Volume G Preface

The Environmental Assessment (EA) for the Ambatovy Project (the project) is intended to meet the information requirements outlined in the Terms of Reference (ToR) in an easily understood and comprehensive package of information. Information is presented in 11 volumes that address specific subject areas. The volumes are as follows, and the structure of each volume is depicted in Figure 1:

- Volume A: Introduction
- Volume B: Environmental Assessment - Mine
- Volume C: Environmental Assessment - Slurry Pipeline
- Volume D: Environmental Assessment - Process Plant
- Volume E: Environmental Assessment - Tailings Facility
- Volume F: Environmental Assessment - Port Expansion
- Volume G: Environmental Assessment - Cumulative Effects
- Volume H: General Appendices
- Volume I: Physical Appendices
- Volume J: Biological Appendices
- Volume K: Social Appendices

Volume A introduces the EA and contains study area and methodological information pertaining to all disciplines and all project components.

For the convenience of readers who wish to read only specific parts of the EA, each of the assessment volumes B through F include descriptions of the project component being addressed. Therefore, a reader who is interested in one particular component may read the corresponding assessment volume.

Volume G contains a cumulative effects assessment that addresses the combined effects of the project components and cumulative effects of the whole project plus other foreseeable developments in Madagascar.

Where appropriate, the EA refers to separate documents in volumes H through K called Appendices, which contain additional technical and baseline information. These volumes also contain environmental assessment appendices for some disciplines with information of relevance to the environmental assessment for multiple components of the project. The glossary, acronyms and references for all volumes are listed in Volume H Appendices 12 and 13.

Figure 1 Environmental Impact Study Structure for the Ambatovy Project

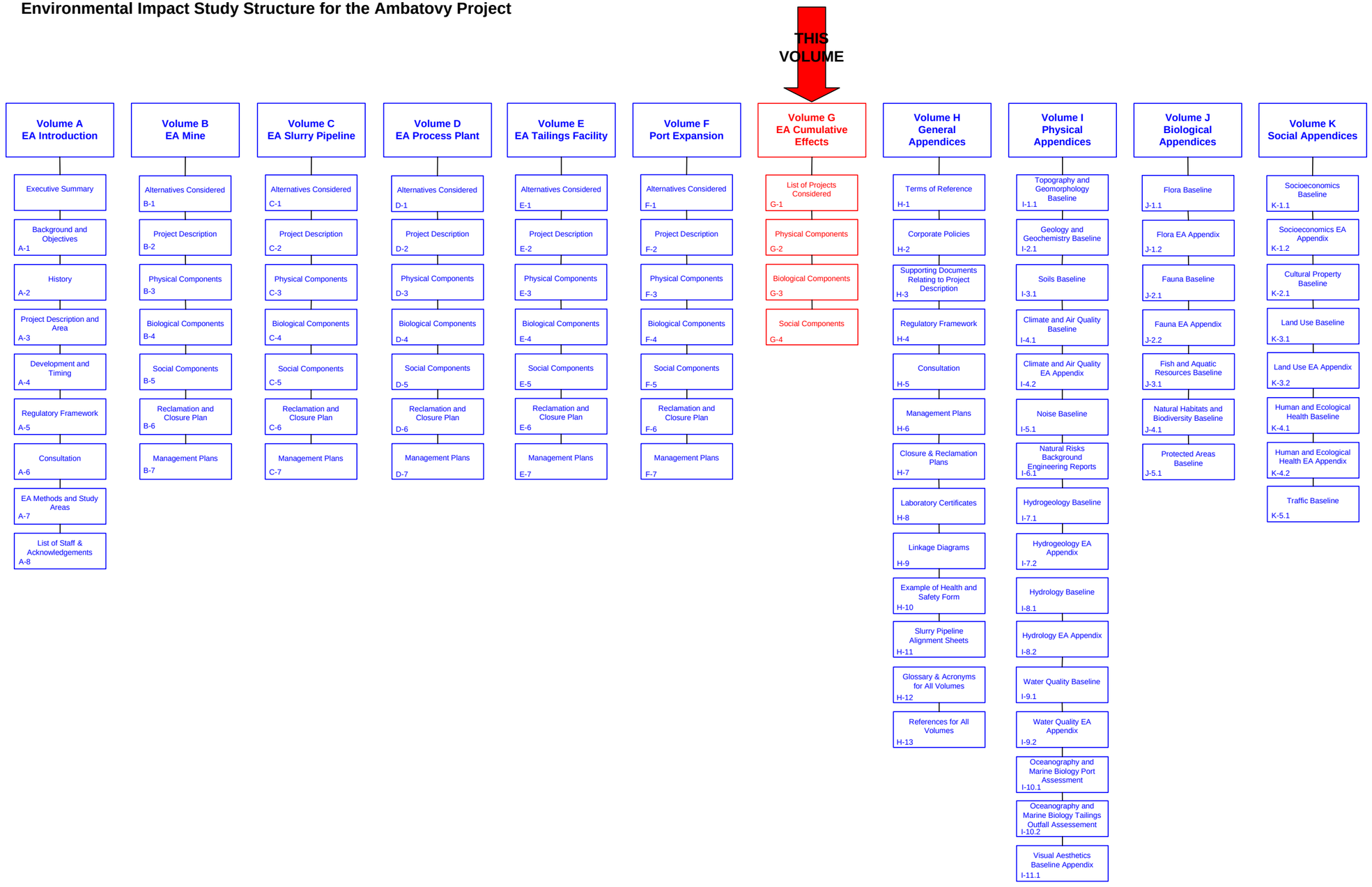


TABLE OF CONTENTS

SECTION **PAGE**

LIST OF TABLES

LIST OF FIGURES

1 LIST OF PROJECTS CONSIDERED

1.1 INTRODUCTION

This Cumulative Effects Assessment (CEA) consists of two parts:

- an assessment of impacts from adding project components together, as relevant; and
- a CEA of impacts of the Ambatovy Project with planned and foreseeable projects.

Environmental Assessment Volumes B through F have generally assessed impacts separately for each of the five project sites. The CEA is an assessment of all impacts for the project combined. The CEA contains a description of combined project impacts, and an integration of other developments in Madagascar.

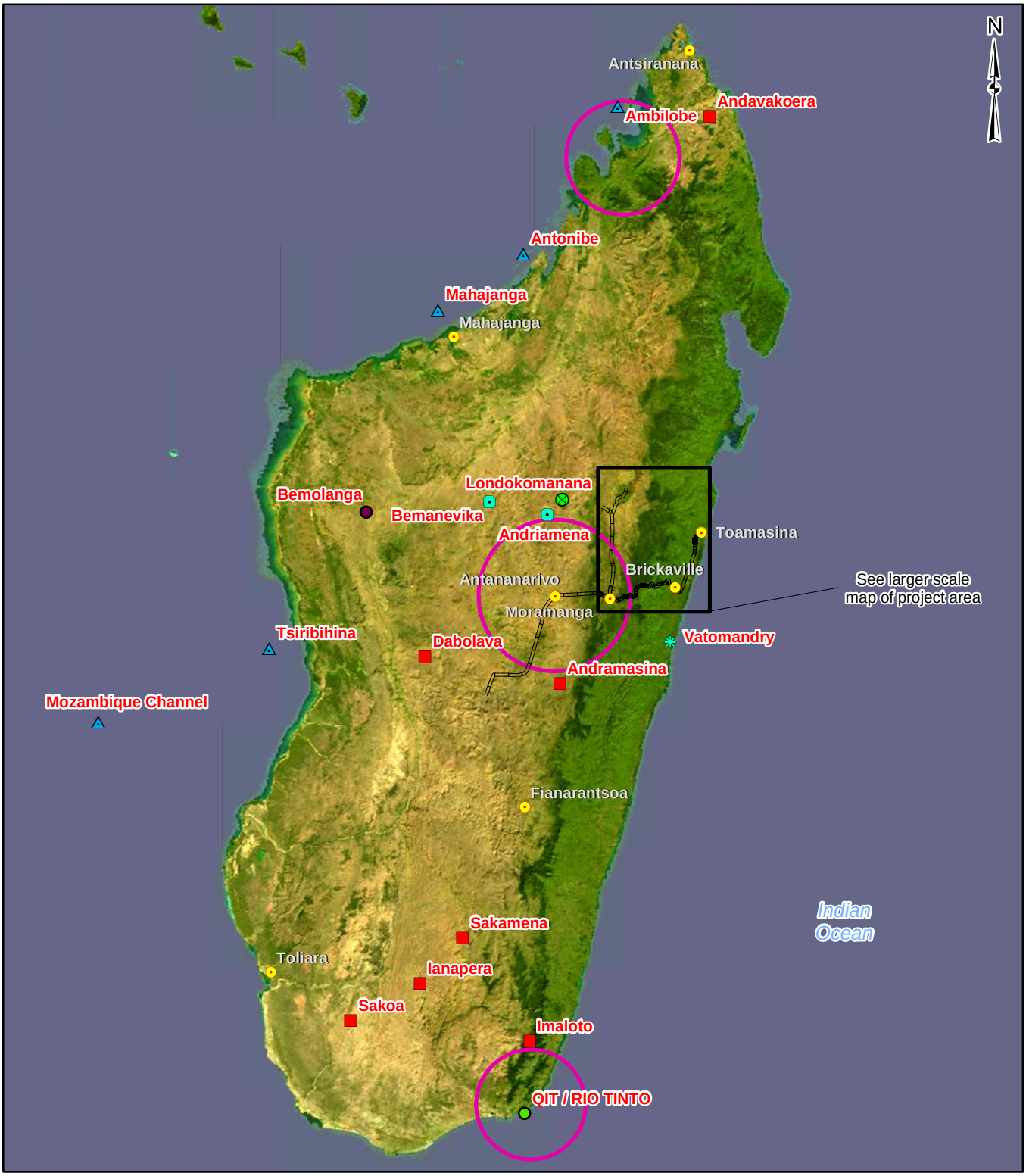
This section includes a description of existing, planned and foreseeable projects as they were understood at the time of the writing of the EA. These projects are discussed under cumulative effects assessment for each discipline.

1.2 EXISTING AND PLANNED PROJECTS OR ACTIVITIES IN MADAGASCAR

Projects will be described first for the island of Madagascar, outside of the Ambatovy Project region. While these are not likely to have a direct link to physical or biological resources affected by the Ambatovy Project, they are likely to influence national and regional economies and workforces, and may have an impact on the country's greenhouse gas emissions. The natural rate of increase for the population of the country (2.8%) and the province where the Ambatovy Project is located (Toamasina Province: 3.0%) should also be considered in any discussion of cumulative effects.

Chrome

Production of chrome in Madagascar has varied from 40,000 to over 1 million tonnes/annum. Most production has been from mines at Andriamena, Bemanevika and Morarano, north of the capital (Figures 1-1 and 1-2). The Morarano Chrome Mine is accessed by a Madarail line that joins the main Toamasina to Antananarivo Line at Moramanga. No information was obtained on any expansion plans for these mines.



LEGEND

- MAJOR CITY
- COAL EXPLORATION
- CHROME MINE
- GRAPHITE MINE
- OFFSHORE OIL EXPLORATION
- ONSHORE OIL EXPLORATION
- TITANIUM DIOXIDE MINE
- OTHER NICKEL - COBALT EXPLORATION
- MADARAIL LINES
- GROWTH POLES OF THE INTEGRATED GROWTH POLES PROJECT

100 0 100 200
SCALE: 1:7,500,000 KILOMETRES

REFERENCE

Datum: WGS 84 Projection: UTM Zone 39S

PROJECT

AMBATOVY PROJECT

TITLE

CUMULATIVE ASSESSMENT PROJECTS: MADAGASCAR

Golder Associates
Calgary, Alberta

PROJECT No.03-1322-172			SCALE AS SHOWN	REV. 0
DESIGN	GJ	22 Aug. 2005		
GIS	TN	01 Nov. 2005		
CHECK	GJ	10 Feb. 2006		
REVIEW	DM	10 Feb. 2006		

FIGURE: 1-1

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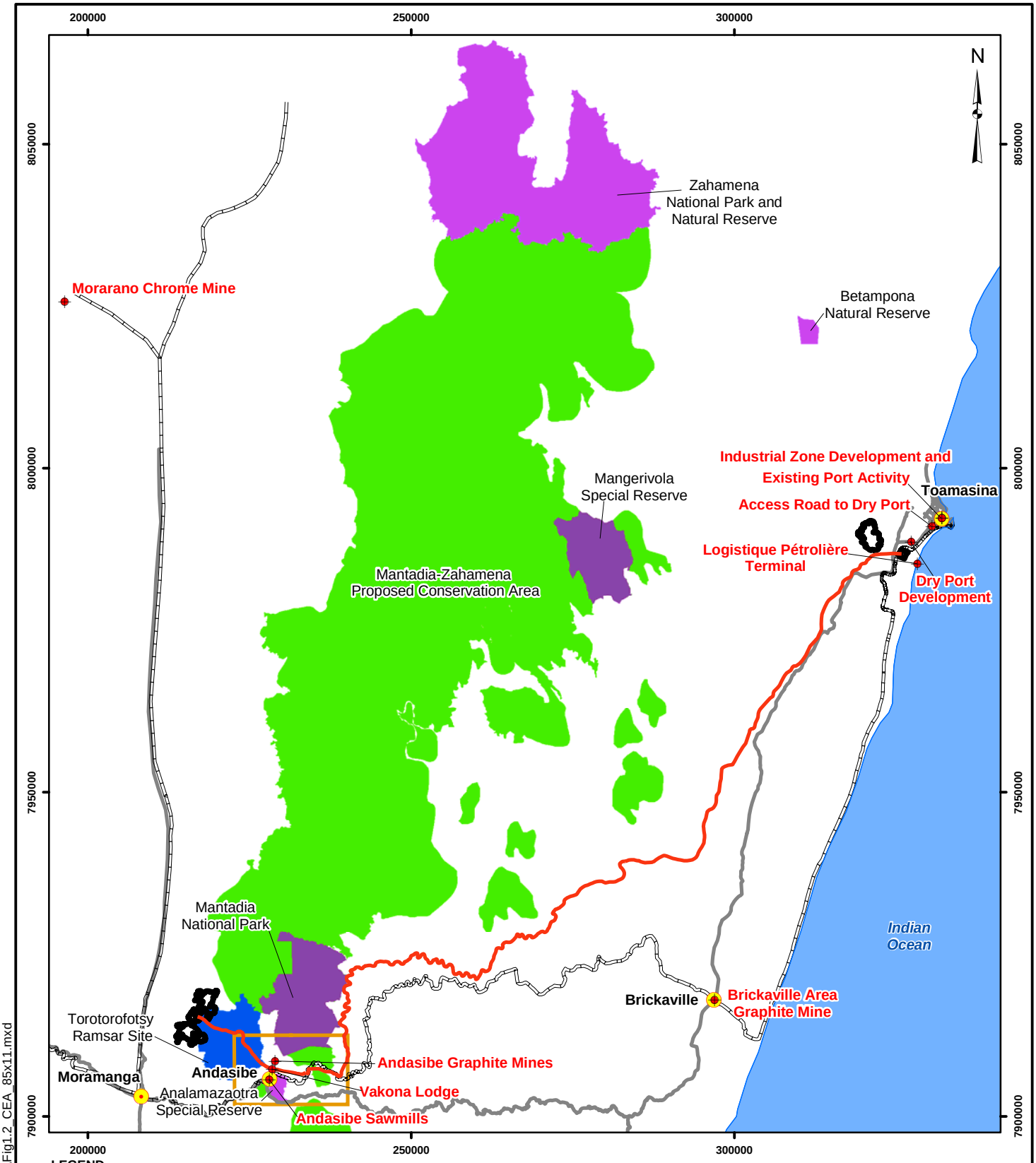

REFERENCE

Protected Area data from Conservation International (2004, 2005) and WCS(2003).
Datum: WGS 84 Projection: UTM Zone 39S.

PROJECT

AMBATOVY PROJECT

TITLE

CUMULATIVE DEVELOPMENT LOCATIONS IN THE REGIONAL STUDY AREA

Golder Associates
Calgary, Alberta

PROJECT No.03-1322-172			SCALE AS SHOWN	REV. 0
DESIGN	GJ	22 Aug. 2005		
GIS	TN	15 Nov. 2005		
CHECK	GJ	10 Feb. 2006		
REVIEW	DM	10 Feb. 2006		

FIGURE: 1-2

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Coal

The Sakoa coal deposit is situated in the south of Madagascar in the Onilahy region. It is over 100 km in length and is estimated to contain over a billion tonnes of coal (Figure 1-1). About 10,000 tonnes per annum is currently being produced, and there are plans to increase this to meet local needs and also for export. In 2003, Vuna Energy signed an agreement with the government to explore the deposit, with the eventual aim of supplying coal to a power station. However, this project is still in the early exploratory phase.

Other coal mines are located at Ianapera and Imaloto in the south (Figure 1-1). No information was obtained on possible expansion plans for existing mines or plans for new mines.

Gold

Most mining for gold in Madagascar is by small mining companies and artisanal miners. There are numerous gold-bearing deposits on the island (Figure 1-3). The Dabolava, Andavakoera, and Andramasina regions were Madagascar's main gold mining centres in the early to mid 20th century with most of production from surface deposits. It is estimated that 51 tonnes of gold were produced from 1897 to 1959 in Madagascar. In the mid 1990s production peaked at 26 to 39 tonnes per year; however, current officially reported gold production has declined and is less than 2 tonnes per year.

Exploration for gold is still ongoing. In 2003, the Government issued exploration licenses to Madagascar Goldfields SARL, PAM Madagascar SARL (PAMM), and Société Bijou Internationale. PAMM currently holds exploration permits for more than 1,900 km^2.

Graphite

The Andasibe graphite mine is situated near Andasibe and is one of four operating mines in eastern Madagascar that produce graphite for local use and export to Europe and the United States (Figure 1-2). The others are located at Toamasina, Brickaville and Vatomandry. In total, Madagascar produces about 14,000 tonnes of graphite per year. No information was obtained on possible expansion plans for these mines.

Figure 1-3 Gold Deposits Within Madagascar

Precious and Semi-Precious Stones

Madagascar has deposits of several varieties of precious and semi-precious stones. Most are collected by artisanal methods and production is irregular. Sapphires and rubies are the most common stones produced, and small quantities of emeralds are also produced. The areas where most are found are described in Table 1-1.

Table 1-1 Precious and Semi-Precious Stone Deposits Within Madagascar

Region	Resource
high plateaus of Antanifotsy and Fianarantsoa	rubies, tourmaline
east	emeralds
north	amethysts, sapphires
south	sapphires, emeralds, rubies, aquamarine

There is a move within the country to switch from artisanal to industrial mining methods, and research into such methods is being undertaken.

Titanium

QIT Madagascar Minerals (QMM), a subsidiary of Rio Tinto, received approval for a titanium dioxide project in 2005. Titanium dioxide is used in the pigment industry. The US$ 585 million mineral sands project represents the largest project in Madagascar's history. Situated on the south coast (Figure 1-2), it will begin operation in 2008 and its initial capacity will be 750,000 tonnes per year of ilmenite. Ore will be shipped to Canada for smelting. The life of the mine is expected to be 40 years. The project includes construction of a deep sea multi-use public port near Fort Dauphin. This port is expected to contribute to development in the region.

Other Mining

Jubilee Platinum resources has announced exploration activity at Londokomanana (Figure 1-1) relating to a large discovery of nickel and copper reserves. In 2005, the pace of geophysical exploration accelerated at the site of this potential mine.

Petroleum

In 2003, Madagascar did not produce crude petroleum and relied on imported petroleum products; the country's only refinery shut down in 2001. The Tsimiroro heavy oil deposit on the western side of Madagascar has an estimated reserve of 26 million barrels, and the Bemolanga oil shale deposit (Figure 1-1) is thought to consist of about 21 billion barrels of reserves but these have yet to be exploited. Oil and gas reserves are also anticipated to occur off the west coast of Madagascar in the Mozambique Channel. Seismic and drilling activity has and is occurring in several areas. Companies that are or have been active in Madagascar are described in Table 1-2.

In 2003, Office Malgache National des Industries Strategiques (OMNIS) reduced the size of the exploration zone to 10,000 km^2 to attract petroleum exploration companies (Yager 2003). In 2005, OMNIS announced the opening of new licenses over the Morandava basin, offshore of western Madagascar. OMNIS has also conducted seismic surveys within the country.

Table 1-2 Petroleum Exploration Activity in Madagascar

Company/Agency	Location	Region
Gulfstream Madagascar	offshore onshore	Antonibe Tsiribihina
Triton Madagascar	offshore	Ambilobe
XPRONET Inc.	offshore	Mozambique Channel
Frontier Marine	offshore	off of Mahajanga
Hunt Oil Inc.	onshore	Tsimiroro Mahajanga Bemolanga
Vuna Energy	onshore	Tsimororo
Vanco Energy Ltd.	offshore	off the west coast
Exxon	onshore	north of Mahajanga

Hydropower

The total installed electrical capacity for Madagascar in 1997 was 220 MW, of which 106 MW was generated by hydroelectric projects. JIRAMA, the state-run hydro company, controls all electrical production. With less than 1% of the potential hydropower in the country being used, there is a lot of room for new facilities. Deregulation has allowed for private investment in the sector. The first private investment may be an upgrade to the Andekaliha hydro facility, which could be refurbished to produce 40 MW (Hydroatlas website 2005).

Deforestation

Madagascar has lost over 80% of its forest cover since 1927, up to 80% of this due to slash and burn agriculture that was widely practiced in the 1970s and early 1980s. The current average national rate of deforestation has slowed and has been estimated at 1.2% (World Bank 2003). Within the eastern forest corridor (an area of about 4,100 km^2), a study by Horning (2001) placed current deforestation rates at about 1.1% per year. In the immediate area of the mine site, there is an overall trend in conversion of primary forest to either cleared areas or degraded forest areas (Land Use baseline: Volume K, Appendix 3.1). Deforestation has occurred at a rate of about 1% per year since 1991. The rate appears to be accelerating slightly, since the conversion of primary zonal forest to degraded forest and cleared areas occurred at a rate of 0.8% between 1957 and 1991.

Madarail

Madarail began operations in 2003. The rail network of over 650 km is made up of the TCE line (from the port of Toamasina to the capital city of Antananarivo), the TA line (from the capital city to Antsirabe) and the MLA line (Moramanga to Morarano Chrome and Ambatosoratra) (Figure 1-1). The track remains the property of the State while the rolling stock is owned by Madarail. Madarail has a five-year investment program estimated at 3.5 million euros. 2004 stock includes about 12 locomotives, 100 commercial wagons and 20 flatbeds. The company is focused on moving petroleum products, chrome ore, cement, containers, fertilizers and other commodities. Freight traffic has increased and Madarail expected to transport over 300,000 tons in 2004. They employ some 900 people.

Due to the presence of this private railway operator, new mining projects are more likely to be developed. Several firms are looking at mining projects along the railway network, counting on the capability of the railway to move large quantities from the mine to the plant or to the sea port. However, no firm plans are available and thus these projects were not considered to be reasonably foreseeable for the assessment.

Madarail plans a five-year US $35 million investment program to modernize the railway and provide a competitive transport alternative to the road. It also hopes to introduce passenger traffic.

Road System

Madagascar has only some 5,900 km of passable roads of the total of 25,500 km due to a lack of maintenance. The amount of passable road decreased between 1960 and 2003 even though the population had increased. In 2003 the Government made road improvements one of its main objectives. A current World Bank-financed project is to maintain and rehabilitate the entire network of primary and secondary roads (7,313 km) by the end of 2008. Most primary roads are paved and have two lanes, while most secondary roads are either paved or gravelled two-lane roads. It is anticipated that the project will employ 18,000 people per year (World Bank 2003).

Moramanga is at the junction of Route Nationale (RN) 2 and RN44, which goes north to the rice producing area of Ambatondrazaka. RN2 is paved and heavily used year round. RN44 has until recently been in a degraded condition however the above-mentioned road repair projects are underway and these have upgraded the road in the Moramanga area.

Integrated Growth Poles Project (IG2P)

A World Bank project is currently being implemented to promote multi-sector development in three regions of Madagascar: the Nosy Be pole, the Antananarivo-Antsirabe pole, and the Fort Dauphin pole (Figure 1-1). The project has been designed to promote tourism development in Nosy Be, export processing zones in the Antananarivo-Antsirabe pole, and mining near Fort Dauphin. Activities include construction and rehabilitation of critical infrastructure for tourism, manufacturing, agribusiness and mining. Activities at Nosy Be include upgrading of roads, ports, public utilities, and the hospital so that 2,000 international-level hotel rooms can be supported by 2010 (US $56 million). For the Antananarivo-Antsirabe pole, main activities include construction of a business park and improvement in administration (US $8 million). At Fort Dauphin, construction of a port for the QMM titanium mine is one component of the project, as is upgrading of existing roads and public utilities to support 850 international-level hotel rooms by 2010 (US $174 million).

1.3 PROJECTS WITHIN THE AMBATOVY PROJECT REGION

The majority of the above resources, projects and infrastructure do not have a direct bearing on the Ambatovy Project from a physical or biological perspective, except potentially for the existing Andasibe graphite mine, the Madarail network and the road network. However, some of the potential projects may have an impact on greenhouse gas emissions.

Several other projects are being planned or implemented for the region, as described below and shown in Figure 1-2.

Protected Areas

The Torotorofotsy Wetlands was designated as a Ramsar wetlands in 2005. The wetlands were fully considered in the EA.

Government and stakeholders are proposing a "*site de conservation*" for the Mantadia-Zahemena corridor, including lands to the east of the proposed mine site and parts of the proposed pipeline corridor (Figure 1-2).

Carbon Project

This World Bank project, coordinated by Conservation International, will promote forest protection and reforestation in the southern end of the Mantadia-Zahemena corridor and in areas linking the corridor to the Analamazaotra special indri lemur reserve. Reforestation activity will be focused on creating natural

forest corridors linking isolated patches of forest and the protected areas. In addition, sustainable cultivation systems (as opposed to slash and burn cultivation) will be promoted. The proposed Ambatovy pipeline will cross portions of this area (Figure 1-2).

Ecotourism

Tourism in Madagascar as a whole is not a large industry and in the past has been affected by political instability. From 2000 to 2004, the number of tourists per year ranged from 61,674 to 228,784, with the lowest number occurring in 2002 when the country was undergoing political strife. The number of tourists that arrived in Toamasina ranged from 12,200 to 45,700 per year over the same time period.

The protected areas and parks of Andasibe are the most visited of ecotourism attractions in Madagascar. The Vakona Lodge is located near Andasibe (Figure 1-2). No data could be found for lodge or National Park usage by tourists.

In addition to the National Parks in the region, the Chutes de la Mort on the Manambolo River 35 km south of Moramanga represents a potential tourist attraction.

Sawmills

Sawmills in the Andasibe area (Figure 1-2) continue to operate, although at a smaller scale than in the past. Specific information on volumes of lumber processed are not available. Other small sawmill operations are present throughout forested areas of Madagascar.

Dry Port and Access Road

The location of the proposed dry port at Toamasina has been staked out but little land clearing or development has taken place. Renewed interest in development of this facility may come about as a consequence of the Ambatovy Project.

Logistique Pétrolière Terminal Project

A new jetty and petroleum storage depot likely will be built by Logistique Pétrolière to the south of Toamasina (Figure 1-2). This jetty may be used by the Ambatovy Project as well as Logistique Pétrolière, and has been considered in the main EA. The facility will be capable of hosting tankers with a capacity of up to 45,000 m^3. The total area of the project is estimated to occupy 17 ha, of which only 5 ha will actually be covered by buildings or facilities. Roads and a rail line will be built to access the site from existing routes. An environmental

assessment has been completed for this development, which will be considered in appropriate cumulative effects disciplines in this EA (Logistique Pétrolière 2005).

