Perseus Yaoure SARL

# ESIA Report
# Yaouré Gold Project, Côte d'Ivoire

## Water Management and Monitoring Plan

February 2018

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# 1. INTRODUCTION

Perseus Yaoure SARL (Perseus) is seeking to develop its brownfield Yaoure Gold Project in the Department of Bouaflé in Côte d'Ivoire.

Perseus has completed an Environmental and Social Impact Assessment (ESIA) process, in compliance with the Mining Code of Côte d'Ivoire, Environment Management and Protection Code and Application Decree, as well as the IFC Performance Standards on Environmental and Social Sustainability. This document has been updated to reflect changes resulting from the completion of the Definitive Feasibility Study (DFS).

The Project Water Management Plan (WMP) has been developed to detail the Project mine water management design, identify potential water impacts and mitigation factors, and provide an overview of monitoring requirements and responsibilities. The WMP is even at this stage a fluid document, and various design details are still evolving although the principles as described in this document remain valid. Hence, diagrams of various infrastructure contained in this document should not be taken as final versions in detail.

The broad objectives of the water management system are to:

- Maintain a low risk of uncontrolled discharge occurring over the project life;
- Operate the TSF as close as possible to a zero-discharge facility;
- Minimise the need to extract water from external water sources;
- Maximise reuse of collected water;
- Minimise disruption to mining operations by efficient mine water management;
- Ensure supply of a reliable and secure water supply for the processing plant; and
- Endeavour to comply with IFC and International Cyanide Management Institute (ICMI) guidance (the Cyanide Code), and discharge standards of Côte d'Ivoire.

Figure 1.1 and Figure 1.2 show the location of the Yaouré Project.

**Figure 1.1**
**Location of the Yaouré Project in Côte d'Ivoire**

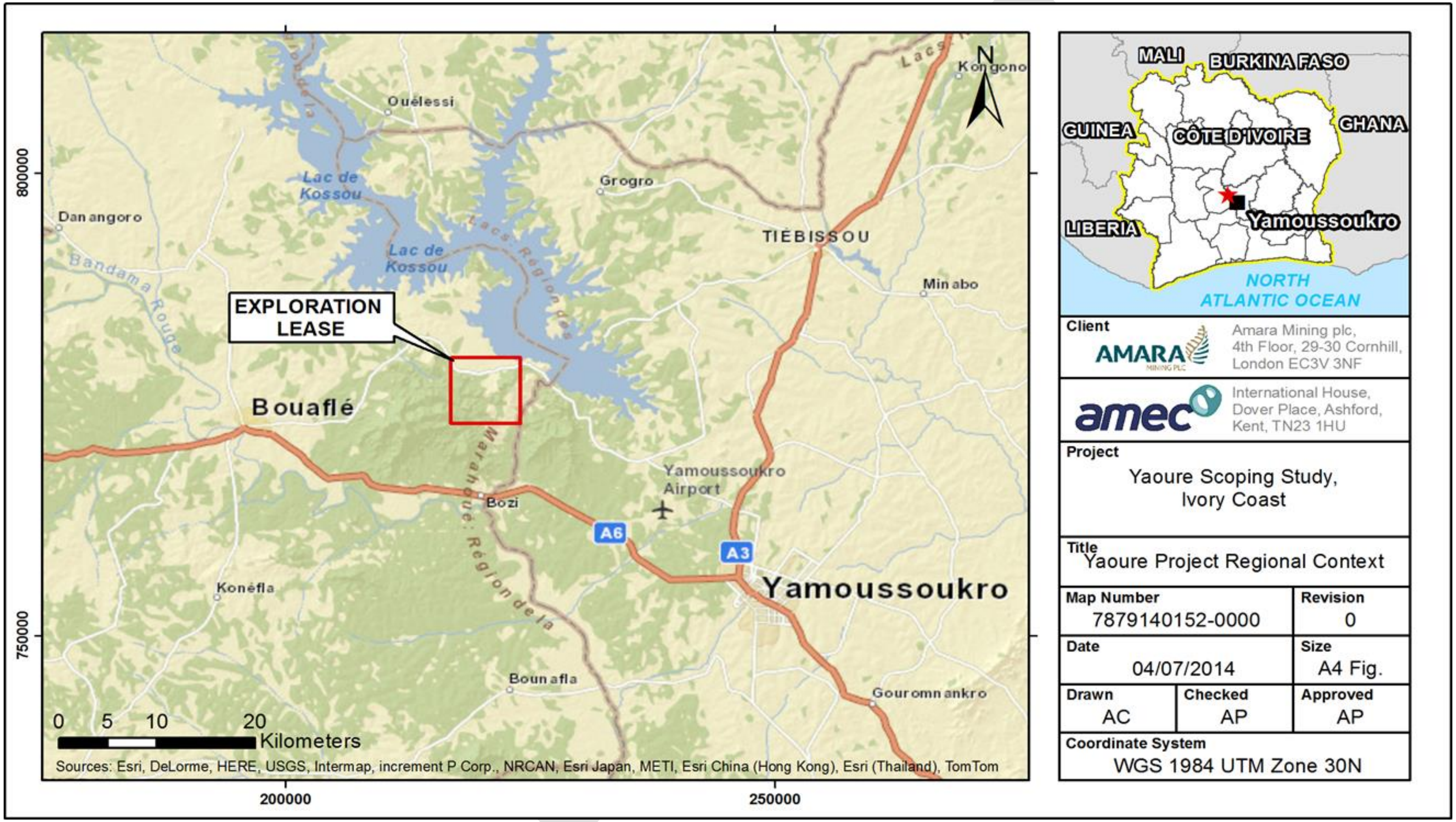
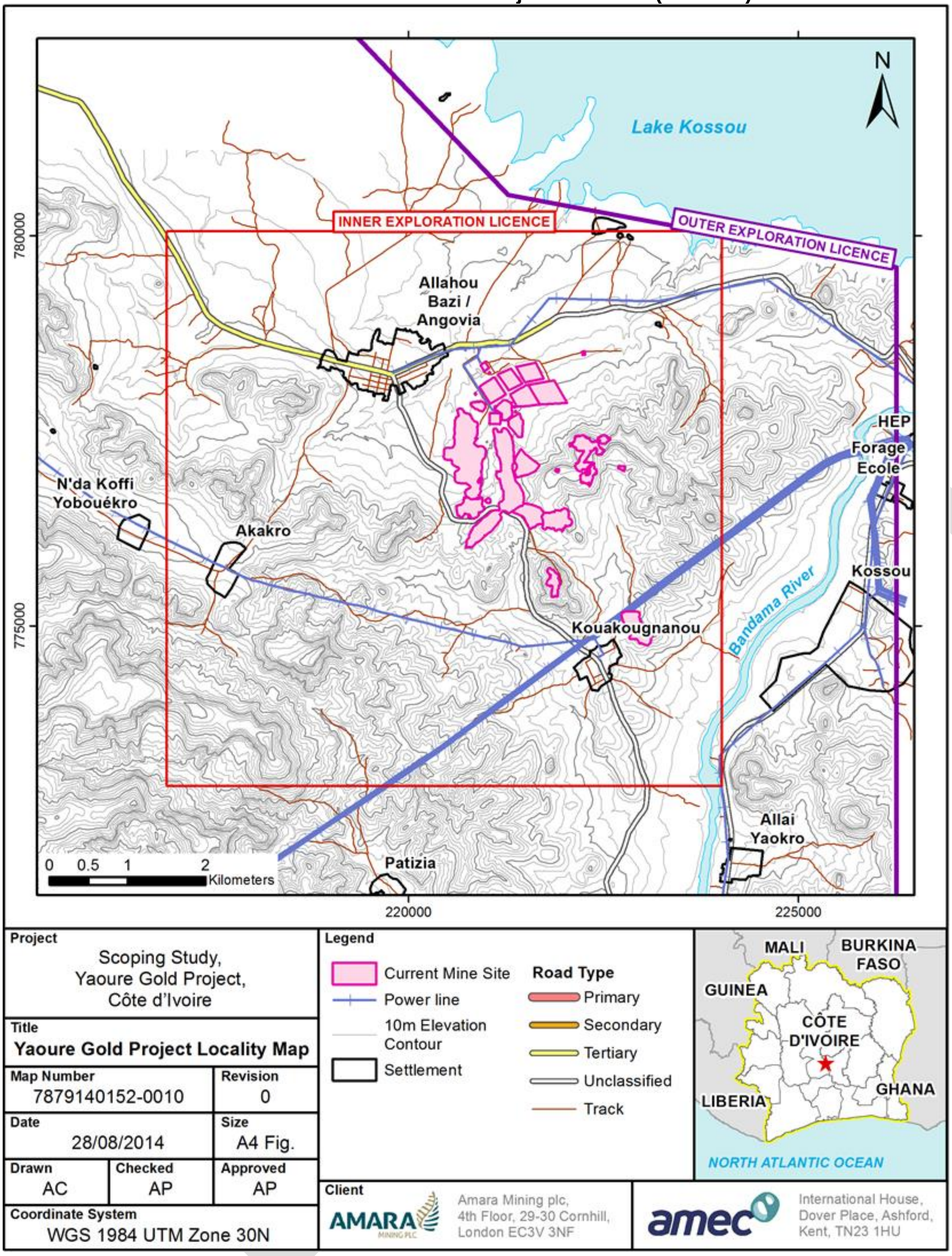


