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**HYDROGEOLOGY OF
ZIO AND YOTO PREFECTURES,
TOGO, WEST AFRICA**

by

Cynthia Hewson Carr

A thesis submitted to
the Faculty of Graduate Studies and Research
in partial fulfillment of
the requirements for the degree of
Master of Science

Department of Earth Sciences

Carleton University

Ottawa, Ontario

December 5, 1988

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ABSTRACT

Zio and Yoto Prefectures in southern Togo cover 4,000 km² and have a population of 350,000, 85% of whom are rural. There is a continuing need for water supply as 60% of rural inhabitants do not have access to clean water. Physical and chemical hydrogeologic data from the recent CUSO rural water supply project in these prefectures were verified then interpreted through simple statistics, contoured mapping, ordered parameter plots, Piper diagrams and hierarchical cluster analysis in order to define the hydrogeology and make recommendations for future rural water supply projects.

In Zio and Yoto, ground water is the only viable water source having sufficient annual recharge, adequate distribution throughout the two prefectures and equal availability throughout the year. Fractures in Precambrian bedrock can provide an average of 3.8 m³/hr from wells averaging 70 m depth and requiring an average pump intake depth of 42 m. Recharge is through the semi-permeable in-situ overburden (weathered bedrock) to the fractures. Flow roughly follows topography and surface water, discharging into major rivers and the ocean.

Unconsolidated sediments of the coastal basin provide an average of 25 m³/hr from wells averaging 85 m depth and requiring an average pump intake depth of 49 m, although 80 m is required in parts of Yoto. Groundwater recharges through the unconfined Continental Terminal aquifer to confined Paleocene and Eocene aquifers below. As flow continues basinward to the ocean, it increases in total dissolved solids, notably carbonates.

Water quality in both the sediments and bedrock generally meets World Health Organization drinking-water standards, although Fe and Mn respectively average 0.25 and 0.32 in bedrock and 0.61 and 0.15 in sediments. Unacceptably high NO_3^- , indicating faecal contamination, was found in < 1% of bedrock wells and low concentrations in 5% of Cretaceous wells near the basin edge.

Future rural water supply projects in Zio and Yoto should exploit groundwater by siting with airphotograph analysis and resistivity geophysics, drilling by the down-the-hole hammer method in bedrock and by mud rotary or hand-digging in sediments, constructing wells to modern standards with attention to water quality protection and using medium to high lift handpumps.

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Chapter 1

INTRODUCTION

Togo is a small West African country bounded on the west by Ghana, the north by Burkina Faso, the east by Benin and the south by the Atlantic Ocean (Figure 1). A population of 3.2 million covers the 57,000 km² surface area, seventy-eight percent of whom live in rural areas (Haub and Kent, 1987).

Zio and Yoto Prefectures are located in the southernmost region of Togo but do not adjoin the ocean (Figure 1). They have a combined surface area of 4,000 km² with 350,000 inhabitants, 85-90% of whom are rural. Zio is peopled by the Ewe tribe, Yoto by the related Ouatchi tribe. Both tribes are sedentary farmers of maize, edible tubers, oil palm, groundnuts and more recently cotton as a cash crop. Per capita annual income is less than US\$250 (based on Haub and Kent, 1987).

Rural people live in villages of 150 to 1500 people; temporary habitations for cultivation and satellite hamlets commonly surround the main village. A village is defined as the area under the jurisdiction of a village chief. Houses are made of compacted earth with a grass thatched roof. Ten percent of houses have improvements such as a tin roof, cement floor and more recently glass windows. Apart from the prefecture centres, there are only two larger villages with electricity, provided for a few hours a day using diesel engines. Until 1987, sanitation for the rural area of Zio and Yoto was minimal.

Traditionally water is collected from a variety of sources. During the rainy season, rainwater is caught flowing from the roof and/or scooped off the ground. As the rains taper off, water is drawn from a series of increasingly distant sloughs and

Figure 1. Location map for Togo and Zio and Yoto Prefectures.

streams. Finally, at the height of the dry season, women (the bearers of water) walk as far as 30 km round trip to draw water from a hole dug in the bed of one of the three major rivers. The consumption of raw surface water causes numerous diseases, notably dysentery, schistosomiasis and guinea worm. A survey of Zio conducted in 1986 by CUSO (a Canadian non-governmental development agency) and International Development Research Center (IDRC) found villages where 70% of residents were infected with guinea worm. The expenditure of energy both in fetching water and in fighting off water related disease significantly reduces the productive capacity of the rural population.

Improvements on the traditional water supply within the private sector include 1) cisterns and roof gutters built by local masons for families rich enough to buy a tin roof and 2) 1-metre wide 20-40 metre deep unlined wells dug by local artisans; however, these are restricted to the southeastern 25% of the area where the geology permits.

Early government-initiated rural water supply programmes resulted in 10 to 20 lined hand-dug wells plus 6 motorized boreholes with overhead cisterns in large (>2000 people) villages. With the onset of the United Nations Drinking-Water Supply and Sanitation Decade (1981-1990), the government of Togo set itself the goal of providing potable water for all inhabitants by the year 2000. Two projects in Yoto and Zio at the beginning of the decade resulted in 110 drilled wells equipped with footpumps. The next project executed by CUSO and funded by Canadian International Development Agency (CIDA) drilled 287 wells between April 1986 and February 1987 of which 200 were productive and equipped with handpumps. This thesis is based on the experience of the author as chief engineer on the CUSO water project from January 1985 to July 1987.

The principal objective of the thesis is to interpret the drilling and water chemistry data generated by the CUSO water project. Aquifers are identified, delimited and physically and chemically characterized. Direction of flow, probable recharge and discharge areas and controls on yield are discussed. In addition, well waters are classified and controls on water quality examined.

The secondary objective is to apply the above interpretations to the problem of finding and exploiting groundwater for rural water supply in Zio and Yoto Prefectures. Recommendations are made for future water supply planners on the most appropriate methods of 1) choosing a water source, 2) accessing water (i.e. digging, augering or drilling), 3) siting water-points, 4) constructing water-points and 5) lifting water.

Chapter 2

PHYSICAL GEOGRAPHY AND GEOLOGY

2.1 RELIEF

Zio and Yoto Prefectures lie between 20 and 160 metres above sea level (m.a.s.l.) sloping gently in the direction of the ocean toward the south-southeast. North of Tsevic (Map 1) the slope is roughly 1° (Gu-Konu, 1981) on a gneisso-granitic peneplain. South of Tsevic is a relatively flat-lying alluvial plateau subdivided by the three major rivers and their tributaries.

2.2 VEGETATION

Due to the dense population (85 people/km²) of subsistence farmers, Zio and Yoto are heavily cultivated. As mentioned in Chapter 1, cultivation is mainly of foodstuffs and cotton. Significant areas of uncultivated land exist only in the north, and mainly in Yoto. Exceptions to this pattern are the reforested Eto Forest Reserve in the centre of Zio, and some natural forest around a remote stretch of the Haho River.

2.3 RAINFALL

Zio and Yoto have a "guinean" climate distinguished by two rainy seasons (the main season from April to July and the small season from September to October) and by little variation in the mean monthly temperature (25° in September to 29° in December) (Gu-Konu, 1981).

Stations based in Tabligbo and Lome have been monitoring rainfall for 37 years. Mean annual rainfall for these two stations is 1183 mm and 811 mm respectively (Gu-Konu, 1981). There are 5 to 6 consecutive dry months annually (Figure 2).

2.4 SURFACE WATER

Surface water flow in Togo varies throughout the year in direct response to rainfall. In Zio and Yoto Prefectures, all but the three major rivers (Mono, Zio and Haho) are ephemeral, and even the Zio and Haho dry up after successive drought years.

The Zio and Haho are small hydrological basins, less than 700 km² each, draining into the shallow and brackish Lake Togo, which in turn flows into the Atlantic Ocean (Figure 3). The Zio has a mean annual flow of 10 m³/s (Gu-Konu, 1981). In contrast, the Mono has a much larger catchment basin, 21,200 km², resulting in a stronger mean annual flow, 118 m³/s (Gu-Konu, 1981). The Mono River flows along the eastern edge of Yoto Prefecture forming the international boundary with Benin.

The drainage pattern created by these rivers and their tributaries varies markedly over the two prefectures as a function of geology. North of Tsevie, on the gneisso-granitic peneplane, the soils are thin and the rocks impermeable, resulting in dendritic drainage, locally fault controlled. South of Tsevie on the alluvial plateau, the soils and underlying sediments are sufficiently permeable to permit infiltration of most rain and surface water; therefore drainage is vertical leaving no surface expression. The contact of northwestern bedrock with southeastern sediments is marked by the abrupt end to all surface water flow other than the major rivers (Figure 3).

Figure 2. Mean annual and mean monthly precipitation for January through December for Tabligbo and Lomé meteorological stations (based on Gu-Konu, 1981).

Figure 3. Drainage of Zio and Yoto Prefectures from the 1:200 000 topographic map.

2.5 GEOLOGY

The changes in relief and drainage patterns along a line trending northeast through Tsevie, discussed in sections 2.1 and 2.4, are due to a profound change in geology along that line. The area to the northwest, covering 75% of the study area, is underlain by high grade metamorphic rock of Precambrian age (Figure 4). The remaining 25% to the southeast is underlain by a Cretaceous and younger wedge composed mainly of unconsolidated sediments lying in a depression in the coastal edge of the Precambrian surface. The difference between the two geological terranes results in two profoundly different hydrogeological regimes. Each regime is considered separately throughout this thesis.

2.5.1 Bedrock

Ninety-five percent of Africa is underlain by Precambrian metamorphic and igneous rocks. Within West Africa, the Precambrian bedrock has been created by or undergone five orogenic events, finally becoming tectonically stable at the end of the Proterozoic (Clifford, 1970; Figure 5). Wright *et al.* (1985) and Sylvain *et al.* (1986) identified these orogenic events:

- 1) Leonian orogeny circa 2950 Ma, the earliest detectable orogeny in West Africa, is largely obscured by the Liberian orogeny.
- 2) Liberian orogeny circa 2750 Ma formed the Archean nucleus of the West African craton located in Guinea, Sierra Leone and Liberia.
- 3) Eburnian tectonic event circa 2000 Ma reactivated the eastern portion of the West African craton resulting in the deposition of the Lower Proterozoic Birimian Formation. At this point the pre-Pan African crust of

Figure 4. Distribution of bedrock and sediments in Zio and Yoto Prefectures.

Togo was in place as evidenced by remanent Eburnian dates in plutons near Agbelouve, Zio Prefecture.

- 4) Formation of the Volta Basin circa 1100 Ma may be associated with the Kibaran orogeny of Central Africa (Clifford, 1970) or with the Aleksod series event in the Tuareg shield of Northern Mali / southern Algeria (Cahen and Snelling, 1984). An epicontinental glaciation circa 700 Ma was followed by the opening of an ocean, shown by ophiolitic sequences 30 km north of the project area sandwiched between Birimian deposits and Pan African rock during the subsequent Pan African Orogeny.
- 5A) Pan African orogeny circa 550 Ma thrust rocks of Zio and Yoto Prefectures over those to the northwest, imbricating ophiolites and sediments and significantly shortening the crust. In Zio and Yoto, the Pan African event involved D2 foliation and amphibolite to granulite facies metamorphism accompanied by emplacement of anatectic domes of granodiorite and other granitoid rocks. A late Pan African event caused a second anatexis, in which younger leucocratic domes cut older domes, and folding of the foliation (D3 deformation).
- 5B) Late Pan African tectonic event circa 500 Ma caused major vertical shear zones more than 1 km wide with mylonitization (D4 deformation) which may be continuous with the trans-continental shear zones passing through Adrar des Iforas and Air to the north. Conjugate faulting occurred thereafter (D5 deformation).

Precambrian bedrock of Zio and Yoto is part of the Dahomeyan basement complex formed during the Pan African event (Cahen and Snelling, 1984). The Dahomeyan stretches from the southeast corner of Ghana through Togo, Benin and much of Nigeria and is sometimes called the Benin-Nigeria Swell or Shield. Synorogenic to

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late orogenic pegmatites and granites from the Dahomeyan yield dates of 640-450 Ma by K/Ar and some Rb/Sr analyses. A Rb/Sr whole rock isochron from orthogneiss intrusive into the Dahomeyan complex gives a date of 1708 ± 64 Ma (Vachette *et al.*, 1979). This age corresponds to the Eburnian orogenic event and is evidence of Pan African reactivation of an Eburnian crust. A few Rb/Sr whole rock isochrons date around 1100 Ma corresponding to the Kibaran orogeny (Wright *et al.*, 1985).

The main theory of origin for the Dahomeyan is that it resulted from a full scale collision between the West Africa craton and the East Sahara craton, creating the Togo Mountains (Wright *et al.*, 1985). Evidence for this theory includes a positive gravity anomaly and the occurrence of deep water sedimentary rocks and ophiolites in the Proterozoic succession. The Dahomeyan would then be reactivated continental crust, having been thrust over oceanic crust to the west. Another theory of origin is that the Dahomeyan is a group of continental fragments, island arcs, and interarc basins (ensialic and ensimatic) accreted onto the West African craton by subduction and collision (Wright *et al.*, 1985).

Resulting from this tectonic activity, four phases of deformation are identified in Zio and Yoto, mentioned above as D2 to D5. In more detail these are (Sylvain *et al.*, 1986):

- D2 - Foliation synmetamorphic with the Pan African, trending 20° azimuth in migmatites and $10-40^\circ$ azimuth in gneisses, dipping steeply to the east.
- D3 - Folding of D2 foliation which is rarely visible. It did not create schistosity, crenulation or displacement.
- D4 - Brittle shearing with associated mylonization very late in the Pan African. Within Zio and Yoto, it is shown principally by the major fault running

from Keve to Game at 30° azimuth and its branches at 60° and by a shear zone running northward (10°) from eastern Yoto.

D5 - Faulting event (post-Pan African) producing conjugate transverse faults at 60° and 110° azimuth.

The principal rock types of the Dahomeyan complex in Zio and Yoto are shown on Map 2 and are described below (Sylvain *et al.* 1986):

M - Migmatites underlie the majority of area and are subdivided into the following three rock types:

- M₁ - Biotitic migmatites locally with amphibole and garnet cover the north-eastern third of Zio. They are mostly metatexite facies, but include small lenses of biotite augen metatexite and larger lenses of diatexites. These migmatites are distinguished by well defined banding.
- M₂ - Biotite and hornblende migmatites of granodioritic composition have quartz-rich leucocratic bands with some potassic feldspar and epidote and mesocratic bands which are commonly mylonitized.
- M₃ - Anatectic orthogneisses with biotite, brown amphibole and garnet are migmatitic in appearance and are at or near granulite facies. They are locally banded and their composition is granitic to granodioritic, unusually rich in K and Mg.
- O - Orthogneisses ranging from metadiorite to metarhyolite are on or near the Keve-Game fault or are within 10 km of it. They are homogeneous, have little fracturing or faulting, resist weathering and typically form inselbergs. Some sections are foliated and/or mylonitic parallel to the fault and the local gneissic foliation.
- G - Gneisses of mixed, unspecific and sedimentary origin occur between the Keve-Game fault and its branch that extends through Agbelouve. They

commonly contain one or more of biotite, muscovite, amphibole or garnet. Banding occurs at all scales. Four bodies of paragneiss, each less than 10 km² include quartzite, meta-arenite and biotite-garnet-sillimanite-muscovite gneiss.

- I - Granitoids of granitic to dioritic composition occur in the shear zone in the northeast corner of Yoto. Most are mylonitized.
- L - Laterites are identified in a restricted area northwest of Gape or on mixed gneiss (G) or biotitic migmatite (M1). Although laterite is not well developed, most bedrock is covered with ferruginous to lateritic soils.

2.5.2 Sediments

The Precambrian basement was uplifted and denuded of all sediments other than in-situ weathering products (laterites etc.) early in the Paleozoic. The Adina fault, a normal fault trending 70° azimuth, formed 5 km offshore. The fault caused more than 2000 metres of Devonian to Upper Cretaceous sediments to be accumulated on the downthrown block while the raised block to the north remained denuded. In the Cretaceous (Maastrichtian), a marine transgression from the south covered both the hanging wall and footwall up to a latitude beyond the present-day edge of the sedimentary basin. Sedimentation to the northwest of the present-day edge was predominantly sublittoral (i.e. limestone) and to the southeast predominantly sublittoral to littoral (marls and clays with carbonate and terrestrial layers). This sequence was uplifted at the end of the Maastrichtian resulting in its erosion roughly back to its present limit and the deposition of fluviodeltaic sediments with large clasts (Sylvain *et al.*, 1986).

In the Lower Paleocene another marine transgression occurred. A flexure or fault oriented SW-NE controlled sedimentation, separating marl deposited in a near-shore environment to the north, from a more distal assemblage of bioclastic limestones and black clays to the south. Neither locale underwent significant detrital deposition. From this time on, the sea gradually retreated.

In the Lower Eocene, sedimentation continued with confined-environment clays, but became progressively less anaerobic and more carbonaceous. The structural line controlling Paleocene sedimentation also prevailed the Eocene.

From Basal Lower Eocene to Middle Eocene time there was carbonate sedimentation with variable amounts of phosphate, indicating an external platform, sublittoral to littoral environment. A second flexure or fault line of the same orientation as the earlier one formed to the southeast, contributing to the buildup of phosphates just south of the line.

The Middle Eocene (Bartonian) sedimentation was controlled by a third flexure/fault southeast of the second and parallel to it. Deposits are sublittoral sandy clays and carbonates with discontinuous beds of organic carbonates. Subsequent to the Bartonian a major regression resulted in the partial erosion of all previous sediments (Maastrichtian to Eocene) which by this time were tilted toward the basin.

The Continental Terminal Formation, of uncertain age and uncertain depositional environment (although terrestrial in appearance and in the lower portion probably a reworked older sediment), was deposited unconformably on top of all earlier sediments. It represents the youngest period of deposition with the exception of

Quaternary to Recent fluvial and fluvio-lacustrine deposits in the major river valleys.

The southern 25% of Zio and Yoto Prefectures is covered by sediments belonging to the Dahomey Basin. The Dahomey Basin stretches from eastern Ghana to Nigeria where it joins with the Benue Trough and Niger Delta. (Figure 5). The basin's position along the African coast may be due to the relative ductility of the more "recently" heated Pan African rocks as compared to the colder Birimian rocks of the stable West Africa Craton in southern Ghana, Ivory Coast and Liberia (Wright *et al.*, 1985). The result is a series of conformable and largely unconsolidated sediments dipping less than 3°, thickening and prograding southeastward toward the ocean. The thickening is in part caused by the three successive flexures or faults previously described downthrown toward the centre of the basin, displacing sediments downward and abruptly thickening the uppermost unit. The post-Eocene marine regression resulted in such deep erosion that each sedimentary unit subcrops below the Continental Terminal in order of decreasing age basinward. The Continental Terminal is flat-lying, covering all younger sediments and the southernmost bedrock edge. In Zio, it is thicker to the north and south than in the centre.

The sedimentary units in Zio and Yoto Prefectures (Sylvain *et al.*, 1986) are described below beginning with the oldest unit. Units CT and F are shown on Map 2. Although they are encountered in wells, units 1) through 5) are not shown on Map 2 because they do not outcrop.

- 1 - Maastrichtian succession (100-200 metres thick) is composed of organic and quartz-rich sand and clays. To the north, sands with continental microflora predominate, becoming argillaceous in the extreme north. To the south the deposits are more argillaceous and calcareous comprising

argillaceous limestones and dolomites with a little glauconite, gypsum and grains of phosphate. Macrofauna and microfauna become marine and more abundant toward the south. The uppermost unit of coarse sand and rounded gravel was deposited during the marine regression.

- 2 - Paleocene succession (30-130 metres thick) is primarily composed of biochemical deposits: carbonates, phosphates and glauconite. To the north, only dense grey clays and sandy clays with little organic content are found. Over the rest of the basin, marls and sandy marls are overlain by a white fossiliferous limestone bed tens of metres thick followed by a monotone dark gray, organic-rich and often fissile marl/clay. A very glauconite-rich sand or calcareous layer only metres thick accurately represents the Paleocene-Eocene transition. This layer is not uniformly present and in some localities is present as a glauconite-free clastic unit.
- 3 - Basal Lower Eocene succession (0-80 metres thick) is composed of marls and clays with some quartz sands and dolomite lenses. The terminal deposits are less dolomitic and gypsum-rich, with calcareous layers which are in places glauconitic. The resulting colour is light grey to beige.
- 4 - Upper Lower Eocene to Middle Eocene succession (0?-20 metres thick) is composed of light grey to beige bioclastic deposits. Basal attapulgitic clays are localized. Phosphatic and argillaceous carbonates poor in quartz and glauconite predominate. Toward the top, the succession becomes more argillaceous and sufficiently phosphatic to be economically exploited. The phosphate exists in the form of pellets, ooids, replacement of tests, grains and lithoclasts.
- 5 - Middle Eocene (Bartonian) succession (0?-70 metres thick) is composed of marls, ochre to dark grey clays and organogenic limestones (sometimes

dolomitic) with sand/clay clastic layers. Gypsum and glauconite are locally abundant in the clays.

- CT - Continental Terminal succession (0-70 metres thick) overlies a profound unconformity with a ravined surface. The deposits are multicolored to red argillaceous clastics of varying grain size. They have a terrestrial appearance, however, this has not been confirmed, nor have they been dated.
- F - Fluvial and fluvio-lacustrine deposits are clay-rich clastic deposits. The fluvial deposits are grey to ochre-beige compact clays and sands becoming more sandy away from the southern lagoons and on bedrock. Fluvial lacustrine deposits along the Mono River are grey and beige organic-rich clays up to 10 metres thick. Some contain peat.

Chapter 3

METHODOLOGY

3.1 DATA SOURCE

Data for this thesis was obtained primarily from measurements and chemical analyses of the wells drilled during the CUSO water project. Well drilling procedures of the CUSO project are described below.

Wells in bedrock were sited by locating fractures where possible on airphotographs or, if not, by resistivity surveys. Wells were drilled by rotary rigs with air and 250 mm (9 7/8") tricone bits through overburden, then by water and 165 mm (6 1/2") down-the-hole hammer through competent bedrock. Locally-made polyvinyl chloride (PVC) casing (124 mm outside - 115 mm inside diameter) was installed. One millimetre horizontal slot well screen made from the same PVC casing was set at water-bearing fractures. If the rock was friable or highly fractured, the annulus was filled with washed coarse sand up to a few metres above the uppermost screen, followed by 5 metres of grout, then backfill, then grout in the uppermost 5 metres to keep out contaminated surface waters. If the rock was competent, the lower annulus was left empty, a rubber packer installed a few metres above the uppermost screen and 5 metres of gravel set above the packer followed by the same sequence of grout, backfill and grout as for friable bedrock wells. All bedrock wells were then developed by air lift pumping and overpumping for a minimum of three hours or until the water ran clear.

In contrast, sedimentary aquifers are sufficiently continuous and numerous to permit drilling anywhere. Wells in sediments were drilled by rotary rigs with mud and

various 250 mm (9 7/8") bits. Wells were equipped with locally-made PVC casing and screen (140 mm outside - 124 mm inside diameter). The annulus was gravel packed to several metres above the well screen, backfilled with fine sand and sealed with at least 5 metres of grout. Wells were then developed with compressed air for a minimum of 2 hours or until sediment-free.

In the last minutes of every well development, a 1.5 litre unacidified water sample was taken by the driller for chemical analysis. Samples were sent to the laboratory of the Direction Generale des Mines, de la Geologie et du Bureau Nationale de Recherches Minières (MGRM) in Lome to analyze for conductivity, hardness, Ca^{++} , Mg^{++} , Na^+ , Fe^{++} , Mn^{++} , SO_4^{-2} , Cl^- , NO_3^- and F^- . Samples were submitted in batches of approximately 20 so that some samples were collected more than one month before analysis. This waiting period permitted some precipitation, notably of iron, which was clearly visible staining the bottom and walls of a few sample containers. pH values are known to be approximately neutral (6 to 8) over the entire area from well site measurements taken at the time of pump installation inspection, although not published. Bicarbonate values were calculated by charge balance of the nine measured ions.

Wells were pump tested days or weeks after drilling. Because there were no piezometers, a step test was used. Three consecutive 1-hour constant discharges of approximately 1/3, 2/3 and 11/10 of airlift discharge during development were followed by recovery. Because commercial pumps capable of fitting into the well casings can pump a maximum of 7 m³/hr, wells with yields of 7 to 25 m³/hr were pumped for only 1 or 2 steps to the point of water level stabilization and the recovery monitored, permitting a reasonable estimate of yield. Wells with yields >25 m³/hr were exempt from testing because the 7 m³/hr pumping rate could not draw

them down and also because only 1 m³/hr is required for a handpump. Yields cited for these wells are estimates based on measurements of airlift discharge throughout well development.

Cement aprons to catch splash and waste from water vessel cleaning were constructed around each well with a cement evacuation channel and soakaway pit. India-Togo Mark II handpumps, with positive displacement in a submerged cylinder, were then installed. Pumps were installed with the intake 10 metres below the dynamic water level for 1 m³/hr discharge as determined from pump test data. The 10 metres are a safety factor allowing for seasonal and annual variations in water level.

Results from siting, chemical analyses, pump testing and installation are reported by Geomines Ltd. (1987). Two additional small sets of analyses, discussed in section 3.2 below, complete the sources of raw data.

3.2 DATA VERIFICATION

3.2.1 Physical Hydrogeology Data

Data relating to physical hydrogeology (i.e. siting, drilling, pump testing and installation) appears to be accurate from the consistency found during data manipulation, with the exceptions noted below. Only one random error has been positively identified; Adeti Kope and Adeti Kondji were recorded as having the same latitude, which is not significant. Two recurring errors which are significant were also found. The first is that static water levels recorded in appendices of Geomines Ltd. (1987) are often different from those recorded in village dossiers of the same

report. Static water levels appearing in appendices were recorded during drilling whereas static water levels in village dossiers were recorded at the time of pump testing when wells were fully developed and recovered; therefore, village dossier values were used. Secondly, wellhead elevations in Geomines Ltd. (1987) are reported to the nearest 10 metres (i.e. ± 5 metres). In cases where the reported elevation was more than 5 metres different from elevations read off the 1:200,000 topographical map (contour interval of 20 m), the map elevation has been substituted. Other elevations (i.e. static water level, etc.) were calculated with respect to the revised wellhead elevations. Nevertheless, all elevation variables quoted in metres above sea level (m.a.s.l.) should be considered to have an error of ± 5 metres. The revised physical hydrogeology data for bedrock wells is tabulated in Appendix 1 and for sedimentary wells in Appendix 2.

3.2.2 Water Chemistry Data

Visual inspection of the water chemistry data while the author was in Togo revealed transcription errors between the original analyses and the Geomines report. A complete revision of Geomines data with original data was not done; therefore, further transcription errors may be present. Indeed, visual inspection in Canada has raised suspicion of further transcription errors as well as errors from other sources. An example of suspected transcription error is the Cl^- value for Afiadenyigba M404F3 (2 mg/l) which appears to be missing two digits.

The most important suspected error is the report of 0 mg/l SO_4^{-2} in 45 of the 196 samples analyzed. These samples are located mainly in sediments or near Agbelouve. Aside from the fact that all natural ground waters contain some sulfate, the zeros are proven to be false by wells M350F1 to M365F1. These 15 wells were drilled in

series and presumably were analyzed in the same batch; all were reported as having 0 mg/l sulfate. In contrast, M352F2, a second well in Tona Kondji drilled and analyzed several months later has 7 mg/l sulfate. Possible explanations for the false zero values are that a laboratory technician recorded values of <10 mg/l as 0 mg/l, or the analytical equipment was subject to failure and values not analyzed were reported by Geomines as 0.

An additional indication of error was found when the bicarbonate calculations resulted in negative values for eight samples. Like SO_4^{-2} , negative and even zero bicarbonate values are not possible in natural groundwaters, indicating either an error in a major ion or a low carbonate value with a significant cation not analyzed (i.e. K^+).

An initial verification of the chemical data was done when 7 wells were found to seriously exceed World Health Organization (WHO) drinking-water standards, particularly nitrate. New samples were taken after pumping the wells for a minimum of 6 hours and analyzed in the same lab as the old samples. Five of the seven new analyses met the WHO standards, suggesting contamination of the old samples, probably during sampling.

A second verification was done by duplicating the analyses of SO_4^{-2} , Cl^- , NO_3^- and F^- for 10 samples in the geochemistry laboratory of the Geological Survey of Canada (GSC) in Ottawa. Concentrations of these four ions remain constant with storage and should compare well with the Direction des Mines (MGRM) data. Samples chosen for re-analysis included 7 samples appearing to have normal results, of which 2 have zero sulphate values, plus 3 samples appearing to have abnormal

SO_4^{-2} analyses, comprising 2 false zero samples and one abnormally high sample.

The results are presented in Table 1a.

In general the results are of the same order of magnitude or closer. Direct comparison of the two does not reflect the significance of the difference i.e. values of 2 and 4 mg/l for the same ion are 100% different. However, if the range of values for that ion is 0 to 100 mg/l, then the difference is only 2% of the range and therefore not significant for data interpretation. For this reason, the difference as a percent of range is included in Table 1b, using the appropriate ranges for wells in bedrock and sediments.

The majority of GSC results are within 10% of MGRM results. Assuming GSC results are accurate, MGRM results showed samples with consistent deviations and erratic values. Because samples used in this verification were not chosen at random and because they are only 10 in number, they are not representative of the project; however, they do give an indication of the reliability of the Geomines water chemistry data. The indication is that the MGRM data, although not precise, should suffice for the purposes of determining potability and of classifying the water and assigning it to an aquifer. Secondly, many but not all of the 0 mg/l sulphate values are in fact very low values, roughly <10 mg/l.

Another method of providing a rough check on data accuracy compares the sum of component concentrations in milligrams per litre with conductivity in microSiemens per centimetre multiplied by an adjustment factor. The factor ranges from 0.55 for carbonate and chloride-rich waters to 0.75 for sulfate and silica-rich waters (Hem, 1985). Since there are no sulfate-rich waters in the sediments (as will be seen in section 5.2.1) a value of 0.60 was chosen for all samples.

Table 1a. GSC and MRGM anion analyses.

Geol - geologic terrane (B=bedrock, S=sediments)

Well #	Village	Geol	SO ₄ ⁼ (ppm)		Cl ⁻ (ppm)		NO ₃ ⁻ (ppm)		F ⁻ (ppm)	
			GSC	MR	GSC	MR	GSC	MR	GSC	MR
M021F4	Nyassive	B	17	0	81	117	189.0	1.0	0.51	0.32
M182F3	Gati Agodo	S	25	40	40	64	69.0	44.0	0.28	0.13
M312F1	Akpave Kope	B	246	320	185	270	1.2	0.2	0.98	0.00
M330F2	Atiho	B	75	0	448	660	19.0	0.0	1.75	0.00
M374F1	Gati Akpafou	S	10	0	11	24	0.0	0.0	0.14	0.10
M379F1	Lowe Attiteg	S	14	11	29	25	0.6	0.0	0.45	0.19
M385F1	Seva	S	12	25	14	30	0.2	5.0	0.29	0.29
M407F3	Bedjra Kope	B	315	306	276	300	1.0	0.0	1.05	0.48
M470F1	Messeko Kond	S	4	0	8	22	0.6	3.3	0.15	0.10
M471F1	Afikou Kondj	S	17	72	12	28	0.4	0.3	0.23	0.33

Table 1b. Difference between GSC and MRGM analyses as % of bedrock or sediments range.

negative value indicates a larger GSC value

(x) - calculation based on 0 NO₃⁻ in M021F4

* - average of absolute % differences

#	Village	SO ₄ ⁼	Cl ⁻	NO ₃ ⁻	F ⁻	Avg	Avg*	Comments
M021F4	Nyassive	-3	4	-149(0)	-6	-38(-1)	41(3)	false 0
M182F3	Gati Agodo	2	14	-54	-18	-14	22	normal
M312F1	Akpave Kope	12	10	-1	-31	-3	14	normal
M330F2	Atiho	-12	25	-15	-56	-14	27	real 0 SO ₄
M374F1	Gati Akpafou	-2	7	0	-5	0	3	real 0 SO ₄
M379F1	Lowe Attiteg	0	-2	-1	-31	-9	9	normal
M385F1	Seva	2	9	10	0	5	5	normal
M407F3	Bedjra Kope	-1	3	-1	-18	-4	6	normal
M470F1	Messeko K	-1	8	6	-6	2	5	false 0 SO ₄
M471F1	Afikou K	9	9	0	12	7	8	high SO ₄
Average		1	9	-21(6)	-16	-7(-3)		
Average*		4	9	24(9)	18		14(10)	

Sums of component concentrations were on average 41% higher than adjusted conductivities. Changing the adjustment factor to 0.70 produced more balanced results (21% higher). This method, called check 1 in this thesis, is tabulated in Appendix 3. Because of the dependence of this test on conductivity, inconsistencies in conductivity measurements were highlighted. For example, M324F1 and F2 Atikole have similar values for all ions, yet F2 has a conductivity more than twice that of F1. To check this and other inconsistencies, conductivity was remeasured on the samples available in Canada. Although these samples were collected more than one year prior to measurement, conductivity was expected to be the same unless precipitation had occurred. The new conductivities were generally higher than the originals with the exception of the high conductivity sedimentary wells near Lowe (wells M378 to M381) which were significantly lower. Precipitate was seen in these sample bottles indicating carbonate loss and, therefore, the original conductivities are considered to be more accurate.

Recalculating check 1 with the new conductivity data gives results with the same average value as the original conductivity (Appendix 3). This correspondence suggests that there is no apparent change; however, by visual inspection there appears to be greater consistency in new conductivity values for samples having similar chemistry; i.e. Atikole M324F1 and F2 have conductivities within 8% of each other.

Another method of chemical data verification called check 2 in this thesis compares total cations in equivalents per millilitre (epm) multiplied by 100 to conductivity in microSiemens per centimetre ($\mu\text{S}/\text{cm}$). It is considered more accurate than check 1 (Hem, 1985) because epm's take charge into consideration. In addition, it is more accurate for the Togo data set because it does not use either carbonate or sulphate

values. Results from check 2 are very similar to those of check 1 with an adjustment factor of 0.70 (Appendix 4). Check 2 was recalculated using the new conductivity measurements (Appendix 4) and again produced results similar to check 1.

Results of check 1 and check 2, with both the original and new conductivity measurements, are summarized in Appendix 5. Samples which have more than 30% difference between the total ions value and the conductivity value (as a percentage of the larger value) are considered unacceptable. Thirty per cent was chosen as the cutoff because it eliminated most of the samples with suspicious values or known errors without eliminating significant numbers of other samples. When comparing the four checks in Appendix 5 (checks 1 and 2 with original conductivity and new conductivity), many samples exceeded the 30% norm for some checks and not for others. For samples showing a lack of consensus, check 2 was given priority over check 1 and new conductivity given priority over the original. Using these criteria, the reliability of 43 samples is considered unacceptable as indicated by an "X" in the final column of Appendix 5. The revised water chemistry data set incorporating new MGRM, GSC and conductivity values is tabulated in Appendix 6.

3.3 DATA ANALYSIS TECHNIQUES

3.3.1 Basic Statistics

Throughout this thesis, conventional statistical methods (found in any introductory textbook) were used to calculate averages, standard deviations, correlation coefficients and linear regressions.

3.3.2 Contoured Maps

Several measurements including static water level, water-bearing horizon and conductivity were plotted on Maps 3 to 5 and contoured to highlight trends in the data.

3.3.3 Ordered Variable Graphs

Many of the physical hydrogeological and all the hydrogeochemical variables have been analyzed with this method. One variable for a group of wells is plotted on a graph such that the ordinate is the magnitude of the variable and the abscissa is the equispaced well numbers ordered by ascending or descending variable magnitude. Using this method, a population with a normal distribution would plot with the smooth form of a vertically compressed tangent function for ascending plots or cotangent for descending plots. Therefore, breaks in an ordered variable plot suggest a change in population, providing a basis on which to divide the wells into groups.

3.3.4 Piper Diagrams

Two Piper diagrams were plotted, one for each of bedrock and sedimentary water chemistry. See Figure 9 on page 48. This method, published by Piper in 1944, is the standard method of presenting large numbers of water chemistry data. A Piper diagram plots the percent of each major cation (Ca^{+2} , Mg^{+2} and Na^{+}) in triangular coordinates on the left triangle and the percent of each major anion (HCO_3^{-} , SO_4^{-2} and Cl^{-}) on the right triangle. Points in the cation triangle are traced up into the diamond with a trajectory parallel to the left edge (100% Na^{+} line). Points in the anion triangle are traced into the diamond parallel to the right edge (100% HCO_3^{-}

HCO₃⁻ line). A sample plots in the diamond where its cation and anion trajectories cross (Piper, 1944).

3.3.5 Hierarchical Cluster Analysis and Tree Plots

This advanced method of cluster analysis and presentation by tree plots was developed and published by Kleiner and Hartigan (1981). The method was performed separately on bedrock and sedimentary water chemistry data using a programme written by Bob Garrett at the GSC. Euclidean distances between the 10 major ions are calculated, then "the two closest ions are joined to form a cluster and the distance of that cluster to any other ion is defined as the maximum distance of the two variables in that cluster to that variable. This process is repeated at each stage, joining the pair of clusters as the maximum distance between their most remote pair of ions. In the final stage, two clusters are joined to form one cluster containing all the ions" (Kleiner and Hartigan, 1981, p.263) and based on the above clustering, each sample is presented on a tree plot. This plotting method translates the basic cluster form shown in Figure 11a and 17a to a representation of each sample such as Figures 11b and 17b using the following principles (refer to Figures 11a and 11b, p. 54): 1) Each ion is represented by a leaf on the tree. 2) Vertical and horizontal lines connecting point A with point B (Figure 11a) are represented by branch AB (Figure 11b) and similarly the lines between points B and C, C and D, D and E, E and F in Figure 11a are represented by branches BC, CD, DE and EF in Figure 11b. Finally the lines between points F and G are represented by the tree trunk FG. 3) The angle between two branches at a division is a function of the maximum distance between the variables above the division. 4) The length of each leaf represents the value of the ion in proportion to the range of values for that ion in the data set. For example, in a data set with a 0 to 400 mg/l range of Na⁺

values, the sample with 400 mg/l would have the maximum leaf length (ie 1.00) and a sample with 200 mg/l would have half that length (0.50). 5) The length of each branch is an average of the leaf lengths above it (Kleiner and Hartigan, 1981).

Chapter 4

BEDROCK

4.1 PHYSICAL HYDROGEOLOGY

One hundred and eighty-seven wells were drilled in bedrock of which 132 were considered productive ($>0.7 \text{ m}^3/\text{hr}$ and WHO quality) and equipped with handpumps. This chapter is an evaluation of the data arising from the exploration and exploitation of these wells.

4.1.1 Fracture Orientation

Both drilling success rate and well yield vary with the orientation (azimuth) of the fracture drilled (Figure 6). Drilling success rate is defined as the number of productive wells (yield $>0.7 \text{ m}^3/\text{hr}$) as a percent of the total number of wells drilled. The most reliable orientations are those which combine high success rate with high yield. In Zio and Yoto, orientations $1-10^\circ$, $51-60^\circ$ and $151-160^\circ$ appear to be the best with $>85\%$ success as opposed to the project norm of 60% , and $>7 \text{ m}^3/\text{hr}$ as opposed to the norm of $3.7 \text{ m}^3/\text{hr}$. In contrast, the most commonly drilled fracture orientations for the project were $81-90^\circ$ and $91-100^\circ$. These orientations had drilling success rates of 56 and 61% respectively, at or slightly below the norm. Yields were high for the $81-90^\circ$ interval, averaging $9.6 \text{ m}^3/\text{hr}$ but for the $91-100^\circ$ interval, yields averaging $3.4 \text{ m}^3/\text{hr}$ were near the norm. Like $81-90^\circ$, the $121-130^\circ$ interval has a high average yield, $9.6 \text{ m}^3/\text{hr}$, and a low success rate, 50% . The low success rate, combined with the fact that the statistics of this interval are based on only 3 wells, makes this interval less reliable than other high-yielding intervals.

Figure 6. Well yields and % productive wells in relation to fracture orientation. Fracture orientations are in 10° azimuth intervals. Number of wells drilled in each interval is in brackets. Hatched bars are optimal intervals in terms of both yield and % productive wells.

Favourable intervals 1-10° and 51-60° correspond to the D4 deformation of brittle shearing and mylonitization most strongly expressed in the Keve-Game fault (30-60°) and the Yoto shear zone (0-10°). Fractures oriented in the 151-160° interval do not appear to correspond to any deformation described in section 2.5.1.

4.1.2 Well Siting

The fractures on which project wells were sited were located by airphoto interpretation and by resistivity survey. Seventy percent of wells sited by airphoto were productive as opposed to 56% of those sited by resistivity. The lower success rate of resistivity was due to the fact that it was used only on sites where no fracture trace was visible on airphotos or where wells sited by airphoto were unproductive. Even with 14% fewer productive wells, resistivity wells have an average yield higher than that of the airphoto wells, 4.2 m³/hr as opposed to 3.5 m³/hr. Although airphoto is suitable for most sites, resistivity produces wells of higher yield and allows site selection under a greater variety of conditions than airphoto.

4.1.3 Depth of Overburden

Bedrock overburden is composed of in-situ weathering products, mainly ferruginous soils locally concretionary at the surface, underlain by clays and an increasing percentage of sand downward as overburden grades into competent bedrock. Additional overburden is restricted to fluvial and fluvial lacustrine sediments along major river courses (Map 2).

The average depth of overburden is 11 metres with a standard deviation of

6 metres. The extreme range is 1.5 to 29 metres. Depth of overburden does not correlate with any other hydrologic variable (Table 2) so that its influence is minimal on the resulting well.

The significance of depth of overburden is in the cost of drilling. Overburden is usually drilled by air rotary method and temporary steel casing installed to bedrock. This process is both time consuming and costly with respect to down-the-hole hammer method used in competent bedrock.

4.1.4 Water-bearing Horizons

Water-bearing horizons in bedrock can be either at the base of overburden, where the soil is not permeable and the groundwater is perched on impermeable bedrock, or in fractures within competent bedrock. Exploitable quantities of water (0.7 m³/hr) were rarely found in overburden. Low yields during airlift and shallow depths in semiconfined perched aquifers makes them vulnerable to drying during periods of climatic change. For this reason, water-bearing horizons in overburden were not exploited.

Bedrock fractures are subvertical with the result that two wells ten metres apart do not necessarily intersect the same fracture; but if they do, the depth at which the fracture is intersected is the same only if the two wells are exactly along strike. For example, wells M303F3 and F4 at Akpapedome, which are 10 metres apart, are in the same fracture as shown by geophysical work, but depth to water-bearing fracture is 54 and 84 metres respectively.

Table 2. Correlation matrix for hydrogeologic variables - Bedrock

Overb - overburden
1Water - major water-bearing fracture
2Water - secondary water-bearing fracture
Head - pressure head

Example:	Overb
Yield	-0.174 ----> correlation coefficient
	124 ----> # of wells used for correlation
	0.053 ----> significance of correlation

[illegible]

Forty percent of productive bedrock wells intersected two or more water-bearing fractures. In these wells, the fracture contributing most to discharge is considered the major water-bearing fracture and is used in statistics, plots and maps of this thesis unless specified otherwise. As a result of this definition, a fracture may be primary in one well and secondary in another.

Depth to major water-bearing fracture averages 45 metres with a standard deviation of 18 metres. Depth to secondary water-bearing fractures average 36 metres with a standard deviation of 13 metres. On average, secondary fractures are 9 metres above major fractures because drilling stopped 5 to 10 m after intersecting a major fracture thereby reducing the chance of intersecting a deeper secondary fracture.

Fracture depth and fracture elevation have a good inverse correlations, -0.66 and significance 0.000 with major fractures and 0.61, significance 0.000 with secondary fractures (Table 2). This means that on topographic highs where fracture elevation is also high, water-bearing fractures are found at shallow depths (i.e. topographic highs have shallowly-fractured resistant cores). Secondary fracture elevation and depth exhibit the same relationship although the correlations are not as good (Table 2).

4.1.5 Well Depth

Wells were drilled to depths ranging from 40 to 112 metres. The average depth was 70 metres with a standard deviation of 20 metres.

