CHAPTER 4
AFFECTED ENVIRONMENT AND HUMAN ENVIRONMENTAL IMPACTS

INTRODUCTION

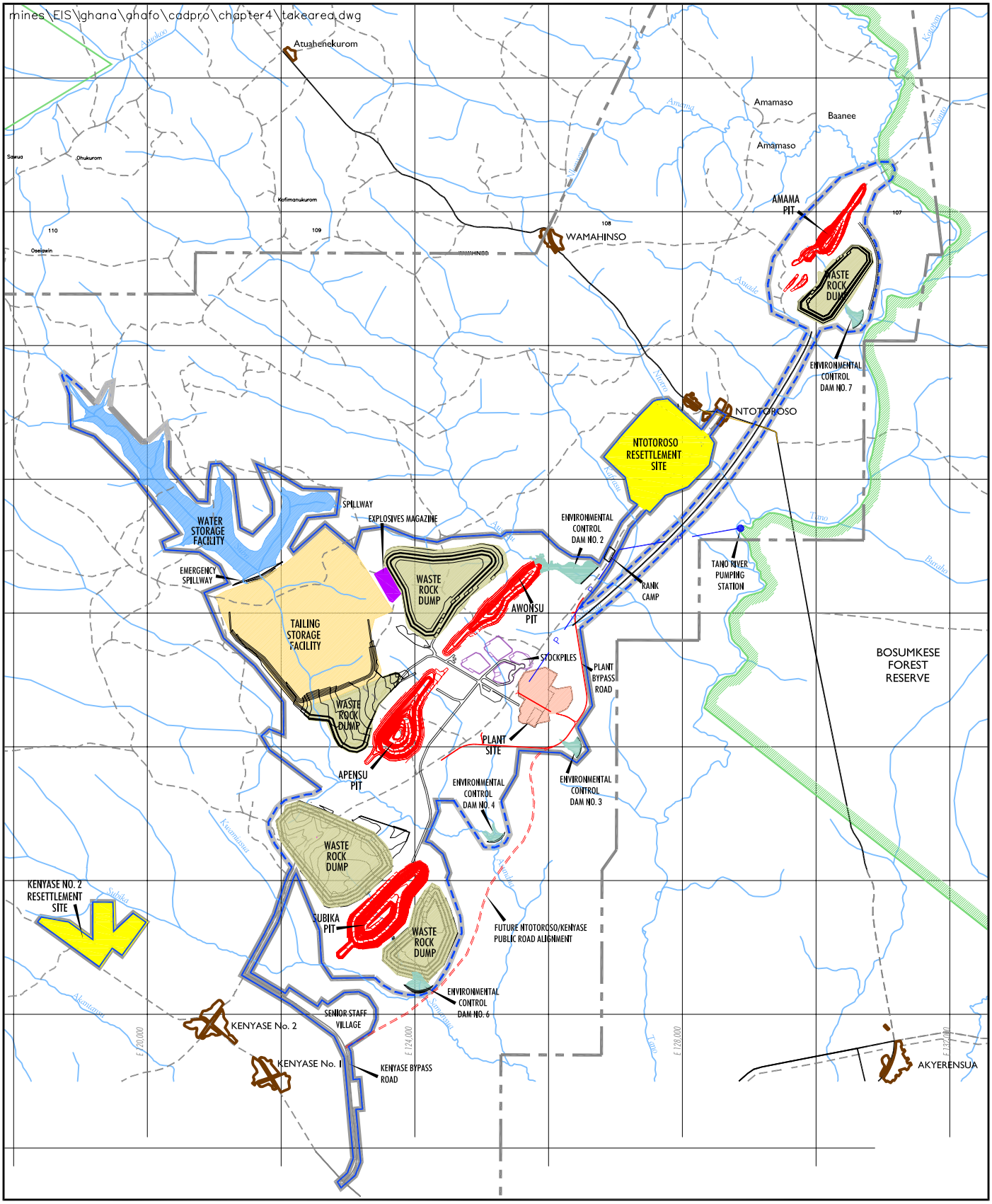
This chapter describes existing human, biological, and physical environmental resources within the Ahafo South Project area, and the direct, indirect, and cumulative impacts predicted to result from continued construction and operation of the Project. Analysis and discussion of impacts address resources in and surrounding the Project area. **Figure 4-1** shows the general Project area for most resources that would be directly affected by the Ahafo South Project. The ***Study area*** boundaries were developed for each resource area and generally extend from the Amama Shelterbelt/Bosumkese Forest reserves on the north and east; communities of Kenyase 1 and 2 on the south; and to the headwaters of the Subri and Awonsu drainages in the west. Study areas for each environmental resource are based on predicted locations of direct and indirect impacts associated with the Project.

Analysis of impacts included in this chapter recognizes the Ahafo South Project is presently under construction. The focus of impact assessment, therefore, is on the reclamation and closure plan (see Closure Plan in *Project Description* section of Chapter 2) and alternatives to the closure plan (see *Alternatives* section in Chapter 3). Cumulative effects that may result from past, present, and reasonably foreseeable development in the region are also described at the end of this chapter. Alternatives that may be evaluated for foreseeable development activities are discussed.

The remainder of this chapter discusses baseline conditions, direct and indirect impacts, alternatives analysis, and cumulative effects for the following environmental and social resources.

- HUMAN ENVIRONMENT
    - Social and Economic Resources
    - Cultural Resources
    - Visual Resources
    - Noise and Vibration

- BIOLOGICAL ENVIRONMENT
    - Biodiversity and Forest Reserves
    - Flora
    - Fauna
    - Wetlands
    - Aquatic Organisms
    - Air Quality



Project/Study Area
Ahafo South Project
Brong Ahafo Region, Ghana
FIGURE 4-1

- PHYSICAL ENVIRONMENT
    - Geology and Minerals
    - Surface Water Resources
    - Groundwater Resources
    - Soil Resources

HUMAN ENVIRONMENT

SOCIAL AND ECONOMIC RESOURCES

INTRODUCTION

Ghana was the first country in sub-Saharan Africa to gain independence, in 1957. While it endured military rule for a period, the country has enjoyed uninterrupted democratic governance since 1992. The country has a comparatively stable political infrastructure, which is capable of attracting substantial foreign investment. In December 2003, Newmont, through its affiliates in Ghana, signed an investment agreement with the government of Ghana. "This agreement applied for the life of any Newmont project in Ghana and it fixes the fiscal regime for our projects," says Bill Zisch, Managing Director of Newmont Ghana Gold, Ltd. "The genesis of this agreement is derived from our need for certainty regarding the terms and conditions for committing foreign investment of over $900 million" (Bill Zisch, Mining Review Africa, June 2004).

Ghana was ranked 8th in the world in 2000 for gold production (Chamber of Mines of South Africa 2005). In 2002, mines in Ghana produced 2.2 million ounces of gold, down 8 percent from production experienced in 2000. The Ghana Minerals Commission reports that revenues generated by gold mining in Ghana in 2002 (the last year of complete annual data) was $646 million (US) with royalties of $15.8 million. Gold accounted for almost 93 percent of the total mineral royalties collected during 2002. Mining and quarrying accounted for 4.72 percent of the national Gross Domestic Product and contributed nearly $620 million to the balance of payments in 2002.

The Ahafo South Project is projected to contribute approximately 500,000 ounces annually over a 15-year period to Ghana's overall export of gold. Production from the Ahafo South Project would represent a 22 percent increase in the 2002 national volume. Assuming the price of gold remains near $380 (US) per ounce and production meets expectations, the Ahafo South Project could generate over $77.5 million or ¢697.6 billion in the form of royalties to the government of Ghana over the anticipated life-of-mine.

Approximately 13,000 people were employed by gold mining in Ghana in 2002, and corporate taxes from large scale mining equaled ¢8,227,057,875 ($.9 million US) (Ghana Minerals Commission 2005). Long-term operations employment in the gold mining sector is expected to grow by 1,050 jobs, an 8 percent increase from the number of total jobs in the sector in 2002. Besides strengthening Ghana's position in the international gold arena, Newmont's Ahafo South mine will strengthen the revenues of the Brong-Ahafo Region and the Asutifi District governments as well as increasing the income of local residents.

Approximately 97 percent of Study area households were engaged in farming as the primary livelihood activity prior to Project construction activities. Only 6 percent were salaried employees. As of April 30,

2005, 458 Ghanaians have been employed in the 29-month construction effort and up to 750 local residents will be able to find long-term employment with either NGGL or an associated contractor when the mine is operational in 2006.

In February 2004, NGGL opened a National Technical Vocational Training Center in Yamfo to provide education and training for employment at the Project or other employment opportunities in the area. By August 2005, 696 local people had completed work orientation training and entered the semi-skilled labor pool, and 314 people completed semi-skilled training in Metals, Administration, and Masonry subjects. Additionally, NGGL has entered into a Memorandum of Understanding with the National Vocational Training Institute to provide training support and infrastructure improvements to the existing facility. NGGL is committed to adhering to the philosophy of sustainable mining: Projects which meet the needs of this generation while ensuring the ability of future generations to meet their needs (White 2003).

NGGL has also committed to development/improvement of a LEEP training facility in the community of Gyedu, which will be managed by ICCES. The facility will provide capacity building to Project affected people focusing on youth. OICI and the training center entered into a Memorandum of Understanding during May 2005 to assist with infrastructure improvements and provide management support. The training facility will initially focus on vocational training to 600 youths from the Project affected area.

Construction of the Ahafo South Project will result in physical and economic displacement of 823 households (5,185 people) living in the Project area, and economic displacement of an additional 878 households (4,390 people) that possess farmland within the Project area. The total number of impacted households is 1,701 households (9,575 people) (pA2005).

As of August 2005, NGGL has compensated residents of the Project a total of $920,694 (US) (¢8,286,246,000) for loss of their homes, and $12,878,990 (US) (¢115,910,910,000) as compensation for those that farm in the Project area. A participatory consultation program was developed for this resettlement and compensation to ensure that there was broad community support for NGGL's actions and attitudes towards local residents. Resettlement villages are being built to a high standard with many amenities not available previously.

In addition to vocational training available to mine workers, NGGL commissioned Opportunities Industrialization Centers International (OICI) to design and implement a sustainable community development program. Phase 1 of the program, launched in February 2005, focuses on economic growth, wealth creation, quality of life, and empowerment for over 823 Project affected households that have been relocated / resettled from the Project area and the 878 Project affected farming households that no longer have access to farming. To ensure sustainability and community ownership of the LEEP program, NGGL will create an advisory committee to include both private (NGGL and other private businesses in the area); public (District Assemblies and Government Ministries); OICI and other non-governmental organization partners; donors; and community representatives (traditional authorities, women, men, youth groups) to obtain expertise and input to finalize Phase 2 of the LEEP. In addition, the advisory committee would secure participation in the process through mobilization of human, material, and financial resources and technical expertise for implementation, monitoring and evaluation of the program.

Phase 2 of the LEEP will be initiated following the start of gold production (projected to be July 2006). The broader community (Project affected and non-affected people) will have an opportunity to participate in Phase 2 programs. In addition to the 5-year LEEP program, NGGL will work with local

communities and regional development planning boards in a participatory fashion to assess additional opportunities to support sustainable community development that will continue throughout the life of the mine.

NGGL expects to build new houses in two resettlement villages. In addition to new housing stock, NGGL assisted local communities in the Study area during the exploration phase by:

- Establishing new water sources (boreholes);
- Renovating existing water sources;
- Supporting the Kenyase town water system; and
- Constructing a water storage facility on the Subri stream which will remain as a permanent source of water for domestic and irrigation use after mine closure.

NGGL is training individuals on five local Community Water and Sanitation committees to manage community water and sanitation infrastructure effectively. In addition programs to inform local resident's of the importance of drinking only potable water, using proper sanitation practices, and instilling a sense of personal responsibility for maintaining water and sanitation facilities have been implemented.

NGGL is committed to maintaining a safe and healthy work environment for all employees at all its places of business in Ghana, and has developed both malaria and HIV/AIDS policies which apply to all full-time NGGL employees, at all company locations in Ghana. NGGL has developed a malaria prevention program to reduce exposure of individuals to malaria. NGGL is committed to reducing and controlling mosquito presence in and around the Study area, potentially protecting residents and workers alike. NGGL has developed a pro-active HIV/AIDS policy and has hired an HIV/AIDS Coordinator for voluntary prevalence testing and counseling. Employees infected with the virus will be counseled and receive anti-retroviral treatment. In addition, NGGL will identify and train peer counselors and community educators to provide services in the field hopefully educating and ultimately protecting people in the Study area. Benefits of these programs would be measured through NGGL's monitoring programs.

Electrical service is not currently available in most of the Study area; Over 90 percent of households use kerosene or paraffin for lighting. Electrification and telecommunication networks within the Study area will be improved due to increased demands created by the Project. Electricity for the Ahafo South Project will be provided by the Volta River Authority (VRA) from 161 kV substations at Kumasi and Sunyani. Development of the Ahafo South Project would provide VRA with a sufficient customer base to enable financing for completion of the previously planned project. Completion of the electric ring circuit will improve power availability to a large portion of northwestern Ghana. Because of demand by Project personnel, mobile phone coverage became available in Kenyase 1 and Kenyase 2 in September 2004 (pA 2005).

BASELINE CONDITIONS

The primary purpose of documenting the socioeconomic setting of the Ahafo South Project is to provide an understanding of socioeconomic forces that have shaped the area. Knowledge of the socioeconomic setting, or the social baseline as it is sometimes called, provides a framework by which

to measure socioeconomic effects of the Project and develop alternatives and programs to effectively mitigate those impacts.

National Overview

Ghana, located in West Africa, is bordered by Togo to the east, Burkina Faso to the north, Ivory Coast to the west, and the Gulf of Guinea to the south. The coastline of Ghana extends 539 km. The total area of the country is 238,540 km^2, making it comparable in size to Great Britain. Land use is divided between arable land (12 percent), permanent crops (7 percent), permanent pastures (22 percent), forests and woodland (35 percent), and various other uses (24 percent).

Ghana was the first country in sub-Saharan Africa to gain independence, in 1957. While it endured military rule for a period, the country has enjoyed uninterrupted democratic governance since 1992. The country has a comparatively stable political infrastructure.

Population: Ghana's population is just under 21 million. Accra, the capital city, has population of 2.8 million (metropolitan area). Kumasi, the country's second largest city, has a population of about 975,000.

Socio-Cultural Profile: English is the official language of Ghana. Local languages spoken include Brong-Ahafo Twi, Fanti, Ga, Ewe, and Dagbani. Native people of Ghana are classified into five major groups: Akan (44 percent), Ewe (13 percent), Moshi Dagomba (16 percent), Ga (8 percent), and Gurma (3 percent). Sixty-three (63) percent of the Ghanaian population consider themselves Christians, 21 percent as followers of local beliefs, and 16 percent Muslims.

Socio-Economic Performance: Ghana's human development indicators, while low, are improving. Life expectancy at birth is 58 years, adult literacy is 73 percent, and school enrolment (combined primary, secondary and tertiary) is 46 percent. Gross national per capita annual income is $270 (US). The national HIV/AIDS prevalence rate in Ghana is 3.1 percent.

Macro-economic Performance: Ghana continues to endure macro-economic challenges. The 1999 terms of trade shock, precipitated by a collapse in the price of chief export commodities – gold and cocoa – and an escalation of petroleum prices following the government's decision to reduce fuel subsidies, led to a pronounced reversal in macro-economic performance. Ghana joined the Heavily Indebted Poor Country debt relief program in 2002.

Reform efforts are being implemented aggressively with some success; Gross Domestic Product (GDP) growth reached 5.3 percent in 2003. The Agricultural sector, comprising 35 percent of GDP, is considered the strongest growth sector, with Information, Communication and Technology sector also considered potentially important. Gold, cocoa, and lumber remain the chief export earners. Mining and quarrying accounted for 4.72 percent of the national GDP and contributed almost $620 million to the balance of payments in 2002.

Asutifi District Overview

The Project is located in the Brong-Ahafo Administration Division approximately 30 km south of Sunyani in the Asutifi District. The Asutifi District includes the Ahafo South Project area and the Study area communities of Kenyase I, Kenyase 2, Ntotoroso, Gyedu, and Wamanhinso. The following presents a general socio-economic profile of the District, based on the District Medium Term

Development Plan (pA 2005). Unless otherwise referenced, the information in this section was summarized from the NGGL Ahafo Project Resettlement Action Plan (pA January 2005 draft).

Population and Demographics

Population: pA estimated that the District's population in 2004 was 89,000. With just two urban (i.e. population >5000) settlements (Kenyase 2, and Hwidem), the district is largely rural (85 percent), about twice the national average. Fifty-one percent of the population is female; 50 percent is of working age (18 to 64). Population growth rate is 2.8 percent per annum.

Ethnicity: The main tribes in the District are Ahafos, Ashantis and Bonos. Others include Wangara, Dagombas, Kuasasis, Fantes, and Ewes. While the majority of Asutifi District residents are migrants (i.e., neither Ashanti nor Bonos), most have lived in the area for generations and identify with the area.

Religion: About 84 percent of residents are Christian with Muslims the majority of the remaining population. A comparative few practice traditional religions exclusively although many residents practice traditional religions as well as identifying themselves as Christians or Muslims.

While there are ethnic and religious minorities, no caste system or prejudiced community exists in the District. The prevailing systems of kinship, marriage, inheritance, and residence are principled but flexible and open to outsiders.

Education: The educational infrastructure is considered adequate in the District with 41 kindergartens, 81 primary, 48 junior secondary, and four senior secondary schools. Still, some 10 percent of the District population has no formal education, and the literacy rate is 55 percent. About 5 percent of kindergarten and 53 percent senior secondary school teachers have teaching diplomas. The absence of adequate housing discourages qualified teachers from accepting positions at local schools and is a key educational constraint. Poverty motivated truancy is a major educational constraint in the Asutifi District as school age children are forced to participate in household income and/or subsistence activities.

Health: The Roman Catholic Saint Elizabeth Hospital in Hwidiem is the only major health care facility in the District. The facility has 30 beds and two doctors on staff. The doctor/patient ratio in the District is 1:42,237, compared with the national average of 1:7,813. The District has five health centers managed by the Ministry of Health, seven community clinics (only three currently functional), three private maternity homes, three homeopathic clinics, and 60 trained midwives.

As in most regions of Ghana, malaria is the primary cause of morbidity and is also a leading cause of mortality, along with meningitis, tetanus, typhoid fever, diarrhea, and hypertension.

Economics

Poverty is widespread in the Asutifi District with 50 percent of residents living below the poverty line. Average household monthly income is $22 (US) (¢202,553.75[1]), with about 25 percent of households surviving on less than $11 (US) (¢100,000) per month. Income inequity is stark; the poorest 40 percent

[1] Ghana's currency, the cedis (¢), trades at ~9,000 to the US$ (February 2005).

of households earn 4 percent of District income (Asutifi District Medium Term Development Plan). The unemployment rate is 17 percent (pA 2005a).

Seventy-seven percent of the employed working age population is involved in agricultural activities. This compares to 71 percent regionally and 57 percent nationally. As further evidence of the agrarian focus of the local economy, 96 percent of Ashanti District residents employed in other sectors are also involved in agriculture peripherally.

The major food crops produced in the area are maize, cassava, plantain, cocoyam and rice. Cocoa is the primary cash crop produced, with coffee, oil palm, cola and cashew produced to a lesser extent. Major vegetables grown include garden eggs, tomatoes, okra and pepper. Fifty-one percent of household expenditures are on food.

Generally, farm holdings in the District are large. The average farm holding of a homestead, which comprises one or more households, is about 2.2 ha. Land for farming is generally acquired through family, as a leasehold, or tenancy.

STUDY AREA OVERVIEW

The Study area lies in the south of the Asutifi District and includes the area socio-economically affected by Project construction and operation activities prioritized by NGGL for community development assistance. The Study area also includes the surrounding communities of Wamahinso, Gyedu, Ntotoroso, Kenyase 1 and 2 and hamlets near those communities. Approximately 33,500 people live in the Study area (pA 2005).

The Project area (2,174 hectares (ha) required for mine development, buffer zones, and resettlement villages) is encompassed by the Study area. People residing in the Project area are considered to be the Project affected people because they have been resettled or relocated in order for construction to begin. Development of the Ahafo South Project will displace 710 households comprised of 4,513 individuals from the Project area.

Unless otherwise referenced, information presented in this section was summarized from the Opportunities Industrialization Centers International (OICI) Census and Livelihood Survey of the Study area (OICI 2004a). The survey was designed to:

- Determine socioeconomic and cultural (livelihood) profile of farm resident households including a gender analysis, for use in the compensation and resettlement program;
- Determine possible impacts of relocation and resettlement and to disaggregate these impacts for women, children, and men (i.e., gender analysis);
- Assess the level of existing skills, knowledge, and training needs to determine if and how community members can be employed by the Project;
- Elicit community perceptions and feelings about resettlement and compensation; and
- Define priority needs of the population by gender and age to develop sustainable community development programs.

This study employed qualitative and quantitative techniques:

- Quantitative methods: OICI enumerators administered a structured questionnaire to all heads of homesteads located in the Project area and to all heads of households with farm fields located in the Project area but who reside elsewhere.

- Qualitative methods: OICI also used a diverse range of participatory tools, including focus groups, transect walks, mapping exercises, puppetry and drama, and key informant interviews to supplement the findings of the structured questionnaire.

The Livelihood Study included a census and socio-economic survey of households working in or resident in the Project area. The study was done in two phases. The first covered permanently established resident homesteads, and the second covered non-resident households who farm in the Project area.

The survey data includes socio-economic and demographic characteristics of respondents; income generating activities and skills of respondents; household production activities; household income and expenditure profiles; household asset holdings including land, access to credit, and household food security; public health and safety issues, as well as general community development problems and priorities. Existing skill levels and gender issues in community daily and economic routines are also assessed.

Specific study questions on gender roles status and responsibility and women's status were asked to both male and female head of households. Approximately 35 percent of the resident and non-resident respondents were women, a significant response considering household heads are traditionally men. Qualitative methods included women's focus groups, women's workload calendars, children's work by gender, and priority matrix by gender and age. Women and children participated actively and contributed in all the data collection exercises.

Socioeconomic factors described below provide the context for analyzing the potential effects that could result from the Project, such as population increases, resettlement of some families, infrastructure improvements, employment opportunities, and opportunities to develop sustainable businesses.

POPULATION AND DEMOGRAPHICS

General: Residents generally engage in subsistence farming, with low incomes due to low production on small family farmsteads, limited non-farm income generating opportunities, and comparably limited access to infrastructure and social services.

Household Size: In general, people in the Study area live in homestead units, which contain two or more households and average 11 persons (pA 2005). There is a near equal distribution of males and females in the area for almost all age categories. Children up to the age of 18 comprise 53.5 percent of the population.

Ethnicity*:* Approximately 27 percent of survey respondents were born in the area. The remaining 63 percent moved from elsewhere in the country or from outside Ghana to settle in the area and farm. Most of Ghana's major ethnic groups are represented in the Study area. Main tribes in the Asutifi District include Ahafos, Ashantis, and Bonos. Over 65 percent of in-migrant households have been residents in the area for more than 25 years.

Religion*:* Christians comprise 61 percent of the total Study area population; Muslims constitute 25 percent, and adherents of traditional religions account for 12 percent of the population.

Educational Status: About 41 percent of Study area residents have no formal education. Of those with an education, 20 percent reached the primary school level only, 32 percent reached middle/junior secondary level, 5 percent reached senior secondary, and 1.4 percent attained tertiary level education. Educational facilities are within a 1-hour walk of approximately 25 percent of the population, a 2-hour walk for 25 percent of the population, and more than a 2-hour walk for 41 percent of pupils in the Study area.

About 42 percent of Project affected residents have no formal education. Of those with an education, 20 percent stopped at primary school, 32 percent at junior secondary school, 5 percent stopped at senior secondary school, and 1percent attained a tertiary level education.

Skill base among Project affected residents is narrow. About 25 percent of those surveyed claimed to have non-farming skills, including driving, mechanical, carpentry, and machine operation.

Health Status, Dependency and Productivity: Illness is common among residents of the Study area. More than half, about 56 percent, reported a sickness or injury within their household during the 4-week period preceding the survey. Respondents indicate that household members that were sick or injured missed up to 2 weeks work or school as a result of illness or injury, while another 21 percent lost more than 2 weeks.

Seventy-nine percent of the OICI survey respondents indicate their household seeks medical attention at clinics or hospitals. Another 17 percent of the respondents self-medicate, while the remainder rely on herbalists, fetish priests, or spiritualists for medical attention. Study area residents may have to travel over 13 km to obtain medical attention.

Child Health and Immunization: About 50 percent of children in the Study area benefit from growth monitoring or immunization programs, suggesting an inadequate public health knowledge base within the Study area communities. According to the OICI survey, 288 Project affected children are below the age of five. A majority (79 percent) were born in hospitals or maternity homes, while 21 percent were delivered at home. Midwives handled 56 percent of the deliveries.

Disabilities: Approximately 10 percent of homesteads include members with either physical or mental disabilities.

Membership in Community Groups: Approximately 70 percent of survey respondents indicate they belong to an identifiable community or social group in the Study area, including farmers associations, cultural groups, and youth development associations. Youth associations typically include people aged 18 to 45.

Participation in Community Life: About 48 percent of households indicate they are active participants in the life of the community while 45 percent describe their level of participation as very active. Over 70 percent of respondents claim they have friends in nearby households from whom they could seek assistance. Assistance sought includes counseling, financial (cash grants and/or loans) and material gifts such as food, water, fuel, and farm inputs.

Membership in Local Administration: A small minority of Study area household members are involved in local government, including the District Assembly, Area Council, Unit Committee, or the Community Development Committee.

ECONOMICS

Economic Activities: Farming is the main occupation in the Study area. Approximately 97 percent of the households surveyed are engaged in farming as their primary livelihood activity. Farmers rely on crop sales to meet household expenditures, including educational expenses, clothing needs, agricultural inputs, medical, funeral, and other personal expenses.

Both cash and food crops are produced. Cash crops include cocoa, oil palm, teak, pineapple, and citrus. Food crops include cereals, legumes, plantain, yam, cocoyam, vegetables, and cassava, and are often produced for both consumption and sale.

Agricultural production is limited by inefficient farming practices, lack of tools and equipment, lack of critical inputs (such as improved seeds and fertilizers), poor soil fertility in some areas, and invasion of elephant grass.

Low production is compounded by high post-harvest losses, largely due to poor storage facilities and a lack of knowledge of post-harvest handling and processing. Most Project affected farmers do not use any crop protection methods, such as pesticides. Those that use chemicals appear to have inadequate knowledge about their safe use.

Weak market links and poor supporting infrastructure, such as irrigation systems, roads, public transportation, electricity, and telecommunication networks, further hamper agricultural development. Farmers also receive low farm gate prices, selling their produce quickly and close-to-home after harvest to meet immediate cash needs and to liquidate accumulated debt.

Fifty-nine percent of Study area residents have sources of income other than farming. Non-farm income sources include trading, food processing, tailoring/sewing, and rent. Prior to Project construction activities, only 6 percent of the respondents confirmed salary earnings. Income from non-farm sources is low; 53 percent of respondents that provided information on income from non-farm sources earned below $55 (US) (¢495,000) from these sources in the last year, while 40 percent received between $55 and $550 (US) (¢4,950,000). A minority, 6 percent, earned more than $550 (US) from non-farm income sources.

Construction of the Project is scheduled to occur over a 29-month period and employ approximately 1,500 people, including 300 expatriates and 1,200 nationals. An additional 350 contractors will augment this workforce to provide security, laboratory, vehicle and equipment maintenance, catering, and transport services. As of April 30, 2005, 458 Ghanaians have been employed in constructing the Project.

In February 2004, NGGL opened a National Technical Vocational Training Center in Yamfo to provide education and training for employment at the Project or other employment opportunities in the area. By August 2005, 696 local people had completed work orientation training and entered the semi-skilled labor pool, and 314 people completed semi-skilled training in Metals, Administration, and Masonry subjects. Additionally, NGGL has entered into a Memorandum of Understanding with the National Vocational Training Institute to provide training support and infrastructure improvements to the

existing facility. NGGL has instituted a bus service between the above communities, training center, and the Project site which allows eligible workers to live at home.

Accurate estimates of weekly payrolls for construction are not possible because over 90 percent of the work force is employed by contractors. Labor expenditures during the construction phase of the Project are shown in **Table 4-1**.

Household Assets: Radios are the most commonly held consumer durable; approximately 86 percent of respondent households own a radio. Other important household assets include mattresses/beds, bicycles, watch/clocks, and sewing machines. About 18 percent of households own television sets, while less than 5 percent have electric irons, refrigerators, motorcycles, or vehicles.

Household Food Security: Food security is not a critical issue in the Study area. Most farmers in the Study area are able to meet food consumption needs from household food production; only 12 percent experienced food shortages in the past year.

Household Livestock Production: Households respondents keep a range of animals on their farms. While poultry predominates (raised by about 82 percent of all households), sheep (39 percent) and goats (30 percent) are also raised. Livestock sales constitute an important income source for a majority of households.

TABLE 4-1
Total Ghanaian Labor Expenditures
Ahafo South Project Construction Phase

Ghanaian Labor Category	Average Pay Rate – Cedi (¢)	Direct Workers Average Monthly Employment No.	Monthly Avg. - Total Cedis (¢)	Monthly Avg. US $
2004 Estimated Labor				
Ghanaian - UnSkilled	2,030,000	80	162,292,345	18,032
Ghanaian - Semi Skilled & Skilled	2,030,000	363	736,903,891	81,878
Ghanaians Indirect	2,030,000	1	2,604,568	289
2004 Sub-Total		**444**	**¢8,116,207,229**	**$901,801**
2005 Estimated Labor				
Ghanaian - Un Skilled	2,030,000	288	585,377,223	65,042
Ghanaian - Semi Skilled & Skilled	2,030,000	535	1,086,911,982	120,768
Ghanaians Indirect	2,030,000	36	73,579,035	8,175
2005 Sub-Total		**860**	**¢20,950,418,876**	**$2,327,824**
2006 Estimated Labor				
Ghanaian - Un Skilled	2,030,000	62	126,700,494	14,078
Ghanaian - Semi Skilled & Skilled	2,030,000	121	246,554,882	27,395
Ghanaians Indirect	2,030,000	22	45,579,933	5,064
2006 Sub-Total		**206**	**¢418,835,309**	**$46,537**

Notes:
Assumes Exchange Rate of ¢9,000 Cedis : 1 US Dollar
Derived from employment data provided by NGGL

LAND OWNERSHIP IN THE STUDY AREA

Within the Project area and throughout the Asutifi District, customary ownership predominates. Specifically, traditional authorities hold land in trust and allocate land at their discretion to families and individuals for cultivation and habitation. Through inheritance, allocated land remains in families.

Historically, traditional authorities encouraged immigration to the area because of a perceived abundance of land. At one point after independence, the national government allocated itself large tracts of land in the Project area in order to establish large-scale government farms. These farms did not flourish and most acquired land was reabsorbed by the respective traditional authorities.

This role and responsibility of the traditional authorities in land allocation is seen by NGGL as crucial to maintain the following:

- Customary ownership of land,
- Mechanisms for land allocation,
- Existing socio-economic system, and
- Avoidance of dependency on NGGL.

LAND USE

The Study area slopes gently from west to east, and is located just west of the Tano River. Soils in the area are predominantly sandy loam. Land uses in the Study area include cultivation, fallow management, and urban uses, as shown in **Table 4-2**.

Cultivation

NGGL estimates that there are 6,907 farm fields in the Study area and farm fields average 0.34 hectares in area; approximately 17 percent of the Study area is under active cultivation. Nearly all households in the Study area cultivate farm fields. The number of fields cultivated ranges from one to eight per household with an average field size of 0.34 ha. The average holding per household in the Study area is approximately 1.44 ha, somewhat smaller than the District average of 2.2 ha.

Project affected households cultivate an average of five fields, for a total of 1.70 ha. Households outside the Project area but farming within its boundaries cultivate an average of three fields totaling 1.02 ha.

TABLE 4-2
Land Use in Ahafo South Study Area

Land Use In Study area	Hectares	Percent
Cultivated Land		
Disturbed / Excavated Land	10.4	0.05
Newly Cultivated Fields	388.8	2.3
Vegetable Farm	4.5	0.03
Mixed Food Crop Fields	1324.8	7.9
Plantain Farm	154.2	0.9
Citrus Plantation	7.6	0.05
Cocoa Plantation	766.5	4.6
Oil Palm Plantation	202.3	1.2
Teak Plantation	4.3	0.03

Sugarcane Farm	0.4	0.00
Vetiver Grass Nursery	4.1	0.02
Subtotal	**2,867.9**	**17.0**
Fallow and Natural Areas		
Forbs Regrowth	2535.6	15.0
Fallow Thicket	3594.0	21.3
Secondary Forest	2532.3	15.0
Forest Reserve	206.0	1.2
Riparian Thicket	204.2	1.2
Elephant Grass	4683.7	27.8
Subtotal	**13,755.8**	**81.6**
Urban Uses		
Homesteads	19.2	0.1
Settlements and Hamlets	166.5	1.0
Roads	36.0	0.2
Schools	1.2	0.01
Sub-Total	**222.9**	**1.3**
TOTAL	**16,779.4**	**100**

Source: pA 2005

Fallow Management

Approximately 51 percent of the Study area is under forbs regrowth, fallow thickets, or secondary forest. Farming households typically practice swidden-fallow agro-forestry, an agricultural system that mimics natural forest cycles. The system begins with clearing and burning a fallow thicket or secondary forest regrowth. The opened field is then planted with a mix of food and cash crops that mature at different rates. Typically, production will begin with a few years of mixed food crop production, including cassava and cocoyam, and proceed through a number of years of cash crop production, including plantain and pineapple. These cultivated fields contain a diverse range of crops. Farmers can "fallow" their fields at any time, but often prefer to move into tree crop production, including cocoa, oil palm, teak, citrus fruits, and recently cedrilla.

The fallowing process is carefully managed, such that the ensuing fallow thicket and secondary forest continues to provide the farming household with a number of useful products, including building materials, fuel, food, and medicine. Fallow also serves to provide soil with an opportunity to regenerate and regain productivity lost during years of cultivation. Typically, farmers will clear fallows after a number of years to re-initiate cultivation of food and cash crops. NGGL recognizes the importance of fallow land to the community, and while this land is not eligible for crop compensation, it is an important part of the agricultural system. Moreover, NGGL recognizes that there are impacts from a loss of fallow land and is monitoring the effects of this loss.

Land Tenure

Land tenure or ownership in the Project area comprises both landlords and tenants, both of which were eligible for compensation. Generally, a landlord is a property holder with exclusive rights to use and/or provide others with rights to use the land. Landlords typically acquire land from traditional rulers or willing sellers by purchase or through family inheritance.

Tenants are persons or households with use rights to land as negotiated under a private agreement with the landlord. There are two types of tenants in the Project area: sharecroppers and caretakers.

Sharecropping is a specific type of land tenancy where the owner of a parcel of land extends farming rights for an agreed upon period of time. Crops produced are shared between the landholder and the farmer based on agreed principles. There are two basic types of sharecroppers: (1) for tree crops (e.g., cocoa or oil palm), farmland is divided at the end of the period (usually 5 years), generally into two equal parcels, between the landholder and the sharecropper; and (2) for food crops (e.g., maize and cassava), the agreement period is usually renewed on a yearly basis. Crop production is divided between the landholder and the sharecropper on a one (sharecropper) to three (landholder) basis, and there is no division of the landholding. In all cases, an agreement is typically signed in the presence of one or more witnesses.

A caretaker, in contrast, is someone who has been employed – by either a landlord or sharecropper – to take care of a farm and usually resides on the farm. In exchange for cultivating the land, the caretaker receives a share of the proceeds from the sale of crops.

Project affected households are evenly divided between landholders (44 percent) and tenants (56 percent). Of those that report themselves as tenants, 28 percent stated that the land belongs to their landlords and 28 percent that the land belongs to their relatives or friends.

Urban Uses

Approximately one percent of land in the Study area is urban including towns, settlements, hamlets, homesteads, public facilities, and utility infrastructure. Major settlements in the Study area include:

Kenyase 1 had an estimates population of 4,019 (pA 2005). The local population is Asantes; in-migrants are Mossi, Frafra, Dagomba, and Ewe. The town has a government clinic with a leprosy unit. Schools include two junior secondary schools, four primary schools, and three nursery/kindergartens, which is also a local government center. The Ghana Prison Service has a facility in Kenyase 1. The primary economic activity is cocoa farming, raising food crops, and sheep rearing. Commercial activities include banking, tailors and dressmakers, hair salons, construction workers, mechanics, bakers, provision shops, drug stores, bars, and a communications center.

Kenyase 2 has an estimated population of 8,321 (pA 2005). The local population is Asantes that originally moved there after a misunderstanding at Kenyase 1. In-migrants are Dagarbas, Ewes, Dagomba, and Fantes. The town has Christian, Muslim, and Traditional religious facilities and a government health center with a medical assistant, nurses, and midwives. Educational facilities include six junior secondary schools, seven primary schools, and three nursery/kindergartens. Multiple government offices including Ministries of Health, Food, and Agriculture are located in Kenyase 2. The main economic activity is farming cocoa and mixed food crops. Commercial activities include hardware, chemical and provision stores, communications centers, hair salons, bookstore, and bars. A large market occurs each Thursday attracting over 1,500 traders and customers.

Ntotoroso has a population of 2,952 (pA 2005). The local people are Asantes while in-migrants include Ewes, Gas, Frafra, Dagartis, and Fantes. Christianity, Islam, and Traditional religions are represented in the town. There are no health care services available in Ntotoroso. The town has two basic schools, a primary school and a nursery/kindergarten. Farming cocoa and growing food crops are the main economic activities. Commercial activities include stores and kiosks, bars, dressmaking, hair salons, and hardware sales. A corn mill and local gin distillery are located in Notoroso.

Wamahinso contains 1,646 people (pA 2005). People born in the village are Asantes, while in-migrants consist of Bonos, Dagartis, Malians, Nigerians, and Burkinabes. Residents practice Christianity, Islam, and Traditional religions. A Traditional Birth Attendant is the extent of the medical services available in the town. A technical school, junior secondary school, primary school, and kindergarten are located in Wamahinso. Primary economic activity is farming cocoa and food crops. Commercial activities include provisions stores, drug stores, hair salons, dressmakers, bars, and a palm oil processing plant.

Gyedu has a population of 1,325 (pA 2005). People born into the village are Asante; in-migrants include Mossis, Dagartis, and Grunshies. Most residents are Christian or practice Traditional religions. A government clinic and a primary school are located in Gyedu. Primary economic activity includes cocoa farming, palm oil plantations, and growing food crops. Commercial activities include provisions stores, hair salons, bars, corn mill, and dress makers.

In addition to urban-type settlements in the Study area, there are several other villages with populations between 100 and 1,000, including Yamfo, Terchire, Adrobaa, and Susuanso. There are over 110 hamlets, sometimes consisting of only one house (population ranges from 2 to 27 people). Most residents in hamlets are settlers from other parts of Ghana, Benin, Togo, or Burkina Faso and are Busangas, Kotokolis, Wangaras, Mossis, Frafras, Sissalas, Dagartis, Kurasis, Dogombas, Ewes, or Brongs.

PUBLIC FACILITIES

Public facilities within the Study area are limited to school buildings, Cocoa Marketing Board (CMB) purchasing sheds, health facilities, and social centers (pA 2005). Forty-one educational facilities are located in communities in the Study area. All school buildings feature concrete floors, metal roofing sheets, and plastered and painted sandcrete walls. Only the school in Kwakyekrom has a supply of potable water, and none have electricity.

The ten CMB sheds in the Study area are used for purchasing and storing cocoa, before being transported to Takoradi for shipment overseas.

Infrastructure

Infrastructure in the Study area includes transportation, water supply and sanitation systems, solid waste management systems, electrical systems, and telecommunication networks (pA 2005).

Transportation

Modes of transportation include – in order of frequency – walking, bicycling, taxis, and private vehicles. Occasionally, buses use the road between Kenyase 2 and Ntotoroso, most recently those buses have been retained by NGGL to transport workers to and from the plant site (pA 2005). Other roads in the Study area include:

- A primary road between Kumasi and Sunyani, and a primary road from Tepa Junction to Hwidiem. Primary roads are single carriageway, two lane, slurry sealed highways.

- From Hwidiem, the Project area is accessed via a secondary road, which passes through Kenyase I to Kenyase 2. Secondary roads are single carriageway, two lane, slurry sealed highways.

- From Kenyase 2, the Project area is accessed along a local distributor, which connects Kenyase 2 and Ntotoroso. Local distributor roads are single carriageway, two lane, lateral roads. This road passes through the community of Kwakyekrom and by a number of rural homesteads. The NGGL Project office is located in Kenyase 2.

- A network of local access roads exists within Kenyase I, Kenyase 2, and Ntotoroso, and other Study area communities with automobile access.

- The Study area is also serviced by single lane access tracks, constructed by NGGL for exploration, and narrow footpaths, which link rural homesteads and farm fields with Ntotoroso and Kenyase 2.

An airport in Kumasi provides service to Accra. The airport in Sunyani does not provide commercial air services at this time.

Water Supply Systems

Rivers, lakes, ponds, and wells are the main sources of water in the Study area. Approximately 59 percent of households draw water from unprotected sources, exposing residents to water borne infections and other health hazards. Water sources are located within 1,000 m of most homesteads. Some sources go dry during the dry season and households must travel longer distances for water. Residents of Kenyase 1, Kenyase 2, and Ntotoroso draw water from protected wells, public outdoor taps, boreholes, or vendor trucks. Potable water supplies in the area are described in **Table 4-3**.

TABLE 4-3
Existing Potable Water Supply Facilities
Ahafo South Study Area

Community	Pipe System (Standpipes)	Borehole Fitted With Hand Pump	Solar-Powered Borehole	Remarks
Ntotoroso	-	5	1	3 boreholes not in use
Gyedu	-	3	-	1 borehole not in use
Wamahinso	-	2	-	Neither borehole functioning
Kenyase I	10	1	-	
Kenyase 2	12	3	-	
TOTAL	**22**	**14**	**1**	

Source: pA 2005.

Sanitation Systems

Most households in the Study area use open pit latrines or have no toilet facilities. Only 16 percent of residents use improved toilet facilities, including covered pit latrines (14 percent) or Ventilated Improved Pit (VIP), or Kumasi VIP (KVIP) latrines (1.5 percent) (SGS 2004a). Covered pit latrines and VIP/KVIP latrines are limited to those at nearby schools and accessible to members of the community. Some private homes may have flush toilets with septic tanks and KVIP latrines. **Table 4-4** describes sanitation facilities in the Study area.

TABLE 4-4
Existing Sanitation Facilities and Status
Ahafo South Study Area

Community	Existing Facilities		Capacity	Seats Available	Status of Existing Facilities
	VIP/KVIP Latrines	Water Closet			
Ntotoroso	3	-	12-seater	3	1 of 3 functioning latrines has a leaking roof and some broken cover slabs
Gyedu	1	-	10-seater	1	Facility in use
Wamahinso	1	-	12-seater	1	Facility in use
Kenyase 1	2	-	12-seater	2	Both in use, with leaking roofs and some broken cover slabs
Kenyase 2	4	1	12-seater 4-seater	4 1	All in use Under construction
TOTAL	**11**	**1**			

Source: pA 2005.

Solid Waste Management Systems

Household refuse is disposed of in shallow surface dumps, which are abandoned when full. Kenyase 2 and Ntotoroso have several dumpsites. Residents do not systematically bury or compost solid waste (pA 2005).

Electrical System

Electrical service is not available in most of the Study area; there is no electricity in the Project area. Over 90 percent of households use kerosene or paraffin for lighting. A few households use batteries or firewood. Residents of Kenyase 1, Kenyase 2, and Ntotoroso have access to electricity. Most households use firewood or charcoal for cooking.

The Northern Electricity Department of the Volta River Authority (VRA) is responsible for distributing power within the Asutifi District. The existing Sunyani–Mim transmission line has a capacity of 34 kV. The 34 kV line in Kenyase terminates at the transformer feeding the NGGL Offices (pA 2005). Refer to the discussion in Chapter 2 regarding the VRA powerline, an associated facility that will supply electricity for the Ahafo South Project.

Telecommunication Networks

Communication services are lacking or restricted in and around the Study area. Government post offices and commercial telephone/postal agencies are located in Kenyase 2, but are not reliable. Neither Kenyase 1, Kenyase 2, nor Ntotoroso has an exchange and subsequently use Sunyani or Kumasi exchanges. Radiophones are also used. Mobile phone coverage became available in Kenyase 1 and Kenyase 2 in September 2004 (pA 2005).

DIRECT AND INDIRECT IMPACTS

The Ahafo South Project is currently under construction and development is proceeding. Social and economic impacts created by the Project are being addressed through programs NGGL has initiated in the Study area. This section describes how NGGL is addressing these impacts.

A Project of this nature and magnitude, even with mitigations in place and others being recommended, would disrupt activities of local residents and irrevocably change the nature of the Study area. Project affected people and residents of the Study area may experience:

- Loss of agriculture as an economic mainstay and cultural lifestyle;
- Displacement and resettlement of homes;
- Disruption of access to several communities;
- Influx of new residents, many of whom may have different cultural expectations and values;
- Potential for spread of infectious diseases, including HIV/AIDS;
- Potential for increase in food and housing cost;
- Improvements to infrastructure;
- Improved housing developments in resettlement communities;
- New employment opportunities;
- Increased annual income and reduction of poverty;
- Change to a predominately cash economy from subsistence livelihoods; and
- Training and educational opportunities.

Loss of Crops, Structures, and Relocation of Families

In accordance with the Resettlement Action Plan (pA 2005), the Resettlement Team adopted a "just in time" approach to resettlement and compensation in order to accommodate the Project development schedule. Negotiation, agreement, and implementation of resettlement and compensation have preceded impacts, but negotiations and public disclosure of the RAP have not been completed because:

- The scope of physical and economic displacement that became apparent in 2004 is larger than envisaged by the Environmental Impact Assessments of September and December 2000, and the definitive Feasibility Study of December 2003;
- The Newmont Board of Directors made its investment decision in December 2003 and identified July 2006 as the date of the first gold pour;

- Project construction schedule follows from the July 2006 target; and
- Project construction schedule drives Project resettlement schedule.

Working with NGGL and Project affected people/households, the Resettlement Negotiation Committee has overseen implementation of resettlement to ensure that the agreed policies, procedures ,and rates are applied fairly. As major points of agreement are reached, the Resettlement Negotiation Committee authorized NGGL to proceed with implementation of agreed upon compensation and resettlement activities. Implementation has always preceded impacts.

Project affected persons were aware of agreements reached and implementation go-aheads. Project affected people have been able to make their views known on the proposals and agreements reached at the negotiations, directly to the Company and to the Resettlement Negotiation Committee through their duly elected representatives.

Therefore, while the Company initiated compensation and resettlement activities prior to the completion of negotiations and public disclosure of the Resettlement Action Plan, Project affected people have been:

- Aware of the negotiations process and the items discussed at the RNC meetings;
- Aware of agreed upon methods to express concerns or grievances and the manner in which the Company would respond;
- Expressing their views on the agreements reached during negotiations both to the Company and the RNC through duly elected representatives;
- Aware when a go-ahead for implementation was given by the RNC; and
- An independent consultant will assess the RAP for compliance with World Bank OD 4.30.

