

ANNEXES - CHAPTER 2

Annexe 2-10 Surface Water and Groundwater Impact Assessment - SENES

CBG EXTENSION PROJECT

ENVIRONMENTAL IMPACT ASSESSMENT

**SURFACE WATER AND GROUNDWATER IMPACT
ASSESSMENT**

Prepared for:

Compagnie des Bauxites de Guinée (CBG)

Direction Générale

B.P. 523

Conakry, République de Guinée

Prepared by:



121 Granton Drive, Suite 12
Richmond Hill, Ontario, Canada
L4B 3N4

September 2014

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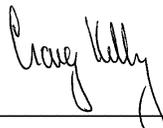


121 Granton Drive, Suite 12
Richmond Hill, Ontario, Canada
L4B 3N4

Prepared by:



Helen Manolopoulos, Ph.D.
Senior Geochemist



Craig Kelly, P.Geo.
Senior Geoscientist

Reviewed by:



Stacey Fernandes, M.A.Sc., P.Eng.
Senior Environmental Engineer

September 2014

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ACRONYMS AND ABBREVIATIONS

CBG	Compagnie des Bauxites de Guinée
CCC	Criterion Continuous Concentration
CCME	Canadian Ministers of the Environment
CF	Conversion Factor
CFU	Colony Forming Unit
COPC	Constituent of Potential Concern
DOC	Dissolved Organic Carbon
EHS	Environmental, Health and Safety
EQS	Environmental Quality Standard
ESIA	Environmental and Social Impact Assessment
EU	European Union
ICP-MS	Inductively Coupled Plasma - Mass Spectrometry
IFC	International Finance Committee
ISQG	Interim Sediment Quality Guideline
mbgs	Meters Below Ground Surface
MTPA	Million Tonnes Per Annum
PAH	Polycyclic Aromatic Hydrocarbon
PEL	Probable Effect Level
RDL	Reportable Detection Limit
SMC	Standard Methods Committee
TDS	Total Dissolved Solids
TKN	Total Kjeldahl Nitrogen
TOC	Total Organic Carbon
TSS	Total Suspended Solids
U.S. EPA	United States Environmental Protection Agency
VEC	Valued Ecosystem Component
WBG	World Bank Group
WHO	World Health Organization

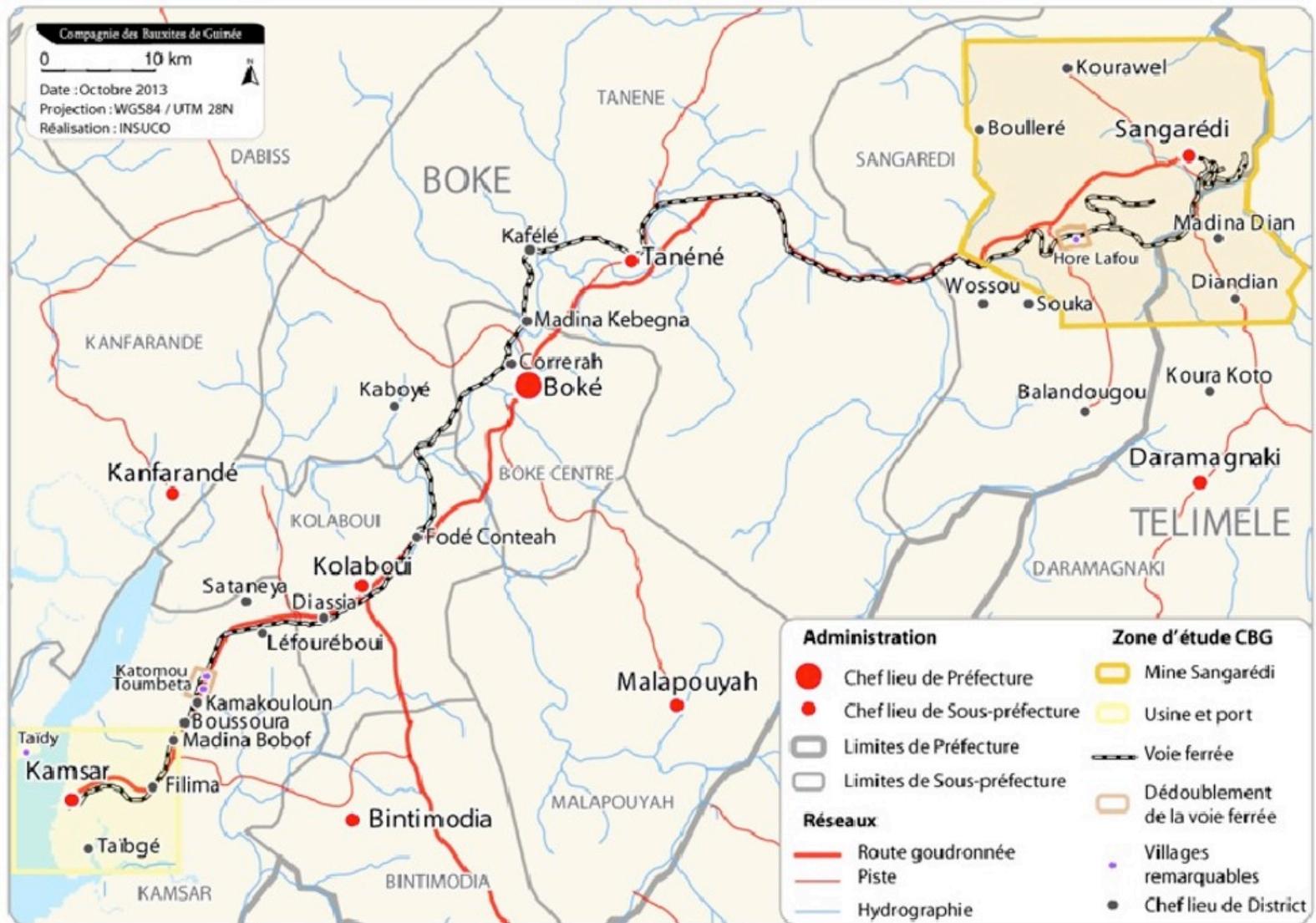
1.0 INTRODUCTION

CBG (Compagnie des Bauxites de Guinée) has exclusive rights to mine bauxite in Guinea's Halco Lease, in the region of Sangarédi, and has been mining the region since 1973. Mining activities are currently permitted on the Sangarédi, N'Dangara, Bidikoum, Silidara and Boundou Wandé plateaus. A railway, covering a distance of 130 km, connects the mining area with the Kamsar Port on the west coast of Guinea, where CBG operates a processing plant (see Figure 1.1). At the Kamsar Processing Facility the bauxite is crushed and dried and then shipped to refineries around the world.

The current operation produces 13.5 million tonnes of bauxite per annum (MTPA). Through the extension of mining activities in the area south of the Cogon River, bauxite production and export activities are expected to increase over the period 2014-2022. CBG is planning on initially increasing the bauxite production rate to 18.5 MTPA; this will be followed by an increase in plant capacity to 22.5 MTPA by year 2022, and a further increase of 5 MTPA to a plant capacity of 27.5 MTPA by year 2022.

SENES Consultants (SENES) was retained to assess the effects of the CBG Production Extension Project (the Project) on surface water and groundwater in the Kamsar Port and Sangarédi Mining areas. The assessment considered current conditions in the two affected areas under existing operations (13.5 MTPA), as well as three additional production scenarios (18.5 MTPA, 22.5 MTPA and 27.5 MTPA) to assess the implication of an increase in the rate of operation.

Figure 1.1: Regional Map Showing Kamsar Port and Sangarédi Mining Areas



2.0 REGULATORY FRAMEWORK

2.1 WATER MANAGEMENT

The World Bank Group/International Finance Corporation's (WBG/IFC) Environmental, Health and Safety (EHS) Guidelines for Mining (2007) provide industry-specific guidance for mining projects with respect to environmental, occupational health and safety, community health and safety and mine closure and reclamation considerations. The Guidelines apply to open-pit, underground, alluvial and solution mining techniques as well as marine dredging for economic recovery (this is not applicable to port operation dredging, which is addressed in the EHS Guidelines for Port and Harbor Facilities). They define target performance levels for water use and quality, wastes, hazardous materials, land use and biodiversity, air quality, noise and vibrations, energy use and visual impacts. The Guidelines include performance levels that can generally be achieved in new facilities using reasonable-cost, currently available control technologies. Where the Guidelines are applied to existing facilities, it is stated that it may be necessary to establish site-specific targets and an implementation schedule for achieving them.

Recommended practices for water management include:

- Establishing a site-wide water balance with due consideration for mine dewatering;
- Developing a sustainable water management plan;
- Limiting the amount of water used;
- Considering water reuse, recycling and treatment programs where feasible; and,
- Consultation with stakeholders to address competing water supply demands.

2.2 SURFACE WATER

The methodology applied for the impact evaluation of surface water and sediment quality involved comparison of surface water and sediment quality data to available benchmarks that are intended to be protective of aquatic biota (freshwater and marine). Consistent with IFC guidance, where Guinea does not have specific guidance, guidelines/criteria published by other international regulatory agencies were adopted. In this regard, water and sediment quality benchmarks published by the U.S. Environmental Protection Agency (U.S. EPA), the Canadian Council of Ministers of the Environment (CCME), and/or the European Union were used as the primary sources of numerical benchmarks.

2.2.1 Water Quality

A summary of available water quality benchmarks from the jurisdictions included in the review is provided in Table 2.4 for constituents that were analyzed in surface water samples. The benchmarks include U.S. EPA chronic criteria (Criterion Continuous Concentration - CCC) and CCME long-term guidelines for the protection of freshwater and marine aquatic life, and European Union Environmental Quality Standards (EQS).

With respect to the U.S. EPA criteria, values included in Table 2.4 for several metals (e.g., arsenic, cadmium, copper, lead, nickel and zinc) are expressed in terms of the dissolved metal fraction. In Appendix A of the Aquatic Life Criteria Table, the U.S. EPA provides conversion factors to express these values in terms of the total metal fraction; conversion factors applied to the CCC in freshwater and marine water are reproduced below in Table 2.1. In Tables 6.5 and 6.9 where summaries of respective surface water quality in the Kamsar Port and Sangarédi Mining areas are provided, these conversion factors were applied to determine the analogous CCC for the total metal fraction for use in the water quality assessment.

Table 2.1: U.S. EPA Conversion Factors for Dissolved Metals

Constituent	Conversion Factor (CF)	
	Freshwater CCC	Marine Water CCC
Arsenic	1.000	1.000
Cadmium	$1.101672 - [\ln(\text{hardness}) * (0.041838)]$	0.994
Copper	0.960	0.830
Lead	$1.46203 - [\ln(\text{hardness}) * (0.145712)]$	0.951
Nickel	0.997	0.990
Selenium	Not available	0.998
Zinc	0.986	0.946

Source: U.S. EPA (2014), Aquatic Life Criteria Table, Appendix A.

As noted in Table 2.4, the freshwater benchmark values for several metals (e.g., cadmium, copper, lead, nickel and zinc) are expressed as a function of hardness (as mg/L of CaCO₃) in the water column. In Tables 6.5 and 6.9, the CCME guideline values for copper, lead, and nickel were adjusted for water hardness as shown in Table 2.2.

Table 2.2: Variation of CCME Hardness-Dependent Freshwater Water Quality Guidelines with Water Hardness

	Water Hardness (mg/L CaCO ₃)	Guideline (µg/L)
Copper	0 to < 82	2
	≥ 82 to ≤ 180	$0.2 * e^{(0.8545[\ln(\text{hardness}))-1.465]}$
	>180	4
Lead	0 to ≤ 60	1
	> 60 to ≤ 180	$e^{(1.273[\ln(\text{hardness}))-4.705]}$
	>180	7
Nickel	0 to ≤ 60	25
	> 60 to ≤ 180	$e^{(0.76[\ln(\text{hardness}))-1.06]}$
	>180	150

Source: CCME (2014), Water Quality Guidelines for the Protection of Aquatic Life, Summary Table.

With respect to the U.S. EPA criteria, the default values included in Table 2.4 for hardness-dependent criteria are calculated for a water hardness of 100 mg/L. In Appendix B of the Aquatic Life Criteria Table, the U.S. EPA provides equations and metal specific parameters to adjust hardness-dependent freshwater dissolved metal criteria for water hardness; the equation and parameters used to adjust the CCCs for cadmium, copper, lead, nickel and zinc in Table 6.9 are reproduced below in Table 2.3.

Table 2.3: Parameters for Calculating Freshwater Dissolved Metals Criteria that are Hardness-Dependent

$CCC \text{ (dissolved)} = \exp \{m_c[\ln(\text{hardness})]+b_c\} * CF$ CCC – Criterion Continuous Concentration			
Constituent	m _c	b _c	Conversion Factor (CF)
Cadmium	0.7409	-4.719	$1.101672-[\ln(\text{hardness})*(0.041838)]$
Copper	0.8545	-1.702	0.960
Lead	1.273	-4.705	$1.46203-[\ln(\text{hardness})*(0.145712)]$
Nickel	0.8460	0.0584	0.997
Zinc	0.8473	0.884	0.986

Source: U.S. EPA (2014), Aquatic Life Criteria Table, Appendix B.

Table 2.4: Available Water Quality Benchmarks

Chemical	WHO - Drinking Water ¹ (mg/L)	EU - Drinking Water ⁴ (mg/L)	EU - Environmental Quality Standards (EQS) ⁵ (mg/L)	U.S. EPA - Water Quality, Aquatic Life ⁶		CCME - Water Quality, Aquatic Life ⁸	
				Chronic (CCC)		Long-term	
				Freshwater (mg/L)	Marine (mg/L)	Freshwater (mg/L)	Marine (mg/L)
Metals							
Aluminum	-	0.2	-	0.087 (I,S) ⁷	-	0.005 pH<6.5 0.1 pH≥6.5	-
Antimony	0.02	0.005	-	-	-	-	-
Arsenic	0.01 (A,T)	0.01	-	0.15 (A,D)	0.036 (A,D)	0.005	0.0125
Barium	0.7	-	-	-	-	-	-
Boron	2.4	1	-	Narrative Statement	Narrative Statement	-	-
Cadmium	0.003	0.005	CaCO ₃ dependent	0.00025 (D,E)	0.0088 (D)	0.00009	0.00012
Chromium (total)	0.05 (P)	0.05	-	-	-	-	-
Chromium (III)	-	-	-	0.074 (D,E)	-	0.001	0.0015
Chromium (VI)	-	-	-	0.011 (D)	0.05 (D)	0.0089	0.056
Copper	2 ²	2	-	Calculated using BLM	0.0031 (D,cc)	CaCO ₃ dependent	-
Iron	-	0.2	-	1 (C)	-	0.3	-
Lead	0.01 (A,T)	0.01	0.0072	0.0025 (D,E)	0.0081 (D)	CaCO ₃ dependent	-
Manganese	-	0.5	-	-	-	-	-
Molybdenum	-	-	-	-	-	0.073	-
Nickel	0.07	0.02	0.02	0.052 (D,E)	0.0082 (D)	CaCO ₃ dependent	-
Selenium	0.04 (P)	0.01	-	-	-	0.001	-
Silver	-	-	-	-	-	0.0001	-
Strontium	-	200	-	-	-	-	-
Uranium	0.03 (P) ³	-	-	-	-	0.015	-
Zinc	-	-	-	0.12 (D,E)	0.081 (D)	0.03	-
Zirconium	-	-	-	-	-	-	-
General Chemistry							
Alkalinity	-	0.2	-	20	-	-	-
Ammonia, total	-	-	-	pH, T & lifestage dependent	pH & T dependent	pH & T dependent	
Ammonia, unionized	-	-	-	-	-	0.019	-
Ammonium	-	0.5	-	-	-	-	-
Chloride	-	250	-	230	-	120	-
Hardness	-	-	-	narrative statement		-	-
pH	-	-	-	6.5-9 (C)	6.5-8.5 (C,P)	6.5-9	7-8.7 & narrative
Sulphate	-	250	-	-	-	-	-

Notes:

¹ World Health Organization (WHO). 2011. Guidelines for Drinking-water Quality, Fourth Edition.

A - provisional guideline value because calculated guideline value is below the achievable quantification level.

P - provisional guideline value because of uncertainties in the health database.

T - provisional guideline value because calculated guideline value is below the level that can be achieved through practical treatment methods, source protection, etc.

² staining of laundry and sanitary ware may occur below guideline values.

³ only chemical aspects of uranium addressed.

⁴ The Council of the European Union (EU). 1998. Council Directive 98/83/EC of 3 November 1998 on the Quality of Water Intended for Human Consumption.

⁵ EU Environmental Quality Standards (EQS). Annual Average values. Directive 2008/105/EC of the European Parliament and of the Council of 16 December 2008

⁶ United States Environmental Protection Agency (U.S. EPA). 2014. Aquatic Life Criteria Table.

CCC - Criterion Continuous Concentration.

A - This recommended water quality criterion was derived from data for arsenic (III), but is applied here to total arsenic, which might imply that arsenic (III) and arsenic (V) are equally toxic to aquatic life and that their toxicities are additive. No data are known to be available concerning whether the toxicities of the forms of arsenic to aquatic organisms are additive. Please consult the criteria document for details.

C - The derivation of this value is presented in the Red Book (EPA 440/9-76-023, July, 1976). The CCC of 20mg/L is a minimum value except where alkalinity is naturally lower, in which case the criterion cannot be lower than 25% of the natural level.

D - Freshwater and saltwater criteria for metals are expressed in terms of the dissolved metal in the water column. See "Office of Water Policy and Technical Guidance on Interpretation and Implementation of Aquatic Life Metals Criteria (PDF)," (49 pp, 3MB) October 1, 1993, by Martha G. Prothro, Acting Assistant Administrator for Water, available on NSCEP's web site and 40CFR§131.36(b)(1). Conversion Factors applied in the table can be found in Appendix A to the Preamble - Conversion Factors for Dissolved Metals.

E - The freshwater criterion for this metal is expressed as a function of hardness (mg/L) in the water column. The value given here corresponds to a hardness of 100 mg/L. Criteria values for other hardness may be calculated per the equation presented in the criteria document.

I - this value for aluminum is expressed in terms of total recoverable metal in the water column.

S - there are three major reasons why the use of Water-Effect Ratios might be appropriate:

1. The value of 87 µg/l is based on a toxicity test with the striped bass in water with pH = 6.5–6.6 and hardness <10 mg/L. Data in "Aluminum Water-Effect Ratio for the 3M Plant Effluent Discharge, Middleway, West Virginia" (May 1994) indicate that aluminum is substantially less toxic at higher pH and hardness, but the effects of pH and hardness are not well quantified at this time.
2. In tests with the brook trout at low pH and hardness, effects increased with increasing concentrations of total aluminum even though the concentration of dissolved aluminum was constant, indicating that total recoverable is a more appropriate measurement than dissolved, at least when particulate aluminum is primarily aluminum hydroxide particles. In surface waters, however, the total recoverable procedure might measure aluminum associated with clay particles, which might be less toxic than aluminum associated with aluminum hydroxide.
3. EPA is aware of field data indicating that many high quality waters in the U.S. contain more than 87 g aluminum/L, when either total recoverable or dissolved is measured.

cc - When the concentration of dissolved organic carbon is elevated, copper is substantially less toxic and use of Water-Effect Ratios might be appropriate.

⁷ for pH 6.5 - 9.0.

⁸ Canadian Council of Ministers of the Environment (CCME). 2014. Canadian Environmental Quality Guidelines. Water Quality Guidelines for the Protection of Aquatic Life. Summary Table.

2.2.2 Sediment Quality

A summary of available sediment quality benchmarks from the jurisdictions included in the review is provided in Table 2.5. As seen from Table 2.5, only the CCME provides sediment quality guidelines and those are only available for a few of the constituents that were measured in sediment. CCME benchmarks include Interim Sediment Quality Guidelines (ISQG) and Probable Effect Levels (PELs). The ISQG defines the constituent level below which effects are expected to occur rarely while the PEL defines the constituent level above which effects are expected to occur frequently.

Table 2.5: Available Sediment Quality Benchmarks

Chemical	CCME - Sediment Quality, Aquatic Life ¹			
	Freshwater (mg/kg dw)		Marine (mg/kg dw)	
	ISQG ²	PEL ³	ISQG ²	PEL ³
Arsenic	5.9	17	7.24	41.6
Cadmium	0.6	3.5	0.7	4.2
Chromium (total)	37.3	90	52.3	160
Copper	35.7	197	18.7	108
Lead	35	91.3	30.2	112
Zinc	123	315	124	271

Notes:

¹ Canadian Council of Ministers of the Environment (CCME). 2014. Canadian Environmental Quality Guidelines. Sediment Quality Guidelines for the Protection of Aquatic Life. Summary Table.

² ISQG - Interim Sediment Quality Guideline.

³ PEL - Probable Effect Level.

2.3 GROUNDWATER

Within the WBG/IFC EHS Guidelines for Mining, there are general recommendations for groundwater protection, which include the following:

- Limiting the infiltration of adverse quality waters through the use of liners and underdrainage systems;
- Providing secondary containment for pipelines, storage facilities that contain adverse-quality solutions;
- Providing leak detection systems where appropriate; and,
- Installing monitoring wells sufficient to determine groundwater levels and quality around process solution containment systems.

The Guidelines do not contain specific chemical standards or criteria for chemical parameters. Previous Environmental and Social Impact Assessments (ESIA) for similar projects in the Guinea bauxite mining industry have employed the World Health Organizations (WHO) health-based guidelines, where applicable, for certain parameters (Knight-Piesold 2008; AECOM

2011). Benchmarks are also available through other institutions that can be referenced to evaluate groundwater quality in the two Project areas.

Available WHO Guidelines for Drinking-water Quality and guidelines provided by the Council of the European Union Directive on the Quality of Water for Human Consumption, and are summarized in Table 2.4.

3.0 PHYSICAL ENVIRONMENT

3.1 GEOLOGY

The geology of Guinea is divided into two major components:

- Superficial alluvial formations, consisting of geologically recent Tertiary-era (Miocene) and Quaternary (Pleistocene) deposits, which contain the ore deposits of bauxite, clay and lateritic duricrusts; and
- Bedrock comprising Paleozoic-era sedimentary rocks, faulted and intruded by sills and dikes of diabase/dolerite of the Mesozoic era.

The bedrock is located at depths of greater than 40 metres below ground surface (mbgs) at Kamsar, and at over 30 metres depth in the Sangarédi area. Bedrock will not be considered further in this technical support document.