Well depth was correlated to other hydrologic variables (Table 2). Well depth has a good correlation with depth to major and secondary water-bearing fractures as

indicated by correlation coefficients of 0.66 and 0.58 respectively. This correlation is due to the policy of drilling approximately 10 metres below a suitable water-bearing horizon.

When depths to water are converted to elevations, the correlation with well depth is not as good and is negative, (i.e. -0.40) for major fracture elevation. In physical terms, where water-bearing fractures have low elevation (i.e. in river valleys and the south), wells need to be deeper to reach the fractures. In other words, the variations in water-bearing fracture elevation are more extreme than topography

4.1.6 Static Water Level

Depth to static water level in bedrock averages 18 metres with a standard deviation of 8 metres. The extreme values are 2.4 metres and 39 metres. This range of values is small in comparison with topographic variation of 50 to 150 m a.s.l. over the same area. Therefore, when depths to static water are converted to elevations, static water level elevations generally follow topography as shown on Map 4. The implication of this is that groundwater, like surface water, flows generally southward toward the ocean and secondarily toward the major rivers Zio, Haho, Klikpa and presumably toward the Mono, although there are no bedrock wells within the Mono basin and within the project area to verify this assumption. River elevations are consistent with this flow pattern as shown on Map 4. Since the major rivers practically dry up before the major rainy season, groundwater levels must be at or below the altitude of the river bed. Four wells show static water levels slightly below the adjacent rivers; Atikole M324F2, Yoto Kope M334F3 and Haho Kpodji M337F1 and F4. The first two are within the measurement error ± 5 metres for static water elevation. The other two wells at Haho Kpodji have static water levels 11 metres

below the Haho River 1.7 km away. These two wells appear to be on a major fault (associated with the Keve-Game fault) which may drain surface water and groundwater in minor faults, although the evidence of 2 wells among 124 productive bedrock wells is not strong.

The absence of springs and the flow pattern discussed above indicate that most of the bedrock surface is recharge area with discharge areas limited to major river valleys. Hydraulic gradients measured from Map 4 typically range from 0.003 to 0.005.

4.1.7 Pump Intake Depth

Depth to pump intake in bedrock wells averages 42 metres with a standard deviation of 10 metres, and a maximum depth of 69 metres.

Recalling from Section 3.1 that pump intakes were set approximately 10 metres below the dynamic water level for 1 m³/hr discharge, pump depth varies between the upper limit of static water level and the lower limit of well depth as controlled by well yield (correlation -0.423 with 0.000 significance). When the yield is high, the dynamic water level is close to the static water level and the pump can be installed at a shallow depth and vice versa.

The ordered plot of depth to pump intake showing corresponding static water level and well depth (Figure 7), shows little relation between pump depth and static water level. The regression line through static water levels gives a poor R² value, 0.185 (Table 3), and the correlation between static water level and pump depth is marginal, 0.28 with a significance of 0.012 (Table 4).

Figure 7. Pump intake depth in relation to static water level and well depth for bedrock wells. Linear regression lines for each variable is shown. Wells are in order primarily of increasing pump depth and secondarily of decreasing static water level.

Table 3. Regression statistics for Figure 7.

	Static Water Levels	Pump Depths	Well Depths
Constant	-12.741	-26.056	-46.589
Standard Error of Y	6.493	3.799	13.561
R Squared	0.185	0.851	0.280
X Coefficient	-0.131	-0.383	-0.357
Std Error of Coef.	0.031	0.018	0.064
Degrees of Freedom	79	79	79

Table 4. Correlation matrix with pump intake depth - Bedrock.

Example:	Well Depth			
Pump	0.524	---->	correlation coefficient	
Depth	81	---->	number of wells used in correlation	
	0.000	---->	significance of correlation	
	Pump Depth	Well Depth	Static W.L. (depth)	Static W.L. (alt)
Pump	1.000	0.524	0.278	0.086
Depth	81	81	81	81
	0.000	0.000	0.012	0.447
Well		1.000	0.119	0.060
Depth		124	123	123
		0.000	0.191	0.513
Static W.L. (depth)			1.000	-0.387
			123	123
			0.000	0.000
Static W.L. (alt)				1.000
				123
				0.000

Pump depth correlates moderately well with depth, coefficient 0.52 with 0.000 significance (Table 4). The ordered plot shows the same relation with much scatter about the well depth regression line (quantified by the r^2 value, 0.35). What is interesting is that the slope of the regression lines for pump depth and well depth are parallel, 0.382 and 0.399. This relation indicates that dynamic water levels at 1 m^3/hr discharge are closer to the well depth than the static water level. Furthermore, dynamic water levels are so low in 35% of wells that the limiting factor on pump depth is well depth.

4.1.8 Yield

Yields in bedrock average 3.7 m^3/hr with a standard deviation of 6.5 m^3/hr indicating a typical range of 0 to 10 m^3/hr with a large percentage (35%) of 0 m^3/hr wells. Note that another 34% of bedrock wells yield between 1 and 5 m^3/hr .

The major factors affecting yield are physical aspects of the fracture: size (length, depth and width), interconnection with other fractures, presence of fault gouge and secondary mineral deposits. Size and interconnection can be appreciated, although not completely defined, from maps and airphotos. Gouge and secondary mineral deposits were not observed during drilling, however, gouge can be obscured by drilling fluid and cuttings. Map 2 shows yield plotted on the 1:200,000 geological map. Some wells on major faults produce high yields (i.e. Maikou M335F1 and Haho Kpodji M337F1 and F4 yield 18, 15 and 10 m^3/hr , respectively), but others produce average yields (i.e. Yoto Kope M334F1 and F2 produce 3.8 and 3.6 m^3/hr , respectively).

The highest yields ($>10 \text{ m}^3/\text{hr}$) are not always associated with faults, a particular rock type, contacts, river valleys or other distinguishing feature. The only unifying factor for these wells is that they have lower water-bearing fracture elevations than the surrounding wells (Map 4). Assuming all fractures are interconnected, these wells have higher pressure heads resulting in higher yields.

The lowest yielding wells and unproductive wells seem to be in the orthogneisses, notably the metadiorites underlying Dono M419 (Map 2). Most wells with low pressure heads, <10 metres, have low yields (Map 3). For example, Afiadenyigba M404F3, Koubinoukoe M318F1 and Agbessia M026F4 have pressure heads of 6, 6 and 3 m respectively and yield 0.5, 0.5 and $0.4 \text{ m}^3/\text{hr}$ respectively.

Statistically, yield correlates with static water level elevation, pressure head and major water-bearing fracture elevation (Table 2) as shown schematically in Figure 8. The correlation with static water level elevation is weak but significant (-0.28 with 0.002 significance) because many other factors also influence yield. The correlation is probably due to the fact that lower static water elevations are more likely to be in discharge areas. Pressure head also has a weak but significant correlation with yield (0.27 with 0.002 significance) quantifying the relationships described above for the extreme high and low yields. The correlation with major water-bearing fracture elevation is better than both static water elevation and pressure head (-0.43 with 0.000 significance).

Yield has a tenuous inverse correlation with well depth. When only productive wells are considered, there is no correlation (i.e. 0.10 with significance 0.258). When productive and non-productive wells are considered, a weak but significant correlation of 0.26 with significance 0.000 reflects the great depth of most dry holes.

Figure 8. Schematic diagram of physical hydrogeology in bedrock terrane.

4.2 HYDROGEOCHEMISTRY

Hydrogeochemistry of bedrock is based on the 103 analyses considered acceptable after the data verification described in section 3.2.2. Table 5 summarizes the data.

4.2.1 Piper Diagram

The 103 bedrock water analyses are plotted on the Piper diagram in Figure 9. The cations are tightly clustered around the point 35% Ca + 30% Mg + 35% Na while the anions stretch from 75% HCO_3^- + 25% Cl to 55% SO_4^{2-} + 45% Cl. It is more usual to find the anions well grouped and the cations spread by ion exchange processes in clay. The reversal in Zio and Yoto may be due to low residence time in the 10 metres of overburden clays allowing little influence on cation chemistry, and the false 0 mg/l SO_4^{2-} values and calculated HCO_3^- values causing an apparent spread in anion chemistry.

The endpoint of the anion range, 55% SO_4^{2-} + 45% Cl^- , is roughly where rainwater adjacent to an ocean plots. The relation to rainwater is coincidental because samples with low total dissolved solids (TDS) generally have >50% HCO_3^- and because TDS in bedrock wells are so high that geologic inputs overprint the original rainwater composition.

The only ion to have any dominance is HCO_3^- ; over half of the samples have >50% HCO_3^- . The only source of HCO_3^- in a high grade metamorphic terrane with <1% metasediments and no known marbles is CO_2 from the atmosphere. CO_2 in groundwater is augmented by plant respiration, oxidation of organic matter and biologically-controlled sulphate reduction in the unsaturated zone (Hem, 1985).

Table 5. Summary of water chemistry data - Bedrock.

Cond - Conductivity
 Avg - Average of bedrock waters
 Std Dv - Standard deviation of bedrock waters
 Min - Minimum value of bedrock waters
 Max - Maximum value of bedrock waters

	Cond (μ S/cm)	Ca ⁺⁺ (ppm)	Mg ⁺⁺ (ppm)	Na ⁺ (ppm)	Fe ⁺⁺ (ppm)	Mn ⁺⁺ (ppm)	HCO ₃ ⁻ (ppm)	SO ₄ ⁼ (ppm)	Cl ⁻ (ppm)	NO ₂ ⁻ (ppm)	F ⁻ (ppm)
Avg	1107	85	43	115	0.3	0.3	344	106	168	7	0.3
Std Dv	467	49	22	73	0.5	0.4	181	126	132	29	0.5
Min	272	10	5	18	0.0	0.0	0	0	2	0	0.0
Max	2600	317	126	475	4.7	4.0	1500	560	855	230	3.1

Figure 9. Piper diagram for bedrock waters (based on Piper, 1944).
Key to numbers in Appendix 7.

How HCO_3^- could become dominant from these processes, especially given a short residence time in the unsaturated zone (no cation exchange), is not clear. One explanation is that biogenic CO_2 deposited as calcite in fractures over millions of years is now being dissolved due to a change in climate.

4.2.2 Ascending Concentration Plots

Ascending concentration plots for Ca^{+2} , Mg^{+2} , Na^+ , HCO_3^- , SO_4^{-2} , Cl^- , Fe^{+2} , Mn^{+2} , NO_3^- , F^- and conductivity were prepared as described in section 3.3.3. Lists of the 103 wells ordered for each ion are in Appendix 7. The form of all major ion plots (Ca^{+2} , Mg^{+2} , Na^+ , HCO_3^- , SO_4^{-2} , Cl^- in Appendix 8) is similar to the concentration plot form (Figure 10). This form shows the samples to be bimodal with most samples in one group and a small but distinct high concentration group. The list of wells which consistently (i.e. in the case of more than 3 ions) place in the high concentration group is given in Table 6. All but two are in the biotitic migmatites (M_1) of the northwest.

Although not a distinct group in themselves, wells which consistently appear at the low end of ascending concentration plots are listed in Table 7.

The low TDS wells are located in several different geological units, but none farther than 1 km from the Keve-Game fault, except the most dilute samples at Bedjeme, which are 2 km away. In addition, all but Agbodjekpoe are on topographic highs, close to hydrologic divides.

Two anomalies are identified in the ascending plots: 1) an area of high SO_4^{-2} wells between Tsueta and Agokpe and 2) an area of high Mg^{+2} wells between Kpodji and

Figure 10. Ascending conductivity plot for bedrock waters.

Table 6. Wells with high total dissolved solids - Bedrock.

Adjra Kope	M336F4 and F5
Atikole	M324F1 and F2
Kplaba	M319F1
Baka Kope	M348F3
Yoto	M175F2 and F3
Bedjra Kope	M407F2 and F3
Hekpoui	M410F1
Hleme	M411F1
Klomekpoe	M409F1
Agohome	M408F1
Z'podji	M403F2
Atiho	M330F2

Table 7. Wells with low total dissolved solids - Bedrock.

Bedjeme	M327F1 and F3
Azi Kope	M432F1
Assi Keve	M325F1
Agbodjekpoe	M329F1 and F2
Gamegble	M315F2 and F5
Amessikpe	M401F1

Agnron. The SO_4^{-2} wells are located on the topographic high between the Zio and Haho Rivers with no apparent geological differentiation from surrounding wells (i.e. Aloyi M237). The Mg^{+2} wells are located between the Keve-Game fault and one of its branches, spread over two geologic units.

Minor ions have a different ordering than the major ions. Iron is uniformly low with a small high concentration group containing some of the high TDS wells identified by major ions plus many of the high SO_4^{-2} group (Appendices 7 and 8). The link with the SO_4^{-2} group suggests a pyrite source for iron in that area. The SO_4^{-2} values are an order of magnitude higher than Fe^{+2} values; therefore, if the Fe^{+2} comes from FeS_2 , Fe^{+2} must be lost (precipitated) from the aqueous phase. Fe accumulation in the solid phase is observed in the masses of laterites (ferric oxyhydroxides) covering the same area (Map 2).

Nitrates are zero throughout most of the bedrock area. Of the 17 samples with >2 mg/l NO_3^- , only 3 are from the high TDS group and two are from the low TDS group (Appendices 7 and 8). This divergence from the normal distribution indicates a non-geologic source (i.e. human activity). These wells tend to be located on topographic highs or on the edge of large towns (i.e. Nyassive and Tovegan) where they are exposed to contamination.

The fluoride plot (Appendix 8) has a jump from zero to the first non-zero value, 0.01 ppm (0.2 mg/l), suggesting that 0.01 ppm is the detection limit.

4.2.3 Hierarchical Cluster Analysis and Tree Plots

The clustering produced for bedrock water chemistry by the Kleiner and Hartigan method described in section 3.3.5 is shown schematically in Figure 11a. The major ions are clustered together suggesting a common source. Bicarbonate is the exception, having the greatest Euclidean distance from all other ions, both major and minor. This may be a result of its non-geologic (i.e. atmospheric) origin and/or as a result of the bicarbonate calculation accumulating the error in all other values. Of the remaining major ions, sulphate has the largest Euclidean distance probably because of the false 0 values. Calcium and chloride have the closest distance, but there is no apparent cause for the association.

The tree plots show little variation in form with a prominent major ion branch and small minor ion branch. The complete set of tree plots is in Appendix 9 and a typical plot is shown in Figure 11b. The most dramatic variation between trees is in their size reflecting the variation in total dissolved solids already identified by the ascending concentration plots in the previous section. Approximately 10 wells have a more pronounced minor ion branch all of which are visible in the ascending concentration plots. The tree plots do not bring any new information to the analysis, but confirm the trends suggested by other methods.

4.3 RELATION OF WATER CHEMISTRY TO GEOLOGY

By and large, water chemistry throughout the bedrock terrane is constant. The consistency is shown graphically by the tight clustering of points on the Piper diagram and by the similarity in form of Kleiner-Hartigan tree plots. This is a reflection of the lack of the variation in lithology of the bedrock. Over half of the

Figure 11a. Hierarchical clustering of ionic data from bedrock waters (based on Kleiner and Hartigan, 1981).

Figure 11b. Typical tree plot for a bedrock water using the clustering from Figure 11a.

wells are in one unit, biotite migmatite.

Between samples, ion concentrations show more variation than the relative proportions of the ions. Low concentration wells identified from the ascending concentration plots in section 4.2.2 are on topographic highs and within 1 km of the Keve-Game fault and the high concentration wells are in topographic lows of the biotite migmatite. The map of conductivity values (Map 5) confirms the trends with a band of low ($<1000 \mu\text{S/cm}$) conductivities along the Keve-Game fault and the high conductivity values ($>1800 \mu\text{S/cm}$) in the biotite migmatites.

Low concentration wells may be associated with the Keve-Game fault because the fault is surrounded by brittle deformation allowing free circulation and renewal of water which in turn reduces TDS. The fault is also surrounded by orthogneisses, most of which are less mafic than the biotite migmatite, more resistant to weathering, and therefore, release less solute into groundwater. In addition, these wells are generally on topographic highs where rainwater reaches the water table for the first time (recharge area) so that it has not had a chance to accumulate many solutes on the way.

The high concentration wells in biotite migmatite are not usually located on topographic highs and not consistently enough on lows to give significant correlation (Table 2). However, from the maps of surface hydrology, yield and conductivity (Figure 3, Maps 2 and 5), the high concentration wells are often in topographic lows. This relationship is reasonable in that topographically low wells are close to discharge areas and therefore, should have higher conductivity where the water has had a longer flow path and residence time. The correlation coefficient for conductivity with yield is low but significant (0.26 with 0.003 significance).

Chapter 5

SEDIMENTS

5.1 PHYSICAL HYDROGEOLOGY

Groundwater in sediments moves by means of porous media flow (i.e. through the open spaces between clasts). Its movement is controlled by the size and degree of interconnection between open spaces which in turn is controlled by lithology, degree of compaction and degree of cementation.

Lithology of sediments in Zio and Yoto, as presented in section 2.5.2, is continuous over a large area (10's of km), although highly variable on a small scale (m and cm) in some environments, particularly near-shore and deltaic. Specific layers within the laterally continuous macrostratigraphic sequence can be identified as aquifers.

Within Zio and Yoto there are 4 main aquifers, each referred to by age:

- 1) Cretaceous (Maastrichtian) aquifer, exploited by 86% of project wells in sediments, is composed of deltaic sands in the north and carbonates in the south.
- 2) Paleocene aquifer, exploited by 7 project wells, is a 10 metre pure carbonate layer and underlying sands.
- 3) Basal Lower Eocene aquifer, exploited by 2 project wells, is composed of thin dolomite and sand layers.
- 4) Continental Terminal aquifer, exploited by 2 project wells, is composed of sands.

The aquifer exploited by each well was determined by the construction of stratigraphic cross-sections through all sedimentary well logs, comparison with well logs

and aquifer identifications from other reports on the same area (Gendron Lefebvre Inc., 1977 and BRGM, 1982) and from water chemistry. Aquifer identification for each well is shown on all maps.

The sediments along the outermost basin edge, lying above the water table in a strip roughly 5 km wide, are known as the "dry wedge". It is very difficult to site wells in the dry wedge because not only are the sediments dry, but fractures in the underlying bedrock are masked from visual and resistivity view by the clay-rich sediments (Figure 12). To date, drilling programmes have either drilled dry holes (i.e. Esse Dzogdedji M423 and Seveho M389) or avoided the area.

For ease of discussion, the sediments of Zio and Yoto have been divided into zones A through D as shown on Figure 13. Zones A, C and D have wells in the Cretaceous aquifer whereas zone B wells are in Paleocene and Eocene aquifers. The two Continental Terminal wells are in zones B and C.

5.1.1 Well Siting

Since each aquifer covers most of the basin, with the exception of the dry wedge, wells can be drilled anywhere. The only restriction is to avoid point-source contamination.

5.1.2 Water-Bearing Horizons

Water-bearing horizons in sediments are the four aquifers already mentioned.

Although a well may intersect several aquifers, the aquifer under consideration here is the uppermost aquifer exploited through a well screen. Most of the aquifers are

Figure 12. Schematic cross-section of Zio and Yoto Prefectures.

Figure 13. Sedimentary zones of Zio and Yoto Prefectures.

uniform so that 2 wells in the same village normally are in the same aquifer, resulting in similar well characteristics.

Isohyphes on the upper surface of the aquifers are shown where possible on Map 3 in depths from surface, and on Map 4 in elevations above mean sea level. Variability in the upper surface of aquifer is evident on both maps. For example, Tchekpo Deve M011 has values of -21, -27, and -34 m.a.s.l. for three Cretaceous wells within 600 m of each other. Given this degree of variation and the ± 5 metre error in elevation, the isohyphes are only a best approximation. Map 3 shows a band of greater depth to Cretaceous aquifer (>60 m) with shallower depths on either side. The same area on Map 4 indicates a gradual basinward deepening of the upper Cretaceous aquifer surface. Therefore, the band must represent an increased thickness of Continental Terminal sediments. This thickening was also observed by Sylvain *et al.* (1986). In the vicinity of Wodenou M468 to Adeti Kope M377, there is a slight basinward rise (<20 m) in the top of the Cretaceous aquifer. This rise coincides with the above band and is expressed as a syncline on Map 2. The Paleocene aquifer, seen between Adjoguidi M378 and Aveta M039, shows a rapid increase in depth and decrease in elevation basinward. The steep gradient may be a reflection of the normal faulting described in section 2.5.2. The Eocene and Continental Terminal aquifers do not have enough points on the maps to discuss.

5.1.3 Well Depth

Wells were generally drilled 5 to 10 metres into the first exploitable aquifer encountered plus another 5 to 10 metres to allow for drawdown. Thus, well depth is closely related to the depth to water. Three of the most shallow wells are dry due either to drilling difficulties resulting in abandonment or to the dry wedge.

Continental Terminal wells are shallow because this formation overlies all other formations. Cretaceous wells vary considerably in depth. The influence of the syncline in zone C is noticeable with shallower depths both north and south of the axis. The Paleocene aquifer is always attained at depth under the long series of Paleocene clays and marls. The Eocene aquifer is intersected (although not always exploited) in the three southernmost wells: Dzovadje M465F1, Aveta M039F2 and Yogan M466F1. These wells are shallow because they are near the northern limit of this unit.

5.1.4 Static Water Level

Static water levels are plotted on Map 3 as depths and on Map 4 as elevations. Overall, there is not much variation but a general tendency to deepen toward the centre of the basin is seen on Map 4 indicating basinward flow. Hydraulic gradients in the Cretaceous aquifer, measured on Map 4, range from 0.001 to 0.004. The hydraulic gradient between Paleocene aquifer wells on Map 4 is not significant. The Eocene and Continental Terminal aquifers do not have enough wells to measure gradient.

If flow is downward into the basin, recharge must be via the Continental Terminal where each aquifer suberops. With little variation in static water level and significant basinward deepening of the upper aquifer surface, the pressure head increases basinward and inversely, decreases toward the basin edge. Near the suberop of each aquifer beneath the Continental Terminal, the aquifers approach unconfined conditions, as is necessary for recharge through the Continental Terminal. This is best shown in the series of wells from Amegnona Kope M100F2

through Kotiko Kondji M359 and Aklobi Kondji M358 to Djata Kope M366F1 in zone A (Map 3).

5.1.5 Pump Intake Depth

To check the relation of pump intake depth to other variables measured in depths, correlation coefficients based on the 48 sedimentary wells with known pump depth were calculated (Table 8). Because of the similarity of static water level to dynamic water level for $1 \text{ m}^3/\text{hr}$ discharge in high-yielding sedimentary wells, static water level correlates well with pump depth (correlation coefficient 0.90 and significance 0.000). In contrast to the bedrock terrane, sedimentary well depth does not correlate with pump depth (significance > 0.1).

Figure 14 shows graphically the relation of pump intake depth to static water level and well depth with simple regression lines through each of the variables. Slopes of the regression lines for static water level and pump depth are approximately equal, -1.055 and -1.052 respectively (Table 9), again showing the close correlation between the two variables. The difference between the two regression coefficients -6.312 and -22.838 is 16.5 metres. This represents the average distance of pump intake below static water level. Ten metres of this distance are the safety factor leaving 6.5 metres as the average difference between static water level and dynamic water level at $1 \text{ m}^3/\text{hr}$ discharge.

Well depth in Figure 14 is clearly unrelated to pump depth as shown by the scatter of points and nearly-horizontal regression line (slope = -0.0132). Because of the difference in slope of the pump depth and well depth regression lines, they converge as the pump depth increases but pump installation necessarily stops short

Table 8. Correlation matrix with pump intake depth - Sediments.

S.W.L. - Static water level

Example: Well
 depth

Pump 0.161 ----> correlation coefficient
depth 48 ----> number of wells used in correlation
 0.276 ----> correlation significance

	Pump depth	S.W.L. (depth)	Well depth
Pump depth	1.000 48 0.000	0.901 48 0.000	0.161 48 0.276
S.W.L. (depth)		1.000 76 0.000	0.142 76 0.220
Well depth			1.000 76

Figure 14. Pump intake depth in relation to static water level and well depth for sedimentary wells with linear regression lines for each variable. Wells in order primarily of increasing pump depth and secondarily of decreasing static water level

Table 9. Regression statistics for Figure 14.

	Static Water Levels	Pump Depths	Well Depths
Constant	-6.312	-22.838	-82.070
Standard Error of Y	6.338	3.064	19.936
R Squared	0.847	0.959	0.009
X Coefficient	-1.055	-1.053	-0.132
Std Error of Coef.	0.066	0.032	0.208
Degrees of Freedom	46	46	46

of convergence. The difference between the pump depth and well depth regression lines at the deepest pump is 15 metres. Approximately 3 metres between pump intake and well bottom is required to prevent aspiration of sediments in the bottom of the well which causes pump wear and to permit vertical flow into the pump intake. Therefore 12 metres is the theoretical distance available for future deepening of the pump intake in response to long term hydrological change. In practice this may not always be possible because the pump intake should not be set below the top of the well screen. Note there are already three wells, Fongbe Boeti M375F1, Atide Apedome M387F2 and Tedo M386F1 whose pumps are less than 10 metres from the bottom of the well. This is because either the static water level is very low or the well has poor transmissivity making the dynamic water level for 1 m³/hr very low.

5.1.6 Yield

Sedimentary wells show a wide range of yields from 0 to 80 m³/hr. Yields <1 m³/hr indicate wells abandoned due to either drilling difficulties or the dry wedge. Thus all regular wells yield more, and in most cases much more, than is required for a handpump (1 m³/hr). All well yields are plotted on Map 2.

The Cretaceous aquifer has its highest yields around Tona Kondji M352, where the aquifer is composed of gravel and coarse sand. The rapid decrease in yield northeast from this high (Map 2) is due to a facies change to argillaceous sand and clays toward the basin edge. For example, an increase in clay content in the gravel and sand aquifer from Afantodji M351F1 to Adjra M560F1 is accompanied by an order of magnitude decrease in yield from 80 to 5 m³/hr. Another factor seen to influence

Cretaceous aquifer yield is length of aquifer intersected and therefore, screen length. For example, in Tsevi Kondji M353F1 (aquifer thickness 9 m, screen length 7.88 m) and Ai Kondji M398F1 (aquifer thickness 5 m, screen length 3.85 m), the aquifer lithology appears to be the same, but the yields are 80 m³/hr and 35 m³/hr respectively.

The Paleocene carbonate aquifer has low yields, <10 m³/hr, except the Lowe wells M379F1 and M380F1, which are in sand below the carbonate. The Eocene and Continental Terminal wells appear to have low yields, <5 m³/hr, however, this figure is based on results of 2 wells each and therefore, is not representative.

In addition to the evaluation of factors influencing yield from trends seen on Map 2, a more rigorous evaluation for all productive sedimentary wells was done by correlating yield to all other numerical well variables (Table 10). Well yields increase only as a function of decreasing aquifer elevation (correlation -0.41, significance 0.000) and decreasing static water level depth (correlation -0.35, significance 0.002). In other words, yield varies directly with pressure head.

5.2 HYDROGEOCHEMISTRY

The hydrogeochemistry of waters from sediments is based on the 56 analyses considered acceptable after data verification as described in section 3.2.2. Table 11 summarizes the data.

Table 11. Summary of water chemistry data - Sediments

Cond - Conductivity
 Avg - Average of bedrock waters
 Std Dev - Standard deviation of bedrock waters
 Min - Minimum value of bedrock waters
 Max - Maximum value of bedrock waters

	Cond (μ S/cm)	Ca ⁺⁺ (ppm)	Mg ⁺⁺ (ppm)	Na ⁺ (ppm)	Fe ⁺⁺ (ppm)	Mn ⁺⁺ (ppm)	HCO ₃ ⁻ (ppm)	SO ₄ ⁼ (ppm)	Cl ⁻ (ppm)	NO ₃ ⁻ (ppm)	F ⁻ (ppm)
Avg	264	32	6	21	0.6	0.2	100	17	35	5	0.2
Std Dev	201	28	6	13	0.6	0.2	100	16	26	13	0.1
Min	0	3	1	7	0.0	0.0	0	0	5	0	0.0
Max	1010	121	34	72	2.6	1.5	459	68	182	69	0.8

5.2.1 Piper Diagram

The sedimentary water analyses are plotted on the Piper diagram in Figure 15. Points in the cation triangle are limited to a band between 5% and 25% Mg. The band can be divided into 3 groups: 1) >50% Ca, 2) >50% Na and 3) <50% Ca, Mg, Na. The low concentration of Mg indicates little dolomite or other magnesium-rich minerals in the area. Anion data is more scattered, but stays on the low sulfate side of a line passing through 100% HCO_3 and 50% $\text{SO}_4 + 50\%$ Cl. The lack of SO_4 indicates little gypsum in the basin. It is not possible to identify groups amongst the anions. The abundance of 0% SO_4 points is clearly anomalous as are the 6 points on or near 0% HCO_3 . Points in the diamond portion of the plot fall into four groups, one in each quadrant made by dividing the diamond along the 50% Na and the 50 $\pm$ 3% HCO_3 lines. Beginning from the left quadrant and proceeding clockwise, these quadrants represent Ca- HCO_3 , Ca- SO_4/Cl , Na-Cl and Na- HCO_3 . The quadrant to which each sample belongs is listed in Table 12.

All samples in quadrant Ca- HCO_3 (group 1) have >50% HCO_3 and all but 2 have >50% Ca, indicating a strong influence by carbonates, mainly limestones. Quadrant Ca- HCO_3 contains more wells than any other quadrant, covering all of zone C, zone B, except for the extreme northeast, and some of zone D.

Quadrant Ca- SO_4/Cl (group 2) is mixed waters. All samples in this quadrant come from the <50% Ca, Mg, Na area of the cation triangle or the <50% HCO_3 , SO_4 , Cl area of the anion triangle, or both. Geographically it covers zone D and some of zone A and the extreme northeast of C.

Figure 15 Piper diagram for sedimentary waters (based on Piper, 1944).
Key to numbers in Table 12.

Table 12. Water chemistry groupings - Sediments.

Key -		Key to Figure 15			
Piper group -		Group based on Piper diagram			
Correlation groups -		Group based on correlation coefficients			
Ascending {} groups -		Group based on ascending concentration plots			
Final groups -		Concluding group assignment			
Key Well #	Village	Piper groups	Correlation groups	Ascending {} groups	Final groups
1 M010F2	Tchekpo Anagal	1	1	1c	1c
2 M011F2	Tchekpo Deve	1	1	1a	1a
3 M011F3	Tchekpo Deve	1	1	1a	1a
4 M039F2	Aveta	2	2	1b*	1b*
5 M182F2	Gati Agodo	2	2	2	2
6 M182F3	Gati Agodo	2	2	2	2
7 M183F2	Gati Soun	2	2	2	2
8 M183F3	Gati Soun	3	2 or 3	3a	3a
9 M186F3	Sedjro	1	1	1a	1a
10 M350F1	Adabadji Kondj	2	3a	3a	3a
11 M350F2	Adabadji Kondj	2	3a	3a	3a
12 M351F1	Afantodji Kond	3	3a	3a	3a
13 M351F2	Afantodji Kond	3+	(3a)	3a	3a
14 M352F2	Tona Kondji	3	(3a)	1c	1c
15 M353F1	Tsevi Kondji	3+	3a	3a	3a
16 M359F1	Kotiko Kondji	3	3a	3a	3a
17 M360F1	Adjra Kope	3+	3a	3a	3a
18 M363F1	Akoutcha Kondj	3+	3a	3a	3a
19 M365F1	Adabian	3	(3a)	3a	3a
20 M366F1	Djata Kope	1	1	1a	1a
21 M367F1	Setekpo	1	1	1a	1a
22 M367F2	Setekpo	3	3b	3b	3b
23 M368F1	Zoti Kope	3	3a	3a	3a
24 M369F1	Akoudokpo	3	3b	3b	3b
25 M370F2	Kpesse Kope	3	3b	3b	3b
26 M371F1	Avedji	1	1	1a	1a
27 M372F1	Davou	3	3b or 2	2	2
28 M375F1	Fongbe Boeti	3+	3	3a	3a
29 M376F2	Anyave	1	1	1b	1b
30 M377F1	Adeti Kope	1	1	1c	1c
31 M377F2	Adeti Kope	1	1	1a	1a
32 M378F1	Adjoguidi	1	1	1b	1b
33 M378F2	Adjoguidi	1	1	1b*	1b*
34 M380F1	Lowe	1	1	1b*	1b*
35 M382F1	Allagbadja	1	1	1a	1a
36 M383F1	Moc Kope	1	1	1b	1b
37 M384F2	Adidome	2	2	2	2
38 M384F3	Adidome	2	1 or 2	2	2
39 M385F1	Seva	1	1	1c	1c
40 M385F2	Seva	1	1	1c	1c
41 M386F1	Tedo	2	2	2	2

Table 12 (continued)

Key Well #	Village	Piper groups	Correlation groups	Ascending [] groups	Final groups
43 M387F2	Atide Apedome	1	1 or 2	1c	1c
44 M388F1	Akpanito	1	1	1b	1b
45 M391F1	Lomegnan Kope	1	1	1a	1a
46 M396F1	Fongbe Apedome	3	3a or 3b	3a	3a
47 M396F2	Fongbe Apedome	2	3a	3a	3a
48 M397F1	Yobo	1	1	1a	1a
49 M397F2	Yobo	1	1	1a	1a
50 M398F1	Ai Kondji	2	2	1c	1c
51 M399F1	Gabadjin	2	2	2	2
52 M467F1	Agblevou	1	1	1b	1b
53 M468F1	Wodenou	1	1	1a	1a
54 M469F1	Kpala	3	2	2	2
55 M470F1	Messeko Kondji	1	1	1a	1a
56 M471F1	Afikou Kondji	3	3	1c	1c

Quadrant Na-Cl (group 3) samples all have $>50\%$ Na^+ and most have $>50\%$ Cl^- , like quadrant Ca-CO_3 indicating unmixed water. All samples come from southwest zone A or extreme northeast zone C.

Quadrant Na-HCO_3 has only 5 samples, all with 0 mg/l SO_4^{-2} . As discussed in section 3.2.2 these are probably low values of sulphate, not zero. A small amount of sulphate, $<10 \text{ mg/l}$, is sufficient to move these samples into quadrant Na-Cl.

Two samples, M385F1 Seva and M396F2 Fongbe Apedome (numbers 39 and 47 respectively on Figure 15), plot by themselves, representing either unique waters or errors in analysis. Check 1 and check 2 in Appendix 5 indicate both these samples are near the limit of acceptability, therefore they are probably in error.

5.2.2 Correlation Coefficients

Results from the Piper diagram, ascending concentration plots and tree plots show the well compositions to be similar enough that many different means of grouping the samples appear to be equally valid. To provide an objective basis for groupings, correlation coefficients were calculated for each of the 56 acceptable wells with every other well using Ca, Mg, Na, Fe, Mn, HCO_3 , SO_4 , Cl, NO_3 , and F data. The resulting matrix of correlation coefficients and their significances are listed in Appendix 10. Most samples can be assigned to one of four groups based on correlations of 0.900 and higher. The remaining 4 to 6 samples are assigned based on correlations of at least 0.700 (significance 0.020). The groups are listed in Table 12. The cause of the four main groupings cannot be determined from coefficients.

In addition to the 4 main groupings, there is a secondary tendency for wells from the same geographic area to correlate positively. For example, zone D wells include the least Ca-HCO_3 -rich group 1 wells and the most Ca-HCO_3 -rich group 2 wells. For example, Atide Apedome M³⁹7F1 and F2 (zone D) have equally good correlations with groups 1 and 2.

5.2.3 Ascending Concentration Plots

Ascending concentration plots for Ca^{+2} , Mg^{+2} , Na^+ , HCO_3^- , SO_4^{-2} , Cl^- , Fe^{+2} , Mn^{+2} , NO_3^- , F^- and conductivity were prepared as described in section 3.3.3. Lists of the 56 wells ordered for each ion are in Appendix 11. The form of major ion plots Ca^{+2} , Mg^{+2} , Na^+ , HCO_3^- , SO_4^{-2} , and Cl^- (Appendix 12) is typified by the conductivity plot (Figure 16).

Piper diagrams and correlation coefficients deal with relative proportions of ion concentrations in each sample whereas ascending concentration plots compare magnitudes of ion concentrations in each sample. This comparison is done by identifying the wells which plot between each break in the ordered concentration plots. Wells which consistently plot together constitute a group. This analysis has allowed a refinement of groups 1 to 3b, particularly the subdivision of group 1 into 1a, 1b, 1b* and 1c; however, the divisions of 1a from 1c and 3a from 3b are not always visible (Figure 16). The group to which each well belongs is indicated in Table 12.

The ascending concentration order of groups shows consistency for the major ions (Table 13). Group 1b* clearly has the highest concentrations followed by 1b, 2, 1a+1c, 3a and 3b.

Figure 16. Ascending conductivity plot for sedimentary waters.

Table 13. List of groups in order of ascending concentration.

Plot	<----Ascending Concentration							
Conductivity	1b*	1b	2	1a	1c	3a	3a+3b	
Ca ⁺²	1b*	1b	1a	2	1c	mix	3a	3b
Mg ⁺²	1b*	1b	1b+2	1a+1c		3a	3a+3b	
Na ⁺	1b*	2+1b			1c+3a+3b		1a+3a+3b	
HCO ₃ ⁻	1b*	1b	1a	2+1c	mix	3a	3a+3b	
SO ₄ ⁻²	1b*	2+1b+3b		1a+c	1c+a		3a	
Cl ⁻	1b*	2+1b	1c	3a+3b+1a+1c			3a+3b+1c	
Fe ⁺²		1b+2+1a		1a+1b	2	3a+3b	1c+3a	
Mn ⁺²		mix						
NO ₃ ⁻	2	3b	2+1c			1a+1b+3a+1c		
F ⁻		1b+1a+c		1c+2	mix	3a(false zero)		

Comparing the ascending concentration order of groups on major ion plots to those on the conductivity plot highlights the differences between groups (Table 13). The major differences are: Group 1 has higher than average Ca^{+2} and HCO_3^- , group 2 somewhat higher SO_4^{-2} , Na^+ and Cl^- , group 3a higher Cl^- , and group 3b much higher SO_4^{-2} . These variations are what causes each group to plot in a different quadrant of the Piper diagram

Minor ion plots present different groupings of samples. Iron is the most similar to the major ions, but even so does not correspond closely. Group 2 and 1c wells both plot anomalously low. The Mn^{+2} plot is essentially flat, putting all samples into one large group except for group 1a and 1c with high concentrations. The drop from 0.005 epm to 0.000 epm in the F^- plot is too drastic to be a real phenomenon. More likely, 0.005 epm (0.1 mg/l) was the detection limit for F^- . Nitrate groups do correspond to major ion groups and also to location. The two highest groups are 2 and 3a from northeast zone C. The next group, with low levels of NO_3^- , is group 2 and group 1c from central zone A and zone D. The remainder have zero nitrates including the entire 1a, 1b and 1b* groups.

Ascending concentration plots are also useful in identifying errors in data. Since the order of samples is similar for each of the major ions, a sample changing rank for only one ion suggests an error in the value, (i.e. the Cl^- value for the M467F1 Agblevou or F^- value for M011F3 Tchekpo Deve). In the iron plot, pairs of wells which have close values for all other ions vary widely. For example, Djata Kope M366F1 and Setekpo M367F1 have a 0.9893 correlation coefficient and rank within 4 samples of each other in every ion except iron where they rank 16 samples apart, suggesting loss of iron due to precipitation. Rust colored stains observed in some sample bottles before analysis adds evidence for iron precipitation. The highest

value of Mn^{+2} from Tedo M386F1 is five times higher than the preceding value, and the preceding value is almost equal to every other value, suggesting an error in the Tedo value.

5.2.4 Hierarchical Cluster Analysis and Tree Plots

Hierarchical cluster analysis described in section 3.3.5 was done on ionic data (including HCO_3^-) for the 56 sedimentary wells, resulting in the clustering shown in Figure 17a. This clustering is reasonable for a sedimentary terrane in that the dissolved cation/anion pairs of common sedimentary minerals are clustered most closely (i.e. Ca^{+2} and HCO_3^- ; Na^+ and Cl^-). Sulphate does not tie in with other major ions probably due to the false zero values. Minor ions, Fe^{+2} , Mn^{+2} , F^- and NO_3^- are independent of the major ions and of each other except for a clustering of Mn^{+2} with NO_3^- , for which there is no apparent reason. This is interpreted as meaning that their occurrence is not associated with any one lithology.

Tree plots for each sample using the above clustering illustrate relative proportions of ions in each sample as seen in the Piper diagram and correlation coefficients combined with magnitudes of ions as seen in the ascending concentration plots.

These plots (Appendix 13) were made using the method described in section 3.3.5. A typical plot is shown in Figure 17b. Unlike the bedrock plots, these plots show large differences. By grouping trees of similar form, groups 1, 2, 3a and 3b can be identified. By grouping (or regrouping) based on tree size, giving a rough indication of TDS, the subgroups 1a, 1b, 1b*, 1c are recognized.

Figure 17a. Hierarchical clustering of ionic data from sedimentary waters (based on Kleiner and Hartigan, 1981).

Figure 17b. Typical tree plot for a sedimentary water using the clustering from Figure 11a.

2

MicroD

5.2.5 Summary of Water Chemistry Classification

Waters from sediments in Zio and Yoto Prefectures are grouped on the basis of chemistry as discussed in the preceding four sections, as well as geographic location. The final group to which each well is assigned is listed in Table 12. Ranges of values, averages and standard deviations of each group are given in Table 14 to quantify and show how consistent the groups are. The Piper diagram (Figure 15) shows wells of each group clustered together and sometimes overlapping. In areas of overlap, groups can be distinguished by their conductivities as seen in Table 14.

Group 1 is distinguished by high Ca^{+2} and HCO_3^- and low Cl^- , group 2 by being neither high nor low in any ion, group 3 by low conductivity with low SO_4^{-2} and high Na^+ and group 3b by low conductivity with high SO_4^{-2} , Na^+ and Cl^- .

5.3 RELATION OF WATER CHEMISTRY TO GEOLOGY

Water chemistry correlates closely with lithology at and above the well screen. Correlations are as follows based on water chemistry groupings of section 5.2.5:

- 1a - In sands with thin bands of carbonate underneath black clay or marl.
- 1b - In sands under the 10 metre carbonate unit below long sections of clay for zone C or in sandy/argillaceous limestone thinly interbedded with clays and sands in zone D.
- 1b* - In the 10 metre pure carbonate unit except for Lowe M380F1 which is screened immediately below the carbonate and gravel packed up through the carbonate.

Table 14. Statistics of water chemistry groups - Sediments.

