| **405** | **Scaffolding Rules**<br>English | This GFI provides the guidelines of erecting tubular scaffolding. |
| **408(N)** | **Protection from lead in lead-based paints.**<br>English/Dutch | This instruction is intended to curtail the use of and provide protection when there is a possibility of exposure to lead-based paint. |
| **410(N)** | **Care of Gas Detection Instruments.**<br>English/Dutch | This instruction provides guidelines for care of gas detection instruments. |

| GFI no | Subject | Scope |
|---|---|---|
| **Section 6**<br>**ENVIRONMENT PROTECTION** | | |
| **611(N)** | **Solid waste handling and disposal.**<br>English/Dutch | This instruction provides guidance for solid waste handling and disposal requirements for waste listed in the appendix of this field instruction. |
| **612** | **Handling and Disposal of spent dry cell batteries and used toner cartridges.**<br>English | This instruction provides guidance for the reduction and the disposal of spent dry cell batteries and toner cartridges in an effective and responsible manner. This is a way to manage waste, generated in oil exploration, production and refining related activities and processes, properly in order to minimize its potential to cause harm to health and the environment and to minimize the risk of potential liabilities. |

# Appendix F: Project Waste Management Plan

*Table of Contents*

## *1.0 Introduction*

In order to manage the waste generated during the PF project, this Waste Management Plan has been prepared. All employees, including Staatsolie and contractors, shall manage waste through implementation of the waste hierarchy, where avoidance and minimization of waste are the most preferred.

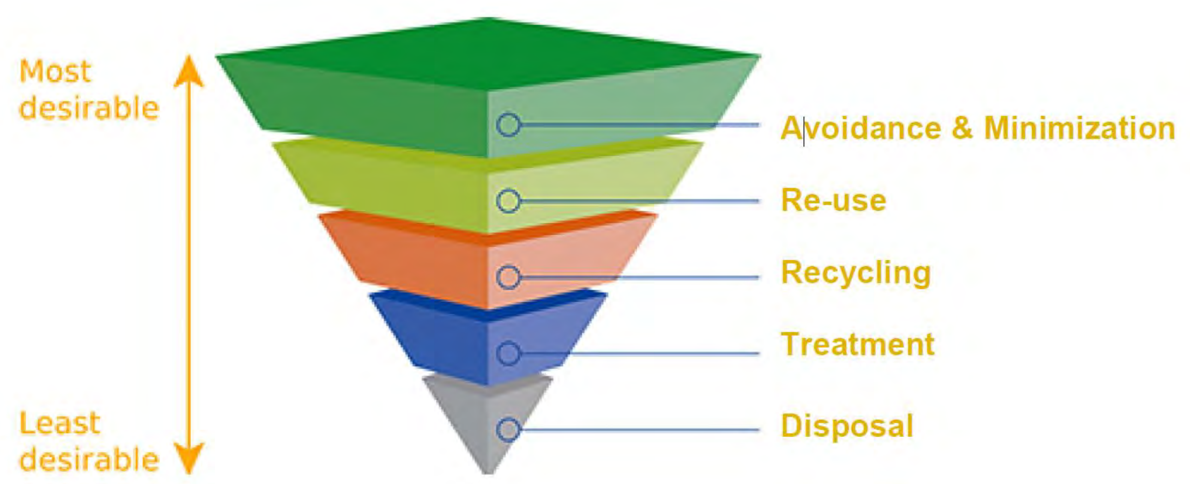


**Figure I-1: Waste Management Hierarchy**

## *2.0 Scope*

This waste management plan applies to the activities carried out for the PF project in the Tambaredjo Oilfield, during construction as well as the operational phase.

## *3.0 Terms and Definitions*

| | |
|---|---|
| Waste Generator | The department/employee carrying out the activity, which results in the material becoming surplus and being designated for discarding. |
| Hazardous waste | Any wastes, which because of its quantity, physical, chemical or infectious characteristics have the potential to cause harm to human health or the environment. |
| Waste Avoidance and minimization | Waste avoidance and minimization are at the top of the waste hierarchy. Avoidance is mostly preferred in the list of waste hierarchy where zero waste is generated.<br>Slight modifications in activities can improve efficiencies in utilizing to reduce waste generation e.g. reducing paper waste by printing double sided. |
| Reuse | The action or practice of using something again, whether for its original purpose (conventional reuse) or to fulfill a different function (creative reuse or repurposing). |
| Recycling | Involves processing used waste materials into new products. |
| Treatment | Waste treatment refers to the activities required to ensure that waste has the least practicable impact on the environment. |

| | |
|---|---|
| Disposal | Wastes that cannot be reused, recycled or treated will be segregated and stored in designated waste storage areas for incineration, disposal in a landfill or for collection by a waste transporter. |
| Landfill | Site for the disposal of waste materials by burial. |