3.1.1 Kamsar Port Area

In the Kamsar area, there are two there are two principal types of soil. The most common soils are those alluvial deposits based on river-marine periodic waterlogging (planosols), but there are also deep lateritic soils in some areas. The planosols soils are characterized by a bleached topsoil that is periodically temporarily saturated with water. The City of Kamsar is reportedly built on a swamp of mud (Poto-Poto) subject to tidal influence, however, elsewhere it is stated that the majority of the town of Kamsar is constructed on reclaimed land, the fill for which was mined from the channel directly opposite the new alumina quays (Knight-Piésold 2008).

Geotechnical studies indicate that the overburden is a varied sequence of silty sands, silts, and clays characteristic of the deltaic environment to depths below 14 mbgs (Knight-Piésold 2008).

3.1.2 Sangarédi Mining Area

Alluvial deposits of loose to variously cemented/duricrust units overlie the bedrock throughout the Mine Site area. In the upper reaches of valleys, late Miocene to early Pleistocene-aged alluvial deposits are present, composed of ferrous laterite layers with intervals of Sangarédi Series bauxite. The alluvial pebbles, gravels, sands, and clays of the Sangarédi Series have undergone intensive tropical weathering (laterization) to produce deposits rich in alumina (often greater than 45% Al₂O₃) on the Sangarédi-area plateaus.

The bauxite deposits occur as flat layers capping the plateaus that extend throughout the Sangarédi region. The combined effects of tropical weathering and good drainage, provided by

the topographic relief, have led to a concentration of alumina and iron oxides within the upper few meters of the sub-surface, through the leaching of the majority of the other oxides. The bauxite layer is generally continuous over the extent of the plateaus, but it is of variable thickness and quality. The average depth of the bauxite is approximately 8 m, and it is typically exposed at surface, where it may form an iron-enriched cap (Knight-Piésold 2008).

3.2 HYDROGEOLOGY

3.2.1 Kamsar Port Area

The coastal area is characterized by shallow aquifers within the unconsolidated sediments of sands, silts, and clays. These aquifers can discharge large amounts of water into the sea, but there is a seasonal fluctuation during the dry season, where the aquifer is susceptible to periodic saltwater intrusion (and groundwater level lowering) near the coast and along the estuaries.

Kamsar receives its water supply from three 90 meter-deep wells located about thirty kilometers northeast of the city. Additional wells have been dug into the surficial aquifer to supplement water supplies. Reportedly, these wells are used for washing, dust control, etc.

3.2.2 Sangarédi Mining Area

There are two aquifers underlying the Sangarédi region. There is an upper aquifer located in the overburden on the plateaus and in alluvial deposits in the river valleys. The water table is found at the base or just below the base of the bauxite deposits; ponds are not developed during the mining process due to intersecting of the water table. Traditional water supply wells for the communities are hand-dug into the water-bearing formations in the shallow aquifer. There is a deep groundwater aquifer that is located in the bedrock in the fractured contact zones between the lightly metamorphosed sedimentary (Paleozoic) and intrusive (Mesozoic) rocks. Groundwater does discharge on occasion as springs into the bottom of the valleys and surface water courses.

4.0 IDENTIFICATION OF VECs

4.1 SURFACE WATER

Valued ecosystem components (VECs) are features of the environment selected to be the focus of the ESIA because of their ecological, social, cultural or economic value and their potential vulnerability to effects of the Project. Increased mining activities, bauxite processing and shipping and transport activities associated with the project may impact water and sediment quality through contaminant releases into air and subsequent deposition onto surface water or directly into surface water. These activities are not expected to affect the surface water hydrology in either the Kamsar Port or Sangarédi Mining areas and thus hydrology was identified as a VEC for the Project.

For this assessment, the VECs for surface water were identified as:

- Freshwater
- Marine

For each of these VEC two sub-components were selected:

- water quality
- sediment quality

The following sections identify project–surface water interactions in each study area for consideration in the impact evaluation.

4.1.1 Kamsar Port Area

There are several project-surface water interactions identified for the Kamsar site. These include:

- Wastewater released from the CBG production facility, including releases from the oil-water separator. There is also an oil-water separator at the fuel storage yard.
- Deposition of dust containing metals, including deposition directly on water and deposition on land that will be transported to the port.
- Physical losses of material during storage.
- Deposition of SO₂ and NO₂ that may affect the water quality.
- Dredging of sediment.

Wastewater releases associated with the Kamsar Port facilities may contaminate surface waters if discharged into the estuary or streams such as the Dougoufissa River. The Project is expected to affect both the quantity and quality of wastewater discharges.

The deposition of air emissions, including dust (and associated metals) and gases such as SO₂ and NO_x, either directly to the water surface or to land from where contaminants are transported to the waterbody, represents the main source of surface water contamination resulting from the Project. It is also assumed that changes in water quality will ultimately likely affect sediment quality as well. To a lesser extent, physical losses of materials during ship loading for example, are also expected to impact surface water quality.

As the Rio Nuñez estuary is relatively shallow in depth, regular dredging, every two to three years, is necessary to maintain an access channel to allow ships to reach the existing loading quay. Furthermore, as the Project ramps up, the turning basin at the existing quay will need to be enlarged for when production reaches 22.4 MTPA, while a second turning basin will be required when production reaches 27.5 MTPA. An estimated 418,000 m³ of material will need to be dredged to implement these changes. Sediment dredging results in a physical disturbance to sediment causing sediment suspension which in turn increases water turbidity and degrades water quality.

4.1.2 Sangarédi Mining Area

There are several project-surface water interactions identified for the mining area. These include:

- Erosion of soil and increased deposition of dust containing metals that will be transported to rivers.
- Deposition of SO₂ and NO₂ that may affect the water quality.

Please note that the potential impacts due to Accidents and Malfunctions (spills, hazardous material handling, etc.) is being addressed separately.

Due to mining activities there is the potential for increase in soil erosion that could affect surface water. There is also the potential for the deposition of air emissions, including dust (and associated metals) and gases such as SO₂ and NO_x, which could affect surface water. It is also assumed that changes in water quality will ultimately likely affect sediment quality as well.

4.2 GROUNDWATER

Groundwater is identified as a VEC for this ESIA. The groundwater VEC has three sub-components:

1. Groundwater flow;
2. Groundwater quantity; and

3. Groundwater quality.

The operation of the port at Kamsar and the mine at Sangarédi can alter the shallow groundwater flow regime through the alteration of the infiltration of precipitation into the subsurface, which can affect the groundwater levels locally, and potentially alter the groundwater flow configuration. At the port, this can be accomplished through the creation of impervious surfaces, thus promoting run-off instead of infiltration. At the mine, infiltration can be affected through the excavation activities at the mine, and the creation of permanent or temporary impervious surfaces.

Groundwater quantity can potentially be affected by the same alteration of the infiltration of precipitation into the subsurface described above. Potential negative effects on groundwater flow regime (i.e., lowering of the water table) can affect the quantity of shallow groundwater resource available for use.

Groundwater quality can potentially be affected due to accidents and malfunctions that create spills or other discharges of hazardous materials. In addition, alterations to the groundwater flow regime (for example, the lowering of the water table) could affect the concentration of naturally occurring parameters in the groundwater. For the Kamsar area, this already occurs on a seasonal basis, with the increase in parameters such as calcium, total dissolved solids, and chloride during the dry season. There is also an interpreted seasonal seawater intrusion aspect to the water quality observed at the Kamsar Port area (Knight-Piésold 2008).

It should be noted that there is no groundwater dewatering as part of the mine or port operations, except for during the construction of the new car dumper building at the port.

5.0 FIELD PROGRAM

5.1 STUDY AREAS

Surface water and sediment sampling for the CBG Production Expansion Project was carried out in April 2014 at the Kamsar Port area where the processing plant is located and in June 2014 at the Sangarédi area where bauxite is mined. In addition, a few well water samples were also collected from Sangarédi during the June sampling campaign. A complete summary of the sampling that was conducted in each area is provided in Table 5.1 for the Kamsar Port area and Table 5.4 for the Sangarédi Mining area. In addition, sampling locations are shown in Figure 5.1 for the Kamsar Port area and Figure 5.5 for the Sangarédi Mine area.

5.1.1 Kamsar Port Area

The Kamsar study area is located within the Rio Nuñez estuary on the Atlantic Ocean where fresh waters from the Rio Nuñez mix with marine waters flowing into creeks and rivers during high tide. The watershed of the Rio Nuñez covers an area of approximately 8,500 km² and includes the watershed of the Tinguilinta River upstream of Boké and other small rivers. The port facilities mainly fall within the catchment of the Dougoufissa River, a tributary of the Rio Nuñez, which flows in a westerly direction along the southern part of Kamsar and drains into the estuary in front of the processing facility (Knight Piésold 2008). The processing facility was built in the early 1970s and includes unloading, crushing, drying and shipping facilities for bauxite export to refineries around the world.

The coast of Guinea experiences a semi-diurnal tidal pattern with two almost equal high tides and two low tides each day. At Kamsar, the tidal range is around 5 m and the tidal influence extends inland as far as Boké, which is 100 km inland from the river mouth (Domain and Bah 2000; Rossi *et al.* 2000). Flows and water levels in the port are strongly influenced by the tides. Surface waters in the port are directly and profoundly influenced by both the tides and the proximity of the estuary to the Atlantic Ocean, resulting in saline and turbid (suspended sediment-rich) waters. Based on the salinity distribution, the Rio Nuñez estuary is considered to be “well-mixed” (Knight Piésold 2008). Due to their saline and turbid nature, the surface water resources are not used by local people as potable water supplies but instead the people rely on shallow hand-dug wells or the water system from Kamsar, which is based on deep wells (Knight Piésold 2008).

Sampling at the Kamsar Port was completed in April with water samples collected from the Dougoufissa River and the Rio Nuñez estuary on the 9th and sediment samples from the same locations on the 14th. A complete listing of samples collected that were from the Kamsar study area is provided in Table 5.1. All samples were collected during high tide.

As seen from Figure 5.1, samples from the Dougoufissa River were collected from three (3) stations: one located upstream of the processing facility in the eastern portion of the river (K-05), one in the lower part of the river near the processing facility (K-06), and one in the mouth of the river adjacent to the processing facility (K-07). Given the strong influence of tides in the area, there are no true upstream and downstream sampling points along the Dougoufissa River, as upstream and downstream is contingent on the effects of tides at the time of sampling (Knight Piésold 2008). Samples from the Rio Nuñez estuary were collected from seven (7) stations along two transects extending progressively north from the mouth of the Dougoufissa River toward the existing loading quay (stations K-08, K-09, and K-10), and progressively west from the river mouth toward and beyond the new ship loader. Station K-04 is located along the jetty, station K-03 at the south end of the ship loader, and stations K-01 and K-02 respectively northwest and southwest of the ship loader.

As the Rio Nuñez estuary is relatively shallow in depth, regular dredging is necessary to maintain an access channel to allow ships to reach the existing loading quay. The current channel is 15 km in length, 8 - 9 m deep, and 120 – 190 m wide. While sediment dredging is only conducted periodically, once every two to three years, the activity results in a physical disturbance to sediment causing sediment suspension which in turn increases water turbidity and degrades water quality. Furthermore, as the Project ramps up, the turning basin at the existing quay will need to be enlarged for when production reaches 22.4 MTPA, while a second turning basin will be required when production reaches 27.5 MTPA. An estimated 418,000 m³ of material will need to be dredged to implement these changes.

Figure 5.1: Sampling Locations at Kamsar Port Area – Processing Facility

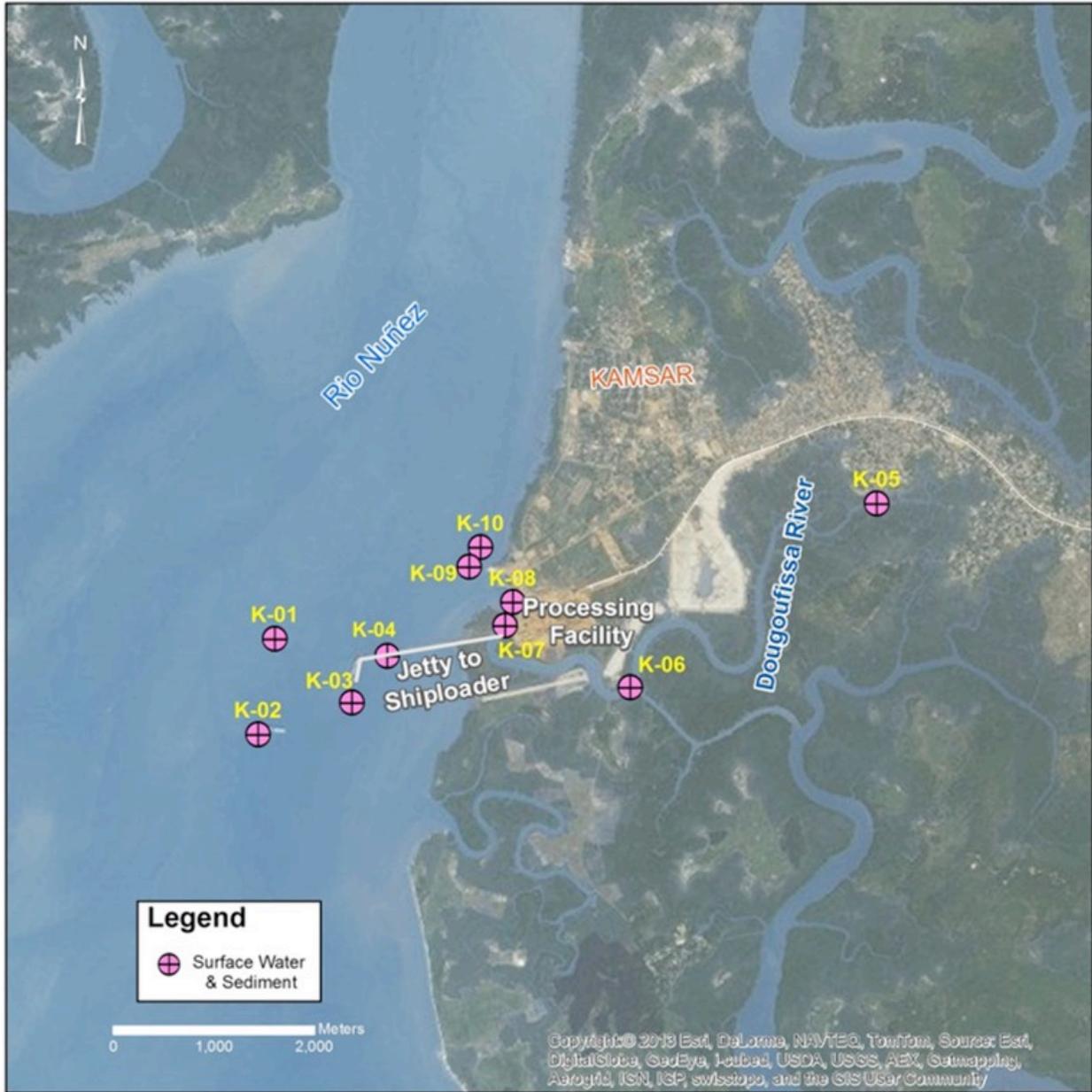


Table 5.1: Listing of Sampling Conducted at the Kamsar Port Area

Station ID	Sampling Date	General Location	Latitude	Longitude	Surface Water			Sediment
					Field Measurements	General Chemistry	Total Metals	Inorganics and Metals
K-05 K-05	09-Apr-14 14-Apr-14	Dougoufissa River	10.65580	-14.58168	✓	✓	✓	✓ ⁽¹⁾
K-06 K-06 K-06 (dup)*	09-Apr-14 14-Apr-14 14-Apr-14	Dougoufissa River	10.63923	-14.60413	✓	✓	✓	✓ ✓
K-07 K-07 (dup)* K-07	09-Apr-14 09-Apr-14 14-Apr-14	Dougoufissa River	10.64482	-14.61550	✓	✓ ✓	✓ ✓	✓ ⁽¹⁾
K-01 K-01 (dup)* K-01	09-Apr-14 09-Apr-14 14-Apr-14	Rio Nuñez	10.64367	-14.63643	✓	✓ ✓	✓ ✓	✓
K-02 K-02	09-Apr-14 14-Apr-14	Rio Nuñez	10.63505	-14.63797	✓	✓	✓	✓
K-03 K-03	09-Apr-14 14-Apr-14	Rio Nuñez	10.63790	-14.62943	✓	✓	✓	✓
K-04 K-04	09-Apr-14 14-Apr-14	Rio Nuñez	10.64210	-14.62620	✓	✓	✓	✓
K-08 K-08 K-08 (dup)*	09-Apr-14 14-Apr-14 14-Apr-14	Rio Nuñez	10.64693	-14.61477	✓	✓	✓	✓ ✓
K-09 K-09 (dup)* K-09	09-Apr-14 09-Apr-14 14-Apr-14	Rio Nuñez	10.65013	-14.61875	✓	✓ ✓	✓ ✓	✓
K-10 K-10	09-Apr-14 14-Apr-14	Rio Nuñez	10.65188	-14.61770	✓	✓	✓	✓

Notes: * dup - duplicate field sample; Field Measurements includes: pH, temperature, dissolved oxygen, and conductivity; General Chemistry includes: alkalinity, hardness, total dissolved solids, dissolved organic carbon, laboratory pH, total suspended solids, dissolved sulphate, and dissolved chloride; Total Metals includes: metal suite; Inorganics and Metals includes: moisture content, total organic carbon, and metal suite.
(1) – sediment jar broke and thus data are not available.

5.1.2 Sangarédi Mine Area

Guinea has distinct wet and dry seasons lasting from May to October and from November to April, respectively. The rainy season which peaks in August, has a monthly rainfall average of more than 500 mm but monthly amounts are very variable at the beginning and end of the season (Rossi *et al.* 2000). Due to the abundant precipitation, an extensive river network has developed within the mining area which mainly falls within the watershed of the Cogon River with rivers such as the Thiapikouré, Boundou Wandé, Lafou, and Pora draining eastward to the Cogon River (see Figure 5.5). A watershed divide occurs in the west end of the study area with streams captured within the Tinguilinta River watershed flowing westward toward the Tinguilinta River. The Tinguilinta River drains an area of 1,891 km² and flows westward to Boké before joining the Rio Nuñez which flows into the Atlantic Ocean in the vicinity of Kamsar (Knight Piésold 2008).

With respect to the main rivers within the mining area, the Boundou Wandé River runs through the middle of the current footprint of the mine operations, the Thiapikouré River to the northwest, and the Lafou River parallel to the operations to the south. As mentioned, all three rivers drain eastward into the Pora River, which in turn flows into the Cogon River, the major river in the region. The cogon River flows northwest to the border with Guinea-Bissau (379 km) and then southwest until it reaches the Rio Komponi estuary in the Atlantic Ocean. Table 5.2 summarizes monthly flows for the cogon River collected by Guinea’s Direction Nationale de l’Hydraulique (reproduced from Knight Piésold 2008). Measurements were taken at the Cogon Bridge flow station corresponding to a drainage area of 3,350 km².

Table 5.2: Monthly Flows in the Cogon River

Cogon River Monthly Flows (m ³ /s)													
	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Annual
Avg.	20.4	11.5	5.6	2.8	1.7	26.6	130.4	283.8	375.8	267.8	102.9	35.1	105.4
Max.	34.0	24.0	15.4	10.1	6.1	123.0	265.8	445.7	656.3	450.4	181.5	47.7	148.3
Min.	10.5	3.2	0.3	0.0	0.0	0.4	44.1	140.0	144.7	132.6	58.8	13.1	67.0
Drainage area = 3,350 km ² at the Cogon Bridge flow station; based on daily average flows. Source: Table reproduced from Knight Piésold (2008), p. 166.													

Some information on the smaller rivers in the mining area was provided by AECOM (2011). The Thiapikouré, Boundou Wandé, Lafou, and Pora rivers, which as mentioned above all flow eastward into the Cogon River, share the following characteristics:

- the river bed rests on bedrock containing anhydrous agates;
- the flow regime is irregular giving rise to floods in August and September and droughts in March and April; and,
- the floodplain is narrow (less than 20 m wide).

Table 5.3 presents information of the watersheds of the Pora, Thiapikouré, Boundou Wandé and Lafou rivers, including basin area and perimeter, slope and flow measured in December during flooding periods.

Table 5.3: Characteristics of Rivers in the Sangarédi Mine Area

River	Basin Area (km²)	Basin Perimeter (km)	Slope (m/km)	Flow during Floods (December) (m³/s)
Pora	20.09	22.62	34.77	60
Thiapikouré	10.76	15.96	29.90	21
Boundou Wandé	16.50	19.20	27.91	29
Lafou	12.62	16.08	22.52	25

Note: table reproduced from AECOM (2011), Table 3.34 (p. 3-98).

A complete listing of samples collected from the Sangarédi Mining area is provided in Table 5.4. All water and sediment samples were collected on June 17th and 18th. Additional information on surface water sampling locations are provided in Table 5.5 while available pictures are presented in Figures 5.2 to 5.4.

Figure 5.2: Lafou River - Station SW6



Figure 5.3: Cogon River – Station SW8



Figure 5.4: Station SW11



Surface water and sediment sampling in the mining area targeted locations upstream and downstream of the current mining operations along the main river systems described above, as well as some locations along streams in areas where mining operations are expected to expand. The Thiapikouré River, which runs between the northern edge of the Boundou Wandé plateau and Sangarédi City, was sampled on a tributary upstream of the city (station SW12) and further downstream within the southern reach of the city (station SW1). The Pora River was sampled at station SW5 at the confluence with the Thiapikouré River. The Lafou River, which runs along the southern edge of the N'Dangara plateau, was sampled upstream at station SW3(2) near the village of Horé Lafou and further downstream at station SW6 just before the confluence with the Boundou Wandé River. The Boundou Wandé River was sampled far upstream at station SW10 near the village of Hamdallaye. The Cogon River was sampled upstream of the main mining operations and the confluence with the Sitako River (station SW7) and downstream of the operations and the confluence with the Pora River (station SW8).

Additional surface water and sediment samples were collected from station SW2 on a stream running along the northern edge of the Koobi (Bowal 22) plateau in the western portion of the mining area; station SW11 on a stream running along the western edge of the Mooule (Bowal 9) plateau in the northern portion of the mining area; and, station SW9 from a stream running through the Sangarédi stockpile area.

An attempt was also made to collect well water from villages within the mining area that may be representative of groundwater quality. Well water samples were collected from two villages: Horé Lafou along the Lafou River, between the Parawi and Kagnaka (Bowal 25) plateaus (station SW3(1)); and, Hamdallaye in the west end of the Boundou Wandé plateau (station SW4). Two additional wells were also selected for sampling but one ended up being dry while the other was connected to a pump that fed a reservoir and was not sampled as there was a potential risk for contamination.

