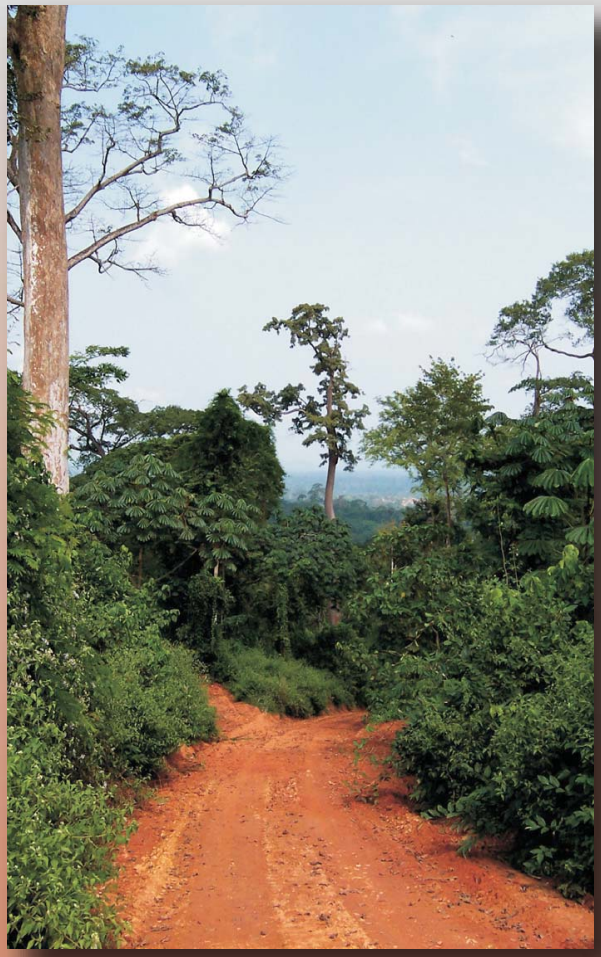
ANNEX C



SUPLEMENTAL INFORMATION FOR EXISTING ENVIRONMENT SECTION

ANNEX C-I

FLORA AND FAUNA SPECIES IN STUDY AREA

Table C1-1
Large Mammals Recorded during Baseline Studies Conducted in Akyem Study Area within Ajenjua Bepo Forest Reserve, Mamang River Forest Reserve, and Outside Forest Reserves (FR)

Species	SGS 1998	SGS 2004	CI 2005	CI 2006	GWS 2007	Ajenjua Bepo FR	Mamang FR	Outside FRs
Order Artiodactyla								
Cephalophus maxwelli (Maxwell's duiker)	+	+		+	+	+	+	+
Cephalophus niger (Black duiker)	+	+			+	+	+	+
Cephalophus niger (Bay duiker)		+					+	
Potomochoerus porcus (Red river hog)		+		+			+	
Neotragus pygmaeus (Royal duiker)	+	+		+	+	+	+	+
Boocerus euryceros (Bongo)		+					+	
Tragelaphus scriptus (Bushbuck)	+	+	+	+	+	+	+	+
Order Primate								
Galagoides demidovi (Bushbaby)	+	+				+	+	+
Galago senegalensis (Bosman's potto)	+	+	+	+		+	+	+
Perodictus potto (Potto)				+		+	+	
Cercopithicus diana (Diana monkey)						+	+	
Cercopithicus petaurista (Spot-nosed monkey)	+	+		+	+	+	+	+
Cercopithicus mona (Mona monkey)	+	+			+	+	+	+
Cercopithicus nicitans (Putty nosed monkey)	+	+				+		
Colobus polykomos (Black and white colobus monkey)							+	
Procolobus verus (Olive colobus)				+			+	
Order Pholidota								
Manis longicaudatus (Long-tailed pangolin)	+	+		+	+	+	+	+
Manis tricuspis (White-tailed pangolin)	+	+				+	+	
Order Carnivora								
Civettictis civette (African civet)	+	+	+	+	+	+	+	+
Genetta maculate (Forest genet)		+					+	
Helogale parvula (Dwarf mongoose)	+	+	+		+			+
Nandinia binotata (Palm civet)		+		+		+	+	+
Atilax paludinosus (Marsh mongoose)		+					+	
Mungos gambinanus (Gambian mongoose)		+				+	+	+
Crossarchus obscurus (Common cusimanse)	+	+		+		+	+	
Poiana leightoni (West African linsang)					+			+
Order Hyracoidea								
Dendrohyrax arboreus (Tree hyrax)	+	+		+	+	+	+	+
Order Rodentia								

Table C1-1 (continued)
Large Mammals Recorded during Baseline Studies Conducted in Akyem Study Area within Ajenjua Bepo Forest Reserve, Mamang River Forest Reserve, and Outside Forest Reserves (FR)

Species	SGS 1998	SGS 2004	CI 2005	CI 2006	GWS 2007	Ajenjua Bepo FR	Mamang FR	Outside FRs
Anomalurus beecrofti (Beecroft's flying squirrel)		+				+	+	
Anomalurus derbianus (Derby flying squirrel)		+		+		+	+	
Anomalurus pelli (Pel's flying squirrel)	+	+		+		+	+	+
Atherus africana (Brush-tailed porcupine)		+		+	+	+	+	+
Hystrix cristata (Crested porcupine)					+			+
Protoxerus strangei (Giant forest squirrel)		+					+	
Cricetomys gambianus (Giant rat)	+	+		+	+	+	+	+
Thryonomys swindeianus (Grasscutter)	+	+	+	+	+	+	+	+
Total Number Species								

Sources: SGS (1998, 2004b), Conservation International (CI 2005, 2006), Ghana Wildlife Society (GWS 2007)

Table C1-2
Species with Conservation Status
Reported for the Akyem Study Area

Scientific Name	Common Name	IUCN Red List Status	CITES Status	Ghana Status
Artiodactyla				
Boocerus euryceros	Bongo	Near Threatened		
Cephalophus dorsalis	Bay duiker	Near Threatened	III	II
Cephalophus maxwelli	Maxwell's duiker	Near Threatened	---	II
Cephalophus niger	Black duiker	Near Threatened	---	II
Neotragus pygmaeus	Royal antelope	Near threatened		
Tragelaphus scriptus	Bush buck	---	---	II
Primates				
Cercopithecus Diana	Diana monkey	Endangered	II	I
Cercopithecus mona	Mona monkey	---	II	I
Cercopithicus nictitans	Putty-nosed monkey	---	---	II
Cercopithecus petaurista	Spot-nosed monkey	--	II	II
Colobus polykomos	Black and white colobus	Near threatened	---	I
Galago senegalensis	Bosman's potto	--	II	I
Galagoides demidovi	Bush baby	--	II	I
Hyrocoidea				
Dendrohyrax arboreus	Tree hyrax	--	---	I
Carnivora				
Genetta maculate	Forest genet	--	---	I
Herpestes sanguinus	Dwarf mongoose	--	---	II
Mungos gambianus	Gambian mongoose	Data Deficient		
Mungos obscurus	Cusimanse	--	---	II
Nandinia binotata	Palm civet	--	---	I
Vivera civetta	African civet	--	---	I
Pholidota				
Manas tetradactyla	Black-bellied pangolin	--	--	I
Manas transpiis	White-bellied pangolin	--	--	I
Rodentia				
Anomalurus beecrofti	Beecroft's flying squirrel	--	--	I
Anomalurus derbianus	Derby flying squirrel	--	--	I
Anomalurus peli	Pel's flying squirrel	Near threatened	III	I
Athururus africanus	Brush-tailed porcupine	--	---	II
Funiscurius substriatus	Red side-striped squirrel	Data Deficient	---	---
Hystrix cristata	Crested porcupine	---	II	II
Protoxerus stangeri	Giant forest squirrel	--	---	II
Chiroptera				
Epomophorus gambianus	Gambian epaulet bat	---	---	II
Epomops franquetti	Singing fruit bat	---	---	II
Hippodiderus abae	Round-leaf bat	Near threatened	---	---
Hipposiderus jonesii	Horseshoe bat	Near threatened	---	---
Hypsignathus montstrosus	Hammer bat	---	---	II
Lissonycteris angolensis angolensis	Angola fruit bat	---	---	II
Megalosgolossus woermanni	Nectar bat	---	---	II
Micropteris pusillus	Lesser epaulet bat	---	---	II
Myoncycteris leptodon	Sierra Leone collared fruit bat	---	---	II
Nannocyctris veldkampii	Little flying cow	---	---	II
Nycteris microtis	Slit-faced bat	---	---	II
Rousettus aegyptiacus	Egyptian fruit bat	---	---	II
Scotonycteris ophiodon	Pohle's fruit bat	Endangered	--	II
Scotonycteris zenkeri	Zenker's fruit bat	Near threatened	--	II

Table C1-2 (continued)
Species with Conservation Status
Reported for the Akyem Study Area

Scientific Name	Common Name	IUCN Red List Status	CITES Status	Ghana Status
Reptilia				
Chameleo gracilis	Chameleon	--	II	--
Kinixys belliana	Hinged tortoise	Vulnerable	II	II
Python regius	Royal python	---	II	--
Python sebae	African python	---	II	---
Varanus exanthematicus	Bosc's monitor	---	II	---
Varanus niloticus	Nile monitor	---	II	II
Birds				
Bleda eximius	Green-tailed bristlebill	Vulnerable	---	---
Bubo poensis	Frazer's eagle owl	---	---	I
Ceratogymna atrata	Black-casqued hornbill	---	---	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
Francolinus bicalcaratus	Double-spurred francolin	---	---	II
Glaucidium tephrontum	Pearl-spotted owlet	---	---	I
Illidopsis rufescens	Rufous-winged illadopsis	Threatened	---	---
Kaupifalco monnogrammicus	Lizard buzzard	---	---	I
Lonchura cucullata	Bronze manakin	---	III	II
Lonchura fringilloides	Magpie mannikan	---	---	II
Milvus migrans	Black kite	---	II	I
Neophron manachus	Hooded vulture	---	II	I
Ploceus cuculatus	Village weaver	---	III	II
Ploceus niggerimus	Veillot's black weaver	---	III	II
Ploceus nigricollis brachypterus	Spectacled weaver	---	III	II
Psittachus erathicus	Grey parrot	---	---	II
Serinus leucopygius	Grey canary	---	---	II
Tauraco macrorhyncus	Verreaux's turoco	---	---	II
Tauraco persa	Guinea turoco	---	---	II
Treron calvus	African green pigeon	---	---	II
Tockus camurus	Red-billed dwarf hornbill	---	---	II
Tockus faciatus semifasciatus	Black-and-white-tailed hornbill	---	---	II
Tropicanus albocristatus	White-crested hornbill	---	---	II
Tutur afer	Red-billed wood dove	---	III	II

Notes:

IUCN (International Union of Nature and Natural Resources) Red List Status

Endangered

A species is Endangered when best available evidence indicates that it is facing a very high risk of extinction in the wild due to:

- Reduced populations (50 to 70 %) in the last 10 years
- Limited geographic range (less than 5,000 km^2)
- Known existence at no more than five locations
- Population is estimated at fewer than 2,500 individuals
- Probability of extinction at least 20 % in 20 years.

Vulnerable

A species is Vulnerable when best available evidence indicates that it is facing a high extinction risk in the wild due to:

- Population reduction of 30 to 50 % over the last 10 years
- Range of occurrence less than 20,000 km^2
- Population size estimated at less than 10,000 mature individuals
- Probability of extinction less than 10 % within 100 years.

TABLE C1 -2 (continued)

Near Threatened
A species is Near Threatened when it does not qualify for Critically Endangered, Endangered, or Vulnerable now but is close to qualifying for or is likely to qualify for a threatened category in the near future.

CITES (Convention on International Trade in Endangered Species of Wild Fauna and Flora) Status
A species is Vulnerable when best available evidence indicates that it is facing a high extinction risk in the wild due to:

- I – Appendix Range Appendix I (International trade not permitted)
- II – Appendix II (Regulated trade permitted)
- III – Appendix III (International trade permitted with permit from source country)

Ghana Status
The Ghana Wildlife Conservation Regulations (WCR) refer to First Schedule and Second Schedule.

- I – First Schedule (Schedule 1) species are completely protected. Hunting, capturing, and destroying these species is prohibited.
- II – Second Schedule (Schedule 2) species cannot be hunted, captured, or destroyed between August 1and December 1. Hunting, capturing, or destroying young or adults accompanied by young of any Second Schedule species is prohibited.

Table C1-3
Small Mammals Recorded in Baseline Studies in Akyem Study Area in Ajenjua Bepo Forest Reserve, Mamang River Forest Reserve, and Outside Forest Reserves

Species	SGS 1998	SGS 2004	CI 2005	CI 2006	GWS 2007	Ajenjua Bepo FR	Mamang FR	Outside FRs
Crocidura buettikoferi (Buettikofer's shrew)				+		+	+	
Crocidura bicolor (Shrew)			+					+
Crocidura crossei/jouvenetae (White-toothed shrew)				+	+	+	+	+
Crocidura flavescens (Red musk shrew)		+				+	+	+
Crocidura muricauda complex (Long-tailed shrew)				+		+	+	
Crocidura obscurior (Pygmy shrew)				+		+	+	
Crocidura olivieri (African giant shrew)				+		+	+	
Euxerus erythropus (Stripped ground squirrel)			+			+		+
Funisciurus anerythrus (Redless Tree squirrel)			+					+
Funisciurus pyrropus (Fire-footed rope squirrel)	+	+	+		+	+	+	+
Funiscurius substriatus (Red side-striped squirrel)	+	+				+	+	+
Grammomys dolichochurus (Thicket rat)			+			+		
Heliosciurus gambianus (Gambian sun squirrel)				+			+	
Hylomyscus alleni (Wood mouse)					+			+
Hylomyscus stella (Wood mouse)		+				+	+	
Lemniscomys striatus (Zebra mouse)		+		+	+		+	+
Lophuromys flavopunctata (Brush-furred mouse)			+			+		
Lophuromys sikapsu (Brush-furred mouse)	+	+				+		+
Malacomys edwardsi (Long-footed rat)		+				+	+	
Mastomys sp.				+			+	
Mastomys erythroleucus (Multimammate rat)				+	+		+	+
Mus minitoides/musculoides (Pygmy mouse)		+			+	+		+
Mus musculus (Common mouse)		+		+		+	+	+
Paracrocidura sp. (Rodent shrew)			+			+		
Praomys natalensis (Soft-furred mouse)		+						+
Praomys tullbergi /rostratus (Soft-furred mouse)	+	+	+	+	+	+	+	+
Total number species	***4***	***11***	***8***	***11***	***6***	***18***	***16***	***15***

Sources: SGS (1998, 2004b), Conservation International (CI 2005, 2006), Ghana Wildlife Society (GWS 2007)

Table C1-4
Bats Recorded during Baseline Studies in Akyem Study Area in Ajenjua Bepo Forest Reserve, Mamang River Forest Reserve, and Outside Forest Reserves (FR)

Species	SGS 1998	SGS 2004	CI 2005	CI 2006	GWS/Geomatrix 2007	Ajenjua Bepo FR	Mamang FR	Outside FRs
Megachiroptera (Fruit Bats)								
Eidelon helvum (Straw-colored bat)			+			+		
Epomops buettikoferi (Buettikofer's epauletted fruit bat)					+			+
Epomops franqueti (Franquet's epauletted fruit bat)	+	+		+	+	+	+	+
Epomops gambianus (Gambian epauletted fruit bat)	+					+	+	+
Epomophorus gambianus (epauletted fruit bat)		+			+	+	+	+
Hypsignathus monstrosus (Hammer bat)		+		+	+	+	+	+
Lissonycteris angolensis (Angola fruit bat)	+	+		+	+	+		+
Megaloglossus woermannii (Nectar Bat)		+			+	+		+
Micropteropus pusillus (Dwarf epauletted fruit bat)		+				+	+	+
Myonycteris torquata (Little collared fruit bat)	+			+		+	+	+
Myonycteris leptodon (No Common name)		+				+	+	+
Nanonycteris veldkampi (Little flying cow)	+	+		+		+	+	+
Rousettus aegyptiacus occidentalis (Egyptian fruit bat)	+	+		+		+	+	+
Scotonycteris ophiodon (Pohle's fruit bat)	+	+				+	+	
Scotonycteris zenkeri (Teardrop fruit bat)		+			+	+	+	+
Microchiroptera (Insect-eating bats)								
Hipposideros caffer guinenensis (Leaf-nosed bat)					+			+
Hipposiderus abae (Round-leaf bat)		+					+	
Hipposiderus jonesii (Horseshoe bat)					+			+
Nycteris microtis (Slit-faced bat)		+						+
Rhinolophus alcyone (Horseshoe bat)				+		+		
Pipistrellus nanus (Banana bat)					+			+
Scotophilus spp. (House bat)					+			+
Scotophilus dinganii (House bat)					+			+
Scotophilus leugaster (House bat)					+			+
Total number species	***7***	***13***	***1***	***7***	***13***	***15***	***12***	***20***

Sources: SGS (1998, 2004b), Conservation International (CI 2005, 2006), Ghana Wildlife Society (GWS 2007)

Table C1-5
Birds Recorded during Baseline Studies in Akyem Study Area in Ajenjua Bepo Forest Reserve, Mamang River Forest Reserve, and Outside Forest Reserves (FR)

Species	SGS 1998	SGS 2004	CI 2005	CI 2006	GWS 2007	Ajenjua Bepo FR	Mamang River FR	Outside FRs
Accipiter badius Shikra					+			+
Accipiter erythropus Red-thighed Sparrowhawk					+			+
Accipiter melanoleucus Black Sparrowhawk					+			+
Accipiter tachiro African Goshawk				+		+		+
Alcedo leucogaster White-bellied Kingfisher					+			+
Alcedo cristata Malachite Kingfisher		+						+
Alcedo quadribrachys Shining-blue Kingfisher					+			+
Alethe diademata Fire-crested Alethe				+	+	+	+	+
Amblyospiza albifrons Grosbeak Weaver					+			+
Andropadus ansorgei Ansorge's Greenbul				+	+		+	+
Andropadus curvirostris Cameroon Sombre Greenbul				+	+	+	+	+
Andropadus gracilirostris Slender-billed Greenbul/bulbul		+		+		+	+	+
Andropadus gracilis Little Grey Greenbul				+				+
Andropadus latirostris Yellow-whiskered Greenbul			+	+	+	+	+	+
Andropadus virens Little Greenbul		+	+	+	+	+	+	+
Andropadus viridis Little woodpecker	+	+1998				+		
Anthoscopus flavifrons Forest Penduline Tit					+			+
Anthreptes collaris Collard sunbird	+	+				+		+
Anthreptes rectirostris Green Sunbird				+	+	+	+	+
Anthreptes seimundi Little Green Sunbird					+			+
Antichromus minutus Marsh Tchagra					+			+
Apalis nigriceps Black-capped Apalis				+	+	+	+	+
Apalis sharpii Sharpe's Apalis			+	+	+	+	+	+
Apaloderma narina Narina's Trogon				+		+	+	
Apus apus Common Swift				+				+
Apus affinis Little (African) Swift	+	+1998		+	+	+		+
Apus barbatus African Black Swift					+			+
Ardeola Ibis Cattle egret	+	+1998				+		
Aviceda cuculoides African Cuckoo Hawk					+			+

Table C1-5 (continued)
Birds Recorded during Baseline Studies in Akyem Study Area in Ajenjua Bepo Forest Reserve, Mamang River Forest Reserve, and Outside Forest Reserves (FR)

Species	SGS 1998	SGS 2004	CI 2005	CI 2006	GWS 2007	Ajenjua Bepo FR	Mamang River FR	Outside FRs
Baeopogon indicator Honeyguide Greenbul/bulbul		+	+	+	+	+	+	+
Bias musicus Black-and-white Flycatcher			+	+	+	+		+
Bleda canicapilla Grey-headed Bristlebill				+	+	+	+	+
Bleda exima Green-tailed bristlebill				+			+	
Bleda syndactyla Red-tailed Bristlebill		+		+	+	+	+	+
Bubo poensis/leucostictus Fraser's/Akun Eagle Owl	+	+		+		+	+	
Buccanodon duchaillui Yellow-spotted Barbet					+			+
Buteo auguralis Red-necked Buzzard			+		+			+
Bycanistes cylindricus Brown-cheeked Hornbill					+			+
Bycanistes fistulator Piping Hornbill					+			+
Calyptocichla serina Golden Greenbul				+	+	+	+	+
Camaroptera brachyura Grey-backed Camaroptera		+	+	+	+	+		+
Camaroptera chloronota Olive-green Camaroptera				+	+	+	+	+
Camaroptera superciliaris Yellow-browed Camaroptera		+	+	+	+	+	+	+
Campephaga quiscalina Purple-throated Cuckoo-Shrike				+		+	+	+
Campethera caroli Brown-eared Woodpecker				+	+	+	+	+
Campethera nivosa Buff-spotted Woodpecker				+	+	+		+
Campethera punctuligera Fine-spotted Woodpecker					+			+
Centropus leucogaster Black-throated Coucal	+	+	+	+	+	+	+	+
Centropus monachus Blue-headed Coucal					+			+
Centropus senegalensis Senegal Coucal				+	+			+
Ceratogymna atrata Black-casqued Hornbill		+			+		+	+
Cercococcyx olivinus Olive long-tailed Cuckoo				+		+		
Ceuthmochares aereus Yellowbill			+	+	+	+	+	+
Ceyx lecontei African Dwarf Kingfisher					+			+
Ceyx pictus African Pygmy Kingfisher					+			+
Chalcomitra adelberti Buff-throated Sunbird				+	+	+	+	+
Chlorocichla simplex Simple Leaflove			+	+	+			+
Chrysococcyx caprius Didric Cuckoo				+	+			+

Table C1-5 (continued)
Birds Recorded during Baseline Studies in Akyem Study Area in Ajenjua Bepo Forest Reserve, Mamang River Forest Reserve, and Outside Forest Reserves (FR)

Species	SGS 1998	SGS 2004	CI 2005	CI 2006	GWS 2007	Ajenjua Bepo FR	Mamang River FR	Outside FRs
Chrysococcyx cupreus African Emerald Cuckoo		+	+	+	+	+	+	+
Chrysococcyx klaas Klaas's Cuckoo			+	+		+	+	+
Cinnyris chloropygia(s) Olive-bellied Sunbird			+	+	+			+
Cinnyris coccinigaster Splendid Sunbird					+			+
Cinnyris cuprea Copper Sunbird					+			+
Cinnyris johannae Johanna's Sunbird				+		+		
Cinnyris superba/superbus Superb Sunbird				+	+			+
Cisticola cantans Singing Cisticola					+			+
Cisticola erythrops Red-faced Cisticola					+			+
Cisticola lateralis Whistling Cisticola				+	+			+
Columba iriditorques Western Bronze-naped Pigeon					+			+
Columba uncinata Afep pigion				+			+	
Coracias cyanogaster Blue-bellied Roller					+			+
Coracina azurea Blue Cuckoo-shrike				+	+	+	+	+
Corythaeola cristat(l)a Great blue turaco/Blue Plantain Eater	+	+				+	+	
Corvus albus Pied Crow	+	+	+	+	+	+		+
Crinifer piscator (Western) Grey Plantain Eater		+				+	+	+
Criniger barbatus Western Bearded Greenbul			+	+	+	+	+	+
Criniger calurus Red-tailed Greenbul		+		+	+	+	+	+
Cuculus clamosus Black Cuckoo				+	+		+	+
Cuclulus solitarius Red-chested Cuckoo		+		+		+	+	
Cyanomitra cyanolaema Blue-throated Brown Sunbird				+	+	+	+	+
Cyanomitra obscura (olivaceus) Western Olive Sunbird			+		+	+		+
Cyanomitra olivacea Olive Sunbird				+		+	+	+
Cypsiurus parvus African Palm Swift					+			+
Deleornis fraseri Fraser's Sunbird				+	+	+	+	+
Denriopicus fuscescens Cardinal wood pecker	+	+				+	+	
Dendropicos gabonensis Gabon Woodpecker				+	+	+	+	+

Table C1-5 (continued)
Birds Recorded during Baseline Studies in Akyem Study Area in Ajenjua Bepo Forest Reserve, Mamang River Forest Reserve, and Outside Forest Reserves (FR)

Species	SGS 1998	SGS 2004	CI 2005	CI 2006	GWS 2007	Ajenjua Bepo FR	Mamang River FR	Outside FRs
Dendropicos pyrrhogaster Fire-bellied Woodpecker				+	+	+	+	+
Dicrurus adsimilis Fork-tailed/Glossy backed Drongo	+	+			+	+	+	+
Dicrurus modestus Velvet-mantled Drongo			+	+	+	+	+	+
Dryoscopus gambensis Northern Puffback				+	+	+	+	+
Dryoscopus sabini Sabine's Puffback					+			+
Dyaphorophyia blissetti Red-cheeked Wattle-eye					+			+
Dyaphorophyia castanea Chestnut Wattle-eye				+	+	+	+	+
Eremomela badiceps Rufous-crowned Erememela				+	+	+	+	+
Erythrocercus mccallii Chestnut-capped Flycatcher				+	+	+	+	+
Estrilda melpoda Orange-cheeked Waxbill				+	+			+
Estrilda troglodytes Black-rumped Waxbill					+			+
Euplectes afer Yellow Billed bishop	+	+				+		+
Euplectes ardens Red-collared Widowbird					+			+
Euplectes hordeaceus Black-winged Bishop		+						+
Euplectes/Euplected hordeaceus Black-winged Red Bishop				+				+
Eurystomus glaucurus Broad-billed Roller			+	+	+		+	+
Eurystomus gularis Blue-throated Roller					+			+
Falco ardosiaceus Grey Kestrel					+			+
Falco cuvierii African Hobby					+			+
Francolinus ahantensis Ahanta Francolin			+	+	+			+
Francolinus alborgularis White throated francolin	+	+1998				+		
Francolinus bicalcaratus Double-spurred Francolin		+			+			+
Francolinus lathami Latham's Forest Francolin				+	+	+	+	+
Fraseria ocreata Fraser's Forest Flycatcher			+	+	+	+	+	+
Glaucidium tephronotum Red-chested Owlet				+		+	+	
Gymnobucco calvus Naked-faced Barbet	+	+	+	+	+	+	+	+
Gymnobucco peli Bristle-nosed Barbet				+	+	+		+
Gypohierax angolensis Palm-nut Vulture					+			+

Table C1-5 (continued)
Birds Recorded during Baseline Studies in Akyem Study Area in Ajenjua Bepo Forest Reserve, Mamang River Forest Reserve, and Outside Forest Reserves (FR)

Species	SGS 1998	SGS 2004	CI 2005	CI 2006	GWS 2007	Ajenjua Bepo FR	Mamang River FR	Outside FRs
Halcyon badia Chocolate-backed Kingfisher				+	+		+	+
Halcyon malimbica Blue-breasted Kingfisher	+	+		+	+	+		+
Halcyon senegalensis Woodland Kingfisher			+	+	+			+
Hedydipn(r)a collaris Collared Sunbird			+	+	+	+	+	+
Hedydipna platura Pygmy Sunbird					+			+
Heliolais erythroptera Red-winged Warbler					+			+
Himantornis haematopus Nkulengu Rail				+		+	+	
Hirundo abyssinica Lesser Striped Swallow				+	+			+
Hirundo daurica Red-rumped Swallow					+			+
Hirundo rustica Barn Swallow					+			+
Hirundo smithii Wire-tailed Swallow					+			+
Hylia prasina/prasuria Green Hylia		+	+	+	+	+	+	+
Hyliota violacea Violet-backed Hyliota					+			+
Illadopsis cleaveri Blackcap Illadposis				+	+	+		+
Illadopsis fulvescens Brown Illadopsis				+	+	+	+	+
Illadopsis puveli Puvel's Illadopsis					+			+
Illadopsis rufescens Rufous-winged Illadopsis					+			+
Illadopsis rufipennis Pale-breasted Illadopsis					+			+
Indicator (minor) conirostris Thick-billed Honeyguide				+	+	+		+
Indicator exilis Least Honeyguide					+			+
Indicator maculatus Spotted Honeyguide				+	+	+		+
Indicator Minor Lesser Honeyguide		+				+	+	+
Ispidina picta Pygmy Kingfisher		+						+
Kanpifalco/Kaupifalco monnogrammicus Lizzard Buzzard	+	+				+		+
Lagonosticta rubricata African Firefinch					+			+
Lagonosticta rufopicta Bar-breasted Firefinch					+			+
Lagonosticta senegala Red-billed Firefinch					+			+
Lamprotornis cupreocauda Copper-tailed Glossy Starling					+			+

Table C1-5 (continued)
Birds Recorded during Baseline Studies in Akyem Study Area in Ajenjua Bepo Forest Reserve, Mamang River Forest Reserve, and Outside Forest Reserves (FR)

Species	SGS 1998	SGS 2004	CI 2005	CI 2006	GWS 2007	Ajenjua Bepo FR	Mamang River FR	Outside FRs
Lamprotornis splendidus Splendid Glossy Starling		+	+	+	+	+	+	+
Laniarius aethiopicus Tropical Boubou					+			+
Laniarius leucorhyncus Sooty Boubou		+				+	+	+
Lonchura bicolor Black-and-white Mannikin					+			+
Lonchura cucullata Bronze Mannikin	+	+			+	+		+
Lonchura fringilloides Magpie Mannikin	+	+				+		+
Lophaetus occipitalis Long-crested Eagle					+			+
Lybius bidentatus Double-toothed Barbet					+			+
Lybius vieilloti/vieilloci Vieillot's Barbet			+	+	+			+
Macrosphenus concolor Grey Longbill				+	+	+	+	+
Macrosphenus kempi Kemp's Longbill			+	+	+	+	+	+
Malacanotus cruentus Fiery-breasted Bush-Shrike				+	+	+		+
Malaconotus multicolor Many-coloured Bush-shrike				+		+		
Malimbus malimbicus Crested Malimbe		+		+	+	+	+	+
Malimbus nitens Blue-billed Malimbe				+	+		+	+
Malimbus rubricollis/rubriceps Red-headed Malimbe			+	+		+	+	+
Malimbus scutatus Red-vented Malimbe	+	+		+	+	+		+
Mandingoa nitidula Green Twinspot					+			+
Megabyas flammulatus Shrike Flycatcher				+	+	+	+	+
Melocichla mentalis African Moustached Warbler					+			+
Merops albicollis White-throated Bee-eater	+	+			+	+		+
Merops gularis Black Bee-eater				+	+		+	+
Merops muelleri Blue-headed Bee-eater					+			+
Merops pusillus Little Bee-eater					+			+
Mesopicus pyrrhogaster Fire-bellied Woodpecker		+				+	+	
Milvus/mixu/Milxus/Mimlrus n/nigricans (African) Black Kite	+	+	+		+	+		+
Motacilla aguimp African Pied Wagtail		+						+
Muscicapa comitata Dusky-blue Flycatcher					+			+

Table C1-5 (continued)
Birds Recorded during Baseline Studies in Akyem Study Area in Ajenjua Bepo Forest Reserve, Mamang River Forest Reserve, and Outside Forest Reserves (FR)

Species	SGS 1998	SGS 2004	CI 2005	CI 2006	GWS 2007	Ajenjua Bepo FR	Mamang River FR	Outside FRs
Muscicapa epulata Little Grey Flycatcher				+	+			+
Muscicapa striata Spotted Flycatcher					+			+
Muscicapa tessmanni Tessmann's Flycatcher					+			+
Muscicapa ussheri Ussher's Flycatcher					+			+
Myioparus griseigularis Grey-throated Flycatcher				+	+	+	+	+
Myioparus plumbeus Lead-coloured Flycatcher					+			+
Necrosyrtes monachus Hooded Vulture		+		+				+
Nectarinia chloraopygia(s) Olive Bellied Sunbird	+	+				+		+
Nectarinia verticalis Olive-backed sunbird	+	+				+		+
Nectarinia olivacea Olive Sunbird		+						+
Neophron monachus Hooded Vulture	+	+1998				+		
Neocossyphus poensis White-tailed Ant-Thrush				+		+	+	
Nicator chloris Western Nicator		+	+	+	+	+	+	+
Nigrita bicolor Chestnut-breasted Negrofinch			+	+	+	+	+	+
Nigrita canicapillus Grey-crowned Negrofinch			+	+	+	+	+	+
Nigrita fusconota White-breasted Negrofinch					+			+
Onychognathus fulgidus Forest Chestnut-winged Starling				+	+			+
Onychognathus hartlaubi Crag chestnut-winged Starling		+					+	
Oriolus brachyrhynchus Western Black-headed Oriole		+		+	+		+	+
Oriolus nigripennis Black-winged Oriole			+	+	+	+		+
Ortygospiza artricollis Quail finch								+
Parus funereus Dusky Tit				+				+
Passer griseus Northern Grey-headed Sparrow					+			+
Pendropicos pyrrhogaster Fire bellied Woodpecker			+			+		
Petronia dentate Bush Sparrow		+						+
Phoeniculus bollei White-headed Wood-hoopoe			+		+	+		+
Phoeniculus castaneiceps Forest Wood-hoopoe					+			+
Pholidornis rushiae Tit-hylia		+			+			+
Phyllastrephus albigularis White-throated Greenbul				+	+	+		+

Table C1-5 (continued)
Birds Recorded during Baseline Studies in Akyem Study Area in Ajenjua Bepo Forest Reserve, Mamang River Forest Reserve, and Outside Forest Reserves (FR)

Species	SGS 1998	SGS 2004	CI 2005	CI 2006	GWS 2007	Ajenjua Bepo FR	Mamang River FR	Outside FRs
Phyllastrephus icterinus Icterine Greenbul				+	+	+	+	+
Phylloscopus trochilus Willow Warbler		+						+
Ploceus albinucha Maxwell's Black Weaver					+			+
Ploceus cucullatus Village Weaver	+	+	+		+	+		+
Ploceus nigerrimus Vieillot's Black Weaver		+	+	+	+			+
Ploceus nigricollis Black-necked Weaver			+		+			+
Ploceus nigerrimus brachypterus Spectacled Weaver		+						+
Ploceus preussi Preuss's Golden-backed Weaver					+			+
Ploceus tricolor Yellow-mantled Weaver				+	+	+	+	+
Poeoptera lugubris Narrow-tailed Starling					+			+
Pogoniulus atroflavus Red-rumped Tinkerbird		+		+	+	+	+	+
Pogoniulus bilineatus Yellow-rumped Tinkerbird		+	+		+	+	+	+
Pogoniulus scolopaceus Speckled Tinkerbird	+	+	+	+	+	+	+	+
Pogoniulus subsulphureus Yellow-throated Tinkerbird				+	+	+	+	+
Poicephalus gulielmi Red-fronted Parrot			+	+	+	+	+	+
Polyboroides typus African Harrier Hawk				+	+			+
Prinia subflava Tawny-flanked Prinia				+	+			+
Prionops caniceps Red-billed Helmet-shrike				+	+	+	+	+
Propicranus albocristatus White crested hornbill			+			+		
Psalidoprocne nitens Square-tailed Saw-wing					+			+
Psalidoprocne obscura Fanti Saw-wing					+			+
Psittacus erithacus Grey Parrot	+	+		+	+	+	+	+
Pycnonotus barbatus Common (Garden) Bulbul	+	+		+	+	+		+
Quelea erythrops Red-headed Quelea					+			+
Quelea quelea Red-billed Quelea					+			+
Rhaphidura Sabini Sabine's Spinetail				+	+			+
Sarothrura pulchra White-spotted Flufftail				+	+			+
Serinus leucopygius Grey Canary		+						+
Smithornis rufolateralis Rufous-sided Broadbill				+		+	+	

Table C1-5 (continued)
Birds Recorded during Baseline Studies in Akyem Study Area in Ajenjua Bepo Forest Reserve, Mamang River Forest Reserve, and Outside Forest Reserves (FR)

Species	SGS 1998	SGS 2004	CI 2005	CI 2006	GWS 2007	Ajenjua Bepo FR	Mamang River FR	Outside FRs
Spermophaga haematina Western Bluebill					+			+
Stiphrornis erythrothorax Forest Robin				+	+	+	+	+
Stizorhina finschi Finsch's Flycatcher Thrush				+	+	+	+	+
Streptopelia semitorquata Red-eyed Dove				+	+			+
Streptopelia senegalensis Laughing Dove					+			+
Strix woodfordii African Wood Owl				+	+	+		+
Sylvietta brachyura Northern Crombec					+			+
Sylvietta denti Lemon-bellied Crombec				+	+	+	+	+
Sylvietta virens Green Crombec			+	+	+			+
Tauraco macrorhynchus Yellow-billed Turaco				+	+	+	+	+
Tauraco persa Green Turaco		+			+	+	+	+
Tchagra australis Brown-crowned Tchagra			+		+			+
Tchagra senegala Black-crowned Tchagra					+			+
Telecanthura ussheri Mottled Spinetail				+				+
Terpsiphone rufiventer Red-bellied Paradise Flycatcher	+	+		+	+	+	+	+
Terpsiphone viridis African Paradise-Flycatcher			+			+		+
Thescelocichla leucopleura Swamp Palm Bulbul				+	+			+
Tockus fasciatus African Pied Hornbill			+	+	+	+	+	+
Tockus fasciatus semifasciatus Black & white tailed hornbill	+	+				+	+	+
Trachyphonus purpuratus Yellow-billed Barbet		+		+	+	+	+	+
Treron australis Green Fruit Pigeon	+	+1998				+		
Treron calvus African Green Pigeon		+	+	+	+	+	+	+
Tricholaema hirsuta Hairy-breasted Barbet			+	+	+	+	+	+
Trochocercus nitens Blue-headed Crested Flycatcher				+	+	+	+	+
Tropicranus albocristatus (cassini) White-crested Hornbill		+		+	+	+	+	+
Turtur afer Blue-spotted Wood Dove	+	+	+	+	+	+		+
Turtur brehmeri Blue-headed Wood Dove		+		+	+	+	+	+
Turtur tympanistria Tambourine Dove	+	+	+	+	+	+	+	+
Vidua macroura Pin-tailed Whydah		+			+			+

Table C1-5 (continued)
Birds Recorded during Baseline Studies in Akyem Study Area in Ajenjua Bepo Forest Reserve, Mamang River Forest Reserve, and Outside Forest Reserves (FR)

Species	SGS 1998	SGS 2004	CI 2005	CI 2006	GWS 2007	Ajenjua Bepo FR	Mamang River FR	Outside FRs
Zosterops senegalensis Yellow White-eye			+	+	+	+		+
Total Number Species	**32**	**72**	**52**	**136**	**203**	**129**	**98**	**235**

Sources: SGS (1998, 2004b), Conservation International (CI 2005, 2006), Ghana Wildlife Society (GWS 2007)
Note: "+1998" indicates that data were collected in 1998 and reported in SGS (2004b).