**Figure 1.2**
**Yaouré Project Location (Detailed)**



## 2. LEGISLATION AND REGULATORY BACKGROUND

Law No. 98-755 of 23 December 1998 on the Water Code defines mechanisms for sustainable management of water resources. It introduces the concept of river basin and watershed management, strengthens the institutional framework in the water sector and puts particular emphasis on planning and cooperation in the management of water resources.

Water management shall aim at ensuring the following key objectives:

- The preservation of aquatic ecosystems and wetlands;
- The protection against any form of pollution, the restoration of surface water, groundwater and sea water within the limits of water territories;
- The protection and management of water resources;
- The development and the resilience of hydraulic facilities and structures;
- The recognition of water as an economic resource, to enable its distribution to meet or reconcile the requirements of different water users;
- The supply of drinking water to the population;
- The health, public safety, and civil protection;
- The conservation and the free flow of water and flood protection;
- Supply of water to agriculture, fisheries and marine cultivation, fishing in freshwater, industry, energy production, transport, tourism, recreation and water sports as well as all other human activities legally pursued;
- The consistent planning of the use of water resources both at the level of the hydrological basin watershed and nationally;
- The improvement of the living conditions of the population, in equilibrium with environmental needs;
- The conditions for a rational and sustainable use of the water resources for present and future generations; and
- The establishment of an institutional framework characterized by the redefinition of the role of stakeholders.

The Law makes provision for:

- Potential permitting or levies for water use through abstraction and the installation of water works (Article 12); and
- Approval of water use for industrial purposes (Article 89).

Water discharge limits are set in CIAPOL Decree No. 01164 of 4 November 2008, see Table 2.1. For comparison, the guidance values of the IFC EHS Guidelines for the mining industry (2007) are also shown in Table 2.1.

The sustainable usage of water is provided for in Decree No. 2013-441 dated June 2013.

**Table 2.1**
**Applicable water discharge standards**

| Parameters | Concentration limit as per CIAPOL (2008) | Concentration limit as per IFC EHS Mining (2007) |
|---|---|---|
| pH | 5.5 - 8.5 (9.5 with chemical treatment) | 6-9 |
| Cadmium (Cd) | n.a. | 0.05 mg/l |
| Lead (Pb) | 0.5 mg/l if the discharge load exceeds 5 g/day | 0.2 mg/l |
| Copper (Cu) | 0.5 mg/l if the discharge load exceeds 5 g/day | 0.3 mg/l |
| Chrome (Cr) | 0.5 mg/l if the discharge load exceeds 5 g/day | n.a. |
| Hexavalent Chrome (Cr-VI) | 0.1 mg/l if the discharge load exceeds 1 g/day | 0.1 mg/l |
| Nickel (Ni) | 0.5 mg/l if the discharge load exceeds 5 g/day | 0.5 mg/l |
| Zinc (Zn) | 2 mg/l if the discharge load exceeds 20 g/day | 0.5 mg/l |
| Manganese (Mn) | 1 mg/l if the discharge load exceeds 10 g/day | n.a. |
| Tin (Sn) | 2 mg/l if the discharge load exceeds 20 g/day | n.a. |
| Iron, aluminium and compounds (Fe +Al) | 5 mg/l if the discharge load exceeds 20 g/day | 2 mg/l |
| Arsenic (As) | 0.05 mg/l if the discharge load exceeds 0.5 g/day | 0.1 mg/l |
| Zinc (Zn) | n.a. | 0.5 mg/l |
| Mercury (Hg) | n.a. | 0.002 mg/l |
| Fluorine compounds (F) | 15 mg/l if the discharge load exceeds 150 g/d | n.a. |
| TSS | 50 mg/l if the discharge load exceeds 15 kg/day, otherwise 150 mg/l | 50 |
| Cyanide (CN) | 0.1 mg/l if the discharge load exceeds 1 g/day | 0.1 mg/l CN_free<br>0.5 mg/l CN_WAD<br>1 mg/l CN_total |
| Total Hydrocarbons | 10 mg/l if the discharge load exceeds 100 g/day | n.a. |
| Phenols | n.a. | 0.5 mg/l |
| COD | 300 mg/l if the discharge load exceeds 150 kg/d, otherwise 500 mg/l | 150 mg/l |
| BOD_5 | 100 mg/l if the discharge load exceeds 50 kg/d, otherwise 150 mg/l | 50 mg/l |
| Oil and Grease | 30 mg/l if the discharge load exceeds 5 kg/d, otherwise 10 mg/l | 10 mg/l |
| Nitrogen compounds | 50 mg/l if the discharge load exceeds 100 kg/day | |
| Temperature | < 40 degrees C | < 3 deg C differential |

# 3. MINE WATER MANAGEMENT

## 3.1 OVERVIEW

The Project mine water management approach and design for surface water and groundwater is discussed in the following sections for the Project facilities including open pit, waste rock dump (WRD), tailings storage facility (TSF), and camp. The integration of the overall mine water management system is described. The details of this are continuing to evolve although the principles remain valid.