Table 5.4: Listing of Sampling Conducted at the Sangarédi Mining Area

Station ID	Sampling Date	General Location	Latitude	Longitude	Surface Water			Sediment
					Field Measurements	General Chemistry	Total Metals	Inorganics and Metals
SW1	17-Jun-14	Thiapikouré River	11.09922	-13.81998	✓	✓	✓	✓
SW12	17-Jun-14	Thiapikouré River	11.11475	-13.83395	✓	✓	✓	
SW12	18-Jun-14							
SW2	17-Jun-14	Bowal 22 Koobi	11.05738	-13.95572	✓	✓	✓	✓
SW11	17-Jun-14	Bowal 9 Mooule (Parawol Aliou)	11.14137	-13.86083	✓	✓	✓	
SW11	18-Jun-14							
SW3(2)	17-Jun-14	Lafou River	11.04550	-13.88875	✓	✓	✓	✓ ⁽¹⁾
SW6(1)	17-Jun-14	Lafou River	11.06033	-13.80740	✓	✓	✓	✓
SW6(2) (dup)*	17-Jun-14						✓	✓
SW5	17-Jun-14	Pora River	11.07735	-13.80028	✓	✓	✓	✓
SW7	17-Jun-14	Cogon River	11.04668	-13.75113	✓	✓	✓	✓
SW8(1)	17-Jun-14	Cogon River	11.14017	-13.75008	✓	✓	✓	✓
SW8(2) (dup)*	17-Jun-14						✓	✓
SW10	17-Jun-14	Bondou Wandé River	11.07893	-13.87995	✓	✓	✓	✓
SW9	17-Jun-14	Sangarédi stockpile area	11.09620	-13.76930	✓	✓	✓	✓

Notes:

* dup - duplicate field sample; Field Measurements includes: pH, temperature, dissolved oxygen, conductivity, and ammonia; General Chemistry includes: alkalinity, hardness, total dissolved solids, dissolved organic carbon, laboratory pH, total suspended solids, dissolved sulphate, and dissolved chloride; Total Metals includes: metal suite; Inorganics and Metals includes: moisture content, total organic carbon, and metal suite.

(1) – sediment jar broke and thus data are not available.

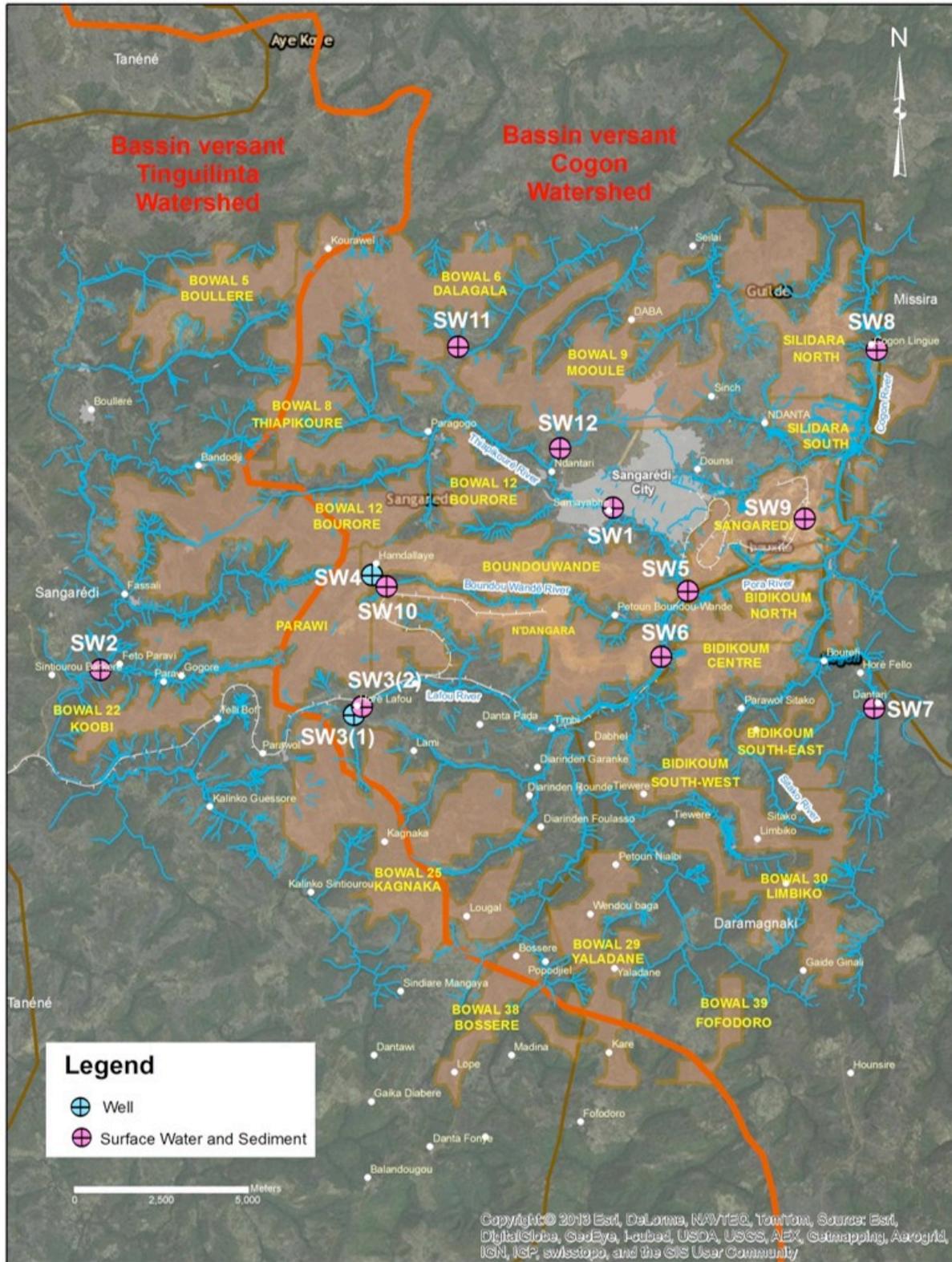
Table 5.4: Listing of Sampling Conducted at the Sangarédi Region – Mining Area (Cont'd)

Station ID	Sampling Date	General Location	Latitude	Longitude	Well Water		
					Field Measurements	General Chemistry	Total Metals
SW4	17-Jun-14	Hamdallaye	11.08195	-13.88380	✓	✓	✓
SW3(1)	17-Jun-14	Lafou	11.04550	-13.88875	✓	✓	✓
<p>Notes: Field Measurements includes: pH, temperature, dissolved oxygen, conductivity, and ammonia; General Chemistry includes: alkalinity, hardness, total dissolved solids, dissolved organic carbon, laboratory pH, total suspended solids, dissolved sulphate, and dissolved chloride; Total Metals includes: metal suite.</p>							

Table 5.5: Description of Sangarédi Sampling Stations

Station	General Location	Comment
SW1	Thiapikouré River	Surface water samples were collected early in the morning at sunrise when the location was quiet and devoid of activity; people use this spot to wash their cars during the day and traces of oil were visible on the water surface during sampling.
SW2	Bowal 22 Koobi	Fairly wide stream like a river with moderate flow; no activity during surface water sampling.
SW3(2)	Lafou River	Small stream, shallow depth, with moderate current; no activity nearby.
SW5	Pora River	Fairly wide stream like a river with moderate flow; no activity during surface water sampling.
SW6	Lafou River	Fairly wide stream like a river with moderate flow; no activity during surface water sampling.
SW7	Cogon River	Narrow stream with weak current.
SW8	Cogon River	Wide river but shallow with strong current; people wash clothes and dishes along the river banks.
SW9	Sangarédi stockpile area	Standing pool of rainwater in the closed mining area on the Sangarédi plateau.
SW10	Bondou Wandé River	Narrow with weak current; lots of seaweed and people washing clothes near opposite bank.
SW11	Bowal 9 Mooule (Parawol Aliou)	Small, shallow stream with moderate current; garment washing near opposite bank.
SW12	Thiapikouré River	Small, shallow stream with moderate current; no activity nearby.

Figure 5.5: Sampling Locations at Sangarédi Mining Area



5.2 SAMPLING METHODS

Surface water and sediment samples were collected from the estuary at the Kamsar Port area using a boat while the rivers were shallow and accessible by foot. Selected pictures from the field campaign are presented below in Figures 5.6 to 5.8.

Figure 5.6: Surface Water Sampling in the Kamsar Port



Figure 5.7: Surface Water sampling in the Thiapikouré River (Station SW12)



Figure 5.8: Collecting Field Measurements at Station SW2

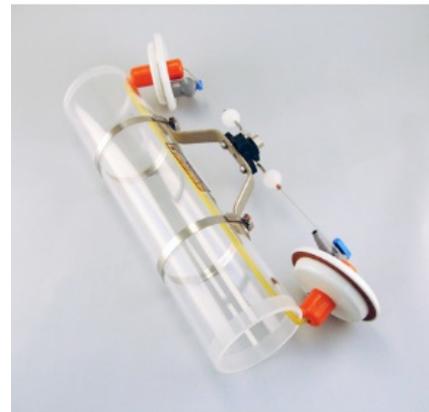


5.2.1 Field Measurements

A hand held YSI Professional Plus (Pro Plus) Instrument equipped with a Quatro 4-port cable was used to take *in-situ* measurements of pH, temperature, dissolved oxygen, conductivity, and ammonium/ammonia (freshwater only) at all surface water stations and wells at both the Kamsar Port and Sangarédi Mining areas.

5.2.2 Surface Water

Surface water samples were collected using an acrylic, Wildco Horizontal Beta sampler shown in the picture, with a 3.2 L capacity and equipped with a 100 ft (30.5 m) polyester line. As indicated in Tables 5.1 and 5.4, a number of sub-samples were collected from the Wildco sampler including two 500-mL samples for the measurement of general chemistry parameters and one 120-mL sample for the measurement of total metals. Preservative nitric acid (2 mL, 18%) was already contained in the 120-mL bottles prior to sample collection. All of the sub-samples collected from the Wildco sampler were bulk (unfiltered).



Approximately 24% of the surface water samples were collected in duplicate where the Wildco sampler was deployed and sub-sampled (for general chemistry and total metals samples) twice. Of the 10 stations that were sampled at the Kamsar Port, duplicate field samples were collected at station K-07 in the Dougoufissa River and stations K-01 and K-09 in the Rio Nunez estuary. Of the 11 stations that were sampled at the Sangarédi Region, duplicate field samples were collected at station SW6 in the Lafou River and station SW8 in the Cogon River. Field and travel blanks were not included in the field program.

All of the sample bottles were pre-washed and acid rinsed, prepped with preservative acid (for total metals only), and packaged into zip-lock bags for travel and storage purposes by the analytical laboratory. All sampling and sample handling was conducted wearing latex gloves to minimize the potential for contamination. Labels on all sample bottles were filled in completely and samples were recorded on the chain of custody form. Water samples were refrigerated and subsequently packed in field coolers using ice packs for shipment to Canada and immediate transfer to the laboratory for analysis (Maxxam Analytics, Mississauga, Ontario, Canada).

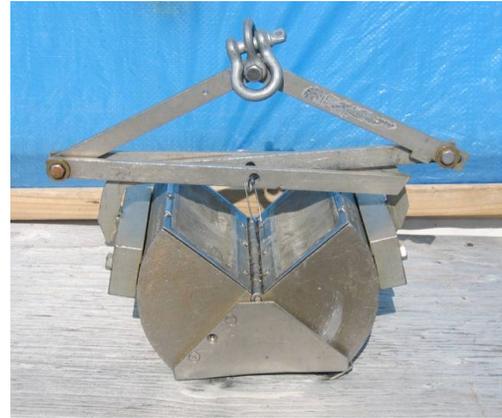
At the laboratory, a number of parameters were determined from the general chemistry sample including the following: alkalinity (as CaCO_3), hardness (as CaCO_3 based on calcium and magnesium), pH, dissolved chloride and sulphate, dissolved organic carbon (DOC), total dissolved solids (TDS), and total suspended solids (TSS). To ensure that sufficient sample volume was collected to complete all of the required analyses, two 500-mL samples were collected for general chemistry parameters at each station; however, when the analyses were completed, enough sample volume was provided with one 500-mL sample although for the Kamsar Port stations, both samples were analyzed due to a miscommunication with the laboratory providing duplicate analyses. A suite of metal determinations were completed on the total metals samples.

5.2.3 Well Water

A few well water samples were collected to provide an indication of groundwater quality in the mining area at Sangarédi. Although groundwater samples are typically collected as dissolved (i.e., filtered through a $0.45\ \mu\text{m}$ filter), in order to simplify the field program with respect to equipment needs and sample preservation and to enable the collection of well samples, a decision was made to collect well samples in an unfiltered form where total metals samples are immediately preserved with nitric acid.

5.2.4 Sediment

Sampling was conducted using a Wildco 6x6" Petite Ponar dredge sampler shown in the picture. The self-tripping sampler features centre hinged jaws and a spring-loaded pin that releases when the sampler makes impact with the sediment-water interface. Features include an under lip attachment that cleans gravel from the jaws that would normally prevent closing and removable side plates that prevent lateral loss of sample. The top is covered with a stainless steel screen which allows water to flow through for a controlled descent. The sampler is constructed of stainless steel with zinc plated steel arms and weights, and is equipped with a safety pin to prevent premature closing.



To collect a sample, the Ponar was lowered to the sediment-water interface, shaken by pulling up on its rope to trigger the jaws to close, and then pulled to the surface. Once out of the water, the Ponar was placed into a clean plastic container and the sediment sample released for sub-sampling. At each station, three separate Ponar grab samples were collected and sub-samples from all three were composited into a single sample for metal determinations to capture variability (heterogeneity) in the sediments. The composite samples were collected into 120 mL glass jars with Teflon lined lids. In addition to metals, moisture content, total organic carbon and grain size (where sample size permitted) were also determined on these samples. Sediment samples were individually packed into zip-lock bags to avoid cross contamination. All sampling and sample handling was conducted wearing latex gloves to minimize the potential for contamination. Labels on all sample jars were filled in completely and samples were recorded on the chain of custody form. Sediment samples were refrigerated and subsequently packed in field coolers using ice packs for shipment to Canada and immediate transfer to the laboratory for analysis (Maxxam Analytics, Mississauga, Ontario, Canada).

Approximately 20% of the sediment samples were collected in duplicate where each time the Petite Ponar was deployed and sub-sampled three times. Of the 10 stations that were sampled at the Kamsar Port, duplicate field samples were collected at station K-06 in the Dougoufissa River and station K-08 in the Rio Nunez estuary. Of the 11 stations that were sampled at the Sangarédi area, duplicate field samples were collected at station SW6 in the Lafou River and station SW8 in the Cogon River.

5.3 QAQC AND LABORATORY ANALYSES

5.3.1 Water Samples

All surface and well water samples for general chemistry and total metals analyses were shipped from Guinea to a laboratory in Canada (Maxxam Analytics, Mississauga, Ontario) for analyses. The laboratory typically uses parameter-specific analytical methods based on standard methods developed or approved by the U.S. EPA or the Standard Methods Committee (SMC). The methods that were used in this analysis are summarized below in Table 5.6.

Table 5.6: Summary of Analytical Methods used to Determine Water Quality Parameters

Analysis	Method Reference
Alkalinity	SM 2320B
Chloride by automated colourimetry	EPA 325.2
Dissolved organic carbon (DOC)	SM 5310B
Hardness (calculated as CaCO ₃)	SM 2340B
pH	SM 4500H+B
Sulphate by automated colourimetry	EPA 375.4
Total dissolved solids (TDS)	APHA 2540C
Total suspended solids (TSS)	SM 2540D
Total metals analysis by inductively coupled plasma - mass spectrometry (ICP-MS)	EPA 6020

As noted in Table 5.6, the analytical technique used to determine metal concentrations in water was inductively coupled plasma-mass spectrometry (ICP-MS). The suite of metals analysed in each total metals sample is as follows:

Aluminum	Cadmium	Lithium	Selenium	Titanium
Antimony	Calcium	Magnesium	Silver	Tungsten
Arsenic	Chromium	Manganese	Sodium	Uranium
Barium	Cobalt	Molybdenum	Strontium	Vanadium
Beryllium	Copper	Nickel	Tellurium	Zinc
Bismuth	Iron	Potassium	Thallium	Zirconium
Boron	Lead	Silicon	Tin	

While every effort was made to expedite the transport of samples to the laboratory for analysis, in some cases samples were received passed the seven-day (7) holding time stipulated by the laboratory for the determination of certain general chemistry parameters such as TDS, TSS, etc. This was true for the general chemistry samples that were collected from the Sanagrédi Mining area on June 17th and received by the laboratory on June 27th; the prescribed analyses were still completed on these samples and the data included with the other results.

With respect to the total metals analysis, samples collected from the Kamsar Port area had to be diluted due to interference from the sample matrix (samples contained high levels of solids and major ions). The reportable detection limits (RDLs) for these samples had to be adjusted accordingly resulting in RDLs 50 times higher than those reported on samples from the Sangarédi Mine area.

As was mentioned previously, surface water samples at five stations were collected in duplicate representing approximately 24% of all samples collected from both the Kamsar Port and Sangarédi Mining areas. The percent difference in parameter concentrations between duplicate field samples is expected to be less than 25%. With only a few exceptions, the percent difference in general chemistry parameter and total metal concentrations was less than 25% and in most cases less than 10%. Higher percentages were generally calculated, as would be expected, when the measured constituent concentrations were very low.

The laboratory certificate of analysis for the samples are included in Appendix B.

5.3.2 Sediment Samples

All sediment samples were shipped from Guinea to a laboratory in Canada (Maxxam Analytics, Mississauga, Ontario) for analyses. The laboratory typically uses parameter-specific analytical methods based on standard methods developed or approved by the U.S. EPA or the SMC. The methods that were used in this analysis are summarized below in Table 5.7. It should be noted that sediment sample sizes were not sufficient for grain size determinations.

Table 5.7: Summary of Analytical Methods used to Determine Water Quality Parameters

Analysis	Sample Type	Method Reference
Moisture	Sediment	R. Carter, 1993
Total Organic Carbon (TOC)	Sediment	LECO Combustion
Strong acid leachable metals by inductively coupled plasma – mass spectrometry	Sediment	EPA 6020 m

As noted in Table 5.7, metal concentrations in sediment samples were determined using inductively coupled plasma - mass spectrometry (ICP-MS) following a high temperature nitric acid digestion. The suite of metals analysed in each sediment sample is as follows:

Aluminum	Cadmium	Lithium	Potassium	Titanium
Antimony	Calcium	Magnesium	Selenium	Uranium
Arsenic	Chromium	Manganese	Silver	Vanadium
Barium	Cobalt	Molybdenum	Sodium	Zinc
Beryllium	Copper	Mercury	Strontium	
Bismuth	Iron	Nickel	Thallium	
Boron	Lead	Phosphorus	Tin	

The laboratory certificate of analysis for the samples are included in Appendix B.

Despite best efforts to carefully pack and preserve all sediment samples, the following jars arrived at the laboratory broken where the samples could not be analyzed:

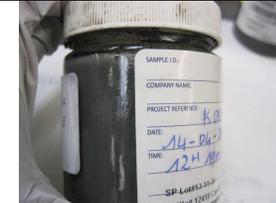
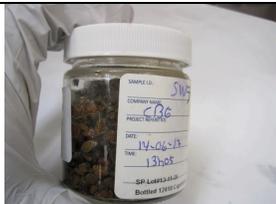
Sediment sample K-05 – Dougoufissa River, Kamsar Port
Sediment sample K-07 – Dougoufissa River, Kamsar Port
Sediment sample SW3(2) – Lafou River, Sangarédi Region

In addition, the following samples arrived with broken lids where sample analysis was still possible:

Sediment sample SW1 – Thiapikouré River, Sangarédi Region
Sediment sample SW6(1) – Lafou River, Sangarédi Region
Sediment sample SW6(2) (duplicate) – Lafou River, Sangarédi Region

Pictures of the various sediment samples are shown in Figure 5.9.

Figure 5.9: Pictures of Sediment Samples Collected from the Kamsar Port and Sangarédi Mining Area

			
Sample K03	Sample K04	Sample K06(1)	Sample K06(2)
			
Sample K08(1)	Sample K08(2)	Sample K09	Sample K10
			
Sample SW1	Sample SW2	Sample SW5	Sample SW6(1)
			
Sample SW6(2)	Sample SW7	Sample SW8(1)	Sample SW8(2)
			
Station SW9	Sample SW10	Sample SW11	Sample SW12

6.0 EXISTING CONDITIONS

6.1 KAMSAR PORT AREA

6.1.1 Wastewater

The processing facility generates wastewater discharges, the volume and quality of which will be affected with the increase in bauxite production. While wastewater discharges were not sampled during the 2014 field program, wastewater sampling was completed in January 2011 by AECOM in support of the 2011 ESIA (AECOM 2011). AECOM sampled wastewater discharges at the following locations shown in Figure 6.1:

- Station WR1 – the output of the oil separator that treats liquid waste (consisting mainly of oily water and water contaminated coolants, lubricants, solvents and degreasers) from the processing facility or transported from N'Dangara;
- Station WR2 – the output of the oil separator in the hydrocarbon storage area;
- Station WR3 – includes septic waste (from offices, workshops and laboratories), cooling water used for the processing facility, and steam and oily water (from the oil separator) released into the gutters of the processing facility.