## *4.0 Responsibilities*

| **Functionary** | **Responsibility** |
|---|---|
| Employees/Departments Staatsolie (Waste Generator) | • Ensure that practices are conducted to avoid unnecessary waste generation by prevention, minimization and reuse of waste.<br>• Separate reusable, recyclable and other waste by placing them in therefore labeled waste bins.<br>• Remove all waste from the construction and operation areas. |
| Project Manager, Operations Manager, EPC Contractor | • Implementation of mitigation measures as provided in chapter 3 of the EMMP. |
| HSEQ Upstream Manager | • Advice on the management of waste that are not covered by this plan.<br>• Manage and analyze waste data and provide advice on improvements of waste management within the company.<br>• Monitor and report on the implementation of this plan. |

## *5.0 Waste management*

### 5.1 Waste segregation

All waste must be placed in designated areas for removal and treatment / disposal. To effectively implement the waste management hierarchy, segregation of waste streams at the source is essential into the following waste streams:

- Recyclables
- Hazardous materials
- Rubble / construction waste
- General waste

Appropriate and clearly labeled waste bins / skips have to be provided at strategic locations. Store hazardous / polluting waste on impermeable ground until it is disposed of / collected.

Prevent littering by staff by providing awareness training and enforcing the Waste Management Plan.

### 5.2 Waste collection, transport, storage and handling

The waste will be stored temporarily on site and then collected and transported to the waste handling facilities of Staatsolie, including the Sarah Maria dumpsite and the land farm. At the time of publication of this report, an ESIA for the new landfill and incinerator has been completed and detailed design is in progress. PF project waste will be considered for disposal at those facilities once available.

### 5.3 Waste Management (disposal/treatment)

Waste types and management thereof are laid out below. The list of service providers needs to be updated as required

Do not allow any burning or burying of waste on site other than at designated and approved areas and in a supervised and safe manner.

| Category | Waste type | Phase | Management | Responsible |
|---|---|---|---|---|
| Domestic / office waste | Paper | Construction, Operations | Incineration / Recycling[3] | SOM |
| | Plastic bottles | Construction, Operations | Recycling | AMRECO |
| | Rubber gloves | Construction, Operations | Incineration | SOM |
| | Glass | Construction, Operations | Reuse / Landfill | SOM |
| | Food waste | Construction, Operations | Incineration[4] | SOM |
| Industrial waste | Water filters bags | Operations | Incineration | SOM |
| | Polymer filter bags | Operations | Incineration | SOM |
| | Flopaam bags | Operations | Reuse/Incineration | SOM |
| | Wooden pallets | Construction, Operations | Reuse/Incineration | SOM |
| | Metal | Construction | Recycling | COBO |
| | Drilling waste | Construction | Mudpit | SOM |
| | Cement | Construction | Reuse (infill) | SOM |
| | Package | Construction | Recycling/Incineration | SOM |
| | Coating cans | Construction | Recycling | COBO |
| | Batteries | Construction, Operations | Recycling | BAP |
| | Expired Chemicals | Operations | Incineration or Export | SOM |
| | Waste of the Jossie Treatment plant | Operations | Handled by Waste Treatment Department | SOM |
| | Contaminated soil | Operations, Decommissioning | Landfarm | SOM |
| | Oil waste | | Oil is currently stored in a holding basin and treatment pond at the landfarm of Staatsolie.<br>Staatsolie also plans to construct a treatment system (centrifuge + decanter) to treat the oil at the landfarm. | SOM |

[3] Paper separation will be implemented in the last quarter of 2019.

[4] Options to reuse food waste, e.g. as animal feed, are being investigated.

| Category | Waste type | Phase | Management | Responsible |
|---|---|---|---|---|
| | | | | |
| Other | Sewage waste (portable toilets) | Construction | Collected and disposed in septic tank | Uitzendbureau Sarah Maria |

### 5.4 Waste reduction

Identify measures to reduce waste on an ongoing basis, e.g.:

- Discourage the use of single use packaging
- Recycle packaging
- Deliver bulk material in re-usable containers rather than bags
- Use pre-mixed concrete rather than batching on-site where possible

## *6.0 Monitoring*

The implementation and effectiveness of the Waste Management Plan must be monitored, e.g. through the following methods:

- Identify and record an inventory of all waste streams for the PF project, e.g. by completing the Weekly Waste Report (Appendix C) and capturing the information in a central database.
- Obtain, file and review waste disposal slips for waste removed from contractors.
- Visually inspect the sites to identify any non-conformances in waste management.
- Audit waste service providers annually to ensure they appropriately manage the waste and are licensed, if required.
- Record waste management practices that are in contravention of the EMPr as environmental incidents.