## 3.2 OPEN PIT WATER MANAGEMENT

Studies conducted as part of the Feasibility Study and Environmental and Social Impact Assessment indicate that mine water management will be required to provide a safe and effective mining operation including:

- Open pit dewatering/depressurisation;
- Surface water controls including run-off mitigation and minimisation of impacts on local drainage systems; and
- Removal of excess water, such as for dust mitigation measures.

### 3.2.1 Groundwater

The Project hydrogeological baseline and groundwater modelling study are detailed in separate component documents attached to the ESIA (Hydrogeological Baseline, Preliminary Groundwater Model).

On the basis of the information available following the completion of the DFS, the preliminary groundwater model indicated long term annual total mine pit inflows of 1,423,000$m^3$ (Year 4) and up to 2,440,000$m^3$ (Year 6).

It is possible that abstraction wells in a tightly fissured bedrock aquifer such as that present may be unable to produce the raw water abstraction rates required for the Process Plant (a total of 337.3$m^3$/hour across the entire site) which includes a total average of 7.3t/hour of bore water to meet the site potable water requirements. Also, total dewatering of the cut faces during excavation may not be possible. Such a hypothesis should be considered as part of the mine plan. If dewatering rates are unable to achieve required drawdown in the time available, alternative strategies could be employed such as installation of lateral horizontal boreholes in the cut faces in order to relieve pressure on the face and aid dewatering and slope stability.

### 3.2.2 Surface water

The two largest undisturbed surface water catchments requiring diversion around mine site infrastructure are approximately 60 hectares (Ha) each. The first catchment (CW02a) drains between the waste dump and the Yaouré North Pit and receives rainfall runoff discharge from the second largest disturbed catchment area on the waste dump (DW06 – 63Ha) via a sedimentation basin. The second catchment (CW02) drains to the north east of the CMA Pit and alongside the existing heap leach pads. Due to the steep slope of the upper reaches of both catchments, the time of runoff concentration for the catchments is quite short at only approximately 20 minutes. The peak flow rates estimated for the 100 year return period 20 minute duration event is approximately 26m3/s for CW02a, which includes the DW06 catchment runoff, and 13m3/s for CW02.

The lower reaches of the catchments near infrastructure and the pit developments have a much shallower slope. In addition to conveying runoff from a larger upstream catchment than the steeper upstream diversion channels, the shallower slope necessitates larger channel cross sectional areas. Trapezoidal channel designs have been developed for CW02a and CW02 and comprise a 1.2 m depth x 3.0m base width channel and a 1.2m depth x 2.0m base width channel, respectively, with 1(V):2(H) side slopes. The channels combine downstream of the CMA pit development, prior to discharge to the environment, and a channel 1.7m depth x 6.0m base width with 1(V):2(H) side slopes will be required to convey flow downstream of the proposed adjacent haul road and subsequent discharge to the environment.

The remaining undisturbed surface water catchments range in size from less than 1 Ha to 57 Ha, with typically shorter times of concentration due to the smaller catchments. The designed channels are vee-shaped for smaller flow rates and trapezoidal for larger flow rates, all with 1(V):2(H) side slopes and depths of 1.2m or less.

All diversion channel designs were based on the Rational Method for estimating peak flow rate, and the following:

- 100 year return period critical duration storm event.
- Manning's n value of 0.029 (gravel lined).
- Channel side slopes of 1(V):2(H).
- Minimum channel slope along the selected diversion alignment.

In the steeper sections of the channel alignments, velocity control measures will be required which can include drop structures, in-channel check dams and meandering channels to reduce the slopes of the channel. Catchpits can also be considered along the channels, which will reduce and delay peak flow rates in the channel in addition to aiding sediment settlement prior to discharge to downstream water courses.

### 3.2.3 Pit Water

Rainfall into the pit and onto the pit slopes will report to a sump (mine sump) at the bottom of the pit. Some small temporary sumps may be constructed in various locations around the pit to locally control water in work areas. These small sumps will discharge to the main pit sump.

Pumps will be used to remove water from the pit to a sediment trap from which water will flow to Kossou Lake or via tributaries to the Bandama River. A number of booster pump stations may be required to pump water from the pit at the required rate and to lower the working pressures along the discharge pipeline.

The main pit sump pump will be connected to a discharge pipeline.

In the event of an extreme storm, if the lower portion of the pit becomes inundated temporarily while pumping operations are carried out to discharge the excess, pit operations may temporarily not be possible in affected areas of the pit.

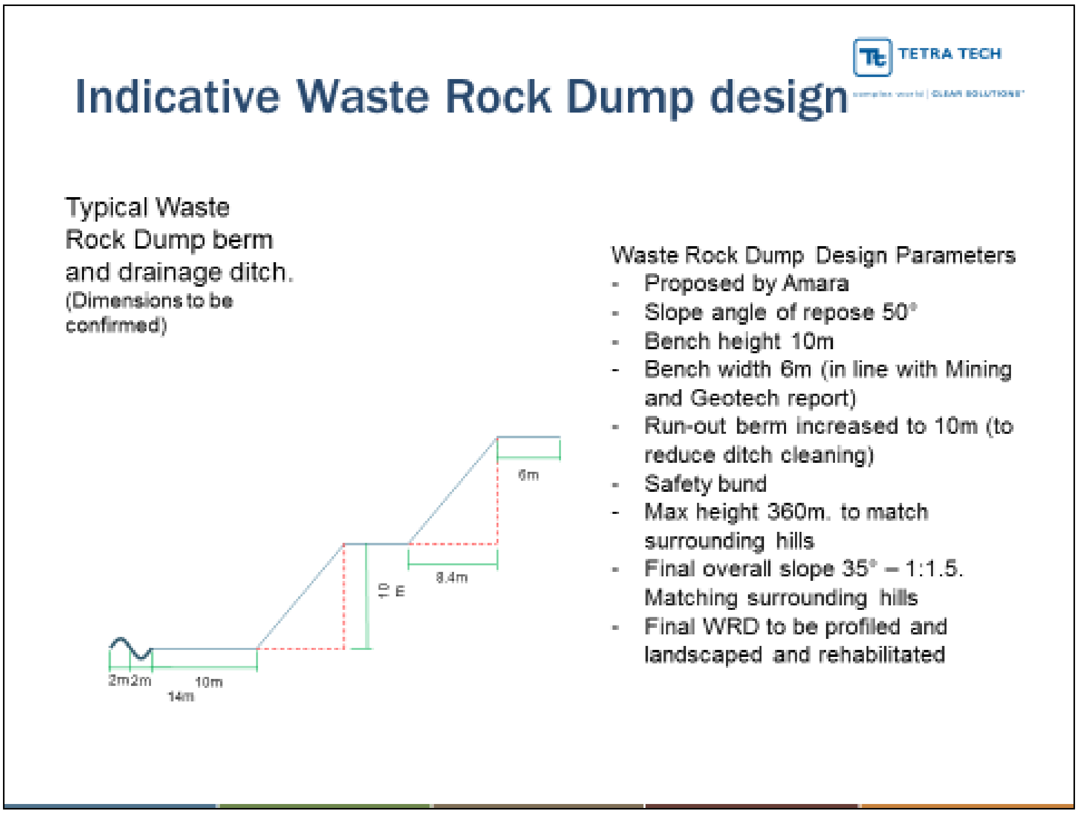
## 3.3 WASTE ROCK DUMP AND STOCKPILE WATER MANAGEMENT

The Waste Rock Dumps (WRDs) and stockpiles will have a detailed design, including options for associated drainage, runoff collection system, water quality management and disposal or transfer of water. Measures for routing runoff external to the WRD to the downstream environment includes perimeter ditches and sediment traps, and provisional design for a WRD is shown in Figure 3.1.