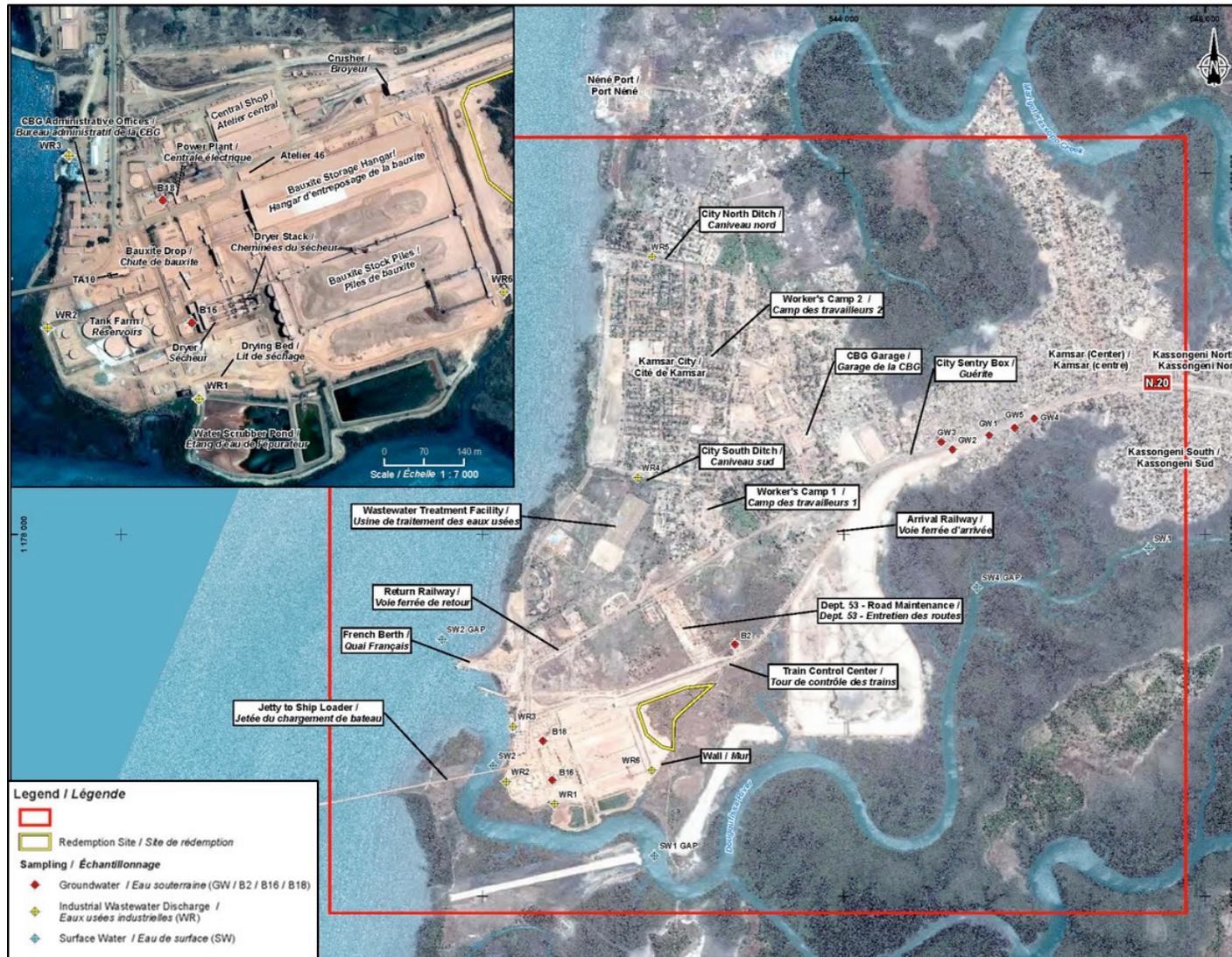
In addition, two samples were collected from the city's gutters: one from the ditch running along the north edge of the city (WR-5) and the other from the ditch running along the south edge of the city (WR-4). These waters are discharged directly into the sea. The gutters were originally used to collect rainwater, but over time, as the city has grown, municipal underground sewers have become overloaded. Consequently, people have found different ways to get rid of their waste, including direct disposal into the gutters.

The ditch along conveyor C-1, C-2 and C-20 receives rainwater runoff from surrounding surfaces and water falling into the underground tunnel exiting the bauxite crusher as well as wastewater produced when cleaning equipment in the crusher building. This water is discharged into the Dougoufissa River. AECOM sampled this water for total suspended solids in May 2011 at station WR-6.

Wastewater from the drying ovens in the scrubber flows into basins lined with a geomembrane which blocks the infiltration of water into the soil. Effluent from the Kamsar wastewater treatment plant also drains into these basins. The water in the scrubber ponds is then returned to the cleaners to clean the hot gas in the drying ovens and to recover dust from bauxite. The contact between the hot gases and the water pumped causes evaporation of a substantial portion of the water. The pond water is used in a closed circuit and is therefore not directly discharged into surface waters.

The wastewater grab samples collected by AECOM (2011) were analyzed for general chemistry parameters, metals and polycyclic aromatic hydrocarbons (PAHs) and the results are reproduced in Table 6.1 where comparisons are made to criteria published by the IFC and the Montreal Metropolitan Community for wastewater discharges into surface waters (freshwater). In interpreting the data, AECOM (2011) stressed that the results are based on single grab samples and recommended that an environmental monitoring program for wastewater discharges be developed and implemented to better assess the quality of these releases. Several of the grab samples had elevated levels of suspended solids, oil and grease, polycyclic aromatic hydrocarbons (PAH) near the oil separator, and heavy metals near the yacht club while samples from the city ditches had elevated levels of phosphorus, nitrogen as well as chloride in the south ditch which was attributed to salt water intrusion.

Figure 6.1: Wastewater Sampling Locations



Source: modified from AECOM (2011), Figure 3.24.

Table 6.1: Mean Concentrations in Principal Wastewater Discharges at Kamsar Port

Constituent	Unit	Benchmark	Concentrations Measured in Wastewaters ⁽⁴⁾							
			WR1 De-Oiler	WR2 Stockyard	WR3 Yacht Club		WR4 Ditch South of City		WR5 Ditch North of City	WR6 Ditch by Crusher
			Jan. 2011	Jan. 2011	Jan. 2011	May 2011	Jan. 2011	May 2011	Jan. 2011	Jan. 2011
General Chemistry										
Ammonia as Nitrogen (NH ₃ -N)	mg/L	12 (pH ≤ 7.5) 6 (7.5 < pH ≤ 8.0) 2 (8.0 < pH ≤ 8.5) 0.7 ⁽³⁾	-	-	1.4	--	9.5	13	16	-
Chloride	mg/L	1500 ⁽³⁾	-	-	9.2	--	3 900	22	21	-
Colony Forming Unit ⁽⁶⁾	CFU	200 CFU/100 mL ⁽³⁾	5±5	5±5	5±5	--	5±5	--	5±5	-
Conductivity	µS/cm	-	252 ⁽⁷⁾	129 ⁽⁷⁾	302 ⁽⁷⁾	18	13,782 ⁽⁷⁾	0.26	411 ⁽⁷⁾	50
Fluoride	mg/L	2 ⁽³⁾	-	-	0.3	-	0.2	<0.1	0.1	-
Total Kjeldahl nitrogen (TKN)	mg/L	10 ⁽¹⁾	-	-	3	-	11	16	18	-
Nitrate	mg/L	-	-	-	5	-	<0.2	<0.02	<0.2	-
Nitrite	mg/L	-	-	-	<0.2	-	<2	<0.02	<0.2	-
Nitrite (N) & Nitrate (N)	mg/L	-	-	-	5	-	<2	<0.02	<0; <0.22	-
Oxygen Concentration ⁽⁷⁾	%	-	6.4	100.1	55.8	-	30	--	2.5	-
Oxygen Concentration ⁽⁷⁾	mg/L	-	0.48	7.87	4.3	-	2.31	--	0.25	-
pH ⁽⁷⁾	pH unit	6 > pH < 9 ⁽¹⁾⁽²⁾ 6 > pH < 9.5 ⁽³⁾	7.1	.25	5.16	-	6.93	--	6.97	-
Salinity ⁽⁷⁾	mg/L	-	0.11	0.06	0.13	-	7.72	--	0.19	-
Sulphate	mg/L	1500 ⁽³⁾	-	-	110	-	530	3.8	<5	-
Total Suspended Solids	mg/L	50 ⁽¹⁾⁽²⁾ ; 30 ⁽³⁾	119 ⁽⁶⁾	11 ⁽⁶⁾	258 ⁽⁶⁾	12	39 ⁽⁶⁾	33	18(6)	62
Temperature ⁽⁷⁾	°C	Deviation < 3°C ⁽²⁾ 45°C ⁽³⁾	30.69	28.12	30.26	-	26.66	-	26,71	-
Mineral oils and grease	mg/L	15 ⁽³⁾	27	<3	96	-	<3	<3	<3	-
Total oil and grease	mg/L	10 ⁽¹⁾⁽²⁾ ; 15 ⁽³⁾	42	<3	120	-	<3	10	5.4	-
Total Phosphorus	mg/L	2 ⁽¹⁾ ; 0.4 ⁽³⁾	-	-	1.8	-	1.5	1.6	2.2	-

Table 6.1: Mean Concentrations in Principal Wastewater Discharges at Kamsar Port (Cont'd)

Constituent	Unit	Benchmark	Concentrations Measured in Wastewaters ⁽⁴⁾							
			WR1 De-Oiler	WR2 Stockyard	WR3 Yacht Club		WR4 Ditch South of City		WR5 Ditch North of City	WR6 Ditch by Crusher
			Jan. 2011	Jan. 2011	Jan. 2011	May 2011	Jan. 2011	May 2011	Jan. 2011	Jan. 2011
Metals										
Aluminum	mg/L	3 ⁽³⁾	0.6	0.057	2.5	-	0.13	0.25	0.1	-
Antimony	mg/L	-	<0.01	<0.01	<0.01	-	<0.01	<0.02	<0.01	-
Arsenic	mg/L	0.1 ⁽²⁾ ; 1 ⁽³⁾	<0.001	0.0013	<0.001	-	0.0025	<0.05	0.003	-
Barium	mg/L	1 ⁽³⁾	<0.02	<0.02	0.023	-	<0.02	<0.02	<0.02	-
Beryllium	mg/L	-	<0.005	<0.005	<0.005	-	<0.005	<0.002	<0.005	-
Boron	mg/L	-	0.42	< 0.05	< 0.05	-	0.9	< 0.05	0.09	-
Cadmium	mg/L	0.05 ⁽²⁾ ; 0.1 ⁽³⁾	<0.0003	<0.0003	<0.0003	-	<0.0003	<0.01	<0.0003	-
Chromium	mg/L	0.1 ⁽²⁾ ; 1 ⁽³⁾	<0.005	<0.005	<0.005	-	<0.005	<0.01	<0.005	-
Cobalt	mg/L	-	<0.005	<0.005	<0.005	-	<0.005	<0.01	<0.005	-
Copper	mg/L	0.3 ⁽²⁾ ; 1 ⁽³⁾	0.076	0.027	2.9	-	<0.005	<0.009	<0.005	-
Iron	mg/L	2 ⁽²⁾ ; 15 ⁽³⁾	0.94	1.7	1.5	-	3	1.7	2	-
Lead	mg/L	0.2 ⁽²⁾ ; 0.1 ⁽³⁾	0.0037	<0.001	0.0044	-	<0.001	<0.01	0.0014	-
Manganese	mg/L	0.1 ⁽³⁾	0.053	0.044	0.17	-	0.094	0.04	0.047	-
Molybdenum	mg/L	-	<0.005	<0.005	<0.005	-	<0.005	<0.01	<0.005	-
Nickel	mg/L	0.5 ⁽²⁾ ; 1 ⁽³⁾	0.018	<0.002	0.047	-	<0.002	<0.01	<0.002	-
Selenium	mg/L	0.02 ⁽³⁾	<0.01	<0.01	<0.01	-	<0.01	<0.05	<0.01	-
Silver	mg/L	0.12 ⁽³⁾	<0.001	<0.001	<0.001	-	<0.001	<0.01	<0.001	-
Sodium	mg/L	-	19	1.9	4.8	-	2000	15	38	-
Tin	mg/L	1 ⁽³⁾	<0.02	<0.02	<0.02	-	<0.02	<0.01	<0.02	-
Vanadium	mg/L	-	0.033	<0.02	0.036	-	<0.02	<0.01	<0.02	-
Zinc	mg/L	0.5 ⁽²⁾ ; 1 ⁽³⁾	0.17	0.028	1.6	-	<0.007	<0.02	0.026	-
Polycyclic Aromatic Hydrocarbons (PAH)										
Acenaphthene	µg/L	-	7	<0.03	-	0.06	-	-	-	-
Anthracene	µg/L	1 ⁽³⁾⁽⁵⁾	6	<0.03	-	0.05	-	-	-	-
Benzo[a]anthracene	µg/L	1 ⁽³⁾⁽⁵⁾	8	<0.03	-	0.22	-	-	-	-
Benzo[a]pyrene	µg/L	1 ⁽³⁾⁽⁵⁾	4.2	<0.008	-	0.12	-	-	-	-

Table 6.1: Mean Concentrations in Principal Wastewater Discharges at Kamsar Port (Cont'd)

Constituent	Unit	Benchmark	Concentrations Measured in Wastewaters ⁽⁴⁾							
			WR1 De-Oiler	WR2 Stockyard	WR3 Yacht Club		WR4 Ditch South of City		WR5 Ditch North of City	WR6 Ditch by Crusher
			Jan. 2011	Jan. 2011	Jan. 2011	May 2011	Jan. 2011	May 2011	Jan. 2011	Jan. 2011
Polycyclic Aromatic Hydrocarbons (PAH) (Cont'd)										
Benzo[b,i,k]fluoranthene	µg/L	1 ⁽³⁾⁽⁵⁾	<6	<0.06	-	0.10	-	-	-	-
Chrysene	µg/L	1 ⁽³⁾⁽⁵⁾	10	<0.03	-	0.34	-	-	-	-
Dibenzo[a,h]anthracene	µg/L	1 ⁽³⁾⁽⁵⁾	<3	<0.03	-	<0.03	-	-	-	-
Fluoranthene	µg/L	1 ⁽³⁾	3	<0.03	--	0.07	-	-	-	-
Fluorene	µg/L	1 ⁽³⁾⁽⁵⁾	11	<0.03	--	0.09	-	-	-	-
Indeno[1,2,3-cd]pyrene	µg/L	1 ⁽³⁾⁽⁵⁾	<3	<0.03	--	<0.03	-	-	-	-
Naphthalene	µg/L	150 ⁽³⁾	15	<0.03	--	0.14	-	-	-	-
Phenanthrene	µg/L	63 ⁽³⁾	46	0.06	--	0.43	-	-	-	-
Pyrene	µg/L	1 ⁽³⁾⁽⁵⁾	16	0.04	--	0.48	-	-	-	-
<p>Notes:</p> <p>(1) Values provided by the IFC for the sanitary disposal of wastewater taken from: <i>Directives Environnementales, Sanitaires et Sécuritaires Générales – Eaux Usées et Qualité des Eaux Ambiantes</i>.</p> <p>(2) IFC, <i>Directives Environnementales, Sanitaires et Sécuritaires – Exploitation Minière</i>, 10 Décembre 2007.</p> <p>(3) Montreal Metropolitan Community, Criteria for Discharge to a Storm Sewer or a Stream of Bylaw No. 2008-47 on Water Treatment (Appendix 1).</p> <p>(4) Unless otherwise specified, analyses were conducted at an accredited Canadian laboratory.</p> <p>(5) A criterion of 1 µg/m³ applies to the total concentration of PAHs.</p> <p>(6) Analyses were completed at a CBG laboratory.</p> <p>(7) Analyses were carried out on-site using a multiprobe analyzer.</p>										

6.1.2 Surface Water Quality

Surface water sampling in the Kamsar Port area was conducted in the vicinity of the CBG Processing Facility, along the Dougoufissa River and within the Rio Nuñez estuary downstream of the river mouth and near the existing loading quay and the new ship loader. Sampling included *in-situ* field measurements of basic water quality characteristics (Table 6.4) and the collection of surface water to determine current constituent levels (Table 6.5). Sediment samples were also collected from the same locations which are shown in Figure 5.1.

The results of *in-situ* field measurements taken with the YSI Pro Plus instrument at the time of surface water sampling are summarized below in Table 6.2. Measurements were taken for pH, temperature, dissolved oxygen, and conductivity.

Table 6.2: Summary of *In-situ* Field Measurements for Kamsar Port

Station	pH ¹	Temperature (°C)	Dissolved Oxygen ²		Conductivity (mS/cm)
			(%)	(mg/L)	
<i>Dougoufissa River (Freshwater)</i>					
K-05	7.90	30.9	107.9	6.47	60.2
K-06	8.00	29.8	118.0	7.49	57.7
K-07	8.00	29.7	118.6	7.42	57.4
<i>Rio Nunez Estuary (Marine Water)</i>					
K-08	8.00	29.7	117.5	7.64	57.4
K-09	8.00	29.1	106.4	6.61	57.1
K-10	8.00	29.4	115.8	7.29	57.4
K-04	8.00	28.9	106.2	6.85	56.9
K-03	8.00	28.8	109.5	6.84	56.8
K-02	7.96	28.6	105.4	6.72	56.4
K-01	7.96	28.7	111.1	7.07	56.4

Notes:

¹ U.S. EPA CCC for pH is 6.5-9.0 in freshwater and 6.5-8.5 in marine water; CCME guideline for pH is 6.5-9.0 in freshwater and 7.0-8.7 in marine water.

² U.S. EPA criterion for dissolved oxygen in freshwater varies from ≥ 3.0 (1-day minimum) to ≥ 6.0 (7-day mean) mg/L for early and other life stages for warm biota; CCME guideline for dissolved oxygen in freshwater varies from ≥ 5.5 to ≥ 6.0 mg/L for early and other life stages respectively for warm biota; CCME guideline for dissolved oxygen in marine and estuarine water is > 8.0 mg/L although when the natural DO level is less than the recommended interim guideline then the natural concentration should become the guideline at the site.

U.S. EPA - United States Environmental Protection Agency. 2013. Aquatic Life Criteria Table; CCC – Criterion Continuous Concentration.

CCME - Canadian Council of Ministers of the Environment. 2013. Water Quality Guidelines for the Protection of Aquatic Life.

As shown in Table 6.2, the field measurements were very similar between all of the stations sampled in both the Dougoufissa River and the Rio Nuñez estuary. A slightly basic pH of 8.0 was measured in both the river and the estuary, which falls within acceptable pH levels for the protection of both freshwater and marine aquatic life. Surface waters at all stations were well aerated and supersaturated with respect to dissolved oxygen, which ranged in concentration from 6.5 mg/L to 7.6 mg/L, and concentrations generally met recommended values for warm aquatic biota. The average surface water temperature measured in mid-April was about 29 °C. The very high specific conductivity of these surface waters, ranging from 56.4 to 60.2 mS/cm, is consistent with the high levels of dissolved salts and TDS shown in Table 6.3. Concentrations of TDS ranged from 34,150 to 36,900 mg/L, while high levels were also reported for major ions such calcium (400 to 460 mg/L), magnesium (1,150 to 1,400 mg/L), sodium (9,800 to 11,000 mg/L), chloride (19,000 to 20,000 mg/L), and sulphate (2,600 to 2,800 mg/L). These observations indicate both the influence of the salt water intrusion on surface water quality resulting in high levels of salts, as well as the effects of tidal action resulting in highly turbid but also well mixed waters throughout the estuary and the Dougoufissa River.

In Table 6.5, constituent concentrations (general chemistry parameters and total metals) are compared to available benchmarks for the protection of marine aquatic life. These include CCC developed by the U.S. EPA and guidelines for chronic exposure developed by the CCME. As was noted in Section 5.3, RDLs were reported by the laboratory for metal constituents measured in Kamsar Port surface water samples because sample dilution was necessary to eliminate interferences with the analysis caused by the sample matrix. Consequently, the detection limits reported in Table 6.5 for most metals with available benchmarks are many times higher than the most conservative benchmark.

Given the high RDLs, the majority of metals included in Table 6.5 were not detected in most samples; however, RDLs typically exceeded the more conservative CCME guideline values. Metal constituents that were detected included boron and strontium on all samples, aluminum and vanadium in most samples from both the river and estuary, and zinc in river samples only. Of these, only zinc has a water quality criterion of 81 µg/L (U.S. EPA CCC), which was exceeded at the most upstream stations in the Dougoufissa River (K-05 and K-06). Zinc was not detected at the remaining stations but the high RDL value of 250 µg/L also exceeds the CCC.

As seen from Figure 6.2, similar concentrations of boron, strontium and vanadium were generally measured between all of the stations in both the river (K-05 to K-06) and the estuary (K-07 to K-10), indicating well mixed surface waters resulting from tidal effects. Concentrations of aluminum (1200 µg/L) and zinc (2300 µg/L) several times higher than the RDLs were measured at the most upstream station in the Dougoufissa River (K-05) but decreased to non-detectable levels in the vicinity of the river mouth as well as throughout the estuary in the case of zinc. This suggests that aluminum and zinc are entering the river from the surrounding watershed

or other sources upstream of the processing facility. As zinc was not detected in the vicinity of the river mouth and all stations within the estuary, the processing facility does not appear to be influencing zinc levels. In the case of aluminum it is evident that activities at the processing facility are influencing aluminum levels in the estuary as concentrations increased moving away from the river mouth toward the ship loader to the west (K-04 to K-01).

It should be emphasized that the existing surface water conditions have been characterized based on limited sampling. However, the results and general trends discussed above agree well with the findings of previous sampling campaigns. In support of the ESIA that was conducted by Knight Piésold (2008), surface waters at stations K-03 and K-10 in the Rio Nuñez estuary near the ship loader and the existing loading quay, respectively, and station K-06 and one additional station (SW-4 GAP) in the Dougoufissa River, were sampled on eight occasions between 2005 and 2007. In addition, station K-05 in the Dougoufissa River was sampled by AECOM in February 2011 (AECOM 2011). The results are summarized in Table 5.2 along with the analogous data collected in 2014. As seen from Table 6.6, although the RDLs for the previous analyses were generally lower, as in 2014 many metal constituents were not detected in surface waters throughout the Kamsar Port area. The lower RDL for arsenic revealed levels measured from 2005 to 2007 above one or both benchmarks for the protection of marine aquatic life of 12.5 µg/L (CCME) 36 µg/L (U.S. EPA CCC) at station K-06 in the Dougoufissa River and stations K-03 and K-10 near the ship loader and existing loading quay in the estuary. While the spatial trend for aluminum concentrations was similar in previous years, the levels were generally higher. With respect to zinc, the average concentration measured over the period 2005 to 2007 at station K-06 in the Dougoufissa River was a couple of orders of magnitude lower and well below the U.S. EPA CCC of 81 µg/L. High levels of major ions were also noted in previous years throughout surface waters in the Kamsar Port area.