For this Project, the Company initiated formal negotiations with a Resettlement Negotiation Committee on 10 February 2004, and began compensation activities in March 2004, as follows:

- Initiation of relocation compensation on 20 March 2004;
- Initiation of crop compensation[2] on 21 March 2004; and
- Initiation of temporary resettlement through payment of a rental allowance on 14 June 2004.

Objectives of the NGGL resettlement program are to:

- Avoid or minimize the number of people resettled and mitigate adverse impacts associated with resettlement;

[2] This date refers to crop compensation related to Project construction; crop compensation related to the exploration program began in the early 1990s.

- Improve livelihoods and standards of living for those adversely affected by land acquisition and resettlement activities; and

- Involve displaced people in the decision making process of resettlement and help them benefit from the Project.

Objective 1: Minimizing the Number of People Affected by Involuntary Resettlement

NGGL has reduced the impacts of physical and economic displacement associated with the Project through the following:

- Minimizing the size of mine infrastructure elements and shortening distances between them, in order to reduce size of the Project area as much as possible;

- Minimizing buffers around mine infrastructure in order to reduce size of the Project area as much as possible without compromising the health and safety of nearby residents; and

- Restricting construction of mine-related infrastructure to rural, sparsely settled areas, distant from towns and major public facilities or infrastructure (pA 2005).

Construction of the Ahafo South Project will result in the physical and economic displacement of 823 households (5,185 Projected affected people) living in the Project area, and the economic displacement of an additional 878 households (4,390 Project affected people) that possess farmland within the Project area. A total of 1,701 households (9,575 people) will be affected by the Project. As of March 2005, of the households physically displaced, 455 households are planning to resettle in the resettlement villages and 255 households plan to be relocated (pA 2005).

The Resettlement Negotiation Committee has defined entitlements for the loss of both residential structures and non-residential structures. A complete description of the resettlement and the relocation packages is contained in the RAP (pA 2005).

Types of impacts considered eligible for compensation include loss of crops, land, structures, access, and business. By August 2005, NGGL had compensated Project affected residents of the Project area a total of $920,694 (US) (¢8.3 billion) for loss of their homes, and $12,878,990 (US) (¢115.9 billion) to those farming in the Project area. In addition to cash compensations, NGGL provided a training allowance for each person or household receiving cash compensation, whether for structures or crops, to attend a money management seminar designed and presented by OICI.

The RAP, written in compliance with World Bank Operational Directive 4.30 - Involuntary Resettlement, has been used as the basis of all mitigations for loss of crops, structures, and access. Highlights of the RAP are discussed below.

Loss of Farm Fields

NGGL estimates there are 6,907 farm fields in the Project area comprising 2,348 ha. Farm fields average 0.34 ha (pA 2005).

Under Ghanaian custom, NGGL cannot purchase or compensate for land, but can only purchase or compensate for assets affixed to land, namely crops and structures. For resettling Project affected

persons/households, NGGL has provided a replacement plot within a Resettlement Village for their residential use. NGGL, via OICI management, is collecting data relateive to those individuals whom desire access to new farm fields but are struggling to acquire the land. NGGL and OICI are coordinating with local traditional leaders to identify available land and establishing contact with affected persons to acquire replacement land of equal area, productivity, and state of preparation for farming, which is based on facilitating traditional ways of allocating land (pA 2005).

Loss of Crops and Income from Farming

The 2004 crop compensation rates were negotiated by the Resettlement Negotiation Committee in February and March 2004. The rates were used to calculate compensation for crop losses, and represented an increase over 2003 rates, particularly for cocoa, the area's principal cash crop. The compensation rates are higher than the standard rates used by the Ghanaian Land Valuation Board.

NGGL has commissioned OICI to provide Financial Management Training Programs for those Project affected farmers that received crop compensation. The program imparts basic money management and business planning skills, and is designed to help non-resident farmers and displaced households apply compensation payments appropriately in support of sustainable livelihood restoration. Up to 40 people are trained over a period of 4 to 6 weeks depending on the progress of the group through each training module. As of August 2005, over 1,200 persons had participated in the program (pA 2005). Response to training was not encouraging initially, until the first group completed the program and had positive feelings about what they had learned.

Loss of Structures

Public facilities located in the Project area which will be demolished include:

- Four schools -- L/A Primary School at Kwakyekrom; and L/A Kindergarten, Primary School and Junior Secondary School at Kodiwohia.

- Four CMB sheds.

Loss of Access

With respect to loss of access, NGGL will realign and upgrade the Kenyase 2 – Ntotoroso local distributor road to ensure safe passage of public and Project traffic in the area. NGGL will also construct new access roads to replace roads that need to be moved out of the Project area from the Kenyase 2 – Ntotoroso local distributor road to the communities of Manu Shed and Dokyekrom.

Loss of Business

The following businesses have been identified in the Project area which will be relocated: six corn mills and two kiosks (separate from residential structures). NGGL has consulted extensively with owners of these businesses, who do not anticipate any loss of income due to the Project and have only requested that NGGL assist them in moving/relocating their structures. NGGL is currently assisting impacted businesses in relocating their structures to the resettlement village.

Resettlement Villages

Kenyase 2 and Ntotorso are "host" communities to resettled residents. NGGL expects to build new houses in these villages. Existing residents of these two communities will be impacted by hosting the resettled households, but both Kenyase 2 and Ntotorso requested to be hosts because of the potential economic benefits.

Objective 2: Improving Livelihoods

Project affected households are engaged in subsistence and cash crop farming with low incomes due in part to small holdings, limited non-farm income generating opportunities, and poor transport infrastructure. Subsequently, NGGL requested OICI to develop programs to mitigate the loss of future income from farming and improve the livelihood of those affected by resettlement. OICI designed a Project-specific Livelihood Enhancement and Community Empowerment Program (LEEP) for the Ahafo South area, based on the census and socioeconomic survey performed in 2004 (OICI 2004). The LEEP was approved by NGGL and representatives of the community. Community consultative workshops were held in December 2004 and January 2005, to review the LEEP and obtain final comment from community representatives.

LEEP Phase 1 is a comprehensive 18-month program, which is the initial phase of a high impact, results oriented, sustainable integrated community development plan that is anticipated to be up to 5 years in duration. The program was designed to initially focus on economic growth, wealth creation, quality of life, and empowerment to give value to people that have been relocated/resettled from the Project area. Phase 1 of the LEEP was implemented in February 2005. Key aspects of the LEEP are presented below:

- Increase economic opportunities for target groups through small and medium enterprise (SMEs) development, increased agriculture production, agri-business development, and vocational and technical skills training for employment by:
  - Improving sustainable food and cash crop production for 750 households;
  - Reducing post-harvest handling and storage losses by 5 percent for 750 households;
  - Creating and strengthening small and medium size enterprises (SMEs) to generate income for 1,500 people;
  - Enhancing technical and vocational skills for 600 youth for direct employment and their capacity to achieve self-employment; and
  - Increasing access to micro-credit for 800 residents for business creation, expansion, and performance.
- Improve the quality of life of target groups through interventions to improve health, nutrition and education.
- Enhance community resiliency and participation by increasing the social/organizational and motivational capacities of resettled and relocated youth.

Phase 2 of the LEEP will be initiated when mine operations begin in July 2006. All Study area residents will have an opportunity to participate in the Phase 2 programs. LEEP recommendations and program components for the Study area are presented in *Creating Sustainable Developments* in this section.

Objective 3: Involving the Affected Public in Decision-Making

Public involvement in the resettlement decision-making process is fully documented in the RAP (pA2005) and summarized in Public Consultation and Disclosure Plan (PCDP). Highlights of the PCDP are discussed below.

Continuing Management

The goal of the PCDP is to improve and facilitate decision-making and build an atmosphere of understanding that will actively involve individuals, groups and organizations that can affect or be affected, in some way, by development of the Ahafo South Project.

Emphasis of the PCDP is to document implementation of a formal program in an objective and simple manner and focusing efforts on the improvement of communications between NGGL and other interested parties. Monitoring and evaluation of program results and behavior of the parties will enable program evolution and improvements over time.

Primary objectives of the program include.

- Keep stakeholders informed of NGGL activities;
- Generate and document broad community support for the Project;
- Improve communications between interested parties;
- Document development of formal public consultation; and
- Establish formal grievance submittal/ resolution mechanisms.

Improvements to Local Infrastructure

Project construction and operation is expected to result in major improvements to existing District and local infrastructure including: transportation, water supply and sanitation systems, solid waste management systems, electrical systems, and telecommunication network.

Public roads in the Project area will be relocated around the proposed plant site and will remain open to the public. Displacement of footpaths and other access roads may disrupt household access to productive assets and/or usage rights and/or livelihood capacities located outside the Project area. In the case of Manushed and Dokyekrom, displacement of the access road may also affect household access to public facilities, including schools, health clinics, and markets.

NGGL will make the following transportation improvements:

- Upgrade Ntotoroso-Kenyase road (SGS 2000b);

- Upgrade Akyerensua-Ntotoroso road (SGS 2000a);

- Construct a 1 km bypass road around Kenyase 1 and Kenyase 2 to allow mine service traffic to avoid these towns, thereby reducing traffic congestion and danger to pedestrians (SGS 2000b); and

- Maintain access to Manushed and Doyekrom from the Ntotoroso – Kenyase 2 road.

In addition, increased demand for airline service to and from Accra would likely enable the airport at Sunyani to obtain a commercial carrier and begin service from Kumasi and Accra.

Supply chain routes that will be used to bring supplies and equipment from Ghanaian ports to the Project has not been determined at this time. Two routes, one beginning at the port in Tema and the other in Takoradi, have been investigated from an engineering standpoint (Logistics Direct 2003). NGGL is developing protocols to address issues regarding potential relocation of structures on the highway rights-of-way to accommodate oversized vehicles and chemical spills, especially cyanide and other hazardous chemicals being transported to the Project site (see *Risks Related to Transporting and Using Chemicals including Sodium Cyanide*).

To date, these protocols include use of pilot cars to accompany every shipment of chemicals to the Project site, as well as conducting safety audits of all transportation routes (Morrow 2005).

Existing drinking and domestic water supplies of some settlements in the Project area or downstream of the various facilities may be affected by construction and subsequent operations. NGGL would provide alternative supplement potable water supplies to residents downstream of Project facilities that are impacted by the Project. NGGL will regularly monitor water quality from all water sources provided by NGGL (SGS 2000b). Some communities may find the current water supply is no longer adequate to supply increased in demand resulting from the influx of new residents. The larger settlements of Kenyase 1, Kenyase 2, Ntotoroso, Wamahinso, and Gyedu have sufficient water supply and are not expected to be impacted by the Project (SGS 2000b).

Electrification and the telecommunications network within the Study area will be improved because of the increased demand created by the Project. Electricity for the Ahafo South Project will be provided by the Volta River Authority (VRA) from 161kV substations at Kumasi and Sunyani via an overhead power line connected ring circuit.

Completion of the ring circuit has been a VRA plan since 1999. Development of the Ahafo South Project would provide VRA with a sufficient customer base to enable financing for completion of the previously planned project. Completion of the ring circuit will improve power availability to a large portion of northwestern Ghana. Refer to Cumulative Impacts in this section for more information about the potential impacts of the powerline.

VRA has completed a line route survey, Environmental Impact Assessment (VRA 2004), right-of-way compensation, and land acquisition associated with the proposed 161 kV powerline routes. Consultants sponsored by NGGL will support VRA's efforts by providing engineering, procurement, logistical support, and help VRA arrange financing. Estimated length of the Kumasi to Sunyani powerline will be 100 km, and Sunyani to Ahafo about 40 km. The estimated installed electrical load is 47 MW with a predicted peak continuous load of 35.98 MW. Refer to Chapter 2 for additional information about the VRA powerline.

IFC has completed discussions with VRA staff and the Ghanaian Forestry Commission regarding the power line route and potential impacts on Natural Habitats and Resettlement. These discussions have addressed many of IFC's concerns regarding impacts of the power line. In addition, the EIS completed for the Ghanaian EPA regarding the power line (VRA 2004) quotes various WBG policies and guidelines that have been committed to be VRA to reduce or eliminate impacts associated with the Project (IFC BTO August 2005).

Population Growth

Ghanaian citizens are free to move within the country if they believe there are employment opportunities in a specific area. There is no means to prevent or control the number of people that could move to the Study area. In-migration is occurring even though there are a limited number of jobs available. NGGL provides a free bus service for eligible Project workers that allows residents outside of the Kenyase-Ntotoroso area to travel and work at the Ahafo South Project without having to move closer to the Project site.

The expected influx of people into the area looking for work with NGGL or with expanding local businesses and services is an impact related to development of the Project, which would result in social and economic pressures on the existing population. Upwards of 850 construction and operations workers, not currently located in the Study area, are expected to seek employment at the mine.

Twenty percent of new employees constructing the mine are expected to be expatriates; 6 percent of the permanent NGGL operations personnel will be expatriates, as well as an unknown number of contractor employees. There would likely be cross-cultural tension as expatriates move into the racially homogeneous Study area, bringing with them differing sets of cultural expectations and mores. Local residents may find themselves dealing with social problems such as prostitution, teen pregnancy, drugs, drunkenness, and increased crime. Prostitution is recognized as an unavoidable consequence of a large influx of wealth, which, aside from the health implications tends to create conflict between spouses, sometimes with breakdowns in marriage and disruption of families and children. Outsiders that fail to find employment may resort to criminal activities. The incidence of HIV/AIDS could increase as a result of the above concerns. At present, the HIV/AIDS infection rate in Ghana is approximately 3 percent, which is one of the lowest rates in Africa.

NGGL is aware that housing the work force can lead to major social problems and increased potential for inflation of housing costs in local communities. Expatriate and senior Ghanaian staff will be provided housing and meals on-site or a housing allowance to obtain accommodation in the Project area. At least 90 percent of the junior staff are from the Study area and are expected to live at home; the remainder will be provided with a housing allowance to obtain rented accommodation in Kenyase or Ntotoroso and will have access to the Project cafeteria. Accommodation facilities for the Project will be in three categories: (1) construction camps; (2) security camp; and (3) operations village.

The first contractors on site are camp construction and earthmoving contractors. These contractors rent houses in local villages for their workforce that is within one hour's travel of the site. NGGL provides free bus transportation to eligible Project workers to the site. The construction management team will be housed in the upgraded Rank camp until the construction camp becomes available.

Construction Camps

The Construction Senior Staff Camp will be located adjacent to the plant area and will house construction and operations expatriates and senior Ghanaian supervisors. The total number of employees is estimated at 300. Approximately 230 personnel will live in the camp, and the balance will reside in the Senior Staff village. Typical construction camp 'A' accommodation will be 4-room unit with shared suites. Other facilities include a dining hall and fully equipped medical clinic, which will be constructed as part of the Construction Senior Staff Camp and retained throughout operations. An allowance has been made to provide first aid supplies in the plant and workshops and an ambulance at the mine site.

The Construction Junior Staff Camp will be located adjacent to the plant area and will house all non-local Ghanaian construction personnel. The number of employees of this type will range between 320 and 600 and construction of this accommodation will be staged to meet the progressive buildup of employees. Accommodation will be in barrack style units with shared facilities.

Security Camp

The security camp will be located on the operations village access road, approximately 1 km from the village and will house 160 personnel.

Operations Village

The operations village will be located approximately 5.5 km southwest of the processing plant. Accommodations will consist of 35 three-bedroom houses supported by various recreational and other facilities (SGS 2004).

Challenges to Social System

Social systems and structures have evolved in the Study area over generations and have responded dynamically to the changing social environment. Development of this Project will involve significant social change, particularly as Project affected residents are relocated/resettled, and residents of the Study area experience a change from living in an agricultural area to living in an industrial area.

The influence of the Ahafo South Project on the various intra and inter-settlement social systems and structures is likely to be experienced in a number of ways. Kinship relationships as well as economic and social sharing of resources are common, providing support (emotional and practical) between residents of the Study area. It is imperative that people (vulnerable population groups in particular) are not left worse off as a result of the Project.

The progressive transfer of management responsibilities from expatriates to Ghanaian nationals is a key corporate objective, and the number of expatriates is expected to decrease significantly by year five as national staff replaces expatriate supervisors and managers.

Changes in personal well-being are often difficult to identify because they cannot easily be measured. People's uncertainty regarding the future; unfulfilled expectations for individual and family lifestyle improvements; and alteration and/or breakdown of social bonds and support mechanisms could impact the well-being of Project affected individuals, households, and communities. The extent of the impact may vary from person to person depending on the support structures that they have access to. In addition, impacts of resettlement could compound emotional stress and contribute to reduced well-

being among affected individuals and their families. Decreased emotional well-being could also lead to alcohol abuse and increased incidences of family violence – something that is currently reported to be negligible among residents of the Study area.
Feelings of loss of well being have been reduced by open and transparent interactions between NGGL and affected individuals and settlements. NGGL holds periodic informational meetings with official and traditional authorities (see *Public Disclosure and Consultation Plan* for a complete listing of meetings held). The main objective is to discuss social impacts and determine how NGGL can assist in mitigating those impacts. Major discussion topics include:

- Potential levels of employment as a measure to control the influx of in-migrates in search of employment;
- Need for additional facilities and services to accommodate increased population;
- Incidence of social problems that may require additional security and/or police presence; and
- Success of training and educational programs on infectious diseases, including HIV/AIDS.

Challenges to Traditional Authority

Paramount and Divisional Chiefs (or Autonomous Chiefs) are located within the Study area in Ntotoroso, Gyedu and Wamahinso. Paramount and Divisional chiefs exert control over various sub-chiefs, that represent major communities within their respective stools (chiefdoms), and village chiefs, that represent smaller communities. At the village level, sub-chiefs or village chiefs, in consultation with elders, typically resolve disputes. Chiefs also play an important role in allocating land within their stool. New residents without ties to traditional leaders may ignore or challenge this authority.

NGGL has included traditional authorities in planning throughout the development of the Project and will continue to value the skills and input of these chiefs and elders in the decision-making process. Traditional authorities have been key participants in building broad community support for the Project. Ten percent of the junior level jobs have been allocated to the discretion of the traditional authorities, called Protocol appointments.

Vulnerable Populations

Vulnerable households are notable for their inability to cope with socio-economic stress due to age, infirmity, physical and mental incapacity, or, if children, with inadequate family support. The Ghana Living Standards Survey includes among the vulnerable:

- Children in difficult circumstances;

- Disadvantaged women, particularly single mothers, malnourished rural pregnant and nursing mothers, teenage mothers, and commercial sex workers;

- Rural agricultural producers, particularly migrant farm hands, settlers and food crop farmers. Notably, food crop farmers comprise nearly two-thirds of those in extreme poverty, almost double the group's share of the total population;

- The elderly with no access to family care and pension;

- Physically challenged persons, particularly those without employable skills or suffering from chronic disease; and

- Unemployed, especially unskilled retrenched workers and unemployed youth.

Vulnerable households are particularly affected by involuntary displacement, with increased rates of sickness and death. The following types of vulnerable people have been identified in the Project area:

- Single, elderly poor, especially those without extended family support;
- Poor female heads-of-household without extended family support;
- Poor persons with disabilities without extended family support; and
- Caretaker/sharecroppers with no buildings or fields of their own or are losing the land they work (pA 2005).

NGGL has addressed vulnerable households on a case-by-case basis, negotiating with the Resettlement Negotiation Committee, traditional authorities, and responsible landlords to provide the necessary support. To date, NGGL has rendered the following types of support:

- Additional assistance with the logistics of resettlement and reconciliation to a new community and home;
- Rental allowances;
- Resettlement near family, friends and neighbors to help maintain informal social/support networks;
- Transportation allowances; and
- Special support as needed.

NGGL monitors rehabilitation of vulnerable homesteads and provides remedial assistance, designed in consultation with the Resettlement Negotiation Committee, to enhance self-sufficiency, and maintain a community support network. The Livelihood Enhancement and Community Empowerment Program targeted those identified and registered as vulnerable, and those not previously identified as such but observed to be coping inadequately with the resettlement process.

Royalties and Taxes

Gold production at the site is predicted to be in excess of 6.8 million ounces during the 15 year life-of-mine (Lycopodium 2003). At the national level, the Project will have a direct positive impact through payment of royalties and taxes related to gold production and NGGL profits. Indirect positive impact through income taxes on increased employment, personal income, profits of local businesses and major suppliers, and purchase of goods and services manufactured and supplied in Ghana.

The Investment Agreement between NGGL and the government of Ghana defines and fixes, in specific terms the effective tax and royalty burden the project will carry during construction and operation. In Ghana, mining companies pay royalty to the central government for the extraction of minerals from territorial land. The royalty constitutes 3.0 percent of NGGL's gross sales paid quarterly to the Internal Revenue Service as stipulated in the Investment Agreement.

Assuming the price of gold remains near $380 (US) per ounce and production meets expectations, the Ahafo South Project could generate over $77.5 million or ¢697.6 billion in the form of royalties to the government of Ghana over the anticipated life-of-mine (Lycopodium 2003). Approximately $11.40 (US) (¢102,600) in royalties would be paid for each ounce. Estimated annual royalty payments over the life-of-mine are shown in **Table 4-5**.

While the central government's consolidated fund captures a majority of the revenue, 10 percent of royalty payments are earmarked for the Asutifi District and local authorities in the Study area (Emmanuel Ato Aubynn 2003). An example of this distribution is presented in **Table 4-6** for year 2010. Royalty payments to the Ghanaian government for this period are estimated to be US $6,950,000 (¢62,550,000,000).

TABLE 4-5
Estimated Royalty Schedule of Payments
Ahafoe South Project

Year of Mine Operation	Estimated Royalty Amount	
	Ghanaian Cedis	2003 US
2006	¢19,422,000,000	$2,158,000
2007	¢59,796,000,000	$6,644,000
2008	¢50,112,000,000	$5,568,000
2009	¢51,075,000,000	$5,675,000
2010	¢62,550,000,000	$6,950,000
2011	¢47,907,000,000	$5,323,000
2012	¢52,686,000,000	$5,854,000
2013	¢66,024,000,000	$7,336,000
2014	¢46,638,000,000	$5,182,000
2015	¢64,359,000,000	$7,151,000
2016	¢57,438,000,000	$6,382,000
2017	¢40,905,000,000	$4,545,000
2018	¢45,783,000,000	$5,087,000
2019	¢27,882,000,000	$3,098,000
2020	¢5,922,000,000	$658,000
Total Estimated Royalties	**¢689,499,000,000**	**$77,611,000**

Source: Ahafo Project Feasibility Study - Lycopodium - Dec 2003, Table 15.1.2

TABLE 4-6
Sample of Potential Royalty Distribution Payments Year 2010

	Cedes	US Dollar
Estimated Royalty Amount - Year 2010	¢62,550,000,000	$6,950,000
Effective Distribution Schedule To Central Government's Consolidated Fund		
80 Percent	¢50,040,000,000	$5,560,000
To Ghana Minerals Commission, Geological Department, Survey Department, Mines Department, and mining-related educational institutions in the country		
10 Percent	¢6,255,000,000	$695,000
To Asutifi District Administration		
6 Percent	¢3,753,000,000	$417,000
To Traditional Council		
2 Percent	¢1,251,000,000	$139,000
To all the local chiefs of communities whose lands fall within the concession, and/or who are within the Ahafo Study area		
2 Percent	¢1,251,000,000	$139,000

Note: Based on 2003 US Dollars.

The Investment Agreement provides a 32.5 percent corporate tax rate for companies not listed on the Ghana Stock Exchange, (Lycopodium 2003). Under Section 8 (1) of the Minerals and Mining Law, 1986 the Ghanaian Government "shall acquire a 10 percent interest in a minerals operation for which no financial contribution shall be paid by government". In practice, this provides the Ghanaian government with a 10 percent share of any dividends paid by the Project. In addition, Section 8 (2) provides the Government with the option to acquire a further 20 percent interest at market value. NGGL is not aware of any instances in which the Government has invoked this clause.

The Ghanaian Additional Profits Tax Law of 1985 provides for payment of additional tax at a rate of 25 percent of the "carry-forward cash balance at year end." This figure is derived after deduction and addition of a number of items to taxable income. However, the gross up of carry forward losses by a rate of return factor, which is set at 35 percent means that it is unlikely that this tax would ever be payable (Lycopodium 2003).

The highest personal income-tax rate in Ghana is 30 percent for annual income over $5,400 (US) (¢48,000,000). A 20 percent rate applies to annual income from $2,700 (¢24,300,000) to $5,400 (US) and a 15 percent rate for annual income from $270 (US) (¢2,430,000) to $2,700 (Ghana Home Page 2005).

Increased Employment Opportunities

Employment by NGGL or one of its contractors has been estimated and is distributed by departments as shown in **Table 4-7.** Additional personnel performing contract functions such as security, laboratory, light vehicle maintenance, catering and worker transport will vary between 300 and 400 over the life of the Project.

TABLE 4-7
Operations Staffing Level at Startup

Category	Employees				Short-Term Contractors			Contractors				
	Expatriate	Sr Staff	Jr Staff	Sub total	Professional / Clerical	Jr Grade	Sub total	Expatriate	Sr Staff	Jr Staff	Sub total	Total
General Management	3	0	0	**3**	0	0	**0**	0	0	0	**0**	**3**
Finance and Admin	2	23	12	**37**	0	3	**3**	0	0	0	**0**	**40**
Human Resources	6	36	15	**57**	11	6	**17**	1	7	9	**17**	**91**
Land and Comm Rel	0.5	5	3	**8.5**	0	0	**0**	6	3	0	**9**	**17.5**
Government Rel / Legal	0	1	0	**1**	0	0	**0**	0	0	0	**0**	**1**
External Relations	0	2	0	**2**	0	0	**0**	0	0	0	**0**	**2**
Geology	2	12	20	**34**	2	97	**99**	6	21	67	**94**	**227**
Security	1	7	4	**12**	0	0	**0**	1	7	109	**117**	**129**
Environment	0.5	16	19	**35.5**	0	20	**20**	1	0	0	**1**	**56.5**
Mining	9	67	192	**268**	0	0	**0**	6	16	66	**88**	**356**
Processing	14	9	80	**103**	0	0	**0**	1	4	24	**29**	**132**
Total	**38**	**178**	**345**	**561**	**13**	**126**	**139**	**22**	**58**	**275**	**355**	**1,055**

Note: Includes Accra and Ahfao South Project based staff.
Source: Lycopodium 2003.

NGGL employment practices adhere to all relevant safeguards and IFC guidance on "Forced Labor and Harmful Child Labor" as well as the Occupational Health and Safety Guidelines (see Chapter 2 and **Appendix A**). NGGL has a well-established Human Resources Department with policies designed to assure sound management of working conditions and to promote fair treatment of workers, employees and contractors.

NGGL has introduced a proactive local recruitment policy with a complementary skills training program to ensure maximum local capture of economic benefits of the Project. This program applies equally to NGGL's contractors.

People that are relocated/resettled, residents of Kenyase I, Kenyase 2, Ntotoroso, Gyedu and Wamahinso are entitled to 80 percent of unskilled positions at NGGL and with its contractors. Residents of the neighboring communities of Yamfo, Terchire, Adrobaa, Susuanso, Hwidiem, Nkaseim, Tanoso, Afrisipa, and Obengkrom are, based on population, also entitled to a relative share of the 10 percent of unskilled positions. The remaining 10 percent of the unskilled jobs will be filled by appointees of government officials, chiefs, and chief farmers (pA 2005).

While specific targets have not been set for skilled recruitment, policies are in place to support and encourage local capture of these positions. All NGGL and contractor positions are advertised first on public notice boards and through the traditional *gong gong* community announcement system in Project area communities identified above. If recruiters are unable to fill positions from this pool, they advertise to a wider community.
Social risks during the Project's life include living up to rising expectations on the part of potential job seekers and other stakeholders in Ghana. The goodwill and broad community support generated by NGGL through public involvement and communications techniques may fade when the bulk of hiring and procurements is completed for the operations phase because not all Study area residents will get jobs nor will all potential vendors get supply contracts.

NGGL has experienced incidents with youth groups from the Kenyasi (October 2003) and Nototoroso (April 2004) areas that were upset because they believed that "outsiders" were getting jobs before local residents. In fact, no one was being hired, and the NGGL Community Relations and Communications teams were able to effectively communicate the realties of the hiring situation to resolve those incidents.

Given that the Study area is rural, few existing residents have appropriate industrial job skills. NGGL is training locally sourced employees but anticipates hiring a number of workers with required skills from other areas in Ghana. NGGL will develop the local community and promote local employment through its education and career-based training programs.

Training and development programs consist of the following key features:

- Maximizing local area employment opportunities. The definition of "local" will be determined during consultation with local chiefs;

- Selection process requires trainees be local residents between 18 and 26 years old with a minimum nine years schooling. Testing will assess cognitive ability, mechanical aptitude, mathematical ability, and language comprehension;

- A centralized competency based training system that provides training needs assessment, training and development programs targeted at job requirements and formal certification and accreditation; and

- Appropriate workshop and classroom facilities with necessary equipment and training aids. The facility is also used for training in all areas, including safety and loss prevention, supervisory and management skills, and general training such as computer software, clerical, and warehousing.

NGGL anticipates this approach will have cost and efficiency implications, particularly at start-up, but is considered essential to obtaining and maintaining compliance with the Newmont Social Responsibility Policy. In the long-term, maximizing use of local labor resources will reduce administration costs and allowances for relocation, accommodation, and transport. Benefits from training programs include:

- Providing long-term stable employment;

- Maximizing local resources;

- Increasing skills in the local area;

- Reducing in-migration and disruption to existing social structure; and

- Minimizing pressure on local housing market to provide in-migrant housing.

Indirect Employment

In addition to the direct employment opportunities with NGGL and its contractors, many new jobs will be created to service the mine, as well as satisfy the needs of local mine employees and their families. Local unemployment is currently estimated at 17 percent. The normal job creation multiplier for local

service industries in the mining sector ranges from three to six indirect jobs for each direct employee (SGS 2000b). Other sources state this multiplier effect could be as high as 10 indirect jobs resulting from each direct job (Chamber of Mines of South Africa 2005).

The construction phase of the Project is expected to create a total of 1,500 new jobs. Given the range of three to six indirect jobs created for every new job, an implied range of 4,500 to 9,000 additional jobs would also be created.

The operations phase of the Project is expected to require a mix of staff including approximately 660 employees, 140 short-term contractor staff, and 350 contactor staff for a total of 1,150 jobs. Indirect employment may range from 3,000 to 6,000 new jobs.

Procurement of Goods and Services

With the exception of electrical power from the VRA, it is not possible to accurately predict the amount of goods and services that will be purchased for the Project. Average expenditures for electrical power required for ore processing range from approximately $18.6 – $21.3 million (US) per year. Payments would be received by VRA and are sensitive to the final conditions of the Power Purchase Agreement Contract negotiated between NGGL and VRA.

Currently there is limited local and national capacity to meet NGGL's needs. NGGL policy to procure locally can improve the income levels, increase entrepreneurial capacity, and broaden potential markets, all of which enables the local economy to reduce long-term dependence on the mine. If NGGL has to import most supplies from outside the area, it could increase conflict about benefits leaving the area. Other procurement opportunities will depend on the goods and services available in the Study area, the district, and in Ghana itself.

Creating Sustainable Developments

Economic expansion will occur in the Study area and at a relatively rapid pace considering the rate of change or rate of growth. Mining is a finite activity, depending on the extent of the reserve. The danger of extraordinary burst of economic growth that results from a Project of this nature into a predominantly subsistence agricultural economy, is that it may not be sustainable in the future, resulting in a boom and bust effect which may leave residents worse off than before the Project was developed. NGGL is committed to adhering to a philosophy of sustainable mining: Projects which meet the needs of this generation while ensuring the ability of future generations to meet their needs (White 2003).

For example, NGGL has committed to development/improvement of a LEEP training facility in the community of Gyedu, which will be managed by ICCES. The facility will provide capacity building to Project affected people focusing on youth. OICI and the training center entered into a Memorandum of Understanding during May 2005 to assist with infrastructure improvements and provide management support. The training facility will initially focus on vocational training to 600 youths from the Project affected area.

Newmont commissioned OICI to design and implement a Project-specific Livelihood Enhancement and Community Empowerment Program (LEEP) for the Ahafo South area (OICI 2004). LEEP Phase I, as described in *Loss of Crops, Structures, and Relocation of Families*, Objective 2: Improving Livelihoods is a comprehensive 18-month program, which is the initial phase of a larger on-going development plan. Phase 2 will be implemented once mine operations begin in July 2006. This ongoing development plan is

based on a draft 5 year plan that will evolve and be modified as required based on the monitoring and evaluation of phase one currently underway. Phase 2 of the LEEP is designed to provide services to Study area residents to create sustainable lifestyles and improve farming and business practices. NGGL is committed to program implementation. Specific objectives include:

- Enhance livelihood capacities of an estimated 2,000 households in income generating activities, alternative livelihoods, and improved farm techniques with programs designed to:
  - Provide training for farmers on increasing crop yield and improving storage methods;
  - Provide training for technical and vocational skills to facilitate employment and self-employment opportunities;
  - Provide training on micro-credit for business creation, expansion and performance;
- Enhance human capabilities of an estimated 2000 households in health, nutrition, and education to improve the quality of life of the households with programs designed to:
  - Increase access to potable water and sanitation facilities for 10,000 people;
  - Rehabilitate and equip health care facilities to improve health and nutrition practices;
  - Provide additional sources of potable water and sanitation facilities;
  - Construct or rehabilitate schools to increase access to quality education, skills training, and recreation;
- Enhance community resiliency and participation of resettled and relocated populations with programs designed to:
  - Provide training and counseling on financial management, entrepreneurial skills, and business development to encourage creation of SMEs for income generation;
  - Provide training in problem solving to increase social/organizational and motivational capacity; and
  - Provide training for local governments to respond to mining operations and community development issues.

Decreasing Poverty

The operational phase of the Project is expected to commence in 2006 with an anticipated mine life of 15 years. Estimated expenditures on wages during the operation phase are shown in **Table 4-8**.

TABLE 4-8
Total Ghanaian Labor Expenditures - Estimated Wage Distribution
Ahafo Project Operations Phase

Ghanaian Labor Category	Monthly Rate (¢)	Direct Workers Total Average per Month	Annual Total (¢)	Annual Total (US $)*
Annual Estimated Labor Expenditures				
Employees				
Senior	8,350,000	179	17,935,800,000	1,992,867
Junior	2,030,000	345	8,404,200,000	933,800
Subtotal		**524**	**¢26,340,000,000**	**$2,926,667**
Short Term Contractors				
Professional / Clerical	8,350,000	13	1,302,600,000	144,733
Junior Grade	2,030,000	126	3,069,360,000	341,040
Subtotal		**139**	**¢4,371,960,000**	**$485,773**
Contractors				
Senior Staff	8,350,000	58	5,811,600,000	645,733
Junior Staff	2,030,000	275	6,699,000,000	744,333
Subtotal		**333**	**12,510,600,000**	**1,390,067**
Estimated Totals			**¢43,222,560,000**	**$4,802,507**

Note: Assumes 10 hours per day and 25 working days per month. *Assumes exchange rate of ¢9000=$1.00 (US).
Source: Derived from employment data provided by NGGL.

The upper limit of poverty in Ghana is an annual per capita income of $100 (US) (¢900,000); $77 (US) (¢693,000) per adult per year is classified as extreme poverty. Income from non-farm sources is low: 53 percent of respondents to the OICI survey (2004b) that provided information on income from non-farm sources earned below $55 (US) (¢495,000) in the last year, while 40 percent received between $55 (US) and $550 (US) (¢4,950,000) in the last year. Average annual income for unskilled workers at the Project is estimated to be ¢24,360,000 ($2,700 (US) per year. Senior Ghanaian staff will earn up to ¢100,200,000 ($11,133 (US) per year.

An estimated additional 5.4 people will be supported by each local worker from the Study area, given the existing population per household of 6.4 (dependency factor). This will be new money invested in the community to use on household and personal needs, thus spreading the reach of the salaries to increases in indirect employment.

From the information provided in the OICI 2004b survey, the following major components are required to reduce poverty in the Study area:

- Small scale processing and storage;
- Income generating activities;
- Increased agricultural production and associated infrastructure; and
- Access to credit.

Potential for Inflation

With increased economic opportunities also come economic risks at the local level. Inflated housing and food prices may be a negative impact of Project development. Of particular concern is the impact that high housing rental prices are currently having on teachers and health workers that have been deployed to the area or enticed by the hope of jobs. High living costs threaten to undermine the ability and desirability of staff to work in the area – and as a spin-off, threatens access of local residents to health care and education. This is of particular concern during the current construction phase, especially before Project accommodations have been built to relieve demand on the local housing market.

Stresses on Banking and Finance

Direct and indirect employment generated by the Ahafo South Project, as well as increased economic activities that are cash based rather than subsistence based, would create pressure on local banking institutions. These institutions are struggling to cope with a limited cash economy. The relatively small number of NGGL employees currently receiving salaries through the banks and people claiming cash compensation have already stressed local banks. Reports of insufficient cash to pay out and poor bureaucratic/administrative systems are common and highlight the inability of local institutions to cope with what will be significant additional pressures. As the economy in the Study area shifts and spin-offs from the Project result in new entrepreneurial enterprises, the need for small-scale loans (micro-financing) will increase.

Risks to Local Residents' Health and Safety

Development and upgrading of roads to service the Project as well as heavy vehicle traffic will likely increase risks to local residents' health and safety. NGGL will mitigate these hazards with strict codes of conduct for mine personnel operating heavy equipment and light vehicles to minimize traffic hazards. Information will be distributed to local residents highlighting health and safety risks in the Study area.

Several types of waste will be generated during construction and operation of the Project including: household waste (sanitary wastewater, domestic trash); non-toxic industrial waste (tires, discarded metal parts and fittings, plastic packaging and containers); waste oil and filters; refinery slags and cupels (recycled into the milling circuit); and solid and liquid laboratory waste (acidic and aqueous solutions, solvents, crucibles, cupels, and slag). These wastes will be properly managed in order to prevent pollution of the physical environment surrounding the infrastructure and reduce exposure to possible health and safety hazards (see *Waste Management* section in Chapter 2).

NGGL recently initiated a Comprehensive Health Survey in the Ahafo area (both the Asutifi and Tano districts) in order to document the current health status of local residents and track any health problems that might arise during construction and operation of the Project. The household survey will include baseline information on:

- Household characteristics
- Household socioeconomic status
- Household morbidity in the area (malaria and other water borne diseases. anemia)

- Prevalence of heavy metals among adults
- Household preventative medicine procedures
- Women and children' health
- Household access to health care

In addition, Comprehensive Health Survey enumerators will interview hospital and health care facilities to determine:

- Prevalence of HIV / STDs using hospital data
- Health facilitiy morbidity patterns.

The Kintampo Health Research Center, located in the Brong Ahafo Region, in conjunction with the University of Colorado Medical Center, will finalizing the survey indicators, determine the sample size and distribution, and collaborate on interpreting the findings. This baseline study will be updated periodically as the basis for analyzing health and morbidity trends and to design approporiate health and social well-being programs for residents.

Waterborne Diseases

Malaria is the most frequently occurring disease in the Study area (pA 2005). Malaria is a complex problem as it requires significant institutional capacity (and some financial input) and education to undertake preventative programs. Various studies have been completed by malaria specialists from the South African Institute of Medical Research, as well as environmental economists from the NGO Africa Fights Malaria, to ascertain the impacts of malaria on heavy industry and mining in Mozambique and Zambia. All these studies conclude that the disease has an impact on productivity in the form of downtime, treatment costs and the costs of preventing the spread of malaria (CIVA 2005).

Construction activities that result in installation of ponds or reservoirs (e.g., water storage facility and environmental control dams) often result in an increase in waterborne disease such as malaria or schistosomiasis (bilharzias). The Project construction camps will be near the planned Subri water storage facility. In order to prevent a major increase in waterborne diseases, NGGL will implement the following measures:

- Establish a fishery resource in the water storage facility and introduce species such as Tilapia, which feed on insect larva, including mosquito larvae;
- Develop an educational program related to waterborne disease and on parasite cycles of selected species such as *Schstosoma spp;*
- Prevent community or residential development adjacent to the water storage facility; and
- Monitor presence of vector-borne diseases in the reservoir (SGS 2000a).

NGGL is committed to reducing and controlling mosquito presence in and around the Study area, potentially benefiting all Project affected people. NGGL has developed a prevention program to reduce exposure of individuals to malaria. The malaria prevention program is summarized below and presented in full in **Appendix A**.

- The NGGL Director of Human Resources is responsible for development, implementation, and maintenance of the Malaria Procedure for Ghana and the guideline addendum;

- Managers of Environmental and Safety Departments are responsible for the safe use and application of anti-mosquito chemicals used in spraying and fogging activities;

- Contractors are responsible for implementation and management of mosquito control programs as outlined and directed by NGGL through purchase order or contract documents; and

- Employees must incorporate anti-malarial precautions seriously in order to protect themselves and their families from mosquito bites.

NGGL will initiate and maintain the following mosquito control activities:

- Personal protection measures (including appropriate information/education and measures to avoid mosquito bites), including:

  - Provide and/or install and maintain mosquito netting over beds in all company provided living/housing facilities. In addition, all living quarters will be stocked with aerosol cans of mosquito spray for individualized mosquito spraying when necessary;

  - Mosquito repellant for individual application will be available to employees, dependents, and visitors to company facilities and work locations;

  - Where possible, houses and villages will be constructed away from marshy areas and water;

  - Install and maintain screening in front of outside doors and windows in houses and office facilities. Living areas (verandas) can also be screened to minimize exposure to mosquitoes; and

  - Provide mosquito protection and anti-malarial prevention education and awareness sessions to the workforce.

- Measures aimed at vector control (control of mosquitoes) in the environment, including:

  - A focused mosquito control spraying and/or fogging program in and around company living, dining, recreational, and working locations;

  - Installation and maintenance of other types of mosquito control devices such as zappers, lights, and propane powered traps where appropriate;

  - Provisions to eliminate or control standing water from meteoric or household sources; and

  - Maintain good housekeeping and environmental practices to reduce and/or eliminate mosquito breeding habitats (e.g., unsanitary rubbish dumps, stacked tires)

- Chemoprophaxis (anti-malaria drugs) including:

  - Provide blood testing at clinical locations to aid in early detection;
  - Recommendations for specific drugs will be made on an individual basis after discussion with a doctor familiar with tropical medicine, medical conditions, and/or personal doctors familiar with individual medical histories; and

  - Inform workers and visitors that anti-malaria drugs do not provide complete protection against malaria and they must take additional personal protection measures.

Portions of the NGGL malaria procedure have been implemented; work and residence areas are regularly fogged and the company provides cans of aerosol spray repellant in individual rooms. Workers are complying with the requirement to minimize the amount of standing water in construction areas. Other provisions will be implemented during the construction and operation phases of the Project.

Increasing Incidence of HIV/AIDS

HIV/AIDS are seen as critical issues in Africa with disastrous long-term consequences. It is well known that the disease follows transport corridors and spreads rapidly in areas where there is an influx of migrant workers. In southern Africa, HIV/AIDS are placing considerable pressure on those caring for ill or disabled miners, typically family members. In households, the impacts are immense. Head of households are dying with little or no provision for their families – many of who are also likely to be or become infected. While this is not yet the case in Ghana, the risk should not be under-estimated.

In African countries with a high incidence of HIV/AIDS, groups most affected are between 16 and 40 years of age, the age of males most likely to seek employment at the Ahafo South Project. Infection rate among women is also increasing.

Increased rates of HIV/AIDS could have an impact on the Ahafo South Project as well. Significant time and resources would be spent developing local skills among residents to fulfill many of the jobs required by the Project. Costs would also be incurred in transporting, housing, and providing medical treatment to expatriate employees filling positions of greater skill. Increased levels of sickness and higher rates of mortality associated with HIV/AIDS would have costs in the financial and productivity arenas as well as having psychological effects on the Project workforce.

In order to mitigate potential spread of HIV/AIDS NGGL has signed a Memorandum of Cooperation with the International Labour Organization under a US Department of Labor funded program. An HIV/AIDS Steering Committee has been formed which includes NGGL's Managing Director for West Africa, as its Executive Sponsor. The committee includes the Director of Human Services as the Focal Person, junior and senior Ghanaian staff employees from all of Newmont's Ghana operations, as well as representatives from the union and major contractors. Medical input is provided by a clinical doctor and a health consultant. The Human Resources Department surveyed 50 employees for baseline medical information, attitudes and beliefs and recently distributed a Behavioral Change Communication at the Ahafo South Project.

NGGL has adopted HIV/AIDS standards based on the International Labour Organization guidelines, best practice in the corporate world, and recommendations of the Ghanaian government through its Ghana Aids Commission (GAC). These guidelines are summarized below and presented in full in **Appendix A.** The workplace and community programs addressing HIV/AIDS are in compliance with Newmont's Social Responsibilty Policy, and represent an ethical response to the threat of HIV/AIDS. NGGL is committed to fully implementing an HIV/AIDS policy with potential to educate and benefit Project affected and non-affected people in the area.

- **HIV/AIDS is a workplace issue:** NGGL recognizes that HIV/AIDS is a workplace issue, and should be treated like any other serious illness/condition at the company's places of business.

- **Ensuring non-discrimination**: NGGL commits to ensuring that there should be no discrimination allowed or tolerated against workers on the basis of real or perceived HIV status.

- **Gender equality**: NGGL recognizes that women are more likely to become infected by HIV and are more often adversely affected by the HIV/AIDS epidemic than men due to biological, socio-cultural, and economic reasons.

- **A healthy work environment**: NGGL's policy is to assure the work environment be healthy and safe for all concerned parties, in order to prevent transmission of HIV.

- **Social dialogue**: NGGL recognizes that successful implementation of its HIV/AIDS policy and programs requires cooperation and trust between management, workers and their representatives, and government, where appropriate, with the active involvement of workers infected and affected by HIV/AIDS.

- **Screening for HIV**: NGGL recognizes that HIV/AIDS screening should not be required of job applicants or persons in employment, and rejects HIV testing as a precondition for recruitment or access to training or promotion.

- **Confidentiality**: NGGL realizes there is no justification for asking job applicants or workers to disclose HIV-related personal information, nor should co-workers be obliged to reveal such personal information about fellow workers. Access to personal data relating to a worker's HIV status should be bound by the rules of confidentiality.

- **Continuation of employment relationship**: NGGL agrees that HIV infection is not a cause for termination of employment, and, as with many other conditions, persons with HIV-related illnesses should be allowed to work for as long as medically fit in available, appropriate work.

- **Preventing new infections**: NGGL believes that HIV infection is preventable, and the prevention of its transmission can only be achieved through a variety of strategies that are appropriately targeted, designed to Ghana-specific cultural realities, and communicated transparently to the NGGL workforce. Prevention can be advanced through changes in behavior, knowledge, treatment, and the creation of a non-discriminatory environment.

- **Care and support:** NGGL commits to assuring that workers, including those HIV+, should be entitled to affordable health care services. NGGL will also provide directly, via insurance schemes or through a third party, anti-retroviral drugs, where medically appropriate.