	Cond ($\mu\text{S/cm}$)	Ca^{++} (cpm)	Mg^{++} (cpm)	Na^{+} (cpm)	Fe^{++} (cpm)	Mn^{++} (cpm)	HCO_3^{-} (cpm)	$\text{SO}_4^{=}$ (cpm)	Cl^{-} (cpm)	NO_3^{-} (cpm)	F^{-} (cpm)
Averages											
3b	75	0.2	0.1	0.6	0.01	0.00	-0.1	0.4	0.6	0.00	0.01
3a	111	0.4	0.2	0.6	0.01	0.01	0.5	0.0	0.7	0.03	0.00
1c	193	1.1	0.4	0.8	0.01	0.01	1.3	0.3	0.7	0.03	0.02
1a	256	2.0	0.4	0.6	0.03	0.01	2.0	0.3	0.7	0.00	0.02
2	334	1.6	0.6	1.2	0.03	0.01	0.9	0.7	1.4	0.37	0.01
1b	515	4.0	0.9	1.3	0.03	0.00	4.5	0.6	1.1	0.00	0.02
1b*	832	5.2	2.4	2.8	0.04	0.01	6.0	1.1	3.3	0.00	0.02
Standard Deviations											
3b	14	0.0	0.0	0.2	0.00	0.00	0.1	0.3	0.1	0.00	0.00
3a	19	0.1	0.0	0.2	0.01	0.00	0.3	0.1	0.2	0.07	0.00
1c	49	0.3	0.1	0.3	0.01	0.00	0.5	0.2	0.2	0.03	0.00
1a	47	0.6	0.1	0.2	0.02	0.00	0.6	0.2	0.2	0.00	0.00
2	107	0.5	0.3	0.2	0.03	0.02	0.3	0.2	0.4	0.41	0.00
1b	59	0.4	0.3	0.5	0.02	0.00	0.3	0.3	0.6	0.00	0.00
1b*	1	0.7	0.3	0.3	0.02	0.00	1.6	0.2	1.4	0.00	0.01
Minimums											
3b	58	0.1	0.1	0.3	0.01	0.00	0.3	0.0	0.5	0.00	0.01
3a	75	0.2	0.2	0.3	0.00	0.00	0.1	0.0	0.3	0.00	0.00
1c	113	0.6	0.2	0.5	0.00	0.00	0.5	0.0	0.4	0.00	0.02
1a	131	0.6	0.2	0.3	0.00	0.00	0.8	0.0	0.2	0.00	0.01
2	138	0.6	0.2	0.9	0.00	0.00	0.3	0.5	0.7	0.00	0.01
1b	400	3.7	0.5	0.3	0.00	0.00	4.1	0.0	0.1	0.00	0.01
1b*	830	4.3	2.0	2.5	0.01	0.00	3.8	0.9	1.8	0.00	0.01
Maximums											
3b	92	0.2	0.2	0.8	0.01	0.00	0.1	0.7	0.7	0.00	0.01
3a	155	0.6	0.2	1.0	0.03	0.01	1.1	0.4	1.1	0.23	0.01
1c	231	1.4	0.7	1.4	0.02	0.01	2.2	0.5	1.0	0.08	0.02
1a	308	3.0	0.6	1.1	0.08	0.02	3.2	0.5	0.9	0.01	0.02
2	526	2.3	1.0	1.5	0.09	0.05	1.2	1.1	1.9	1.11	0.02
1b	555	4.7	1.3	1.9	0.05	0.01	4.8	0.9	1.9	0.00	0.02
1b*	833	6.0	2.8	3.1	0.06	0.01	7.5	1.4	5.1	0.00	0.04

- 1c - In sands, clays or gravels with thin carbonate layers underneath black clay except that zone A wells Tchekpo Anagali M010F2, Tona Kondji M352F2 and Ai Kondji M398F1 have no carbonate. These wells are near Tchekpo Deve M011F2 and F3 Adabadji Kondji M350F1 and F2 which contain carbonates; therefore, they either have marls/carbonates which were not recorded in the logs or are close enough to such sediments to influence water chemistry.
- 2 - In sands above sandy/argillaceous limestones and under black clay in zone D or in sands below thin black clay and/or other clays in zones A and C.
- 3a - In sands under black clay with an absence of carbonate/marl, except that M350F1 and F2 and M351F1, as mentioned above, have calcareous layers.
- 3b - In gravels and coarse sands under black clay with an absence of carbonate/marl.

Cretaceous aquifers produce waters of group 1a, 1b (zone D), 1c, 2, 3a and 3b.

Paleocene aquifers produce waters of group 1b* and 1b (zone B). The one reliable analysis from an Eocene well (Aveta M039F2) is group 1b*, and the one analysis from the Continental Terminal is group 3a. The fact that group 1b is found in both Cretaceous and Paleocene aquifers is due to their lithological similarity, although they can be separated by Ca:Mg ratios because Paleocene carbonates are more dolomitic.

The chemical compositions of groups 1a, 1c, 3a and 3b form a series. Na^+ and especially Cl^- values remain uniform, providing a common reference for all groups.

Beginning with the most dilute, group 3b is little more than rainwater (average conductivity 75 $\mu\text{S}/\text{cm}$). Group 3a has more Ca^{+2} , Mg^{+2} and HCO_3^- . The decreases in SO_4^{-2} and F^- are not valid due to false zeros in both. Group 1c contains even more Ca^{+2} , Mg^{+2} and HCO_3^- , plus a little Na^+ and NO_3^- . Group 1a has still more Ca^{+2} , Mg^{+2} and HCO_3^- , but does not have the increased Na^+ or NO_3^- of group 1c. This leads to the conclusion that all originate from one rainwater source which picks up Ca^{+2} , Mg^{+2} , and HCO_3^- in proportion to its interaction with calcareous sediments, increasing basinward and westward. Group 1c water also picks up Na^+ from ion exchange in clays and NO_3^- from human activities.

Group 2 waters also come from the Cretaceous aquifer but are not part of the above series. They appear to have two different origins. Group 2 wells from zone D (except Tedo) have group 1b-type calcareous horizons below the well screen and similar lithology and position in the basin as group 3; therefore, these waters are considered to be a mixture of group 1b and 3a waters. Group 2 wells from zone C are far from any calcareous or marl layer and near group 3a wells. They all have high NO_3^- , as does Tedo. The only source of nitrate in a country which does not use fertilizers is decomposition of organic matter resulting from human and animal activity. This type of organic contamination raises Ca^{+2} , Mg^{+2} , SO_4^{-2} , Cl^- and conductivity as well as NO_3^- , relative to Na^+ and HCO_3^- (LIGS, 1980). Therefore, group 2 (zone C) waters are probably organically contaminated group 3a waters.

There are 2 unusual wells which merit special mention. Aveta M039F2 is more Na^+ and Cl^- -rich and less Ca^{+2} and HCO_3^- -rich than other 1b* members. This may be because it is the only well to exploit the Eocene aquifer or because of a saline intrusion (BRGM, 1982) into the southern part of zone B. Saline wells of similar stratigraphy drilled during a previous project (i.e. Lebe C7, Abobo WN1 and Dekpo

WN2 (Gendron Lefebvre Inc., 1977)) plot near Fongbe Apedome M396F2 on the Piper diagram. Aveta plots about half way between the other two 1b* samples and Fongbe Apedome suggesting that the saline intrusion is affecting Aveta. Note also that Dzovadje M465F1 which is closer to the main saline zone has Cl^- and conductivity values similar to Aveta.

Adabadji M350F1 and F2 plot in the $\text{Ca-SO}_4/\text{Cl}$ quadrant in spite of being group 3a waters. This is due to the occurrence of a calcarous layer directly below the screen. The input of Ca^{+2} and HCO_3^- is sufficient to reduce Na^+ to <50% of cations resulting in the anomalous plot.

Chapter 6

IMPLICATIONS FOR RURAL WATER SUPPLY

The primary objectives of rural water supply are to improve health and reduce time and energy consumed in obtaining water. In order to achieve these goals, standards of water quality, quantity and distance from each home are set. Togo follows the WHO drinking-water quality guidelines and uses 20 litres/ person/day at a maximum distance of 1 km from dwellings as a guideline. Programmes and projects should be designed to these standards and ideally allow for a raising of standards with time. In this chapter, the major technical issues involved in designing rural water supplies are discussed in the context of physical hydrogeology and hydrochemistry of Zio and Yoto Prefectures.

6.1 WATER SOURCE

The three possible sources of water are rainwater, surface water and groundwater. Rainwater provides a reasonable quantity of water, requiring only 0.08% to be harvested as shown by calculations below.

Mean Annual Requirement:

$$20 \text{ L/p/day} \times 350,000 \text{ people} \times 85\% \text{ rural} \times 365 \text{ days} = 2.2 \times 10^6 \text{ m}^3/\text{yr}$$

Annual Rainfall Available:

$$1 \text{ m rainfall} \times 4,000 \text{ km}^2 \text{ surface area} \times 70\% \text{ recovery}^* = 2.8 \times 10^9 \text{ m}^3/\text{yr}$$

% Available Rainfall Required:

$$\frac{2.2 \times 10^6 \text{ m}^3/\text{yr}}{2.8 \times 10^9 \text{ m}^3/\text{yr}} = 0.08\%$$

* Recovery factor allows for evaporation, infiltration, splash, etc. losses.

70% is conservative for most surfaces.

In addition, only 0.08% or 3.2 km² would be required for the rainwater catchment surface. However, the five month dry period and moderate annual rainfall make the storage facilities required to assure daily allocation of water through the dry season prohibitively expensive. From CUSO designs and cost estimates, the least expensive means of providing water from rainfall is approximately 10 times the cost of providing the same quantity of water by well and handpump.

The only reliable source of surface water for Zio and Yoto is the Mono River, with a mean annual flow of 118 m³/s (section 2.4). The percent of annual flow required would only be 0.06% as calculated below.

Mean Annual Discharge

$$118 \text{ m}^3/\text{s flow} \times (3.15 \times 10^7 \text{ s/yr}) = 3.72 \times 10^9 \text{ m}^3/\text{yr}$$

% Mean Annual Discharge Required

$$\frac{2.2 \times 10^6 \text{ m}^3/\text{yr}}{3.72 \times 10^9 \text{ m}^3/\text{yr}} = 0.06\%$$

This is probably an acceptable figure, allowing for continued downstream use of the river. However, the seasonal drop in flow can bring daily % of discharge required to 6 or 60%, which may not be acceptable. Assuming that sufficient surface water is available, the cost of distributing it 100 km across the two prefectures from where it flows along the Benin border (Figure 3) is impractical. In addition, the biological (and possibly chemical) quality of the Mono River water would require treatment to attain drinking quality standards, further increasing operation and maintenance costs.

Groundwater recharge is normally estimated by hydraulic budget equations, however runoff and evapotranspiration data were not available. Recharge was therefore

calculated on the basis of one-dimensional vertical flow from surface to several metres below the water table as follows (based on Freeze and Cherry, 1979, p. 212-213):

Mean Annual Recharge (Bedrock):

$$\begin{aligned} & \text{hydraulic conductivity}^* \times \text{hydraulic gradient}^{**} \times \text{area}^{***} = \text{recharge} \\ & (10^{-6} \text{ m/s} \times 3.15 \times 10^7 \text{ s/yr}) \times (0.004) \times (4 \times 10^9 \text{ m}^2 \times 50\% \text{ area} \\ & \times 75\% \text{ bedrock}) = 2 \times 10^8 \text{ m}^3/\text{yr} \end{aligned}$$

Mean Annual Recharge (Sediments):

$$\begin{aligned} & (10^{-5} \text{ m/s} \times 3.15 \times 10^7 \text{ s/yr}) \times (0.003) \times (4 \times 10^9 \text{ m}^2 \times 50\% \text{ area} \\ & \times 25\% \text{ sediments}) \times (0.003) = 5 \times 10^8 \text{ m}^3/\text{yr} \end{aligned}$$

Mean Annual Recharge (Total):

$$(2 \times 10^8 \text{ m}^3/\text{yr}) + (5 \times 10^8 \text{ m}^3/\text{yr}) = 7 \times 10^8 \text{ m}^3/\text{yr}$$

- * fractured metamorphic rocks range from 10^{-4} to 10^{-8} m/s;
silty sands range from 10^{-3} to 10^{-7} m/s (Freeze and Cherry, 1979)
- ** estimated from Map 4
- *** section 4.1.6 indicated that most of Zio and Yoto is recharge area,
however not all zones are equally permeable therefore 50% is a
conservative estimate

The hydraulic conductivities used in the above calculations are very approximate due to the vertical and lateral variations in the upper 100 m of Zio and Yoto. To check the resulting recharge rate, annual recharge is compared to annual precipitation.

Recharge as % of Rainfall:

$$\frac{7 \times 10^8 \text{ m}^3/\text{yr}}{1 \text{ m/yr} \times 4 \times 10^9 \text{ m}^2} = 20\%$$

Twenty percent is a reasonable figure, indicating that the calculated recharge is also reasonable. The percent of mean annual recharge required to serve the rural population of Zio and Yoto is calculated below.

% Mean Annual Recharge Required:

$$\frac{2.2 \times 10^6 \text{ m}^3/\text{yr}}{7 \times 10^8 \text{ m}^3/\text{yr}} = 0.3\%$$

Since only 0.3% of mean annual recharge is currently required, the demand is easily met by groundwater. In addition, groundwater is available throughout the year, thereby eliminating the need for storage and it is generally available within 1 km of bedrock villages and anywhere in sediments. Two exceptions are the dry wedge and the zone northwest of Assahoun where drilling success was greatly reduced. In these areas, groundwater from adjacent productive areas can be transported in or rainwater exploited, as appropriate.

Groundwater quality generally meets WHO standards (WHO, 1984) as shown in Figure 18. The exceptions are Fe^{+2} and Mn^{+2} which are consistently high. Both iron and manganese standards are set for aesthetic reasons of color and taste, and therefore, are not serious enough to treat or cap wells. Owners of such wells need to be informed that the visible impurity is non-toxic and advised to precipitate and settle it out by drawing and storing water a day in advance.

6.2 WATER ACCESSING METHOD

In bedrock terrane, the competent rock cannot be penetrated to 70 m (the average well depth) in less than one month by any method but rotary. The higher the compressor rating, the faster the completion. Time constraints and relative costs of different rig and compressor sizes and labour will determine the most appropriate rig. Air and water are adequate drilling fluids for overburden and competent rock respectively. The 100 m well depth limit, set for the CUSO project, was insufficient to reach suspected water-bearing fractures in the low-success area north and west of Assahoun (Geomines Ltd., 1987). Therefore, rigs must be equipped to drill at least 120 metres.

Figure 18. Water chemistry as % of World Health Organization drinking-water standards (WHO, 1984). Dashed line indicates the WHO standard. "Cond" is conductivity.

In the sedimentary basin, unconsolidated sediments are easily penetrated; however, well walls collapse without the use of drilling mud, thus a rotary rig is necessary. The Paleocene limestone can be extremely porous, causing rapid drilling mud loss and necessitating special mud additives such as mica flakes, grated cassava ("gari") or coconut shells. Tens of metres of pure dense clays require effective clay cutters. Wells average 85 metres but the rig should be outfitted to drill 200 metres to accommodate 150 metres depth to first water in the extreme south (BRGM, 1982). In the dry wedge, wide diameter wells designed to give large storage capacities can exploit silty sands and silts that can not be exploited by drilling.

6.3 WATER-POINT LOCATION

In bedrock, the principal techniques for finding groundwater are airphoto interpretation and resistivity surveys. Airphoto interpretation locates well sites on suitably continuous and optimally oriented (1-10°, 51-60°, and 151-160°) fractures on the photo which are then located on the ground. This method is fast and inexpensive.

Resistivity surveys involve the transmission of a current through the ground and interpretation of the numeric results. This requires sophisticated and costly equipment and 1 to 2 orders of magnitude more time than airphoto interpretation, resulting in a per-site survey cost significantly higher than airphoto interpretation. The advantage of resistivity is that it can find fractures in areas where no suitable fractures are visible on airphotos, and in general produce wells of higher yields (section 4.1.2). Therefore, the most appropriate method of site selection is a combination of the two methods, using airphoto interpretation where exploitable

fractures are visible on airphotos and resistivity on the remaining sites and sites where airphoto wells are unproductive.

Because of the numerous widespread aquifers in sediments, groundwater can be found at any site, except for the dry wedge. Therefore, wells can be located where it is most convenient for the users.

Well location controls water quality not only in regional chemistry, but also with respect to contamination. To keep conductivity below 1500 $\mu\text{S}/\text{cm}$, discharge areas in bedrock should be avoided, particularly those in biotite migmatite M_1 . Sources of contamination in Zio and Yoto include 1) human and animal waste which is either concentrated in a latrine/corral or spread randomly around the village periphery, 2) domestic waste concentrated in a small compost heap and 3) fertilizers that are becoming more common, particularly in areas of cotton cultivation. The main contaminant from all three sources is NO_3^- . It enters groundwater in recharge areas, particularly where surface materials are sandy or silty (i.e. Continental Terminal), the water table is high and the depth to bedrock is shallow (Farmer *et al.*, 1982). Nitrate is transported in the same direction as groundwater flow, although at a slower rate due to adsorption (Freeze and Cherry, 1979). Wells with high NO_3^- are all located in the shallowest part of the Cretaceous aquifer and along the river. Undoubtedly the Continental Terminal above them is also contaminated. To avoid contaminants, wells should be sited as follows:

- 1) in confined aquifers
- 2) up gradient from point sources or large villages
- 3) where depth to bedrock is greatest
- 4) where depth to water table is greatest (Map 3).

6.4 WATER-POINT CONSTRUCTION

In light of the groundwater source, the water point is a well. Well construction techniques have been developed to the extent that there is general agreement as to what makes a good well. The elements which need to be stressed for Zio and Yoto are: 1) use of a graded gravel pack (minimum 40 mm (1.5")) carefully placed around the centred screen when exploiting silty and clayey sands 2) use of 15 bar PVC casing to withstand the compressive stresses in long sections of clays, and 3) a significant length of grout at surface (i.e. 10 metres) to prevent the many sources of contamination at the wellhead (i.e. spill water, wash water or animal droppings) from flowing down the well annulus.

As mentioned previously, wells average 70 m depth in bedrock and 85 m depth in sediments. The interior diameter of finished wells should allow for pump installation, generally a minimum of 100 mm (4"). Allowance for tool case, gravel packs, backfill and grout give minimum drilling diameters of 150 and 230 mm (6" and 9") in bedrock and sediments respectively.

Wide diameter wells are estimated to average 30 metres depth with a 1 metre diameter. Wells should be lined to prevent collapse, grouted at surface like borholes, and a sanitary water lifting device installed.

Locally, groundwaters are aggressive, requiring the use of PVC (or other inert material). Very high levels of Mn^{++} in some wells leave MnO_2 deposits on well screens, reducing their efficiency. The 1 mm slotted screen easily available in Togo provides sufficiently large slots that clogging takes >10 years at which time it can be removed with hydrochloric or hydroxyacetic acid (Driscoll, 1986).

6.5 WATER LIFTING DEVICE

The choice of water lifting device is probably the most controversial one made in rural water supply because 1) it is the part that the users have their hands on and viewers see, and 2) existing methods have proven unreliable and thus have become the forefront of water supply technology development.

The limitations imposed on the choice by the hydrogeological conditions are:

- 1) The pump must be able to lift water easily from 45 metres, the average pump depth in sediments, and if possible from 81 meters, the greatest pump depth. At these depths, suction pumps, which only operate above roughly 7 metres, are not suitable.
- 2) The pump diameter cannot exceed the interior well diameter (115 mm in bedrock wells and 124 mm in sedimentary wells of the CUSO project) minus 25 mm case.
- 3) All pump materials must be resistant to corrosion and be treatable with strong acids after encrustation.

Apart from these limitations, sociological, logistic and financial considerations dominate the choice. In most cases a high yielding, medium to high-lift, "village level operation and maintenance" handpump is the best choice. Villages with large populations (i.e. >2000 people) or large water requirements may be more suited to motorized pumping, thereby reducing the number of wells required. Motorized pumps which fit the CUSO wells have a maximum discharge of approximately 7 m³/hr. Villages with hand-dug wells and shallow lifts may find windlasses or other non-pump lifting devices more appropriate. Such decisions need to be assessed in light of the latest techniques and price for each hydrologic unit.

Chapter 7

CONCLUSIONS

Groundwater in bedrock areas of Zio and Yoto can be exploited from fractures, particularly those oriented at 1-10°, 51-60° and 151-160° but not from overburden. Well siting by airphoto interpretation was effective over most of the area; 70% of wells sited by airphoto were productive. Resistivity surveys, used only on difficult sites, resulted in a 56% drilling success rate but the wells have a higher average yield than those sited by airphotographs. This suggests that resistivity is more precise in locating fractures. For reasons of cost and time, its use should be restricted. Static water levels are reasonably constant in depth, 10-40 m. Yields are low for motorized pumps averaging 3.8 m³/hr but sufficient for handpumps. The low yields result in an average pump intake depth 24 m below the average static water level and no significant correlation between pump depth and static water level. Well depths average 70 m. There is a tendency, although not a strong one for topographically lower wells to have deeper water-bearing fractures, deeper static water levels, deeper pump depths, deeper well depths and higher yields than topographically high wells. Groundwater flow is primarily toward the ocean and secondarily toward the major rivers. Hydraulic gradients are typically 0.003 to 0.005 with most of the surface of the bedrock terrane acting as a recharge area.

In terms of water chemistry, bedrock wells have variable total dissolved solids (TDS), as shown by the 272 to 2600 μ S/cm conductivity range. A low TDS group is situated in a band extending 1 km to either side of the Keve-Game fault. High TDS wells are in M₁ biotite migmatites. In spite of the variation in TDS, chemical composition is reasonably uniform with no dominant ion and low concentrations of

Mg^{+2} and SO_4^{-2} . The composition and its uniformity are a reflection of the uniformity of rock type throughout the bedrock terrane.

Within the coastal sedimentary basin of Zio and Yoto, 85% of wells exploit the Cretaceous aquifer. Most of the remaining 15% are in the Paleocene, 2 are in Eocene beds and 2 in the Continental Terminal. Because of the variability in lithology on a small scale, there is great variability in physical hydrogeologic conditions, giving a large range of yields, static water levels, pump depths and well depths. Yet, the low end of the range of yields (in correctly drilled wells) is so high that all wells produce enough for a handpump and even for motorized pumps ($>5\text{m}^3/\text{hr}$). Because of the 100% success rate, there are no hydrogeological constraints on well site selection. A zone of very high yielding wells (up to $80\text{ m}^3/\text{hr}$) occurs along the northern limit of the Cretaceous aquifer in zone A. Wells in Paleocene and Eocene aquifers appear to have lower yields and greater well depths, although there are not many wells on which to base this statement. The Continental Terminal aquifer is semi-confined whereas all others are fully confined. Recharge to the confined aquifers is from the overlying Continental Terminal sediments through their subcrops. Groundwater in the sedimentary terrane flows down-dip toward the ocean with typical hydraulic gradients of 0.001 to 0.004.

Water chemistry in the sedimentary basin is more complex than in bedrock. There is a series of 4 water groups in the Cretaceous aquifer, ranging from very dilute NaCl (rain/ocean spray) waters in the uppermost coarse clastic part of the aquifer becoming increasingly mineralized and CaCO_3 -rich basinward following the facies change which introduces horizons of marl and impure limestones. Wells in the Paleocene are deeper, have higher TDS and are more carbonate-rich than in the Cretaceous. There is some evidence of the saline intrusion in the 2 wells nearest

the coast. Some wells in the recharge area of the Cretaceous aquifer, along its erosional edge, appear to be contaminated with domestic or faecal waste.

With respect to future rural water supply projects for Zio and Yoto, groundwater is the only feasible water source. It is best exploited by high compression down-the-hole-hammer drilling in bedrock and mud rotary or hand-digging in sediments. Routine siting on optimal fractures by airphoto interpretation should be complemented by resistivity surveys at difficult locations. Wells should be constructed to modern drilling standards, paying special attention to grout seals and clean gravel packs. Lifting devices can be medium to high lift positive displacement pumps with the option to upgrade to motorized pumps where yields permit, notably in sediments.

Water quality is mediocre in bedrock, where conductivity averages 1110 $\mu\text{S}/\text{cm}$, and is good in sediments, where conductivity averages 260 $\mu\text{S}/\text{cm}$. In general, wells from both terranes meet WHO drinking-water standards with the exception of Fe and Mn. Special user training should accompany such wells as alternate aquifers and treatment are not feasible. In addition, two bedrock wells exceeded the NO_3 standard and several sedimentary wells along the basin edge approach the standard as a result of contamination. The risk of contamination can be minimized by careful well siting and construction.

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APPENDIX 1. PHYSICAL HYDROGEOLOGY DATA - BEDROCK

(after Geomines, 1987)

well number
 VILLAGE village name
 ALT wellhead altitude (metres)
 FO fracture orientation (degrees azimuth)
 SITE well siting method: S = geophysics, P = airtphoto
 OVERBURDEN overburden (metres depth), (metres above sea level)
 1WATER major water bearing fracture (metres depth), (metres above sea level)
 2WATER secondary water bearing fracture (metres depth), (metres above sea level)
 DEPTH well depth (metres)
 S.W.L. static water level (metres depth), (metres above sea level)
 PUMP pump intake depth (metres)
 YIELD well yield (cubic metres per hour)
 +/- well success (+ = productive, - = unproductive)

#	VILLAGE	ALT	FO	SITE	OVERBURDEN	1WATER	2WATER	DEPTH	S.W.L.	PUMP	YIELD +/-	
		(m)	(m)		(m) (masl)	(m) (masl)	(m) (masl)	(m) (masl)	(m) (masl)	(m)	(m ³ /hr)	
M013F3	AGBELOUVE	122	65	S	14.92 107	32.28 60	---	---	57.25 55	2.54 119	57 2.00 +	
M013F4	AGBELOUVE	120	65	S	25.48 95	32.49 88	---	---	43.40 77	10.31 110	36 1.03 +	
M013F5	AGBELOUVE	120	80	P	7.74 112	49.00 71	---	---	55.00 65	4.50 116	--- 10.00 +	
M021F2	NYASSIVE	95	80	P	16.00 79	39.86 55	---	---	48.00 47	14.69 80	36 1.80 +	
M021F3	NYASSIVE	95	50	P	16.72 76	45.39 50	47.00 48	52.47 40	12.43 82	39 3.60 +		
M021F4	NYASSIVE	95	55	P	9.46 86	32.00 63	---	---	50.00 45	10.20 85	--- 1.30 +	
M026F2	AGBESSIA	90	152	S	14.65 75	18.00 72	59.00 31	67.37 23	5.00 85	---	0.40 +	
M026F3	AGBESSIA	90	80	S	10.79 79	---	---	91.60 -2	---	---	--- 0.00 -	
M026F4	AGBESSIA	90	65	S	16.80 73	17.00 73	---	---	79.56 10	13.96 76	---	0.40 +
M029F3	AGNRON	87	138	P	7.06 80	32.75 54	---	---	42.85 44	12.39 75	---	4.50 +
M029F4	AGNRON	87	138	P	15.18 72	56.50 31	47.00 40	61.25 26	12.48 75	---	1.20 +	
M098F2	BATOUNE	100	155	P	5.15 95	32.55 66	24.44 76	40.00 60	21.75 78	36	2.00 +	
M113F2	NYIGBE 1	125	112	S	8.60 116	41.15 84	---	---	51.65 73	14.86 110	42 3.00 +	
M115F3	TOKPEVIA	148	154	S	6.00 142	34.80 113	26.70 121	57.40 91	14.35 134	39	1.24 +	
M115F4	TOKPEVIA	148	154	P	5.39 143	34.59 113	---	---	43.15 105	19.91 128	---	3.00 +
M120F3	TOVEGAN	100	85	P	8.71 91	27.30 73	32.40 68	40.00 60	6.33 92	36	2.68 +	
M120F4	TOVEGAN	100	105	P	5.25 95	53.61 46	---	---	61.27 39	12.04 88	39	2.68 +
M140F2	AVEGAN	85	70	P	3.76 81	---	---	84.67 0	---	---	---	0.00 -
M140F3	AVEGAN	85	95	S	7.62 77	13.00 72	---	---	99.45 -14	---	---	0.00 -
M148F2	AGBOZONE	115	88	P	12.85 102	27.50 88	22.45 93	43.12 72	12.7 102	---	---	5.00 +
M164F4	ADEKPOUI	95	110	S	7.45 88	---	---	94.61	---	---	---	0.00 -
M165F2	AGBADJANEKEN	116	180	P	13.62 102	31.25 95	32.95 83	43.00 72	24.92 91	---	---	4.00 +
M174F2	ATTI TOUVI	110	145	P	12.10 97	79.00 31	---	---	85.67 24	---	---	0.17 -
M174F3	ATTI TOUVI	110	145	P	12.90 97	---	---	85.49 25	---	---	---	0.00 -
M175F2	YOTO	105	15	P	5.65 99	32.25 73	---	---	43.30 62	1.20 98	---	2.50 +
M175F3	YOTO	105	15	P	3.30 102	35.00 70	15.10 90	43.17 62	4.70 100	---	---	6.55 +
M176F2	DJEBBAKONDJI	115	37	P	4.50 111	---	---	95.64 29	---	---	---	0.00 -
M180F2	ANGLOU KOPE	105	100	P	9.67 95	42.00 62	32.00 73	43.75 57	22.10 82	39	1.25 +	
M180F3	ANGLOU KOPE	105	84	P	11.09 92	---	---	75.50 29	---	---	---	0.00 -
M180F4	ANGLOU KOPE	105	4	P	14.66 90	44.66 60	31.13 74	46.78 56	20.29 85	36	2.27 +	
M196F2	BANI KOPE	90	166	S	6.45 84	---	---	85.47 5	---	---	---	0.00 -
M227F3	ALOVI	110	158	S	15.23 95	67.71 22	---	---	92.56 16	22.16 88	36 16.00 +	

#	VILLAGE	ALT (m)	PD (°)	SITE	OVERBURDEN (m) (masi)	1WATER (m) (masi)	2WATER (m) (masi)	DEPTH (m) (masi)	S.W.L. (m) (masi)	PUMP (m)	YIELD +/- (m3/hr)	
M237F4	ALOYI	110	158	G	10.80 99	87.10 23	---	90.41 20	22.59 87	36	36.00	+
M237F5	ALOYI	110	158	P	14.95 95	85.96 24	---	97.67 16	23.10 87	---	12.00	+
M301F1	AFOKPONAVE	103	55	F	17.75 85	81.52 21	---	57.17 16	24.47 79	54	2.87	+
M301F2	AFOKPONAVE	103	55	F	12.15 91	56.51 46	---	61.65 41	26.45 77	51	2.50	+
M302F1	ANAZIVE	103	72	F	8.74 95	42.57 60	---	47.80 55	19.43 64	39	4.00	+
M303F1	AKAPEDOME	103	---	G	8.80 94	---	---	89.27 14	---	---	0.00	-
M303F2	AKAPEDOME	103	---	G	8.01 95	---	---	97.87 9	---	---	0.00	-
M303F3	AKAPEDOME	103	---	G	4.59 98	49.10 54	14.62 86	55.00 48	12.42 91	36	3.46	+
M303F4	AKAPEDOME	103	---	G	6.18 97	17.65 85	---	47.14 60	12.39 91	36	3.60	+
M304F1	WDEVE	103	116	G	16.17 87	61.60 41	35.77 87	66.20 37	14.81 88	39	1.70	+
M305F1	ADADEKPE	103	125	G	6.96 96	---	---	103.04 0	---	---	0.00	-
M305F4	ADADEKPE	103	125	G	11.03 92	---	---	98.33 5	---	---	0.00	-
M305F5	ADADEKPE	103	90	G	15.65 87	---	---	90.37 13	---	---	0.00	-
M306F1	AGBETIME	90	140	F	11.40 79	52.30 38	---	50.00 30	21.90 68	48	2.40	+
M307F1	DZAKPO	115	160	P	8.10 107	50.11 65	26.00 89	57.00 58	18.70 96	36	10.00	+
M308F1	TSUETA	110	85	F	5.25 105	93.30 17	---	103.00 7	12.44 98	51	0.90	+
M308F2	TSUETA	110	14	F	13.49 97	---	---	103.00 7	---	---	0.00	-
M309F1	EGBE	100	40	P	19.92 80	56.35 44	---	70.71 29	23.55 76	54	1.12	+
M309F2	EGBE	100	40	F	18.82 81	41.00 59	---	47.85 52	26.86 73	---	3.27	+
M310F1	TOUNGUMASSE	100	94	F	16.32 94	---	---	60.13 20	---	---	0.00	-
M310F2	TOUNGUMASSE	100	77	F	28.80 71	37.54 62	---	43.54 56	29.10 71	39	2.06	+
M311F1	AKOLI KOPE	120	96	F	2.96 117	32.37 86	---	43.45 77	1.15 119	31	1.25	+
M312F1	AKPAVE KOPE	120	96	P	1.60 118	49.31 71	---	57.20 63	23.12 97	45	5.31	+
M313F1	AGBOKPE	139	142	F	3.43 136	---	---	93.73 45	---	---	0.00	-
M313F2	AGBOKPE	139	96	F	6.92 132	44.51 94	---	52.64 86	17.45 126	---	1.06	+
M314F1	GAMEGBLE	125	145	P	14.90 110	---	---	52.55 31	---	---	0.00	-
M314F2	GAMEGBLE	125	60	F	20.30 105	28.50 97	---	87.46 38	14.15 111	69	0.90	+
M314F3	GAMEGBLE	125	74	G	11.70 113	24.40 101	20.50 105	45.00 80	7.30 118	30	4.50	+
M314F4	GAMEGBLE	125	---	G	15.85 109	23.79 101	---	73.33 52	---	---	0.00	-
M314F5	GAMEGBLE	125	---	P	12.60 112	38.95 96	---	55.20 70	7.30 118	---	0.84	+
M315F1	TSINGOE	80	87	F	4.80 75	23.12 57	---	48.02 32	14.10 66	36	3.00	+
M315F2	TSINGOE	90	84	P	4.58 75	24.10 56	---	43.00 37	15.99 64	---	5.50	+
M316F1	AGADJAKPE	90	3	P	9.81 80	48.53 41	---	57.10 33	14.16 76	51	3.60	+
M317F1	TITONOU	125	27	G	7.20 118	62.00 63	27.35 98	69.35 56	14.26 111	42	2.00	+
M318F1	KOURINOUKPE	90	12	F	8.21 82	17.12 73	---	93.35 43	10.96 79	57	0.54	+
M319F1	FLABA	137	44	G	10.00 127	39.00 98	30.00 107	51.40 86	19.55 117	39	2.12	+
M320F1	AGBODJEPKO	139	46	G	13.30 126	53.00 86	26.00 113	60.00 79	16.30 123	36	12.00	+
M320F2	AGBODJEPKO	139	46	G	10.00 129	29.00 110	---	81.45 58	16.52 122	66	0.70	+
M321F1	KOTSO KOPE	139	160	G	17.40 122	---	---	93.45 46	---	---	0.00	-
M321F2	KOTSO KOPE	139	---	-	4.50 135	---	---	93.45 46	---	---	0.00	-
M321F3	KOTSO KOPE	139	42	G	11.70 127	31.50 108	---	50.00 89	19.79 119	39	3.00	+
M321F4	KOTSO KOPE	139	42	G	15.75 123	42.50 97	26.60 102	51.40 68	19.90 119	36	3.27	+
M322F1	AMAVEGAN	90	85	F	13.66 76	40.46 50	29.56 60	67.16 23	23.57 66	45	0.80	+
M323F1	AGOKPOE	90	92	P	3.17 87	62.72 27	---	68.87 21	28.30 62	45	5.50	+
M324F1	ATIKOLE	100	170	G	11.65 86	67.50 33	---	75.50 25	20.45 80	48	4.00	+
M324F2	ATIKOLE	100	55	G	12.35 88	76.50 24	---	61.65 13	23.14 77	36	36.00	+
M325F1	ASSI KEVE	120	20	F	9.25 111	18.00 102	---	48.87 71	14.78 105	32	0.92	+
M326F1	NYANYETCHI	100	94	G	9.25 91	52.48 48	---	60.93 39	21.10 79	42	3.50	+
M327F1	BEDJEME	90	10	G	9.83 80	35.66 54	26.10 62	40.00 50	8.58 81	30	16.00	+
M327F2	BEDJEME	90	10	F	7.42 83	34.60 55	---	47.82 42	20.20 70	---	6.54	+
M327F3	BEDJEME	90	10	F	8.30 84	31.32 59	---	47.56 42	14.12 76	---	1.95	+

* VILLAGE	ALT (m)	PO (°)	SITE (°)	OVERBURDEN (m) (mass)	1WATER (m) (mass)	2WATER (m) (mass)	DEPTH (m) (mass)	S.W.L. (m) (mass)	PUMP (m) (m³/hr)	YIELD (m³/hr)
M328F1 AGAMANE	110	10	G	17.30 97	33.20 77	30.90 79	51.45 59	14.35 45	79	1.70
M329F1 AGBODJEKPOE	120	138	P	26.86 93	33.92 86	29.60 90	54.91 65	14.6 106	7	1.4
M329F2 AGBODJEKPOE	120	50	P	19.57 100	76.00 44	54.00 66	60.61 39	15.47 104	40	1.81
M330F1 ATING	121	65	F	19.75 109	---	---	---	---	---	---
M330F2 ATING	121	173	P	14.60 105	68.00 52	---	75.50 48	15.77 111	41	1.7
M331F1 MOTSI	90	140	G	7.80 82	15.95 74	---	45.45 48	17.65 66	27	1.7
M332F1 BEGBE	95	104	P	10.74 85	50.50 44	43.50 52	57.45 38	12.90 62	45	6.77
M337F1 GAME KOVE	105	92	P	29.10 76	44.00 61	---	61.35 44	---	---	---
M337F2 GAME KOVE	105	5	P	17.90 91	56.36 49	29.31 76	61.35 44	11.54 97	16	3.14
M337F3 GAME KOVE	105	75	F	6.06 99	45.13 60	---	53.20 50	17.90 97	---	1.20
M334F1 YOTO KOPE	80	35	G	17.10 67	35.40 45	40.50 40	48.80 31	16.32 64	16	3.78
M334F2 YOTO KOPE	80	50	G	22.61 57	40.77 39	22.19 46	48.73 31	16.53 67	16	3.80
M334F3 YOTO KOPE	85	---	G	18.70 66	67.40 16	64.00 21	72.05 13	26.70 58	42	4.73
M334F4 YOTO KOPE	85	68	G	4.40 81	---	---	85.60 -1	---	---	0.00
M334F5 YOTO KOPE	85	100	G	7.73 77	34.58 50	---	40.00 45	15.49 70	---	1.60
M335F1 MAIKOU KOPE	95	28	G	5.03 90	57.77 38	---	63.00 32	14.10 81	30	18.00
M336F1 ADJA KOPE	124	40	G	8.96 125	---	---	106.95 27	---	---	0.00
M336F2 ADJA KOPE	124	---	G	8.55 125	---	---	99.37 35	---	---	0.00
M336F3 ADJA KOPE	124	101	G	5.7 129	---	---	85.74 48	---	---	0.00
M336F4 ADJA KOPE	124	100	G	27.14 111	47.65 36	22.00 102	55.19 79	21.21 117	42	1.41
M336F5 ADJA KOPE	124	100	G	12.97 121	50.23 24	---	60.15 74	20.92 113	45	2.90
M337F1 HAHO KPODJI	65	14	F	1.95 67	51.15 14	50.40 15	53.14 10	26.15 39	39	15.00
M337F2 HAHO KPODJI	70	85	F	8.90 61	---	---	102.07 -22	---	---	0.00
M337F3 HAHO KPODJI	70	101	G	10.14 69	---	---	85.54 -16	---	---	0.00
M337F4 HAHO KPODJI	65	14	F	3.66 61	52.26 13	---	35.18 10	25.77 39	79	10.29
M338F1 AVEDJE	115	116	F	4.10 111	---	---	44.99 20	---	---	0.00
M338F2 AVEDJE	115	98	F	2.52 112	58.40 37	27.50 78	64.50 51	9.98 105	57	2.25
M338F3 AVEDJE	115	98	F	14.15 101	73.30 42	47.27 68	79.30 26	10.33 105	---	12.60
M339F1 NGUSROU KOPE	125	92	F	16.61 106	74.00 31	---	30.59 44	10.33 115	46	4.00
M340F1 KOLD 1	80	74	G	6.40 74	---	---	99.50 -20	---	---	0.00
M341F1 KOPE KOPE	120	54	F	8.31 112	---	---	93.45 27	---	---	0.00
M341F2 KOPE KOPE	120	100	G	10.31 110	---	---	99.31 21	---	---	0.00
M342F1 ATTI ATCHAVE	110	70	F	4.55 105	---	---	97.40 17	---	---	0.00
M342F2 ATTI ATCHAVE	110	20	F	6.70 104	---	---	73.14 7	---	---	0.00
M343F1 ATT KOPE	128	112	G	9.20 127	---	---	61.40 41	---	---	0.00
M343F2 ATT KOPE	128	112	G	11.67 124	---	---	49.57 3	---	---	0.00
M344F1 MEKOUALE	115	76	G	7.73 97	---	---	112.00 -27	---	---	0.00
M345F1 ATTI KAKPE	104	177	G	9.98 94	---	---	99.34 1	---	---	0.00
M346F1 TEDANOE	125	70	G	11.55 112	21.75 37	---	81.16 44	24.21 72	74	1.77
M347F1 ALLAGBADJA	110	126	G	5.80 109	22.00 73	---	47.14 67	25.45 64	74	1.54
M348F1 BAKA KOPE	130	90	G	12.67 117	---	---	49.57 7	---	---	0.00
M348F2 BAKA KOPE	130	48	G	4.27 126	41.87 49	45.55 34	49.29 91	21.21 104	16	1.61
M348F3 BAKA KOPE	130	48	F	2.85 126	78.70 52	74.00 56	87.00 47	20.90 104	---	2.57
M349F1 AKI	111	66	G	15.45 95	---	---	44.21 1	---	---	0.00
M400F1 ATTI NAMESSI	126	5	G	9.73 126	29.00 106	---	94.34 25	---	---	0.00
M400F2 ATTI NAMESSI	124	5	G	10.71 121	---	---	99.55 33	---	---	0.00
M401F1 AMESSI	120	5	G	16.65 102	64.97 55	---	71.69 48	---	---	1.72
M402F1 SALATCE	110	164	F	24.71 75	26.06 64	---	55.21 45	24.62 75	45	1.53
M403F1 KPODJI	115	90	G	21.62 93	58.00 57	49.00 66	67.26 48	18.60 76	62	0.80
M403F2 KPODJI	120	5	G	8.92 111	52.75 66	45.80 71	55.24 65	27.17 80	54	6.00
M404F1 FIADENYIGBA	80	66	F	13.69 66	---	---	99.80 -20	---	---	0.00

*	NAME	AGE	SEX	SIZE	EFF. PROD.	WATER		WATER		DEPTH	S.W.L.		PUMP	FIELD	+
						m	mas	m	mas		m	mas			
M404F2	AFIADENYIGBA	80	86	F	11.7	59	---	---	---	40.77	---	---	---	---	-
M404F3	AFIADENYIGBA	80	86	F	11.7	71	10.55	57	---	70.79	---	17.76	67	---	1.54
M405F1	ATCHAVE	80	86	F	17.7	87	41.20	58	29.45	40.10	51	19.70	52	31	2.07
M405F2	ATCHAVE	80	86	F	11.85	88	20.00	78	---	40.17	57	17.88	62	---	2.54
M405F3	ATCHAVE	80	86	F	15.52	74	22.98	67	---	40.22	49	15.21	75	66	1.48
M406F1	BEDJFA	90	84	G	12.87	77	41.00	49	---	40.28	45	---	---	---	-
M406F2	BEDJFA	90	84	G	16.71	77	22.00	52	---	40.00	47	16.48	71	78	2.21
M406F3	BEDJFA	90	84	G	12.75	75	29.00	61	---	40.07	47	16.00	72	79	14.40
M408F1	AGCHOME	100	86	G	15.55	84	79.38	21	---	62.50	18	27.78	71	39	26.00
M409F1	HEFEDJE	95	76	G	8.45	87	75.07	20	---	65.61	9	7.51	67	24	7.20
M410F1	HEFEDJE	100	70	F	5.15	95	20.45	77	14.38	47.12	57	11.63	68	---	14.40
M411F1	HEFEDJE	95	84	G	11.29	87	75.90	19	41.76	76.62	18	14.35	81	24	26.00
M412F1	MANGOTIDE	100	74	G	10.59	87	---	---	---	60.77	10	---	---	---	0.00
M412F2	MANGOTIDE	100	74	G	5.14	80	---	---	---	60.40	1	---	---	---	0.00
M413F1	NYANYAME	90	84	F	5.19	81	---	---	---	60.21	0	---	---	---	0.00
M414F1	BATIYOU	100	70	G	15.10	84	---	---	---	64.84	5	---	---	---	0.00
M414F2	BATIYOU	100	70	G	14.21	86	---	---	---	64.79	5	---	---	---	0.00
M415F1	QUELENDU	110	89	F	11.47	96	---	---	---	64.95	15	---	---	---	0.00
M416F1	HEFEDJE	75	64	F	10.51	84	74.00	41	---	40.10	32	14.02	61	30	24.00
M416F2	HEFEDJE	70	67	F	4.66	85	36.41	34	---	40.17	27	21.68	48	33	24.00
M419F1	DOND	105	---	---	11.17	84	---	---	---	65.54	19	---	---	---	0.00
M419F2	DOND	105	66	F	15.27	89	59.29	46	---	70.41	32	23.65	81	66	0.60
M419F3	DOND	105	---	---	7.80	97	---	---	---	76.57	25	---	---	---	0.00
M419F4	DOND	105	66	F	20.41	85	---	---	---	70.71	32	---	---	---	0.00
M420F1	ETDE	105	117	F	5.57	88	---	---	---	61.50	27	---	---	---	0.00
M420F2	ETDE	105	72	F	5.30	89	62.56	42	20.00	67.06	38	12.65	92	36	12.00
M420F3	ETDE	105	72	F	5.55	89	27.30	77	20.77	40.28	60	4.65	100	---	1.90
M421F1	YAVATSI	55	65	F	1.97	81	34.75	20	20.98	40.15	15	20.76	30	33	18.00
M421F2	BATOUNE	80	80	F	24.15	56	70.15	11	---	76.42	4	17.37	67	42	2.40
M422F1	ESSE	80	84	G	17.10	80	---	---	---	61.00	40	---	---	---	0.00
M422F2	ESSE	80	84	G	18.45	82	---	---	---	65.59	36	---	---	---	0.00
M424F1	FOFO	120	82	G	7.15	107	44.10	76	42.20	49.23	71	25.18	95	---	12.00
M425F1	DOUDOU	100	150	G	13.33	87	---	---	---	65.54	14	---	---	---	0.00
M425F2	DOUDOU	100	90	G	15.71	85	---	---	---	65.57	14	---	---	---	0.00
M426F1	HEFEDJE	115	80	G	9.25	106	74.70	41	70.57	79.63	35	23.97	91	---	3.27
M426F2	HEFEDJE	115	65	G	5.80	109	44.17	71	42.02	49.28	66	25.38	90	---	14.40
M427F1	GUENDJI	120	75	G	15.95	107	---	---	---	65.65	24	---	---	---	0.00
M427F2	GUENDJI	120	115	G	13.72	106	32.00	87	---	42.17	77	21.72	96	---	2.40
M428F1	ATINOUFOE	100	75	G	5.57	91	---	---	---	65.54	14	---	---	---	0.00
M429F1	TOVE	85	38	P	5.22	79	51.29	34	---	57.20	28	16.48	69	---	4.50
M430F1	AGOTINE	140	20	P	15.50	127	---	---	---	73.42	67	---	---	---	0.00
M431F1	ELIO	120	40	F	4.45	115	---	---	---	65.00	55	---	---	---	0.00
M432F1	ATI	120	115	F	28.48	90	32.45	88	---	40.52	76	21.92	98	---	0.40
M433F1	SATI	85	103	F	7.65	77	---	---	---	76.65	9	---	---	---	0.00
M434F1	AGBODAMCU	100	87	F	12.92	87	---	---	---	75.58	20	---	---	---	0.00
M435F1	NYIDJE	105	80	F	10.46	95	---	---	---	73.31	32	---	---	---	0.00
M435F2	NYIDJE	105	22	F	20.57	84	---	---	---	77.30	32	---	---	---	0.00
M436F1	NYIDJE	125	5	F	20.28	105	24.29	101	---	55.09	30	10.23	115	---	0.40
M436F2	NYIDJE	125	97	F	5.87	119	43.93	61	---	60.00	63	9.45	116	---	1.80
M437F1	DEKAME	75	67	F	8.65	86	35.67	39	---	45.00	20	12.46	63	---	12.00
M438F1	DJAKPO	80	80	F	4.96	75	---	---	---	71.78	9	---	---	---	0.00