Toamasina Port

Toamasina (Tamatave) is the nation's chief port and handles about 80% of the nation's imports and exports (Photograph 1). It is connected by rail with Antananarivo. Main exports from the port include sugar, coffee, cloves and rice. The port system has essentially been left untouched since independence in 1960, though in some areas, the private sector itself has begun to manage port facilities. In 2003, the port handled 1.5 million tons of traffic, of which 800,000 tons were in containers. From 1997 to 2003, container traffic increased at an average rate of 10% per year (DG Market website 2005).

Overall, however, growth prospects for export products in Madagascar are limited due to inadequate transport and security facilities (World Bank 2003).

Although not selected as a growth pole for the World Bank IG2P project (see above), port activity at Toamasina will likely increase as a result of this project that is intended to stimulate the manufacturing industry in the Antsirabe-Antananarivo pole. In fact, the increase in volume of goods shipped from Toamasina is one of the indicators to monitor the success of the IG2P project.

Photograph 1 Aerial View of the Port at Toamasina

New Toamasina Industry

Food processing is a chief industry within the city of Toamasina, but no data or information could be obtained on future growth.

2 CUMULATIVE AND COMBINED EFFECTS FOR PHYSICAL DISCIPLINES

2.1 TOPOGRAPHY AND GEOMORPHOLOGY

2.1.1 Ambatovy Project Combined Effects

2.1.1.1 Introduction

The five major components of the project overlap to produce combined effects as indicated in Table 2.1-1.

Table 2.1-1 Matrix of Overlapping Project Effects for Topography and Geomorphology[(a)]

Project Components	Mine	Slurry Pipeline	Process Plant	Tailings facility	Port Expansion
mine		X	-	-	-
slurry pipeline			X	-	-
process plant				-	-
tailings facility					-
port expansion					

[(a)] X Indicates that an overlapping (combined) effect occurs.

- Indicates that no cumulative effects occur.

Shading indicates not applicable.

Impacts on topography overlap where the physical footprints of different project components overlap or are immediately adjacent to one another. This occurs only in the case of the mine and slurry pipeline (at the west end of the pipeline) and the process plant and slurry pipeline (at the east end of the pipeline). The way that cumulative topographic changes affect other disciplines such as visual aesthetics and hydrology are addressed separately in other sections of Volume G.

2.1.1.2 Assessment of Combined Project Effects

Predicted impacts (environmental consequences) of the mine, slurry pipeline and process plant have all been rated low in the individual component assessments. Although there is a small area of overlap at each end of the pipeline, the impact of the pipeline on topography is superseded by the impacts of the other developments at each end, and effectively does not present any additional impact.

The environmental consequences of the combined projects are summarized in Table 2.1-2.

Table 2.1-2 Residual Combined Impact Classification for Topography and Geomorphology

Phase	Direction	Magnitude	Geographic Extent	Duration	Reversibility	Frequency	Environmental Consequence
Issue: Mine – Pipeline							
construction / operations / closure	negative	low-moderate	local	medium-term	yes	medium	low
Issue: Process Plant – Pipeline							
construction / operations / closure	negative	low	local	medium-term	yes	medium	low

2.1.2 Cumulative Effects With Other Projects and Activities

2.1.2.1 Introduction

The topography and geomorphology study area for assessment of potential cumulative effects between the project and other projects and activities includes all areas within 5 km of the project sites. The project has the potential to overlap with the following projects and activities to impact topography and geomorphology:

- deforestation and potential erosion effects due to logging and tavy agriculture overlap with the effects of all project elements;
- near Andasibe, the graphite mines have a long-term impact on topography that overlaps with the effects of the slurry pipeline; and
- at Toamasina, the effects of the plant overlap with new development in the same area, including southern Toamasina industrial development, dry port development and the Logistique Pétrolière fuel depot project.

2.1.2.2 Assessment of Cumulative Effects

Deforestation due to logging and tavy agriculture, and erosion of bare soils along the slurry pipeline and close to other project elements is expected to continue during the project. These activities will create a small additional negative impact on topography. Topographic impacts are considered low, but regional in extent and medium-term in duration. The environmental consequence is low (Table 2.1-3).

Graphite mining at the Andsibe graphite mine is expected to continue during project operation, and will also create a small additional negative impact on topography. Topographic impacts are considered low, local in extent and long-term in duration. The environmental consequence is low (Table 2.1-3).

Development of new industrial activity south of Toamasina will contribute to cumulative topographic impacts in this area. Projects planned specifically include dry port development, at which shipping containers will be stored and tall cranes and other machinery to move the crates will be visible; and the Logistique Pétrolière fuel depot area which will be characterized by large fuel tanks, jetty into the ocean and visible pipeline networks. Because the existing topography in the area is flat, the projects will all have relatively small impacts; topographic impacts are considered negligible, but regional in extent and long-term in duration. The environmental consequence is negligible (Table 2.1-3).

Table 2.1-3 Residual Cumulative Impact Classification for Topography and Geomorphology

Phase	Direction	Magnitude	Geographic Extent	Duration	Reversibility	Frequency	Environmental Consequence
Issue: Cumulative Agriculture and Forest Removal Close to the Slurry Pipeline and Other Project Components							
construction / operations / closure	negative	low	regional	medium-term	yes	high	low
Issue: Graphite Mining in Vicinity of Slurry Pipeline							
construction / operations / closure	negative	low	local	long-term	no	moderate	low
Issue: Cumulative Development of Industry South of Toamasina							
construction / operations / closure	negative	negligible	regional	long-term	no	moderate	negligible

2.1.3 Conclusions

Combined effects between Ambatovy Project components occur at both ends of the slurry pipeline, but these effects are minor and do not result in greater impact ratings than the mine alone at the west end of the pipeline or the process plant alone at the east end of the pipeline.

The main cumulative effects between the project and other planned activities will be due to regional impacts on the landscape due to logging and tavy agriculture. These impacts are widespread in Madagascar and overlap with all project elements, although at a local level such impacts have occurred for a long period of time and are accepted by most people. A separate, low cumulative impact occurs due to the combined effects of the slurry pipeline with graphite mines in the area of Andasibe.

2.2 GEOLOGY AND GEOCHEMISTRY

No combined project effects or cumulative effects are predicted for geology or geochemistry.

2.3 SOILS

2.3.1 Ambatovy Project Combined Effects

2.3.1.1 Introduction

The five major components of the project overlap to produce combined effects as indicated in Table 2.3-1.

Table 2.3-1 Matrix of Overlapping Project Effects for Soils[(a)]

Project Components	Mine	Slurry Pipeline	Process Plant	Tailings Facility	Port Expansion
mine		X	-	-	-
slurry pipeline			X	-	-
process plant				-	-
tailings facility					-
port expansion					

[(a)] X Indicates that an overlapping (combined) effect occurs.

- Indicates that no cumulative effects occur.

Shading indicates not applicable.

The effects of the mine will not overlap with the process plant, tailings facility or port expansion as they are not close enough to physically impact the same soils. The tailings facility and port expansion do not physically overlap any of the soils affected by the slurry pipeline. While there is a small overlap between the slurrypipeline and the process plant, it is negligible in area. The mine and slurry pipeline will overlap on the western portion of the slurry pipeline route.

The overlapping effects between the mine and slurry pipeline are addressed below.

2.3.1.2 Assessment of Combined Project Effects

At the western end of the slurry pipeline, the mine will disturb a total of 1,734 ha of soils and the slurry pipeline will disturb an additional 54 ha within the mine terrestrial local study area (LSA). Combined, the mine and pipeline will result in a total disturbance of 1,788 ha of soils. At the eastern end of the slurry pipeline, the plant will disturb a total of 322 ha of soils and the slurry pipeline will disturb an additional 0.8 ha within the Toamaina terrestrial LSA. Combined, the plant and pipeline will result in a total disturbance of about 323 ha of soils.

The combined impacts at both ends of the slurry pipeline are not rated higher than the impacts in the individual mine and process plant assessments, as they were considered high in magnitude in the immediate local area during operations in both individual assessments. The incremental addition to impacts considered by combining the pipeline at each location is not large.

These impacts will be mitigated as described in the soils sections for the mine (Volume B, Section 3.3) for the slurry pipeline (Volume C, Section 3.2) and for the process plant (Volume D, Section 3.2). Both combined impacts during construction and operations are high in magnitude, local in geographic extent, and medium-term in duration. Effects at the mine are reversible while effects at the process plant are only partly reversible (Table 2.3-2). The frequency of disturbance throughout construction and operations will be medium. Mine and slurry pipeline areas will be reclaimed at closure, while the process plant will likely be used for continuing industrial purposes (Volume D, Section 6).

Table 2.3-2 Residual Combined Impact Classification for Soil Combined Effects

Phase	Direction	Magnitude	Geographic Extent	Duration	Reversibility	Frequency	Environmental Consequence
Issue: Mine – Pipeline: Combined Soil Disturbance							
construction/operations	negative	high	local	medium-term	yes	medium	low
closure	negative	negligible	local	medium-term	yes	low	negligible
Issue: Plant – Pipeline: Combined Soil Disturbance							
construction/operations	negative	high	local	medium-term	partial	medium	high
closure	negative	high	local	medium-term	partial	low	high

2.3.2 Cumulative Effects With Other Projects and Activities

2.3.2.1 Introduction

The study area for assessment of potential cumulative effects between the project and other projects and activities includes all areas within 100 km of the project sites. The project has the potential to overlap with the following projects and activities to disturb soils:

- Deforestation due to logging and tavy agriculture overlaps with the effects of the mine and slurry pipeline.
- The Logistique Pétrolière terminal and dry port development at Toamasina will overlap with effects of the process plant.

2.3.2.2 Assessment of Cumulative Effects

Deforestation in the area of the mine and slurry pipeline occurs at a rate of about 1% per year. However, with the implementation of the project, including proposed mitigation for forest management, protection of specific azonal areas and forest restoration along the pipeline, as well as implementation of the Carbon Project, deforestation due to logging and tavy agriculture is not expected to cause any additional cumulative impact with the project.

The Logistique Pétrolière terminal close to the process plant is a small disturbance (up to 17 ha) (Logistique Petrolière 2005) within the cumulative Effects Assessment (CEA) Study Area, but does not overlap with any of the project soil disturbances. Similarly, the dry port development will impact an area of poor, sandy coastal soils, but these impacts do not overlap with project soil disturbances. Therefore, soil impacts at the Logistique Pétrolière terminal and the dry port are not expected to contribute measurable cumulative effects on soils. The cumulative effects are rated as negligible.

Table 2.3-3 Residual Cumulative Impact Classification for Soils

Phase	Direction	Magnitude	Geographic Extent	Duration	Reversibility	Frequency	Environmental Consequence
Issue: Cumulative Effects							
construction / operations	negative	negligible	regional	medium-term	yes	medium	negligible

(a) Positive rankings are not rated.

2.3.3 Conclusions

The main combined effects between project components are the combined effects of the mine and slurry pipeline for soil disturbance within the mine terrestrial LSA and combined effects of the process plant and slurry pipeline in the plant LSA. The combined local effects are negative in direction and high in environmental consequence within the combined impact footprints for construction and operations (as compared to similar high ratings for each of the mine and process plant, individually). Negative and negligible environmental consequence are predicted for closure in the mine LSA (as compared to low ratings for each of the mine and pipeline, individually). Negative and high environmental consequences are predicted for closure in the process plant LSA, (consistent with a high rating for the process plant).

The main cumulative effects between the project and other activities are soil disturbance from deforestation in and adjacent to the Mantadia-Zahamena Corridor, and the Logistique Pétrolière terminal and dry port developments at Toamasina. The cumulative soil disturbance effects are negligible in both magnitude and environmental consequence.

2.4 CLIMATE AND AIR QUALITY

2.4.1 Ambatovy Project Combined Effects

The effects of the mine will not overlap with the process plant as they are not close enough to cumulatively impact air quality. Even though a detailed assessment was not conducted for the port expansion, cumulative effects are not anticipated as port emissions are expected to be significantly less than the process plant. There will be no effect on air quality from the slurry pipeline or tailings facility; therefore, there is no combined effect with the other project components.

2.4.2 Cumulative Effects With Other Projects and Activities

2.4.2.1 Introduction

The study area for assessment of potential cumulative effects between the project and other projects and activities includes all areas within 100 km of the project sites. A potential cumulative effect is that community and industrial emissions from Toamasina may combine with air emissions from the process plant and port expansion. The mine is located far from any industrial activities; therefore, there are no cumulative effects to assess.

2.4.2.2 Assessment of Cumulative Effects

Existing air emissions from the city of Toamasina include vehicle exhaust and other fuel combustion sources that may combine with air emissions from the process plant and port expansion during certain meteorological conditions. The air emissions from Toamasina are not easily quantifiable; therefore, a residual cumulative impact could not be determined. It should be noted that the process plant would be considered the largest industry in the Toamasina region. Monitoring of air quality with respect to the plant has been described in Volume D, Section 3.3. The program will be designed to also monitor for potential cumulative effects.

2.4.3 Conclusions

The two main sources of air emissions from the project are the mine and the process plant. These two project components are too far apart geographically to produce a cumulative effect on air quality.

The main cumulative effect between the project and other activities is the combined effect on air quality from Toamasina emissions and emissions from the process plant. Air emissions and air quality in Toamasina were not quantified. However, the proposed plant monitoring will define the actual air quality and emissions in the vicinity of the plant. The emissions from the plant will meet World Bank ambient level guidelines.

2.5 NOISE

2.5.1 Ambatovy Project Combined Effects

Noise effects from the project will attenuate or diminish with distance from each respective project activity. The project components with high operations-related noise (i.e., the mine and process plant) are too far apart for cumulative noise effects between project components to occur.

2.5.2 Cumulative Effects With Other Projects and Activities

The study area for assessment of potential cumulative effects between the project and other projects and activities includes all areas within 100 km of the project sites. Noise from project activity is considered to be a localized effect. The only project or activity that is close enough to Ambatovy Project components to potentially have a cumulative effect on noise is the Logistique Pétrolière project. The Environmental Assessment (EA) for Logistique Pétrolière indicated that

operational noise effects would be negligible (Logistique Pétrolière 2005). Therefore no cumulative noise effects are expected.

2.6 NATURAL RISKS

2.6.1 Ambatovy Project Combined Effects

2.6.1.1 Introduction

When extreme natural hazards such as cyclones, floods or earthquakes occur, they have the potential to act on more than one project component at the same time. As a result, the physical effects on people or the environment from natural hazards acting on the project components combine in some cases.

In this section, "combined effects" refers to a case where a natural hazard such as a cyclone occurs, causing effects on two or more project components simultaneously, and resulting in impacts on people or the environment that are more severe than from one project component alone. For example, extreme natural hazards affecting the slurry pipeline could combine together with effects on the mine, tailings facility or plant site to bring about incrementally larger natural risk effects. Likewise, natural hazard effects on to the process plant and tailings facility could combine together and result in greater natural risk effects than either one of these project components could alone.

The most likely scenario for combined natural risk effects between project components is for an extreme natural hazard to act on more than one project component. An example would be the occurrence of an extreme rainfall event during a cyclone which causes both a pipeline rupture due to a landslide along the slurry pipeline and an overtopping of the tailings facility dam, in turn resulting in impacts to the same watershed by both releases. The less likely (very remote) scenario is for two different extreme natural hazards to occur simultaneously and act on two different project components, in turn resulting in combined impacts on people or the environment.

Table 2.6-1 indicates where project components are physically close enough for extreme natural hazards to act on more than one project component at a time and result in effects that combine from each project component.

Table 2.6-1 Matrix of Combined Project Effects for Natural Risks[(a)]

Project Components	Mine	Slurry Pipeline	Process Plant	Tailings Facility	Port Expansion
mine		X	-	-	-
slurry pipeline			X	X	-
process plant				X	-
tailings facility					-
port expansion					

[(a)] X Indicates that an overlapping (a combined) effect occurs.

- Indicates that no cumulative effects occur.

Shaded area not applicable.

The natural risk scenarios for all project components are summarized in Table 2.6-2. Matrices of combined or cumulative risk consequences from potential combinations of project components are presented in Tables 2.6-3 through 2.6-6. They indicate the possible natural risks consequences which may occur in combination for each set of project components that combine. Only risk scenarios with overall risk ratings of "5" (Low Category) or greater are included in Tables 2.6-3 through 2.6-6. Volume B, Section 3.6 provides an explanation of the risk ranking.

At the mine site, a severe landslide brought about by heavy rain could cause simultaneous consequences of a flood from the settling ponds and a release from the pipeline (Table 2.6-3). Such a combined event, though unlikely, would result in combined downstream effects.

Table 2.6-2 Natural Risk Scenarios for All Project Components

Natural Hazard	Project Component Risk Scenarios				
	Mine	**Slurry Pipeline**	**Process Plant**	**Tailings Facility**	**Port Expansion**
cyclone -high rain	landslide in watershed resulting in breach or overtopping of embankments releasing sediment laden water to the environment; heavy rain resulting in breach or overtopping of embankments releasing sediment laden water to the environment; flooding over the spillway; failure of waste dump resulting in flow slide; erosion and failure of embankments releasing sediment laden water to the environment	pipeline rupture due to landslide or erosion releasing slurry to the environment	overflow bermed containment areas releasing aggressive chemicals, limestone, coal or sulphur to the environment	landslide in watershed resulting in breach or overtopping of tailings or water pond embankments releasing process water to the environment; heavy rain resulting in breach or overtopping of tailings or water pond embankments releasing process water or tailings to the environment; flooding over the spillway	n/a
cyclone – high wind	high winds causing waves at embankment and overtopping or erosion of embankments releasing sediment laden water to the environment	n/a	damaged buildings or debris carried off-site by wind presenting danger to people	high winds causing waves and overtopping or breeching of tailings or water pond embankments releasing process water or tailings to the environment	damage to port infrastructure carried off-site by wind presenting danger to people
seismic / geotechnical	landslide in watershed resulting in breach or overtopping of embankments releasing sediment laden water to the environment; liquification of embankment or failure causing overtopping or breach releasing sediment laden water to the environment; liquification of waste dump causing flow slide	pipeline rupture due to landslide or erosion releasing slurry to the environment	damage to plant infrastructure and possible contaminant releases	liquefaction of tailings or water pond embankment or failure causing overtopping or breach releasing process water or tailings to the environment	damage to port infrastructure and possible contaminant releases
tsunami	n/a	n/a	inundation of plant site and erosion of water control berms releasing contaminants to the environment	erosion of embankments releasing contaminants to the environment	inundation of port and damage to infrastructure releasing contaminants to the environment

n/a: not applicable.

Downstream of the tailings facility, the slurry pipeline crosses a watershed that could be impacted by a tailings facility release. A pipeline failure occurring at the same time and also within the watershed would result in cumulative risks to environmental and social resources in the watershed (Table 2.6-4). Such a combined event is extremely unlikely.

At the process plant, there is potential for a pipeline release to combine with an overtopping of water control structures within the facility which would send both slurry and other chemicals into the environment. Conservative planning of the plant site ensures this is an extremely unlikely scenario.

In the watershed between the process plant and tailings facility, there is potential for releases from both areas to combine in the event of an extreme flood. This flood would have to be sufficiently serious to cause released contaminants to travel far downstream. Such a severe flood is extremely unlikely.

Table 2.6-3 Matrix of Combined Risk Consequences: Mine and Slurry Pipeline[(a)]

Mine Risk Consequence	Slurry Pipeline Risk Consequence	
	pipeline rupture releasing slurry to the environment	pipeline leak
flooding and damage to downstream resources	X	-
overtopping of embankments causing release of sediment laden water to the environment	X	-
breach of embankments causing release of sediment laden water to the environment	X	-

[(a)] X Indicates that a combined effect could occur.

- Indicates that no cumulative effects occur.

Table 2.6-4 Matrix of Combined Risk Consequences: Tailings Facility and Slurry Pipeline[(a)]

Tailings Facility Risk Consequence	Slurry Pipeline Risk Consequence	
	Pipeline Rupture Releasing Slurry to the Environment	Pipeline Leak
overtopping of tailings embankment causing release of process water into the environment	X	-
breach of tailings embankment causing release of tailings and process water into the environment	X	-
flooding and damage to downstream resources	X	-
minor slump leading to temporary release of tailings and/or process water into the environment	-	-
major slump leading to loss of freeboard and breach of tailings embankment causing major release of tailings and/or process water to the environment	X	-

[(a)] X Indicates that a combined effect could occur.

- Indicates that no cumulative effects occur.

Table 2.6-5 Matrix of Combined Risk Consequences: Process Plant and Slurry Pipeline[(a)]

Process Plant Risk Consequence	Slurry Pipeline Risk Consequence	
	Pipeline Rupture Releasing Slurry to the Environment	Pipeline Leak
aggressive chemicals transferred to environment via storm drainage	X	X
stockpiled limestone, coal or sulphur overflow containment and transport to environment via storm drainage	X	X
construction or operation materials and damaged building components rendered airborne and hazardous by storm winds	-	-

(a) X Indicates that a combined effect could occur.

\- Indicates that no cumulative effects occur.

Table 2.6-6 Matrix of Combined Risk Consequences: Tailings Facility and Process Plant[(a)]

Tailings Facility Risk Consequence	Process Plant Consequence		
	Aggressive Chemicals Transferred to Environment Via Storm Drainage	Stockpiled Limestone, Coal or Sulphur Overflow Containment Via Storm Drainage	Construction or Operation Materials and Damaged Building Components Rendered Airborne by High Winds
overtopping of tailings embankment causing release of process water into the environment	-	-	-
breach of tailings embankment causing release of tailings and process water into the environment	X	X	-
flooding and damage to downstream resources	X	X	-
minor slump leading to temporary release of tailings and/or process water into the environment	-	-	-
major slump leading to loss of freeboard and breach of tailings embankment causing major release of tailings and/or process water to the environment	X	X	-

(a) X indicates that a combined effect could occur.

\- - indicates that no cumulative effects occur.

In summary, although several kinds of natural risk consequences may combine to produce cumulative consequences, all of these combinations are considered extremely unlikely. All identified risks are being managed through mitigation measures to achieve high international standards as described in the natural risks section of each component EA.

2.6.2 Cumulative Effects With Other Projects and Activities

2.6.2.1 Introduction

The study area for assessment of potential cumulative effects between the project and other projects and activities includes all areas within 10 km of the project sites. The project has the potential to act cumulatively with the following projects that could produce impacts on people or the environment in the event of an extreme natural event:

- slumping and eroding slopes as a result of tavy agricultural practices and forest clearing could impact the same watercourses as a flood or release event from the mine, pipeline, or tailings facility would impact;
- a contaminant release event due to flooding or damage to buildings at the Logistique Pétrolière Terminal or other developments south of Toamasina could combine with releases from the process plant;
- a spill of chemicals from future Madarail traffic due to a slide or seismic event damaging the railway may occur together with a pipeline rupture, as the pipeline parallels the railway in some areas; and
- floodwater runoff from Andasibe area graphite mines could combine with that from a pipeline rupture in the same watershed.

2.6.2.2 Assessment of Cumulative Effects

Extreme events such as very heavy rainfall that leads to slope instability and flooding over large areas can result in natural risks that affect other developments and land use activities in addition to the project itself. However, in most cases the project is sufficiently distant from other projects and activities that any flooding large enough to bring the effects of the different activities together would also greatly dilute the contaminants released by the project. This is the case with the Andasibe graphite mines and with tavy agriculture. These activities could result in small incremental impacts with the project during extreme events, but the cumulative effect is only a negligible change from the project alone.

A natural event causing spills from both a Madarail cargo train and releases from the slurry pipeline could cause a locally elevated cumulative environmental consequence, but the probability of such an event occurring is very low.

A natural event resulting in flood-runoff of contaminants from the project and the Logistique Pétrolière terminal and other industrial developments south of Toamasina could result in an elevated cumulative impact in local small watersheds and especially in the marine environment. Again, the probability of such an event is very low.

2.6.3 Conclusions

The potential exists for components of the Ambatovy Project to combine with one another to produce higher effects than each project component separately if an extreme natural event occurs. Likewise, in the case of extreme natural events such as serious seismic activity or large-scale flooding, specific natural risks associated with the project can act cumulatively with natural risks associated with other projects and activities to produce greater hazards than the project alone. The impacts of these possible events have not been rated or modelled, however, because their probability of occurrence is extremely low.

Following mitigation for each individual project component, increased risks of natural hazards to the public and environment as a result of the project in combination with other projects are estimated to be low and within international standards.

2.7 HYDROGEOLOGY

No combined project effects or cumulative effects are predicted for hydrogeology.

2.8 HYDROLOGY

2.8.1 Ambatovy Project Combined Effects

2.8.1.1 Introduction

The five major components of the project overlap to produce combined effects as indicated in Table 2.8-1.

Table 2.8-1 Matrix of Overlapping Project Effects for Hydrology [(a)]

Project Components	Mine	Slurry Pipeline	Process Plant	Tailings Facility	Port Expansion
mine		X	-	-	
slurry pipeline			-	-	
process plant				-	
tailings facility					
port expansion					

[(a)] X Indicates that an overlapping (combined) effect occurs.

- Indicates that no cumulative effects occur.

Shaded area not applicable.

There are potential combined effects associated with the mine and slurry pipeline components due to the overlap of their respective LSAs near the mine and Torotorofotsy Wetlands. The combined effects of the pipeline and the mine, in the immediate area of the mine footprint, have been assessed together in Volume B, Section 3.8. There are no combined effects expected in individual receiving streams at locations away from the mine footprint but within the mine LSA. There is a potential for combined effects in the Torotorofotsy Wetlands, however these impacts are temporally separated because while mine impacts on hydrology will occur in the operations phase, hydrology impacts as a result of the slurry pipeline are primarily associated with construction of the pipeline watercourse crossings. Construction will require in-stream activity which may affect water levels for short periods of time. Impacts following crossing construction are expected to be negligible.

The effects of the mine will not overlap with the process plant or tailings facility, as they are not close enough to physically impact the same watersheds and water bodies. As a result, there will not be any cumulative changes in water levels, flows, or sediment levels. Similarly, no combined effects are expected between the pipeline, process plant or tailings facility.

2.8.2 Cumulative Effects With Other Projects and Activities

2.8.2.1 Introduction

The hydrology study area for assessment of potential cumulative effects between the Ambatovy Project and other projects and activities includes all areas within 100 km of the project sites. The project has the potential to overlap with other projects and activities to impact hydrology as follows:

- Changes in flows and increased sediment levels associated with the slurry pipeline may overlap with effects from other activities and infrastructure (e.g., logging, unpaved roads, operation of the Madarail line, and operation of graphite mines).
- Changes in flows in the various streams and rivers affected by the project may overlap with effects of existing and future hydropower development.

2.8.2.2 Assessment of Cumulative Effects With Other Projects

As discussed in Volume C, Section 3.6, construction of the slurry pipeline may result in high magnitude changes in flows, water levels, and sediment levels at watercourse crossing locations. These changes, however, are expected to be of short duration during pipeline installation and will not extend into operations or

closure after the streambeds have been re-established and the streambanks have been reclaimed and stabilized.

Combined impacts of the slurry pipeline and deforestation (e.g., within the Torotorofotsy Ramsar site and Mantadia-Zahamena Corridor proposed Conservation Area) on sediment levels will be limited due to the short duration of construction-related effects. Similar combined impacts would also be expected for the slurry pipeline and the existing network of unpaved roads.

Bridge abutments along the Madarail line may affect water levels and flow velocities at railway watercourse crossings, as well as sediment yield from the right-of-way. The proposed slurry pipeline and railway line are located in close proximity (i.e., within 2 km) for about 12 km east of Andasibe. It is expected, however, that no changes in water levels or velocities associated with the slurry pipeline will be measurable at the railway watercourse crossing locations. In addition, any changes that do occur would be of short duration during construction and would not be measurable during pipeline operation.