To ensure that all NGGL employees understand and learn to deal with HIV/AIDS in the company's places of business throughout Ghana, NGGL has committed to:

- ***Assuring*** that non-discriminatory policies, procedures and practices regarding HIV+ workers are instituted and maintained;
- ***Providing*** information and communication to its workers about the disease and how to prevent infection;
- ***Treating*** HIV/AIDs in the same manner as any other progressive or debilitating illness; and
- ***Developing*** clearly-defined procedures that reflect Ghanaian practices, procedures, culture, and legislation.

NGGL hired an HIV/AIDS Coordinator in April 2005 to coordinate the voluntary prevalence testing and counseling programs. In addition, NGGL will identify and train peer counselors and community educators to provide services in the field.

ALTERNATIVES ANALYSIS

Potential impacts to social and economic resources associated with implementation of closure alternatives would be similar to those described for the current Ahafo South Project, with the following exceptions for potential closure alternatives:

- Development of an aquaculture facility associated with mine pit lakes would provide economic benefits to local residents after closure and water filling the mine pits. This assumes that quality of water in pit lakes would be acceptable for aquaculture development.
- Development of irrigation systems using stored water in pit lakes and the water storage reservoir to enhance crop production through the dry season. This assumes that quality of water in the pit lakes would be acceptable for agricultural purposes.
- Reducing slopes of waste rock disposal facilities would provide additional land to use for subsistence farming after cessation of mining.
- Post-closure use of the reclaimed tailing storage facility for farm land would provide economic benefits to local residents.
- Construction and operation of a water treatment facility for pit lakes, waste rock seepage, and/or tailing effluent could provide additional employment opportunities.

NO PROJECT ALTERNATIVE

The No Project alternative has not been considered in previous EIS documents. Because the Project has already been licensed, no specific review of alternatives was required by the Ghanaian EPA prior to the beginning of construction. It is possible to understand the potential impacts of the No Project Alternative by switching the effects associated with the impacts listed above for the proposed Project. There would be no impacts on the local economy. No local residents would have to be resettled or relocated, and agricultural land would not be lost to Project development.

If the mine were not developed, there would be reduced funds to relieve the economic challenges currently faced by Ghana. Gold is a vital part of Ghana's national and international economic viability. Ghana has traditionally ranked in the top 10 gold producing countries in the world. If the Ahafo South Project does not proceed from construction to operation, 6.8 million ounces of gold would not be added to the country's overall export of the commodity, a loss of approximately 500,000 ounces per year. Potential royalties generated by the Project (estimated at an average of $5.2 million (US) per year) would not occur, thereby, directly impacting revenue available to the national government, Brong-Ahafo Region, Asutifi District governments, local traditional authorities, and affecting the overall gross domestic product of the country.

Local residents have been employed in the construction effort but up to 750 long-term jobs currently reserved for local residents would not be realized if the Project does not go forward. Potential income of approximately $2,700 (US) per year per local unskilled laborer would not be realized. Sustainable development programs and vocational education programs designed to train local residents would not be conducted and farming would remain the principal economic activity because of the lack of training leading to other opportunities. In addition, skilled mine workers from other locations in Ghana would not have to opportunity to work at the Ahafo South Project.

NGGL would not make any additional infrastructure improvements if the No Project Alternative is implemented. Electrification and telecommunications within the Study area would not be improved, at least not at the same pace that they would be if the Project goes forward, because of the lack of a customer base.

Newmont is currently the second largest gold producer in the world and believes that the Ahafo South Project will be a major contributor to its ongoing production. If the Project did not go forward at this point, Newmont would lose its initial investment and would have to review its decision to explore, develop, and produce in other areas of Ghana.

CULTURAL RESOURCES

BASELINE CONDITIONS

World Bank Operational Policy 4.11, Safeguarding Cultural Property in an IFC-Financed Project is an international best management practice, which requires developers to identify and preserve archaeological (prehistoric), paleontological, historical, religious resources, and unique natural features. Previous EIS documents concerning the Ahafo South Project did not include a survey of cultural resources of the Study area because such inventories or surveys are not required by the Ghana EPA for obtaining a mine license through the EIS process. There is no Ghana federal office on cultural resources.

SGS (2005) completed a cultural heritage survey of the Ahafo South Project Study area in March 2005. The survey identified 18 sites, which are shown on **Figure 4-2**. These include cemeteries, shrines, water bodies, a tree, and a hill.

The Ahafos believe these sites are associated with the sacred. They are locations defined as much by their physical properties as by the spiritual forces that the people of Ahafo believe occupied and operated from these locations. Sacred sites are where spiritual forces operate to influence human life. These sites are also interactive locations where humans could influence the sacred as well through the

performance or the lack thereof of particular rituals. Thus, what constituted the basis for the Ahafos understanding of human and physical environment was the notion that there existed physical entities through which one could interact with the spiritual and that could also be harnessed to achieve particular ends.

Sites located within or near the boundary of the Project area include:

- **Site 4 -** Asuo Kofi Shrine located adjacent to the Awonsu Pit within the Project area. The SGS survey reports that libations are poured in this section of the Kofi stream.

- **Site 16 -** is a public cemetery located on the Project area boundary about 1 km from Kenyase No. 2 along the Kenyase-Ntotroso road. The cemetery is about 10 years old and does not appear to have been maintained for some time.

Sites located within the Study area include several adjacent to the Ntotroso Resettlement Site:

- **Site 1 -** the River Tano Shrine, located about 60 m from the bridge on the Ntotroso-Acherensua Road. The shrine consists of a black pot placed under a babadua tree. Empty bottles of schnapps have been placed close to the pot after the traditional libations have been drunk.

- **Site 2 -** the Apomasu Shrine located between Ntotroso and Gyedu in a wall surrounded by various plants.

- **Sites 17 and 18 -** are the Ta Kofi Shrine and the Royal Cemetery. The shrine is over 300 years old and is home to the god Ta Kofi and his brother Asare. The shrine is a large pot with empty schnapps bottles all around; the area also services as the burial ground for the royal family.

- **Site 3 -** the Royal Mausoleum, is also near Ntotroso. The burial site was established 20 years ago and about 30 royals have been buried at this site. The last burial was in February 2005, indicating that the site is still in use.

Another cluster of cultural sites located near Kenyase No. 1 and No. 2 villages include:

- **Site 6** - is the Ta Kwame Shrine, located in a priest's house. The shrine is more than 200 years old and is used for ritual purposes on sacred days.

- **Sites 7 and 8** - are the Kenyase Bo Shrine and the Adampa Shrine, which are located in a building considered to be sacred ground. The shrines are more than 200 years old.

- **Site 9 -** is a royal cemetery that was established 200 years ago.

- **Site 10** - is the Kotopa sacred pond, which is fed by an underground spring.

- **Site 11 -** is the Antoa Odumase sacred tree, which is a *Millicia ecelsa* tree.

mines\EIS\ghana\ahafo\cadpro\chapter2_site_base.dwg

WAMAHINSO

AMAMA PIT

WASTE ROCK DUMP

ENVIRONMENTAL CONTROL DAM NO. 7

17&18

2

1

NTOTOROSO

NTOTOROSO RESETTLEMENT SITE

3

WATER STORAGE FACILITY

SPILLWAY

EXPLOSIVES MAGAZINE

ENVIRONMENTAL CONTROL DAM NO. 2

TANO RIVER PUMPING STATION

RANK CAMP

EMERGENCY SPILLWAY

4

WASTE ROCK DUMP

AWONSU PIT

15

TAILING STORAGE FACILITY

STOCKPILES

PLANT BYPASS ROAD

BOSUMKESE FOREST RESERVE

WASTE ROCK DUMP

PLANT SITE

APENSU PIT

ENVIRONMENTAL CONTROL DAM NO. 4

ENVIRONMENTAL CONTROL DAM NO. 3

WASTE ROCK DUMP

KENYASE NO. 2 RESETTLEMENT SITE

16

SUBIKA PIT

WASTE ROCK DUMP

FUTURE NTOTOROSO/KENYASE PUBLIC ROAD ALIGNMENT

14

ENVIRONMENTAL CONTROL DAM NO. 6

SENIOR STAFF VILLAGE

KENYASE No. 2

12

9

6

7&8

KENYASE No. 1

KENYASE BYPASS ROAD

11

10

AKYERENSUA

Konkontreso

Kasuso

0 Kilometers 3

1:63,360

Contour Interval = 6 Meters

Existing Primary Road

Existing Secondary Road

Proposed Haul Road

Forest Reserve Boundary

Pipeline

VRA Overhead Powerline

Lease Boundary

Project Area

Project Area Undetermined

11 Cultural Site Location and I.D.

NOTE: Sites 5 and 13 are not within the map perimeters (See description in the text)

Cultural Sites
Ahafo South Project
Brong Ahafo Region, Ghana
FIGURE 4-2

Site 12 - is the Abra bra Tano Shrine, a 200-year old shrine to the river god. This is considered to be the oldest shrine in the area and is respected by all gods and spirits.

- **Site 13 -** is the Apaeemu Shrine, a shrine to the river god Asubontem located at the confluence of the Tano River and Subri stream.

- **Site 14 -** is a royal cemetery, which is about 30 years old and contains the bodies of 25 members of the royal family.

- **Site 15 -** the Asuo Skia Shrine, is located about 7 km west of the NGGL Kenyase Camp. This shrine is a large black pot surrounded by 12 stones, 2 calabashes, and many empty schnapps bottles.

Tano River - Taboos and the Sacred Fish

The Tano River is seen as necessary for life itself, yet is also believed to be capable of bringing great hardship; death from drowning, and destruction to crops and fields when it overflows its banks. Taboos and prohibitions govern the ways in which people use this source of water. The Sacred Fish serve as the physical embodiment of the god, punishing those who fail to demonstrate respect and rewarding the pious with the substance necessary for life.

According to Ahafo traditions, water deities such as Tano, Bea, Bosomtwe, and Bosompo are "God's sons." Water deities in a sense partake of the nature of god – they derive from him and share his spirit. It ought to be noted that one of the Ahafo's attributes of god is "Amosu," he who gives rain and thus makes the rivers and the sea full of water and life. It is not surprising that Ahafos consider this water deity Tano as an intermediary; the relationship between god and Tano is considered as one of sovereign and delegated minister. The description "Sons of God" is in Ahafo tradition limited to just these water deities and is not an expression used in tradition of all deities known in Ahafo or among the Akans.

The following is a narrative by the Paramount Chief of Kenyase No 2 Nana Kwabena Nsiah Ababio – March 6th 2005 (SGS 2005):

The essence of the journey to the confluence of the River Tano and Subri is to pour libation and invoke the river god Asubonten to protect us and ensure fertility of our women and the land. The god Asubonten originally belonged to us. One day the King of the Ashantis, Otumfo Nana Osei Kwadwo (1764 – 1777) invited the priest of Asubonten to help trace a missing item – no clues were given as to what was missing. The priest told the King that the missing item was solid gold located under his stool. When they saw the gold, the King blessed the priest and instructed the priest to take good care of the people of Kenyase. Asubonten is the same as Tano because it came from the river.

The shrine is visited on festive occasion once a year. We would cite some incantations, which invited the fishes to appear. The fishes one with gold and the other with white clay on top of their heads will appear and rest on the rocks.

- *A brass pan is carried by a man. The pan contains gold and the god*
- *The pan is lowered and the water dripping from the fish is collected in the pan*
- *A sheep is slaughtered. The head of the sheep is cut off.*
- *Then one of the fish swallows the head of the sheep*

But it must be noted that if there is a Christian among us the fish would not appear because they would feel that their powers were being tested or tempted. The appearance of the fish was a sign of good omen. After the ceremony we moved from the River to a spot called 'Asuee ye a eto so mienu' (2nd Rest stop) where libation would be poured.

Then Kenyase No. 1 men and women would come and meet the delegation amid songs and drumming. Kenyase No. 2 people would also come and meet them at Ama ma Tano stream (Giver of Children) – the Stream is the boundary between the two communities.

At this stage pregnant women would bare their chest and abdomen and water from the brass pan will be sprinkled on the pregnant women for safe delivery.

The brass pan (in which resides the god) would be taken to the Palace of the Paramount Chief (K2) and the Chief would be briefed about the journey. It was a joyous occasion for the people of Kenyase No. 1 and 2. Drinks would be distributed. Pregnant women would come to the priest who would predict the sex and number of children to be delivered by the pregnant women. The fishes in the River Tano cannot be eaten because they are the children of the River god. However, if the fish moved into any of the River's tributary then it could be eaten. The River is sacred throughout the whole of Ahafo land. The belief extends as far as the Bibiani area.

Bosumkese Hill

Site 5 - is the Bosumkese Hill, which is considered sacred by the people within the Study area. Opanyin Yaw Donkor was reported to have located the hill circa 1920, when he came from Bomaa to establish Ahyiayem village. Every year the Chief of Bomaa sacrifices a sheep to the god, which dwells in the hill. It is a taboo for women to partake of the sheep that is slaughtered to the god or even go near the hill while in their menstrual period.

The hill is located within the Bosumkese Forest Reserve and consists of solid stone standing about 150 m and extending over a kilometer. The forest around the hill provides abundant snails, game, and rain. The hill is not thought to be a god by the Ahafos; it simply gives a concrete manifestation of god's being and his presence. Furthermore, they see the hill as physically "closer" to the sky than ordinary ground and are easy to associate it with god. The hill is a point of contact which draws together not only people in the area but also spiritual beings and god. To the people of Ahyiayem, Bomaa and neighboring communities, the god provides protection by warding off calamities.

DIRECT AND INDIRECT IMPACTS

Potential impacts to cultural resources include loss of artifacts and historical/archaeological information from disturbance of Site 4. Disturbance of graves at Site 16 could result because of construction and operation of the Project. No impact is anticipated to other cultural sites within the Study area.

Shrines can be moved by making a libation and paying the chief to intervene with the gods to allow the move. Even though not required, NGGL will notify the national museum of discovery of cultural artifacts or historical features, and will allow museum professionals an opportunity to evaluate any findings. If they determine that collection of additional data is warranted prior to further disturbance of the site, NGGL likely will allow such data collection.

Newmont Standard S.021, Management of Heritage Sites, was adopted to ensure that each Newmont managed facility properly respect and adequately protect all sites with heritage significance or potential heritage significance within the Project's sphere or influence.

Evaluation of conformace with the Standard will occur during annual 5 Star Assessments regularly scheduled for all Newmont operations sites. Performance will be publicly reported during the first quarter of the following year. Management of Heritage Sites will be implemented according to Newmont 5 Star specifications taking into consideration the following.

- Protocols for land and building disturbance, objectives, targets and key responsibilities;
- Inventory of all sites and exclusion zones in accordance with the cultural norms of relevant stakeholders. Where cultural norms require confidentiality, there must be processes to ensure confidentiality;
- A list of contacts relevant to particular sites of significance. As above, this list must be kept in accordance with the cultural norms of relevant stakeholders; and
- Records of unauthorized disturbances, and corresponding investigations.

A management procedure, including documented processes at a minimum for:

- Identifying and assessing sites, including actual and potential risks and impacts of mine development to sites;
- Use of appropriate qualified professionals to assist with identification and management of sites;
- Culturally sensitive storage of relevant records;
- Reviewing knowledge of sites to ensure information remains current and correct;
- Communicating to relevant employees and contractors site locations and appropriate protocols;
- Ensure training and awareness on procedures for employees and contractors to take if artifacts are discovered during their work;
- Incident reporting and investigation;
- Penalties for breaches; and
- Emegency and rapid response to sites with cultural or religious significance.

- Documentation of the site's approach, including procedures for land disturbance, objectives, targets and key responsibilities;

- An inventory of all sites, exclusion zones and their location. The inventory must be in accordance with the cultural norms of relevant stakeholders. Where cultural norms require confidentiality, there must be processes to ensure confidentiality;

- A list of contacts relevant to the particular sites of significance. As above, this list must be in line with the cultural norms of relevant stakeholders;

- Records of unauthorized disturbances, and corresponding investigations;

- A management procedure, including documented processes for:

- Identifying and assessing sites, including actual and potential risks and impacts of the operation to sites;
- Culturally sensitive storage of relevant records;
- Reviewing knowledge of sites to ensure information remains current and correct;
- Communicating to relevant employees and contractors site locations and appropriate protocols;
- Ensuring employees and contractors know what to do if they discover any artifacts while performing their work;
- Incident reporting and investigation;
- Penalties for breaches;
- Emergency and rapid response relating to sites with cultural or religious significance;

- Processes of engagement to ensure protocols remain appropriate and in line with expectations of local people; and

- Program that ensures staff and contractors receive an appropriate level of cross-cultural training for their responsibilities.

Potential impacts to cultural resources include loss of artifacts and historical/archaeological information from disturbance of Site 4. Disturbance of graves at Site 16 could result because of construction and operation of the Project. No impact is anticipated to other cultural sites within the Study area.

ALTERNATIVES ANALYSIS

Potential impacts to cultural resources associated with implementation of closure alternatives would be similar to those described for the current Ahafo South Project. One exception might be that the alternative to reduce slopes on waste rock disposal facilities would increase land area covered by the dumps, thereby possibly covering any cultural resources if present in those areas.

NO PROJECT ALTERNATIVE

Implementation of the No Project Alternative would eliminate the potential impacts on cultural resources that are described for the Project and closure alternatives. Once NGGL completes reclamation of the area disturbed by initial construction activities, baseline conditions associated with cultural resources are expected to resume.

VISUAL QUALITY

BASELINE CONDITIONS

Objectives of the visual resource investigation are to identify and describe important visual resources that could be affected by the Project and related activities. Visual resources include landscapes that may be seen while traveling through the area.

Topography of the Ahafo South Study area consists of rolling hills from 200 m in the valleys to 300 m along ridgelines, with highest elevations in the Bosumkese Forest Reserve to the north. Tourism and recreation are not prominent activities in and around the Study area. Heavily vegetated hills and valleys

in varying shades of green characterize the area. Undulating horizontal lines visible through the atmospheric haze represent the hills relative to depth of field.

Texture, pattern, and color are heavily influenced by dominance of vegetation. Villages offer a contrast by clearing nearly all vegetation and exposing natural reddish-yellow soil. The Tano River is fed by many seasonal tributary streams to form the main drainage along the east side of the Project area.

The Project area can be viewed from several different locations. Most sustained visual impact, although distant, will occur along the road from Akyerensua to Ntotoroso. Portions of the waste rock disposal facilities and plant site will be visible to the west from the road. Another view from the same road to the north will offer a sustained, distant view of the Amama waste rock disposal facility. Subika waste rock disposal facilities will be visible from Kenyase No. 1 and No. 2 villages. All views would require a break in foreground vegetation in order to see mine-related facilities. Potential viewers would be local residents and other travelers.

Viewpoints were established for evaluating visual contrasts. Factors considered in selecting these views include angle of observation, number of viewers, duration of view, relative apparent size of the Project, season of use, and lighting conditions. The views were selected to represent locations on roads approaching the Project area from which a person may be expected to view mine-related site features. Three views were identified and evaluated as shown on **Figure 4-3**:

- **View-1** is located along the road from Akyerensua to Ntotoroso at the highest point, approximately 215 m elevation. The view is toward the west approximately 3.5 km to the plant site, with the Apensu and Awonsu waste rock disposal facilities in the background.

- **View-2** is located along the road from Akyerensua to Ntotoroso from the bridge over the Tano River approximately 3 km north of View-1. View-2 is looking north approximately 3 km to the Amama waste rock disposal facility.

- **View-3** is from Kenyase No. 1 and No. 2 villages looking northeast approximately 2.5 km to the Subika waste rock disposal facilities.

DIRECT AND INDIRECT IMPACTS

Ahafo South Project activities would result in significant modification to the existing landscape. Clearing the forest to construct mine-related facilities would create a change in texture and color. The constructed plant facilities and waste rock disposal facilities would result in changes to line, form, texture, and color. Mine pit highwall colors of yellow- to reddish-brown would contrast with the existing green hues of natural vegetation, especially during clear periods of bright sunlight. The mine pits would be difficult to see unless the viewer was near the edge of the excavation. Natural topography and vegetation of the Study area will serve as positive elements in the effort to minimize visual contrasts. Rolling hills provide shielded views to travelers along roads in the Study area. Vegetation along roads can also hinder an open view of the landscape.

Most views have long distances to the mine facilities which would moderate the contrast to natural landscape. A distance of 1.6 km is generally considered the extent at which human-made features are visible in clear conditions; features beyond this distance are not discernable and visual impacts become minimal. Contrasts in color and/or shape are further mitigated by the natural occurrence of humid atmospheric haze.

- **View-1** is toward the plant site and adjacent waste rock disposal facilities to the west. Although this is a sustained side-view for travelers on the road, it is not considered a significant impact due to the distance of about 3.5 km to mine-related facilities. However, there may be a visual impact relative to night lighting from the plant.

- **View-2** is also from the road for travelers heading north towards Ntotoroso. The topography flattens approaching the Tano River bridge providing a view of the Amama waste rock disposal facility. The view would appear approximately 3 km distant, then about 1.5 km before the road turns and nearby hills block the view.

- **View-3** is from the Kenyase No. 1 and No. 2 villages. This view is northeast looking across the Samansua drainage at Subika waste rock disposal facilities. The distance is approximately 2.5 km and is the most significant visual contrast for the Project because of the number of viewers present in the villages. The waste rock disposal facilities will rise 40 to 60 m above the elevation of the communities and create a new horizon line. The Subika mine pit highwall may be visible at certain times during optimal atmospheric conditions, even though the viewing distance is over 3 km.

ALTERNATIVES ANALYSIS

Potential impacts to visual quality associated with implementation of closure alternatives could include the following:

- If a water treatment facility is constructed to treat poor quality water that may develop from waste rock disposal facilities, tailing storage facility, and/or pit lakes, this structure may be visible, depending on its location dimensions.

- Reduction of slopes on waste rock disposal facilities may reduce visual impacts because of the reduced overall height of these features.

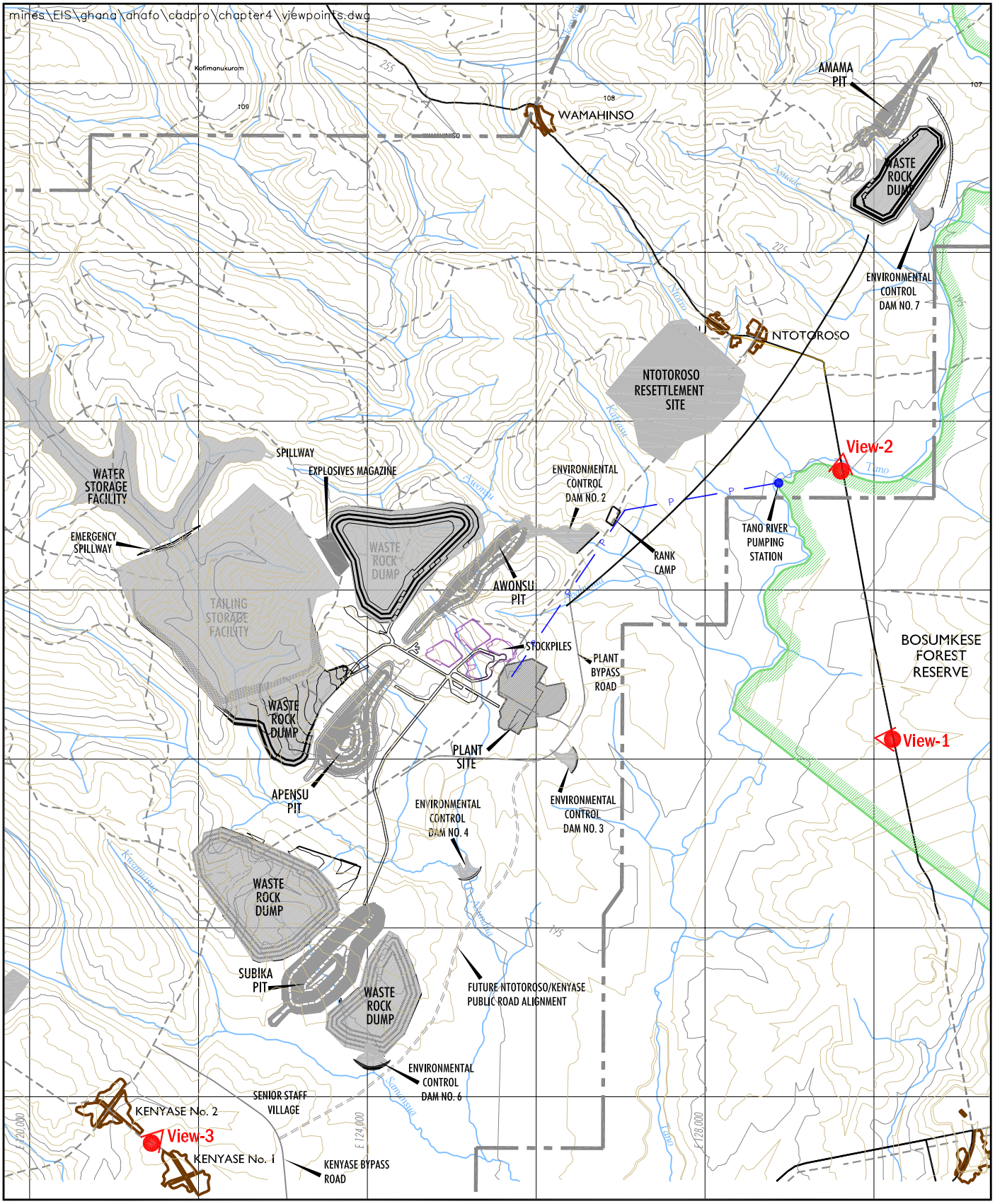
NO PROJECT ALTERNATIVE

Implementation of the No Project Alternative would eliminate the potential impacts on visual resources that are described for the Project and closure alternatives. Once NGGL completes reclamation of the area disturbed by initial construction activities, baseline conditions associated with visual resources are expected to resume.

NOISE AND VIBRATION

BASELINE CONDITIONS

The Ghana EPA established Ambient Noise Level Guidelines for residential areas with negligible or infrequent transportation at 55 decibels (dB) between 0600-2200 hours and 48 dB between 2200-0600 hours. The Ghana EPA asserts that noise levels above 45 dB may impair sleep, while 70 dB leads to emotional upset, irritability and other tensions (Ghana Home Page 2005).



View-Point Locations
Ahafo South Project
Brong Ahafo Region, Ghana
FIGURE 4-3

The World Health Organization (WHO) established noise level guidelines for various land uses. For residential dwellings or areas used for human habitation and sleep, WHO recommends that sound levels be no higher than 50-55 dB for 16 hours of exposure during daytime, and 45 dB for 8 hours of exposure at night. WHO also recommends that persons should never be exposed to a maximum sound level (fast Lmax) greater than 110 dB, nor a peak sound pressure level (instantaneous, not fast Lmax) greater than 140 dB for adults and 120 dB for children (WHO 1999).

The generally accepted standard regulation in most countries, including Ghana, is that a noise level of more than 85 dB for an 8-hour daily exposure is potentially damaging. In Ghana, there is no law governing worker exposure to hazardous noise levels at mine sites. However, the mine's inspectorate uses a noise level of 85 dBA for an 8-hour daily exposure as the standard when advising mining companies on the importance of hearing protection (Amedofu 2002).

Noise Terminology and Descriptors

Noise can be characterized as excessive or unwanted sound. Because a person's response to noise is subjective, the perception of noise varies from person to person. The human ear responds to a very wide range of noise intensities. The decibel scale used to describe noise is a logarithmic rating system that accounts for the large differences in audible sound intensities. This scale accounts for the human perception that loudness doubles with an increase of 10 dB. Therefore, a 70-dB sound level will sound twice as loud as a 60-dB sound level. For increases or decreases in a noise source, people generally cannot detect differences of 1 dB. Although differences of 2 or 3 dB can be detected under ideal laboratory situations, they are difficult to discern in an active outdoor noise environment. A 5-dB change would likely be perceived under normal listening conditions. A new noise source with different sound characteristics than the existing ambient noise could be perceived even if its sound levels were markedly lower than the ambient noise level.

Because of the logarithmic scale used to describe noise, a doubling of noise source strength produces a 3-dB increase in average noise. For example, two adjacent, discrete noise events occurring simultaneously would result in a 3-dB increase over the sound level produced by only one event. Such an increase would not be perceived as a doubling in noise *loudness*, which requires a 10-dB increase.
When addressing the effects of noise on people, it is necessary to consider the frequency response of the human ear, or those frequencies that people hear well. Sound measuring instruments are therefore often designed to "weight" sounds based on the way people hear. Frequency-weighting most often used to evaluate environmental noise is A-weighting because it best reflects how humans perceive sound. Measurements from instruments using this system are reported in "A-weighted decibels," or dBA.

Noise levels are decreased by distance, obstructions such as buildings or terrain, atmospheric absorption, and absorption by ground and vegetation. Sounds from line sources (e.g., fairly continuous roadway traffic) decrease by approximately 3 dBA for each doubling of distance from the source. Sounds from point sources (i.e., bulldozer) decrease by 6 dBA when distance from the source is doubled.

Existing Noise Levels

The Ahafo South Study area is dominated primarily by undeveloped forest, farmland, sparse residences, and population centers. The nearest densely populated areas to the Ahafo South Project area are Kenyase No. 1 and Kenyase No. 2 villages, Kenyase No. 2 Resettlement Site, Ntotoroso, and two

resettlement sites currently underway – Kenysase No. 2 and Ntotoroso resettlement sites (**Figure 4-1**). The Study area has few industrial noise sources and no major roadways, and the existing sound levels in the Project vicinity are expected to be low. Outside of the populated towns and villages, the existing noise environment is assumed to be fairly quiet (i.e., in the upper 30s to mid-40s dBA). Sound levels in the populated villages of Kenyase No. 1, Kenyase No. 2, and Ntotoroso would likely be somewhat higher due to noise from human activities and occasional automobiles.

Existing sound levels at most locations in the Project area are likely below the Ghana EPA guideline value for residential locations of 55 dBA during the day and 48 dBA at night, and the WHO recommended value of 50 to 55 dB during the day and 45 dBA at night.

DIRECT AND INDIRECT IMPACTS

The Project would increase the general level of noise and vibration within the vicinity of its operations. Mining activities would generate noise and vibrations which can be classified as follows:

- Continuous or semi-continuous noise produced by haul trucks, heavy equipment (e.g., dozers, loaders, shovels, excavators, etc.), excavation equipment (e.g., drills, grizzly screens, jaw crushers, etc.), and processing activities and equipment at the plant site (e.g., ball and SAG mills, crushers, loaders, compressors, pumps, etc.). Vibration associated with these sources is generally low and localized.

- Intermittent noise, air over-pressure, and vibration could result from blasting at the mine pits.

The relative remoteness of the various mining areas and plant site from the population centers, towns, and villages and the existing vegetation cover indicates that noise and vibration will not be a significant issue in the more densely populated regions of Kenyase 1 and 2, the Kenyase 2 Resettlement Site, Ntotoroso, and the Ntotoroso Resettlement Site. However, areas surrounding the Project site, but not within the Project boundary, are also sparsely populated. Therefore, some residential dwellings near the mining areas or plant site may be subject to noise and vibration impacts.

Continuous Noise

This category of noise, generated from sources listed above (excluding blasting), may have some localized effect on residents near each mine-related activity area. Primary noise-producing activities would be related to mine pits, waste rock disposal facilities, haul roads, and the plant site.

Mine Pits - Excavation in the mine pits would require use of relatively loud equipment including drills, excavators, loaders, and grizzly screens. Although operation of this equipment would be expected to generate high levels of noise, it typically operates in a pit below ground elevation. Therefore, the pit walls act as an intervening noise barrier, which substantially reduces noise affecting distant residential receivers. The highest potential for noise impacts from these sources would occur at early stages of mining activity in each area (Subika, Apensu, Awonsu, and Amama mine pits) when the equipment would be operating near ground elevation.

Waste Rock disposal facilities - After rock in a mine pit is blasted, the ore and waste rock are sorted and waste transported to a disposal facility, typically adjacent to the mine pit and ore to a stockpile near the processing plant. Noise from this activity includes loading haul trucks with a loader and transporting the material to upper elevations of a waste rock disposal facility or ore stockpile and

dumping the material. Dumping activity often includes noise from revving the truck engine to lift the truck bed and impact noise from the dumped waste rock and ore striking other rocks. A waste rock disposal facility will grow in elevation as mining progresses, and the truck travel routes and dumping locations gradually become more elevated. Therefore, the greatest potential for noise impacts from this activity occurs after the dump has increased in elevation to a point where there is little or no intervening terrain or vegetation between the dump and any nearby residential receivers.

Haul Roads - The ore and waste rock is transported to various locations on the mine site using haul roads. Most waste rock transport distances will be relatively short since the waste rock disposal facilities typically are located adjacent to a mining pit. However, ore from the pit will be transported via trucks to the plant site for processing, sometimes a longer distance from the pit.

Plant Site - There are numerous noise sources at a mine processing plant site. Major noise generators at a plant site typically include a ball mill, SAG mill, several rock or pebble crushers, and front-end loaders. Secondary noise contributors could include various compressors and pumps, gold processing equipment, smaller mobile equipment and vehicles, and transformers at the plant site power substation.

Sound levels from the presumed dominant noise sources described above were modeled at individual receiver locations in the Project area to determine where potential noise impacts may occur. Modeled receiver locations included population centers of Kenyase No. 1 and No. 2 villages, Ntotoroso village, nearby resettlement sites, senior camp village, current Rank Mining camp, on-site construction camp, and locations near the Project boundary. Locations near the Project boundary were included because individual dwellings may exist outside the main population centers. Because specific sound level information for some equipment was not available (i.e., ball/SAG mills), the predicted levels discussed are approximations of potential noise levels that could occur in the Project area. Equipment locations and numbers were based on current predictions of mine activity during years 3 and 4 of the Project, when some level of activity is expected to occur at all mine pits (i.e., Subika, Apensu, Awonsu, and Amama). This analysis also assumes no noise reduction measures are proposed for the plant site, and the ball/SAG mills are not expected to be enclosed.

Noise modeling results indicate the relative remoteness of mine pits, waste rock disposal facilities, and plant site would reduce noise at these locations to less than 48 dBA in Kenyase No. 1 and No. 2 villages, Ntotoroso village, senior camp, Rank Mining camp (currently being occupied by construction workers), and the two resettlement areas. However, noise from mine-related activities at dwellings or locations of human habitation near or within the mine site could exceed 48 dBA on occasion.

Noise from the equipment at the plant site, particularly noise from the ball mill, SAG mill, crushers, and front-end loaders, could be as high as 67 dBA in areas of human habitation at the construction camp on the plant site. Sound levels as high as 67 dBA would likely disrupt the sleep of worker/residents living in the camp. Off-site noise from equipment at the plant site could exceed 48 dBA at dwellings located outside the Project area, but within 1,000 m of plant equipment.

Near the waste rock disposal facilities, haul trucks dumping waste rock could produce noise levels exceeding 48 dBA at residences within approximately 500 m of the dump site where there is a clear line-of-sight to the dumping activity. Similarly, noise from excavation and drilling equipment when the equipment is operating near original ground elevation at the beginning of mining activities could exceed 50 dBA within approximately 1,000 m where there is a clear line-of-sight to the equipment.

According to both the Ghana EPA and WHO guidelines, sound levels exceeding 48 dBA would constitute a noise impact during night-time hours. Because all Project activity is expected to occur 24-hours a day, significant noise impacts could occur at dwellings within 1,000 m of the plant site, within 500 m of waste rock disposal facilities, or within 1,000 m of mining activities, using the assumptions stated above.

NGGL will provide appropriate noise protection equipment to all employees working in an environment where noise exceeds the acceptable international level (>85 dB). Noise that affects areas of worker accommodations, such as the construction camp, will be assessed for appropriate residential noise conditions.

Intermittent Noise and Vibrations

Vibration induced by blasting will be minimized through controlled blasting technology. All buildings and infrastructure within 500 m of the ultimate pit rim will be relocated. A 500 m buffer zone will be established around mine pits as a safety and security zone in accordance with Ghanaian regulations. Although blasting noise, air over pressure, and vibration at private residences near the mine pits may be noticeable and temporarily disrupt resident activities, relocation of dwellings from within the 500 m buffer zone will ensure that no health or safety issues occur.

Similarly, although noise from blasts would likely be audible in the two resettlement areas and the villages of Ntotoroso, Kenyase No. 1, and Kenyase No. 2, the distance between these population centers and the potential blast locations ranges from 1,800 m (from the Awonsu mine pit to nearest location in the Ntotoroso Resettlement Site) to 2,100 m or more (from Subika mine pit to the nearest locations in Kenyase No. 1 and No. 2 villages). These distances will ensure that no health or safety issues occur, including the possible deterioration of their living environment and properties (e.g., cracks in buildings). However, noise arising from blasting operations can have a psychological impact on some people even if such nuisance occurs only once or twice a day. It is relatively common to have people confusing air over pressure with level of vibration. NGGL will post blasting times in nearby villages to avoid surprise effects on area residents and provide blasting demonstrations for public witnessing under the supervision of the Ghanaian EPA and traditional authorities.

ALTERNATIVES ANALYSIS

Because the Ahafo South Project is currently under construction, no Project alternatives were identified for the mining portion of the Project. However, several alternatives have been identified relating to the closure of the mine associated with management of pit lakes, waste rock disposal facilities, and tailing storage facility. Noise at off-site sensitive receivers related to any of the closure alternatives would likely be similar to the current Project. Any closure alternative would likely require some use of earth-moving equipment. Noise from such equipment would be similar to noise generated by mining equipment, but it is anticipated that less equipment would be required than during the most intensive mining scenario considered, and the closure activities would be expected to be relatively short-term. Therefore, noise impacts specific to any of the closure alternatives are expected to be similar to or less than noise levels during implementation of the Project.

NO PROJECT ALTERNATIVE

Implementation of the No Project Alternative would eliminate the potential impacts on noise and vibration described for the Project and closure alternatives. Once NGGL completes reclamation of the area disturbed by initial construction activities, baseline conditions associated with noise and vibration are expected to resume.

BIOLOGICAL ENVIRONMENT

BIODIVERSITY

Biodiversity is a measure of the variety of life, and its processes, including the variety of living organisms, genetic differences among them, and the communities and ecosystems in which they occur (Langner and Flather 1994). Biodiversity is often interpreted as a measure of biological complexity and variation within the Project area. Although there is no specific regulatory guidance on methods for assessing and monitoring biodiversity, the concept is widely interpreted as a measure of ecosystem integrity and stability. Following the Convention on Biological Diversity at the 1992 UNEP Earth Summit, international projects funded by the World Bank and many other lending institutions undergo biodiversity assessments and monitoring. A description of NGGL's Biodiversity Management Program is included in Chapter 5 – *Environmental and Social Action Plan.*

The Star rating system for plant and animal species in Ghana provides a measure of "bioquality" which considers the quality and quantity of species. The Star Rating system rates individual plant and wildlife species on their conservation priorities, with most consideration given to rarity and risk of extinction.

Numerous methods are used to collect vegetation and wildlife information based on site conditions, nature of local biota, and concerns to be addressed. Few standards or protocols exist, especially in regard to collection and analysis of biological resource information, as these resources relate to mining.

FLORA

Hawthorne and Abu-Juam (1995) indicate that biodiversity must include a measure of "bioquality", which considers quality, as well as, quantity of species. In Ghana, a measure of bioquality has been developed that rates individual plant species on their conservation priority, with most consideration given to rarity and risk of extinction. Of the approximately 3,600 plant species in Ghana, most species with the exception of some weed species, have been assigned star ratings as shown in **Table 4-9**. Star ratings for composite species in plant communities are incorporated into a weighted model whose output is a "genetic heat index" for a given community. The genetic heat index reflects the concentration of rare species in plant communities, rather than the number of species per unit area and allows for identification of genetic hotspots, thus allowing prioritization of conservation areas.

TABLE 4-9
Star Ratings for Plant Species in Ghana

Star Rating	Description
Black	Highly significant in context of global biodiversity; Rare globally and not widespread in Ghana.
Gold	Significant in context of global biodiversity; fairly rare globally and/or nationally.
Blue	Mainly of national biodiversity interest; e.g. globally widespread, nationally rare; or globally rare but of no concern in Ghana due to commonness.
Scarlet	Common and widespread commercial species with potential seriously threatened by overexploitation.
Red	Common and widespread commercial species; under significant pressure from exploitation.
Pink	Common and widespread commercial species; not currently under significant pressure from exploitation.
Green	Species common and widespread in tropical Africa; no conservation concern.
Other	Unknown, or non-forest species e.g. ornamentals or savannah plants.

Numbers of species classified by star rating are shown in **Table 4-10**. No species of high conservation concern (Black and Gold Star) were recorded within or adjacent to the Project area. The largest category (71.5%) was green star species, which contains plants widespread and common throughout tropical Africa and of no conservation concern (SGS 2000a, 2000b).

TABLE 4-10
Plant Species Occurrence by Star Rating in Ghana and Project Area

Star Rating	Star Species Numbers Listed in Ghana	Star Species Numbers Found in Project Area
Black	52	0
Gold	208	0
Blue	414	8
Scarlet	14	9
Red	40	5
Pink	19	11
Green	1044	216
Other	-	53
Total	**1791**	**302**

Source: SGS 2000a, 2000b.

The highest recorded genetic heat index value of 36 (average 32) was recorded for sites within the Amama Shelterbelt Forest Reserve. Lowest genetic heat index values were recorded for sites in fallow areas and grasslands. Intermediate index values were recorded for cocoa plantations (average 23). On a national scale, these genetic heat index values are very low compared with Ankansa National Park and Neung North Forest Reserve, which have the highest ratings in Ghana with average index values of 301 and 269, respectively.

FAUNA

Dispersion and variety of habitats in the Project area support a diversity of wildlife species that have varying habitat requirements, life histories, and conservation status. Of the 215 vertebrate species documented to be present in the Project area, 113 species occurred exclusively in the Forest Reserves, 12 species occurred exclusively outside of the Forest Reserves, and 90 species were present in the Forest Reserves and outside the Forest Reserves (**Table 4-11**). Large mammals and birds in the Project area are more strongly associated with the Forest Reserves than other groups. In general, reptiles,

amphibians, bats, and other small mammals appear to have similar affinities for habitats in and outside of Forest Reserves.

TABLE 4-11
Numbers of Vertebrate Species Relative to Forest Reserves

Vertebrate Group	Present Only Inside Forest Reserves	Present Only Outside Forest Reserves	Present In and Outside Forest Reserves
Birds	82	5	70
Large Mammals	25	6	3
Bats	3	0	5
Small Mammals	0	1	5
Reptiles	6	0	7
Total	**113**	**12**	**90**

Source: SGS 2000a, 2000b.

FOREST RESERVES

Natural conditions of the Project area are part of the broad Eastern Guinean Forest (World Wildlife 2003), which has been further characterized as the Moist Semi-Deciduous Zone, Northwest Sub-Type (Hall and Swaine 1981 as cited by Hawthorne and Abu-Juam 1995). Currently, plant communities of the Amama Shelterbelt Forest Reserve and Bosumkese Forest Reserve most closely represent natural forest types of the region; however, they have been severely degraded by fire, logging, and encroachment by agriculture.

Flora and Fauna

The Bosumkese and Amama Shelterbelt Forest Reserves contain remnants of the Eastern Guinean Forest that at one time covered extensive areas of central Ghana including the Project area. Typically, forest communities are characterized by a three-story canopy structure with emergent tall trees often exceeding 50 m in height, with the uppermost canopy having a mixture of evergreen and deciduous species. Dominant species include *Nesogordonia papaverifera*, *Celtis mildbraedii*, *Argomuerella macrophylla*, *Sterculia rhinopetala*, *Aframomum stanfieldii*, *Ricinodendron heudelotii* and *Masonia altissima*.

The western side of the Bosumkese Forest Reserve is extensively degraded, but a reforestation program is underway to restore portions of the degraded forest (SGS 2005). Crops are being grown in degraded parts of the forest reserve and two fast-growing trees, *Cedrela odorata* and *Tectona grandis* have been planted.

On the basis of open canopies and low timber volume the Bosumkese Forest Reserve is rated as forest Condition 5 (SGS 2005) (**Table 4-12**). Vegetation surveys conducted in the Bosumkese Forest Reserve recorded from 25 to 36 species distributed among 16 to 20 families (SGS 2005). Common species include *Griffonia simplicifolia*, *Antiaris africana*, and *Baphia nitida*.

According to Hawthorne and Abu-Juam (1995), the Bosumkese Forest Reserve had a Condition 4 forest; however, SGS (2004a) reports that the forest reserve has degraded over the last ten years and only a small patch is Condition 4, with most being Condition 5 or 6 (**Table 4-12**).

TABLE 4-12
Forest Reserve Condition Scores

Score	Description
1	EXCELLENT: with few signs (<2 %) human disturbance, with good canopy and virgin or late secondary forest throughout
2	GOOD: with <10 % heavily disturbed. Logging damage restricted or light and well dispersed. Fire damage none or peripheral.
3	SLIGHTLY DEGRADED: Obviously disturbed or degraded and usually patchy, but with good forest predominant; maximum 25 % with serious scars and poor regeneration; maximum 50 % slightly disturbed, with broken upper canopy.
4	MOSTLY DEGRADED: Obviously disturbed and patchy, with poor quality forest predominant; 25-50 % with serious scars; maximum 75 % disrupted canopy or forest slightly burned throughout.
5	VERY POOR: forest with coherent canopy < 25 % or more with half the forest with serious scars and poor forest regeneration; or almost all heavily burned with conspicuous pioneer species throughout.
6	NO SIGNIFICANT FOREST LEFT: Almost all deforested with savanna, plantation, or farm; <2 % good forest; or 2-5 % very disturbed forest remaining; or 5-10 % left in extremely poor condition.

Source: Hawthorne and Abu-Juam 1995

Vegetation surveys in the Amama Shelterbelt Forest Reserve identified areas disturbed by agriculture and introduction of non-native *Cedrela odorata*; however, nearby areas of good quality forest dominated by primary and secondary forest species were also observed (SGS 2005). This forest was Condition 3 or 4 because it has a partially closed overstory canopy and a predominance of native tree species.

The forest zone in which the Project area occurs is considered one of the most productive in Ghana in terms of economic values associated with timber production (Hawthorne and Abu-Juam 1995); however, within the Project area itself, outside of the Forest Reserves, there are only a few isolated trees of merchantable size and quality. Faunal characteristics of the Forest Reserves are similar to and included in the *Fauna* section presented above.

BIODIVERSITY MANAGEMENT PROGRAM

NGGL recognizes that the activities of exploring for and developing mineral resources may have an impact on biodiversity. Likewise companies engaged in exploration and mineral resource development can be a positive force for biodiversity conservation. Through sound environmental management, many, if not all, of the risks or impacts to biodiversity from mineral resource development can be avoided or mitigated. Further, there are good business reasons for mining companies, including NGGL, to contribute to efforts to ensure the healthy functioning of ecosystems in and around their areas of operation. To this end NGGL is committed to forming an effective partnership between business, non-governmental organizations (NGO), and the Ghanaian government which will focus on biodiversity conservation in and around the Ahafo South Project area.