* VILLAGE	ALT (M)	PD (M)	SITE	OVERBURDEN		WATER		TEMPERATURE		DEPTH		S.W.M.		F.M.	WELL
				CM	INCHES	CM	INCHES	CM	INCHES	CM	INCHES	CM	INCHES		
M439F1 AGBLEVE	100	96	F	4.52	18	5.114	5	---	---	25.15	40	16.55	5	---	---
M440F1 GLOZOU KOPE	110	86	F	4.52	18	---	---	---	---	27.12	42	---	---	---	---
M441F1 GARE KOPE	100	71	F	4.52	18	11.67	45	---	---	27.12	42	17.40	57	---	---
M442F1 GARE KOPE	---	---	F	4.52	18	42.5	16	---	---	27.55	50	17.45	51	---	---
M443F1 TOLONE	---	---	F	4.52	18	49.75	59	40.5	50	31.1	54	20	---	---	---
M443F2 TOLONE	---	---	F	4.52	18	51.1	74	44.1	---	32.1	54	17.5	4	---	---
M447F1 LEVAC	115	101	F	4.52	18	45.5	5	41	54	27.5	52	17.5	15	---	---
M448F1 PEEBOME	---	---	F	4.52	18	---	---	---	---	27.1	42	---	---	---	---
M449F1 TOLLOU KOPE	115	114	F	4.52	18	41.0	54	---	---	27.1	42	17.55	57	51	9.22
M449F1 KOTU	85	81	F	4.52	18	34.55	---	31.1	55	40.75	42	14.35	---	---	---

APPENDIX 2. PHYSICAL HYDROGEOLOGY DATA - SEDIMENTS

(after Geomines, 1987)

well number
 VILLAGE village name
 ZONE zone
 AQ aquifer exploited
 ALT wellhead altitude (metres)
 DWATER top of major aquifer (metres depth, metres above sea level)
 DWATER top of secondary aquifer (metres depth, metres above sea level)
 SCREEN screen length (metres)
 DEPTH well depth (metres)
 S.W.L. static water level (metres depth, metres above sea level)
 PUMP pump intake depth (metres)
 YIELD well yield (cubic metres per hour)
 +/- well success (+ = productive, - = unproductive)

#	VILLAGE	ZONE	AQ	ALT	DWATER	DWATER	SCREEN	DEPTH	S.W.L.	PUMP	YIELD	+/-		
				m	(m, msl)	(m, msl)	(m)	(m)	(m, msl)	(m)	(m ³ /hr)			
M011F0	TCHERFO ANAG	A	+	45	51	-13	---	7.94	88.13	25.1	20	42.00	25.00	+
M011F0	TCHERFO DEVE	A	+	55	39	-14	---	7.84	102.75	39.65	16	60.00	5.14	+
M011F0	TCHERFO DEVE	A	+	55	75	-11	---	8.82	82.89	75.20	20	60.00	5.00	+
M011F4	TCHERFO DEVE	A	+	55	82	-17	---	7.83	90.35	52.87	1	60.00	18.00	+
M019F0	ANETA	B	+	30	60	-10	---	7.76	73.33	12.00	8	---	5.00	+
M019F0	AMEBNONA KOF	A	+	30	91	9	---	5.86	96.59	70.27	20	---	7.20	+
M182F0	GATI AGODO	C	+	50	43	7	---	7.80	61.20	25.00	21	42.00	35.00	+
M182F0	GATI AGODO	C	+	50	47	3	---	7.68	65.27	34.00	16	45.00	15.00	+
M183F0	GATI SQUN	C	+	60	57	-7	---	7.76	79.27	36.75	23	57.00	12.00	+
M187F0	GATI SQUN	C	+	62	54	8	---	7.85	61.07	74.00	28	45.00	17.00	+
M174F0	FONGBE DZOGBE	C	+	40	78	-13	---	7.84	87.56	22.00	18	---	5.00	+
M186F0	SEDJRO	C	+	20	56	-16	---	7.77	67.20	20.70	-1	30.00	40.00	+
M186F0	SEDJRO	C	+	20	51	-11	---	7.84	60.88	12.00	6	30.00	50.00	+
M189F0	AMEGRLEVE	C	+	55	75	-10	---	7.80	65.63	47.63	11	---	12.00	+
M354F1	ADABADJI KON	A	+	35	77	-42	---	7.88	85.51	18.60	16	30.00	70.00	+
M354F0	ADABADJI KON	A	+	35	75	-40	---	7.88	84.44	18.42	17	30.00	70.00	+
M351F1	AFANTODJI KO	A	+	40	78	-18	---	7.88	98.57	79.15	2	45.00	60.00	+
M351F0	AFANTODJI KO	A	+	40	72	-12	---	7.88	94.79	32.26	5	45.00	60.00	+
M352F1	TONA KONDJI	A	+	50	90	-10	---	11.82	102.20	35.00	15	45.00	70.00	+
M352F0	TONA KONDJI	A	+	50	73	-17	---	7.84	92.55	33.40	17	---	40.00	+
M353F1	TSEVI KONDJI	A	+	40	80	-40	---	7.86	92.72	14.10	26	42.00	80.00	+
M354F1	ADOSSI KONDJ	A	+	45	35	-40	---	7.88	93.99	22.70	22	30.00	50.00	+
M355F1	LOGO KOPE	A	+	30	57	-17	---	7.88	72.42	16.54	13	30.00	55.00	+
M356F1	GBEMINA KON	A	+	35	76	-41	---	9.22	95.87	21.13	14	---	60.00	+
M357F1	AKPLAGASSOU	A	+	30	97	-17	---	5.90	102.87	72.42	8	---	40.00	+
M358F1	AKLOBE KONDJ	A	+	35	68	-17	---	9.78	107.97	45.27	40	75.00	45.00	+
M359F1	KOTIVO KONDJ	A	+	30	60	0	---	7.86	97.96	65.17	25	75.00	25.00	+
M360F1	KOJRA KOPE	A	+	30	29	1	---	7.80	94.00	71.84	18	---	5.04	+
M361F1	SEKIN	A	+	180	---	---	---	0.00	77.62	---	---	---	0.00	-
M361F1	ADETI KONDJI	A	+	30	65	-5	---	11.82	117.30	64.20	16	---	16.00	+
M367F1	AKOUTCHA KON	A	+	30	12	-12	---	5.88	111.80	51.52	28	67.00	40.00	+
M364F1	BADA KONDJI	A	+	35	100	-15	---	7.84	106.22	68.23	16	---	5.00	+

* VILLAGE	ZONE	AD	ALT (m)	1WATER (m) (mass)	2WATER (m) (mass)	SCREEN (m)	DEPTH (m)	S.W.L. (m) (mass)	FLME (m)	FLPI (m) (mass)	+			
M365F1 ADABIAN	A	F	16	114	-55	---	---	7.85	115.79	31.5	8	---	---	---
M366F1 DJATA KOPE	A	F	40	106	-66	---	---	11.85	107.87	16.7	16	---	---	---
M367F1 SETEKPO	A	F	65	107	-40	---	---	7.87	107.7	35.7	7	---	---	---
M367F2 SETEKPO	A	F	65	99	-3	---	---	8.7	107.9	56.7	7	---	---	---
M368F1 LOTO KERE	A	F	74	91	-55	---	---	11.75	107.44	14.97	16	---	---	---
M369F1 AKEDDOBU	A	F	51	87	-17	---	---	7.87	107.57	16.78	17	---	---	---
M370F1 KRESSE KOPE	A	F	5	88	-5	---	---	7.76	87.8	18.5	20	45.0	10.0	+
M370F2 KRESSE KOPE	A	F	50	88	-5	---	---	8.8	107.03	16.1	24	47.0	10.0	+
M371F1 AKEDJO	A	F	4	7	-7	---	---	8.65	84.78	31.12	12	48.0	18.0	+
M372F1 DAVOU	A	F	75	80	-47	---	---	7.48	95.48	18.00	17	11.0	5.0	+
M374F1 SAKI AKAPETI	C	F	75	-5	-1	---	---	7.84	84.83	17.50	18	11.0	15.0	+
M375F1 FONGBE BOETI	C	CT	55	76	-19	---	---	7.87	49.03	18.50	17	45.0	11.5	+
M376F1 ANYAVE	C	F	70	40	-10	---	---	7.79	60.16	---	---	---	0.0	-
M376F2 ANYAVE	C	F	70	67	-33	---	---	7.70	77.03	14.65	15	10.0	10.0	+
M377F1 ADETI KOPE	C	F	41	54	-14	---	---	7.90	75.11	12.00	28	42.0	10.0	+
M377F2 ADETI KOPE	C	F	40	55	-15	---	---	7.85	72.92	14.85	5	48.0	6.0	+
M378F1 ADJUGUIDI	B	F	30	85	-55	---	---	8.00	111.86	21.24	9	---	7.56	+
M378F2 ADJUGUIDI	B	F	30	86	-56	---	---	7.80	101.68	22.23	8	---	9.45	+
M379F1 LOWE ATTITES	B	F	30	99	-79	---	---	7.31	126.62	9.03	11	30.0	60.0	+
M380F1 LOWE	B	F	18	117	-99	---	---	7.87	135.81	11.00	7	30.0	35.0	+
M381F1 TOUNOUKOUTI	B	F	70	92	-62	---	---	4.00	99.00	33.50	-4	---	3.00	+
M382F1 ALLAGBADJA	C	F	75	70	5	---	---	7.80	88.70	50.00	25	66.0	15.0	+
M383F1 MOE KOPE	D	K	40	61	-21	---	---	7.85	79.94	41.33	-1	63.0	3.60	+
M384F1 ADIDOME	D	K	60	48	12	---	---	7.79	61.33	54.20	6	---	0.20	-
M384F2 ADIDOME	D	K	60	73	-13	---	---	7.77	79.56	50.84	9	63.0	6.00	+
M384F3 ADIDOME	D	K	60	79	-19	---	---	7.76	85.23	55.36	5	66.0	20.0	+
M385F1 SEVA	D	K	80	72	8	---	---	7.75	84.26	51.00	29	66.0	9.00	+
M385F2 SEVA	D	K	80	81	-1	---	---	11.66	88.61	51.00	29	66.0	6.00	+
M386F1 TEDC	D	K	80	67	13	---	---	7.76	73.83	61.00	19	66.0	20.0	+
M387F1 ATIDE APEDOM	D	K	70	74	-4	---	---	7.87	84.48	46.70	23	---	36.0	+
M387F2 ATIDE APEDOM	D	K	70	55	15	---	---	7.80	68.76	46.60	23	63.0	8.00	+
M388F1 AKPANITO	D	K	45	60	-15	---	---	11.74	93.41	32.40	13	---	7.20	+
M389F1 SEVEHO	D	K	90	---	---	---	---	0.00	91.65	---	---	---	0.00	-
M390F1 TSIVE ATIVE	D	K	80	---	---	---	---	0.00	28.51	---	---	---	0.00	-
M391F1 LOMEGNAN KOP	C	K	40	50	-10	---	---	7.70	79.24	27.50	13	54.0	4.00	+
M396F1 FONGBE APEDO	C	F	30	50	-20	---	---	7.77	61.28	18.71	11	---	40.0	+
M396F2 FONGBE APEDO	C	F	30	51	-21	---	---	7.92	65.82	22.35	8	---	29.0	+
M397F1 YUBO	C	K	30	40	-10	---	---	7.87	65.61	21.19	9	42.0	12.0	+
M397F2 YUBO	C	K	30	44	-14	---	---	7.88	54.86	17.22	13	30.0	50.0	+
M398F1 AI KONDI	A	F	35	73	-38	---	---	7.85	79.64	27.72	7	---	35.0	+
M399F1 GABADJIN	A	F	80	69	11	---	---	7.90	79.62	56.99	24	---	29.0	+
M465F1 DZOVADJE	B	CT	25	30	-5	43	-18	15.60	79.38	31.00	-6	---	5.50	+
M466F1 YOGON	B	E	15	60	-45	---	---	8.00	80.00	9.00	6	---	1.25	-
M467F1 AGBLEVOU	B	F	40	91	-51	---	---	7.80	111.92	32.80	7	---	7.20	+
M468F1 WODENOU	C	F	40	63	-23	---	---	7.80	77.06	33.80	6	---	2.20	+
M469F1 KPALA	D	F	60	73	-13	---	---	8.00	83.48	52.60	7	---	12.0	+
M469F2 KPALA	D	F	60	73	-13	---	---	7.84	78.91	42.00	18	---	20.0	+
M470F1 MESSEKO KOND	A	F	50	78	-28	---	---	7.91	84.58	15.00	35	---	20.0	+
M471F1 AFIKOU KONDI	A	F	27	74	-47	---	---	7.92	84.44	22.00	5	---	25.0	+
M473F1 AKLADJENOU	A	F	12	78	-66	---	---	7.92	87.91	9.00	2	---	40.0	+

APPENDIX 1: CHEMISTRY

data from Geomines, 1967

well number
 VILLAGE village name
 GEOL geology: B = bedrock, S = sediments
 Ca++ calcium
 Mg++ magnesium
 Na+ sodium
 Fe++ iron
 Mn++ manganese
 HCO3- bicarbonate-calculated (negative values repeated by 0.0 in calculations)
 SO4= sulphate
 Cl- chloride
 NO3- nitrate
 F- fluoride
 COND conductivity (microSiemens per centimetre)
 TDS total dissolved solids (sum of ions)
 TDSo total dissolved solids (0.7 * old conductivity)
 DIFo difference (TDS-TDSo) (larger of TDS or TDSo)
 TDSn total dissolved solids (0.7 * new conductivity)
 DIFn difference (TDS-TDSn) (larger of TDS or TDSn)

#	VILLAGE	GEOL	Ca++	Mg++	Na+	Fe++	Mn++	HCO3-	SO4=	Cl-	NO3-	F-	COND	TDS	TDSo	DIFo	TDSn	DIFn	
			(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	old new	(ppm)	0.7*Co	%	0.7*Cn	%	
M011F2	TOHE-PO ANAGAL	S	18	4	15	0.30	0.30	66	0	25	0.1	0.43	166	127	116	8			
M011F2	TOHE-PO DEVE	S	45	4	7	0.27	0.20	119	17	22	0.1	0.37	273	219	195	11			
M011F3	TOHE-PO DEVE	S	49	5	14	0.30	0.20	149	18	23	0.1	0.45	308	260	216	17			
M011F4	TOHE-PO DEVE	S	7	2	0	0.10	0.10	-32100	10	27	0.7	0.37	1110	49	751	-44			
M012F2	AGRELOUVE	B	95	36	176	0.10	0.10	417	0	241	0.1	0.30	820	928	574	28			
M012F4	AGRELOUVE	B	57	30	77	0.10	0.30	255	0	152	0.1	0.30	1150	894	885	-10	626	-9	
M012F5	AGRELOUVE	B	46	20	89	0.10	0.20	262	38	127	0.1	0.25	952	676	732	66	475	23	
M012F1	MYAGSIVE	B	46	22	42	0.11	0.25	86	113	101	12.5	0.00	754	609	474	528	-16	566	-23
M012F3	MYAGSIVE	B	36	21	54	0.26	0.26	35	146	92	4.1	0.30	686	813	785	491	-16	569	-21
M012F4	MYAGSIVE	B	51	27	5	0.11	0.40	238	0	117	1.0	0.32	740	856	481	518	-7	546	-20
M012F1	MYRESSIA	B	35	19	56	0.10	0.10	227	1	152	20.0	0.10	1152	1250	661	817	6	875	-1
M012F4	MYRESSIA	B	116	21	129	0.10	0.10	497	295	145	0.1	1.07	1426	1271	1277	1000	22	890	20
M012F3	AGNACON	B	66	45	66	0.10	0.10	289	53	142	0.0	0.40	333	662	582	10			
M012F4	AGNACON	B	69	37	55	0.10	0.10	281	44	113	10.2	0.41	757	844	609	576	12	591	3
M012F2	AVETA	S	86	30	72	0.40	0.20	229	47	182	0.0	0.94	633	1010	648	582	10	707	-8
M012F2	BATOLME	B	45	21	101	0.10	0.10	304	19	106	0.0	0.18	714	1093	576	530	16	763	-22
M012F2	AMEGNONA KOFE	S	11	3	29	0.60	0.20	89	7	17	0.0	0.30	111	157	75	50			
M012F2	MYAGRE 1	S	44	15	7	0.20	0.20	236	5	57	4.0	0.30	581	487	407	16	574	-10	
M012F7	TOREVIH	S	129	37	131	0.20	0.20	115	215	240	0.0	0.60	1166	969	816	16			
M012F4	TOREVIH	B	117	35	140	0.10	0.30	256	220	214	0.5	0.50	1751	1165	984	946	4	816	17
M012F2	TOREHAN	B	71	49	346	0.10	0.10	655	246	237	5.5	1.00	1709	1569	1614	1196	26	1112	31
M012F4	TOREHAN	B	78	46	228	0.11	0.10	433	170	336	22.0	0.44	1515	1366	1368	1061	24	1029	4
M012F1	AGRELOUVE	B	44	22	55	0.21	0.10	287	19	92	0.0	0.24	657	722	550	461	16	505	8
M012F2	AGRELOUVE	B	62	28	69	0.20	0.10	556	7	42	122.1	0.30	688	846	943	622	24	552	37
M012F2	KOTO	B	91	57	347	0.30	0.20	407	303	402	126.0	1.66	1923	1740	1636	1346	16	1216	26
M012F2	KOTO	B	41	33	211	0.20	0.20	503	144	153	94.0	0.17	1086	982	760	23	1197	-16	

#	VILLAGE	SEUL	Lat	Ng	Var	Fe	Mo	NO3	SO4	Cl	NO2	F	COAL	TOB	TOB	TOB	TOB	TOB
		(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)
M180F2	ANOLU KOFI	B	55	35	65	0.10	1.41	20	57	117	10.6	1.1	549	549	577	577	577	577
M180F4	ANOLU KOFI	B	50	30	69	0.10	1.41	20	57	117	10.6	1.1	549	549	577	577	577	577
M180F2	GATI AGGDC	B	77	12	75	0.40	0.10	75	28	61	44.0	0.17	770	770	770	770	770	770
M182F3	GATI AGGDC	B	72	12	75	0.40	0.10	75	28	61	44.0	0.17	770	770	770	770	770	770
M183F2	GATI SDUN	B	21	11	75	0.40	0.10	49	35	51	42.0	0.12	759	759	759	759	759	759
M183F3	GATI SDUN	B	8	2	19	0.10	0.10	27	17	24	0.10	0.10	104	104	104	104	104	104
M184F3	FONGBE DZOGBED	B	8	2	11	0.80	0.10	-10.10	3	24	122.0	0.21	48	48	48	48	48	48
M186F2	SEDURO	B	81	8	15	1.00	0.10	268	8	27	0.9	0.21	171	171	171	171	171	171
M186F3	SEDURO	B	60	5	14	1.00	0.10	196	9	27	0.9	0.21	202	202	202	202	202	202
M199F2	AMEGELEVE	B	15	2	46	0.20	0.10	171	23	23	0.1	0.15	125	125	125	125	125	125
M237F3	ALBYI	B	77	46	171	0.10	0.10	575	154	104	0.0	0.00	1005	1005	1005	1005	1005	1005
M237F4	ALBYI	B	75	44	170	0.20	0.10	516	155	109	0.0	0.00	1282	1282	1282	1282	1282	1282
M301F1	AFOKPONAVE	B	50	26	76	0.20	0.10	267	9	62	0.0	0.00	699	699	699	699	699	699
M301F2	AFOKPONAVE	B	75	29	50	0.10	0.40	757	0	97	0.0	0.00	817	817	817	817	817	817
M302F1	ANAZIVE	B	81	29	125	0.50	0.26	509	23	178	0.0	0.00	1000	1000	1000	1000	1000	1000
M303F4	AKPAPEHOME	B	65	28	120	1.70	0.40	-19.0	22	215	0.0	0.00	1428	1428	1428	1428	1428	1428
M304F1	WOEVE	B	124	39	87	0.10	0.50	405	122	153	0.0	0.00	1219	1219	1219	1219	1219	1219
M306F1	AGBETIME	B	68	25	25	0.20	0.20	311	0	57	0.0	0.00	617	617	617	617	617	617
M307F1	DZAKPO	B	52	29	110	0.70	0.22	264	145	85	0.0	0.00	409	409	409	409	409	409
M308F1	TSUETA	B	126	57	96	0.60	0.70	125	44	100	0.0	0.00	1769	1769	1769	1769	1769	1769
M309F1	EGBE	B	66	20	150	0.10	0.20	400	115	181	0.0	0.00	721	721	721	721	721	721
M309F2	EGBE	B	47	23	57	0.70	0.20	104	55	166	0.0	0.25	1771	1771	1771	1771	1771	1771
M310F2	TOUNGUMABEE	B	100	25	49	0.10	0.20	217	40	110	0.0	0.20	90	90	90	90	90	90
M311F1	ANOLI KOFI	B	75	52	172	0.5	0.22	7	411	217	0.0	0.00	1441	1441	1441	1441	1441	1441
M312F1	AFAYE KOFI	B	124	54	148	1.50	0.45	145	72	170	0.0	0.00	1337	1337	1337	1337	1337	1337
M313F2	AGOKFE	B	116	51	214	0.20	0.20	70	-194	211	0.0	0.00	1857	1857	1857	1857	1857	1857
M314F1	GAMESELE	B	54	21	49	0.10	0.10	204	4	75	0.0	0.00	574	574	574	574	574	574
M314F2	GAMESELE	B	17	38	56	0.10	0.10	287	0	64	0.0	0.00	1370	1370	1370	1370	1370	1370
M314F3	GAMESELE	B	45	21	50	0.90	0.20	252	0	74	0.0	0.25	535	535	535	535	535	535
M315F1	TSINGOE	B	105	20	155	0.2	0.20	462	75	306	0.0	0.00	1492	1492	1492	1492	1492	1492
M315F2	TSINGOE	B	95	22	151	0.10	0.10	465	78	329	0.0	0.27	1351	1351	1351	1351	1351	1351
M316F1	AGADJAFI	B	77	29	143	0.10	0.10	545	46	11	0.0	0.00	111	111	111	111	111	111
M317F1	TITONGU	B	27	5	120	0.70	0.20	-421.0	27	445	0.0	0.00	554	554	554	554	554	554
M318F1	KOUINGLO	B	71	47	57	0.10	0.10	400	15	142	0.0	0.00	925	925	925	925	925	925
M319F1	FLABEA	B	154	20	188	0.30	0.20	487	26	273	0.0	0.00	1923	1923	1923	1923	1923	1923
M320F1	AGBODJE PO	B	147	47	94	0.30	0.20	263	291	160	0.4	0.00	1751	1751	1751	1751	1751	1751
M320F2	AGBODJE PO	B	137	49	122	0.10	0.20	299	317	166	0.0	0.00	1751	1751	1751	1751	1751	1751
M321F3	KOTSO KOFI	B	61	22	75	0.50	0.20	172	32	49	0.0	0.00	565	565	565	565	565	565
M321F4	KOTSO KOFI	B	60	21	66	0.20	0.20	145	47	61	0.0	0.00	1500	1500	1500	1500	1500	1500
M322F1	AMAVEGAN	B	59	32	44	0.10	0.20	10	17	141	0.0	0.00	574	574	574	574	574	574
M323F1	AGOKPOE	B	79	38	152	0.20	0.20	240	49	252	0.0	0.00	1282	1282	1282	1282	1282	1282
M324F1	ATIKOLE	B	198	20	199	1.10	0.40	258	404	176	0.0	0.00	1200	1200	1200	1200	1200	1200
M324F2	ATIKOLE	B	166	56	225	0.60	0.50	418	561	346	0.0	0.00	2247	2247	2247	2247	2247	2247
M325F1	ASSEI F.E.E	B	74	22	55	0.20	0.20	229	14	66	0.0	0.00	7448	7448	7448	7448	7448	7448
M326F1	NYANVETCHI	B	48	22	119	0.20	0.20	244	21	124	0.0	0.00	54	54	54	54	54	54
M327F1	BEJEME	B	24	9	15	0.10	0.20	75	0	61	0.0	0.00	212	212	212	212	212	212
M327F2	BEJEME	B	23	8	13	0.10	0.20	67	42	71	0.4	0.20	265	265	265	265	265	265
M328F1	AGAMARE	B	48	22	128	0.10	0.20	417	0	170	0.0	0.00	1148	1148	1148	1148	1148	1148
M329F1	AGBODJE POE	B	55	29	51	0.20	0.10	287	10	27	0.0	0.00	576	576	576	576	576	576
M329F2	AGBODJE POE	B	54	28	52	0.40	0.20	444	18	0	0.0	0.00	591	591	591	591	591	591
M330F2	ATIKOLE	B	198	20	199	0.20	0.50	570	0	601	0.0	0.00	795	795	795	795	795	795

#	VILLAGE	SECT	3000		4000		5000		6000		7000		8000		9000		10000		11000		12000		13000		14000		15000		16000		17000		18000		19000		20000		
			(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	
M010F1	M010F1	B	57	34	57	0.20	0.20	421	4	42	0.0	0.00	1000	201	552	5-4	-18	-21	25																				
M010F2	BABBE	B	38	96	21	0.20	0.20	346	52	152	0.0	0.00	981		723	555	5																						
M010F3	CAME + OVE	B	35	31	140	0.20	0.20	311	45	125	0.0	0.00	870		673	505	10																						
M010F4	GMME + OVE	B	30	14	145	0.20	0.20	310	23	155	0.0	0.00	869	515	590	505	10	5-1	1																				
M010F5	KOTO + OVE	B	66	14	55	0.20	0.20	257	3	121	0.0	0.00	800		700	550	10																						
M010F6	KOTO + OVE	B	71	41	98	0.20	0.20	275	77	120	0.0	0.00	825		751	545	10																						
M010F7	KOTO + OVE	B	50	30	201	0.20	0.20	456	0	57	0.0	0.00	874		722	455	10																						
M010F8	KOTO + OVE	B	70	45	57	0.20	0.20	508	73	15	0.0	0.00	850		800	524	10																						
M010F9	MAY + OVE	B	42	29	55	0.20	0.20	477	0	50	0.0	0.00	1400		675	520	-21																						
M010F10	ADJA + OVE	B	110	100	151	0.20	0.20	425	105	650	0.0	0.00	1000	2400	1044	1101	-4	1701	17																				
M010F11	ADJA + OVE	B	117	106	154	0.20	0.20	511	104	855	0.0	0.00	1941	1500	2109	1059	10	1820	14																				
M010F12	HAMO + OVE	B	75	25	55	0.20	0.20	405	24	65	0.0	0.00	745		705	522	10																						
M010F13	HAMO + OVE	B	61	25	55	0.20	0.20	285	53	55	0.0	0.00	830		662	583	10																						
M010F14	AVEDJE	B	147	45	115	0.20	0.20	417	70	250	0.0	0.00	1449	1751	1048	1014	3	974	7																				
M010F15	AVEDJE	B	127	50	89	0.20	0.20	150	210	159	1.0	0.00	1051	1375	921	946	-3	895	3																				
M010F16	MOUSFOU + OVE	B	71	20	47	0.20	0.20	315	0	151	0.0	0.00	875		569	470	17																						
M010F17	TEDAHCE	B	60	42	115	0.20	0.20	510	51	104	0.0	0.00	1000	565	906	700	23	678	25																				
M010F18	ALLAGBADJA	B	115	29	150	0.20	0.20	550	56	177	0.0	0.00	1715	1075	1194	921	16	750	31																				
M010F19	BAHA + OVE	B	151	51	120	0.20	0.20	305	125	204	0.0	0.00	1500	1023	1113	1073	4	860	23																				
M010F20	BAHA + OVE	B	140	47	105	0.20	0.20	151	174	121	24.0	0.00	1050	1447	1005	875	13	1010	-1																				
M010F21	ADABADJI + ONDJ	B	8	2	11	0.20	0.20	15	0	24	0.0	0.00	105		75	75	-2																						
M010F22	ADABADJI + ONDJ	B	8	2	11	0.20	0.20	17	0	25	0.0	0.00	110		74	77	-4																						
M010F23	ARANTOJI + ONDJ	B	4	2	17	0.20	0.20	19	0	40	0.0	0.00	107		59	75	16																						
M010F24	ARANTOJI + ONDJ	B	4	2	15	0.20	0.20	55	0	15	0.0	0.00	117		102	62	20																						
M010F25	TONA + ONDJ	B	5	2	19	0.20	0.00	0	0	0	0.0	0.00	75		26	55	-52																						
M010F26	TONA + ONDJ	B	11	8	12	0.20	0.20	61	0	20	0.0	0.00	105	107	124	87	33	56	20																				
M010F27	THE 1 + ONDJ	B	7	2	12	0.20	0.10	37	0	15	0.0	0.00	50		74	56	24																						
M010F28	ADUSSA + ONDJ	B	11	2	23	0.20	0.20	0	0	0	0.0	0.00	110		50	77	-75																						
M010F29	LOGO + OVE	B	0	0	0	0.20	0.20	0	0	21	0.0	0.00	50		21	60	-57																						
M010F30	GBEMINA + ONDJ	B	0	0	0	0.20	0.00	0	0	19	0.0	0.00	50		18	60	-71																						
M010F31	AKPLAGASEOU	B	0	0	0	0.20	0.00	0	0	19	0.0	0.00	50		19	60	-70																						
M010F32	AKLGBI + ONDJ	B	11	2	28	0.20	0.10	94	0	18	0.0	0.00	105		155	74	21																						
M010F33	AKTIND + ONDJ	B	5	2	14	0.20	0.00	13	0	29	0.0	0.00	75		63	53	17																						
M010F34	ADJHA + OVE	B	4	2	17	0.20	0.10	50	0	22	0.0	0.00	105		101	75	25																						
M010F35	ADOTI + ONDJ	B	0	0	0	0.20	0.10	0	0	24	0.0	0.00	50		24	60	-62																						
M010F36	ADOUTEHA + ONDJ	B	10	3	15	0.20	0.00	56	0	22	0.0	0.00	108		110	75	21																						
M010F37	BADA + ONDJ	B	6	2	41	0.20	0.10	95	0	21	0.0	0.10	87		167	61	64																						
M010F38	ADABIAN	B	7	3	14	0.20	0.10	5	0	40	0.0	0.11	125		69	85	-21																						
M010F39	DJATH + OVE	B	45	4	7	2.20	0.20	117	27	22	0.0	0.27	175		217	195	10																						
M010F40	SETE + OVE	B	45	4	14	0.20	0.20	130	20	23	0.0	0.28	185		238	200	16																						
M010F41	SETE + OVE	B	5	2	18	0.30	0.10	-15(00)	35	26	0.0	0.13	92		87	64	26																						
M010F42	ZOTI + OVE	B	7	2	14	0.20	0.20	17	0	30	0.0	0.22	125		71	88	-19																						
M010F43	ADOUO + OVE	B	3	1	15	0.20	0.10	-9(00)	17	24	0.0	0.13	74		60	52	14																						
M010F44	FESSE + OVE	B	2	1	15	0.20	0.10	19	17	15	0.0	0.16	57		70	40	47																						
M010F45	FESSE + OVE	B	3	1	7	0.20	0.10	4	1	16	0.0	0.21	58		33	41	-15																						
M010F46	AVEDJI	B	38	5	4	0.20	0.50	124	0	32	0.0	0.08	150		214	177	17																						
M010F47	DAVOU	B	12	2	21	0.20	0.20	21	31	26	0.0	0.20	175		115	97	15																						
M010F48	GATI + AFADOU	B	8	2	24	0.10	0.10	57	0	24	0.0	0.10	100	115	115	71	38	87	26																				
M010F49	PONGEE BOETI	B	13	3	20	0.20	0.20	55	0	26	0.0	0.16	155		137	109	21																						
M010F50	ANYAVE	B	75	6	25	0.20	0.20	257	22	27	0.0	0.16	400		405	280	32																						
M010F51	ADOTI + OVE	B	27	6	10	0.20	0.20	77	14	37	0.0	0.29	235	235	175	185	8	167	7																				

#	VILLAGE	SEDL	Ca++	Mg++	Na+	Fe++	Mn++	CO3--	SiO4--	Cl--	NO3--	F--	SO4--	PO4--	NO2--	NO-	NO3-	NO2-	NO-
		(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)
M377F2	ADETI KOPE	S	29	7	7	0.10	0.10	65	17	22	1.1	0.71	212	219	157	148	147	147	147
M378F1	ADJUGUIDI	S	74	16	33	0.80	0.10	250	47	52	1.1	0.74	320	40	464	179	16	180	40
M378F2	ADJUGUIDI	S	121	24	62	1.20	0.10	459	68	65	1.1	0.75	320	307	501	551	27	446	44
M379F1	LOME ATTITESOM	S	26	2	14	0.40	0.20	70	11	25	1.1	0.75	211	474	147	147	147	147	147
M380F1	LOME	S	100	24	55	1.20	0.20	411	44	100	1.1	0.74	321	371	752	580	22	464	55
M381F1	TDUNOKOUTI	S	85	21	171	0.70	0.10	904	54	94	1.1	0.40	741	668	1440	518	34	466	66
M382F1	ALLAGBADJA	S	27	2	11	0.60	0.20	66	11	25	1.1	0.71	212	153	147	147	147	147	147
M383F1	MOE KOPE	S	79	9	43	1.50	0.20	282	1	69	1.1	0.75	316	493	465	368	14	245	24
M384F2	ADIDONE	S	43	6	30	0.10	0.10	70	42	67	1.1	0.71	321	371	360	368	14	245	24
M384F3	ADIDONE	S	46	5	24	0.10	0.10	64	39	64	1.1	0.71	400	390	244	280	17	272	11
M385F1	SEVA	S	22	5	32	0.10	0.20	88	25	31	1.1	0.79	232	253	206	162	22	174	14
M385F2	SEVA	S	29	5	22	0.10	0.10	106	7	30	1.1	0.70	232	272	204	162	21	190	7
M386F1	TEDO	S	31	10	30	0.10	1.50	75	22	46	1.1	0.72	344	344	261	241	8	160	-3
M387F1	ATIDE APEDONE	S	27	4	19	0.10	0.10	72	18	37	1.1	0.71	222	257	174	155	11	162	8
M387F2	ATIDE APEDONE	S	26	3	22	0.10	0.10	71	23	29	1.1	0.79	227	232	177	159	10	162	8
M388F1	AKPANITO	S	94	19	35	1.20	0.10	295	43	47	1.1	0.77	555	751	526	369	26	267	49
M391F1	LOMEGNAN KOPE	S	39	5	21	0.20	0.10	127	24	24	1.1	0.78	250	344	241	175	27	171	29
M396F1	FONGBE APEDONE	S	6	2	12	0.60	0.10	4	2	24	1.1	0.79	113	65	65	79	-16		
M396F2	FONGBE APEDONE	S	6	2	7	0.20	0.10	-700	0	25	1.1	0.70	95	51	51	67	-23		
M397F1	VOBO	S	45	6	25	0.80	0.10	160	18	30	1.1	0.75	285	720	235	200	30	224	21
M397F2	VOBO	S	37	4	20	0.70	0.10	133	11	23	1.1	0.70	263	229	229	184	20		
M398F1	AI KONDJI	S	13	4	15	0.10	0.10	32	20	22	1.1	0.70	113	128	110	79	28	90	19
M399F1	GABADJIN	S	34	2	21	1.70	0.20	45	54	37	1.1	0.79	256	196	196	179	9		
M401F1	AMESSIKPE	S	45	25	46	0.40	0.20	304	22	34	1.1	0.79	471	522	479	333	30	365	24
M402F1	GAZATOE	B	64	31	85	0.10	0.40	439	20	123	1.1	0.40	952	779	783	666	15	545	36
M403F1	KPODJI	B	56	31	39	0.30	0.20	224	18	105	1.1	0.91	641	669	475	449	5	468	1
M403F2	KPODJI	B	135	110	120	0.20	0.10	586	8	396	1.1	0.48	1886	1247	1357	1320	5	673	36
M404F3	AFIADENYISBA	B	82	54	117	0.10	0.10	713	89	2	1.1	0.56	1000	928	1058	700	34	650	39
M405F1	ATCHAVE GBAFA	B	65	72	73	0.30	0.40	315	10	283	1.1	0.17	1183	1385	629	628	1	970	-13
M405F2	ATCHAVE GBAFA	B	109	80	109	0.10	0.10	416	32	327	1.1	0.41	1390	1267	1676	977	10	887	16
M406F1	SANDUTA	B	76	76	198	0.20	0.20	611	171	179	1.1	0.67	1574	1547	1312	1192	16	1063	17
M407F2	BEDJRA KOPE	B	121	50	200	0.20	0.60	255	314	366	1.1	0.48	1676	1956	1258	1312	14	1269	-8
M407F3	BEDJRA KOPE	B	131	50	200	0.30	0.60	276	306	300	1.1	0.48	1724	2040	1265	1267	5	1429	-11
M408F1	AGHONE	B	160	58	149	0.20	0.30	197	362	300	1.1	0.42	1574	1227	1227	1102	10		
M409F1	KLOHEPOE	B	161	59	147	0.60	0.30	357	352	217	1.1	0.44	1612	1294	1294	1126	17		
M410F1	HEKPOUI	B	124	76	154	3.50	2.00	126	622	185	1.1	0.67	1626	1714	1714	1172	17		
M411F1	HLEME	B	167	82	194	0.60	0.50	442	297	358	1.1	0.55	2060	1542	1542	1400	9		
M417F1	KPEDONE	B	64	33	80	0.10	0.10	405	14	87	1.1	0.38	657	668	687	460	10	466	32
M418F1	HEDJENE	B	99	59	143	0.10	0.60	566	104	163	1.1	0.60	1250	1137	1135	875	30	746	30
M419F2	DONO	B	82	36	66	0.20	0.10	359	44	111	1.1	0.60	740	632	699	518	26	456	35
M420F2	ETOE KOPE	B	41	19	83	0.10	0.10	327	20	42	1.1	0.60	555	1420	549	389	29	716	-23
M420F3	ETOE KOPE	B	65	29	114	0.61	0.10	317	51	137	1.1	0.76	975	1284	744	680	8	899	-17
M421F1	VAVATSI	B	111	60	155	0.20	0.20	12	335	356	1.1	0.40	1470	1524	1030	1027	0	1067	-3
M422F1	BATOUNE	B	82	41	93	0.10	0.20	486	0	126	1.1	0.60	909	730	628	676	27	511	36
M424F1	FOKPO	B	76	32	131	0.20	0.30	382	111	125	1.1	0.66	952	906	859	686	20	604	26
M426F1	HEKPOE	B	139	54	145	0.30	0.40	364	170	290	1.1	0.44	1763	1147	1167	1234	16	940	31
M426F2	HEKPOE	B	76	32	129	0.20	0.30	369	109	131	1.1	0.64	980	916	846	686	19	643	24
M427F2	GUENOJI	B	135	48	38	0.10	0.80	120	227	200	1.1	0.66	1342	1063	773	979	-18	744	7
M432F1	AZI KOPE	B	39	14	22	0.10	0.10	113	24	41	1.1	0.42	370	287	287	259	10		
M436F1	NYIGBE 2	B	54	30	54	0.10	1.60	173	54	135	1.1	0.57	666	774	505	466	6	542	-7
M436F2	NYIGBE 2	B	66	28	67	0.10	0.20	201	20	162	1.1	0.53	816	660	631	571	5	462	23

#	VILLAGE	GEOLOGICAL	Ca++	Mg++	Na+	Fe++	Mn++	HCO3-	SO4=	Cl-	NO3-	F-	COND		TDS	TDSa	DIFa	TDSa	DIFa
			(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(uS/cm)		(ppm)	.74Ca	%	.74Ca	%
													old	new					
M437F1	DEKANE	B	48	52	118	0.10	0.10	299	49	208	0.4	0.41	1176	993	775	823	-6	695	10
M439F1	AGBLEVE	B	68	26	57	0.10	0.30	313	42	71	0.3	0.28	714	622	578	500	14	435	25
M441F1	GAPE KOVE	B	57	36	51	0.20	0.20	402	0	50	1.4	0.33	512	730	598	358	40	511	15
M441F2	GAPE KOVE	B	67	42	70	0.10	0.20	455	0	84	0.4	0.37	740	713	719	518	28	499	31
M442F1	TODONE	B	78	23	74	0.10	0.30	306	53	102	0.3	0.46	833	1316	637	583	8	921	-31
M442F2	TODONE	B	77	27	72	0.10	0.30	312	37	105	0.8	0.48	833	1135	628	583	7	795	-21
M443F1	LONVO	B	110	62	36	0.10	0.10	419	0	107	140.0	0.31	1000		875	700	20		
M445F1	TOUTOU KOPE	B	73	31	56	0.20	0.10	373	0	89	0.0	0.32	740	748	623	518	17	524	16
M446F1	KPOTA	B	128	68	475	0.30	0.40	1500	71	230	5.6	0.60	1420	1270	2479	994	60	889	64
M465F1	DZOUADJE	S	94	17	332	0.20	0.10	964	19	148	9.5	0.41	770		1584	539	66		
M467F1	AGBLEVOU	S	77	15	7	1.00	0.10	263	30	5	0.1	0.39	555		416	369	7		
M468F1	MODENOU	S	44	5	12	0.20	0.10	139	0	30	0.0	0.22	285	251	231	200	14	176	24
M469F1	KPALA	S	18	4	30	2.60	0.10	52	23	44	3.4	0.18	222	329	177	155	12	230	-23
M469F2	KPALA	S	20	3	21	0.10	0.10	41	8	46	0.6	0.25	240	316	140	168	-16	221	-37
M470F1	MESSEKO KONDJI	S	12	3	7	0.30	0.10	30	0	22	3.3	0.10	131	113	77	92	-16	79	-2
M471F1	AFIKOU KONDJI	S	7	2	17	0.70	0.10	-63(0)	72	28	0.3	0.33	131	138	127	92	28	97	24
M473F1	AKLADJENDU	S	8	3	6	0.20	0.10	9	0	25	3.3	0.10	107	374	55	75	-26	262	-79