Graphite mines in the Andasibe area are believed to affect sediment concentrations within receiving waterbodies, e.g., the Sahatany River which is a tributary to the larger Sahatandra River. If the slurry pipeline crossing of the Sahatany River (XR16+100) is buried, there may be a combined effect on river sediment levels resulting from the pipeline and the upstream graphite mines. However, the combined effect would be of very short duration, occurring during the excavation and laying of the pipe across the channel. The effect would end following restoration of the streambed and stabilization of the streambanks.

The project is not expected to have any measurable effect on streamflows in larger streams and rivers that are, or could be, used for hydropower production. The watershed areas affected by the mine are very small in comparison to the watersheds captured by hydropower developments. Consequently, the increased runoff rate from disturbed mine areas would be negligible compared to flows that could be used for hydropower generation. Similarly, the construction of pipeline watercourse crossings may affect local water levels for very short durations, but no effects on average flow rates or volumes are expected. Based on the above discussion, no combined effects are anticipated between the project and current or future hydropower developments.

2.8.2.3 Combined Effects With Other Projects- Residual Impacts

The combined impacts of the Ambatovy Project with other projects and activities are summarized in Table 2.8-2.

Table 2.8-2 Residual Cumulative Impact Classification for Hydrology

Phase	Direction	Magnitude	Geographic Extent	Duration	Reversibility	Frequency	Environmental Consequence
Issue: Slurry pipeline and other developments: Change in flows and sediment levels (logging, unpaved roads, railway, graphite mines).							
construction / operations / closure	negative	**flows:** negligible **sediment**: high	local / regional	short-term	yes	low	**flows:** negligible **sediment:** moderate
Issue: Ambatovy Project and Other Developments: Changes in flows (hydropower)							
construction / operations / closure	negative	negligible	local / regional	short-term to long-term	yes	high (average conditions)	negligible

2.8.3 Conclusions

Any impacts on flows or water levels from the project are expected to be non-detectable at locations affected by other projects and activities. The combined impact is therefore considered negligible. Impacts on sediment levels associated with pipeline construction at watercourse crossing locations will be of high magnitude but of short duration. These impacts also reflect a high combined impact of short duration at one crossing location where effects from upstream graphite mining are considered.

2.9 WATER QUALITY

2.9.1 Ambatovy Project Combined Effects

2.9.1.1 Introduction

The potential combined effects of the mine, slurry pipeline, process plant and tailings facility on water quality are identified in Table 2.9-1.

Table 2.9-1 Matrix of Overlapping Project-Related Changes in Water Quality[(a)]

Project Components	Mine	Slurry Pipeline	Process Plant	Tailings Facility	Port Expansion
mine		X	-	-	n/e
slurry pipeline			X	X	n/e
process plant				X	n/e
tailings facility					n/e
port expansion					

[(a)] X Indicates that an overlapping (combined) effect occurs.

\- Indicates that no cumulative effects occur.

n/e Not evaluated in this section. A separate Cumulative Effects Assessment (CEA) has been completed for marine effects in Volume G, Section 2.10.

Shading indicates not applicable.

The changes in water and sediment quality due to activities in the mine area will not overlap with effects from the process plant or tailings facility because these project components are not close enough to physically impact the same watercourses and water bodies.

The slurry pipeline route connects the mine area to the process plant area, and runs less than 1 km south of the tailings facility. Therefore, there is a potential that predicted changes in water and sediment quality in the watercourses and water bodies due to the slurry pipeline could add to substance concentration changes caused by project activities at the mine, process plant or tailings facility. These combined effects are discussed below in Section 2.9.1.2.

Changes in water and sediment quality due to the tailings facility, which is primarily due to the seepage from the tailings facility, may combine with changes in water quality due to the process plant. The construction and operation of the process plant has the potential to affect water quality in watercourses that are downstream of the tailings facility. These combined effects are discussed below in Section 2.9.1.3.

2.9.1.2 Combined Effects of the Slurry Pipeline and Mine, Tailings Facility and Process Plant

There is a potential that predicted changes in water and sediment quality in the watercourses and water bodies due to the slurry pipeline could be affected by the mine, process plant or tailings facility. However, the effect of these other project components on water and sediment quality at the pipeline crossings is predicted to be negligible due to the following:

- negligible changes due to the slurry pipeline (Volume C, Section 3.7);
- small to negligible changes predicted for the most downstream assessment nodes in the mine, process plant and tailings facility local study areas (LSAs) (Volume B, Section 3.9; Volume D, Section 3.8 and Volume E, Section 3.10, respectively); and
- further dilution of the predicted substance concentration downstream of the mine, process plant and tailings facility LSAs.

Therefore, the combined effects of changes in water and sediment quality due to the slurry pipeline and the mine, tailings facility and process plant are predicted to be negligible.

2.9.1.3 Combined Effects of the Tailings Facility and Process Plant

Potential water quality changes due to process plant and the tailings facility may overlap because watercourses potentially affected by the process plant (i.e., the Ivondro River) are connected to watercourses that are downstream of the tailings facility.

Water and sediment quality predictions in the tailings facility area focused on a reach of the Ambolona River and three upper tributaries to the river. These watercourses are downstream of the tailings facility and are within the tailings facility LSA. The tailings facility was predicted to cause increases in three metals (i.e., copper, manganese and zinc) in the Ambolona River at the most downstream location of the LSA. About 4 km downstream from this location, the Ambolona flows into the Ivondro River. The drainage area of the Ivondro River near the confluence of the Ambolona is about 2,500 km^2, which is substantially more than the drainage area of the Ambolona at the downstream end of the tailings facility study area (approximately 25 km^2). Since the Ambolona River contributes a very small portion of the flows to the Ivondro River, water and sediment quality in the latter river will not be affected by the predicted increases in the concentrations of copper, manganese and zinc in the Ambolona River.

The process plant was predicted to cause negligible changes in water and sediment quality in the Ivondro River due to the low proportion of Ivondro River flow diverted to the process plant and erosion control measures implemented at the water intake site (Volume D, Section 3.8.5). Negligible changes in water and sediment quality were also predicted for watercourses receiving discharges from the process plant sediment ponds (Volume D, Section 3.8.5).

The combined effects of the process plant and tailings facility on changes in water and sediment quality are predicted to be negligible, since each of these project components are predicted to result in negligible changes in substance concentrations within the water column and bottom sediments.

2.9.2 Cumulative Effects With Other Projects and Activities

2.9.2.1 Introduction

The study area for assessment of potential cumulative changes in water and sediment quality for the Ambatovy Project and other projects and activities includes all areas within 100 km of the project sites. These areas are consistent with the areas used for assessing cumulative hydrology effects and are expected to capture the physical extent of potential cumulative effects. Projects and

activities that could potentially add to changes in water or sediment quality from the Ambatovy Project include:

- Andasibe graphite mine with the mine and slurry pipeline;
- deforestation due to logging and tavy agriculture with the mine and slurry pipeline; and
- the Madarail and road network with the slurry pipeline.

The Andasibe graphite mine is situated about 15 km from the mine LSA and adjacent to the slurry pipeline. The graphite mine is within the cumulative assessment area for water and sediment quality changes for both the mine and slurry pipeline. The area where deforestation may occur (i.e., Mantadia-Zahamena area) includes watercourses that the mine and slurry pipeline could also effect. The slurry pipeline is within 100 km of potential developments of the Madarail and road network and therefore, the same drainage basins could be affected.

The potential for cumulative effects between each of the above activities and projects and the Ambatovy Project are assessed in the following sections.

2.9.2.2 Assessment of Cumulative Effects

Andasibe Graphite Mine

The maximum predicted changes in water and sediment quality within the Ambatovy mine LSA are small for all assessed substances with the exception of chromium in the water column. However, predicted chromium concentrations in the water column decrease substantially from the outlet of the mine water management ponds to the most downstream assessment nodes (ranging from 5 to 10 km) within the LSA. Based on a qualitative extrapolation of these predicted reductions, chromium concentrations are expected to return to near baseline levels within 15 km downstream of the LSA due to dilution from downstream watershed or tributary flows. Therefore, no cumulative changes in water or sediment quality are predicted with in the combination of the Andasibe graphite mine and the Ambatovy mine.

The Andasibe graphite mine is believed to primarily affect water quality by increasing suspended sediment concentrations within receiving water bodies, including the Sahatany River which is a tributary to the larger Sahatandra River. The slurry pipeline route includes a crossing at the Sahatany River which may cause a combined effect on suspended sediment concentrations. Changes in suspended sediment concentrations are discussed in Section 2.8 of this volume.

Deforestation and Madarail and Road Network

Effects of deforestation in the Mantadia-Zahamena area due to logging and tavy agriculture could overlap with the water and sediment quality changes due to activities at the mine. Deforestation can cause changes in runoff quantities and quality. If substantial deforestation occurs within any of the basins downstream of the mine, this could result in a cumulative change in water and sediment quality in the basin where harvesting occurs. However, mitigation activities could be implemented, including specific harvesting methods and reducing the area harvested, to ensure that runoff quality and quantity are similar to natural background levels. This would results in negligible combined change in water and sediment quality. In any case the additive contribution from the Ambatovy Project is negligible.

Deforestation and the expansions or upgrades of the Madarail and road network could add to changes in water quality due to the slurry pipeline. These activities have the potential to increase suspended sediment concentrations in watercourses that are along the slurry pipeline route. The potential for cumulative effects on suspended sediment concentrations from deforestation, the Madarail network, and the road network and the slurry pipeline are discussed in Section 2.8 of this volume.

2.9.3 Conclusions

Potential combined changes in water and sediment quality for the following project components were identified:

- the slurry pipeline and the mine, tailings facility and process plant; and
- the process plant and the tailing facility.

The assessment of the potential combined effects on water and sediment quality between these project components indicated that the combined effects will be negligible.

The Andasibe graphite mine, deforestation and Madarail and road network in Madagascar were identified to have the potential to add to water and sediment quality changes due to the Ambatovy Project. However, assessment of water and sediment quality changes due to these activities and projects indicates that the cumulative effects with the Ambatovy Project will be negligible.

2.10 OCEANOGRAPHY

2.10.1 Ambatovy Project Combined Effects

2.10.1.1 Introduction

Marine ecology and oceanography may be affected by a combination of two parts of the Ambatovy Project: the port expansion and tailings facility marine outfall (Table 2.10-1).

Table 2.10-1 Matrix of Overlapping Project-Related Changes in Marine Ecology and Oceanography[(a)]

Project Components	Mine	Slurry Pipeline	Process Plant	Tailings Facility	Port Expansion
mine		-	-	-	-
slurry pipeline			-	-	-
process plant				-	-
tailings facility					X
port expansion					

[(a)] X Indicates that an overlapping (combined) effect occurs.

- Indicates that no cumulative effects occur.

Shading indicates not applicable.

2.10.1.2 Combined Effects of the Port Expansion and Marine Outfall

During the construction phase of the project, port expansion activity will have a low environmental consequence on turbidity, water quality and underwater noise, and a potentially very high environmental consequence on introduction of exotic species. In general, these impacts will be confined within the area of the port. Construction activity for the marine outfall will have a low environmental consequence on turbidity, underwater noise and artisanal fisheries. The projects therefore both have the potential to impact underwater noise and turbidity during the construction phase, but as impacts are localized in two distinct areas, little or no physical overlap is predicted. During the construction phase, therefore, combined project effects are very minor and will not result in higher effects than those predicted in the separate assessments for the port expansion and marine outfall.

During the operations phase, the port expansion is expected to have low environmental consequence on turbidity and water quality and a potentially very high environmental consequence on exotic species, due to release of ballast water of arriving ships. The marine outfall is expected to have a low environmental

consequence on water quality and artisanal fisheries. Impacts on water quality may spatially overlap, but in large part will be separate. During the operations phase, therefore, combined project effects will likewise not result in higher effects than those predicted in the separate assessments for the port expansion and marine outfall.

2.10.2 Cumulative Effects With Other Projects and Activities

Other projects and activities in the Toamasina area with potential effects on the marine environment will occur at the same time as the project. The development of industry in the Toamasina area, and economic growth throughout Madagascar has the potential to increase shipping volumes at the port of Toamasina, separate from the increase due to the project. In addition, the development of a fuel storage facility and jetty by Logistique Pétrolière in the vicinity of the marine outfall pipeline may add to cumulative effects.

Increases in shipping traffic at the port of Toamasina may have effects on the turbidity and water quality of the port area, which would add to the predicted low effects of the project. In addition, depending on the mitigation employed by ships to protect from the introduction of exotic species, the release of ballast water may result in the risk of introduction of invasive exotic plant and animal species. Although the potential exists for additive cumulative effects in turbidity, water quality, and exotic species introductions, the development of cleaner and more efficient operating guidelines by the port, which is an initiative that the project will support, will largely nullify these impacts, and may result in the possibility of improvement from existing baseline conditions. For example, the current fuel spill contingency plan for the port will be reviewed to ensure a rapid and effective response should the need arise. No cumulative effects are predicted at the port expansion-site.

The Logistique Pétrolière terminal is expected to have negligible impacts on turbidity, water quality, noise and artisanal fisheries (Logistique Pétrolière 2005). Because this terminal project will also involve the arrival of ships from foreign ports, it will also involve a risk of exotic species introductions in ballast water. Spatially, the terminal project will overlap closely with the location of the marine outfall pipeline, resulting in cumulative effects on artisanal fishers using the area. However, because the Logistique Pétrolière project is only anticipated to have negligible effects, the extent of the cumulative impacts will be very small. Construction of the two projects is likely to occur during different time periods, reducing the potential for cumulative construction impacts involving large amounts of shipping traffic. Cumulative effects are not expected to be greater than the magnitude of effects on turbidity, water quality, noise, artisanal fisheries and exotic species already predicted for the Ambatovy Project alone. During

operations of both projects, there is the potential for increased cumulative risk of ship collisions. However, Ambatovy Project mitigations, including working with port authorities on a revision of the regional traffic movement control system, is predicted to offset potential cumulative negative effects.

2.11 VISUAL AESTHETICS

2.11.1 Ambatovy Project Combined Effects

2.11.1.1 Introduction

The five major components of the project overlap to produce combined effects as indicated in Table 2.11-1.

Table 2.11-1 Matrix of Overlapping Project Effects for Visual Aesthetics[(a)]

Project Components	Mine	Slurry Pipeline	Process Plant	Tailings facility	Port Expansion
mine		X	-	-	-
slurry pipeline			X	X	-
process plant				X	-
tailings facility					-
port expansion					

[(a)] X Indicates that an overlapping (combined) effect occurs.

- Indicates that no cumulative effects occur.

Shading indicates not applicable.

Visual impacts will be additive where viewsheds of project elements overlap. The viewsheds of the mine, tailings facility and process plant each overlap part of the slurry pipeline route, and in these areas the effects of the slurry pipeline will be considered as an additive impact to the effects of the other project elements. In addition, the viewsheds of the process plant and tailings facility overlap.

2.11.1.2 Assessment of Combined Project Effects

The mine and slurry pipeline impact areas overlap each other for a distance of about 6 km at the west end of the pipeline route (Volume B, Section 3.10, Figure 3.10-1). Although these viewsheds overlap, most of the combined viewshed is located within and adjacent to the mine site, where residents and tourists will not be located. The most important combined effect will occur at the Torotorofotsy Wetlands, where small portions of the mine, as well as the cleared right-of-way (RoW) of the slurry pipeline will be visible to both residents and

tourists. The additive visual effect does not extend beyond the mine local study area (LSA) and is expected to be moderate in magnitude, local in extent, medium-term in duration, reversible, and medium in frequency. The combined visual effect will be most evident during pipeline construction, but the impact will be reduced when the RoW is revegetated.

The slurry pipeline and tailings facility impact areas overlap each other for a distance of about 5 km near the east end of the pipeline route (Volume E, Section 3.11, Figure 3.11-1). The areas of overlapping viewsheds are not highly populated and are not frequently used by visitors, but the overlap includes a section of Route Nationale (RN) 2. The additive visual effect does not extend beyond the tailings facility LSA and is expected to be low in magnitude, local in extent, medium-term in duration, reversible, and medium in frequency.

The slurry pipeline and plant viewsheds overlap for a distance of about 3 km along the east end of the pipeline route. The plant viewshed overlaps the same portion of RN2 that the tailings facility and slurry pipeline also overlap. The additive visual effect may extend beyond the process plant LSA because tall process plant facilities and emissions plumes may be visible beyond 5 km from the plant. The combined effect along the pipeline route is expected to be low in magnitude, regional in extent, medium-term in duration, reversible, and medium in frequency.

The tailings facility and plant viewsheds overlap sporadically within the area between these two developments. This overlap area includes several portions of RN2, and also includes southern portions of Toamasina. The additive visual effect may extend beyond the process plant LSA because tall process plant facilities and emissions plumes may be visible beyond 5 km from the plant. The combined effect within the overlapping viewsheds is expected to be low in magnitude, regional in extent, medium-term in duration, reversible, and medium in frequency.

The environmental consequences of the combined projects are summarized in Table 2.11-2.

Table 2.11-2 Residual Combined Impact Classification for Visual Aesthetics

Phase	Direction	Magnitude	Geographic Extent	Duration	Reversibility	Frequency	Environmental Consequence
Issue: Mine – Pipeline							
construction / operations	negative	moderate	local	medium-term	yes	medium	low
Issue: Tailings Facility – Pipeline							
construction / operations	negative	low	local	medium-term	yes	medium	low
Issue: Process Plant – Pipeline							
construction / operations	negative	low	regional	medium-term	yes	medium	moderate
Issue: Process Plant – Tailings Facility							
construction / operations	negative	low	regional	medium-term	yes	medium	moderate

2.11.2 Cumulative Effects With Other Projects and Activities

2.11.2.1 Introduction

The visual aesthetics study area for assessment of potential cumulative effects between the project and other projects and activities includes all areas within 5 km of the project sites.

The project has the potential to overlap with the following projects and activities to impact visual aesthetics:

- Deforestation due to logging and tavy agriculture overlaps with the effects of the mine and slurry pipeline on the Torotorofotsy Wetlands.
- Forest clearing and slope erosion due to agricultural land use along the slurry pipeline east of the Mantadia-Zahamena forest corridor.
- At Toamasina, the visual effects of the plant overlap with new development in the same area, including southern Toamasina industrial development, dry port development and the Logistique Pétrolière fuel depot project.

2.11.2.2 Assessment of Cumulative Effects

Deforestation in the area of the mine and slurry pipeline, in both the Torotorofotsy Ramsar site and the Mantadia-Zahamena Corridor Proposed Conservation Area presently occurs at a rate of about 1% per year. However, with the implementation of the project, including proposed mitigation for forest

management, protection of specific azonal areas and forest restoration along the pipeline, as well as implementation of the Carbon Project, deforestation due to logging and tavy agriculture is not expected to cause any additional cumulative visual impact with the project. Therefore, deforestation in these areas will not contribute to cumulative effects.

Deforestation and erosion of bare soils in agricultural areas along the slurry pipeline is expected to continue during the project. These activities will create a small additional negative visual effect; however, this occurs primarily in remote areas and those viewing this effect will be residents who are adapted to the types of visual effects caused by such activity. Therefore, the contribution of deforestation and agricultural activity to cumulative effects is negligible.

Development of new industrial activity south of Toamasina will contribute to cumulative visual impacts in this area. Projects planned specifically include dry port development, at which shipping containers will be stored and tall cranes and other machinery to move the crates will be visible; and the Logistique Pétrolière fuel depot area which will be characterized by large fuel tanks, jetty into the ocean and visible pipeline networks. These developments will be visible from RN2, southern Toamasina and other rural areas within the process plant LSA. Presently, there is no plan for the removal of any of these developments, once established.

The magnitude of the impacts combined is considered moderate; there is a small incremental increase of visual effects beyond the Toamasina area effects indicated for the Ambatovy Project alone in Table 2.11-2, but the effects remain classified as moderate. The effects will be visible at a regional level and will be long-term, with an overall moderate environmental consequence.

The residual effects of the combined developments are summarized in Table 2.11-3.

Table 2.11-3 Residual Cumulative Impact Classification for Visual Aesthetics

Phase	Direction	Magnitude	Geographic Extent	Duration	Reversibility	Frequency	Environmental Consequence
Issue: Cumulative agriculture and forest removal along slurry pipeline							
construction / operations / closure	negative	negligible	local	long-term	yes	moderate	negligible
Issue: Cumulative development of industry south of Toamasina							
construction / operations / closure	negative	moderate	regional	long-term	no	moderate	moderate

2.11.3 Conclusions

The main combined effects between Ambatovy Project components are the combined effects of the process plant with the slurry pipeline and tailings facility near Toamasina. The combined effects of these projects result in moderate visual impacts in viewing areas such as RN2, southern Toamasina, and rural areas along the slurry pipeline route in this area. Another important combined impact will occur within the Torotorofotsy Ramsar Site, which is more sensitive due to its potential as an ecotourism destination. At this location, a low combined impact will occur due to the effects of both the slurry pipeline and mine.

The main cumulative effects between the project and other planned activities will be due to development of new industrial projects south of Toamasina. The dry port development north of the process plant, and the Logistique Pétrolière fuel depot area northeast of the process plant will both increase the visibility of heavy industry from RN2, southern Toamasina and other rural areas within the process plant LSA.

3 CUMULATIVE AND COMBINED EFFECTS FOR BIOLOGICAL DISCIPLINES

3.1 FLORA

3.1.1 Ambatovy Project Combined Effects

3.1.1.1 Introduction

This section of the EA provides an evaluation of potential cumulative effects of the combined influences of project components on flora.

3.1.1.2 Identification of Project Component Combined Effects

The individual components of the project are located along a natural ecological gradient from mid-altitude interior forest to low-altitude coastal forest. Associated with this natural gradient of climate, topography and soils are changes in plant community composition and structure, which is linked to the occurrence of different vegetation types from the mine site to the Toamasina coastline.

Table 3.1-1 summarizes the vegetation types that are anticipated to be impacted by the various components of the project. Because species composition and plant community structure are in part a function of the natural ecological gradient, not all components of the project will have overlapping effects. Thus, potential cumulative effects between project components are dependent upon the particular vegetation class in question because each class is associated with its own geographic range. Taking the vegetation types of most interest to this assessment into consideration, potential combined effects between project components are outlined in Table 3.1-2.

Table 3.1-1 Vegetation Types Influenced by Individual Project Components

Vegetation Type	Mine	Slurry Pipeline	Plant Site	Tailings Facility	Port Expansion
Forested					
azonal thicket	Y				
azonal forest	Y	N			
azonal disturbed	Y				
azonal type transitional forest	Y	N			
transitional forest	Y	Y			
primary zonal forest	Y	Y			
degraded/heavily logged zonal forest	Y	Y			
marsh edge forest	N	N			
Eucalyptus and other woodlots/ plantations	Y	Y	N	Y	
agroforest and secondary forest vegetation				Y	
degraded residual coastal woodland			Y		
Non-forested vegetated					
beach ridge complex		Y	Y		
coastal shrubland/grassland complex		Y	Y		Y[(a)]
shrubland			Y		
herbaceous vegetation cover and pasture	Y	Y			
marsh herbaceous vegetation	Y	Y	Y	Y	
marsh herbaceous vegetation/rice paddies	Y				
non-forest slash and burn/tavy matrix	N	Y	Y	Y	
non-forested marsh edge (disturbed)	N				
rice paddies	Y	Y	Y	Y	
Aquatic					
ephemeral pond	Y				
river/water	N	N	Y		
canal			Y		N

[(a)] Due to railway access link from port to plant.

Y Yes; the vegetation type is impacted by the project component.

N No; the vegetation type occurs within the local study area but is not impacted by the project component.

Blank cells indicate vegetation type does not occur in the Local Study Area.

Table 3.1-2 Matrix of Overlapping Project Effects for Flora

Project Components	Mine	Slurry Pipeline	Process Plant	Tailings facility	Port Expansion
mine		X	X [(a)]	X[(a)]	-
slurry pipeline			X	X	X
process plant				X	X
tailings facility					-
port expansion					

[(a)] Linkage due to wetlands

X Indicates that an overlapping (combined) effect occurs.

- Indicates that no cumulative effects occur.

Shading indicates not applicable.

3.1.1.3 Assessment of Combined Project Effects

Loss or Alteration to Plant Communities

All project components contribute to direct loss and alteration of vegetation due to site clearing activities. Combined effects to wetlands as a result of altered hydrologic regimes or water quality occur at the mine site and tailings facility. Indirect effects to vegetation from fugitive dust and dispersion of SO_2 and NO_X occur at the mine site and the extreme western portion of the slurry pipeline.

Vegetation types that have been severely disturbed by influences of land settlement but offer some biological value to the project region in terms of native species diversity include:

- degraded/heavily logged zonal forest;
- degraded residual coastal woodland;
- beach ridge complex;
- coastal shrubland/grassland complex; and
- shrubland.

Table 3.1-3 Direct Flora Impact Areas for all Local Study Areas Combined

Vegetation Type	Area Within LSA (Baseline) (ha)	Area Impacted (ha)	Proportion of Area in LSA Impacted (%)
Forested			
azonal thicket	133	112	85
azonal forest	826	525	64
azonal disturbed	421	347	83
azonal type transitional forest	438	97	22
transitional forest	1,051	246	23
primary zonal forest	5,892	331	6
degraded/heavily logged zonal forest	8,709	111	1
marsh edge forest	36	0	0
Eucalyptus & other woodlots/plantations	1,593	51	3
agroforest and secondary forest vegetation	66	27	41
degraded residual coastal woodland	166	29	18
forested subtotal	*19,329*	*1,877*	*10*
Non-forested vegetated			
beach ridge complex	231	3	1
coastal shrubland/grassland complex	837	224	27
shrubland	105	6	6
herbaceous vegetation cover and pasture	2,980	84	3
marsh herbaceous vegetation	369	32	9
marsh herbaceous vegetation/rice paddies	1,012	12	1
non-forest slash and burn/tavy matrix	34,321	1,864	5
non-forested marsh edge (disturbed)	195	0	0
rice paddies	686	66	10
non-forested subtotal	*40,737*	*2,292*	*6*
Aquatic and non-vegetated			
village	514	16	3
access corridor (road/rail)	29	15	52
industry (buildings or exploration areas)	18	0	0
ephemeral pond	5	4	87
river/water	200	0	0
quarry	15	1	7
canal	38	1	2
non-vegetated subtotal	*819*	*37*	*5*
Total	**60,885**	**4,206**	**7**

Note Due to rounding, subtotals and total may not add precisely to expected values.

For the degraded/heavily logged zonal forest, beach ridge complex and shrubland, a low environmental consequence is predicted primary because of the low magnitude of effects (1%, 1% and 6% affected, respectively; Table 3.1-3) and because the effects will be localized (Table 3.1-4).

For the degraded residual coastal woodland and the coastal shrubland/grassland complex, the magnitude of effects are localized, but high (18% and 27%, respectively; Table 3.1-3). However, a low environmental consequence is predicted for these vegetation types for the following reasons:

- they are not unique to the coastal region;
- they do not represent native plant communities but rather, are degraded and altered from the lowland littoral rainforest ecosystems that once existed in the region;
- they occur within the highly disturbed region of Toamasina, which is characterized by a mix of native, exotic and unwanted plant species;
- industrial activities and human land uses in this region are expected to increase over time; and
- no locally endemic species were found within these habitats.

Other vegetation classes important for human use are discussed in the cumulative effects section for land use (Volume G, Section 4.3). These include the agroforest and secondary forest, plantations and woodlots, and rice paddy classes.

Plant communities with high biodiversity value are characterized by either high species diversity, an assemblage of species unique to the habitat, or both. These types of communities are of most interest to this assessment and are represented by the following vegetation classes:

- azonal vegetation types;
- ephemeral pond;
- azonal type transition forest;
- transitional forest;
- marsh edge forest;
- primary zonal forest; and
- marsh herbaceous vegetation (i.e., wetlands).