Constituent	Unit	Reportable Detection Limit (RDL)	Marine Water Guidelines – Protection of Aquatic Life		Dougoufissa River			Rio Nuñez Estua	
			U.S. EPA (CCC) ¹	CCME (Chronic) ²	Upstream		River Mouth	River Mouth	
					K-05	K-06	K-07	K-08	K-09
General Chemistry Parameters									
Dissolved Chloride	mg/L	200	-	-	19500	19500	20000	20000	
Dissolved Organic Carbon (DOC)	mg/L	0.2	-	-	2.2	1.4	1.3	1.7	
Dissolved Sulphate	mg/L	10	-	-	2650	2600	2625	2800	
Hardness (as CaCO ₃)	mg/L	1.0	-	-	6650	6600	6475	6300	
pH	pH Unit	N/A	6.5-8.5	7.0 - 8.7	7.87	7.90	7.91	7.86	
Total Alkalinity (as CaCO ₃)	mg/L	1	-	-	130	120	120	120	
Total Dissolved Solids (TDS)	mg/L	20	-	-	36900	35100	35300	35900	
Total Suspended Solids (TSS)	mg/L	10	-	-	140	115	128	80	
Total Metals									
Aluminum	µg/L	250	-	-	1200	<250	288	<250	
Antimony	µg/L	25	-	-	<25	<25	<25	<25	
Arsenic	µg/L	50	36 (D)	12.5	<50	<50	<50	<50	
Barium	µg/L	100	-	-	<100	<100	<100	<100	
Beryllium	µg/L	25	-	-	<25	<25	<25	<25	
Bismuth	µg/L	50	-	-	<50	<50	<50	<50	
Boron	µg/L	500	-	-	4700	4300	4400	4700	
Cadmium	µg/L	5	9.9 (D)	0.12	<5	<5	<5	<5	
Calcium	mg/L	10	-	-	460	400	425	440	
Chromium (total)	µg/L	250	-	-	<250	<250	<250	<250	
Cobalt	µg/L	25	-	-	<25	<25	<25	<25	
Copper	µg/L	50	3.7	-	<50	<50	<50	<50	
Iron	µg/L	5000	-	-	<5000	<5000	<5000	<5000	
Lead	µg/L	25	8.5 (D)	-	<25	<25	<25	<25	
Lithium	µg/L	250	-	-	<250	<250	<250	<250	
Magnesium	mg/L	2.5	-	-	1300	1200	1300	1300	
Manganese	µg/L	100	-	-	<100	<100	<100	<100	
Molybdenum	µg/L	25	-	-	<25	<25	<25	<25	
Nickel	µg/L	50	8.3 (D)	-	<50	<50	<50	<50	
Potassium	mg/L	10	-	-	410	380	390	420	
Selenium	µg/L	100	-	-	<100	<100	<100	<100	
Silicon	µg/L	2500	-	-	3100	<2500	<2500	<2500	
Silver	µg/L	5	-	-	<5	<5	<5	<5	
Sodium	mg/L	5	-	-	11000	10000	11000	11000	
Strontium	µg/L	50	-	-	8100	7300	7550	7900	
Tellurium	µg/L	50	-	-	<50	<50	<50	<50	
Thallium	µg/L	2.5	-	-	<2.5	<2.5	<2.5	<2.5	
Tin	µg/L	50	-	-	<50	<50	<50	<50	
Titanium	µg/L	250	-	-	<250	<250	<250	<250	
Tungsten	µg/L	50	-	-	<50	<50	<50	<50	
Uranium	µg/L	5	-	-	<5	<5	<5	<5	
Vanadium	µg/L	25	-	-	32	37	36	<25	
Zinc	µg/L	250	81 (D)	-	2300	300	<250	<250	
Zirconium	µg/L	50	-	-	<50	<50	<50	<50	

Notes:

¹ United States Environmental Protection Agency (U.S. EPA). 2014. Aquatic Life Criteria Table; CCC – Criterion Continuous Concentration.

² Canadian Council of Ministers of the Environment (CCME). 2014. Water Quality Guidelines for the Protection of Aquatic Life.

Figure 6.2: Total Concentrations of Selected Metal Constituents Measured in Kamsar Port Surface Waters



Table 6.4: Kamsar Port Surface Water Quality Measured in 2014 Compared to Previous Sampling Campaigns

Constituent	Units	K-05 (SW-1)		K-06 (SW-1 GAP)		K-07 (SW-2)		K-03 (SW-3 GAP)		K-10 (SW-2 GAP)	
		2014	2011 ⁽¹⁾	2014	2005-2007 ⁽²⁾	2014	2011 ⁽¹⁾	2014	2005-2007 ⁽²⁾	2014	2005-2007 ⁽²⁾
Total Dissolved Solids	mg/L	36900	NA	35100	NA	35300	NA	34150	NA	35800	NA
Dissolved Organic Carbon	mg/L	2.15	NA	1.4	480	1.325	NA	1.2	4410	1.3	1965
pH	pH Unit	7.865	7.27	7.895	7.97	7.91	7.65	7.92	8.05	7.81	8.05
Total Suspended Solids	mg/L	140	NA	114.5	133	127.5	NA	105	87.3	72	62
Dissolved Sulphate	mg/L	2650	NA	2600	2175	2625	NA	2600	2225	2800	22385
Dissolved Chloride	mg/L	19500	19000	19500	16613	20000	17000	19500	17500	20000	17375
Aluminum	µg/L	1200	3200	250	673	288	1200	390	219	270	277
Antimony	µg/L	<25	<10	<25	<6	<25	<10	<25	<6	<25	<6
Arsenic	µg/L	<50	4.1	<50	34.9	<50	1.6	<50	127	<50	28.3
Barium	µg/L	<100	<20	<100	<30	<100	<20	<100	<30	<100	<30
Beryllium	µg/L	<25	<5	<25	<2	<25	<5	<25	<2	<25	<2
Boron	µg/L	4700	3800	4300	2930	4400	3700	4200	3050	4900	3270
Cadmium	µg/L	<5	<0.3	<5	<1	<5	<0.3	<5	<1	<5	<1
Calcium	µg/L	460000	NA	400000	325000	425000	NA	410000	345000	450000	361000
Chromium	µg/L	<250	11	<250	<30	<250	<5	<250	<30	<250	<30
Cobalt	µg/L	<25	<5	<25	<30	<25	<5	<25	<30	<25	<30
Copper	µg/L	<50	<5	<50	3.25	<50	<5	<50	3.19	<50	3.64
Iron	µg/L	<5000	NA	<5000	1750	<5000	NA	<5000	794	<5000	771
Lead	µg/L	<25	2.2	<25	0.75	<25	<1	<25	0.688	<25	1
Magnesium	µg/L	1300000	NA	1200000	1006000	1300000	NA	1200000	1055000	1400000	1081000
Manganese	µg/L	<100	1100	<100	41.1	<100	38	<100	31.2	<100	15.7
Molybdenum	µg/L	<25	7.6	<25	<30	<25	10	<25	<30	<25	<30
Nickel	µg/L	<50	3.8	<50	5.63	<50	<2	<50	5.63	<50	5.71
Potassium	µg/L	410000	NA	380000	335000	390000	NA	380000	355000	430000	360000
Selenium	µg/L	<100	<10	<100	<RDL	<100	<10	<100	<RDL	<100	<RDL
Silver	µg/L	<5	<1	<5	0.181	<5	<1	<5	0.256	<5	0.221
Sodium	µg/L	11000000	9900000	10000000	8325000	11000000	9700000	10000000	6465000	11000000	7657000
Strontium	µg/L	8100	NA	7300	6680	7550	NA	7400	7138	8000	7600
Tin	µg/L	<50	<20	<50	<50	<50	<20	<50	<50	<50	<50
Titanium	µg/L	<250	NA	<250	<50	<250	NA	<250	<50	<250	<50
Vanadium	µg/L	32	<20	37	6.25	36	<20	37	<10	<25	12.9
Zinc	µg/L	2300	NA	300	5.44	<250	NA	<250	6.75	<250	24.2
Zirconium	µg/L	<50	<7	<50	NA	<50	<7	<50	NA	<50	NA

Notes:
 (1) Data collected by AECOM (2011)
 (2) Data collected by Knight Piésold (2008)

6.1.3 Sediment Quality

Sediment samples were collected from the same locations where surface water samples were collected, shown in Figure 5.1.

Concentrations of metals as well as the total organic carbon (TOC) and moisture content of sediments collected from the Dougoufissa River and Rio Nuñez sstuary are summarized in Table 6.7. Sediment data from the Dougoufissa River are only available for station K-06 which is located just upstream of the processing facility; samples K-05 and K-07 broke during the trip to the laboratory. Where available, Table 6.7 also includes CCME sediment quality guidelines for the protection of freshwater and marine aquatic life. As discussed in Section 2.2.2, these include Interim Sediment Quality Guidelines (ISQG) and Probable Effect Levels (PELs), which are available for arsenic, chromium, copper, lead, mercury and zinc.

The moisture content of all sediment samples typically ranged from about 40% to 60% and the TOC concentration ranged from 4,800 at station K-04 to 17,000 mg/kg at station K-03 in the estuary. As shown in Table 6.7, low concentrations falling below the RDL were generally measured for several metals including antimony, bismuth, cadmium, mercury, selenium, silver, and tin. The concentrations of arsenic and chromium exceeded the ISQG for both freshwater and marine waters on all sediment samples. The concentrations of aluminum and metal constituents exceeding sediment quality guidelines in Kamsar sediment samples are summarized in Figure 6.3.

While aluminum data are not available for the Dougoufissa River from the 2014 baseline study, aluminum levels were previously determined by AECOM (2011) at three locations within the river mouth near the processing facility. The average aluminum concentration reported for these locations by AECOM was 11,000 µg/g, which is generally lower than what was measured in the estuary. The lowest aluminum concentration in the estuary was measured at station K-04 (9400 µg/g) along the jetty. Concentrations along the west transect ranged from 20,000 to 28,000 µg/g while concentrations along the north transect were slightly lower ranging from 16,000 to 20,000 µg/g. As seen from Figure 6.3, the same trend in concentrations was generally noted for all of the metals included in the figure with the lowest concentration measured at station K-04, the highest concentration at station K-03 and with slightly higher concentrations noted along the west transect in the vicinity of the jetty and ship loader. In addition, metal concentrations generally decreased moving from the Dougoufissa River (K-06) into the estuary along the north transect (K-08 to K-10). These metals are being influenced and assimilated into river and estuary sediments by similar processes.

It is again emphasized that the existing sediment conditions were characterized based on limited sampling. Sediment sampling in the Kamsar Port area was previously completed by AECOM

(2011) in May 2011 where 5 sites (SM1 to 2 and SM4 to 7) around the ship loader were sampled and three sites at the mouth of the Dougoufissa River near the processing facility. In addition to metals, the sediment samples were also analyzed for organics including phenols, volatile organic compounds and PAHs. The results showed elevated levels of aluminum and iron in several samples which could indicate the presence of bauxite mixed in with the sediment. With respect to CCME benchmarks however, none of the available benchmarks for either metals or organics were exceeded.

6.1.4 Groundwater Quality

AECOM (2011) sampled four wells that were located within the Kamsar Port facility. The wells were sampled during May-June 2011, which is during the dry season. These well locations are presented in Figure 6.1 (wells B2A/B, B16 and B18). This water also exhibited exceedances of sodium and chlorine (B2A and B16), as well as aluminum (B2A).

TABLE 6.3: Summary Sediment Quality for the Kambui Port Processing Facility

Constituent	Unit	Reportable Detection Limit (RDL)	CCME - Sediment Quality, Aquatic Life ¹				Freshwater		Rio Nuñez Estuary - North Transect		
			Freshwater		Marine Water		Dougoufissa River		Closest to Dougoufissa River Mouth		
			ISQG	PEL	ISQG	PEL	Just upstream of Processing Facility		K-08	K-09	K-10
Inorganics											
Moisture	%	1	-	-	-	-	61	54	56	47	
Total Organic Carbon	mg/kg	500	-	-	-	-	16500	13000	13000	1000	
Metals											
Aluminum	µg/g	250	-	-	-	-	N/A	18000	20000	1600	
Antimony	µg/g	0.2	-	-	-	-	<2.0	<2.0	<2.0	<2.0	
Arsenic	µg/g	1	5.9	17	7.24	41.6	11	8.7	8.5	8.9	
Barium	µg/g	0.5	-	-	-	-	13	10	12	9.0	
Beryllium	µg/g	0.2	-	-	-	-	0.81	0.66	0.74	0.59	
Bismuth	µg/g	1	-	-	-	-	<1.1	<1.2	<1.3	<1.4	
Boron	µg/g	5	-	-	-	-	32	26	28	24	
Cadmium	µg/g	0.1	0.6	3.5	0.7	4.2	<0.10	<0.10	<0.10	<0.10	
Calcium	µg/g	50	-	-	-	-	5100	9750	7500	8600	
Chromium	µg/g	5	37.3	90	52.3	160	79	66.5	70	57	
Cobalt	µg/g	0.1	-	-	-	-	6.3	5.1	5.8	4.8	
Copper	µg/g	0.5	35.7	197	18.7	108	5.3	4.2	4.3	3.1	
Iron	µg/g	250	-	-	-	-	29000	26000	28000	2400	
Lead	µg/g	1	35	91.3	30.2	112	11	8.2	9.0	6.8	
Lithium	µg/g	1	-	-	-	-	38.5	30	33	26	
Magnesium	µg/g	50	-	-	-	-	6600	5250	5900	4900	
Manganese	µg/g	1	-	-	-	-	190	190	220	150	
Mercury	µg/g	0.05	0.170	0.486	0.130	0.700	<0.050	<0.050	<0.050	<0.050	
Molybdenum	µg/g	0.5	-	-	-	-	0.91	0.63	0.60	0.56	
Nickel	µg/g	0.5	-	-	-	-	12	9.8	11	8.6	
Phosphorous	µg/g	50	-	-	-	-	450	435	450	390	
Potassium	µg/g	200	-	-	-	-	3500	2600	3000	2300	
Selenium	µg/g	0.5	-	-	-	-	<0.50	<0.50	<0.50	<0.50	
Silver	µg/g	0.2	-	-	-	-	<0.20	<0.20	<0.20	<0.20	
Sodium	µg/g	100	-	-	-	-	21000	10000	15000	1000	
Strontium	µg/g	1	-	-	-	-	64	68	66	56	
Thallium	µg/g	0.05	-	-	-	-	0.0655	0.055	0.061	<0.05	
Tin	µg/g	5	-	-	-	-	<5.0	<5.0	<5.0	<5.0	
Titanium	µg/g	25	-	-	-	-	66	71	70	65	
Uranium	µg/g	0.05	-	-	-	-	1.5	1.1	1.3	0.84	
Vanadium	µg/g	25	-	-	-	-	35.5	31	30	26	
Zinc	µg/g	5	123	315	124	271	29	25	25	19	

Notes:

¹ Canadian Council of Ministers of the Environment (CCME). 2014. Sediment Quality Guidelines for the Protection of Aquatic Life.

ISQG – Interim Sediment Quality Guideline.

PEL – Probable Effect Level.

Bold – highlighted values in bold font denote concentrations exceeding the ISQG; **Bold** - highlighted and underlined values in bold font denote concentrations exceeding both the ISQG and PEL.

Figure 6.3: Concentrations of Selected Metal Constituents Measured in Kamsar Port Sediments

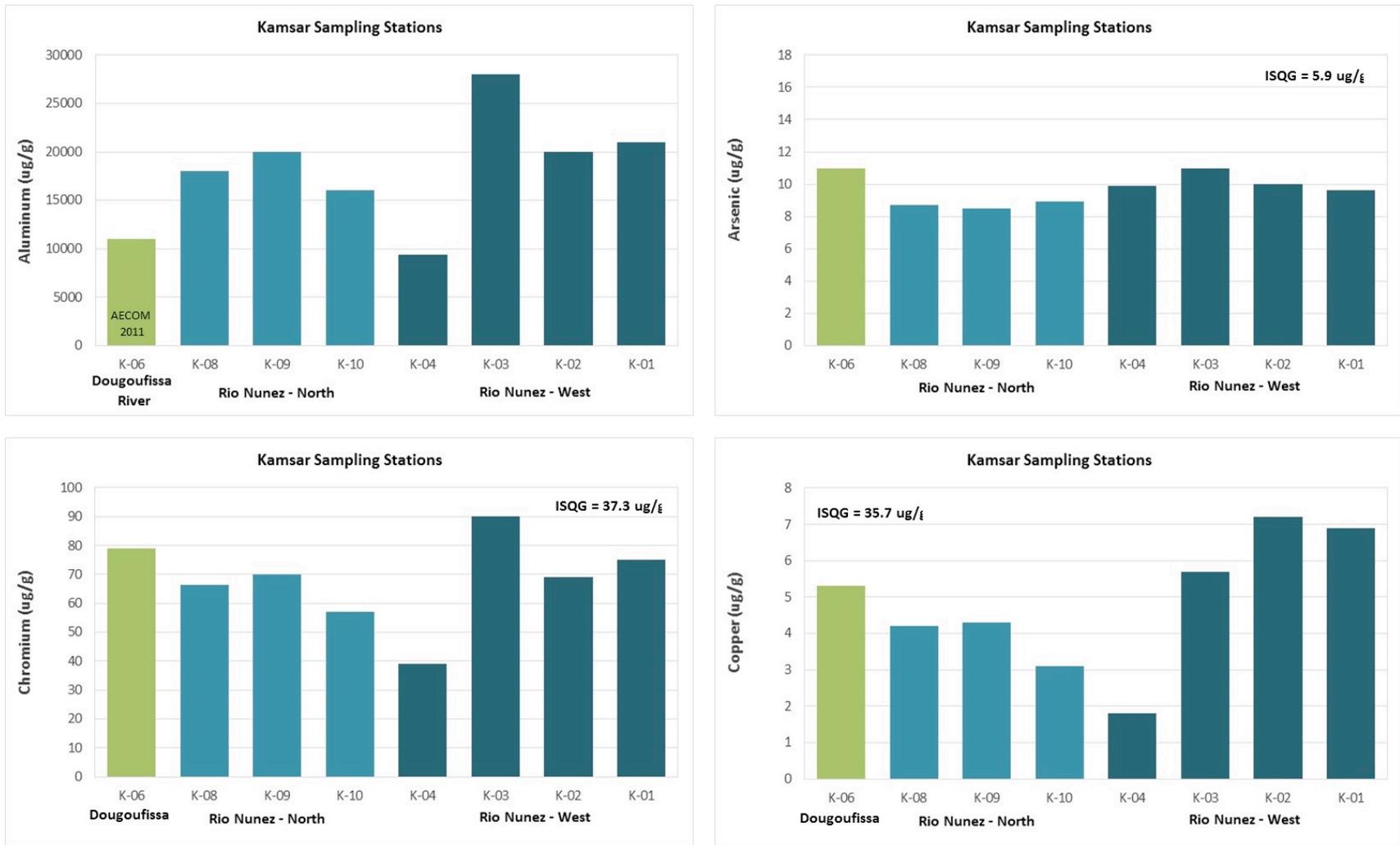
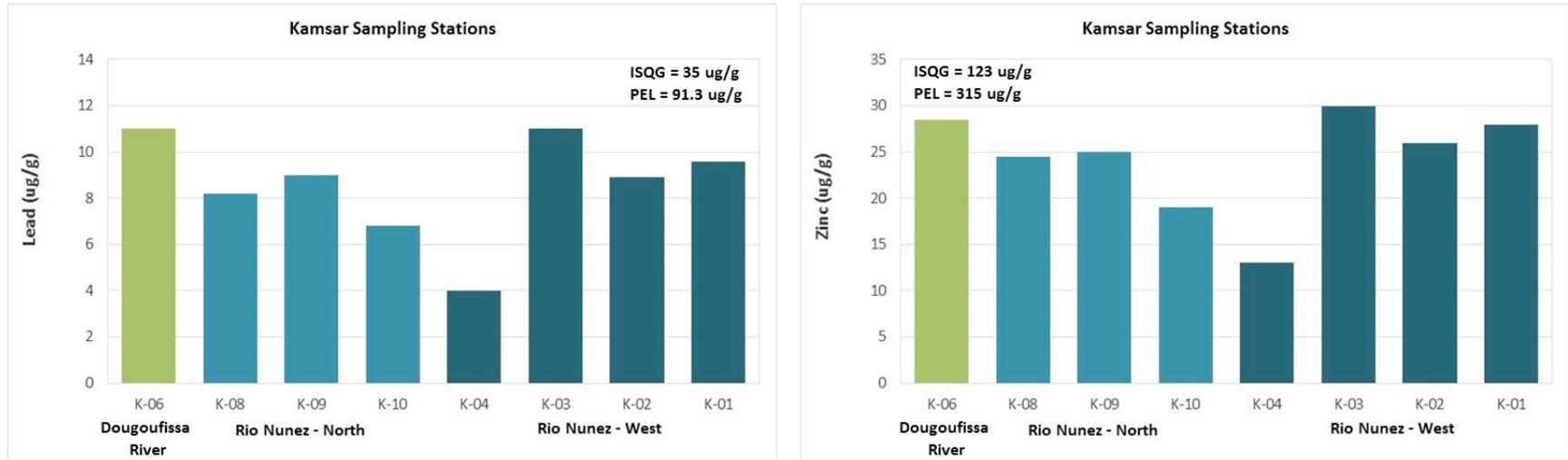


Figure 5.3: Concentrations of Selected Metal Constituents Measured in Kamsar Port Sediments (cont'd)



6.2 SANGARÉDI MINING AREA

6.2.1 Hydrology

Resulting from the abundant precipitation, an extensive river network has developed within the mining area which mainly falls within the watershed of the Cogon River with rivers such as the Thiapikouré, Boundou Wandé, Lafou, and Pora draining eastward to the Cogon River (see Figure 5.5). A watershed divide occurs in the west end of the study area with streams captured within the Tinguilinta River watershed flowing westward toward the Tinguilinta River. The Tinguilinta River drains an area of 1,891 km² and flows westward to Boké before joining the Rio Nuñez which flows into the Atlantic Ocean in the vicinity of Kamsar (Knight Piésold 2008).

With respect to the main rivers within the mining area, the Boundou Wandé River runs right through the middle of the current footprint of the mine operations, the Thiapikouré River to the northwest, and the Lafou River parallel to the operations to the south. All three rivers drain eastward into the Pora River, which in turn flows into the Cogon River. Further south, the Sitako River, which drains the Bidikoum plateau, also enters the Cogon River. The Cogon River is the largest river in the area and flows northwest to the border with Guinea-Bissau (379 km) and then southwest until it reaches the Rio Komponi estuary in the Atlantic Ocean.

6.2.2 Surface Water Quality

Surface water sampling in the mining area targeted locations upstream and downstream of the current mining operations along the main river systems, as well as some locations along streams in areas where mining operations are expected to expand. *In-situ* field measurements and sediment samples were also collected from the same locations which are shown in Figure 5.5. Sampling was conducted in June during the wet season with surface water temperatures ranging from 25.9 to 29.9 °C.