The biodiversity management program will be incorporated into the Ahafo South environmental management program to promote biodiversity conservation related to the following activities. Of obvious importance is the proximity of Forest Reserve areas to the Ahafo South mine development and future foreseeable actions which may encroach upon established Forest Reserve areas.

On-Site Biodiversity Management

- Interim Reclamation and Management
- Final Reclamation and Management

Off-Site Biodiversity Management

- Natural Habitat Biodiversity Improvement
- Natural Habitat Conservation Management
- Biodiversity Offset Projects (Forest Reserve Impact Mitigation)

Biodiversity Partnership

NGGL has established a partnership with Conservation International, an internationally recognized NGO, to collectively explore opportunities for integrating biodiversity management into the Ahafo South Project. The general areas of focus for the partnership are listed below and will form the basis for NGGL's Biodiversity Management Program.

1. Integrate biodiversity conservation with NGGL's environmental policies, operating standards, and management system.
2. Develop and apply indicators for tracking and benchmarking performance in regard to biodiversity conservation.

3. Share biodiversity information and scientific and technical expertise to assess biodiversity resources, identify biodiversity priority areas, and implement landscape scale conservation planning methodology and pilot projects.

4. Identify opportunities to make strategic investment in regional efforts to achieve clear and measurable conservation outcomes in areas of interest to members of the partnership.

5. Promote biodiversity conservation within the mining sector.

6. Communicate and promote with key stakeholders about the partnership and it key activities.

Biodiversity Partnership Work Plan

NGGL and Conservation International have identified a work plan which will be implemented at the Ahafo South Project area during 2005. The work plan activities are presented below and are designed to develop a full understanding of biodiversity conditions in an around the Project area to determine management opportunities related to current and future foreseeable actions which may impact local biodiversity and likewise identify, where necessary, offsite projects which enhance biodiversity conditions in areas which contain greater biodiversity value.

<u>Integration of Biodiversity Conservation with NGGL Environmental Standards and the Development of Meaningful Biodiversity Indicators</u>

- Identify and implement best management practices which promote biodiversity management and conservation at and near the Ahafo South Project area.

- Establish clear baseline characteristics of current and future mining areas and evaluate both existing and potential primary and secondary impacts on biodiversity.

- Identify and implement management plans which are focused on protection, restoration, and impact mitigation of both local and regional biodiversity resources.

- Evaluate the opportunity to apply project learning into development of a "best practice manual" which illustrates biodiversity management related to development induced impacts which could be used to promote best practices for the global mining sector.

Integration of NGGL's Environmental Management Strategies Relative to Landscape-Scale Conservation Planning and Priority Setting

Implement a regional-scale landscape conservation planning process with the objective of protecting biodiversity conservation value within and or near mining projects areas while incorporating community based development considerations. The methodologies to be implemented will include the following.

- Rapid Biological Assessments (RBA): Conducted in and surrounding the Ahafo Project areas. The RBA is designed to collect biodiversity information to determine existing conditions, identify critical habitat, and serve as a baseline to monitor change. The RBA will be coordinated via Conservation International's Rapid Assessment Program (RAP) to generate quick assessments of the diversity and conservation significance of plants, mammals, birds, reptiles, amphibians, and select insect groups. International scientists will work together with host country scientists and institutions.

- Opportunities and Pressure Assessments (OPA): An OPA will be conducted to identify existing and potential future pressures on ecosystem health which will be used to identify potential opportunities for biodiversity management, conservation, and restoration. The OPA involves identification of key local and regional stakeholders, descriptions of the biological context, descriptions and prioritization of potential biodiversity management, conservation, and restoration opportunities which will be presented as a set of recommendations which target identified pressures.

- Develop and implement a Biodiversity Action Plan (BAP): A BAP will be developed which synthesizes information collected by the RBA, OPA and resulting recommendation. The BAP will delineate areas for specific biodiversity management, current and future rehabilitation and/or restoration with the objective of promoting protection of faunal and floral species. The BAP will be developed relative to the mining life-cycle such that the phases of interim reclamation and post-closure reclamation will be evaluated and managed from a biodiversity perspective.

- The BAP development and implementation will integrate alliances with local community, private-business, government and NGO's and include both local and regional applications. The final BAP will be published along with a detailed biological survey report.

Identification of Opportunities for NGGL to Make Targeted, Outcome Driven Conservation Investments in Ghana

- NGGL recognizes the need for biodiversity conservation capacity building at both local and regional levels. To that end, the project will strive to increase conservation awareness and build conservation management capacity in and around the Ahafo Project areas. In addition, NGGL recognizes that protection of critical, biologically diverse habitat in areas not associated with the mining project may result in greater conservation value. The following details the conservation investments that have been identified.

- Conservation Awareness and Capacity Building (CACB) will be developed associated with the 4-P workshop designed to identify problems, issues, threats, and challenges in and around the Ahafo South Project area. The Partnership will identify local and national key audiences (including NGGL workforce) to be included in conservation messaging and education. Communication tools and events will be developed and implemented with specific indicators which can be readily measured and communicated to demonstrate increased awareness and outcome based improvements.

- Biodiversity Offsets will be developed specifically for the Ahafo Project should future foreseeable actions result in disturbance to Forest Reserve areas near the Ahafo Project. NGGL is currently engaged with and international NGO partner related to another mining project in Ghana and will apply similar programs at the Ahafo Project area as opportunities arise. The objective of partnership it to promote the concept of net-loss biodiversity management through offsets. These efforts will explore, develop and document, through pilot projects across numerous industry sectors, the best practices for designing, and implementing biodiversity offset project focused on contributing to protection of a broad species representation and conditions which promote sustainable conservation of high-value resources.

Promotion of Biodiversity Conservation Concepts within the Mining Sector

- The partnership will explore opportunities for engaging other Ghanaian companies and industry associations as positive forces for biodiversity conservation.

DIRECT AND INDIRECT IMPACTS

Currently planned mining activities for the Ahafo South area will have no direct impacts on either the Amama Shelterbelt or Bosumkesee Forest Reserves as no facilities would be located in these areas. Indirect impacts may occur related to potential induced activity related to improved access and or use of Forest Reserve areas due to the presence of mining in the area. Potential indirect impacts include:

- Increased mortality to species hunted for bushmeat;

- Increased illegal harvest of timber and other forest products; and

- Increased removal of native vegetation for crop production.

ALTERNATIVES ANALYSIS

Alternatives related to closure that promote agricultural production would be important as they may reduce agricultural development in remaining Forest Reserve areas. Measures that would increase agricultural production include:

- Placing growth media of adequate depth and quality to support crop production on reclaimed areas;

- Applying fertilizer and organic material to reclaimed sites supporting crop production;

- Maintaining existing cycles of crop production and fallow periods to allow sustainable crop production; and

- Planting trees of commercial value on sites not amenable to crop production because of steep slope, coarse growth medium, or accessibility concerns.

NO PROJECT ALTERNATIVE

Implementation of the No Project Alternative would eliminate the potential impacts to ecological biodiversity that are described for the Project and closure alternatives. Once NGGL completes reclamation of the area disturbed by initial construction activities, baseline conditions associated with biodiversity are expected to resume.

FLORA

VEGETATION COMPOSITION

The natural vegetation of the Project area is part of the broad Eastern Guinean Forest (World Wildlife 2003), which has been further characterized as the Moist Semi-deciduous Zone, Northwest Sub-type (Hall and Swaine 1981 as cited by Hawthorne and Abu-Juam 1995). Currently, plant communities of the Amama Shelterbelt Forest Reserve and Bosumkese Forest Reserve most closely represent natural forest types of the region; however, they have been substantially degraded by fire, logging, and encroachment by agriculture.

The Project area is in the broad transition fire-prone zone where wetter forest vegetation to the south intergrades with drier savannah vegetation to the north. Fires and practices that remove overstory forest vegetation have led to a general shift to plant communities adapted to drier conditions. Following extensive nation-wide fires in 1983, many areas previously dominated by trees and shrubs have been colonized by dense stands of elephant grass (*Saccharum spontaneous*), especially on moister sites.

Most vegetation in the Project area, outside of the Forest Reserves, has been altered by fire, logging, agricultural activities, and other disturbances associated with human development. This vegetation is composed of a mixture of plant communities in early stages of ecological succession, crops and plantations, patches of second growth forest, and riparian communities along rivers and streams. This mosaic of altered plant communities reflects various stages of swidden-fallow agroforestry, a system that mimics natural forest cycles (pA 2005). The system begins with clearing and burning fallow thickets of secondary forest regrowth. Newly opened fields are then planted with a mix of food and cash crops that mature at different rates. Typically, production begins within a few years of mixed food crop production including cassava and cocoyam and then proceeds through several years of cash crop production. Fields typically contain a diverse range of crops. Scattered tall trees that emerge from the cropped areas include *Ceiba pentandra*, *Bombax buouozopenze*, and *Triplochiton sceroxylon*.

Vegetation in the Project area, outside of the Forest Reserves, has been extensively fragmented and has little resemblance to the native forest communities once typical of the region. Recent studies of the Project area utilizing interpretation of satellite imagery and coordinated on-the-ground verification surveys (SGS 2004a) found that about 28 percent of the Project area supports elephant grass, 21 percent is fallow thicket, 15 percent is forb regrowth, 15 percent is secondary forest, 10 percent is cultivated food crops, 7 percent is cultivated plantations (cocoa, oil palm, teak, and plantain), and about 1 percent is forest reserve. Less than 2 percent of the Project area is unvegetatated (e.g., towns, roads, villages).

Studies of the Project site (SGS 2000a, 2005) identified 302 plant species comprised of trees, shrubs, forbs, grasses, and lianas. Highest levels of species diversity in the Project area were recorded in small patches of savanna vegetation, second-growth forests, and fallowed agricultural land. In general, lowest levels of species diversity are associated with plantation crops.

GHANAIAN STANDARDS

In June, 1995, the Ghana EPA established procedures for preparing an EIA, depending on the nature, complexity, and location of projects. Ghana's Mining and Environmental Guidelines (1994) also provide guidance for preparation of an EIA. The Minerals and Mining Law (1986) Part IX contains general requirements for mining companies to explore and operate in an environmentally responsible manner. Environmental Guidelines for Mining in Production Forest Reserves in Ghana provide direction for exploration, mining, post-mine closure, reclamation and monitoring.

Ghana's Wildlife Conservation Regulations, First and Second Schedule, identify wildlife species with protected status and define the level of protection. First Schedule animals are completely protected and the hunting capturing, or destroying of these species is prohibited. Second Schedule wildlife species cannot be hunted, captured, or destroyed between August 1 and December 1. Hunting, capturing, or destroying young or adults accompanied by young are prohibited.

WORLD BANK, INTERNATIONAL FINANCE CORPORATION, AND WORLD HEALTH ORGANIZATION STANDARDS

World Bank projects must address effects of a project on biodiversity. Biodiversity is defined at three levels (ecosystem, species, and genetic) and is often interpreted as a measure of biological complexity and variation within project areas. Although there is little specific regulatory guidance on methods of assessing and monitoring biodiversity, the concept is widely interpreted, especially internationally, as a measure of ecosystem integrity and stability. Following the Convention on Biological Diversity at the 1992 UNEP Earth Summit, international projects funded by World Bank and many other large lending institutions are required to undergo biodiversity assessment and monitoring. No standards for baseline assessment or monitoring of biological resources during mining operations and no standards for post-mining reclamation have been adopted.

The Ahafo South Project will comply with IFC Operational Policy 4.04 – Natural Habitats. Although the Project Area has been described as "degraded due to agricultural and logging activities" (SGS 2004a), portions of the Amama Shelterbelt Forest Reserve adjoining the Bosumkese Forest Reserve retain a characteristic three-story structure with emergent tall trees (often exceeding 50 m in height) and a mixture of deciduous and evergreen species typical of undisturbed, natural habitat. NGGL recognizes that attention must be focused on activities associated with mine development to ensure natural habitats are protected from adverse impacts. Development which may affect natural habitats and forest reserves would not occur prior to completion of detailed baseline studies and impact assessments designed to accurately depict existing biodiversity conditions within these areas, assess potential impacts, and identify management practices and mitigation measures.

DIRECT AND INDIRECT IMPACTS

Construction of the Ahafo South mine and ancillary facilities would directly affect vegetation, soil, and subsoil. Of the total area disturbed by mining activity, more than 50 percent is agricultural land in various food and cash crops, about 40 percent is early seral vegetation associated with cycles of fallow

and cropping (e.g., forb regrowth, fallow thicket, secondary forest, and elephant grass), and about one percent has no vegetation.

Most vegetation to be removed for the Project would be agricultural crops and plant communities composed of pioneer species, having colonized areas that were cultivated as part of the cropping/fallow cycle of agroforestry. A few trees of merchantable size would also be removed; however, the species removed would be of little timber value. Most trees present in the Project area remain following early logging and a long history of agricultural development, and generally are not desirable timber species.

Loss of crop land and early seral vegetation would be a site-specific, long-term, high-magnitude, irreversible impact on sites where disturbed land would not be revegetated (i.e., mine pits and water reservoir); consequently, crop and timber production potential on this land would be permanently lost. The mine pits would fill or partially fill with water. Permanent loss of potential vegetation production on land that would not be reclaimed would reduce available land for vegetation production locally, but would be a small incremental reduction on a regional basis.

Loss of cropland and other vegetation on areas to be revegetated would be a site-specific and local, reversible, long-term impact. With successful reclamation, mined land would likely be capable of supporting crop production within 5 years of project completion; however, little information exists concerning long-term productivity of reclaimed mine land in Ghana for crops and timber. Commercial timber stands would require considerably longer (more than 20 years) to become reestablished.

Operations within the mine footprint would remove native plants; however no plants of conservation priority (i.e., black star or gold star) would be affected. Most of the plants removed would be pink star or green star species. Pink star species are common and widespread commercial species not currently under pressure from exploitation. Green star species are common and widespread in tropical Africa and of no conservation concern. Development of the mine footprint would not increase potential for affected species to be listed on the IUCN Red List or to become black star or gold star species (i.e., species of high conservation priority in Ghana). Impacts on biodiversity would be of increased magnitude and long-term inside the mine footprint, but there would be no effect on local and regional biodiversity.

Removal of vegetation from the mine footprint would have indirect effects on vegetation locally as a result of increased human population density and associated demands for crop production. With removal of land from production and resettlement of affected villages to adjacent areas, population densities would increase locally. Also, with construction and operation of the mine, more people would come to the area seeking jobs or would be employed at the mine. Site-specific and local reductions in crop land from the mine footprint would increase demand for unaffected land outside of the mine disturbance area for crop production, charcoal, and other natural amenities derived from plant communities.

With increased local demands for production of food crops and cash crops, fallow cycles would likely shorten, reducing the productivity of land over the long term. Impacts associated with less arable land and increased demands for arable land, and reduced agricultural productivity would be medium magnitude, long duration impacts that would be realized locally.

NGGL recognizes that the activities of exploring for and developing mineral resources may have an impact on biodiversity. Likewise companies engaged in exploration and mineral resource development can be a positive force for biodiversity conservation. Through sound environmental management, many,

if not all, of the risks or impacts to biodiversity from mineral resource development can be avoided or mitigated. Further, there are good business reasons for mining companies, including NGGL, to contribute to efforts to ensure the healthy functioning of ecosystems in and around their areas of operation. To this end, NGGL is committed to seek to work in effective business-NGO-government partnerships focused on biodiversity conservation in and around the Ahafo South Project area.

ALTERNATIVES ANALYSIS

Partial backfill of mine pits would provide more area for revegetation after cessation of mining, assuming that backfill material would extend above the level of groundwater saturation. This alternative would also result in reduced size of waste rock disposal facilities and areas subject to revegetation.

The waste rock disposal facility closure alternative of reducing slope angles would increase land available for growing crops on the dump itself; however, the larger disturbance footprint that would result from reduced slope angles may offset potential benefits of this alternative. Increasing soil depth over the waste rock disposal facilities would promote growth of agricultural and forest species. Increased soil depth would increase potential moisture and nutrient storage in the rooting zones of vegetation. Capping the waste rock disposal facilities would benefit crop growth if suitable growth medium were placed over the capping material. Moisture would collect at the interface of the capping material and growth medium allowing plants to capture water that could otherwise percolate below rooting zones in the porous waste rock.

Reclamation of the tailing storage facility to support use as farm land would reduce permanent losses of crop and forest production; however, suitable depth and types of growth medium would need to be placed over the tailing material. Sufficient depth of soil placed over the tailing is needed to provide adequate rooting depth for crop species. Land reclaimed at the Abosso Mine (Ghanaian mine closure) indicates that post-mine land use for agricultural production of oil palms is feasible on tailing material.

NO PROJECT ALTERNATIVE

Implementation of the No Project Alternative would eliminate potential impacts to flora described for the Project and closure alternatives. Once NGGL completes reclamation of the area disturbed by initial construction activities, baseline conditions associated with flora are expected to resume.

FAUNA

Like flora, fauna of the Project area has been extensively affected by alteration and fragmentation of habitat resulting from fire, logging, human settlement, and agricultural activities. Bush meat hunting has also reduced numbers and geographic distribution of many mammalian species, especially those associated with forest communities.

LARGE MAMMALS

Thirty-five species of large mammals were recorded in the Project area (**Table 4-13**) (SGS 2000a, 2000b, 2005) including eight primates, five carnivores and eight hoofed animals, all protected in Ghana (First Schedule, Ghana Wildlife Conservation Regulations, 1995). Of the 35 species of large mammal

documented in the Project area, 25 species were found only in Forest Reserves, six species were found only outside Forest Reserves, and four species were found inside and outside of Forest Reserves.

TABLE 4-13
Large Mammals Documented in Project Area

Scientific Name	Common Name	In Forest Reserves	Outside Forest Reserves
Cephalosphus dorsalis	Bay duiker	X	---
Cephalophus macwellii	Maxwell's duiker	X	X
Cephalosphus niger	Black duiker	X	---
Neotragus pygmaeus	Royal duiker	X	---
Tragelaphus scripts	Bush buck	X	---
Potamocheurus porcus	Red river hog	X	---
Boocerus eurycerus	Bongo	X	---
Synerus caffer nanus	Forest buffalo	X	---
Cercopithecus mona	Mona monkey	X	---
Cercopithicus petaurista	Lesser spot-nosed monkey	X	---
Cercopithecus aethiops	Green monkey	X	---
Colobus polykomos	Western pied colobus	X	---
Procolobus versus	Black and white colobus	X	---
Procolobus verus	Olive colobus	X	---
Galagoides demidovi	Bush baby	X	X
Galago senegalensis	Bossman's potto	X	X
Manis tetradactyla	Black-bellied pangolin	X	---
Manis triapiis	White-bellied pangolin	X	---
Phataginus tricuspis	Tree pangolin	X	---
Vivera civeta	Afican civet	X	---
Nandinia binotata	Two-spotted civet	X	---
Genetta maculata	Forest genet	X	---
Mungos obscura	Cusimanse	---	X
Herpestes sanguinus	Dwarf mongoose	X	X
Dendrohyrax arboreus	Tree hyrax	X	---
Cricetomys gambianus	Giant rat	---	X
Atherurus africanus	Brush-tailed porcupine	X	---
Thryonomys nderianus	Cane rat/grasscutter	---	X
Protexerus stangeri	Giant forest squirrel	X	---
Epixerus erythropus	Ground squirrel	---	X
Protoxerus aubinii	Slender-tailed squirrel	---	X
Funisicurus pyropus	Fire-footed rope squirrel	X	---
Funisciurus substriatus	Kintampo rope squirrel	---	X
Anomalurus peli	Pel's flying squirrel	X	---
Anomalurus beecrofti	Beecroft's flying squirrel	X	---

BATS

Eight species of fruit bats were documented in the Project area (**Table 4-14**) (SGS 2000a). This large number of bat species is among the highest in Africa (SGS 1998, 2004a). These bats feed on fruit, pollen, and nectar and are highly beneficial in helping pollinate native trees and shrubs and dispersing seeds over large areas (Nowak 1997; Thomas 1991). Most bats appear to forage and roost in habitats both inside and outside of Forest Reserves, with the exception of Zenker's fruit bat and Woermann's bat, which appear to be obligate forest species.

TABLE 4-14
Bats Documented in Project Area

Scientific Name	Common Name	Outside Forest Reserves	Inside Forest Reserves
Epomophorus gambianus	Gambian epaulet bat	X	X
Hypsignathus monstrosus	Hammerhead bat	X	---
Micropteris pusillus	Lesser epaulet bat	X	X
Myonycteris leptodon	Sierra leone collared fruit bat	X	X
Epomops franqueti	Franquet's bat	X	X
Nannoncteris veldkampi	Veldkamp's bat	X	X
Megaloglossus woermanni	Woermann's bat	---	X
Scotonycteris zenkeri	Zenker's fruit bat	---	X

Source: SGS 2000a.

Fruit bats in Ghana have not been completely studied but it is known that they are migratory from the coastal and upland forests into the savanna zones at the start of the rainy season, retreating back into the forest, months later when the rains end (Thomas 1991). It appears that some species of Ghanaian fruit bats give birth to young at the beginning of the rainy season (May-June) and some may also give birth during the shorter rainy season in November.

SMALL MAMMALS

Six species of small mammals, all rodents, were found in the Project area (**Table 4-15**). The most frequently encountered small mammals were the grass rat and striped grass rat. The pygmy mouse and big-eared swamp rat were the most infrequent. Most were found in forested and un-forested habitats.

TABLE 4-15
Small Mammals Identified in Project Area

Scientific Name	Common Name	Outside Forest Reserves	Inside Forest Reserves
Mus minitoides	Pygmy mouse	X	X
Lophuromys sikapusi	Grass rat	X	X
Arvicanthus niloticus	Nile rat	X	X
Praomys tullbergi	Tullberg's soft-furred mouse	X	X
Malacomys longipes	Big-eared swamp rat	X	--
Lemniscomys striatus	Striped grass rat	X	X

Source: SGS 2000a.

BIRDS

At total of 167 bird species were recorded during Project area surveys (**Appendix B**), with most species observed in the Amama Shelterbelt Forest Reserve (94 species) and Bosumkese Forest Reserve (84 species) (SGS 2005). The majority of birds observed are adapted to habitats in forest or at forest edges. Birds occupying habitat outside of the Forest reserves are able to adapt to early stages of ecological succession and relatively high levels of human activity and are characterized as habitat generalists. Birds restricted to the Forest Reserves often have specific habitat or breeding requirements provided only by forest habitats. For example, some forest species require cavities in large trees for nesting, which are only available in mature forest stands in later stages of ecological succession.

The high diversity of bird species found in forest habitats is an indication of the quality and size of patches of forest habitat (Beier *et al.* 2002). Presence of forest species such as the hornbills and turacos, which are dependent on large fruiting trees, indicates high-quality habitat within parts of the Bosumkese and Amama Shelterbelt Forest Reserves (SGS 2005).

REPTILES AND AMPHIBIANS

Sixteen species of amphibians and reptiles were recorded in the Study area (**Table 4-16**) (SGS 2000a, 2000b, 2005). Of the total number of reptiles and amphibians documented in the Project area, seven species were found only in the Forest Reserves, two species were found only outside of the Forest Reserves, and seven species were found both inside and outside of the Forest Reserves. As previously stated, natural conditions in the Forest Reserves has been substantially degraded.

TABLE 4-16
Reptiles and Amphibians in Project Area

Species	Common Name	Outside Forest Reserves	Inside Forest Reserves
Reptiles			
Dendroaspis viridis	Green mamba	X	X
Naja melanoleuca	Black cobra	X	X
Bitis gabonicus	Gaboon viper	---	X
B. arientans	Puff adder	---	X
Thelotornis kirtlandi	Twig snake	---	X
Crocodylus niloticus	Nile crocodile	---	X
Varanus niloticus	Nile monitor	---	X
Agama agama	Rainbow lizard	X	X
Mabuya affinis	Common skink	X	X
Chameleo gracilis	Chameleon	---	X
Python regius	Royal python	X	---
P. sebae	African python	---	X
Kinixys belliana	Hinged tortoise	---	X
Amphibians			
Bufo regularis	Common toad	X	X
Rana galamensis	Common frog	X	X
Hyperolius fusciventris	African tree frog	---	X

Source: SGS 2000a, 2000b, 2005.

Another measure of species diversity in the Project area relates to the rarity and human demand for species as bushmeat. The Forestry Commission of Ghana (2002) proposed evaluating species diversity based on a genetic heat index similar to that developed by Hawthorne and Abu-Juam (1995) for vegetation (see discussion of biodiversity for *Flora*). This index would rank species on a Star rating system basis as shown in **Table 4-17**. No black, gold, or scarlet star species are present in the Project area. Most species have red, pink, or green star ratings.

TABLE 4-17 Wildlife Ratings for Rarity and Human Demand	
Star Rating for Wildlife Species	**Characteristics**
Black	Upper Guinea endemics
Gold	Guinea-Congolian endemics
Scarlet	Preferred bushmeat vary rare
Red	Preferred bushmeat not common
Pink	Preferred bushmeat, common
Green	Pan tropical

Source: Forestry Commission of Ghana 2002.

In Ghana, the six most preferred bushmeat species, in descending order of preference, are grasscutter, Maxwell's duiker, royal duiker, bushbuck, brush-tailed porcupine, and black duiker (Forest Conservation Archives 2002). All of these species are present in the Project area and are a source of bushmeat. The grasscutter has been documented only in habitats outside Forest Reserves, whereas Maxwell's duiker, royal duiker, and bushbuck are present both inside and outside Forest Reserves. The black duiker and brush-tailed porcupine have been documented only in Forest Reserves. Based on the star rating system to assess genetic heat, the Project area would have a relatively low genetic heat index for wildlife.

SPECIES OF CONSERVATION CONCERN

Several species in the Project area have national or international conservation status. Species documented from the Project area with conservation status are listed in **Table 4-18**. Conservation status is designated by one of the following:

- Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES), which deals with species involved in international trade; Appendix I species are threatened with extinction and CITES prohibits international trade in these species. Appendix II species are not now threatened or endangered but may become so if trade is not controlled. Appendix III species in Ghana are regulated under international trade at the request of the Ghanaian government.

- International Union for Conservation of Nature and Natural Resources (IUCN or the World Conservation Union), which evaluates species based on their level of extinction risk on its Red List. Species on the Red List are ranked as critically endangered (CR), endangered (EN), and vulnerable (VU).

- Ghana Wildlife Conservation Regulations, First Schedule and Second Schedule. First Schedule species are completely protected. Hunting, capturing, destroying is prohibited. Second Schedule species cannot be hunted, captured, or destroyed between August 1 and December 1. Hunting capturing, or destroying of any young or adult accompanied by young of any Second Schedule species is prohibited.

TABLE 4-18
Species with Conservation Status Documented for Project Area

Scientific Name	Common Name	IUCN Red List Status	CITES Status	Ghana Status
Artiodactyla				
Cephalophus dorsalis	Bay duiker	Lower Risk	III	II
Cephalophus maxwelli	Maxwell's duiker	Lower Risk	--	II
Cephalophus niger	Royal duiker	Lower Risk	--	II
Potamocheurus porcus	Red river hog	--	--	II
Syncerus caffer nanus	Forest buffalo	Lower Risk – Conservation Dependent	--	I
Tragelaphus eurycerus	Bongo	Lower Risk	III	I
Tragelaphus scriptus	Bush buck	--	--	II
Primates				
Cercopithecus mona	Mona monkey	--	II	II
Cercopithecus petaurista	Spot-nosed monkey	--	--	II
Cercopithicus aethiops	Green monkey	--	--	II
Colobus polykomos	Black and white colobus	Lower Risk-Near Threatened	--	I
Colobus polykomos	Western pied colobus	Lower Risk – Near Threatened	--	I
Galago senegalensis	Bosman's potto	--	--	I
Galagoides demidovi	Bush baby	--	--	I
Procolobus versus	Olive colobus	Endangered	--	I
Hyrocoidea				
Dendrohyrax arboreus	Tree hyrax	--	--	I
Carnivora				
Genetta maculata	Forest genet	--	--	I
Herpestes sanguinus	Dwarf mongoose	--	--	II
Hydracoidea				
Mungos obscurus	Cusimanse	--	--	II
Nandinia binotata	Two-spotted civet	--	--	I
Vivera civetta	African civet	--	--	I
Pholidota				
Manas tetradactyla	Black-bellied pangolin	--	--	I
Manas transpiis	White-bellied pangolin	--	--	I
Phataginus tricuspis	Tree pangolin	--	--	I
Rodentia				
Athururus africanus	Brush-tailed porcupine	--	--	II
Funisciurus substriatus	Green side-striped squirrel	Data Deficient	--	II
Funisciurus substriatus	Kintampo rope squirrel	Data Deficient	--	II
Protoxerus aubinii	Slender-tailed squirrel	Data Deficient	--	II
Protoxerus stangeri	Giant forest squirrel	--	--	II
Anomalurus peli	Pel's flying squirrel	Endangered	III	I
Anomalurus beecroftii	Beecroft's flying squirrel	--	--	I
Reptilia				
Crocodilius niloticus	Nile crocodile	---		I
Kinixys belliana	Hinged tortoise	Data Deficient	II	II
Python regius	Royal python	--	II	II
Birds				
Bleda eximia	Green-tailed bristlebill	--	--	II
Buteo auguralis	Red-necked buzzard	--	--	I
Bycanistes cylindricus	Brown-cheeked Hornbill	--	II	II
Bycanistes fistulator	Piping hornbill	--	--	II
Bubo poensis	Fraser's hawk eagle	--	--	I

TABLE 4-18
Species with Conservation Status Documented for Project Area

Scientific Name	Common Name	IUCN Red List Status	CITES Status	Ghana Status
Ceratogyman elata	Yellow-casqued hornbill	--	II	II
Ceratogymna atrata	Black-casqued hornbill	--	--	II
Columba iriditorques	Western bronze-naped pigeon	--	--	II
Columba unicincta	Afep pigeon	--	--	II
Corythaeola cristata	Great blue turaco	--	--	II
Crinifer piscatorax	Grey plantain eater	--	II	II
Elanus caeruleus	Black-shouldered kite	--	--	II
Euplectus orix	Red bishop	--	--	II
Falco ardosiacus	Grey kestrel	--	--	I
Falco cuvierii	African hobby	--	--	I
Francolinus ahantensis	Ahanta francolin	--	--	II
Francolinus bicalcaratus	Double-spurred francolin	--	--	II
Gypohierax angolensis	Palm-nut vulture	--	--	I
Kaupifalco monogrammicus	Lizard buzzard	--	--	I
Lagonostica senegala	Senegal fire-finch	--	III	II
Lochura cucullata	Orange-cheeked waxbill	--	III	II
Lonchura cucullata	Bronze manakin	---	III	II
Lophaetus occipitalis	Long-crested eagle	--	--	I
Milvus migrans	Black kite	---	II	I
Neophron manachus	Hooded vulture	---	II	I
Ploceus cuculatus	Village weaver	---	III	II
Ploceus niggerimus castaoneofuscus	Veillot's black weaver (western)	--	III	II
Ploceus niggerimus niggerimus	Viellot's black weaver (eastern)	--	III	II
Ploceus superciliousus	Village weaver	--	III	II
Poicipphalus gulielmi	Red-fronted parrot	--	--	II
Poicipphalus robustus	Brown-necked parrot	--	---	II
Polyboroides typus	African harrier hawk	--	--	I
Psittachus erathicus	Grey parrrot	--	---	II
Streptopelia decipiens	Mourning dove	--	---	II
Streptopelia semitorquata	Red-eyed dove	--	--	II
Strix woodfordii	African wood owl	--	--	I
Tauraco macrorhyncus	Yellow-billed turaco	--	--	II
Tauraco persa	Green-crested tauroco	--	--	II
Tockus albocristatus	White-crested hornbill	--	--	II
Tockus fasciatus	African pied hornbill	--	--	II
Tockus nasutus	African grey hornbill	--	--	II
Treron australis	Green fruit pigeon	--	--	II
Turtur afer	Red-billed wood dove	---	III	II
Turtur brehmeri	Blue-headed wood pigeon	--	--	II
Treron calvus	African green pigeon	--	--	II
Turtur typanistra	Tambourine dove	--	---	II
Vidua macroura	Pin-tailed whydah	--	III	II

FAUNA CHANGES

Biological surveys conducted in the Project area, outside of Forest Reserves in 1997, 1999, and 2005 indicate trends in faunal composition and distribution associated with habitat alterations resulting from increased levels of human development outside of the Forest Reserves. Data collected in 1997 and 1999 recorded 24 mammal species compared to five species in 2005. Species recorded in recent surveys are typical of degraded habitats and include slender mongoose, giant rat, grasscutter, striped ground squirrel, and green side-striped squirrel. Mammals usually associated with forest habitat, recorded in earlier surveys, that were not found in surveys conducted in 2005 include bushbuck, red river hog, black duiker, Maxwell's duiker, royal antelope, African civet, African palm civet, cusimanse, spot-nosed monkey, green monkey, Demidoff's galago, Bossman's potto, long-tailed pangolin, tree pangolin. One species of international concern, Pel's flying squirrel (IUCN Endangered) was recorded in 1997 but not 2005 (SGS 2005).

Changes in species observed between surveys in the late 1990s and 2005 may be attributable to reduced numbers and distributions of species, associated with habitat degradation and increased human activities, or insufficient survey intensity to find species that are widely distributed, with low population densities. Generally, wildlife observed in Forest Reserves were similar among the sampling surveys conducted on 1997, 1999, and 2005, with the exception of bongo and olive colobus, which were not observed in 2005. Lack of observations in 2005 of these species may indicate reduced numbers and range of distribution, or survey intensity sufficient to detect widely distributed species with low population densities.

DIRECT AND INDIRECT IMPACTS

Direct effects from development of mine pits, waste rock disposal facilities, tailing storage facility, and other ancillary facilities would have the potential to remove wildlife habitat for species adapted to relatively high levels of human activity. Loss of habitat would reduce local availability of forage, security, and breeding cover for wildlife inhabiting the area. All species dependent on these sites would be killed or displaced. Displaced animals may be incorporated into adjacent populations, depending on variables such as species behavior, density, and habitat quality. Adjacent populations may experience increased mortality, decreased reproductive rates, or other compensatory or additive responses.

Removal of habitat, displacement, and direct mortality from the mine development would mostly affect wildlife species that are habitat generalists that have adapted to high levels of human activity. Mammalian species that would be affected include Maxwell's duiker, bush baby, Bossman's potto, cusimanse, dwarf mongoose, giant rat, grasscutter, ground squirrel, slender-tailed squirrel, five species of fruit bat, and six species of small mammals. Eight species of reptiles and amphibians and 75 species of birds would also have the potential to be adversely affected. The larger, more-mobile species would generally flee from construction activities to adjacent habitats; whereas, smaller, less-mobile species and young of some species would be killed during the construction phase of the Project.

Following mining, the mine pits would fill with water to near pre-mine groundwater levels. These mine pit areas would be permanently lost as habitat for terrestrial species. Depending on water quality in the pit lakes, some species of bats, birds, and other wildlife may be able to use the pit lakes as a drinking water source. If water in the pit contains high concentrations of heavy metals or other toxic constituents, long-term ingestion by wildlife may pose a risk to some species.

Loss of habitat and displacement from areas of disturbance would be long duration with increased site-specific and local impacts. Direct mortality would be short-term, site specific, and result in some species being killed. Direct mortality would not affect the viability of local wildlife populations or increase the potential for new species to be listed on the IUCN or Ghana Wildlife Regulations, First Schedule list.

Several species that are protected under the First Schedule, Ghana Wildlife Regulations have been documented to use habitats in the area of the mine footprint and other facility sites (i.e., black kite, hooded vulture, bush baby, Bosman's potto). It is unlikely that adults of black kite and hooded vulture would experience direct mortality from development of the mine because they are mobile and would avoid human activities. Black kite and hooded vultures are common scavengers around villages and nest in trees. If trees with active black kite and hooded vulture nests were destroyed, young and eggs would be lost; however, these species are common and loss of a small number of nests would not affect local or regional populations. The bush baby and Bosman's potto are nocturnal, tree-dwelling primates that may seek shelter in trees that would be removed by mine construction activities; consequently, they may be vulnerable to mortality associated with clearing of vegetation for the Project.

Habitat loss and mortality of species with conservation priority (First Schedule Ghana Wildlife Regulations), as a result of the Ahafo South Project, may result in site-specific loss of individuals. Individuals of conservation priority may be reduced or eliminated on mined areas. Future developments would not likely have detectable effects on local or regional population numbers or result in loss of population viability or reduction in biodiversity.

NGGL recognizes the importance of preserving habitat and has developed programs to ensure healthy functioning ecosystems are maintained through management practices, protection and conservation measures, restoration projects, and other mitigation measures. These programs are discussed in more detail in Chapter 5 – *Environmental and Social Action Plan*.

ALTERNATIVES ANALYSIS

Pit lake management alternatives involving partial backfilling the pit would reduce risk to wildlife associated with high concentrations of trace elements that may be present in the water. Pumping and treating water from pit lakes would improve water quality and allow aquatic species to use this habitat. Fencing around the mine pit rims would prevent or minimize terrestrial wildlife from entering the pits. If the pit lake were to have suitable water quality to sustain aquaculture, this source of protein could reduce the tendency to supplement dietary protein needs with bush meat, although it would need to be combined with a conservation education program for local Ghanaians.

Waste rock disposal facility alternatives would have similar effects as those described for the current project. Some species of wildlife could use additional habitat developed on the waste rock disposal facilities if slopes are reduced. Reclamation of the tailing storage facility to support crop production would benefit "generalist" species of wildlife that utilize habitat with high levels of human activity.

NO PROJECT ALTERNATIVE

Implementation of the No Project Alternative would eliminate the potential impacts to fauna that are described for the Project and closure alternatives. Once NGGL completes reclamation of the area disturbed by initial construction activities, baseline conditions associated with fauna are expected to resume.

WETLANDS

The government of Ghana has developed a National Wetlands Conservation Strategy to identify and protect wetlands with significant ecological functions and values (Ghana Ministry of Lands and Forestry 1999). The National Wetlands Conservation Strategy identifies wetlands as a range of habitats that have common features, the most important of which is continuous, seasonal, or periodic water or saturated soils. Wetlands include areas of marsh, fen, peat, or water, whether natural or artificial or flowing, fresh, brackish or salty. The National Wetlands Conservation Strategy discourages the following activities in wetlands with significant ecological functions and values:

- Physical draining of wetland water.
- Draining streams and water courses feeding the wetlands.
- Human settlements and their related infrastructural developments in wetlands.
- Disposal of solid waste and effluents in wetlands.
- Mining in wetlands.

DIRECT AND INDIRECT IMPACTS

The Ahafo South Project would result in the filling of riparian/wetland areas in the Subri drainage as a result of construction of the tailing storage facility and the water storage dam. Although wetlands would be lost through construction of ancillary facilities, new wetlands would be created by the water storage facility and environmental control dams. The net effect would likely be that more riparian/wetland areas would be created than destroyed. None of the wetlands that could be affected have been identified as having high ecological functions and values, warranting conservation priority.

Indirect impacts to wetlands would result from altered streamflows in drainages downstream from water impoundments and the mine pits. Changes in hydrological regime would have potential to reduce areas of wetlands downstream from these facilities. Due to the seasonal nature of surface water flow in these tributary drainages, however, these hydrologic effects should be minor. Non-point sediment discharge from soil disturbance associated with mine development and operation could be deposited in wetlands if such sediment loss is not controlled near the source areas.

ALTERNATIVES ANALYSIS

Pit lake management alternatives would result in no additional impacts to wetlands. Waste rock disposal facility alternatives would have similar effects as those described for the current project. Some additional wetland areas could be filled if the waste rock disposal facility slopes are reduced.

Constructing a capping system on waste rock disposal facilities to reduce infiltration could increase surface water flow downstream which could benefit wetland hydrology. Reclamation of the tailing storage facility to support crop production could provide for opportunities to develop wetlands on the reclaimed surface. Implementation of a water treatment facility at the waste rock disposal facility and/or tailing storage sites would improve water quality in the vicinity of these facilities that could also benefit wetland hydrology.

NO PROJECT ALTERNATIVE

Implementation of the No Project Alternative would eliminate potential impacts to wetlands that are described for the Project and closure alternatives. Once NGGL completes reclamation of the area disturbed by initial construction activities, baseline conditions associated with wetlands are expected to resume.

AQUATIC ORGANISMS

FISH

Nine species of fish belonging to five families were sampled from the three stations on the Tano River (**Table 4-19**) (SGS 2000a, 2000b).

Fishes of the Family Characidae (characins) were the most common, comprising more than 50 percent of the catch at each station. Cichlids (tilapia family) were the next most common group of fishes. Members of the Family Osteoglossidae (bony-tongued fishes) and Anabantidae (climbing perch) were scarce and encountered only at Acherensua, while catfish of the Family Bagridae were caught exclusively at Yamfo.

TABLE 4-19
Fish Species Composition at Tano River Sample Sites

Family/Species	Fish Number and (% Composition)		
	Ntotoroso	Acherensua	Yamfo
Characidae (characins)			
Brycinus nurse	10 (41.7)	1 (4.3)	8 (16.0)
Brycinus macrolepidotus	1 (4.2)	2 (8.7)	20 (40.0)
Brycinus leuciscus	1 (4.2)	5 (21.7)	8 (16.0)
Brycinus longipinnis	1 (4.2)	6 (18.8)	-
Cichlidae (tilapia)			
Pelmatochromis guntheri	8 (33.3)	6 (18.8)	6 (12.0)
Sarotherodon galilaeus	3 (12.5)	1 (4.3)	5 (10.0)
Osteoglossidae (bony-tongued fishes)			
Heterotis niloticus	-	1 (4.3)	-
Anabantidae (climbing perch)			
Ctenopoma petherici	-	1 (4.3)	-
Bagridae (catfish)			
Chrysichthys maurus	-	-	3 (6.0)
Total number of fish	**24**	**23**	**50**

Source: SGS 2000a and 2000b.

BENTHIC INVERTEBRATES

A summary of species richness of benthic invertebrates at each sampling station is presented in **Table 4-20** (SGS 2000a, 2000b). Benthic invertebrates consisted mainly of nymphs and larvae of insects, round worms (nematodes) and snails. Midge larvae (Chironomidae) were dominant at each station, except for Acherensua where mayfly nymphs (Ephemeroptera) were equally well represented. Of the five species of midge larvae encountered, *Stenochironomus* sp. was the most abundant (**Table 4-21**).

At Ntotoroso, midge larvae, *Stenochironomus* sp. were of the highest density (93.3 individuals/m^2), followed by nematodes (88.9 individuals/m^2). *Stenochironomus* sp. also had the highest density at Yamfo. However, at Acherensua, the mayfly nymph, *Caenomedea* sp. was the benthic organism with the highest density (137.8 individuals/m^2).

Chironomids, mainly *Stenochironomus* sp. were most abundant at Ntotoroso and Yamfo, while mayfly nymphs were the most abundant at Acherensua. Differences in density appeared to be attributable to the variations in the substrates. Chironomid larvae prefer soft muddy bottoms.

BIODIVERSITY

There are few data in Ghana concerning species diversity of fish and benthic invertebrates in various types of aquatic habitats in central Ghana. There is little harvest of fish from the Tano River because traditionally fishing is not allowed on portions of the river due to spiritual values. It is likely that biodiversity of the Tano River over the area sampled is probably typical of other perennial streams in central Ghana.

DIRECT AND INDIRECT IMPACTS

Construction of the water storage facility, tailing storage facility, and environmental control dams in the Subri drainage could affect fish and aquatic insects present in the stream by altering natural patterns of flow in the stream. These facilities and the mine pits would reduce water flow to the Tano River from the Subri sub-basin. Following construction, the water storage facility would likely become a productive habitat for fish and aquatic invertebrates. Some increases in sediment load to the Tano River also could result from construction of mine-related facilities, although the environmental control dams are expected to contain most sediment from disturbance areas.

The water storage facility would likely result in increased breeding habitat for mosquitoes and aquatic invertebrates such as snails. Because mosquitoes are carriers of malaria, and snails are host for a stage in the life cycle of a parasite that causes the disease bilharzia in humans, humans may be negatively affected by enhanced habitat for aquatic organisms.

Mine pits remaining after mining would partially fill with water. Depending on water quality, these water bodies may become habitat for fish and other aquatic organisms. If water quality is poor, fish and aquatic organisms likely would not become established in pit lakes.

TABLE 4-20
Number of Benthic Invertebrate Species Recorded at Tano River Sample Stations

Station	Number of Species
Ntotoroso	8
Acherensua	14
Yamfo	9

Source: SGS 2000a, 2000b.

TABLE 4-21
Density and Percent Compositions of Benthic Invertebrates Sampled in Tano River

Group	Family/Species	Mean Number per m²			Composition (%)		
		Ntotoroso	Acherensua	Yamfo	Ntotoroso	Acherensua	Yamfo
Coleoptera	*Elmidae*						
	Potamodytes sp	4.4	31.1	4.4	1.3	6.6	1.9
Diptera	Chironommidae						
	Stictochironomus sp	26.7	62.2		8.0	13.2	-
	Stenochironomus sp	93.3	71.1	93.3	28.0	15.1	38.9
	Crytptochironomus sp	-	48.9	17.8	-	10.4	7.4
	Orthoclidus sp	-	4.4	-	-	0.9	-
	Polypedilum fuscipenne	-	-	17.8	-	-	7.4
	Ceratoponidae						
	Unknown	53.3	40.0	53.3	16.0	8.5	22.2
Ephemeroptera	Caenidae						
	Caenomedea sp	53.3	137.8	8.9	16.0	29.2	3.7
	Leptophlebiidae						
	Thraulus sp	4.4	26.7	-	1.3	5.7	-
	Adenophleboides	-	4.4	-	-	0.9	-
	Tricorithydae						
	Dicercomyzon sp	-	4.4	-	-	0.9	-
Trichoptera	Ecnomidae						
	Economus sp	-	13.3	-	-	2.8	-
	Leptoceridae						
	Leptocerus sp	-	8.9	-	-	1.9	-
	Polycentropodidae						
	Dipseudopsis capensis	-	-	17.8	-	-	7.4
Odonnata	Gomphidae						
	Ictinogomphus sp	-	13.3	-	-	2.8	-
	Lestinogomphus sp				2.7	-	1.9
Nematoda	Unknown sp.	88.9	-	22.5	26.7	-	9.3
Gastropoda	Planorbidae						
	Unknown sp.	-	4.4	-	-	0.9	-

ALTERNATIVES ANALYSIS

Pit lake management alternatives involving partial backfilling the pit would eliminate potential for habitat for fish and aquatic organisms in these water bodies; however, they would only be backfilled if water quality was expected to be poor and if partial backfilling was determined to be the most economical method for minimizing effects of the water. The alternative of pumping and treating water from pit lakes would improve water quality and allow fish and aquatic species to develop in this habitat.

Development of an aquaculture facility would introduce some fish species to the lakes for economic benefit by local residents.

Waste rock disposal facility alternatives would have similar effects as those described for the current project. Implementation of a water treatment facility at the waste rock disposal facility and/or tailing storage sites would improve water quality in the vicinity of these facilities that could also benefit fish and aquatic organisms in the overall Project area.

NO PROJECT ALTERNATIVE

Implementation of the No Project Alternative would eliminate the potential impacts to aquatic organisms that are described for the Project and closure alternatives. Once NGGL completes reclamation of the area disturbed by initial construction activities, baseline conditions associated with aquatic organisms are expected to resume.