Table 3.1-4 Residual Cumulative Impact Classification for Combined Project Components on Plant Communities

Component	Direction	Magnitude	Geographic Extent	Duration	Reversibility	Frequency	Environmental Consequence
azonal forest	negative	high	local	long-term	irreversible	medium	high
azonal thicket	negative	high	local	long-term	irreversible	medium	high
disturbed azonal	negative	high	local	long-term	irreversible	medium	high
ephemeral pond	negative	high	local	long-term	irreversible	medium	high
azonal type transitional forest	negative	high	local	long-term	irreversible	medium	high
transitional forest	negative	high	local	long-term	irreversible	medium	high
primary zonal forest	negative	low	local	long-term	reversible	medium	low
marsh edge forest	neutral	n/a	n/a	n/a	n/a	n/a	n/a
Torotorofotsy wetlands	negative	low	local	medium-term	reversible	high	low
other wetlands	negative	low	local	long-term	irreversible	medium to high	low
degraded zonal forest	negative	low	local	medium-term	reversible	moderate	low
degraded residual coastal woodland	negative	moderate	local	long-term	irreversible	moderate	low
beach ridge complex	negative	low	local	long-term	reversible and irreversible	moderate	low
coastal shrubland/ grassland complex	negative	moderate	local	long-term	reversible and irreversible	moderate	low
shrubland	negative	low	local	long-term	irreversible	moderate	low

Azonal and Transitional Vegetation Types

Site clearing activities will cause the greatest impacts to ephemeral ponds, and azonal, azonal type transitional and transitional vegetation types within the western portion of the project area. Residual impacts during construction and operation for the mine and slurry pipeline are predicted to be of high magnitude and continue over the long-term (Table 3.1-4). Overall, the environmental

consequence of the combined project components on azonal and transition vegetation types during construction, operation and closure is predicted to be high.

For azonal and transitional vegetation types not directly affected by mining activities and pipeline construction, the effects of dust, SO_2 and NO_X were assessed. Based on the analysis, these emissions are predicted to result in a low environmental consequence to the health of azonal and transitional vegetation present within the mine site and western portion of the slurry pipeline.

Primary Zonal Forest Vegetation

Following mitigation, analysis indicated there would be a low environmental consequence to primary zonal forest as a result of project activities at the mine site and along the western portion of the slurry pipeline. The extent of effects will be restricted to the two local study areas but will extend beyond the life of the project (long-term duration). The magnitude of effects will be low and may be considered irreversible. However, with the use of native species during closure, a level of reversibility will be achieved as the forest reaches maturity.

For zonal vegetation not directly affected by mining activities and pipeline construction, the effects of dust, SO_2 and NO_X were assessed. Based on the analysis, these emissions are predicted to result in a low environmental consequence to the health of zonal vegetation occurring within the mine site and western portion of the slurry pipeline.

Wetlands

Based on an analysis of the direct and indirect effects of the project on the Torotorofotsy and other wetlands near project sites, a low environmental consequence was predicted. Changes in hydrology were predicted to have a negligible effect on these wetlands while changes to water quality were conservatively estimated to result in a low effect. Vegetation, water quality and sediment quality will be monitored.

Compensation for Loss of Azonal, Transitional and Primary Zonal Forest

Combined effects of the project on azonal, transitional and zonal vegetation types will in part be mitigated through the proponent's commitment to conserve or rehabilitate forest lands within the project area and elsewhere. At the mine site, the forest management buffer zone provides connectivity between the two azonal protection areas and between these areas and the Mantadia-Zahamena conservation corridor. The on-site azonal protection areas account for 305 ha

while the remainder of the management zone represented by azonal, transitional and primary forest vegetation types amounts to 2,989 ha (Table 3.1-5).

The proponent will work with government, communities and NGO's to establish an off-site azonal conservation area approximately 70 km north-east of the mine site at Ankera. An initial reconnaissance field survey indicated that the area has potential to represent a virtually undisturbed azonal forest protection zone as compensation for loss of azonal vegetation at the mine site. This azonal off-site outcrop covers an area of approximately 3,850 ha.

These efforts are above and beyond all other on-site reclamation efforts proposed as part of the closure plans for each project component.

Table 3.1-5 Summary of Commitments to Proposed Forest Management Zones, Rehabilitation Areas and Conservation Zones

Project Component	Conservation Efforts [a]		Loss of Forest Cover [d]	Net Loss or Gain (ha)
	Description	Area (ha)	Area (ha)	
mine	on-site azonal conservation areas	305	1,697	5,447
	forest management zone	2,989 [b]		
	off-site azonal conservation area	approx. 3,850 [c]		
slurry pipeline	zonal forest rehabilitation	60	116	-56
process plant	n/a	0	29	-29
tailings facility	n/a	0	34	-24
port expansion	n/a	0	0	0
Total		**7,204**	**1,876**	**5,328**

[a] To be conservative, proposed reclamation of the Carbon Project and all additional reclamation efforts proposed as part of the closure plans for each project component have not been included.

[b] Includes only moderately logged zonal forests and azonal, azonal type transitional and transitional vegetation classes that occur outside of the mine footprint and azonal conservation areas. All other non-forested or heavily logged areas that will not be disturbed as a result of the mine plan were not included in the total value presented.

[c] Estimated from the reconnaissance field survey.

[d] Includes all azonal, zonal and all other types of forest vegetation classes including degraded forests, woodlots, etc.

Loss of Plant Species

The risk of species loss exists within azonal and transitional vegetation types at the mine site and extreme western portion of the slurry pipeline. This issue is not a concern in the central and eastern portions of the slurry pipeline or in the Toamasina area because of the general disturbed conditions of habitat and

because no locally endemic species were found or are expected to occur in these central and eastern regions.

The issue of species loss with respect to azonal and transitional vegetation types will be addressed through a number of mitigative measures aimed to ensure that viable populations of all species of concern are secure during construction, operations and following closure of the mine. As a result, a neutral environmental consequence is predicted (Table 3.1-6).

Table 3.1-6 Residual Cumulative Impact Classification for Combined Project Components on Loss of Plant Species

Component	Direction	Magnitude	Geographic Extent	Duration	Reversibility	Frequency	Environmental Consequence
plant species	neutral	n/a	n/a	n/a	n/a	n/a	n/a

Introduction of Exotic and Unwanted Plant Species

The issue of exotic and unwanted plant species is applicable to the mine site and the portion of the slurry pipeline that passes through the Mantadia-Zahamena conservation corridor. This issue is not a concern in the central and eastern portions of the slurry pipeline or in the Toamasina area because of the disturbed condition of habitat which currently supports a significant cover of exotic and unwanted species. The efforts involved in controlling or eliminating these species in the central and eastern project regions would be impractical for maintaining or enhancing biological diversity of the region. These efforts would be better directed in other areas (i.e., at the mine site and within the Mantadia-Zahamena conservation corridor) where the results would have a positive impact on unique and natural vegetation types.

After mitigation, a low environmental consequence is predicted (Table 3.1-7).

Table 3.1-7 Residual Cumulative Impact Classification for Combined Project Components on Introduction of Exotic or Unwanted Plant Species

Component	Direction	Magnitude	Geographic Extent	Duration	Reversibility	Frequency	Environmental Consequence
exotic or unwanted plant species	negative	low	local	medium-term	reversible	medium	low

3.1.2 Regional Cumulative Effects with Other Projects and Activities

3.1.2.1 Introduction

It is the goal of this section of the EA to determine the incremental effect of the Ambatovy Project to flora in combination with other planned and foreseeable human and natural related disturbances in the region.

3.1.2.2 Identification of Other Projects and Activities Contributing to Regional Cumulative Effects

A common regional cumulative effects study area was used for flora, fauna and biodiversity. The geographic extent was based on the known distribution of the *Indri* (Figure 3.1-1) since it covers a large portion of the eastern littoral and mid-altitude zonal forest from the Mangoro River to the Antainambalana River. It also includes the Mantadia and Zahamena National Parks, and the Mantadia-Zahamena corridor. The study area is large enough to include the primary vegetation types of the eastern zonal and littoral forest, and the diversity of flora species that inhabit these areas. In addition, the spatial boundary includes the combined effects from all components of the Ambatovy Project in addition to a number of developments and activities that may generate cumulative impacts on plant communities.

The following projects and future activities are located within the study area and have the potential to overlap with effects from the Ambatovy Project (Section 1, Volume G):

- deforestation due to logging and tavy agriculture;
- four graphite mines (Andasibe, Toamasina, Brickaville, and Vatomandry);
- the segment of the Madarail system operating within the study area;
- paved and unpaved roads;
- Andasibe sawmill;
- urban centers and villages;
- the Logistique Pétrolière fuel Terminal Project;
- ecotourism; and
- reforestation brought about by the Carbon Project.

LEGEND

- MAJOR CITY
- MADARAIL LINES
- CUMULATIVE EFFECTS STUDY AREA FOR FLORA, FAUNA AND BIODIVERSITY

100 0 100 200

SCALE: 1:7,500,000 KILOMETRES

REFERENCE

Datum: WGS 84 Projection: UTM Zone 39S

PROJECT

AMBATOVY PROJECT

TITLE

FLORA AND FAUNA CUMULATIVE EFFECTS STUDY AREA

Golder Associates
Calgary, Alberta

PROJECT No.03-1322-172.6500		SCALE AS SHOWN	REV. 0
DESIGN	GJ	22 Aug. 2005	
GIS	TN	01 Nov. 2005	
CHECK	GJ	08 Feb. 2006	
REVIEW	DM	08 Feb. 2006	

FIGURE: 3.1-1

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3.1.2.3 Assessment of Regional Cumulative Effects

Clearance of the eastern rainforest for firewood, building materials, and development of pasture and agriculture lands between 1993 and 2000 has occurred at a rate of between 1.1% and 1.6% per year (Horning 2001; Dufils 2003). It has been estimated that at the current rate of clearing, all but the steepest slopes will be deforested by 2025 (Green and Sussman 1990). These data indicate that past, current, and future deforestation likely represents the largest incremental impact to loss of plant communities in the cumulative effects study area during the life of the Ambatovy mine. Thus, for certain vegetation types, the magnitude and geographic extent of impacts from deforestation are predicted to be higher relative to all other projects and activities in the study area, including the Ambatovy project.

These clearing activities will impact primary zonal forest the most because it supports the desired species used in home construction and is a source of firewood and charcoal, which is highly sought after by villagers who live within the vicinity of these forests. The potential for logging activities to impact azonal vegetation types in the mid-altitude eastern forest region is predicted to be negligible. Azonal forest outcrops in the region are uncommon and the only intact site known to occur in the cumulative effects region will likely be designated as a conservation area as part of the biodiversity offsets planned for the project (Volume B, Section 4.1). Wetlands may not be directly impacted by deforestation; however, through changes in hydrology regimes and increased sedimentation from new logging roads and erosion of cut-over areas, indirect impacts to wetlands may occur. Deforestation within the regional cumulative effects study area may result in the extirpation or extinction of plant species, which was not predicted for the project because of the extensive mitigation efforts proposed. Deforestation will also bring about an increase in the introduction of exotic and unwanted plant species to the affected areas through alteration of habitat and changes in land use. Thus, the magnitude and geographic extent of impacts from deforestation are predicted to be higher relative to all other projects and activities in the study area, including the Ambatovy project.

Activities associated with the graphite mines, urbanization, establishment of villages and ecotourism lodges, and development of public transport systems will also result in the loss or alteration to plant communities in the study area from construction through to closure of the Ambatovy Project. Historic and current effects to plant communities from these developments would be similar to effects predicted for the Ambatovy Project and result in similar effects as outlined above. Although the magnitude of impacts on plant communities from these developments is unknown, it is expected that the magnitude from each

development is likely less than the project because they are not expected to affect azonal forest.

Protection of azonal and transitional vegetation types through the establishment of on-site and off-site conservation areas will offset residual impacts of the project. These azonal offsets represents 2.4 times the amounts of these habitats impacted by the project (Table 3.1-5). Overall, all azonal and zonal conservation activities comprise 3.8 times all the forest areas impacted (Table 3.1-5). Also other projects in the regional study area are not expected to disturb azonal and transitional habitats. Therefore, the overall regional cumulative effects on these habitats is predicted to be positive.

A number of the off-site biodiversity offsets will benefit zonal forests. These initiatives include buffer zone forest management planning and forest restoration along the pipeline. In addition, the regional carbon project will have an overall positive effect on zonal flora. These efforts will all off-set some of the negative effects associated with the loss of primary zonal forest in the region from the project and other activities. However, logging will continue to impact the region. Thus, a low negative to positive environmental consequence is predicted for the primary zonal forest vegetation type. As noted above, the presence of the project should overall improve flora conservation regionally, as compared to the status quo.

There will be low impacts to wetlands as a result of the combined effects of the Ambatovy Project and other projects and activities. While no mitigation is predicted for wetlands in deforestation areas, effects will likely be isolated. Thus, the impacts are predicted to be additive and low in magnitude during construction, operation and closure phases of the project resulting in a low environmental consequence in the cumulative effects study area.

Because of extensive mitigation effects the project is not predicted to result in the loss of plant species. However regionally, deforestation from other activities remains a threat. This may be tempered by the government's plans to increase protection of the mid-altitude eastern rainforest. Thus, the environmental consequence to loss of species is predicted to be low in the cumulative effects region, the same as it would be without the project.

Introduction of exotic or unwanted plant species was predicted to result in a low environmental consequence for the project because of planned mitigation aimed to control the spread of these species into sensitive areas. These control measures will not be implemented in deforested areas. However, as land use

changes when forests are cleared, the importance of exotic or unwanted species as an issue of concern is diminished. Thus, the environmental consequence to the introduction of exotic and unwanted plant species is predicted to be low in the cumulative effects region. Again, the residual environmental consequence is overshadowed by contributions other than the project, and would be the same without the project.

Table 3.1-8 Residual Regional Cumulative Impact Classification for the Ambatovy Project on Loss or Alteration of Plant Communities, Loss of Species and Introduction of Exotic or Unwanted Plant Species

Component	Direction	Magnitude	Geographic Extent	Duration	Reversibility	Frequency	Environmental Consequence
loss or alteration of plant communities							
azonal and transitional vegetation types	positive	n/a	n/a	n/a	n/a	n/a	n/a
primary zonal forest	negative to positive	low	regional	long-term	reversible	medium	low negative to positive
wetlands	negative	low	regional	medium-term	irreversible and reversible	medium to high	low
other forest vegetation types with biological value	negative	low	regional	long-term	reversible	medium	low
loss of species							
loss of species	negative	low	regional	long-term	irreversible	medium	low
exotic or unwanted plant species							
exotic or unwanted plant species	negative	low	regional	medium-term	reversible	medium	low

3.1.3 Conclusions

Site clearing activities will cause the greatest impacts to azonal and transitional vegetation types within the mine site and extreme western portion of the slurry pipeline. However, planned mitigation and off-site compensation integrated with government sponsored conservation within the Mantadia-Zahamena Corridor is predicted to result in a net regional cumulative positive effect to azonal flora. Site clearing activities will also affect primary zonal forest within the mine site and western portion of the slurry pipeline. Following mitigation, analysis indicated there would be a low negative to positive cumulative environmental consequence to this vegetation type.

For wetlands, the cumulative impact from site clearing activities will result a low environmental consequence.

Cumulative effects of the project on azonal, transitional and zonal vegetation types will in part be off set through the proponent's commitment to conserve or rehabilitate forest lands within the project area and elsewhere. A forest management plan will set out the strategy to provide connectivity between the two azonal protection areas at the mine site and between these areas and the Mantadia-Zahamena conservation corridor. Forest rehabilitation efforts to be carried out along the slurry pipeline corridor immediately east of the mine footprint and within the Mantadia-Zahamena conservation corridor will reduce the amount of disturbed land along the pipeline route in addition to providing a measure of connectivity between existing patches of managed and conserved forest zones. The proponent will also negotiate with stakeholders, the terms of agreement to establish an off-site azonal conservation area as compensation for loss of azonal vegetation at the mine site.

The main cumulative effect between the Ambatovy Project and other activities is site clearing of primary zonal forest within the mid-altitude rainforest. The magnitude of the cumulative impact is not certain because historic rates of deforestation may not be applicable in the future due to the government's more recent conservation initiatives. Taking both past and present scenarios into consideration, a low negative to positive environmental consequence is predicted.

There is no additive negative effect associated with the project and other projects and activities in the region to azonal and transitional vegetation types because the mine is the only project expected to particularly impact these habitats. The establishment of on-site and off-site azonal protection areas, among other mitigation, is predicted to off-set the impacts of the project. The success of these project activities will be linked with the government's conservation measures for the Mantadia-Zahamena Corridor.

3.2 FAUNA

3.2.1 Ambatovy Project Combined Effects

3.2.1.1 Introduction

As the project is located along a natural, although highly altered, ecozone gradient from mid-altitude forest to low-altitude forest, not all habitats occur throughout the project area. Therefore, not all components of the project will have overlapping effects on faunal populations, except where a species occurs in more than one habitat. Table 3.2-1 summarizes the natural habitats that are anticipated to be impacted by the various components of the project. Components in the Toamasina area were considered together and include the

process plant, tailings facility, and port expansion. Although the various project components are also predicted to influence human land use areas (e.g., tavy, agriculture, woodlots and plantations), natural habitats support the most species, particularly for rare species (Volume J, Appendix 4.1), so the cumulative effects assessment focuses on these habitats.

Habitats in the slurry pipeline Local Study Area (LSA) occur in both the mine and the Toamasina LSAs (Table 3.2-1) so there is the potential for overlapping effects between the pipeline and these components (Table 3.2-2). However, the effects of the mine will not overlap with the process plant, tailings facility or port expansion as they are not close enough to physically impact the same habitats and will not result in changes in the same faunal populations. The overlapping effects of the process plant, tailings facility and port expansion are already addressed together in Volume D, Section 4.2 within the Toamasina fauna LSA. The other overlapping effects, between the mine and slurry pipeline, and the slurry pipeline, process plant, tailings facility and port expansion are addressed in the following sections.

Table 3.2-1 Habitats Influenced by Individual Project Components

Habitat Type	Mine Site	Slurry Pipeline	Toamasina Area[(a)]
azonal forest	Y	N	N
transitional forest	Y	Y	N
zonal forest	Y	Y	N
ephemeral pools	Y	N	N
marsh edge	N	N	N
wetlands	N	Y	Y
streams	Y	Y	Y
coastal shrub	N	Y	Y
coastal woodland	N	N	Y
shrubland	N	Y	Y

[(a)] Includes process plant, tailings facility, and port expansion.

Y = Yes.

N = No.

Table 3.2-2 Matrix of Overlapping Project Effects for Fauna[(a)]

Project Components	Mine	Slurry Pipeline	Process Plant	Tailings Facility	Port Expansion
mine		X	-	-	-
slurry pipeline			X	X	X
process plant				X	X
tailings facility					X
port expansion					

[(a)] X Indicates that an overlapping (combined) effect occurs.

- Indicates that no cumulative effects occur.

Shading indicates not applicable.

3.2.1.2 Assessment of Combined Project Effects

Mine and Slurry Pipeline

The mine and slurry pipeline have impacts that overlap spatially and temporally in the following areas:

- site clearing and fragmentation of habitats during construction and operations;
- change in water flows during construction and operations;
- sensory disturbance during construction and operations;
- edge effects, including dust, introduction of non-native and invasive species, and microclimatic changes, during construction and operations;
- direct mortality from site clearing, nuisance fauna, collisions and hunting/collecting; and
- barriers to movement.

Changes in air and water quality were not considered a valid effect pathway for the slurry pipeline component. Therefore, no cumulative effects with the mine are predicted for these disciplines.

Direct Habitat Loss

Site Clearing

Residual combined impacts and environmental consequences of direct habitat loss on fauna as a result of site clearing for construction and operation of the mine and slurry pipeline are presented in Table 3.2-3. Environmental consequences for azonal, transitional, ephemeral pond and stream habitats as a result of site clearing were predicted to be high in the mine area. These

consequences were anticipated because >20% of these habitats within the LSA will be lost and the effects are long-term. Of these habitats, only the transitional forest and streams will also be impacted by the pipeline component and impacts from the pipeline were predicted to be low. As the mine impact to these habitats is already predicted to be high, the environmental consequence for these habitats will not change with the addition of the pipeline impacts.

Zonal forest is the only other habitat predicted to be impacted by both the mine and pipeline components. The impacts to zonal forest were predicted to be low for both components and as the effects will remain local, the combined environmental consequence to zonal habitats from mine and pipeline components is also predicted to be low. The marsh edge habitat will not be impacted by the mine; therefore, no cumulative effects are predicted for this habitat.

Table 3.2-3 Residual Combined (Mine and Pipeline) Impact Classification for Impacts Related to Direct Habitat Loss

Component	Direction	Magnitude	Geographic Extent	Duration	Reversibility	Frequency	Environmental Consequence
Issue: Site Clearing							
transitional	negative	high	local	long-term	irreversible	low	high
zonal	negative	low	local	long-term	reversible	low	low
wetlands	neutral	negligible	n/a	n/a	n/a	n/a	n/a
streams	negative	high	local	long-term	reversible	low	high
local endemic species	negative	moderate	local	long-term	reversible	low	moderate
species only in azonal and transitional forest habitats	negative	moderate	local	long-term	reversible	low	moderate
other species	negative	low	local	long-term	reversible	low	low
Issue: Change in Water Flows							
habitats	neutral to negative	low to high	regional	long-term	reversible	moderate	moderate to high

n/a Not applicable.

The three local endemic fauna species occurred in azonal, transitional and zonal forests of the mine area and the environmental consequence to populations of these species was predicted to be moderate. Assessment of cumulative effects is only relevant for the transitional and zonal forests, as the pipeline does not impact azonal habitats. With successful mitigation, including preservation of on-site conservation areas and reclamation of zonal forests, the environmental consequence to species from combined project impacts will remain moderate.

Therefore, the combined effects from site cleaning for the mine and slurry pipeline are not predicted to change the environmental consequence.

Change in Hydrology

Residual impacts to habitats due to changes in hydrology were predicted to be moderate to high for the mine area and negligible to low for the pipeline component. The vegetation communities within the watershed basins in the mine LSA are predicted to be negatively impacted during mine operations due to moderate to high increases of average flows during the wet season. As impacts from the pipeline component should be local, short-term and reversible and occur only during construction, they are not predicted to be additive with potential changes in habitats predicted for the mine area. Therefore, the environmental consequence of changes in hydrology to faunal habitat as a result of the combined mine and slurry pipeline components are predicted to remain at moderate to high.

Indirect Habitat Loss

Residual combined impacts and environmental consequences of indirect habitat loss on fauna as a result of construction and operation of the mine and slurry pipeline are presented in Table 3.2-4.

Table 3.2-4 Residual Combined (Mine and Pipeline) Impact Classification for Fauna due to Indirect Habitat Loss

Taxon	Direction	Magnitude	Geographic Extent	Duration	Reversibility	Frequency	Environmental Consequence
Issue: Sensory Disturbance during Construction Phase – Noise							
species using vocalization for breeding	negative	low to moderate	local	short-term	reversible	high	low
wary species	negative	low to moderate	local	short-term	reversible	high	low
other species	negative	negligible	local	short-term	reversible	high	negligible
Issue: Edge Effects							
faunal species	negative	low to moderate	local	medium to long-term	reversible	high	low to moderate

Sensory Disturbance

Noise

The residual impacts to fauna from project-generated noise were predicted to be negative and negligible to low for the mine component during construction and operations (Volume B, Section 4.2). Noise effects were also predicted to be negligible to low for the pipeline component, but only during construction (Volume C, Section 4.2). Therefore, cumulative effects of noise from the two components will only occur during the construction phase and will be highly localized. The combined cumulative effects of noise on fauna during this period are predicted to remain negligible to low.

Light

Light effects were not considered a valid effect pathway for the pipeline component as construction will occur during the day. Therefore, no cumulative effects of light on fauna are predicted.

Edge Effects

The environmental consequence of edge effects is negative and moderate for azonal and transitional habitats in the mine area because the magnitude of the habitat loss is moderate, the duration is long-term and the effects will be continuous. The pipeline component is predicted to result in a moderate environmental consequence to zonal, specifically degraded zonal, forest.

Effects to other habitats were predicted to have a low environmental consequence in both LSAs because the magnitude of the areal extent of the impact was low. The combined impacts to habitats due to edge effects, therefore, results in a moderate environmental consequence for azonal, transitional and zonal habitats.

The impacts on faunal populations due to edge effects are predicted to be local, medium to long-term depending on habitat and occur continuously. The effects on faunal populations are unknown; however, as discussed in the mine EA, the effects will be greatest on species using remnant azonal and transitional habitats as their primary habitat. Impacts are predicted to be low for species using abundant zonal habitats or ephemeral pond and wetlands habitats that will have low impacts due to edge effects.

Direct Mortality

The combined impacts of direct mortality caused or induced by the project are predicted to have a low to moderate environmental consequence on faunal populations (Table 3.2-5). Site clearing at the mine will have the highest magnitude of impact, whereas the potential for animal-vehicle collisions and induced hunting/collecting as a result of access creation for the pipeline will have

the longest duration of impacts, although of low magnitude. Cumulative effects of the project components will occur only where faunal populations overlap. Therefore, the combined impacts will be greatest for wide-ranging species, particularly if their populations extend beyond the study areas.

Fragmentation and Barriers to Movement

Fragmentation of habitats as a result of mine construction and operation was predicted to be low to moderate. Moderate effects were predicted for wide-ranging species because, although the magnitude of impacts will be low, the effects are regional for species whose populations extend outside the LSA. Fragmentation impacts from the pipeline were predicted to be negligible, as the pipeline will be located primarily on already degraded landscapes. For both components mitigation such as crossing structures and reclamation, particularly within the Mantadia-Zahamena corridor, will maintain connectivity of habitats and minimize many of the impacts of fragmentation due to construction and operation of the mine and slurry pipeline. Therefore, the combined impacts of fragmentation on fauna are predicted to remain low for all but wide-ranging species that are negatively affected by habitat fragmentation (Table 3.2-6). Thus no changes in environmental consequences are predicted for combined impacts from the mine and slurry pipeline.

Table 3.2-5 Residual Combined (Mine and Pipeline) Impact Classification for Fauna due to Direct Mortality

Taxon	Direction	Magnitude	Geographic Extent	Duration	Reversibility	Frequency	Environmental Consequence
Issue: Direct Mortality							
slow-moving or sedentary species	negative	low	local	short to long-term	reversible	medium	low
rare species	negative	low	local	short to long-term	reversible	medium	low
wide-ranging species	negative	low	regional	short to long-term	reversible	medium	moderate
other species	negative	low	local	short to long-term	reversible	medium	low

There will be an increase in the impact to movement of fauna as a result of the combined mine and slurry pipeline components where the components overlap in the mine LSA. The impacts are predicted to be additive but low in magnitude during both construction and operation. The increased impacts during construction will occur during the brief period of pipeline construction when human activity and noise will temporarily overlap in a localized area. During operations, the maintenance road that will be constructed and maintained along

the pipeline will be an additional barrier to fauna that are unwilling to cross. However, as this road will only have an occasional monitoring vehicle traveling along it, the magnitude of the impacts to faunal movement is predicted to remain low. With the implementation of mitigation measures such as crossing structures, buried pipelines and reforestation, linkages between habitat patches and to regional corridors should be maintained. Therefore, the incremental increases in impacts are not predicted to change the predicted environmental consequences described in either EA (Table 3.2-6). Impacts as a result of barriers to movement from combined mine and pipeline effects are predicted to be greatest (moderate) for wide ranging species where populations overlap and extend outside the study areas and low for all other species.