Table C1-6
Herpetofauna Recorded during Baseline Studies in Akyem Study Area in Ajenjua Bepo Forest Reserve, Mamang River Forest Reserve, and Outside Forest Reserves (FR)

Species	SGS 1998	SGS 2004	CI 2005	CI 2006	GWS 2007	Ajenjua Bepo FR	Mamang River FR	Outside FRs
Anurans (Frogs and Toads)								
Afrixalis dorsalis (Reed frog)				+			+	
Amnirana galamensis (White-lipped frog)					+			+
Arthroleptis poecilonotus (Squeaker)				+	+	+	+	+
Bufo maculates (Flat-backed toad)				+		+	+	
Bufo regularis (Common toad)	+	+		+	+	+	+	+
Dicroglossus occipitalis (Common frog)					+			+
Hemisus marmoratus (Shovel-nosed frog)				+			+	
Hoplobatrachus occipitalis (Crowned bull frog)				+			+	+
Hyperolius baumanni (Tree frog)			+					+
Hyperolius concolor (Tree frog)				+				+
Hyperolius fusciventris (Tree frog)				+				+
Hyperolius nitidulus (Tree frog)				+			+	
Hyperolius picturatus (Tree frog)				+			+	
Hyperolius sylvaticus		+					+	
Hyperolius sp.				+				+
Leptopelis hyloides				+		+	+	
Leptopelis occidentalis (Tree frog)				+		+	+	
Lygodactylus conraui					+			+
Phrynobatrachus accraensis (River frog)				+	+		+	+
Phrynobatrachus calcaratus (River frog)				+		+	+	
Phrynobatrachus plicatus (River frog)				+			+	
Phrynomantis microps (frog)			+					+
Ptychadena bibroni (frog)			+					+
Ptychadena longirostris (frog)				+			+	
Ptychadena mascareniensis (frog)				+			+	
Ptychadena oxyrhnchus (frog)				+			+	
Ptychadena pumilio (frog)				+			+	
Rana galamensis		+				+	+	+
Riopa fernandi					+			+
Silurana tropicalis (Clawed frog)				+			+	
Typhlonectes species							+	

Table C1-6 (continued)
Herpetofauna Recorded during Baseline Studies in Akyem Study Area in Ajenjua Bepo Forest Reserve, Mamang River Forest Reserve, and Outside Forest Reserves (FR)

Species	SGS 1998	SGS 2004	CI 2005	CI 2006	GWS 2007	Ajenjua Bepo FR	Mamang River FR	Outside FRs
Caecilians								
Geotrypetes seraphini				+		+		
Lizards and skinks								
Agama agama (Rainbow lizard)	+	+		+	+	+	+	+
Cameleo gracilis (Graceful chameleon)		+			+			+
Cnemaspis spinicollis (Gecko)				+		+		
Cophoscincopus durus (Skink)				+		+		
Hemidactylus brooki (Brook's gecko)			+	+	+	+	+	+
Hemidactylus faciatus (House gecko)				+		+	+	
Hemidactylus muriceus				+		+	+	
Hemidactylus sp.				+		+		
Lygodactylus conraui (Gecko)					+			+
Lygosoma guineensis (Writhing skink)				+		+		
Mabuya affinis (Common Skink)		+						+
Mabuya blandingii (Skink)	+					+		
Mabuya perotetii (African skink)		+	+		+			+
Panapsis sp.				+		+	+	
Panapsis togoensis				+		+	+	
Riopa fernandi (Togo fire skink)			+		+			+
Trachylepis affinis (Brown skink)				+		+	+	
Trachylepis albilabris (Guinea mabuya)				+		+	+	
Trachylepis maculabris				+		+	+	
Varanus exanthematicus (Bosc's monitor)					+			+
Varanus niloticus (Nile monitor)					+			+
Snakes								
Aparallactus modestus (Centipede eater)				+		+		
Atheris chlorechis (Bush viper)				+			+	
Bitis arietans (Puff adder)			+		+			+
Bitis gabonica (Gaboon viper)		+	+		+	+	+	+
Causus maculates (Night adder)					+			+
Dendroaspis viridis (Green mamba)	+	+			+	+	+	+
Dispholidus lypus (Boomslang)					+			+
Echis ocelatus (Carpet viper)					+			+
Gonionotophis kingii (Colubrid)				+		+		

Table C1-6 (continued)
Herpetofauna Recorded during Baseline Studies in Akyem Study Area in Ajenjua Bepo Forest Reserve, Mamang River Forest Reserve, and Outside Forest Reserves (FR)

Species	SGS 1998	SGS 2004	CI 2005	CI 2006	GWS 2007	Ajenjua Bepo FR	Mamang River FR	Outside FRs
Hormonotus modestus (House snake)				+		+		
Lamprophis virgatus (House snake)				+			+	
Leptotyphlops sp. (Blind snake)				+		+		
Lycophidion nigromaculatum (Wolf snake)				+		+		
Naja melanoleuca (Forest cobra)	+	+	+		+	+	+	+
Naja nigricollis (Spitting cobra)					+			+
Philothamnus semivariegatus (Green tree snake)					+			+
Python regius (Royal python)			+		+	+		+
Python sebae (African python)					+			+
Natriciteres variegata (Colubrid)				+		+		
Psammophis phillipsi (Sand snake)				+	+			+
Thelotornis kirtlandii (Twig snake)		+		+	+	+	+	+
Tortoises and Turtles								
Pelomedusa subrufa (Marsh terrapin)					+			+
Kinixys homeana/belliana (Hinged tortoise)		+			+	+	+	+
Total number species	***5***	***12***	***10***	***45***	***30***	***34***	***37***	***39***

Sources: SGS (1998, 2004b), Conservation International (CI 2005, 2006), Ghana Wildlife Society (GWS 2007)

ANNEX C-2

AQUATIC RESOURCES SUPPLEMENTAL INFORMATION

FISH STUDIES DISCUSSION

Geomatrix (2008c) documented 34 fish species representing 14 different families during seasonal sampling at 11 sites in the Study Area (**Table 3-3**). This compares with 23 species from nine families of fish recorded from four sites during earlier work conducted in the Study Area by SGS (2004c). Fish caught during the study represent about 50 percent of all the species known to occur within the Pra River drainage basin (SGS 2004c). Considering the limited portion of the Pra River watershed represented by the Study Area, this high percentage is considered to indicate a diverse and healthy fish population is present. SGS (2004c) reported fish production (i.e., catch per unit effort) in the Study Area was relatively low and most of the fish were of small size classes. Based on studies by Geomatrix, this does not appear to be an accurate representation of the fish populations in the rivers and streams in the Study Area. It is more likely that the low fish catch by SGS was the result of sampling methods used rather than changes in the actual abundance and diversity of fish populations in the Study Area.

During the SGS study, the highest fish production in the watershed occurred in the Mamang River at Kotokuom, during the wet season. During the wet season sampling conducted by Geomatrix, the highest catches were made in the upper Pra near Abodum and in the Afosu and Abesu Streams that are tributary to the Mamang River. The efficiency of sampling gear is limited during the high flows in the main stem reaches of the Pra and Mamang Rivers. As a result wet season data are not necessarily representative of the true diversity of populations present in these areas. In the dry season, the highest and most diverse fish populations were found in the main stem Pra and Mamang Rivers. This is the expected result as fish populations are concentrated in the main channels of these rivers as flows recede during the dry season.

The single most diverse and highest catch, in numbers of fish came from the Pra River, west of Ntronang, at station SW22 where approximately 1,600 fish represented by 15 species from eight different families were identified. Two other stations yielded approximately 1,000 fish in the Geomatrix study during the dry season sampling. These were completed at the Mamang River stations at Mamanso and near Nkwanten with 14 and 12 species recorded, respectively. The lower Pra River stations near Kotokuom and Ofoase Praso also had good species diversity with 11 and 12 species identified, respectively.

Two families of fish dominated all catches numerically; the minnows and carps family (Cyprinidae) and the African tetras and tiger fishes (Alestidae). The minnows from the genus Barbus were captured at every sample station during the Geomatrix aquatic studies (Geomatrix 2008c). *Barbus trispilos* and *B. puncititaeniatus* were the most common and often dominated the catches in numbers. *B. trispilos* was present at every station sampled by Geomatrix both main stem rivers and tributary streams. This is in contrast to the results of the SGS (2004c) study that concluded that *Barbus* spp. "need to be protected because of their restricted habitat requirements." The other two most common and widespread species are African tetras from the Alestidae family; *Brycinus leuciscus* and *Micralestes occidentalis*.

One of these four species of fish was the most common (highest number) at virtually every sample location. The only exceptions to this were during the wet season at the main stem river stations on the Pra and Mamang Rivers where high flows limited sampling to gill nets. All of these common species are small fish and were therefore less susceptible to capture by the gill nets employed during the wet season sampling at the main stem stations. SGS (2004c) used gill nets exclusively in their sampling and this may explain the reason these species were largely absent from their study. Geomatrix captured these fishes in large numbers at every station where seine nets were used in sampling. The best example of this was the Pra River station SW22 where these four species combined to account for 1,101 of the 1,613 fish collected at this site. Another *Barbus* species (*B. subinensis*) added another 483. Thus, these five species from two families accounted for 1,584 out of 1,613 fish or 98 percent of the catch at this site.

Distributions of fish species varied during the wet and dry seasons. During the wet season, Geomatrix encountered higher numbers of fish in the tributary streams than during the dry season sampling. For example, 12 species from five families were represented in a catch of 365 fish from the Abesu Stream near Old Abirem during the wet season. This same location had six species from three families (207 total fish catch) during the dry season. This indicates a use of the tributary streams during the wet season for spawning, rearing and refuge from high flows in the main stem rivers. Some of the fish that use these tributary streams during the wet season return to the main stem rivers as water levels drop during the dry season. The Alestidae family of African tetras were common in the tributaries during the wet season and completely absent during the dry season. This pattern of seasonal use by members of this fish family was also observed in aquatic studies in the Tano River basin (Geomatrix 2007c). This seasonal use pattern appears to be an important part of the life history of at least some fishes in the Study Area.

Some seasonal patterns in fish presence seem to be based on the ability to catch fish and therefore are not necessarily indicative of changes in fish distribution (e.g., more catfishes were caught during the dry season in comparison with the wet season). It may not be the circumstance that there were fewer of these species present during the wet season; the more likely explanation is that the high water levels prevented sampling gear used by the investigators from effectively encountering these bottom oriented species. Seines used for sampling were typically 2 metres deep whereas water depths in some reaches were 8 to 10 metres or more. Therefore, bottom dwelling fishes were not within the reach of the nets. The situation was different during the dry season when water depths were typically less than 2 metres and therefore all fish in the water column were susceptible to being captured. A difference that does seem to be a reflection of the season was lower catches of fish predator species (e.g., tiger fish) during the dry season. These species may have moved lower in the watershed as flows declined and therefore were less common during the dry season when catches of these fish declined at the same time the efficiency of sampling increased because water conditions were better for the sampling gear employed and overall catches were higher. For example, the total fish catch during the wet season was 1,591 fish whereas dry season total catch was 6,356 fish or four times the wet season catch.

None of the fish species that were recorded from the Study Area are on the IUCN Red List. The majority of fish in the Study Area are caught for eating, but only a few are important food species (SGS 2004c). Based on observations made during the Geomatrix study, there seemed to be a focus by local residents on catching the various catfish or mud fish species, as well as the tiger fish and African Pike when these latter species were available.

FISH SPECIES DIVERSITY

SGS (2004c) found the highest diversity of fishes in the dry season was found in the Pra and Mamang Rivers near their confluence at Kotokuom; whereas, the highest diversity during the wet season was in the Pra River at Teshie Praso. They concluded that differences in diversity during the dry and wet seasons appear to be due to migratory behaviour of fish. Geomatrix (2008c) found the highest diversity during the wet season in the upper Pra River and the Abesu Stream new Old Abirem. As discussed above, however, these results are likely due to high water levels during the wet season where fish are more dispersed in the flood plain and/or water depths made fishing gear less efficient.

During the dry season, Geomatrix found the highest diversity in the main stem Pra and Mamang River sampling sites. The highest diversity and largest catches were in the middle reaches of both rivers in the Study Area. Smaller catches and lower diversity in the tributary stations were thought to be indicative of movement of fish from these areas and into the main stem reaches during the low flow period.

Fish appear to move from the Pra River and Mamang River during the wet season into the tributaries for spawning, rearing and refuge from the high flows in the main river channels. Fish then return to the main stem rivers as flows decrease in the tributaries during the dry season. Some tributaries dry up completely while others retain some flow and/or pools of water where remaining fish are able to survive until the next wet season.

BENTHIC INVERTEBRATES DISCUSSION

SGS (2004c) collected benthic invertebrate samples at each of the sites where they conducted fish sampling. Diversity and biotic indices indicated that the most enriched or polluted river was the Mamang River at Nkwanten during the dry season (SGS 2004c). During the wet season, the reach with a benthic fauna indicating the least water quality degradation was the Mamang River at Kotokuom. During the dry season, the highest diversity of macroinvertebrates was in the Mamang River at Kotokuom (22 species). The lowest diversity was also recorded for the Mamang River at Mamanso during the dry season (8 species). Diversity in the Pra River was similar at all sites and did not vary much between wet and dry seasons (11 to13 species). The highest species diversity during the wet season was 32 species at Mamanso on the Mamang River. The lowest diversity during the wet season (11 species) was at Teshie-Praso on the Pra River (SGS 2004c).

Blay (2008a and 2008b) also collected benthic invertebrate samples at the 11 fish sampling stations in the Study Area (Geomatrix 2008c). Almost all the samples were dominated by the larvae of true flies (Diptera), mayflies (Ephemeroptera) and worms (oligochaeta). The diptera larvae were dominated by the family chironomidae that are abundant in most aquatic habitats and are generally tolerant of degraded habitat and water quality conditions. They are well adapted to the fine sediment that dominates most of the sampled habitats. The mayfly larvae were from the family Caenidae which is adapted to quiet and even stagnant environments by virtue of their gills being adapted to function in silty environments. The oligochaete worms are segmented worms like earthworms but in this case are aquatic and commonly inhabit streams, marshes and other freshwater environments. All of these groups are adapted for the silty and degraded conditions common to Study Area streams and rivers. In general, dry season samples have higher densities of organisms than was found during the wet season. It was sometimes difficult to sample in the main channels at some of the study sites during the wet season because of high flow levels. Thus, it is possible that marginal or flood plain habitat was sampled during the wet season with less established benthic fauna. All dry season samples were taken from the main channels of the stream or river in an area that was permanently wetted and therefore may be more representative of conditions at these sites. In general, dry season samples were also more diverse than wet season samples in the number of taxa represented in the samples.

ANNEX C-3

GEOLOGY AND GEOCHEMISTRY SUPPLEMENTAL INFORMATION

DISCUSSION OF REGIONAL GEOLOGIC TERRAINS IN GHANA

A primary feature of the geology of Ghana is the parallel alignment of narrow (15 to 40 kilometres (km) wide), somewhat evenly spaced, northeasterly trending belts of folded Birimian metavolcanic rocks (**Figure 3-5**). Between these belts are broad (approximately 60 to 90 km wide) sedimentary "basins" consisting predominantly of Birimian turbidity sedimentary rock sequences (Ghana Minerals Commission and WGM 1998; Ireland *et al.* 2001).

Across southwestern Ghana, these belts can be divided geologically into four distinct terrains based on the major rock type or systems that outcrop (**Figure 3-5**). These systems include:

1. An early Proterozoic terrain (Birimian System) with older metavolcanics (intrusive dikes and lava flows) of basaltic and andesitic composition. These metavolcanic units exhibit pillow structures indicating subaqueous eruption of the original basaltic lava. These metavolcanics underly younger sedimentary sequences comprised of greywacke, turbidities, volcaniclastics, and argillites. Together these units form five sub-parallel belts of volcanic rock separated by broad "basins" of sedimentary rocks. Although difficult to determine because of folding and faulting, the total thickness of the Birimian in Ghana may be as much as 10,000 to 15,000 meters. The contact between the sediments and volcanics is poorly exposed (Ghana Minerals Commission and WGM 1998). The Birimian system hosts most of the country's gold mineral deposits and outcrops over as much as one-third of the southwestern part of the country.

2. 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).

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

4. Intrusive rocks (primarily granitoids) that have been emplaced in Birimian and Tarkwaian rocks, some of which (Belt-type) are intrusive equivalents of the Birimian Volcanics.

The Birimian and Tarkwaian sequence exhibits a strong northeast-southwest oriented structural fabric that is a manifestation of both the axial planes of major tight isoclinal folds (anticlinal sedimentary basins and synclinal volcanic belts) and major fault systems. The rocks typically dip more than 60°. Regional fault systems often exhibit a complex history of thrusting, normal and strike slip motion. Metamorphism in the Birimian is "low-grade" greenschist facies except near intrusive contacts where amphibolite assemblages occur in the metasediments.

DISCUSSION OF GOLD MINERALISATION PROCESSES

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 (**Figure 3-5**), which together with their associated intrusives, occur over approximately one third of the country (Wright and Hastings 1985). The remainder of the gold produced comes mainly from the blanket conglomerate deposits (possible paleo placers) of the Tarkwaian System and from placer mines exploiting material derived from both the Birimian and Tarkwaian source rocks.

The Birimian Gold Belts are a set of six parallel, evenly spaced, northeast trending volcanic ridges over 300 km long (see for example the Ashanti Belt, **Figure 3-5**). Steeply dipping, regional shears bound these ridges, which are separated by basins containing metamorphosed pyroclastic and metasedimentary rocks (**Figure 3-5**).
Within the Birimian, primary gold is associated with a typical submarine exhalative volcano-sedimentary facies developed along narrow laterally continuous zones at the boundary between volcanic belts and the sedimentary basins. This primary, syn-sedimentary gold was subjected to migration and concentration in northeast trending regional shear zones during metamorphism and the emplacement of the Birimian intrusives, as well as during major structural events.

LOCAL GEOLOGIC SETTING DISCUSSION

The Akyem deposit is localized in the hanging wall (upper side or plate) of a regional fault that trends to the northeast (N70°E) parallel to regional structures, and dips about 60 degrees to the southeast (**Figures 3-6** and **3-7**), parallel to the foliation developed in the Birimian host rock. The planar fault structure (thrust fault) (Feybesse 1999; Lescuyer 1999) is intensely sheared and exhibits a mylonitic to cataclastic fragmental texture consisting of lens of metavolcanic fragments in a matrix of sheared and plastically deformed graphitic material. The presence of graphitic rubble zones suggests reactivation of the fault zone over time. The fault occurs in fine-grained, gray-green massive to locally sheared Birimian mafic metavolcanic rocks exhibiting chlorite and carbonate alteration that locally contain euhedral magnetite. Immediately overlying the metavolcanics is a distinctive gray-green-pink unit containing blue quartz phenocrysts in a mylonitic matrix (quartz epiclastic rock). The upper and lower contacts of this unit are typically sheared and brecciated and the upper contact of this unit is locally in sharp contact withoverlying light gray-tan chert (Monthel *et al.* 2001). This unit is considered sedimentary and represents a distinctive marker between the metavolcanic and metasedimentary units of the Birimian.

The overlying metasedimentary rocks are for the most part turbidite sequences consisting of greywacke, argillites, black carbonaceous siltstone, and fine-grained arkosic sandstones. This unit grades upwards into a saprolitically weathered zone (deeply weathered bedrock largely altered to clay) that ranges from 10 to 50 meters thick. 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 meters, red lateritic clay is developed as subsoil.

MINERALISATION DISCUSSION

The Akyem deposit is localized along a southeast dipping, graphite-bearing, mylonitic fault zone that ranges from 1 to 15 meters thick. Mineralisation is present almost exclusively in the hanging wall, with the fault structure defining a sharp base to the mineralisation of the deposit (**Figure 3-7**). Ore above the fault ranges in thickness from 10 to 100 meters and is developed in two principal shoots, both of which plunge to the southeast parallel to the fault. Associated, sub parallel structures have created dilation zones in rocks of the upper plate that have enhanced the development of mineralisation. The deposit is developed over approximately 2,500 meters in strike length (along the fault) and ore has been delineated to a depth of about 400 meters down the southeast dipping fault structure. Based on this delineation drilling, ore grade mineralisation likely continues at depth below the zone of current exploration. Mineralisation thins both to the northeast and southwest along the strike of the localizing fault structure.

Gold is hosted in each of the three units described above including the lower mafic volcanic, quartz epiclastic, and the upper greywacke units. Ore grades follow alteration patterns with the most intense alteration and highest gold grades occurring nearest the fault zone and in general decreasing away from the zone. Gold typically occurs as fine-grained disseminations in moderate to intense hydrothermally altered, metamorphic volcanic and sedimentary host rocks. Locally some visible gold is present.

ALTERATION AND MINERALOGY DISCUSSION

Alteration is largely restricted to hanging wall rocks with the assemblages most intimately associated with higher-grade gold mineralisation containing abundant quartz (silica flooding and veining), extensive patchy appearing iron and calcium carbonate replacements, and minor pyrite. Three patterns of alteration assemblages, mineral zonation and gold grades are recognized at Akyem and are briefly described in **Table C3-1** from more distal assemblages (chlorite, sericite and green mica) to more proximal assemblages (quartz, iron-carbonate, pyrite).

TABLE C3-1
Alteration Assemblages, Zonation and Gold Grades

Stage	Mineralogy	Grade g/t Gold	Comment
Alteration 1 Weak	Calcite-Chlorite	0-0.6	Weak alteration; carbonate and clay alteration on the margins of ore deposit; best developed in mafic volcanics and sediments. Low gold grade.
Alteration 2 Moderate	Iron-Carbonate Chlorite Sericite Pyrite Magnetite	0.6-3.0 (avg. 2.0)	Moderate alteration; iron dolomite and ankerite with chlorite, calcite and pyrite (0-3%, avg. <1%); typically occurs adjacent to quartz-iron carbonate veins and within and adjacent to mineralized shear zones. Moderate gold grade.
Alteration 3 Intense	Quartz Iron-Carbonate Sericite Pyrite	> 3.0	Intense alteration; silicification and silica flooding of sediments and volcanic rocks; silicification ranges from pervasive to veining to flooding, iron and calcium carbonates abundant in irregular patchy replacements, sericitization, and disseminated sulfides (0-3%, avg. <2%); typically occurs in the immediate hanging wall of the shear zone. Higher gold grade.

Note: g/t = grams per ton

Pyrite is present in amounts that vary from 0 to 3 percent (visual estimates) and occurs in zones of both moderate and intense alteration. Pyrite typically occurs as euhedral grains along quartz vein selvages and along foliation planes of strongly foliated rock. Waste rock typically contains 1 to 1.5 percent and averages <1 percent sulfide. The ore averages about 2 percent sulfide. The only visible sulfide identified is pyrite. Other sulfides identified during metallurgical testing or from polished section prepared for mineralogic work were chalcopyrite, sphalerite, and galena. Iron oxides of hematite and magnetite are also locally present (Tebea 2005). Oxides to sulfide transitions in saprolite are abrupt and occur over distances of 2 to 5 meters.

GEOCHEMICAL CHARACTERIZATION DISCUSSION

Before mining to confirm baseline conditions and as mining proceeds, The Company would perform standard waste rock evaluations (Bucknam 2002) to assess conditions that could impact water quality. If a change in condition is recognized by this testing, The Company would work to abate any potential negative effects.

The Company's Environmental Standard for waste rock characterization follows guidance established by the U.S. Bureau of Land Management (USBLM) and Nevada Division of Environmental Protection (NDEP), as applicable:

> U.S. Bureau of Land Management (USBLM), 1996. State of Nevada Acid Rock Drainage Testing Requirements. Information Bulletin No. NV-96-097. Nevada State Office, Reno, Nevada, USA. March 14, 1996.
>
> Nevada Division of Environmental Protection (NDEP), 1990. Waste Rock and Overburden Evaluation. Bureau of Mining Regulation and Reclamation, Carson City, Nevada, USA. September 14, 1990.

A description of The Company's waste rock material testing methods in consideration of requirements of NDEP and USBLM guidelines is described in Newmont (2006a and 2006b).

Internal company guidelines require collection and analysis of representative samples based on the following classifications:

- Lithology (type of rock),
- Mineralogy (minerals contained in the rock),
- Sulfide mineralisation zone (rock that contains sulfide minerals),
- Color,
- Fracturing,
- Oxidation zone (rock near land surface that has weathered resulting in the loss of sulfide minerals) and
- Secondary mineralisation.

For Akyem Phase 1 baseline testing, 207 samples were prepared using rock collected from 11 boreholes. Based on the descriptions provided by field geologists, sample intervals representing different rock types were selected based on the above classifications and

analyzed for: 1) mineralogy and whole-rock chemistry, i.e. metals, using semi-quantitative x-ray fluorescence, and 2) static acid-base accounting (ABA) parameters, including acid neutralization potential (ANP), acid generation potential (AGP), and net carbonate value (NCV).

ABA tests evaluate the potential for rock to release acid and trace metals. Rocks can contain both sulfide minerals and carbonate minerals that affect release of acid and trace metals. Sulfide minerals are unstable in the presence of oxygen (air) and weather (oxidize) to sulfate, which produces acidity. Carbonate minerals can neutralize the acidity produced by weathering of the sulfide minerals.

AGP represents the potential to produce acidity and is measured by analyzing total sulfur and residual sulfur after pyrolysis in the laboratory. ANP estimates the rock's potential to neutralize acid and is measured by analyzing total carbon and hydrochloric acid insoluble carbon, i.e. any carbon other than carbonate minerals.

NCV is the sum of ANP plus AGP. It provides an estimate of the net acid-base potential of the rock. Positive NCV indicates a net neutralizing potential, while negative NCV indicates a net acid-generating potential. The magnitude of the NCV provides an indication of the strength of the neutralizing or generating potential. NCV is typically reported as percent carbon dioxide. The U.S. Bureau of Land Management (US BLM 1996) and The Company use the following criteria for classifying rock by NCV.

Criteria for NCV 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: Bucknam 2002)

The U.S. Bureau of Land Management (US BLM 1996) uses net neutralizing potential (NNP), in units of tons of calcium carbonate per 1,000 tons of waste rock ($CaCO_3$/1,000 tons), and ANP:AGP ratios to classify the acid generating potential of rock. If the US BLM NNP criteria are converted to percent CO_2 (%CO_2) (NNP/22.7 = NCV), then rock with an NCV less than -0.9 %CO_2 is considered to be acid generating and rock with an NCV greater than 0.9 %CO_2 is classified as non-acid generating. Rock with NCV in the range of -0.9 to 0.9 %CO_2 has an uncertain potential to generate acid. The US BLM criteria applied to the NCV classification above is roughly as follows: acid generating (HA and A), uncertain (SA, N, I, SB), and non acid generating (B and HB).

A summary of the Phase 1 results sorted by drill hole (borehole) are contained in **Table C3-2,** which provides ANP, AGP, and NCV averages for each borehole, as well as averages for the oxide and sulfide zones within each borehole. Average NCV for the sulfide zone (10 boreholes) are classified as basic (1-5 $\%CO_2$) while the oxide zone (7 boreholes) NCV averages range from inert to basic. The Phase 1 NCV classification shows little potential for acid generation.

Based on the Phase 1 testing of 207 samples, The Company identified 4 major and 12 minor waste rock types present within the mine pit. For Phase 2 of the geochemical testing programme, The Company prepared 16 composite samples (rock mixed together from multiple boreholes and depths) representative of each waste rock type to be encountered during mining. The Phase 2 single rock-type composite samples were submitted for ABA analyses, mineralogy and whole-rock metals. NCV results from Phase 2 were compared to the Phase 1 data to confirm the previously assigned NCV classification for each of the 16 rock types. In addition, specialized tests were performed to further assess the potential for acidity and metals release. **Table C3-3** shows NCV results for the 16 composite samples, summarized by borehole interval and rock type, as well as the Phase 1 static testing results samples collected within the composite intervals.

Mineralogical data from the 16 composite samples show they contain up to 35 percent carbonate minerals and as much as 2 percent of the predominant sulfide mineral pyrite (**Table C3-4**), although arsenopyrite has been reported. Although carbonates have potential to neutralize any acid that may be generated from weathering of the sulfides, these carbonates primarily consist of up to 35 percent ankerite (a calcium-iron carbonate), which dissolves to a lesser degree than pure calcium carbonate (calcite). The ankerite may have less neutralization capacity than would be the case of the calcite were the carbonate mineral present. Another factor contributing to the potential for acid generation is that the ankerite contains iron, which can be slowly released during weathering to form iron hydroxide, and in turn lower the pH.

Because of the presence of ankerite, described above, tests beyond the traditional ANP test were performed to better predict potential for acid neutralization capacity. The Company employed a hydrogen peroxide treatment to quickly oxidize the iron, correcting for potential for released iron to precipitate as an iron hydroxide prior to testing the neutralization potential. This acid neutralization potential acidity test (ANPA) was performed on a weighted sulfide composite sample prepared for each Phase 1 borehole. **Table C3-2** shows the ANPA results**.** Calculating the NCV using the ANPA in place of the ANP, results in slightly lower net neutralizing potential for the sulfide-zone sample, but the NCV classifications remain basic (1-5 $\%CO_2$). Thus, NCV values based on the ANPA show that sulfide waste rock would have no tendency to produce acid.

Results of static acid-base accounting, including ANPA, are contained in **Table C3-5** for the 16 Phase 2 composite samples. The major waste-rock types that contain sulfide (greywacke and mafic volcanic) and oxide waste-rock type (saprolite) are represented by samples 1-4 in **Table C3-5**. NCV classifications based on ANPA for both sulfide-containing rock types are basic (1-5 $\%CO_2$), indicating no potential for acid generation. The major oxide composite (saprolite) is classified as slightly basic (0.1 to 1 $\%CO_2$).

TABLE C3-2
Results of Phase 1 Static Acid-Base Accounting Tests Sorted by Drillhole
Akyem Gold Mining Project

				Arithmetic Averages						
Drill Hole ID	**Core Interval (meters)**	**Zone**	**Number of Samples**	**ANP ($\%CO_2$)**	**AGP ($\%CO_2$)**	**NCV based on ANP ($\%CO_2$)**	**ANP: AGP**	**ANPA ($\%CO_2$)**	**NCV based on ANPA ($\%CO_2$)**	**NCV Classification**
KD002	0-48.4	Oxide	8	1.01	-0.01	1.00	101			Slightly Basic
	48.4-93.3	Sulfide	5	10.89	-1.34	9.55	8	3.946	2.61	Basic
	0-93.3	Drill Hole	13	5.24	-0.58	4.67	9			
KD118	0-51.1	Oxide	8	0.50	0.00	0.50	50			Slightly Basic
KP024	0-24	Oxide	3	0.09	0.00	0.09	9			Inert
	24-202	Sulfide	29	6.56	-0.91	5.65	7	4.056	3.15	Basic
	0-202	Drill Hole	32	5.97	-0.82	5.15	7			
KP122	260-416.6	Sulfide	24	7.57	-0.78	6.79	10	3.789	3.01	Basic
KP123	294.3-394.7	Sulfide	14	9.49	-0.51	8.97	19	3.792	3.28	Basic
KP125	126.8-262.7	Sulfide	20	6.96	-0.56	6.41	12	3.563	3.00	Basic
KP134	165-250	Sulfide	11	6.57	-0.75	5.82	9	3.618	2.86	Basic
KP148	0-12	Oxide	1	0.43	0.00	0.43	43			Slightly Basic
	12-255	Sulfide	39	6.57	-0.69	5.87	10	3.668	2.98	Basic
	0-255	Drill Hole	40	6.41	-0.67	5.74	10			
KR031	0-12	Oxide	2	0.30	0.00	0.30	30			Slightly Basic
	12-93	Sulfide	13	6.43	-0.66	5.77	10	3.768	3.11	Basic
	0-93	Drill Hole	15	4.06	-0.42	3.63	10			
KR032	0-12	Oxide	1	1.07	0.00	1.07	107			Basic
	12-144	Sulfide	18	6.76	-0.71	6.06	10	3.734	3.03	Basic
	0-144	Drill Hole	19	6.45	-0.67	5.78	10			
KR035	0-12	Oxide	2	0.15	0.00	0.15	15			Slightly Basic
	12-70	Sulfide	9	9.26	-0.24	9.02	39	4.025	3.79	Basic
	0-70	Drill Hole	11	7.60	-0.19	7.41	40			

Note: ANP = acid neutralization potential; ANPA = acid neutralization potential acidity; AGP = acid generation potential; NCV = net carbonate value. ANPA was performed on a depth weighted composite sample representing the sulfide core interval. For ANP and AGP values that equal 0.00, it was assumed to equal 0.01 for purposes of calculating ANP:AGP ratios.
Source: Newmont internal data provided by Charles Bucknam/Newmont Inverness as Excel spreadsheets, 2005.

TABLE C3-2 (continued)

Criteria for ANP:AGP Ratios:
Rock is assumed to be potentially acid-generating if ANP:AGP ≤ 1.0. Rock is not considered potentially acid generating if ANP:AGP > 3.0. For samples having ANP:AGP between 1.0 and 3.0, the rock has uncertain potential to generate acid (USBLM 1996).

Criteria for NCV 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	

NCV Classification based on document "Newmont Standard Waste Rock Evaluation Methods – Protocol for NCV Classification Studies".

TABLE C3-3
Summary of Phase 2 NCV Confirmation Composite Samples
Akyem Gold Mining Project

Phase 2 Composite Sample ID	Drill Hole ID (Bottom-Top of Sample Interval in meters)	ANP ($\%CO_2$)	AGP ($\%CO_2$)	ANP: AGP	NCV ($\%CO_2$)	Lithology	NCV Classification
Akyem NCV 01 GW B	KP148 (90-96)	3.88	-0.49	7.9	3.40	GW*	Basic
	KP148 (96-102)	4.76	-0.04	119	4.71	GW*	Basic
	KP148 (102-108)	4.99	-1.44	3.5	3.55	GW*	Basic
	KP148 (108-114)	3.99	-0.31	13	3.68	GW*	Basic
	KP148 (114-120)	5.72	-1.27	4.5	4.46	GW*	Basic
Akyem NCV 02 GW HB	KP123 (348.4-353.75)	11.12	-0.12	93	11.00	GW*	Highly Basic
	KP123 (353.75-359.9)	14.11	-0.53	27	13.59	GW*	Highly Basic
	KP123 (359.9-366)	15.09	-0.70	22	14.40	GW*	Highly Basic
	KP123 (366-371.78)	14.43	-0.96	15	13.47	GW*	Highly Basic
	KP123 (371.78-378)	11.51	-0.81	14	10.70	GW*	Highly Basic
	KP123 (378-384.1)	14.23	-0.56	25	13.67	GW*	Highly Basic
	KP123 (384.1-390)	15.51	-0.26	60	15.24	GW*	Highly Basic
Akyem NCV 03 MV HB	KP122 (368-374.2)	13.28	-1.21	11	12.06	MV*	Highly Basic
	KP122 (374.2-380)	11.61	-0.09	129	11.52	MV*	Highly Basic
	KP122 (380-386)	12.42	-0.09	138	12.33	MV*	Highly Basic
	KP122 (386-392)	13.63	-0.10	136	13.53	MV*	Highly Basic
	KP122 (392-398.15)	14.06	-0.07	201	13.99	MV*	Highly Basic
	KP122 (398.15-404)	8.69	-1.60	5.4	7.09	MV*	Highly Basic
	KP122 (404-410)	7.17	-1.79	4.0	5.38	MV*	Highly Basic
	KP122 (410-416.63)	13.91	-1.20	12	12.71	MV*	Highly Basic
Akyem NCV 04 SAP I	KD118 (0-6)	0.00	0.00	1.0	0.00	SAP*	Inert
	KD118 (6-12)	0.00	0.00	1.0	0.00	SAP*	Inert
	KD118 (12-18)	0.00	0.00	1.0	0.00	SAP*	Inert
	KD118 (18-24)	0.00	0.00	1.0	0.00	SAP*	Inert
	KD118 (24-30)	0.00	0.00	1.0	0.00	SAP*	Inert
	KD118 (30-36)	0.00	0.00	1.0	0.00	SAP*	Inert
Akyem NCV 05 SAP SB	KP024 (0-12)	0.17	0.00	17	0.17	SAP	Slightly Basic
	KP148 (0-12)	0.43	0.00	43	0.43	SAP	Slightly Basic
	KR031 (0-6)	0.35	0.00	35	0.35	SAP	Slightly Basic
	KR035 (0-6)	0.19	0.00	19	0.19	SAP	Slightly Basic
	KR031 (6-12)	0.26	0.00	26	0.26	SAP	Slightly Basic
	KR035 (6-12)	0.10	0.00	10	0.10	SAP	Slightly Basic
	KD002 (35.67-42.12)	0.19	0.00	19	0.19	SAP	Slightly Basic
Akyem NCV 06 QE B-HB	KP148 (204-210)	6.06	-1.84	3.4	4.22	QE	Basic
	KP148 (186-192)	6.02	-0.71	8.6	5.30	QE	Highly Basic
	KP148 (192-198)	6.51	-0.83	7.8	5.67	QE	Highly Basic
	KP148 (198-204)	6.42	-0.07	91	6.35	QE	Highly Basic
Akyem NCV 07 QV B-HB	KP024 (157.32-162.85)	5.53	-1.50	3.7	4.03	QV	Basic
	KP024 (169-175)	2.48	-0.26	9.6	2.22	QV	Basic

TABLE C3-3 (continued)
Summary of Phase 2 NCV Confirmation Composite Samples
Akyem Gold Mining Project

Phase 2 Composite Sample ID	Drill Hole ID (Bottom-Top of Sample Interval in meters)	ANP ($\%CO_2$)	AGP ($\%CO_2$)	ANP: AGP	NCV ($\%CO_2$)	Lithology	NCV Classification
	KP024 (193-199)	6.09	-1.59	3.8	4.49	QV	Basic
	KP123 (329.8-335.85)	4.46	-0.74	6.0	3.72	QV	Basic
	KP122 (338.5-344.3)	4.69	-0.82	5.7	3.87	QV	Basic
	KP148 (162-168)	13.85	-0.07	199	13.77	QV	Highly Basic
Akyem NCV 08 GMY-GRAP HB	KD002 (69.23-81.2)	12.13	0.00	1213	12.13	GMY	Highly Basic
	KP024 (199-202)	8.17	-1.15	7.1	7.02	GMY	Highly Basic
	KP134 (243-250)	10.89	-0.96	11	9.93	GMY	Highly Basic
	KP148 (252.2-255.02)	7.78	-0.77	10	7.00	GMY	Highly Basic
	KR031 (90-93)	9.79	-0.70	14	9.09	GRAP	Highly Basic
	KR032 (138-144)	8.70	-0.74	12	7.97	GRAP	Highly Basic
Akyem NCV 09 GW SB	KP148 (12-24)	0.37	0.00	37	0.37	GW	Slightly Basic
	KR035 (12-18)	0.11	0.00	11	0.11	GW	Slightly Basic
	KP148 (24-46)	0.50	-0.02	25	0.49	GW	Slightly Basic
Akyem NCV 11 MV B	KD002 (42.12-48.35)	4.62	-0.07	66	4.55	MV	Basic
	KP024 (162.85-169)	5.06	-2.60	2.0	2.46	MV	Basic
	KP148 (246-252.2)	4.32	-1.60	2.7	2.72	MV	Basic
Akyem NCV 12 MV1 HB	KR035 (65-70)	16.09	-0.07	230	16.02	MV1	Highly Basic
	KD002 (81.2-93.3)	14.57	-0.25	58	14.31	MV1	Highly Basic
	KP123 (390-394.7)	14.65	-0.46	32	14.20	MV1	Highly Basic
Akyem NCV 13 QV SB	KP024 (72-78)	0.43	-0.17	2.5	0.25	QV	Slightly Basic
	KP122 (344.3-350.3)	1.87	-0.88	2.1	0.99	QV	Slightly Basic
Akyem NCV 14 QV SA	KP123 (335.85-342.1)	0.10	-0.31	0.3	-0.21	QV	Slightly Acid
	KP123 (342.1-348.4)	0.15	-0.39	0.4	-0.24	QV	Slightly Acid
Akyem NCV 15 SAP B	KR032 (0-12)	1.07	0.00	107	1.07	SAP	Basic
	KD002 (30.42-35.67)	3.28	0.00	328	3.28	SAP	Basic
Akyem NCV 16 GRAP I	KD118 (36-42)	0.01	0.00	1.0	0.01	GRAP	Inert
Akyem NCV 17 MV1 B	KD118 (42-51.1)	3.96	0.00	396	3.97	MV1	Basic

Note: ANP = acid neutralization potential; AGP = acid generation potential; NCV = net carbonate value. For ANP and AGP values that equal 0.00, it was assumed to equal 0.01 for purposes of calculating ANP:AGP ratios.
Source: Newmont internal data provided by Charles Bucknam/Newmont Inverness as Excel spreadsheets, 2005.

TABLE C3-3 (continued)

Lithology Key

GMY = Graphitic Mylonite	QE = Quartz-Epiclastic Unit
GRAP = Graphitic Shear Breccia	QV = Quartz Vein
GW = Greywacke	SAP = Saprolite
MV = Mafic Volcanic Unit	* = Denotes a major waste classification

Criteria for ANP:AGP Ratios:
Rock is assumed to be potentially acid-generating if ANP:AGP ≤ 1.0. Rock is not considered potentially acid generating if ANP:AGP > 3.0. For samples having ANP:AGP between 1.0 and 3.0, the rock has uncertain potential to generate acid (USBLM 1996).