PHYSICAL ENVIRONMENT

Topography of the Project area consists of low rounded hills with elevations ranging from 110 to 540 m above mean sea level (amsl). Seasonal streams and tributaries of the Tano River basin drain the broad, relatively flat valleys. Land use in the Ahafo South Project area consists primarily of subsistence farms with small-scale commercial farming, intermingled with areas of forest regrowth and remnants of secondary forest. The Ahafo South Project shares a boundary with the Bosumkese Forest Reserve. The Amama Shelterbelt Forest Reserve intersects the Ahafo Concession to adjoin the Bosumkese Forest Reserve.

AIR QUALITY

BASELINE CONDITIONS

According to a country profile on environment in Ghana performed by the Japan National Cooperation Agency in 1999, air pollution in Ghana is not currently of a "serious" nature. The main areas of compromised air quality are industrial and mining areas. Vehicular emissions are not considered problematic, and the U.S. Environmental Protection Agency (USEPA) monitors air quality in the city of Accra in collaboration with the Vehicle Examination and Licensing Division of the Ministry of Road and Transport.

Industrial emissions sources in Ghana include aluminum smelter and alumina transportation, oil refineries, cement and asbestos plants, steel works, sawmills and wood processing plants, and gold, bauxite and manganese mines. The nearest industrial/mine site to the Ahafo South Project is the Bibiani Mine approximately 70 km southeast. Emissions from these sources include:

- Fluorides
- Sulfur dioxide and other sulfur oxides
- Nitrogen dioxide and other nitrogen oxides
- Carbon monoxide
- Condensed sulfate particles
- Condensed nitrate particles

- Alumina dust
- Asbestos particles
- Cement dust
- Iron oxides
- Antimony oxides
- Dust

No ambient air quality measurements are available for the Project area, except for some dust-fall information (Winges 2005). NGGL has implemented an air quality monitoring program to establish a baseline condition prior to commencing mining operations. Dust emissions will be monitored during construction to ensure standards are met. Air quality in the Project area would likely meet organization standards (WHO, EU, World Bank, USEPA), with the exception of high wind and dust periods (such as during the Harmattan wind period). Under these circumstances, concentrations of particulate matter may exceed standards for short periods. The particulate matter in these cases is mainly composed of silicon dioxide minerals.

DIRECT AND INDIRECT IMPACTS

Tables 4-22 and **4-23** show operating statistics and emission inventory completed for Phase I of the Ahafo South Project. Phase I is for the first 5 years of operation where the southern mine pits would be developed. Units are given in millions of U.S. tons per year (MMTPY), vehicle miles traveled (VMT) and U.S. tons per year (TPY). Fugitive dust sources from the Project could total over 380 U.S. tons per year, with main contributions resulting from wind erosion of exposed areas, waste rock and ore mining, and dumping rock at the waste rock disposal facilities.

TABLE 4-22
Mine Operating Statistics – Ahafo South Project

Pit	Ore Rem Shov (MMTPY)[a]	Ore Haul VMT [b]	Ore Blast /Year	Waste Rem Shov (MMTPY)[a]	Waste Haul VMT [b]	Waste Blasts /Year	Water Truck Hours	Water Truck VMT	Total Dump Truck VMT	Open Ha
Prior to Year 5 – Southern Mine Pits	7.76	208,169	160	31.449	84,241	640	8,760	87,600	292,410	2,174

Source:
(a) Newmont Mining Corporation AHAFO Project Report, January 2004, Table 2.3
(b) Measurements taken from Treatment Site General Project Site Plan Figure, Dated June 8, 2004, Lycopodium
Note: MM = million; TPY = U.S. tons per year; VMT = vehicle miles traveled; Ha = hectares.

Impacts to air quality resulting from emissions presented in **Table 4-23** can be estimated using air quality modeling techniques. Air quality models are commonly used to determine concentration increases caused by increases in emission rates. An air quality model is a mathematical representation of atmospheric behavior that allows concentrations to be calculated from meteorological data and information on quantities and locations of emissions being released.

For the current Project, the Industrial Source Complex Short Term Version 3 (ISCST3) model was used. The ISCST3 model was developed by the USEPA and is the most commonly used air quality model in the United States. Emission rates used in the model are specified in **Table 4-23**. Emissions were placed in a series of area and volume sources used to represent various mine pits, waste rock

disposal facilities, hopper, and roads considered to be sources of dust at the mine. A total of 349 separate emission sources were identified in the model.

Since on-site meteorological data were not available for the Project area, a screening approach was used where a series of one-hour meteorological scenarios are provided to the model, involving different combinations of wind speed, wind direction, and atmospheric mixing conditions. A total of 6,480 different one-hour meteorological scenarios were used in the model.
Concentrations were computed at a series of 6,536 locations, called receptors, in the Project area. These receptors were placed on a regularly spaced grid covering an area 17,000 by 15,000 meters, with the mining operation roughly at the center of the grid. The spacing of receptors was set at 200 meters.

TABLE 4-23
Annual PM_{10} Fugitive Emissions Summary for Ahafo South Mine

Year	Fugitive Dust Emission from Mine-Related Activity or Disturbance Area (U.S. tons per year)										
	Ore Rem Shov	Ore Dump	Ore Haul	Ore Blast	Waste Rem Shov	Waste Haul	Waste Blast	Waste Dumping	Water Truck	Wind Erosion	Area Total
Prior to Year 5	2.4	7.4	24.5	0.6	70.8	9.9	3.6	67.7	4.6	195.9	**387.4**

Assumptions

Value	Variables	Value	PM10 Emission Factors
100	wet days	3.485	E_scrap (lbs/hr)
0.3	PM10/TSP	0.005	Waste E_shov (lbs/ton)
1.5	bulk density (ton/bcy)	0.001	Ore E_shov (lbs/ton)
0.5	control water	0.002	Ore E_dump (lbs/ton)
0.4	control suppressant	0.075	E_wind (ton/acre/yr)
0.5	water sprays on truck dump	0.235	Waste E_haul (lbs/vmt)
8.6	silt (%)	0.235	Ore E_haul (lbs/vmt)
15	speed ore (mph)	0.105	Water E_haul (lbs/vmt)
15	speed waste (mph)	3.485	E_grade (lbs/hr)
10	speed water (mph)	11.250	Waste E_blast (lbs/blast)
2.5	tire correction factor	7.875	Ore E_blast (lbs/blast)
200	mean dump truck weight	0.009	Waste E_drag (lbs/yd^3)

Assumptions, aside from those listed, include the following:
1. Projected Waste and Ore amounts were estimated from **Table 2.3** – Life-of-Mine Ore, Gold, and Waste Rock Production, Ahafo South Project (Newmont Mining Corporation AHAFO Project Report, January 2004).
2. Total Ore – 105,601,548 tonnes over 15 year period
3. Total Waste – 360,078,314 tonnes over 15 year period
4. Ore and Waste Rear Haul Dump Trucks have an approximate payload of 100 U.S. tons and travel at 10 mph
5. Ore and Waste number of blasts per year were provided directly by Newmont via email correspondence and are equal to 500 to 800, with 20% of the blasts used for ore and 80% used for waste
6. Open acres that would be susceptible to wind erosion were estimated from Table 2-2, Surface Disturbance by Mine Component (Newmont Mining Corporation AHAFO Project Report, January 2004).
7. Pit areas were estimated from Take Area drawings provided by Newmont Mining Company.
8. The water truck will be in operation 24 hours a day for a total of 8,760 hours per year
9. Haul road distances were estimated from Take Area drawing provided by Newmont Mining Company and Treatment Site General Project Site Plan Figure (Lycopodium June 8, 2004).
10. Fugitive dust emissions from vehicular traffic on the Notoroso-Kenyase Public Road and the proposed Bypass Road were not included in this emission inventory

Note: PM_{10} = particulate matter at 10-micron size; TSP = total suspended particulates; TPY = U.S. tons per year; bcy = bank cubic yard; mph = miles per hour; lbs = U.S. pounds; hr = hour; yr = year; yd3 = cubic yard; vmt = vehicle miles traveled; Rem = ???; Shov = shovel.

One-hour concentrations were calculated at each of the 6,536 receptors for every one of the 6,480 meteorological scenarios and the results were sorted to find the peak value at each receptor. The final step in the process was to estimate longer averaging time concentrations for these peak values. The

method provides simple factors for estimating 24-hour and annual average concentrations from one-hour concentrations. These values simply involve multiplying the one-hour value by 0.4 to obtain the 24-hour estimate and by 0.08 to obtain the annual average estimate.

Results of the modeling analysis are depicted in **Figures 4-4** and **4-5** showing isopleths of PM_{10} concentrations (particulate matter 10-micron size) for the 24-hour and annual time averages, respectively. The figures may be compared to previously mentioned guidelines or standards.

mines\EIS\ghana\ahafo\cadpro\chapter4\air_24hr.dwg

WAMAHINSO
AMAMA PIT
WASTE ROCK DUMP
ENVIRONMENTAL CONTROL DAM NO. 7
NTOTOROSO
NTOTOROSO RESETTLEMENT SITE
WATER STORAGE FACILITY
SPILLWAY
EXPLOSIVES MAGAZINE
EMERGENCY SPILLWAY
WASTE ROCK DUMP
TAILING STORAGE FACILITY
ENVIRONMENTAL CONTROL DAM NO. 2
TANO RIVER PUMPING STATION
CAMP
AWONSO PIT
STOCKPILES
PLANT BYPASS ROAD
BOSUMKESE FOREST RESERVE
WASTE ROCK DUMP
PLANT SITE
APENSU PIT
ENVIRONMENTAL CONTROL DAM NO. 4
ENVIRONMENTAL CONTROL DAM NO. 3
WASTE ROCK DUMP
KENYASE NO. 2 RESETTLEMENT SITE
SUBIKA PIT
WASTE ROCK DUMP
FUTURE NTOTOROSO/KENYASE PUBLIC ROAD ALIGNMENT
ENVIRONMENTAL CONTROL DAM NO. 6
SENIOR STAFF VILLAGE
KENYASE No. 2
KENYASE No. 1
KENYASE BYPASS ROAD
AKYERENSUA
Konkontreso
Kosuso
Dwenase
Kofimanukurom
Tawiakurom
Osekawin
Amamokurom

25
50
75
100
125

N

0 Kilometers 3

1:63,360
Contour Interval = 6 Meters

- Existing Primary Road
- Existing Secondary Road
- Proposed Haul Road
- Forest Reserve Boundary
- Pipeline
- Lease Boundary
- Take Area
- Take Area Undetermined
- Isopleths of 24-Hour PM-10 Concentrations (µg/m³) Predicted From Mining Sources

Isopleths of 24-Hour PM_{10} Concentrations
Ahafo South Project
Brong Ahafo Region, Ghana
FIGURE 4-4

mines\EIS\ghana\ahafo\cadpro\chapter4\air_24hr.dwg

WAMAHINSO

NTOTOROSO

NTOTOROSO RESETTLEMENT SITE

ENVIRONMENTAL CONTROL DAM NO. 7

ENVIRONMENTAL CONTROL DAM NO. 2

TANO RIVER PUMPING STATION

RANK CAMP

SPILLWAY

EXPLOSIVES MAGAZINE

WATER STORAGE FACILITY

EMERGENCY SPILLWAY

WASTE ROCK DUMP

TAILING STORAGE FACILITY

AWONSU PIT

STOCKPILES

PLANT

PLANT BYPASS ROAD

ENVIRONMENTAL CONTROL DAM NO. 3

APENSU PIT

ENVIRONMENTAL CONTROL DAM NO. 4

SUBIKA PIT

FUTURE NTOTOROSO/KENYASE PUBLIC ROAD ALIGNMENT

ENVIRONMENTAL CONTROL DAM NO. 6

KENYASE NO. 2 RESETTLEMENT SITE

KENYASE No. 2

KENYASE No. 1

SENIOR STAFF VILLAGE

KENYASE BYPASS ROAD

BOSUMKESE FOREST RESERVE

AKYERENSUA

Konkontreso

Kosuso

10

20

N

0 Kilometers 3

1:63,360

Contour Interval = 6 Meters

Existing Primary Road

Existing Secondary Road

Proposed Haul Road

Forest Reserve Boundary

Pipeline

Lease Boundary

Take Area

Take Area Undetermined

Isopleths of Annual Average PM-10 Concentrations ($\mu g/m^3$) Predicted From Mining Sources

Isopleths of Annual Average PM_{10} Concentrations

Ahafo South Project

Brong Ahafo Region, Ghana

FIGURE 4-5

For comparative purposes using U.S. ambient air quality standards, a relatively small area surrounding the processing facilities shows concentrations in excess of the ambient air quality standards for both 24-hour and annual averages. The primary cause of high dust concentration in the modeled area in **Figures 4-4** and **4-5** is the dumping of ore from mining operations at the primary crusher site near the processing plant. A true comparison with ambient standards would require addition of an existing or background level to these increases by the mining sources, but background concentrations are not available. Therefore, there is uncertainty in the model results with respect to quantifying impacts from the Ahafo South Project.

Fugitive dust emissions will be controlled using direct water application, chemical binders or wetting agents, and by revegetation of disturbed areas concurrent with operations. Haul and access roads will be kept wet or sealed to reduce fugitive dust on crops and other vegetation. Dust suppression sprays and dry dust collection systems will be installed on ore crushing circuits and transfer points in the processing plant.

ALTERNATIVES ANALYSIS

Potential impacts to air quality resources associated with implementation of closure alternatives would be similar to those described for the current South Ahafo Project. If the waste rock disposal facility slopes were decreased, additional earthwork and generation of dust would occur.

NO PROJECT ALTERNATIVE

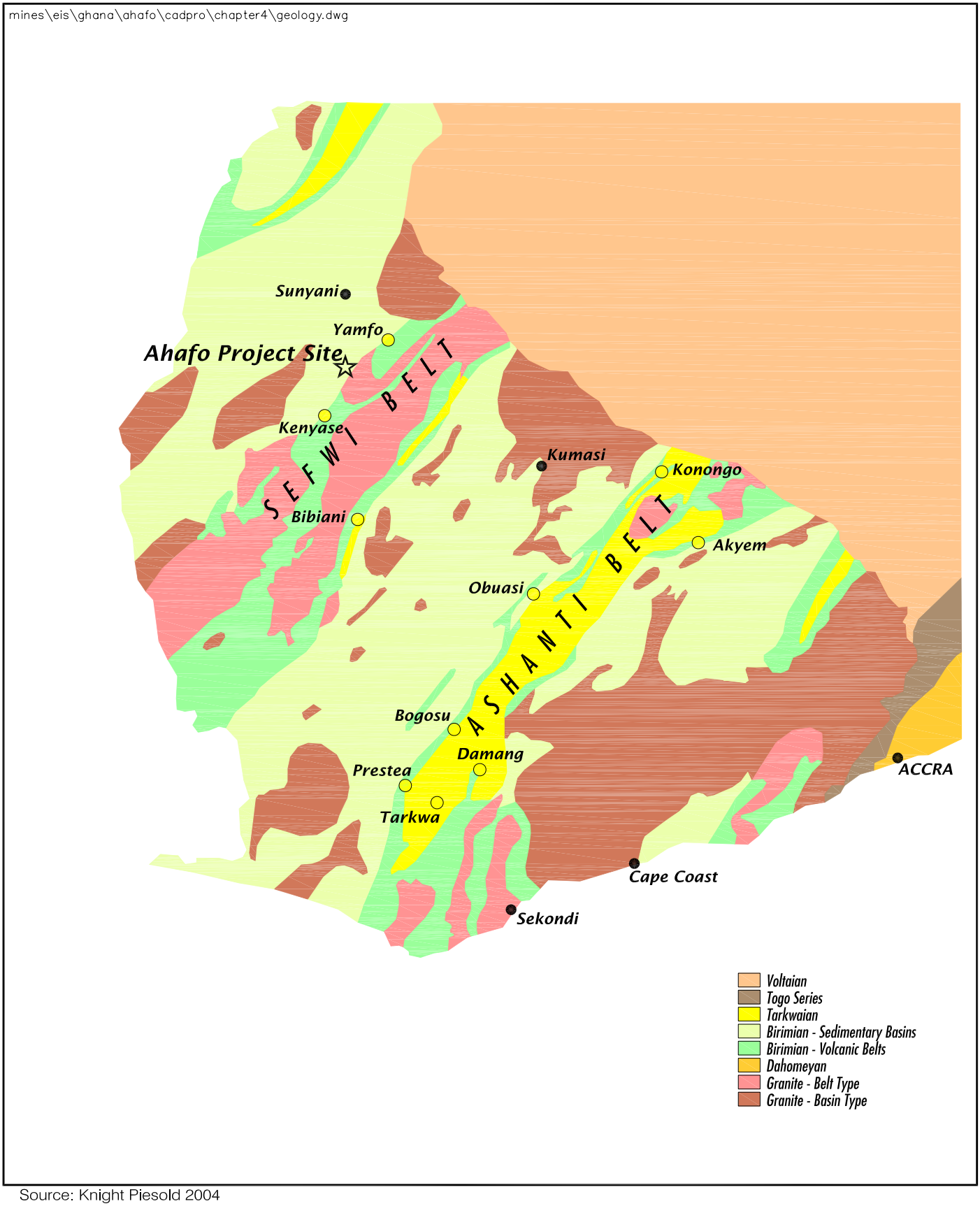
Implementation of the No Project Alternative would eliminate the potential impacts to air quality that are described for the Project and closure alternatives. Once NGGL completes reclamation of the area disturbed by initial construction activities, baseline conditions associated with air quality are expected to resume.

GEOLOGY AND MINERALS

The Ahafo Project area occurs within Kwahu Plateau region of the Ashanti Uplands of west-central Ghana. The Kwahu Plateau forms a major physiographic drainage divide that trends form northwest to southeast and ranges in elevation from 450 to 762 m. This drainage divide separates rivers draining to the north and into the Volta River drainage from a number of smaller rivers that drain to the south, many of them to the Gulf of Guinea.

REGIONAL GEOLOGIC SETTING

Ghana falls mostly within the Precambrian Guinea Shield of the West African Craton, which stabilized, in the early Proterozoic (about 2000 Ma). These early Proterozoic rocks comprise extensive northeast-trending belts of folded, metamorphosed volcanic and sedimentary rocks (i.e. Birimian and Tarkwaian units) (**Figure 4-6**). Intruded into the Birimian rocks are large masses of granite and granodiorite. Late Proterozoic to Paleozoic sedimentary rocks of the Voltaian System overly the older Precambrian rocks and consist of sandstone, mudstone, conglomerates, limestone and tillites (Ghana Mineral Commission and Watts, Griffin, and McQuade (WGM) 1998). Across southwestern Ghana, the area can be divided geologically into four distinct terrains, based on the major rock type or systems that outcrop:



Source: Knight Piesold 2004

Geology of Southwest Ghana
Ahafo South Project
Brong Ahafo Region, Ghana
FIGURE 4-6

- An early Proterozoic terrain (Birimian System) with older metavolcanics (intrusive dikes and mafic lava flows) of basaltic and andesitic composition. These mildly metamorphosed volcanic units exhibit pillow structures indicating subaqueous eruption of the original basaltic lavas. These metavolcanics underlie younger sedimentary sequences comprised of greywacke, turbidites, volcaniclastics and argillites. Together these units form six sub-parallel belts of volcanic rock separated by broad "basins" of sedimentary rocks (**Figure 4-6**). The Ahafo gold deposits are developed on the flank of one of these northeast-southwest trending belts, the Sefwi Volcanic Belt, and along its contact with Sunayani Basin sediments to the northeast.

- The Tarkwaian System is a distinctive sequence of clastic sediments, which were deposited in sedimentary basins that form the core of many of the Birimian volcanic belts (i.e., 250 km long Ashanti Belt. Tarwkwaian sediments are generally lacking in the vicinity of the Ahafo deposits.

- The Voltaian Basin, in which are preserved the late Precambrian to Paleozoic sediments that mantle the craton.

- Intrusive rocks that have been emplaced in Birimian and Tarkwaian rocks, some of which (Belt-type) are intrusive equivalents of the Birimian Volcanics. These intrusive rocks host most of the gold mineralization at Ahafo.

Gold is principally associated with belts of Proterozoic Birimian and Tarkwaian rocks. The bulk of the gold, about 80 percent, comes from primary lode occurrences within Birimian rocks, which together with their associated intrusives; occur over slightly more than one third of the country (Wright and Hastings 1985). The remainder of the gold produced comes mainly from the blanket conglomerate deposits of the Tarkwaian System and from placer mines exploiting material derived from both the Birimian and Tarkwaian source rocks.

Local Geologic Setting

The Ahafo project is located at the northern flank and along the southeast margin of the Sefwi Belt. The Ahafo deposit is developed in Birimian volcano-clasitc sedimentary rocks that occur in proximity to volcanic and plutonic rocks. Gold mineralization is intimately associated with mylonitic shear zones that occur near the contact of metavolcanic and volcanio-clastic sediments with overlying granitic and granodioritic intrusive units.

Presence of saprolitic weathering zones developed in near surface rock as the result of intense weathering and leaching in the tropical climates mask much of the actual outcrop in the areas. Studying core samples drilled within the deposits and adjacent areas is necessary to delineate most of the geology described. Saprolitic zones typically range in thickness from 5 m to as much as 50 m in the Ahafo area. The saprolite consists of lateritic clay and quartz fragments with as much as 25 percent weathered rock remaining within the saprolite. Near the surface, in the upper 1 to 5 m, red lateritic clay is developed as a subsoil and in places a distinct well indurated ferricrete (iron cemented) surface layer are developed.

The Ahafo deposits are localized along northeast trending regional strike-slip or thrust fault structures that tend to be parallel to regional foliation and the axial planes of folds within the Birimian host rock. Ore can also be located along the intersection of these northeast-tending structures with cross faults

that apparently produced dilated (open) zones for mineral deposition. Within the Ahafo South Project area, the Kenyase Fault is one of these major northeast-trending fault structures and the fault separates different types of lithologies in the hanging wall (above the fault) and footwall (below the fault) zones.

Rocks below the fault are typically mixed weakly metamorphosed volcano-clastic sediments interbedded with mafic volcanic units. Rocks above the fault are typically granitoids (rocks with granitic compositions and textures of unclear origin). These granitoid rocks were thrust over the volcanic units and in the process were deformed plastically, forming imbricated sheared and foliated mylonitic zones. The northeast-trending planar fault structures themselves are the focus and the conduit for gold mineralization and the rocks within the fault and immediately overlying them are intensely sheared.

The faults occur in fine-grained, gray-green massive to locally sheared Birimian mafic metavolcanic rocks exhibiting chlorite and carbonate alteration. The Ahafo South deposits are developed over approximately 5,000 m in strike length (along the fault), and ore has been delineated to a depth of about 400 m down the southeast dipping fault structure. The metasedimentary rocks beneath the thrust zone (northeast) are, for the most part, turbidite sequences consisting of greywacke, argillites, black carbonaceous siltstone, and minor chert horizons.

The Ahafo South deposits consist of four mineralized deposit zones, which may, in part, be connected by zones of low-grade mineralization. These deposits extend over a distance of about 13 km and are called, from southwest to northeast, the Subika, Apensu, Awonsu, and Amama deposits. The trend of mineralization extends as much as 25 km to the northeast in a series of exploration target areas (Ahafo North Project) that are currently being drill tested.

The Apensu and Awonsu deposits are both associated with a southeast dipping regional sheared contact between granitoid rock and metasedimentary/volcano-clastic rocks. Gold occurs within the cataclastic graphitic mylonite unit of the shear zone and in sheared hanging wall rock over widths of 20 to 60 m at grades of 2 to 5 grams/ton (g/t).

Gold occurs with pyrite and quartz in primary ore and is rarely associated with arsenopyrite and rutile. In the oxide or weathered zone, gold occurs as inclusions within or associated with goethite (pseudomorphed after pyrite). Manganese oxides are also common. The saprolytic weathered zone is absent in the Subika deposit.

GEOCHEMICAL CHARACTERIZATION OF ROCK

Geologic formations (materials) hosting gold deposits exhibit broad variability in structural setting, porosity, permeability, and mineralogical composition. The process of mining gold can change hydrologic conditions and potentially change the nature of rock-water interactions in the mining area. In order to assure that changing conditions are recognized and potential negative effects are abated, NGGL has developed standard waste rock evaluation methods for prediction of potential impacts to the environment (Bucknam 2002) Internal company guidelines require analysis of representative geologic samples that are collected based on lithology, mineralogy, sulfide mineralization, color, fracturing, oxidation and secondary mineralization. Materials for testing can include drill samples and assay laboratory samples.

Under NGGL internal guidelines, representative composite samples are prepared and tested for potential to release pollutants by meteoric water test procedures. Additional sample aliquots are

tested by static acid/base accounting analysis, or other equivalent tests to measure potential for acid generation incurred by oxidative dissolution of sulfides and neutralizing effects produced by dissolution of carbonate minerals. Where static testing has indicated a potential for net acid generation, kinetic testing typically is conducted to estimate the rate at which these competing acid generation-acid neutralization processes occur. The condition of net acid generation, usually termed acid mine drainage (AMD) or acid rock drainage (ARD), arises from rapid oxidation of certain sulfide minerals in an environment with insufficient net neutralizing capacity, and often occurs where such minerals are exposed to air and water.

Sampling and characterization of geologic materials contained within the following mine facilities have been initiated by NGGL based on general mining experience at other sites; these sites typically have potential for ARD or release of chemical constituents to the environment:

- Open Pit Mines
- Waste Rock Disposal Facilities
- Tailing Storage Facility
- New Roads

Geochemical Characterization Approach

One of NGGL's major goals in the Ahafo South Project characterization is to understand site specific geochemical processes that result from exposure of geologic materials to weathering. In response to this information, alternatives and/or mitigation measures can be designed that minimize or abate potential adverse effects of those processes. Disturbing or processing geologic materials in each of the four mine-related facilities listed above has potential to change local rock-water interactions from existing conditions, thereby initiating geochemical reactions that may require additional mitigation steps.

Prediction of potential metal release over the long-term can be difficult due to the complexity of weathering processes and the number of physical, chemical, biochemical, mineralogical, and hydrogeological variables involved. Therefore, NGGL developed material sampling and analysis strategies that optimize data required to model and predict potential geochemical impacts, not only before mining begins, but during mining to identify potential changes in these variables as they are encountered.

Specific geochemical data needs that allow an understanding of these geochemical processes include:

- Baseline water quality data;
- Chemical analysis of ore material (oxide and sulfide);
- Chemical analysis of waste rock (oxidized and sulfide-bearing); and
- Chemical analysis of process solutions.

Having this information available would provide input to potential alternatives and/or mitigation measures. Once data are available, models can be developed or revisited to predict changes to: (1) quality of water that would result from exposure of fresh geologic material to surface weathering

processes during construction of mine roads, pits, and waste rock disposal facilities; (2) quality of water that could seep from waste rock disposal facilities and discharge from the tailing storage facility underdrain system; (3) quality of water that may collect in open mine pits during and after operations; and (4) chemical constituents that would be present in process solutions.

DIRECT AND INDIRECT IMPACTS

Geochemical Characterization Status

This section summarizes completed and ongoing geochemical characterization studies for the Ahafo South Project. Primary concerns are the quality of water that could seep from waste rock disposal facilities and the tailing storage facility, and water that would collect in the mine pits. Construction of mine roads also exposes geologic materials to weathering, although most roads are constructed in weathered saprolite.

Potential for Acid Rock Drainage

Following NGGL standard methodology (Bucknam 2002), separate composite samples of oxide intervals and sulfide intervals were prepared from recovered drill cores whose locations were designed to be representative of subsurface geologic material present within the volume of rock to be removed by the mine pits. These samples were analyzed using static test procedures (acid-base accounting) as an initial assessment for potentially acid generating (PAG) rock at the Ahafo South Project. **Table 4-24** presents results of static acid-base accounting tests sorted by pit name, drillhole identification number, and composite type.

All sulfide composite sample tests resulted in classifications ranging from slightly basic to highly basic, with the exception of one sulfide composite from Apensu that resulted in a slightly acid determination (**Table 4-24**. Oxide composites were typically neutral or inert to slightly basic. These data suggest that material taken from Ahafo mine pits will have little tendency to produce acid.

TABLE 4-24
Results of Static Acid-Base Accounting Tests
Ahafo South Project

Pit	Drill Hole ID	Interval	ANPA	ANP	AGP	NCV ANP	NCV ANPA	Classification
Amama	BKP 006	Oxide		0.07	0	0.07		Inert
		Sulfide	3.4	5.95	-0.29	5.66	3.11	Basic
		Average		4.61	-0.22	4.39		Basic
	BKP 007	Oxide		0.03	0	0.03		Inert
		Sulfide	3.43	6.65	0	6.65	3.43	Basic
		Average		4.81	0	4.81		Basic
	BKR 014	Oxide		3.69	-0.07	3.62		Basic
		Sulfide	3.41	4.89	-0.17	4.72	3.24	Basic
		Average		4.29	-0.12	4.17		Basic
	BKP 019	Average (all oxide)		0.08	-0.01	0.07		Inert
	BKP 037	Oxide		4.57	-0.09	4.48		Basic
		Sulfide	3.29	5.06	-0.41	4.66	2.88	Basic
		Average		4.86	-0.27	4.58		Basic
	BKP 038	Oxide		0.13	0	0.13		Inert

TABLE 4-24
Results of Static Acid-Base Accounting Tests
Ahafo South Project

Pit	Drill Hole ID	Interval	ANPA	ANP	AGP	NCV ANP	NCV ANPA	Classification
		Sulfide	3.31	7.27	-0.5	6.77	2.81	Basic
		Average		4.89	-0.33	4.56		Basic
	BKP 039	Oxide		0.12	0.03	0.15		Inert
		Sulfide	3.18	5.41	-0.6	4.81	2.58	Basic
		Average		2.77	-0.29	2.48		Basic
	BKP 051	Oxide		3.59	-0.07	3.52		Basic
		Sulfide	3.3	5.89	-0.58	5.31	2.72	Basic
		Average		4.84	-0.35	4.5		Basic
	BKP 057	Average (all oxide)		0.16	-0.02	0.14		Slightly Basic
	BKR 012	Average (all oxide)		3.38	-0.02	3.35		Basic
	BKR 013	Oxide		5.65	-0.24	5.41		Highly Basic
		Sulfide	3.05	5.28	-0.95	4.33	2.1	Basic
		Average		5.56	-0.42	5.14		Highly Basic
Subika	RC 287	Oxide		0.12	0	0.12		Neutral
		Sulfide	3.54	3.66	-0.28	3.38	3.26	Basic
		Average		3.15	-0.24	2.92		Basic
	RC 288	Average	2.65	3.1	-0.12	2.98	2.53	Basic
	RC 297	Average	3.2	4.19	-0.37	3.82	2.83	Basic
	RC 304	Oxide		3.15	-0.08	3.07		Basic
		Sulfide	3.62	5.59	-0.49	5.09	3.13	Basic
		Average		5.42	-0.46	4.96		Basic
	RC 354	Oxide		2.27	0	2.27		Basic
		Sulfide	3.16	4.3	-0.56	3.74	2.6	Basic
		Average		3.89	-0.45	3.45		Basic
	RC 349	Oxide		1.29	0	1.29		Basic
		Sulfide	3.4	5.24	-0.38	4.86	3.02	Basic
		Average		3.92	-0.25	3.67		Basic
Apensu	KCD 008	Oxide		0.03	0	0.03		Neutral
		Sulfide	3.107	4.13	-0.78	3.36	2.33	Basic
		Average		2.34	-0.44	1.91		Basic
	KCR 106	Average		0.22	0	0.22		Slightly Basic
	KCP 004	Oxide		0.18	0	0.18		Slightly Basic
		Sulfide	3.124	5.12	-0.73	4.39	2.4	Basic
		Average		3.71	-0.52	3.19		Basic
	KCP 174	Average	3.148	4.28	-0.73	3.55	2.42	Basic
	KCP 177	Oxide						
		Sulfide	3.312	3.02	-0.27	2.75	3.04	Basic
		Average						
	KCR 036	Average		0.12	0	0.12		Slight Basic
	KCR 037	Average		0.55	-0.01	0.54		Slight Basic
	KCR 094	Average		0.07	0	0.07		Neutral
	KCR 095	Average		0.03	0.06	0.09		Neutral
	KCP 007	Oxide						
		Sulfide	3.389	1.34	-0.16	1.19	3.23	Basic
		Average						
	KCP 038	Oxide		0.85	-0.03	0.82		Slightly Basic
		Sulfide	3.211	4.93	-0.56	4.36	2.65	Basic
		Average		2.89	-0.3	2.59		Basic
	KCP 179	Oxide		1.51	0	1.51		Basic

TABLE 4-24
Results of Static Acid-Base Accounting Tests
Ahafo South Project

Pit	Drill Hole ID	Interval	ANPA	ANP	AGP	NCV ANP	NCV ANPA	Classification
		Sulfide	3.243	5.36	-0.08	5.27	3.16	Basic
		Average		4.88	-0.07	4.8		Basic
	KCR 040	Average		0.13	0	0.13		Basic
	KCR 041	Average		1.97	-0.11	1.86		Basic
	KCR 107	Oxide		0.23	-0.23	-0.01		Neutral
		Sulfide	0.713	0.85	-1.08	-0.24	-0.37	Slightly Acid
		Average		0.3	-0.33	-0.03		Neutral
Awonsu	KEP 16	Oxide		0.01	0	0.01		Inert
		Sulfide	3.094	3.32	-0.17	3.15	2.92	Slightly-Highly Basic
		Average		1.33	-0.07	1.26		Basic
	KEP 63	Average (all sulfide)	3.446	3.5	-0.17	3.33	3.28	Basic - Highly Basic
	KEP 65	Oxide		0	0	0		Inert
		Sulfide	2.915	2.86	-0.08	2.77	2.83	Basic
		Average		2.29	-0.07	2.22		Basic
	KEP 67	Average (all sulfide)	3.504	2.22	-0.09	2.12	3.41	Basic - Highly Basic
	KEP 132	Average (all sulfide)	3.105	2.39	-0.06	2.33	3.04	Inert - Basic
	KEP 138	Average (all sulfide)	3.518	4.27	-0.08	4.2	3.44	Basic - Highly basic
	KEP 180	Average (all sulfide)	3.141	2.92	-0.16	2.77	2.98	Basic
	KEP 183	Average (all sulfide)	2.382	2.02	-0.13	1.89	2.25	Basic
	KEP 186	Average (all sulfide)		3.37	-0.09	3.28		Basic - Highly Basic
	KER 65	Average (all oxide)		0.18	0	0.18		Inert - Slightly Basic
	KER 67	Average (all oxide)		0.09	0	0.09		Inert - Slightly Basic
	KER 152	Oxide		0	0	0		Inert
		Sulfide		4.87	0	4.87		Basic
		Average		1.22	0	1.22		Basic
	KER 153	Oxide		0	0	0		Inert - Slightly Basic
		Sulfide		5.89	-0.1	5.79		Basic
		Average		0.93	-0.01	0.92		Slightly Basic
	KER 154	Average (all oxide)		0	0	0		Neutral

Note: ANPA = acid neutralization potential acidity; ANP = acid neutralization potential; AGP = acid generation potential; NCV = net carbonate value.

Criteria for Classification

Highly Acidic (HA)		NCV	< -5 % CO_2
Acidic (A)	-5 <	NCV	< -1 %
Slightly Acidic (SA)	-1 <	NCV	<-0.1
Neutral (N)	-0.1<	NCV	< 0.1 and (ANP > 0.1 or AGP < -0.1)
Inert (I)	-0.1<	NCV	< 0.1 and (ANP < 0.1 and AGP > -0.1)
Slightly Basic (SB)	0.1 <	NCV	< 1
Basic (B)	1<	NCV	< 5
Highly Basic (HB)	5 <	NCV	

Source: Newmont 2003b, c, d, e.

Some Net Carbonate Value (NCV) data are available from NGGL's Phase II assessment of potential environmental releases. **Table 4-25** summarizes differences between material classified as ore and material classified as waste rock. While most waste rock to be mined at Ahafo would be oxidized (non-PAG), small amounts of unoxidized sulfides may have potential to generate acid. The bulk of

proposed mine pit excavation would occur within geologic formations having net acid neutralizing potential. Mean NCV for both ore and waste rock are 3.6 and 1.6, respectively, which are considered "basic" by the NCV classification (see bottom of **Table 4-24**). Lowest NCV for ore (-0.85) is "slightly acidic", and lowest NCV for waste rock (0.00) is considered "neutral" or "inert".

X-ray diffraction and x-ray florescence analysis demonstrate that primary (sulfide) ore typically contains between 3 and 12 percent carbonate minerals and approximately 1 percent sulfide minerals (**Table 4-26**). Ankerite-dolomite accounts for the bulk of carbonate minerals present while calcite and siderite are present in lesser amounts. Pyrite is the predominant sulfide mineral present, although arsenopyrite is reported. Oxide ore typically contains only trace amounts of ankerite-dolomite and pyrite, but may contain 8 percent or more goethite and up to 33 percent kaolinite.

The ankerite-dolomite solid solution series is a subgroup of carbonates having lower solubility than calcite and, as a result, these minerals may be kinetically less active or available than calcite for neutralization of acid generated by dissolution of sulfides. In addition, the ankerite end-member of the series contains up to 33 percent iron by weight that can result in substantial delayed acid formation when any iron released during dissolution re-precipitates as ferric hydroxide. Traditional static acid neutralization potential titrations do not fully account for the mineralogic component or its elevated iron content. However, NGGL employed a hydrogen peroxide treatment to oxidize the iron, correcting for the iron precipitation component, and allowing more confidence in the determination of inert to basic NCV for samples from the Ahafo South deposits.

TABLE 4-25
Statistical Comparison of Net Carbonate Value of Ahafo Ore and Waste Rock

	Ore Material*			Waste Rock Material**		
	Minimum	Mean	Maximum	Minimum	Mean	Maximum
NCV	-0.85	3.55	9.08	0.00	1.58	6.30
C TOTAL %	0.04	1.18	3.02	0.04	0.51	1.80
CAI %	0.00	0.06	0.59	0.00	0.07	0.32
S TOTAL %	0.00	0.61	1.64	0.00	0.09	0.31
SAP %	0.01	0.22	0.44	0.00	0.06	0.17
ANP	0.00	4.09	10.74	0.00	1.63	6.31
AGP	-1.81	-0.54	0.00	-0.24	-0.05	0.00

*12 Composite Samples of Subika Ore and 27 Composite Samples of Apensu Ore

**3 Composite Samples of Subika Waste Rock and 21 Composite Samples of Apensu Waste Rock

C TOTAL % = Total Carbon — ANP = Acid Neutralization Potential

CAI % = Residual Carbon After Pyrolysis — AGP = Acid Generation Potential in Percent CO2

S TOTAL % = Total Sulfur — NCV = net carbonate value = ANP + AGP

SAP % = Residual Sulfur After Pyrolysis

Source: Newmont 2003b, c, d, e.

Although current evidence indicates that sufficient neutralization capacity exists to prevent acid generation, NGGL will conduct an extensive environmental monitoring program to confirm the preliminary results. In addition, NGGL will be completing more detailed geochemical characterization of geologic materials, including kinetic testing, meteoric water mobility testing, or equivalent.

Data collected to date will be used along with additional baseline data currently being collected to provide input to the ongoing evaluation of potential geochemical effects of mine-related facilities, including pit lakes. This study will provide additional information on the presence or absence of

potential ARD impacts. As part of the adaptive management approach, additional mitigation measures can be considered and implemented, as necessary, to address potential impacts.

TABLE 4-26
Average Composition of Oxide and Sulfide Zone Mineralogy
Ahafo South Project

Proposed Open Cut Mine Pit	Rock Zone	% Qz	% Plag	% Musc	% Kaol	% Chlor	% Cal	% Ank	% Pyr	% Goe	% Rut
Amama	Sulfide	17	48	14	6	2	2	12	1	1	Tr
	Oxide	27	19	15	33	1	0	0	0	8	Tr
	Trans	22	48	19	0	4	2	4	1	3	Tr
Subika	Sulfide	9	59	25	2	3	2	8	1	0	Tr
	Trans	21	49	18	2	4	1	5	Tr	3	Tr
Apensu	Sulfide	25	40	23	0	0	0	12	1.2	0	0
	Oxide	37	7	32	16	0	0	0	0	8	0
Awonsu	Sulfide	20	42	28	0	11	5	3	<1	0	<1
	Oxide	33	24	26	11	5	0	0	0	6	Tr

% Qz - Weight Percent Quartz
% Plag - Weight Percent Plagioclase
% Musc - Weight Percent Muscovite
% Kaol - Weight Percent Kaolinite
% Chlor - Weight Percent Chlorite and Smectite Combined
% Cal - Weight Percent Calcite
% Rut - Weight Percent Rutile
% Goe - Weight Percent Goethite
Tr - Trace

Source: Newmont 2003b,c,d,e.
Note: Data are based on semi-quantitative x-ray diffraction and x-ray fluorescence analysis.

Phase II characterization of waste rock composite samples will include Synthetic Precipitation Leachability Procedure (SPLP), Biological Acid Production Potential (BAPP), and PAG and are being conducted to confirm results from Phase I. Available whole rock data, however, indicate that levels of some trace elements are present in excess of published estimates of average crustal abundance for that element. For example, **Table 4-27** compares published average crustal abundance of selected trace elements with the mean concentration of those trace elements measured in 281 samples from the Apensu mine pit area.

While the presence of whole rock concentrations above those found in average crustal rocks does not necessarily lead to a conclusion that constituents can be mobilized and released to the environment, it raises the possibility that some trace metals could be released in concentrations exceeding water quality standards, including arsenic, barium, antimony, and selenium. As described in the *Surface Water Resources* and *Groundwater Resources* sections of this chapter, background concentrations of arsenic and mercury in surface water and arsenic, chromium, mercury, and nitrate in groundwater exceed primary drinking water standards.

ALTERNATIVES ANALYSIS

Construction of a low permeability layer on the waste rock disposal facilities would minimize the amount of precipitation infiltrating through the rock piles (see Chapter 2 for description of waste rock disposal facility construction and reclamation) should additional testing indicate acid generation potential exists in the waste rock materials. Partial backfill of the mine pits would use some waste rock that would otherwise have been disposed in the waste rock disposal facilities for placement in a saturated condition beneath the water table in the mine pits. In addition to reducing the size of waste rock disposal facilities, this alternative could reduce leaching of metals from the rock in and adjacent to the mine pits due to reducing conditions below the water table in the mine pits.

TABLE 4-27
Whole Rock Data for Apensu Mine Pit Area
Compared to Average Crustal Values

	Concentration in parts per million (ppm)							
	Arsenic	**Barium**	**Beryllium**	**Cobalt**	**Chromium**	**Copper**	**Molybdenum**	**Nickel**
Average Crustal Abundance	2.1	340	1.9	30	140	68	1.1	90
Mean – Apensu Pit	37.40	714.20	2.05	19.77	80.06	53.19	10.55	40.72
Maximum – Apensu Pit	209.50	1443.38	6.18	106.40	345.72	307.75	55.02	106.60
Minimum – Apensu Pit	0.00	118.81	0.60	2.20	7.79	8.79	2.60	7.39
	Lead	**Antimony**	**Selenium**	**Tin**	**Sulfur**	**Thallium**	**Vanadium**	**Zinc**
Average Crustal Abundance	10	0.2	0.05	2.2	360	0.53	190	79
Mean – Apensu Pit	8.83	9.62	6.42	1.05	301.04	1.55	107.38	70.56
Maximum – Apensu Pit	188.17	24.17	12.16	6.40	871.56	19.78	464.00	305.63
Minimum – Apensu Pit	0.00	2.40	0.80	0.00	8.98	-15.96	22.56	20.58

Source: Source: Porterfield 1984; Butler and Harrod 1989; Kaye and Laby 1993; Greenwood and Earnshaw 1997; Hooey *et al.* 1993; Cox 1989; McGraw-Hill 1992; James and Lord 1992; Newmont 2005.

NO PROJECT ALTERNATIVE

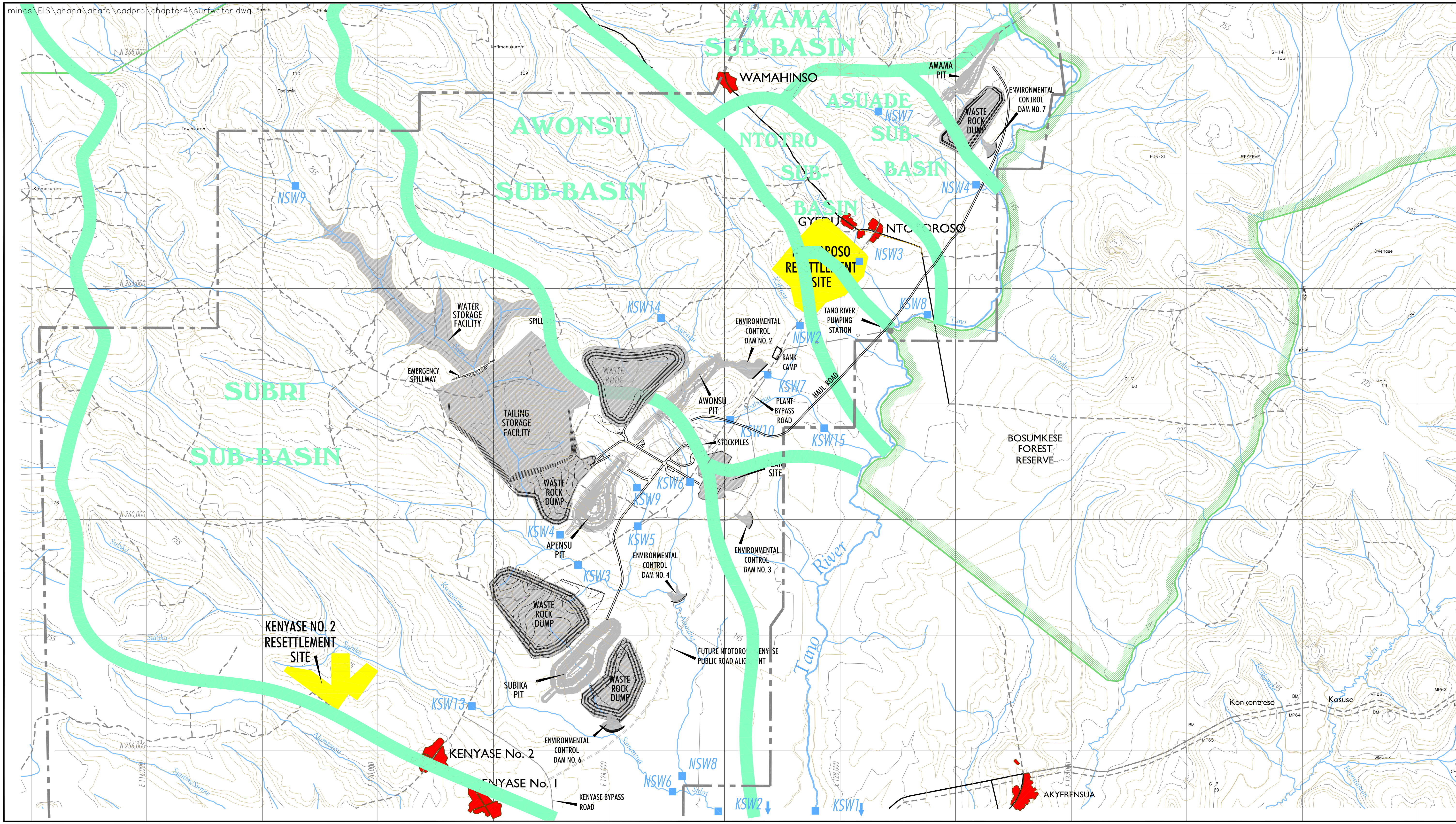
Implementation of the No Project Alternative would eliminate the potential impacts to geology and minerals that are described for the Project and closure alternatives. Once NGGL completes reclamation of the area disturbed by initial construction activities, baseline conditions associated with geology and minerals are expected to resume. The No project Alternative would also eliminate recovery of approximately 112.5 Mt of ore over the life of the Project.