Ditches are to be constructed along portions of the toe of the WRD embankment to intercept water that would otherwise have flowed into the WRD area and to reduce the potential for erosion of the toe of the embankment. This water may include runoff from the WRD embankment and from natural areas.

Downstream of the toe ditch areas, sediment traps will be constructed to reduce total effluent sediment loading. Periodically, the traps should be dredged to maintain settlement capacity.

**Figure 3.1**
**Indicative Waste Rock Dump Design**




## 3.4 PROCESS PLANT WATER MANAGEMENT

All process areas of the plant will have containment bunds to catch any spillage from the process and direct rainfall. Water within the bunds will be returned to the process stream. Surface water runoff within the plant area will be directed to an attenuation dam that has been appropriately sized to allow for a 24 hour 1:100 year rainfall event. Weir arrangements will be included in the drains prior to the attenuation dam to settle out the majority of fine sand and silt, and will be cleared as part of regular maintenance. Excess water in the attenuation dam will be discharged to environment. All surface water from outside the plant area will be diverted.

## 3.5 TAILINGS MANAGEMENT FACILITY WATER MANAGEMENT

**Error! Reference source not found.**1 (by Knight Piésold) summarises the presumed sequence of construction of the TSF following completion of the DFS.

**Table 3.1 Staged Embankment Construction**

| Stage | Tailings Storage (Cumulative) (Mt) | TSF Embankment Elevation*1 (m RL) | Maximum TSF Embankment Height (m) |
|---|---|---|---|
| 1*2 | 6.05 | 280.8 | 28.8 |
| 2 | 9.35 | 285.0 | 33.1 |
| 3 | 12.65 | 288.7 | 36.7 |
| 4 | 15.95 | 291.9 | 40.0 |
| 5 | 19.25 | 294.9 | 43.9 |
| 6 | 22.55 | 297.6 | 45.6 |
| 7 | 25.85 | 300.2 | 48.2 |
| 8 | 30.00 | 303.4 | 51.4 |

*1 Includes a minimum freeboard and stormwater capacity for the greater of: (i) 1 in 1,000 year recurrence interval, 72 hour storm event occurring on an average conditions pond, or (ii) 1 in 100 year wet rainfall sequence pond.

*2 Stage 1 embankment designed for 22 month storage capacity.



Observations from the average conditions modelling are summarised below:

- The supernatant pond volume remains at the minimum operating volume throughout operation until 2024, after which point is greater than the minimum operating volume for 1-2 months during the wet season each year (with the peak wet season volume increasing each year).
- Subsequent to 2024 (prior to which the supernatant pond remains at the minimum operating volume). The peak volume increases from 20,000 $m^3$ in 2024 to 59,000 $m^3$ in 2028.
- The facility ceases operating in September 2033, with 59,000 $m^3$ within the supernatant pond, and the water balance remains positive after decommissioning (increasing pond volume). The supernatant pond volume in the final 12 months of operation ranges from 10,000 $m^3$ to 59,000 $m^3$.
- TSF recycle rates for each year of operation are provided in Table 3.5. The maximum and minimum rates show the range of monthly values throughout each year. The recycle rates are expressed as a percentage of water in slurry reporting to the TSF.

**Table 3.2: Average conditions – TSF recycle rates**

| Year | Total Recycle Volume (m³/year) | Average Monthly Recycle Rate (%) | Maximum Monthly Recycle Rate (%) | Minimum Monthly Recycle Rate (%) |
|---|---|---|---|---|
| 2019* | 682,000 | 19% | 39% | 5% |
| 2020 | 3,320,000 | 62% | 48% | 6% |
| 2021 | 3,549,000 | 66% | 81% | 51% |
| 2022 | 3,602,000 | 67% | 84% | 50% |
| 2023 | 3,666,000 | 68% | 86% | 50% |
| 2024 | 3,718,000 | 69% | 86% | 50% |
| 2025 | 3,754,000 | 70% | 86% | 50% |
| 2026 | 3,790,000 | 70% | 87% | 49% |
| 2027 | 3,825,000 | 71% | 87% | 49% |
| 2028* | 1,937,000 | 72% | 86% | 49% |

* 2019 operation comprises May-December only; 2028 operation comprises January-June only.

Process water shortfall is expected to occur under average climatic conditions with no make-up water from river abstraction. Hence abstraction from alternative sources (eg. Bores and/or Bandama River) is required to make up the shortfall under average climatic conditions.

A principal objective is to enable operation of the TSF as a zero discharge facility as far as possible. Hence, the TSF is a key focus of the water balance model. In wet conditions, excess water can build up on the TSF and so recycle to the process plant needs to be the maximum and other water sources may not be required (refer Table 3.2). In dry conditions there may be a deficit in the TSF; if there is insufficient water in the TSF to fulfil all the process needs, then it will need to be augmented with arisings from dewatering.

In practice, TSF and site wide water management will be handled on a much shorter time-frame so most of the significant surpluses and deficits will be smoothed out. The current water balance model will be refined to allow this (and to determine dewatering arisings contributions to process water as required) once operations has commenced.

## 3.6 WATER SUPPLY

Current water balance modelling indicates that under average climatic conditions, external make-up water will be necessary. Consequently, the design includes for a contingency abstraction from the Bandama River to enable water to be taken if necessary

Process and camp water potable water supplies will come from dewatering arisings via appropriate water treatment plant(s). Effluent will be treated in a waste water treatment plant prior to discharge to the environment in accordance with Ivorian regulations.

Operational mine surface water management, operating essentially as an internal circuit, is not expected to impact on surrounding natural surface water systems.

## 3.7 SITE WIDE WATER BALANCE

A water balance has been produced based on available rainfall and evaporation data, preliminary process data and infrastructure configurations, and most significantly by TSF design criteria, all completed as part of the DFS.

The water balance model is a dynamic model inasmuch as it has been and will continue to be updated as new data become available. Future development will also include the integration of more automated 'switches' in order to determine, for example, how much water from the TSF supernatant pond to return to the process plant. This in turn will inform the ongoing Mine Water Management Plan through the operation of the mine.

The model covers average, wet and dry rainfall conditions. These sequences are derived from the long term Bouaflé rainfall record as included in Attachment 1 to the ESIA Climate Baseline.

TSF water recycling will occur wherever possible to minimise the use of pit groundwater inflows and borehole dewatering arisings. Subject to actual dewatering volumes, it may be that these arisings will be in excess of requirements and so will need to be discharged to the environment. Water quality is expected to be benign, enabling this to take place without treatment other than settling of suspended solids with respect to water pumped from the open pit.