# Appendix G: Handling of oil spills and leakage

## *1.0 Introduction and scope*

Oil / hydrocarbon spills can occur due to human error, equipment failures and circumventing maintenance procedures.

This plan is applicable for the PF Project and is based on the existing procedures and plans of Staatsolie with regards to oil spill preparedness and response.

## *2.0 Prevention of oil spills*

Prevention of spills has a lot to do with operational procedures. Following the maintenance procedures and operations protocols ensures a safe operation. The latter aids in the goal to prevent occurrence of oil spills within the implementation process of the company's HSEQ policy and core values.

## *3.0 Minimize impact on the environment*

In order to minimize the impact on the environment, in case of an oil spill, the following measures will be implemented:

- Daily monitoring by operators.
- Markings and signs will be placed to indicate the locations of the pipelines. Guards will be placed for the protection of the manifolds.
- Maintenance activities as required.

## *4.0 Response*

In case of an accidental spill or leak, the response will be as follows:

- Notification
  - Notify relevant parties (in accordance with the "Meldingsprocedure" – Figure J-1).
- Containment activities
  - Place sorbents for later removal.
- Reclaiming and clean-up activities
  - Recover contaminated soil.
  - Transport contaminated soil to the Landfarm facility of Staatsolie, for treatment.
- Monitoring
  - n/a.

## MELDINGSPROCEDURE

**Staatsolie Oil Spill Response Team**

**t.b.v.**

**Upstream**

**1. Indien U melding krijgt van een oil spill, handel dan als volgt:**
Vraag de melder naar:
- Locatie en omvang van de olievlek
- Naam, adres en telefoonnummer van de melder in geval van een buitenstaander
- Naam en afdeling in geval van een Staatsolie employee
- Overige bijzonderheden zoals: eventuele schade of persoonlijke ongelukken, de richting waar de olie naartoe gaat en of de spill toeneemt

**2. Indien het een spill betreft op Saramacca, bel of meld de Head Guard van Saramacca en geef de informatie door:**
Head Guard:
- Internelijn: 444#
- Buitenlijn: 375222 tst 444#

**3. De Head Guard meldt vervolgens de desbetreffende afdeling en vraagt voor verificatie van de informatie:**
- Gedurende werktijd, via het kantoor van de desbetreffende afdeling
- Na werktijd en in het weekend, de desbetreffende afdelings standby operator (zie lopende roosters)

**OPERATIONELE AFDELINGEN**

| Locatie | Telefoon Kantoor |
|---|---|
| CS | 68847, 63217, 63217 |
| JS | 67870, 67871, 67874, 67877 |
| SM & LP | 65840, 65846 |
| CT TA-58 | 65870, 65873, 65876 |
| FP TA-58/45 | 65840, 65844, 65843 |
| Calcutta/ Huwz | 68840, 68844, 68856, 68857 |
| TNW | 68848, 68849, 68872, 68873 |

**4. Na verificatie wordt in geval van:**
- Een kleine spill, deze door de <u>operationele afdeling</u> direct aangepakt
**<u>Actie: Afdelingsleiding of Shift Foreman</u>**
- Een grote spill in openbaar water of op de openbare weg, door een Strike Team lid , of de afdelingsleiding aan de Guard gevraagd om het SORT lid conform het wachtdienstrooster te melden. Bij geen response van dit lid, moet steeds het volgend SORT-lid op het wachtdienstrooster worden gebeld.
**<u>Actie: SORT leden</u>**

**SORT-LEDEN**

| Functionaris | Telefoon Kantoor | Thuis |
|---|---|---|
| P. Brunings | 66502 | 08515353 |
| H. Chin A Lien | 66480 | 08583122 |
| R. Parran | 68844 | 08923766 |
| S. Gopal | 65843 | 0374072 / 08683973 |
| A. Schuitemaker | 66850 | 431974 / 08660070 |
| S. Cheuk A Lam | 65873 | 400275 / 08749000 |
| D. Riedewald | 65840 | 08814953 |
| C. Monsels | 65220 | 08727224 |
| S. Oedit | 66553 | 08854311 |
| A. Entingh | 68847 | 328998 / 08591345 |
| S. Mangalsing | 66714 | 08710554 |

**5. Indien het een spill betreft op TLF of bij de pipeline TLF-Paranam wordt de Guard van TLF door de Head Guard van Saramacca hiervan op de hoogte gebracht.**
Head Guard TLF: - Telefoon: 480501 tst 62235
- Telefoon: 486294 tst 62235

**Figure J-1**

# SRK Report Distribution Record

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| Sue Reuther | SRK Consulting | PDF | 8 Aug 2019 | S Reuther |

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