Table 3.2-6 Residual Combined Impact Classification for Fauna due to Fragmentation and Barriers to Movement

Taxon	Direction	Magnitude	Geographic Extent	Duration	Reversibility	Frequency	Environmental Consequence
Issue: Fragmentation							
wide-ranging species	negative	low	regional	long-term	reversible	high	moderate
other species	negative	low	local	long-term	reversible	high	low
Issue: Barriers to Movement							
wide-ranging species	negative	low	regional	long-term	reversible	high	moderate
wary species	negative	low	local	long-term	reversible	high	low
other species	negative	low	local	long-term	reversible	high	low

Slurry Pipeline, Tailings Facility, Process Plant and Port

The slurry pipeline and components in the Toamasina LSA (tailings facility, process plant and port) have impacts that overlap spatially and temporally in the following areas:

- site clearing and fragmentation of habitats during construction and operations;
- change in water flows during construction and operations;
- sensory disturbance during construction and operations;
- edge effects, including dust and microclimatic changes, during construction and operations;
- direct mortality from site clearing and collisions during construction and operations; and

- barriers to movement during construction and operations.

Changes in air and water quality were not considered a valid impact pathway for the slurry pipeline component. For the Toamasina components, introduction of non-native and invasive species and increased mortality from hunting/collecting were not considered valid impact pathways. Therefore, no cumulative effects are predicted for these potential impacts.

Direct Habitat Loss

Site Clearing

Residual combined impacts and environmental consequences of direct habitat loss on fauna as a result of construction and operation of the slurry pipeline, process plant, tailings facility and port are presented in Table 3.2-7. Combined impacts to fauna are predicted to occur only in areas where populations overlap.

As discussed in Volume D, Section 4.2, with the exception perhaps of wetlands, habitats in the Toamasina area do not represent high quality faunal habitat. Residual environmental consequence on faunal species was predicted to be low and remains so when all project components are considered locally.

Two rare fauna species occur in wetlands in the process plant and tailings facility areas. The environmental consequence to populations of these species was predicted to be low. Cumulative impacts to these species will likely remain low as only a small proportion of wetlands within the same coastal system along the pipeline will be impacted.

Change in Hydrology

Residual impacts to habitats due to changes in hydrology were predicted to be negligible to low for the pipeline component and moderate to high for the Toamasina area. The vegetation communities within the watershed basins in the Toamasina LSA are predicted to be negatively impacted during operations due to changes in water levels, and the impacts extend outside the LSA for two of the three basins. As impacts from the pipeline component should be local, short-term and reversible and occur only during construction, they are not predicted to contribute to potential changes in habitats predicted for the Toamasina area.

Table 3.2-7 Residual Combined (Pipeline and Toamasina Components) Impact Classification for Impacts Related to Direct Habitat Loss

Component	Direction	Magnitude	Geographic Extent	Duration	Reversibility	Frequency	Environmental Consequence
Issue: Site Clearing							
faunal species	negative	low	local	long-term	reversible	low	low
Issue: Change in Water Flows							
habitats	neutral to negative	low to high	regional	long-term	reversible	moderate	moderate to high

Indirect Habitat Loss

Residual combined impacts and environmental consequences of indirect habitat loss on fauna as a result of construction and operation of the slurry pipeline, process plant, tailings facility and port are presented in Table 3.2-8.

Table 3.2-8 Residual Combined (Pipeline and Toamasina Components) Impact Classification for Fauna due to Indirect Habitat Loss

Taxon	Direction	Magnitude	Geographic Extent	Duration	Reversibility	Frequency	Environmental Consequence
Issue: Sensory Disturbance – Noise							
species using vocalization for breeding	negative	low to moderate	local	medium-term	reversible	high	low
wary species	negative	low to moderate	local	medium-term	reversible	high	low
other species	negative	low	local	medium-term	reversible	high	low
Issue: Edge Effects							
faunal species	negative	low	local	medium to long-term	reversible	high	low

Sensory Disturbance

Noise

Cumulative effects of noise on fauna will only occur during the construction phase of the project along the route where the pipeline is being built. Once the pipeline has been constructed, no cumulative effects of noise on fauna are predicted. Noise effects on fauna were predicted to be low for the pipeline component and primarily occur during construction (Volume C, Section 4.2). Wetlands, coastal shrub and shrubland habitats were predicted to be affected by noise above World Bank maximums in the Toamasina area. However, as

baseline values regularly exceed these standards and species richness, particularly rare species, is relatively low, impacts to fauna in this area are predicted to be low. Therefore, the combined effects of noise on fauna in the Toamasina area were also predicted to low. Therefore, as the pipeline noise effects will be local and temporary, combined effects are unlikely to be additive so cumulative effects of noise on fauna should be low.

Light

Light effects were not considered a valid effect pathway for the pipeline component as construction will occur during the day. Therefore, no cumulative effects of light on fauna are predicted.

Edge Effects

The environmental consequence of edge effects is negligible to low for fauna in the Toamasina area, primarily because of high levels of existing human disturbance in the area. The residual impact to fauna due to edge effects along the pipeline are also predicted to be negligible to low because the pipeline is largely built along areas of existing disturbance and reclamation following pipeline construction will restore habitats.

The combined impacts on faunal populations due to edge effects are predicted to be low because impacts will be restricted to the local area, occur continuously and be medium to long-term in duration depending on habitat.

Direct Mortality

The combined impacts of direct mortality caused or induced by the project are predicted to have a negligible to moderate environmental consequence on faunal populations (Table 3.2-9) because most of the area to be cleared in both areas is already disturbed. Combined effects of the project components will occur only where faunal populations overlap and combined impacts will be greatest for wide-ranging species, particularly if their populations extend beyond the study areas. For all affected species, the impact duration will be long-term in areas where roads are not decommissioned, but the effects are reversible if remaining populations can compensate for losses.

Table 3.2-9 Residual Combined (Pipeline and Toamasina Components) Impact Classification for Fauna due to Direct Mortality

Taxon	Direction	Magnitude	Geographic Extent	Duration	Reversibility	Frequency	Environmental Consequence
Issue: Direct Mortality							
slow-moving or sedentary species	negative	negligible to low	local	medium- to long-term	reversible	medium	negligible to low
rare species	negative	negligible to low	local	medium- to long-term	reversible	medium	negligible to low
wide-ranging species	negative	low	regional	medium- to long-term	reversible	medium	low to moderate
other species	negative	low	local	short- to long-term	reversible	medium	negligible to low

Fragmentation and Barriers to Movement

Fragmentation impacts in both the pipeline and Toamasina LSAs were predicted to be negligible because components will be located primarily on already degraded landscapes (Table 3.2-10). For both components mitigation such as culvert crossing structures and reclamation will maintain or restore connectivity of habitats and reduce impacts.

Impacts as a result of barriers to movement from combined slurry pipeline, process plant, tailings facility and port effects are predicted to be greatest (moderate) for wide-ranging species where populations overlap and extend outside the study areas (Table 3.2-10). Residual combined impacts to other species are predicted to be low. Barriers will remain over the long-term, particularly where roads will be left in place, and occur continuously until forested areas are re-established post-closure. However, in areas where potential barriers occur in primary habitats, mitigations, such as crossing structures, buried pipelines and reforestation, will be used to maintain linkages between habitat patches.

Table 3.2-10 Residual Combined (Pipeline and Toamasina Components) Impact Classification for Fauna due to Fragmentation and Barriers to Movement

Taxon	Direction	Magnitude	Geographic Extent	Duration	Reversibility	Frequency	Environmental Consequence
Issue: Fragmentation							
wide-ranging species	negative	negligible	regional	long-term	reversible	high	negligible
other species	negative	negligible	local	long-term	reversible	high	negligible
Issue: Barriers to Movement							
wide-ranging species	negative	low	regional	long-term	reversible	high	moderate
wary species	negative	low	local	long-term	reversible	high	low
other species	negative	low	local	long-term	reversible	high	low

No changes in environmental consequence are predicted for combined impacts from the slurry pipeline and Toamasina components and no additional mitigation is recommended.

3.2.2 Regional Cumulative Effects With Other Projects and Activities

3.2.2.1 Introduction

It is the goal of this section of the EA to determine the incremental effect of the project in combination with other foreseeable projects and disturbances on fauna.

3.2.2.2 Identification of Other Projects and Activities Contributing to Regional Cumulative Effects

The assessment is focused on determining the cumulative residual effects (i.e., effects after mitigation) from projects and activities that are likely to proceed within a defined period of time and geographic space.

The temporal boundary is the period of construction through closure for the project.

The spatial boundary for the cumulative effects assessment was determined based on the geographic extent of a wide-ranging species that may be potentially impacted by the project. Of the species observed or expected to occur in the project area, the Indri is a species with one of the largest distributions that also

uses a diversity of habitats occurring in the entire project area. The distribution of the Indri covers a large portion (about 50%) of the eastern littoral and mid-altitude zonal forest from the Mangoro River to the Antainambalana River (Volume G, Section 3.1, Figure 3.1-1). It also includes the Mantadia and Zahamena National Parks, and the Mantadia-Zahamena Corridor. The study area is large enough to include the primary natural habitats of the eastern zonal and littoral forest, and the diversity of fauna species that inhabit these habitats. In addition, the spatial boundary includes the combined effects from all components of the project in addition to several developments and activities that may generate cumulative impacts on fauna.

The following projects and activities are located within the study area and have the potential to overlap with effects from the Ambatovy Project (Volume G, Section 3.1, Figure 3.1-1):

- deforestation due to logging and tavy agriculture;
- four graphite mines (Andasibe, Toamasina, Brickaville and Vatomandry);
- chrome mine (Andriamena);
- copper-nickel exploration (Bemanevika);
- new petroleum terminal (Logistique Pétrolière Terminal);
- segment of the Madarail system operating within the study area;
- paved and unpaved roads;
- Andasibe sawmill;
- urban centres and villages;
- ecotourism; and
- reforestation brought about by the Carbon Project.

3.2.2.3 Assessment of Regional Cumulative Effects

Deforestation represents the biggest existing and predicted impact to fauna and faunal habitat within the Ambatovy cumulative effects study area (see Volume G, Section 3.1).

Regional government initiatives (e.g., Carbon Project, Mantadia-Zahemena Conservation Corridor) will offset some of the deforestation that will continue to occur in the regional study area. Site clearing and habitat fragmentation and degradation resulting from the development of mine exploration and development, forestry, urbanization, establishment of villages and ecotourism

lodges, and development of public transport systems has and will also effect fauna and faunal habitat in the study area from construction through closure of the project. Impacts from these projects are predicted to be similar in nature to those from the Ambatovy Project, although likely with a lower magnitude. Site clearing will remove habitats, result in direct mortality of individual animals, increase access and influence microclimatic conditions. These impacts could result in changes in faunal distribution and abundance.

Changes in the distribution and abundance of people and the associated need for services can have both positive and negative effects on fauna. Expansion of urban centres can result in greater displacement and higher mortality for fauna, through direct and indirect effects. However, a potential increase in tourism to protected areas can be positive for conservation of habitats (Section 3.5, this Volume), but will also require careful management of people such that the activity of tourists does not negatively effect fauna in these areas. The incremental effect of changes in the human activity patterns as a result of the project relative to other developments is predicted to be low, therefore the cumulative impacts to fauna are also predicted to be low.

Relative to the other projects and activities in the regional study area (Figure 3.1-1), the magnitude of the incremental impacts from the combined components of the project on fauna and faunal habitats is expected to be low to moderate from construction through closure. With reforestation brought about by the Carbon Project, Dynatec's participation in the Forest Management Plan, reforestation of key sections of the slurry pipeline corridor, and off-site azonal habitat conservation, the impact of the Ambatovy Project on zonal forests and faunal species occupying these habitats is predicted to be low negative to positive. On and off-site conservation of azonal and transitional habitats, including ephemeral pools, is therefore predicted to offset some of the impacts of the Ambatovy Project on these habitats. As the other projects in the regional study area are not expected to disturb azonal and transitional habitats, the overall cumulative effects are also predicted to be low negative to positive in the regional area.

The geographic extent of the cumulative impacts on faunal populations should be limited to the regional study area, with most effects occurring in areas within and adjacent to the mine, slurry pipeline, process plant, tailings facility and port expansion footprint (Table 3.2-11). The duration of the impacts will be long-term, extending from construction through closure, and the frequency will be medium (construction and reclamation activities occur periodically over the life of the mine).

Table 3.2-11 Residual Regional Cumulative Impact Classification for the Ambatovy Project on Fauna

Phase	Direction	Magnitude	Geographic Extent	Duration	Reversibility	Frequency	Environmental Consequence
Issue: Impacts to Azonal, Transitional and Ephemeral Pool Habitats							
construction - closure	negative to positive	negligible to low	local	long-term	irreversible	medium	low negative to positive
Issue: Impacts to Other Habitats							
construction - closure	negative to positive	negligible to low	local	long-term	irreversible	medium	low negative to positive

3.2.3 Conclusions

The main cumulative effects of project components are the combined impacts of the mine and slurry pipeline on species occupying rare habitats, including local endemics, and riparian and wetlands habitats potentially impacted by changes in water quantity and quality; and combined impacts of the pipeline, process plant and tailings facility on species occupying wetlands habitats. During closure, ongoing reclamation will reduce impacts, except for azonal and transitional habitat, ephemeral pools and natural wetlands.

Initiatives such as the Carbon Project, and public awareness programs on the ecological benefits of conducting land use practices away from conservation and reclamation areas should provide positive benefits to fauna and faunal habitats. Combined with the proponent's involvement in a buffer zone Forest Management Plan, plus on and off site azonal conservation areas, fauna distribution and abundance should increase in previously altered habitats in the regional study area.

3.3 FISH AND AQUATIC RESOURCES

3.3.1 Ambatovy Project Combined Effects

3.3.1.1 Introduction

The major components of the project overlap to produce combined effects as indicated in Table 3.3-1. The port expansion will not affect freshwater aquatic resources and therefore is not addressed further in this assessment.

Table 3.3-1 Matrix of Overlapping Project Effects for Fish and Aquatic Resources[(a)]

Project Components	Mine	Slurry Pipeline	Process Plant	Tailings facility
mine		X	-	-
slurry pipeline			X	-
process plant				X
tailings facility				
port expansion				

[(a)] X Indicates that an overlapping (combined) effect occurs.

\- Indicates that no cumulative effects occur.

Shading indicates not applicable.

The effects of the mine will not overlap with the process plant or tailings facility as they are not close enough to physically impact the same aquatic resources components. The tailings facility and process plant overlap some aquatic resources; similarly the process plant may overlap some aquatic habitats affected by the slurry pipeline.

These overlapping effects are addressed below.

3.3.1.2 Assessment of Combined Project Effects

Mine and Slurry Pipeline

The mine and slurry pipeline have impacts that will overlap spatially and temporally in the east flowing drainages of the Torotorofotsy River and in the Torotorofotsy Wetlands. These impacts relate to:

- downstream aquatic habitat disturbance (physical alterations and water quality) and fish community (species and health) during construction and operations in the Torotorofotsy River drainages; and
- artisanal fisheries during operations.

Combined, the mine and the slurry pipeline will affect aquatic resources in five 1st Order streams and one 3rd Order stream in the Torotorofotsy River drainage sub-basin. The primary effect will be disturbance of aquatic habitat and fish communities, primarily through the sedimentation of waters of the Torotorofotsy River, its tributaries and the Torotorofotsy Wetlands, although mitigation will be in place to control these impacts.

Fish communities within these drainages include two regionally endemic fish species, which appear to use the upper reaches of the watercourses as refugia, but which are also present in the tributaries entering the Torotorofotsy Wetlands. Impacts on the populations of these species and their health may occur during construction and /or operations and were rated local in extent for both the mine and pipeline. Effects on species and health were rated high in magnitude for the watercourses directly impacted by the mine activities alone; however were assessed as low in magnitude for downstream community effects. Pipeline effects on communities (species) and health after mitigation was rated as having a low magnitude of impact, but with unknown environmental consequences because of uncertainties regarding the impact of water quality (Total Suspended Solids [TSS]) changes.

The combined cumulative project effect from the pipeline and mine has been rated moderate in magnitude and moderate in overall environmental consequence (Table 3.3-2) because of:

- the possibility of undisturbed populations of endemic fish;
- few data on critical habitats for the species and the apparent use of unmodified habitats in 1st Order primary forest drainages;
- the fragmented nature of existing populations of these endemic species regionally; and
- potential additional habitat alterations to the Torotorofotsy Wetlands.

Artisanal fisheries can be affected by access changes as a result of the mine and the slurry pipeline route / or service roads during construction and operations. As access is likely to be controlled within the mine, the effect of the mine alone was rated as having a low environmental consequence. The additional access afforded by the slurry pipeline and its service road/construction access roads was rated high in magnitude during construction and moderate during operations for the pipeline route overall, and thus could have a higher magnitude effect on artisanal fisheries in the Torotorofotsy Wetlands area. Therefore the cumulative consequence has been rated as moderate (Table 3.3-2).

Table 3.3-2 Residual Combined Impact Classification for Fish and Aquatic Resources Mine- Pipeline

Phase	Direction	Magnitude	Geographic Extent	Duration	Reversibility	Frequency	Environmental Consequence
Issue: Mine – Pipeline: Habitat , Fish Community Disturbance and Fish Health							
construction / operations	negative	low / high	local	medium-term	no	medium	moderate
Issue: Mine – Pipeline: Artisanal Fisheries							
construction / operations	negative	low /high	local	long-term	yes/no	medium/high	moderate

Slurry Pipeline and Processing Plant

The slurry pipeline and processing plant will have impacts that overlap in the Ivondro River and a common tributary crossed by the slurry pipeline and the plant site water pipeline access route.

Individually, the effects of habitat disturbance as a result of the slurry pipeline construction and operation, the Ivondro water intake and pumphouse, and the water pipeline crossings were rated as local and low in magnitude. The effects of short-term water quality changes (TSS) as a result of pipeline construction were high in magnitude, but were low during operations, and with unknown environmental consequences to communities and fish health due to lack of specific life history information on the sensitivity of aquatic biota. Mitigation is expected to control these impacts. Effects on communities and species as a result of the water intake will also be mitigated (i.e., fish screening), and the potential impacts on artisanal fisheries were rated low for the water pumphouse (plant site related activities) and the slurry pipeline crossing. Therefore, the cumulative environmental consequence of the combined project remains low (Table 3.3-3).

Table 3.3-3 Residual Combined Impact Classification for Fish and Aquatic Resources Pipeline-Plant

Phase	Direction	Magnitude	Geographic Extent	Duration	Reversibility	Frequency	Environmental Consequence
Issue: Pipeline - Plant: Habitat , Fish Community Disturbance and Fish Health							
construction / operations	negative	low / high	local	medium-term	yes/no	low/medium	low
Issue: Pipeline - Plant: Artisanal Fisheries							
construction / operations	negative	low	local	medium-term	no	low/medium	low

Tailings Facility and Processing Plant

The tailings facility and processing plant have been addressed separately in Volume D (Section 4.3) and Volume E (Section 4.3), although because of their close spatial relationship, it is anticipated that many of the physical effects will overlap.

Additional overlaps are expected for artisanal fisheries due to available access from service corridors, and the likelihood that artisanal fishers may move or use various watercourses (Ivondro River, tailings tributaries, Pangalanes Canal) throughout the Toamasina area. Outside of the specific tailings inundation area, the individual effects were local in extent and low in magnitude.

Table 3.3-4 Residual Combined Impact Classification for Fish and Aquatic Resources Tailings-Plant

Phase	Direction	Magnitude	Geographic Extent	Duration	Reversibility	Frequency	Environmental Consequence
Issue: Tailings - Plant: Habitat , Fish Community Disturbance and Fish Health							
construction / operations	negative	low / high	local	medium-term	yes/no	low/medium	low
Issue: Tailings - Plant: Artisanal Fisheries							
construction / operations	negative	low	local	medium-term	no	low/medium	low

Overlaps from tailings water quality (tailings releases, seepage, TSS during construction and operation) and the plant site (air emissions) affecting local and regional water quality may also occur and indirectly affect aquatic biota health, community structure and quality of fish for use by artisanal fishers. However, mitigation and monitoring (Volume D, Sections 3.2, 3.7 and 3.8) will be employed to reduce impacts and the environmental consequences of the combined project are rated low (Table 3.3-4).

3.3.2 Cumulative Effects With Other Projects and Activities

3.3.2.1 Introduction

The study area for assessment of potential cumulative effects to fish and aquatic resources between the project and other projects or activities includes all areas within the regional study area and the contiguous or overlapping watercourses or drainages.

The project has the potential to overlap with the following ongoing activities to impact fish and aquatic resources:

- Deforestation due to logging and tavy agriculture will overlap with the effects of the mine, slurry pipeline, tailings and ancillary facilities (access routes) on aquatic habitats, water quality and biota in watercourses within the project boundaries.
- Access allowed by roads to the Andasibe graphite mine, the Andasibe Sawmill and other areas, will overlap with the effects of additional service roads and the slurry pipeline access corridor.
- Effects on downstream water quality due to the Andasibe graphite mine (mainly TSS), affecting tributaries to the Sahatandra River overlaps with the slurry pipeline route and crossings of these watercourses.
- Population growth in centres such as Moramanga and Toamasina due to other projects overlapping with the effects of the mine, process plant, tailings facility and port expansion to create a larger population that may influence the level of harvest of fish and aquatic biota by artisanal fisheries.

3.3.2.2 Assessment of Cumulative Effects

Deforestation from tavy and logging on the steep slopes and riparian habitats along drainages, with resulting severe sedimentation and loss of canopy, has resulted in significant negative impacts to the aquatic ecosystem and is one of the primary factors responsible for the attrition of endemic fishes in Madagascar (Benstead et al. 2000). Many of the island's endemic fish species exhibit extremely localized distributions, and are therefore particularly vulnerable to degradation of aquatic habitats in small footprints or geographic areas.

Deforestation in the area of the mine and slurry pipeline, in both the Torotorofotsy Ramsar site and the Mantadia-Zahamena Corridor Proposed Conservation Area presently occurs at a rate of about 1% per year. However, with the implementation of the project, including proposed mitigation for forest management, protection of specific azonal areas and forest restoration along the pipeline, as well as implementation of the Carbon Project, deforestation due to logging and tavy agriculture is not expected to cause any additional cumulative impact within this initial portion of the pipeline. However; deforestation specifically in the Andasibe area, due to graphite mining and sawmill operations, is expected to continue during the project. If the deforestation occurs on riparian slopes, these activities will create an additional cumulative negative effect at watercourse crossings along the slurry pipeline.

Tavy will continue to occur annually in many areas along the remainder of the slurry pipeline, along the access and service roads and the tailings area. It is also likely that improved and additional access will encourage development of agriculture, including deforestation or tavy in many drainages along the extent of the project. Although mitigation from re-vegetation and forest planting along the pipeline/service areas will moderate potential effects, a cumulative negative effect is expected in drainage basins affected by the development or ancillary activities.

The combined area of effect will be regional, as it will potentially encompass all watercourses and drainages from the mine to the port which support tavy and/or logging near the project operation. The cumulative magnitude of this effect is considered moderate. The impact will be medium-term in duration, reversible, and medium in frequency (Table 3.3-5). The overall environmental consequence to aquatic resources is expected to be moderate.

The Andasibe graphite mine impacts downstream water quality (mainly due to TSS), affecting tributaries to the Sahatandra River which overlaps with the slurry pipeline route and crossings of these watercourses. This activity will create an additional negative cumulative impact on fish species, fish health and aquatic habitat at watercourse crossings along the slurry pipeline and/or the access roads. The combined area of effect is likely to be small, although downstream impacts could extend the area. The magnitude is likely to be high during construction, but moderate to low during operations, regional in extent, medium-term in duration , and exhibit a low overall environmental consequence (Table 3.3-5).

The presence of roads to the Andasibe graphite mine, the Andasibe Sawmill and other areas, will overlap with the effects of additional service roads and the slurry pipeline access corridor. If additional watercourse crossings occur, this could produce an additional negative effect. Any upgrades to the railway (i.e., track replacement and maintenance; replacement of culverts or bridge) to service the project will also produce additional negative cumulative impacts on aquatic resources. The combined area of effect is expected to be small, but will depend upon the extent of roads and/ or railway construction or upgrades. The magnitude is likely to be high during construction, but low during operations, regional in extent, medium-term in duration, and exhibit a low overall environmental consequence (Table 3.3-5).

Population growth in the Moramanga and Toamasina areas due to other activities is difficult to predict during the timeframe of the project, but is predicted to be relatively small based on the other projects known at the present time. Increased population could place more pressure on available aquatic resources during both construction and operation. However, overall there is expected to be a negligible

additional cumulative effect from other projects due to population growth (Table 3.3-5).

Table 3.3-5 Residual Cumulative Impact Classification for Fish and Aquatic Resources

Phase	Direction	Magnitude	Geographic Extent	Duration	Reversibility	Frequency	Environmental Consequence
Issue: Deforestation and Tavy Effects							
construction / operations	negative	moderate	regional	medium-term	yes	medium	moderate
Issue: Water Quality – Graphite Mine							
construction / operations	negative	high / low	regional	medium-term	yes	medium	low
Issue: Roads, Railway, New and Upgraded Linear Development							
construction / operations	negative	high /low	regional	medium-term	yes	medium	low
Issue: Population Change							
construction/ operations	negative	low	regional	long-term	no	medium	negligible

3.3.3 Conclusions

Combined effects between project components occur within the mine and slurry pipeline, the slurry pipeline and processing plant, and the tailings facility and processing plant. The combined effects on the Torotorofotsy River tributary and the wetlands are negative and moderate in environmental consequence for aquatic habitat and resources and negative and moderate in environmental consequence for artisanal fisheries impacts. The combined effects on aquatic resources and artisanal fisheries affected by the slurry pipeline and plant are negative, but low in environmental consequence. Similarly, the combined effects from the tailings facility and processing plant on aquatic resources and artisanal fisheries were negative but low in environmental consequence.

The main cumulative effects between the project and other regional activities are deforestation and tavy agriculture activities adjacent to the mine, the slurry pipeline, the processing area and several other small developments; decreased water quality related to the graphite mine; and the effects of road development and railway upgrades on aquatic habitat and water quality at watercourse crossings. The deforestation effects are negative and moderate in environmental consequence, however, the cumulative effects of other activities are expected to have a low to negligible environmental consequence on fish and aquatic resources, provided mitigation activities are appropriate and effective.

3.4 NATURAL HABITATS AND BIODIVERSITY

3.4.1 Ambatovy Project Combined Effects

3.4.1.1 Introduction

This section of the Environmental Assessment provides an evaluation of potential cumulative effects of the combined project components on natural habitats and biodiversity. This is a necessary precursor to assessing cumulative effects from the whole project with other planned and foreseeable projects.

Similar to the component-specific effects, the analysis is focused on direct influences of habitat loss and fragmentation on natural habitats and biodiversity. Other cumulative project-related changes such as noise, light, physical barriers, access, air quality, hydrology and water quality on plants, fauna and fish species are assessed in Sections 3.1, 3.2 and 3.3 of this volume.

3.4.1.2 Identification of Project Component Combined Effects

The first step in assessing the combined effects of individual project components is to determine which components have the potential to overlap and generate additive or synergistic impacts. The individual components of the project are located along a natural ecozone gradient from mid-altitude forest to low-altitude forest. Associated with this natural gradient of soil, moisture and nutrient regimes are changes in flora community composition and structure (Volume G, Section 3.1), which is linked to the occurrence of different natural habitats from the mine site to the Toamasina coast line. In addition, the extent of natural and human-induced degradation of the landscape varies from 96% in the Toamasina study area, 94% along the pipeline corridor, and 89% in the mine site study area.