There are principal water inputs and outputs to elements of the mine infrastructure and relationships with the surrounding water environment. These elements comprise:

- Open pit;
- Waste dumps;
- Process plant;
- TSF;
- Other hardstanding areas;
- Raw water and potable water tank;
- Water and wastewater treatment plants.

The water balance model include all the assumptions employed regarding areas, fundamental mining and processing criteria and run-off coefficients (the last informed by the hydrological evaluation by the project TSF designers Knight Piésold). Plant site shortfalls for average conditions (prior to river abstraction) are provided in Table 3.3, as well as required river abstraction rates, including and excluding the provision of surplus pit dewatering into the WSP. Peak shortfalls occur in 2019, primarily due to the predominantly oxide tailings blend in the initial months of operation, resulting in poor recovery of supernatant from the TSF.

**Table 3.3: Average conditions – Plant Site shortfall and river abstraction**

| Year | Including Pit Dewatering | | Excluding Pit Dewatering | |
|---|---|---|---|---|
| | Process Water Shortfall Volume ($m^3$/year) | Required River Abstraction Rate (L/s) | Process Water Shortfall Volume ($m^3$/year) | Required River Abstraction Rate (L/s) |
| 2019* | 1,005,000 | 64 | 2,669,000 | 113 |
| 2020 | **730,000** | **76** | **1,789,000** | **123** |
| 2021 | 433,000 | 29 | 1,560,000 | 63 |
| 2022 | 178,000 | 24 | 1,507,000 | 62 |
| 2023 | 82,000 | 5 | 1,443,000 | 60 |
| 2024 | 134,000 | 6 | 1,392,000 | 57 |
| 2025 | 290,000 | 9 | 1,355,000 | 55 |
| 2026 | 305,000 | 11 | 1,319,000 | 54 |
| 2027 | 283,000 | 13 | 1,284,000 | 53 |
| 2028* | 206,000 | 13 | 608,000 | 51 |

* 2019 operation comprises May-December only; 2028 operation comprises January-June only.

# 4. IMPACTS FOR MANAGEMENT

## 4.1 SURFACE WATER

### 4.1.1 Construction Phase

During the construction phase, areas of the site will be stripped of vegetation and soil, which will leave soils exposed. This may lead to an increase in the amount and velocity of surface runoff, which will change the volume and pattern of surface runoff and reduce infiltration. This may impact surface water bodies by increasing the runoff volume and peak flow rate, whilst decreasing the lag time between the start of rainfall and peak flow. Further, the increased soil erosion can result in a decrease in surface water quality due to an increase in sediment load (turbidity). The increased sediment load can change the sediment transport capacity of perennial streams, causing sedimentation and erosion along the river course and river banks.

Surface water can be contaminated due to accidental release of fuel or oil during construction works (including leaks of oil and fuel from construction vehicles and machinery), and also due to inappropriate waste disposal practices.

Another source of contamination may be washing and servicing of heavy construction equipment and unmanaged discharge of resulting waste water into the environment.

Excavations can trigger slope instability and cause landslides that may result in large volumes of sediment released into surface water bodies.

### 4.1.2 Operation phase

The mining project will result in some alteration to the drainage landscape. Headwaters of some sub-catchments will be removed, which will change the downstream flow regime although in many cases they are ephemeral and only flow during the wet season (not yet monitored for a full cycle).

Surface water collected at the mine site may be contaminated and may impact downstream users or ecosystems if released to the environment. Potential sources of contaminated water include water collected in the open pit, contact water in the process plant area, runoff collected in the TSF in excess of the holding capacity, and runoff from the WRD and stockpiles. Contaminants of potential concern that could be released from the WRD include arsenic, and suspended solids. Contaminants of potential concern from the TSF are arsenic, WAD cyanide and suspended solids. The release of collected waters to the environment may also impact the drainage channel erosion and sedimentation.

Surface water contamination may also result from erosion and uncontrolled runoff from the WRD and stockpiles.

The mine infrastructure (WRD, TSF, process plant, road embankments, pipelines etc) may block or alter surface flows and runoff.

Surface water contamination may also result from inadequate handling and storage or accidental spills of process reagents/chemicals and non-hazardous and hazardous materials from the Project site (mainly process plant and camp).

Road surfaces may generate increased sediment load in the runoff to water courses. Apart from the sediment load, elevated amounts of pollutants including hydrocarbons, rubber, and metal can contaminate the water courses of the receiving environment.

Contamination may result from accidental spills in case of leaky pipelines or pipeline ruptures.

### 4.1.3 Closure and post-closure phase

During the closure and post-closure phase, potential impacts may result from the following, if no mitigation measures are taken:

- Release of tailings material and contamination of downstream surface water from failure of the TSF;
- Contamination due to waste rock erosion; and
- Contamination due to failure of mine water management structures to meet acceptable discharge water quality targets.

## 4.2 GROUNDWATER

### 4.2.1 Construction phase

Water supply for construction will primarily be sourced from mine pit sumps and bores until construction of the TSF and any water storage facilities are completed. These abstractions from the open pit will provide the additional benefit of some, albeit limited, advanced dewatering for the open pit. Additional water supply bores will be used if required.

Dewatering will be necessary to make the working environment safe and dry for soil stripping and for excavations.

The clearing of vegetation and soil from the plant, camp, WRD, open pit footprint and TSF footprint (vegetation only) will potentially locally change the magnitude (increase or decrease) of groundwater recharge.

If not properly managed, groundwater contamination could occur through accidental spillage to the soil zone of hazardous or toxic materials either through use (i.e., movement, maintenance, refuelling of site vehicles and plant) or from storage (i.e., oils, fuels, solvents, lixiviants and curing compounds).

The greatest number of personnel will be on site during the construction phase and will put pressure on water supply and water disposal (sewage) at the construction camp and employee facilities. Water supply will be from groundwater sources, following treatment to drinking water standards. Potential (unmitigated) contamination of groundwater could occur through discharge of untreated sewage.

### 4.2.2 Operation phase

As the open pit develops laterally and vertically dewatering boreholes will result in significant drawdown that will decline radially from the open pit (although distortion will occur along preferential flow features such as fracture zones). Preliminary groundwater flow model predictions indicate that long term groundwater pumping may be required, although based upon the available hydrogeological data and the uncertainty of the fracture distribution and the geometry of the regolith/bedrock interface away from the mine it is far from certain whether this rate will be necessary or even achievable.

The drawdown in the bedrock could impact on the closest village wells. If realised this would be a major impact and of high significance. The reduction in groundwater levels could result in reduced groundwater baseflow to watercourses within the extent of drawdown with associated potential impacts to groundwater users.

The low permeability ground conditions may not be conducive to management of groundwater inflow by advanced dewatering bores external to the open pit. Opportunistic groundwater abstraction from bores targeting fracture zones will be undertaken. Groundwater and rainwater inflows to the open pit will be removed by pumping from in-pit sumps. Water will either be returned for use in the processing plant or discharged to environment. Potential exists for contamination of groundwater from seepage of contaminated discharge water. It is anticipated that dewatering water quality will be good apart from potential high suspended solid content.