Criteria for NCV 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	

NCV Classification based on document "Newmont Standard Waste Rock Evaluation Methods – Protocol for NCV Classification Studies".

TABLE C3-4
Mineralogical Composition of Samples from Akyem Mine Pit Area

Sample	% Qz	% Plag	% Ank	% Sid	% Cal	% Musc	% Chlor	% Kaol	% Pyr	% Goe	% Rut
NCV 01 GW B	22	37	15			18	7		1		0.4
NCV 02 GW HB	32	26	30			11			1		0.5
NCV 03 MV HB	23	27	35			8	6		1.5		0.9
NCV 04 SAP I	43					16		25		16	0.7
NCV 05 SAP SB	38	9				25	3	15		10	0.4
NCV 06 QE B-HB	27	42	14			16			1.5		0.3
NCV 07 QV B-HB	50	22	12			14			2		0.5
NCV 08 GMY-GRAP HB	36	17	27			16	2		1.5		0.5
NCV 09 GW SB	52	10				33			0.5	5	0.7
NCV 11 MV B	41	26	16			11	4		2		1.3
NCV 12 MV1 HB	29	20	23	8		12	7		1		0.1
NCV 13 QV SB	72	17	6			4			1		0.6
NCV 14 QV SA	94	3	2						0.5		
NCV 15 SAP B	33	32	7		2	17	6			3	1
NCV 16 GRAP I	49		2			36	4			9	1.8
NCV 17 MV1 B	29	22	9			18	8			14	0.5

% Qz - Weight Percent Quartz; % Plag - Weight Percent Plagioclase; % Ank – Weight Percent Ankerite; % Sid - Weight Percent Siderite; % Cal - Weight Percent Calcite; %Musc - Weight Percent Muscovite; % Chlor - Weight Percent Chlorite; % Kaol - Weight Percent Kaolinite; %Pyr - Weight Percent Pyrite; % Goe - Weight Percent Goethite; % Rut - Weight Percent Rutile; Tr – Trace.

Source: Newmont (2005a).

TABLE C3-5
Summary of Phase 2 NCV Confirmation Testing
Akyem Gold Mining Project

PHASE 2 COMPOSITE SAMPLE ID	ANPA ($\%CO_2$)	Carbon (%)	CAI (%C)	SAP-550C (%S)	Sulfur (%)	ANP ($\%CO_2$)	AGP ($\%CO_2$)	ANP: AGP	NCV ($\%CO_2$)	ANPA NCV ($\%CO_2$)	LITHOLOGY	NCV CLASSIFICATION
Akyem NCV 01 GW B	3.08	1.58	0.11	0.19	0.81	5.40	-0.85	6.4	4.55	2.23	GW*	Basic
Akyem NCV 02 GW HB	3.71	3.62	0.12	0.24	1.04	12.9	-1.09	12	11.8	2.62	GW*	Basic
Akyem NCV 03 MV HB	3.64	3.29	0.16	0.31	0.99	11.5	-0.93	12	10.6	2.71	MV*	Basic
Akyem NCV 04 SAP I	0.53	0.25	0.23	0.19	0.02	0.08	0.00	8.0	0.08	0.53	SAP*	Slightly Basic
Akyem NCV 05 SAP SB	0.57	0.20	0.31	0.15	0.01	0.00	0.00	1.0	0.00	0.57	SAP	Slightly Basic
Akyem NCV 06 QE B-HB	2.60	1.63	0.08	0.22	0.97	5.66	-1.02	5.5	4.64	1.58	QE	Basic
Akyem NCV 07 QV B-HB	2.69	1.68	0.09	0.20	1.06	5.84	-1.19	4.9	4.65	1.50	QV	Basic
Akyem NCV 08 GMY-GRAP HB	3.21	2.89	0.42	0.23	0.90	9.08	-0.91	9.9	8.17	2.30	GMY	Basic
Akyem NCV 09 GW SB	0.58	0.28	0.25	0.24	0.28	0.14	-0.06	2.4	0.08	0.52	GW	Slightly Basic
Akyem NCV 11 MV B	2.40	1.27	0.07	0.34	1.37	4.39	-1.42	3.1	2.97	0.98	MV	Slightly Basic
Akyem NCV 12 MV1 HB	3.27	4.36	0.36	0.24	0.55	14.66	-0.42	35	14.2	2.85	MV1	Basic
Akyem NCV 13 QV SB	0.67	0.51	0.12	0.13	0.51	1.45	-0.52	2.8	0.93	0.15	QV	Slightly Basic
Akyem NCV 14 QV SA	0.00	0.05	0.06	0.05	0.26	0.00	-0.29	0.0	-0.29	-0.29	QV	Slightly Acid
Akyem NCV 15 SAP B	1.19	0.77	0.15	0.13	0.06	2.26	0.00	226	2.26	1.19	SAP	Basic
Akyem NCV 16 GRAP I	0.00	0.21	0.22	0.10	0.01	0.00	0.00	1.0	0.00	0.00	GRAP	Inert
Akyem NCV 17 MV1 B	2.26	1.30	0.10	0.15	0.06	4.39	0.00	439	4.39	2.26	MV1	Basic

Note: % =percent; ANP = acid neutralization potential; ANPA = acid neutralization potential acidity; ANPA NCV =net carbonate value calculated with the ANPA value; AGP = acid generation potential; CAI =carbon after hydrochloric acid loss; CAP-550C =carbon after pyrolysis at 550°C; CAP-650C =carbon after pyrolysis at 650°C; C =carbon; CO2 =carbon dioxide; NCV = net carbonate value; S =sulfur; SAP-550C =sulfur after pyrolysis at 550°C; SAP-650C =sulfur after pyrolysis at 650°C; SCIS =sodium carbonate insoluble sulfur; SHCI =hydrochloric acid insoluble sulfur; SHNO3 =nitric acid insoluble sulfur. For ANP and AGP values that equal 0.00, it was assumed to equal 0.01 for purposes of calculating ANP:AGP ratios.
Source: Newmont internal data provided by Charles Bucknam/Newmont Inverness as Excel spreadsheets, 2005.

TABLE C3-5 (continued)

Lithology Key

GMY = Graphitic Mylonite	QE = Quartz-Epiclastic Unit
GRAP = Graphitic Shear Breccia	QV = Quartz Vein
GW = Greywacke	SAP = Saprolite
MV = Mafic Volcanic Unit	* = Denotes a major waste classification

Criteria for ANP:AGP Ratios:

Rock is assumed to be potentially acid-generating if ANP:AGP ≤ 1.0. Rock is not considered potentially acid generating if ANP:AGP > 3.0. For samples having ANP:AGP between 1.0 and 3.0, the rock has uncertain potential to generate acid (USBLM 1996).

Criteria for NCV 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	

NCV Classification based on document "Newmont Standard Waste Rock Evaluation Methods – Protocol for NCV Classification Studies".

Minor waste-rock types are represented by samples NCV 05 through NCV 12 in **Table C3-5.** Based on the NCV results using ANPA analyses, one sample (quartz vein) is classified as slightly acidic (-1 to -0.1 $\%CO_2$) one sample (graphitic shear breccia) is inert (-0.1 to 0.1 $\%CO_2$), 4 samples (saprolite, greywacke, mafic volcanic, quartz vein) are slightly basic (0.1 to 1 $\%CO_2$), and 6 samples are basic (1-5 $\%CO_2$). The slightly acidic, inert, and slightly basic NCV classifications (6 samples) indicate an uncertain potential to generate acid, while the basic classification (6 samples) indicates no potential for acid generation. The volume of minor waste rock material present within the proposed mine pit is a small portion of the total rock volume that would be mined so considered as a whole, the ANPA-based NCV data show that ore and waste rock from the Akyem pit would have little potential to generate acid upon exposure to atmospheric conditions.

Because the whole-rock chemical data from the 207 Phase 1 samples and the 16 composite Phase 2 samples contain levels of some trace elements in excess of published estimates of average crustal abundance for that element (**Table C3-6**), additional geochemical characterization was performed on the 16 Phase 2 composite samples to evaluate the possibility of release of trace metals exceeding water quality standards. While whole-rock concentrations above those found in average crustal rocks does not guarantee that constituents will be released to the environment, it raises the possibility that they could be released in concentrations exceeding water quality standards. The specialized tests performed included Synthetic Precipitation Leachability Procedure (SPLP), Biological Acid Production Potential (BAPP), and Peroxide Acid Generation (PAG) analyses.

SPLP testing provides screening-level information about the potential to release metals and anions when rinsed with rain water. **Table C3-7** provides SPLP results, showing metals that exceed the Ghanaian Drinking Water Company standards in boldface type. Exceedances are found for the following metals: aluminum (Al), antimony (Sb), arsenic (As), beryllium (Be), cadmium (Cd), lead (Pb), mercury (Hg), manganese (Mn), molybdenum (Mo), nickel (Ni), selenium (Se), thallium (Tl). Those trace metals with exceedances in more than two samples include Al, Sb, and As.

BAPP tests of seven selected samples were performed to determine if bacteria present can generate enough sulfuric acid from oxidation of sulfides in the sample to maintain acidic conditions. A final pH less than 3.5 combined with a final PAG pH (discussed below) less than 4.5 indicates a potential for bacteria to maintain acidic conditions, which can potentially overwhelm the neutralizing capacity of the rock. In addition, BAPP solutions were analyzed for trace metals to provide information on the potential to release metals under the BAPP test conditions. Results of BAPP testing **(Table C3-8)** show that the slightly acid quartz vein sample (sample NCV PII 14) has the potential for bacteria to sustain acid generation (BAPP pH = 2.79 and PAG pH = 3.16). However, due to the small amount of waste rock represented by this rock type, any acid generated would readily be neutralized by the basic NCV characteristics of the waste rock types present in abundance in the mine pit. A limited number of BAPP solutions (7) showed exceedances of the Ghanaian Drinking Water Company standards for Al, Sb, As, Be, boron (B), Cd, chromium (Cr), copper (Cu), iron (Fe), Pb, Mn, Hg, Ni, Se, and zinc (Zn).

Peroxide acid generation (PAG) tests were performed to determine the maximum acidity generated from the oxidation of all reactive sulfides and the concentrations of trace elements present in the final oxidized solution. Final PAG pH values >4.5 indicate that there is little potential for acid production. PAG test results for the 16 composite samples **(Table C3-9)** show that there is little potential for acid generation, as the final PAG solution pH was 6.99 or higher for all samples, excluding the minor slightly acidic quartz vein rock type (pH = 3.16) discussed above. PAG solutions produced trace metals exceedances, in more than one sample, for Sb, As, Fe, Mn, Pb, Mo, and Se.

Two tailings samples generated from metallurgical bench-scale work were chemically analyzed to assess the potential for acid generation and trace metal release (Knight Piesold 2002). Analyses included mineralogy, whole-rock chemistry, chemistry of the tailings slurry water, and acid-base accounting. One sample was an oxide tailings sample and the other was a sulfide tailings sample. The mineralogical results were similar to those presented earlier for the various waste rock types. Both pyrite and ankerite were present in trace amounts in the oxide sample and were classified as accessory in the sulfide sample. Both samples were found to have very low potential for acid generation. Both samples were significantly enriched in Sb and Mo above crustal averages. Transition metals and potassium were measured in significant concentrations in the tailings slurry water; cyanide was also present at moderate to high levels.

In summary, Phase 1 and Phase 2 data indicate that sufficient neutralization capacity exists to prevent acid generation in the waste rock facilities, tailings storage facility, and mine pit area (pit lake). Testing also shows the potential for trace metals to be released from various rock types. However, these static test results do not necessarily reflect how the rock will behave in the natural environment over time. The Company will perform additional geochemical testing as part of operations or as needed to address refinements in the mine plan. These tests should provide additional information about the potential for release of trace metals in the natural environment over time.

TABLE C3-6
Whole Rock Data for Akyem Mine Pit Area Compared to Average Earth Crustal Values

	Concentration in parts per million (ppm)								
	As	**Ba**	**Be**	**Cd**	**Co**	**Cr**	**Cu**	**Mn**	**Mo**
Average Crustal Abundance	2.1	340	1.9	0.16	30	140	68	1,060	1.1
Phase 1 Oxide Samples (n=26)									
Mean	73	911	1.5	0.05	44	186	105	1,451	13
Maximum	1,388	1,613	3.0	0.2	97	446	298	2,894	36
Minimum	0	86	0.4	0	12	41	2	163	0
Phase 1 Sulfide Samples (n=181)									
Mean	14	1,007	0.9	0.02	26	162	52	924	23
Maximum	236	9,258	2.4	0.6	56	372	146	2,740	758
Minimum	0	95	0	0	2.6	72	0	65	0
Phase 2 Composite Samples (n=17)									
Mean	107	832	0.05	1.5	55	84	62	1,164	24
Maximum	1,449	1,561	0.6	4.8	105	264	140	2,278	132
Minimum	0	138	0	0	13	14	0	26	4
	Ni	**Pb**	**Sb**	**Se**	**Sn**	**S**	**Tl**	**V**	**Zn**
Average Crustal Abundance	90	10	0.2	0.05	2.2	360	0.53	190	79
Phase 1 Oxide Samples (n=26)									
Mean	90	20	17	7	0.7	541	0.7	207	162
Maximum	250	110	70	11	8.8	9,444	7.4	432	1,036
Minimum	22	4	0	4	0	0	0	86	45
Phase 1 Sulfide Samples (n=181)									
Mean	58	41	16	6	0.2	8,224	2.7	138	132
Maximum	338	716	72	11	18	27,279	26	313	818
Minimum	7	0	0	2	0	0	0	7	11
Phase 2 Composite Samples (n=17)									
Mean	65	100	31	1.5	14	5,271	2	147	69
Maximum	149	627	87	10	22	13,708	6	417	185
Minimum	3	0	0	0	0	69	0	3	0

Note: As = Arsenic; Ba = Barium; Be = Beryllium; Cd = Cadmium; Co = Cobalt; Cr = Chromium; Cu = Copper; Mn = Manganese; Mo = Molybdenum; n = Number of Samples; Ni = Nickel; Pb = Lead; Sb = Antimony; Se = Selenium; Sn = Tin; S = Sulfur; Tl = Thallium; V = Vanadium; Zn = Zinc.
Source: Porterfield 1984; Butler and Harrod 1989; Kaye and Laby 1993; Greenwood and Earnshaw 1997; Huheey *et al.* 1993; Cox 1989; McGraw-Hill 1992; James and Lord 1992; Newmont 2005b.

TABLE C3-7
Results of Synthetic Precipitation Leaching Procedure Tests, Akyem Gold Mining Project

Sample ID	Laboratory ID	Arsenic by ICP-MS (mg/l)	Barium by ICP (mg/l)	Beryllium by ICP-MS (mg/l)	Boron by ICP-MS (mg/l)	Calcium by ICP (mg/l)	Cadmium by ICP-MS (mg/l)	Chromium by ICP (mg/l)	Cobalt by ICP (mg/l)	Copper by ICP (mg/l)
Akyem NCV 01 GW B	NM-200732-1	<0.0001	0.36	<0.0001	**0.946**	8.52	0.00012	<0.01	<0.01	<0.01
Akyem NCV 01 GW B	1006293-001	0.0024	0.40	<0.0001	0.0564	8.03	<0.00010	<0.01	<0.01	<0.01
Akyem NCV 02 GW HB	NM-200732-2	0.0022	0.10	0.0001	0.171	8.86	0.00016	<0.01	<0.01	<0.01
Akyem NCV 02 GW HB	1006293-002	**0.0156**	0.09	<0.0001	0.0454	7.37	<0.00010	<0.01	<0.01	<0.01
Akyem NCV 03 MV HB	NM-200732-3	**0.0125**	0.30	<0.0001	0.164	8.40	<0.00010	<0.01	<0.01	<0.01
Akyem NCV 03 MV HB	1006293-003	**0.0138**	0.31	<0.0001	0.0493	8.43	<0.00010	<0.01	<0.01	<0.01
Akyem NCV 04 SAP I	NM-200732-4	**0.0119**	0.06	0.0001	0.102	0.62	0.00020	<0.01	<0.01	<0.01
Akyem NCV 04 SAP I	1006293-004	<0.0001	0.07	<0.0001	0.0574	0.354	<0.00010	<0.01	<0.01	<0.01
Akyem NCV 05 SAP SB	NM-200732-5	0.0003	0.08	<0.0001	0.0984	0.94	<0.00010	<0.01	<0.01	<0.01
Akyem NCV 05 SAP SB	1006293-005	<0.0001	0.09	<0.0001	0.0588	0.760	<0.00010	<0.01	<0.01	<0.01
Akyem NCV 06 QE B-HB	NM-200732-6	0.0005	0.30	<0.0001	0.0947	7.12	<0.00010	<0.01	<0.01	<0.01
Akyem NCV 06 QE B-HB	1006293-006	0.0033	0.31	<0.0001	0.0587	7.10	<0.00010	<0.01	<0.01	<0.01
Akyem NCV 07 QV B-HB	NM-200744-23	0.0095	0.39	<0.0001	0.0627	9.62	0.00031	<0.01	0.01	<0.01
Akyem NCV 07 QV B-HB	1006293-007	0.0084	0.35	<0.0001	0.0510	8.91	0.00028	<0.01	<0.01	<0.01
Akyem NCV 08 GMY-GRAP HB	NM-200744-24	**0.0918**	0.14	<0.0001	0.0735	14.3	0.00012	<0.01	0.01	<0.01
Akyem NCV 08 GMY-GRAP HB	1006293-008	**0.0903**	0.11	<0.0001	0.0625	12.8	<0.00010	<0.01	<0.01	<0.01
Akyem NCV 09 GW SB	NM-200744-25	0.0011	0.17	<0.0001	0.0824	10.2	<0.00010	<0.01	<0.01	<0.01
Akyem NCV 09 GW SB	1006293-009	0.0006	0.14	<0.0001	0.0658	9.04	<0.00010	<0.01	<0.01	<0.01
Akyem NCV 11 MV B	NM-200744-27	0.0007	0.31	<0.0001	0.0697	13.3	<0.00010	<0.01	0.01	<0.01
Akyem NCV 11 MV B	1006293-011	**0.0379**	0.25	**0.107**	0.0119	11.0	**0.862**	<0.01	<0.01	<0.01
Akyem NCV 12 MV1 HB	NM-200744-28	**0.0310**	---	<0.0001	0.0550	---	<0.00010	---	---	---
Akyem NCV 13 QV SB	NM-200744-29	**0.0177**	---	<0.0001	0.0488	---	<0.00010	---	---	---
Akyem NCV 14 QV SA	NM-200744-30	0.0051	---	<0.0001	0.144	---	<0.00010	---	---	---
Akyem NCV 15 SAP B	NM-200744-31	0.0031	---	<0.0001	0.0543	---	<0.00010	---	---	---
Akyem NCV 16 GRAP I	NM-200744-32	**0.0193**	---	<0.0001	0.125	---	<0.00010	---	---	---
Akyem NCV 17 MV1 B	NM-200744-33	**0.0161**	---	<0.0001	0.0694	---	<0.00010	---	---	---
QBH1	NM-202063-1	0.0074	<0.010	<0.0001	0.0659	0.605	<0.00010	<0.010	<0.010	<0.010
QBH2	NM-202063-2	**0.0179**	0.014	<0.0001	0.0135	5.67	<0.00010	<0.010	<0.010	<0.010
QBH3	NM-202063-3	**0.0292**	<0.010	<0.0001	0.0139	5.08	<0.00010	<0.010	<0.010	<0.010
QBH4	NM-202063-4	**0.0139**	<0.010	<0.0001	0.0116	6.47	<0.00010	<0.010	<0.010	<0.010
Ghana Water Co. Drinking Water Standards[1]		**0.01**	0.7	NE	**0.3**	NE	**0.003**	0.05	NE	1
U.S. EPA Drinking Water Standards[1]		---	---	**0.004**	---	NE	---	---	NE	---

TABLE C3-7 (continued)
Results of Synthetic Precipitation Leaching Procedure Tests, Akyem Gold Mining Project

Sample ID	Laboratory ID	Iron by ICP (mg/l)	Lead by ICP-MS (mg/l)	Lithium by ICP-MS (mg/l)	Magnesium by ICP (mg/l)	Manganese by ICP (mg/l)	Mercury by CVAA (mg/l)	Molybdenum by ICP-MS (mg/l)	Nickel by ICP-MS (mg/l)	Phosphorus by ICP (mg/l)
Akyem NCV 01 GW B	NM-200732-1	<0.05	0.0006	0.0989	1.55	0.010	0.0002	0.0408	**0.1242**	<0.05
Akyem NCV 01 GW B	1006293-001	<0.05	0.0001	0.0008	1.6	<0.01	---	0.0017	0.0006	---
Akyem NCV 02 GW HB	NM-200732-2	<0.05	0.0043	0.0015	2.64	<0.01	0.0002	0.0017	0.0014	<0.05
Akyem NCV 02 GW HB	1006293-002	<0.05	<0.0001	0.0009	2.53	<0.01	---	0.0006	0.0005	---
Akyem NCV 03 MV HB	NM-200732-3	<0.05	0.0008	0.0009	2.49	<0.01	0.0002	0.0012	0.0018	<0.05
Akyem NCV 03 MV HB	1006293-003	<0.05	<0.0001	0.0008	2.58	<0.01	---	0.0047	0.0010	---
Akyem NCV 04 SAP I	NM-200732-4	<0.05	0.0027	0.0012	0.270	0.060	0.0002	0.0092	0.0022	<0.05
Akyem NCV 04 SAP I	1006293-004	<0.05	<0.0001	0.0003	0.265	0.064	---	<0.0001	0.0007	---
Akyem NCV 05 SAP SB	NM-200732-5	<0.05	0.0003	0.0007	0.270	**0.11**	0.0002	0.0006	0.0005	<0.05
Akyem NCV 05 SAP SB	1006293-005	<0.05	0.0002	0.0002	0.263	**0.11**	---	<0.0001	0.0007	---
Akyem NCV 06 QE B-HB	NM-200732-6	<0.05	0.0003	0.0006	2.17	<0.01	0.0005	0.0004	0.0007	<0.05
Akyem NCV 06 QE B-HB	1006293-006	<0.05	0.0009	<0.0001	2.21	<0.01	---	0.0019	0.0010	---
Akyem NCV 07 QV B-HB	NM-200744-23	<0.05	0.0009	0.0009	3.26	<0.01	0.0002	**0.155**	0.0005	<0.05
Akyem NCV 07 QV B-HB	1006293-007	<0.05	<0.0001	0.0005	3.05	<0.01	---	**0.112**	0.0007	---
Akyem NCV 08 GMY-GRAP HB	NM-200744-24	<0.05	0.0003	0.0016	4.87	<0.01	0.0002	0.0664	0.0022	<0.05
Akyem NCV 08 GMY-GRAP HB	1006293-008	<0.05	<0.0001	0.0013	4.43	<0.01	---	0.0496	0.0012	---
Akyem NCV 09 GW SB	NM-200744-25	<0.05	0.0001	0.0002	3.13	0.080	**0.0018**	0.0269	0.0004	<0.05
Akyem NCV 09 GW SB	1006293-009	<0.05	0.0004	<0.0001	2.84	0.074	---	0.0199	0.0006	---
Akyem NCV 11 MV B	NM-200744-27	<0.05	<0.0001	0.0015	4.85	<0.01	0.0002	0.0238	0.0008	<0.05
Akyem NCV 11 MV B	1006293-011	<0.05	**1.534**	<0.0001	4.16	<0.01	---	<0.0001	**0.101**	---
Akyem NCV 12 MV1 HB	NM-200744-28	---	<0.0001	0.0105	---	---	0.0005	0.0179	0.0014	---
Akyem NCV 13 QV SB	NM-200744-29	---	<0.0001	0.0055	---	---	0.0003	0.0173	0.0006	---
Akyem NCV 14 QV SA	NM-200744-30	---	0.0025	0.0023	---	---	0.0002	0.0096	0.0004	---
Akyem NCV 15 SAP B	NM-200744-31	---	<0.0001	0.0059	---	---	0.0002	0.0155	0.0008	---
Akyem NCV 16 GRAP I	NM-200744-32	---	<0.0001	0.0017	---	---	0.0002	0.0026	0.0003	---
Akyem NCV 17 MV1 B	NM-200744-33	---	<0.0001	0.0055	---	---	0.0002	0.0014	0.0012	---
QBH1	NM-202063-1	<0.050	0.0014	0.0013	0.146	0.086	<0.0001	0.0024	0.0007	<0.05
QBH2	NM-202063-2	<0.050	0.0005	0.0014	1.76	0.011	<0.0001	0.0006	0.0003	<0.05
QBH3	NM-202063-3	<0.050	0.0002	0.0016	1.82	<0.010	<0.0001	0.0005	0.0003	<0.05
QBH4	NM-202063-4	<0.050	0.0004	0.0019	2.09	<0.010	<0.0001	0.0004	0.0002	<0.05
Ghana Water Co. Drinking Water Standards[1]		0.3	**0.01**	NE	NE	**0.1**	**0.001**	**0.07**	**0.02**	NE
U.S. EPA Drinking Water Standards[1]		---	---	NE	NE	---	---	---	---	NE

TABLE C3-7 (continued)
Results of Synthetic Precipitation Leaching Procedure Tests, Akyem Gold Mining Project

Sample ID	Laboratory ID	Potassium by ICP (mg/l)	Selenium by ICP-MS (mg/l)	Silver by ICP (mg/l)	Sodium by ICP (mg/l)	Strontium by ICP (mg/l)	Sulfur by ICP (mg/l)	Tellerium by ICP-MS (mg/l)	Thallium by ICP-MS (mg/l)
Akyem NCV 01 GW B	NM-200732-1	1.40	**0.0402**	<0.010	3.4	2.42	6.27	<0.0001	<0.0001
Akyem NCV 01 GW B	1006293-001	1.47	<0.0001	<0.010	2.9	2.55	---	0.0006	<0.0001
Akyem NCV 02 GW HB	NM-200732-2	1.00	0.0020	<0.010	2.7	0.280	3.53	0.0002	0.0001
Akyem NCV 02 GW HB	1006293-002	1.30	<0.0001	<0.010	2.0	0.253	---	0.0002	<0.0001
Akyem NCV 03 MV HB	NM-200732-3	0.800	0.0028	<0.010	3.0	2.67	5.89	0.0003	<0.0001
Akyem NCV 03 MV HB	1006293-003	1.57	<0.0001	<0.010	2.6	2.77	---	0.0001	<0.0001
Akyem NCV 04 SAP I	NM-200732-4	0.400	<0.0001	<0.010	3.4	0.020	2.37	<0.0001	0.0003
Akyem NCV 04 SAP I	1006293-004	0.104	<0.0001	<0.010	2.8	0.024	---	0.0001	<0.0001
Akyem NCV 05 SAP SB	NM-200732-5	1.20	0.0002	<0.010	4.4	0.120	1.16	<0.0001	<0.0001
Akyem NCV 05 SAP SB	1006293-005	0.94	<0.0001	<0.010	3.8	0.121	---	<0.0001	<0.0001
Akyem NCV 06 QE B-HB	NM-200732-6	1.10	<0.0001	<0.010	3.7	2.81	4.23	<0.0001	<0.0001
Akyem NCV 06 QE B-HB	1006293-006	0.743	<0.0001	<0.010	3.2	2.87	---	0.0001	<0.0001
Akyem NCV 07 QV B-HB	NM-200744-23	0.700	0.0038	<0.010	3.2	6.28	8.37	0.0016	<0.0001
Akyem NCV 07 QV B-HB	1006293-007	0.297	<0.0001	<0.010	2.3	5.93	---	0.0012	<0.0001
Akyem NCV 08 GMY-GRAP HB	NM-200744-24	1.80	0.0014	<0.010	3.9	0.470	11.4	<0.0001	<0.0001
Akyem NCV 08 GMY-GRAP HB	1006293-008	1.26	<0.0001	<0.010	2.8	0.427	---	0.0000	<0.0001
Akyem NCV 09 GW SB	NM-200744-25	1.60	0.0027	<0.010	3.7	1.37	11.1	<0.0001	<0.0001
Akyem NCV 09 GW SB	1006293-009	1.17	<0.0001	<0.010	3.0	1.24	---	<0.0001	<0.0001
Akyem NCV 11 MV B	NM-200744-27	0.700	0.0021	<0.010	4.0	3.87	10.6	<0.0001	<0.0001
Akyem NCV 11 MV B	1006293-011	0.174	**0.101**	<0.010	3.0	3.37	---	<0.0001	**0.0042**
Akyem NCV 12 MV1 HB	NM-200744-28	---	0.0050	---	---	---	---	0.0013	0.0006
Akyem NCV 13 QV SB	NM-200744-29	---	0.0067	---	---	---	---	<0.0001	<0.0001
Akyem NCV 14 QV SA	NM-200744-30	---	0.0079	---	---	---	---	<0.0001	<0.0001
Akyem NCV 15 SAP B	NM-200744-31	---	0.0013	---	---	---	---	<0.0001	<0.0001
Akyem NCV 16 GRAP I	NM-200744-32	---	0.0006	---	---	---	---	<0.0001	<0.0001
Akyem NCV 17 MV1 B	NM-200744-33	---	0.0015	---	---	---	---	<0.0001	<0.0001
QBH1	NM-202063-1	0.177	0.0010	<0.010	4.59	<0.010	0.96	0.0002	0.0009
QBH2	NM-202063-2	1.91	0.0005	<0.010	4.26	0.041	0.58	0.0001	0.0005
QBH3	NM-202063-3	2.05	0.0003	<0.010	4.90	0.033	0.31	0.0001	0.0004
QBH4	NM-202063-4	0.852	0.0003	<0.010	5.21	0.063	0.32	0.0001	0.0002
Ghana Water Co. Drinking Water Standards[1]		NE	**0.01**	NE	NE	NE	NE	NE	NE
U.S. EPA Drinking Water Standards[1]		NE	---	0.1	NE	NE	NE	NE	**0.002**

TABLE C3-7 (continued)
Results of Synthetic Precipitation Leaching Procedure Tests, Akyem Gold Mining Project

Sample ID	Laboratory ID	Tin by ICP (mg/l)	Titanium by ICP (mg/l)	Vanadium by ICP (mg/l)	Zinc by ICP (mg/l)
Akyem NCV 01 GW B	NM-200732-1	<0.050	<0.050	<0.050	<0.050
Akyem NCV 01 GW B	1006293-001	<0.050	<0.050	<0.050	<0.050
Akyem NCV 02 GW HB	NM-200732-2	<0.050	<0.050	<0.050	<0.050
Akyem NCV 02 GW HB	1006293-002	<0.050	<0.050	<0.050	<0.050
Akyem NCV 03 MV HB	NM-200732-3	<0.050	<0.050	<0.050	<0.050
Akyem NCV 03 MV HB	1006293-003	<0.050	<0.050	<0.050	<0.050
Akyem NCV 04 SAP I	NM-200732-4	<0.050	<0.050	<0.050	<0.050
Akyem NCV 04 SAP I	1006293-004	<0.050	<0.050	<0.050	<0.050
Akyem NCV 05 SAP SB	NM-200732-5	<0.050	<0.050	<0.050	<0.050
Akyem NCV 05 SAP SB	1006293-005	<0.050	<0.050	<0.050	<0.050
Akyem NCV 06 QE B-HB	NM-200732-6	<0.050	<0.050	<0.050	<0.050
Akyem NCV 06 QE B-HB	1006293-006	<0.050	<0.050	<0.050	<0.050
Akyem NCV 07 QV B-HB	NM-200744-23	<0.050	<0.050	<0.050	<0.050
Akyem NCV 07 QV B-HB	1006293-007	<0.050	<0.050	<0.050	<0.050
Akyem NCV 08 GMY-GRAP HB	NM-200744-24	<0.050	<0.050	<0.050	<0.050
Akyem NCV 08 GMY-GRAP HB	1006293-008	<0.050	<0.050	<0.050	<0.050
Akyem NCV 09 GW SB	NM-200744-25	<0.050	<0.050	<0.050	<0.050
Akyem NCV 09 GW SB	1006293-009	<0.050	<0.050	<0.050	<0.050
Akyem NCV 11 MV B	NM-200744-27	<0.050	<0.050	<0.050	<0.050
Akyem NCV 11 MV B	1006293-011	<0.050	<0.050	<0.050	<0.050
Akyem NCV 12 MV1 HB	NM-200744-28	---	---	---	---
Akyem NCV 13 QV SB	NM-200744-29	---	---	---	---
Akyem NCV 14 QV SA	NM-200744-30	---	---	---	---
Akyem NCV 15 SAP B	NM-200744-31	---	---	---	---
Akyem NCV 16 GRAP I	NM-200744-32	---	---	---	---
Akyem NCV 17 MV1 B	NM-200744-33	---	---	---	---
QBH1	NM-202063-1	<0.050	<0.050	<0.050	<0.050
QBH2	NM-202063-2	<0.050	<0.050	<0.050	<0.050
QBH3	NM-202063-3	<0.050	<0.050	<0.050	<0.050
QBH4	NM-202063-4	<0.050	<0.050	<0.050	<0.050
Ghana Water Co. Drinking Water Standards[1]		NE	NE	NE	3
U.S. EPA Drinking Water Standards[1]		NE	NE	NE	---

Notes: --- = not analyzed or not applicable; <= concentration is present at less than the stated detection limit; CVAA= cold vapor atomic absorption; ICP= inductively coupled plasma spectroscopy; MS= mass spectroscopy; mg/L = milligrams per liter; NE= not established; SU = standard units

[1] Ghana Water Company Drinking Water Criteria used as the primary screening criteria and the United States Environmental Protection Agency (U.S. EPA) drinking water criteria was used when the Ghana Water Co. had no established standard. (Note: No World Health Organization Drinking Water Criteria were available for Ghana Water Co. Criteria that had no established standard.)

TABLE C3-8
Results of Biological Acid Production Procedure (BAPP) Tests, Akyem Gold Mining Project

Sample ID	Laboratory ID	Final pH[2] (SU)	Acid Production Classification	Aluminum by ICP (mg/l)	Antimony by ICP-MS (mg/l)	Arsenic by ICP-MS (mg/l)	Barium by ICP (mg/l)	Beryllium by ICP-MS (mg/l)
Akyem NCV PII 04 SAP I	NM-200687-1	**2.06**	Acid Producing	**530**	0.0033	<0.0076	0.07	**0.0581**
Akyem NCV PII 05 SAP B	NM-200687-2	**3.18**	Slightly Acid Producing	**522**	0.0003	<0.0076	0.04	**0.0297**
Akyem NCV PII 09 GW SB	NM-200687-3	**2.60**	Acid Producing	**430**	**0.2331**	<0.0076	0.05	**0.0471**
Akyem NCV PII 13 QV SB	NM-200687-5	3.54	Negative	**531**	**0.1393**	**0.101**	0.15	**0.0064**
Akyem NCV PII 14 QV SA	NM-200687-6	**2.79**	Acid Producing	**120**	**1.913**	**0.0504**	0.09	**0.0045**
Akyem NCV PII 16 GRAP I	NM-200687-7	**3.09**	Slightly Acid Producing	**441**	0.0015	**0.0364**	0.04	**0.0300**
Akyem QBH1	NM-202616-1	3.53	Negative	**262**	0.0008	0.0077	0.049	**0.0125**
Ghana Water Co. Drinking Water Standards[1]		---	0.2	**0.2**	**0.005**	**0.01**	0.7	NE
U.S. EPA Drinking Water Standards[1]		---	---	---	---	---	---	**0.004**

Sample ID	Laboratory ID	Boron by ICP-MS (mg/l)	Calcium by ICP (mg/l)	Cadmium by ICP-MS (mg/l)	Chromium by ICP (mg/l)	Cobalt by ICP (mg/l)	Copper by ICP (mg/l)	Iron by ICP (mg/l)
Akyem NCV PII 04 SAP I	NM-200687-1	0.0164	173	**0.0583**	**3.10**	5.78	**5.34**	**82.3**
Akyem NCV PII 05 SAP B	NM-200687-2	0.0699	142	**0.0514**	**0.49**	20.0	**3.46**	**0.9**
Akyem NCV PII 09 GW SB	NM-200687-3	0.0642	478	**0.0692**	**2.15**	14.6	**11.5**	**24.3**
Akyem NCV PII 13 QV SB	NM-200687-5	**0.414**	414	**0.0822**	**5.66**	38.6	**21.6**	**493**
Akyem NCV PII 14 QV SA	NM-200687-6	**4.04**	80.9	**0.0573**	**9.95**	67.9	**8.79**	**211**
Akyem NCV PII 16 GRAP I	NM-200687-7	0.218	113	**0.0252**	**0.84**	29.9	**3.2**	**1.2**
Akyem QBH1	NM-202616-1	0.0617	504	**0.0251**	**0.287**	3.32	0.575	**5.16**
Ghana Water Co. Drinking Water Standards[1]		**0.3**	NE	**0.003**	**0.05**	NE	**1**	**0.3**
U.S. EPA Drinking Water Standards[1]		---	NE	---	---	NE	---	---

TABLE C3-8 (continued)
Results of Biological Acid Production Procedure (BAPP) Tests, Akyem Gold Mining Project

Sample ID	Laboratory ID	Lead by ICP-MS (mg/l)	Lithium by ICP-MS (mg/l)	Magnesium by ICP (mg/l)	Manganese by ICP (mg/l)	Mercury by CVAA (mg/l)	Molybdenum by ICP-MS (mg/l)
Akyem NCV PII 04 SAP I	NM-200687-1	**0.0154**	0.1758	129	**422**	<0.0001	0.0008
Akyem NCV PII 05 SAP B	NM-200687-2	0.0044	0.8579	313	**350**	**0.0011**	0.0010
Akyem NCV PII 09 GW SB	NM-200687-3	**0.0442**	0.2473	307	**779**	**0.0020**	0.0019
Akyem NCV PII 13 QV SB	NM-200687-5	**0.0231**	0.4236	1,820	**111**	**0.0067**	0.0257
Akyem NCV PII 14 QV SA	NM-200687-6	**0.727**	0.0639	137	**24.7**	**0.0019**	0.067
Akyem NCV PII 16 GRAP I	NM-200687-7	0.0023	0.6605	205	**452**	0.0003	0.0010
Akyem QBH1	NM-202616-1	**0.0132**	0.3709	371	**102**	0.0008	0.0013
Ghana Water Co. Drinking Water Standards[1]		**0.01**	NE	NE	**0.1**	**0.001**	0.07
U.S. EPA Drinking Water Standards[1]		---	NE	NE	---	---	---

Sample ID	Laboratory ID	Nickel by ICP-MS (mg/l)	Phosphorus by ICP (mg/l)	Potassium by ICP (mg/l)	Selenium by ICP-MS (mg/l)	Silver by ICP (mg/l)	Sodium by ICP (mg/l)	Strontium by ICP (mg/l)
Akyem NCV PII 04 SAP I	NM-200687-1	**2.405**	0.23	43.3	**0.0221**	<0.010	44.1	1.35
Akyem NCV PII 05 SAP B	NM-200687-2	**4.254**	0.13	25.2	**0.0207**	<0.010	35.1	1.21
Akyem NCV PII 09 GW SB	NM-200687-3	**2.098**	<0.05	0.8	**0.0276**	<0.010	37.4	7.02
Akyem NCV PII 13 QV SB	NM-200687-5	**1.204**	8.66	0.4	**0.0388**	<0.010	61.3	9.94
Akyem NCV PII 14 QV SA	NM-200687-6	**1.895**	1.23	0.1	**0.0259**	<0.010	36.7	6.48
Akyem NCV PII 16 GRAP I	NM-200687-7	**4.618**	0.10	108	**0.0150**	<0.010	33.2	2.95
Akyem QBH1	NM-202616-1	**2.113**	---	20.8	**0.0121**	<0.010	89.3	4.34
Ghana Water Co. Drinking Water Standards[1]		**0.02**	NE	NE	**0.01**	NE	NE	NE
U.S. EPA Drinking Water Standards[1]		---	NE	NE	---	0.1	NE	NE

TABLE C3-8 (continued)
Results of Biological Acid Production Procedure (BAPP) Tests, Akyem Gold Mining Project

Sample ID	Laboratory ID	Sulfur by ICP (mg/l)	Tellerium by ICP-MS (mg/l)	Thallium by ICP-MS (mg/l)	Tin by ICP (mg/l)	Titanium by ICP (mg/l)	Vanadium by ICP (mg/l)	Zinc by ICP (mg/l)
Akyem NCV PII 04 SAP I	NM-200687-1	1,380	0.0032	**0.0032**	<0.050	0.07	<0.050	**5.90**
Akyem NCV PII 05 SAP B	NM-200687-2	1,320	0.0001	0.0004	<0.050	<0.050	<0.050	**8.83**
Akyem NCV PII 09 GW SB	NM-200687-3	1,630	0.0015	0.0002	<0.050	<0.050	<0.050	**7.33**
Akyem NCV PII 13 QV SB	NM-200687-5	2,360	0.0890	0.0001	<0.050	0.10	0.13	**9.22**
Akyem NCV PII 14 QV SA	NM-200687-6	778	0.0284	<0.0001	<0.050	0.10	<0.050	**4.06**
Akyem NCV PII 16 GRAP I	NM-200687-7	1,260	0.0001	0.0008	<0.050	0.07	<0.050	**11.5**
Akyem QBH1	NM-202616-1	---	<0.0001	0.0002	<0.050	<0.050	<0.050	**5.09**
Ghana Water Co. Drinking Water Standards[1]		NE	NE	NE	NE	NE	NE	**3**
U.S. EPA Drinking Water Standards[1]		NE	NE	**0.002**	NE	NE	NE	---

Notes: --- = not analyzed or not applicable; <= concentration is present at less than the stated detection limit; CVAA= cold vapor atomic absorption; DWC= drinking water criteria; ICP= inductively coupled plasma spectroscopy; MS= mass spectroscopy; mg/L = milligrams per liter; NE= not established; SU = standard units

[1] Ghana Water Company Drinking Water Criteria used as the primary screening criteria and the United States Environmental Protection Agency (U.S. EPA) drinking water criteria was used when the Ghana Water Co. had no established standard. (Note: No World Health Organization Drinking Water Criteria were available for Ghana Water Co. Criteria that had no established standard.)