Table 3.4-1 summarizes the natural habitats that are anticipated to be impacted by the various components of the project. Components in the Toamasina area include the process plant, tailings facility and port expansion. Although the various project components are also predicted to influence human land use areas (e.g., tavy agriculture, woodlots and plantations), natural habitats are linked to the highest biodiversity potential (Volume J, Section 4.1); the assessment was focused on these ecotypes. Because the composition of habitats within each project component study area is a function of the natural ecozone gradient, not all components of the project will have overlapping effects. For example, primary natural habitats impacted by the mine site (e.g., azonal, transitional and ephemeral pools) are not influenced by project components in the Toamasina area (Table 3.4-1). Consequently, there is no potential for cumulative effects on

natural habitats and biodiversity due to mine site effects overlapping with either the process plant, tailings facility or port expansion effects. (Table 3.4-2).

Table 3.4-1 Natural Habitats Influenced by Individual Project Components

Natural Habitat Type	Mine Site	Slurry Pipeline	Toamasina Area[(a)]
azonal forest	Y	Y	N
transitional forest	Y	Y	N
zonal forest	Y	Y	N
ephemeral pools	Y	N	N
wetlands	N	Y	Y
coastal shrub	N	Y	Y
shrub land	N	Y	Y

[(a)] Includes process plant, tailings facility and port expansion.
Y = Yes; N = No.

Table 3.4-2 Matrix of Overlapping Project Effects for Natural Habitats and Biodiversity[(a)]

Project Components	Mine	Slurry Pipeline	Process Plant	Tailings Facility	Port Expansion
mine		X	-	-	-
slurry pipeline			X	X	X
process plant				X	X
tailings facility					X
port expansion					

[(a)] X Indicates that an overlapping (combined) effect occurs.
- Indicates that no cumulative effects occur.
Shading indicates not applicable.

In contrast, some habitats impacted by the mine site are also influenced by the western portion of the slurry pipeline, resulting in an overlap of effects (Tables 3.4-1 and 3.4-2). Similarly, natural habitats occurring in the Toamasina area are impacted by the eastern portion of slurry pipeline and infrastructure associated with the process plant, tailings facility and port expansion. Cumulative effects between the mine site and slurry pipeline, and between the slurry pipeline and Toamasina project components are evaluated in the following section.

3.4.1.3 Assessment of Project Component Combined Effects

Combined effects from the mine site and slurry pipeline were already analyzed in Volume B, Section 4.4. Similarly, the combined effects from the slurry pipeline and project components in the Toamasina area were assessed in Volume D, Section 4.4. For both the mine site study area and the Toamasina study area, fragmentation analyses included the segment of the slurry pipeline that influenced natural habitats and associated biodiversity within these study areas. It should be emphasised that off-site biodiversity off-sets are only included in the cumulative effects analysis, where all other foreseeable projects are also considered (Section 3.4.2). A summary of the assessment for combined project effects on biodiversity is provided in Table 3.4-3.

Table 3.4-3 Residual Cumulative Impact Classification for Combined Project Components on Natural Habitats and Biodiversity

Phase	Direction	Magnitude	Geographic Extent	Duration	Reversibility	Frequency	Environmental Consequence
Mine – Pipeline Components							
construction / operations	negative	high	regional	long-term	irreversible	medium	high
closure	negative	moderate	regional	medium-term	reversible	medium	moderate
Pipeline – Toamasina Components							
construction / operations	negative	moderate-high	local	long- term	irreversible	medium	moderate-high
closure	negative	moderate	local	medium-term	reversible	medium	low

3.4.2 Regional Cumulative Effects with Other Projects and Activities

3.4.2.1 Introduction

It is the goal of this section of the EA to determine the incremental effect from the project (as determined in Section 3.4.1.3) in combination with other planned and foreseeable human and natural related disturbances on natural habitats and biodiversity. Ambatovy Project biodiversity off-sets are also included.

3.4.2.2 Identification of Other Projects and Activities Contributing to Regional Cumulative Effects

The first step in assessing the incremental effects from the project on natural habitats and biodiversity is to define the temporal and spatial boundaries, and then determine which projects and activities to include in the assessment.

The temporal boundary is defined by the period of construction through closure for the project. Defining the spatial boundary or regional study area is more complicated. The size of the area should be large enough to capture the relevant human and natural disturbances that influence biodiversity in combination with the project, but not too large as to dilute the incremental effects of the project (Canadian Environmental Assessment Agency 1999). For example, the spatial boundary for assessing regional cumulative effects may be delineated by a drainage basin, watershed, ecozone, species range or the annual home range of individuals within a local population.

After considering these physical and biological parameters, the geographic extent for evaluating cumulative impacts associated with the project was based on the known distribution of the Indri (Volume G, Section 3.1, Figure 3.1-1). The distribution covers a large portion (approximately 50%) of the eastern littoral and mid-altitude zonal forest from the Mangoro River to the Antainambalana River. It also includes the Mantadia and Zahamena National Parks, and the Mantadia-Zahamena corridor. The study area is large enough to include the primary natural habitats of the eastern zonal and littoral forest, and the diversity of flora and fauna species that inhabit these habitats. In addition, the spatial boundary includes the combined effects from all components of the project (Section 3.5.1) in addition to several developments and activities that may generate cumulative impacts on natural habitats and biodiversity.

The following projects and activities are located within the study area and have the potential to overlap with effects from the project (Volume G, Section 3.1, Figure 3.1-1):

- deforestation due to logging and tavy agriculture;
- four graphite mines (Andasibe, Toamasina, Brickaville and Vatomandry);
- segment of the Madarail system operating within the study area;
- paved and unpaved roads;
- Andasibe sawmill;
- urban centres and villages;
- ecotourism; and
- reforestation brought about by the carbon project.

3.4.2.3 Assessment of Regional Cumulative Effects

It has been estimated that at the current rate of clearing, all but the steepest slopes will be deforested by 2025 (Green and Sussman 1990). Deforestation rates in Madagascar are described in Section 1 of this volume. These data indicate that past, current and future deforestation likely represents the largest incremental impact (through direct habitat loss and fragmentation) to natural habitats and biodiversity in the study area during the life of the Ambatovy mine. Thus, the magnitude and geographic extent of impacts from deforestation are predicted to be higher relative to all other projects and activities in the study area, including the Ambatovy Project.

The alteration and breaking apart of habitats associated with tavy, graphite mines, urbanization, establishment of villages and ecotourism lodges, and development of public transport systems has and will also influence biodiversity in the study area from construction through closure of the project. Historic and current effects to the landscape and species from these developments would be similar to effects predicted for the project. Examples of these effects include an overall reduction in the capacity of the study area to support flora and fauna, and negative changes in patch area, edge and connectivity which influence physical and chemical microclimatic conditions, and population and community dynamics (see Volume B, Section 4.4.4.2). Although the magnitude of the impact on natural habitats and biodiversity from these developments is unknown, because they have only marginally influenced azonal forest, it is expected that the magnitude from each development is likely less than the project.

Relative to the other projects and activities in the regional study area, the magnitude of the incremental impacts from the combined components of the Ambatovy mine on natural habitats and biodiversity is expected to be moderate from construction through closure (Table 3.4-3). Mitigations such as implementation of a local conservation project (carbon project), and public awareness programs from construction through closure on the ecological benefits of conducting land use practices away from conservation and reclamation areas should help reverse impacts to the regional study area. In addition, the proponent's involvement in a Forest Management Plan for the mine area may increase the amount of protected land to sustain biodiversity potential in an area that is currently about 64% disturbed, based on the mine LSA (Volume J, Section 1.1).

Within the regional study area, the geographic extent of the impacts on flora and fauna populations should be limited to the local areas within and adjacent to the mine, slurry pipeline, process plant, tailings facility and port expansion. The duration of the impacts will be long-term, extending from construction through

closure, and the frequency will be medium (construction and reclamation activities occur periodically over the life of the mine).

Development of the ore bodies will remove the ferricrete substrate which supports the azonal forest, and habitat loss of this ecotype (and associated ephemeral pools) will be irreversible (Volume B, Section 4.4). Similarly, loss of wetlands in the Toamasina area will likely be irreversible (Volume D, Section 4.4). However, because the pisolite substrate associated with transitional forest contains natural fissures, some reclamation of this ecotype may be possible, making the impacts partially reversible. Early seral stages of zonal forest and degraded forest can be expected to establish relatively quickly on reclamation areas (Volumes B, C and D, Section 4.4).

Impacts to population and community dynamics associated with the project during construction and operation should begin to diminish with a correspondent increase in stability in the ecosystem during phased closure of mine areas. It is important to acknowledge that habitats and the ecosystem within and adjacent to the project area will likely not return to current conditions. Populations, communities and ecosystems are constantly responding to natural and human-induced environmental perturbations, and are in a state of dynamic equilibrium (Holling 1973; Matthews et al. 1996). The post-development state of an ecosystem may be equally functional with the desired structure and composition, but it will not be the same as before development (Landis and McLaughlin 2000).

A number of regional off-site compensatory mitigations (biodiversity off-sets) have been mentioned above. They comprise:

- forest buffer zone management at the mine site;
- participation in the local and regional management of the Torotorofotsy Ramsar site;
- primary forest reclamation within the Mantadia-Zahamena Corridor along the pipeline RoW as part of the regional carbon project; and
- conservation of an off-site azonal habitat area.

The areas to be protected or reclaimed have been compared to the project footprint that impacts less disturbed native vegetation in Volume G, Section 3.1. Overall these biodiversity compensation initiatives will promote a net increase in biodiversity of three times, as compared to the no project alternative. As discussed during consultation in September 2005 (Volume A, Section 6), these off-site conservation actions are all directly related to a range of on-site mitigations. Such linkage and close geographic proximity to a project site are

generally regarded as good attributes for biodiversity off-sets (Kate et. al. 2004). Regionally then, there are a number of government plus Ambatovy Project conservation initiatives that will promote net positive trends to biodiversity.

Taking all available facts into consideration, the environmental consequence of cumulative direct impacts from the project on natural habitats and biodiversity is predicted to be low negative to positive (Table 3.4-4).

Table 3.4-4 Residual Regional Cumulative Impact Classification for the Ambatovy Project on Natural Habitats and Biodiversity

Phase	Direction	Magnitude	Geographic Extent	Duration	Reversibility	Frequency	Environmental Consequence
construction - closure	negative to positive	low	local	long-term	irreversible	medium	low negative to positive

3.4.2.4 Conclusions

The greatest combined impacts of project components will result from disturbance to azonal and transitional forest, and ephemeral pools in the mine-slurry pipeline area, and wetlands in the slurry pipeline-Toamasina area. The geographic extent of impacts will be regional in the mine-slurry pipeline area as habitats associated with the Mantadia-Zahamena corridor will be partially influenced. However, effects should be limited to local species and habitats in the slurry pipeline-Toamasina area.

Residual impacts during construction and operation are predicted to be of moderate to high magnitude, and continue over the long-term. During closure, ongoing reclamation and protection of conservation areas are anticipated to reverse residual impacts (except for the loss of azonal habitat, ephemeral pools, and wetlands) to a low or moderate magnitude. Overall, the environmental consequence of the impacts from combined project components on natural habitats and biodiversity is predicted to be moderate to high during construction and operation, and low to moderate during closure.

Although the project will influence endemic azonal and ephemeral pool habitats and associated species, the negative impact should be localized and of moderate magnitude compared to the historic, current and future effects of regional deforestation activities (tavy agriculture and logging). Indeed, when all biodiversity off-set initiatives are also considered, there is predicted to be a net gain of three times the biodiversity, compared to the no project option. On top of this, a number of regional government initiatives will also promote a positive trend for biodiversity conservation regionally. Other human-related activities

such as urban centres, graphite mines, and transportation systems that have not affected azonal habitat are qualitatively estimated to account for lower incremental effects on natural habitats and biodiversity in the regional study area.

Mitigations such as implementation of the corridor restoration project, off-site azonal habitat conservation and public awareness programs from construction through closure of the project on the ecological benefits of conducting land use practices away from conservation and reclamation areas will all help reverse impacts to the regional study area. In addition, the proponents' involvement in a Forest Management Plan may increase biodiversity potential in the eastern forest corridor. Weighing all available facts, the residual cumulative impact classification for the project on biodiversity, is predicted to be low negative to positive.

To ensure a net positive gain in areas to help preserve biodiversity, monitoring will be implemented to track the success of the conservation developments. The monitoring program will focus on indicators that respond rapidly to project-related disturbance to mitigation as needed. Details have been provided in appropriate project site volumes and biological discipline sections.

3.4.3 Economic Valuation of Habitats and Biodiversity

3.4.3.1 Introduction

This economic assessment concerns environmental and social impacts to habitats and biodiversity caused by the project. These include effects on biology, hydrology, air, and socio-economics, as a result of construction, operation, and decommissioning of the mine, slurry pipeline, process plant, tailings facility and port expansion, as applicable. Many of these potential impacts cause negative externalities (see below), which include losses of natural resources, many of which do not enter the market. Economic valuation tools have been developed to ascertain some of these values, which are used here to estimate the economic value of the potential impact to natural resources by the project. Where possible we have considered approaches recently applied in this subject area in Madagascar. However, it must be emphasized that methodology to apply valuation of biodiversity to individual projects is still a developing field. This section is included in this volume, since the analysis concerns combined project effects from all sites on biodiversity.

Objectives

This section assesses the external costs or benefits of the project as it relates to habitats or biodiversity as required by the Terms of Reference. This environmental valuation is conducted with the acknowledgement that there are

many conceptual and empirical problems inherent in producing a quantitative estimate of environmental externalities.

Based on other sections of this EA, a number of compensation measures, including offset programs, are to be implemented as part of the project (see the flora impact assessment, environmental management plans, and Resettlement Action Plan). Off-site compensation is used to offset unavoidably high on-site residual impacts to biodiversity. This compensation is considered in the economic valuation for better comparison of project and non-project scenarios.

3.4.3.2 Method

The method of the economic valuation includes four stages: i) definition of natural resources as ecosystem goods and services, for consideration; ii) categorization and selection of ecosystem goods and services for valuation; iii) literature review and data collection; and iv) data analysis. The second and third stages assist the scoping of the key goods and services as determined by the environmental and socio-economic impact assessments. The four stages of the economic valuation are described below.

Natural Resources as Goods and Services

Natural resources can be considered a capital stock of materials or information that exists at a point in time (Costanza et al. 1997). Each form of natural capital stock generates a flow of services that can directly or indirectly enhance the welfare of humans.

Ecosystem services consist of a flow of material, energy, and information from natural capital stocks that combine with manufactured and human capital to produce human welfare (Costanza et al. 1997). For the purpose of this assessment, ecosystem goods and services are referred to collectively here as ecosystem services.

Table 3.4-5 lists a range of ecosystem services considered here for valuation. The list was originally developed for a study of the world's ecosystem services and natural capital (Costanza et al. 1997). The authors attempt to prevent potential double counting of services by distinguishing different aspects of the same service. The authors point out that while it is important to recognize that a minimum level of ecosystem infrastructure is necessary, this base value is not included in the analysis.

Economic Valuation Categories

It is recognized that many of the economic benefits of ecosystem services are related to the value they hold for services other than direct consumption. The valuation of ecosystem services that are not directly consumed require various degrees of estimation. This estimation therefore considers both 'use' and 'non-use', categorized as shown in Table 3.4-6 and defined below. An increasing trend in estimation of values occurs from left to right in the table. The total economic valuation of project impacts will therefore use both quantitative and qualitative analysis.

Definitions of the use and non-use values categories are provided below:

Direct use – these values derive from the actual consumption of products from ecosystems. The consumption does not have to be depleting the resource and can include functions such as tourism.

Indirect use – these values derive from the presence of the ecosystem and do not involve consumption of any part of the ecosystem itself but of the services generated by the ecosystem including hydrological benefits.

Option values – this type of value is based on the potential value of the ecosystem for some future direct or indirect use. Although the benefit may not be currently experienced, there is value gained by knowing it can be used in the future.

Bequest values - this is similar to option value, but the perceived value is from knowing that future generations (including one's own offspring) will have the ability to use the ecosystem (any type of value).

Existence values – this value comes from the satisfaction (or utility) one receives from simply knowing that the ecosystem exists. For example, though a person has never been to the Amazon or Madagascar rain forest, one can still gain a value from knowing that it exists (and contains high diversity, picturesque waterfalls, etc.).

Table 3.4-5 Ecosystem Goods, Services and Functions Considered In This Valuation

Number	Ecosystem Good or Service	Ecosystem Functions	Examples
1	gas regulation	regulation of atmospheric chemical composition	CO_2/O_2 balance, O_3 for UVB protection, and SOx levels
2	climate regulation	regulation of global temperature, precipitation, and other biologically mediated climatic processes at global or local levels	greenhouse gas regulation, DMS production affecting cloud formation
3	disturbance regulation	capacitance, damping and integrity of ecosystem response to environmental fluctuations	storm protection, flood control, drought recovery and other aspects of habitat response to environmental variability mainly controlled by vegetation structure
4	water regulation	regulation of hydrological flows	provisioning of water for agricultural (such as irrigation) or industrial (such as milling) processes or transportation
5	water supply	storage and retention of water	provisioning of water by watersheds, reservoirs and aquifers
6	erosion control and sediment retention	retention of soil within an ecosystem	prevention of loss of soil by wind, runoff, or other removal processes, storage of silt in lakes and wetlands
7	soil formation	soil formation processes	weathering of rock and the accumulation of organic material
8	nutrient cycling	storage, internal cycling, processing and acquisition of nutrients	nitrogen fixation, N, P and other elemental or nutrient cycles
9	waste treatment	recovery of mobile nutrients and removal or breakdown of excess or xenic nutrients and compounds	waste treatment, pollution control, detoxification
10	pollination	movement of floral gametes	provisioning of pollinators for the reproduction of plant populations
11	biological control	trophic-dynamic regulation of populations	keystone predator control of prey species, reduction of herbivory by top predators
12	refugia	habitat for resident and transient populations	nurseries, habitat for migratory species, regional habitats for locally harvested species, or overwintering grounds
13	food production	that portion of gross primary production extractable as food	production of fish, game, crops, nuts, fruits by hunting, gathering, subsistence farming, or fishing
14	raw materials	that portion of gross primary production extractable as raw materials	the production of lumber, fuel or fodder
15	genetic resources	sources of unique biological materials and products	medicine, products for materials science, genes for resistance to plant pathogens and crop pests, ornamental species (pets and horticultural varieties of plants)
16	recreation	providing opportunities for recreational activities	eco-tourism, sport fishing, and other outdoor recreational activities
17	cultural	providing opportunities for non-commercial uses	aesthetic, artistic, educational, spiritual, and/or scientific values of ecosystems

Source: Costanza et al. 1997.

Table 3.4-6 Value Categories used in this Economic Valuation

Value	Use Values			Non-use Values	
	Direct use	Indirect use	Option Values	Bequest Values	Existence Values
description	outputs directly consumable	functional benefits	future direct and indirect values	use and non-use value of environmental legacy	value of knowledge from continued existence
examples	food, wood, non-timber forest products (ntfp), pasture, recreation, health	flood control, storm protection, nutrient cycles	biodiversity, conserved habitats	habitats, prevention of irreversible change	habitat, species, genetics, ecosystem

Source: Pearce and Moran, 1994.

3.4.3.3 Selection Of Ecosystem Goods And Services For Valuation

The environmental and socio-economic baseline studies and impact assessments prepared for the project were reviewed to determine the key ecosystem services for analysis from the several listed in Table 3.4-5. The scoping of key ecosystem services for valuation avoided the selection of social and market related issues for valuation, maintaining the focus of this study on ecosystem services.

Key issues identified as a result of the environmental studies are: potential impacts to air quality; water quality; hydrology; flora; fauna; fish; soils; and, land use. Environmental protection, mitigation, reclamation, and offset measures proposed by the proponent in the development of the project are expected, in many instances, to result in residual negative impacts to these resources that are of negligible environmental consequence.

We are able to quantify, approximately, the values of disturbance according to the biome categories presented by Costanza et al. (1997), based on the linkage to land use categories presented in the EA (see Land Use sections of EA). The linkage between the land use/biome category potentially affected by the project and ecosystem service is shown in Table 3.4-7. These linkages are based on those presented by Costanza et al. (1997) and the World Bank Environment Paper 101 (discussion paper), Assessing the Economic Value of Ecosystem Conservation (Pagiola et al 2004).

Table 3.4-8 lists each of the ecosystem services linked to the project and their assessed relevance locally, nationally and globally. Ecosystem services deemed highly relevant to the project are analyzed and valuated, while those deemed of moderate relevance are assessed qualitatively. The remainder are predicted to be

of low relevance, to have no impact, or the impacts are predicted to be adequately mitigated, therefore no valuation is done. This corresponds to the approach throughout the EA, in which the environmental consequence of potential impacts to environmental components is assessed (Volume A, Section 7).

Table 3.4-7 Linkage between Biome/Land Use Category and Ecosystem Goods and Services

Biome	1[(a)]	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
coastal estuaries	-	-	√	x	x	x	x	√	-	x	√	√	√	√	-	√	√
seagrass/algae beds	-	-	-	x	x	x	x	√	-	x	-	-	-	√	-	-	-
coral reefs	-	-	√	x	x	x	x	-	√	x	√	√	√	√	-	√	√
tropical forest	-	√	√	√	√	√	x	√	√	-	-	-	√	√	√	√	√
grass/rangeland	√	√	-	√	-	√	√	-	√	√	√	-	√	-	√	√	-
tidal marsh/mangrove	√	-	√	√	√	√	-	-	√	-	-	√	√	√	-	√	√
swamp/floodplain	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
lakes/rivers	-	-	-	√	√	-	-	-	√	-	-	-	√	-	-	√	-
rock	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
cropland	-	-	-	-	-	-	-	-	-	√	√	-	√	-	-	-	-
urban	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	-	-

Legend: √ Indicates a clear linkage between biome and ecosystem services.
x indicates a link between the biome and ecosystem services does not occur or is known to be negligible.
- indicates a lack of available information

Numbered ecosystems services refer to the same numbers in Tables 3.4-5 and 3.4-8.

The linkages between biome/land use and ecosystem service, and the above consideration of relevance indicates that the following ecosystem services are relevant to economic valuation for this project: (1) gas regulation; (3) disturbance regulation; (4) water regulation; (5) water supply; (6) erosion control and sediment retention; (9) waste treatment; and (13) food production.

Literature Review and Data Collection

Values to natural resources assigned as part of the project's socioeconomic study were used in valuation, where applicable. Other sources of valuation include reports on valuation of greenhouse gas (GHG) emissions and watershed protection in Madagascar, a series of studies prepared by the Programme d'Evaluation Economique des Ressources Naturelles, which include valuations of water quality, soil conservation, effects of soil erosion on rice production, non-timber forest products, and national parks in Madagascar, and global average values of ecosystem goods and services presented by Costanza et al. (1997).

Table 3.4-8 Relevance of Potential Effects to Key Ecosystem Goods and Services

Number	Key Ecosystem Goods And Services	Global	National	Local
1	gas regulation	high	moderate	-
2	climate regulation	low	-	-
3	disturbance regulation	-	moderate	high
4	water regulation	-	low	high
5	water supply	-	low	high
6	erosion control and sediment retention	-	low	high
7	soil formation	-	-	low
8	nutrient cycling	-	-	low
9	waste treatment	-	-	high
10	pollination	-	-	low
11	biological control			low
12	refugia	-	low	-
13	food production	-	-	high
14	raw materials	-	-	low
15	genetic resources	low	low	-
16	recreation	-	-	-
17	cultural	low	low	low

Legend: high = deserving attention, quantifiable, and analysed in this section.
moderate = potentially significant but not quantifiable.
low = minimal effect.
- either no effect or adequately mitigated so no negative economic effect.

3.4.3.4 Large Scale Mitigation and Conservation Offsets

This EA reviews a wide range of mitigation and some compensation measures designed to reduce the impact of the project. With regard to the potential impacts on biodiversity and natural environments, some of the largest mitigation measures include 1) on site conservation areas at the mine, 2) forest management buffer zone in the area around the mine, 3) forest rehabilitation efforts and 4) an offsite conservation area as a "biodiversity offset" intended to compensate for the irreversible effects of azonal vegetation removal. Thus the combined effects of the project on azonal, transitional and zonal vegetation types will in part be mitigated and compensated through the proponent's commitment to conserve or rehabilitate forest lands within the project area and elsewhere. The on-site azonal protection areas account for 305 ha while the remainder of the management zone represented by azonal, transitional and primary forest vegetation types amounts to 2,989 ha (Volume G-3.1 Flora, Table 3.1-5). At the mine site, the forest management buffer zone provides connectivity between the two azonal protection areas and between these areas and the Mantadia-Zahamena conservation corridor.

Additionally, forest rehabilitation efforts to be carried out along the slurry pipeline corridor immediately east of the mine footprint (kilometre post R0+000 to R2+000) and within the Mantadia-Zahamena conservation corridor (kilometre post R16+000 to R26+000) will amount to 60 ha. This rehabilitation work combined with the efforts of the Regional Carbon Project, will reduce the amount of disturbed land along the pipeline route in addition to providing a measure of connectivity between existing patches of managed and conserved forest zones.

The proponent will work with government, communities and NGO's to establish an off-site azonal conservation area approximately 70 km north of the mine site at Ankera. An initial reconnaissance field survey indicated that the area has potential to represent a virtually undisturbed azonal forest protection zone as compensation for loss of azonal vegetation at the mine site. This azonal off-site outcrop covers an area of approximately 3,850 ha (Volume G-3.1 Flora, Table 3.1-5). These efforts are above and beyond all other on-site reclamation efforts proposed as part of the closure plans for each project component.

The impact of these conservation offsets on environmental valuation of the project residual impacts are taken into account in the analysis presented below.

Data Analysis

The valuation of the ecosystem services affected by the project is quantified based on the results of the environmental assessment results, which indicate the overall significance of the potential effects by consideration of the magnitude, geographic extent, duration, reversibility, and frequency. It is important to note that environmental offsets contribute positively to the valuation of ecosystem services, therefore these offsets are calculated as negative values, reducing the overall 'cost' of the negative effects.

3.4.3.5 Gas Regulation

The Ambatovy Project will generate large amounts of greenhouse gases (GHG), approximately 2 million tons of CO_2 equivalents (ECO_2) per year of operations (Volume D, Section 3.3). There are currently no regulations controlling greenhouse gas (GHG) emissions in Madagascar. There is a possibility of future regulation under an expanded Kyoto Protocol or similar international GHG emission reduction agreement. Such an agreement is currently under discussion internationally, but there is no certainty that these or other international discussions will lead to a legally binding regulation for GHG emission control and/or reduction in Madagascar. However, the project will continue to evaluate technically and financially feasible options to reduce GHG emissions. In

addition, biodiversity mitigation and compensatory off-site conservation areas will help offset direct and indirect GHG emissions.

Changes in land use associated with the development of the project could result in indirect GHG emissions. Indirect GHG emissions are associated with a change in ecosystem structure. Approximately 1,877 ha of forest will be cleared, including degraded/heavily logged zonal forest and degraded residual coastal woodland (Volume G, Section 3.1 [Flora], Table 3.1-3), although because of progressive clearing and reclamation, not all of this land will be cleared at once.

Total carbon storage in the trees in Madagascar ranges from 80 tonnes per hectare (t/ha) to 450 t/ha at average altitude (Rarivoarivelomanana, 2001). Typical carbon retention of 200 t/ha therefore results in a one-time release of 375,200 tons of carbon during project forest clearing. Because of the nature of project operations, much cleared vegetation is not expected to recover until after closure. Although irreversible impacts to specific azonal forest types is predicted to occur (i.e., regrowth is not expected to match the biodiversity and/or assemblage of species of the disturbed vegetation), vegetation is expected to eventually recover to a zonal forest type. However, due to the time value of money, the carbon lost in 2006 through 2009 is more costly than the carbon regained by future regrowth.