The results of *in-situ* field measurements taken with the YSI Pro Plus instrument at the time of surface water sampling are summarized in Table 6.65. Measurements were taken for pH, temperature, dissolved oxygen, conductivity as well as ammonium (NH₄⁺ as nitrogen), which was converted to total ammonia (NH₃ as nitrogen) using pH and temperature data.

As shown in Table 6.6, pH measurements in the Sangarédi rivers were acidic ranging from 5.03 to 6.47. The pH increased moving downstream of the mining operations to the east and north along the Cogon River where the highest pH value was recorded at station SW8. The standing surface water in the vicinity of the Sangarédi stockpile at the east end of the mining site was neutral (station SW9). The pH measured at all river stations in the mining area fell below the acceptable range of 6.5-9.0 for the protection of freshwater aquatic life recommended by the U.S.

EPA and CCME. Surface waters at all river stations were undersaturated with respect to dissolved oxygen which ranged in concentration from 3.8 to 7.7 mg/L. These dissolved oxygen concentrations generally fell below acceptable levels recommended by the U.S. EPA and CCME for the protection of freshwater warm aquatic biota for all life stages. The specific conductivity was orders of magnitude lower than the levels measured in surface waters at the Kamsar Port area with levels ranging from 9.6 to 21.5 $\mu\text{S}/\text{cm}$. Concentrations of total ammonia as nitrogen ranged from 0.28 mg-N/L to 0.87 mg-N/L and were well below U.S. EPA criteria and CCME guidelines recommended for total ammonia in freshwater for the protection of aquatic life. Ammonia levels do not appear to be elevated in surface waters, at least at the time of sampling, as might be expected with the use of explosives for blasting purposes during mining operations.

Additional field measurements on rivers in the Sangarédi Mining area were taken during the dry season in November and December of 2013 (Sylvatrop 2014). In this study, 21 sites spread over 11 rivers within the Cogon River basin were sampled with the objective of developing inventories of fish and aquatic macroinvertebrates. Measurements of pH indicated more neutral levels ranging from 6.8 to 8.3 while measurements of conductivity were similar ranging from 8.7 to 26.2 $\mu\text{S}/\text{cm}$. In another field campaign completed by AECOM during the wet (June) and dry (January) seasons in 2011 on two sites along the Boundou Wandé river upstream and downstream of mining operations and two sites along the Thiapikouré River upstream and downstream of Sangarédi, more acidic pH values were reported ranging from as low as 3.7 to 6.9. In the same study conductivity values ranged from 9 to 99 $\mu\text{S}/\text{cm}$.

Concentrations of general chemistry parameters and total metals measured in surface waters in the Sangarédi Mining area are summarized in Table 6.7. Where available, Table 6.7 also includes applicable water quality criteria/guidelines for the protection of freshwater aquatic life. These include CCC developed by the U.S. EPA and guidelines for chronic exposure developed by the CCME.

Consistent with the much lower conductivity levels measured in surface waters in the Sangarédi area relative to the Kamsar Port area, much lower levels of TDS, hardness and major ions were also observed. Total dissolved solids concentrations in Sangarédi rivers ranged from non-detectable (<10 mg/L) to 16 mg/L, hardness from 2.0 to 6.2 mg/L (as CaCO_3), while sulphate and chloride were not detected (<1 mg/L) at any of the stations that were sampled. The concentrations of major ions generally increased moving downstream of the mining operations; east toward the Pora River to station SW5 and north (downstream) along the Cogon River to station SW8. Concentrations of calcium ranged from 0.45 to 1.9 mg/L; magnesium from 0.23 to 0.54 mg/L; potassium from <0.20 to 0.82 mg/L; and, sodium from 0.40 to 1.5 mg/L. In addition, concentrations of boron and strontium were also several orders of magnitude lower in Sangarédi

surface waters relative to the Kamsar Port area with boron levels falling below the detection limit (<10 mg/L) and strontium ranging from 3.7 to 7.3 µg/L.

The majority of total metals concentrations reported in Sangarédi surface waters were below RDLs. With respect to cadmium, copper, lead and selenium, the RDL exceeded the most conservative criterion or guideline value included in Table 6.7. Given the lower RDL values reported on the Sangarédi total metals samples, a greater number of metal constituents were measured in Sangarédi surface waters relative to the Kamsar Port area. These include aluminum, barium, manganese, silicon and strontium that were detected at all of the river stations including in most cases station SW9 in the stockpile area. Iron, vanadium and zinc were also detected at most stations and lead and silver at station SW5 only in the Pora River. As seen from Figure 6.4, that were no discernible trends regarding metal concentrations in Sangarédi surface waters although higher concentrations of most metals, including lead and silver which are not shown, were generally measured in the Pora River (station SW5) downstream of the Thiapikouré, Boundou Wandé and Lafou rivers. Aluminum concentrations were highest at the upstream stations in the Lafou (SW3(2)) and Boundou Wandé (SW10) rivers and higher along the Cogon River at the station downstream of the mining operations (SW8) relative to the upstream station (SW7), although this trend was not noted for all detectable metals.

In comparing total metal concentrations to available criteria and guideline values included in Table 6.76, exceedances were noted for iron, lead, silver and zinc concentrations at station SW5 in the Pora River. Exceedances were also noted for iron at station SW2 (1100 µg/L) near Bowal 22 (Koobi) in the west end of the mining area, station SW6 (565 µg/L) downstream in the Lafou River, and station SW8 (480 µg/L) downstream in the Cogon River. During the 2011 study, AECOM (2011) reported most metal concentrations along the Boundou Wandé and Thiapikouré rivers as falling below RDLs. Measured concentrations were reported for aluminum (30 to 210 µg/L), barium (<20 to 23 µg/L), calcium (<0.5 to 7.1 mg/L), iron (730 to 6900 µg/L), manganese (14 to 260 µg/L), sodium (0.6 to 5.0 mg/L), zinc (5 to 10 µg/L). The upper limits of some of these concentration ranges exceed the CCME and/or U.S. EPA CCC benchmarks including aluminum, iron, and zinc.

Table 6.6: Summary of *In-situ* Field Measurements for Sangarédi Mining Area

Station	Location	pH ¹	Temperature (°C)	Dissolved Oxygen		Conductivity (µS/cm)	Ammonium (NH ₄ -N mg/L)	Total Ammonia (NH ₃ -N mg/L) ³
				(%)	(mg/L)			
Surface Water								
SW2	Adjacent to Bowal 22 - Koobi	5.94	25.9	65.4	5.31	10.5	0.28	0.28
SW12	Thiapikouré River	5.15	27.7	57.8	4.50	9.8	0.35	0.35
SW1	Thiapikouré River	5.69	27.5	60.0	4.79	9.6	0.70	0.70
SW10	Boundou Wandé River	5.68	29.9	51.4	3.83	11.0	0.50	0.50
SW3(2)	Lafou River	5.03	25.9	63.5	5.08	12.8	0.79	0.79
SW6	Lafou River	6.03	26.7	N/D	6.00	9.8	0.30	0.30
SW5	Pora River	6.06	27.6	97.7	7.70	21.5	0.87	0.87
SW7	Cogon River (upstream)	5.40	25.2	47.9	4.00	8.7	0.47	0.47
SW8	Cogon River (downstream)	6.47	29.1	89.4	6.83	18.5	0.74	0.74
SW11	Adjacent Bowal 9 - Mooule	5.40	26.0	85.4	6.93	14.3	0.49	0.49
SW9	Sangarédi stockpile area	7.06	33.5	94.6	6.70	17.7	0.75	0.76
Well Water								
SW3(1)	Horé Lafou_well	7.09	29.0	33.0	2.53	267.8	0.68	0.69
SW4	Hamdallaye_well	6.97	29.1	44.1	3.37	291.0	0.71	0.72
Notes:								
¹ U.S. EPA CCC and CCME guideline for pH in freshwater is 6.5-9.0.								
² U.S. EPA criterion for dissolved oxygen in freshwater varies from ≥3.0 (1-day minimum) to ≥6.0 (7-day mean) mg/L for early and other life stages for warm biota; CCME guideline for dissolved oxygen in freshwater varies from ≥5.5 to ≥6.0 mg/L for early and other life stages respectively for warm biota.								
³ U.S. EPA chronic (30-day rolling average) criterion for total ammonia in freshwater is 1.9 mg-N/L (at pH=7.0 and T=20 °C); CCME guideline for total ammonia varies with pH and temperature ranging from 1.97 mg-N (1.97 mg-N/L at pH=7.0 and T=30 °C to 29.6 mg-N/L at pH=6.0 to T=25 °C).								
U.S. EPA - United States Environmental Protection Agency. 2014. Aquatic Life Criteria Table; CCC – Criterion Continuous Concentration.								
CCME - Canadian Council of Ministers of the Environment. 2014. Water Quality Guidelines for the Protection of Aquatic Life.								

Constituent	Unit	Reportable Detection Limit (RDL)	Guidelines - Protection of Aquatic Life (Freshwater)		Bowal 22 Koobi	Thiapikouré River		Bondou Wandé River	Lafou River	
			U.S. EPA (CCC) ¹	CCME (Chronic) ²	SW2	SW12	SW1	SW10	SW3(2)	SW6
General Chemistry										
Dissolved Chloride	mg/L	1	-	120	<1	<1	<1	<1	<1	<1
Dissolved Organic Carbon (DOC)	mg/L	0.20	-	-	2.1	0.57	0.84	1.2	<0.20	
Dissolved Sulphate	mg/L	1	-	-	<1	<1	<1	<1	<1	
Hardness (as CaCO ₃)	mg/L	1.0	-	-	2.9	2.0	2.7	3.1	2.7	
pH	pH	N/A	-	6.5 - 9	6.39	6.36	6.57	6.35	6.24	
Total Alkalinity (as CaCO ₃)	mg/L	1.0	-	-	3.2	2.8	4.1	3.3	3.7	
Total Dissolved Solids (TDS)	mg/L	10	-	-	12	14	12	<10	<10	
Total Suspended Solids (TSS)	mg/L	10	-	-	<10	<10	<10	<10	<10	
Total Metals										
Aluminum	µg/L	5.0	87	100 (P)	52	40	27	69	82	
Antimony	µg/L	0.50	-	-	<0.50	<0.50	<0.50	<0.50	<0.50	<
Arsenic	µg/L	1.0	150 (D)	5	<1.0	<1.0	<1.0	<1.0	<1.0	<
Barium	µg/L	2.0	-	-	5.0	4.6	3	5.3	5.3	
Beryllium	µg/L	0.50	-	-	<0.50	<0.50	<0.50	<0.50	<0.50	<
Bismuth	µg/L	1.0	-	-	<1.0	<1.0	<1.0	<1.0	<1.0	<
Boron	µg/L	10	-	-	<10	<10	<10	<10	<10	
Cadmium	µg/L	0.10	0.025 (DH)	0.09	<0.10	<0.10	<0.10	<0.10	<0.10	<
Calcium	mg/L	0.200	-	-	0.800	0.620	1000	0.940	0.590	0
Chromium (total)	µg/L	5.0	-	-	<5.0	<5.0	<5.0	<5.0	<5.0	
Cobalt	µg/L	0.50	-	-	<0.50	<0.50	<0.50	<0.50	<0.50	<
Copper	µg/L	1.0	0.60 (DH)	2 (H)	<1.0	<1.0	<1.0	<1.0	<1.0	<
Iron	µg/L	100	1000	300	1100	<100	650	300	<100	
Lead	µg/L	0.50	0.053 (DH)	1 (H)	<0.50	<0.50	<0.50	<0.50	<0.50	<
Lithium	µg/L	5.0	-	-	<5.0	<5.0	<5.0	<5.0	<5.0	
Magnesium	mg/L	0.050	-	-	0.320	0.230	240	0.300	0.300	0
Manganese	µg/L	2.0	-	-	12	4.9	9	7.7	5.6	
Molybdenum	µg/L	0.50	-	73	<0.50	<0.50	<0.50	<0.50	<0.50	<
Nickel	µg/L	1.0	3.4 (DH)	25 (H)	<1.0	<1.0	<1.0	<1.0	<1.0	
Potassium	mg/L	0.200	-	-	0.650	<0.200	250	0.340	<0.200	0
Selenium	µg/L	2.0	-	1	<2.0	<2.0	<2.0	<2.0	<2.0	<
Silicon	µg/L	50	-	-	2500	1900	1600	1500	2100	1
Silver	µg/L	0.10	-	0.1	<0.10	<0.10	<0.10	<0.10	<0.10	<
Sodium	mg/L	0.100	-	-	0.850	0.490	720	0.610	0.630	0
Strontium	µg/L	1.0	-	-	4.1	3.7	4.0	4.8	4.2	
Tellurium	µg/L	1.0	-	-	<10	<10	<10	<10	<10	
Thallium	µg/L	0.050	-	-	<0.050	<0.050	<0.050	<0.050	<0.050	<0
Tin	µg/L	1.0	-	-	<1.0	<1.0	<1.0	<1.0	<1.0	
Titanium	µg/L	5.0	-	-	<5.0	<5.0	<5.0	<5.0	<5.0	
Tungsten	µg/L	1.0	-	-	<1.0	<1.0	<1.0	<1.0	<1.0	
Uranium	µg/L	0.10	-	15	<0.10	<0.10	<0.10	<0.10	<0.10	<
Vanadium	µg/L	0.50	-	-	0.62	<0.50	<0.50	0.5	<0.50	<
Zinc	µg/L	5.0	7.84 (DH)	30	<5.0	5.6	10	5.3	<5.0	<
Zirconium	µg/L	1.0	-	-	<1.0	<1.0	<1.0	<1.0	42	

Notes:

¹ United States Environmental Protection Agency (U.S. EPA). 2014. Aquatic Life Criteria Table; CCC – Criterion Continuous Concentration.

² Canadian Council of Ministers of the Environment (CCME). 2014. Water Quality Guidelines for the Protection of Aquatic Life.

D – converted from dissolved concentration to total concentration using Appendix A – Conversion Factors for Dissolved Metals (US EPA 2014); conversion for cadmium and lead assumed a mean water hardness of 4.0 mg
DH – converted from dissolved concentration to total concentration as outlined for D and adjusted for hardness using Appendix B – Parameters for Calculating Freshwater Dissolved Metals Criteria that are Hardness Depen

Figure 6.4: Total Concentrations of Selected Metal Constituents Measured in Sangarédi Surface Waters

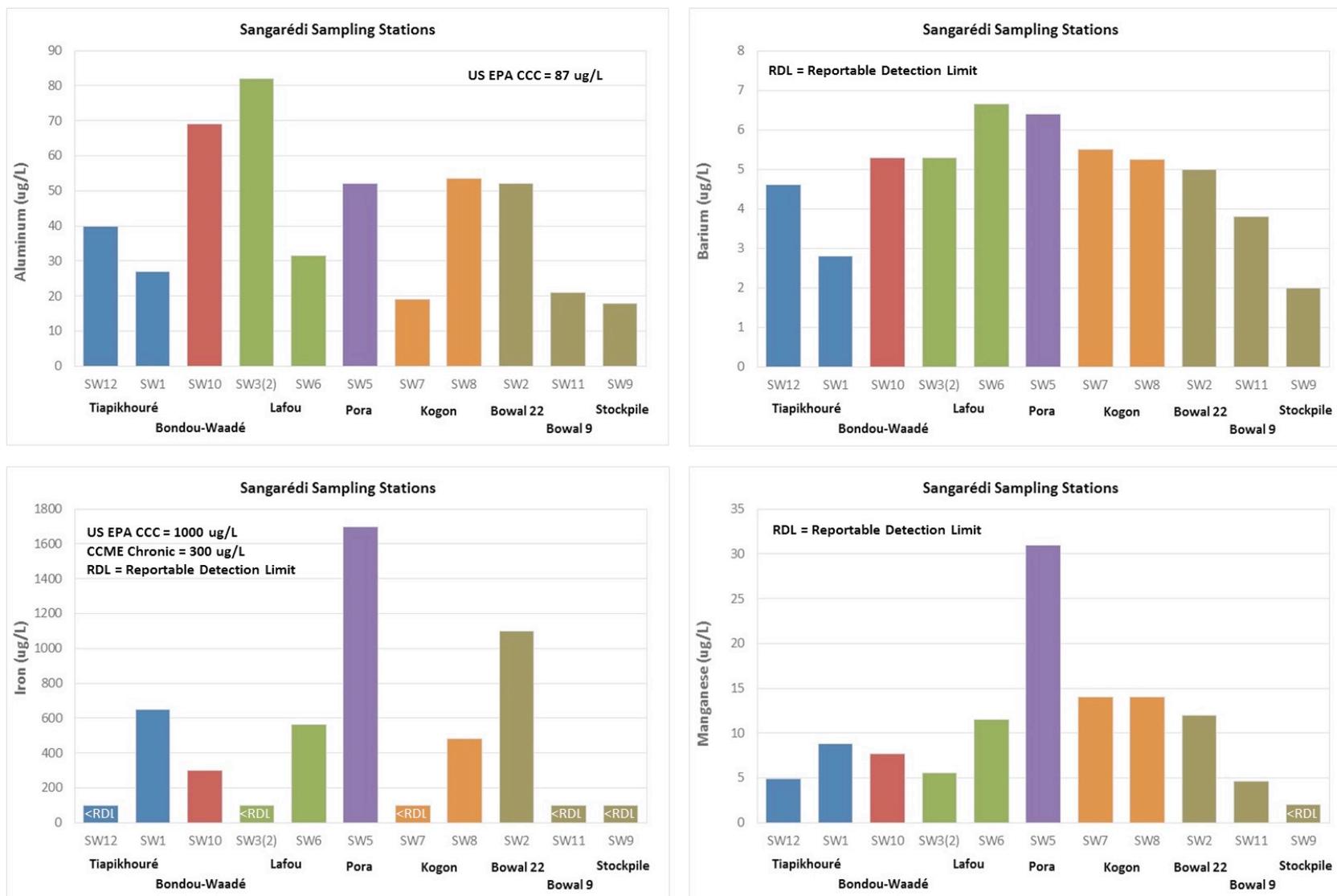
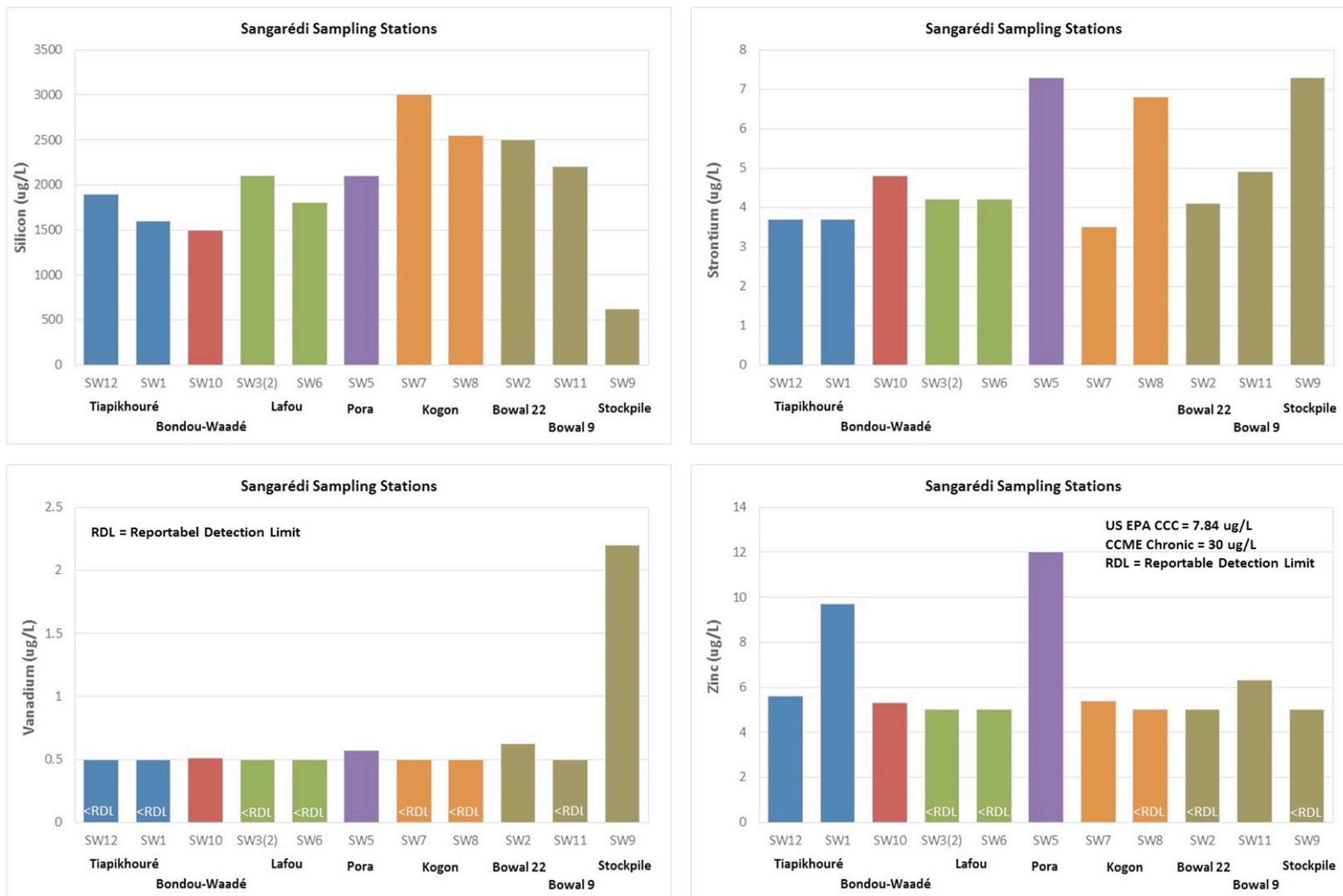


Figure 6.5: Total Concentrations of Selected Metal Constituents Measured in Sangarédi Surface Waters (Cont'd)



6.2.3 Sediment Quality

Concentrations of metals as well as the TOC and moisture content of sediments collected from waterbodies in the Sangarédi Region are summarized in Table 6.8. Where available the table also includes available CCME sediment quality guidelines for the protection of freshwater aquatic life. These include ISQG and PELs, which are available for arsenic, chromium, copper, lead, mercury and zinc.

The moisture content of all sediment samples typically ranged from about 20% to 30% with the exception of sediment from the Boundou-Waadé River (SW10) which had a moisture content of 63%. The TOC content was also higher in this sample with a concentration of 140,000 mg/kg relative to a range of 6,800 to 37,000 mg/kg measured in the remaining samples.