[2] Final pH <3.5 indicates the sample has potential to maintain acidic conditions via biologically induced oxidation in the presence of bacteria.

TABLE C3-9
Results of Peroxide Acid Generation Tests, Akyem Gold Mining Project

Sample ID	Laboratory ID	Final pH[2] (SU)	Aluminum by ICP (mg/l)	Antimony by ICP-MS (mg/l)	Arsenic by ICP-MS (mg/l)	Barium by ICP (mg/l)	Beryllium by ICP-MS (mg/l)	Boron by ICP-MS (mg/l)	Calcium by ICP (mg/l)	Cadmium by ICP-MS (mg/l)
Akyem NCV 01 GW B	NM-200683-19	7.51	<0.01	0.0021	0.0003	0.18	<0.0001	0.200	14.9	0.00017
Akyem NCV 02 GW HB	NM-200683-20	7.77	<0.01	**0.0705**	0.0008	0.05	<0.0001	0.0603	11.5	<0.00010
Akyem NCV 03 MV HB	NM-200683-21	8.02	<0.01	**0.0199**	0.0009	0.30	<0.0001	0.185	13.8	0.00027
Akyem NCV 04 SAP I	NM-200683-22	7.55	<0.01	0.0008	0.0002	0.33	<0.0001	0.0327	2.06	<0.00010
Akyem NCV 05 SAP SB	NM-200683-23	7.50	<0.01	<0.0008	0.0001	0.15	<0.0001	0.0223	0.94	<0.00010
Akyem NCV 06 QE B-HB	NM-200683-24	9.28	<0.01	**0.0158**	0.0002	0.45	<0.0001	0.0660	14.0	0.00029
Akyem NCV 07 QV B-HB	NM-200683-25	8.95	<0.01	**0.0952**	0.0003	0.50	<0.0001	0.0770	15.0	0.00228
Akyem NCV 08 GMY-GRAP HB	NM-200683-26	9.75	<0.01	**0.0630**	0.0037	0.15	<0.0001	0.0924	21.9	0.00068
Akyem NCV 09 GW SB	NM-200683-27	8.41	<0.01	**0.0989**	<0.0001	0.12	<0.0001	0.0218	4.62	0.00012
Akyem NCV 11 MV B	NM-200683-29	8.65	0.11	**0.0523**	0.0005	0.37	<0.0001	0.0312	21.7	0.00087
Akyem NCV 12 MV1 HB	NM-200683-30	8.40	<0.01	**0.0317**	0.0030	0.07	<0.0001	0.0265	10.3	<0.00010
Akyem NCV 13 QV SB	NM-200683-31	9.03	<0.01	**0.0086**	0.0003	0.16	<0.0001	0.0723	12.5	0.00022
Akyem NCV 14 QV SA	NM-200683-32	**3.16**	**0.72**	**0.0167**	0.0003	0.22	0.0001	0.0785	1.77	0.00061
Akyem NCV 15 SAP B	NM-200683-33	6.99	0.16	0.0022	0.0012	0.16	<0.0001	0.0286	23.9	<0.00010
Akyem NCV 16 GRAP I	NM-200683-34	7.77	**0.96**	0.0042	**0.0457**	0.08	<0.0001	0.0428	1.76	<0.00010
Akyem NCV 17 MV1 B	NM-200683-35	8.24	0.01	**0.0084**	**0.0105**	0.10	<0.0001	0.0165	13.3	<0.00010
Akyem QBH1	NM-202062-5	6.58	0.16	0.0014	0.0048	<0.010	<0.0001	0.0080	1.80	**0.01343**
Ghana Water Co. Drinking Water Standards[1]		---	**0.2**	**0.005**	**0.01**	0.7	NE	0.3	NE	**0.003**
U.S. EPA Drinking Water Standards[1]		---	---	---	---	---	0.004	---	NE	---

TABLE C3-9 (continued)
Results of Peroxide Acid Generation Tests, Akyem Gold Mining Project

Sample ID	Laboratory ID	Chromium by ICP (mg/l)	Cobalt by ICP (mg/l)	Copper by ICP (mg/l)	Iron by ICP (mg/l)	Lead by ICP-MS (mg/l)	Lithium by ICP-MS (mg/l)	Magnesium by ICP (mg/l)	Manganese by ICP (mg/l)	Mercury by CVAA (mg/l)
Akyem NCV 01 GW B	NM-200683-19	0.03	<0.01	<0.01	<0.3	<0.0001	0.0178	0.31	<0.01	0.0002
Akyem NCV 02 GW HB	NM-200683-20	0.01	<0.01	<0.01	<0.3	<0.0001	0.0033	0.43	<0.01	0.0001
Akyem NCV 03 MV HB	NM-200683-21	0.02	<0.01	<0.01	<0.3	<0.0001	0.0019	0.27	<0.01	0.0001
Akyem NCV 04 SAP I	NM-200683-22	<0.01	<0.01	<0.01	<0.3	0.0001	0.0004	0.43	**1.32**	0.0001
Akyem NCV 05 SAP SB	NM-200683-23	0.01	<0.01	<0.01	<0.3	<0.0001	0.0003	0.78	**0.93**	0.0001
Akyem NCV 06 QE B-HB	NM-200683-24	0.01	<0.01	<0.01	<0.3	0.0005	0.0007	0.33	**0.31**	0.0001
Akyem NCV 07 QV B-HB	NM-200683-25	0.02	<0.01	<0.01	<0.3	<0.0001	0.0013	0.83	0.03	0.0001
Akyem NCV 08 GMY-GRAP HB	NM-200683-26	0.01	<0.01	<0.01	<0.3	0.0001	0.0016	0.93	0.02	0.0001
Akyem NCV 09 GW SB	NM-200683-27	<0.01	<0.01	<0.01	<0.3	0.0004	0.0014	1.25	**2.98**	0.0001
Akyem NCV 11 MV B	NM-200683-29	0.02	<0.01	<0.01	**0.3**	0.0034	0.0019	6.78	0.04	0.0001
Akyem NCV 12 MV1 HB	NM-200683-30	0.01	<0.01	<0.01	<0.3	0.0005	0.0033	3.31	<0.01	0.0001
Akyem NCV 13 QV SB	NM-200683-31	0.02	<0.01	<0.01	<0.3	0.0010	0.0015	0.88	<0.01	0.0001
Akyem NCV 14 QV SA	NM-200683-32	0.02	1.17	0.20	**0.9**	**5.21**	0.0005	0.21	**0.23**	0.0001
Akyem NCV 15 SAP B	NM-200683-33	0.01	0.03	<0.01	**0.3**	**0.039**	0.0024	1.56	0.01	0.0001
Akyem NCV 16 GRAP I	NM-200683-34	0.02	0.01	<0.01	**1.7**	0.0024	0.0009	0.56	**0.61**	0.0001
Akyem NCV 17 MV1 B	NM-200683-35	<0.01	0.01	<0.01	<0.3	0.0004	0.0027	3.35	**0.48**	0.0001
Akyem QBH1	NM-202062-5	0.029	<0.010	0.056	**2.42**	0.0014	0.0004	1.15	**0.176**	---
Ghana Water Co. Drinking Water Standards[1]		0.05	NE	1	**0.3**	**0.01**	NE	NE	**0.1**	0.001
U.S. EPA Drinking Water Standards[1]		---	NE	---	---	---	NE	NE	---	---

TABLE C3-9 (continued)
Results of Peroxide Acid Generation Tests, Akyem Gold Mining Project

Sample ID	Laboratory ID	Molybdenum by ICP-MS (mg/l)	Nickel by ICP-MS (mg/l)	Phosphorus by ICP (mg/l)	Potassium by ICP (mg/l)	Selenium by ICP-MS (mg/l)	Silver by ICP (mg/l)	Sodium by ICP (mg/l)	Strontium by ICP (mg/l)
Akyem NCV 01 GW B	NM-200683-19	**0.0842**	0.0006	<0.05	1.4	0.0027	0.04	2.7	1.40
Akyem NCV 02 GW HB	NM-200683-20	0.0410	0.0005	<0.05	1.2	0.0061	0.02	1.7	0.41
Akyem NCV 03 MV HB	NM-200683-21	**0.1446**	0.0005	<0.05	1.0	0.0028	0.02	2.5	1.42
Akyem NCV 04 SAP I	NM-200683-22	0.0050	0.0013	<0.05	0.7	0.0017	<0.01	1.8	0.15
Akyem NCV 05 SAP SB	NM-200683-23	0.0095	0.0006	<0.05	0.6	0.0021	<0.01	1.6	0.04
Akyem NCV 06 QE B-HB	NM-200683-24	**0.109**	0.0008	<0.05	1.8	0.0039	0.02	4.4	2.30
Akyem NCV 07 QV B-HB	NM-200683-25	**1.20**	0.0005	<0.05	2.2	**0.0144**	<0.01	2.3	8.84
Akyem NCV 08 GMY-GRAP HB	NM-200683-26	**0.338**	0.0010	<0.05	1.8	0.0067	<0.01	2.1	1.22
Akyem NCV 09 GW SB	NM-200683-27	0.0449	0.0015	<0.05	1.7	**0.0111**	0.01	1.9	0.46
Akyem NCV 11 MV B	NM-200683-29	**0.416**	0.0012	<0.05	0.6	0.0088	<0.01	1.9	4.07
Akyem NCV 12 MV1 HB	NM-200683-30	0.0283	0.0005	<0.05	1.6	0.0041	<0.01	1.8	0.34
Akyem NCV 13 QV SB	NM-200683-31	**0.113**	0.0004	<0.05	0.9	**0.0214**	<0.01	2.3	5.98
Akyem NCV 14 QV SA	NM-200683-32	**0.105**	**0.0323**	<0.05	1.0	**0.0381**	**0.15**	2.6	0.96
Akyem NCV 15 SAP B	NM-200683-33	0.0141	0.0022	<0.05	0.5	0.0029	<0.01	1.7	0.18
Akyem NCV 16 GRAP I	NM-200683-34	0.0027	0.0025	<0.05	2.1	0.0017	<0.01	1.6	0.03
Akyem NCV 17 MV1 B	NM-200683-35	0.0014	0.0008	<0.05	1.2	0.0018	<0.01	2.0	0.07
Akyem QBH1	NM-202062-5	0.0015	0.0011	<0.05	1.12	0.0028	<0.01	1.28	0.030
Ghana Water Co. Drinking Water Standards[1]		**0.07**	**0.02**	NE	NE	**0.01**	NE	NE	NE
U.S. EPA Drinking Water Standards[1]		---	---	NE	NE	---	**0.1**	NE	NE

TABLE C3-9 (continued)
Results of Peroxide Acid Generation Tests, Akyem Gold Mining Project

Sample ID	Laboratory ID	Sulfur by ICP (mg/l)	Tellerium by ICP-MS (mg/l)	Thallium by ICP-MS (mg/l)	Tin by ICP (mg/l)	Titanium by ICP (mg/l)	Vanadium by ICP (mg/l)	Zinc by ICP (mg/l)
Akyem NCV 01 GW B	NM-200683-19	12.9	<0.0001	<0.0001	<0.050	<0.050	<0.050	<0.050
Akyem NCV 02 GW HB	NM-200683-20	8.31	<0.0001	<0.0001	<0.050	<0.050	<0.050	<0.050
Akyem NCV 03 MV HB	NM-200683-21	11.4	<0.0001	<0.0001	<0.050	<0.050	<0.050	<0.050
Akyem NCV 04 SAP I	NM-200683-22	1.84	<0.0001	<0.0001	<0.050	<0.050	<0.050	<0.050
Akyem NCV 05 SAP SB	NM-200683-23	1.11	<0.0001	<0.0001	<0.050	<0.050	<0.050	<0.050
Akyem NCV 06 QE B-HB	NM-200683-24	10.9	<0.0001	<0.0001	<0.050	<0.050	<0.050	<0.050
Akyem NCV 07 QV B-HB	NM-200683-25	14.1	<0.0001	<0.0001	<0.050	<0.050	<0.050	<0.050
Akyem NCV 08 GMY-GRAP HB	NM-200683-26	17.9	<0.0001	<0.0001	<0.050	<0.050	<0.050	<0.050
Akyem NCV 09 GW SB	NM-200683-27	6.29	<0.0001	<0.0001	<0.050	<0.050	<0.050	<0.050
Akyem NCV 11 MV B	NM-200683-29	14.1	<0.0001	<0.0001	<0.050	<0.050	<0.050	<0.050
Akyem NCV 12 MV1 HB	NM-200683-30	6.25	<0.0001	<0.0001	<0.050	<0.050	<0.050	<0.050
Akyem NCV 13 QV SB	NM-200683-31	7.19	<0.0001	<0.0001	<0.050	<0.050	<0.050	<0.050
Akyem NCV 14 QV SA	NM-200683-32	20.1	0.0034	<0.0001	<0.050	<0.050	<0.050	0.15
Akyem NCV 15 SAP B	NM-200683-33	2.19	<0.0001	<0.0001	<0.050	<0.050	<0.050	<0.050
Akyem NCV 16 GRAP I	NM-200683-34	0.28	<0.0001	<0.0001	<0.050	<0.050	<0.050	<0.050
Akyem NCV 17 MV1 B	NM-200683-35	0.95	<0.0001	<0.0001	<0.050	<0.050	<0.050	<0.050
Akyem QBH1	NM-202062-5	3.69	0.0001	0.0001	<0.050	<0.050	<0.050	<0.050
Ghana Water Co. Drinking Water Standards[1]		NE	NE	NE	NE	NE	NE	3
U.S. EPA Drinking Water Standards[1]		NE	NE	0.002	NE	NE	NE	---

Notes: --- = not analyzed or not applicable; <= concentration is present at less than the stated detection limit; CVAA= cold vapor atomic absorption; DWC= drinking water criteria; ICP= inductively coupled plasma spectroscopy; MS= mass spectroscopy; mg/L = milligrams per liter; NE= not established; SU = standard units

[1] Ghana Water Company Drinking Water Criteria used as the primary screening criteria and the United States Environmental Protection Agency (U.S. EPA) drinking water criteria was used when the Ghana Water Co. had no established standard. (Note: No World Health Organization Drinking Water Criteria were available for Ghana Water Co. Criteria that had no established standard.)

[2] Final pH <4.5 indicates the sample has potential to generate acid.

ANNEX C-4

WATER RESOURCES SUPPLEMENTAL INFORMATION

WATER RESOURCES SUPPLEMENTAL INFORMATION

SURFACE WATER QUANTITY

Pra River

Using mean monthly flow data from the Hydrological Division of the Ministry of Works and Housing in Accra (SGS 2004d), the mean annual discharge for the Pra River at Ofoase-Praso (SW-27; 2,045 km^2 watershed area) is 12.5 cubic metres per second (m^3/sec), with mean monthly flows shown on **Table C4-1**. **Figure C4-1** contains a hydrograph and data for Pra River mean monthly total flows for the period of record (1960-1978 and 1991-1999) at SW-27.

Mean monthly flows were estimated for the Pra River at Praso Kuma (located upstream of the Study Area near SW-21; 875 km^2 watershed area) using the area-ratio method and measurements for the Pra River at Ofoase-Praso discussed above. Mean monthly flow estimates for the Pra River at Praso Kuma are summarized in **Table C4-2**. Using these monthly estimates, mean annual flow for the Pra River at Praso Kuma is 5.4 m^3/sec.

TABLE C4-1
Mean Monthly Flow Measured for Pra River at Ofoase-Praso Bridge (SW-27)
(1960-1978 & 1991-1999)

Month	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
Flow (meter^3/second)	1.8	1.4	2.1	4.0	5.9	21.7	28.6	17.5	20.3	26.2	12.0	4.9

Source: Hydrological Division of the Ministry of Works and Housing (Accra) in SGS 2004d.

TABLE C4-2
Mean Monthly Flow Calculated for Pra River at Praso Kuma (SW-21)

Month	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
Flow (meter^3/second)	0.77	0.60	0.90	1.71	2.52	9.29	12.24	7.49	8.69	11.21	5.14	2.10

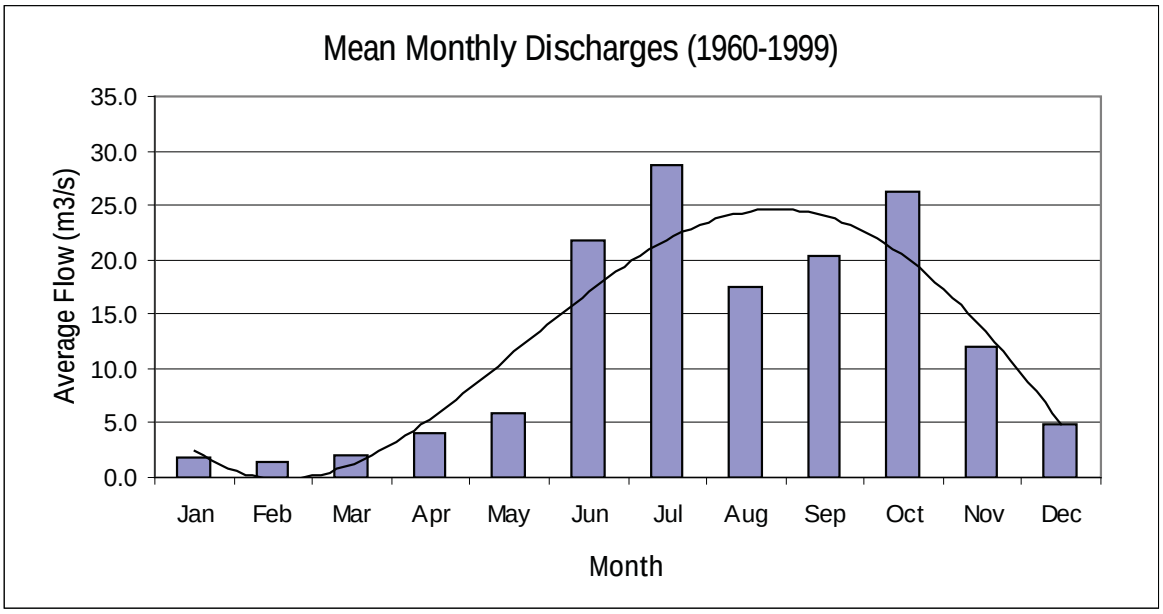
Source: SGS 2004g.

In April-May 2007, two continuous recording stream gauging stations were installed on the Pra River by Clear Creek Consultants (2008b) at SW-21 (PRA-1, upstream at Praso Kuma) and SW-27 (PRA-2, downstream at Ofoase-Praso). **Figures C4-2** and **C4-3** are hydrographs for these stations showing flow measured in February-June 2004 and May-December 2007. The following are selected flow data for these two Pra River stations (Clear Creek Consultants 2008b):

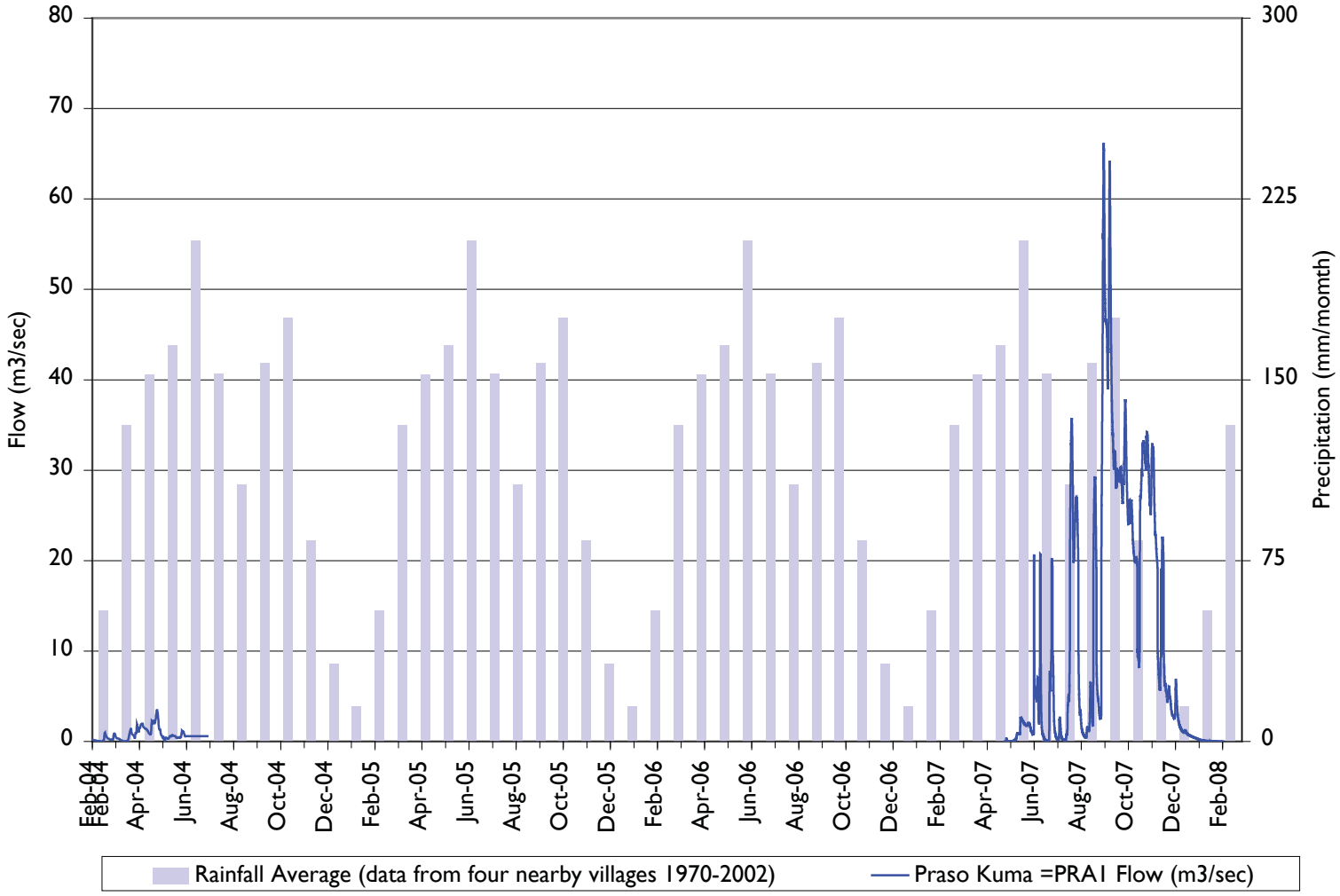
Discharge at Ofoase-Praso - 1960 to 1978 and 1991 to 1999

Flows in m3/s

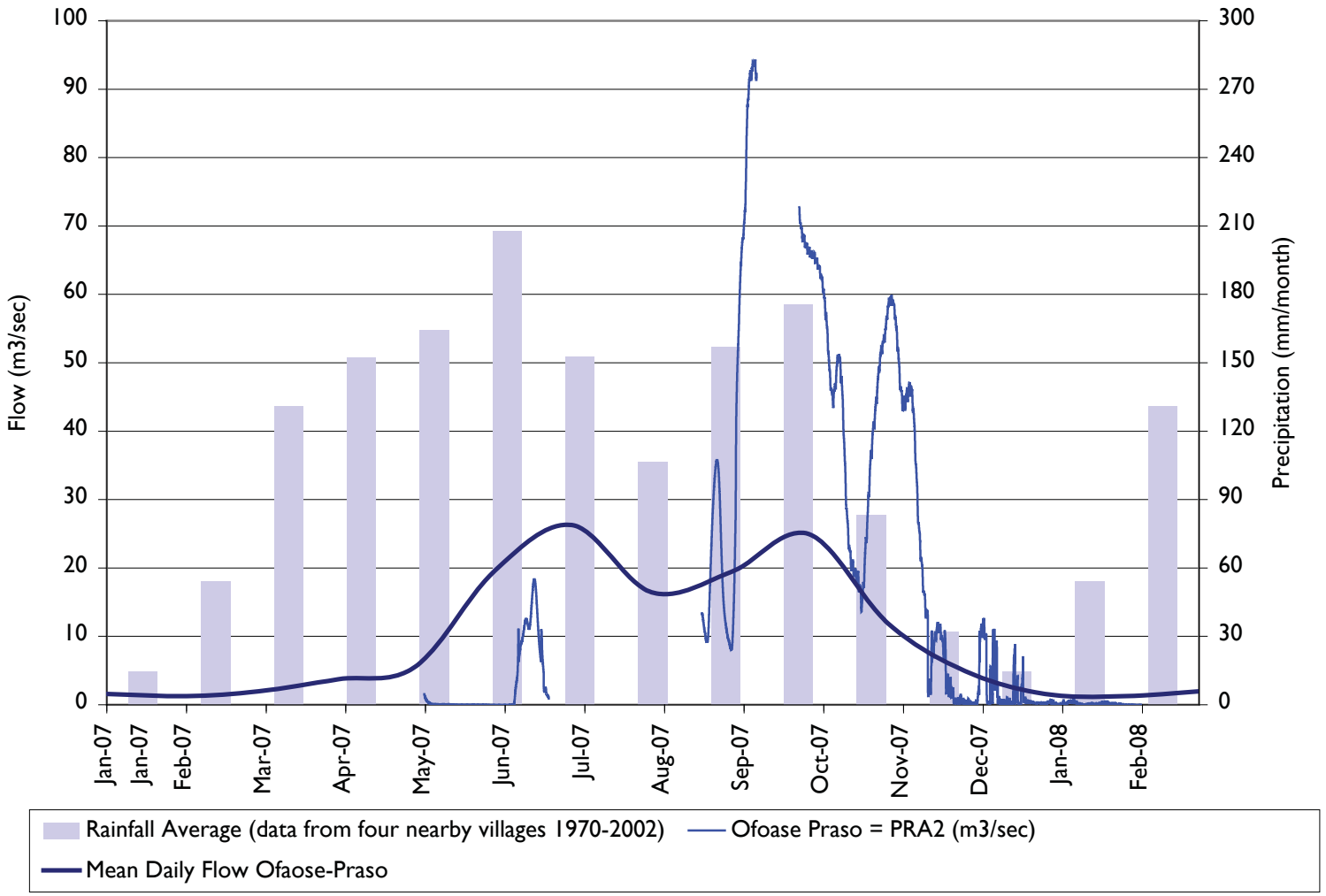
	Month												
Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean for the year
1960	NR	NR	6.4	10.3	7.5	30.2	23.2	15.4	12.4	69.0	26.1	10.6	21.1
1961	2.4	1.5	0.0	2.9	1.2	32.8	57.4	8.7	13.3	37.0	13.8	4.2	14.6
1962	0.4	0.0	NR	7.4	14.7	53.0	70.9	41.9	11.9	22.4	39.1	19.2	25.5
1963	6.5	5.1	5.7	5.3	6.0	26.9	62.3	53.1	54.4	87.8	23.1	8.8	28.8
1964	5.5	2.9	5.8	6.9	11.8	42.2	11.7	11.5	21.4	19.2	12.8	8.5	13.3
1965	3.6	5.1	4.5	5.8	6.6	40.3	37.5	35.1	39.1	46.0	NR	13.4	21.5
1966	5.0	3.1	5.4	9.1	6.2	18.9	70.7	26.5	28.8	38.2	20.2	9.7	20.1
1967	4.2	2.2	2.4	7.1	7.5	29.2	23.5	5.5	14.5	12.8	5.5	2.2	9.7
1968	1.1	1.1	1.1	2.0	9.3	38.5	82.5	80.9	113.8	NR	30.8	14.4	34.1
1970	NR	NR	5.2	4.7	9.4	10.8	6.5	2.3	11.2	25.4	20.8	4.5	10.1
1971	2.4	1.5	3.3	3.8	2.1	6.6	18.5	17.5	25.8	19.0	3.6	2.1	8.9
1972	1.1	0.7	1.7	11.2	13.1	32.3	12.4	8.7	5.8	13.8	3.9	2.3	8.9
1973	1.1	0.2	0.4	5.1	4.8	7.5	14.6	21.0	19.4	21.4	7.4	1.0	8.7
1974	0.2	0.7	0.4	2.1	0.6	0.4	2.8	18.3	33.5	19.2	8.9	1.1	7.4
1975	0.3	0.0	0.1	0.7	2.9	7.1	25.4	3.5	5.0	19.7	4.1	2.8	6.0
1976	0.3	0.2	0.7	0.3	2.8	33.4	8.1	1.4	2.2	NR	9.6	1.1	5.5
1977	0.2	0.0	0.0	0.0	0.0	4.1	1.6	0.0	0.4	19.8	0.8	0.1	2.2
1978	0.0	0.0	0.0	0.7	NR	27.9	0.7	0.1	9.1	12.1	3.9	0.0	4.9
1991	NR	NR	0.5	NR	16.3	NR	52.3	33.4	16.0	13.8	5.4	2.5	AE
1992	0.6	NR	NR	NR	7.0	1.9	3.3	0.9	6.9	32.9	12.6	1.3	7.5
1993	0.5	0.3	0.3	NR	NR	NR	NR	NR	NR	NR	7.1	1.2	AE
1994	0.3	0.3	0.3	0.5	0.6	1.3	3.5	3.3	1.9	3.5	7.2	3.6	2.2
1995	NR	NR	NR	3.2	5.3	NR	NR	NR	NR	22.7	13.6	2.2	AE
1996	0.0	0.0	0.7	1.1	0.9	6.0	25.2	5.8	9.0	18.1	4.9	2.3	6.2
1997	1.5	0.5	0.7	0.9	4.5	32.6	35.2	20.1	8.5	11.3	12.1	7.3	11.3
1998	1.8	3.7	NR	NR	NR	NR	NR	NR	NR	NR	2.0	2.1	AE
1999	1.4	0.9	1.4	0.9	1.6	15.3	37.1	4.2	23.5	17.0	13.4	4.1	10.1
Mean	***1.8***	***1.4***	***2.1***	***4.0***	***5.9***	***21.7***	***28.6***	***17.5***	***20.3***	***26.2***	***12.0***	***4.9***	12.5
Std	***1.9***	***1.6***	***2.3***	***3.4***	***4.6***	***15.6***	***25.1***	***19.7***	***23.7***	***19.3***	***9.5***	***4.9***	8.6
Max	***6.5***	***5.1***	***6.4***	***11.2***	***16.3***	***53.0***	***82.5***	***80.9***	***113.8***	***87.8***	***39.1***	***19.2***	34.1
Min	***0.0***	***0.0***	***0.0***	***0.0***	***0.0***	***0.4***	***0.7***	***0.0***	***0.4***	***3.5***	***0.8***	***0.0***	2.2



Flow Hydrograph for Pra River
at Ofoase-Praso (1960-1978 & 1991-1999)
Akyem Gold Mining Project
Eastern Region, Ghana
FIGURE C4-1



Flow Hydrograph for Pra River
at Prasokuma (Feb-June 2004 & May-Dec 2007)
Akyem Gold Mining Project
Eastern Region, Ghana
FIGURE C4-2



Flow Hydrograph for Pra River
at Ofoase-Praso (Feb-June 2004 & May-Dec 2007)
Akyem Gold Mining Project
Eastern Region, Ghana
FIGURE C4-3

SW-21 (PRA-1): Pra River at Praso Kuma (drainage area = 875 km^2)

- Feb-June 2004 flow measurements = 0.066 to 3.66 m^3/sec
- Minimum flow in May 2007 was zero m^3/sec
- Peak flows in September 2007 = 60 m^3/sec, with sustained flows >10 m^3/sec
- Calculated bankfull discharge = 62 m^3/sec

SW-27 (PRA-2): Pra River at Ofoase-Praso Bridge (drainage area = 2,045 km^2)

- 1991-1999 flow measurements = 0 to 107 m^3/sec
- Minimum flow in May 2007 was zero m^3/sec
- Peak flows in September-October = 80 m^3/sec, with sustained flows >20 m^3/sec
- Calculated bankfull discharge = 94 m^3/sec

Mamang River

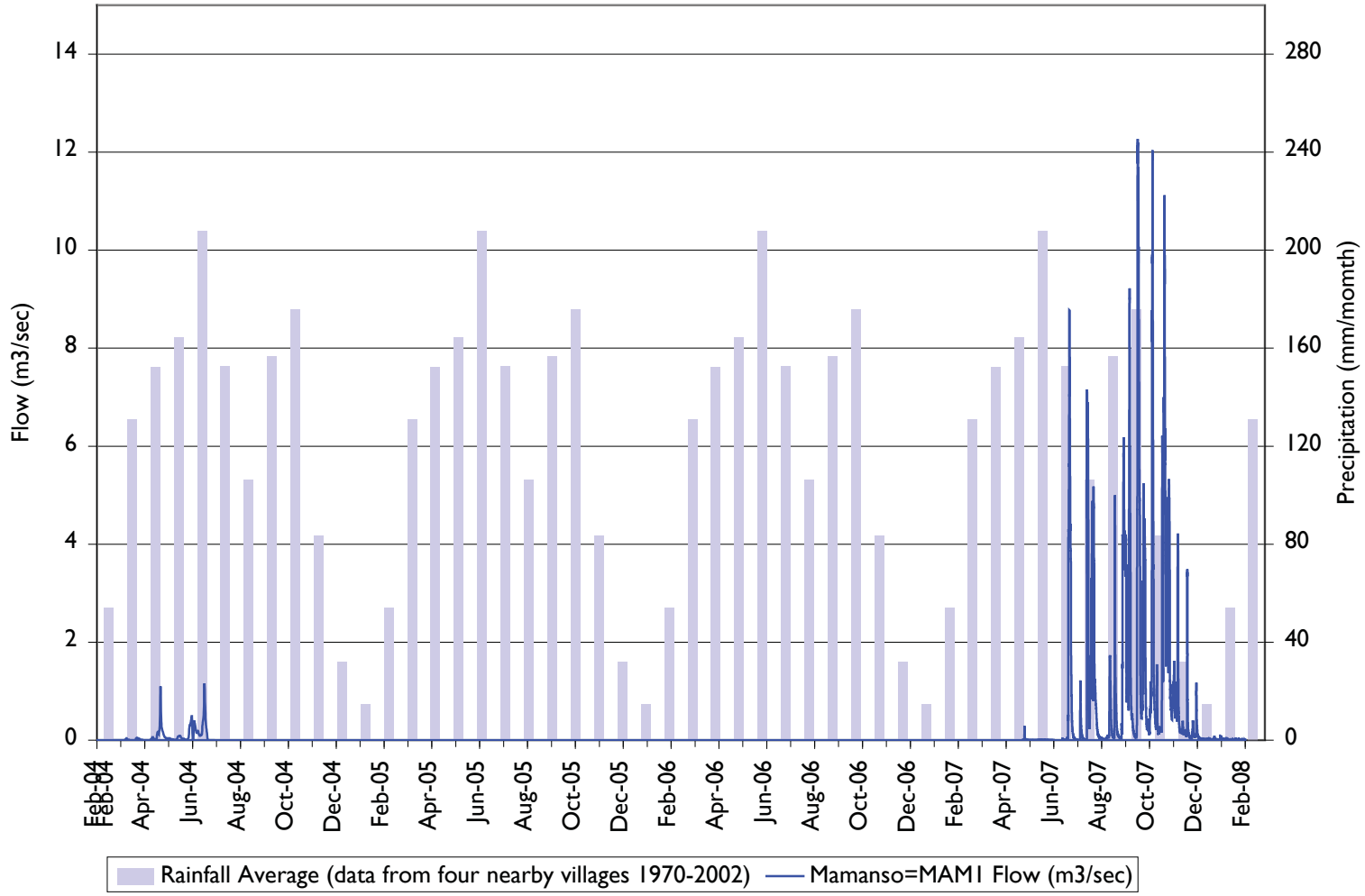
The Mamang River watershed covers an area of approximately 475 km^2. Mean monthly flows based on flow measured for the Pra River at Ofoase-Praso (2,045 km^2) were calculated by the area-ratio method for five locations within the Mamang basin, assuming the Pra and Mamang River basins have similar watershed characteristics. Mean monthly flow estimates for the Mamang River at three monitoring sites are summarized in **Table C4-3**. Using these monthly averages, mean annual discharge for the Mamang River at its mouth (SW-25, 475 km^2 watershed area) is 2.9 m^3/sec.