Water may seep from the bottom of the TSF and could impact groundwater levels and quality. There will be an underdrainage system installed that will collect seepage and transport it to a collection sump, as well as a cut-off trench and a downstream seepage collection system.
Groundwater contamination could also occur through accidental spillage to the soil zone of hazardous or toxic materials either through use (i.e., movement, maintenance, refuelling of site vehicles and plant), from storage (i.e., oils, fuels, solvents, lixiviants, curing compounds), or from sewerage at the camp area.

Furthermore, leakage from water transfer and tailings pipelines, if not mitigated by design, could impact groundwater quality where contaminants are present.

An increase in population will put increased pressure on water supplies although groundwater is generally the minority supply source. There will additionally be potential impact to groundwater from contamination due to increased untreated sewage.

#### 4.2.3 Closure and post-closure phase

The open pit will remain open following the end of mining. Once open pit dewatering ceases then groundwater levels will start to recover and a lake will form. The open pit will become a point of recharge with lateral discharge to groundwater.
Seepage from the TSF facilities will continue during mine closure with potential to impact groundwater quantity and quality.

Groundwater contamination could also occur through accidental spillage to the soil zone of hazardous or toxic materials during decommissioning of facilities (ie process plant, storage tanks etc) and structures (i.e., transfer pipeline, sewerage systems etc).

### 4.3 GROUNDWATER MODELLING

In order to carry out the assessment and provide some quantitative basis for evaluation, a groundwater model has been developed as part of the DFS. This is described in Appendix 38 of the ESIA.

A 3D numerical groundwater flow model was developed for the Yaouré project area and used to predict pit groundwater inflow rates and the potential impact of mine dewatering on local village water supplies over the proposed mine life (2018 to 2026). Total pit groundwater inflows were predicted up to a maximum of 55L/s. Installation of an ex-pit dewatering bore targeting the CMA structure resulted in similar combined (bore and pit) dewatering rates as those without an ex-pit dewatering bore. Drawdown in both the weathered and fresh rock at Angovia was predicted to be up to approximately 2.5m over the life of mine. The water level drawdown predicted in the other adjacent towns (Akakro and Kouakou) was predicted to be less than one metre. No significant impact was predicted as a result of pit dewatering on either Lake Kossou or the Bandama River.

Annual pit dewatering volumes (capturing both surface water and groundwater inflows) were estimated for individual pits at key stages of the mine development. A pit dewatering strategy and system design was produced based on the final pit plans, with pump specifications provided based on the removal of the 100 year return period 24 hour rainfall event (plus groundwater inflows during this period) within both 3-5 days and 7 days of occurrence of the event.

The key potential project risks associated with water management include mine dewatering impact on nearby village water supply wells; local groundwater/surface water contamination as a result of either seepage or overflow from the TSF; inadequate site water management leading to discharge of contaminated water to the natural environment and/or flooding of the mine site and pits; inundation of the pits during and/or after large storm events or associated with interception of highly transmissivity zones; and pit wall instability due to elevated pore water pressures in the pit walls.

# 5. MITIGATION AND MANAGEMENT MEASURES

## 5.1 SURFACE WATER

### 5.1.1 Construction phase

During the construction phase, the following mitigation measures will be implemented:

- Vegetation and top soil will only be stripped prior to the commencement of construction works;
- To prevent contamination of water as a result of washing and/or servicing of heavy construction equipment, workshops with bunded bays and fuelling stations with sufficient bunding and retention structures will be constructed. Impervious surfaces and hydrocarbon traps will be placed in the workshop areas and a fuel station drainage system will be in place for water treatment prior to release;
- All equipment using hydraulic fluid, oil, fuel or any other substance that has the potential to contaminate surface water if released into the environment will be subject to a preventative maintenance programme;
- Where possible, undisturbed water will be kept separate from sediment laden or otherwise potentially contaminated water;
- Runoff with a large sediment load will be expected from any areas of recently exposed soil or rock. This runoff will be captured and directed via berms or ditches towards specially constructed sediment control structures. Sediment control structures may comprise a series of settlement ponds with additional incorporated filtration measures where required. The number, location and dimensions of settlement ponds, plus requirements for flow attenuation measures will depend on the volume of water requiring treatment, silt load characteristics, topography and access constraints;
- Roads will be inclined either side of centre or all to one side, ensuring runoff drains and minimising water accumulation on the road surface;
- There will be a longitudinal road drainage system for the management of surface water runoff. Road drains will be constructed with appropriate gradient to ensure that sediment does not settle and block the drain;
- Grassed longitudinal road drains with check dams will be constructed when required. Check dams are necessary to reduce erosion and lower the speed of water during storm events;
- Adequate drainage management is required in borrow areas and quarries. Consideration will be given to minimising erosion and runoff from any aggregate or the overburden stock piles. A silt fence will be installed on the down-gradient side of the stockpile and an up gradient side ditch to divert water runoff from eroding the base of the stockpile and collecting further sediment. Silt loaded runoff will be captured and directed via berms or ditches towards specially constructed sediment control structures. Sediment control structures may comprise a series of settlement ponds where required; and
- Emergency procedures will be in place, specifying the steps to be taken in an event of accidental spill of fuel or oil (see Emergency Response Plan).

### 5.1.2 Operation phase

During the operation phase, the following mitigation measures will be implemented:

- Solids settled in the sedimentation pond and drainage channels will be removed during the dry season to maintain sedimentation capacity;
- Erosion protection/control measures and storm water management infrastructure such as perimeter drainage channels and bund walls will be monitored and maintained regularly;
- Undisturbed runoff water will be discharged into an area of vegetation for dispersion or infiltration. Silt traps, gravel, sand bags, and silt fencing may be required at the discharge point in order to prevent erosion and remobilisation of deposited silt. Discharge points will be located a sufficient distance from any watercourses to allow adequate infiltration or settlement of suspended solids prior to entering the watercourse;
- Check dams will be installed at regular intervals within any contact or non-contact water diversions as required. Check dams reduce the velocity of water and therefore allow settlement of coarser sediment particles as well as silt at low flow conditions. Reduction in flow velocity will also prevent scouring of the drainage channel itself;
- Silt traps will be installed where required and where practical for maintenance purposes along drainage channels;
- Hydrocarbon traps will be regularly monitored. Residues from the hydrocarbon traps will be stored and managed according to Perseus's waste management procedure;
- All equipment using hydraulic fluid, oil, fuel or any other substance that has the potential to contaminate surface water if released into the environment will be subject to a preventative maintenance programme;
- Procedures laid down in the Emergency Response Plan will be followed in the event of a spill;
- Mine water will be pumped from the open pit to settlement ponds where water will be utilised for dust suppression or transferred to the raw water pond for reuse in the plant where supply shortfalls are anticipated. Excess produced water will be discharged to the environment in accordance with IFC effluent water and Ivorian Water Quality standards;
- WRD surfaces will be contoured and profiled, to be stable and resistant to long term erosion. Dump development will be regularly monitored to check that construction is as per design;
- The runoff from the WRD will be collected in a drainage system and discharged to environment after passing through sediment traps and where IFC effluent and Ivorian Water Quality standards are met;
- All waste will be stored in accordance with Perseus's waste management procedures;
- Perimeter storm drains will divert clean surface water runoff around the process plant and ROM pad. Plant operations will be bunded and collected water pumped back to the plant. Contact water will be settled in attenuation dams and discharged into the environment after its quality meet IFC effluent water and Ivorian Water Quality standards;
- The quality and volume of any discharge from the tailings management facility will be regularly monitored;

- The return water pipeline will be tested for leaks and weaknesses prior to being placed into operation. Leak detection inspections will be conducted along the entire pipeline on a regular basis; and
- Roads will be maintained regularly. Maintenance will include routine emptying of accumulated sediments from the culverts, check dams, and silt traps.