As shown in Table 6.10, low concentrations falling below the RDL were generally measured for several metals including bismuth, boron, cadmium, mercury, selenium, silver, and tin. The chromium concentration in all Sangarédi sediment samples exceeded both the ISQG and PEL. The ISQG for arsenic was exceeded in all river samples except in sediment from the Boundou Wandé River (SW10) and the stream near Bowal 9 (Mooule) (SW11) in the north end of the mining area. In addition, the PEL for arsenic was exceeded at the downstream station (SW1) in the Thiapikouré River and at the upstream station (SW7) in the Cogon River. Exceedances of the ISQG were also noted for copper at SW5 in the Pora River and SW11, lead at SW1 and SW5, and zinc at SW5. The greatest number of guideline exceedances were noted in the Pora River, at station SW5 which occurs downstream of the Thiapikouré, Boundou Wandé and Lafou rivers. At this station, arsenic, copper, lead and zinc concentrations exceeded respective ISQG values while the chromium concentration exceeded the PEL.

The concentrations of aluminum and metal constituents exceeding sediment quality guidelines in Sangarédi sediment samples are summarized in Figure 6.5. Aluminum concentrations ranged from 32,000 µg/g at stations SW1 downstream in the Thiapikouré River to 76,000 µg/g at station SW11 in the stream near Bowal 9 (Mooule) in the northern portion of the mining area. Concentrations appear to decrease moving eastward towards the Pora River. It is noteworthy that the concentrations of all of the metal constituents included in Figure 6.5 were higher at station SW7 in the Cogon River which is upstream of the main mining operations relative to station SW8 which occurs downstream of the confluence with the Pora River and mining operations.

Constituent	Units	Reportable Detection Limit (RDL)	CCME - Sediment Quality, Aquatic Life (Freshwater) ¹		Thiapihouré River		Bondou Wandé River	Lafo
			ISQG	PEL	SW12	SW1	SW10	S
			mg/g dw	mg/g dw				
Inorganics								
Moisture	%	1	-	-	25	17	63	
Total Organic Carbon	mg/kg	500	-	-	42000	6800	140000	
Metals								
Aluminium	µg/g	250	-	-	75000	32000	60000	
Antimony	µg/g	0.2	-	-	0.57	2.4	0.21	
Arsenic	µg/g	1	5.9	17	5.1	18	1.8	
Barium	µg/g	0.5	-	-	41	20	46	
Beryllium	µg/g	0.2	-	-	0.95	0.40	1.8	
Bismuth	µg/g	1	-	-	<1.0	<1.0	<1.0	
Boron	µg/g	5	-	-	<5.0	<5.0	<5.0	
Cadmium	µg/g	0.1	0.6	3.5	<0.10	<0.10	<0.10	
Calcium	µg/g	50	-	-	270	590	250	
Chromium	µg/g	5	37.3	90	260	430	100	
Cobalt	µg/g	0.1	-	-	8.0	2.5	5.0	
Copper	µg/g	0.5	35.7	197	30	27	21	
Iron	µg/g	250	-	-	96000	150000	24000	
Lead	µg/g	1	35	91.3	22	39	15	
Lithium	µg/g	1	-	-	13	1.1	12	
Magnesium	µg/g	50	-	-	840	150	940	
Manganese	µg/g	1	-	-	140	89	41	
Mercury	µg/g	0.05	0.170	0.486	<0.050	<0.050	0.086	
Molybdenum	µg/g	0.5	-	-	1.9	3.7	0.97	
Nickel	µg/g	0.5	-	-	24	12	20	
Phosphorous	µg/g	50	-	-	850	560	1100	
Potassium	µg/g	200	-	-	600	<200	630	
Selenium	µg/g	0.5	-	-	<0.50	<0.50	<0.50	
Silver	µg/g	0.2	-	-	<0.20	<0.20	<0.20	
Sodium	µg/g	100	-	-	<100	<100	110	
Strontium	µg/g	1	-	-	5.1	2.3	5.0	
Thallium	µg/g	0.05	-	-	0.12	<0.050	0.1	
Tin	µg/g	5	-	-	<5.0	<5.0	<5.0	
Titanium	µg/g	25	-	-	470	430	N/A	
Uranium	µg/g	0.05	-	-	2.0	2.5	1.7	
Vanadium	µg/g	25	-	-	260	330	120	
Zinc	µg/g	5	123	315	39	100	29	

Notes:

¹ Canadian Council of Ministers of the Environment (CCME). 2013. Sediment Quality Guidelines for the Protection of Aquatic Life.

ISQG – Interim Sediment Quality Guideline.

PEL – Probable Effect Level.

Highlighted – highlighted values in bold font denote concentrations exceeding the ISQG; **Highlighted and underlined** – highlighted and underlined values in bold font denote concentrations exceeding both the ISQG and PEL.

Figure 6.5: Concentrations of Selected Metal Constituents Measured in Sangarédi Region Sediments

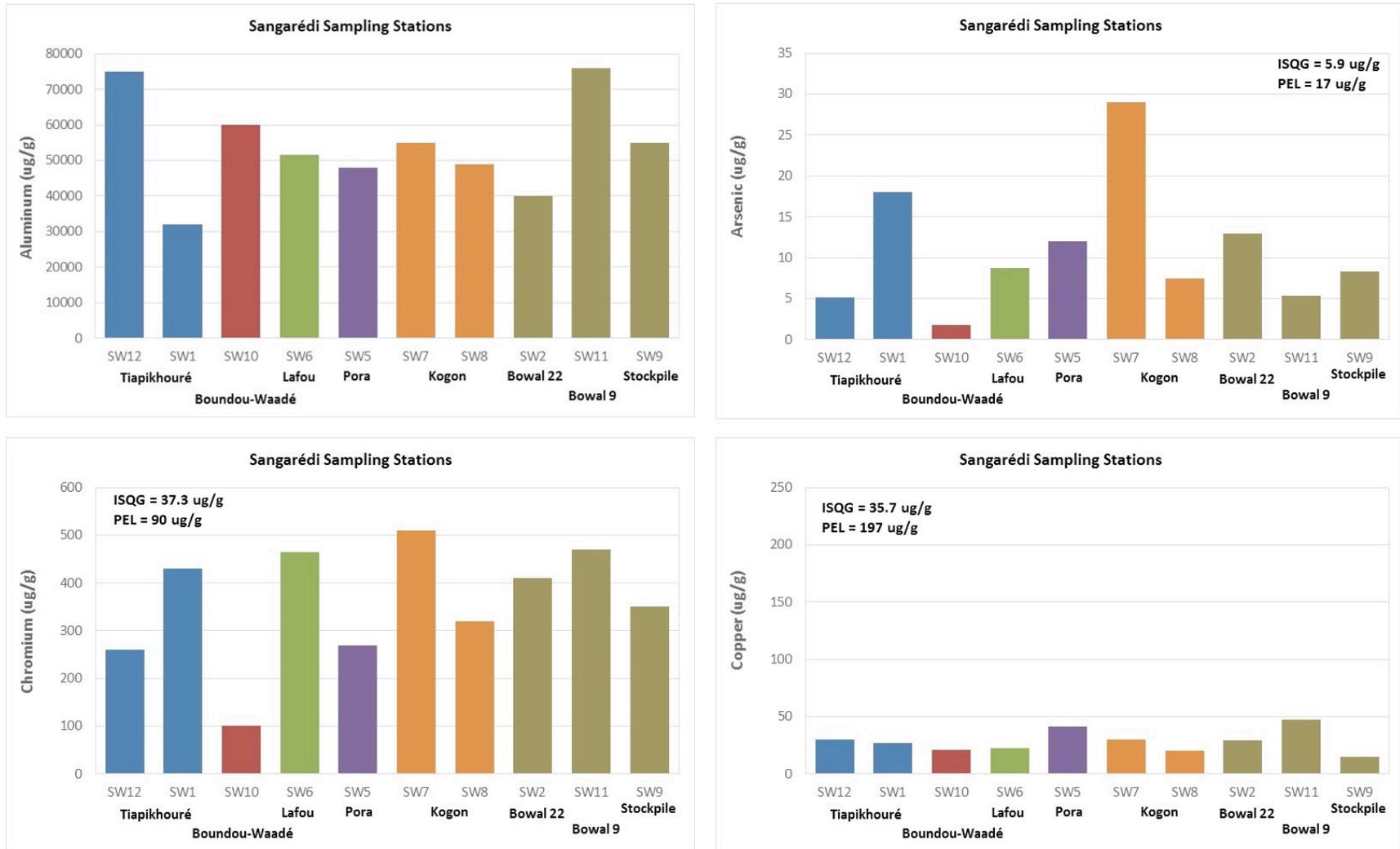
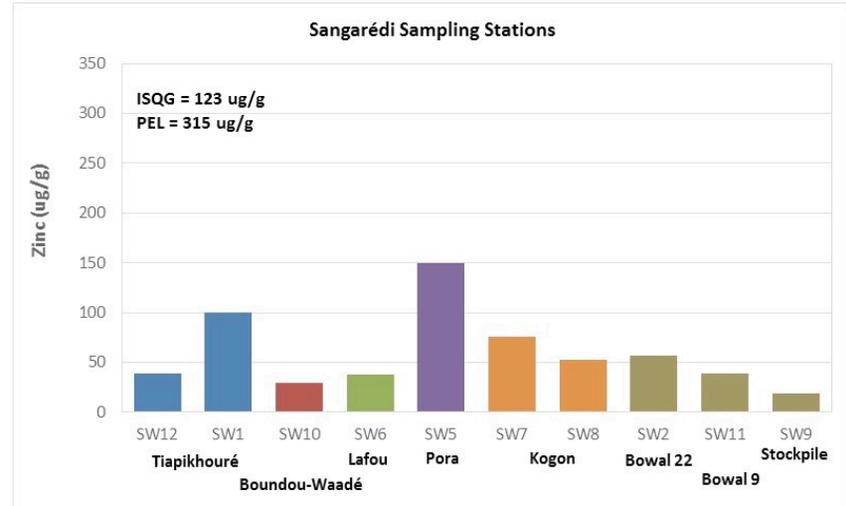
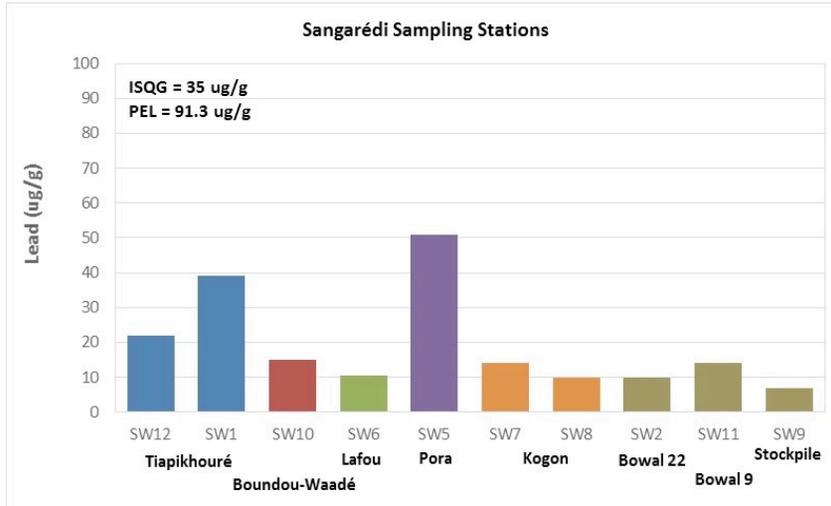


Figure 5.6: Concentrations of Selected Metal Constituents Measured in Sangarédi Region Sediments (cont'd)



6.2.4 Well Water Quality

A few well water samples were also collected from villages within the mining area to obtain an indication of groundwater quality.

Concentrations of general chemistry parameters and total metals measured in well water samples collected from a few villages in the Sangarédi Region are summarized in Table 6.9. It should be noted that the metal samples were not filtered during sample collection or prior to analysis. Thus, concentrations shown in 8 are for total constituent concentrations. Where available, Table 6.9 also includes applicable guidelines for drinking water quality. These include Guidelines for Drinking-water Quality by the World Health Organization (WHO) and the European Union (EU) Council Directive 98/83/EC (November 3rd, 1998) on the quality of water intended for human consumption.

As seen from Table 6.9, iron (1100 µg/L) and manganese (110 µg/L) concentrations in the well sample from Horé Lafou both exceeded the EU guideline values of 200 µg/L for iron and 50 µg/L for manganese.

Table 6.9: Summary of Well Water Quality for the Sangarédi Mining Area

Constituent	Unit	Reportable Detection Limit (RDL)	Drinking Water Guidelines		Horé Lafou	Hamdallaye
			WHO ¹	EU ²	SW3(1)	SW4
General Chemistry						
Dissolved Chloride	mg/L	1	-	250	<1	<1
Dissolved Organic Carbon (DOC)	mg/L	0.20	-	-	0.30	<0.20
Dissolved Sulphate	mg/L	1	-	250	<1	<1
Hardness (CaCO ₃)	mg/L	1.0	-	-	120	130
pH	pH	N/A	-	-	7.62	7.77
Total Alkalinity (as CaCO ₃)	mg/L	1.0	-	-	130	140
Total Dissolved Solids (TDS)	mg/L	10	-	-	166	176
Total Suspended Solids (TSS)	mg/L	10	-	-	<10	<10
Total Metals						
Aluminum	µg/L	5.0	-	200	<5.0	6.9
Antimony	µg/L	0.50	20	5	<0.50	<0.50
Arsenic	µg/L	1.0	10	10	<1.0	<1.0
Barium	µg/L	2.0	700	-	18	<2.0
Beryllium	µg/L	0.50	-	-	<0.50	<0.50
Bismuth	µg/L	1.0	-	-	<1.0	<1.0
Boron	µg/L	10	2400	1000	<10	<10
Cadmium	µg/L	0.10	3	5	<0.10	<0.10
Calcium	µg/L	200	-	-	28000	36000
Chromium (total)	µg/L	5.0	50	50	<5.0	<5.0
Cobalt	µg/L	0.50	-	-	<0.50	<0.50
Copper	µg/L	1.0	2000	2000	<1.0	<1.0
Iron	µg/L	100	-	200	1100	<100
Lead	µg/L	0.50	10	10	<0.50	<0.50
Lithium	µg/L	5.0	-	-	16	7.1
Magnesium	µg/L	50	-	-	11000	8700
Manganese	µg/L	2.0	-	50	110	24
Molybdenum	µg/L	0.50	-	-	<0.50	<0.50
Nickel	µg/L	1.0	70	20	<1.0	<1.0
Potassium	µg/L	200	-	-	1800	990
Selenium	µg/L	2.0	40	10	<2.0	<2.0
Silicon	µg/L	50	-	-	29000	35000
Silver	µg/L	0.10	-	-	<0.10	<0.10
Sodium	µg/L	100	-	200000	13000	15000
Strontium	µg/L	1.0	-	-	200	85
Tellurium	µg/L	1.0	-	-	<10	<10
Thallium	µg/L	0.050	-	-	<0.050	<0.050
Tin	µg/L	1.0	-	-	<1.0	<1.0
Titanium	µg/L	5.0	-	-	<5.0	<5.0
Tungsten	µg/L	1.0	-	-	<1.0	<1.0
Uranium	µg/L	0.10	30	-	<0.10	<0.10
Vanadium	µg/L	0.50	-	-	<0.50	3.5
Zinc	µg/L	5.0	-	-	<5.0	5.1
Zirconium	µg/L	1.0	-	-	<1.0	<1.0
Notes:						
¹ World Health Organization (WHO). 2011. Guidelines for Drinking-water Quality, Fourth Edition.						
² The Council of the European (EU). 1998. Council Directive 98/83/EC of November 1998 on the Quality of Water Intended for Human Consumption.						

7.0 IMPACT EVALUATION

People that live in the area use surface water and groundwater for potable purposes as well as for agriculture.

The ESIA presents an analysis of how the Project will interact with its physical environment. The environmental assessment process progressed through the following steps:

- The project components were identified and selected while considering a number of key factors, including constraints related to public safety, environmental, socio-economical and terrestrial conditions and cost;
- Field data about the host environment was being obtained where applicable and practical, and VECs were selected, based on a number of criteria, including public value and scientific interest;
- The Project Team collaborated to identify ways that the Project might affect the environment. The Project Team then identified ways to mitigate those potential impacts;
- Once the Project Description was finalized, residual impacts (i.e., those that remain after mitigation) were predicted; and,
- Residual impacts were characterized and the significance of these impacts was determined by considering the value of the VEC and the potential importance of the impact.

Please note that the potential impacts due to Accidents and Malfunctions (spills, hazardous material handling, etc.) is being addressed separately.

7.1 WASTEWATER

Everyday discharge of wastewater coming from additional operations of the project is only considered a source of impact for surface water. For everyday wastewater discharges after improvement of CBG procedures and installations aiming to prevent contaminant discharge to surface water, the magnitude of the impact is considered medium (see Table 7.1).

For the change in surface water quality by everyday wastewater discharges, the intensity of the impact is considered low, because uncertainty exists on the efficiency of the foreseen implementation measures related to the new procedures on the management of hazardous materials and maintenance operations.

The geographic extent is regional since the effects extend beyond the project site but are limited to the study area. The duration is limited to the operation phase.

Table 7.1: Summary of Wastewater Impacts on Surface Water

Impacts	Criteria	Classification
Change in surface water quality by everyday wastewater discharges after improvement of CBG procedures and operations aiming to prevent contaminant discharge to surface water.	Value - High Intensity - Low Geographic Extent - Local Duration - Long	Medium

7.2 SURFACE WATER

7.2.1 Methodology

CBG is currently planning to expand its bauxite production rate starting with 18.5 MTPA, to a plant capacity of 22.5 MTPA by January 2017 and a further increase of 5 MTPA to a plant capacity of 27.5 MTPA by 2022. In the assessment of potential impacts to surface water quality, the existing condition (13.5 MTPA), and three expanded production scenarios were considered:

- Existing - 13.5 MTPA;
- Expansion to 18.5 MTPA;
- Expansion to 22.5 MTPA; and
- Expansion to 27.5 MTPA.

Estimates of dust deposition in each study area that were output from the air quality assessment, were used to estimate constituent concentrations in surface waters. Where potential impacts to surface water quality are identified it is assumed that impacts to sediment quality may also be observed over time. However, the limited surface water/sediment dataset precludes any quantitative evaluation of potential impacts to sediment quality.

7.2.2 Assessment

7.2.2.1 Kamsar Port Area

The predicted annual average dust deposition rates over water and land in the Kamsar Port area for the existing and the three future production expansion scenarios are presented in Table 7.2 and Table 7.3, respectively. The dust (including metal constituents) deposition rates for the three future production expansion scenarios are either lower or similar to the existing scenario due to the mitigation measures that will be implemented during expanded phases of the Project. For

instance, the expected increase in dust emissions resulting from the higher production rate at the processing facility at Kamsar will be offset by the addition of dust suppression systems. Hence, increased production is not expected to result in any change to the water quality and sediment quality in the marine environment in the Kamsar Port Area.

Table 7.2: Predicted Deposition Rates over Surface Water at Kamsar Port Area

Scenario	Average over Water - Deposition Rate in g/m ² /s							
	TSP	Al	Sb	As	Cd	Cr	Cu	Ni
Existing (13.5 MTPA)	1.2x10 ⁻⁶	3.2x10 ⁻⁷	4.5x10 ⁻¹²	3.5x10 ⁻¹¹	3.0x10 ⁻¹³	1.4x10 ⁻⁹	1.5x10 ⁻¹⁰	7.4x10 ⁻¹¹
18.5 MTPA	1.1x10 ⁻⁶	2.9x10 ⁻⁷	4.1x10 ⁻¹²	3.2x10 ⁻¹¹	2.8x10 ⁻¹³	1.2x10 ⁻⁹	1.4x10 ⁻¹⁰	6.7x10 ⁻¹¹
22.5 MTPA	6.4x10 ⁻⁷	1.7x10 ⁻⁷	2.6x10 ⁻¹²	1.9x10 ⁻¹¹	1.8x10 ⁻¹³	7.1x10 ⁻¹⁰	8.0x10 ⁻¹¹	4.2x10 ⁻¹¹
27.5 MTPA	1.2x10 ⁻⁶	3.3x10 ⁻⁷	4.7x10 ⁻¹²	3.6x10 ⁻¹¹	3.2x10 ⁻¹³	1.4x10 ⁻⁹	1.6x10 ⁻¹⁰	7.7x10 ⁻¹¹

Table 7.3: Predicted Deposition Rates over Land at Kamsar Port Area

Scenario	Average over Land - Deposition Rate in g/m ² /s							
	TSP	Al	Sb	As	Cd	Cr	Cu	Ni
Existing (13.5 MTPA)	2.4x10 ⁻⁶	6.3x10 ⁻⁷	1.0x10 ⁻¹¹	7.0x10 ⁻¹¹	7.2x10 ⁻¹³	2.6x10 ⁻⁹	3.0x10 ⁻¹⁰	1.7x10 ⁻¹⁰
18.5 MTPA	2.0x10 ⁻⁶	5.4x10 ⁻⁷	9.3x10 ⁻¹²	5.9x10 ⁻¹¹	6.5x10 ⁻¹³	2.2x10 ⁻⁹	2.6x10 ⁻¹⁰	1.5x10 ⁻¹⁰
22.5 MTPA	1.1x10 ⁻⁶	2.9x10 ⁻⁷	6.4x10 ⁻¹²	3.3x10 ⁻¹¹	4.6x10 ⁻¹³	1.2x10 ⁻⁹	1.4x10 ⁻¹⁰	1.1x10 ⁻¹⁰
27.5 MTPA	1.6x10 ⁻⁶	4.1x10 ⁻⁷	8.8x10 ⁻¹²	4.6x10 ⁻¹¹	6.3x10 ⁻¹³	1.7x10 ⁻⁹	2.0x10 ⁻¹⁰	1.4x10 ⁻¹⁰

Potential acidification of surface water due to emissions of SO₂ and NO₂ was also considered. Although the air quality assessment showed that concentrations will increase with production, the prevailing wind direction is northeast (not onto the water), as can be seen with the annual NO₂ figures provided in the air quality assessment report. Thus, it is not expected that the operation would have an effect on the pH of the surface waters.

Another consideration for Kamsar is that the Port is regularly dredged, once every two to three years. This activity was last undertaken in 2012 and approximately 100,000 m³ of material was removed. In addition, as the Project ramps up, the turning basin at the existing quay will need to be enlarged for when production reaches 22.4 MTPA, while a second turning basin will be required when production reaches 27.5 MTPA. An estimated 418,000 m³ of material (over approximately 75 hectares) will need to be dredged to implement these changes. During and for a short period of time following dredging, it is expected that elevated constituent concentrations would be observed in surface water. In addition, this obviously represents a significant disturbance to sediment. It is anticipated that dredging will occur every two to three years.