TABLE C4-3
Mean Monthly Flow Calculated for Mamang River and Tributaries

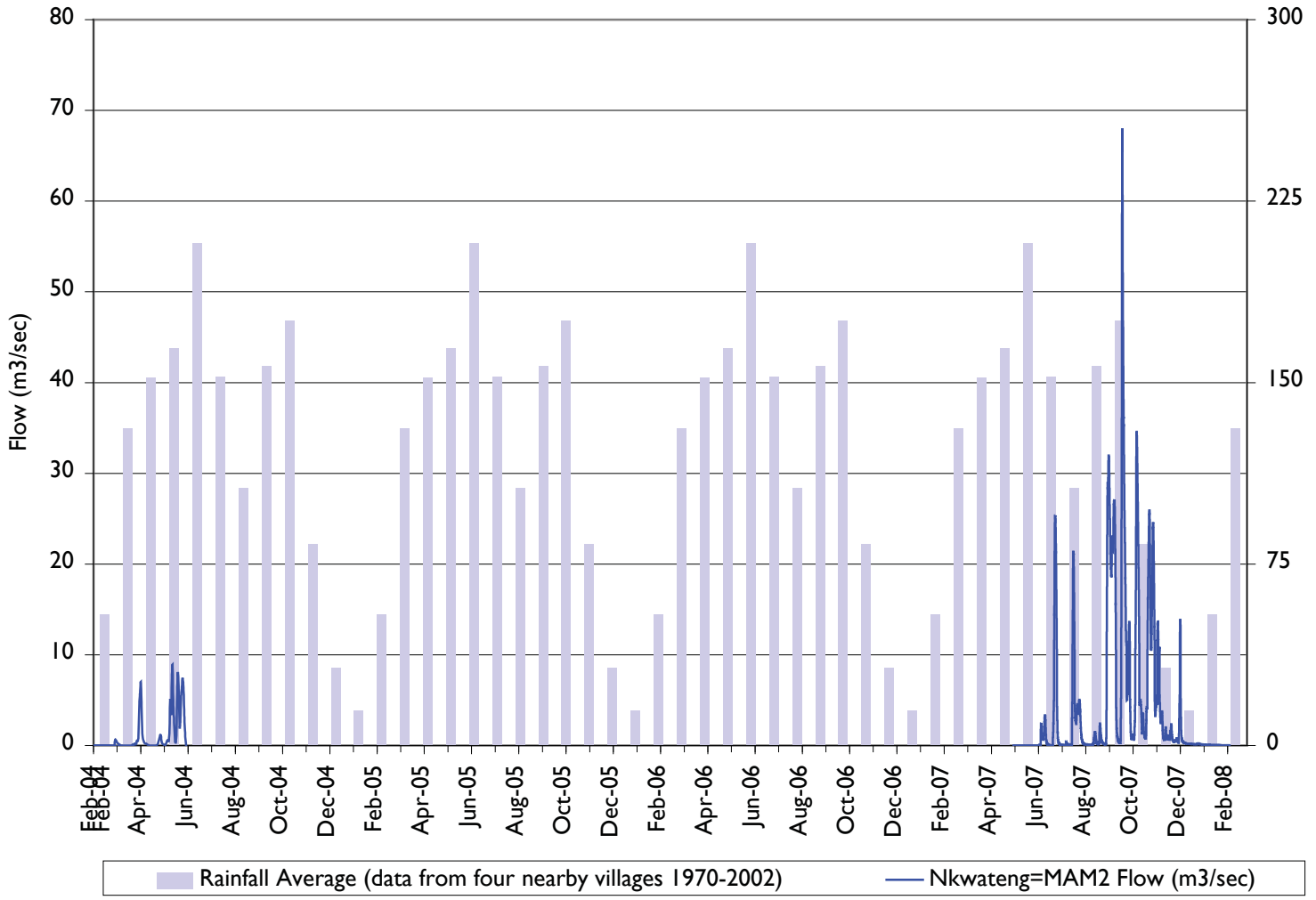
Surface Water Site & Watershed Area	Mean Monthly Flow ($metre^3$/second)												
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Mean
SW-25: Mamang River at Kotokuom (475 km^2)	0.42	0.32	0.49	0.93	1.37	5.04	6.64	4.06	4.71	6.08	2.78	1.14	2.90
SW-24: Mamang River at Nkwanten (384 km^2)	0.34	0.26	0.39	0.75	1.11	4.07	5.37	3.28	3.81	4.92	2.25	0.92	2.35
SW-28: Mamang River at Mamanso (98 km^2)	0.09	0.07	0.10	0.19	0.28	1.03	1.36	0.83	0.97	1.25	0.57	0.23	0.60
Adenkyerensu stream (10 km^2)	0.01	0.01	0.01	0.02	0.03	0.11	0.15	0.09	0.10	0.13	0.06	0.02	0.06
Afosu stream (7.4 km^2)	0.01	0.01	0.01	0.01	0.02	0.08	0.1	0.06	0.07	0.09	0.04	0.02	0.05

Source: SGS 2004g.

In April-May 2007, two continuous recording stream gauging stations were installed on the Mamang River by Clear Creek Consultants (2008b) at SW-28 (MAM-1, upstream) and SW-24 (MAM-2, downstream). **Figures C4-4** and **C4-5** are hydrographs for these stations showing flow measured in 2007, and some individual flow measurements in February-June 2004 and May-December 2007. The following are selected flow data for these two stations (Clear Creek Consultants 2008b):



Flow Hydrograph for Mamang River
at Mamanso (Feb-June 2004 & May-Dec 2007)
Akyem Gold Mining Project
Eastern Region, Ghana
FIGURE C4-4



Flow Hydrograph for Mamang River
at Nkwateng (Feb-June 2004 & May-Dec 2007)
Akyem Gold Mining Project
Eastern Region, Ghana
FIGURE C4-5

SW-28: Mamang River at Mamanso (drainage area = 98 km^2)

- April-June 2004 flow measurements = 0.009 – 0.56 m^3/sec
- Minimum flow in May 2007 was zero m^3/sec
- Peak flow in September 2007 = 12.2 m^3/sec, with flow receding to 0.05 m^3/sec by early December
- Calculated bankfull discharge = 12 m^3/sec

SW-24: Mamang River at Nkwanten (drainage area = 384 km^2)

- April-June 2004 flow measurements = 0.021 – 9.86 m^3/sec
- Minimum flow in May-early June was zero m^3/sec
- Peak flow in September 2007 = 68 m^3/sec, with flow receding to 0.5 m^3/sec by early December
- Calculated bankfull discharge = 32 m^3/sec

Tributary Streams

Principal tributary streams in the Study Area include the Afosu, Adentosu, Akwasi, and Adenkyerensu, all of which are ephemeral. Instantaneous flow measurements for tributary streams by Clear Creek Consultants (2008b) in July and October 2007 ranged from 0 to 0.5 m^3/sec. Calculated mean monthly flows for the Adenkyerensu and Afosu streams are presented in **Table C4-3**.

SURFACE WATER QUALITY

Laboratory analysis for metals in surface water samples was conducted at the SGS Laboratory in Amsterdam, Netherlands, while all other physio-chemical constituents were analyzed at the SGS Laboratory in Accra, Ghana. All laboratory analyses were performed in accordance with "Standard Methods for the Examination of Water and Wastewater" of the American Public Health Association (1995).

Water quality standards or guidelines for the parameters analyzed are presented in **Table C4-4**. These standards are associated with drinking water from the Ghana Standards Board/Ghana Water Company (GSB/GWC), United States Environmental Protection Agency (USEPA), and World Health Organisation (WHO). The drinking water standard with the lowest concentration for each parameter, if available, was used for comparison of analytical results in the attached statistical summaries.

Statistical summaries of chemical analyses of surface water samples collected from the 28 monitoring stations between 2001 and 2007 (SGS 2004g; Clear Creek Consultants 2008b) are presented in **Table C4-5**. These data are compared to the water quality standards and guidelines shown in **Table C4-4**. The statistical summaries of all surface water quality data are grouped into the following categories: Pra River, Pra River tributaries, Mamang River, Mamang River tributaries, and Afosu stream.

TABLE C4-4
Water Quality Standards and Guideline Values

Parameter	Drinking Water Standards or Guidelines (all units in milligrams per litre, unless otherwise noted)			
	U.S. Environmental Protection Agency		World Health Organisation (WHO)	Ghana GSB/GWC
	Primary	Secondary		
Aluminum	--	0.05 – 0.2	0.2	0.2
Antimony	0.006	--	0.020	0.005
Arsenic	0.01	--	0.010	0.010
Barium	2.0	--	0.7	0.7
Beryllium	0.004	--	--	--
Boron	--	--	0.5	0.3
Cadmium	0.005	--	0.003	0.003
Calcium	--	--	--	--
Chromium	0.1	--	0.05	0.05
Iron	--	0.3	--	0.3
Potassium	--	--	--	--
Copper	1.3	1.0	2.0	1.0
Mercury	0.002	--	0.006	0.001
Lead	0.015	--	0.01	0.01
Magnesium	--	--	--	--
Manganese	--	0.05	0.4	0.5
Molybdenum	--	--	0.07	--
Sodium	--	--	--	200
Nickel	--	--	0.07	0.02
Selenium	0.05	--	0.01	0.01
Thallium	0.002	--	--	--
Vanadium	--	--	--	--
Silver	--	0.1	--	--
Zinc	--	5.0	--	3.0
Total Dissolved Solids	--	500	--	1,000
Total Suspended Solids	--	--	--	50*
Total Phosphorus	--	--	--	--
Free Cyanide	0.2	--	0.07	0.01
Total Cyanide	--	--	--	1.0*
Chloride	--	250	--	250
Fluoride	4.0	2.0	1.5	1.5
Ammonium	--	--	--	1.0*
Nitrate	10	--	50	50
Nitrite	1.0	--	3.0	3.0
Sulfate	--	250	--	250
Color (Pt-Co Scale)	--	15	--	15
pH (std. unit)	--	6.5 – 8.5	--	6.5 – 8.5
Conductivity (uS/cm)	--	500	--	1,500*
Turbidity (NTU)	--	--	--	75*
Total Coliform (MPN/100 ml)	--	--	<2	--
Fecal Coliform (MPN/100 ml)	--	--	<2	--
BOD	--	--	--	50*
COD	--	--	--	250*

Notes:

1. GSB/GWC = Ghana Standards Board/Ghana Water Company.
2. uS/cm = microSiemens per centimeter; NTU = nephelometric turbidity units; MPN = most probable number; ml = millilitre; BOD = biochemical oxygen demand; COD = chemical oxygen demand.
3. Values with a single asterisk * are from Newmont Ghana Draft Memorandum Speed Limit Table, May 2, 2007. These values can be used when no other standards are available.

-- No standard available.

Table C4-5
Surface Water Chemistry (2001-2007)
Akyem Project
Eastern Region, Ghana

Surface Water	Statistic	Bicarbonate, as CaCO3 mg/L	Carbonate, as CaCO3 mg/L	Alkalinity, Total, as CaCO3 mg/L	Aluminum, Dissolved mg/L	Aluminum, Total mg/L	Ammonia, Undistilled mg/L	Antimony, Dissolved mg/L	Antimony, Total mg/L	Arsenic, Dissolved mg/L	Arsenic, Total mg/L	Barium, Dissolved mg/L
Afosu Stream	Total # Samples Analysed	23	23	48	16	61	26	17	25	19	41	18
	Total Non Detect	0	19	0	7	6	23	17	25	11	13	0
	Maximum	171	2.5	289	1.1	27.5	0.18	0.01U	0.01U	0.006	0.036	0.0394
	Mean	108	1	99	0.2	2	0.02	NA	NA	0.004	0.01	0.02
	Standard Deviation	28	1	45	0.3	4	0.04	NA	NA	0.002	0.01	0.01
Mamang Tributaries	Total # Samples Analysed	47	47	117	24	148	47	29	51	29	86	29
	Total Non Detect	0	38	0	9	9	33	22	42	16	25	0
	Maximum	192	2.5	259	2.2	24	0.25 [a]	0.01U	0.01U	0.01	0.0144	0.09
	Mean	113	1	93	0.4	2	1	0.006	0.003	0.005	0.004	0.05
	Standard Deviation	42	1	46	1	4	7	0.005	0.005	0.002	0.004	0.02
Mamang River	Total # Samples Analyzed	42	42	41	16	53	46	21	46	22	50	22
	Total Non Detect	0	42	0	5	3	31	20	42	13	20	0
	Maximum	223	2.5U	181	3.5	8	0.93 [a]	0.01U	0.01U	0.005	0.4	0.30
	Mean	74	NA	71	1	2	1.4	0.01	0.004	0.003	0.01	0.05
	Standard Deviation	35	NA	39	1	2	9	0.01	0.005	0.002	0.06	0.05
Pra River Tributaries	Total # Samples Analyzed	12	12	23	5	28	14	7	14	8	19	7
	Total Non Detect	0	10	0	0	2	10	5	12	5	7	0
	Maximum	189	2.5	152	1.4	18.1	0.59 [a]	0.01U	0.01U	0.005	0.02	0.08
	Mean	100	1	89	0.4	2	1	0.01	0.004	0.005	0.01	0.04
	Standard Deviation	45	1	31	1	3	2	0.01	0.005	0.001	0.004	0.02
Pra River	Total # Samples Analyzed	33	33	44	16	54	38	20	39	23	42	20
	Total Non Detect	0	29	0	7	3	29	20	37	13	19	0
	Maximum	104	2.5	182	2.3	15.9	0.06	0.01U	0.01	0.005	0.01	0.04
	Mean	68	1	72	1	2	0.01	NA	0.004	0.003	0.005	0.03
	Standard Deviation	14	1	30	1	3	0.01	NA	0.005	0.002	0.004	0.005
Water Quality Standards	USEPA MCL PRIMARY							0.006	0.006	0.01	0.01	2
	USEPA MCL SECONDARY				0.05 to 0.2	0.05 to 0.2						
	WHO DWG				0.2	0.2		0.02	0.02	0.01	0.01	0.7
	GSB/GWC DWG				0.2	0.2		0.005	0.005	0.01	0.01	0.7

Note: mg/L = milligrams per liter.

a = anomalous values from March 2004 were discarded; value shown is second highest maximum in data set.

U = value is detection limit
NA = not applicable
ND = no data
Shaded cell: value exceeds lowest std.

USEPA = U.S. Environmental Protection Agency
WHO = World Health Org.
DWG = Drinking Water Goal
GSB/GWC = Ghana Stds Board and Water Co.

Table C4-5
Surface Water Chemistry (2001-2007)
Akyem Project
Eastern Region, Ghana

Surface Water	Statistic	Beryllium, Dissolved mg/L	Beryllium, Total mg/L	Bismuth, Total mg/L	Bismuth, Dissolved mg/L	Boron, Dissolved mg/L	Boron, Total mg/L	Cadmium, Dissolved mg/L	Cadmium, Total mg/L	Calcium mg/L	Chloride mg/L	Chlorine, Total mg/L	Chromium, Dissolved mg/L	Chromium, Total mg/L
Afosu Stream	Total # Samples Analysed	18	26	10	13	10	11	18	33	33	27	62	17	33
	Total Non Detect	18	25	6	10	9	10	15	26	0	0	0	8	16
	Maximum	0.005U	0.005U	0.00003	0.00003	0.1	0.1	0.0008	0.01U	55	17	18	0.04	0.05
	Mean	NA	NA	0.00002	0.00001	NA	NA	0.0004	0.002	20	6	3	0.005	0.006
	Standard Deviation	NA	NA	0.00001	0.00001	NA	NA	0.0004	0.004	10	4	4	0.009	0.009
Mamang Tributaries	Total # Samples Analysed	32	49	11	30	21	19	29	75	66	54	140	29	72
	Total Non Detect	29	49	9	27	21	18	27	49	0	2	0	16	37
	Maximum	0.016	0.005U	0.00001	0.00004	0.1U	0.10	0.0008	0.01	51.6	24.1	21.8	0.0056	0.16
	Mean	0.004	NA	0.00001	0.00001	NA	NA	0.001	0.003	22	9	3	0.004	0.009
	Standard Deviation	0.004	NA	2.03E-13	5.71E-06	NA	NA	0.0004	0.004	9	6	4	0.001	0.019
Mamang River	Total # Samples Analyzed	21	46	10	25	11	20	21	48	46	46	17	21	45
	Total Non Detect	21	46	10	22	11	15	19	28	0	5	3	9	20
	Maximum	0.005U	0.005U	0.00001U	0.00002	0.1U	0.125	0.0008	0.01U	34.7	48.7	43.2	0.0082	0.017
	Mean	NA	NA	NA	0.00001	NA	0.09	0.0004	0.001	12	8	6	0.003	0.004
	Standard Deviation	NA	NA	NA	3.3E-06	NA	0.03	0.0004	0.002	6	10	13	0.002	0.004
Pra River Tributaries	Total # Samples Analyzed	7	14	3	9	4	7	7	16	15	15	18	7	16
	Total Non Detect	7	14	3	9	4	5	6	11	0	0	0	4	8
	Maximum	0.005U	0.005U	0.00001U	0.00001U	0.1U	0.1	0.0008	0.01U	31.4	22.3	18	0.005	0.011
	Mean	NA	NA	NA	NA	NA	0.08	NA	0.002	20	14	3	0.004	0.004
	Standard Deviation	NA	NA	NA	NA	NA	0.04	NA	0.003	8	6	5	0.002	0.004
Pra River	Total # Samples Analyzed	20	39	10	23	9	19	20	38	41	39	24	20	38
	Total Non Detect	20	39	10	22	9	15	17	23	0	1	3	9	17
	Maximum	0.005U	0.005U	0.00001U	0.00002	0.1U	0.1	0.0008	0.003	43.6	15	26.7	0.0078	0.012
	Mean	NA	NA	NA	NA	NA	0.08	0.0004	0.001	13	5	7	0.003	0.003
	Standard Deviation	NA	NA	NA	NA	NA	0.04	0.0004	0.001	7	4	9	0.002	0.003
Water Quality Standards	USEPA MCL PRIMARY	0.004	0.004					0.005	0.005				0.1	0.1
	USEPA MCL SECONDARY										250			
	WHO DWG					0.5	0.5	0.003	0.003				0.05	0.05
	GSB/GWC DWG					0.3	0.3	0.003	0.003		250		0.05	0.05

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NA = not applicable
ND = no data
Shaded cell: value exceeds lowest std.

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GSB/GWC = Ghana Stds Board and Water Co.

Table C4-5
Surface Water Chemistry (2001-2007)
Akyem Project
Eastern Region, Ghana

Surface Water	Statistic	COD mg/L	Cobalt, Dissolved mg/L	Cobalt, Total mg/L	Copper, Dissolved mg/L	Copper, Total mg/L	Cyanide, Total mg/L	Cyanide, Free mg/L	Fluoride, Undistilled mg/L	Hardness, as CaCO3 mg/L	Iron, Dissolved mg/L	Iron, Total mg/L	Lead, Dissolved, mg/L	Lead, Total mg/L	Magnesium mg/L
Afosu Stream	Total # Samples Analysed	26	18	26	18	86	24	31	44	70	17	83	15	30	33
	Total Non Detect	0	10	12	10	17	24	27	5	0	2	0	10	9	0
	Maximum	301	0.01	0.011	0.006	2.35	0.01U	0.031	1	341	14.6	50.7	0.005	0.01	44
	Mean	45	0.01	0.004	0.003	0.14	NA	0.01	0	96	1	5	0	0	11
	Standard Deviation	65	0.00	0.004	0.002	0.38	NA	0.01	0	65	3	8	0	0	7
Mamang Tributaries	Total # Samples Analysed	48	29	52	29	190	43	64	91	164	24	189	21	70	66
	Total Non Detect	0	17	24	17	41	42	47	10	0	1	0	18	33	0
	Maximum	336	0.0177	0.0182	0.011	4.8	0.01	0.012	3.6	456	3.6	130	0.005	0.0126	25
	Mean	47	0.009	0.005	0.004	0.1	NA	0.007	0	95	1	5	0	0	10
	Standard Deviation	72	0.003	0.004	0.003	0.5	NA	0.004	0	66	1	11	0	0	5
Mamang River	Total # Samples Analyzed	37	21	46	21	55	41	42	47	54	17	51	16	42	46
	Total Non Detect	0	11	19	8	22	41	42	0	0	0	0	11	6	0
	Maximum	265	0.01	0.024	0.044	1.45	0.01U	0.01U	0.8	202	3.7	21	0.005	0.0119	28
	Mean	48	0.006	0.004	0.006	0.03	NA	NA	0	57	2	5	0	0	6
	Standard Deviation	40	0.005	0.005	0.009	0.2	NA	NA	0	31	1	3	0	0	4
Pra River Tributaries	Total # Samples Analyzed	13	7	14	7	30	11	13	16	29	5	29	5	16	15
	Total Non Detect	0	4	6	2	8	11	13	3	0	0	1	4	5	0
	Maximum	242	0.01	0.01	0.007	2.1	0.01U	0.01U	0.5	251.3	1.4	39	0.005	0.01	10.6
	Mean	44	0.01	0.004	0.004	0.11	NA	NA	0	88	1	4	0	0	7
	Standard Deviation	62	0.004	0.004	0.003	0.39	NA	NA	0	43	1	8	0	0	2
Pra River	Total # Samples Analyzed	30	20	37	20	57	35	36	39	53	16	54	14	38	41
	Total Non Detect	0	9	17	9	17	35	35	7	0	0	0	9	4	0
	Maximum	70.3	0.01	0.01	0.005	0.89	0.01U	2.83	0.9	158.3	2.1	26.3	0.005	0.01	14.6
	Mean	29	0.005	0.003	0.003	0.04	NA	NA	0	60	1	4	0	0	5
	Standard Deviation	17	0.005	0.003	0.002	0.1	NA	NA	0	28	1	4	0	0	2
Water Quality Standards	USEPA MCL PRIMARY				1.3	1.3		0.2	4				0.015	0.015	
	USEPA MCL SECONDARY				1	1			2		0.3	0.3			
	WHO DWG				2	2		0.07	1.5				0.01	0.01	
	GSB/GWC DWG				1	1		0.01	1.5		0.3	0.3	0.01	0.01	

U = value is detection limit
NA = not applicable
ND = no data
Shaded cell: value exceeds lowest std.

USEPA = U.S. Environmental Protection Agency
WHO = World Health Org.
DWG = Drinking Water Goal
GSB/GWC = Ghana Stds Board and Water Co.

Table C4-5
Surface Water Chemistry (2001-2007)
Akyem Project
Eastern Region, Ghana

Surface Water	Statistic	Manganese, Dissolved mg/L	Manganese, Total mg/L	Mercury, Dissolved mg/L	Mercury, Total mg/L	Molybdenum, Dissolved mg/L	Molybdenum, Total mg/L	Nickel, Dissolved mg/L	Nickel, Total mg/L	Nitrate mg/L	Nitrite mg/L	Ortho-phosphorous mg/L	Phosphorous, Total mg/L	Phosphate mg/L	Potassium mg/L
Afosu Stream	Total # Samples Analysed	20	81	18	27	18	24	18	36	86	75	16	11	85	33
	Total Non Detect	0	1	14	24	18	24	10	16	7	24	6	6	11	0
	Maximum	1	21	0.0002	0.002	0.01	0.01U	0.01	0.3	14.5	67	0.04	0.22	2	9.8
	Mean	0	1	0.000	0.000	0.006	NA	0.006	0.03	1	2	0	0	0	2
	Standard Deviation	0	3	0.000	0.000	0.005	NA	0.004	0.07	3	10	0	0	1	2
Mamang Tributaries	Total # Samples Analysed	31	183	29	60	31	47	29	83	193	182	33	19	198	66
	Total Non Detect	1	4	24	55	31	45	18	33	13	37	11	5	25	0
	Maximum	2	48	0.0003	0.002	0.01U	0.028	0.0139	1	35	151	1.5	1.3	136	24
	Mean	1	1	0.0001	0.0003	NA	0.005	0.009	0.07	2	2	0	0	1	5
	Standard Deviation	1	5	0.0001	0.0004	NA	0.006	0.003	0.184	4	13	0	0	10	5
Mamang River	Total # Samples Analyzed	21	56	21	39	21	42	21	43	54	54	26	16	52	46
	Total Non Detect	0	5	16	32	21	41	11	21	1	25	0	0	0	0
	Maximum	0.19	7	0.0002	0.001	0.01U	0.052	0.01	0.08	2.7	1	0.69	0.55	1.76	19
	Mean	0	0	0.0001	0.0002	0.006	0.005	0.007	0.007	1	0	0	0	0	6
	Standard Deviation	0	1	0.0001	0.0002	0.005	0.009	0.003	0.012	1	0	0	0	0	4
Pra River Tributaries	Total # Samples Analyzed	7	31	7	14	8	12	7	16	32	31	8	6	30	15
	Total Non Detect	0	0	6	13	8	12	4	8	0	8	3	1	3	0
	Maximum	2	4	0.0002	0.001	0.01U	0.01	0.01	0.061	2.7	20	0.06	0.28	2	16
	Mean	1	1	0.0001	NA	NA	NA	0.007	0.010	0	1	0	0	0	7
	Standard Deviation	1	1	0.0001	NA	NA	NA	0.004	0.016	1	4	0	0	0	5
Pra River	Total # Samples Analyzed	20	58	19	34	20	33	20	34	58	56	20	16	52	41
	Total Non Detect	1	4	14	34	20	33	9	21	4	27	1	0	2	0
	Maximum	0.12	2	0.00042	0.0002U	0.01U	0.01	0.01	0.01	1.81	0.12	0.21	0.36	0.87	10
	Mean	0	0	0.0001	NA	NA	NA	0.005	0.004	0	0	0	0	0	5
	Standard Deviation	0	0	0.0001	NA	NA	NA	0.004	0.004	0	0	0	0	0	2
Water Quality Standards	USEPA MCL PRIMARY			0.002	0.002					10	1				
	USEPA MCL SECONDARY	0.05	0.05												
	WHO DWG	0.4	0.4	0.006	0.006	0.07	0.07	0.07	0.07	50	3				
	GSB/GWC DWG	0.5	0.5	0.001	0.001			0.02	0.02	50	3				

U = value is detection limit
NA = not applicable
ND = no data
Shaded cell: value exceeds lowest std.

USEPA = U.S. Environmental Protection Agency
WHO = World Health Org.
DWG = Drinking Water Goal
GSB/GWC = Ghana Stds Board and Water Co.

Table C4-5
Surface Water Chemistry (2001-2007)
Akyem Project
Eastern Region, Ghana

Surface Water	Statistic	Salinity mg/L	Selenium, Dissolved mg/L	Selenium, Total mg/L	Silver, Dissolved mg/L	Silver, Total mg/L	Silica mg/L	Sodium mg/L	Strontium, Dissolved mg/L	Strontium, Total mg/L	Sulfate mg/L	Thallium, Dissolved mg/L	Thallium, Total mg/L	Tin, Dissolved mg/L	Tin, Total mg/L	Tungsten, Total mg/L	Tungsten, Dissolved mg/L
Afosu Stream	Total # Samples Analysed	56	18	26	9	10	43	33	7	9	74	18	24	10	15	7	9
	Total Non Detect	0	15	19	9	10	0	0	0	0	6	18	23	8	11	4	6
	Maximum	1.6	0.01	0.01	0.01U	0.01U	71.2	40.3	0.125	0.121	114	0.02U	0.01U	0.0001	0.01	0.00001	0.00003
	Mean	0.16	0.01	0.00	NA	NA	24	12	0	0	8	NA	0.0042	0.00004	0.0007	0.00001	0.00001
	Standard Deviation	0.21	0.005	0.005	NA	NA	14	7	0	0	15	NA	0.01	0.00004	0.0026	1.3E-13	0.00001
Mamang Tributaries	Total # Samples Analysed	118	29	51	18	22	98	66	11	19	183	32	45	14	30	11	19
	Total Non Detect	0	20	35	18	22	0	0	0	0	5	30	36	7	22	8	15
	Maximum	160	0.01	0.02	0.01U	0.01U	85	29.3	0.282	0.294	91.5	0.02U	0.072	0.0001	0.00019	0.00003	0.00002
	Mean	2	0.007	0.004	NA	NA	26	13	0	0	11	0.01	0.01	0.00003	0.0000	0.00001	0.00001
	Standard Deviation	15	0.005	0.005	NA	NA	18	7	0	0	16	0.01	0.01	0.00004	0.0000	0.00001	3.2E-06
Mamang River	Total # Samples Analyzed	9	22	42	11	19	40	46	10	15	53	21	41	13	32	10	15
	Total Non Detect	0	16	30	11	19	0	0	0	0	5	20	39	9	28	10	14
	Maximum	0.2	0.01	0.03	0.01U	0.01U	59.5	45	0.158	0.153	24.4	0.02U	0.03	0.0001	0.01	0.00001U	0.0134
	Mean	0.111	0.005	0.005	NA	NA	15	13	0	0	6	NA	0.0044	0.00005	0.0016	NA	NA
	Standard Deviation	0.033	0.005	0.006	NA	NA	9	8	0	0	5	NA	0.01	0.00004	0.0037	NA	NA
Pra River Tributaries	Total # Samples Analyzed	17	7	14	4	7	14	15	3	5	31	9	11	3	10	3	5
	Total Non Detect	0	5	10	4	6	0	0	0	0	0	8	10	2	9	3	5
	Maximum	0.3	0.01	0.01	0.01U	0.01	75.7	32	0.245	0.246	70.7	0.02U	0.01U	0.0001	0.01	0.00001U	0.00001U
	Mean	0.124	0.006	0.004	NA	0.007	22	19	0	0	12	NA	NA	NA	NA	NA	NA
	Standard Deviation	0.056	0.005	0.005	NA	0.004	17	9	0	0	14	NA	NA	NA	NA	NA	NA
Pra River	Total # Samples Analyzed	15	20	38	9	19	29	41	9	12	58	20	36	12	29	9	12
	Total Non Detect	0	14	29	9	17	0	0	0	0	9	20	36	9	23	8	10
	Maximum	0.1	0.01	0.01	0.01U	0.01	20.2	25.3	0.126	0.125	41	0.02U	0.01U	0.0001	0.017	0.00001	0.00007
	Mean	0.094	0.005	0.005	NA	0.008	12	10	0	0	6	NA	NA	0.00004	0.0023	NA	0.00002
	Standard Deviation	0.023	0.005	0.005	NA	0.004	4	5	0	0	6	NA	NA	0.00004	0.0047	NA	0.00002
Water Quality Standards	USEPA MCL PRIMARY		0.05	0.05								0.002	0.002				
	USEPA MCL SECONDARY				0.1	0.1					250						
	WHO DWG		0.01	0.01													
	GSB/GWC DWG		0.01	0.01				200			250						

Note: mg/L = milligrams

U = value is detection limit
NA = not applicable
ND = no data
Shaded cell: value exceeds lowest std.

USEPA = U.S. Environmental Protection Agency
WHO = World Health Org.
DWG = Drinking Water Goal
GSB/GWC = Ghana Stds Board and Water Co.

Table C4-5
Surface Water Chemistry (2001-2007)
Akyem Project
Eastern Region, Ghana

Surface Water	Statistic	Uranium, Total mg/L	Uranium, Dissolved mg/L	Vanadium, Dissolved mg/L	Vanadium, Total mg/L	Zinc, Dissolved mg/L	Zinc, Total mg/L	Fecal Coliform MPN/100ml	Total Coliform MPN/100ml
Afosu Stream	Total # Samples Analysed	18	22	16	18	21	82	19	19
	Total Non Detect	14	12	9	6	4	7	10	2
	Maximum	0.05	0.05	0.01	0.036	0.06	0.67	900	1600
	Mean	0.03	0.02	0.01	0.01	0.02	0.09	104	580
	Standard Deviation	0.03	0.03	0.00	0.01	0.02	0.11	229	679
Mamang Tributaries	Total # Samples Analysed	29	48	29	37	33	179	39	38
	Total Non Detect	19	25	18	13	6	11	17	3
	Maximum	0.05	0.05	0.01	0.031	0.07	6.1	1600	1600
	Mean	0.03	0.02	0.01	0.01	0.03	0.14	118	503
	Standard Deviation	0.02	0.02	0.00	0.01	0.02	0.47	276	631
Mamang River	Total # Samples Analyzed	21	36	21	26	23	55	33	33
	Total Non Detect	11	14	11	6	2	7	15	9
	Maximum	0.05	0.05	0.01	0.018	0.322	0.6	900	1600
	Mean	0.03	0.02	0.01	0.01	0.05	0.06	82	276
	Standard Deviation	0.03	0.02	0.00	0.00	0.06	0.12	179	482
Pra River Tributaries	Total # Samples Analyzed	7	13	7	9	9	29	11	11
	Total Non Detect	5	7	4	3	2	3	4	1
	Maximum	0.05	0.05	0.01	0.013	0.083	0.3	500	1600
	Mean	0.03	0.02	0.01	0.01	0.03	0.07	79	471
	Standard Deviation	0.03	0.02	0.00	0.01	0.02	0.09	150	618
Pra River	Total # Samples Analyzed	18	32	18	21	22	57	30	30
	Total Non Detect	9	12	9	6	4	8	19	9
	Maximum	0.05	0.05	0.01	0.016	0.071	1.1	1600	1600
	Mean	0.03	0.01	0.01	0.01	0.03	0.11	114	325
	Standard Deviation	0.03	0.02	0.005	0.01	0.02	0.20	313	594
Water Quality Standards	USEPA MCL PRIMARY	0.03	0.03						
	USEPA MCL SECONDARY					5	5		
	WHO DWG							2	2
	GSB/GWC DWG					3	3		

ıs per liter; MPN = most probable number; ml = milliliter.

U = value is detection limit
NA = not applicable
ND = no data
Shaded cell: value exceeds lowest std.

USEPA = U.S. Environmental Protection Agency
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GSB/GWC = Ghana Stds Board and Water Co.

Ionic chemistry of surface water was examined by plotting major cation and ion data on trilinear, or Piper, diagrams. The diagram for the Pra River and its tributaries using water quality data from the statistical summaries is presented in **Figure C4-6**. The Piper diagram for the Mamang River and tributaries is shown in **Figure C4-7**.

Bicarbonate is the dominant anion in surface water samples from the Pra River, Mamang River, and their tributaries. None of the major cations (i.e., calcium (Ca), magnesium (Mg), sodium (Na), and potassium (K)) used for the analysis was dominant. There is more variability in the ionic chemistry of samples from the Mamang River compared to Pra River samples; however, the variability is low in both drainages. The following trends in ionic chemistry were noted:

- Relative increase in sodium in dry season samples compared to wet season samples. This may be due to an increase in the influence of groundwater chemistry during low surface water flow conditions.

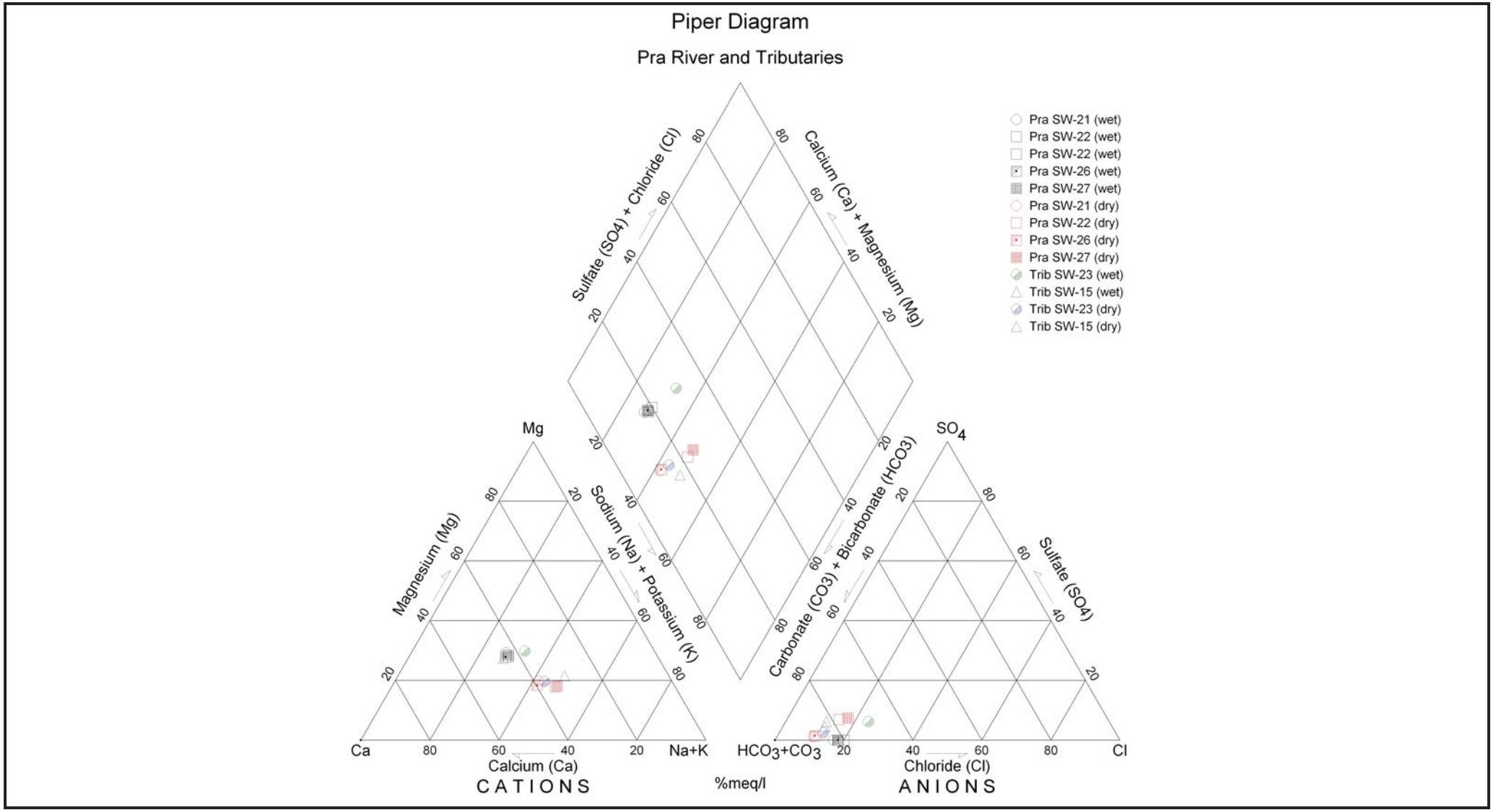
- In tributary streams, there is a relative increase in bicarbonate in dry season samples compared to wet season samples. This trend is not apparent in main stem samples from the Pra River and Mamang River.

- An apparent linear trend exists in the cation data between sodium and calcium/magnesium, which may be due to cation exchange reactions or the relative influence of groundwater on river water chemistry.

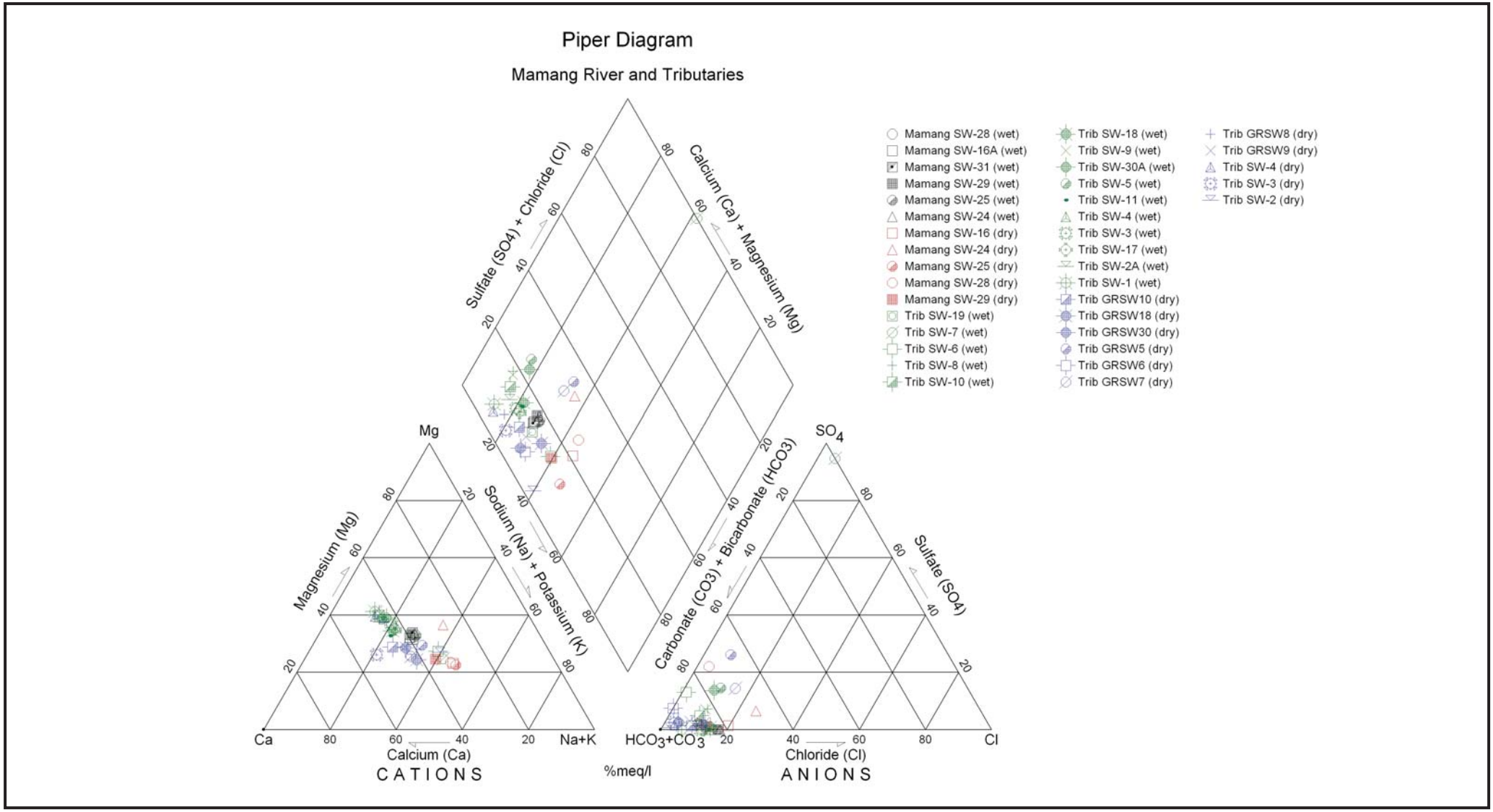
SPRINGS AND SEEPS

For the 10 spring/seep locations established in 2007 by Clear Creek Consultants (2008c), three sampling events were conducted during early-March, late-July, and mid-November. Statistical summaries of chemical analyses of spring/seep water samples collected in 2007 are presented in **Table C4-6**. These data are compared to the water quality standards and guidelines shown in **Table C4-4**.