NEW DATA (from MGRM AND GSC)

M421F4	NYASSIVE	B	51	23	60	0.10	0.40	82	17	81	189.0	0.51	740	856	504	518	97	599	84
M426F2	AGRESSIA	B	92	80	196	0.10	0.10	391	119	152	0.0	2.10	1162	1250	1933	813	127	875	118
M165F2	AGRADJAMELEN	B	42	77	69	0.20	0.10	308	7	42	0.0	0.60	888	846	545	622	88	592	92
M175F2	YOTO	B	56	42	247	0.2	0.20	264	75	402	1.25	1.88	1923	1740	1194	1346	89	1218	98
M175F3	YOTO	B	54	47	211	0.11	0.20	270	115	153	1.25	3.13	1086	1710	855	760	112	1197	71
M182F3	GATI AGODO	S	32	12	32	0.40	0.10	74	35	40	69.0	0.28	392	458	285	274	104	321	89
M184F3	FONGBE DZOGRED	S	56	7	11	0.00	0.10	94	4	24	0.0	0.21	98	100	196	69	286	70	280
M312F1	AKPAVE KOPE	B	124	59	148	0.60	0.45	433	246	185	1.2	0.98	1587	1548	1199	1111	108	1084	111
M330F2	ATIND	B	186	95	249	0.30	0.50	815	75	448	19.0	1.75	395	2370	1689	277	683	1659	114
M374F1	GATI AKPAFOU	S	8	2	24	0.10	0.10	66	10	11	0.0	0.14	102	119	122	71	171	83	146
M379F1	LOME ATTITEGOM	S	26	2	14	0.40	0.20	58	14	29	0.6	0.45	200	474	145	140	103	332	44
M385F1	SEVA	S	22	5	32	0.10	0.20	137	12	14	0.2	0.29	232	255	223	162	137	179	125
M407F3	BEDJRA KOPE	B	131	50	200	0.30	0.60	303	315	276	1.0	1.05	1724	2040	1278	1207	106	1428	89
M410F1	HEI-POUI	B	134	79	164	4.70	2.00	291	277	185	0.0	0.63	1626		1137	1138	100		
M443F1	LONVO	B	92	74	36	0.10	0.10	230	0	107	105.0	0.31	1000		644	700	92		
M470F1	MESSEKO KONDJI	S	12	3	7	0.30	0.10	51	4	8	0.6	0.15	131	113	86	92	94	79	109
M471F1	AFIKOU KONDJI	S	7	2	17	0.70	0.10	35	17	12	0.4	0.23	131	138	91	92	100	97	94

APPENDIX 4. CHECK 2

(data from Gecamines, 1987)

well number
 VILLAGE village name
 GEOL geology (B = bedrock, S = sediments)
 Ca++ calcium
 Mg++ magnesium
 Na+ sodium
 Fe++ iron
 Mn++ manganese
 CAT*100 sum of cations * 100
 CONDo old conductivity (microSiemens per centimetre)
 DIFo % difference $(100(CAT*100-CONDo)/(larger\ of\ CAT*100\ or\ CONDo))$
 CONDn new conductivity (microSiemens per centimetre)
 DIFn % difference $(100(CAT*100-CONDn)/(larger\ of\ CAT*100\ or\ CONDn))$

#	VILLAGE	GEOL	Ca++ (epm)	Mg++ (epm)	Na+ (epm)	Fe++ (epm)	Mn++ (epm)	CAT*100 (epm)	CONDo (uS/cm)	DIFo %	CONDn (uS/cm)	DIFn %
M010F2	TCHÉKPO ANAGALI	S	0.80	0.33	0.65	0.0107	0.0109	180	166	8		
M011F2	TCHÉKPO DEVE	S	2.25	0.33	0.50	0.0788	0.0073	297	278	6		
M011F3	TCHÉKPO DEVE	S	2.45	0.41	0.61	0.0215	0.0073	349	308	12		
M011F4	TCHÉKPO DEVE	S	0.35	0.16	0.90	0.0036	0.0036	52	1116	-95		
M013F3	AGBELOUVE	B	4.74	2.96	5.92	0.0036	0.0036	1367	820	40		
M013F4	AGBELOUVE	B	2.64	2.47	3.35	0.0036	0.0000	847	1150	-26	894	-5
M013F5	AGBELOUVE	B	4.79	1.65	3.87	0.0036	0.0073	1032	952	8	678	34
M021F2	NYASSIVE	B	2.30	2.63	1.87	0.0036	0.0091	681	754	-10	609	-16
M021F3	NYASSIVE	B	1.80	2.14	2.33	0.0093	0.0095	630	669	-9	813	-22
M021F4	NYASSIVE	B	2.54	1.89	2.61	0.0036	0.0146	707	8	-5	856	-17
M026F2	AGBESSIA	B	1.75	1.56	8.53	0.0036	0.0036	1184	1162	2	1050	-5
M026F4	AGBESSIA	B	6.89	5.92	5.61	0.0036	0.0036	1643	1428	23	1271	21
M029F3	AGNRON	B	3.29	3.70	2.87	0.0036	0.0036	987	833	16		
M029F4	AGNRON	B	3.44	3.04	2.39	0.0036	0.0036	889	757	15	844	5
M039F2	AVETA	S	4.29	2.47	3.13	0.0143	0.0073	991	633	16	1010	-2
M098F2	BATOUNE	B	2.25	1.73	4.39	0.0036	0.0036	837	714	15	1093	-23
M100F2	AMEGNONA KOPE	S	0.55	0.25	1.26	0.0215	0.0073	209	111	47		
M113F2	NYIGBE I	B	2.20	1.23	3.04	0.0072	0.0073	649	581	10	763	-15
M115F3	TOKPEVIA	B	6.44	3.04	5.70	0.0072	0.0255	1521	1166	23		
M115F4	TOKPEVIA	B	5.84	2.88	6.09	0.0036	0.0291	1484	1751	9	1165	21
M120F3	TOVEBAN	B	3.54	4.03	15.14	0.0036	0.0036	2072	1709	25	1589	30
M120F4	TOVEBAN	B	1.90	3.95	14.70	0.0036	0.0036	2055	1515	26	1896	8
M148F2	AGBOZONE	B	2.20	1.81	3.70	0.0072	0.0036	771	657	15	722	6
M165F2	AGBADJANEKEN	B	3.09	6.42	3.00	0.0072	0.0036	1252	888	29	846	32
M175F2	YOTO	B	4.54	4.69	15.09	0.0322	0.0073	2436	1923	21	1740	29
M175F3	YOTO	B	2.05	2.71	9.18	0.0072	0.0073	1395	1086	22	1710	-18
M180F2	AHLOU KOPE	B	2.74	2.88	2.83	0.0036	0.0149	847	869	-3	945	-10
M180F4	AHLOU KOPE	B	2.50	2.47	4.26	0.0036	0.0036	923	1180	-22	976	-5
M182F2	GATI AGODO	S	1.65	0.99	1.52	0.0143	0.0036	417	370	11	426	-2
M182F3	GATI AGODO	S	1.60	0.99	1.39	0.0143	0.0036	399	392	2	458	-13
M183F2	GATI SOUN	S	1.55	0.90	1.52	0.0143	0.0036	399	359	10	82ppt	
M183F3	GATI SOUN	S	0.40	0.16	0.83	0.0036	0.0036	140	104	26	104	26

	VILLAGE	GEOLOG	Ca++ (ppm)	Mg++ (ppm)	Na+ (ppm)	Fe++ (ppm)	Mn++ (ppm)	CAT+100 (ppm)	CONDc (uS/cm)	DIFc %	CONDn (uS/cm)	DIFn %
M184F3	FONGBE DZOGBEDJI	S	0.30	0.16	0.49	0.0286	0.0036	97	98	-1	100	-3
M186F2	SEDJRO	S	4.04	0.49	0.65	0.0358	0.0036	523	131	75		
M186F3	SEDJRO	S	2.99	0.41	0.61	0.0358	0.0036	405	303	25		
M189F2	AMEGBELEVE	S	0.65	0.15	2.09	0.0072	0.0036	291	125	57	100	54
M237F3	ALDYI	B	3.84	3.76	7.44	0.0036	0.0036	1507	1005	33	1283	15
M237F4	ALDYI	B	3.74	3.62	7.39	0.0072	0.0036	1477	1282	17	1284	13
M301F1	AFOKPOMAVE	B	2.50	2.14	3.31	0.0072	0.0036	795	699	12	599	25
M301F2	AFOKPOMAVE	B	3.44	2.39	2.17	0.0036	0.0146	852	917	5	892	-4
M303F1	ANAZIVE	B	4.04	3.21	5.44	0.0179	0.0131	1272	1000	21	660	46
M303F4	AKFAPEDOME	B	3.24	3.13	5.22	0.0466	0.0146	1165	1428	-16	1557	-23
M304F1	MOEVE	B	6.69	3.21	3.78	0.0036	0.0182	1370	1215	11	1230	10
M306F1	AGBETINE	B	3.39	2.06	1.17	0.0072	0.0109	660	617	-		
M307F1	DZAKPO	B	2.59	3.39	4.78	0.0107	0.0080	978	806	7	679	10
M308F1	TSLETA	B	6.79	4.69	4.18	0.0215	0.0109	1568	1369	10	1172	25
M309F1	EGBE	B	7.29	2.47	8.35	0.0036	0.0036	1412	721	49	790	44
M309F2	EGBE	B	3.35	2.88	2.91	0.0107	0.0146	816	1730	-53	778	5
M310F2	TOUNOUNASSE	B	4.99	2.88	2.13	0.0107	0.0073	1002	910	9	745	26
M311F1	AKOLI KOPE	B	3.79	4.29	7.48	0.0215	0.0116	1559	1492	4	1757	-11
M312F1	AKPAVE KOPE	B	6.19	4.85	6.44	0.0215	0.0164	1752	1587	9	1548	12
M313F2	AGOKPE	B	3.79	4.94	8.87	0.0107	0.1456	1975	1851	6	1918	3
M314F2	GAMGBELE	B	2.69	1.73	1.74	0.0036	0.0036	617	574	7	491	20
M314F3	GAMGBELE	B	0.50	3.13	2.87	0.0036	0.0036	650	1330	-51	1006	-35
M314F5	GAMGBELE	B	2.40	1.65	2.17	0.0222	0.0109	626	555	11	483	23
M315F1	TSINGBE	B	5.24	5.76	6.74	0.0072	0.0109	1776	1492	16	937	47
M315F2	TSINGBE	B	4.69	5.10	6.52	0.0036	0.0036	1652	1351	16	1230	26
M316F1	AGADJIAFE	B	3.64	3.13	6.22	0.0036	0.0036	1300	1110	15	1256	3
M317F1	TITONGU	B	1.35	0.41	4.35	0.0107	0.0109	613	884	-31	677	-9
M318F1	AKUBINOUKOE	B	3.54	3.54	3.76	0.0036	0.0036	1087	925	15	1116	-3
M319F1	AKLABA	B	7.68	5.76	8.18	0.0107	0.0109	2164	1923	11	1874	13
M320F1	AGBODJEFKFO	B	7.34	3.54	4.09	0.0107	0.0109	1498	1351	10	1258	16
M320F2	AGBODJEFKFO	B	6.84	4.03	5.31	0.0036	0.0109	1619	1351	17	1313	19
M321F1	KOTSOKOPE	B	3.04	1.81	3.26	0.0179	0.0073	814	666	18	560	31
M321F4	KOTSOKOPE	B	2.99	1.73	2.87	0.0072	0.0073	761	1500	-49	565	26
M322F1	AMAVEGAN	B	2.94	2.63	1.91	0.0036	0.0109	751	574	24	652	13
M323F1	AGOKFOE	B	3.94	3.13	6.61	0.0072	0.0073	1369	1282	6	1258	8
M324F1	ATIKOLE	B	9.38	5.76	8.61	0.0394	0.0146	2381	1200	50	1945	18
M324F2	ATIKOLE	B	8.28	5.59	14.18	0.0215	0.0182	2810	2247	20	2100	25
M325F1	ASSI KEVE	B	1.70	1.81	2.39	0.0072	0.0036	591	3448	-83	579	2
M326F1	NYANYETCHI	B	2.40	2.63	4.74	0.0107	0.0036	978	840	14	720	26
M327F1	BEDJENE	B	1.20	0.74	0.76	0.0036	0.0073	273	312	-12		100
M327F3	BEDJENE	B	1.15	0.49	1.22	0.0036	0.0036	287	285	1	272	5
M328F1	AGANANE	B	2.30	2.63	5.57	0.0036	0.0036	1050	1148	-9	916	13
M329F1	AGBODJEFKFOE	B	2.74	2.39	2.17	0.0072	0.0036	732	578	21	620	15
M329F2	AGBODJEFKFOE	B	3.19	2.30	2.26	0.0143	0.0073	778	591	24	602	23
M330F2	ATINDO	B	9.28	7.82	10.83	0.0107	0.0182	2796	395	86	2370	15
M331F1	MOTSI	B	3.34	2.80	2.91	0.0072	0.0073	907	1200	-24	601	34
M332F1	BEGBE	B	1.90	8.06	1.33	0.0107	0.0073	1133	980	13		
M333F2	GAMBE KOVE	B	1.75	1.73	6.09	0.0036	0.0036	957	870	9		
M333F3	GAMBE KOVE	B	1.50	1.97	6.48	0.0072	0.0036	996	869	13	916	8
M334F1	YOTO KOPE	B	3.29	2.80	3.74	0.0107	0.0036	985	800	19		
M334F2	YOTO KOPE	B	3.49	3.37	4.26	0.0036	0.0036	1114	925	17		

#	VILLAGE	GEO.	Ca++ (ppm)	Mg++ (ppm)	Na+ (ppm)	Fe++ (ppm)	Mn++ (ppm)	CAT-100 (ppm)	CONDn (uS/cm)	DIFn %	CONDn (uS/cm)	DIFn %
M334F3	YOTO KOPE	B	2.59	2.47	4.39	0.0076	0.0076	946	899	26		
M334F5	YOTO KOPE	B	3.64	3.70	4.05	0.0036	0.0073	1140	892	22		
M335F1	MAIKOU KOPE	B	2.10	2.39	4.26	0.0036	0.0036	875	1400	-57		
M336F4	ADJA KOPE	B	15.47	10.12	8.31	0.0107	0.0437	3395	3070	11	2430	28
M336F5	ADJA KOPE	B	15.82	10.37	8.44	0.0072	0.0546	3466	2941	15	2600	25
M337F1	NAHO KPODJI	B	3.74	2.14	3.70	0.0036	0.0162	960	746	22		
M337F4	NAHO KPODJI	B	4.64	2.39	2.96	0.0036	0.0072	940	827	11		
M338F2	AVEDJE	B	7.14	3.46	5.00	0.0036	0.0291	1563	1449	7	1391	11
M338F3	AVEDJE	B	6.34	4.11	3.87	0.0036	0.0146	1434	1351	6	1279	11
M339F1	NOUSROU KOPE	B	3.54	2.71	1.87	0.0000	0.0000	813	675	17		
M346F1	TEDAHOE	B	3.99	3.46	5.00	0.0215	0.0036	1247	1000	20	969	22
M347F1	ALLAGBADJA	B	5.49	3.21	6.61	0.0072	0.0218	1574	1315	14	1076	30
M348F2	BAKA KOPE	B	7.53	4.20	5.35	0.0143	0.0291	1712	1553	10	1228	38
M348F3	BAKA KOPE	B	6.99	3.87	4.61	0.0036	0.0255	1549	1250	19	1447	7
M350F1	ADABADJI KONDJI	S	0.40	0.25	0.46	0.0072	0.0109	114	109	5		
M350F2	ADABADJI KONDJI	S	0.40	0.25	0.46	0.0072	0.0109	114	110	4		
M351F1	AFANTODJI KONDJI	S	0.45	0.25	0.74	0.0072	0.0036	145	107	26		
M351F2	AFANTODJI KONDJI	S	0.45	0.25	0.70	0.0107	0.0109	141	117	17		
M352F1	TONA KONDJI	S	0.25	0.16	0.83	0.0107	0.0000	125	78	36		
M352F2	TONA KONDJI	S	0.60	0.66	0.52	0.0036	0.0036	179	119	33	137	23
M353F1	TSEVI KONDJI	S	0.35	0.16	0.52	0.0107	0.0036	105	50	24		
M354F1	ADGSSI KONDJI	S	0.55	0.25	1.22	0.2665	0.0036	230	110	52		
M358F1	AKLOBI KONDJI	S	0.55	0.25	1.22	0.0286	0.0036	205	106	48		
M359F1	KOTIKO KONDJI	S	0.25	0.16	0.61	0.0107	0.0000	107	75	27		
M360F1	ADJRA KOPE	S	0.45	0.25	0.74	0.0000	0.0036	144	108	25		
M363F1	AKOUTCHA KONDJI	S	0.50	0.25	0.78	0.0143	0.0000	154	106	30		
M364F4	BADA KONDJI	S	0.30	0.16	1.78	0.0072	0.0036	226	87	61		
M365F1	ADABIAN	S	0.35	0.25	0.61	0.0072	0.0036	122	125	-3		
M366F1	DJATA KOPE	S	1.25	0.33	0.30	0.0788	0.0109	297	279	6		
M367F1	SETEKPO	S	2.25	0.33	0.61	0.0215	0.0109	322	285	11		
M367F2	SETEKPO	S	0.25	0.16	0.78	0.0107	0.0036	121	92	24		
M368F1	ZOTI KOPE	S	0.35	0.16	0.61	0.0107	0.0073	114	125	-9		
M369F1	AKOUDOKPO	S	0.15	0.08	0.65	0.0072	0.0036	90	74	17		
M370F1	KPESSE KOPE	S	0.10	0.08	0.83	0.0072	0.0036	102	57	44		
M370F2	KPESSE KOPE	S	0.15	0.06	0.30	0.0107	0.0036	55	58	-5		
M371F1	AVEDJI	S	1.90	0.41	0.61	0.0107	0.0182	295	257	14		
M372F1	DAVOU	S	0.60	0.16	0.91	0.0537	0.0036	173	138	30		
M374F1	GATI AKPAFOU	S	0.40	0.16	1.04	0.0036	0.0036	161	102	37	119	26
M375F1	FONGBE BOETI	S	0.65	0.25	1.00	0.0036	0.0109	191	155	19		
M376F2	ANYAVE	S	3.74	0.49	1.13	0.0036	0.0036	537	400	26		
M377F1	ADETI KOPE	S	1.35	0.49	0.74	0.0215	0.0036	261	235	10	238	9
M377F2	ADETI KOPE	S	1.45	0.58	0.30	0.0036	0.0036	233	212	9	210	10
M378F1	ADJOGUIDI	S	3.69	1.32	1.44	0.0286	0.0036	546	540	17	400	38
M378F2	ADJOGUIDI	S	6.04	1.97	2.70	0.0645	0.0036	1078	620	23	637	41
M379F1	LOME ATTITEBOME	S	1.30	0.16	0.61	0.0143	0.0073	209	200	4	474	-56
M380F1	LOME	S	5.14	2.80	2.52	0.0286	0.0073	1030	673	21	670	36
M381F1	TOUNOUKOUTI	S	4.24	2.55	11.79	0.0251	0.0036	1661	740	60	668	64
M382F1	ALLAGBADJA	S	1.35	0.16	0.46	0.0215	0.0072	262	202	0	153	24
M383F1	MOE KOPE	S	3.94	0.74	1.37	0.0537	0.0073	661	526	20	493	25
M384F2	ADIDOME	S	1.15	0.49	1.30	0.0036	0.0036	395	526	-25	371	6
M384F3	ADIDOME	S	2.30	0.41	1.64	0.0036	0.0036	376	400	-5	390	-4

#	VILLAGE	SEOL	Ca++ (ppm)	Mg++ (ppm)	Na++ (ppm)	Fe++ (ppm)	Mn++ (ppm)	24°+100 (ppm)	CONDn (uS/cm)	D1Pn %	CONDn LE cm	D1Pn %
M385F1	SEVA	5	1.10	0.41	1.79	0.0070	0.0070	261	232	21	258	12
M385F2	SEVA	5	1.45	0.41	0.96	0.0070	0.0070	282	222	19	270	4
M386F1	TEDO	5	1.55	0.82	1.30	0.0070	0.0040	272	244	8		
M387F1	ATIDE AFEDOME	5	1.35	0.33	0.83	0.0070	0.0070	251	222	12	257	10
M387F2	ATIDE AFEDOME	5	1.30	0.25	0.96	0.0070	0.0070	251	227	17	212	8
M388F1	AFRANITO	5	4.59	0.82	1.52	0.0070	0.0070	708	555	22	782	40
M391F1	LOMEGNAN KOPE	5	1.95	0.41	0.91	0.0070	0.0070	728	250	14	244	20
M396F1	FONGRE AFEDOME	5	0.30	0.10	0.52	0.0066	0.0070	192	112	-10		
M396F2	FONGRE AFEDOME	5	0.30	0.16	0.30	0.0070	0.0070	78	95	-12		
M397F1	KORO	5	1.25	0.49	1.49	0.0066	0.0070	266	235	26	320	17
M397F2	KORO	5	1.25	0.33	1.87	0.0051	0.0070	207	253	14		
M398F1	AZI KONGE	5	0.65	0.33	0.65	0.0070	0.0070	104	117	21	125	22
M399F1	SABADJIN	5	1.70	0.25	0.51	0.0049	0.0073	285	230	12		
M401F1	WRESSIJE	5	2.25	2.06	2.46	0.0143	0.0077	641	470	20	522	18
M402F1	GAZATGE	5	2.19	4.20	2.70	0.0070	0.0140	1110	552	14	779	30
M403F1	KEDJJI	5	2.75	2.55	1.70	0.0107	0.0073	706	641	9	669	5
M407F1	KEDJJI	5	6.74	9.45	5.22	0.0072	0.0070	2102	1886	10	1247	41
M404F2	AFIADENYIGEN	5	4.09	4.44	5.39	0.0070	0.0070	1060	1000	27	928	32
M405F1	ATCHAVE BEAF	5	4.24	5.92	3.16	0.0107	0.0146	1337	1163	11	1385	-3
M405F2	ATCHAVE BEAF	5	5.44	6.58	4.74	0.0070	0.0070	1677	1390	17	1267	24
M406F1	SANOUTA	5	2.79	5.25	6.61	0.0072	0.0073	1867	1574	16	1547	17
M407F2	BEDJRA KOPE	5	6.54	4.11	6.70	0.0072	0.0218	1938	1876	3	1956	-1
M407F3	BEDJRA KOPE	5	6.54	4.11	6.70	0.0107	0.0218	1938	1724	11	2040	-5
M408F1	AGOHOME	5	7.46	4.77	6.48	0.0072	0.0109	1925	1574	18		
M409F1	KLOMEFOE	5	8.00	4.55	5.79	0.0215	0.0109	1931	1612	17		
M410F1	HEYFOU	5	6.29	6.25	7.10	0.0252	0.0723	2027	1626	20		
M411F1	KLENE	5	6.30	6.75	6.44	0.0215	0.0182	2356	2000	15		
M417F1	KPEDOME	5	3.19	2.71	3.48	0.0070	0.0070	940	657	30	666	29
M418F1	HEDJENE	5	4.94	4.85	5.22	0.0070	0.0218	1604	1250	22	1137	29
M419F2	DONO	5	4.09	2.96	2.87	0.0072	0.0070	994	740	20	622	34
M420F2	ETOE KOPE	5	2.05	1.50	3.61	0.0070	0.0070	727	555	23	1023	-29
M420F3	ETOE KOPE	5	2.24	2.39	4.96	0.0004	0.0070	1059	973	8	1264	-16
M421F1	VAUATEI	5	5.54	4.94	6.74	0.0072	0.0073	1723	1470	15	1524	12
M422F1	BATOME	5	4.09	2.37	4.05	0.0070	0.0073	1152	909	21	750	37
M424F1	KOFOE	5	3.79	2.63	5.70	0.0072	0.0109	1214	952	20	906	25
M426F1	HEFDOE	5	5.94	4.44	6.31	0.0107	0.0146	1771	1567	6	1143	25
M426F2	HEFDOE	5	3.79	2.63	5.61	0.0072	0.0109	1205	950	19	918	24
M427F2	GUENDJI	5	6.74	3.95	1.65	0.0070	0.0291	1227	1242	-2	1060	14
M432F1	AZI KOPE	5	1.95	1.15	0.96	0.0070	0.0070	406	370	9		130
M436F1	NYIGRE 1	5	2.69	2.71	2.35	0.0070	0.0064	780	660	15	774	1
M436F2	NYIGRE 2	5	2.29	2.30	2.91	0.0070	0.0073	650	618	4	667	23
M437F1	DEKAME	5	2.40	4.28	5.10	0.0070	0.0070	1181	1176	0	997	16
M439F1	AGBLEVE	5	3.29	2.14	2.48	0.0070	0.0109	812	714	11	622	23
M441F1	BAPE KOPE	5	2.84	2.95	3.22	0.0072	0.0077	804	512	26	770	4
M441F2	BAPE KOPE	5	2.24	2.46	3.04	0.0070	0.0073	925	740	25	717	23
M442F1	TODOME	5	2.69	1.89	3.22	0.0070	0.0109	802	537	8	1016	-31
M442F2	TODOME	5	2.84	1.89	3.12	0.0070	0.0109	868	533	8	1175	-22
M443F1	LONVO	5	3.48	5.10	1.57	0.0070	0.0070	1216	1000	16		
M445F1	KOUTOU KOPE	5	2.64	2.55	2.44	0.0072	0.0070	864	740	14	748	13
M446F1	KOFOE	5	3.79	5.59	20.00	0.0107	0.0146	2267	1821	57	1270	61
M445F2	DZIVATGE	5	4.65	1.40	14.44	0.0072	0.0070	2054	770	63		

	VILLAGE	SEX	Age (yrs)	Wgt (kg)	Hgt (cm)	Arm (cm)	Wrist (cm)	Mid arm (cm)	Hand (cm)	Forearm (cm)	Mid leg (cm)	Calf (cm)	Heel (cm)
M467F1	AGBLEVOU	S	2.24	3.17	1.17	1.138	1.115	34	33	-			
M468F1	MODENOU	S	2.24	3.41	1.22	1.117	1.100	34	33	-	125	10	
M469F1	KPALA	S	2.40	3.17	1.13	1.100	1.080	28	28	15	10	-1	
M470F1	AKALA	S	2.00	3.25	1.19	1.100	1.100	27	27	-10	11	-1	
M471F1	MESSENG KONTI	S	2.00	3.25	1.19	1.100	1.100	27	27	-11	11	-1	
M472F1	AFIKOU KONDJI	S	2.25	3.12	1.14	1.125	1.100	28	28	-1	10	-1	
M473F1	AKLADIENOL	S	2.40	3.25	1.25	1.100	1.100	31	31	-14	11	-15	

NEW DATA (from MGRM and SSC)

M165F2	AGBESSIA	S	4.59	6.35	2.17	0.0075	0.0075	197	187	41	1250	37	
M166F2	AGBAGUANEKEN	S	2.10	6.35	2.10	0.0072	0.0075	114	98	22	846	26	
M175F2	VOTO	S	2.75	3.78	1.14	0.0072	0.0073	2169	1917	11	1740	20	
M175F3	VOTO	S	2.59	3.67	1.12	0.0039	0.0073	1575	1065	31	1710	-8	
M164F3	FONGBE DZOGEEUJI	S	2.79	0.58	0.46	0.0000	0.0036	385	98	75	100	74	
M410F1	HEKEDUI	S	5.69	5.50	2.12	0.1250	0.0728	2056	1626	21			
M443F1	LONVO	S	4.59	6.95	1.57	0.0036	0.0036	1225	1000	18			

APPENDIX 5. SUMMARY OF CHECKS

#	well number
VILLAGE	village name
MOOT-	bicarbonate-calculated
CHEM 1	check 1 - Appendix D1 - using old and new conductivities
CHEM 2	check 2 - Appendix A1 - using old and new conductivities
SUMMARY	summary of checks
-O-	chemical analysis acceptable
-X-	chemical analysis unacceptable
-X old O-	new values unacceptable due to previous analysis acceptable
-replace-	replace with new analysis from same well

#	VILLAGE	MOOT- calc	CHEM 1		CHEM 2		SUMMARY
			old	new	old	new	
M010F0	TOHE-PO HANGAL	36	8		8		OK
M010F0	TOHE-PO DELE	119	11		9		OK
M010F0	TOHE-PO DELE	149	17		12		OK
M010F4	TOHE-PO DELE	-12	-34		-95		X
M010F0	AGBELOUVE	417	36		40		X
M010F4	AGBELOUVE	158	-30	-6	-26	-8	OK
M010F5	AGBELOUVE	362	9	35	8	34	X but OK
M020F0	NYASSIVE	26	-18	-27	-10	-16	OK
M020F0	NYASSIVE	35	-18	-31	-5	-22	OK
M020F4	NYASSIVE	228	-7	-20	-1	-17	OK
M020F2	AGRESSIA	227	6	-1	2	-5	OK
M020F4	AGRESSIA	497	22	30	27	31	X
M020F0	AGNRON	289	12		16		OK
M020F1	AGNRON	281	13	3	15	5	OK
M020F0	AVETA	229	10	-8	16	-2	OK
M020F0	BATOUNE	304	16	-22	15	-23	OK
M100F0	AMEGNONA KOPE	89	50		47		X
M110F0	NYIGBE 1	286	16	-10	10	-15	OK
M115F0	TOKPEVIA	115	16		23		OK
M115F4	TOKPEVIA	256	4	17	9	21	OK
M120F0	TOVEGAN	655	26	31	25	30	X
M120F4	TOVEGAN	433	24	4	26	6	OK
M140F0	AGBOZONE	287	16	8	15	6	OK
M160F0	AGBADJANE-EN	556	34	37	29	32	X
M170F0	YOTO	407	18	26	21	29	OK
M170F3	YOTO	303	22	-18	22	-18	OK
M180F0	AMOLOU KOPE	230	-6	-13	-3	-10	OK
M180F4	AMOLOU KOPE	309	-22	-6	-22	-5	OK
M180F0	GATTI AGODO	70	9	-5	11	-2	OK
M180F0	GATTI AGODO	39	-4	-18	2	-13	OK
M180F0	GATTI SCUN	49	6		10		OK
M180F0	GATTI SCUN	27	22	20	26	26	OK
M184F0	FONGBE DIOGRED	-106	59	59	-1	-3	X
M186F0	SEDJRO	268	77		75		X
M186F0	SEDJRO	196	31		25		OK
M189F0	AMEGBLENE	131	61	56	57	54	X

#	VILLAGE	MOON- (1990)	CHED: 1		CHED: 2		SUMMARY
			old	new	old	new	
M237F3	ALDYI	579	26	15	27	15	OK
M237F4	ALDYI	518	15	15	17	15	OK
M201F1	AFOKPONAVE	267	17	20	17	20	OK
M201F2	AFOKPONAVE	357	9	10	8	10	OK
M201F3	AWADIVE	509	24	25	21	25	OK
M201F4	AKPAPEDOME	-179	-27	-25	-19	-25	OK
M204F1	KOEVE	408	10	8	11	8	OK
M206F1	ABBETIME	211	11	10	11	10	OK
M207F1	DIAPPO	224	7	10	7	10	OK
M208F1	TSUETH	328	9	11	10	11	OK
M209F1	EGBE	400	40	41	40	41	OK
M209F2	EGBE	104	-33	17	-37	5	OK
M210F2	TOUNOUMASSE	317	8	25	9	25	OK
M211F1	AKOU KOPE	70	-5	-10	4	-11	OK
M212F1	AKPAVE KOPE	146	1	3	0	12	OK
M212F2	AGOKPE	310	-1	-4	0	3	OK
M214F2	GAMEGBLE	204	13	26	7	20	OK
M214F3	GAMEGBLE	287	-50	-32	-51	-35	OK
M214F5	GAMEGBLE	253	13	24	11	23	OK
M213F1	TSINGGE	462	11	14	10	17	OK
M213F2	TSINGGE	465	16	23	16	26	OK
M216F1	AGADJAKPE	545	19	3	19	7	OK
M217F1	TITONOU	-421	-7	21	-21	-10	OK
M219F1	YOUNOUNKOE	400	17	10	17	10	OK
M219F2	PLABA	487	8	10	10	17	OK
M220F1	AGBODJEPFO	260	9	12	10	16	OK
M220F2	AGBODJEPFO	299	7	16	17	19	OK
M221F1	KOTSO KOPE	372	24	26	18	21	OK
M221F4	KOTSO KOPE	305	-47	25	-46	26	OK
M222F1	AMAVEGAN	30	4	43	24	17	OK
M223F1	AGOKPOE	340	1	7	6	9	OK
M224F1	ATIKOLE	358	46	10	50	18	OK
M224F2	ATIKOLE	408	10	22	20	25	OK
M225F1	ASSI KEVE	229	-87	4	-87	2	OK
M225F2	NYANYETCHI	344	15	27	14	26	OK
M227F1	BEDJEME	96	-14	4	-12	5	OK
M227F2	BEDJEME	67	-1	4	1	5	OK
M328F1	AGAMANE	417	-6	15	-9	13	OK
M329F1	AGBODJEKPOE	387	28	22	21	15	OK
M329F2	AGBODJEKPOE	444	32	31	24	23	OK
M330F2	ATINGO	570	84	6	86	15	OK
M331F1	NOTSI	481	-19	35	-24	24	OK
M332F1	BEGBE	346	6	10	13	10	OK
M333F2	GAME KOVE	310	10	7	9	6	OK
M333F3	GAME KOVE	310	12	7	12	6	OK
M334F1	YOTO KOPE	390	20	10	19	10	OK
M334F2	YOTO KOPE	375	17	10	17	10	OK
M334F3	YOTO KOPE	486	32	10	28	10	OK
M334F5	YOTO KOPE	538	27	10	22	10	OK
M335F1	MAIKOU KOPE	477	-31	10	-37	10	OK
M336F4	ADJA KOPE	428	-4	17	11	28	OK

	AGE	H000- AGE	CH200-1		CH200-2		SUMMARY
			OLD	NEW	OLD	NEW	
M336F3	ADJA KOPE	311	2	14	15	15	OK
M337F1	HANO KPOOJI	418	26		22		OK
M337F4	HANO KPOOJI	258	10		11		OK
M338F1	A EJE	417	1			11	OK
M338F2	A EJE	181	10	0	9	11	OK
M339F1	KOOSPO KOPE	219	17		17		OK
M344F1	FEA-KOE	500	22	25	22	22	OK
M347F1	ALLAGBADJA	551	16	21	14	20	X out OK
M348F1	BAKA KOPE	225	1	22	19	28	OK
M348F2	BAKA KOPE	141	17	1	19		OK
M350F1	KOHEWOTI KONDJI	28	10		5		OK
M350F2	KOHEWOTI KONDJI	27	14		1		OK
M351F1	KOHEWOTI KONDJI	19	16		26		OK
M351F2	KOHEWOTI KONDJI	55	21		17		OK
M352F1	KONA KONDJI	-	-52		26		X
M352F2	KONA KONDJI	21	23	27	23	23	OK
M353F1	FEETI KONDJI	27	24		24		OK
M354F1	ADISSI KONDJI	-	-35		52		X
M355F1	LOBO KOPE	-	-27				X
M356F1	SEBEMINA KONDJI	-	-71				X
M357F1	A PLAGASSOU	-	-70				X
M358F1	A LCH KONDJI	44	52		48		X
M359F1	KUTIND KONDJI	12	17		27		OK
M360F1	KOORA KOPE	50	25		25		OK
M361F1	ADETI KONDJI	-	-52				X
M363F1	A DUTCHA KONDJI	56	31		20		OK
M364F1	BADU KONDJI	95	64		61		X
M365F1	ADARIAN	5	-21		-3		OK
M366F1	DJATA KOPE	110	10		6		OK
M367F1	SETERPO	130	16		11		OK
M367F2	SETERPO	-16	26		24		OK
M368F1	ZOTI KOPE	17	-19		-9		OK
M369F1	A OUDOKPO	-9	14		17		OK
M370F1	KRESSE KOPE	19	42		44		X
M370F2	KRESSE KOPE	4	-19		-5		OK
M371F1	AVEDI	124	17		14		OK
M372F1	DAVOU	21	15		20		OK
M374F1	GATI AKFAFOU	57	38	28	37	26	OK
M375F1	FONGBE BOETI	65	21		19		OK
M376F2	ANYAVE	253	22		26		OK
M377F1	ADETI KOPE	77	8		10		OK
M377F2	ADETI KOPE	65	6	7	9	10	OK
M378F1	ADJOGUIDI	250	19	40	17	36	X out OK
M378F2	ADJOGUIDI	459	27	44	23	41	X out OK
M379F1	LOME ATITTESOM	70	6	-55	4	-56	X
M380F1	LOME	411	22	38	21	36	X out OK
M381F1	TOUNOUKOUTI	904	64	68	60	64	X
M382F1	ALLAGBADJA	66	1	25	0	24	OK
M383F1	MOE KOPE	262	24	29	20	25	OK
M384F2	ADIDOME	70	-29	0	-25	5	OK
M384F3	ADIDOME	60	-10	-11	-6	-4	OK

#	VILLAGE	HCOT- (PRM)	CHECK 1		CHECK 2		SUMMARY
			old	new	old	new	
M385F1	SEVA	88	22	14	2	12	
M385F2	SEVA	106	21		12		
M386F1	TEDO	75	8		6		
M387F1	ATTIE APEDOME	70	11	-7	12		
M387F2	ATTIE APEDOME	71	10	8	1	2	
M388F1	AKRANITO	295	26	49	22	46	
M391F1	LOMEGNAN KOPE	127	27	29	24	25	
M396F1	FONGBE APEDOME	4	-19		-1		
M396F2	FONGBE APEDOME	-7	-27		-16		
M397F1	YOB0	180	20	21	26	17	OK
M397F2	YOB0	177	20		14		OK
M398F1	AI GONDJI	72	28	19	21	22	OK
M399F1	GABADJIN	45	9		12		OK
M401F1	AMESSI-PE	304	30	24	26	14	OK
M402F1	GAZATOE	439	15	30	14	30	OK but OK
M403F1	KPODJI	324	5	1	9	5	OK
M403F2	KPODJI	386	3	36	10	41	OK but OK
M404F2	AFIADENYISBA	713	34	39	27	32	
M405F1	ATCHAVE GBAPA	315	1	-13	11	-7	OK
M405F2	ATCHAVE GBAPA	418	10	16	17	24	OK
M406F1	SANDUTA	611	16	17	16	17	OK
M407F2	BEDJRA KOPE	255	-4	-8	3	-1	OK
M407F3	BEDJRA KOPE	276	5	-11	11	-5	OK
M408F1	AGGHOME	197	10		18		OK
M409F1	KLOMEPOE	357	13		17		OK
M410F1	HEKFOUI	126	13		21		OK
M411F1	HLEME	442	9		15		OK
M417F1	KPEDOME	405	33	32	30	29	
M419F1	MEDJENE	566	23	30	22	29	OK
M419F2	DONO	359	26	35	26	34	
M420F2	ETOE KOPE	327	29	-23	23	-29	OK
M420F3	ETOE KOPE	317	6	-17	8	-18	OK
M421F1	VAVATSI	12	0	-3	15	12	OK
M422F1	BATOUNE	486	23	38	21	37	OK but OK
M424F1	FOKPO	382	22	26	22	35	OK
M426F1	HEKPOE	364	-6	31	0	35	OK but OK
M426F2	HEKPOE	369	19	24	19	24	OK
M427F2	GUENDJI	120	-18	3	-9	14	OK
M432F1	AZI KOPE	113	10		9		OK
M436F1	NYIGBE 2	173	8	-7	15	1	OK
M436F2	NYIGBE 2	301	5	23	4	23	OK
M437F1	DEKAME	259	-6	10	0	16	OK
M439F1	AGBLEVE	313	14	25	11	23	OK
M441F1	GAPE KOPE	402	40	15	36	9	OK
M441F2	GAPE KOPE	455	28	31	25	28	
M442F1	TODOME	306	8	-31	8	-31	
M442F2	TODOME	312	7	-21	6	-22	OK
M443F1	LONVO	419	20		18		OK
M445F1	TOUTOU KOPE	373	17	16	14	13	OK
M446F1	KPOTA	1500	60	64	57	61	
M465F1	DZOVADE	964	66		63		

#	VILLAGE	HCOS- (age)	CHECK 1		CHECK 2		SUMMARY
			old	new	old	new	
M467F1	AGBLEVOU	283	7		-2		OK
M468F1	MODENDU	139	14	24 ?	9	20	OK
M469F1	KPALA	52	12	-23 ?	16	-20	OK
M469F2	KPALA	41	-16	-37 ?	-10	-31 ?	X
M470F1	MESSEKO KONDJI	30	-16	-2	-11	3	OK
M471F1	AFI*OU KONDJI	-63	28 ?	24 ?	-2	-7	X
M472F1	A*LAJENDU	9	-26 ?	-79 ?	-14	-75 ?	A

NEW DATA (from MGRM and GSC)

M021F4	NYASSIVE	82	-3	-16			OK
	old data:	228	-7	-20 ?	-5	-17	replace
M026F2	AGEESSIA	391	21 ?	15	41 ?	37 ?	X
	old data:	227	6	-1	2	-5	OK
M165F2	AGBADJANEKEN	308	-12	-6	22 ?	26 ?	OK
	old data:	556	34 ?	37 ?	29 ?	32 ?	X, replace
M175F2	VOTO	264	-11	-2	11	30 ?	OK
	old data:	407	16	26 ?	21 ?	29 ?	replace
M175F3	VOTO	270	11	-29 ?	21 ?	-6	OK
	old data:	200	27 ?	-18	22 ?	-16	replace
M182F1	SATI AGOOU	74	-	-11			OK
	old data:	0-	-4	-16	2	-13	replace
M184F1	FIORRE DUSHED	94	68	64 ?	13 ?	74 ?	X
	old data:	-106	56 ?	59 ?	-1	-3	X
M211F1	APPALE KOFI	477	7	10			OK
	old data:	198	1	0	9	12	replace
M211F2	ATIME	815	68 ?	12			OK
	old data:	570	64 ?	6	66 ?	15	replace
M224F1	SATI AKAFOU	66	41 ?	22 ?			X
	old data:	57	36 ?	28 ?	37 ?	26 ?	OK
M225F1	LOWE ATTITEBOM	52	1	-56 ?			X
	old data:	70	6	-55 ?	4	-56 ?	X
M285F1	SEVA	127	27 ?	20 ?			OK
	old data:	86	22 ?	14	20 ?	12	replace
M407F1	BEDURA KOFI	203	5	-11			OK
	old data:	276	5	-11	11	-5	replace
M410F1	HEKPOUI	291	0		21 ?		OK
	old data:	126	12		20 ?		replace
M443F1	LONVO	230	-8		18		OK
	old data:	419	20 ?		18		replace
M470F1	MESSEKO KONDJI	51	-6	8			OK
	old data:	30	-16	-2	-11	3	replace
M471F1	AFI*OU KONDJI	33	0	-6			OK
	old data:	-63	28 ?	24 ?	-2	-7	X, replace

APPENDIX 6. REVISED WATER CHEMISTRY DATA

(after Geomines (1987) and Appendix 5)

well number
 VILLAGE village name
 GEOL geology (B = bedrock, S = sediments)
 COND conductivity (microSiemens per centimetre)
 Ca++ calcium
 Mg++ magnesium
 Na+ sodium
 Fe++ iron
 Mn++ manganese
 HCO3- bicarbonate-calculated (negative values replaced by 0)
 SO4= sulphate
 Cl- chloride
 NO3- nitrate
 F- fluoride