A summary of the impacts associated with the project is included in Table 7.4. The only potential impact noted was for changes in sediment quality due to dredging. This would have a high impact on the sediment within the area dredged. The duration is short but on a periodic basis throughout the project.

Table 7.4: Summary of Surface Water Impacts for Kamsar

VEC (Sub-component)	Impacts	Criteria	Classification
Surface water – Marine (water quality)	Change in surface water quality by deposition of air releases.	Value of VEC - High Intensity - None Geographic Extent - Local Duration - Long	No residual impact.
Surface water – Marine (sediment quality)	Change in sediment quality resulting from water quality changed due to deposition of air releases.	Value of VEC - High Intensity - None Geographic Extent - Local Duration - Long	No residual impact.
Surface water – Marine (water quality)	Change in surface water quality due to suspension of sediments during dredging.	Value of VEC - High Intensity - Low Geographic Extent - Local Duration - Short	Medium
Surface water – Marine (sediment quality)	Change in sediment quality due to an increase in the extent of dredging.	Value of VEC - High Intensity - High Geographic Extent - Local Duration - Short	High

7.2.2.2 Sangarédi Mining Area

The predicted annual average dust deposition rates over land at Sangarédi for the existing and the three future production expansion scenarios are presented in Table 7.5. Deposition rates go up as production increases with the exception of the 27.5 MTPA scenario. In that scenario, mining activities will be in a different area and the locations where extraction is occurring will be closer together while the route along the haul road connecting the mining area with the storage area at the port is direct. Thus, although the predicted concentrations are higher in the 27.5 MTPA scenario, the area of impact is smaller and thus the average value is lower than the other scenarios. It is acknowledged that there is the potential for a larger impact on some of the smaller rivers, this risk is expected to be highest in the 27.5 MTPA due to the higher concentrations.

The results shown in Table 7.5 indicate that the deposition of dust and associated metals can increase by almost 60%. See *CBG Air Quality Impact Assessment* for details regarding the different assumptions used for each scenario.

Table 7.5: Predicted Deposition Rates over Land at Sangarédi Mining Area

Scenario	Average over Land - Deposition Rate in g/m ² /s							
	TSP	Al	Sb	As	Cd	Cr	Cu	Ni
Existing (13.5 MTPA)	3.5x10 ⁻⁷	2.4x10 ⁻⁸	3.1x10 ⁻¹³	2.6x10 ⁻¹²	2.0x10 ⁻¹⁴	1.0x10 ⁻¹⁰	1.1x10 ⁻¹¹	5.0x10 ⁻¹²
18.5 MTPA	5.2x10 ⁻⁷	3.4x10 ⁻⁸	4.3x10 ⁻¹³	3.7x10 ⁻¹²	2.9x10 ⁻¹⁴	1.4x10 ⁻¹⁰	1.6x10 ⁻¹¹	7.0x10 ⁻¹²
22.5 MTPA	6.1x10 ⁻⁷	3.8x10 ⁻⁸	4.8x10 ⁻¹³	4.1x10 ⁻¹²	3.2x10 ⁻¹⁴	1.6x10 ⁻¹⁰	1.8x10 ⁻¹¹	7.9x10 ⁻¹²
27.5 MTPA	5.1x10 ⁻⁷	2.7x10 ⁻⁸	3.4x10 ⁻¹³	3.0x10 ⁻¹²	2.3x10 ⁻¹⁴	1.1x10 ⁻¹⁰	1.3x10 ⁻¹¹	5.6x10 ⁻¹²

A (quasi) mass balance approach was used to assess the impacts of the increased dust deposition (and its metal constituents) to the surface water quality of rivers included within the Sangarédi Mine study area. Figure 7.1 shows the river network and surface water sampling locations relative to the mining operations. As limited information on drainage areas and flow rates are available for these river systems, the assessment focused on the Cogon River for which flow statistics are available from the Guinea Alumina Project (Knight Piésold 2008). For the assessment, the entire mine area was conservatively assumed to occur within the drainage area of the Cogon River and 50% of the deposition to land was assumed to find its way into the Cogon River.

The predicted surface water concentrations in the Cogon River resulting from air deposition in the Sangarédi Mine area are presented in Table 7.6. The maximum measured concentrations in the two samples collected from the Cogon River (SW7 and SW8) are compared to the predicted concentrations in the Existing scenario and the predicted values agree well with the measured data. The concentrations of all metals that were modelled are predicted to remain low with the possible exception of aluminum. Aluminum surface water concentrations in the Sangarédi Mine area may potentially be impacted by increased production rates.

Table 7.6: Predicted Surface Water Concentrations Resulting from Air Deposition

Scenario	Incremental Concentrations (µg/L) in Cogon River due to Air Deposition						
	Al	Sb	As	Cd	Cr	Cu	Ni
Existing (13.5 MTPA)	65	0.001	0.007	0.00006	0.28	0.031	0.014
18.5 MTPA	91	0.001	0.010	0.00008	0.38	0.044	0.019
22.5 MTPA	102	0.001	0.011	0.00009	0.43	0.049	0.021
27.5 MTPA	73	0.001	0.008	0.00006	0.31	0.035	0.015
Max Measured	54	<0.5	<1.0	<0.1	<5.0	<1.0	<1.0

This screening-level assessment indicated that it is possible that the project will have an influence on water quality in the area, particularly for aluminum. It is noted that impacts may be more significant to smaller rivers and streams due to lower flow rates; however, these effects would be localized.

The pH in surface waters in the area ranges from 5 to 6.5, which is somewhat acidic. DOC in the samples collected from the area are in the range of 1 to 2 mg/L. In general, more inorganic and organic aluminum is present as the water pH decreases, and more organic aluminum is present as the DOC concentration increases (Gensemer and Playle 1999).

It is noted that impacts may be more significant to smaller rivers and streams due to lower flow rates. These effects are expected to be localized.

The water quality guideline for aluminum used in the assessment is 87 µg/L from the U.S. EPA. This value is based on toxicity test with the striped bass in water with pH 6.5–6.6 and hardness <10 mg/L. There is potential for this value to be approached or exceeded in the expansion scenarios, particularly the 22.5 MTPA scenario. The mobility and availability (therefore toxicity) of aluminum is highly influenced by pH and presence of dissolved organic carbon. Appendix A provides a brief discussion on the speciation of aluminum in natural waters.

There is generally more inorganic and organic Al as water pH decreases, and there is generally more organic Al as the concentration of DOC increases (Gensemer and Playle 1999). The pH in surface waters in the area ranges from 5 to 6.5, which is somewhat acidic. DOC in the samples collected from the area are in the range of 1 to 2 mg/L. It is also noted that temperature can have an effect, at low temperature (2°C) aluminum species are expected to remain in their most toxic form compared to that which would occur at higher temperature (20°C).

Currently aluminum concentrations in sediment range from 32,000 µg/g to 76,000 µg/g without any obvious spatial distribution. These concentrations are within the range of values measured

world-wide (WHO 1997). If there are changes to the water quality, this could also influence sediment quality, particularly in areas where there may be deposition. Considering that this is an active mining and, although data are limited, there is no obvious indication of impacts on sediment to date, it is not expected that there would be wide-spread changes to the aluminum levels in sediment as the project progresses; however, localized areas of increased aluminum in sediment may occur.

Potential acidification of surface water due to emissions of SO₂ and NO₂ was also considered. Although the air quality assessment showed that there are short-periods of high concentrations, the annual average concentrations are low. Hence it is not expected that the operation would have an effect on the pH of the surface waters.

With respect to water consumption, CBG operates a water treatment plant in Sangarédi to provide water for the operations as well as a portion of the potable water for the city. The pumping station is located on the Cogon River downstream of the dam to ensure that water is available, even during the dry season. There will be an increase in water consumption at Sangarédi due to the expanded mining activities, as there will be additional water required for dust suppression during the dry season. As provided in the project description, at Sangarédi the estimated increase in water consumption is 496 m³/d, or 0.006 m³/s, from the Cogon River for the 27.5 MTPA scenario. Due to the significant flow of the Cogon River and the presence of a dam, it is expected that the impact of additional pumping on this resource would be low.

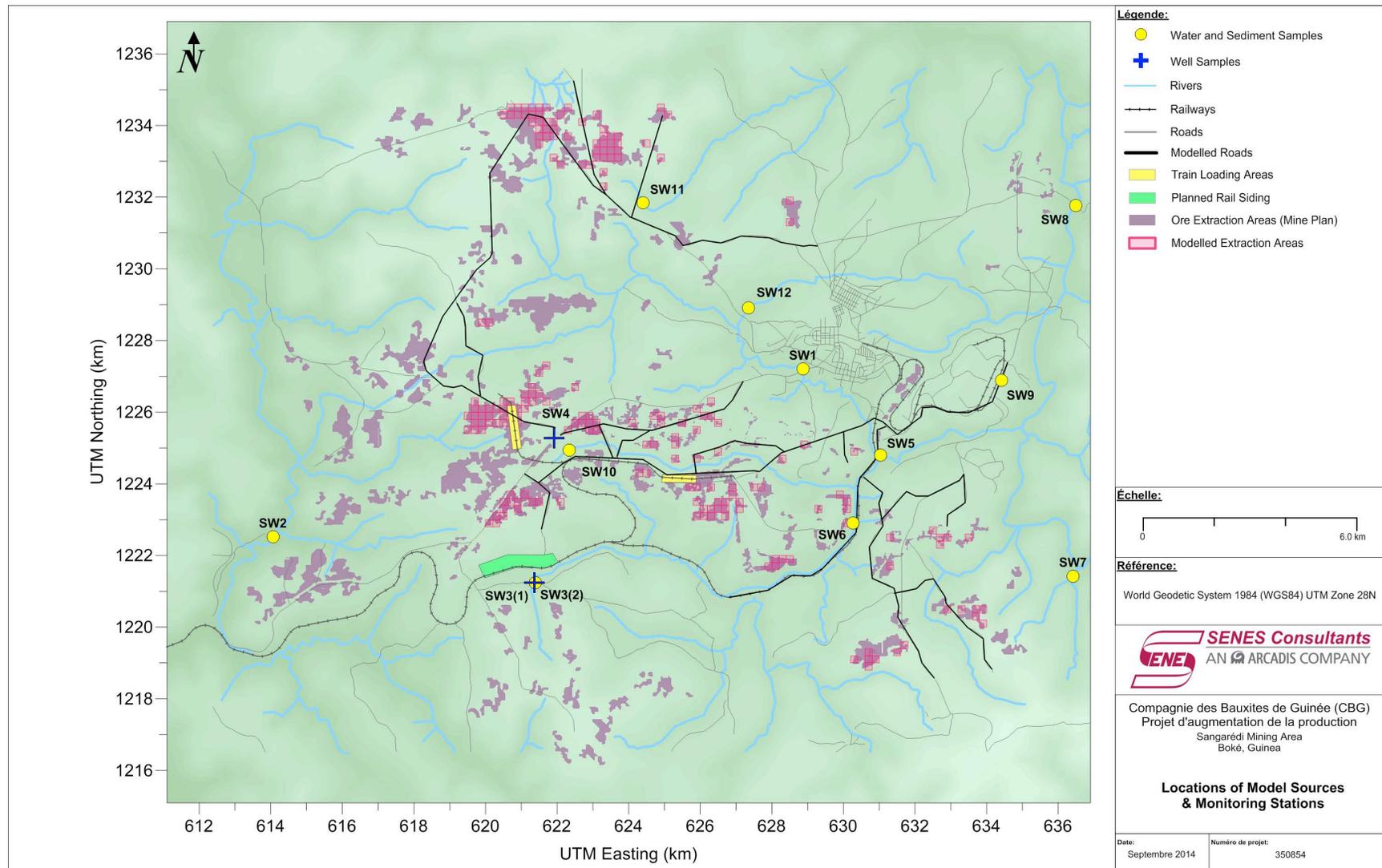
A summary of the impacts associated with the project is included in Table 7.7.

Table 7.7: Summary of Surface Water Impacts for Sangarédi

VEC (Sub-component)	Impacts	Criteria	Classification
Surface water – Freshwater (water quality)	Change in surface water quality by erosion / deposition of air releases.	Value of VEC - High Intensity - Low Geographic Extent - Local Duration - Long	Moderate
Surface water – Freshwater (sediment quality)	Change in sediment quality resulting from water quality changes.	Value of VEC - High Intensity - Low Geographic Extent - Local Duration - Long	Moderate

These impacts are due to the releases from air and any mitigation measures are discussed in that assessment.

Figure 7.1: Water and Sediment Sampling Locations in the Sangarédi Mining Area



7.3 GROUNDWATER

7.3.1 Methodology

In the case of groundwater, the scope of field studies was limited to sampling of a couple of traditional wells in the Sangarédi Mine area. Information on groundwater quality that was available from previous studies was briefly summarized above in Section 6.1.4. The assessment relied to a great extent on professional judgement based on knowledge of the scale of proposed new construction at the Kamsar Port area, the method and scale of extraction at the Sangarédi Mine area, and communicated local knowledge of the shallow geologic and hydrogeologic regimes in the two study areas.

7.3.2 Assessment

7.3.2.1 Kamsar Port Area

The production expansion project requires the installation of a new car dumper along with associated rail yard modifications. This decision was based on the fact that the forty year old existing unloading facility requires high maintenance and that the new car dumper will provide a safer unloading operation. The unloading will produce dust especially during the dry season. A dust control system will be provided in order to maintain a clean working environment in the car dumper vault.

In addition, water for consumption is obtained from deep wells at the village of Sogolon (30 km northeast of Kamsar) and the Tinguilinta River from a pumping station near Batafong Boké. Of the daily water volume of 11,000 m³, CBG distributes over 5,000 m³ of water daily to CBG workers in Kamsar City. During the Project, additional water at Kamsar will be provided from the Batafong pumping station; there will be no additional pumping from wells at Sogolon. The estimated increase in consumption from the Batafong pumping station is 1381 m³/d for the scenario of 27.5 MTPA. The watershed of the Tinguilinta River is 3750 km² upstream of Boké. CBG will obtain water in a manner that will not have a substantial change from current conditions.

7.3.2.2 Sangarédi Mining Area

At present, there is a paucity of groundwater monitoring in the Sangarédi Mining area, which has been operating for several decades. There has been on-going extraction, and there may have been impacts to groundwater from spills and/or related day-to-day operations (e.g., residues from blasting).

Limited groundwater monitoring of local water wells has not indicated adverse impacts related to general chemistry or metal parameters.

There is an expected increase in the water quantity available to the shallow aquifer at Sangarédi due to increased infiltration from exposed excavations, prior to rehabilitation, as described in the Water TSD and associated impact matrix.

7.3.2.3 Summary

The Groundwater VEC subcomponents, and their potential impact sources, criteria, and pre-mitigation magnitude classification are summarized in Table 7.8.

Table 7.8: Summary of Groundwater Impacts

VEC Subcomponent	Potential Impact Source	Criteria	Magnitude
Groundwater Flow	Kamsar Port - Change in Water Levels due to Dewatering – Car Dumper Construction	Value – High Intensity – Low Extent – Single Point Duration - Short	Low
	Sangarédi Mine – Change in Water Levels - Increased rate of extraction and area in operation	Value – High Intensity – Medium Extent – Local Duration - Long	High
Groundwater Quantity	Kamsar Port - Change in Water Quantity due to Dewatering – Car Dumper Construction	Value – High Intensity – Low Extent – Single Point Duration - Short	Low
	Sangarédi Mine - Change in Water Quantity - Increased rate of extraction and area in operation	Value – High Intensity – Medium Extent – Local Duration - Long	High
Groundwater Quality	Kamsar Port - Change in Water Quantity due to Dewatering – Car Dumper Construction	Value – High Intensity – Low Extent – Single Point Duration - Short	Low
	Sangarédi Mine - Change in Water Quality - Increased rate of extraction and area in operation – blasting residue infiltration	Value – High Intensity – High Extent – Local Duration - Long	High

The pre-mitigation magnitude of the effects are classified as either low or high, due to the high relative score that was accorded the VECs related to the physical environment, and the extent and duration of the effect.

At Kamsar, the potential effects of dewatering at the new car dumper construction are considered to have the largest potential effect of any construction activity; most of the other activities do not entail dewatering, and the port site itself has already been affected by continuing operations with respect to the presence of impervious surfaces, increased run-off, etc. over a period of decades. Note that the potential effect from dewatering is of short duration, restricted to the length of time that the excavations related to the car dumper construction are open.

The magnitude of the potential impacts from the increased rate of extraction and area in operation does not change under the 18.5 MTPA, 22.5 MTPA, or 27.5 MTPA scenarios. The

higher relative score of the physical environment groundwater VEC is the driver for the estimated magnitude of the potential impacts.

8.0 MITIGATION

8.1 SURFACE WATER AND SEDIMENT

If there is a need to have additional sources of wastewater discharge, the effluent should respect IFC discharge criteria.

Some mitigation measures have been incorporated into the current project plans which will minimize dust emissions and/or the potential effect of project-related emissions (i.e., increased ambient concentrations of COPC). These measures have been described in further detail in the air quality assessment.

It is also recommended to re-vegetate excavation surfaces to minimize soil erosion.

With respect to dredging, potential mitigative measures to minimize the impact include selecting the appropriate timing, methodology, rate and following best practices. Although the impact on sediment quality will be substantial, it is more important to consider this in the context of the ecological receptors present in the harbour.

8.2 GROUNDWATER

8.2.1 Kamsar Port Area

The impact sources are related to construction of the new facilities at the Kamsar port and processing plant, specifically the dewatering associated with the construction of the new car dumper. The mitigation efforts for groundwater quantity and flow are related to discharging the water to the Dougoufissa River or ocean. The effects of dewatering on the water levels in the shallow aquifer are localized (expected radius of influence <100 metres) and of short duration, due to the clayey nature of the near-surface soils and the shallow penetration of the water table. With respect to groundwater quality due to dewatering, the implementation of reasonable best management practices in the vicinity of the dewatered excavations should adequately protect against producing an adverse effect on the local shallow aquifer water quality. Measures should be undertaken to provide filtration to minimize the amount of total dissolved and total suspended solids that are discharged during dewatering.

8.2.2 Sangarédi Mining Area

There are potential positive effects on groundwater flow and quantity due to the potential for increased infiltration of precipitation into the subsurface resulting from the exposure of subsurface soil from mine excavation activities. Blasting activities can also increase infiltration by creating surficial fractures in the soils/laterites. In the absence of a vegetated surface,

infiltration directly into the subsurface can be expected to be greater under the post-extraction scenario.

Despite the above, re-vegetation of the excavation surfaces is still recommended, in that it helps prevent soil erosion, fixates nutrients to the soils, and promotes habitat for flora and fauna. Under a scenario of progressive rehabilitation of the excavation surfaces, the change in the infiltration compared to the pre-extraction condition is expected to be negligible.

For the Mine Site, therefore, the potential for increasing infiltration of precipitation into the subsurface due to the exposure of the ore-bearing soils can be mitigated through rehabilitation (i.e., vegetation) of the excavation surfaces post-extraction. These effects have been re-classified as “Medium” in the Impact Assessment Matrix. In reality, however, the effects of excavation surface exposure on infiltration may not be measurable; the temporal changes in infiltration over time may fall within the natural seasonal variations of precipitation/infiltration.

The groundwater quality could be affected by the current mining activities through infiltration of precipitation into the soil, facilitated by the creation of soil fractures from the blasting. Explosive residues could therefore more easily lead to groundwater contamination by infiltration after a rainfall. The Project will increase the frequency of blasting. Although this could represent an additional risk for groundwater contamination, blasting activities have been occurring throughout the mine area since the onset of operations. Since there is no baseline (pre-mining) groundwater quality data for the region, especially proximal to the mined plateaus, and no groundwater monitoring regime has been in place since mining first commenced, it is impossible to judge whether groundwater has already been affected by mining activities through this interaction.

The potential effect of blasting residues being able to infiltrate into the water table is classified as high pre-mitigation, due to the lack of knowledge of current groundwater quality conditions within the Mine Site area described above. However, nitrotoluenes degrade readily in groundwater to ammonia, nitrates/nitrites, and other compounds. The nitrates and ammonia are not generally further attenuated naturally, and can ultimately discharge to surface water courses. The residual effect of this has been classified as medium, due to a lack of knowledge of current groundwater quality conditions within the Mine Site area. The residual effect can be also potentially be mitigated through the rehabilitation of the exposed excavation surfaces, which would remove a more direct pathway for potential blast residue infiltration.

9.0 MONITORING

9.1 SURFACE WATER AND SEDIMENT

An environmental monitoring program should be developed that includes any wastewater discharges to the environment to ensure that the quality of the releases respect the applicable benchmarks.

Routine monitoring of surface water and sediment in the Kamsar Port and Sangarédi Mine areas is recommended in order to augment the limited database currently in existence and to help establish spatial and temporal trends of constituents in each area. At a minimum, it is recommended that the monitoring program of existing conditions be repeated; however, it should be expanded over time to encompass new areas of operation with the establishment of additional upstream and downstream stations to help assess the impacts of mining activities on surface water and sediment quality. It is also important to gather information on the seasonal variability.

9.2 GROUNDWATER

9.2.1 Kamsar Port Area

As noted in Section 8.0, measures should be taken to provide filtration to minimize the amount of total dissolved solids (TDS) and total suspended solids (TSS) that are discharged during dewatering. On-site monitoring of the discharge using portable monitoring equipment should be implemented during the dewatering phase of the car dumper construction.

9.2.2 Sangarédi Mining Area

Limited groundwater monitoring of local water wells has not indicated adverse impacts related to general chemistry or metal parameters. Other parameter suites have not been tested (e.g., petroleum hydrocarbons, blasting residue compounds).

It is recommended that, as part of the detailed design of the Mining Plan for Sangarédi, a “baseline” (i.e., existing conditions) shallow groundwater monitoring network be established in proximity to plateaus that have already been completely extracted and plateaus that are currently still being exploited. The network could be employed to provide a basic characterization of the groundwater quality regime in the vicinity of the mine operations. Monitoring wells should also be installed in the vicinity of several plateaus that have not been extracted, and ideally, that are distant enough, and upgradient or cross-gradient from, other extracted plateaus, so that they may be considered to provide relative “baseline” groundwater quality information. This could be conducted in concert with monitoring of the discharge from springs that may provide potable water to residents, or merely discharge to surface water courses. Groundwater samples should be

analyzed for general chemistry, metals as well as petroleum hydrocarbons, and blasting residue compounds where appropriate.

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