SURFACE WATER RESOURCES

BASELINE CONDITIONS

The Ahafo South Project area is located in the upper part of the Tano River basin and is drained by a number of seasonal (ephemeral) streams that are tributary to the Tano River. The seasonal streams divide the Project area into a number of smaller sub-basins. From the Project area, the Tano River flows southward to the Atlantic Ocean near the Ghana-Côte d'Ivoire border. The Tano River flows year-round (perennial) and is a vital water body for the region as a source of potable water for several towns and villages within and around the Project area.

All streams and rivers within and surrounding the Ahafo South Project area in relation to the mine pits and other facilities are shown on **Figures 4-1** and **4-7**. All mine-related facilities would be located west of and within 5 km of the Tano River. Two of the mine pits and associated waste rock disposal facilities – Subika and Apensu – would be located entirely within the Subri sub-basin; the Awonsu mine pit and waste rock disposal facility would lie mostly in the Awonsu sub-basin, with smaller portions in the Subri sub-basin. The Amama mine pit and waste rock disposal facility would be mostly in a small unnamed sub-basin that drains directly to the Tano River between the Asuade and Amama sub-basins. The water storage facility and tailing storage facility are both located in the Subri sub-basin. The processing plant site is located in the Subri and Awonsu sub-basins, as well as a small unnamed sub-basin that drains directly to the Tano River.



N

0 Kilometers 3

1:63,360

Contour Interval = 6 Meters

- Existing Primary Road
- Existing Secondary Road
- Proposed Haul Road
- Lease Boundary
- Forest Reserve Boundary
- Pipeline
- Drainage Basin Divide
- Surface Water Monitoring Site (KSW11, KSW12, NSW1 and NSW5 Are Beyond Map View, KSW4 and KSW9 are Springs)
- Existing Settlement
- Resettlement Site

Surface Water Monitoring Sites
Ahafo South Project
Brong Ahafo Region, Ghana
FIGURE 4-7

Several studies and documents have been completed that describe surface water resources for the Ahafo South Project area:

- In October 1997, SGS conducted a study of the Centenary Project area, which includes both the northern and southern portions of the Ahafo Project area.

- In June-July 1999, Burgéap (France) completed a study of surface water and groundwater resources around the proposed mining sites. The study included an evaluation of various potential water supply sources for the proposed Project.

- In September-October 1999, SGS performed an assessment of surface water in the Project area.

- In October 2000, SGS conducted a hydrologic study of the Ntotoroso Concession which consisted of field visits to areas that may be potentially affected by the proposed mining project, as well as updating existing information on water resources of the Project area.

- In 2000, two Environmental Impact Statements were completed by SGS (2000a, 2000b) that describe water resources in the Ntotoroso and Sefwi Belt Project areas.

- In September 2004, SGS (2004) completed an Environmental Impact Statement for the Ahafo South Project. This is the most recent document that describes water resources in the Project area.

Surface Water Quantity and Use

Streams in the Ahafo South Project area generally drain southeast to the Tano River, including the Suraw/Suntim, Subri, Awonsu, Ntotro, Asuade, and Amama drainages (**Figure 4-7**). Mine-related facilities and pits would be located within the Subri sub-basin, Awonsu sub-basin, Asuade sub-basin, and three small unnamed sub-basins that drain directly to the Tano River.

Tano River

The Tano River is the largest water body in the Project area, receiving water from various tributary streams. The river flows year-round (perennial) through a well-defined channel protected by a canopy of tall trees. The Tano River generally gains flow downstream because of tributary channel flows and discharge of groundwater to the channel. The river supports fish; however, it is traditionally forbidden to catch and eat fish from portions of the Tano River in and surrounding the Project area.

The Tano River is a source of potable water for the town of Sunyani and other small towns and villages located within and around the Project area. Water from the river is pumped and treated through several treatment plants operated by Ghana Water Company Limited. For the Ahafo South Project, monthly pumping rates over a 7-month period (May through November) from the Tano River for makeup water would vary from about 0.2 to 0.6 m^3/sec (Knight Piesold Consulting 2004), depending on the month and flow, at a location on the southern end of the Ntotro sub-basin and transported via pipeline to the plant site (**Figure 4-7**).

To the north of the Project area, water is pumped daily from the Tano River, treated at the 1962 water pumping station located near Abesem, and distributed via a network of pipes to several towns, including Sunyani, Tanoso, Susuanso, and Yamfo. A smaller pump and treat operation is located near

Akyerensua where potable water is piped to Subrinso, Akyerensua, Hwidiem, Kenyase 1, Kenyase 2, and New Dormaa. The Tano River is also a direct source of domestic water for various villages and hamlets located along its watercourse.

Suraw/Suntim Stream

The Suraw/Suntim stream originates west of the towns Kenyase 1 and Kenyase 2. Its mainstream length and watershed area are approximately 16 km and 3,500 ha, respectively. The sub-basin seasonally drains the southern portion of the Project area and joins the Tano River 2 km southeast of Hwidiem. No mining-related activities would occur within this watershed.

Subri Stream

The Subri stream is the largest sub-basin in the Project area. Its mainstream length and watershed area are approximately 25 km and 12,900 ha, respectively. Its channel is generally well-defined and passes through several swampy areas, particularly after it crosses the Kenyase-Ntotoroso road. The Subri sub-basin includes sites for the Subika and Apensu mine pits, associated waste rock disposal facilities, water storage facility, and tailing storage facility. Portions of the plant site, Awonsu mine pit and waste rock disposal facility also would be located in the Subri sub-basin.

On its way to the Tano River, the Subri stream receives water from several tributaries, including the Apinsu, Asundua, and Subika/Samansua streams. All these water bodies in the Subri sub-basin have seasonal flow and typically become dry from November to April. Peak flow can result in flow depths of over 1 m in the main Subri channel that has an average width of about 5 m. The Subri stream joins the Tano River approximately 2.5 km south of Subrinso village and 3 km downstream of the Akyerensua water pumping station.

Several hamlets are located within the Subri sub-basin and use water from this stream for potable and domestic purposes. During the dry season, inhabitants of these hamlets obtain water from small dugouts located in the stream channel or they may walk to the Tano River (3 to 5 km).

Awonsu Stream

The Awonsu stream drains the watershed immediately north of the Subri sub-basin. Its mainstream length and watershed area are approximately 14.8 km and 3,850 ha, respectively. It joins the Tano River about 2 km after it crosses the Kenyase-Ntotoroso road. Like the Subri, the Awonsu stream has seasonal flow conditions and is used as a water source by people living in small hamlets within the watershed. More than half of the Awonsu mine pit and associated waste rock disposal facility would be located within the Awonsu sub-basin. A small portion of the plant site also would be located in this watershed.

Ntotro Stream

The Ntotro stream is in a small sub-basin (670 ha) located southeast of Wamahiniso village and contains the village of Ntotoroso. This seasonal stream previously was a source of water for Gyedu and Ntotoroso. The inhabitants of these two villages now have access to several boreholes, open wells, and a pedal flow system. No mine-related facilities would be located in the Ntotro sub-basin, except for a portion of the Ntotoroso resettlement site.

Asuade and Amama Streams

These two streams are located at the north end of the Project area on either side of the small unnamed sub-basin that contains the proposed Amama mine pit and waste rock disposal facility. A small portion of the waste rock disposal facility would also lie in the Asuade sub-basin; this drainage covers an area of about 775 ha. The Amama sub-basin would not be directly affected by the mine facilities. The small unnamed sub-basin between these two drainages, which covers an area of about 350 ha and would contain all of the Amama mine pit and most of the waste rock disposal facility, is located adjacent to the Tano River northeast of the town of Ntotoroso.

Because limited flow measurement data are available for Project area streams (especially prior to 1999), and the streams are typically dry from November to April, indirect methods (area-ratio) were used to estimate stream runoff flows to the main water bodies such as the Subri and the Awonsu streams. A current meter was used to calculate stream flow in the field using mean stream velocity at various locations along the stream cross-section. Where narrow or shallow channel conditions were encountered the float method was used to obtain mean velocities. Stream channel depth and width were then used with velocity measurements to determine total flow.

Three v-notch weirs were installed at the upstream, midstream, and downstream reaches of the Subri stream. The bucket-and-timer method, as well as, the standard empirical equation for v-notch weirs, were used when possible as accuracy checks for flow measurements obtained by other methods. At the upstream location of the Subri stream, the weir was completely submerged and thus neither of the methods for flow accuracy checking was possible.

Tano River Basin

Discharge information on the Tano River near Hwidiem (downstream southern end of Project area) was obtained from the Hydrological Division of the Ministry of Works and Housing in Accra. Data are for the period 1969-96, but numerous gaps are in the records. The Tano River watershed at Hwidiem covers an area of approximately 285,000 ha. Mean monthly flow data obtained since 1969 are summarized in **Table 4-28**. Using these monthly averages, mean annual discharge for the Tano River at Hwidiem is 5.9 m^3/sec. Mean annual discharge for a specific year ranges from 3.4 m^3/sec recorded in 1994-95 to 9.0 m^3/sec for 1972-73. It is reported that the river dried completely in 1983, but no measurement records are available for that year.

TABLE 4-28
Mean Monthly Flow Measured for Tano River at Hwidiem (1969-1996)

Month	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
Flow (meters^3/sec)	1.7	1.6	2.0	3.7	5.6	10.6	8.0	4.4	8.4	15.6	6.3	3.1

Source: Hydrological Division of the Ministry of Works and Housing (Accra) *in* SGS 2000a, 2004.

Subri Sub-Basin

One set of flow measurements obtained at weirs upstream (near proposed water storage reservoir), midstream, and downstream were recorded as follows for a single event in 1999:

- Upstream weir = 0.02 m^3/sec
- Midstream weir = 0.07 m^3/sec
- Downstream weir = 0.01 m^3/sec
- Farther downstream near mouth = 0.04 m^3/sec

The midstream flow may have been influenced by runoff due to heavy rainfall, which occurred during fieldwork. The difference between flow at the midstream and downstream weirs may also be accounted for by wetland storage and ponds created by local people for domestic water supply purposes.

Mean annual and monthly runoff figures for the entire Subri sub-basin were assessed using runoff data obtained for the Tano River at Hwidiem (period of 1969-96). This assessment method assumes comparable watershed characteristics and thus similar runoff generating conditions. Mean annual runoff of the Subri stream based on these Tano River records was calculated to be 0.27 m^3/sec (or a yearly discharge of approximately 8.5 x 10^6 m^3). A mean annual flow of 0.43 m^3/sec was derived by extrapolation from mean annual flow (4.16 m^3/sec) for the Tano River basin at Tanoso (125,000 ha). Mean monthly flows for the Subri stream (12,900 ha) and one of its tributaries (Subika stream; 3,300 ha) are presented in **Table 4-29**.

The portion of Subri watershed that would contribute runoff into the water storage facility is 2,900 ha. Mean annual and monthly runoff for this catchment were also estimated from runoff data obtained for the Tano River at Hwidiem (period of 1975-91), considering that the two basins have comparable watershed characteristics. Mean annual runoff of the Subri sub-basin calculated from these records is 0.07 m^3/sec (or a yearly discharge of approximately 2.2 x 10^6 m^3).

TABLE 4-29
Mean Monthly Flow Calculated for Subri Watershed

Surface Water Site & Watershed Area	Monthly Runoff ($meters^3$/sec)												
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Mean
Tano River at Hwidiem (285,000 hectares)	1.7	1.6	2.0	3.7	5.6	10.6	8.0	4.4	8.4	15.6	6.3	3.1	5.92
Subri Sub-basin (12,900 hectares)	0.08	0.07	0.09	0.17	0.25	0.48	0.36	0.20	0.38	0.71	0.29	0.14	0.27
Subika Sub-basin (3,300 hectares)	0.02	0.02	0.02	0.04	0.06	0.12	0.09	0.05	0.10	0.18	0.07	0.04	0.07

Source: SGS 2000a, 2004.

Mean annual runoff volume of the Subri sub-basin was calculated using two methods: (1) area-ratio method using a runoff coefficient of 0.2 and data obtained for the Tano River at Hwidiem (285,000 ha) and at Tanoso (125,000 ha); and (2) extrapolation from rainfall data. **Table 4-30** summarizes results of these runoff volume calculations for the water storage facility.

TABLE 4-30
Annual Runoff Calculated Into Water Storage Facility

Estimation Method	Annual Volume (meters³)		
	Mean Year	Dry Year (10-yr return period)	Wet Year (10-yr return period)
Area-ratio method -- Hwidiem flow data	2.2×10^6	1.2×10^6	4.0×10^6
Area-ratio method -- Tanoso flow data	2.9×10^6	1.5×10^6	4.9×10^6
Extrapolation from rainfall data	2.9 to 4.3 x 10^6 *	Not applicable	6.5 to 9.4 x 10^6 *

* Infiltration rates used were 150 mm and 100 mm for the two values indicated, respectively.
Source: Burgéap 1999; SGS 2004.

The difference between mean annual flow values obtained using data for the Tano River at Tanoso and at Hwidiem is likely due to the larger watershed area at Hwidiem. For purposes of the water storage facility, using the Tanoso data probably is more representative. Mean monthly flows estimated using data for the Tano River at Hwidiem (period of 1975-91) are in **Table 4-31**.

TABLE 4-31
Mean Monthly Flow Calculated for Water Storage Facility

Surface Water Site & Watershed Area	Monthly Runoff (meters³/sec)											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Tano at Hwidiem (285,000 hectares)	1.7	1.6	2.0	3.7	5.6	10.6	8.0	4.4	8.4	15.6	6.3	3.1
Water Storage Facility (2900 hectares)	0.02	0.02	0.02	0.04	0.06	0.11	0.08	0.04	0.09	0.16	0.06	0.03

Source: SGS 2004.

Flow frequency curves obtained from studies of the Tano River basin at Tanoso were extrapolated by means of the area-ratio method for the Subri watershed. Estimated 2-year, 7-day low flows for the entire Subri sub-basin and the water storage facility catchment area are 0.06 and 0.01 m³/sec, respectively. Peak flood flow for storms of return periods up to 100 years in the Subri water storage facility area were calculated from storm rainfall using the runoff-coefficient method (**Table 4-32**).

TABLE 4-32
Peak Flood Flows Calculated for Water Storage Facility

Storm Return Period (years)	Time of Concentration (hours)	Rainfall Amount (mm)	Time to Peak (hours)	Runoff (m³/sec)	Total Flood Flow (m³/sec)	Flood Volume / 2 hours (m³)
5	3.71	98.5	3.23	114.4	114.5	0.82×10^6
10	3.71	127.7	3.23	175.0	174.0	1.26×10^6
25	3.71	166.7	3.23	263.0	263.0	1.89×10^6
50	3.71	195.5	3.23	307.3	307.3	2.21×10^6
100	3.71	224.7	3.23	353.8	353.9	2.55×10^6

Source: SGS 2000a, 2004.
Note: mm = millimeters; m = meters; sec = second.

Awonsu Sub-Basin

Mean annual and monthly runoff for the Awonsu watershed (3,850 ha) were calculated using runoff data obtained for the Tano River at Hwidiem (period of 1969-96), considering that the two basins have similar watershed characteristics. Mean annual runoff estimated for the Awonsu sub-basin based on

these records is 0.08 m^3/sec (or a yearly discharge of approximately 2.5 x 10^6 m^3). Mean monthly flows were further estimated using the same data obtained for the Tano River at Hwidiem (**Table 4-33**).

TABLE 4-33
Mean Monthly Flow Calculated for Awonsu Sub-Basin

Surface Water Site & Watershed Area	Monthly Runoff ($meters^3$/sec)												
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean
Tano at Hwidiem (285,000 hectares)	1.7	1.6	2.0	3.7	5.6	10.6	8.0	4.4	8.4	15.6	6.3	3.1	5.92
Awonsu (3,850 hectares)	0.02	0.02	0.03	0.05	0.08	0.14	0.11	0.06	0.11	0.21	0.09	0.04	0.08

Source: SGS 2000a.

The estimated 2-year, 7-day low flow for the Awonsu Basin is 0.02 m^3/sec. Peak flood flow for storms of return periods up to 100 years in the Awonsu basin were calculated from storm rainfall amounts using the runoff coefficient method (**Table 4-34**).

Rivers, lakes, ponds, and boreholes/wells are the main sources of water in the Project area. Approximately 60 percent of households draw their water from unprotected sources, exposing residents to water-borne infections and other health hazards. Residents in the villages of Kenyase 1, Kenyase 2, and Ntotoroso obtain water from several boreholes fitted with hand-pumps. Vendor trucks also supply potable water to some areas.

TABLE 4-34
Peak Flood Flows Calculated for Awonsu Sub-Basin

Storm Return Period (years)	Time of Concentration (hours)	Rainfall Amount (mm)	Time to Peak (hours)	Total Flood Flow (m^3/sec)	Flood Volume / 2 hours (m^3)
5	2	98.5	2.2	223.0	1.6×10^6
10	2	127.7	2.2	341.0	2.5×10^6
25	2	166.7	2.2	512.6	3.7×10^6
50	2	195.5	2.2	598.9	4.3×10^6
100	2	224.7	2.2	690.1	5.0×10^6

Note: mm = millimeters; m = meters; sec = second.
Source: SGS 2000a.

Water from the Tano River is pumped and treated by several treatment plants operated by Ghana Water Company Limited for Sunyani and several small towns/villages in the Project area. A large northern treatment plant (6,800 m^3/day or 1.8 million gal/day) is located near Abesem, with water distributed by pipeline to Sunyani, Tanoso, Susuanso, and Yamfo. A southern smaller treatment plant (270 m^3/day or 71,000 gal/day) is located near Akyerensua where potable water is piped to Subrinso, Akyerensua, Hwidiem, Kenyase 1, Kenyase 2, and New Dormaa. The Tano River is also a direct source of domestic water for various villages and hamlets located along its watercourse.

Water from the Subri River provides domestic water to several hamlets. The Awonsu stream is used as water supply by people living in small hamlets in the watershed area. During the dry season, these villagers fetch water from small dugouts excavated into the stream channel.

Surface Water Quality

Several monitoring stations have been established on the Tano River and its tributaries in the Ahafo South Project area. These stations are shown on **Figure 4-7** and listed in **Table 4-35**. The monitoring program started in 1998 and consists of flow measurements and collection of samples for laboratory analysis of chemical constituents. Sample locations have been chosen to characterize water quality in the region and to focus on locations where impacts could occur from the Ahafo South Project.

All laboratory analyses were conducted at the SGS Laboratory in Accra, Ghana, according to "Standard Methods for the Examination of Water and Wastewater" of the American Public Health Association, 1995 edition. Some parameters were analyzed directly by SGS in the field using Hach® kit equipment and methodologies. Field and laboratory analytical results for surface water samples are tabulated in **Appendix C.** Also included in **Appendix C** (**Tables C-4** and **C-5**) are statistical summaries of water quality data for all surface water monitoring stations combined, as well as for each individual sub-basin.

TABLE 4-35
Surface Water Monitoring Locations
Ahafo South Project Area

Sample Name	Location
KSW1	Tano River below bridge on Acherensua-Hwidiem road; near Acherensua water pumping station.
KSW2	Subri Stream (lower) below bridge on Acherensua-Hwidiem road.
KSW3	Subri Stream (middle) below bridge on Kenyase-Ntotoroso road.
KSW4	Spring 1 in Subri sub-basin; no water quality data for this site.
KSW5	Subri Stream tributary on Kenyase-Ntotoroso road.
KSW6	Asundua Stream (Subri tributary) below culvert on Kenyase-Ntotoroso road.
KSW7	Awonsu Stream below bridge on Kenyase-Ntotoroso road.
KSW8	Tano River below bridge on Ntotoroso-Acherensua road.
KSW9	Spring 2 in Subri sub-basin
KSW10	Ababusua Stream (Awonsu tributary) on Kenyase-Ntotoroso road.
KSW11	Subin Stream south of Project area on Acherensua-Hwidiem road.
KSW12	Suraw/Suntim Stream on Hwidiem-Kenyase road.
KSW13	Subika Stream (Subri tributary) on Kenyase-Ntotoroso road.
KSW14	Awonsu Stream (upper) above mine facilities.
KSW15	Awonsu Stream at lease boundary below confluence of Ababusua stream.
NSW1	Suraw/Suntim Stream on Hwidiem-Acherensua Road near Tano River.
NSW2	Kafrasu Stream (Awonsu tributary) on Kenyase-Ntotoroso road.
NSW3	Ntotro Stream on Kenyase-Ntotoroso road; fetching point for of Ntotoroso village.
NSW4	Asuade Stream near confluence with Tano River.
NSW5	Amama Stream north of Project area.
NSW6	Subika Stream (Samansua) near mouth before it joins Subri River.
NSW7	Asuade Stream (upper) above mine facilities.
NSW8	Subri Stream (Asundua stream) near confluence of Samansua stream.
NSW9	Subri Stream (upper) above Water Storage Facility.

Note: See **Figure 4-7** for station locations, except KSW1, KSW2, KSW11, KSW12, and NSW1 which are located south of the figure view; and NSW5 which is located north of the figure view.

Water quality standards or guidelines for the parameters analyzed are listed in **Table 4-36**. These standards are from Nevada USA, United States Environmental Protection Agency (USEPA), World Health Organization (WHO), and Ghana Environmental Protection Agency (EPA). Most standards in **Table 4-36** are applicable to drinking water, both surface water and groundwater. The last column in **Table 4-36** shows the lowest drinking water standard from the various references. **Table 4-36** includes

aquatic life standards that are applicable for in-stream water quality where aquatic life is present. Many of the tributary streams are ephemeral with flow only during periods of heavy rainfall and, therefore, have no aquatic life most of the time.

The World Bank (WB), International Finance Commission (IFC), and Ghana EPA also have "effluent" based standards which are applicable to any discharges that might occur from the mine project. In general, these effluent standards are equivalent to or higher than the aquatic life and drinking water standards presented in **Table 4-36**.

TABLE 4-36
Water Quality Standards and Guideline Values

Parameter	Standards or Guidelines (all units in milligrams per liter, unless otherwise noted)					
	Aquatic Life	Drinking Water				Most Stringent Drinking Water Standard
	Nevada USA	Nevada USA	USEPA	WHO	Ghana EPA (GHEPA)	
Physical Parameters						
pH (std. units)	6.5 – 9.0	5.0 – 9.0	6.5 – 8.5	6.5 – 8.0	6.5 – 9.0	6.5 – 8.5
Conductivity (uS/cm)	---	---	500	---	1500	500
TDS	---	500	---	600	1000	500
TSS	25 – 80	---	---	---	50	50
Turbidity (NTU)	10 – 50	---	---	5	75	5
Color (TCU)	---	75	---	---	150	75
Common Ions						
Sodium	---	---	---	200	---	200
Chloride	---	250	250	250	250	250
Fluoride	---	---	4**	1.5	---	1.5
Sulfate	---	250	250	250	250	250
Hardness	---	---	---	300	---	300
Nutrients and Cyanide						
Nitrate	90	10	10**	50	50	10
Nitrite	0.06	---	1**	3	---	1
Phosphorus	0.1	---	---	---	2	2
Cyanide, free	0.0052	0.2	0.2	0.07	0.2	0.07
Cyanide WAD	---	---	---	---	0.6	0.6
Cyanide total	---	---	---	---	1	1
Metals						
Aluminum	---	---	0.05 - 0.2	0.1	---	0.05
Antimony	---	0.146	0.006**	0.02	1.5	0.006
Arsenic	0.18 (III)	0.05	0.01**	0.01	0.1	0.01
Barium	---	2	2**	0.7	---	0.7
Beryllium	---	---	0.004**	---	---	0.004
Boron	---	---	---	0.5	---	0.5
Cadmium	0.0013*	0.005	0.005**	0.003	0.1	0.003
Chromium	0.01 (VI)	0.1 (total)	0.1** (total)	0.05 (VI)	0.5 (total) - 0.1 (VI)	0.1 (total) - 0.05 (VI)
Copper	0.0142*	---	1	2	0.5	0.5
Iron	1	---	0.3	0.3	3.5	0.3
Lead	0.0013*	0.05	0.015	0.01	0.1	0.01
Manganese	---	---	0.05	0.4	---	0.05
Mercury	0.000012	0.002	0.002**	0.001	0.005	0.001
Molybdenum	0.019	---	---	0.07	---	0.07
Nickel	0.189*	0.0134	---	0.02	0.5	0.0134
Selenium	0.005	0.05	0.05**	0.01	---	0.01
Silver	0.0069*	---	0.1	---	---	0.1
Thallium	---	0.013	0.002**	---	---	0.002
Zinc	0.127*	---	5	4	2	2
Biological and Organics						
Total Coli form -(MPN/100ml)	---	---	5%	<2	400	<2
Fecal Coli form -(MPN/100ml)	---	200	5%	<2	10	<2
BOD	---	---	---	---	50	50
COD	---	---	---	---	250	250

Note:
1. USEPA = United States Environmental Protection Agency; WHO = World Health Organization; GHEPA = Ghana Environmental Protection Agency.
2. uS/cm = microSiemens per centimeter; TDS = total dissolved solids; TSS = total suspended solids; NTU = nephelometric turbidity units; TCU = true color units; WAD = weak acid dissociable; MPN = most probable number; ml = milliliter; BOD = biological oxygen demand; COD = chemical oxygen demand.
3. Values with a single asterisk * are hardness dependent; concentrations reported in this table are based on a hardness of 150 mg/l for comparison purposes only.
4. Values with a double-asterisk ** in the third column are primary drinking water standards for USEPA.

Results of chemical analyses from 1998-2005 (see **Table C-5** in **Appendix C**) show that quality of surface water in the Project area is typical of water found in wet tropical regions of Ghana. A statistical summary of surface water quality data is presented in **Table 4-37**. In general, surface water exhibits a low conductivity (10 to 65 micromhos per centimeter (µm/cm)) and total dissolved solids (TDS; 1 to 1,520 milligrams per liter (mg/l)), near neutral pH (6.2 to 8.0 standard units), moderately hard to hard (37 to 216 mg/l), and low to moderate nutrient concentrations (e.g., nitrate, nitrite, and phosphorus). Nitrate was elevated (47 mg/l) in only one surface water sample (KSW14; upper Awonsu stream), which exceeds the water quality standard of 10 mg/l.

TABLE 4-37
Summary of Surface Water Quality
Ahafo South Project

Parameter	Concentration (milligrams per liter, unless otherwise noted in first column)			
	Minimum	Maximum	Mean	Lowest Drinking Water Standard
Specific Conductance (micromhos/cm)	10	65	27	500
True Color (TCU)	<5	150	23	75
Total Suspended Solids	0.1	937	30	50
Total Dissolved Solids	1.2	1520	183	500
Turbidity (NTU)	<0.1	1800	49.4	5
pH (standard units)	6.2	8.0	7.2	6.5 – 8.5
Calcium	7.3	61.9	20.1	---
Chloride	<0.5	51.6	6.8	250
Cyanide, free	<0.01	0.10	0.01	0.07
Magnesium	1.7	20.7	8.5	---
Potassium	1.6	29.0	7.5	---
Sodium	2.7	46.1	18.1	200
Sulfate	<0.1	71.4	8.4	250
Total Alkalinity	36	242	106	---
Total Hardness	37	216	94	300
Silica	19.4	31.9	27.9	---
Nitrate	<0.01	47.0	0.96	10
Nitrite	<0.01	0.82	0.05	1
Phosphorus	0.01	1.50	0.30	2
Aluminum	<0.01	57.0	1.85	0.05
Antimony	<0.01	0.10	0.10	0.006
Arsenic	<0.001	0.021	0.002	0.01
Cadmium	<0.01	<0.02	0.01	0.003
Chromium	<0.001	<0.010	0.010	0.1
Cobalt	<0.01	<0.01	0.01	---
Copper	<0.01	0.01	0.01	0.5
Fluoride	0.1	0.6	0.4	1.5
Iron	0.02	198	5.64	0.3
Lead	<0.001	<0.010	0.010	0.01
Manganese	<0.01	103	0.84	0.05
Mercury	<0.001	0.010	0.001	0.001
Nickel	<0.001	0.090	0.010	0.0134
Selenium	<0.001	0.005	0.001	0.01
Silver	<0.01	0.01	0.01	0.1
Zinc	<0.003	3.98	0.14	2

Note:
1. See **Appendix C** for complete water quality database. See **Table 4-36** for complete list of water quality standards.
2. TCU = true color units; NTU = nephelometric turbidity units.
3. Below detectable concentrations are set equal to the detection limit value for statistical calculations.
4. Concentrations reported for metals are "total".

With the exception of a few analyses for arsenic, only non-filtered surface water samples were analyzed as "total" constituents. Therefore, high levels of total suspended solids (TSS = up to 937 mg/l) in some samples may be the primary reason for elevated concentrations of some constituents, especially metals. The water quality standard for TSS is 50 mg/l.

Based on the most stringent drinking water quality standards presented in **Table 4-37**, at least one surface water sample exceeded respective standards for the following constituents: true color, TSS, TDS, turbidity, free cyanide, nitrate, aluminum, antimony, arsenic, iron, manganese, mercury, nickel, and zinc. The following parameters have associated water quality standards but have not been analyzed in surface water samples for the Ahafo South Project: barium, beryllium, boron, molybdenum, and thallium.

Tano River

The Tano River flows year-round and is the largest water body in the Project area. Of the 24 surface water monitoring stations in the Project area, two are on the Tano River (KSW1 downstream of Project area, and KSW8 in upper end of Project area). In addition to the region-wide exceedances of water quality standards for turbidity, TSS, iron, manganese, and aluminum, the Tano River exhibits occasional (7% of samples) elevated mercury and nickel concentrations. Monitoring station KSW1 is the only station in the Project area exhibiting exceedances of the lowest nickel standard (0.0134 mg/l).

Suraw/Suntim Sub-Basin

The Suraw/Suntim sub-basin joins the Tano River approximately 2 km southeast of Hwidiem. Water chemistry is similar to other streams in the region with exceedances of standards detected for color, turbidity, TSS, iron, manganese, and aluminum.

Subri Sub-Basin

The Subri stream and tributaries comprise the largest sub-basin in the Project area. Of the 24 surface water monitoring stations in the Project area, 10 of them are within the Subri sub-basin. Water quality is similar to other streams in the region with exceedances of water quality standards for color, turbidity, TSS, iron, manganese, and aluminum. The standard for mercury (0.001 mg/l) was exceeded in the upper Subri sub-basin (NSW9), Subika stream (KSW13), and downstream of their confluence (KSW2). Samples from spring KSW9 exceeded the 0.01 mg/l standard for arsenic (75% of samples) and the 2.0 mg/l standard for zinc (50% of samples). One sample from station NSW9 (upper watershed) also exceeded slightly the arsenic standard.

Awonsu Sub-Basin

Located immediately north of the Subri sub-basin, the Awonsu sub-basin exhibits seasonal flow. Five surface water monitoring stations are located in this sub-basin. In addition to the region-wide exceedances of turbidity, iron, manganese, aluminum, and TSS, water samples from the Awonsu sub-basin exhibit occasional elevated mercury at two locations along the main stream (KSW14: 29% of samples, and KSW7: 7% of samples). In addition, KSW14 is the only surface water monitoring station in the Project area exhibiting an exceedance of the water quality standard for nitrate (14% of samples).

Ntotro Sub-Basin

The small Ntotro sub-basin contains the village of Ntotoroso located north-northeast of the Awonsu sub-basin. One monitoring station (NSW3) is located on the Ntotro stream, which exhibits seasonal flow. Water quality is similar to other streams in the region with some exceedances of water quality standards for turbidity, TSS, iron, manganese, aluminum, and mercury.

Asuade and Amama Sub-Basins

The Asuade and Amama streams drain the north end of the Project area. Of the 24 surface water monitoring stations in the Project area, two are within the Asuade sub-basin (NSW4 and NSW7) and one in the Amama sub-basin (KSW5). Water quality is similar to other streams in the region with water quality exceedances for turbidity, iron, manganese, and aluminum. Concentrations of mercury and TSS exceeded the standards of 0.001 mg/l and 50 mg/l, respectively, in the Asuade headwaters (NSW7: mercury 67% of samples, and TSS 17% of samples). Samples from the Asuade sub-basin (NSW7) also exhibited zinc (13% of samples) and arsenic (25% of samples) above the standards of 2.0 mg/l and 0.01 mg/l, respectively.

DIRECT AND INDIRECT IMPACTS

Surface Water Quantity and Use

Construction of the mine and ancillary facilities would directly affect about 2,174 ha (**Table 2-2**) through removal of vegetation, soil, and subsoil. Many of these facilities are located across drainage bottoms such that natural seasonal flow would be blocked and/or diverted around them. The drainages are all tributary to and on the west side of the Tano River, and are dry most of the year (i.e., ephemeral). The following is a summary of primary mine-related facilities and their location relative to drainages (see **Figure 4-7**):

- **Subika Mine Pit:** This pit would be excavated over an area of 88 ha across the upper Samansua stream, which is a seasonal tributary to the Subri stream.

- **Apensu Mine Pit:** The northernmost part of this mine pit would cross the upper part of a tributary seasonal stream of the Asundua stream in the Subri sub-basin. This mine pit would ultimately affect an area of 74 ha.

- **Awonsu Pit:** The northernmost part of this 52-ha pit would intercept the seasonal Awonsu stream and a short upper segment of a small tributary channel. The southern part of the pit would cross the uppermost segment of a tributary channel to the seasonal Asundua stream in the Subri sub-basin.

- **Amama Mine Pit:** This mine pit would be excavated over an area of 36 ha in a small unnamed sub-basin that drains directly to the Tano River, located between the Asuade and Amama sub-basins.

- **Subika Mine Waste Rock Disposal Facilities:** These two rock piles would be constructed over a total area of 276 ha on two sides of the Subika mine pit across the upper Samansua stream, which is a seasonal tributary to the Subri stream. The northernmost waste rock disposal facility would also cross the upper part of a small channel that is tributary to the Asundua stream in the Subri sub-basin.

- **Apensu Waste Rock Disposal Facility:** This rock pile would be located on 93 ha along the downstream side of the tailing storage facility embankment in the Subri stream sub-basin.

- **Awonsu Waste Rock Disposal Facility:** This rock pile would be constructed on 165 ha in the upper part of two small channels that are tributary to the Awonsu stream. The waste rock disposal facility would be located on the west side of the Awonsu mine pit.

- **Amama Waste Rock Disposal Facility:** This rock pile would be constructed on the southeast side of the Amama mine pit in a small unnamed sub-basin that drains directly to the Tano River. This 73-ha waste rock disposal facility area would be located between the Asuade and Amama sub-basins. A small portion of the waste rock disposal facility would be in the Asuade sub-basin.

- **Tailing Storage Facility:** This facility would be constructed across the drainage bottom of the Subri stream, between the Apensu waste rock disposal facility and water storage dam. The impoundment will cover an area of about 460 ha at the end of mining and processing.

- **Water Storage Facility:** This impoundment would collect water draining from the upper portion of the Subri sub-basin (2,900 ha), immediately upstream of the tailing storage facility. The impoundment will cover an area of about 280 ha when full. A spillway at the water storage facility would direct excess water into a tributary of the Awonsu stream.

- **Environmental Control Dams:** Five small earthen dam structures would be constructed in the Subri sub-basin, Awonsu sub-basin, and unnamed sub-basin that contains the Amama mine pit and waste rock disposal facility to collect water that runs off disturbed areas and to allow sediment to settle behind the dams.

- **Plant Site:** Most processing facilities would be constructed in an unnamed sub-basin that drains directly to the Tano River. No drainage channels would be directly affected by these facilities that would cover an area of about 113 ha. Some relatively small ore stockpiles (run-of-mine ROM storage pad), however, would be located in the upper portion of a tributary channel to the seasonal Asundua stream in the Subri sub-basin.

- **Pumping Station:** The makeup water pumping station would be located on the Tano River approximately 2.6 km east of the plant site. The water transmission pipeline from the pumping station to the plant site would cross the Awonsu sub-basin and an unnamed sub-basin that drains directly to the Tano River.

- **Senior Staff Village and Kenyase Bypass:** The senior staff camp, operations village, and Kenyase bypass road would be located in the Subika stream drainage which is within the Subri sub-basin.

With the exception of the water storage facility, tailing storage facility, and environmental control dams, seasonal surface water that flows toward the mine facilities listed above would be diverted around them in channels designed to transport the 100-year, 24-hour storm event. Runoff from disturbed areas and water that collects in the mine pits during operations (direct precipitation and some groundwater seepage) would be diverted to one of the environmental control dams. Settled stormwater runoff and collected groundwater would then be released to the environment providing that it meets discharge standards. Excess water that collects in the tailing storage facility would be recycled to a process water pond at the plant site.

Outside of the direct disturbance areas described above, no disturbance would occur to drainages in the Project area. New roads associated with the mine Project, including the new Ntotoroso/Kenyasi public road, would require construction of culverts at the stream channel crossings. These roads and stream crossings, however, would not affect surface water flow rates or quality in the drainages. Some short-term increases in sediment load to the drainages could occur during construction of the road crossings.

Changes in topography resulting from mining activities (pits and waste rock disposal facilities), and construction of the tailing storage facility, water storage dam, plant site, and other associated project facilities would progressively modify watershed characteristics of the Tano River sub-basins listed above. Overland runoff volume and peak could be higher as a result of vegetation removal for land development. Consequently, the surface water flow regime in the Project area would be changed, especially in the Subri sub-basin where the tailing storage and water storage facilities would be located.

A pump station is planned for the Tano River east of the plant site to provide for additional makeup water during initial stages of filling the water storage facility. A water right would be obtained for the desired quantity, which would be pumped only during one wet period (i.e., May through November) to minimize adverse effects on fisheries and other beneficial users. The percentage of water pumped from the river as a portion of total stream flow would be about 2 percent for normal conditions and up to 19 percent for low flow conditions (Knight Piésold Consulting 2004). Pumping would not occur during low flow conditions, however. The pump station would not require damming or changing the course of the river. The pump station and associated piping and access road will be removed after the pumping program is completed and the area closed and revegetated.

If quality of water that collects in environmental control dams is acceptable (see **Table 4-36**), this water could be discharged back to the natural drainages, even though this water is planned for distribution to the tailing storage facility.

Any surface water captured by mine-related facilities and not released back into the natural drainages would be lost to downstream water users, including the Tano River. This would have a direct effect on stream users, particularly hamlets located directly downstream of the water and tailing storage facilities in the Subri sub-basin. However, NGGL has committed to provide alternative source(s) of water for those residents that remain in the Subri sub-basin. Some tributary streams in the Project area are ephemeral and contain water only during periods of heavy rainfall.

The water storage and tailing storage facilities would capture runoff from about 2,900 ha or 25 percent of the entire Subri sub-basin, and 0.01 percent of the entire Tano River basin. Mean annual runoff into the water storage facility is approximately 2.9×10^6 m^3/year. Water impoundment would cause an average water loss of about 2.4×10^6 m^3/year due to evaporation (SGS 2000a, 2004). Waste rock

disposal facilities can increase overland runoff due to steeper slopes and less vegetative cover; however, these effects would be localized.

The water storage facility would be about 5 km long along the Subri stream when full. The Awonsu stream would receive overflow from the water storage facility by spillway; frequency of this overflow would be rare. Outflow could be 30 m^3/sec, which compares to about 690 m^3/sec for a 100-yr flood in the Awonsu stream (SGS 2000a, 2004).

The tailing storage facility would be about 2 km long and 2 km wide along the Subri stream immediately downstream from the water storage facility. Any flow in upper reaches of the Subri sub-basin would be retained in the water storage facility and not enter the tailing storage facility. Direct precipitation falling onto the water and tailing storage facilities would be collected in the impoundments.

Mine pit dewatering could increase stream flow if discharged to drainages. Estimated maximum pumping rates would be 0.07 m^3/sec, which would be negligible when compared to peak flood flows in the drainages. Water from mine pit dewatering systems would be discharged to drainages only if quality is acceptable; otherwise, this water would be discharged to the tailing storage facility and/or the plant site for makeup water.

Indirect effects on surface water quantity may occur from increased human population density and associated demands for crop production. With removal of land from production and resettlement of affected villages to adjacent areas, population densities would increase locally. Also, with construction and operation of the mine, more people will come to the area seeking jobs or would be employed at the mine. This could increase demand for surface water outside the mine disturbance area.

After cessation of mining and processing, the water storage facility would remain and continue to intercept water from the upper part of the Subri sub-basin. Water that collects in this impoundment, however, would be available for users within and surrounding the basin. Water loss due to evaporation and seepage from the water body would continue. During extreme precipitation events, water could also be discharged to the Awonsu stream via the spillway. The tailing storage facility, waste rock disposal facilities, and plant site would be reclaimed with soil and vegetation, and therefore, would approach pre-mine runoff conditions. Most precipitation that falls onto these facilities would run-off or evapotranspirate from the reclaimed surfaces.

The mine pits would remain open after cessation of mining, with diversion channels surrounding them to prevent natural surface water runoff from entering the pits. No water discharge would occur from the pit lakes that would develop after cessation of mining.

Surface Water Quality

Potential impacts to surface water quality from mine-related facilities can result from direct disturbance to the land (increased erosion and sedimentation), exposure of fresh rock and mineral surfaces to weathering and leaching (potential for acid generation and/or increased leaching of metals), and accidental spills of chemicals and petroleum products used for mine processing activities.

During mining and processing operations, no discharge of process effluent or other impacted water is planned from the tailing storage facility, mine pits, waste rock disposal facilities, plant site, and environmental control dams. Water may be periodically discharged from the water storage facility,

mine dewatering system, and/or environmental control dams if quality meets applicable standards (see **Table 4-36**) and is approved by the Ghana EPA. NGGL intends to incorporate a risk-based approach for water discharges, with approval from Ghana EPA that considers beneficial use of water in the affected drainage(s).

During implementation of the Project, particularly the construction phase, land disturbance in the Subri sub-basin, Awonsu sub-basin, and unnamed sub-basin containing the Amama mine pit and waste rock disposal facility would result in increased erosion and sedimentation. The Amama mine pit and waste rock disposal facility are from 0.5 to 1 km from the Tano River and, therefore, are of particular concern with respect to erosion and sedimentation that could reach the Tano River. All other mine-related facilities, except for some road segments, would be located at least 2 to 4 km from the Tano River. The roads would be constructed with ditches to collect and convey water runoff from road surfaces to sediment traps or ponds.

Environmental control dams (**Figure 4-7**) would be constructed downgradient from each waste rock disposal facility and mine pit area to collect and settle sediment in runoff water from these areas. A short-term increase in erosion and sedimentation may result during construction of the water pumping station within the Tano River channel, and the water transmission pipeline that would extend from the river across two sub-basins to the plant site.

Implementation of Best Management Practices (BMPs) would prevent or reduce increased sediment load to streams outside of direct disturbance areas. Such BMPs would include: clearing land only when necessary and during the dry season; revegetating disturbed areas promptly; placing silt fences and straw bales down-slope of disturbed areas; constructing ditches and settling traps/ponds in close proximity to disturbed areas; and protecting native vegetation along drainage channels.

An increase in suspended solids can render surface water less suitable for human consumption. As described previously in the *Surface Water Quality* section, baseline levels of suspended sediment usually are high. Due to the ephemeral flow conditions of most streams in the Project area, many communities have more than one source of water. Those with a single stream water source still manage to obtain water through dugouts excavated into the streambed during the dry season. Inhabitants in the Project area would be relocated due to their proximity to Project facilities.

In order to evaluate potential for acid rock generation for the waste rock disposal facilities and tailing storage facility, numerous oxide and sulfide composite samples in the mine pit areas were tested using static testing methodology (acid-base accounting) (see *Geology and Minerals* section in this chapter). Results show low to non-existent acid-generation potential and very high neutralization capacity for representative waste rock. Small amounts of unoxided sulfide ore material are considered "slightly acidic". Overall, there is low risk of acid mine drainage from the various waste rock disposal facilities and the tailing storage facility.

Concentrations of metals that could mobilize from tailing material were evaluated by analyzing two samples (oxide-ore and primary-ore tailing) for multi-element composition. Results of the solids analysis indicate that both samples were enriched in arsenic and antimony, with concentrations of about 100 mg/kg and 5 to 10 mg/kg, respectively (SGS 2000a, 2004). Representative tailing slurry samples indicate

the samples generally are slightly alkaline (pH = 9 to 10), with elevated concentrations of antimony (0.5 mg/l), arsenic (2 mg/l), copper (14 mg/l), iron (6 mg/l), and nickel (2 mg/l) (SGS 2000a). Concentrations of total cyanide and weak acid dissociable (WAD) cyanide were approximately 20 mg/l in the oxide-ore tailing slurry water sample, and 160 mg/l in the primary-ore water sample (SGS 2000a, 2004).

Potential for Release of Mine Process Solutions

NGGL recently completed a process feasibility study that included analysis of process solution chemistry, providing data on potential constituents in process solutions at the plant facility. Data derived from processing various ore types are presented in **Table 4-38**, including cyanide concentrations in process solutions.

Analytical results of pregnant solution after leaching ore for three of the mine pit areas show elevated concentrations of arsenic, copper, iron, nickel, and zinc. These samples also showed cyanide concentrations up to 150 mg/l (total), 130 mg/l (free), and 140 mg/l (WAD). NGGL has initiated a study to predict site-specific cyanide levels and degradation pathways to confirm this observation. This effort will include modeling that incorporates solution pH, total solution volume, ambient temperature, barometric pressure, concentrations of metals and metal complexes, thermodynamic and Henry's Law behavior of hydrogen cyanide, precipitation of solution species during transport, and porosity of media in which solutions flow. Purpose of the study is to estimate potential cyanide fluxes at the site, and assesses the relative importance of various cyanide degradation mechanisms.

TABLE 4-38
Analysis of Pregnant Solution After Leaching Ore
Ahafo South Project

Constituent	Apensu/Awonsu		Amama		Subika	
	Oxide Ore	Primary Ore	Oxide Ore	Primary Ore	Oxide Ore	Primary Ore
Arsenic (As)	<0.2	0.85	<0.20	<0.20	<0.1	<0.1
Copper (Cu)	0.82	4.21	0.34	1.64	0.96	2.22
Iron (Fe)	<0.05	1.2	0.06	0.75	0.12	0.05
Lead (Pb)	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Nickel (Ni)	1.24	1.01	0.32	0.76	0.62	0.23
Silver (Ag)	---	---	0.1	0.11	0.2	0.17
Zinc (Zn)	<0.02	0.11	1.82	0.62	0.69	0.29
Cyanide (total)	1.3	6.1	50	110	150	140
Cyanide (free)	0.52	2.2	34	79	130	110
Cyanide (WAD)	1.3	4.4	48	99	140	130

Note: Concentrations in milligrams per liter (mg/l). CN = cyanide; WAD = weak acid dissociable.
Source: Newmont 2004b; Lycopodium 2003.