In an effort to offset adverse effects, the proponent will reclaim and/or conserve approximately 7,000 ha of forested land considered equivalent, in terms of biodiversity, to the area to be cleared. This conservation area will include some grassland and wetland, which also have marginal carbon sequestration capacity. It is assumed that reclaimed and conserved forest has a capacity for carbon retention of 200 t/ha and is subject to typical direct costs of forest management, indirect opportunity costs, fire (10% of the forest every three years) and deforestation (20% over 10 years) (Rarivoarivelomanana, 2001). This estimate determines that the proponent is contributing to the storage of approximately 1.4 million tons of carbon per year.

3.4.3.6 Disturbance Regulation

The valuation of disturbance regulation from the project includes an analysis of potential effects to coastal estuaries, coral reefs, tropical forest, and swamps/floodplains. The EA indicates that negative impacts to coastal estuaries and coral reefs as a result of the project are expected to be of low environmental consequence (Volume F, Section 3.3). Negative impacts to hydrology (changes in streamflows and water levels in receiving water bodies, and changes in sediment levels in receiving water bodies) in forest and swamp biomes are predicted to be moderate during pipeline construction but very short-term, and

moderate to high during construction of the tailings facility. Changes in sediment levels during mine operations is predicted to be of moderate environmental consequence if extreme weather events occur, although additional studies are ongoing to better predict effects of such severe cyclones. These negative impacts are predicted to be local (i.e., restricted to the LSA) and to occur for less than 30 years.

Kramer et al. (1997) found that the Net Present Value (NPV) of watershed protection of the Vohitra River watershed in eastern Madagascar was US$ 126,700, based on the benefits of alleviating flood damage by establishing the Mantadia National Park. Kramer et al. admit that the value of this benefit seems modest, however it is affected considerably by the low per capita GNP of Madagascar, and does not consider the cost of other ecosystem services such as control of soil erosion.

3.4.3.7 Water Regulation

Costanza et al. (1997) have estimated the water regulation services provided by a range of habitats globally. The following values were determined by for water regulation, by biome: US$ 6/ha/yr for tropical forest; US$ 3/ha/yr for grass/rangelands; US$ 30/ha/yr for swamps and floodplains; and US$ 5,445/ha/yr for lakes and rivers.

The economic costs with loss of water regulation associated with this project are related to the loss of forest (1,877 ha, including degraded/heavily logged zonal forest and degraded residual coastal woodland), grass/rangeland (224 ha), swamps and floodplains (307 ha), and watercourses (1ha) (Volume G-3.1 Flora, Table 3.1-3). These estimates indicate that the value of water regulation provided by the biomes disturbed by the project is US$ 26,589/year, which over the project life is US$ 805,130. This estimate is conservative as it does not include areas which will be reclaimed and revegetated during project operations and closure.

3.4.3.8 Water Supply

Water supply is an environmental service provided by forests, wetlands and rivers. Wetlands, specifically marshes and floodplains, generate significant value in terms of water supply. Estimates for the value of this service provided by different biomes by Costanza et al. (1997) are: US$ 8/ha/yr for tropical forest; US$ 7,600/ha/yr for swamps and floodplains; and US$ 2,117/ha/yr for lakes and rivers. The main areas where the project risks high impact on this environmental service is for the Torotorofotsy Wetlands and its source rivers and the area downstream of the tailings basins. Because this service is extremely localized,

the off-site conservation compensation site will have no impact on the local loss of service provision. No large streams will be impacted; however, 41 ha of marsh area will be disturbed, particularly at the tailings facility where these features will be lost.

Although engineered dams and water release systems will significantly mitigate this impact of habitat loss for water supply, the population will be moving from a service provided by nature to one that requires human management during and following the project. With project mitigation measures, the only residual impacts on water supply will be direct impacts downstream of the tailings basins and the risk of disturbance of the Torotorofotsy Wetlands. The assessment has determined that the risk to the Torotorofotsy Wetlands will be mitigated adequately to be considered a low risk. As such, we assess that the total economic impact of the project on water supply will be low and localized, therefore no estimate has been made.

3.4.3.9 Erosion Control and Sediment Retention

Erosion control and sediment retention are ecosystem services provided primarily by forest and grassland biomes. These biomes represent approximately 2051 ha of the area disturbed by the project (Volume G-3.1 Flora, Table 3.1-3), consisting of 1,737 ha of forested land (including secondary forest and woodlots, but not including degraded forest) and 314 ha of grass and shrub land (not including marsh or tavy land).

The EA determined that residual impacts to soils are mainly based on soil loss from project operations, rather than soil erosion which is largely mitigated. However, soil erosion can occur due to the disturbance of vegetation during construction and operations. Project closure is expected to return sites to natural soil erosion rates.

Erosion control and sediment retention can be valued with regards to the effects of soil erosion to agriculture, particularly rice production. On-site erosion of arable lands (i.e., loss of soil and removal of biogenic salts and organic fertilizing) is not expected to occur. Implications from off-site erosion (i.e., sedimentation of surface water and potential impacts to vegetation and water quality) are more likely to occur from the project. Potential effects of sedimentation to flora and fish are assessed in the EA and are found to have only local impacts with low overall environmental consequence due to mitigation measures. (Potential effects to fish as a food source is discussed below as the ecosystem service of food production.) The conservation of forests in the protected areas is expected to further mitigate potential effects downslope/down

stream of the project disturbances. However, these benefits are not expected to be significant and cannot be accurately quantified.

3.4.3.10 Waste Treatment

Natural environments provide the environmental service of waste treatment. Estimated economic values for this service by biome (Costanza et al. 1997) are: US$ 87/ha/yr for tropical forest; US$ 87/ha/yr for grass/rangelands; US$ 6,696/ha/yr for tidal marsh and mangrove; US$ 1,659/ha/yr for swamps and floodplains; US$ 665/ha/yr for lakes and rivers; and US$ 5,445/ha/yr for coral reefs. The capacity for waste treatment of the forests, wetlands, rivers and marine environments impacted by the project may be diminished by the project activities. This is particularly the case for the Torotorofotsy Wetlands which may experience greater water flow during mining operations as well as increased sedimentation during extreme cyclones above the design capacity of the retention ponds. The technical details of the impacts of the project on the waste treatment capacity of the wetland are well beyond of scope of this EA, and would require years of study and monitoring. The proponents are committed to assisting management groups with responsibility for the Torotorofotsy Ramsar site.

3.4.3.11 Food Production

Effects to food production as a result of the project can result from loss of current land use for agriculture, gathering and hunting, as well as indirect loss of potential land for tavy or other land modifications for food use. The project will disturb approximately 78 ha of existing plantation and agroforestry land and 66 ha of rice paddies. An additional 1,864 ha of slash and burn (tavy) land will be disturbed.

The average local rice yield in is 1.5 t/ha, at an average annual price of 600 fmg/kg, which takes in to account seasonal variations (Volume K, Appendix 1.1 Prices for Agricultural Production, Mangoro Region). The loss of rice production therefore averages 59,400,000 fmg (US$ 6,527) each year. Although this value may appear small, the amount is significant because rice currently represents 26% of total income and is culturally important. Wage employment, however, has resulted in a reduction in household agricultural activity and reduced reliance on subsistence agriculture.

Although tavy has been banned and surveys conducted for the SEIA indicated that few people practice tavy (13% near the mine site), it was observed that coffee and bananas are often grown in tavy plots. Banana represent one of the highest value crop, at an average price of 2,000 fmg/kg, although the local production of banana and crops other than rice is not known. Livestock also

represent high value agriculture, with meat products worth up to 20,000 fmg/kg year round, although land use for local production of livestock and wild meat products is not known. Wild honey and mushrooms are also collected in forests near the project (Volume K, Appendix 1.1) for consumption and sale. No formal study of hunting and gathering economy has been conducted, however it is recognized that these activities represent measurable subsistence and income sources (Volume K, Appendix 1.1).

Potential impacts to freshwater fish, which is important to the local diet, as well as freshwater shrimp, crayfish, and eels, are generally expected to be low. However, the elimination of riparian areas and streams at the mine site and tailings facility can have effects to fish as a local food source. The area of this fish bearing water impacted, including river and canal, is 1 ha (Volume G-3.1 Flora, Table 3.1-3). Additional water bodies such as marsh (44 ha) and rice paddies (66 ha) can also support fish.

Although impacts to food production from the project are difficult to value, rice production represents a measurable indicator. A loss of approximately US$ 6,527 each year results in a NPV of lost rice production of US$ 203,270 during the project, in addition to loss of income and subsistence from other agricultural activities and hunting, fishing, and gathering.

3.4.3.12 Raw Materials

Wood is the primary raw material gathered from lands near the project, which is largely cut as wage labour for permitted out of area timber merchants (Volume K, Appendix 1.1). Wood is also cut as fuelwood or for making charcoal, both for personal use and for wage labour. Other harvested raw materials include grass for weaving, beeswax and medicinal herbs. Although the forested and non-forested lands impacted by the project are known to support the harvest of these various raw materials, volumes and values of the materials are not known. The project itself, namely the extraction and production of ore from the mine site, represents the most commercially viable use of raw material. However, it is recognized that economic activity surrounding the current extraction and production of raw materials account, on average, for 45% of income in the study area (Volume K, Appendix 1.1). This represents 481,500 fmg per person each year, based on an annual per capita income of 1,070,000 fmg (US$ 118) in the area (Volume K, Appendix 1.1). For example, the Andasibe commune population is approximately 7,884, therefore this loss of raw materials could be valued up to US$ 418,900 per year, or US$ 12.5 million through the life of the project.

3.4.3.13 Conclusions – Economic Valuation of Biodiversity

The economic evaluation of biodiversity is a developing area, especially with regard to considering impacts from a single project as opposed to eco-regional analyses. However, economic evaluation helps to address in an alternate fashion a range of impacts that are otherwise very difficult to appraise and compare. Biodiversity impacts were assessed through consideration of a range of ecological services provided by biodiversity that the EA has shown will be affected by the project. In addition, project benefits from biodiversity offsets are described in terms of carbon sequestration.

From a local perspective, the following ecological services have been evaluated: habitat disturbance; regulation and maintenance of water flows; erosion control and sediment retention; waste treatment; food production; and supply of raw materials. With respect to these services, estimates in dollar terms of predicted project impacts after mitigation have been calculated. Summing costs provided in this section produces a total project lifetime cost of US$13,635,100.

From a regional and global perspective greenhouse gas (GHG) management has also been examined. The project will continue to evaluate technically and financially feasible options to improve efficiencies and in turn reduce emissions. In addition, the mitigation and compensation plan for biodiversity covering about 7,000 ha will contribute to the storage of carbon. Predicted annual sequestration of 1.4 million tons ECO2 represents approximately 70% of annual operational emissions of 2.0 million tons ECO2. As for other aspects of the success of proposed off-site conservation areas, the realization of such sequestration benefits regionally will closely depend on good integration with the government's conservation plans for the Mantadia-Zahamena Corridor.

It must be emphasized that the individual costs used to produce the total were based on many assumptions discussed earlier in this section. However, these costs can be compared to the much larger project local economic benefits provided by the project. US$3.2 billion is predicted to be spent in Madagascar over the life of the project (Section 4.1 of this volume).

3.5 PROTECTED AREAS

3.5.1 Ambatovy Project Combined Effects

3.5.1.1 Introduction

The five major components of the project overlap to produce combined effects as indicated in Table 3.5-1.

The effects of the mine will not overlap with the process plant, tailings facility or port expansion as they are not close enough to physically impact the same protected areas and will not result in changes in the same population centres. The process plant, tailings facility and port expansion do not physically overlap any of the protected areas affected by the slurry pipeline.

Table 3.5-1 Matrix of Overlapping Project Effects for Protected Areas[(a)]

Project Components	Mine	Slurry Pipeline	Process Plant	Tailings facility	Port Expansion
mine		X	-	-	-
slurry pipeline			-	-	-
process plant				X	X
tailings facility					X
port expansion					

[(a)] X Indicates that an overlapping (combined) effect occurs.

\- Indicates that no cumulative effects occur.

Shading indicates not applicable.

The overlapping effects of the process plant, port expansion and tailings facility are already addressed together in Volume D, Section 4.5. The other overlapping effects, between the mine and slurry pipeline, are addressed below.

3.5.1.2 Assessment of Combined Project Effects

The mine and slurry pipeline have impacts that overlap spatially and temporally in the following areas:

- clearing or fragmentation within the Torotorofotsy Ramsar site during construction and operations; and
- water quality (sedimentation) effects on the Torotorofotsy Ramsar site during construction.

The mine will impact 300 ha of the Torotorofotsy Ramsar Site and the slurry pipeline will impact 70 ha of the Torotorofotsy Ramsar Site. Combined, the mine and pipeline will result in clearing of vegetation from 370 ha within this 9,300 ha area (4%). These impacts will be mitigated as described in the soils and flora sections for the mine (Volume B, Sections 3.3 and 4.1) and for the slurry pipeline (Volume C, Sections 3.2 and 4.1). This impact is moderate in magnitude, regional in geographic extent because it extends beyond one LSA, medium-term in duration and is reversible. The frequency of disturbance throughout construction and operations will be medium (Table 3.5-2). Because impacts were rated as local in extent in the individual mine and pipeline assessments, they were considered low in magnitude in both individual assessments.

Both the mine and pipeline have the potential to contribute to the sedimentation of waters of the Torotorofotsy Wetlands, although mitigation (Volume B, Section 3.9 and Volume C, Section 3.7) will control these impacts. In the individual sections for the mine and slurry pipeline, these impacts were rated as low in environmental consequence. This combined impact is low in magnitude and local in geographic extent because, even with the effects of the slurry pipeline included, impacts are contained within the mine LSA. The impacts are medium-term in duration and are reversible. The frequency of sedimentation effects throughout construction and operations will be medium (Table 3.5-2). Therefore, the environmental consequences of the combined project remain low.

The hydrology assessment of combined project effects (Volume G, Section 2.8.1.2) discusses effects on water volumes in the Torotorofotsy Wetlands. The combined project affects are negligible on water volumes.

Table 3.5-2 Residual Combined Impact Classification for Protected Areas

Phase	Direction	Magnitude	Geographic Extent	Duration	Reversibility	Frequency	Environmental Consequence
Issue: Mine – Pipeline: Clearing or Fragmentation of Torotorofotsy Wetlands							
construction / operations	negative	moderate	regional	medium-term	yes	medium	moderate
Issue: Mine – Pipeline: Water quality Changes							
construction / operations	negative	low	local	medium-term	yes	medium	low

3.5.2 Cumulative Effects With Other Projects and Activities

3.5.2.1 Introduction

The protected area study area for assessment of potential cumulative effects between the project and other planned projects and activities includes all areas within 100 km of the project sites.

The project has the potential to overlap with the following projects and activities to impact protected areas:

- Deforestation due to logging and tavy agriculture overlaps with the effects of the mine and slurry pipeline on the Torotorofotsy Wetlands.
- Deforestation promoted by existing forest access allowed by roads to the Andasibe graphite mine the Andasibe Sawmill and other areas that overlap with the effects of the slurry pipeline on the Mantadia-Zahamena Corridor Proposed Conservation Area.
- Population growth in Moramanga due to other projects overlapping with the effects of the mine to create a larger population that may visit nearby protected areas for tourism.
- Population growth in Toamasina due to ongoing industrial development overlaps with the effects of the process plant, tailings facility and port expansion to create a larger population that may visit nearby protected areas.
- Reforestation brought about by the Carbon Project.

3.5.2.2 Assessment of Cumulative Effects

Deforestation in the area of the mine and slurry pipeline, in both the Torotorofotsy Ramsar site and the Mantadia-Zahamena Corridor Proposed Conservation Area presently occurs at a rate of about 1% per year. However, with the implementation of the project, including proposed mitigation for forest management, protection of specific azonal areas and forest restoration along the pipeline, as well as implementation of the Carbon Project, deforestation due to logging and tavy agriculture is not expected to cause any additional cumulative impact with the project. Therefore, deforestation in protected areas does not contribute to cumulative effects of the project.

Deforestation in the Andasibe area, due to graphite mining and sawmill operations, is expected to continue during the project. These activities will create a small additional negative effect within, or adjacent to the Mantadia-Zahamena Corridor Proposed Conservation Area. This effect will occur cumulatively with

the effects of the slurry pipeline through the Mantadia-Zahamena Corridor Proposed Conservation Area. The combined area of effect is expected to be small, and the cumulative magnitude of this effect is considered low. The impact will be regional in extent, medium-term in duration, reversible, and medium in frequency (Table 3.5-3). The overall environmental consequence is moderate.

Population growth in the Moramanga and Toamasina areas due to other activities is difficult to predict during the timeframe of the project, but is predicted to be relatively small based on the other planned projects known at the present time. Positive effects are predicted for increased populations because higher rates of tourism will increase the income and awareness of Madagascar's protected areas system, in the context of a country that is increasingly promoting ecological tourism for its economic and environmental benefits. Higher populations in Moramanga and Toamasina will lead to increased visitation to protected areas such as Analamazaotra Special Reserve, Mantadia National Park, Mantadia-Zahamena Corridor proposed conservation area, Betampona Natural Reserve and Mangerivola Special Reserve (Table 3.5-3).

Table 3.5-3 Residual Cumulative Impact Classification for Protected Areas

Phase	Direction	Magnitude	Geographic Extent	Duration	Reversibility	Frequency	Environmental Consequence
Issue: Pipeline and Other Developments: Clearing or Fragmentation of Mantadia-Zahamena Corridor							
construction / operations	negative	low	regional	medium-term	yes	medium	moderate
Issue: Mine and Other Developments: Moramanga Population Change							
construction / operations	positive[(a)]	n/a	n/a	n/a	n/a	n/a	n/a
Issue: Process Plant, Tailings Facility, Port and Other Developments: Toamasina Population Change							
construction / operations	positive[(a)]	n/a	n/a	n/a	n/a	n/a	n/a

[(a)] Positive rankings are not rated.

n/a Not applicable

3.5.3 Conclusions

The main combined effects between project components are the combined effects of the mine and slurry pipeline for clearing and water quality impacts in the Torotorofotsy Ramsar site, as described above; and combined population effects of the process plant, tailings facility and port expansion, as described in Volume D, Section 4.5. The combined effects on the Torotorofotsy Wetlands are negative and moderate in environmental consequence for clearing of land (as compared to low ratings for each of the mine and pipeline, individually) and negative and low in environmental consequence for water-related impacts

(as combined effects on Toamasina's population are positive in the context of potential for increased tourism in protected areas (having also been rated positive for each of the project components individually).

The main cumulative effects between the project and other foreseeable activities are deforestation in and adjacent to the Mantadia-Zahamena Corridor, due to the slurry pipeline and several other small developments; and increased populations in Moramanga and Toamasina, due to a variety of project components and other pending projects leading to industrial growth in these areas. The deforestation effects are negative and moderate in environmental consequence (having been rated low in environmental consequence for the pipeline alone). The cumulative effects on populations in Moramanga and Toamasina are positive in the context of potential for increased tourism in protected areas.

4 CUMULATIVE AND COMBINED EFFECTS FOR SOCIAL DISCIPLINES

4.1 SOCIOECONOMICS

4.1.1 Introduction and Project Description

The socioeconomic impact analyses presented in other volumes of this EA, already take into account existing conditions within Madagascar and where appropriate (such as in the Toamasina area) have analysed combined effects from adjacent project components. In this Volume (Volume G), we present a macroeconomic overview of the whole project to explore cumulative impacts at the national level. The overview was prepared by SNC Lavalin for the project proponents.

The Ambatovy Project is a Foreign Direct Investment (FDI) program designed to develop the Ambatovy and Analamay laterite nickel ore deposits located in a 1,300 hectare area near Moramanga in the Aloatro-Mangoro region of Madagascar.

The development plan includes an open pit mine and ore preparation plant located near the ore bodies and a 195 kilometre pipeline to move the ore, as a slurry, to processing facilities at a new plant site located 10 km west of the port of Toamasina, in the region of Antsinanana. These facilities will convert the raw material to a mixed sulphide ore suitable for final refining to nickel (and cobalt). At the present time it is assumed that the final refining process will be performed at a plant located outside Madagascar.

Based on the projected ore reserves, the Project is designed to process 125 million tonnes of high grade ore mined over a 20 year period. In addition, further economic plant operation would be realized by treating lower grade material that will be stockpiled during mining operations. This would extend the total operating life of the process plant to 27 years.

The Project is designed to be largely self sufficient. Potential supply of excess power capacity to the national grid could add to Madagascar's electricity resources. In addition, the Project will build other infrastructure facilities including sulphuric acid, hydrogen, hydrogen sulphide, nitrogen and lime plants, port enhancements and tailings disposal. The Project also includes upgrades to the regional road and rail systems and water pumping stations to supply water to the work sites.

Construction of the mine site, pipeline, processing plant and infrastructure facilities will take approximately three years. The planned life-cycle of the Project is 30 years. However, the infrastructure developed during this period, together with the skills acquired by Malagasy workers, will ensure sustainable economic benefits over a much longer term.

4.1.1.1 Project Ownership

The Ambatovy Project is a Joint Venture between Dynatec Corporation, a Canadian mining company and leading provider of hydrometallurgical process technology, and Sumitomo Corporation, an integrated Japanese trading and investment company.

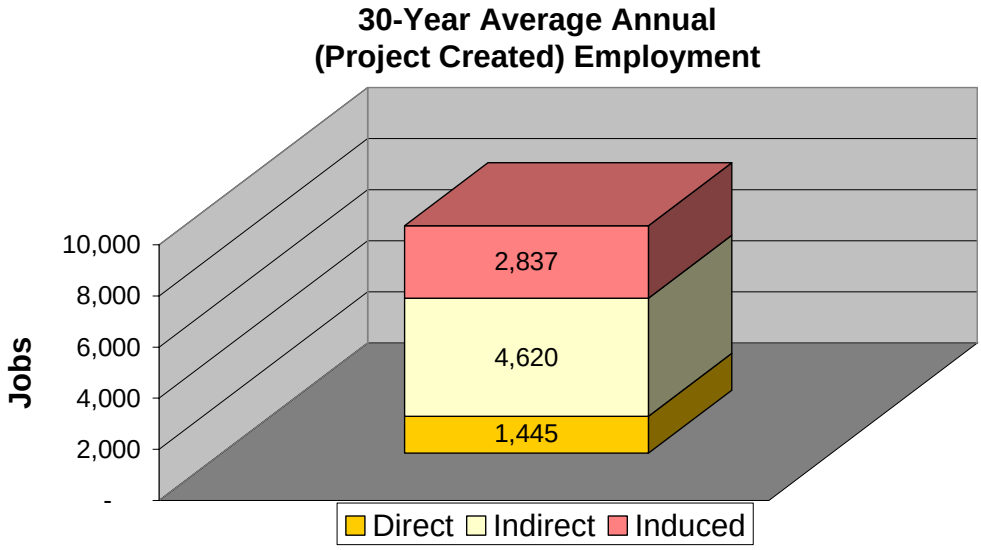
4.1.1.2 Project Costs

The target capital cost of the Project, excluding refinery, is estimated to be approximately US$2.15 billion spread over the 3 year construction period.

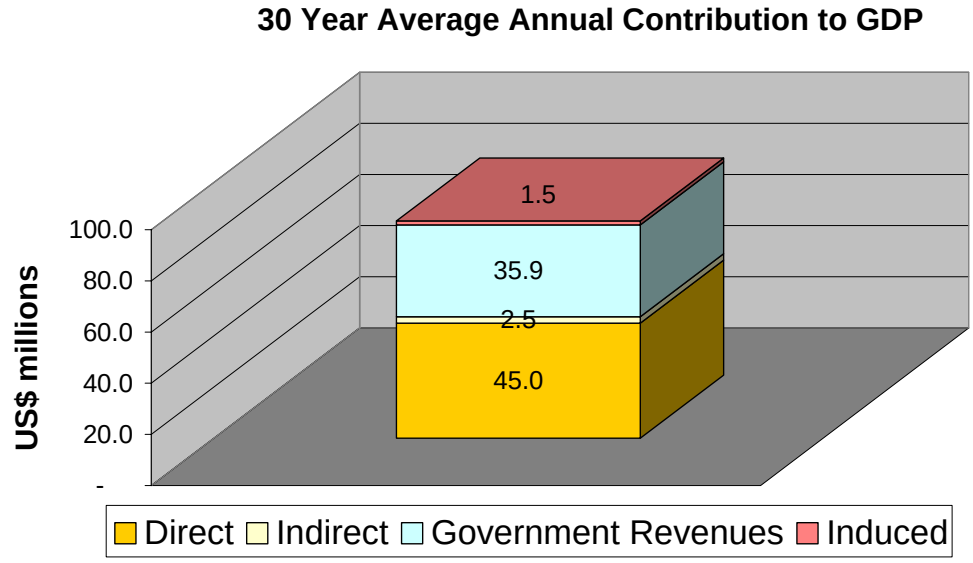
Total operating costs are estimated to be US$4.65 billion over the 27 year operating period or approximately US$172 million per year.

4.1.2 EXPECTED BENEFITS TO MADAGASCAR

Early economic assessments of the Project impact on Madagascar's economy show that there will be significant direct and indirect benefits resulting from the Project. Perhaps the most important of the findings is the expected impact on employment and, hence, the potential positive impact on the country's objective to reduce poverty. Approximately 9,000 direct, indirect and induced jobs are expected to be created as a result of the Project, excluding jobs created as a result of Government revenue-spending.



Over the 30 year Project life cycle, US$ 3.2 billion (over US$100 million annually) will be spent in Madagascar and the Project is expected to contribute over US$2.5 billion (US$ 80 million annually) to Madagascar's Gross Domestic Product (GDP). This is approximately 2% of 2004 GDP.



The economic benefits will be derived from three major areas of activity:

- direct Project investment;
- increased consumption of workers employed both directly and indirectly as a result of the Project; and
- government spending of increased revenues generated from the Project.

It is expected that the Ambatovy Project will:

- Increase local capital investment in Madagascar by over US$1.3 billion (over 30 years) or US$45 million annually and create 1,400–2,000 direct jobs for local workers, through the Project lifetime.
- Generate over US$80 million lifetime or approximately US$2.8 million annual income and 4,600 indirect jobs, in other sectors, through local Project expenditures.
- Induce the creation of approximately 2,800 jobs in other sectors to satisfy the demands of increased consumer spending.
- Contribute approximately US$25 million annually to government revenues, of which about 50% might be used to create additional indirect job opportunities.

4.1.2.1 Construction Period

Of the Project capital cost (approximately US$2.15 billion), about US$500 million is expected to be spent in Madagascar through the placement of orders for equipment and materials, contracts for services to be provided by local enterprises, and payments to the government in the form of duties and taxes. This money is scheduled to be spent in the three year construction period of the Project. Some major local material purchases in this period are expected to be for sand and aggregate used in construction.

A portion of the money spent in Madagascar is expected to be used, by local Malagasy companies, to procure imported items. Of the US$500 million capital expenditures, over US$300 million is expected to remain in Madagascar and circulate within the Malagasy economy to provide jobs in other sectors. These jobs result from the need to satisfy both the supply- and demand-side requirements generated by Project activities. Taxes will be paid to the Malagasy government by foreign workers and money will be spent locally to create demand for consumer items.

During the construction period, the Project will create an average of approximately 1,700 direct jobs for local workers. However, with an estimated additional US$245 million (US$80 million per year), excluding government revenues, expected to be added directly to the economy, for equipment, materials and services, indirect employment will be significant. Job creation will be multiplied as the need to satisfy the supply-side requirements of the Project creates indirect employment opportunities in other sectors of the economy, thus starting an economic "ripple" effect. Approximately 8,900 indirect jobs are expected to be created through supply-side activities.