A trilinear Piper diagram for all of the spring/seep water quality data using the statistical summaries is presented in **Figure C4-8**. Bicarbonate is the dominant anion in the samples. None of the major cations (i.e. Ca, Mg, Na, K) used for the analysis was dominant. An exception to this generalization is the sample from Adentosu (ADET-1) which has a dominant sulfate anion.



Piper Diagram for Pra River
and Tributaries
Akyem Gold Mining Project
Eastern Region, Ghana
FIGURE C4-6



Piper Diagram for Mamang River
and Tributaries
Akyem Gold Mining Project
Eastern Region, Ghana
FIGURE C4-7

Table C4-6
Seep Chemistry (2007)
Akyem Project
Eastern Region, Ghana

Seep Water	Statistic	Bicarbonate, as CaCO3 mg/L	Carbonate, as CaCO3 mg/L	Alkalinity, Total, as CaCO3 mg/L	Aluminum, Dissolved mg/L	Aluminum, Total mg/L	Ammonia, Undistilled, mg/L	Antimony, Dissolved mg/L	Antimony, Total mg/L	Arsenic, Dissolved mg/L	Arsenic, Total mg/L	Barium, Dissolved mg/L	Barium, Total mg/L	Beryllium, Dissolved mg/L	Beryllium, Total mg/L
All Seep Samples	Total # Samples Analysed	18	18	18	18	18	18	18	18	18	18	18	18	18	18
	Total # Non Detect	0	18	0	7	3	14	18	18	18	18	3	8	18	18
	Maximum	220	2.5U	360	2.3	15	0.083	0.01U	0.01U	0.005U	0.01U	0.051	0.1	0.005U	0.005U
	Mean	133.7	2.50	220	0.22	1.70	0.02	NA	NA	NA	NA	0.02	0.03	NA	NA
	Standard Deviation	58.5	0	96	0.570	3.840	0.018	NA	NA	NA	NA	0.012	0.019	NA	NA
Water Quality Standards	USEPA MCL PRIMARY							0.006	0.006	0.01	0.01	2	2	0.004	0.004
	USEPA MCL SECONDARY				0.05 to 0.2	0.05 to 0.2									
	WHO DWG				0.2	0.2		0.02	0.02	0.01	0.01	0.7	0.7		
	GSB/GWC DWG				0.2	0.2		0.005	0.005	0.01	0.01	0.7	0.7		

Note: mg/L = milligrams per liter.

U = value is detection limit
NA = not applicable
ND = no data
Shaded cell: value exceeds lowest std.

USEPA = U.S. Environmental Protection Agency
WHO = World Health Org.
DWG = Drinking Water Goal
GSB/GWC = Ghana Stds Board and Water Co.

Table C4-6
Seep Chemistry (2007)
Akyem Project
Eastern Region, Ghana

Seep Water	Statistic	Boron, Dissolved mg/L	Boron, Total mg/L	Cadmium, Dissolved mg/L	Cadmium, Total mg/L	Calcium mg/L	Chloride mg/L	Chromium, Dissolved mg/L	Chromium, Total mg/L	Cobalt, Dissolved mg/L	Cobalt, Total mg/L	Copper, Dissolved mg/L	Copper, Total mg/L	Fluoride, Undistilled mg/L	Hardness, as CaCO3 mg/L
All Seep Samples	Total # Samples Analysed	18	18	18	18	18	18	18	18	18	18	18	18	18	18
	Total # Non Detect	18	17	18	18	0	0	13	8	18	0	17	16	9	0
	Maximum	0.1U	0.12	0.0008U	0.001U	42	23	0.025	0.032	0.01U	0.005	0.013	0.021	0.17	11
	Mean	NA	NA	NA	NA	23.61	11.6	0.01	0.01	NA	0.01	NA	0.01	0.12	6.43
	Standard Deviation	NA	NA	NA	NA	9.993	4.6	0.005	0.008	NA	0.000	NA	0.003	0.024	2.850
Water Quality Standards	USEPA MCL PRIMARY			0.005	0.005			0.1	0.1			1.3	1.3	4	
	USEPA MCL SECONDARY						250					1	1	2	
	WHO DWG	0.5	0.5	0.003	0.003			0.05	0.05			2	2	1.5	
	GSB/GWC DWG	0.3	0.3	0.003	0.003		250	0.05	0.05			1	1	1.5	

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Shaded cell: value exceeds lowest std.

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Table C4-6
Seep Chemistry (2007)
Akyem Project
Eastern Region, Ghana

Seep Water	Statistic	Iron, Dissolved mg/L	Iron, Total mg/L	Lead, Dissolved mg/L	Lead, Total mg/L	Magnesium mg/L	Manganese, Dissolved mg/L	Manganese, Total mg/L	Mercury, Dissolved mg/L	Mercury, Total mg/L	Molybdenum, Dissolved mg/L	Molybdenum, Total mg/L	Nickel, Dissolved mg/L	Nickel, Total mg/L
All Seep Samples	Total # Samples Analysed	18	18	18	18	18	18	18	18	18	18	18	18	18
	Total # Non Detect	4	0	13	8	0	10	2	18	18	17	18	17	17
	Maximum	1.5	7.7	0.017	0.1	24	0.092	0.13	0.0001U	0.00005U	0.012	0.01U	0.015	0.011
	Mean	0.28	1.62	0.01	0.02	13.59	0.03	0.04	NA	NA	NA	NA	NA	NA
	Standard Deviation	0.510	2.347	0.004	0.023	6.475	0.030	0.037	NA	NA	NA	NA	NA	NA
Water Quality Standards	USEPA MCL PRIMARY			0.015	0.015				0.002	0.002				
	USEPA MCL SECONDARY	0.3	0.3				0.05	0.05						
	WHO DWG			0.01	0.01		0.4	0.4	0.006	0.006	0.07	0.07	0.07	0.07
	GSB/GWC DWG	0.3	0.3	0.01	0.01		0.5	0.5	0.001	0.001			0.02	0.02

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NA = not applicable
ND = no data
Shaded cell: value exceeds lowest std.

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Table C4-6
Seep Chemistry (2007)
Akyem Project
Eastern Region, Ghana

Seep Water	Statistic	Nitrate mg/L	Nitrite mg/L	Ortho-Phosphorous mg/L	Phosphorous, Total mg/L	Potassium mg/L	Selenium, Dissolved mg/L	Selenium, Total mg/L	Silver, Dissolved mg/L	Silver, Total mg/L	Silica mg/L	Sodium mg/L	Sulfate mg/L
All Seep Samples	Total # Samples Analysed	18	18	18	18	18	18	18	18	18	18	18	18
	Total # Non Detect	0	0	12	11	0	18	18	18	18	0	0	0
	Maximum	1.2	0.082	0.82	1.2	3.7	0.01U	0.01U	0.01U	0.01U	22	13	34
	Mean	0.43	0.01	0.06	0.18	1.15	NA	NA	NA	NA	14.4	8.8	13.9
	Standard Deviation	0.305	0.017	0.190	0.258	0.887	NA	NA	NA	NA	4.5	2.5	8.9
Water Quality Standards	USEPA MCL PRIMARY	10	1				0.05	0.05					
	USEPA MCL SECONDARY								0.1	0.1			250
	WHO DWG	50	3				0.01	0.01					
	GSB/GWC DWG	50	3				0.01	0.01				200	250

U = value is detection limit
NA = not applicable
ND = no data
Shaded cell: value exceeds lowest std.

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DWG = Drinking Water Goal
GSB/GWC = Ghana Stds Board and Water Co.

Table C4-6
Seep Chemistry (2007)
Akyem Project
Eastern Region, Ghana

Seep Water	Statistic	Thallium, Dissolved mg/L	Thallium, Total mg/L	Uranium, Total mg/L	Uranium, Dissolved mg/L	Vanadium. Dissolved mg/L	Vanadium Total mg/L	Zinc, Dissolved mg/L	Zinc, Total mg/L
All Seep Samples	Total # Samples Analysed	18	18	18	18	18	18	18	18
	Total # Non Detect	18	18	18	18	18	15	17	17
	Maximum	0.02U	0.02U	0.05U	0.05U	0.01U	0.025	0.021	0.048
	Mean	NA	NA	NA	NA	NA	0.01	NA	NA
	Standard Deviation	NA	NA	NA	NA	NA	0.005	NA	NA
Water Quality Standards	USEPA MCL PRIMARY	0.002	0.002	0.03	0.03				
	USEPA MCL SECONDARY							5	5
	WHO DWG								
	GSB/GWC DWG							3	3

Note: mg/L = milligrams per liter

U = value is detection limit
NA = not applicable
ND = no data
Shaded cell: value exceeds lowest std.

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GSB/GWC = Ghana Stds Board and Water Co.

Table C4-6
Seep Chemistry (2007)
Akyem Project
Eastern Region, Ghana

Seep Water	Statistic	Temp Field °C	Electrical Conductivity field uS/cm	pH field s.u.	Total Dissolved Solids mg/L	Total Suspended Solids mg/L
All Seep Samples	Total # Samples Analysed	18	18	17	16	16
	Total Non Detect	NA	NA	NA	0	0
	Minimum	24.2	107.1	5.72	94	5
	Maximum	27.9	440	7.8	490	43
	Mean	25	266	7	221	17
	Standard Deviation	1	113	0	106	11
Water Quality Standards	USEPA MCL PRIMARY					
	USEPA MCL SECONDARY		500	6.5-8.5	500	
	WHO DWG					
	GSB/GWC DWG			6.5-8.5	1000	

Note: C = Celsius; uS/cm = microSiemens per centimeter; s.u. = standard units; mg/L = milligrams per liter.

ND = no data
NA = not applicable
U = value is detection limit
Shaded cell: value exceeds lowest std.

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WHO = World Health Org.
DWG = Drinking Water Goal
GSB/GWC = Ghana Stds Board and Water Co.

STREAMBED SEDIMENT

Streambed sediment was collected by Clear Creek Consultants (2008b) from the Mamang River and selected tributaries in October-November 2007 (SW-11, SW-16A, SW-17, SW-19, SW-28, and SW-31). All samples showed detectable concentrations of aluminum, iron, manganese, and zinc (Clear Creek Consultants 2008b). Grain size distribution for the six samples generally show fine-grained sediment with half the sediment less than 2 millimetres (mm). Graphs of sediment grain size distribution and concentrations for aluminum, iron, copper, and zinc are included in **Figure C4-9**.

GROUNDWATER QUANTITY

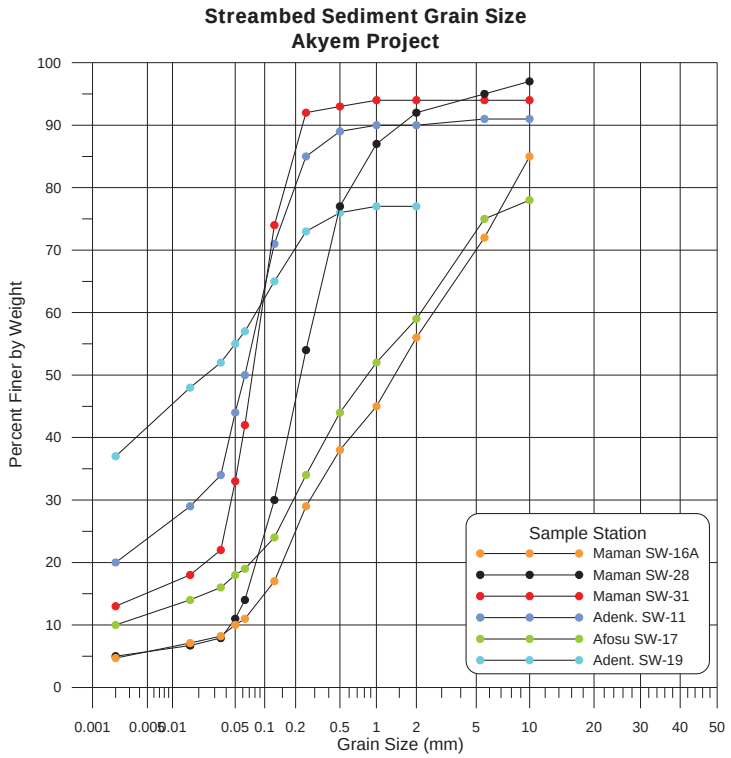
Eleven groundwater monitoring wells (MW- and BH- wells) were completed/tested by SGS (2005) in saprock. All 11 wells are completed to depths of 61 metres (m) or less.

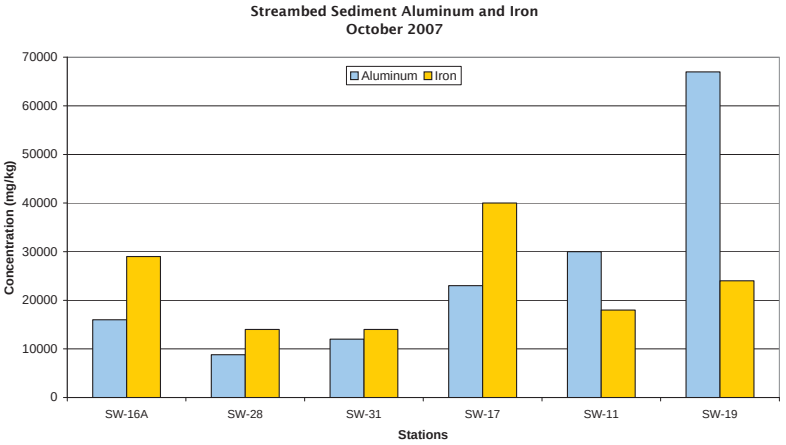
Nineteen groundwater monitoring piezometers (PZ- and KPW- piezometers) were completed/tested by Golder (2004b, 2006) in the proposed mine pit area. Nine of the piezometers are completed in bedrock to depths between 100 and 200 m. Two piezometers are completed in saprolite, and the remaining eight piezometers are completed in saprock (7 to 63 m depth).

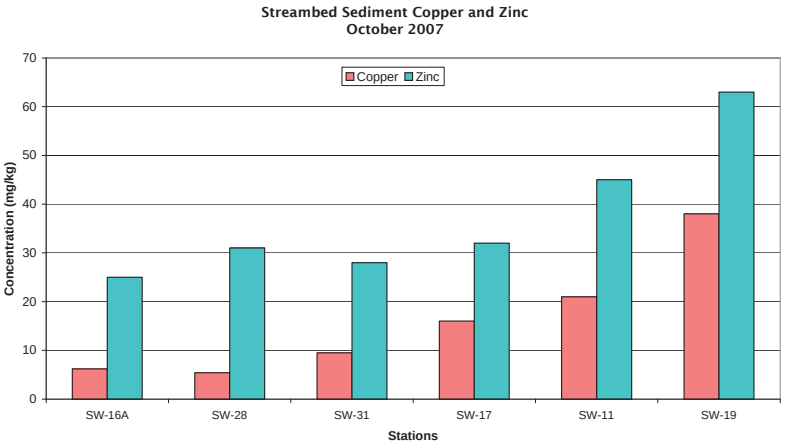
Eleven production/test wells (PW- wells) were completed by Knight Piesold (2006) in the Study Area to investigate the potential for a water supply for the mine operations. All of these wells are completed to depths between 41 and 63 m in saprock and/or shallow bedrock.

Groundwater flow generally follows local topography from upland to lowland areas. Regional groundwater in the Mine Area generally flows from north to south toward the Mamang River. Groundwater hydrographs for selected wells and piezometers in the Study Area for the period 2004-2008 are shown on **Figures C4-10, C4-11,** and **C4-12**. These graphs show that groundwater levels generally fluctuate about 1 to 2 metres on an annual basis. The water levels typically show a gradual rising trend starting in about April-May, continuing until about October-November, after which the water levels decline until April-May. These trends generally lag slightly behind the primary rainy seasons that extend from March through October.

Aquifer tests have been conducted on various sets of piezometers and monitoring wells in the Mine Area. A graph of average hydraulic conductivity data and summary tables of test results are included in **Figure C4-13**. The following summarizes aquifer testing results:

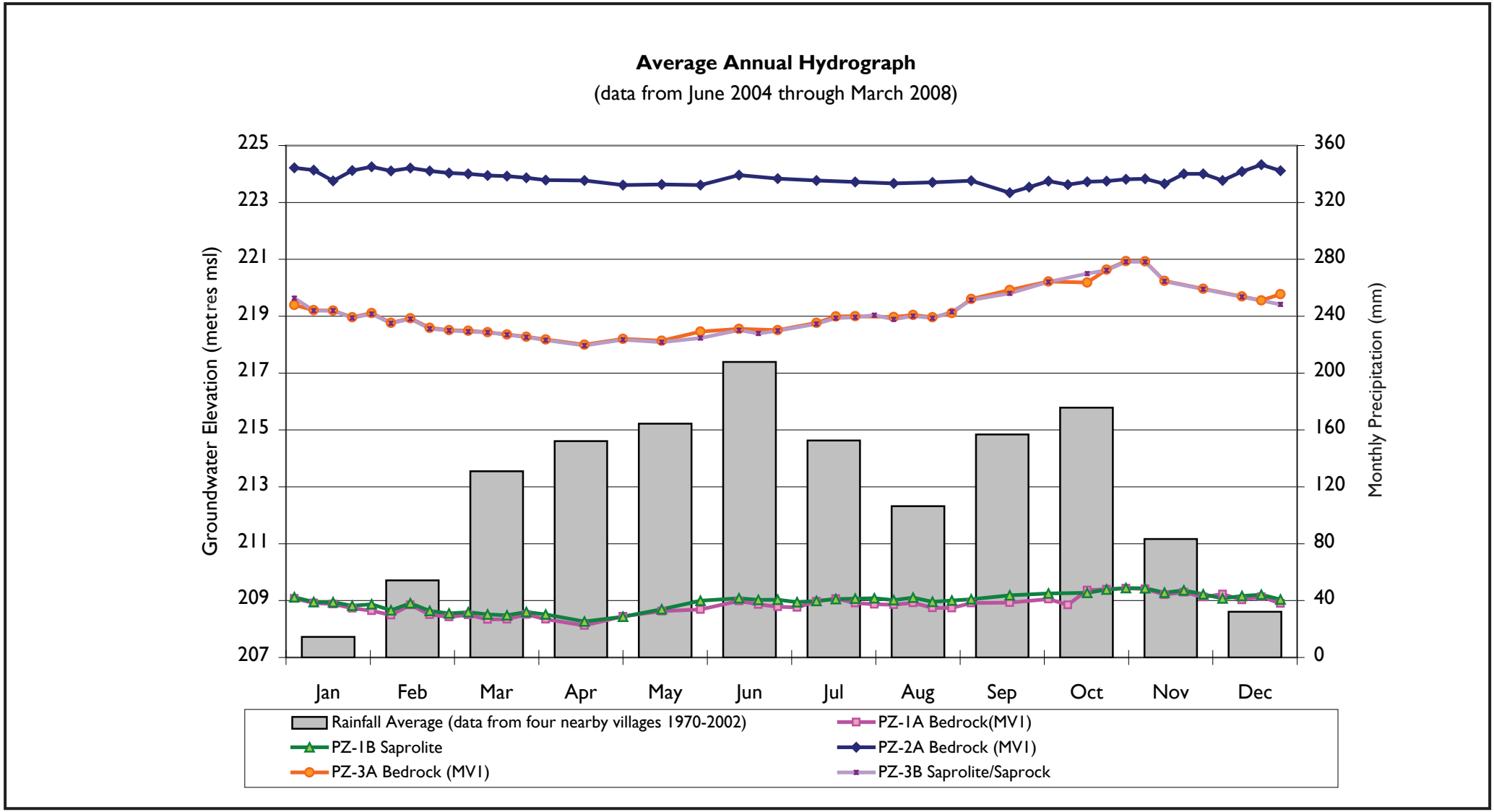




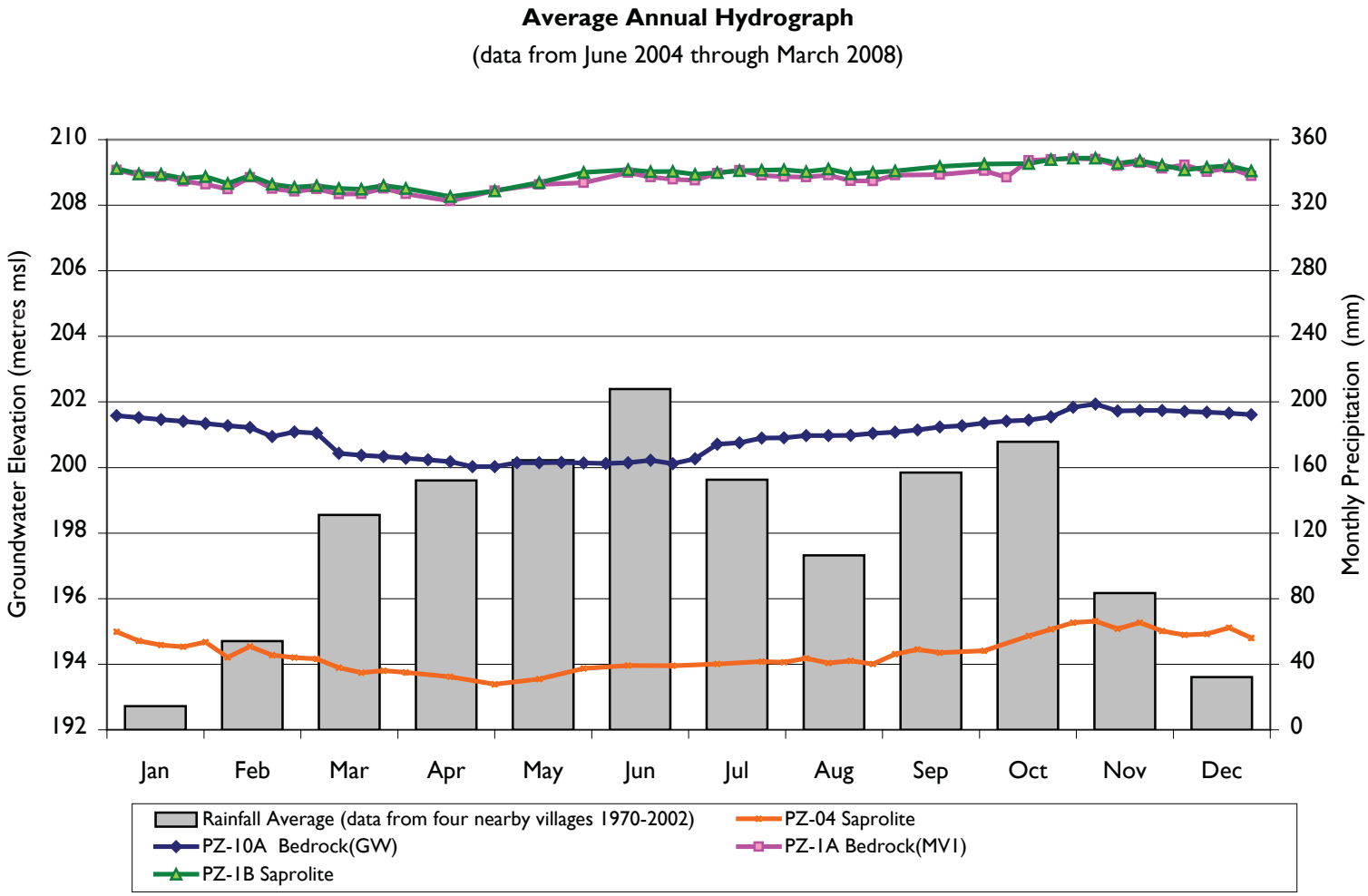


Source: Clear Creek Consultants (2008b).

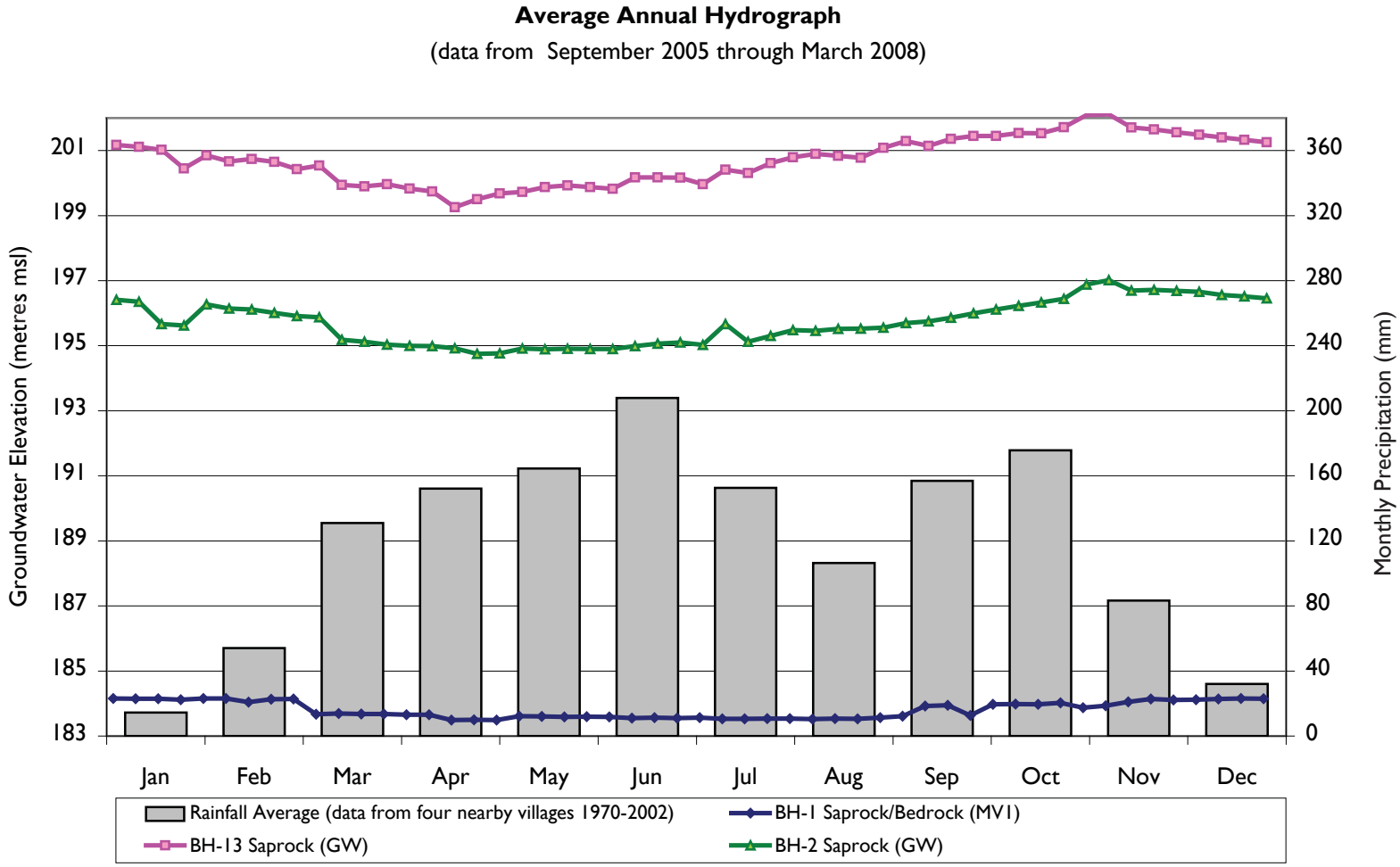
Streambed Sediment Characteristics
Akyem Gold Mining Project
Eastern Region, Ghana
FIGURE C4-9



Groundwater Level Hydrographs
for Wells PZ-1A/1B, PZ-2A, & PZ-3A/3B
Akyem Gold Mining Project
Eastern Region, Ghana
FIGURE C4-10



Groundwater Level Hydrographs
for Wells PZ-1A/1B, PZ-4, & PZ-10A
Akyem Gold Mining Project
Eastern Region, Ghana
FIGURE C4-11

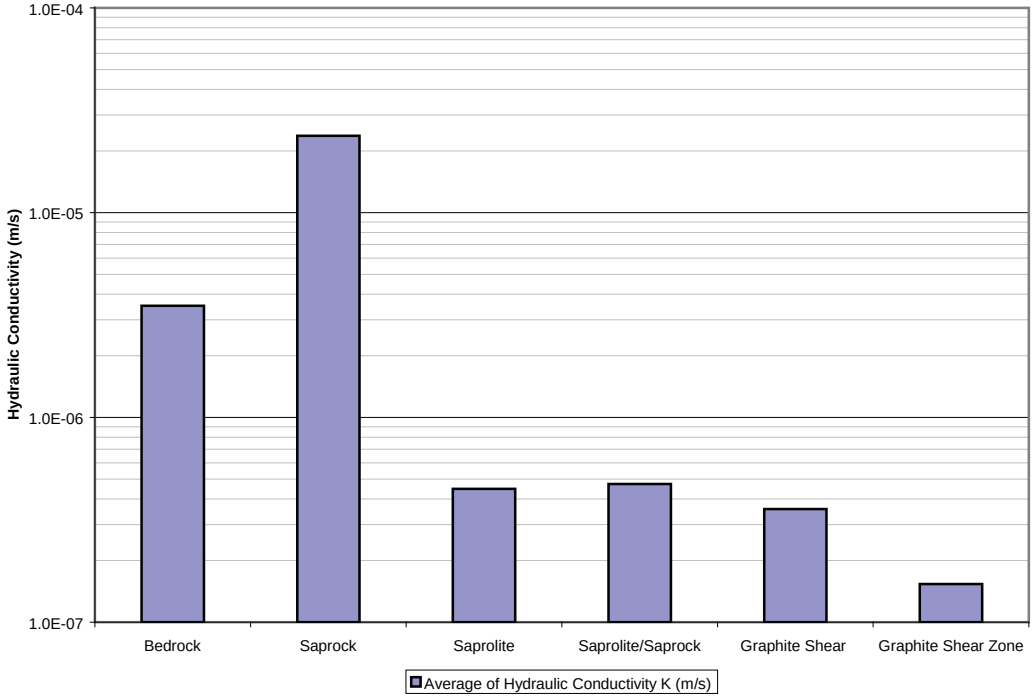


Groundwater Level Hydrographs
for Wells BH-1, BH-2, & BH-13
Akyem Gold Mining Project
Eastern Region, Ghana
FIGURE C4-12

Well ID	Average of Hydraulic Conductivity K (m/s)	Average of Transmissivity T (m2/d)	Average of Storage S	Lithology Completed in
BH-1	1.5E-06	4	2.6E-03	Saprock/Bedrock (MV1)
BH-10	1.7E-06	3	1.2E-03	Saprock (Schist)
BH-13	9.4E-06	18	6.6E-08	Saprock (GW)
BH-14	1.8E-04	458	9.1E-03	Saprock (Schist)
BH-16	9.1E-06	9	2.4E-03	Saprock (Schist)
BH-18	1.3E-05	32	5.2E-05	Saprock (GW)
BH-2	3.2E-06	6	1.5E-03	Saprock (GW)
BH-3	8.8E-06	17	4.5E-03	Saprock (GW)
BH-4	3.6E-06	6	9.3E-04	Saprock (GW)
BH-8	1.4E-06	2	8.5E-04	Saprock (Schist)
KGTS002	5.0E-07			Saprolite
KGTS003	6.0E-07			Saprolite
KGTS004	3.0E-09			Saprolite/Saprock
KGTS005	4.0E-08			Saprolite
KGTS007	6.0E-09			Saprolite/Saprock
KGTS008	2.0E-08			Saprolite
KGTS009	2.0E-07			Saprolite
KGTS010	2.0E-07			Saprolite
KGTS011	2.0E-07			Saprolite
KGTS012	2.0E-08			Saprolite
KGTS013	2.0E-08			Saprolite
KPW-01	1.6E-07	1	7.0E-05	Bedrock
KPW-02	4.2E-07	3	1.0E-04	Bedrock
PW003		7		Bedrock (GW)
PW004		76		Bedrock (GW)
PW005		105		Bedrock (GW)
PW007		21		Bedrock (GW)
PW009		8		Bedrock (GW)
PW013		47		Bedrock (GW)
PW014		8		Bedrock (GW)
PW016		12		Bedrock (GW)
PZ-10a	7.0E-07			Bedrock
PZ-1a	9.0E-06			Bedrock (MV1)
PZ-1b	3.3E-09			Saprolite
PZ-2a	2.0E-08			Bedrock (MV1)
PZ-3a	1.2E-06			Bedrock (MV1)
PZ-3b	5.6E-08			Saprolite/Saprock
PZ-4	2.0E-06			Saprolite
PZ-7a	9.4E-07			Bedrock
PZ-7b	5.4E-07			Saprock
PZ-8a	9.2E-07			Bedrock
PZ-8b	2.9E-06			Saprolite/Saprock
PZ-9a	1.2E-06			Bedrock

Lithology	Average of Hydraulic Conductivity K (m/s)	Average of Transmissivity T (m2/d)	Average of Storage S
Bedrock	5.5E-07	2	8.5E-05
Bedrock (GW)		36	
Bedrock (MV1)	8.4E-06		
Saprock	5.4E-07		
Saprock (GW)	8.1E-06	17	1.4E-03
Saprock (Schist)	6.2E-05	186	3.4E-03
Saprock/Bedrock (MV1)	1.5E-06	4	2.6E-03
Saprolite	4.5E-07		
Saprolite/Saprock	4.7E-07		
Graphite Shear	3.6E-07		
Graphite Shear Zone	1.5E-07		

Simplified Lithology	Average of Hydraulic Conductivity K (m/s)	Average of Transmissivity T (m2/d)	Average of Storage S
Bedrock	3.5E-06	24	8.5E-05
Saprock	2.4E-05	62	2.3E-03
Saprolite	4.5E-07		
Saprolite/Saprock	4.7E-07		
Graphite Shear	3.6E-07		
Graphite Shear Zone	1.5E-07		



Average Hydraulic Conductivity
for Major Rock Types
Akyem Gold Mining Project
Eastern Region, Ghana
FIGURE C4-13

- Golder Associates (2004b) tested 12 piezometers in the proposed mine pit area. These piezometers are completed in each of the major units – saprolite, saprock, and bedrock. Falling head tests were performed in nine of these piezometers with a geometric mean hydraulic conductivity of 7×10^{-7} metres per second (m/sec) for saprolite and saprock, and 6×10^{-7} m/sec for bedrock. The hydraulic conductivity measured in fractured intervals of the upper bedrock unit was 5×10^{-6} m/sec. In addition, Golder Associates (2004b) performed packer tests in four boreholes in the fault shear zone, with a geometric mean hydraulic conductivity of 3×10^{-7} m/sec. Well yields for the tests were up to 80 litres per minute (l/min).

- SGS (2005) tested 10 monitoring wells throughout the Project Area. These wells are completed in greywacke and schist saprock with depths ranging from 24 to 61 m. Results of SGS (2005) aquifer tests for the 10 monitoring wells indicate hydraulic conductivity is in the range of 2×10^{-4} to 9×10^{-7} m/sec. Average hydraulic conductivity for the 10 wells is 2×10^{-5} m/sec. Well yields for the test were from about 50 to 500 l/min.

- Golder Associates (2006) tested two deep pumping wells: KPW-1 (200 m depth) and KPW-2 (150 m depth), both located in the proposed mine pit area. Range in hydraulic conductivities from testing these two wells was 1×10^{-6} to 2×10^{-9} m/sec. Falling head tests performed on four additional bedrock piezometers had a geometric mean hydraulic conductivity of 9×10^{-7} m/sec. Air lift water yield from these tests ranged 4 to 18 l/min.

- Knight Piesold (2006) tested eight production/test wells in the Project Area. Hydraulic conductivity values are from 8×10^{-5} to 4×10^{-6} m/sec. Sustained yields during the tests were in the range of 18 to 360 l/min.

The graph in **Figure C4-13** shows average hydraulic conductivity for all tests conducted in the following lithologic units (from upper to lower depths):

- Saprolite: 4.5×10^{-7} m/sec
- Saprolite/Saprock: 4.7×10^{-7} m/sec
- Saprock: 2.4×10^{-5} m/sec
- Bedrock: 3.5×10^{-6} m/sec
- Graphite Shear Zone: 1.5×10^{-7} to 3.6×10^{-7}m/sec

GROUNDWATER QUALITY

Laboratory analysis for metals in groundwater samples was conducted at the SGS Laboratory in Amsterdam, Netherlands, while all other physio-chemical constituents were analyzed at the SGS Laboratory in Accra, Ghana. All laboratory analyses were performed in accordance with "Standard Methods for the Examination of Water and Wastewater" of the American Public Health Association (1995). Water quality standards or guidelines for the parameters analyzed are presented in **Table C4-4**. The drinking water standard with the lowest concentration for each parameter, if available, was used for comparison of analytical results in statistical summaries.

Statistical summaries of chemical analyses of groundwater samples collected from monitoring wells between 2001 and 2007 are presented in **Table C4-7**. These data are compared to the water quality standards and guidelines shown in **Table C4-4**.

Ionic chemistry of groundwater was examined by plotting major cation and ion data on Piper diagrams. Graphic water quality data from the statistical summaries of the monitoring wells is presented in **Figure C4-14**. The Piper diagram for groundwater samples from village wells is shown in **Figure C4-15**. Groundwater samples from monitoring wells are either weakly Mg-dominant (two wells), Na-dominant (five wells), or Ca-dominant (three wells). Bicarbonate is the dominant anion in monitoring well samples. There are no apparent trends in major ion data from monitoring wells, although more variability in cation concentrations is noted in monitoring well samples compared to village well samples.

Dominant anions in village well samples are bicarbonate and chloride. There is an apparent linear trend between these anions. There are no apparent trends in cations in village well samples. Most wells do not display a dominant cation, although a few are calcium-dominant and even fewer are sodium-dominant. A comparison of water quality data from bored wells and hand dug wells revealed no apparent trends.

Table C4-7
Groundwater Chemistry (2001-2007)
Akyem Project
Eastern Region, Ghana

Surface Water	Statistic	Bicarbonate, as CaCO3 mg/L	Carbonate, as CaCO3 mg/L	Alkalinity, Total, as CaCO3 mg/L	Aluminum, Dissolved mg/L	Aluminum, Total mg/L	Ammonia, Undistilled mg/L	Antimony, Dissolved mg/L	Antimony, Total mg/L	Arsenic, Dissolved mg/L	Arsenic, Total mg/L	Barium, Dissolved mg/L	Barium, Total mg/L	Beryllium, Dissolved mg/L	Beryllium, Total mg/L
Village Wells	Total # Samples Analysed	89	89	102	90	199	113	86	105	86	110	90	104	86	100
	Total Non Detect	3	88	0	70	95	77	82	93	52	76	10	22	86	100
	Maximum	290	7.5	306	0.27	22	1.2	0.0012	0.009	0.05	0.12	0.7	0.68	0.005U	0.005U
	Mean	124	NA	117	0.03	1	0.04	0.008	0.01	0.01	0.01	0.10	0.09	NA	NA
	Standard Deviation	71	NA	57	0.04	2	0.13	0.01	0.02	0.01	0.01	0.14	0.13	NA	NA
Monitoring Wells	Total # Samples Analysed	17	17	53	17	70	81	17	67	17	66	17	64	17	66
	Total Non Detect	0	17	0	17	64	61	14	61	2	36	0	0	17	66
	Maximum	326	0.2U	264	0.1U	8.4	2.1	0.0013	0.037	0.06	0.06	0.16	0.21	0.0001U	0.005U
	Mean	170	NA	133	NA	0.3	0.06	0.0003	0.01	0.01	0.01	0.08	0.07	NA	NA
	Standard Deviation	79	NA	69	NA	1.0	0.26	0.0004	0.01	0.02	0.01	0.04	0.05	NA	NA
Water Quality Standards	USEPA MCL PRIMARY							0.006	0.006	0.01	0.01	2	2	0.004	0.004
	USEPA MCL SECONDARY				0.05 to 0.2	0.05 to 0.2									
	WHO DWG				0.2	0.2		0.02	0.02	0.01	0.01	0.7	0.7		
	GSB/GWC DWG				0.2	0.2		0.005	0.005	0.01	0.01	0.7	0.7		

Note: mg/L = milligrams per liter.