It should be noted that the efficiency of structural mitigation measures is based on their design capacity. When the design capacity is reached or exceeded, their efficiency reduces. Sedimentation of water courses can be minimised but not avoided as flow may exceed the design capacity of drains. Likewise, culverts and spillways may cause flooding if their design capacity is exceeded. The likelihood of an exceedance depends on the design criteria and is currently 1:100 per year.

### 5.1.3 Closure and post-closure phase

During the closure phase, the following mitigation measures will be implemented:

- Water in the TSF pond will be drained prior to closure to reduce the potential for overtopping and erosion of the embankments. If the supernatant water does not meet discharge standards, it will be treated prior to discharge into the environment;
- The WRD and TSF will be covered with stockpiled soil and vegetated to provide stability against erosion;
- Profiling and contouring will be used to minimise ponding on the tailings management facility surface;
- Diversions and spillway(s) will be in place to minimise potential erosion of the cover from surface water;
- Discharge waters will continue to be treated during the closure period where IFC standards are not met. Active systems will be transitioned to passive systems following appropriate trial periods.

## 5.2 GROUNDWATER

### 5.2.1 Construction phase

Groundwater levels and water quality will be monitored during the construction phase according to the water management plan. Temporary diversion of run-off can be used to supplement watercourse flow where considered necessary.

Standard operating procedures for handling of hydrocarbons and chemicals are to be followed. Any spills will be contained and remediated as soon as possible, and records kept. All fuels and lubricants will be kept in bunded areas/containers. Chemicals will be stored in appropriate containers above ground with suitable secondary containment (sufficient to contain the contents combined with a 24 hour storm event). The holding facilities will be inspected annually by a qualified person and repairs undertaken where required by appropriately qualified personnel.

All sewage in the construction camp and mine camp will be collected and treated to IFC standards prior to discharge into the natural environment.

### 5.2.2 Operation phase

During mine operations the most significant impact to groundwater will be due to a reduction in groundwater levels associated with dewatering of the open pit. Monitoring of open pit inflows and groundwater levels will be conducted to ascertain the extent and rate of drawdown propagation to enable the update of the conceptual hydrogeological understanding and groundwater flow modelling to refine predictions. Compensation to watercourses may be achieved through potential discharge of dewatering water at appropriate locations and diversion of runoff water. Sediment traps will be used to ensure settlement of entrained particulates prior to discharge. Water quality measurements will be made at the point of discharge.

Direct impact of groundwater level reduction on village boreholes would be mitigated by compensation water from the dewatering borehole arisings, or possibly from drilling deeper bores further from the pit. The latter could provide a legacy positive impact for the project for local communities.

Groundwater quality monitoring will be conducted around and downstream of the WRD, TSF and stockpiles. Collected seepage will be discharged to the environment following appropriate treatment.

Groundwater monitoring points downstream of the TSF will be regularly measured for level and quality to ascertain systematic change from baseline conditions and assess potential impacts to receptors.

Any excess water discharged from the TSF will be treated as necessary to ensure compliance with IFC water quality standards.

To minimise infiltration of contaminated water to groundwater, contact surface water will be collected, contained and, if required, treated before discharge or reuse (i.e., for dust suppression). Oil interceptors will be used and maintained on hardstanding areas. Discharge water quality and downstream groundwater levels and quality will be monitored.

All fuels and lubricants will be kept in bunded areas/containers in accordance with best practice. Chemicals will be stored in appropriate containers above ground with suitable secondary containment (sufficient for a 24 hour storm event). The holding facilities will be inspected annually by a qualified person and repairs undertaken where required by appropriately qualified personnel. All process areas at the plant site have bunds to contain any spillage. Spillages and collected rainfall within the bunded areas are pumped to the process plant for reuse.

Leak detection equipment will be used for the TSF return water pipeline and the plant site equipped with an appropriate leak response system.
Increased pressure on water supplies in communities associated with an influx of people will be assessed and monitored through groundwater level and quality monitoring. A review of the community water supply situation will be conducted during the operation phase.

### 5.2.3 Closure phase

Monitoring of groundwater level and quality will continue during the closure period to identify any impacts and develop a management strategy where required.

Seepage from the TSF will gradually decrease as the tailings consolidate and hydraulic conductivity of materials reduces. Rainfall and run-off recharge to the TSF will be minimised by covering the facility with material. Groundwater quality and level will continue to be measured around and downstream of the TSF during the closure period.

Discharge waters will continue to be treated during the closure period where IFC standards are not met. Active systems will be transitioned to passive systems follow appropriate trial periods.

Appropriate standard operating procedures (SOPs) and best practice will be followed during removal and disposal of hazardous or toxic materials storage facilities and decommissioning of structures/facilities. Any spills will be contained and remediated as soon as possible and records kept.

# 6. MONITORING PROGRAMME

Monitoring of groundwater and surface water will be conducted during construction, operations, and closure. The detailed monitoring programme and implementation plan will be developed during detailed project design.

Monitoring scope and frequency will be tailored to the requirements and objectives for each location and project phase, so that monitoring remains focussed and relevant. Scope and frequency of the monitoring programme will be regularly reviewed to maintain this. For example, the following are likely priorities:

- Construction – suspended solids and possible leakages from vehicles, plant and stores; frequent observations (daily) and sampling (monthly or more frequently in rainy periods).
- Operation – suspended solids, arsenic, WAD cyanide in relation to the TSF and delivery/return pipelines, drinking/health parameters in relation to dewatering boreholes that might provide input to potable water treatment plant, relevant Ivorian discharge parameters for any treated environmental release. Sampling mainly monthly, more frequent surface water flow/quality monitoring following significant rainfall events.
- Closure – suspended solids, leakages from vehicles and plant, WAD cyanide in residual TSF supernatant pond until drained, arsenic in groundwater seepage until confirmed benign/insignificant.