#	VILLAGE	GEOL	COND (uS/cm)	Ca++ (ppm)	Mg++ (ppm)	Na+ (ppm)	Fe++ (ppm)	Mn++ (ppm)	HCO3- (ppm)	SO4= (ppm)	Cl- (ppm)	NO3- (ppm)	F- (ppm)
M010F2	TCHERPO ANAGALI	S	100	10	4	15	0.30	0.30	00	0	25	0.0	0.43
M011F2	TCHERPO DEVE	S	278	45	4	7	2.20	0.20	119	17	23	0.0	0.27
M011F3	TCHERPO DEVE	S	306	49	5	14	0.00	0.20	149	18	23	0.1	0.45
M011F4	TCHERPO DEVE	S	1116	7	2	0	0.10	0.10	-32101	19	29	0.7	0.13
M013F3	AGBELOUVE	B	820	95	36	136	0.10	0.10	417	0	241	0.0	0.00
M013F4	AGBELOUVE	B	894	53	30	77	0.10	0.00	255	0	152	0.0	0.00
M013F5	AGBELOUVE	B	952	96	20	89	0.10	0.20	362	38	127	0.2	0.26
M021F2	NYASSIVE	B	809	46	32	43	0.10	0.25	86	113	101	12.5	0.00
M021F3	NYASSIVE	B	817	36	26	54	0.26	0.26	35	146	93	4.2	0.00
M021F4	NYASSIVE	B	856	51	23	60	0.10	0.40	82	17	81	189.0	0.51
M026F2	AGBESSIA	B	1250	35	19	196	0.10	0.10	227	1	152	230.0	2.10
M026F4	AGBESSIA	B	1271	138	72	129	0.10	0.10	497	295	145	0.0	1.07
M029F3	AGNRON	B	833	66	45	66	0.10	0.10	289	53	142	0.0	0.40
M029F4	AGNRON	B	844	69	37	55	0.10	0.10	281	44	113	10.2	0.41
M039F2	AVETA	S	1010	86	30	72	0.40	0.20	229	47	182	0.0	0.84
M098F2	BATOUNE	B	1093	45	21	101	0.10	0.10	304	19	106	0.0	0.18
M100F2	AMEGNONA KOPE	S	111	11	3	29	0.00	0.20	89	7	17	0.0	0.00
M113F2	NYIGBE 1	B	763	44	15	70	0.20	0.20	286	6	57	4.0	0.00
M113F3	TOKPEVIA	B	1166	129	37	131	0.20	0.70	115	315	240	0.0	0.00
M113F4	TOKPEVIA	B	1165	117	35	140	0.10	0.00	256	220	214	0.5	0.50
M120F3	TONEGAN	B	1589	71	49	348	0.10	0.10	655	248	237	5.5	1.00
M120F4	TONEGAN	B	1898	38	48	338	0.10	0.10	433	170	338	22.0	0.44
M148F2	AGBOZONE	B	722	44	22	85	0.20	0.10	287	19	92	0.0	0.24
M163F2	AGBADJANEKEN	B	846	42	77	69	0.20	0.10	308	7	42	0.0	0.60
M175F2	YOTO	B	1740	56	46	347	0.2	0.20	204	75	402	1.25	1.88
M175F3	YOTO	B	1710	54	47	211	0.11	0.20	270	115	153	1.25	3.13
M180F2	AHLOU KOPE	B	945	55	35	65	0.10	0.41	230	57	117	12.5	0.00
M180F4	AHLOU KOPE	B	976	50	30	98	0.10	0.10	305	22	131	0.0	0.00
M182F2	GATI AGODO	S	426	33	12	35	0.40	0.10	70	26	61	44.0	0.13
M182F3	GATI AGODO	S	458	32	12	32	0.40	0.10	74	25	40	69.0	0.28
M183F2	GATI SOUN	S	82ppt	31	11	35	0.40	0.10	49	38	61	42.0	0.12

VILLAGE	GEOLOGICAL	COND	Ca++	Mg++	Na+	Fe++	Mn++	-CO3-	SO4=	Cl-	NO3-	F-
	(uS/cm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)
M183F3 GATI SOUN	5	104	8	2	19	0.10	0.10	27	13	24	0.0	0.10
M184F3 FONGBE DZOGBEDJI	5	100	6	2	11	0.80	0.10	-106(0)	3	24	122.0	0.21
M186F2 SEDJRO	5	131	81	6	15	1.00	0.10	268	8	23	0.4	0.31
M186F3 SEDJRO	5	703	60	5	14	1.00	0.10	146	9	27	0.0	0.23
M189F2 AMEGBLEVE	5	173	10	2	48	0.20	0.10	101	0	25	0.1	0.15
M237F2 ALOYI	8	1287	77	46	171	0.10	0.10	539	159	104	0.0	0.00
M237F4 ALOYI	8	1284	75	44	170	0.20	0.10	518	155	108	0.0	0.00
M201F1 AFOKPONAVE	8	599	50	26	76	0.20	0.10	367	9	62	0.0	0.00
M201F2 AFOKPONAVE	8	892	79	39	50	0.10	0.40	353	0	97	0.0	0.00
M202F1 ANAZIVE	8	1000	81	39	125	0.50	0.76	509	20	138	0.0	0.00
M202F4 ANPAREDOME	8	1557	65	38	120	1.30	0.40	-79(0)	329	216	0.0	0.60
M204F1 MOEVE	8	1230	174	39	87	0.10	0.50	405	132	153	0.0	0.00
M206F1 AGGETIME	8	617	68	25	26	0.20	0.30	311	0	53	0.0	0.00
M207F1 DZAH PO	8	679	52	29	110	0.30	0.22	264	143	88	0.0	0.00
M208F1 TSUETA	8	1172	136	57	96	0.60	0.30	225	441	100	0.0	0.00
M209F1 EGBE	8	790	66	30	192	0.10	0.10	400	116	181	0.0	0.00
M209F2 EGBE	8	778	47	35	67	0.30	0.40	104	85	166	0.0	0.26
M210F2 TOUNGUMASSE	9	745	100	35	49	0.30	0.20	217	92	103	0.0	0.00
M211F1 AKOLI KOPE	8	1757	76	52	172	0.60	0.32	70	413	207	0.3	0.00
M212F1 AKFAVE KOPE	8	1546	124	55	148	0.60	0.45	433	246	185	1.2	0.98
M213F2 AGOKPE	8	1418	116	60	204	0.30	4.00	213	414	271	0.0	0.00
M214F2 GAMEGBLE	8	451	54	21	40	0.10	0.10	304	4	39	0.0	0.00
M214F3 GAMEGBLE	8	1006	10	38	66	0.10	0.10	267	0	64	0.0	0.00
M214F5 GAMEGBLE	8	483	46	20	50	0.90	0.30	250	0	74	0.1	0.38
M215F1 TSINGOE	8	1492	105	70	155	0.20	0.30	462	75	306	0.0	0.00
M215F2 TSINGOE	8	1230	98	62	150	0.10	0.10	465	78	239	31.0	0.77
M216F1 AGADJAKPE	8	1256	73	38	143	0.10	0.10	545	46	110	0.0	0.00
M217F1 TITONDU	8	677	27	5	100	0.30	0.30	-421(0)	23	445	0.0	0.00
M218F1 KOUBINOUKOE	8	1118	71	43	87	0.10	0.10	400	15	142	0.0	0.00
M219F1 KPLABA	8	1874	154	70	188	0.30	0.30	487	286	273	0.0	0.00
M220F1 AGBODJEKPO	8	1258	147	43	94	0.30	0.30	263	291	160	6.4	0.00
M220F2 AGBODJEKPO	8	1313	137	49	122	0.10	0.30	299	317	166	0.0	0.00
M221F3 KOTSO KOPE	8	560	61	22	75	0.50	0.20	372	32	49	0.0	0.00
M221F4 KOTSO KOPE	8	565	60	21	66	0.20	0.20	305	43	61	0.0	0.00
M223F1 ANAVEGAN	8	652	59	32	44	0.10	0.30	30	10	241	0.0	0.00
M223F1 AGOKPOE	8	1258	79	38	152	0.20	0.20	340	49	252	0.0	0.00
M224F1 ATIKOLE	8	1945	188	70	198	1.10	0.40	358	404	338	0.0	0.00
M224F2 ATIKOLE	8	2100	166	68	326	0.60	0.50	408	560	346	0.0	0.00
M225F1 ASSI KEVE	8	579	34	22	55	0.20	0.10	229	14	66	0.0	0.00
M226F1 NYANYETCHI	8	720	48	32	109	0.30	0.10	344	31	124	0.0	0.00
M227F1 BEDJENE	8	312	24	9	18	0.10	0.20	96	0	41	0.0	0.00
M227F3 BEDJENE	8	272	23	6	28	0.10	0.10	67	42	31	0.4	0.33
M228F1 AGANAHE	8	916	46	32	128	0.10	0.10	417	0	130	0.0	0.00
M229F1 AGBODJEKPOE	8	620	55	29	50	0.20	0.10	367	10	27	0.0	0.30
M229F2 AGBODJEKPOE	8	602	64	28	52	0.40	0.20	444	0	18	0.0	0.00
M230F2 ATIND	8	2270	186	95	249	0.30	0.50	815	75	448	19.0	1.75
M231F1 MOTSI	8	601	67	34	67	0.20	0.20	481	0	42	0.0	0.00
M232F1 BEGBE	8	980	36	98	31	0.30	0.20	346	52	162	0.0	0.00
M233F2 GAME KOPE	8	670	35	21	140	0.10	0.10	310	45	125	0.0	0.60
M233F3 GAME KOPE	8	916	30	24	149	0.20	0.10	310	23	155	0.0	0.48
M234F1 KOTO KOPE	8	800	66	34	86	0.30	0.10	393	0	121	0.0	0.00

#	VILLAGE	GEOLOGICAL	COND (US/CM)	Ca++ (PPM)	Mg++ (PPM)	Na+ (PPM)	Fe++ (PPM)	Mn++ (PPM)	HCO3- (PPM)	SO4=	Cl- (PPM)	NO3- (PPM)	F- (PPM)
M334F2	VOTO KOPE	B	925	70	41	98	0.10	0.10	275	77	121	0.0	0.0
M334F3	VOTO KOPE	B	699	52	30	101	0.10	0.10	466	0	57	0.0	0.0
M334F5	VOTO KOPE	B	892	71	45	97	0.10	0.20	556	77	16	0.5	0.74
M336F1	MAIKOU KOPE	B	1406	42	29	98	0.10	0.10	477	0	30	0.0	0.00
M336F4	ADJA KOPE	B	2420	310	127	191	0.30	1.20	428	178	852	0.0	0.50
M336F5	ADJA KOPE	B	2600	317	126	194	0.20	1.50	511	104	855	0.0	0.54
M337F1	HAHO KPODJI	B	746	75	26	85	0.10	0.50	409	24	65	0.0	0.0
M337F4	HAHO KPODJI	B	833	81	29	68	0.10	0.20	268	63	99	12.0	0.80
M338F2	AVEDJE	B	1391	147	42	115	0.10	0.80	417	70	260	0.0	0.00
M338F3	AVEDJE	B	1279	127	50	89	0.10	0.40	153	310	189	1.9	0.35
M339F1	NGUSROU KOPE	B	675	71	33	47	0.00	0.00	319	0	103	0.0	0.00
M346F1	TEDANOE	B	969	80	42	115	0.60	0.10	503	61	104	0.0	0.56
M347F1	ALLAGBADJA	B	1315	110	39	152	0.20	0.60	552	56	173	0.0	0.60
M348F2	BAKA KOPE	B	1226	151	51	123	0.40	0.60	226	326	234	0.0	0.56
M348F3	BAKA KOPE	B	1447	140	47	166	0.10	0.70	191	274	221	24.0	0.70
M350F1	ADABADJI KONDJI	S	109	8	3	11	0.20	0.30	28	0	24	0.0	0.00
M350F2	ADABADJI KONDJI	S	110	8	3	11	0.20	0.30	27	0	25	0.0	0.00
M351F1	AFANTODJI KONDJI	S	107	9	3	17	0.20	0.10	19	0	40	0.0	0.00
M351F2	AFANTODJI KONDJI	S	117	9	3	16	0.30	0.20	55	0	18	0.0	0.00
M352F1	TONA KONDJI	S	78	5	2	19	0.30	0.00	0	0	0	0.0	0.00
M352F2	TONA KONDJI	S	137	12	6	12	0.10	0.10	61	7	20	3.7	0.30
M353F1	TSEVI KONDJI	S	80	7	2	12	0.30	0.10	37	0	16	0.0	0.00
M354F1	ADOSSI KONDJI	S	110	11	3	28	0.00	0.10	0	0	0	0.0	0.00
M355F1	LOBO KOPE	S	90	0	0	0	0.00	0.00	0	0	21	0.0	0.00
M356F1	BRENINA KONDJI	S	90	0	0	0	0.10	0.00	0	0	18	0.0	0.00
M357F1	AKFLAGASSOU	S	90	0	0	0	0.10	0.00	0	0	19	0.0	0.00
M358F1	AKLOBI KONDJI	S	106	11	3	28	0.20	0.10	94	0	18	0.0	0.00
M359F1	KOTIKO KONDJI	S	75	5	2	14	0.30	0.00	13	0	29	0.0	0.00
M360F1	ADJRA KOPE	S	108	9	3	17	0.00	0.10	50	0	22	0.0	0.00
M362F1	ADETI KONDJI	S	90	0	0	0	0.00	0.00	0	0	24	0.0	0.00
M363F1	AKGUTCHA KONDJI	S	108	10	3	18	0.40	0.00	56	0	22	0.0	0.00
M364F1	BADA KONDJI	S	87	6	2	41	0.20	0.10	95	0	21	0.0	2.20
M365F1	ADABIAN	S	125	7	3	14	0.20	0.10	5	0	40	0.0	0.11
M366F1	DJATA KOPE	S	279	45	4	7	2.20	0.30	113	23	22	0.0	0.27
M367F1	SETEKPO	S	285	45	4	14	0.60	0.30	130	20	23	0.0	0.28
M367F2	SETEKPO	S	92	5	2	18	0.30	0.10	-16(0)	35	26	0.0	0.13
M368F1	ZOTI KOPE	S	125	7	2	14	0.30	0.20	17	0	30	0.0	0.22
M369F1	AKOUDOKPO	S	74	3	1	15	0.20	0.10	-9(0)	17	24	0.0	0.13
M370F1	KPESSE KOPE	S	57	2	1	19	0.20	0.10	19	13	15	0.0	0.16
M370F2	KPESSE KOPE	S	58	3	1	7	0.30	0.10	4	1	16	0.0	0.21
M371F1	AVEDJI	S	253	38	5	14	0.30	0.50	124	0	32	0.0	0.28
M372F1	DAVOU	S	138	12	2	21	1.50	0.10	21	31	26	0.0	0.29
M374F1	GATI AKPAFOU	S	119	8	2	24	0.10	0.10	57	0	24	0.0	0.10
M375F1	FONGBE BOETI	S	155	13	3	23	0.10	0.30	65	0	26	6.5	0.16
M376F2	ANYAVE	S	400	75	6	26	0.10	0.10	253	22	27	0.0	0.16
M377F1	ADETI KOPE	S	238	27	6	17	0.60	0.10	77	14	37	0.0	0.29
M377F2	ADETI KOPE	S	210	29	7	7	0.10	0.10	65	17	32	0.1	0.31
M378F1	ADJOGUIDI	S	540	74	16	33	0.30	0.10	250	43	52	0.0	0.24
M378F2	ADJOGUIDI	S	830	121	24	62	1.60	0.10	459	68	65	0.0	0.27
M379F1	LOWE ATTITEGOME	S	474	26	2	14	0.40	0.20	70	11	25	0.0	0.19
M380F1	LOWE	S	833	103	34	58	0.80	0.20	411	44	100	0.0	0.34

#	VILLAGE	SEDL	COND	Ca++	Mg++	Na+	Fe++	Mn++	NO3-	SO4=	Cl-	NO2-	F-
		(g/g cm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)
M381F1	TOUNOUKOUTI	S	668	85	31	271	0.70	0.11	804	54	94	0.1	0.40
M382F1	ALLAGBADJA	S	153	27	2	11	0.30	0.20	66	11	25	0.0	0.21
M383F1	MOE KOPE	S	493	79	6	43	1.50	0.20	181	1	29	0.0	0.35
M384F2	ADIDOME	S	371	43	5	20	0.10	0.10	71	42	67	1.7	0.32
M384F1	ADIDOME	S	390	46	5	24	0.10	0.10	50	39	69	0.2	0.29
M385F1	SEVA	S	255	22	3	32	0.10	0.20	137	12	14	0.2	0.29
M385F2	SEVA	S	272	29	5	22	0.10	0.10	106	7	20	5.0	0.31
M386F1	TEDO	S	344	71	10	30	0.10	1.50	75	22	46	40.0	0.22
M387F1	ATIDE APEDOME	S	257	27	4	19	0.10	0.10	72	16	33	0.9	0.32
M387F2	ATIDE APEDOME	S	232	26	7	22	0.10	0.10	71	23	29	2.3	0.29
M388F1	AFANITO	S	555	94	10	35	1.20	0.10	295	43	47	0.0	0.37
M391F1	LOMEGNAN KOPE	S	244	39	5	21	0.20	0.10	127	24	24	0.2	0.28
M396F1	FONGBE APEDOME	S	113	6	2	12	0.80	0.10	4	2	24	14.0	0.19
M396F2	FONGBE APEDOME	S	95	6	2	7	0.20	0.10	-7(0)	0	25	11.0	0.10
M397F1	YORO	S	320	45	6	25	0.80	0.10	160	18	30	0.3	0.35
M397F2	YORO	S	263	37	4	20	0.70	0.10	132	11	23	0.0	0.43
M398F1	AI KONJJI	S	128	13	4	15	0.10	0.10	32	20	22	4.1	0.30
M399F1	GBADJIN	S	256	34	3	21	1.70	0.20	45	54	37	0.4	0.39
M401F1	AMESEKPE	S	522	45	25	48	0.40	0.20	304	22	34	0.0	0.29
M402F1	GAZATOE	S	952	64	31	85	0.10	0.40	479	20	123	0.0	0.40
M403F1	KPODJI	S	669	56	21	39	0.30	0.20	224	18	105	0.0	0.91
M403F2	KPODJI	S	1666	175	110	120	0.20	0.10	586	8	398	0.0	0.48
M404F1	AFIADENVIGBA	S	928	82	54	117	0.10	0.10	713	89	2	0.0	0.56
M405F1	ATCHAVE GBABA	S	1285	85	72	73	0.30	0.40	315	10	283	0.0	0.17
M405F2	ATCHAVE GBABA	S	1267	109	80	109	0.10	0.10	418	32	327	0.5	0.41
M406F1	SANDUTA	S	1547	76	76	198	0.20	0.20	611	171	179	0.0	0.87
M407F2	BEDJRA KOPE	S	1956	171	50	200	0.20	0.20	255	314	306	0.0	0.48
M407F3	BEDJRA KOPE	S	2040	171	50	200	0.30	0.60	303	315	276	1.0	1.05
M408F1	AGHOMIE	S	1574	160	58	149	0.20	0.30	197	362	300	0.0	0.43
M409F1	KLOMEPOE	S	1612	161	59	147	0.20	0.30	357	352	217	0.0	0.44
M410F1	HEKPOUI	S	1626	134	79	164	4.70	2.00	291	277	185	0.0	0.63
M411F1	HLEME	S	2000	167	82	194	0.60	0.50	442	297	358	0.0	0.55
M417F1	KPEDOME	S	668	64	32	80	0.10	0.10	405	14	87	0.0	0.38
M418F1	HEDJENE	S	1127	99	59	143	0.10	0.60	366	104	163	0.0	0.00
M419F2	DONO	S	652	82	36	66	0.20	0.10	359	44	111	0.0	0.00
M420F2	ETOE KOPE	S	1023	41	19	83	0.10	0.10	327	20	42	16.5	0.00
M420F3	ETOE KOPE	S	1284	65	29	114	0.01	0.10	317	51	133	34.0	0.76
M421F1	WAWATSI	S	1524	111	60	155	0.20	0.20	12	335	356	0.0	0.40
M422F1	BATOUPE	S	909	82	41	93	0.10	0.20	486	0	126	0.0	0.00
M424F1	FOKPO	S	906	76	32	121	0.20	0.30	382	111	125	0.0	0.66
M426F1	HEKPOE	S	1763	139	54	145	0.30	0.40	364	170	290	0.1	0.44
M426F2	HEKPOE	S	919	76	32	129	0.20	0.30	369	109	131	0.1	0.64
M427F2	GUENDJI	S	1063	135	48	38	0.10	0.60	120	227	200	0.0	0.66
M430F1	AZI KOPE	S	370	39	14	22	0.10	0.10	113	24	41	33.0	0.42
M436F1	NYIGBE 2	S	774	54	33	54	0.10	1.00	172	54	135	0.0	0.53
M436F2	NYIGBE 2	S	660	66	28	67	0.10	0.20	173	20	102	17.0	0.53
M437F1	DENAME	S	993	46	52	118	0.10	0.10	299	49	208	0.4	0.41
M439F1	AGBLEVE	S	622	58	26	37	0.10	0.30	313	42	71	0.3	0.28
M441F1	GAPE KOPE	S	730	57	36	51	0.20	0.20	402	0	50	1.4	0.33
M441F2	GAPE KOPE	S	717	57	42	70	0.10	0.20	455	0	84	0.4	0.37
M442F1	TSDOME	S	1216	76	23	74	0.10	0.30	306	57	102	0.3	0.46

#	VILLAGE	SEDL	COND	Ca++	Mg++	Na+	Fe++	Mn++	AlO3-	SO4=	Cl-	NO3-	F-
		(US CM)		(PPM)	(PPM)	(PPM)	(PPM)	(PPM)	(PPM)	(PPM)	(PPM)	(PPM)	(PPM)
M442F2	TODONE	8	1175	77	63	72	0.10	0.11	312	27	1.5	0.5	0.45
M443F1	LONVO	3	1000	92	74	36	0.10	0.10	210	1	1.1	0.5	0.7
M445F1	TOUTOU KOPE	3	749	73	71	56	0.10	0.11	277	1	3-	1	0.21
M446F1	KROTA	3	1270	128	66	475	0.10	0.10	1500	71	22	5.5	0.1
M465F1	DZOMADJE	3	770	64	17	222	0.10	0.11	464	14	1.6	0.5	0.41
M467F1	AGBLEVOL	3	555	77	15	1	0.10	0.10	262	20	5	0.1	0.7-
M468F1	WODENOU	3	251	44	5	10	0.10	0.11	128	1	3	1	0.12
M469F1	KPALA	3	729	18	4	20	0.1	0.11	52	27	24	1.4	0.15
M469F2	KPALA	3	715	20	3	21	0.10	0.10	41	5	46	0.5	0.27
M470F1	MESSEPO KONDJI	3	112	12	3	1	0.10	0.10	51	4	8	0.5	0.15
M471F1	AFIYOG KONDJI	3	128	1	2	17	0.10	0.10	75	17	11	0.4	0.1
M477F1	AKLADJENOU	3	774	3	3	5	0.10	0.11	9	1	25	0.1	0.1

APPENDIX 7. WATER CHEMISTRY IN ASCENDING CONCENTRATION ORDER - BEDROCK

ORDER	Conductivity (uS/cm)	Ca++ (ppm)	Mg++ (ppm)	Na+ (ppm)
1	272 M327F3 BEDJEHE	1.15 M327F3 BEDJEHE	0.49 M327F3 BEDJEHE	0.78 M327F1 BEDJEHE
2	312 M327F1 BEDJEHE	1.20 M327F1 BEDJEHE	0.74 M327F1 BEDJEHE	0.96 M432F1 AZI KOPE
3	370 M432F1 AZI KOPE	1.50 M333F3 GAME KOV	1.15 M432F1 AZI KOPE	1.13 M306F1 AGBETINE
4	395 M330F2 ATIHO	1.70 M325F1 ASSI KEV	1.23 M113F2 NYIGBE 1	1.22 M327F3 BEDJEHE
5	483 M314F5 GAMEBBLE	1.75 M333F2 GAME KOV	1.56 M420F2 ETOE KOP	1.35 M332F1 BEGBE
6	491 M314F2 GAMEBBLE	1.80 M021F3 NYASSIVE	1.65 M314F5 GAMEBBLE	1.57 M443F1 LONVO
7	522 M401F1 AMESSIKP	1.90 M120F4 TOVEBAN	1.65 M013F5 AGBELOUV	1.65 M427F2 GUENDJI
8	565 M321F4 KOTSO KO	1.90 M332F1 BEGBE	1.73 M333F2 GAME KOV	1.70 M403F1 KP00JI
9	579 M325F1 ASSI KEV	1.95 M432F1 AZI KOPE	1.73 M098F2 BATOUNE	1.74 M314F2 GAMEBBLE
10	599 M301F1 AFOKPONA	2.05 M420F2 ETOE KOP	1.73 M321F4 KOTSO KO	1.87 M339F1 NOUSROU
11	602 M329F2 AGBODJEK	2.10 M165F2 AGBADJAN	1.73 M314F2 GAMEBBLE	1.87 M021F2 NYASSIVE
12	613 M306F1 AGBETINE	2.20 M148F2 AGBOZONE	1.81 M148F2 AGBOZONE	1.91 M322F1 AMAVEBAN
13	620 M329F1 AGBODJEK	2.20 M113F2 NYIGBE 1	1.81 M325F1 ASSI KEV	2.09 M401F1 AMESSIKP
14	652 M322F1 AMAVEBAN	2.25 M401F1 AMESSIKP	1.89 M442F2 TODONE	2.13 M310F2 TOUNOUNA
15	669 M403F1 KP00JI	2.25 M098F2 BATOUNE	1.89 M021F4 NYASSIVE	2.17 M329F1 AGBODJEK
16	675 M339F1 NOUSROU	2.30 M021F2 NYASSIVE	1.97 M333F3 GAME KOV	2.17 M314F5 GAMEBBLE
17	699 M334F3 YOTO KOP	2.30 M328F1 AGAMAHE	2.06 M401F1 AMESSIKP	2.17 M301F2 AFOKPONA
18	714 M439F1 AGBLEVE	2.35 M309F2 EGBE	2.06 M306F1 AGBETINE	2.26 M329F2 AGBODJEK
19	720 M326F1 NYANYETC	2.40 M437F1 DEKAME	2.14 M439F1 AGBLEVE	2.35 M436F1 NYIGBE 2
20	722 M148F2 AGBOZONE	2.40 M326F1 NYANYETC	2.14 M021F3 NYASSIVE	2.35 M021F3 NYASSIVE
21	730 M441F2 GAPE KOV	2.40 M314F5 GAMEBBLE	2.14 M301F1 AFOKPONA	2.39 M325F1 ASSI KEV
22	740 M021F4 NYASSIVE	2.50 M301F1 AFOKPONA	2.14 M337F1 HANO KPO	2.39 M029F4 AGNRON
23	746 M337F1 HANO KPO	2.50 M180F4 AHLOU K	2.30 M436F2 NYIGBE 2	2.44 M445F1 TOUTOU K
24	748 M445F1 TOUTOU K	2.54 M021F4 NYASSIVE	2.30 M329F2 AGBODJEK	2.48 M439F1 AGBLEVE
25	763 M113F2 NYIGBE 1	2.59 M334F3 YOTO KOP	2.39 M329F1 AGBODJEK	2.61 M021F4 NYASSIVE
26	774 M436F1 NYIGBE 2	2.59 M307F1 DZAKPO	2.39 M337F4 HANO KPO	2.83 M180F2 AHLOU K
27	778 M309F2 EGBE	2.64 M013F4 AGBELOUV	2.39 M307F1 DZAKPO	2.87 M321F4 KOTSO KO
28	800 M334F1 YOTO KOP	2.69 M175F3 YOTO	2.39 M420F3 ETOE KOP	2.87 M029F3 AGNRON
29	809 M021F2 NYASSIVE	2.69 M314F2 GAMEBBLE	2.39 M301F2 AFOKPONA	2.91 M436F2 NYIGBE 2
30	813 M021F3 NYASSIVE	2.69 M436F1 NYIGBE 2	2.47 M180F4 AHLOU K	2.91 M309F2 EGBE
31	816 M436F2 NYIGBE 2	2.74 M329F1 AGBODJEK	2.47 M013F4 AGBELOUV	2.96 M337F4 HANO KPO
32	833 M337F4 HANO KPO	2.74 M180F2 AHLOU K	2.47 M334F3 YOTO KOP	3.00 M165F2 AGBADJAN
33	833 M029F3 AGNRON	2.79 M403F1 KP00JI	2.55 M403F1 KP00JI	3.04 M113F2 NYIGBE 1
34	844 M029F4 AGNRON	2.79 M175F2 YOTO	2.55 M445F1 TOUTOU K	3.04 M441F2 GAPE KOV
35	870 M333F2 GAME KOV	2.94 M322F1 AMAVEBAN	2.63 M322F1 AMAVEBAN	3.13 M442F2 TODONE
36	879 M307F1 DZAKPO	2.99 M321F4 KOTSO KO	2.63 M424F1 FOKPO	3.18 M405F1 ATCHAVE
37	888 M165F2 AGBADJAN	3.19 M402F1 GAZATOE	2.63 M326F1 NYANYETC	3.31 M301F1 AFOKPONA
38	892 M301F2 AFOKPONA	3.19 M329F2 AGBODJEK	2.63 M426F2 HEKPOE	3.35 M013F4 AGBELOUV
39	892 M334F3 YOTO KOP	3.24 M420F3 ETOE KOP	2.63 M328F1 AGAMAHE	3.61 M420F2 ETOE KOP
40	906 M424F1 FOKPO	3.29 M029F3 AGNRON	2.63 M021F2 NYASSIVE	3.70 M148F2 AGBOZONE
41	909 M422F1 BATOUNE	3.29 M334F1 YOTO KOP	2.71 M339F1 NOUSROU	3.70 M402F1 GAZATOE
42	910 M310F2 TOUNOUNA	3.29 M436F2 NYIGBE 2	2.71 M436F1 NYIGBE 2	3.70 M337F1 HANO KPO
43	916 M333F3 GAME KOV	3.34 M441F2 GAPE KOV	2.80 M334F1 YOTO KOP	3.74 M334F1 YOTO KOP
44	918 M426F2 HEKPOE	3.39 M439F1 AGBLEVE	2.88 M180F2 AHLOU K	3.78 M318F1 KOUNINDU
45	925 M334F2 YOTO KOP	3.39 M306F1 AGBETINE	2.88 M115F4 TOKPEVIA	3.78 M304F1 MOEVE
46	945 M180F2 AHLOU K	3.44 M029F4 AGNRON	2.88 M309F2 EGBE	3.87 M338F3 AVEDJE
47	952 M013F5 AGBELOUV	3.49 M334F2 YOTO KOP	2.88 M310F2 TOUNOUNA	3.87 M013F5 AGBELOUV
48	952 M402F1 GAZATOE	3.54 M339F1 NOUSROU	3.04 M115F3 TOKPEVIA	4.05 M422F1 BATOUNE

ORDER	Conductivity (uS/cm)	Ca++ (epa)	Mg++ (epa)	Na+ (epa)
49	969 M346F1 TEDAHDE	3.54 M318F1 KOLUBINDU	3.04 M029F4 AGNRON	4.05 M334F5 YOTO KOP
50	976 M180F4 AHLOLOU K	3.64 M316F1 AGADJAKP	3.13 M323F1 AGOKPOE	4.09 M320F1 AGBODJEK
51	980 M332F1 BEBDE	3.64 M449F1 TOUTOU K	3.13 M316F1 AGADJAKP	4.18 M308F1 TSUETA
52	1000 M443F1 LONVO	3.64 M334F5 YOTO KOP	3.21 M347F1 ALLAGBAD	4.26 M334F2 YOTO KOP
53	1000 M302F1 ANAZIVE	3.74 M237F4 ALOYI	3.21 M304F1 MOEVE	4.26 M180F4 AHLOLOU K
54	1023 M420F2 ETOE KOP	3.74 M337F1 HMO KPO	3.21 M302F1 ANAZIVE	4.39 M334F3 YOTO KOP
55	1063 M427F2 GUENDJI	3.79 M311F1 AKOLI KO	3.37 M422F1 BATOUNE	4.39 M098F2 BATOUNE
56	1086 M175F3 YOTO	3.79 M424F1 FOKPO	3.37 M334F2 YOTO KOP	4.61 M348F3 BAKA KOP
57	1093 M098F2 BATOUNE	3.79 M406F1 SANDUTA	3.46 M338F2 AVEDJE	4.74 M326F1 NYAMVETC
58	1118 M318F1 KOLUBINDU	3.79 M426F2 HEKPOE	3.46 M441F2 BAPE KOV	4.74 M405F2 ATCHAVE
59	1135 M442F2 TODONE	3.84 M442F2 TODONE	3.46 M346F1 TEDAHDE	4.78 M307F1 DZAKPO
60	1137 M418F1 HEDJENE	3.84 M237F3 ALOYI	3.54 M320F1 AGBODJEK	4.96 M420F3 ETOE KOP
61	1148 M328F1 AGAHANE	3.94 M323F1 AGOKPOE	3.54 M318F1 KOLUBINDU	5.00 M338F2 AVEDJE
62	1150 M013F4 AGBELOUV	3.94 M301F2 AFOKPOWA	3.62 M237F4 ALOYI	5.00 M346F1 TEDAHDE
63	1165 M115F4 TOKPEVIA	3.99 M346F1 TEDAHDE	3.70 M334F5 YOTO KOP	5.13 M437F1 DEKAME
64	1166 M115F3 TOKPEVIA	4.04 M302F1 ANAZIVE	3.70 M029F3 AGNRON	5.22 M403F2 KP0DJ1
65	1172 M308F1 TSUETA	4.04 M337F4 HMO KPO	3.78 M175F2 YOTO	5.31 M320F2 AGBODJEK
66	1176 M437F1 DEKAME	4.09 M422F1 BATOUNE	3.78 M237F3 ALOYI	5.35 M348F2 BAKA KOP
67	1230 M315F2 TSINGOE	4.24 M405F1 ATCHAVE	3.87 M175F3 YOTO	5.44 M302F1 ANAZIVE
68	1230 M304F1 MOEVE	4.59 M443F1 LONVO	3.87 M348F3 BAKA KOP	5.57 M328F1 AGAHANE
69	1256 M316F1 AGADJAKP	4.79 M013F5 AGBELOUV	3.95 M427F2 GUENDJI	5.61 M426F2 HEKPOE
70	1258 M320F1 AGBODJEK	4.89 M315F2 TSINGOE	3.95 M120F4 T0VEGAN	5.70 M115F3 TOKPEVIA
71	1258 M323F1 AGOKPOE	4.94 M418F1 HEDJENE	4.03 M320F2 AGBODJEK	5.70 M424F1 FOKPO
72	1267 M405F2 ATCHAVE	4.99 M310F2 TOUNOUNA	4.11 M407F3 BEDJRA K	6.09 M115F4 TOKPEVIA
73	1279 M338F3 AVEDJE	5.24 M315F1 TSINGOE	4.11 M338F3 AVEDJE	6.09 M333F2 GAME KOV
74	1283 M237F3 ALOYI	5.44 M405F2 ATCHAVE	4.11 M407F2 BEDJRA K	6.22 M418F1 HEDJENE
75	1284 M420F3 ETOE KOP	5.49 M347F1 ALLAGBAD	4.20 M402F1 GAZATOE	6.22 M316F1 AGADJAKP
76	1284 M237F4 ALOYI	5.54 M421F1 VAVATSI	4.20 M348F2 BAKA KOP	6.31 M426F1 HEKPOE
77	1313 M320F2 AGBODJEK	5.79 M313F2 AGOKPE	4.28 M311F1 AKOLI KO	6.39 M409F1 KLONEPOE
78	1315 M347F1 ALLAGBAD	5.84 M115F4 TOKPEVIA	4.28 M437F1 DEKAME	6.44 M312F1 AKPAVE K
79	1351 M315F1 TSINGOE	6.19 M312F1 AKPAVE K	4.44 M426F1 HEKPOE	6.48 M333F3 GAME KOV
80	1385 M405F1 ATCHAVE	6.34 M338F3 AVEDJE	4.69 M308F1 TSUETA	6.48 M408F1 AGOHONE
81	1391 M338F2 AVEDJE	6.44 M115F3 TOKPEVIA	4.77 M408F1 AGOHONE	6.52 M315F2 TSINGOE
82	1447 M348F3 BAKA KOP	6.54 M407F3 BEDJRA K	4.85 M418F1 HEDJENE	6.61 M347F1 ALLAGBAD
83	1470 M421F1 VAVATSI	6.54 M407F2 BEDJRA K	4.85 M312F1 AKPAVE K	6.61 M323F1 AGOKPOE
84	1492 M311F1 AKOLI KO	6.69 M304F1 MOEVE	4.85 M409F1 KLONEPOE	6.74 M421F1 VAVATSI
85	1500 M336F4 ADJA KOP	6.69 M410F1 HEKPOUI	4.94 M313F2 AGOKPE	6.74 M315F1 TSINGOE
86	1533 M348F2 BAKA KOP	6.74 M403F2 KP0DJ1	4.94 M421F1 VAVATSI	7.13 M410F1 HEKPOUI
87	1547 M406F1 SANDUTA	6.74 M427F2 GUENDJI	5.10 M315F2 TSINGOE	7.39 M237F4 ALOYI
88	1574 M408F1 AGOHONE	6.79 M308F1 TSUETA	5.59 M324F2 ATIKOLE	7.44 M237F3 ALOYI
89	1587 M312F1 AKPAVE K	6.84 M320F2 AGBODJEK	5.76 M319F1 KPLABA	7.48 M311F1 AKOLI KO
90	1612 M409F1 KLONEPOE	6.94 M426F1 HEKPOE	5.76 M324F1 ATIKOLE	8.18 M319F1 KPLABA
91	1626 M410F1 HEKPOUI	6.99 M348F3 BAKA KOP	5.76 M315F1 TSINGOE	8.31 M336F4 ADJA KOP
92	1724 M407F3 BEDJRA K	7.14 M338F2 AVEDJE	5.92 M405F1 ATCHAVE	8.44 M411F1 HLEME
93	1763 M426F1 HEKPOE	7.34 M320F1 AGBODJEK	6.09 M443F1 LONVO	8.44 M336F5 ADJA KOP
94	1874 M319F1 KPLABA	7.53 M348F2 BAKA KOP	6.25 M406F1 SANDUTA	8.61 M406F1 SANDUTA
95	1886 M403F2 KP0DJ1	7.68 M319F1 KPLABA	6.33 M165F2 AGBADJAN	8.61 M324F1 ATIKOLE
96	1898 M120F4 T0VEGAN	7.98 M408F1 AGOHONE	6.50 M410F1 HEKPOUI	8.70 M407F3 BEDJRA K
97	1918 M313F2 AGOKPE	8.03 M409F1 KLONEPOE	6.58 M405F2 ATCHAVE	8.70 M407F2 BEDJRA K
98	1923 M175F2 YOTO	8.28 M324F2 ATIKOLE	6.75 M411F1 HLEME	8.87 M313F2 AGOKPE
99	1945 M324F1 ATIKOLE	8.33 M411F1 HLEME	7.82 M330F2 ATIND	9.18 M175F3 YOTO

ORDER	Conductivity (uS/cm)	Ca++ (ppm)	Mg++ (ppm)	Na+ (ppm)
100	1956 M407F2 BEDJRA K	9.28 M330F2 ATIND	8.06 M332F1 BEBDE	10.83 M330F2 ATIND
101	2000 M411F1 MLEHE	9.38 M324F1 ATIKOLE	9.05 M403F2 KPODJI	14.18 M324F2 ATIKOLE
102	2100 M324F2 ATIKOLE	15.47 M336F4 ADJA KOP	10.12 M336F4 ADJA KOP	14.70 M120F4 TOVEGAN
103	2941 M336F5 ADJA KOP	15.82 M336F5 ADJA KOP	10.37 M336F5 ADJA KOP	15.09 M175F2 YOTO

ORDER	Fe++ (epm)	Mn++ (epm)	HC03- (epm)	SO4= (epm)
1	0.0000 M339F1 NOUBROU	0.0000 M013F4 AGBELOUV	0.20 M421F1 VAVATSI	0.00 M329F2 AGBOOJEK
2	0.0004 M420F3 ETOE KOP	0.0000 M339F1 NOUBROU	0.50 M322F1 ANAVEGAN	0.00 M445F1 TOUTOU K
3	0.0036 M420F2 ETOE KOP	0.0036 M329F1 AGBOOJEK	0.57 M021F3 NYASSIVE	0.00 M301F2 AFOKPONA
4	0.0036 M021F2 NYASSIVE	0.0036 M237F4 ALOYI	1.09 M327F3 BEDJEHE	0.00 M013F4 AGBELOUV
5	0.0036 M418F1 MEDJENE	0.0036 M301F1 AFOKPONA	1.14 M311F1 AKOLI KO	0.00 M441F2 GAPE KOV
6	0.0036 M021F4 NYASSIVE	0.0036 M420F3 ETOE KOP	1.35 M021F4 NYASSIVE	0.00 M328F1 AGAWANE
7	0.0036 M405F2 ATCHAVE	0.0036 M437F1 DEKAME	1.41 M021F2 NYASSIVE	0.00 M339F1 NOUBROU
8	0.0036 M029F4 AGNRON	0.0036 M029F4 AGNRON	1.58 M327F1 BEDJEHE	0.00 M306F1 AGBETINE
9	0.0036 M402F1 GAZATOE	0.0036 M334F3 YOTO KOP	1.70 M309F2 EBBE	0.00 M334F3 YOTO KOP
10	0.0036 M442F2 TODOME	0.0036 M405F2 ATCHAVE	1.85 M432F1 AZI KOPE	0.00 M314F5 GAMEGBLE
11	0.0036 M348F3 BAKA KOP	0.0036 M334F2 YOTO KOP	1.89 M115F3 TOKPEVIA	0.00 M334F1 YOTO KOP
12	0.0036 M115F4 TOKPEVIA	0.0036 M443F1 LONVO	1.97 M427F2 GUENDJI	0.00 M422F1 BATOUNE
13	0.0036 M013F5 AGBELOUV	0.0036 M334F1 YOTO KOP	2.51 M338F3 AVEDJE	0.00 M327F1 BEDJEHE
14	0.0036 M439F1 AGBLEVE	0.0036 M148F2 AGBOZOME	2.84 M436F1 NYIGBE 2	0.00 M443F1 LONVO
15	0.0036 M314F2 GAMEGBLE	0.0036 M333F3 GAME KOV	3.13 M348F3 BAKA KOP	0.08 M314F2 GAMEGBLE
16	0.0036 M436F2 NYIGBE 2	0.0036 M403F2 KPDDJI	3.24 M408F1 AGOHOM	0.10 M165F2 AGBADJAN
17	0.0036 M338F3 AVEDJE	0.0036 M333F2 GAME KOV	3.49 M313F2 AGOKPE	0.12 M113F2 NYIGBE 1
18	0.0036 M180F2 AHLOU K	0.0036 M432F1 AZI KOPE	3.67 M403F1 KPDDJI	0.17 M403F2 KPDDJI
19	0.0036 M338F2 AVEDJE	0.0036 M328F1 AGAWANE	3.68 M308F1 TSUETA	0.19 M301F1 AFOKPONA
20	0.0036 M237F3 ALOYI	0.0036 M237F3 ALOYI	3.71 M348F2 BAKA KOP	0.21 M329F1 AGBOOJEK
21	0.0036 M315F2 TSINGOE	0.0036 M327F3 BEDJEHE	3.76 M325F1 ASSI KEV	0.21 M405F1 ATCHAVE
22	0.0036 M432F1 AZI KOPE	0.0036 M029F3 AGNRON	3.77 M180F2 AHLOU K	0.21 M322F1 ANAVEGAN
23	0.0036 M316F1 AGADJAKP	0.0036 M326F1 NYANYETC	4.15 M314F5 GAMEGBLE	0.29 M325F1 ASSI KEV
24	0.0036 M427F2 GUENDJI	0.0036 M445F1 TOUTOU K	4.18 M013F4 AGBELOUV	0.31 M318F1 KOUNINDOU
25	0.0036 M318F1 KOUNINDOU	0.0036 M325F1 ASSI KEV	4.19 M407F2 BEDJRA K	0.35 M021F4 NYASSIVE
26	0.0036 M422F1 BATOUNE	0.0036 M165F2 AGBADJAN	4.19 M115F4 TOKPEVIA	0.37 M403F1 KPDDJI
27	0.0036 M337F4 HANO KPO	0.0036 M420F2 ETOE KOP	4.31 M320F1 AGBOOJEK	0.40 M148F2 AGBOZOME
28	0.0036 M443F1 LONVO	0.0036 M180F4 AHLOU K	4.33 M307F1 DIAKPO	0.40 M098F2 BATOUNE
29	0.0036 M337F1 HANO KPO	0.0036 M314F2 GAMEGBLE	4.60 M029F4 AGNRON	0.42 M420F2 ETOE KOP
30	0.0036 M098F2 BATOUNE	0.0036 M098F2 BATOUNE	4.69 M113F2 NYIGBE 1	0.42 M402F1 GAZATOE
31	0.0036 M320F2 AGBOOJEK	0.0036 M318F1 KOUNINDOU	4.71 M148F2 AGBOZOME	0.42 M436F2 NYIGBE 2
32	0.0036 M120F4 TOVEGAN	0.0036 M346F1 TEDAHOM	4.72 M337F4 HANO KPO	0.46 M401F1 AMESSIKP
33	0.0036 M334F5 YOTO KOP	0.0036 M120F4 TOVEGAN	4.74 M029F3 AGNRON	0.48 M180F4 AHLOU K
34	0.0036 M180F4 AHLOU K	0.0036 M315F2 TSINGOE	4.90 M437F1 DEKAME	0.48 M333F3 GAME KOV
35	0.0036 M327F1 BEDJEHE	0.0036 M316F1 AGADJAKP	4.91 M320F2 AGBOOJEK	0.48 M302F1 ANAZIVE
36	0.0036 M322F1 ANAVEGAN	0.0073 M323F1 AGOKPOE	4.93 M436F2 NYIGBE 2	0.50 M337F1 HANO KPO
37	0.0036 M301F2 AFOKPONA	0.0073 M334F5 YOTO KOP	4.97 M407F3 BEDJRA K	0.50 M432F1 AZI KOPE
38	0.0036 M334F3 YOTO KOP	0.0073 M175F3 YOTO	4.98 M098F2 BATOUNE	0.65 M326F1 NYANYETC
39	0.0036 M327F3 BEDJEHE	0.0073 M327F1 BEDJEHE	4.98 M401F1 AMESSIKP	0.67 M405F2 ATCHAVE
40	0.0036 M334F2 YOTO KOP	0.0073 M421F1 VAVATSI	4.99 M314F2 GAMEGBLE	0.77 M442F2 TODOME
41	0.0036 M441F2 GAPE KOV	0.0073 M310F2 TOUNOUMA	4.99 M321F4 KOTSD KO	0.79 M013F5 AGBELOUV
42	0.0036 M333F2 GAME KOV	0.0073 M113F2 NYIGBE 1	5.06 M180F4 AHLOU K	0.87 M439F1 AGBLEVE
43	0.0036 M436F1 NYIGBE 2	0.0073 M013F5 AGBELOUV	5.08 M333F2 GAME KOV	0.87 M327F3 BEDJEHE
44	0.0036 M013F4 AGBELOUV	0.0073 M175F2 YOTO	5.09 M333F3 GAME KOV	0.89 M321F4 KOTSD KO
45	0.0036 M029F3 AGNRON	0.0073 M441F2 GAPE KOV	5.10 M306F1 AGBETINE	0.92 M029F4 AGNRON
46	0.0036 M304F1 WGEVE	0.0073 M337F4 HANO KPO	5.11 M442F2 TODOME	0.94 M333F2 GAME KOV
47	0.0036 M437F1 DEKAME	0.0073 M403F1 KPDDJI	5.13 M439F1 AGBLEVE	0.96 M316F1 AGADJAKP
48	0.0036 M328F1 AGAWANE	0.0073 M422F1 BATOUNE	5.17 M405F1 ATCHAVE	1.02 M437F1 DEKAME
49	0.0039 M175F3 YOTO	0.0073 M329F2 AGBOOJEK	5.19 M420F3 ETOE KOP	1.02 M323F1 AGOKPOE
50	0.0072 M329F1 AGBOOJEK	0.0073 M406F1 SANDUTA	5.20 M310F2 TOUNOUMA	1.04 M175F2 YOTO