U = value is detection limit
NA = not applicable
ND = no data
Shaded cell: value exceeds lowest std.

USEPA = U.S. Environmental Protection Agency
WHO = World Health Org.
DWG = Drinking Water Goal
GSB/GWC = Ghana Stds Board and Water Co.

Table C4-7
Groundwater Chemistry (2001-2007)
Akyem Project
Eastern Region, Ghana

Surface Water	Statistic	Bismuth, Total mg/L	Bismuth, Dissolved mg/L	Boron, Dissolved mg/L	Boron, Total mg/L	Cadmium, Dissolved mg/L	Cadmium, Total mg/L	Calcium mg/L	Chloride mg/L	Chlorine, Total mg/L	Chromium, Dissolved mg/L	Chromium, Total mg/L	COD mg/L	Cobalt, Dissolved mg/L	Cobalt, Total mg/L
Village Wells	Total # Samples Analysed	3	17	72	78	86	106	123	117	134	86	103	95	86	105
	Total Non Detect	3	17	72	53	38	48	0	0	0	67	78	13	70	79
	Maximum	0.00001U	0.00001U	0.1U	0.22	0.045	0.058	78.9	410	106.1	0.05	0.095	221	0.048	0.25
	Mean	NA	NA	NA	0.10	0.01	0.01	31	26	3	0.01	0.01	24	0.01	0.01
	Standard Deviation	NA	NA	NA	0.02	0.01	0.01	18	43	10	0.01	0.01	38	0.01	0.04
Monitoring Wells	Total # Samples Analysed	2	17	ND	32	17	62	60	81	19	17	64	10	17	66
	Total Non Detect	2	17	ND	26	2	37	0	0	14	0	42	9	1	41
	Maximum	0.00001U	0.00001U	ND	0.18	0.00014	0.074	76.3	102	0.1	0.0068	0.058	39	0.0048	0.012
	Mean	NA	NA	ND	0.10	0.0001	0.004	30	10	0.1	0.003	0.005	13	0.001	0.003
	Standard Deviation	NA	NA	ND	0.03	0.00005	0.01	21	14	3.E-17	0.002	0.008	9	0.001	0.003
Water Quality Standards	USEPA MCL PRIMARY					0.005	0.005				0.1	0.1			
	USEPA MCL SECONDARY								250						
	WHO DWG			0.5	0.5	0.003	0.003				0.05	0.05			
	GSB/GWC DWG			0.3	0.3	0.003	0.003		250		0.05	0.05			

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Table C4-7
Groundwater Chemistry (2001-2007)
Akyem Project
Eastern Region, Ghana

Surface Water	Statistic	Copper, Dissolved mg/L	Copper, Total mg/L	Cyanide, Total mg/L	Cyanide, Free mg/L	Fluoride, Undistilled mg/L	Hardness, as CaCO3 mg/L	Iron, Dissolved mg/L	Iron, Total mg/L	Lead, Dissolved, mg/L	Lead, Total mg/L	Magnesium mg/L	Manganese, Dissolved mg/L	Manganese, Total mg/L	Mercury, Dissolved mg/L	Mercury, Total mg/L
Village Wells	Total # Samples Analysed	86	247	105	125	144	174	90	255	90	102	123	86	250	90	101
	Total Non Detect	42	69	86	106	12	3	49	31	73	82	0	3	6	89	100
	Maximum	0.19	1.1	0.01	2.8	0.8	452	1.2	26	0.0056	2.3	65	2	9	0.00034	0.001U
	Mean	0.01	0.05	0.01	0.03	0.2	99	0.1	1	0.004	0.05	13	0.2	0.4	0.0001	NA
	Standard Deviation	0.03	0.12	0.003	0.25	0.1	99	0.3	2	0.002	0.24	11	0	1	0.0001	NA
Monitoring Wells	Total # Samples Analysed	17	66	71	71	74	17	17	72	17	59	60	17	66	17	53
	Total Non Detect	2	53	70	71	7	0	1	4	2	43	0	0	5	17	47
	Maximum	0.0008	0.019	0.2	0.01U	0.9	274.7	2.9	31	0.00181	0.81	43.7	0.331	1.6	0.0002U	0.0006
	Mean	0.0005	0.01	NA	NA	0.2	126	0.4	1	0.0004	0.04	10	0.1	0.21	NA	0.0002
	Standard Deviation	0.0002	0.01	NA	NA	0.2	82	1	5	0.0005	0.12	10	0.1	0.30	NA	0.0001
Water Quality Standards	USEPA MCL PRIMARY	1.3	1.3		0.2	4				0.015	0.015				0.002	0.002
	USEPA MCL SECONDARY	1	1			2		0.3	0.3				0.05	0.05		
	WHO DWG	2	2		0.07	1.5				0.01	0.01		0.4	0.4	0.006	0.006
	GSB/GWC DWG	1	1		0.01	1.5		0.3	0.3	0.01	0.01		0.5	0.5	0.001	0.001

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Table C4-7
Groundwater Chemistry (2001-2007)
Akyem Project
Eastern Region, Ghana

Surface Water	Statistic	Molybdenum, Dissolved mg/L	Molybdenum, Total mg/L	Nickel, Dissolved mg/L	Nickel, Total mg/L	Nitrate mg/L	Nitrite mg/L	Ortho-phosphorous mg/L	Phosphorous, Total mg/L	Phosphate mg/L	Potassium mg/L	Salinity mg/L	Selenium, Dissolved mg/L	Selenium, Total mg/L
Village Wells	Total # Samples Analysed	86	104	86	108	257	219	93	78	161	123	167	86	105
	Total Non Detect	86	98	52	65	4	77	25	32	10	0	0	81	85
	Maximum	0.01U	0.011	0.045	0.048	41	6	0.6	9	2.8	41	9	0.01U	0.025
	Mean	NA	0.01	0.01	0.01	3.3	0.2	0.1	0.2	1	3	0.2	0.01	0.01
	Standard Deviation	NA	0.004	0.01	0.01	4.9	1	0.1	1	1	5	1	0.004	0.01
Monitoring Wells	Total # Samples Analysed	17	66	17	66	80	81	ND	32	59	69	ND	17	62
	Total Non Detect	16	63	0	40	19	69	ND	4	17	0	ND	15	45
	Maximum	0.001	0.054	0.0062	0.039	5	0.5	ND	2	1.72	42	ND	0.001U	0.032
	Mean	NA	0.01	0.004	0.01	0.5	0.02	ND	0.3	0.2	4	ND	0.001	0.01
	Standard Deviation	NA	0.01	0.001	0.01	1.0	0.1	ND	0.4	0.3	7	ND	0.0001	0.01
Water Quality Standards	USEPA MCL PRIMARY					10	1						0.05	0.05
	USEPA MCL SECONDARY													
	WHO DWG	0.07	0.07	0.07	0.07	50	3						0.01	0.01
	GSB/GWC DWG			0.02	0.02	50	3						0.01	0.01

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Shaded cell: value exceeds lowest std.

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Table C4-7
Groundwater Chemistry (2001-2007)
Akyem Project
Eastern Region, Ghana

Surface Water	Statistic	Silver, Dissolved mg/L	Silver, Total mg/L	Silica mg/L	Sodium mg/L	Strontium, Dissolved mg/L	Strontium, Total mg/L	Sulfate mg/L	Thallium, Dissolved mg/L	Thallium, Total mg/L	Tin, Dissolved mg/L	Tin, Total mg/L	Tungsten, Total mg/L	Tungsten, Dissolved mg/L
Village Wells	Total # Samples Analysed	72	78	159	123	13	7	228	89	99	13	7	3	17
	Total Non Detect	72	78	0	0	0	0	31	89	99	10	6	1	7
	Maximum	0.01U	0.01U	80	72	0.61	0.24	152	0.02U	0.01U	0.0001U	0.0002	0.00032	0.0013
	Mean	NA	NA	28	19	0.3	0.1	9	NA	NA	0.0001	0.0001	0.0001	0.0001
	Standard Deviation	NA	NA	17	12	0.1	0.1	14	NA	NA	0.00003	0.0001	0.0002	0.0003
Monitoring Wells	Total # Samples Analysed	ND	33	45	69	17	2	77	17	62	17	53	2	17
	Total Non Detect	ND	30	0	0	0	0	28	15	59	17	49	1	7
	Maximum	ND	0.01	37.3	40	459	0.251	73	0.00003	0.026	0.0001U	0.14	0.00004	0.00043
	Mean	ND	0.01	15	20	27	0.2	8	0.00001	0.005	NA	0.009	0.00003	0.0001
	Standard Deviation	ND	0.003	7	7	111	0.01	16	4.9E-06	0.006	NA	0.02	0.00002	0.0001
Water Quality Standards	USEPA MCL PRIMARY								0.002	0.002				
	USEPA MCL SECONDARY	0.1	0.1					250						
	WHO DWG													
	GSB/GWC DWG				200			250						

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Shaded cell: value exceeds lowest std.

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Table C4-7
Groundwater Chemistry (2001-2007)
Akyem Project
Eastern Region, Ghana

Surface Water	Statistic	Uranium, Total mg/L	Uranium, Dissolved mg/L	Vanadium, Dissolved mg/L	Vanadium, Total mg/L	Zinc, Dissolved mg/L	Zinc, Total mg/L	Fecal Coliform MPN/100ml	Total Coliform MPN/100ml
Village Wells	Total # Samples Analysed	72	85	85	79	86	244	115	115
	Total Non Detect	48	51	68	66	62	63	103	80
	Maximum	0.05U	0.05U	0.012	0.36	0.86	4.8	1600	1600
	Mean	0.04	0.03	0.01	0.02	0.04	0.27	16	130
	Standard Deviation	0.02	0.02	0.003	0.04	0.09	0.63	149	385
Monitoring Wells	Total # Samples Analysed	13	17	17	2	17	63	32	32
	Total Non Detect	11	0	1	0	0	22	31	22
	Maximum	0.05U	0.00072	0.0024	0.0025	0.115	0.15	140	1600
	Mean	0.04	0.0001	0.0010	0.002	0.04	0.04	NA	80
	Standard Deviation	0.02	0.0002	0.0007	0.001	0.03	0.03	NA	286
Water Quality Standards	USEPA MCL PRIMARY	0.03	0.03						
	USEPA MCL SECONDARY					5	5		
	WHO DWG							2	2
	GSB/GWC DWG					3	3		

Note: mg/L = milligrams per liter; MPN = most probable number; ml = millilter.

U = value is detection limit
NA = not applicable
ND = no data
Shaded cell: value exceeds lowest std.

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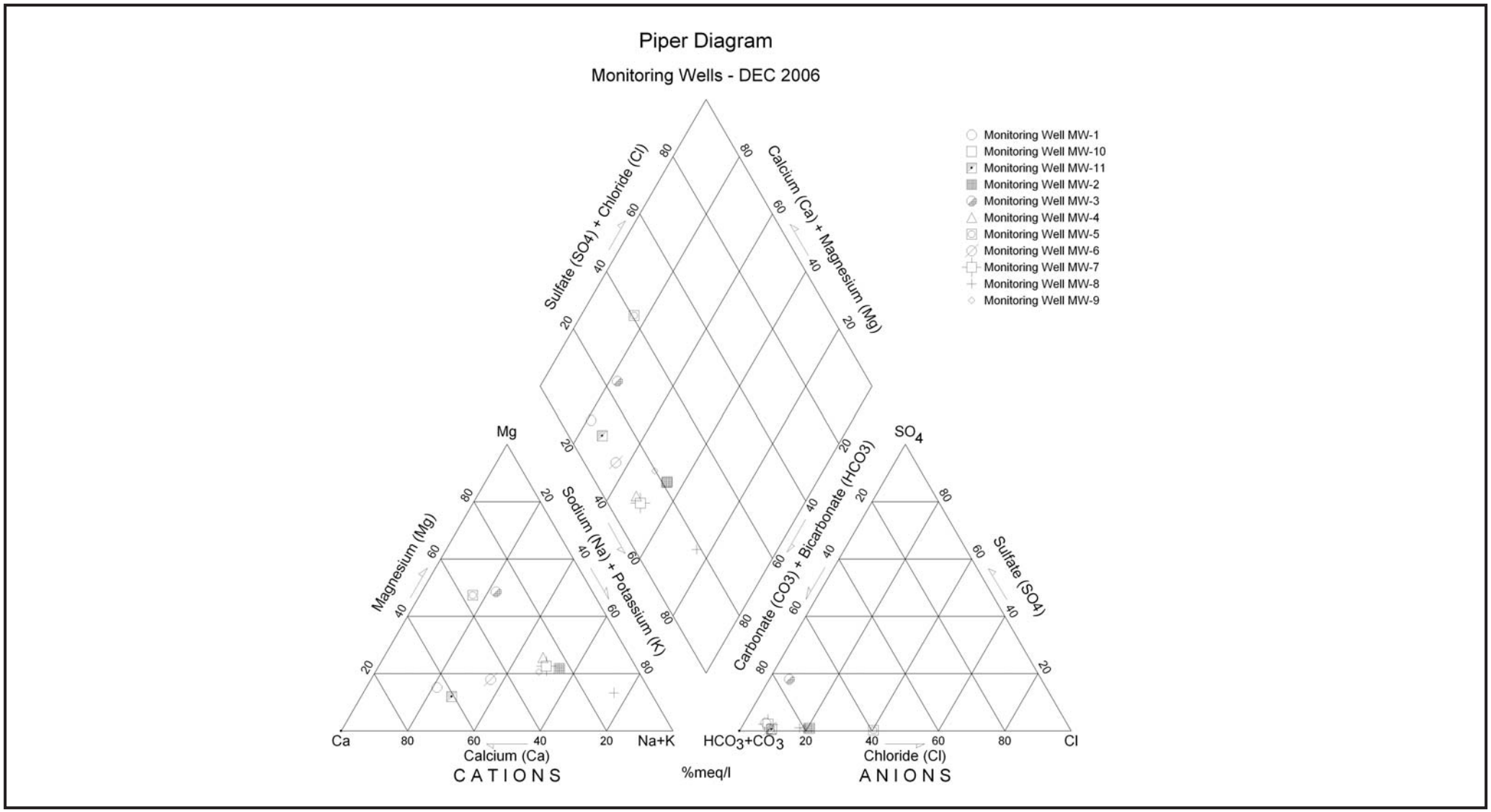
Table C4-7
Groundwater Chemistry (2001-2007)
Akyem Project
Eastern Region, Ghana

Groundwater Type	Statistic	Apparent Colour	True Colour	DO Field mg/L	Temp Field °C	Field Electrical Conductivity uS/cm	Lab Electrical Conductivity uS/cm	pH field s.u.	pH lab s.u.	Total Dissolved Solids mg/L	Total Suspended Solids mg/L	Turbidity, field NTU	Turbidity, lab NTU
Village Wells	Total # Samples Analysed	137	196	7	95	109	204	109	204	312	244	82	189
	Total Non Detect	17	90	0	NA	NA	NA	NA	NA	0	24	0	2
	Minimum	0	0	0.5	25.5	12.5	0.1	5	3	3.3	0.1	0	0
	Maximum	95	26	3	31.3	1255	749	7	7	840	418.3	37	147
	Mean	18	5	1.3	27	342	189	6	6	197	24	3	5
	Standard Deviation	16	5	0.8	1.1	239	171	0.4	1	123	60	6	16
Monitoring Wells	Total # Samples Analysed	59	59	17	36	70	ND	58	10	60	60	50	17
	Total Non Detect	54	50	0	NA	NA	ND	NA	NA	0	33	6	0
	Minimum	5	0	0.39	21.4	7.9	ND	5	5.8	64	0.1	0	0
	Maximum	200	10	1.8	27.4	665	ND	7	7	530	332.4	660	20
	Mean	8	5	0.84	25	73	ND	7	7	211	11	19	1
	Standard Deviation	25	2	0.44	2	124	ND	0.4	0.4	95	48	97	5
Water Quality Standards	USEPA MCL PRIMARY												
	USEPA MCL SECONDARY		15			500	500	6.5-8.5	6.5-8.5	500			
	WHO DWG												
	GSB/GWC DWG		15					6.5-8.5	6.5-8.5	1000			

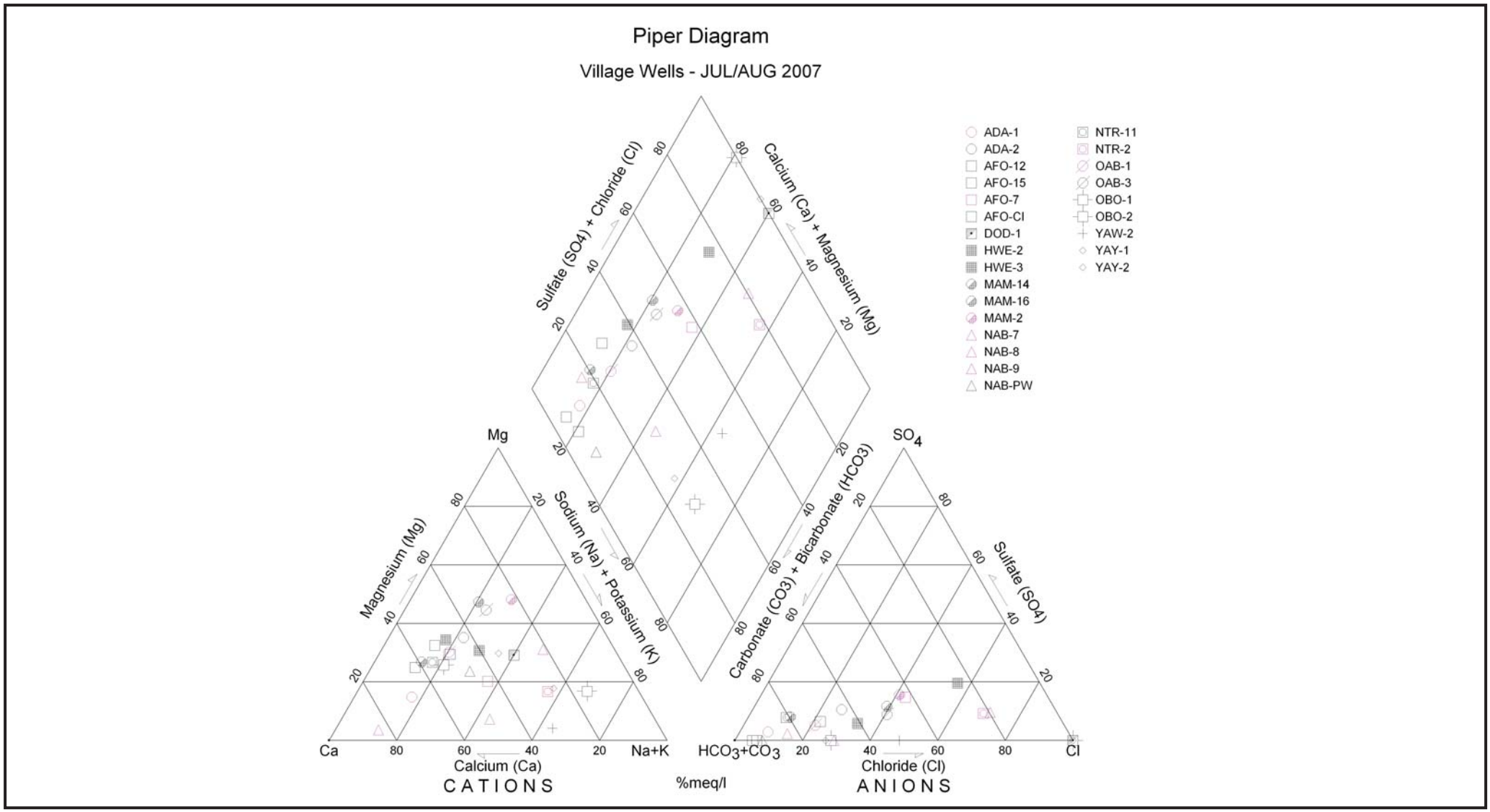
Note: DO = dissolved oxygen; mg/L = milligrams per liter; C = Celsius; uS/cm = microSiemens per centimeter; s.u. = standard units; NTU = nephelometric turbidity units.

ND = no data
NA = not analyzed
U = value is detection limit
Shaded cell = value exceeds lowest std.

USEPA = U.S. Environmental Protection Agency
WHO = World Health Org.
DWG = Drinking Water Goal
GSB/GWC = Ghana Stds Board and Water Co.



Piper Diagram for Monitoring Wells
Akyem Gold Mining Project
Eastern Region, Ghana
FIGURE C4-14



Piper Diagram for Village Wells
Akyem Gold Mining Project
Eastern Region, Ghana
FIGURE C4-15

ANNEX C-5

SOIL RESOURCES
SUPPLEMENTAL INFORMATION

GEOLOGIC AND LANDFORM RELATIONSHIPS

Soil in the Proposed Mining Area developed from two principal geologic units and their associated alluvial deposits. Soil developed on Lower Birimian rocks have the widest distribution, while the granitic unit is far less prevalent and occurs only in the southern-most areas within the Proposed Mining Area. Soil series occurring on similar topographic positions in the two units exhibit similar drainage and development with comparable series occurring in sequence from uplands to lowlands in each geology unit.

In the lower Birimian unit, the upland soil sequence begins with the red Kobeda and Bekwai series located on upper slopes and summits. The better drained and frequently stonier Kobeda series occurs on steep upper slopes and high summits while the Bekwai series occurs on slightly less steep upper slopes and lower summits. The moderately-well drained, brown Nzima series occurs lower in the landscape than Bekwai on middle to upper slopes and low ridges. The lowland sequence begins with the imperfectly drained, yellowish brown Kokofu series of lower-slope colluvial materials relatively free of coarse fragments with the poorly drained, grayish brown Oda and Temang series occurring in clayey and sandy valley bottom alluvial deposits, respectively.

The soil series developed in granitic rock are well to poorly drained, loamy to sandy textured, and deep to very deep. Profiles have a notable amount of weather resistance quartz that comprises the majority of the sand and coarse fragments common to soil from this geologic unit, especially the sandy valley bottom soil. While quartz fragments are common, concretions occur less frequently than in soil of lower Birimian origin.

The deep Swedru and Nsaba soil series occur on the upper and middle slopes of the granitic geologic unit, respectively. The well drained Swedru series is slightly redder than the moderately-well drained Nsaba series. The lowland sequence begins with the Akroso series. Similar to Kokofu, this series is moderately well drained and generally free of coarse fragments. The valley bottom soils include Nta, which occurs on very gentle lower slopes, and Ofin, which occurs on floodplains. The profiles of the Nta and Ofin series range from poorly to imperfectly drained and have very few coarse fragments.

SOIL SURVEY

Map units consisting of complexes and consociations were mapped within the Proposed Mining Area as shown in **Figure 3-12** (Geomatrix and Soil Research Institute (SRI) 2008)**.** A total of 484 soil profiles were examined at regular intervals along transects and traverses to describe and classify the soil. Sixteen representative profiles were sampled to assess agronomic properties. As part of a separate sampling program, surface soil samples were collected from 73 sites for analysis of soil element concentrations. All observation points and sample sites are shown in **Figure 3-12**. Additional information regarding the soil observed at each point is provided in the 2008 soil resources technical report (Geomatrix and SRI 2008).

SOIL LABORATORY ANALYSES

Findings of laboratory analyses support the discussion in Sections 3, 4, and 5 of this document and are included in this Annex as a supplement to the data previously presented. Sampling and analytical methods, results, and findings of data validation are presented in the 2008 soil resources technical report (Geomatrix and SRI 2008).

Agronomic Parameters

Samples for agronomic analysis were collected from 16 typical profiles representing the nine dominant series. Kobeda and Ofin were not sampled due to their very limited occurrence within the Proposed Mining Area and expected comparability to the Bekwai and Temang series, respectively. The objective of this sampling was to characterize the common range of physical and chemical characteristics of the dominant series in the Proposed Mining Area. Results of the analyses are summarized in **Table C5-1**.

Textures and associated physical properties were notably different across topographic sequences and between the lower Birimian and granitic series. Within the sequences, the middle and upper-slope series have the highest clay and coarse fragment contents. The granitic series are more coarsely textured than similar lower Birimian series. Coarse fragment content was variable, but generally higher for subsoil horizons and series at more elevated landscape positions.

The water erodibility for the fine earth fraction (Kf) and whole earth fraction (Kw), which accounts for the affects of coarse fragments, was calculated using the soil profile descriptions and analytical results. The data show that without considering the affects of coarse fragments, the erosion hazard is very high for many series. The armoring affects of the coarse fragments in upland series notably reduces erosion hazard, especially in the most vulnerable landscape positions.

Soil profiles are highly leached due to the high precipitation and long period of soil development. Soil pH and organic matter concentrations are low and usually decline with depth in the soil profiles. All soil series in the Proposed Mining Area are acidic, with most pH below 5.0 standard units (s.u.). Organic matter concentrations decline precipitously below the uppermost 15 centimeters, reflecting the high rates of biological activity. The low organic matter content of the soil and dominance of low-activity clay resulted in low cation exchange capacities throughout the soil survey area.

The high rate of biological activity, low organic matter, high precipitation, acidity and low exchange capacity have resulted in low concentrations of nutrients, especially in subsoil horizons. Although nitrogen concentrations are variable, the greatest concentrations are found in upland series and topsoil horizons. The carbon:nitrogen ratios of the various samples suggests that nitrogen is widely available for plant uptake in all series. In contrast, the concentration of available phosphorus is very low in all soil types, especially the lower Birimian series and subsoil horizons, and can be a limiting factor in plant growth. Potassium is also likely to be limiting in most series. The lowest concentrations are found in the subsoil of upland series, with series of granitic origin having lower concentrations than lower Birimian series in similar landscape positions.

ANNEX C5 - TABLE C5-1
Summary of Agronomic Analytical Results

Series	Sites	Strata	Samples	Value	Very Fine Sand (%)	Sand (%)	Silt (%)	Clay (%)	Total Coarse Fragments by Weight (%)	Kf	Kw	pH	Organic Carbon (%)	Organic Matter (%)	Series	Sites
BEKWAI	2	Topsoil	2	Min	3	34	59	2	25	0.31	0.10	5.5	2.5	4.4	BEKWAI	2
				Mean	**3**	**35**	**62**	**3**	**46**	**0.40**	**0.17**	**5.7**	**3.0**	**5.2**		
				Max	4	37	64	4	67	0.65	0.23	5.9	3.5	6.0		
		Subsoil	8	Min	1	15	35	8	16	0.28	0.11	3.7	0.3	0.5		
				Mean	**8**	**28**	**48**	**24**	**54**	**0.32**	**0.17**	**4.0**	**0.4**	**0.8**		
				Max	23	41	59	34	69	0.36	0.24	4.7	0.8	1.4		
NZIMA	3	Topsoil	3	Min	6	27	57	4	0	0.27	0.40	3.9	1.3	2.2	NZIMA	3
				Mean	**7**	**31**	**61**	**8**	**0**	**0.34**	**0.47**	**4.1**	**1.4**	**2.5**		
				Max	8	35	64	16	0	0.46	0.52	4.5	1.7	3.0		
		Subsoil	10	Min	2	16	40	18	0	0.40	0.07	3.6	0.2	0.4		
				Mean	**4**	**24**	**47**	**29**	**65**	**0.47**	**0.13**	**3.8**	**0.5**	**0.8**		
				Max	6	34	59	36	88	0.52	0.35	4.0	0.6	1.1		
KOKOFU	2	Topsoil	2	Min	6	32	39	6	0	0.32	0.35	3.9	0.7	1.2	KOKOFU	2
				Mean	**7**	**43**	**51**	**6**	**3**	**0.36**	**0.42**	**4.1**	**1.0**	**1.8**		
				Max	9	55	62	6	5	0.38	0.50	4.4	1.4	2.4		
		Subsoil	6	Min	2	11	36	16	0	0.36	0.12	3.6	0.1	0.2		
				Mean	**5**	**28**	**44**	**28**	**17**	**0.43**	**0.29**	**3.8**	**0.3**	**0.5**		
				Max	10	48	55	34	62	0.50	0.38	4.0	0.5	0.9		
ODA	1	Topsoil	2	Min	2	18	64	4	0	0.45	0.54	4.4	0.4	0.7	ODA	1
				Mean	**2**	**21**	**68**	**11**	**0**	**0.49**	**0.54**	**4.5**	**1.3**	**2.2**		
				Max	2	24	72	18	0	0.51	0.55	4.7	2.1	3.7		
		Subsoil	3	Min	2	11	50	14	0	0.54	0.45	4.2	0.1	0.1		
				Mean	**2**	**22**	**57**	**21**	**0**	**0.54**	**0.49**	**4.9**	**0.2**	**0.3**		
				Max	4	36	61	30	0	0.55	0.51	6.0	0.3	0.6		
TEMANG	1	Topsoil (1 sample)			**1**	**56**	**42**	**2**	**0**	**0.42**	**0.37**	**4.3**	**1.0**	**1.7**	TEMANG	1
		Subsoil	2	Min	0	37	32	8	0	0.37	0.15	4.7	0.2	0.3		
				Mean	**3**	**48**	**41**	**11**	**32**	**0.37**	**0.30**	**4.8**	**0.2**	**0.3**		
				Max	6	60	49	14	65	0.37	0.45	4.9	0.2	0.3		
SWEDRU	1	Topsoil	1	Min	9	52	46	2	0	0.30	0.31	6.5	2.8	4.7	SWEDRU	1
				Mean	**9**	**52**	**46**	**2**	**0**	**0.34**	**0.31**	**6.5**	**2.8**	**4.7**		
				Max	9	52	46	2	0	0.36	0.31	6.5	2.8	4.7		
		Subsoil	4	Min	6	24	37	6	0	0.31	0.15	4.0	0.2	0.3		
				Mean	**8**	**37**	**43**	**20**	**15**	**0.31**	**0.27**	**4.6**	**0.4**	**0.7**		
				Max	11	57	50	28	50	0.31	0.36	5.7	0.7	1.3		
NSABA	2	Topsoil	2	Min	8	32	34	2	0	0.22	0.28	4.0	0.6	1.0	NSABA	2
				Mean	**10**	**48**	**48**	**4**	**3**	**0.33**	**0.36**	**4.2**	**1.1**	**1.9**		
				Max	11	64	62	6	5	0.43	0.44	4.5	1.6	2.8		
		Subsoil	8	Min	3	18	27	8	0	0.31	0.07	3.8	0.3	0.4		
				Mean	**6**	**35**	**44**	**21**	**27**	**0.37**	**0.26**	**4.0**	**0.4**	**0.6**		
				Max	11	63	62	30	74	0.44	0.43	4.1	0.6	1.0		
AKROSO	2	Topsoil	2	Min	5	31	43	2	0	0.20	0.39	3.9	1.0	1.7	AKROSO	2
				Mean	**7**	**42**	**55**	**3**	**0**	**0.37**	**0.44**	**4.3**	**1.2**	**2.0**		
				Max	10	53	67	4	0	0.62	0.49	4.6	1.3	2.3		
		Subsoil	7	Min	2	20	15	4	0	0.39	0.09	4.1	0.0	0.1		
				Mean	**7**	**49**	**38**	**13**	**7**	**0.44**	**0.35**	**4.3**	**0.3**	**0.5**		
				Max	11	81	72	24	48	0.49	0.62	4.8	0.7	1.2		
NTA	2	Topsoil	4	Min	4	63	10	2	0	0.15	0.15	4.6	0.2	0.4	NTA	2
				Mean	**6**	**75**	**22**	**2**	**5**	**0.24**	**0.23**	**5.1**	**0.8**	**1.3**		
				Max	8	88	35	2	18	0.34	0.29	5.5	1.7	3.0		
		Subsoil	6	Min	1	55	9	2	16	0.21	0.09	3.6	0.1	0.1		
				Mean	**4**	**75**	**15**	**9**	**39**	**0.25**	**0.14**	**4.7**	**0.2**	**0.3**		
				Max	9	88	31	36	56	0.29	0.24	5.4	0.3	0.4		

Source: Geomatrix 2008

Source: Geomatrix

ANNEX C5 - TABLE C5-1

Summary of Agronomic Analytical Results

Strata	Samples	Value	Total Nitrogen (%)	Carbon:Nitrogen Ratio	Phosphorus - Bray's (ppm)	Potassium (ppm)	Total Exchangeable Bases (meq/100g)	Exchangeable Acidity (meq/100g)	Cation Exchange Capacity (meq/100g)	Base Saturation (%)
Topsoil	2	Min	0.24	10.5	2.94	199.4	9.91	0.10	10.0	99.0
		Mean	**0.28**	**10.7**	**4.48**	**222.9**	**13.86**	**0.10**	**14.0**	**99.2**
		Max	0.32	10.9	6.02	246.3	17.81	0.10	17.9	99.4
Subsoil	8	Min	0.02	8.7	0.05	35.2	1.53	0.20	3.6	31.4
		Mean	**0.04**	**10.4**	**0.22**	**57.7**	**2.33**	**2.08**	**4.4**	**54.0**
		Max	0.09	13.0	0.84	86.0	4.10	3.80	5.5	95.3
Topsoil	3	Min	0.11	10.3	0.56	66.5	3.93	0.25	4.8	64.2
		Mean	**0.13**	**10.8**	**0.89**	**76.9**	**4.77**	**1.13**	**5.9**	**80.8**
		Max	0.16	11.5	1.05	86.0	6.25	2.30	6.5	96.2
Subsoil	10	Min	0.02	8.6	0.05	19.5	1.14	1.75	4.2	19.7
		Mean	**0.05**	**10.2**	**0.40**	**37.1**	**1.97**	**3.16**	**5.1**	**39.5**
		Max	0.07	12.0	2.38	70.4	2.61	5.30	6.6	59.9
Topsoil	2	Min	0.08	8.4	1.05	31.3	2.38	0.30	3.1	76.0
		Mean	**0.11**	**9.5**	**1.26**	**58.6**	**3.06**	**0.53**	**3.6**	**84.3**
		Max	0.13	10.6	1.47	86.0	3.74	0.75	4.0	92.6
Subsoil	6	Min	0.01	10.4	0.05	19.5	1.04	1.30	3.0	23.2
		Mean	**0.03**	**12.8**	**0.35**	**23.5**	**1.54**	**2.60**	**4.1**	**38.8**
		Max	0.05	17.0	1.82	31.3	1.95	3.45	5.2	56.5
Topsoil	2	Min	0.04	10.6	0.29	121.2	10.68	0.10	12.1	88.0
		Mean	**0.12**	**10.7**	**0.76**	**132.9**	**11.89**	**0.78**	**12.7**	**93.6**
		Max	0.20	10.8	1.22	144.7	13.10	1.45	13.2	99.2
Subsoil	3	Min	0.01	6.0	0.21	140.8	12.15	0.10	13.5	90.0
		Mean	**0.02**	**9.1**	**0.41**	**166.8**	**16.18**	**0.80**	**17.0**	**94.9**
		Max	0.03	10.7	0.76	191.6	19.75	1.35	20.7	99.4
Topsoil (1 sample)			**0.09**	**11.2**	**3.41**	**43.0**	**3.56**	**0.10**	**3.7**	**97.3**
Subsoil	2	Min	0.01	9.0	1.47	62.6	3.30	0.25	3.6	93.0
		Mean	**0.02**	**12.5**	**1.91**	**68.4**	**3.84**	**0.28**	**4.1**	**93.3**
		Max	0.02	16.0	2.35	74.3	4.37	0.30	4.7	93.6
Topsoil	1	Min	0.25	11.0	3.76	219.0	17.45	0.10	17.6	99.4
		Mean	**0.25**	**11.0**	**3.76**	**219.0**	**17.45**	**0.10**	**17.6**	**99.4**
		Max	0.25	11.0	3.76	219.0	17.45	0.10	17.6	99.4
Subsoil	4	Min	0.03	6.3	0.05	19.5	1.67	0.10	3.4	49.1
		Mean	**0.05**	**8.4**	**0.81**	**45.0**	**3.20**	**0.64**	**3.8**	**81.8**
		Max	0.09	10.0	2.88	70.4	4.20	1.73	4.3	97.7
Topsoil	2	Min	0.05	10.3	1.00	27.4	2.22	0.10	2.5	89.9
		Mean	**0.11**	**10.8**	**2.24**	**50.8**	**4.30**	**0.18**	**4.5**	**94.2**
		Max	0.16	11.4	3.47	74.3	6.38	0.25	6.5	98.5
Subsoil	8	Min	0.02	8.3	0.05	15.6	1.68	0.38	2.1	50.0
		Mean	**0.04**	**11.0**	**1.00**	**25.9**	**2.31**	**1.01**	**3.3**	**70.4**
		Max	0.06	16.0	2.64	31.3	2.77	1.83	4.3	81.6
Topsoil	2	Min	0.09	9.4	1.59	35.2	1.06	0.10	1.4	73.6
		Mean	**0.12**	**10.3**	**2.56**	**58.6**	**5.15**	**0.24**	**5.4**	**86.3**
		Max	0.14	11.2	3.53	82.1	9.24	0.38	9.3	98.9
Subsoil	7	Min	0.01	3.0	0.24	19.5	2.21	0.20	2.7	76.1
		Mean	**0.03**	**9.7**	**1.48**	**36.3**	**4.12**	**0.56**	**4.7**	**87.4**
		Max	0.08	14.0	4.47	66.5	7.95	1.45	8.6	95.5
Topsoil	4	Min	0.02	10.2	2.10	11.7	1.38	0.05	1.5	91.8
		Mean	**0.08**	**10.6**	**3.01**	**59.6**	**5.80**	**0.10**	**5.9**	**96.2**
		Max	0.17	11.5	3.94	117.3	11.72	0.15	11.8	99.6
Subsoil	6	Min	0.01	5.0	1.81	11.7	1.11	0.05	1.2	33.7
		Mean	**0.02**	**10.8**	**4.34**	**50.2**	**2.77**	**1.22**	**4.0**	**79.3**
		Max	0.02	16.0	8.22	164.2	9.18	3.78	12.2	96.1

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Elemental Concentrations

Samples analyzed for elemental concentrations were collected from 78 sites representing 10 different series. These sample sites included the 16 typical series profiles, 25 sites with evidence of anthropogenic influences and 32 sites located on a grid within the mineralized zone. The purpose of soil elemental analyses was to assess whether prior contamination has occurred and whether concentrations are naturally elevated.

Notable differences between the soil elemental concentrations of typical profile sites, areas of anthropogenic influence, and the mineralized zone were not found. Comparison of soil elemental concentrations to concentrations observed elsewhere in Ghana and worldwide suggests that the concentrations observed are within the natural range for soils. It is unlikely that human health risks associated with the concentrations of the investigated elements exist in the Proposed Mining Area.

SOIL CLASSIFICATION

Representative soil profiles were classified according to the World Reference Base for soil resources (WRB) system (FAO 1976). The primary Ghanaian series encountered during the survey and their classifications are provided in **Table C5-2.** These classifications reflect the most appropriate classification for the dominant phases of the soil series observed. However, these classifications may not be appropriate for each pedon observed.

TABLE C5-2
Taxonomic Classification of Soil Series

Series	Clasification
Akroso	Plinthic Acrisol
Bekwai	Ferric Acrisol
Kobeda	Endoleptic Acrisol to Lithic Leptosol
Kokofu	Plinthic Acrisol
Nsaba	Plinthic Acrisol
Nta	Gleyic Arenosol
Nzima	Ferric Acrisol
Oda	Eutric Gleysol
Ofin	Gleyic Fluvisol
Swedru	Plinthic Acrisol
Temang	Gleyic Fluvisol

AGRICULTURAL SUITABILITY

The 2008 soil survey (Geomatrix and SRI 2008) assessed suitability of the soil for rain-fed agricultural uses according to FAO (1976) methods, which are based primarily on the morphological properties of the soils and landscape characteristics. The series were rated according to the orders of suitable (S), non-suitable (N) and further separated into the

following suborders: highly suitable (SI), moderately suitable (S2) marginally suitable (S3), presently not suitable (N1) and permanently not-suitable (N2). The major limitations affecting the assessments were soil depth, contents of gravels and stones, infertility or textural problems (s), soil erosion hazard (e), and wetness and flooding problems (w).