The Malagasy government may choose to use the revenues generated from income taxes and duty payments to implement its programs for infrastructure development and poverty reduction and this will create additional jobs.

Consumer spending, by both direct and indirect workers, including those in government-created jobs, should result in the creation of even more jobs in order to meet the demand-side requirements of this spending. Induced job creation is estimated to result in the creation of about 3,800 additional jobs.

4.1.2.2 Operations Period

The pattern of economic growth is expected to remain about the same during the 27 year period of operations with over US$1 billion (approximately US$40 million per year), excluding government revenues, being injected into the local economy. Although construction will be complete, there will still be a demand for local materials, including limestone and coal. Madagascar has local sources of supply for these materials and it is an objective of the Project to encourage the development of these resources within the timeframe of the Project life-cycle. The Malagasy government will also begin to receive corporate taxes and royalty payments from product sales, once production begins.

Approximately 1,500 permanent direct jobs, representing 80% of the total site workforce, will be created for local workers during the 27 years of Operations. Preliminary analysis suggests that for every direct job created by the Project, four additional indirect or induced jobs are likely to be created in other sectors of the economy.

4.1.2.3 Long-Term Sustainable Benefits

In addition, the Project will make a significant investment in programs and activities that should provide sustainable benefits to the long term economic development of the country through:

- Education and Training Programs (key to Project success).
- Health & Safety and other social programs to help provide an improved working environment and higher standard of living for the Malagasy people.
- Infrastructure improvement in road and rail upgrades, port expansion, water and waste treatment programs, communication systems.
- Legacy infrastructure (power plant and ancillary process plants) that will remain to benefit other projects and industries and to provide a foundation for future development and growth.

It is anticipated that Project activities will stimulate local industrial development and further economic growth over the Project lifetime such that the contribution made by Malagasy enterprises will increase steadily over this time period.

4.1.2.4 Other Potential Benefits

Assessment of additional potential Project benefits to Madagascar's economy is ongoing, including evaluation of:

- foreign exchange earnings;
- contribution to the country's economic growth;
- impact on external trade; and
- impact on manufacturing industry gross output.

4.1.3 LOCAL EDUCATION, TRAINING AND EMPOWERMENT

Perhaps the most important programs from the point of view of Madagascar's industrial development are the Project's education and training programs for local labour and local enterprises. These programs constitute the Owner's "Local Resource Development Initiative" to promote local participation in the Project in accordance with Project Policy. The Policy states that:

"The Management of the Ambatovy Nickel Project is committed to maximizing sustainable benefits to the local community using a combined strategy of

development and use of local goods, services and personnel without compromising Project objectives."

US$8 million will be allocated for construction training and US$2 million for training in operations and maintenance. Training centres will be established in appropriate areas to enable local recruitment and provide necessary skills training.

Graduates of the programs (both individuals and enterprise) will receive a qualification certificate and will be listed in a resource data base available to all potential employers. Over the Project duration, approximately 3,500 trainees are expected to participate in these programs and will form a pool of resources with new skills applicable to existing and future industrial projects. All Project participants will receive general Project orientation training and basic training in Health and Safety policies and procedures relative to their areas of work.

4.1.3.1 Education and Training

Training for individuals will be provided in technical, administrative and general skill areas.

Technical skills training for Construction and Operations will include:

- civil – general and semi-skilled labour;
- piling – general labour;
- piping – general and semi-skilled labour;
- mechanical - general and semi-skilled labour;
- structural - general and semi-skilled labour;
- electrical - general and semi-skilled labour;
- instrumentation - general and semi-skilled labour;
- equipment mechanics;
- equipment operations;
- boiler operations; and
- computer operations.

Administrative skills:

- industrial relations management;
- clerical and secretarial functions;
- timekeeping; and
- security.

General skills:

- camp cleaning and maintenance; and
- catering.

4.1.3.2 The Ambatovy Empowerment Program

The Ambatovy empowerment program is designed to enable local companies (of all sizes) to participate in the Project. There will be a special focus on Small and Medium Enterprises (SMEs). This program is based on a very successful program developed for a project in Mozambique, but adapted to meet Madagascar's special needs.

The program will:

- provide skills training for local labour;
- promote SME training programs and mentor local SMEs to enable them to be competitive and successful;
- actively encourage the use of local contractors;
- actively encourage the establishment of joint ventures between international and local contractors (with the assistance of development agencies);
- allocate selected work packages, solely for execution by local SMEs; and
- maximize local spending for labor, materials and services.

The program will be developed and managed by the Owner in co-operation and co-ordination with the EPCM contractor, the African Project Development Facility (APDF) and appropriate Malagasy government agencies.

Key components of the SME empowerment program include:

Training:

- Tendering Training. How to tender.
- Induction Training. How to execute contracts (planning, contract administration, engineering, Quality Control (QC), Health, Safety & Environment (HSE), Industrial Relations (IR)).
- On Demand Training: QA/QC, Business Management etc.

Training modules will be written and presented in Malagasy with periodic updates.

Mentorship:

- Custom made Mentorship Plans for individual SMEs.
- Business Mentorship: Financial/Commercial assistance.
- Technical Mentorship: On/Off Site Technical assistance including Safety, QA/QC and IR.

4.2 CULTURAL PROPERTY

No combined project effects or cumulative effects are predicted for cultural property.

4.3 LAND USE

4.3.1 Ambatovy Project Combined Effects

4.3.1.1 Introduction

The five major components of the project overlap to produce combined effects as indicated in Table 4.3-1.

Table 4.3-1 Matrix of Overlapping Project Effects for Land Use[(a)]

Project Components	Mine	Slurry Pipeline	Process Plant	Tailings Facility	Port Expansion
mine		X	X	X	X
slurry pipeline			X	X	X
process plant				X	X
tailings facility					X
port expansion					

[(a)] X Indicates that an overlapping (combined) effect occurs.
Shading indicates not applicable.

Overlapping effects in terms of land use are defined two ways. Firstly, they are defined by whether multiple components of the project are affecting the same kinds of land use. There is at least one form of land use (i.e., removal of soils and vegetation) for each project that overlaps every other project component, so all projects overlap based on this criterion. Secondly, overlap is defined in terms of population effects (i.e., increase in population density); a given local population that is affected by changes in land use due to more then one project also produces an additive effect. Based on this criterion, the port expansion, tailings facility and process plant produce an overlapping effect. The overlapping effect of the pipeline on local populations is considered negligible, both at the eastern and western end of the route.

4.3.1.2 Assessment of Combined Project Effects

All project components contribute to alteration of land use areas (removal of soils and vegetation). Impacts due to alteration of hydrologic regimes occur at the mine and tailings facility, but are not additive as they only impact watersheds immediately downstream.

The process plant, tailings facility and port expansion will contribute to a change in land users (increases in population density) in some areas near the projects, primarily the process plant. Due both to the loss of land use (agricultural) areas in the region, and the increase in population, land use pressure will increase.

Alteration of Soils and Vegetation

The effects of all projects combined on specific types of land use are quantified in Table 4.3-2.

Table 4.3-2 Land Use Impact Areas for all Local Study Areas Combined

Type of Area	Area Within LSA (Baseline) (ha)	Area Impacted (ha)	Proportion of Area in LSA Impacted (%)
degraded residual coastal woodland	166	29	17
azonal/transitional forest and scrub	2,833	1,303	46
primary zonal forest and marsh edge	5,927	336	6
degraded primary zonal forest	8,018	108	6
agroforest/secondary forest	66	27	41
plantation	2,190	47	2
woodlot	44	4	10
beach ridge complex	231	3	13
coastal shrubland/grassland complex	837	223	27
rice paddies	686	65	9
shrubland/herbaceous/pasture	3,038	90	3
tavy matrix	34,644	1,883	5
village/urban	514	15	3
wetlands	1,381	34	2
access corridor (road/rail)	29	15	50
industry (buildings or exploration areas)	21	3	14
canal	38	0	0
quarry	15	1	7
river/water	200	0	0
seasonal pond	5	4	80
total	**60,883[(a)]**	**4,191[(b)]**	**7**

[(a)] Varies slightly from terrestrial biology EA due to larger extent of area along mine water intake pipeline corridor.

[(b)] May not add up as written due to rounding.

LSA = Local Study Area.

Based on area, the largest land use area affected by the project is tavy matrix, which is the primary land use type affected by both tailings facility and the slurry pipeline. Several of the land use types indicated in Table 4.3-2 have low importance for land users, but the most important are:

- 27 ha of agroforest and secondary forest affected;
- 51 ha of plantations and woodlots affected;
- 65 ha of rice paddies affected;
- 15 ha of villages or urban areas affected; and
- 3 ha of industrial areas affected.

Treated relative to the total areas of these kinds of land use activities in the large region that the project occupies, the effects of the project are generally small. However, because populations are generally poor and will have trouble finding new, high-quality land use areas, effects should be considered based on the

impacts to individuals, which may be high in some cases. Social effects are addressed in the Socioeconomics EA sections and Section 4.3 in Volume G.

Population Change Effects on Land Use

The project will result in the in-migration of a considerable number of people into the Local Study Area (LSA) and surrounding areas. As a result, there may be increased pressure on lands for residential housing, agricultural land use and the cutting of trees for charcoal or building materials. In turn, this trend has the potential to have social impacts on both existing and new land users. These subjects are addressed in the socioeconomic section (Volume G, Section 4.1).

4.3.2 Cumulative Effects With Other Projects and Activities

4.3.2.1 Introduction

The land use study area for assessment of potential cumulative effects between the project and other projects and activities includes all areas within the terrestrial LSAs of all of the project sites.

The project has the potential to overlap with the following projects and activities to impact land use:

- Deforestation due to logging and tavy agriculture overlaps with the effects of the mine and slurry pipeline on the Torotorofotsy Wetlands.
- The Regional Carbon Project has implications for land use that overlap with the effects of the slurry pipeline.
- Population growth in Moramanga due to other projects overlapping with the effects of the mine to create a larger population that may visit nearby protected areas for tourism.
- Population growth in Toamasina due to ongoing industrial development overlaps with the effects of the process plant, tailings facility and port expansion to create a larger population that may visit nearby protected areas.
- Ongoing industrial development in Toamasina including the dry port, dry port access road, and the Logistique Pétrolière Terminal will convert lands used for other land uses to industrial use.

4.3.2.2 Assessment of Cumulative Effects

Deforestation in the area of the mine and slurry pipeline presently occurs at a rate of about 1% per year. The project will contribute to this effect in the short-term. However, through mitigations, including proposed mitigation for forest management, protection of specific azonal areas and forest restoration along the pipeline, as well as implementation of the Carbon Project, the project is not expected to cause any additional cumulative impact with existing tavy and logging activity. Therefore, the cumulative effects of the project with exiting deforestation for forest land users will be negligible.

The Regional Carbon Project will promote re-forestation within the Mantadia-Zahamena corridor, including in areas along the planned slurry pipeline route. Reforestation, both within the carbon project and along the pipeline, will promote some kinds of land use (non-timber forest product use, for example, and other sustainable initiatives) while discouraging other kinds of land use, such as tavy agriculture. The cumulative effects of these projects are expected to be generally positive, but may have negative effects on a few land users.

Population growth in the Moramanga and Toamasina areas due to other activities is difficult to predict during the timeframe of the project, but is predicted to be relatively small based on the other projects known at the present time. These changes will produce both positive and negative effects for land use: land use pressures will grow, and values of agricultural produce will increase. Some land users may be able to make a better income under these conditions, but lands may be degraded if land use pressure is excessive near these urban centres.

Industrial development near Toamasina, including a dry port, a new access road to Toamasina, and a Logistique Pétrolière fuel terminal will take up lands for new industrial use; however, the lands affected are already designated for industry and are not heavily used for any other kind of land use. Logistique Pétrolière (2005) predicts a negligible impact on land use due to their project. Cumulative effects due to these developments are expected to be negligible.

4.3.3 Conclusions

There are two main combined effects between project components: combined effects on specific kinds of land use, and combined effects of population change due to multiple project components that affect one major population centre (Toamasina). The combined effects on terrain include 27 ha of agroforest and secondary forest, 51 ha of plantations and woodlots, 65 ha of rice paddies and 15 ha of villages or urban areas. These effects have the potential to be locally important and are addressed in terms of residual impacts in the socioeconomic

EA sections. Combined effects on population change in Toamasina will create additional pressures on land use, although the extent of this impact is difficult to define.

The main cumulative effect between the project and other planned and foreseeable activities are population growth effects in the Moramanga and Toamasina areas due to the project and other activities. The magnitude of the cumulative impact is predicted to be small based on the other planned projects known at the present time. These changes will produce both positive and negative effects for land users.

4.4 HUMAN AND ECOLOGICAL HEALTH

4.4.1 Ambatovy Project Combined Health Effects

4.4.1.1 Introduction

This section presents human and aquatic life health assessments due to cumulative effects of chemical changes in water and air related to individual components of the Ambatovy Project (the project).

The cumulative effects on terrestrial flora and fauna health are evaluated in Volume G, Sections 3.1 and 3.2; and cumulative effects on fish and aquatic resources due to physical changes (such as hydrology and river sedimentation) are presented in Volume G, Section 3.3.

The potential combined effects of the mine, slurry pipeline, process plant and tailings facility on human and aquatic life health are identified in Table 4.4-1.

Table 4.4-1 Matrix of Overlapping Project-Related Changes in Human and/or Aquatic Life Health[(a)]

Project Components	Mine	Slurry Pipeline	Process Plant	Tailings facility	Port Expansion
mine		X	-	-	n/e
slurry pipeline			X	X	n/e
process plant				X	n/e
tailings facility					n/e
port expansion					

[(a)] X Indicates that an overlapping (combined) effect occurs.

- Indicates that no cumulative effects occur.

n/e Not evaluated in this section. A separate Cumulative Effects Assessment (CEA) has been completed for marine effects in Volume G, Section 2.10.

Shading indicates not applicable.

The basis for the prediction of overlapping health effects in the above matrix is the co-location and co-occurrence of environmental quality. Thus, both the location and distance that a stressor (e.g., water or air contaminant) extends from a mine component form the underlying basis for this matrix. For example, potential health effects due to changes in air or water quality in the mine area will not overlap with potential health effects from the process plant or tailings facility because these project components are not close enough to cumulatively impact the quality of the same air or water resources (Volume G, Sections 2.4 and 2.9).

There is a potential that water and sediment quality in water bodies affected by the slurry pipeline could also be affected by project activities from the mine, process plant or tailings facility sites (Volume G, Section 2.9). The influence of the cumulative water and sediment quality effects to human and aquatic life is discussed below in Section 4.4.1.2.

Because there will be no effects on air quality from the slurry pipeline (Volume G, Section 2.4), cumulative health effects due to combined activities from the pipeline component and other project components are not expected to occur and therefore not assessed further.

Changes in water and sediment quality due to the tailings facility may combine with the same type of changes due to activities in the process plant site (Volume G, Section 2.9). These combined water quality effects may cause cumulative human and aquatic life health impacts that are discussed in Section 4.4.1.3.

4.4.1.2 Combined Health Effects of the Slurry Pipeline and Mine, Tailings Facility or Process Plant

Although the stressors affecting water and sediment quality arising from the slurry pipeline could overlap with those from the mine, process plant or tailings facility, the combined human and aquatic life health effects due to these cumulative stressors are predicted to be negligible due to the following:

- negligible health impacts due to changes in water quality from the slurry pipeline (Volume C, Section 5.4);
- low to negligible health impacts due to changes in water quality at most downstream assessment nodes in the mine, tailings and process plant study areas (Volumes B, D and E, Section 5.4); and
- further dilution of the predicted substance concentration downstream of the mine, process plant and tailings facility local study areas and consequent decreasing of health risks downstream.

4.4.1.3 Combined Health Effects of Tailings Facility and Process Plant

The combined water quality effects from the tailings facility and process plant are predicted to have negligible health effects towards human and aquatic biota due to the following:

- low to negligible health impacts due to changes in water quality at the most downstream assessment nodes in the tailings facility area (Volume E, Section 5.4);
- negligible health impacts due to changes in water quality in the process plant area (Volume D, Section 5.4); and
- further dilution of the predicted substance concentration downstream of the process plant and tailings facility local study areas and consequent decreasing of health risks downstream.

4.4.2 Cumulative Health Effects With Other Projects and Activities

4.4.2.1 Introduction

The study area for assessment of potential cumulative health effects to human and aquatic life for the Ambatovy Project and other activities is defined by a 100 km radius from each project component. This is consistent with the areas

used for assessing cumulative water and air quality effects and is expected to capture the spatial range of potential cumulative effects.

Projects and future activities that could potentially add to stressors from the Ambatovy Project components include:

- Andasibe graphite mine impacts on surface water bodies in combination with the Ambatovy mine and slurry pipeline activities;
- deforestation due to logging and tavy agriculture in the Mantadia-Zahamena area and consequent changes in water quality that would be cumulative with those from the mine and slurry pipeline activities;
- Madarail and road network expansion and consequent changes in water quality that would be cumulative with those from activities along the slurry pipeline; and
- community and industrial air emissions from Toamasina that would be cumulative with air emissions from the process plant.

The potential for cumulative health effects between each of the above activities and projects and the Ambatovy Project are assessed in the following sections.

4.4.2.2 Assessment of Cumulative Health Effects

Andasibe Graphite Mine

No cumulative changes in water or sediment quality are predicted between the graphite mine and the Ambatovy mine area (refer to Volume G, Section 2.9); consequently, no cumulative human and aquatic life health effects are expected.

Potential cumulative water quality effects from the graphite mine and the slurry pipeline are related to increasing suspended sediment concentrations within receiving water bodies and are discussed in Volume G, Sections 2.9 and 3.3.

Deforestation and Madarail and Road Network

Changes in surface water runoff quantities and quality from deforestation in the Mantadia-Zahamena area could overlap with the water and sediment quality changes due to activities at the mine. However, the cumulative changes in water and sediment quality are predicted to be negligible (Volume G, Section 2.9). Therefore, cumulative human and aquatic life health effects are unlikely to occur due to combined emissions in water bodies from deforestation and the Ambatovy mine.

Deforestation and the expansions of rail and road networks could add to changes in water quality due the slurry pipeline. Those changes are related to potential increase in suspended sediment concentrations and are addressed in Volume G, Sections 2.9 and 3.3.

Community and Industrial Emissions from Toamasina

No human health effects are expected in the local study area due to short or medium-term emissions specifically from the process plant site (Volume D, Section 5.4). However, air emissions from the city of Toamasina and the planned Logistique Pétrolière fuel depot may accumulate with air emissions from the process plant during certain meteorological conditions. Hydrocarbon vapours (generally very minor related to tank breathing losses) will be released from Logistique Pétrolière operations (Logistique Pétrolière 2005). Those combined emissions may collectively influence the air quality to which people will be exposed in the process plant local study area. The air emissions from Toamasina have not been quantified (Volume G, Section 2.4). A residual cumulative human health impact was not determined. As noted elsewhere, stakeholders consultation will be ongoing. Off-site monitoring for air quality will be conducted relative to plant operations (Volume D, Section 3.3).

4.4.3 Conclusions

A potential for combined human and/or aquatic life health impacts for the following project components was identified:

- the slurry pipeline and the mine, tailings facility and process plant; and
- the process plant and the tailing facility.

The assessment of the potential combined effects on human and aquatic life health due to changes in water and sediment quality between these project components indicated that the cumulative effects will be negligible.

The Andasibe graphite mine, future deforestation, future development of Madarail and road network expansion were identified as potential sources of chemicals in water resources which could contribute to cumulative effects on human and aquatic life health due to the Ambatovy Project. Qualitative analysis of the potential cumulative effects suggests that they would be negligible.

Community and industrial emissions from Toamasina may eventually combine with air emissions from the process plant and collectively influence the air quality to which humans may be exposed. Air emissions from Toamasina were

not quantified, therefore cumulative impacts to human health were not determined. Consultation and monitoring will be ongoing during operations to ensure that local ambient conditions meet or improve upon World Bank criteria.

4.5 TRAFFIC

4.5.1 Ambatovy Project Combined Effects

4.5.1.1 Introduction

The five major components of the project overlap to produce combined effects as indicated in Table 4.5-1.

Table 4.5-1 Matrix of Overlapping Project Effects for Traffic[(a)]

Project Components	Mine	Slurry Pipeline	Process Plant	Tailings Facility	Port Expansion
mine		X	-	-	-
slurry pipeline			X	X	-
process plant				X	-
tailings facility					-
port expansion					

[(a)] X Indicates that an overlapping (combined) effect occurs.

- Indicates that no cumulative effects occur.

Shading indicates not applicable.

Overlapping effects in terms of traffic will occur when more than one project component will result in increased traffic on the same roadway. Increased traffic levels will be observed on Route Nationale (RN) 2 between Toamasina and Moramanga due to the mine and slurry pipeline (construction phase only). Increased traffic on the portion of RN2 immediately outside of Toamasina will occur due to both the process plant and tailings facility, in addition to the traffic destined for Moramanga.

4.5.1.2 Assessment of Combined Project Effects

Changes in traffic along the full length of RN2 between Toamasina and Moramanga are summarized in Table 4.5-2. The table addresses the construction period for the mine and pipeline, which combine to create the heaviest traffic loads along this road compared to the rest of the life of the project (operations). No significant combined project effects for traffic will occur after construction. The total predicted increase in traffic is mainly in the form of transport trucks and

totals about 3% of existing traffic volumes (considering four or more wheeled vehicles only).

Table 4.5-2 Traffic Changes, Construction Phase: Full Length of Route Nationale 2 (Weekday)

Type of Traffic	Baseline Level[(a)]	Increase due to Pipeline	Increase due to Mine	Total Increase (% of Baseline)
private cars	243	0	0	0%
buses / transports for people	212	2	0	1%
transports for goods	647	10	32	6%
total	**1,102**	**12**	**32**	**3%**

Note: All figures relate to number of one way trips.

(a) Weekday baseline levels quoted; weekend numbers are similar and impacts will not differ substantially between weekends and weekdays.

Changes in traffic along RN2 between Toamasina and the process plant access road are summarized in Tables 4.5-3 and 4.5-4. Table 4.5-3 addresses the construction period of the project and Table 4.5-4 addresses the operations phase. Increases in traffic (considering four or more wheeled vehicles only) total about 11% in the construction phase and 7% in the operations phase.

Table 4.5-3 Traffic Changes, Construction Phase: Route Nationale 2 Near Toamasina (Weekday)

Type of Traffic	Baseline Level[(a)]	Increase due to Pipeline	Increase due to Mine	Increase due to Plant and Tailings Facility	Total Increase (% of Baseline)
private cars	326	0	0	20	6%
buses / transports for people	204	2	0	32	17%
transports for goods	319	10	32	0	13%
Total	**849**	**12**	**32**	**52**	**11%**

Note: All figures relate to number of one way trips.

(a) Weekday baseline levels quoted; weekend numbers are similar and impacts will not differ substantially between weekends and weekdays.

Table 4.5-4 Traffic Changes, Operations Phase: Route Nationane 2 Near Toamasina (Weekday)

Type of Traffic	Baseline Level[(a)]	Increase due to Mine	Increase due to Plant and Tailings Facility	Total Increase (% of Baseline)
private cars	326	0	20	6%
buses / transports for people	204	0	28	14%
transports for goods	319	8	0	3%
Total	**849**	**8**	**48**	**7%**

Note: All figures relate to number of one way trips.

(a) Weekday baseline levels quoted; weekend numbers are similar and impacts will not differ substantially between weekends and weekdays.

Increases in traffic volumes will have effects on traffic congestion, accident rates, noise, vibration and vehicle emissions. All increases will be approximately proportional to the increased percentages of traffic numbers indicated in Table 4.5-4. Slightly higher effects on congestion, emissions and vibration may occur because the size of vehicles (large trucks and buses) due to the project are generally larger than the average existing size of vehicles on the road. However, percentages for accident rate increases should be kept below the rates of traffic volume increase through a program of driver training and vehicle maintenance that will make project vehicles safer than the average vehicles presently on the road.

In total along RN2, increased accidents have been estimated at less than one per year due to process plant traffic, two per year due to pipeline traffic (construction period only), and two accidents due to mine traffic, for a total combined increase of about five accidents per year along the full length of RN2 during the maximum impact period (before mitigation). Strict driver codes of conduct will be established, training programs for drivers employed by the project will be provided, and vehicles will be maintained in good condition to maximize the safety of project traffic and reduce accident rates.

4.5.2 Cumulative Effects With Other Projects and Activities

4.5.2.1 Introduction

The traffic study area for assessment of potential cumulative effects between the project and other projects and activities includes RN2 between Antananarivo, Moramanga and Toamasina, RN44 between Moramanaga and the mine access road, the direct access road between the process plant and the port, railway routes between Antananarivo, Moramanga and Toamasina.

4.5.2.2 Assessment of Cumulative Effects

The project has the potential to result in cumulative effects due to increased traffic in combination with other exiting and potential projects as listed in Table 4.5-5. For external projects, traffic numbers are not known, but the relative contribution to each additional project to traffic in each case is expected to be relatively small.

Table 4.5-5 Cumulative Effects Along Traffic Routes Used by the Project

Route	Projects Contributing to Traffic
RN2 (Antananarivo – Moramanga)	Ambatovy Project Antananarivo Growth Poles project and general development Exploration at Londokomanana (Nickel-Cobalt)
RN2 (Moramanga – Toamasina)	Ambatovy Project Logistique Pétrolière Terminal Andasibe and Brickaville Graphite Mines Andasibe Sawmills
RN44 (Moramanga – mine road)	Ambatovy Project Chrome mines at Bemanevika and Andriamena Exploration at Londokomanana (Nickel-Cobalt) Agricultural Traffic
port-plant direct access road	Ambatovy Project Logistique Pétrolière Terminal Dry Port Traffic Southern Toamasina Industrial Zone Development
railway (Antananarivo-Toamasina or any part thereof)	Ambatovy Project Logistique Pétrolière Terminal Morarano Chrome Project Increasing Volume of Shipments from Toamasina Port Antananarivo Growth Poles project and general development

The greatest cumulative effect of projects is expected to occur along the new direct access road between the port and process plant. Several projects have a relatively high probability to require this road for substantial traffic volumes, including the Ambatovy Project, Logistique Pétrolière Terminal, and a dry port development. Cumulatively, these developments will result in a substantial traffic increase both on the portion within Toamasina (which is presently congested) and south of Toamasina (which is presently a little-used dirt road). This cumulative impact will mainly be mitigated by improvement of the road.

In addition, the following mitigations will be employed:

- speed limits;
- procedures for oversized vehicles – advance vehicle;
- traffic lights as necessary;
- controlled railway crossings as necessary; and
- cooperation between industry to formulate a traffic management plan.

4.5.3 Conclusions

Project components will produce combined effects along RN2 between Moramanga and Toamasina; the largest combined effects will be observed on the portion of RN2 from Toamasina to the process plant access road during the construction phase, when contributions will occur from mine traffic, pipeline traffic, process plant traffic and tailings facility traffic. The combined impacts will result in increases in 6% for cars, 17% in buses/personnel transports and 13% in truck traffic along this road segment.

The project will contribute to traffic along RN2, RN44, a new access road between the port and process plant, new access roads to the pipeline and tailings facility, and railway lines between the process plant and the port. Within the towns of Moramanga and Toamasina, the project will contribute to urban traffic levels. In each case, other projects and general development will contribute to cumulative development. The magnitude of the cumulative impact is difficult to predict during the timeframe of the project, but is predicted to be relatively small based on the other projects known at the present time, except along the direct port-plant access road. Several new projects will contribute to traffic along this route, which is presently little-used, resulting in a low to moderate impact on traffic and social effects on residents along the route, after mitigation.

Social effects of changes in traffic volumes in relation to direct residual impacts on people are discussed in the socioeconomics EA sections.