Results of whole rock analyses presented in **Table 4-27** indicate that levels of antimony, arsenic, barium, and selenium are high in rock from the Apensu mine pit area, compared with average levels in the earth's crust. Concentration of selected analytes in tailing slurry and pregnant solutions are elevated including antimony, arsenic, copper, iron, nickel, and free cyanide. Photodegradation of tailing slurry water is expected to rapidly reduce cyanide concentrations in the supernatant pond to below 50 mg/l. In addition, tailing slurry would be recycled would not be discharge from the tailing storage facility. As

described in the *Geology and Minerals* section of this chapter, NGGL is in the process of more detailed geochemical characterization of geologic material from the Ahafo South Project to confirm and validate current geochemical data analysis.

Typical reagents to be used for mine processing include sodium cyanide, lime, caustic, hydrochloric acid, activated carbon, and flocculants. These materials would be transported and stored according to the compatibility principle in a secure area within the plant site. A fuel storage area also would be located in the plant site with approved containment for gasoline and diesel. Accidental spillages of oil could occur from drums stored in inappropriate conditions or from vehicles that have mechanical problems.

Discharge of water containing cyanide or other chemicals would be prevented by operating all gold extraction and processing operations using a water/chemical solution recycle system. Secondary containment has been designed for all process piping, tanks, and conveyor systems transporting chemically-treated ore to prevent releases to the environment during upset conditions. From the treatment plant, process residues would be pumped to the tailing storage facility where solids would settle. Supernatant water containing cyanide would be collected by floating pumps and piped to the process water pond at the plant site. Therefore, no effluent would be released to the environment, except possibly under an accident.

A package sewage treatment plant located near the plant site and senior staff village would be used to treat sewage from the plant, mine contractor's area, and mine housing areas. Treated effluent would be discharged to local drainages. Effluent will be monitored periodically to ensure compliance with relevant discharge standards. Parameters would include pH, conductivity, turbidity, total suspended solids, chemical oxygen demand, biological oxygen demand, total and fecal coli form bacteria, free chlorine, nitrate, and phosphate. Operation of the sewage treatment plant is expected to have no adverse impacts to surface water quality.

Only inert, dry solid wastes generated by the mine operations would be buried in a landfill constructed in the waste rock disposal facilities. This landfill will be constructed to minimize both the rate of infiltration and quantity of runoff available for infiltration. This landfill is expected to have no adverse impact on surface water quality.

After cessation of mining and processing, the water storage facility would remain and continue to intercept water from the upper part of the Subri sub-basin. Water from this reservoir would only be discharged via the spillway during extreme precipitation events; however, the quality should have no adverse impact to the receiving water (Awonsu stream). The tailing storage facility, waste rock disposal facilities, and plant site would be reclaimed with soil and vegetation, and therefore, would approach pre-mine runoff conditions. This runoff may have increased levels of sediment during the first few years of reclamation until vegetation becomes well established. The mine pits would remain open with diversion channels surrounding them to prevent natural surface water runoff from entering the pits. No water discharge would occur from the mine pit lakes that would develop after cessation of mining.

ALTERNATIVES ANALYSIS

A closure alternative that addresses potential poor quality water in pit lakes could consist of partial backfill of the mine pits to levels above the ultimate pit lake surfaces. This action would prevent direct contact with pit lake water by humans and wildlife. This alternative would also reduce the size of waste rock disposal facilities and place the material in a saturated reducing environment within the mine pits.

Another alternative that addresses potential poor quality water in pit lakes is the treatment of water in the pit lakes to achieve water quality standards or risk-based criteria. Treatment could be accomplished by pumping water through an external treatment facility and/or using method(s) to treat water within the pit lake (in-situ).

A closure alternative that addresses potential water quality problems from the waste rock disposal facilities would consist of constructing a cap (design not specified) that would further limit the amount of precipitation infiltrating into the rock piles. The cap could consist of additional growth media that would increase storage of precipitation and release by evapotranspiration, or incorporate low permeability material on the top of the dumps to inhibit infiltration of precipitation. A low permeability layer, however, may increase surface water runoff from the dump surfaces. The quality of this water should be good because it would have infiltrated through growth media and not waste rock.

Another alternative that addresses potential poor quality water migrating through the waste rock disposal facilities and/or tailing storage facility is to collect and treat any water that discharges as seeps from the toe of dumps and tailing storage embankments. This action would improve water quality so that any of this water that continues to move downgradient as surface water would meet water quality standards.

NO PROJECT ALTERNATIVE

Implementation of the No Project Alternative would eliminate the potential impacts to surface water resources that are described for the Project and closure alternatives. Once NGGL completes reclamation of the area disturbed by initial construction activities, baseline conditions associated with surface water resources are expected to resume.

GROUNDWATER RESOURCES

BASELINE CONDITIONS

Information about hydrogeological conditions in the Ahafo South Project area has been obtained from site observations, exploration drilling logs, monitoring wells, and boreholes. In general, groundwater is present in localized confined to semi-confined aquifers within fractured, weathered bedrock. Confinement is provided by low permeability overlying saprolite and underlying competent bedrock. Unconfined groundwater occurs locally in alluvial silt, sand and gravel zones along major rivers and streams.

Several studies and documents have been completed that describe groundwater resources for the Ahafo South Project area:

- In February 1997, Steffen, Robertson and Kirsten (SRK) completed a study of the northern portion of the Ahafo Project area, with two main objectives: (a) assess potential groundwater inflow into the open pits; and (b) estimate groundwater supply potential for the mine operation.

- In 1999, Burgéap completed a hydrogeological study in the Ahafo South Project area, with objectives similar to those described above for SRK.

- In 2004, Golder Associates completed several piezometers in the proposed Apensu pit area to evaluate potential dewatering and pit wall stability conditions. Tests were performed in these piezometers to estimate hydraulic conductivity. Water levels were monitored periodically in the piezometers during 2004.

- In 2000, two Environmental Impact Statements were completed by SGS (2000a, 2000b) that describe water resources in the Ntotoroso and Sefwi Belt Project areas.

- In September 2004, SGS (2004) completed an Environmental Impact Statement for the Ahafo South Project. This is the most recent document that describes water resources in the Project area.

Groundwater Quantity and Use

Primary porosity and permeability are low in geological formations of the Project area (metasediments and granitoids). The occurrence of groundwater is associated with fractures and weathered zones in the bedrock formations. The typical aquifer system is composed of relatively low permeability weathered zone drained by fractures underneath. As stated above, these zones are confined or semi-confined by lower permeability overlying saprolite and underlying solid bedrock. The more productive fractures appear to have an orientation of about N90°E and N140°E (Burgéap 1999).

A localized shallow perched aquifer occurs above ferricrete horizons to depths of about 3 m generally in low-lying areas. Springs develop in areas of sufficient local recharge where the perched groundwater is forced to emerge as a result of ferricrete outcrop.

A regional semi-confined weathered/fractured aquifer occurs at the saprolite/saprock/bedrock zone contact. The aquifer may extend a few meters into the greywacke bedrock if sufficient weathering and jointing occurs. The base of the aquifer comprises the slightly unfractured bedrock at a depth of up to 50 m. Average aquifer thickness is likely in the range of 5 to 10 m. Due to high variations in depth of the saprolite zone, aquifer thickness varies over short distances. This aquifer is recharged both by infiltration of precipitation and by groundwater through-flow.

The third aquifer type identified is the deeper fractured bedrock where water may occur within discrete structures (i.e., fault and shear zones) in the bedrock. This aquifer can occur at various depths throughout the bedrock profile, but is less likely to occur below depths of 80 to 100 m.

Groundwater yield from individual wells or boreholes generally is not sufficient for industrial purposes, but can supply smaller quantities to villages for domestic purposes. The best permanent yields, which can be expected in a borehole, do not typically exceed 20 to 30 m^3/hour (Burgéap 1999).

Results of hydraulic conductivity tests performed in eight piezometers completed in the Apensu mine pit area show values in the range of 3.7×10^{-2} to 3.0×10^{-6} cm/sec (Golder Associates 2004). These piezometers are completed in saprolite, saprock, or bedrock. Average hydraulic conductivity for the eight tests is 2.5×10^{-5} cm/sec which indicates that the rock overall has low permeability. Piezometer depth ranges from 17 to 80 m. Depth to water is greatest in the bedrock, and shallowest in the saprolite, with most water levels in the range of 20 to 30 m below ground surface. Three piezometers have water levels at depths of 1 to 5 m below ground surface. In the first half of 2004, highest water levels occurred in February-March, declining up to a meter in May-June-July.

Table 4-39 is a list of drinking water boreholes/wells and exploration boreholes that are monitored in the Ahafo South Project area. Two of the four drinking water boreholes do not have water quality analyses; these boreholes will be sampled for baseline conditions, however. The exploration boreholes are located in the vicinity of the Apensu and Awonsu mine pits and plant site.

TABLE 4-39
Groundwater Monitoring Locations

Well/Borehole Name	Location
Potable Supply Boreholes/Wells	
KDBH1	Kenyase village well near Catholic Church
KDBH2	Prison Camp well on Kenyase-Ntotoroso road
NDBH1	Ntotoroso village well in Ntotro watershed; no water quality samples.
NDW	Kwakyekrom village open well; no water quality samples.
Monitoring Boreholes	
KBH1 – KBH4	Exploration boreholes in vicinity of Apensu Mine Pit
KBH5	Exploration borehole at Awonsu Mine Pit area
KBH6	Exploration borehole at plant site opposite Kwakyekrom

Groundwater Quality

In general, groundwater in the Project area exhibits low conductivity (5 to 102 mS/cm), slightly acidic to neutral pH (5.4 to 7.3 standard units), and low nutrient concentrations (SGS 2000a, 2004). Nitrate, however, has a wide range of concentrations from <0.01 to 268 mg/l.

Analytical results of samples from monitoring boreholes KBH1 through KBH6 and water supply wells KDBH1 and KDBH2 are tabulated in **Appendix D**. A statistical summary of all groundwater samples is presented in **Table 4-40**). Comparison of these background groundwater data to the most stringent drinking water quality standards (**Tables 4-36** and **4-40**, and **Appendix D**) shows that:

- Aluminum exceeded the lowest drinking water standard of 0.1 mg/l one or more times in five of the six monitoring boreholes and prison camp supply well KDBH2, with a range of <0.1 to 27 mg/l.

- Arsenic exceeded the lowest drinking water standard of 0.01 mg/l in only one sample from monitoring borehole KBH5 (0.012 mg/l).

- Iron exceeded the lowest drinking water standard (secondary) of 0.3 mg/l at all monitoring boreholes, with a range of up to 36 mg/l.

- Manganese exceeded the lowest drinking water standard (secondary) of 0.05 mg/l one or more times in all monitoring boreholes and village supply well KDBH1, with a range of <0.01 to 1.5 mg/l.

- Mercury exceeded the lowest drinking water standard of 0.001 mg/l only in KBH1 (0.003 mg/l).

- Nickel exceeded the lowest drinking standard of 0.0134 mg/l in KBH2, KBH3, and KDBH1, with a range of 0.02 to 0.1 mg/l.

- Nitrate exceeded the lowest drinking water standard of 10 mg/l in samples from monitoring boreholes KBH1 (180 mg/l) and KBH2 (268 mg/l), both of which are monitoring boreholes located in the Apensu mine pit area. Reasons for these high nitrate levels are unknown. The nitrate standard was also slightly exceeded (13.5 mg/l) in Kenyase village well KDBH1.

- The standard for total dissolved solids (secondary) of 500 mg/l was exceeded in samples from KBH2 (775 mg/l) and KDBH1 (501 mg/l).

Elevated concentrations of these metals, especially iron, manganese, and aluminium, likely are associated with elevated levels of suspended solids. With the exception of a few samples analyzed for arsenic, only non-filtered samples were analyzed for total metal concentrations. The dissolved fraction of metals for at least the monitoring borehole samples, if analyzed, probably would have been at lower concentrations, and possibly below the water quality standards.

Total suspended solids (TSS) and turbidity were high in some groundwater samples (up to 740 mg/l and up to 3,000 NTU, respectively). Lowest drinking water standards for TSS and turbidity are 50 mg/l and 5 NTU, respectively. The elevated TSS and turbidity levels are in samples from monitoring boreholes; this is typical of wells that are not completely developed. The well screen does not adequately filter-out the fine-grained suspended sediment.

Microbiological testing of groundwater samples shows adverse impacts of some samples by total and fecal coli form bacteria. These effects generally can often be correlated with seasonal precipitation patterns (i.e., higher concentrations during the wet seasons). These elevated bacteria levels, as well as elevated nitrate concentrations, are indicative of improper or non-existent sewage systems for villages (see *Social and Economic Resources* section in this chapter).

DIRECT AND INDIRECT IMPACTS

Groundwater Quantity and Use

Groundwater quantity could be affected by pumping wells for mine potable supply and mine pit dewatering. Previous groundwater investigations determined that most boreholes are located on or adjacent to the major shear zone within aquifers located at the contact between weathered and competent bedrock (Burgéap 1999). Best permanent yield from an individual well or borehole is about 20 to 30 m^3/hour.

Expected potable water demand for the Ahafo South Project is approximately 260 m^3/day. It is planned that five wells would be completed approximately 5 km from the mine area to provide potable water to the plant site. An additional three wells would be completed about 5 km from the operations village area to supply potable water to that facility. All eight potable supply wells would each pump up to 12 m^3/hour periodically to maintain sufficient water in holding tanks. Pumping groundwater at these relatively low intermittent rates should not have adverse effects on groundwater levels or quantity in the Project area. Groundwater resources are an important source of water supply for domestic and drinking purposes. In the various villages and hamlets, borehole locations are generally greater than 1 km from mine facilities.

TABLE 4-40
Summary of Groundwater Quality
Ahafo South Project

Parameter	Concentration (milligrams per liter, unless otherwise noted in first column)			
	Minimum	Maximum	Mean	Lowest Drinking Water Standard
Specific Conductance (micromhos/cm)	6	102	41	500
True Color (TCU)	<5	5	5	75
Total Suspended Solids	<0.1	740	109	50
Total Dissolved Solids	45	775	270	500
Turbidity (NTU)	<0.1	3000	234	5
pH (standard units)	5.4	7.3	6.6	6.5 – 8.5
Calcium	10.8	64.3	38.8	---
Chloride	0.02	16.2	7.04	250
Cyanide, free	<0.01	0.01	0.01	0.07
Magnesium	1.7	23.0	10.0	---
Potassium	0.32	51.6	8.64	---
Sodium	7.4	77.5	28.2	200
Sulfate	<0.1	16.3	2.5	250
Total Alkalinity	5.7	274	104	---
Total Hardness	15.8	244	113	300
Nitrate	<0.01	268	47	10
Nitrite	<0.01	3.78	0.73	1
Phosphorus	0.01	6.64	1.67	2
Aluminum	<0.1	27.2	4.1	0.05
Antimony	<0.1	<0.1	0.1	0.006
Arsenic	<0.001	0.012	0.003	0.01
Cadmium	<0.01	<0.01	0.01	0.003
Chromium	<0.01	0.10	0.02	0.1
Cobalt	<0.01	<0.01	0.01	---
Copper	<0.01	0.14	0.03	0.5
Iron	0.01	35.6	5.02	0.3
Lead	<0.01	<0.01	0.01	0.01
Manganese	<0.01	1.54	0.38	0.05
Mercury	<0.001	0.003	0.001	0.001
Nickel	<0.01	0.10	0.01	0.0134
Selenium	<0.001	<0.001	0.001	0.01
Silver	<0.001	0.010	0.008	0.1
Zinc	<0.01	0.67	0.24	2

Note:
1. See **Appendix D** for complete water quality database. See **Table 4-36** for complete list of water quality standards.
2. TCU = true color units; NTU = nephelometric turbidity units.
3. Below detectable concentrations are set equal to the detection limit value for statistical calculations.
4. Concentrations reported for metals are "total".

The four mine pits would be dewatered with sumps constructed inside the pits. Dewatering wells currently are not anticipated for the mine pits due to low permeability (average of 2.5×10^{-5} cm/sec from eight tests in Apensu mine area) of rock in the mine pit areas (Golder Associates 2004). As a result, groundwater drawdown surrounding the mine pits would be localized and not expected to affect wells at nearby boreholes for villages and hamlets. Assuming rates of 30 m^3/hour are drained into or pumped from each mine pit, groundwater drawdown would occur for several hundred meters around each mine pit (SGS 2000a, 2004). Water extracted from the mine pits would be discharged to the environmental control dams and/or tailing storage facility, depending on water quality.

Groundwater flow intercepted by water supply wells and the mine pits could reduce flow in nearby streams where the groundwater is interconnected with surface water. These connections, however, are not well understood in the Project area. These impacts, if any, are expected to be minor and localized because most surface water in the Project area, with the exception of the Tano River, flows primarily in response to major rain events.

After cessation of mining and dewatering, pit lakes would develop in each mine pit, with water levels eventually approaching pre-mine elevations. Final pit lake levels are expected to approach pre-mine groundwater levels in these areas (approximately 20 to 30 m below ground surface). Timing for pit lake filling is unknown, but is expected to be slow due to the low permeability of rock surrounding the mine pits. Evaporation from lake surfaces would reduce groundwater quantity. Direct precipitation on these pit lakes, however, would offset some of the evaporative loss.

An alluvial cutoff trench to be constructed at the water storage facility and tailing storage facility would reduce groundwater flow in the alluvium downgradient from these sites. The amount of groundwater flow in alluvium in these areas, however, is limited due to the low thickness and permeability of the alluvial deposits. The water storage facility, however, would likely increase groundwater recharge to bedrock beneath the impoundment.

After cessation of mining and processing, groundwater pumping would cease for potable needs at the mine site (except for a small amount to support reclamation activities). The mine pits also would be allowed to fill with recovered groundwater and direct precipitation. The final lake surface in each mine pit would reach a steady-state elevation that approaches pre-mine groundwater levels. A closure alternative of partial pit backfill could eliminate the pit lakes if backfill levels are above ultimate pit lake levels.

Groundwater Quality

Quality of groundwater in the Project area could be adversely affected by the waste rock disposal facilities, tailing storage facility, ore stockpiles, process water pond, mine pits, septic systems, and landfill. Each of these mine-related facilities is discussed below with respect to potential impacts on groundwater quality.

The tailing storage facility design incorporates a low permeability clay liner on the bottom surface that would restrict movement of tailing slurry water into the subsurface. A synthetic liner would be located at the base of the tailing impoundment area where the supernatant pond would be located to further inhibit seepage. In addition, a cutoff trench would be excavated through alluvium and highly weathered sedimentary rock at the dam site; a seepage collection drain is proposed upstream of the cutoff wall where collected water would be pumped to a sump and then back into the tailing storage facility or to the plant site for recycle. In the unlikely event that seepage from the tailing storage facility gets into the local groundwater system, the water may be affected by elevated concentrations of cyanide, antimony, arsenic, copper, iron, and/or nickel (see *Direct and Indirect Effects – Surface Water Quality* section above). A closure alternative considered in Chapter 3 consists of water treatment for effluent from the tailing storage facility seepage collection drain for as long as necessary to achieve water quality standards.

To prevent groundwater quality impacts in the process facility area, the process water pond would have multiple geomembrane liners and a leachate collection system. The ore stockpiles (ROM pad) would be constructed on low permeability clay material.

Tests of material to be placed in the waste rock disposal facilities show low potential for acid generation potential, along with a high neutralization potential (see the *Surface Water Quality* section above and the *Geology and Minerals* section in this chapter). There is potential, however, that water infiltrating through waste rock would have elevated concentrations of some metals (e.g., antimony, arsenic, barium, and selenium), which could migrate down to groundwater and/or emanate as seeps from the toe of dumps.

During mining, dewatering would create a groundwater cone-of-depression surrounding each pit that would keep groundwater flowing toward the mine pits. Therefore, no impacts would occur to groundwater quality in these areas. After cessation of mining, however, dewatering would cease and the pits would fill to steady-state pre-mine groundwater levels after several years. At that time, water in the pit lakes could mix with the natural groundwater flow system intercepted by the pits. Quality of water that would develop in the pit lakes is being evaluated relative to ongoing geochemistry studies described in the *Geology and Minerals* section above. Kinetic testing of rock will provide information to confirm results of current whole rock and acid-base-accounting work completed to date.

A pit lake study initiated by NGGL will provide information regarding the relationship between the formation of an open body of water and the groundwater flow system in the vicinity of each mine pit. The study will evaluate whether water loss associated with the evaporative surface formed by the pit lake would effectively create a "sink" in the water table that would cause groundwater to flow towards the pit after mining ceases. In other cases, groundwater inflow could equilibrate with groundwater outflow and the mixing of groundwater with water in the pit would be analyzed to determine whether any offsite effects may need to be addressed in the closure plan.

If any chemicals used for mine processing (i.e., sodium cyanide, lime, caustic, hydrochloric acid, activated carbon, and flocculants) are accidentally released in sufficient quantities to the environment, they could infiltrate and impact shallow groundwater. The packaged sewage treatment plants would be located at the plant site and senior staff village would not impact groundwater. Treated sewage released to drainages would not cause a groundwater quality problem. As stated in the *Groundwater Quality* section above for *Baseline Conditions*, groundwater in some parts of the Project area shows impacts by total and fecal coli form bacteria. Inert, dry solid wastes generated by the mine Project would be buried in a landfill constructed in a waste rock disposal facility to minimize both the rate of infiltration and quantity of runoff available for infiltration.

After cessation of mining and processing, the water storage facility would remain and continue to intercept water from the upper part of the Subri sub-basin. Some of the water that collects in this impoundment would infiltrate into the subsurface and increase recharge of relatively good quality water in the Project area. This may have an indirect benefit of improving the quality of groundwater that could be impacted by the waste rock disposal facilities and/or mine pits. All facilities associated with the plant site, such as the ore stockpiles and process water pond, would be removed and the site would be revegetated.

The tailing storage facility and waste rock disposal facilities would be reclaimed with soil and vegetation. This would minimize infiltration of precipitation into these facilities; however, some infiltration would continue. Any seepage that discharges from the base of the reclaimed waste rock disposal facilities would go directly to groundwater or emanate as seeps from the toe of the rock piles. This water may have elevated concentrations of some metals as described above. Any seepage that continues from the

base of the reclaimed and detoxified tailing storage facility would collect in the seepage collection system and need to be discharged back to the tailing storage facility or to a natural drainage if the quality is acceptable.

ALTERNATIVES ANALYSIS

A closure alternative that addresses potential poor quality water in pit lakes could consist of partial backfill of the mine pits to levels above the ultimate pit lake surfaces. This action would prevent direct contact with pit lake water by humans and wildlife, and reduce water quality impacts to groundwater within and surrounding the mine pits. Another alternative that addresses poor quality water in pit lakes is the treatment of water in the pit lakes to achieve water quality standards or risk-based criteria. Treatment could be accomplished by pumping water through an external treatment facility and/or using method(s) to treat water within the pit lake (in-situ).

A closure alternative that addresses potential water quality problems from the waste rock disposal facilities would consist of constructing a cap (design not specified) that would limit the amount of precipitation infiltrating into the rock piles. The cap could consist of additional growth media that would increase storage of precipitation and release by evapotranspiration, or incorporate low permeability material on the top of the dumps to inhibit infiltration of precipitation. These alternatives would reduce or eliminate seepage from the base of waste rock disposal facilities that could then move down to groundwater.

Another alternative that addresses potential poor quality water migrating through the waste rock disposal facilities and/or tailing storage facility is to collect and treat any water that discharges as seeps from the toe of dumps and the tailing storage facility underdrain collection system. This action would improve water quality so that any of this water that infiltrates to groundwater would meet water quality standards.

NO PROJECT ALTERNATIVE

Implementation of the No Project Alternative would eliminate potential impacts to groundwater resources that are described for the Project and closure alternatives. Once NGGL completes reclamation of the area disturbed by initial construction activities, baseline conditions associated with groundwater resources are expected to resume.

SOIL RESOURCES

BASELINE CONDITIONS

Detailed soil investigations were used for mapping soil types in the Ahafo South Project area and surrounding areas. Examinations, measurements, recordings, soil identification, and descriptions were made at regular intervals along existing roads, footpaths, forest reserve boundaries, streams and rivers courses and along specially cut traverses. At representative examination points, chisel and auger borings were made and the soil was examined, identified, and described in detail in accordance with using United Nations Food and Agricultural Organization (FAO) methods (FAO 1990a). Results of these profile descriptions were used to classify soil according to the Revised Legend of the Soil Map of the World (FAO 1990b). These soil types were also described to the series level in accordance with established Ghanaian soil series descriptions. Descriptions and classifications were then used to evaluate suitability for agricultural production according to FAO methods (FAO 1976).

Results of observations were plotted on a base map and the soil boundaries drawn on the map by interpolation. Working base maps, originally at a scale of 1:50,000 were reduced to the publishing scale of 1:100,000. Soil types mapped by SGS (2000a, 2000b) for the Project area are shown on **Figure 4-8**.

The soil study area (surveyed area) exhibits various soil types. Unique properties of each soil formed as the result of the forest vegetation cover, prevailing weather conditions of high rainfall regime and high and constant temperatures, and variations in relief across the area. Intensive farming activities, for production plantation and food crops, and other human activities within this densely populated area have also influenced the nature of the soil. Anthropogenic influences have resulted in nutrient depletion, soil erosion, petroplinthite (ironpan or ironstone) formation, and overall degradation of soil quality. Bush burning in previous years has also altered vegetation with much of the uncultivated areas now dominated by elephant grass.

Soil in the surveyed area developed from variable parent materials including Lower and Upper Birimian rocks, granitic rocks, and colluvial-alluvial deposits of the Tano River and its tributaries. Three soil associations mapped within the area are the Bekwai, Fwidiem, and Birim-Chichiwere associations. A total of 14 soil series were identified within these associations.

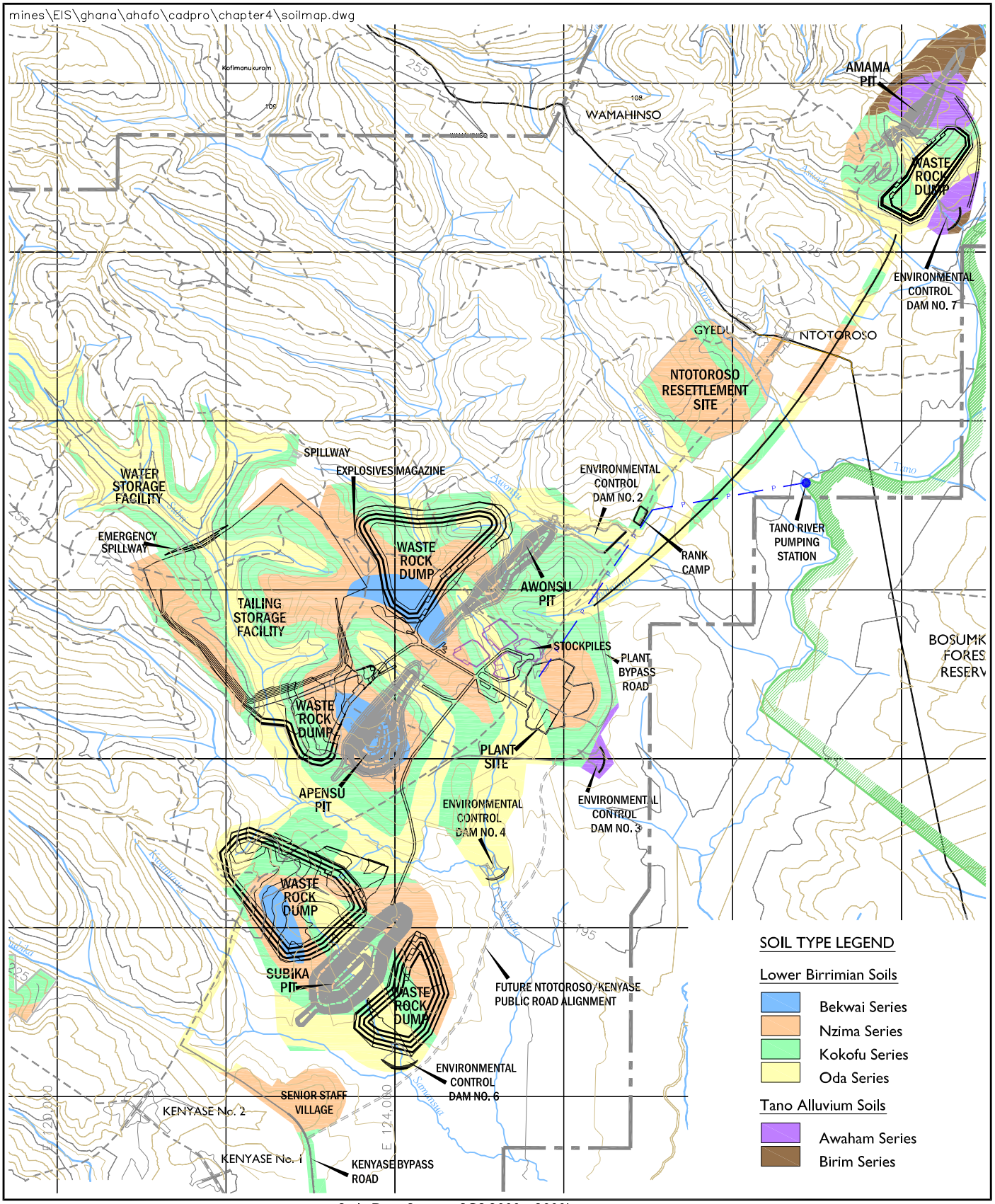
Bekwai Soil Association – Soil Developed Over Lower Birimian Rocks

These Bekwai soil types are extensive and cover approximately 70 percent of the surveyed area. The soil types are distributed across the central, northern, and western portions of the surveyed area and occur over nearly all of the area that will be disturbed as part of the Ahafo South Project.

Soil types in this association exhibit heavy texture, are acidic, and most are low in base saturation. In addition, most soil types in this association are relatively low in nutrient holding potential as a result of dominance by low activity clay. Bekwai and Nzima soil series located on summits and upper slopes of uplands and ridges are deep to moderately deep, well-drained with an abundance of petroplinthite, quartz gravel, and stones. Sheets of petroplinthite are exposed or at shallow depths. The Kokofu soil series dominates the middle to lower slopes. These soil types are deep to very deep, moderately well to imperfectly drained soil free of concretions and gravel. Valley bottoms of rivers and streams carry deep, poorly drained, dark gray topsoil with strongly mottled gray subsoil.

Bekwai series (Ferric Acrisol)

Soil in this series developed in-situ on summits and upper slopes of gentle rolling and undulating uplands. They are red, well drained, and deep to moderately deep (75 to 150 cm). Topsoil is thick (8 to 20 cm), brown to dark reddish brown humous-stained, loam to clay loam, weak medium granular, with few petroplinthite and quartz concretions. Fine to coarse roots are common. The subsoil is thick (120 to 150 cm), dark red to reddish brown, clay loam to clay texture, massive and firm, sticky, moderate to strong and medium to coarse sub-angular blocky. Subsoil exhibits common to abundant petroplinthite, quartz gravel, and stones. Quartz veins may be encountered in some of the subsoil. The substratum is deeply weathered, red, silt loam with few concretions and pieces of decomposed phyllite.



Soils Data Source: SGS 2000a, 2000b

N

0 Kilometers 3

1:63,360

Contour Interval = 6 Meters

- Existing Primary Road
- Existing Secondary Road
- Proposed Haul Road
- Forest Reserve Boundary
- Lease Boundary

Soil Map
Ahafo South Project
Brong Ahafo Region, Ghana
FIGURE 4-8

Nzima series (Ferric Acrisol)

Soil in this map unit occurs on upper and middle slopes below Bekwai series on the landscape, on summits of low-lying uplands, and along ridges. This soil type is similar to Bekwai series in morphology but somewhat less well drained internally and paler. The soil is deep (>150 cm) and well drained. Topsoil is thin (5 to 10 cm), humus-stained, dark brown to strong brown, weak medium and granular structure, and with few to frequent quartz and petroplinthite concretions and gravel. Subsoil is thick (120 to 150 cm), yellowish red to red, clay, with sticky consistence and strong coarse sub-angular blocky structure. Quartz and petroplinthite gravel and stones are abundant and quartz veins within the subsoil. The substratum extends downwards to about 150 cm and is yellowish red to strong brown, clay loam to clay with red mottles and few petroplinthite concretions and pieces of decomposing phyllite rock.

Kokofu series (Humic Lixisol)

This series developed in hill wash colluvial materials occurring on middle and lower slopes sites and in upland depressions. This soil unit is deep (>150 cm) and imperfectly drained. The topsoil is thick (10 to 20 cm), dark grayish brown to dark yellowish brown sandy loam to loam with weak fine and medium granular structure and no concretions or stones. Subsoil is thick (>150 cm), yellowish brown to yellowish red clay loam and silty clay with olive gray mottles, massive, and firm consistence. The subsoil is non-concretionary and gravelly with weakly developed sub-angular blocky structure.

Oda series (Eutric Fluvisol)

Soil of the Oda series occurs along streams and tributaries. Profiles are deep (>200 cm) and poorly drained. Undisturbed topsoil is thick (10 to 20 cm), dark gray to brown, strongly mottled, dark yellowish brown, humus-stained, sandy loam and clay loam, with rusted root channels and weak fine and medium granular structure. The subsoil is thick (>160 cm), dark gray strongly and distinctly mottled dark yellowish brown, yellowish brown and dark red, clay loam and silty clay, with plastic, sticky consistence, no structure and few gravel and stones at the profile base.

Occurring within the valley bottom soil are patches of sandy soil with rounded quartz gravel and stones (Temang series, Dystruic Fluvisol) or very deep fine sandy soil (Chichiwere series, Gleyic Arenosol).

Fwidiem Soil Association – Soil Developed Over Upper Birimian Rocks

Soil of this association developed over upper Birimian rocks, especially over hornblende schists. This association is primarily located in the vicinity of the Donkokrom, Tontkorm, Buronikurom and Obenkrom settlements. This association is limited in extent (<20% of the surveyed area) and covers the extreme southeastern portion of the surveyed area. Current plans for the Ahafo South Project development do not identify any disturbances of this association. However, due to the close proximity to the project site, it is possible that some of the soil would be disturbed as part of operations associated with RFD or in conjunction with resettlement activities.

Soil of this series has higher base saturation and more nutrient holding potential relative to soil of the Bekwai Association. The Fwidiem and Subin series found on upland areas of this association are well drained, deep to moderately deep (70 to 100 cm), clay loam and clay. Middle to lower slopes are covered with very deep soil (>100 cm), containing little gravel and stones in the subsoil. The Auym soil is found along mid-slopes and is moderately well to imperfectly drained loam and clay loam. The Densu

soil is found along lower slopes and valley bottoms of rivers and streams and is poorly drained with sandy loam topsoil and clayey subsoil.

Fwidiem series (Chromic Luvisol)

This soil series developed in-situ on summits and along ridges. The soil is well-drained and deep (>75 cm) exhibits thick dark reddish brown to brown topsoil (20 to 30 cm) with loam to clay loam texture and moderate medium granular structures, containing many fine and medium roots. The subsoil is moderately thick (50 to 80 cm) with uniform appearance with dusky red color and clay loam to clay textures, strong medium sub-angular blocky structure. Medium and coarse roots and petroplinthite gravel and rock fragments are common in the subsoil.

Subin (Chromic Luvisol)

This soil occurs below Fwidiem series and on upper slopes and summits of low ridges and uplands. The soil is well drained and very deep (100 to 150 cm). The dark reddish brown topsoil is usually thick (8 to 20 cm) loam with weak medium granular structure and many fine roots. The thick clay subsoil (80 to 150 cm) is dark red to dusky red and has moderate medium to coarse sub-angular blocky structure with common medium and coarse roots. Petroplinthite gravel and rock fragments are common in the subsoil.

Ayum series (Gleyic Luvisols)

These are colluvial soil types occurring on middle and lower slope sites of gently sloping topography. The soil is very deep (>150 cm) and moderately well to imperfectly drained with common mottling of the subsoil. Topsoil is thick (10 to 25 cm), black to very dark grayish brown loam and sandy loam with weak to moderate medium granular structure and common fine roots. The sandy loam and clay loam subsoil is very thick (>150 cm) ranging from pale brown to yellowish brown with strong gray mottles. The soil has moderate to strong sub-angular blocky structures and is firm and massive with petroplinthite and quartz gravel and stones embedded throughout.

Densu series (Eutric Fluvisols)

The soil occurs within the lower part of the valleys of Abuasua stream and its tributaries. The soil is very deep (>150 cm) poorly drained alluvial soil. The dark gray brown to dark gray topsoil is thin to moderately thick (0 to 10 cm) clay loam and clay with weak medium granular structure, many fine roots and no concretions or gravels. The subsoil is thick (>100 cm) structureless clay loam and clay with rusted root channels and few quartz gravel and stones at the base of the profile. The subsoil color is yellowish brown to olive brown and strongly mottled dark gray.

Birim-Chichiwere Soil Association – Soil Developed Over Tano River Alluvium

This soil developed extensively on alluvial deposits of the Tano River along the northern and eastern portion of the surveyed area. The soil is limited in extent and covers less than 10 percent of the surveyed area. Current plans indicate that the disturbance in the Project area would affect only a few hectares of this soil association as it occurs on the periphery of the development.

The Samfi, Awaham and Birim/Chichiwere series were all encountered as components of the Birim - Chichiwere Soil Association. These soil types range from shallow to very deep, sandy to silty clay, moderately to poorly developed, dark brown to reddish brown, free of coarse fragments to concretionary and gravelly, and imperfectly to poorly drained (hydromorphic).

Samfi series (Dystric Leptosols)

These are minor soil types on high terraces above the Tano River floodplains. The soil is very shallow to shallow (20 to 30 cm) moderately well drained, gray to strong brown with dark gray topsoil (5 to 10 cm). The thin (15 to 20 cm) structureless subsoil primarily consists of conglomerate pebbles, gravel, and stones.

Awaham series (Dystric Cambisol)

The soil is very deep (>100 cm), very dark gray to yellowish red, strongly mottled strong brown, hydromorphic soil, on extension and flat plains with pure stand of elephant grass. Topsoil is thick (8 to 20 cm), very dark gray to dark brown mottled strong brown, humus-stained loam with weak fine granular structure with many fine roots. The subsoil is thick (>80 cm), light yellowish brown to gray strongly mottled reddish and strong brown clay loam with weakly developed structure and abundant rounded quartz gravel and stones.

Birim series (Eutric Fluvisol)

This soil occurs along the Tano River developed on recent alluvial deposits on low-lying terrace land. The soil is very deep (>150 cm), poorly drained, and has varied textured layers of sandy to clay. The relatively thin (5 to 8 cm) humus-stained topsoil is dark grayish brown to olive brown loam and clay loam with weak medium granular structure and many fine roots. The firm and massive subsoil is thick (>120 cm), brown to reddish brown strongly mottled pale and strong brown to yellowish red loam and clay loam with no evident structure.

The Chichiwere Series (Gleyic Arenosol) is also found in this mapping unit closely associated with Birim series on raised recent terrace, adjacent to the riverbed. The soil is very deep (>200 cm), with thin (5 to 6 cm) loam and weak fine granular topsoil overlying very deep (>150 cm) pale to yellowish brown structureless sandy subsoil.

Methods for Evaluating Agricultural Suitability

Soil types of the surveyed area were assessed for their suitability for rain-fed agricultural uses, according to FAO (1976) methods. The exercise is based on the inherent morphological properties of the soil and landscape characteristics.

The soil is rated according to Orders Suitable (S) and Non-suitable (N) and further broken down into suborders. The suborders of suitable were Highly Suitable (S1). Moderately Suitable (S2) and Marginally Suitable (S3). Suborders of Non-suitable were Presently Not Suitable (N1) and Permanently Not Suitable (N2). The major suitability classes used in the assessment were soil limitations such as soil depth, contents of gravel and stones, infertility or textural problems (s); soil erosion hazards (e); and wetness and flooding problems (w).

Results of Soil Suitability Evaluation

Soil types of the surveyed area were evaluated into three suborders with four suitability classes of S2s, S2se, S3sw, and N2se.

Moderately Suitable Soil (S2)

S2e (Kokofu, Ayum, and Awaham Series)

Soil in this suitability class exhibits deep to very deep, well to moderately well drained topsoil overlying thick uniform subsoil free of gravel and stones. These soil types have good physical conditions for root development and hold, are easy to till, exhibit high to medium water holding capacity, and have relatively high fertility. These soil types have rapid external drainage and good internal drainage.

These soil types were found to support plantation crops of cocoa, oil palm, and citrus and a wide range of food, horticultural, vegetable and legume crops. The main limitation is quick depletion of plant nutrients soon after cropping. Adequate organic and inorganic fertilization is necessary to maintain high crop yields.

S2se (Bekwai, Fwidiem, Subin, and Nzima Series)

Soil in this class developed in-situ on ridge crests and is moderately deep to deep, red to dusky red and well to moderately well drained. Few to abundant iron-manganese concretions, gravel, quartz gravel, and stone are embedded in the clay subsoil.

These soil types have been intensively and extensively used for cultivation resulting in depletion of nutrients and erosion of the topsoil. Together they form the most extensive soil types being used in production of both plantation and arable crops. This soil type is being used for cultivation of cocoa, citrus, oil palm, maize, plantain, cassava, yams, cocoyam, vegetables, and legumes.

Soil limitations for crop production include rapid decline in soil fertility, susceptibility to soil erosion, high contents of gravel and stones that reduce their exploitable volumes and make them droughty soon after rain. Soil and water conservation measures as well as effective fertilization with both organic and inorganic fertilizers are necessary to boost agricultural production.

Marginally Suitable Soil (S3)

S3sw (Oda, Densu, and Birim Series)

Soil in this suitability class developed over colluvial and alluvial deposits on lower slopes and river and stream valleys. This soil type is deep to very deep and imperfectly to poorly drained with groundwater found at shallow depths. Soil in this class is subjected to flooding and water logging during the rainy seasons. Soil color is strong brown to gray and strongly mottled. This soil exhibits variable textures from sand to silty clay with weak fine to medium granular topsoil structures. The subsoil is structureless or with only moderately developed structures. Quartz and iron-manganese gravel and stones may be found within the subsoil.

Limitations for use of these soil types are unfavorable moisture conditions and textural limitations. Under effective drainage management and flooding and water logging controls, this soil could be used for production of rice, legumes, vegetables, sugarcane, and for fish farming.

Permanently Not-Suitable Soil (N2)

N2se (Samfi series)

This suitability class includes soil that is not suitable for agricultural production. The soil is limited in depth and contains stones, gravel, and concretions, occurring mostly on steep-sided inselbergs and uplands. The soil is to be left for natural forestry generation and wildlife and is typically either bare or covered with thicket.

Discussion

The soil resources inventory and assessment exercises encountered 14 soil types at soil series level, 11 of which comprised separate mapping units. Soil development has been affected mainly by high temperatures (mean monthly temperatures ranging from 23.9 to 28.4°C), high precipitation (125 to 200 cm annually), dominant vegetation, rolling and undulating nature of the landscape, and varied parent materials. The long period of time over which these factors have influenced pedogenesis across the surveyed area has resulted in deep, highly weathered soil.

Under tropical environmental conditions, most of the soil has been developed to mature stage with typical morphological characteristics. Most of the soil on summits of low-lying uplands and ridges to middle slopes is well to moderately well drained and moderately deep to very deep. These soil types have fair to good moisture retention capacity as the result of their subsoil alluvial clay content. Summits and slopes of steep-sided inselbergs and mountains carry shallow and highly concretionary stony and gravely soil that becomes droughty soon after rain events and is susceptible to severe erosion, and poor in plant nutrients. The soil in the valleys is deep to very deep, imperfectly to poorly drained, mostly gray with mottles. These soil types are liable to flooding and water logging during wet seasons. Texture ranges from sandy to clayey, and exhibits problems related to water management.

Laterite (plinthite) is found near the surface, immediately below the dark humus stained topsoil of most upland soil in the surveyed area. The laterite found in these soil types occurs as a result of natural processes that result in depletion of soluble salt and silica and enrichment of iron and aluminum. Lateritic materials have irreversibly hardened where the soil has gone through periodic wet and dry cycles, (ironstone; petroplinthite). Where intense agriculture and deforestation has resulted in erosion of surface materials or drying and/or heating of soil materials, laterite is more commonly found in hardened sheets that inhibit infiltration, tillage, root growth, and agricultural production.

Intensive agricultural practices employed throughout much of the surveyed area have also reduced nutrient contents and infiltration rates relative to natural conditions. In tropical soil such as those surveyed, nutrient cycling naturally occurs very rapidly due to high moisture and temperature and attendant high rates of biological activity. Decaying organic materials (such as leaf litter) is rapidly consumed by microbes and oxidized to release nutrients that are quickly taken-up by other plants and organisms. Where plants have been cleared, these nutrients released into the soil solution are not consumed as effectively and are easily leached from the soil. As a result of the agricultural activity and natural processes, soil over much of the surveyed area has been leached of the bases rendering them

acidic and low in plant nutrients. Poor performances of crops are common in the surveyed area. Effective fertilization and anti-erosion methods are needed if the soil is to be used for prolonged agricultural production.

Direct and Indirect Impacts

The Ahafo South Project would result in a total of 2,174 ha of surface disturbance (**Table 2-2**) and direct soil impacts. Soil salvage efforts would remove topsoil prior to mining. Potential impacts on the physical, chemical, and biological properties of the soil resource include, reduced fertility, loss of soil structure, reduced infiltration and water holding capacity, erosion, and reduced productivity relative to premine conditions. Nearly all impacts to the soil resource analyzed are a direct result of surface disturbances, soil handling, and closure operations associated with the proposed mine plan. However, potential indirect impacts include affects on soil properties as a result of increased agricultural activity in the area immediately surrounding the Project area.

Soil handling operations would affect physical, chemical, and biological properties of the soil. The degree of these affects is dependant on the soil handling methods employed during salvage and redistribution efforts. The expected impacts are based on experience with soil handling operations and impacts to soil resources, an understanding of tropical soil, review of the soil resources available for salvage, and consideration of the activities associated with the Ahafo South Project. Erosion rates, nutrient levels, and precise salvage depths and volumes cannot be quantifiably determined as this information was not gathered as part of the soil survey.

Soil Salvage Depths and Volumes

Soil in the Project area is characterized with surficial materials (topsoil) better suited to plant growth than subsurface materials (subsoil). Relative to subsoil, topsoil has higher nutrient content, higher ph (less acidic), higher organic carbon content, and exhibits better tilth. In addition to being less suitable with regards to these properties, subsoil often contains lateritic materials that could harden irreversibly upon drying and impede root growth. Only topsoil would be salvaged for the current project.