ORDER	Fe++ (epa)	Mn++ (epa)	HC03- (epa)	SO4=
				(epa)
51	0.0072 M334F5 ADJA KOP	0.0073 M321F4 KOTSD KO	5.22 M339F1 NOUGROU	1.06 M420F3 ETOE KOP
52	0.0072 M237F4 ALOYI	0.0073 M434F2 NY16BE 2	5.36 M420F2 ETOE KOP	1.08 M332F1 BEBDE
53	0.0072 M323F1 AGSI KEV	0.0073 M332F1 BEBDE	5.57 M323F1 AGOKPOE	1.10 M029F3 AGNRON
54	0.0072 M301F1 AFOKPONA	0.0073 M401F1 ANESSIKP	5.64 M324F1 NYANYETC	1.12 M434F1 NY16BE 2
55	0.0072 M113F2 NY16BE 1	0.0080 M307F1 DZAKPO	5.67 M332F1 BEBDE	1.19 M180F2 AHOLOU K
56	0.0072 M404F1 SANDUTA	0.0091 M021F2 NYASSIVE	5.78 M301F2 AFOKPONA	1.27 M344F1 TEDAHNE
57	0.0072 M315F1 TSINGOE	0.0095 M021F3 NYASSIVE	5.84 M409F1 KLOHEPOE	1.31 M337F4 HAH KPO
58	0.0072 M333F3 GANE KOV	0.0109 M315F1 TSINGOE	5.86 M324F1 ATIKOLE	1.37 M347F1 ALLAGBAD
59	0.0072 M424F2 HEKPOE	0.0109 M424F1 FOKPO	5.93 M013F3 AGBELOUV	1.46 M338F2 AVEDJE
60	0.0072 M165F2 AGBADJAN	0.0109 M442F2 TODONE	5.97 M424F1 HEKPOE	1.52 M334F5 YOTO KOP
61	0.0072 M424F1 FOKPO	0.0109 M320F1 AGBODJEK	6.01 M301F1 AFOKPONA	1.56 M315F1 TSINGOE
62	0.0072 M321F4 KOTSD KO	0.0109 M320F2 AGBODJEK	6.05 M424F2 HEKPOE	1.56 M330F2 ATIHO
63	0.0072 M304F1 AGBETIME	0.0109 M408F1 AGDHONE	6.11 M445F1 TOUTOU K	1.60 M175F3 YOTO
64	0.0072 M403F2 KPDDJI	0.0109 M304F1 AGBETIME	6.15 M334F2 YOTO KOP	1.60 M334F2 YOTO KOP
65	0.0072 M347F1 ALLAGBAD	0.0109 M319F1 KPLABA	6.27 M424F1 FOKPO	1.62 M315F2 TSINGOE
66	0.0072 M115F3 TOKPEVIA	0.0109 M308F1 TSUETA	6.35 M329F1 AGBODJEK	1.77 M309F2 EBDE
67	0.0072 M421F1 VAVATSI	0.0109 M322F1 AMAVEGAN	6.43 M334F1 YOTO KOP	1.91 M310F2 TOUNOUNA
68	0.0072 M323F1 AGOKPOE	0.0109 M439F1 AGBLEVE	6.55 M318F1 KOLUBINDU	2.16 M418F1 HEDJENE
69	0.0072 M408F1 AGDHONE	0.0109 M424F2 HEKPOE	6.64 M304F1 WOEVE	2.16 M336F5 ADJA KOP
70	0.0072 M445F1 TOUTOU K	0.0109 M314F5 GANEGBLE	6.68 M324F2 ATIKOLE	2.27 M424F2 HEKPOE
71	0.0072 M175F2 YOTO	0.0109 M409F1 KLOHEPOE	6.70 M337F1 HAH KPO	2.31 M424F1 FOKPO
72	0.0072 M148F2 AGBOZONE	0.0116 M311F1 AKOLI KO	6.83 M338F2 AVEDJE	2.35 M021F2 NYASSIVE
73	0.0072 M407F2 BEDJRA K	0.0131 M302F1 ANAZIVE	6.84 M328F1 AGAHNE	2.75 M304F1 WOEVE
74	0.0093 M021F3 NYASSIVE	0.0146 M338F3 AVEDJE	6.85 M405F2 ATCHAVE	2.87 M334F4 ADJA KOP
75	0.0107 M405F1 ATCHAVE	0.0146 M402F1 GAZATOE	7.02 M336F4 ADJA KOP	2.98 M307F1 DZAKPO
76	0.0107 M334F4 ADJA KOP	0.0146 M324F1 ATIKOLE	7.10 M120F4 TOVEGAN	3.04 M021F3 NYASSIVE
77	0.0107 M309F2 EBDE	0.0146 M424F1 HEKPOE	7.11 M312F1 AKPAVE K	3.23 M237F4 ALOYI
78	0.0107 M324F1 NYANYETC	0.0146 M405F1 ATCHAVE	7.20 M402F1 GAZATOE	3.31 M237F3 ALOYI
79	0.0107 M320F1 AGBODJEK	0.0146 M301F2 AFOKPONA	7.25 M411F1 HLENE	3.54 M120F4 TOVEGAN
80	0.0107 M319F1 KPLABA	0.0146 M309F2 EBDE	7.27 M329F2 AGBODJEK	3.54 M424F1 HEKPOE
81	0.0107 M310F2 TOUNOUNA	0.0146 M021F4 NYASSIVE	7.46 M441F2 GANE KOV	3.56 M404F1 SANDUTA
82	0.0107 M407F3 BEDJRA K	0.0149 M180F2 AHOLOU K	7.52 M443F1 LONNO	3.84 M410F1 HEKPOUI
83	0.0107 M424F1 HEKPOE	0.0164 M312F1 AKPAVE K	7.57 M315F1 TSINGOE	4.58 M115F4 TOKPEVIA
84	0.0107 M332F1 BEBDE	0.0182 M330F2 ATIHO	7.62 M315F2 TSINGOE	4.72 M427F2 GUENDJI
85	0.0107 M307F1 DZAKPO	0.0182 M411F1 HLENE	7.97 M422F1 BATOUNE	5.12 M312F1 AKPAVE K
86	0.0107 M403F1 KPDDJI	0.0182 M304F1 WOEVE	7.97 M334F3 YOTO KOP	5.70 M348F3 BAKA KOP
87	0.0107 M334F1 YOTO KOP	0.0182 M324F2 ATIKOLE	7.99 M319F1 KPLABA	5.95 M319F1 KPLABA
88	0.0107 M330F2 ATIHO	0.0182 M337F1 HAH KPO	8.24 M344F1 TEDAHNE	6.06 M320F1 AGBODJEK
89	0.0107 M313F2 AGOKPE	0.0218 M407F2 BEDJRA K	8.35 M302F1 ANAZIVE	6.18 M411F1 HLENE
90	0.0143 M329F2 AGBODJEK	0.0218 M407F3 BEDJRA K	8.37 M336F5 ADJA KOP	6.45 M338F3 AVEDJE
91	0.0143 M348F2 BAKA KOP	0.0218 M418F1 HEDJENE	8.50 M237F4 ALOYI	6.54 M407F2 BEDJRA K
92	0.0143 M401F1 ANESSIKP	0.0218 M347F1 ALLAGBAD	8.82 M334F5 YOTO KOP	6.56 M115F3 TOKPEVIA
93	0.0179 M302F1 ANAZIVE	0.0255 M348F3 BAKA KOP	8.83 M237F3 ALOYI	6.56 M407F3 BEDJRA K
94	0.0215 M344F1 TEDAHNE	0.0255 M115F3 TOKPEVIA	8.94 M314F1 AGADJAKP	6.60 M320F2 AGBODJEK
95	0.0215 M312F1 AKPAVE K	0.0291 M427F2 GUENDJI	9.05 M347F1 ALLAGBAD	6.79 M348F2 BAKA KOP
96	0.0215 M311F1 AKOLI KO	0.0291 M338F2 AVEDJE	9.19 M175F2 YOTO	6.97 M421F1 VAVATSI
97	0.0215 M308F1 TSUETA	0.0291 M115F4 TOKPEVIA	9.28 M418F1 HEDJENE	7.33 M409F1 KLOHEPOE
98	0.0215 M409F1 KLOHEPOE	0.0291 M348F2 BAKA KOP	9.60 M403F2 KPDDJI	7.53 M408F1 AGDHONE
99	0.0215 M411F1 HLENE	0.0364 M434F1 NY16BE 2	9.65 M175F3 YOTO	8.41 M324F1 ATIKOLE
100	0.0215 M324F2 ATIKOLE	0.0437 M334F4 ADJA KOP	10.02 M404F1 SANDUTA	8.60 M311F1 AKOLI KO
101	0.0322 M314F5 GANEGBLE	0.0546 M336F5 ADJA KOP	10.13 M165F2 AGBADJAN	8.62 M313F2 AGOKPE

ORDER	Fe++ (ppm)	Mn++ (ppm)	HCO ₃ - (ppm)	SO ₄ = (ppm)
102	0.0394 M324F1 ATIKOLE	0.0728 M410F1 HEKPOUI	11.46 M410F1 HEKPOUI	9.18 M308F1 TSUETA
103	0.1683 M410F1 HEKPOUI	0.1456 M313F2 ABOKPE	13.36 M330F2 ATIND	11.66 M324F2 ATIKOLE

ORDER	C1- (epm)	N03- (epm)	F- (epm)
1	0.51 M329F2 AGBODJEK	0.00 M329F1 AGBODJEK	0.000 M329F1 AGBODJEK
2	0.76 M329F1 AGBODJEK	0.00 M329F2 AGBODJEK	0.000 M329F2 AGBODJEK
3	0.87 M327F3 BEDJEME	0.00 M316F1 AGADJAKP	0.000 M308F1 TSUETA
4	0.96 M401F1 AMESSIKP	0.00 M347F1 ALLAGBAD	0.000 M334F2 YOTO KOP
5	1.02 M334F5 YOTO KOP	0.00 M318F1 KOUBINOU	0.000 M021F3 NYASSIVE
6	1.10 M314F2 GAMEGBLE	0.00 M436F1 NYIGBE 2	0.000 M310F2 TOUNOUMA
7	1.16 M432F1 AZI KOPE	0.00 M319F1 KPLABA	0.000 M420F2 ETOE KOP
8	1.16 M327F1 BEDJEME	0.00 M029F3 AGNRON	0.000 M311F1 AKOLI KO
9	1.18 M165F2 AGBADJAN	0.00 M348F2 BAKA KOP	0.000 M418F1 HEDJEME
10	1.18 M420F2 ETOE KOP	0.00 M098F2 BATOUME	0.000 M113F2 NYIGBE 1
11	1.50 M334F3 YOTO KOP	0.00 M115F3 TOKPEVIA	0.000 M115F3 TOKPEVIA
12	1.50 M306F1 AGBETINE	0.00 M406F1 SANOUTA	0.000 M334F1 YOTO KOP
13	1.61 M113F2 NYIGBE 1	0.00 M421F1 VAVATSI	0.000 M339F1 NOUSROU
14	1.72 M321F4 KOTSO KO	0.00 M320F2 AGBODJEK	0.000 M313F2 AGOKPE
15	1.75 M301F1 AFOKPONA	0.00 M165F2 AGBADJAN	0.000 M338F2 AVEDJE
16	1.86 M325F1 ASSI KEV	0.00 M321F4 KOTSO KO	0.000 M314F2 GAMEGBLE
17	2.00 M439F1 AGBLEVE	0.00 M411F1 HLENE	0.000 M334F3 YOTO KOP
18	2.09 M314F5 GAMEGBLE	0.00 M322F1 AMAVEGAN	0.000 M332F1 BEGBE
19	2.28 M021F4 NYASSIVE	0.00 M180F4 AHLOU K	0.000 M180F4 AHLOU K
20	2.37 M441F2 GAPE KOV	0.00 M323F1 AGOKPOE	0.000 M315F1 TSINGOE
21	2.40 M337F1 HAHU KPO	0.00 M237F4 ALOYI	0.000 M237F4 ALOYI
22	2.48 M307F1 DZAKPO	0.00 M324F1 ATIKOLE	0.000 M021F2 NYASSIVE
23	2.51 M445F1 TOUTOU K	0.00 M301F2 AFOKPONA	0.000 M301F2 AFOKPONA
24	2.60 M148F2 AGBOZONE	0.00 M324F2 ATIKOLE	0.000 M316F1 AGADJAKP
25	2.62 M021F3 NYASSIVE	0.00 M304F1 MOEVE	0.000 M304F1 MOEVE
26	2.74 M301F2 AFOKPONA	0.00 M325F1 ASSI KEV	0.000 M318F1 KOUBINOU
27	2.79 M337F4 HAHU KPO	0.00 M307F1 DZAKPO	0.000 M307F1 DZAKPO
28	2.82 M308F1 TSUETA	0.00 M326F1 NYANYETC	0.000 M319F1 KPLABA
29	2.85 M021F2 NYASSIVE	0.00 M309F2 EGBE	0.000 M422F1 BATOUME
30	2.88 M436F2 NYIGBE 2	0.00 M327F1 BEDJEME	0.000 M320F1 AGBODJEK
31	2.91 M339F1 NOUSROU	0.00 M409F1 KLOHEPOE	0.000 M013F4 AGBELOUV
32	2.91 M310F2 TOUNOUMA	0.00 M405F1 ATCHAVE	0.000 M326F1 NYANYETC
33	2.93 M237F3 ALOYI	0.00 M313F2 AGOKPE	0.000 M320F2 AGBODJEK
34	2.93 M346F1 TEDAHOE	0.00 M328F1 AGAMAHE	0.000 M180F2 AHLOU K
35	2.96 M442F2 TODOME	0.00 M339F1 NOUSROU	0.000 M321F4 KOTSO KO
36	2.96 M403F1 KPODJI	0.00 M013F4 AGBELOUV	0.000 M301F1 AFOKPONA
37	2.99 M098F2 BATOUME	0.00 M407F2 BEDJRA K	0.000 M322F1 AMAVEGAN
38	3.02 M443F1 LONVO	0.00 M403F2 KPODJI	0.000 M306F1 AGBETINE
39	3.05 M237F4 ALOYI	0.00 M346F1 TEDAHOE	0.000 M323F1 AGOKPOE
40	3.10 M316F1 AGADJAKP	0.00 M403F1 KPODJI	0.000 M327F1 BEDJEME
41	3.19 M029F3 AGNRON	0.00 M148F2 AGBOZONE	0.000 M324F1 ATIKOLE
42	3.30 M180F2 AHLOU K	0.00 M332F1 BEGBE	0.000 M237F3 ALOYI
43	3.39 M334F2 YOTO KOP	0.00 M410F1 HEKPOUI	0.000 M324F2 ATIKOLE
44	3.41 M334F1 YOTO KOP	0.00 M333F2 GAME KOV	0.000 M328F1 AGAMAHE
45	3.47 M402F1 GAZATOE	0.00 M301F1 AFOKPONA	0.000 M302F1 ANAZIVE
46	3.50 M326F1 NYANYETC	0.00 M333F3 GAME KOV	0.000 M337F1 HAHU KPO
47	3.53 M424F1 FOKPO	0.00 M306F1 AGBETINE	0.000 M325F1 ASSI KEV
48	3.53 M333F2 GAME KOV	0.00 M334F1 YOTO KOP	0.009 M405F1 ATCHAVE
49	3.55 M422F1 BATOUME	0.00 M310F2 TOUNOUMA	0.009 M098F2 BATOUME
50	3.58 M013F5 AGBELOUV	0.00 M334F2 YOTO KOP	0.013 M148F2 AGBOZONE

ORDER	C1- (epm)	N03- (epm)	F- (epm)
51	3.67 M328F1 ABAMAHE	0.00 M314F2 GAMEGBLE	0.014 M013F5 AGBELOUV
52	3.70 M180F4 AHLOU K	0.00 M334F3 YOTO KOP	0.014 M309F2 EGBE
53	3.70 M426F2 HEKPOE	0.00 M445F1 TOUTOU K	0.015 M439F1 AGBLEVE
54	3.75 M420F3 ETOE KOP	0.00 M403F1 GAZATOE	0.015 M401F1 AMESSIKP
55	3.81 M436F1 NYIGBE 2	0.00 M418F1 HEDJENE	0.016 M443F1 LONVO
56	3.89 M302F1 ANAZIVE	0.00 M336F4 ADJA KOP	0.017 M445F1 TOUTOU K
57	4.01 M029F3 AGNRON	0.00 M302F1 ANAZIVE	0.017 M327F3 BEDJENE
58	4.01 M318F1 KOUBINDOU	0.00 M336F5 ADJA KOP	0.019 M338F3 AVEDJE
59	4.29 M013F4 AGBELOUV	0.00 M408F1 AGOHOME	0.019 M441F2 GAPE KOV
60	4.32 M304F1 MOEVE	0.00 M337F1 HAHO KPO	0.020 M314F5 GAMEGBLE
61	4.32 M175F3 YOTO	0.00 M422F1 BATOUNE	0.021 M421F1 VAVATSI
62	4.37 M333F3 GAME KOV	0.00 M401F1 AMESSIKP	0.021 M402F1 GAZATOE
63	4.51 M320F1 AGBODJEK	0.00 M308F1 TSUETA	0.021 M029F3 AGNRON
64	4.57 M332F1 BEGBE	0.00 M237F3 ALOYI	0.022 M405F2 ATCHAVE
65	4.60 M418F1 HEDJENE	0.00 M315F1 TSINGOE	0.022 M437F1 DEKAME
66	4.68 M320F2 AGBODJEK	0.00 M338F2 AVEDJE	0.022 M029F4 AGNRON
67	4.68 M309F2 EGBE	0.00 M426F2 HEKPOE	0.022 M432F1 AZI KOPE
68	4.88 M347F1 ALLAGBAD	0.00 M314F5 GAMEGBLE	0.023 M408F1 AGOHOME
69	5.05 M406F1 SANDUTA	0.00 M426F1 HEKPOE	0.023 M409F1 KLOMEPOE
70	5.22 M410F1 HEKPOUI	0.00 M013F5 AGBELOUV	0.023 M120F4 TOVEGAN
71	5.22 M312F1 AKPAVE K	0.00 M439F1 AGBLEVE	0.023 M426F1 HEKPOE
72	5.33 M338F3 AVEDJE	0.00 M424F1 FOKPO	0.025 M403F2 KPDDJI
73	5.64 M427F2 GUENDJI	0.00 M311F1 AKOLI KO	0.025 M407F2 BEDJRA K
74	5.84 M311F1 AKOLI KO	0.00 M427F2 GUENDJI	0.025 M442F2 TODOME
75	5.87 M437F1 DEKAME	0.01 M327F3 BEDJENE	0.025 M333F3 GAME KOV
76	6.04 M115F4 TOKPEVIA	0.01 M437F1 DEKAME	0.026 M115F4 TOKPEVIA
77	6.12 M409F1 KLOMEPOE	0.01 M441F2 GAPE KOV	0.026 M336F4 ADJA KOP
78	6.23 M348F3 BAKA KOP	0.01 M334F5 YOTO KOP	0.027 M021F4 NYASSIVE
79	6.60 M348F2 BAKA KOP	0.01 M405F2 ATCHAVE	0.028 M436F1 NYIGBE 2
80	6.74 M315F2 TSINGOE	0.01 M115F4 TOKPEVIA	0.028 M436F2 NYIGBE 2
81	6.77 M115F3 TOKPEVIA	0.01 M442F2 TODOME	0.028 M336F5 ADJA KOP
82	6.80 M322F1 AMAVEGAN	0.02 M407F3 BEDJRA K	0.029 M411F1 HLEME
83	7.11 M323F1 AGOKPOE	0.02 M312F1 AKPAVE K	0.029 M348F2 BAKA KOP
84	7.33 M338F2 AVEDJE	0.02 M175F2 YOTO	0.032 M333F2 GAME KOV
85	7.64 M313F2 AGOKPE	0.02 M175F3 YOTO	0.032 M347F1 ALLAGBAD
86	7.70 M319F1 KPLABA	0.03 M338F3 AVEDJE	0.032 M165F2 AGBADJAN
87	7.79 M407F3 BEDJRA K	0.06 M113F2 NYIGBE 1	0.033 M410F1 HEKPOUI
88	7.98 M405F1 ATCHAVE	0.07 M021F3 NYASSIVE	0.034 M426F2 HEKPOE
89	8.18 M426F1 HEKPOE	0.10 M320F1 AGBODJEK	0.035 M424F1 FOKPO
90	8.46 M408F1 AGOHOME	0.16 M029F4 AGNRON	0.035 M346F1 TEDAHOE
91	8.63 M315F1 TSINGOE	0.20 M021F2 NYASSIVE	0.035 M427F2 GUENDJI
92	8.63 M407F2 BEDJRA K	0.22 M180F2 AHLOU K	0.037 M348F3 BAKA KOP
93	9.22 M405F2 ATCHAVE	0.27 M420F2 ETOE KOP	0.039 M334F5 YOTO KOP
94	9.53 M120F4 TOVEGAN	0.27 M436F2 NYIGBE 2	0.040 M420F3 ETOE KOP
95	9.53 M324F1 ATIKOLE	0.31 M330F2 ATIHO	0.041 M315F2 TSINGOE
96	9.76 M324F2 ATIKOLE	0.35 M120F4 TOVEGAN	0.041 M337F4 HAHO KPO
97	10.04 M421F1 VAVATSI	0.39 M348F3 BAKA KOP	0.041 M406F1 SANDUTA
98	10.10 M411F1 HLEME	0.50 M315F2 TSINGOE	0.048 M403F1 KPDDJI
99	11.23 M403F2 KPDDJI	0.53 M337F4 HAHO KPO	0.052 M312F1 AKPAVE K
100	11.34 M175F2 YOTO	0.53 M432F1 AZI KOPE	0.055 M407F3 BEDJRA K
101	12.64 M330F2 ATIHO	0.55 M420F3 ETOE KOP	0.092 M330F2 ATIHO

ORDER	C1- (epa)	N03- (epa)	F- (epa)
102	24.03 M336F4 ADJA KDP	1.69 M443F1 LONVO	0.099 M175F2 YOTO
103	24.12 M336F5 ADJA KDP	3.05 M021F4 NYASSIVE	0.165 M175F3 YOTO

Appendix B. Ascending ion concentration order - Bedrock.

ASCENDING NO₃ PLOT - BEDROCK

ASCENDING F PLOT - BEDROCK

Appendix 9. Tree plots - Bedrock.

(in map pocket)

APPENDIX IC. WATER CHEMISTRY CORRELATION MATRIX - SEDIMENTS

(based on 10 ions from Appendix 6)

Example: M011F2

M010F2 0.826 ----> correlation coefficient of M010F2 with M011F2
0.003 ----> significance of above coefficient

[illegible]

	M353F1	M359F1	M360F1	M363F1	M365F1	M366F1	M367F1	M367F2	M368F1	M369F1	M370F2	M371F1	M372F1	M375F1
M010F2	0.966 0.000	0.669 0.035	0.956 0.000	0.964 0.000	0.556 0.095	0.806 0.005	0.865 0.001	0.096 0.792	0.735 0.016	0.238 0.509	0.601 0.066	0.938 0.000	0.594 0.070	0.953 0.000
M011F2	0.668 0.035	0.247 0.492	0.640 0.046	0.669 0.035	0.182 0.614	0.998 0.000	0.992 0.000	-0.127 0.726	0.351 0.320	-0.100 0.783	0.209 0.563	0.965 0.000	0.388 0.268	0.661 0.038
M011F3	0.726 0.018	0.268 0.455	0.702 0.024	0.732 0.016	0.176 0.628	0.987 0.000	0.999 0.000	-0.131 0.718	0.368 0.295	-0.094 0.797	0.215 0.550	0.977 0.000	0.410 0.239	0.725 0.018
M039F2	0.887 0.001	0.822 0.004	0.880 0.001	0.865 0.001	0.787 0.007	0.707 0.022	0.736 0.015	0.391 0.264	0.872 0.001	0.506 0.135	0.799 0.006	0.815 0.004	0.737 0.015	0.852 0.002
M182F2	0.829 0.003	0.810 0.005	0.827 0.003	0.808 0.005	0.770 0.009	0.615 0.059	0.652 0.041	0.496 0.145	0.847 0.002	0.589 0.073	0.790 0.007	0.711 0.021	0.787 0.007	0.829 0.003
M182F3	0.748 0.013	0.596 0.069	0.745 0.013	0.741 0.014	0.529 0.116	0.637 0.048	0.678 0.031	0.298 0.404	0.640 0.046	0.365 0.300	0.558 0.094	0.708 0.022	0.629 0.051	0.779 0.008
M183F2	0.735 0.015	0.821 0.004	0.736 0.015	0.710 0.022	0.805 0.005	0.514 0.129	0.541 0.106	0.651 0.042	0.845 0.002	0.714 0.020	0.822 0.004	0.583 0.077	0.852 0.002	0.736 0.015
M183F3	0.875 0.001	0.897 0.000	0.881 0.001	0.860 0.001	0.798 0.006	0.422 0.224	0.501 0.141	0.669 0.035	0.906 0.000	0.776 0.008	0.866 0.001	0.559 0.093	0.927 0.000	0.871 0.001
M186F3	0.713 0.021	0.229 0.525	0.688 0.028	0.722 0.019	0.131 0.718	0.976 0.000	0.990 0.000	-0.214 0.553	0.331 0.350	-0.165 0.649	0.170 0.638	0.976 0.000	0.339 0.338	0.713 0.021
M350F1	0.935 0.000	0.914 0.000	0.934 0.000	0.914 0.000	0.853 0.002	0.563 0.090	0.621 0.055	0.390 0.266	0.946 0.000	0.563 0.090	0.876 0.001	0.741 0.014	0.717 0.020	0.906 0.000
M350F2	0.917 0.000	0.929 0.000	0.916 0.000	0.894 0.001	0.878 0.001	0.539 0.108	0.594 0.071	0.417 0.231	0.958 0.000	0.591 0.072	0.897 0.000	0.715 0.020	0.722 0.018	0.887 0.001
M351F1	0.790 0.007	0.993 0.000	0.793 0.006	0.757 0.011	0.977 0.000	0.318 0.370	0.367 0.296	0.599 0.068	0.997 0.000	0.773 0.009	0.988 0.000	0.497 0.144	0.758 0.011	0.761 0.011
M351F2	0.990 0.000	0.688 0.028	0.989 0.000	0.996 0.000	0.532 0.113	0.665 0.036	0.756 0.011	0.134 0.712	0.733 0.016	0.288 0.421	0.601 0.066	0.838 0.003	0.614 0.059	0.987 0.000
M352F2	0.884 0.001	0.559 0.093	0.885 0.001	0.890 0.001	0.455 0.187	0.733 0.016	0.788 0.007	0.053 0.884	0.612 0.060	0.149 0.682	0.482 0.159	0.858 0.002	0.501 0.140	0.859 0.002
M353F1	1.000 0.000	0.779 0.008	0.999 0.000	0.998 0.000	0.643 0.045	0.645 0.044	0.731 0.016	0.232 0.519	0.820 0.004	0.396 0.257	0.705 0.023	0.822 0.004	0.679 0.031	0.993 0.000
M359F1		1.000 0.000	0.786 0.007	0.748 0.013	0.971 0.000	0.231 0.520	0.292 0.412	0.630 0.051	0.993 0.000	0.809 0.005	0.991 0.000	0.425 0.221	0.763 0.010	0.754 0.012
M360F1			1.000 0.000	0.998 0.000	0.648 0.043	0.617 0.058	0.707 0.022	0.245 0.495	0.824 0.003	0.410 0.240	0.711 0.021	0.801 0.005	0.681 0.030	0.992 0.000

	M376F2	M377F1	M377F2	M378F1	M378F2	M380F1	M382F1	M383F1	M384F2	M384F3	M385F1	M385F2	M386F1	M387F1
M010F2	0.865 0.001	0.961 0.000	0.855 0.002	0.912 0.000	0.901 0.000	0.947 0.000	0.906 0.000	0.959 0.000	0.810 0.005	0.764 0.010	0.894 0.001	0.980 0.000	0.867 0.001	0.944 0.000
M011F2	0.976 0.000	0.886 0.001	0.927 0.000	0.964 0.000	0.950 0.000	0.915 0.000	0.960 0.000	0.941 0.000	0.741 0.014	0.746 0.013	0.765 0.010	0.903 0.000	0.710 0.021	0.886 0.001
M011F3	0.995 0.000	0.896 0.001	0.905 0.000	0.983 0.000	0.980 0.000	0.944 0.000	0.956 0.000	0.966 0.000	0.727 0.017	0.715 0.020	0.841 0.002	0.938 0.000	0.731 0.016	0.899 0.000
M039F2	0.687 0.028	0.953 0.000	0.886 0.001	0.796 0.006	0.741 0.014	0.836 0.003	0.855 0.002	0.817 0.004	0.930 0.000	0.905 0.000	0.673 0.033	0.859 0.002	0.903 0.000	0.926 0.000
M182F2	0.602 0.066	0.873 0.001	0.790 0.007	0.708 0.022	0.658 0.039	0.736 0.015	0.778 0.008	0.725 0.018	0.905 0.000	0.871 0.001	0.622 0.055	0.793 0.006	0.981 0.000	0.871 0.001
M182F3	0.653 0.041	0.795 0.006	0.730 0.017	0.721 0.019	0.694 0.026	0.735 0.016	0.738 0.015	0.723 0.018	0.768 0.010	0.728 0.017	0.662 0.037	0.783 0.007	0.972 0.000	0.802 0.005
M183F2	0.474 0.166	0.793 0.006	0.716 0.020	0.593 0.071	0.533 0.113	0.610 0.061	0.693 0.026	0.597 0.068	0.904 0.000	0.873 0.001	0.495 0.145	0.678 0.031	0.932 0.000	0.804 0.005
M183F3	0.469 0.171	0.761 0.011	0.569 0.086	0.567 0.088	0.544 0.104	0.603 0.065	0.641 0.046	0.619 0.056	0.831 0.003	0.758 0.011	0.662 0.037	0.710 0.022	0.806 0.005	0.792 0.006
M186F3	0.996 0.000	0.869 0.001	0.876 0.001	0.972 0.000	0.975 0.000	0.937 0.000	0.935 0.000	0.964 0.000	0.673 0.033	0.662 0.037	0.842 0.002	0.929 0.000	0.696 0.025	0.867 0.001
M350F1	0.590 0.072	0.883 0.001	0.751 0.012	0.692 0.027	0.650 0.042	0.760 0.011	0.759 0.011	0.765 0.010	0.850 0.002	0.809 0.005	0.672 0.033	0.817 0.004	0.863 0.001	0.856 0.002
M350F2	0.558 0.094	0.869 0.001	0.739 0.015	0.664 0.036	0.617 0.058	0.731 0.016	0.741 0.014	0.738 0.015	0.852 0.002	0.814 0.004	0.636 0.048	0.792 0.006	0.855 0.002	0.841 0.002
M351F1	0.314 0.377	0.712 0.021	0.568 0.087	0.430 0.215	0.371 0.292	0.498 0.143	0.570 0.085	0.524 0.120	0.799 0.006	0.769 0.009	0.416 0.232	0.593 0.071	0.757 0.011	0.696 0.026
M351F2	0.778 0.008	0.872 0.001	0.702 0.024	0.826 0.003	0.836 0.003	0.881 0.001	0.788 0.007	0.887 0.001	0.710 0.021	0.634 0.049	0.933 0.000	0.930 0.000	0.815 0.004	0.865 0.001
M352F2	0.795 0.006	0.893 0.001	0.824 0.003	0.886 0.001	0.874 0.001	0.950 0.000	0.788 0.007	0.869 0.001	0.696 0.025	0.638 0.047	0.859 0.001	0.903 0.000	0.821 0.004	0.847 0.002
M353F1	0.738 0.015	0.891 0.001	0.719 0.019	0.797 0.006	0.794 0.006	0.852 0.002	0.798 0.006	0.870 0.001	0.773 0.009	0.704 0.023	0.881 0.001	0.917 0.000	0.848 0.002	0.885 0.001
M359F1	0.246 0.493	0.651 0.042	0.480 0.161	0.363 0.303	0.311 0.381	0.438 0.205	0.496 0.145	0.465 0.176	0.744 0.014	0.703 0.023	0.402 0.249	0.544 0.104	0.716 0.020	0.640 0.046
M360F1	0.715 0.020	0.876 0.001	0.698 0.025	0.779 0.008	0.777 0.008	0.840 0.002	0.774 0.009	0.851 0.002	0.759 0.011	0.686 0.029	0.876 0.001	0.903 0.000	0.843 0.002	0.869 0.001

	M376F2	M377F1	M377F2	M378F1	M378F2	M380F1	M382F1	M383F1	M384F2	M384F3	M385F1	M385F2	M386F1	M387F1
M363F1	0.749 0.013	0.880 0.001	0.705 0.023	0.803 0.005	0.806 0.005	0.859 0.002	0.789 0.007	0.873 0.001	0.747 0.013	0.674 0.033	0.903 0.000	0.920 0.000	0.835 0.003	0.875 0.001
M365F1	0.135 0.711	0.583 0.077	0.465 0.176	0.264 0.461	0.190 0.599	0.334 0.346	0.432 0.213	0.353 0.317	0.725 0.018	0.711 0.021	0.215 0.551	0.424 0.222	0.651 0.041	0.560 0.092
M366F1	0.969 0.000	0.880 0.001	0.928 0.000	0.959 0.000	0.943 0.000	0.903 0.000	0.957 0.000	0.925 0.000	0.750 0.013	0.756 0.011	0.749 0.013	0.889 0.001	0.705 0.023	0.884 0.001
M367F1	0.992 0.000	0.906 0.000	0.913 0.000	0.982 0.000	0.976 0.000	0.939 0.000	0.967 0.000	0.964 0.000	0.757 0.011	0.746 0.013	0.835 0.003	0.940 0.000	0.746 0.013	0.914 0.000
M367F2	-0.168 0.643	0.214 0.553	0.121 0.739	-0.040 0.912	-0.094 0.796	-0.046 0.900	0.102 0.779	-0.066 0.857	0.533 0.113	0.501 0.141	-0.034 0.926	0.042 0.908	0.356 0.313	0.270 0.450
M368F1	0.345 0.329	0.726 0.018	0.567 0.087	0.453 0.188	0.401 0.251	0.519 0.125	0.589 0.074	0.553 0.097	0.802 0.005	0.767 0.010	0.463 0.178	0.623 0.054	0.766 0.010	0.715 0.020
M369F1	-0.124 0.733	0.303 0.395	0.159 0.660	0.001 0.998	-0.053 0.884	0.026 0.943	0.167 0.645	0.038 0.918	0.584 0.076	0.547 0.102	0.051 0.890	0.145 0.689	0.447 0.196	0.344 0.330
M370F2	0.184 0.611	0.613 0.060	0.464 0.177	0.304 0.393	0.242 0.501	0.369 0.294	0.466 0.175	0.400 0.252	0.750 0.013	0.723 0.018	0.303 0.395	0.477 0.163	0.681 0.030	0.605 0.064
M371F1	0.970 0.000	0.944 0.000	0.922 0.000	0.976 0.000	0.964 0.000	0.966 0.000	0.967 0.000	0.993 0.000	0.769 0.009	0.755 0.012	0.851 0.002	0.973 0.000	0.792 0.006	0.930 0.000
M372F1	0.390 0.265	0.673 0.033	0.541 0.107	0.490 0.150	0.456 0.186	0.476 0.164	0.592 0.071	0.484 0.157	0.848 0.002	0.793 0.006	0.505 0.137	0.575 0.082	0.720 0.019	0.733 0.016
M375F1	0.743 0.014	0.870 0.001	0.688 0.028	0.788 0.007	0.792 0.006	0.835 0.003	0.790 0.007	0.866 0.001	0.755 0.012	0.683 0.030	0.895 0.001	0.917 0.000	0.861 0.001	0.876 0.001
M376F2	1.000 0.000	0.874 0.001	0.863 0.001	0.978 0.000	0.986 0.000	0.941 0.000	0.936 0.000	0.968 0.000	0.686 0.029	0.665 0.036	0.877 0.001	0.941 0.000	0.713 0.021	0.881 0.001
M377F1		1.000 0.000	0.954 0.000	0.936 0.000	0.902 0.000	0.942 0.000	0.966 0.000	0.944 0.000	0.919 0.000	0.896 0.001	0.806 0.005	0.961 0.000	0.899 0.000	0.989 0.000
M377F2			1.000 0.000	0.925 0.000	0.874 0.001	0.908 0.000	0.952 0.000	0.889 0.001	0.879 0.001	0.888 0.001	0.668 0.035	0.881 0.001	0.821 0.004	0.929 0.000
M378F1				1.000 0.000	0.993 0.000	0.984 0.000	0.951 0.000	0.971 0.000	0.767 0.010	0.740 0.015	0.881 0.001	0.964 0.000	0.790 0.007	0.930 0.000
M378F2					1.000 0.000	0.977 0.000	0.924 0.000	0.969 0.000	0.708 0.022	0.672 0.034	0.919 0.000	0.961 0.000	0.754 0.012	0.902 0.000
M380F1						1.000 0.000	0.916 0.000	0.967 0.000	0.745 0.013	0.708 0.022	0.898 0.000	0.969 0.000	0.808 0.005	0.917 0.000

M376F2 M377F1 M377F2 M378F1 M378F2 M380F1 M382F1 M383F1 M384F2 M384F3 M385F1 M385F2 M386F1 M387F1

M382F1	1.000	0.959	0.887	0.881	0.783	0.949	0.834	0.973
	0.000	0.000	0.001	0.001	0.008	0.000	0.003	0.000

M383F1	1.000	0.769	0.741	0.700	0.990	0.807	0.939
	0.000	0.009	0.014	0.000	0.000	0.005	0.000

M384F2	1.000	0.991	0.595	0.807	0.879	0.937
	0.000	0.000	0.070	0.005	0.001	0.000

M384F3	1.000	0.514	0.765	0.841	0.909
	0.000	0.128	0.010	0.002	0.000

M385F1	1.000	0.924	0.714	0.821
	0.000	0.000	0.020	0.004

M385F2	1.000	0.862	0.960
	0.000	0.001	0.000

M3E6F1	1.000	0.901
	0.000	0.000

A387F1	1.000
	0.000

M387F2

M388F1

M391F1

M396F1

M396F2

M397F1

M397F2

M398F1

M399F1

	M387F2	M388F1	M391F1	M396F1	M396F2	M397F1	M397F2	M398F1	M399F1	M467F1	M468F1	M469F1	M470F1	M471F1
M010F2	0.921 0.000	0.880 0.001	0.908 0.000	0.516 0.127	0.354 0.316	0.930 0.000	0.926 0.000	0.831 0.003	0.650 0.042	0.762 0.011	0.907 0.000	0.828 0.003	0.927 0.000	0.775 0.009
M011F2	0.859 0.002	0.983 0.000	0.960 0.000	0.150 0.680	0.081 0.825	0.954 0.000	0.954 0.000	0.664 0.036	0.722 0.018	0.949 0.000	0.979 0.000	0.538 0.109	0.924 0.000	0.523 0.121
M011F3	0.882 0.001	0.998 0.000	0.984 0.000	0.153 0.673	0.044 0.905	0.982 0.000	0.983 0.000	0.686 0.029	0.700 0.024	0.962 0.000	0.987 0.000	0.572 0.084	0.962 0.000	0.598 0.068
M039F2	0.885 0.001	0.736 0.015	0.775 0.008	0.720 0.019	0.644 0.045	0.780 0.008	0.763 0.010	0.919 0.000	0.769 0.009	0.571 0.085	0.772 0.009	0.902 0.000	0.757 0.011	0.717 0.020
M182F2	0.856 0.002	0.653 0.041	0.705 0.023	0.820 0.004	0.710 0.022	0.700 0.024	0.681 0.030	0.932 0.000	0.773 0.009	0.468 0.173	0.666 0.036	0.905 0.000	0.665 0.036	0.740 0.014
M182F3	0.802 0.005	0.685 0.029	0.722 0.018	0.668 0.035	0.522 0.121	0.718 0.019	0.704 0.023	0.825 0.003	0.672 0.034	0.557 0.094	0.681 0.030	0.755 0.012	0.699 0.025	0.682 0.030
M183F2	0.799 0.006	0.538 0.109	0.598 0.068	0.862 0.001	0.773 0.009	0.580 0.079	0.556 0.095	0.928 0.000	0.805 0.005	0.327 0.356	0.535 0.111	0.900 0.000	0.527 0.117	0.716 0.020
M183F3	0.820 0.004	0.517 0.126	0.604 0.064	0.801 0.005	0.609 0.062	0.601 0.066	0.584 0.076	0.917 0.000	0.721 0.019	0.276 0.441	0.496 0.145	0.987 0.000	0.554 0.096	0.910 0.000
M186F3	0.847 0.002	0.991 0.000	0.971 0.000	0.110 0.763	-0.002 0.996	0.976 0.000	0.980 0.000	0.628 0.052	0.635 0.049	0.971 0.000	0.989 0.000	0.523 0.121	0.963 0.000	0.557 0.094
M350F1	0.821 0.004	0.630 0.051	0.682 0.030	0.796 0.006	0.661 0.030	0.704 0.023	0.692 0.027	0.862 0.001	0.634 0.049	0.440 0.203	0.684 0.029	0.922 0.000	0.688 0.028	0.734 0.016
M350F2	0.804 0.005	0.600 0.067	0.653 0.041	0.819 0.004	0.715 0.020	0.674 0.033	0.661 0.037	0.857 0.002	0.633 0.050	0.404 0.247	0.657 0.039	0.922 0.000	0.655 0.040	0.715 0.020
M351F1	0.665 0.036	0.368 0.201	0.432 0.213	0.931 0.000	0.860 0.001	0.448 0.195	0.433 0.212	0.788 0.000	0.582 0.077	0.126 0.729	0.428 0.218	0.899 0.000	0.406 0.245	0.627 0.052
M351F2	0.867 0.001	0.785 0.007	0.834 0.003	0.514 0.129	0.286 0.424	0.863 0.001	0.859 0.002	0.801 0.005	0.547 0.102	0.661 0.038	0.797 0.006	0.839 0.002	0.875 0.001	0.859 0.002
M352F2	0.815 0.004	0.812 0.004	0.843 0.002	0.400 0.252	0.250 0.486	0.862 0.001	0.849 0.002	0.789 0.007	0.548 0.101	0.768 0.010	0.829 0.003	0.721 0.019	0.909 0.000	0.727 0.017
M353F1	0.881 0.001	0.755 0.012	0.808 0.005	0.621 0.055	0.413 0.236	0.834 0.003	0.829 0.003	0.842 0.002	0.596 0.069	0.597 0.068	0.775 0.009	0.896 0.000	0.831 0.003	0.858 0.002
M359F1	0.620 0.056	0.298 0.403	0.371 0.291	0.935 0.000	0.842 0.002	0.389 0.266	0.375 0.286	0.760 0.011	0.528 0.117	0.050 0.892	0.352 0.319	0.893 0.001	0.351 0.320	0.646 0.044
M360F1	0.867 0.001	0.732 0.016	0.789 0.007	0.628 0.052	0.414 0.234	0.816 0.004	0.809 0.005	0.839 0.002	0.579 0.080	0.575 0.082	0.752 0.012	0.896 0.000	0.817 0.004	0.864 0.001