Moderately Suitable Series

Kokofu and Akroso series – S2e

These series have good physical conditions for root development and hold, are easy to till, and are generally free of coarse fragments. They have rapid external drainage, good internal drainage, and the water holding capacity is high to medium. The main limitations are the low nutrient availability and high erosion hazard.

In the Proposed Mining Area, these series were found to support plantation crops of cocoa, oil palm, citrus and wide range of food, horticultural, vegetable and legume crops. Adequate organic and inorganic fertilization is necessary for constant high crop yields. Anti-erosion practices may be required to conserve the soil resource.

Bekwai, Nzima, Swedru and Nsaba series – S2se

These series also have good physical conditions for root development and hold, but their subsoils often have common coarse fragments including quartz gravels. They have very rapid external drainage, very good internal drainage, and the water holding capacity is low to medium. Their limitations for crop production are their susceptibility to soil erosion (which is exacerbated due to their landscape position), rapidly declining soil fertility following cultivation, occasionally high coarse fragment content.

In the Proposed Mining Area, these soils have been intensively and extensively used for cultivation resulting in depletion of nutrients and erosion of the topsoil. Together they form the most extensive soils being used in the production of plantation and arable crops, including cocoa, citrus, oil palm, maize, plantain, cassava, yams, cocoyam, vegetables and legumes. Soil and water conservation measures, as well as effective fertilization with both organic and inorganic fertilizers are necessary to increase or sustain agricultural production.

Marginally Suitable Soil

Oda, Temang, Nta, and Ofin series – S3sw

These series are subjected to flooding and waterlogging during the rainy seasons. The textures are commonly very fine (clay) or coarse (sand), which are preferred for cultivation less than loamy materials. The main limitations for their use are unfavourable moisture conditions and textural limitations.

In the Proposed Mining Area, these soils are extensively used for oil palm cultivation and are less suitable for most other crops. Drainage management, fertilization, and water logging controls may be required to sustain production or increase suitability for a wider variety of crops.

Permanently Non-Suitable Soil

Kobeda Series – N2

This series is poorly developed, moderately deep, excessively drained and has high coarse fragment content. While this series is suitable for forestry, its most common use, these properties make it generally unsuitable for agricultural production.

ANNEX C-6

NOISE
SUPPLEMENTAL INFORMATION

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 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 would 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, similar 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. The frequency weighting most often used to evaluate environmental noise is the "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 (e.g., bulldozers) decrease by 6 dBA when distance from the source is doubled.

Noise levels can be described using many types of noise descriptors. This noise section primarily uses the A-weighted Leq and L90 noise descriptors for discussing the existing and the steady future sound levels in the project vicinity. The L90 is the sound level exceeded 90% of the time and is often considered representative of the background sound level. The Leq is the level of a constant sound that has the same sound energy as the actual fluctuating sound. As such, it can be considered an energy-average sound level. The Leq gives most weight to the highest and longest duration sound levels because they contain the most sound energy. The Leq noise metric has been found to be highly correlated to community response to noise and is the noise descriptor used most often by international organizations and U.S. agencies when discussing hourly sound levels. Finally, the Lmax is a short-term noise level typically used to represent the highest level associated with a noise event. The "fast" Lmax is the highest 1/8 second sound level.

For general comparison purposes, **Table C6-1** lists typical A-weighted sound levels of common noise sources and activities. The noise levels in the table listed for *specific* sources (e.g., a motorcycle accelerating) at referenced distances represent the approximate maximum levels during that event. Such maximum levels typically occur nearly instantaneously, and generally are not sustained continuously over a prolonged period of time. Similarly, the noise levels listed for general sources or environments (e.g., inside a computer equipment room) represent more sustained levels for the general conditions listed.

TABLE C6-1
Common Noise Levels, Sources and Subjective Human Evaluation

Noise Level (dBA)	Noise Source	Subjective Human Evaluation
120 110	• Jet take-off at 100 feet • Hard rock concert • Motorcycle accelerating a few feet away	Deafening
100 90	• Automobile horn 10 feet away • Gas lawnmower 3 feet away • Diesel truck driving by 50 feet away • Inside a computer equipment room	Very Loud
80 70	• Very loud speech - 3 feet away • Crackling plastic food wrapper 2 feet away • Car driving by at 55 mph 50 feet away • Outdoors in a commercial area	Loud
60 50	• Normal speech 3 feet away • Typical office activities • Background noise in a conference room	Moderate
40 30	• Library background noise • Quiet suburban environment at night • Typical background noise in a residence • Whisper 3 feet away • Typical broadcast studio	Faint
20 10	• Concert hall background noise • Human breathing	Very Faint
0	• Threshold of hearing or audibility	

Source: Egan (1988); Cavanaugh and Tocci (1998); Burge (2002).

NOISE MEASUREMENT METHODOLOGY

The long-term noise measurements were conducted using two Larson Davis Model 820 sound level meters, which comply with the Type 1 tolerance requirements of the American National Standards Institute (ANSI). Both meters were field calibrated before and after each measurement, and each meter had been calibrated at an accredited laboratory within the past 12 months. Measurements were conducted using the "fast" time averaging function. Overall levels were measured using the A-weighting scale. The microphones of the meters were fitted with appropriate wind screens and set approximately 1.5 meters above the ground (at a typical listening height).

The sound level meters were set to continuously measure the hourly Leq, L90, and other parameters. The long-term measurements were unattended most of the time but were visited several times during the week, both during the day and at night. Area noise sources were noted during the setup and retrieval of the meters and during these visits, and some general observations regarding the existing noise environment follow.

NOISE MEASUREMENT RESULTS AND DISCUSSION

Mamanso (M1) – Measurements were conducted at the Newmont Community Centre. This location is representative of the main part of town where most of the residents live. There are some residents closer to the proposed mine, but they are also closer to the main north-south road. The Community Centre is located about one hundred meters off the main road where baseline sound levels are lower and more representative of the village as a whole.

The measured sound levels differ greatly between the May and October surveys. During the May survey, the L90S ranged from approximately 40 to 60 dBA during both the day and the night. During the October survey the L90S ranged from approximately 40 to 83 dBA during the day and 44 to 68 dBA at night. The levels during the October survey are noticeably louder than during the May survey, and the reasons for this are not completely understood. Weather data were analyzed and no pattern was seen with any of the measured parameters, such as wind and rain that correlated to the periods of high sound levels. One possible explanation is that the high sound levels were due to crickets, because the sound levels spike at sundown (between 6 and 7 p.m.), which is when temperatures drop and crickets come out. This phenomenon is much more apparent in the October survey during the wet season. This is supported by the fact that crickets were consistently noted as the primary audible source during the attended measurements.

New Abirem South (M2) - Measurements were conducted at one of Newmont's residences located in the southwest area of New Abirem. This location is representative of the residences in New Abirem located closest to the proposed mine and away from the main north-south road.

The measured sound levels differ somewhat between the May and October surveys. During the May survey, L90S ranged from approximately 30 to 52 dBA during the day and night. During the October survey, the L90S ranged from approximately 30 to 69 dBA during the day and 41 to 62 dBA at night. During the daytime, the levels during the October survey were as much as 17 dBA louder than the May survey, while at night the levels were approximately 10 dBA louder. Again, the reasons for this are not completely understood, but crickets are suspected.

New Abirem North (M3) - Measurements were conducted at one of Newmont's residences located in the northwest area of New Abirem. This location is representative of the residences in New Abirem located closest to the proposed mine and away from the main north-south road.

The measured sound levels differ somewhat between the May and October surveys. During the May survey, L90S ranged from approximately 38 to 55 dBA during both day and night. During the October survey, the L90S ranged from 35 to 66 dBA during the day and 41 to 62 dBA at night. During the daytime, the highest levels during the October survey were approximately 10 dBA louder than the May survey, while at night the levels were similar. Again, the reasons for these differences are not completely understood.

Afosu (M4) - Measurements were conducted in front of the Methodist Church in Afosu. This location is representative of the closest residents in Afosu to the proposed mine. The church is located on the main street in Afosu but about 200 meters away from the main north-south road.

The measured sound levels differ greatly between the May and October surveys. During the May survey, L90S ranged from approximately 42 to 55 dBA during the day and 30 to 49 dBA at night. During the October survey, the L90S ranged from approximately 40 to 78 dBA during the day and 41 to 71 dBA at night. The levels during the October survey were relatively loud, and crickets are suspected as the primary noise source.

Adausena (M5) - Measurements were conducted near the top of the hill in Adausena, where there is a direct line of sight to the proposed pit. This location is representative of the residences in the village closest to the proposed mine.

The measured sound levels differ somewhat between the May and October surveys. During the May survey, L90S ranged from approximately 35 to 66 during the day and 38 to 57 dBA at night. During the October survey, the L90S ranged from approximately 36 to 75 dBA during the day and 48 to 63 dBA at night. During the daytime, the loudest levels during the October survey were approximately 10 dBA louder than the loudest May levels. During the night time, the quietest levels in the October survey were approximately 10 dBA louder than the quietest May levels. Again, the reasons for this are not completely understood, but crickets are suspected.

Hweakwae (M6) - Measurements were conducted in front of the Catholic Church in Hweakwae. This location is representative of Hweakwae residences located closest to the proposed mine.

In Hweakwae, the measured sound levels are similar between the May and October surveys. During the May survey, the L90S ranged from approximately 38 to 65 dBA during the day and 38 to 57 dBA at night. During the October survey, the daytime L90S ranged from 40 to 69 dBA while the night time levels ranged from 44 to 60 dBA.

ANNEX C-7

SOCIOECONOMICS
SUPPLEMENTAL INFORMATION

NATIONAL OVERVIEW

Ghana gained independence in 1957, the first country in sub-Saharan Africa to do so. While Ghana endured military rule for a period, the country has enjoyed uninterrupted democratic governance since 1992. With its comparatively stable political infrastructure and strong social capital base, the country is atypical of the region.

In the 2000 census, Ghana's population was estimated at about 21 million people. The US Department of State, Bureau of African Affairs estimated the 2007 national population at 23 million (NGRL 2008). As the population increased, so did the country's population density per square kilometre (km^2). It has more than doubled from 36 persons in 1970 to 79 persons in 2000. The 2007 population density estimate is 88 persons per km^2 (GRRL 2008).

Accra, the capital city, had a population of 2,825,800 (metropolitan area) in 2000. Kumasi, the country's second largest city, had an estimated population of 975,800 in 2000. English is the official language of Ghana. Local languages spoken include Brong, AsanteTwi, Fanti, Ga, Ewe, and Dagbani. The native people of Ghana are classified into 5 major groups: the Akan (44 percent), the Ewe (13 percent), Moshi Dagomba (16 percent), the Ga (8 percent), and the Gruma (3 percent). Christians make up 63 percent of the population. Followers of traditional beliefs make up 21 percent, and Moslems make up 16 percent of the population (GRRL 2008).

Ghana's economy is predominantly rural-based as agriculture and mining drive the current economy. Cocoa, timber, and pineapples are the main export crops while gold mining has become one of the biggest primary sources of foreign exchange. The emerging value-added industrial sector products include cassava, fruits, and cocoa by-products.

Ghana's human development indicators, while low, are improving. In 2001, life expectancy at birth was 58; adult literacy was 73 percent; school enrolment (combined primary, secondary and tertiary) was 46 percent, and per capita income was estimated at $2,250 (USD). 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 remove fuel subsidies, led to a pronounced reversal in macro-economic performance. Ghana joined the Heavily Indebted Poor Country (HIPC) debt relief programme in 2002.

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 2,241,125 ounces of gold, down 8 percent of the production experienced in 2000. The Ghana Minerals Commission reports that revenues in USD generated by gold mining in Ghana in 2002 (the last year of complete annual data) was $646,030,832 USD with royalties of $15,843,015 USD (15,999,861 GH¢). Gold accounted for almost 93 percent of the total mineral royalties collected during 2002. Over 12,900 people were employed by gold mining in 2002, and corporate taxes from large scale mining equalled $914,118 USD (923,168 GH¢) (CIVA 2005).

The country's economy has performed well in recent years. In 2006, real Gross Domestic Product (GDP) growth reached 6.2 percent, which was the highest rate since the early 1990s. The economy has to date proved resilient to the energy shortages that began in September 2006 with GDP rising to 6.3 percent in 2007 (GRRL 2008). In December 2007,

inflation rose to 12.7 percent. Some of the reasons for this are the surge in the international crude oil prices (GRRL 2008), which resulted in increases in domestic prices of petroleum products. On average there was a 12 percent increase in the per litre price of petrol during the last quarter of 2007, while the prices for kerosene and gas used for cooking also increased sharply and electricity tariffs increased by approximately 100 percent (GRRL 2008).

According to the GRRL (2008), food prices rose sharply from 9.3 percent in September 2007 to 10.5 percent in December 2007. This increase can be attributed to the increase in transport costs, the adverse climatic conditions experienced during the first quarter of the year, and the impact of floods that affected the major food-growing areas of the country.

The fifth Ghana Living Standards Survey (GLSS 5) compared data from 1991 to data from 2006; indicating poverty in 2006 has declined since 1991. The indicators show a downward trend in poverty from 39.5 percent in Fiscal Year 1998/1999 to 28.5 percent in Fiscal Year 2005/2006 (GRRL 2008). Poverty-related expenditures increased from ¢233.9 GH¢ million in 2002 to ¢1,237.4 GH¢ million in 2006. This represents 21.7 percent of the 2002 total government expenditure compared to 34.9 percent of total government expenditure in 2006 (GRRL 2008).

The Cedi has remained relatively stable against major currencies throughout 2007 and has successfully been re-denominated: ten thousand cedis became one Ghana Cedi (GH¢), equivalent to one hundred Ghana Pesewas (i.e. ¢10,000 = Gh¢1 = 100 Gp). All figures in this report are presented in GH¢.

EASTERN REGION / BIRIM NORTH DISTRICT OVERVIEW

The Eastern Region's (Region) population of 2,108,852 million is comprised of 49 percent males and 51 percent females in 2000. It is the third most populous region after Ashanti and Greater Accra Regions. The population structure indicates that 41.7 percent are younger than 15, while 5.8 percent are older than 64 years.

The Birim North District (District) registered a population of 123,579 in 2000 (Official Census) with an annual growth rate of 3.4 percent, using this growth rate the District population for 2006 is estimated to be 152,401 persons. Analysis of the 2000 census revealed that children between the ages of 0-14 years constitute 16 percent of the total District's population. Males constitute approximately 49 percent (60,982) of the population while the female population stands at 62,597 or approximately 51 percent. Male/female population ratio is 1:1.02.

The District had 4 percent of the total Eastern Region population according to the 2000 census, and 6.5 percent of total area of the region (1,250 km^2 as compared to 19,323 km^2). The District had a lower population density (99 persons per km^2) than the average for the Region of 109 persons per km^2, reflecting the prevalence of relatively small size settlements in the District.

Of the 140 settlements in the District, in 2000, only two - Ayirebi and Akuase - could be described as urban. These urban settlements contained 1.4 percent of the district's population while the rural settings had 98.6 percent of the population. Only settlements with a population of 5,000 or more are classified as towns.

The Region has four main ethnic groupings: Akan (52 percent), the Ga-Dangme (19 percent), the Ewes (16 percent), and the Guans (13 percent). The Ewes are the only non-indigenous ethnic group. The Akan predominate in 11 of the 17 districts (2000 Census). The major languages spoken are Akan and Krobo (GRRL 2008).

Three main Traditional Groupings are represented in the District. The predominant group is the Akim Kotoku Traditional Authority to which an estimated 85 percent of the District's population owes allegiance. The Kotoku Traditional Authority is headquartered at Akim Oda. The other two groupings are Akim Abuakwa and Akim Bosome. Settlements owing allegiance to Abuakwa Traditional Authority are Chia, Adubiase and Odumase, while Ofoase, Brenase and Anyinase owe allegiance to the Bosome Traditional Authority. The population of the District is predominantly Akims. Most tribal groups maintain inheritance practices with assets passed through the female line. However positions of traditional authority are almost exclusively male. Most of the country's major tribal groups (Ashantes, Kwahus, Ewes, Northerners, Ga-Adangbes, Akuapems and Fantes) are also represented. The non-Akims are sometimes landowners and constitute the traditional authorities in a sizeable number of settlements.

About 92 percent of residents of the Region are Christian, 4 percent are Muslim and 3 percent practice other religious beliefs. Traditional religions are practiced mostly in Afram Plains, Asuogyaman, Akwapim North and Akim West Districts. (GRRL 2008). The majority of the District's inhabitants are Christians (83 percent of the total population) and Muslim (6 percent). Most Moslems are living in New Juaben and West Akim Districts. In parallel with these mainstream religions, fetishism is still common place, especially in rural settlements and hamlets (GRRL 2008).

The main economic activities in the District include farming, small-scale industrial activities, small scale mining and commerce. The majority (73.5 percent) of the District's labour force works in the agriculture sector, with 15.2 percent working in commerce and 3.8 percent in services.

DISTRICT GOVERNMENT

The Birim North District Assembly is the highest administrative and political authority in the District and is empowered to make and enforce by-laws. The District Assembly has 70 percent elected members and 30 percent government appointees, and is headed by the District Chief Executive, who is appointed by the President with the approval of two-thirds of the District Assembly. The District Assembly (DA) includes two Members of Parliament, 42 elected members and 18 government appointees.

The DA is responsible for development through preparation, implementation and management of District development plans. The main sources of revenue (**Table C7-1**) to the Birim North District Assembly are government grants and internally generated funds.

- Government grants include funds from the District Assembly Common Fund, Ghana Education Trust Fund, HIPC Funds and others.

- Internally generated funds sources include taxes, fees and fines, licenses, rents, money from investments and business operations.

Table C7-1
Sources of Revenue for the Birim North District: 2002-2005 (in GH¢)

Source	2002	2003	2004	2005
Internally generated funds	42,510	58,650	144,637	168,675
Government grants	44,667	148,400	859,991	889,127
Total	87,178	207,051	1,004,629	1,057,802

Source: GRRL 2008

Although there has been a steady increase in internally generated funds since 2002, problems that prevent the District from collecting revenues more efficiently include:

- Lack of vehicles,
- Residents are not aware that they need to pay taxes and
- Most of tax collectors are not equipped with current methods of revenue collection.

LAND TENURE DESCRIPTION

There are two main categories of land in Ghana – public or State lands and private lands. A separate category of land that falls in between these categories is "vested land." Vested land refers to land with dual ownership where the legal interest is vested in the state and managed by the Lands Commission on behalf of the stool/skin. The beneficiary or equitable interest remains with the stool/skin. Thus, no grant of vested land can be made by the stool/skin. All such transactions are made on their behalf by the state agency managing it and revenue accrues to their benefit.

Public lands refer to those acquired by the Government through legislation, in the public interest. Private lands comprise land held customarily in stools/skins for and on behalf of the land owning communities, family/clan lands and all lands owned by individuals.

Families or individuals may acquire land by outright purchase or through lease over periods of time - either 50 or 90 years. The Constitution prohibits freehold transactions in land. The landless who have no money to purchase or lease land may have access to land through the sharecropping 'abunu/abusa' system. In the 'abunu' system, the produce or revenue derived from the sale of the produce is shared evenly between landowner and land user. In the 'abusa' system, the produce from the land or derived revenue is shared such that one-third goes to the landowner and two-thirds to the land user (sharecropper). This is a common practice determined through negotiation between the user and landlord and depends on the type of crops planted.

AGRICULTURAL LAND USE DISCUSSION

Farming is the primary occupation of people in the Study Area. Although cocoa was the most important crop in the past, as evidenced by cocoa farms bordering the fringes of the forest reserves and the presence of the Afosu Cocoa Research Institute, it has given way to oil palm and citrus in many areas. Oil palm is now the leading cash crop in the area (SGS 2004f).

Apart from the three tree crops (cocoa, oil palm and citrus), cola is cultivated on farms in the northern section of the Study Area with a ready market at Afosu. Food crops such as plantain, cocoyam, cassava and maize are planted as intercrops in the young tree crops of oil palm and citrus. In some areas, food crops have been established for subsistence; these are prominent around settlements and hamlets. Productive oil palm, cocoa, citrus and food crop farms are located in the Proposed Mining Area south of the Ajenjua Bepo Forest Reserve (SGS 2004f).

The main agricultural system used in the Study Area employs traditional inputs, namely land, family labour and simple tools and equipment (cutlass, hoe and axe). The majority of farmers rely on their own stock for planting materials and the natural fertility of the land for production. Farming is labour intensive, not mechanized and agro-chemicals are seldom applied. They farmers seldom employ additional labour for farm work. As a result, most food crop farms are generally small averaging less than a hectare and thus surpluses for the market are meagre (SGS 2004f).

Most farmers practice mixed food crop farming on a land rotation system. The system employs slash and burn and zero-tillage techniques for land preparation. Farmers rotate farmland to allow some fields to lie fallow (abandoned or unused). After burning, plots are typically farmed and harvested for two years before being left fallow. Secondary burning and cultivation usually occurs 5 to 10 years after the plot has been abandoned. With this system, the crops are able to tap nutrients from all zones of the soil (SGS 2004f).

Tree Crop Production

In the area north of the Auro River Forest Reserve and the Mamang River Forest Reserve, oil palm and cocoa production dominate agricultural practices. Oil palm is prominent in areas south and southeast of the Ajenjua Bepo Forest Reserve and along the course of the Pra River at the north western border of the Study Area. Cocoa farms are established along fringes of forest reserves and the central section of the Pra River and are also scattered on a limited scale in the northern section and very prominently along the fringes of the steep slopes adjoining the Ajenjua Bepo Forest Reserve (SGS 2004f).

Oil Palm

Oil palm is dispersed throughout the Study Area but primarily occurs in areas south and southeast of the Ajenjua Bepo Forest Reserve and to the northwest along the Pra River. In some higher elevations oil palm is interspersed with citrus. Oil palm is cultivated on gentle slopes with less than 5 to 6 percent gradient with age classes ranging from one to 15 years.

Beginning in the late 1970s, the Ghana Oil Palm Development Company established extension services to advise farmers on agronomic husbandry practices to ensure good yields. In addition, the Ghana Oil Palm Development Company sponsored out grower farmers and established six collection centres in the Study Area where farmers can sell fresh fruit bunches of oil palm.

Citrus

Citrus production has increased in the Study Area because these plants do well in areas unsuitable for both cocoa and oil palm. The campaign to promote the crop was launched in parts of the Eastern Region by Adventist Development and Relief Agency in collaboration with the University of Ghana- Agricultural Research Station. The programme is being embraced by farmers with suitable land due to the attractive credit package which supplies improved planting materials and funds for initial farm maintenance.

Citrus is becoming the preferred replacement crop on steeper land within the Study Area. Most citrus crops have been established since 1996. Given the suitability of the area for citrus, the Ghana Citrus Farmers Association is organising farmers into groups to facilitate marketing of citrus for export, and for processing plants at Tema, Asamankese, Nsawam and Oda. Currently, about 200 hectares of citrus have been established by 271 farmers in the Study Area under the sponsorship of the Adventist Development and Relief Agency (SGS 2004f).

Cocoa

Cocoa farming is extensive along the fringes of steep slopes bordering the forest reserves, along the banks of the Pra and Mamang Rivers and near settlements. Cocoa farming has declined in the Study Area due, in part, to relatively high incidences of pests and diseases including the Cocoa Swollen Shoot Virus caused by the fungus *Phytophtora palmivora*. There are established cocoa farms in the area ranging in age from 5 to 30 years (SGS 2004f). Production of dry cocoa beans in the Study Area averages about 300 kilograms/hectare/year as compared with a national average of 400 kilograms/hectare/year (rePlan 2007b). The average cropped area for cocoa is about 2.3 hectares (SGS 2004f). In view of the prominence accorded to oil palm and citrus through the extension of technology (e.g. improved planting materials, fertilizers, and credit), cocoa farming is gradually phasing out in the Study Area.

The cocoa industry in the area is well serviced with the ready markets provided by the Produce Buying Company of Ghana Cocoa Board and several private cocoa buying companies. All towns in the northern section of the Study Area have cocoa marketing centres operated by these governmental or private cocoa buying companies. Cocoa extension services to farmers are limited.

Mixed Tree Crops and/or Mixed Food Crops

Mixed food crop farms of plantain, cassava, cocoyam, maize and rice have been established for subsistence and are found near settlements and hamlets. Plantain has declined due to the *Black sigatoka* disease found throughout the Study Area. Food crops are also planted as intercrops between young oil palm, cocoa and citrus plants to provide subsistence for the

family and shade for the growing permanent crop. Mixed cropping helps farmers cushion the effect of failure of any one crop. However, it also tends to mean smaller plant populations and hence lower yields per unit of land and low return per unit of input. The average cropped area per holder ranges from 0.4 hectare to one hectare (SGS 2004f).

Bush Fallows

Bush fallows are generally divided into forb re-growth and thickets. Forb re-growth consists of soft-stemmed leafy herbs, which establish on abandoned farmlands. Once a farm is abandoned, these plants quickly establish and form dense foliage 1 to 2 metres or higher. Remnants of food crops are usually present as well as coppice shoots growing from stumps of felled trees. The re-growth is generally dominated by *Chromolaena odorata* and remnants of food crops including cassava, cocoyam, plantain, banana and pawpaw.

Thickets are fallow farmland, 3 to 7 years old, characterized by impenetrable masses of shrubs, climbers, coppice shoots, young trees and relics of food crops reaching heights of 6 metres.

FOREST RESERVES LAND USE DISCUSSION

Three forest reserves are present in the Study Area. The Mamang River Forest Reserve (53 square kilometres) and Auro River Forest Reserve (7.2 square kilometres) are outside the Proposed Mining Area and would not be directly affected by mine development. The Ajenjua Bepo Forest Reserve (5.9 square kilometres) is within the Proposed Mining Area with approximately 74 hectares lying within the proposed mine pit area. A fourth forest reserve, the Kagease Forest Reserve (27.9 square kilometres), is located several kilometres east of the Study Area.

Use of natural resources from the three forest reserves contributes to household food security throughout the Study Area. Hunting of certain species is allowed in the forest reserves under special seasons controlled by Ghanaian wildlife regulations. Both legal and illegal hunting and trapping have been noted to occur in all forest reserves. Community members also use the forest reserves to pick fruit, mushrooms and medicinal plants and to cut wood.

DESCRIPTIONS OF URBANIZED AREAS IN STUDY AREA

Afosu: Afosu is the largest settlement in the Area but it was still classified as a settlement not a town because its population is below 5,000 in the 2000 national census. Estimates made by the Ghana Statistical Service project a population of 5,325 in 2008. The District Police station is located here. The Cocoa Research Institute has its main facility in Afosu and the Cocoa Marketing Board maintains a station in the town. There is a small health post run by the Ministry of Health. The Asuopra Rural Bank has a branch operation in this town and there are two sawmills and a carpentry shop in addition to drinking spots, hairdressers, and stores. There is a communications centre in Afosu but no post office. There are seven formal religious centres including Christian, Catholic, and Islamic facilities.

New Abirem: New Abirem is the capital of the Birim North District and several ministries maintain officers in the town, including the offices of the District Assembly, Town & Country Planning, Information Services, National Mobilization Program, Electoral Commission, Electricity Cooperative, Food & Agriculture, and Range Forestry. There is a Ministry of Health clinic in New Abirem with 39 employees. Commerce in New Abirem includes two markets providing various goods, drinking spots, and two Ghanaian rural banks. There are three churches in New Abirem: Methodist, Presbyterian, and Roman Catholic. Population for 2008 is projected to be almost 4,000 people, up from an estimated 3,245 people in 2000.

Mamanso: Mamanso is a small settlement south of New Abirem, which is projected to have 2,663 people in 2008. There is a small health clinic and limited commercial activity in the settlement. The majority of the residents are subsistence farmers engaged in the cultivation of oil palm and cocoa. Excess food crops are sold at the New Abirem markets. There is no community centre or entertainment in Mamanso. There are nine religious facilities in Mamanso serving Christians, Catholics, and Muslims.

Old Abirem: Old Abirem is a small community south of Mananso at the southern edge of the Study Area. The 2000 population was estimated at 1,400 people living in 330 houses most of which are in poor condition. The Ghana Statistical Service projected a population of 1,306 people for 2008. Most of the residents of Old Abirem are farmers, primarily engaged in the production of oil palm with lesser emphasis on growing cocoa, vegetables, maize, and plantain. There are two chemist shops in the settlement but residents must travel to New Abirem for medical care. In addition to a few shops and drinking spots, there are three cocoa buying companies operating in Old Abirem. There are religious facilities to serve both Christians and Muslims.

Adausena: This settlement has been recorded as the first settlement established within the Study Area. The National Census estimated that 1,162 persons lived in the settlement in 2000 and projects an increase to 1,429 people in 2008. Inhabitants are predominantly subsistence farmers; however, the settlement economy is dominated by the cultivation of cash crops including oil palm, citrus, cocoa, plantain, and cassava. Excess food crops are sold at either the New Abirem or Ntronang markets. Six Cocoa Purchasing Companies operate in Adausena and its environs. The only food processing facility in the community is a small oil palm processing plant belonging to the Church of Pentecost. There is also a small-scale sawmill, which employs between 3 and 15 employees. The community has a chemical store, 12 drinking spots, eight salons, and 12 stores. There is no entertainment or community centre. There are three Christian churches in Adausena. The Royal Family maintains a Palace in Adausena.

Hweakwae: The inhabitants of Hweakwae are primarily subsistence farmers engaged in the cultivation of food crops - plantain, cassava, cocoyam, and cash crops such as oil palm, cocoa and citrus. The National Census estimated that 1,016 persons lived in Hweakwae in 2000 and projected an increase to 1,249 people in 2008. The community has 10 stores, 10 drinking spots, five hair salons, and two chemical stores. There is no entertainment or community centre. There are five churches in Hweakwae serving Christians, Catholics, and Muslims.

Ntronang: The National Census estimated that 2,247 persons lived in Ntronang in 2000 and projected an increase to 2,756 people in 2008. There is a police station in Ntronang as well as a small health clinic. Ntronang is the only other settlement in the Study Area besides New Abirem which has a formal market supplied by farmers in the surrounding settlements. Other commercial activities include stores, drinking spots, salons, and a chemical store. There are five churches in Ntronang serving Christians and Catholics. The Royal Family maintains a palace in Ntronang.

DISCUSSION OF INFRASTRUCTURE IN STUDY AREA

Education

Spread among the settlements in the Study Area are 18 kindergartens; 23 primary schools (catering to children aged 1 to 6) and 15 junior secondary schools (ages 14 to 16). The only senior secondary school in the area is in New Abirem (ages 17 to 19). Children from hamlets attend schools in neighboring settlements as do Yayaaso's children who have access to a primary school but no secondary schools (GRRL 2008).

Health Care

Malaria is the most predominant disease in the Study Area. The true prevalence of HIV/AIDS in the Study Area is unknown, but the 4.2 percent rate for the Eastern Region is the highest in the country (2007 Ghana HIV Sentinel Survey Report). The prevalence rate for the District is 3 percent and this data is based on 869 antenatal screenings conducted in New Abirem in 2006 (GRRL 2008). It is impossible to know if this data can reliable be extrapolated across the Study Area. In New Abirem, all new antenatal clinic attendees are counseled to have an HIV/AIDS test. The first quarter 2007 data also indicate that the prevalence rate is staying relatively constant at 3.2 percent (GRRL 2008).

Access to health care for most residents in the Study Area is difficult at best. The major facility in the area is in New Abirem where a primary health care centre is currently undergoing an upgrade. When complete, this facility will attain the status of a hospital - the only one in the District. For more complicated in-patient treatment patients are presently referred to Holy Cross Family Hospital in Nkawkaw or Saint Dominique in Akwatia – both a significant travel distance from the Study Area. There is no qualified doctor in the Study Area and where permanent facilities exist these are rudimentary with limited staff and medicines. OICI's ongoing survey found that in 2005, most of the 300 households interviewed were located within 2 miles from medical assistance.

The International SOS Baseline Health Survey 2006, as cited in GRRL (2008) found that malaria was meso-endemic at the time of the survey and indicated stable patterns of transmission throughout the year in the Study Area. There were however, distinct seasonal peaks in transmission, with increases in transmission towards the end of the rainy season.

Further findings of the survey include:

- 29 percent of the children younger than 5 years sampled for malaria at the time of the survey tested positive for the disease. This survey was conducted at the beginning of the main rainy season when vector densities were still low, so it is possible that a late rainy season survey would find higher rates of malaria. There are significant differences in the malaria seroprevalence rates between villages with some of the highest rates found in Hweakwae and Adausena.

- Knowledge about malaria and prevention of infection were inadequate – only 65 percent of the respondents knew that the mosquito was the only means of acquiring malaria.

- Only 15 percent of households owned an insecticide-treated mosquito net.

- It is estimated that only 29 percent of the children younger than five slept under an insecticide-treated mosquito net prior to the International SOS survey interview.

- Only 18 percent of the children who are younger than five and experienced a fever in the two weeks prior to the interview, were treated with Artemisinin-based combination therapy (ACT) as recommended in the National Malaria Control Programme guidelines (GRRL 2008).

The true prevalence of HIV/AIDS in the Study Area is unknown, but the 4.2 percent rate for the Eastern Region is the highest in the country (GRRL 2008). The prevalence rate for the Birim North District is 3 percent and this data is based on 869 antenatal screenings conducted in New Abirem in 2006 (Newfields 2007 cited in GRRL 2008). It is not possible to know if this data can be reliably extrapolated across the Study Area.

Malnutrition is present in the Study Area, even though there are good breastfeeding practices. The level of children that are underweight (17.3 percent) or wasted (8 percent) correlate with country statistics (GRRL 2008).

Although the coverage of the World Health Organisation's expanded immunization programme is good in the District and is seen as a model for rural health in the country, only 58 percent of the children in the Study Area participated in growth monitoring and 42 percent participated in immunization, as reported by both International SOS and OICI, in GRRL (2008).

Water Supply

The International SOS survey, as cited in GRRL (2008), found that in 2005, 93.7 percent of the respondents interviewed in the Study Area had access to an improved drinking water source, either through a public tap (54.4 percent) or a protected well (38.9 percent). Only 6.3 percent of those interviewed make use of unimproved drinking water sources (GRRL 2008).

Sanitation

The International SOS survey, as cited in GRRL (2008), found that in 2005, 89 percent of the surveyed population in the Study Area had access to toilet facilities:

- Of these, 63 percent had access to improved sanitation facilities:
  - 31.1 percent ventilated improved pit latrine (VIP/KVIP)
  - 34.8 percent pit latrine with a slab (covered pit latrine)

- 33.7 percent had access to unimproved sanitation facilities:
  - 22.6 percent open pit latrine.

Solid Waste Management

The International SOS survey, as cited in GRRL (2008), found that in 2005, the respondents interviewed disposed of their household waste in the following manner:

- 66 percent throw it on the communal dump
- 13 percent dump it within their own compound
- 13 percent dump it in the street
- 3 percent burn it, and
- 3 percent bury it.

Electrical System

Under the Ghanaian Self Help Electrification Project, electricity has been extended to all settlements in the Study Area and Yaw Tano, the largest of the hamlets in the Proposed Mining Area.

Communications Network

A government post office and some commercial telephones are located in New Abirem. Yayaaso, Adausena and Hweakwa have some fixed telephone lines (GRRL 2008). All the Study Area communities have access to a mobile telephone network.

In 2006, the Company commissioned the construction of a communications tower, located between New Abirem and Adausena, to improve communications in the area. The cost involved was $300,000 USD and as it is permanent infrastructure, the tower will remain in the area even if the Project does not go ahead.

Safety and Security

Police and fire-fighting infrastructure is limited in the Study Area. There are no fire personnel or equipment. There are three police stations in the Study Area, at New Abirem, Afosu and Ntronang. Traditional authority structures generally deal with many of the local disputes and conflicts, and only serious crimes are reported to the police.

In general the types of crimes reported are minor (petty theft, verbal assaults, etc.) but there is concern among residents that an influx of strangers to the area will increase levels

of crime. Health workers in New Abirem noted that levels of physical violence were currently low with few reported cases of family violence and some alcohol related incidents. Traditional authority structures deal with many of the local disputes and conflicts and that crimes considered being serious are taken to the police.

AGRICULTURE AND NATURAL RESOURCE USE DISCUSSION

The 2004 SIA survey found that cassava is the most common food crop cultivated in the Study Area. Sixty-eight (68) percent of the 280 respondents reported that cassava is their main food crop. The second most common food crop is plantain being produced by 56 percent of the respondents. However, plantain production has declined due to the *Black Sigatoka* disease found throughout the Study Area (CIVA 2005). Other food crops cultivated include maize, cocoyam, yam, rice, okro, pepper, and garden eggs.

Major cash crops include oil palm, cocoa, citrus, and cola. Oil palm is the most frequently cultivated cash crop in the Study Area. The Ghana Oil Palm Development Company (GOPDC) has a strong presence in the Study Area and provides extension and monitoring services to those farmers who participate in its out-growers programme.

For food crops the average cropped area per holder ranges from 0.4 ha (cocoyam) to 1 ha (rice-paddy), whereas for cash crops the average cropped area per holder ranges between 2.3 ha (cocoa) to 5 ha (oil palm). Yields of cultivated crops are average, perhaps due to low-level of extension services, credit, etc. For example the District Agriculture Development Unit of the Ministry of Food and Agriculture, which exists to ensure sustained agricultural development and agribusiness in the District, has 28 technical field staff. Of these 28 technical officers, only 8 have motorbikes to enable them visit farmers on regular basis (CIVA 2005).

The presence of Ghana Oil Palm Development Company (GOPDC) is likely the major contributing factor to the predominance of oil palm cultivation. The Company provides extension and monitoring services. In the Study Area, GOPDC has assisted over 1,450 farmers to date, with each farmer cultivating on the average 1.6 ha. The total assistance package to each farmer is worth between 496.87 and 600.38 GH¢. Farmers commit to selling crops to the GOPDC, and use their trees as collateral for the loans. According to the GOPDC Zonal Officer the loan recovery rate is between 50-80 percent.

Livestock Production

Livestock rearing is a secondary occupation in the Study Area. Cattle-rearing is confined to settlements such as New Abirem, Afosu, Ntronang, and Nkwanten. There are a few sheep and goats in the settlements and hamlets, and local poultry is also available. With respect to the ruminants (e.g. cattle, sheep and goats), the establishment of Pueraria *spp*. as cover crop in oil palm farms provides grazing for these animals. There are grasses and sedges in some areas to supplement livestock feeding. New Abirem, Afosu, Ntronang, Nkwanten, Nkawkaw, and Kade serve as the sources of supply of meat for inhabitants in the Study Area. The ongoing OICI survey found that in 2005, 91.6 percent of the respondent households owned poultry. Apart from a small amount of intensive poultry farmers, poultry are generally free range (GRRL 2008).

Fishery Resource

Apart from the Pra, Mamang and Afosu rivers, most streams are dry during a portion of the year. There is no organised fishing in the Study Area. Fresh and smoked fish are imported from Tema, Accra, Nkawkaw, and Kade to meet local demand (CIVA 2005).

Forest Reserves

Use of natural resources from forest reserves contributes to household food security throughout the Study Area. Local residents are allowed to pick fruits, mushrooms, medicinal plants, and to cut wood in the forest reserves, which can be sold as cash crops or used for household purposes. Hunting is not allowed in forest reserves.

Medicinal Plants

Several species of medicinal plants are harvested from within forest reserves as cash crops or for household use. Medicinal plants occurring in the Study Area are shown in **Table C7-2**.

TABLE C7-2
Plants of Medicinal Value

Plant	Use
Black pepper (awisa, hwenteaa)	Boils
Awedeaaba	Hernia
Akuama	Stomach ache
Prekese	Hypertension
Pampan	Waist pains
Ekoro	Waist pains, toothache
Sese	Stomach ache, ulcer

Source: CIVA 2005