Depth of soil salvage is dependant upon topsoil materials available, which varies throughout the surveyed area. Results of the soil survey indicate that the median salvage depths range from a minimum of 5 cm for the Densu Series to a maximum of 17.5 cm for the Ayum Series (**Table 4-41**). The median soil in the area proposed for disturbance (predominately the Bekwai Association) ranges from 7.5 cm for the Nzima series to 15 cm for the KoKofu and Oda Series. Due to variability of soil, it is likely that some salvage depths would exceed the minimum and maximum limits shown in **Table 4-41**. While salvage depths would be series and site specific, it is not anticipated that soil from the various series would be segregated and stockpiled separately. Segregation by series would only be undertaken if necessary to preserve soil properties for selective placement in the reclaimed landscape (NGGL 2004).

TABLE 4-41
Topsoil Depth by Series
Ahafo South Project

Association	Series (Map Unit)	Topsoil Depth (cm)		
		Minimum	Maximum	Median
Bekwai	Bekwai	8	20	14
	Nzima	5	10	7.5
	KoKofu	10	20	15
	Oda	10	20	15
Fwidiem	Fwidiem	20	30	25
	Subin	8	20	14
	Ayum	10	25	17.5
	Densu	0	10	5
Birim-Chichiwere	Samfi	5	10	7.5
	Awaham	8	20	14
	Birim	5	8	6.5

Source: NGGL

Estimated areas of soil series within the Ahafo South Project area are listed in **Table 4-42**. These volumes were based on median salvage depths for each soil series. Areas and volumes were rounded to reflect precision of the survey. Based on these results, median salvage depth of soil across all types (weighted average) would be approximately 13 cm across 3,125 ha for the Project area. However, soil would only be salvaged for the disturbance areas that total 2,174 ha. This would result in an estimated total salvaged soil volume of approximately 3,000,000 m^3.

TABLE 4-42
Estimated Topsoil Salvage Area and Volume
Ahafo South Project

Association	Series (Map Unit)	Median Depth (centimeter)	Disturbance (hectare)	Volume ($meter^3$)
Bekwai	Bekwai	14.0	120	168,000
	Nzima	7.5	800	600,000
	KoKofu	15.0	1,100	1,650,000
	Oda	15.0	1,050	1,575,000
Fwidiem	Fwidiem	25.0	--	--
	Subin	14.0	--	--
	Ayum	17.5	--	--
	Densu	5.0	--	--
Birim-Chichiwere	Samfi	7.5	--	--
	Awaham	14.0	45	63,000
	Birim	6.5	10	6,500
Total			**3,125**	**4,062,500**

Note: Not all areas included in this table for the Project area would be subject to soil salvage; only those areas to be disturbed would have soil salvage, which would total approximately 3,000,000 $meters^3$.

Depth of soil in the reclaimed landscape is dependant on the volume of material salvaged and the number of hectares over which the soil is to be replaced. Facilities and structures that may not require resoiling during closure include the mine pits, water storage facility, environmental control dams, asphalt and other usable access roads and buildings. Since soil would be stripped from all of these sites prior to salvage, soil could be replaced on the regraded landscape to a depth greater than that found prior to mining. The water storage facility and mine pits account for approximately 530 ha of disturbance that may not be resoiled. This amounts to an approximate increase in volume and attendant average replacement depths from 13 to 15.6 cm (20% increase). The additional surface area of waste rock disposal facility, soil loss during handling, and cover requirements for the tailing storage facility would offset some of the excess that would otherwise be realized by not resoiling these facilities.

AFFECTS OF SOIL HANDLING

Soil salvage and redistribution affects structure of the soil. As soil is handled, peds (natural soil aggregates) are crushed and the larger natural pore spaces are eliminated. After soil is redistributed, large temporary pore spaces are created. These pores do not exhibit the same interconnectivity as that found in undisturbed soil and the structure providing them is less stable. Many of the pores that occur in the short-term following redistribution would shrink as the soil settles over time.

Soil compaction from compression often occurs coincident with the destruction of soil structure. Some compaction of soil would occur during grubbing and clearing activities prior to salvage and again during redistribution of the topsoil. Compaction leads to an increase in bulk density, root inhibition, and reduced infiltration. These impacts could in turn lead to reduced plant productivity, increased runoff, and erosion. Further compounding this effect is the fact that soil with low activity clay, such as many of the upland soil types of the Bekwai Soil Association, has slight capacity to shrink and swell which would otherwise act to resist and reverse compaction. Effects of compaction are further increased through reduction in organic matter content and drying at high temperatures.

Active microbes would continue to oxidize organic carbon and release nutrients into the soil even after salvage. This oxidation combined with the partial blending of topsoil with subsoil that would occur during salvage operations would reduce the organic matter content of salvaged topsoil relative to natural conditions. As the soil is replaced on the regraded surface for reclamation, the soil would again be aerated and subjected to increases in temperature that would increase the rate of biological activity and result in further reduced organic matter content. Without plants to immobilize nutrients released during these processes, they would be easily leached from the soil.

Reduction in organic matter and nutrients resulting from soil handling operations could influence other soil properties. When organic matter is depleted, soil structure becomes weak and crusting following rainfall or saturation could become more common. Crusts forming on the soil surface inhibit shoot sprouting, decrease infiltration rates and often result in increased runoff and erosion. Decline in organic matter could also lead to a reduction in cation exchange capacity (the ability of the soil to retain nutrients) and exchangeable bases (nutrients) and eventually to further acidification.

Immediately following replacement, soil would not be protected from intense rainfall events. Water erosion potential could be high during heavy precipitation due to this exposure. Potential for erosion is further exacerbated by previously described impacts to soil structure and other characteristics reducing

infiltration rates. Soil replaced on steep slopes (e.g., embankments and the waste rock disposal facility) would be especially vulnerable to water erosion.

Potential Effects of Planned Salvage and Replacement Depths

Salvaging only topsoil for replacement on reclaimed surfaces would result in differences between the soil of the postmine landscape and the premine condition. Many of these differences would be a function of topsoil thicknesses and properties of the underlying material.

Topsoil redistributed over coarse waste rock would result in coarse fragments nearer the surface than found in the premine condition. Where erosion or anthropogenic influences result in removal of the topsoil, this rock could become exposed and render the soil unsuitable for cultivation. If fine growth materials are absent at lower depths in the profile, the water holding capacity would be greatly reduced and sites would become dry in the absence of frequent rainfall or irrigation. Fine materials found in association with these coarse fragments would result in less rooting depth and water holding capacity than premine conditions.

In areas where topsoil is redistributed over spoil materials, such as oxidized materials (e.g., saprolite) or subsoil, textures, rooting depths, and stratification may be similar to premine conditions. Comparability of premine and postmine conditions is dependent on specific chemical and physical makeup of the spoil materials with rooting depth and permeability rates being affected to the most notable extent. Where spoil material is high in clay content or lateritic (including plinthite) materials, permeability of materials may be reduced and rooting depth may be limited at the topsoil/subsoil interface. Such impacts would be exacerbated if these materials are allowed to dry and harden prior to topsoil redistribution.

Topsoil redistributed over potentially acid generating materials with a high concentration of soluble metals (e.g., tailing storage facility) may be affected. Testing of tailing would be conducted prior to soil placement to determine potential for trace metal movement into the soil cover. Cover depths should be adequate to provide sufficient growth medium without roots contacting underlying materials that may have elevated metal levels.

Indirect Effects

As farming operations and other agricultural activities are removed in advance of mining, farming operations would likely relocate to nearby sites. In addition, as the local population increases in response to employment associated with the Ahafo South Project, farming activities could increase to provide food and otherwise respond to increased demand and perceived opportunities for improved livelihood. Relocated and new agricultural operations could impact soil in areas adjacent to the mine area as previously uncultivated areas become tilled and use of existing cultivated areas intensifies.

Expected impacts to soil would be similar to the current effects of agriculture on soil in the area. Such effects could include reduced nutrient and organic matter content, destruction of soil structure, increased erosion, petroplinthite formation, acidification and various other related impacts. The magnitude and duration of possible effects cannot be determined without knowing the precise conditions of available resources in the area and more accurately estimating details of these operations. Adverse indirect impacts to soil resources, however, generally are expected to be short-term.

ALTERNATIVES ANALYSIS

Closure alternatives address plans for pit lake management, waste rock disposal facility construction and closure, and tailing storage facility closure. Effects of the various alternatives on soil resources are similar to the existing mine plan with a few exceptions.

Effects to the soil resource associated with the mine pit partial backfill alternative are similar to the current Project. However, implementation of this alternative could reduce soil material available for replacement on other disturbed areas. Creation of earthen surfaces rather than open pit lakes would require additional resoiling and revegetation following mining. The amount of soil material available for respread minewide is relatively static following initial mine development as soil not salvaged would be negatively impacted by mining operations. It is assumed that all soil required for reclamation would be salvaged prior to commencement of mining operations in any given salvage area. Appropriate planning would be necessary to ensure adequate, and possibly additional, materials are available for salvaged for use reclamation. If additional materials are available and salvaged, proper design should ensure that no additional adverse soil impacts occur.

Effects to soil resources resulting from fencing/berming the mine pit rim are expected to be comparable to the current Project. If this berm in covered with soil and revegetated, overall soil balance would be slightly impacted.

Reduced slopes on the waste rock disposal facilities would further reduce erosion potential and likely increase infiltration. Reductions in erosion may be countered by additional surface disturbance associated with relatively higher levels of use for agriculture. This additional disturbance could result in higher erosion rates on slopes as more areas are disturbed and devoid of cover. Without increasing soil replacement thickness, rooting depths would not be improved and water holding capacity would not increase.

Maximizing soil replacement depth on waste rock disposal facilities would provide greater rooting depth, allow higher moisture retention, and likely reduce coarse fragment content within the root zone. Net impact of these effects would be increased agricultural productivity relative to the current closure plan. If additional soil (e.g., subsoil) is not salvaged in conjunction with this alternative, it would be necessary to reduce replacement depths on other areas to account for increased depths on waste rock disposal facilities. The result of these commensurate reductions would likely neutralize benefits of increased depths on waste rock disposal facilities.

To ensure benefits of maximizing soil replacement depth are realized, additional cover material must be salvaged prior to commencement of mining operations. Since the current plan includes salvage of all topsoil, it would be necessary to salvage subsoil to achieve greater soil volumes. Subsoil would be separately salvaged and stockpiled and eventually replaced on the regraded landscape prior to topsoil replacement. Review of material quality would be necessary prior to salvage to ensure materials are of appropriate quality.

Constructing a capping system on waste rock disposal facilities to reduce infiltration would likely rely on both surface runoff and evapotranspiration to reduce deep infiltration to the waste rock. Such a capping system would require selective handling of soil materials, potentially including subsoil materials, suitable for construction. The capping system would affect soil balance and availability of the resource for

replacement in other reclaimed areas. If additional materials are not salvaged, reduced depths and related affects on the soil balance could reduce soil productivity elsewhere on the mine.

The capping system would likely influence properties of soil within the rooting depth of plants. To achieve maximum evapotranspiration, it would be necessary to select capping materials that are conducive to plant growth and effectively retain moisture (likely fine textures). If capping materials are more suitable for plant growth than the current plan, productivity would be increased. Potential impacts could include an increase in soil erosion due to increased runoff rates and quantities. Selective handling of fine textured soil to lower infiltration rates could result in increased surface flow which, in turn, could result in increased erosion.

Post closure use of the tailing storage facility for farm land would require soil materials be replaced at depths adequate to support agricultural crops and prevent degradation of the soil resource. Mine tailing are expected to have high concentrations of a various soluble materials (e.g., trace elements and salts). Proper capping structures would be required to prevent upward migration of these constituents as a result of capillary action during dry seasons and saturated flow during wet seasons. In addition, material thicknesses or other factors would need to be adjusted to ensure crop rooting depths would not reach the tailing material.

In order to accomplish these objectives, additional cover material would be required (potentially subsoil materials salvaged prior to mining). The stated intention of using the area for crop production would require that materials be conducive to crop production (i.e., good nutrient content, low coarse fragment content). Selective handling of materials for placement on the tailing storage facility would affect the overall soil balance and potentially reduce the productive capacity of other soil mine-wide. If these areas are farmed instead of the slopes of the waste rock storage facility, minewide soil loss may be reduced.

NO PROJECT ALTERNATIVE

Implementation of the No Project Alternative would eliminate the potential impacts to soil that are described for the Project and closure alternatives. Once NGGL completes reclamation of the area disturbed by initial construction activities, baseline conditions associated with soil resources are expected to resume.

CUMULATIVE EFFECTS

Cumulative effects are the impacts on the environment which result from the incremental impact of the project when added to other related past, present, or reasonably foreseeable future actions in the Project area. Analysis of cumulative impacts determines whether an action contributes to or has an additive effect to impacts associated with other activities.

The geographic area evaluated for cumulative impact analysis varies by resource or environmental discipline. The central feature of the Project area is the mineralized trend that extends from the Ahafo South Project site northwesterly to the Ahafo North area (**Figure 4-1**). Other principal land uses in the Project area are Forest Reserves, subsistence farming, and villages. Mine development in the Ahafo Project area and exploration activity associated with mineralized trends have affected local communities, transportation corridors, employment, and land uses within the area.

PAST AND PRESENT ACTIVITIES

Land use in the cumulative effects area consists of subsistence farming, hamlets and villages, mining, mineral exploration, and Forest Reserves. NGGL's current mine development encompasses the Ahafo South Project area summarized in the *Project Description* section. NGGL's future mine development planning includes the Ahafo North Project area. The Ahafo North Project area is included along with the Ahafo South Project in the former Sefwi Belt Gold Project permitted by Centenary Gold Mining Company Ltd. in 2000.

REASONABLY FORESEEABLE FUTURE ACTIONS

Mine development and mineral exploration, subsistence farming, and forest preservation are expected to be activities that would continue in the future. In addition, construction of a 161 kV electrical transmission line by the VRA would occur in the cumulative effects area.

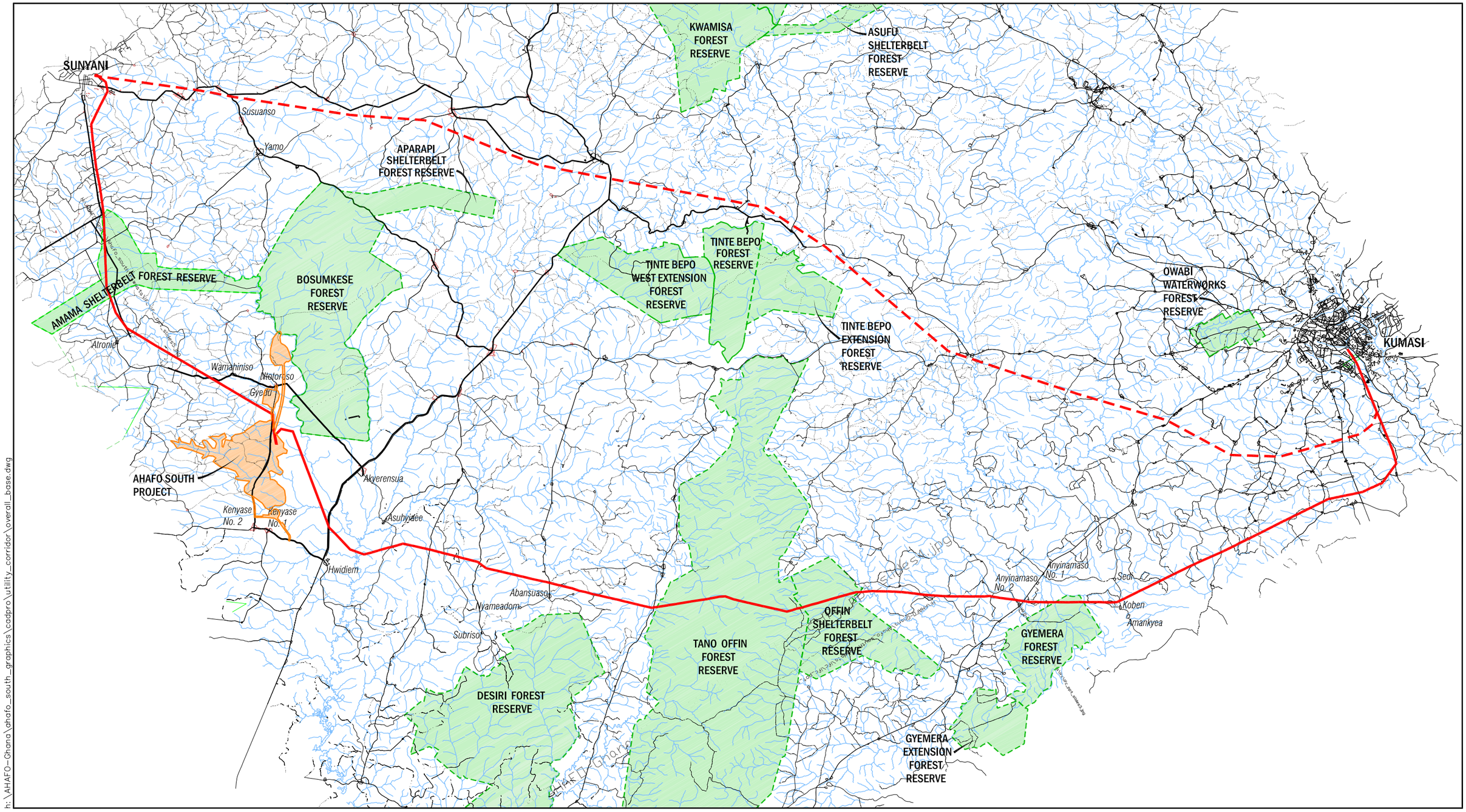
VRA TRANSMISSION LINE

Kumasi to Sunyani Transmission Project

The Volta River Authority (VRA) proposes to construct a 161 kV electrical power transmission line from Kumasi to Sunyani to provide an alternative power supply route to the load centers located in Brong Ahafo, Northern, Upper East, and Upper West Regions of Ghana (**Figure 4-9**). The proposed transmission line is designed to improve the reliability of power supply to the whole of northern Ghana (Ghana EPA 2005).

The power line was originally planned in 2000 and final route selection resulted from consideration of several alternatives. The selected route was chosen to minimize impacts to certain sensitive areas (e.g., a shrine and high bio-diversity forest areas).

The IFC considers the VRA power line to be an "associated facility" to the Ahafo South Project. As such, the IFC has reviewed the EIS for the power line project to ensure no gross policy violations exist. IFC and NGGL representatives met with VRA personnel and received assurances that the transmission line project would be constructed in accordance with World Bank Policies and Guidelines. VRA



h:\AHAFO-Ghana\ahafo_south_graphics\cadpro\utility_corridor\overall_base.dwg

N

0 Kilometer 10
1:300,000

Volta River Authority Proposed Power Corridor
Volta River Authority Old Proposed Power Corridor
Main Roads
Secondary Roads
Hydrologic Features

Volta River Authority Power Corridor
Ahafo South Project
Brong Ahafo Region, Ghana
FIGURE 4-9

corporate policy states that all new lines will be built in accordance with World Bank Policies and Guidelines. In recognition of these commitments, VRA is finalizing a Resettlement Action Plan for relevant areas of this transmission line.

VRA signed a Memorandum of Understanding with the Forest Commission (October 20, 2003) which addresses conditions under which the transmission line may be built. The Memorandum of Understanding provides assurances that access to Forest Reserves (considered Critical Natural Habitat by IFC) will not violate IFC Policy regarding degradation of Forest Reserves. IFC Policies and Guidelines also require monitoring of the right-of-way to ensure that further encroachment is not occurring into the Forest Reserves.

Figure 4-9 indicates the proposed corridor for the VRA powerline project and the approximate location of the original planned corridor. The proposed corridor crosses 4 Forest Reserve areas including the Gyemera, Offin, Tano Offin, and Amama forest reserves. The Gyemera, Offin, and Amama forest reserves have been graded by the Ghana Forestry Commission to be mostly degraded to poor condition. The Offin and Amama Reserves are considered convalescence areas while the Offin Reserve has been designated for timber production. The Tano Offin Reserve is a slightly degraded reserve area designated as a Globally Significant Biodiversity Area (GSBA). **Table 4-43** identifies the specific compartments that would be crossed and are immediately adjacent to the proposed corridor. Each compartment that would be traversed by the proposed powerline has been reviewed by the VRA and the Ghanaian Forestry Commission. As indicated in the EIS completed by the VRA for the powerline project, adjustments have been made in the corridor to avoid environmentally sensitive areas within each Forest Reserve. The corridor depicted in **Figure 4-9** is the result of those adjustments. Additionally, biodiversity experts from the Resource Management Support Centre of the Ghana Forestry Commission will oversee field work prior to and during the initial stages of construction to address any potential site-specific conservation concerns should they be encountered. (Per. Com. E. Obiaw, RMSC, 25-Aug-05)

TABLE 4-43
VOLTA RIVER AUTHORITY
PROPOSED UTILITY CORRIDOR – KUMASI TO SUNYANI

Forest Reserve	Compartment Designation	Forest Reserve Overall Category
Gyemera Forest Reserve	2,4,6,8,9,10	4 – Mostly Degraded
Offin Forest Reserve	18,19,20,21,22,23,24,25,31	4- Mostly Degraded
Tano Offin Forest Reserve	15,16,16A,17,17A,21,22,22A,23,24	3 – Slightly Degraded
Amama Forest Reserve	7,8,9,10,11,12,13,14,15,16,17	5- Very Poor

Source: Ghanaian Forestry Commission

The proposed powerline would cross seven districts of Ashanti and Brong Ahafo Regions of Ghana. The districts include Kumasi Metropolitan Assembly; Bosumtwe-Atwima-Kwanwoma District; Atwima District Assembly; Ahafo-Ano South District Assembly; Ahafo-Ano North District Assembly; Asutifi District Assembly; and Sunyani District Assembly. The powerline would be constructed in a 30-m wide corridor and will span the districts identified above. Total length of the facility is approximately 150 km. The powerline would also supply the NGGL Project at Ahafo.

The powerline would consist of constructing steel transmission towers ranging from 30 to 35 m in height. Height of the towers would provide a minimum of 7.5 to 8 m clearance between lines and open ground, and 8 m clearance for roads.

Tower corridor track would be constructed to an approximate width of 3 m along the centerline of the line route. Access tracks to the corridor track would be constructed from the closest public roads. These access and corridor tracks would be maintained throughout the construction and operational phase of the project. Use of these tracks would eliminate need for construction of additional tracks during the operational phase.

Access track routes would be cleared of tree stumps, shrubs, and other vegetation that would cause obstruction for machinery, equipment, and maintenance staff. Cut trees would be stacked to the side of the cleared track routes.

Construction of the right-of-way for the transmission line would require clearing and grubbing of vegetation to a width of 30 m for the entire length of the line. Vegetation would be cleared to a height of 1.25 m above ground level. Trees on the edge of the cleared area that have branches that span into the 30-m cleared right-of-way or could topple into the right-of-way would either be felled or pruned to meet the clearing requirements.

Construction of individual transmission line towers would require clearing an area approximately 5 m by 5 m with an additional 2 m buffer on two sides. Typically, foundations for the towers would consist of concrete pads and concrete chimney footings. Regrading of the site would ensure that water would drain away from each of the foundations.

All material used in construction of the transmission line would be imported. Imported parts would be delivered by ship to either the Tema or Takoradi port or by air through Kotoka International Airport. After clearance, parts would be stored at the construction contractor's storage site. During construction, materials would be transported to the corridor via trucks. Vehicle movements would be minimized as work camps would be sited close to the proposed construction sites.

Once towers have been erected and lines strung, tests and measurements would be conducted to ensure the line performs as designed. Soil conditions along the right-of-way would be inspected for compaction and erosion. Mitigation would occur as necessary. Areas of bare soil would be colonized by native cover plants. No herbicides would be used to control invasive species; all vegetation control would be done manually.

Operation and maintenance of the line would be conducted in accordance with accepted international standards (International Electrotechnical Commission). VRA also has specific procedures addressing public safety and health and welfare of the maintenance crew outlined in the Volta River Authority Corporate Safety Rules.

Maintenance activities to be conducted during the operational life of the transmission line include surveillance of transmission line, towers, and the right-of-way. Routine and emergency repairs as well as vegetation control would be conducted. Surveillance would be conducted using helicopters for aerial inspection, foot patrol for routine physical examination of the line and its components, and security patrol to inspect for vandalism, tampering, and general security of the line.

Scheduled maintenance programs would be carried out to repair aging towers, lines, and accessories. Maintenance actions could include re-insulation of line sections, painting towers, replacement of corroded towers and transmission line components, replacement of conventional bolts and nuts with anti-theft fasteners, and road maintenance.

The construction phase of the Kumasi to Sunyani Project is expected to require 18 months to complete.

Land Take – Resettlement

VRA's acquisition of the right-of-way for the transmission line would affect land ownership and land use in the corridor. Land uses that would be affected by the construction and operation of the powerline include agricultural land, potential agricultural land, residential land, and Forest Reserves (Jimira, Ofin Shelterbelt, Tano Ofin, and Amama Shelterbelt). The land take is linear (transmission line corridor and access tracks) and would encompass 472 ha.

Employment – Health and Safety

Approximately 25 percent of the construction work force of about 200 workers would be recruited from outside the local labor force because of the skills needed for construction of the transmission line. A total of 50 skilled workers from outside local communities would be used and these workers would be accommodated in work camps. Potential impacts on local population and demographics are not expected to require additional mitigation.

Even though the majority of the work force would be recruited from local communities, 50 workers imported to work on the project would pose a risk for spread of sexually transmitted diseases. This risk does require mitigation to manage the potential impact.

Public Safety

The operational phase of the transmission line project would result in creation of public safety issues including transportation of workers and materials to the corridor, potential exposure to electromagnetic fields, potential collapse of towers, and electrocution from fallen wires. These potential hazards require mitigation to ensure public safety.

Mitigation Measures for VRA Power Line

Land Take – Resettlement - Compensation

VRA maintains a policy of compensating project-affected people before construction. Since 2000, VRA has hand an internal real estate office that offers more favorable rates than the Land Valuation Board. In an effort to address past concerns about delays in compensation payments, VRA now estimates the maximum rate possible for local compensation and pays that amount directly. When the Land Valuation Board's official review of compensation is complete, VRA will pay any difference between the Land Valuation Board's rate and that paid previously by VRA.

To address loss of land and buildings as a result of the transmission line project, VRA has estimated compensation to individuals for displacement to total ¢2.5 billion. Compensation for crop loss as a result

of the construction and operation of the power line is estimated at ¢6.2 billion. This amount would be paid to project-affected persons prior to initiation of the project.

Public Safety

VRA would assist the District Response Initiative HIV/AIDS Team with public education in the local communities to create awareness for these diseases. VRA would also educate workers as to the dangers of sexually transmitted diseases.

VRA would secure towers against vandalism and theft. In addition, anti-climbing guards would be installed to further discourage passers-by from climbing towers. Measures would also be implemented to address hazards associated with tower collapse, electromagnetic field exposure, and electrocution.

Biodiversity

Biodiversity experts from the Resource Management Support Centre (RMSC) of the Ghana Forestry Commission will oversee field work prior to and during the initial stages of construction to identify any potential site-specific conservation issues should they be encountered. During this process, VRA and RSMC personnel will work together to identify and implement appropriate mitigation measures or alternatives to ensure significant conversion or degradation of critical habitat does not occur. NGGL personnel will monitor this process managed by the VRA and RMSC to support biodiversity management associated with the power line construction.

Ahafo North Project

The Ahafo North Project area is located along a trend of mineralized rock extending from the Ahafo South Project area northeasterly for a distance of approximately 40 km (**Figure 4-1**). The Ahafo North Project was previously part of an approved mining lease issued to Centennary Gold Mining Company. The mining lease is comprised of the Subenso, Yamfo, and northern portion of the Bosumkese concessions. NGGL acquired the concessions in 2002.

NGGL's acquisition of the mining lease for the Sefwi Belt Gold Project area combined with acquisition of the Ntotoroso Gold project in the Ahafo South Project has resulted in NGGL's revision to previously approved development plans for the Ahafo properties. As a consequence, NGGL is evaluating operation of the Ahafo North Project area as future development that may use mine infrastructure associated with current Ahafo South Project operations. Should NGGL decide to proceed with the Ahafo North Project, an ESIA would be compiled in accordance with IFC Policies and Guidelines disclosing all elements of the Project.

The dividing point between the Ahafo South and Ahafo North areas is the Amama Shelterbelt and Bosumkese Forest Reserves. Exploration of the Ahafo mineralized zone has occurred over several years and involved numerous investigators.

Based on current planning, the Ahafo North Project can be viewed from two distinct operational scenarios. The first scenario would entail the use of shared facilities between the Ahafo South and the Ahafo North Project areas, and the second scenario would entail construction of new facilities in the Ahafo North area as presented below. No specific time-frame has been finalized by NGGL regarding development of the Ahafo North Project.

Ahafo North Area Characteristics

- Six mine pits to develop ore from defined and projected ore reserves;
- Continued exploration activity to further define mineable reserves;
- Development of waste rock disposal facilities at each mine pit;
- Installation of water management systems to address potential groundwater inflow to mine pits;
- Diversion structures and water control systems to manage surface water in the vicinity of mine pit and waste rock disposal sites;
- Installation of power lines and other utility corridors to support mine operations in the North area; and
- Reclamation and closure of disturbance areas associated with mining in the North area.

Ahafo North Project Area Development Alternatives

NGGL has identified several mine components associated with future development of the Ahafo North Project that would be evaluated to determine whether alternative geographic locations should be considered for mine components, alternative methods of operation for facilities, and options for closure and reclamation. The primary alternatives that would be considered by NGGL include the following.

Processing Alternatives

Alternative 1: Ore Transport between Project Areas

- Construction and operation of a haul road linking mine pits in the North area to mine processing facilities located in the South area.
- Evaluate use of conveyor system to deliver ore from the North area to Ahafo South Project milling operations. This alternative would also eliminate construction of a haul road across the Forest Reserves by replacing the road with a conveyor system.
- Expansion of the Ahafo South Project tailing storage facility capacity to accommodate added production from mining in the North area.

Alternative 2: Processing Facilities

- Construction and operation of a mill and tailing storage facility in the Ahafo North Project area. This alternative would eliminate the need for construction of a haul road across the Forest Reserve Areas linking ore production in the north to existing milling operations at the Ahafo South Project site.

General Ahafo North Area Alternatives

- Backfill mine pits in Ahafo North Project area. This alternative would consider sequential mining of pits in the north complex whereby open pits that have been mined could be used for disposal of waste rock from subsequent pit developments. This alternative could reduce or eliminate the need for external waste rock disposal facilities for some pits.

- Pit lake water management options. Alternatives to be considered include plans that address exposure of humans and wildlife to poor quality pit lake water. If pit lake water is acceptable, other options could include aquaculture.

- Water treatment – active and passive systems. Depending on predicted water quality to reside in pits, water treatment options would be considered for short-term and long-term systems.

- Closure and reclamation options. A variety of closure options will be evaluated to recognize post-mining land uses; principally subsistence farming.

Alternatives that would be evaluated would be supported by environmental baseline data collection. Baseline investigations would be specifically designed to obtain information necessary to design the Ahafo North Project as well as alternatives.

SOCIAL AND ECONOMIC RESOURCES

With full operational development of the Ahafo North Project, employment, training, and infrastructure improvements resulting from future development could continue for 20 years, providing a longer time-frame to create the base for economic security and social adjustment after closure.

Cumulative negative impacts are expected to continue as the Ahafo Project develops to its full potential when the North Phase comes on-line. More households would need to be resettled, more crops would need to be compensated, and more businesses would have to be relocated. Social and economic pressures of population growth would continue as additional people move to the area to find employment requiring accommodations and community services.

CULTURAL RESOURCES

Portions of the Bosumkese Forest Reserve are within the Ahafo North Project area. A hilly block of land covering 2,204 ha in the north part of the reserve is listed as a hill sanctuary/sacred area (Bosumkese Hill) in Hawthorne, W. and M. Abu-Juam. 1995. Future mining plans that could affect this known sanctuary would not be allowed and NGGL would not propose to disturb them. Because of the uncertainty of cultural sites or properties located within the entire Ahafo Project area, potential cumulative impacts associated with mine development and other land use activities on cultural resources are unknown.

VISUAL RESOURCES

Land use in the cumulative effects area consists of subsistence farming, hamlets and villages, mining, mineral exploration, and forest reserves. The Ahafo North Project, as currently planned, would consist of six mine pits, waste rock disposal facilities, and a haul road connecting the North area to the Ahafo South area. In addition, the tailing storage facility at Ahafo South would likely be expanded to

accommodate processing of ore from the Ahafo North area. All of these areas would result in cumulative impacts to visual quality similar to those described above for the Ahafo South Project. The Ahafo North Project is located approximately 2 to 5 km north of the Ahafo South Project area.

NOISE AND VIBRATION

Development of the North Ahafo Project would include six more mine pits. Construction of these pits and associated waste rock disposal facilities would have similar noise impacts to the communities and residences near them as identified for the Ahafo South Project. However, in addition to impacts identified for the Ahafo South mine pits, ore from the North Project mine pits may be processed at the Ahafo South plant site, requiring lengthy hauling of ore. The haul road would be located near some populated settlements, individual residential dwellings, and/or in the Forest Reserves. Trucks traveling on this haul road may result in noise impacts to populations in the vicinity of the roadway.

Construction of the electrical transmission line would occur in the cumulative effects area and would require additional construction noise and occasional noise from the transmission line itself. Noise from construction of the line would be short-term. Long-term noise from operation of the transmission line would be localized.

BIODIVERSITY - FOREST RESERVES

Development of the Ahafo North and its relation to the Ahafo South project may potentially affect the Bosumkese Forest Reserve. The current project permit (Ghana EPA 2001) approved a haul road corridor located along the western boundary of the Bosumkese Forest Reserve area. Development of the haul road corridor or any other facilities which may affect Forest Reserve areas would not occur prior to completion of detailed baseline studies and impact assessments designed to quantify potential impacts and identify management practices, mitigation measures.

In addition, NGGL is currently developing a Biodiversity Management Program for its Ghanaian operations. The Biodiversity Management Program is further discussed in Chapter 5. NGGL is committed to implement the Biodiversity Management Program for any future activity that may affect Forest Reserve areas.

FLORA

The proposed haul road for the Ahafo North Project would extend between the Ahafo South and North Project sites. The haul road would traverse agricultural land and fallow lands in early stages of ecological succession and forest habitat within Forest Reserves areas.

Removal of vegetation in the Forest Reserves would result in the long-term, site-specific loss of timber and other forest products. This loss would extend for the duration of mining or longer if the road were not abandoned and reclaimed following mining.

Forest Reserve areas are potentially important for timber production although parts of these areas are currently degraded from fire, logging, and encroachment of agricultural activities. If the road were not abandoned and reclaimed, there would be a long-term loss of timber production potential, which would be a significant local impact. If the road were abandoned and revegetated with native, locally adapted

trees and shrubs, production of timber and other forest products would recover to pre-project levels within 20 to 30 years.

Removal of vegetation from Forest Reserve areas would not have significant local or regional effects on floral biodiversity. Plant communities in these areas are composed of relatively common species that have a low genetic heat index and, consequently, are of low conservation priority.

A haul road through Forest Reserve areas would have indirect cumulative effects on vegetation associated with increased human access to portions of these areas adjacent to the road. The haul road would provide improved access to areas of the Forest Reserves adjacent to the road, which would lead to increased exploitation of forest products such as wood and charcoal. Increased opportunity for access also would likely lead to increased development of agriculture within the Reserves. These indirect effects would further degrade the forest communities and result in long-term reductions in timber production potential of the Forest Reserves.

If the haul road were not reclaimed and converted to a public road, the road would greatly increase access to the forest reserves resulting in degradation from logging, charcoal production, farming, and hunting. If the road were converted to a public road, encroachment of human activities would likely extend from the road into the Forest Reserves for a distance of 4 or 5 km.

Construction of the transmission line would remove vegetation during construction and maintenance activities. To prevent trees from falling on the transmission line, a right-of-way at least 60 m wide would need to be cleared of tall vegetation. With shading from tall trees removed, understory vegetation, including aggressive weeds would flourish. Clearing of strips of right-of-way through Forest Reserves would facilitate human access and conversion of forest vegetation to crop production. Losses in timber production potential on the cleared right-of-way would be long-term.

FAUNA

A haul road through the Forest Reserves Areas would have indirect effects on wildlife and wildlife habitat associated with increased human access to portions of the Reserves adjacent to the road. Currently, access to most areas of the Reserves is limited to tracks and trails. The haul road would provide improved access to areas of the Reserves adjacent to the road, which would lead to increased exploitation of wildlife for bushmeat. Increased opportunity for access would likely lead to increased development of agriculture within the Forest Reserves, which would further degrade the forest communities and render them unsuitable for species which are adapted to forest communities. Adverse affects on habitat and wildlife from increased human access would extend 4 to 5 km from the road.

A haul road within the Forest Reserves would have similar types of impacts to the haul road outside of the reserve; however, impacts on wildlife and habitat in the Reserves would be qualitatively different based on species composition differences between forest and non-forest habitats. Of the 215 vertebrate species documented for the Project area, 113 species were recorded exclusively in the Forest Reserves, 12 species were recorded exclusively outside of the Forest Reserves, and 90 species were present in the Forest Reserves and outside the Forest Reserves. Large mammals and birds in the Project area are more strongly associated with the Forest Reserves than other groups. Bats and small mammals appear to have similar affinities for habitats inside and outside of the Forest Reserves; however, two bat species appear to be forest-habitat obligates.

The haul road in a Forest Reserves would have the potential to affect species with First Schedule conservation status (Ghana Wildlife Conservation Regulations). Under the First Schedule, hunting, capturing, or destroying any species listed in this Schedule are prohibited. In addition, a number of Second Schedule wildlife species are also restricted to habitats in the forest reserves.

It is unlikely that construction activities would cause significant direct mortality to large mammals in the Forest Reserves; however, construction noise, human activities, and haul traffic would displace many species 1 km or farther from the haul road. Currently, there are no roads in the areas of the Forest Reserves that could be traversed by a haul road; consequently, wildlife species are not accustomed to high noise and human activity levels. Animals not habituated to noise and human activities tend to react strongly to new disturbances.

A haul road would directly remove habitat in the Forest Reserves and would reduce the quality of habitat on both sides of the road up to a distance of 1 km or more. Over time, some species of wildlife would become accustomed to traffic and noise associated with haul road and reoccupy adjacent habitat not directly altered by the road.

Removal of habit in a Forest Reserves would have the potential to adversely affect more than 150 species of birds. Most birds restricted to forest habitats have specific, relatively specific habitat needs, which are provided only by sufficiently large relatively intact patches of forest. A haul road would directly remove habitat but would also break the forest habitat into smaller patches, which would lead to losses in species diversity in the fragmented forest habitats. Beier *et al.* (2002) found that bird diversity in forests of central Ghana is directly correlated with the size of the patch of forest habitat.

Removal and degradation of habitat in the Forest Reserves would constrict wildlife adapted to forest habitats into a smaller area, which would increase competition for food and space and render them more vulnerable to mortality from hunting. Displacement and habitat degradation would be a significant long-term, site-specific, local, and regional impact. It would be of moderate magnitude, but qualitatively would have a high probability of adversely affecting species of high conservation priority.

Habitat quality adjacent to the haul road would also have the potential to be directly degraded by dust from the road. Dust could reduce productivity of some plant species or render them unpalatable to wildlife resulting in further habitat degradation.

Impacts to wildlife regionally would also result from impaired movement and associated genetic exchange and utilization of habitat. Currently, forest habitats in Ghana are fragmented and greatly reduced in spatial extent. The Bosumkese Reserve is the easternmost Forest Reserve, linked by the Amama Shelterbelt Forest Reserve to a contiguous chain of Forest Reserves in the western part of Ghana (e.g., Asukese, Mpameso, Bia North, Goa, and Ayum forest reserves). This contiguous chain of Forest Reserves supports remnant populations of elephants, chimpanzees, bongos, and forest buffalo, all species experiencing shrinking ranges in Ghana (Parren and Sam 2003).

The haul road through the Bosumkese Forest Reserve would be a barrier to east-west movement of many species that would move through the Amama Forest Reserve to the Bosumkese Forest Reserve, or from the Bosumkese Reserve to other Reserves to the west. The haul road would be a substantial impediment to wildlife movement among the contiguous blocks of Forest Reserves that are islands of forest in habitat extensively developed for agriculture and human habitation. Potential to recover high-priority wildlife populations would be reduced by the increased habitat fragmentation caused by the haul

road. If the road were abandoned and reclaimed following mining, impacts from the road on wildlife movement and species diversity would likely be residual and significant for several years. An unknown period of time probably would be required for wildlife affected by the road to resume use of reclaimed habitat as part of their regional movement patterns.

Construction of the transmission line would affect wildlife by altering habitat from construction and maintenance activities that would remove large trees 30 m or more from the transmission line. Danger from tall trees falling on the transmission line would necessitate removal of a strip of trees at least 60 m. This would reduce habitat values for wildlife dependent on forest habitat. Like the proposed haul road, a transmission line through Forest Reserve areas would increase human access into the Reserves, adversely affecting direct and indirect effects on wildlife. Direct mortality to large birds could result from electrocution to large birds, if they perch on conductors and contact structures that are grounded.

FLORA

Development of the Ahafo North and South projects would have similar effects on vegetation; however, more land area would be affected cumulatively. Cumulative effects on vegetation would be similar in magnitude and duration to direct effects of developing the Ahafo South Project.

With removal of land from production and resettlement of affected villages to adjacent areas, human population densities would increase locally. Also, with construction and operation of foreseeable future mining operations, more people would come to the area seeking jobs or would be working at the mine. Site-specific and local reductions in crop land from mining activities would increase the demand for unaffected land outside of the mine disturbance area for crop production, charcoal, and other natural amenities derived from plant communities.

With increased local demands for production of food crops and cash crops, fallow cycles would likely shorten, reducing productivity of land. Cumulative impacts associated with less arable land and increased demands for arable land would be medium magnitude, long duration, and significant locally.
The proposed haul road for the Ahafo North Project would extend between the Ahafo South and North Project sites. The haul road would traverse agricultural land and fallow lands in early stages of ecological succession. The loss of crop land and other agriculture land in various production/fallow cycles would be a significant long-term, high-magnitude, site-specific and local impact. Generation of dust from the haul road would have adverse site-specific and local effects on vegetation and crops adjacent to the haul road. Deposition of dust on crops and other vegetation would have the potential to reduce photosynthetic rates and associated productivity.

Construction of the transmission line would remove vegetation during construction and maintenance activities. To prevent trees from falling on the transmission line, a right-of-way at least 60 m wide would need to be cleared of tall vegetation. With shading from tall trees removed, understory vegetation, including aggressive weeds would flourish. Clearing of strips of right-of-way through forest reserves would facilitate human access and conversion of forest vegetation to crop production. Losses in timber production potential on the cleared right-of-way would be long-term.

FAUNA

Indirect effects of reasonably foreseeable future developments would result from increased population density and reductions in wildlife habitat. Human populations would increase in density and,

consequently, greater demand would be placed on habitats undisturbed by mining activities to provide bushmeat. Currently, hunting for bushmeat is severely affecting populations of wildlife in Ghana (Forest Conservation Archives 2002). Three of the species that would be displaced from mining activities (i.e., grasscutter, Maxwell's duiker, and royal duiker) are preferred bushmeat species and would be subject to increased hunting pressure as a result of increased population densities and decreased local habitat. Indirect effects from construction and operation of reasonably foreseeable mining activities would be long term, local, and of medium magnitude. There would likely be an incremental increase in mortality for bushmeat species, locally; however, effects from the reasonably foreseeable mining developments on populations of animals utilized as bushmeat would not be detectable regionally.

Development of Ahafo North would result in and additional loss of habitat, and reductions in availability of forage, security, and breeding cover for wildlife inhabiting the area. Human populations would increase in density and, consequently, greater demand would be placed on habitats undisturbed by mining activities to provide bushmeat. Cumulatively, impacts from the Ahafo North and South projects would be additive in terms of lost or degraded habitats, mortality, and displacement from human activities.

Impacts on wildlife from construction and use of the haul road would include loss of habitat, displacement from habitat adjacent to the road, and direct mortality from construction activities and haul traffic on the road. Construction and operation of the haul road outside of the Forest Reserves would have similar impacts on wildlife to construction as described under impacts of mine pits, waste dumps, and ancillary facilities. Traffic on the haul road also would have the potential to kill wildlife, especially reptiles, amphibians, and mammals with limited abilities to escape oncoming vehicles.

Eight species of mammal recorded for the Project area are listed by the International Union for the Conservation of Nature and Natural Resources (ICUN). Mammals listed as "Least Concern- Near Threatened" include the bay duiker, black duiker, royal antelope, and western pied colobus. Mammals listed as "Data Deficient" include the slender-tailed squirrel and Kintampo rope squirrel. The forest buffalo is listed as "Least Concern – Conservation Dependent". The mammal of highest international concern is the Pel's flying squirrel, listed by IUCN as "Endangered".

WETLANDS

Cumulative impacts from the Ahafo South and Ahafo North projects would have additive effects on wetlands. The mine pits, waste rock disposal facilities, and haul road may remove or fill some wetland areas. Construction of the transmission line also may affect some wetland areas for the access roads and tower pads. Sediment generated by runoff from new roads could affect some wetland areas. Sediment control measures would likely be implemented to prevent or minimize increased sediment load to surface water and wetlands.

AQUATIC ORGANISMS

Cumulative effects from the Ahafo North and Ahafo South projects would result from activities that would alter existing drainage patterns and hydrology of streams supporting fish and aquatic organisms. Sediment generated from runoff of sediment from new roads could affect fish and other aquatic organisms in the Tano River and its tributaries. Sediment control measures would be implemented to prevent or minimize increased sediment load to surface water.

GEOLOGY AND MINERALS

The Ahafo North Project development would increase the extent of effects to geology and minerals as a result of the increased disturbance area (i.e., more mine pits and waste rock disposal facilities). Types of impacts would likely be similar to those of the Ahafo South Project given that the same methods of mining operation and construction would likely be employed for both projects. In addition, the geology and mineralogy between the two areas are similar.

WATER RESOURCES

The Ahafo North Project, as currently planned, would consist of the following major mine facilities: six mine pits, waste rock disposal facilities, and haul road connecting the North area to the Ahafo South area. In addition, the tailing storage facility at Ahafo South would likely be expanded to accommodate processing of ore from Ahafo North. All of these areas would result in potential impacts to surface water and groundwater resources similar to those described previously for the Ahafo South Project. As described above for *Geology and Minerals*, however, any changes between the two areas with respect to geology and minerals may result in different potential for acid mine drainage and release of metals from waste rock and mine pit walls. This could result in quality of seepage water and pit lake water that is not similar between the Ahafo South and North Project sites.

SOIL RESOURCES

The Ahafo North Project development would increase the extent of effects to soil resources as a result of increased disturbance areas. Types of impacts would likely be similar to those of the Ahafo South Project given that the same methods of operation and construction would likely be employed for both projects. However, differences in soil types, premine land uses, and the details of operations would likely result in differing magnitudes of impact. In addition, disturbance in the Bosumkese Forest Reserve could permanently affect the ability of soils there to support vegetation communities comparable to those present prior to disturbance. The precise impacts resulting from the Ahafo North Project development cannot be determined without further investigation of baseline conditions and defined methods of operation.