Baseline monitoring sites (Figure 6.1) will be supplemented by additional monitoring sites targeting facilities as required. Short-term targeted monitoring sites will be used during the construction phase specifically for recording quality and quantity of discharge water. A summary of the main targets and objectives for groundwater and surface water monitoring are:

- Environmental monitoring of groundwater level and quality:
  - Upstream (background) and downstream of the project area;
  - Around the open pit, across the project area and outside the anticipated extent of drawdown; and
  - At, and downstream of, potentially contaminating facilities including:
    - WRD and stockpiles – around facility and downgradient of prevailing groundwater flow direction;
    - TSF –embankment piezometers and downgradient monitoring bores to be installed;
    - Fuel and hazardous material storage areas – monitoring around and downgradient of each facility; and

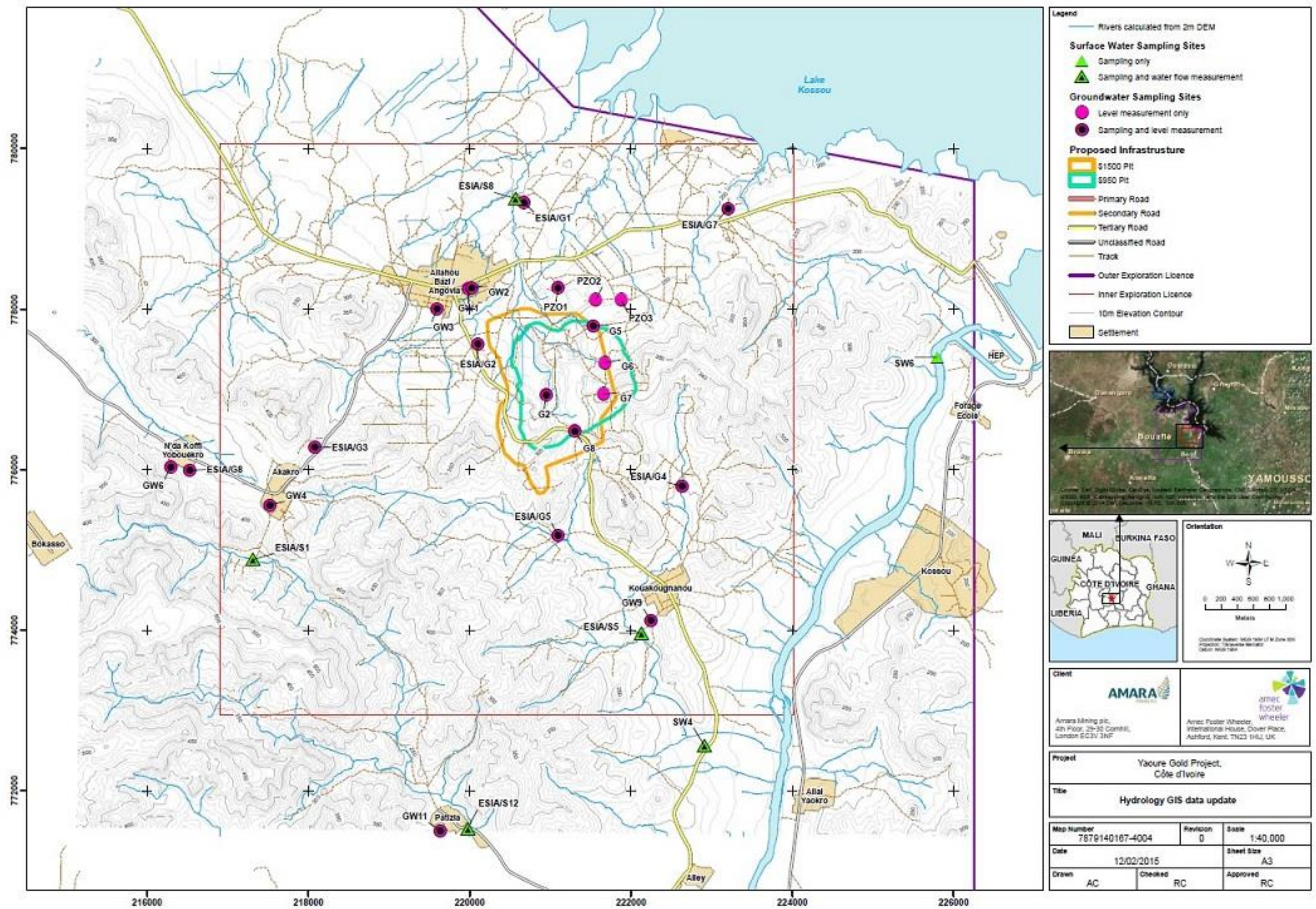
- Sewage treatment plant – monitoring downgradient of the facility.

- Environmental monitoring of surface water flow, stage and quality:
  - Daily and monthly flow and river stage monitoring at the main project site sub-catchments and upstream and downstream of the project site;
  - Surface water quality monitoring upstream and downstream of the project area; and
  - Surface water quality monitoring downstream of the TSF, WRD, stockpiles, open pit, camp and any points of contact water discharge.
- Monitoring of quantity and quality of water discharged to the environment (treated camp waste water, produced dewatering water, TSF excess water, attenuation pond discharges etc);
- Monitoring of abstraction rates, water levels, and water quality at all groundwater wells (advanced dewatering wells and camp water supply wells);
- Monitoring of abstraction rates from the open pit sump;
- Recording of inflows, outflows, and water transfer to the process plant;
- Recording of groundwater seepages and inflows to the open pit (visual inspection, record location, measure flows, take photographs);
- Monitoring of groundwater level and water quality for community wells in the potentially impacted area; and
- Meteorology monitoring (precipitation, humidity, wind speed, temperature, evaporation) at the mine area and potentially separate precipitation monitoring in selected catchments.

The monitoring frequency will depend on the type and purpose of the measurement and will be defined for each monitoring station during detailed planning. More frequent (continuous/hourly / daily) measurements will be made where the rate of change is anticipated to be quick (ie, pumping from the open pit sump), where impacts from change are expected to be significant and rapid, or for monitoring seasonal trends (ie, groundwater and river flow response to rainfall). Automated data recording systems will be used for high frequency data collection. A lower frequency (weekly/monthly/quarterly) of measurements will be adopted where short-term variation is anticipated to be small. Event based monitoring may occur at some localities (ie, where overflow from attenuation/storage ponds occurs). The frequency of measurements will be reviewed as part of the annual monitoring report.

Groundwater quality will be assessed using measurement of field parameters (pH, Electrical Conductivity, temperature, and oxidation reduction potential), biological testing, and laboratory analysis for selected analytes. Analysis suites will be determined during development of the detailed monitoring programme and will be derived to characterise water chemistry and identify occurrence of any facility specific parameters. Collected data will be validated and stored in a data management system. Monthly monitoring reports will be produced and compiled, and form a part of the annual monitoring review.

**Figure 6.1**
**Topography and Drainage of the Project Locality and Current Monitoring Locations**



## 7. RESPONSIBILITIES FOR IMPLEMENTATION

While the Chief Executive Officer (CEO) of Perseus will take ultimate responsibility for company environmental and social performance, a suitably experienced person, with appropriate authority will be appointed to take the day to day responsibility for the implementation of the WMP, supported by Environmental and Community Liaison staff as necessary.

Any contractors, especially during the construction phase (and during operation if a contract mining approach is adopted by Perseus), will be managed by Perseus so that they adopt the same water management standards and management/mitigation measures as described in this management plan and the ESIA.

## 8. REVIEW AND UPDATE

The Water Management Plan should be regularly updated taking into account the following aspects as applicable:

- Operational experience and results of trialling;
- Ongoing stakeholder consultation;
- Changes in mine construction, operations and closure plans;
- New regulatory requirements and changed legislative framework; and
- Ongoing environmental monitoring.

A review should be conducted annually to ascertain whether the WMP requires update. The person appointed to take the day to day responsibility for the implementation of the WMP will be responsible for identifying the need and completing any updates.

## 9. REFERENCES

- Climate Baseline
- Emergency Response Plan
- Hydrogeological Baseline
- Preliminary Groundwater Model
- Surface Water Baseline.