	M387F2	M388F1	M391F1	M396F1	M396F2	M397F1	M397F2	M398F1	M399F1	M467F1	M468F1	M469F1	M470F1	M471F1
M363F1	0.876 0.001	0.762 0.011	0.815 0.004	0.584 0.076	0.364 0.301	0.842 0.002	0.837 0.003	0.828 0.003	0.576 0.081	0.615 0.059	0.777 0.008	0.879 0.001	0.844 0.002	0.866 0.001
M365F1	0.520 0.124	0.196 0.587	0.258 0.473	0.944 0.000	0.930 0.000	0.270 0.451	0.252 0.482	0.692 0.027	0.511 0.131	-0.046 0.899	0.266 0.457	0.809 0.005	0.223 0.536	0.482 0.158
M366F1	0.860 0.001	0.979 0.000	0.957 0.000	0.141 0.698	0.076 0.824	0.945 0.000	0.944 0.000	0.672 0.033	0.749 0.013	0.943 0.000	0.967 0.000	0.536 0.110	0.911 0.000	0.525 0.119
M367F1	0.900 0.000	0.998 0.000	0.987 0.000	0.183 0.613	0.074 0.839	0.982 0.000	0.981 0.000	0.712 0.021	0.736 0.015	0.949 0.000	0.983 0.000	0.599 0.067	0.954 0.000	0.617 0.058
M367F2	0.318 0.371	-0.089 0.806	0.001 0.999	0.674 0.033	0.638 0.047	-0.049 0.894	-0.079 0.829	0.591 0.072	0.576 0.082	-0.323 0.363	-0.155 0.669	0.624 0.054	-0.131 0.718	0.496 0.145
M368F1	0.691 0.027	0.395 0.258	0.462 0.179	0.922 0.000	0.831 0.003	0.479 0.162	0.465 0.175	0.800 0.006	0.589 0.073	0.150 0.680	0.450 0.192	0.917 0.000	0.436 0.208	0.667 0.035
M369F1	0.376 0.285	-0.052 0.887	0.042 0.909	0.829 0.003	0.770 0.009	0.015 0.966	-0.009 0.980	0.630 0.051	0.533 0.113	-0.319 0.370	-0.076 0.836	0.730 0.017	-0.062 0.865	0.542 0.105
M370F2	0.581 0.078	0.243 0.499	0.313 0.378	0.949 0.000	0.891 0.001	0.324 0.361	0.308 0.387	0.740 0.015	0.549 0.100	-0.015 0.968	0.297 0.405	0.867 0.001	0.273 0.446	0.583 0.077
M371F1	0.897 0.000	0.976 0.000	0.968 0.000	0.299 0.402	0.190 0.600	0.981 0.000	0.982 0.000	0.723 0.018	0.670 0.034	0.913 0.000	0.997 0.000	0.654 0.040	0.967 0.000	0.616 0.058
M372F1	0.780 0.008	0.455 0.187	0.540 0.107	0.715 0.020	0.570 0.086	0.504 0.138	0.480 0.161	0.912 0.000	0.854 0.002	0.210 0.561	0.387 0.270	0.921 0.000	0.424 0.222	0.858 0.002
M375F1	0.883 0.001	0.755 0.012	0.809 0.005	0.621 0.056	0.392 0.263	0.835 0.003	0.821 0.003	0.832 0.003	0.589 0.073	0.594 0.070	0.768 0.010	0.888 0.001	0.827 0.003	0.871 0.001
M376F2	0.873 0.001	0.996 0.000	0.984 0.000	0.123 0.736	-0.013 0.972	0.986 0.000	0.989 0.000	0.662 0.037	0.658 0.039	0.965 0.000	0.981 0.000	0.559 0.093	0.971 0.000	0.619 0.056
M377F1	0.961 0.000	0.907 0.000	0.928 0.000	0.535 0.111	0.430 0.215	0.929 0.000	0.919 0.000	0.898 0.000	0.810 0.005	0.778 0.008	0.920 0.000	0.841 0.002	0.902 0.000	0.741 0.014
M377F2	0.879 0.001	0.900 0.000	0.895 0.001	0.396 0.257	0.376 0.285	0.885 0.001	0.873 0.001	0.806 0.005	0.809 0.005	0.822 0.004	0.917 0.000	0.681 0.030	0.858 0.002	0.551 0.099
M378F1	0.913 0.000	0.988 0.000	0.990 0.000	0.230 0.524	0.102 0.778	0.989 0.000	0.984 0.000	0.768 0.010	0.720 0.019	0.945 0.000	0.976 0.000	0.654 0.040	0.984 0.000	0.683 0.029
M378F2	0.895 0.001	0.988 0.000	0.990 0.000	0.168 0.643	0.013 0.972	0.992 0.000	0.990 0.000	0.729 0.017	0.670 0.034	0.956 0.000	0.966 0.000	0.622 0.055	0.993 0.000	0.699 0.025
M380F1	0.890 0.001	0.952 0.000	0.960 0.000	0.285 0.426	0.148 0.683	0.971 0.000	0.964 0.000	0.773 0.009	0.650 0.042	0.911 0.000	0.956 0.000	0.680 0.030	0.987 0.000	0.698 0.025

	M387F2	M388F1	M391F1	M396F1	M396F2	M397F1	M397F2	M398F1	M399F1	M467F1	M468F1	M469F1	M470F1	M471F1
M382F1	0.951 0.000	0.958 0.000	0.960 0.000	0.404 0.247	0.314 0.377	0.954 0.000	0.950 0.000	0.815 0.004	0.827 0.003	0.845 0.002	0.961 0.000	0.740 0.015	0.904 0.000	0.658 0.039
M383F1	0.919 0.000	0.971 0.000	0.974 0.000	0.328 0.355	0.183 0.613	0.989 0.000	0.990 0.000	0.749 0.013	0.668 0.035	0.893 0.001	0.984 0.000	0.701 0.024	0.975 0.000	0.689 0.028
M384F2	0.924 0.000	0.744 0.014	0.781 0.008	0.697 0.025	0.635 0.049	0.758 0.011	0.741 0.014	0.946 0.000	0.939 0.000	0.541 0.106	0.737 0.015	0.901 0.000	0.682 0.030	0.723 0.018
M384F3	0.884 0.001	0.724 0.018	0.749 0.013	0.675 0.032	0.654 0.040	0.725 0.018	0.709 0.022	0.896 0.001	0.933 0.000	0.528 0.117	0.728 0.017	0.843 0.002	0.640 0.046	0.626 0.053
M385F1	0.848 0.002	0.867 0.001	0.902 0.000	0.225 0.532	-0.032 0.929	0.918 0.000	0.918 0.000	0.708 0.022	0.527 0.117	0.807 0.005	0.834 0.003	0.683 0.030	0.935 0.000	0.842 0.002
M385F2	0.950 0.000	0.951 0.000	0.970 0.000	0.413 0.236	0.243 0.498	0.982 0.000	0.979 0.000	0.820 0.004	0.701 0.024	0.852 0.002	0.955 0.000	0.778 0.008	0.969 0.000	0.772 0.009
M386F1	0.891 0.001	0.751 0.012	0.792 0.006	0.727 0.017	0.591 0.072	0.790 0.007	0.775 0.008	0.908 0.000	0.758 0.011	0.592 0.071	0.758 0.011	0.862 0.001	0.760 0.011	0.748 0.013
M387F1	0.990 0.000	0.914 0.000	0.941 0.000	0.537 0.110	0.410 0.240	0.935 0.000	0.925 0.000	0.919 0.000	0.861 0.001	0.766 0.010	0.907 0.000	0.866 0.001	0.890 0.001	0.791 0.007
M387F2	1.000 0.000	0.904 0.000	0.940 0.000	0.521 0.123	0.360 0.307	0.928 0.000	0.918 0.000	0.931 0.000	0.877 0.061	0.745 0.013	0.874 0.001	0.880 0.001	0.877 0.001	0.852 0.002
M388F1		1.000 0.000	0.993 0.000	0.178 0.622	0.052 0.887	0.990 0.000	0.990 0.000	0.718 0.019	0.718 0.019	0.954 0.000	0.983 0.000	0.609 0.062	0.970 0.000	0.647 0.043
M391F1			1.000 0.000	0.245 0.495	0.094 0.797	0.996 0.000	0.993 0.000	0.781 0.008	0.753 0.012	0.926 0.000	0.968 0.000	0.684 0.029	0.974 0.000	0.730 0.017
M396F1				1.000 0.000	0.941 0.000	0.253 0.481	0.238 0.508	0.689 0.028	0.506 0.136	-0.077 0.833	0.231 0.520	0.804 0.005	0.195 0.589	0.511 0.132
M396F2					1.000 0.000	0.096 0.792	0.080 0.827	0.548 0.101	0.447 0.195	-0.176 0.626	0.132 0.717	0.637 0.048	0.032 0.930	0.244 0.497
M397F1						1.000 0.000	0.999 0.000	0.760 0.011	0.703 0.023	0.927 0.000	0.978 0.000	0.679 0.031	0.986 0.000	0.720 0.019
M397F2							1.000 0.000	0.737 0.015	0.683 0.029	0.929 0.000	0.980 0.000	0.663 0.037	0.985 0.000	0.705 0.023
M398F1								1.000 0.000	0.892 0.001	0.528 0.117	0.682 0.030	0.951 0.000	0.714 0.020	0.879 0.001
M399F1									1.000 0.000	0.539 0.108	0.656 0.040	0.789 0.007	0.608 0.063	0.699 0.025

M387F2 M388F1 M391F1 M396F1 M396F2 M397F1 M397F2 M398F1 M399F1 M467F1 M468F1 M469F1 M470F1 M471F1

M467F1	1.000	0.938	0.373	0.941	0.476
	0.000	0.000	0.288	0.000	0.164
M468F1		1.000	0.598	0.964	0.573
		0.000	0.068	0.000	0.083
M469F1			1.000	0.627	0.889
			0.000	0.052	0.001
M470F1				1.000	0.696
				0.000	0.025
M471F1					1.000
					0.000

APPENDIX II. WATER CHEMISTRY IN ASCENDING CONCENTRATION ORDER - SEDIMENTS

ORDER	Conductivity (uS/cm)	Ca++ (epm)	Mg++ (epm)	Na+ (epm)
1	58 M370F2 KPESSE K	0.15 M369F1 AKOUDOKP	0.08 M369F1 AKOUDOKP	0.30 M396F2 FONGBE A
2	74 M369F1 AKOUDOKP	0.15 M370F2 KPESSE K	0.08 M370F2 KPESSE K	0.30 M467F1 AGBLEVOU
3	75 M359F1 KOTIKO K	0.25 M367F2 SETEKPO	0.16 M396F2 FONGBE A	0.30 M011F2 TCHEKPO
4	80 M353F1 TSEVI KO	0.25 M359F1 KOTIKO K	0.16 M368F1 ZOTI KOP	0.30 M366F1 DJATA KO
5	92 M367F2 SETEKPO	0.30 M396F1 FONGBE A	0.16 M471F1 AFIKOU K	0.30 M370F2 KPESSE K
6	95 M396F2 FONGBE A	0.30 M396F2 FONGBE A	0.16 M372F1 DAVOU	0.30 M470F1 MESSEKO
7	104 M183F3 GATI SOU	0.35 M365F1 ADABIAN	0.16 M396F1 FONGBE A	0.30 M377F2 ADETI KO
8	107 M351F1 AFANTODJ	0.35 M353F1 TSEVI KO	0.16 M359F1 KOTIKO K	0.48 M382F1 ALLAGBAD
9	108 M360F1 ADJRA KU	0.35 M471F1 AFIKOU K	0.16 M183F3 GATI SOU	0.48 M350F2 ADABADJI
10	108 M363F1 AKOUTCHA	0.35 M368F1 ZOTI KOP	0.16 M382F1 ALLAGBAD	0.48 M350F1 ADABADJI
11	109 M350F1 ADABADJI	0.40 M183F3 GATI SOU	0.16 M367F2 SETEKPO	0.52 M396F1 FONGBE A
12	110 M350F2 ADABADJI	0.40 M350F2 ADABADJI	0.16 M353F1 TSEVI KO	0.52 M353F1 TSEVI KO
13	113 M398F1 AI KONDJ	0.40 M350F1 ADABADJI	0.25 M351F2 AFANTODJ	0.52 M468F1 MODENOU
14	113 M396F1 FONGBE A	0.45 M351F2 AFANTODJ	0.25 M365F1 ADABIAN	0.52 M352F2 TONA KON
15	117 M351F2 AFANTODJ	0.45 M360F1 ADJRA KO	0.25 M350F1 ADABADJI	0.61 M359F1 KOTIKO K
16	119 M352F2 TONA KON	0.45 M351F1 AFANTODJ	0.25 M351F1 AFANTODJ	0.61 M368F1 ZOTI KOP
17	125 M365F1 ADABIAN	0.50 M363F1 AKOUTCHA	0.25 M375F1 FONGBE B	0.61 M371F1 AVEDJI
18	125 M368F1 ZOTI KOP	0.60 M470F1 MESSEKO	0.25 M360F1 ADJRA KO	0.61 M186F3 SEDJRO
19	131 M470F1 MESSEKO	0.60 M352F2 TONA KON	0.25 M470F1 MESSEKO	0.61 M365F1 ADABIAN
20	131 M471F1 AFIKOU K	0.60 M372F1 DAVOU	0.25 M399F1 GABADJIN	0.61 M011F3 TCHEKPO
21	138 M372F1 DAVOU	0.65 M398F1 AI KONDJ	0.25 M363F1 AKOUTCHA	0.61 M367F1 SETEKPO
22	155 M375F1 FONGBE B	0.65 M375F1 FONGBE B	0.25 M350F2 ADABADJI	0.65 M369F1 AKOUDOKP
23	166 M010F2 TCHEKPO	0.80 M010F2 TCHEKPO	0.25 M387F2 ATIDE AP	0.65 M398F1 AI KONDJ
24	202 M382F1 ALLAGBAD	0.90 M469F1 KPALA	0.33 M367F1 SETEKPO	0.65 M010F2 TCHEKPO
25	212 M377F2 ADETI KO	1.10 M385F1 SEVA	0.33 M469F1 KPALA	0.70 M351F2 AFANTODJ
26	222 M387F1 ATIDE AP	1.30 M387F2 ATIDE AP	0.33 M010F2 TCHEKPO	0.74 M377F1 ADETI KO
27	222 M469F1 KPALA	1.35 M382F1 ALLAGBAD	0.33 M398F1 AI KONDJ	0.74 M360F1 ADJRA KO
28	227 M387F2 ATIDE AP	1.35 M377F1 ADETI KO	0.33 M366F1 DJATA KO	0.74 M351F1 AFANTODJ
29	232 M385F2 SEVA	1.35 M387F1 ATIDE AP	0.33 M011F2 TCHEKPO	0.74 M471F1 AFIKOU K
30	232 M385F1 SEVA	1.45 M385F2 SEVA	0.33 M387F1 ATIDE AP	0.78 M367F2 SETEKPO
31	235 M377F1 ADETI KO	1.45 M377F2 ADETI KO	0.33 M397F2 YOBO	0.78 M363F1 AKOUTCHA
32	250 M391F1 LOMEGNAN	1.55 M183F2 GATI SOU	0.41 M385F2 SEVA	0.83 M387F1 ATIDE AP
33	253 M371F1 AVEDJI	1.55 M386F1 TEDO	0.41 M186F3 SEDJRO	0.83 M183F3 GATI SOU
34	256 M399F1 GABADJIN	1.60 M182F3 GATI AGO	0.41 M371F1 AVEDJI	0.87 M397F2 YOBO
35	263 M397F2 YOBO	1.65 M182F2 GATI AGO	0.41 M384F3 ADIDOME	0.91 M391F1 LOMEGNAN
36	278 M011F2 TCHEKPO	1.70 M399F1 GABADJIN	0.41 M011F3 TCHEKPO	0.91 M399F1 GABADJIN
37	279 M366F1 DJATA KO	1.85 M397F2 YOBO	0.41 M391F1 LOMEGNAN	0.91 M372F1 DAVOU
38	285 M367F1 SETEKPO	1.90 M371F1 AVEDJI	0.41 M468F1 MODENOU	0.96 M385F2 SEVA
39	285 M468F1 MODENOU	1.95 M391F1 LOMEGNAN	0.41 M385F1 SEVA	0.96 M387F2 ATIDE AP
40	285 M397F1 YOBO	2.15 M384F2 ADIDOME	0.49 M376F2 ANYAVE	1.00 M375F1 FONGBE B
41	303 M186F3 SEDJRO	2.20 M468F1 MODENOU	0.49 M397F1 YOBO	1.04 M384F3 ADIDOME
42	308 M011F3 TCHEKPO	2.25 M367F1 SETEKPO	0.49 M384F2 ADIDOME	1.09 M397F1 YOBO
43	344 M386F1 TEDO	2.25 M397F1 YOBO	0.49 M377F1 ADETI KO	1.13 M376F2 ANYAVE
44	359 M183F2 GATI SOU	2.25 M366F1 DJATA KO	0.58 M377F2 ADETI KO	1.30 M384F2 ADIDOME
45	370 M182F2 GATI AGO	2.25 M011F2 TCHEKPO	0.66 M352F2 TONA KON	1.30 M469F1 KPALA
46	392 M182F3 GATI AGO	2.30 M384F3 ADIDOME	0.74 M383F1 MOE KOPE	1.30 M386F1 TEDO
47	400 M376F2 ANYAVE	2.45 M011F3 TCHEKPO	0.82 M386F1 TEDO	1.39 M182F3 GATI AGO
48	400 M384F3 ADIDOME	2.99 M186F3 SEDJRO	0.82 M388F1 AKPANITO	1.39 M385F1 SEVA

ORDER	Conductivity (uS/cm)	Ca++ (epm)	Mg++ (epm)	Na+ (epm)
49	526 M384F2 ADIDOME	3.69 M378F1 ADJOGUID	0.90 M183F2 GATI SOU	1.44 M378F1 ADJOGUID
50	526 M383F1 MOE KOPE	3.74 M376F2 ANYAVE	0.99 M182F2 GATI AGO	1.52 M388F1 AKPANITO
51	540 M378F1 ADJOGUID	3.84 M467F1 AGBLEVOU	0.99 M182F3 GATI AGO	1.52 M182F2 GATI AGO
52	555 M467F1 AGBLEVOU	3.94 M383F1 MOE KOPE	1.23 M467F1 AGBLEVOU	1.52 M183F2 GATI SOU
53	555 M388F1 AKPANITO	4.29 M039F2 AVETA	1.32 M378F1 ADJOGUID	1.87 M383F1 MOE KOPE
54	830 M378F2 ADJOGUID	4.69 M388F1 AKPANITO	1.97 M378F2 ADJOGUID	2.52 M380F1 LOME
55	833 M380F1 LOME	5.14 M380F1 LOME	2.47 M039F2 AVETA	2.70 M378F2 ADJOGUID
56	833 M039F2 AVETA	6.04 M378F2 ADJOGUID	2.80 M380F1 LOME	3.13 M039F2 AVETA

ORDER	Fe++ (epa)	Mn++ (epa)	HC03- (epa)	SO4= (epa)
1	0.0000 M360F1 ADJRA KO	0.0000 M359F1 KOTIKO K	-0.26 M367F2 SETEKPO	0.00 M365F1 ADABIAN
2	0.0036 M376F2 ANYAVE	0.0000 M363F1 AKOUTCHA	-0.14 M369F1 AKOUDOKP	0.00 M351F2 AFANTODJ
3	0.0036 M398F1 AI KONDJ	0.0036 M376F2 ANYAVE	-0.11 M396F2 FONGBE A	0.00 M368F1 ZOTI KOP
4	0.0036 M387F1 ATIDE AP	0.0036 M377F1 ADETI KO	0.06 M396F1 FONGBE A	0.00 M351F1 AFANTODJ
5	0.0036 M384F2 ADIDOME	0.0036 M377F2 ADETI KO	0.07 M370F2 KPESSE K	0.00 M350F2 ADABADJI
6	0.0036 M377F2 ADETI KO	0.0036 M182F2 GATI AGO	0.08 M365F1 ADABIAN	0.00 M359F1 KOTIKO K
7	0.0036 M385F1 SEVA	0.0036 M378F1 ADJOGUID	0.22 M359F1 KOTIKO K	0.00 M396F2 FONGBE A
8	0.0036 M387F2 ATIDE AP	0.0036 M183F2 GATI SOU	0.28 M368F1 ZOTI KOP	0.00 M375F1 FONGBE B
9	0.0036 M183F3 GATI SOU	0.0036 M378F2 ADJOGUID	0.32 M351F1 AFANTODJ	0.00 M360F1 ADJRA KO
10	0.0036 M375F1 FONGBE B	0.0036 M186F3 SEDJRO	0.34 M372F1 DAVOU	0.00 M363F1 AKOUTCHA
11	0.0036 M384F3 ADIDOME	0.0036 M370F2 KPESSE K	0.44 M350F2 ADABADJI	0.00 M371F1 AVEDJI
12	0.0036 M386F1 TEDO	0.0036 M397F2 YOBO	0.44 M183F3 GATI SOU	0.00 M468F1 WODENOU
13	0.0036 M385F2 SEVA	0.0036 M351F1 AFANTODJ	0.47 M350F1 ADABADJI	0.00 M350F1 ADABADJI
14	0.0036 M352F2 TONA KON	0.0036 M372F1 DAVOU	0.52 M398F1 AI KONDJ	0.00 M010F2 TCHEKPO
15	0.0072 M396F2 FONGBE A	0.0036 M352F2 TONA KON	0.57 M471F1 AFIKOU K	0.00 M353F1 TSEVI KO
16	0.0072 M391F1 LONEGNAN	0.0036 M397F1 YOBO	0.60 M353F1 TSEVI KO	0.02 M383F1 MOE KOPE
17	0.0072 M350F2 ADABADJI	0.0036 M470F1 MESSEKO	0.73 M399F1 GABADJIN	0.02 M370F2 KPESSE K
18	0.0072 M369F1 AKOUDOKP	0.0036 M396F2 FONGBE A	0.80 M183F2 GATI SOU	0.04 M396F1 FONGBE A
19	0.0072 M365F1 ADABIAN	0.0036 M469F1 KPALA	0.82 M360F1 ADJRA KO	0.08 M470F1 MESSEKO
20	0.0072 M350F1 ADABADJI	0.0036 M396F1 FONGBE A	0.84 M470F1 MESSEKO	0.15 M352F2 TONA KON
21	0.0072 M351F1 AFANTODJ	0.0036 M468F1 WODENOU	0.84 M469F1 KPALA	0.15 M385F2 SEVA
22	0.0107 M359F1 KOTIKO K	0.0036 M182F3 GATI AGO	0.91 M351F2 AFANTODJ	0.19 M186F3 SEDJRO
23	0.0107 M351F2 AFANTODJ	0.0036 M367F2 SETEKPO	0.92 M363F1 AKOUTCHA	0.23 M397F2 YOBO
24	0.0107 M470F1 MESSEKO	0.0036 M183F3 GATI SOU	0.98 M384F3 ADIDOME	0.23 M382F1 ALLAGBAD
25	0.0107 M010F2 TCHEKPO	0.0036 M369F1 AKOUDOKP	1.00 M352F2 TONA KON	0.25 M385F1 SEVA
26	0.0107 M370F2 KPESSE K	0.0036 M391F1 LONEGNAN	1.06 M377F2 ADETI KO	0.27 M183F3 GATI SOU
27	0.0107 M368F1 ZOTI KOP	0.0036 M471F1 AFIKOU K	1.06 M375F1 FONGBE B	0.29 M377F1 ADETI KO
28	0.0107 M468F1 WODENOU	0.0036 M388F1 AKPANITO	1.07 M010F2 TCHEKPO	0.35 M377F2 ADETI KO
29	0.0107 M371F1 AVEDJI	0.0036 M360F1 ADJRA KO	1.07 M382F1 ALLAGBAD	0.35 M011F2 TCHEKPO
30	0.0107 M367F2 SETEKPO	0.0036 M387F2 ATIDE AP	1.14 M384F2 ADIDOME	0.35 M369F1 AKOUDOKP
31	0.0107 M353F1 TSEVI KO	0.0036 M467F1 AGBLEVOU	1.15 M182F2 GATI AGO	0.35 M471F1 AFIKOU K
32	0.0143 M039F2 AVETA	0.0036 M387F1 ATIDE AP	1.16 M387F2 ATIDE AP	0.37 M387F1 ATIDE AP
33	0.0143 M182F3 GATI AGO	0.0036 M385F2 SEVA	1.17 M387F1 ATIDE AP	0.37 M397F1 YOBO
34	0.0143 M183F2 GATI SOU	0.0036 M384F2 ADIDOME	1.22 M182F3 GATI AGO	0.37 M011F3 TCHEKPO
35	0.0143 M363F1 AKOUTCHA	0.0036 M365F1 ADABIAN	1.22 M386F1 TEDO	0.42 M367F1 SETEKPO
36	0.0143 M182F2 GATI AGO	0.0036 M353F1 TSEVI KO	1.26 M377F1 ADETI KO	0.42 M398F1 AI KONDJ
37	0.0215 M377F1 ADETI KO	0.0036 M398F1 AI KONDJ	1.73 M385F2 SEVA	0.46 M376F2 ANYAVE
38	0.0215 M367F1 SETEKPO	0.0036 M384F3 ADIDOME	1.86 M366F1 DJATA KO	0.46 M386F1 TEDO
39	0.0215 M011F3 TCHEKPO	0.0073 M380F1 LOWE	1.95 M011F2 TCHEKPO	0.48 M387F2 ATIDE AP
40	0.0215 M382F1 ALLAGBAD	0.0073 M011F2 TCHEKPO	2.03 M371F1 AVEDJI	0.48 M469F1 KPALA
41	0.0251 M397F2 YOBO	0.0073 M399F1 GABADJIN	2.09 M391F1 LONEGNAN	0.48 M366F1 DJATA KO
42	0.0251 M471F1 AFIKOU K	0.0073 M011F3 TCHEKPO	2.14 M367F1 SETEKPO	0.50 M391F1 LONEGNAN
43	0.0286 M397F1 YOBO	0.0073 M039F2 AVETA	2.17 M397F2 YOBO	0.52 M182F3 GATI AGO
44	0.0286 M378F1 ADJOGUID	0.0073 M382F1 ALLAGBAD	2.25 M385F1 SEVA	0.58 M182F2 GATI AGO
45	0.0286 M380F1 LOWE	0.0073 M383F1 MOE KOPE	2.29 M468F1 WODENOU	0.62 M467F1 AGBLEVOU
46	0.0286 M396F1 FONGBE A	0.0073 M385F1 SEVA	2.45 M011F3 TCHEKPO	0.65 M372F1 DAVOU
47	0.0358 M186F3 SEDJRO	0.0073 M368F1 ZOTI KOP	2.61 M397F1 YOBO	0.73 M367F2 SETEKPO
48	0.0358 M467F1 AGBLEVOU	0.0109 M375F1 FONGBE B	3.21 M186F3 SEDJRO	0.79 M183F2 GATI SOU
49	0.0430 M388F1 AKPANITO	0.0109 M366F1 DJATA KO	3.76 M039F2 AVETA	0.81 M384F3 ADIDOME
50	0.0537 M372F1 DAVOU	0.0109 M010F2 TCHEKPO	4.10 M378F1 ADJOGUID	0.87 M384F2 ADIDOME
51	0.0537 M383F1 MOE KOPE	0.0109 M351F2 AFANTODJ	4.15 M376F2 ANYAVE	0.89 M388F1 AKPANITO

ORDER	Fe++ (ppm)	Mn++ (ppm)	HCO3- (ppm)	SO4= (ppm)
52	0.0609 M399F1 GABADJIN	0.0109 M367F1 SETEKPO	4.63 M383F1 MOE KOPE	0.89 M378F1 ADJOGUID
53	0.0645 M378F2 ADJOGUID	0.0109 M350F1 ADABADJI	4.63 M467F1 AGBLEVDU	0.92 M380F1 LOME
54	0.0788 M366F1 DJATA KO	0.0109 M350F2 ADABADJI	4.84 M388F1 AKPANITO	0.98 M039F2 AVETA
55	0.0788 M011F2 TCHEKPO	0.0182 M371F1 AVEDJI	6.74 M380F1 LOME	1.12 M399F1 GABADJIN
56	0.0931 M469F1 KPALA	0.0546 M386F1 TEDO	7.52 M378F2 ADJOGUID	1.42 M378F2 ADJOGUID

ORDER	C1- (epm)	M07- (epm)	F- (epm)
1	0.14 M467F1 AGBLEVOU	0.00 M376F2 ANYAVE	0.000 M351F2 AFANTODJ
2	0.23 M470F1 MESSEKO	0.00 M010F2 TCHEKPO	0.000 M351F1 AFANTODJ
3	0.34 M471F1 AFIKOU K	0.00 M377F1 ADETI KO	0.000 M359F1 KOTIKO K
4	0.39 M385F1 SEVA	0.00 M365F1 ADABIAN	0.000 M350F1 ADABADJI
5	0.45 M370F2 KPESSE K	0.00 M378F2 ADJOGUID	0.000 M360F1 ADJRA KO
6	0.45 M353F1 TSEVI KO	0.00 M366F1 DJATA KO	0.000 M350F2 ADABADJI
7	0.51 M351F2 AFANTODJ	0.00 M397F2 YOBO	0.000 M363F1 AKOUTCHA
8	0.56 M352F2 TONA KON	0.00 M367F1 SETEKPO	0.000 M353F1 TSEVI KO
9	0.62 M398F1 AI KONDJ	0.00 M183F3 GATI SOU	0.005 M183F3 GATI SOU
10	0.62 M360F1 ADJRA KO	0.00 M367F2 SETEKPO	0.005 M396F2 FONGBE A
11	0.62 M363F1 AKOUTCHA	0.00 M350F1 ADABADJI	0.006 M365F1 ADABIAN
12	0.62 M366F1 DJATA KO	0.00 M388F1 ZOTI KOP	0.006 M183F2 GATI SOU
13	0.65 M397F2 YOBO	0.00 M351F1 AFANTODJ	0.007 M369F1 AKOUDOKP
14	0.65 M186F3 SEDJRO	0.00 M369F1 AKOUDOKP	0.007 M182F2 GATI AGO
15	0.65 M367F1 SETEKPO	0.00 M383F1 MOE KOPE	0.007 M367F2 SETEKPO
16	0.65 M011F3 TCHEKPO	0.00 M370F2 KPESSE K	0.008 M470F1 MESSEKO
17	0.65 M011F2 TCHEKPO	0.00 M359F1 KOTIKO K	0.008 M376F2 ANYAVE
18	0.68 M396F1 FONGBE A	0.00 M371F1 AVEDJI	0.008 M375F1 FONGBE B
19	0.68 M350F1 ADABADJI	0.00 M363F1 AKOUTCHA	0.009 M469F1 KPALA
20	0.68 M183F3 GATI SOU	0.00 M372F1 DAVOU	0.010 M396F1 FONGBE A
21	0.68 M391F1 LOMEGNAN	0.00 M388F1 AKPANITO	0.011 M372F1 DAVOU
22	0.68 M369F1 AKOUDOKP	0.00 M382F1 ALLAGBAD	0.011 M382F1 ALLAGBAD
23	0.71 M396F2 FONGBE A	0.00 M350F2 ADABADJI	0.011 M370F2 KPESSE K
24	0.71 M010F2 TCHEKPO	0.00 M011F2 TCHEKPO	0.012 M368F1 ZOTI KOP
25	0.71 M382F1 ALLAGBAD	0.00 M353F1 TSEVI KO	0.012 M468F1 WODENOU
26	0.71 M350F2 ADABADJI	0.00 M039F2 AVETA	0.012 M386F1 TEDO
27	0.73 M372F1 DAVOU	0.00 M468F1 WODENOU	0.012 M471F1 AFIKOU K
28	0.73 M375F1 FONGBE B	0.00 M380F1 LOME	0.012 M378F2 ADJOGUID
29	0.73 M367F2 SETEKPO	0.00 M351F2 AFANTODJ	0.012 M186F3 SEDJRO
30	0.76 M376F2 ANYAVE	0.00 M186F3 SEDJRO	0.013 M378F1 ADJOGUID
31	0.82 M387F2 ATIDE AP	0.00 M360F1 ADJRA KO	0.014 M011F2 TCHEKPO
32	0.82 M359F1 KOTIKO K	0.00 M378F1 ADJOGUID	0.014 M366F1 DJATA KO
33	0.85 M385F2 SEVA	0.00 M011F3 TCHEKPO	0.015 M371F1 AVEDJI
34	0.85 M397F1 YOBO	0.00 M377F2 ADETI KO	0.015 M367F1 SETEKPO
35	0.85 M368F1 ZOTI KOP	0.00 M467F1 AGBLEVOU	0.015 M391F1 LOMEGNAN
36	0.85 M468F1 WODENOU	0.00 M391F1 LOMEGNAN	0.015 M182F3 GATI AGO
37	0.90 M371F1 AVEDJI	0.00 M385F1 SEVA	0.015 M384F3 ADIDOME
38	0.90 M377F2 ADETI KO	0.00 M397F1 YOBO	0.015 M387F2 ATIDE AP
39	0.93 M387F1 ATIDE AP	0.00 M384F3 ADIDOME	0.015 M385F1 SEVA
40	1.04 M377F1 ADETI KO	0.01 M399F1 GABADJIN	0.015 M377F1 ADETI KO
41	1.04 M399F1 GABADJIN	0.01 M471F1 AFIKOU K	0.016 M398F1 AI KONDJ
42	1.13 M182F3 GATI AGO	0.01 M470F1 MESSEKO	0.016 M385F2 SEVA
43	1.13 M351F1 AFANTODJ	0.01 M387F1 ATIDE AP	0.016 M352F2 TONA KON
44	1.13 M365F1 ADABIAN	0.03 M384F2 ADIDOME	0.016 M377F2 ADETI KO
45	1.24 M469F1 KPALA	0.04 M387F2 ATIDE AP	0.017 M384F2 ADIDOME
46	1.30 M386F1 TEDO	0.05 M469F1 KPALA	0.017 M387F1 ATIDE AP
47	1.33 M388F1 AKPANITO	0.06 M352F2 TONA KON	0.018 M380F1 LOME
48	1.47 M378F1 ADJOGUID	0.07 M398F1 AI KONDJ	0.018 M383F1 MOE KOPE
49	1.72 M182F2 GATI AGO	0.08 M385F2 SEVA	0.018 M397F1 YOBO
50	1.72 M183F2 GATI SOU	0.10 M375F1 FONGBE B	0.019 M388F1 AKPANITO
51	1.83 M378F2 ADJOGUID	0.18 M396F2 FONGBE A	0.021 M399F1 GABADJIN

ORDER	C1- (epa)	N03- (epa)	F- (epa)
52	1.89 M384F2 ADIDOME	0.23 M396F1 FONGBE A	0.021 M467F1 AGBLEVOU
53	1.95 M384F3 ADIDOME	0.68 M183F2 GATI SOU	0.023 M010F2 TCHEKPO
54	1.95 M383F1 MOE KOPE	0.71 M182F2 GATI AGO	0.023 M397F2 YOBO
55	2.82 M380F1 LOWE	0.74 M386F1 TEDO	0.024 M011F3 TCHEKPO
56	5.13 M039F2 AVETA	1.11 M182F3 GATI AGO	0.044 M039F2 AVETA

Appendix 12. Ascending ion concentration plots - Sediments.

Appendix 13. Tree plots - Sediments.

(in map pocket)

3

MICROD

MAP I

WELL LOCATION

ZIO AND YOTO PREFECTURES, TOGO

LEGEND

- BEDROCK WELL
- CRETACEOUS WELL
- △ PALEOCENE WELL
- ◻ EOCENE WELL
- CONTINENTAL TERMINAL WELL
- LOCATION OF WELL
- F2 2ND ("forage") WELL IN THE VILLAGE
- M026 VILLAGE NUMBER

NA KOPE
JI KONDJI
JI KONDJI
ONDJI
ONDJI
KONDJI
ASSOU
KONDJI
KONDJI
KOPE
KONDJI
CHA
KONDJI
NI
.

GEOLOGY AND WELL YIELD

ZIO AND YOTO PREFECTURES, TOGO

LEGEND

- BEDROCK WELL
- CRETACEOUS WELL
- △ PALEOCENE WELL
- ◻ EOCENE WELL
- CONTINENTAL TERMINAL WELL

24 0 WELL YIELD (m³ / hr)

GEOLOGY (After Sylvain et al., 1986)

- M MIGMATITE
 - M₁ BIOTITE MIGMATITE
 - M₂ BIOTITE AND HORNBLENDE MIGMATITE
 - M₃ ANATECTIC ORTHOGNEISS
- O ORTHOGNEISS
- G MIXED GNEISS
- I GRANITOID
- CT CONTINENTAL TERMINAL
- F FLUVIAL AND FLUVIO-LACUSTRINE DEPOSITS
- L LATERITE

SYMBOLS

— BEDROCK / SEDIMENT CONTACT

$MA_{10} = 1$
 $MA_{11} = 1.5MA_{10}$

M350 ADABADJ
M351 AFANTOD
M352 TONA KO
M353 TSEVI KO
M354 ADOSSI KO
M357 AKPLAGA
M358 AKLOBI K
M359 KOTIKO K
M360 ADJURA K
M362 ADETI KO
M363 AKOUTCH
M364 BADA KO
M398 AI KONDU
M399 GABADJIN
M471 AFIKOU K

IA KOPÉ
KONDJI
JI KONDJI
NDJI
NDJI
ONDJI
ASSOU
KONDJI
KONDJI
OPÉ
NDJI
IA
ONDJI
I
V
KONDJI

CYNTHIA CARR, 1988

O ORTHOGNEISS

G MIXED GNEISS

I GRANITOID

CT CONTINENTAL TERMINAL

F FLUVIAL AND FLUVIO-LACUSTRINE DEPOSITS

L LATERITE

SYMBOLS

BEDROCK / SEDIMENT CONTACT

OTHER GEOLOGICAL CONTACT

FAULT

SYNCLINE

ANTICLINE

MYLONITIC

MAP 3

DEPTH TO STATIC WATER LEVEL AND WATER BEARING HORIZON

ZIO AND YOTO PREFECTURES, TOGO

LEGEND

- BEDROCK WELL
- CRETACEOUS WELL
- △ PALEOCENE WELL
- ◻ EOCENE WELL
- CONTINENTAL TERMINAL WELL

— 16/57 — DEPTH TO STATIC WATER LEVEL (m)

— 16/57 — DEPTH TO WATER BEARING HORIZON (m)

— 60K — ISOHYPSE OF TOP OF CRETACEOUS

— 60P — ISOHYPSE OF TOP OF PALEOCENE

— 60E — ISOHYPSE OF TOP OF EOCENE

MAP 4

ELEVATION OF STATIC WATER LEVEL AND WATER BEARING HORIZON

ZIO AND YOTO PREFECTURES, TOGO

LEGEND

- BEDROCK WELL
- CRETACEOUS WELL
- △ PALEOCENE WELL
- ◻ EOCENE WELL
- CONTINENTAL TERMINAL WELL
- 97
51 — ELEVATION OF STATIC WATER LEVEL (m) •
- ELEVATION OF WATER BEARING HORIZON (m) •
- RIVER ELEVATION (m)
- ◻ BRIDGE ELEVATION (m) (1 - 5 m above river)

—20K— ISOPOTENTIAL OF CRETACEOUS AQUIFER

—80B— ISOPOTENTIAL OF BEDROCK WELLS

— 60E — ISOHYPSE OF TOP OF EOCENE

SCALE 1:200 000

CYNTHIA CARR, 1988

—20K— ISOPOTENTIAL OF CRETACEOUS AQUIFER

—80B— ISOPOTENTIAL OF BEDROCK WELLS

• VALUES ARE ± 5 METRES

CYNTHIA CARR, 1988

4 of /de 4

Microl

MAP 5

CONDUCTIVITY

ZIO AND YOTO PREFECTURES, TOGO

LEGEND

- BEDROCK WELL
- ◊ CRETACEOUS WELL
- △ PALEOCENE WELL
- ◻ EOCENE WELL
- CONTINENTAL TERMINAL WELL

675 CONDUCTIVITIES IN $\mu\text{S}/\text{cm}$

-1000 B- CONTOUR OF BEDROCK WELL CONDUCTIVITY

-1000 K- CONTOUR OF CRETACEOUS WELL CONDUCTIVITY

-1000 P- CONTOUR OF PALEOCENE CONDUCTIVITY

SCALE 1 : 200 000

CYNTHIA CARR, 1988

**Low
Mineralization
Group**

M327F3

M327F1

M325F1

M113F2

M306F1

M321F4

M013F4

M436F1

M309F2

M420F3

M333F3

M029F3

M237F4

M237F3

M302F1

M314F2

M432F1

M420F2

M401F1

M329F1

M329F2

M301F1

M148F2

M098F2

M021F3

M021F2

M334F3

M180F2

M180F4

M436F2

M029F4

M301F2

M307F1

M337F4

M334F2

M310F2

M013F5

M402F1

M316F1

M323F1

M304F1

M347F1

M115F4

M332F1

M443F1

2F1

M420F2

M401F1

M329F1

M329F2

M314F5

3F2

M098F2

M021F3

M021F2

M334F3

M439F1

M403F1

4F4

M436F2

M029F4

M301F2

M307F1

M334F1

M333F2

5F2

M310F2

M013F5

M402F1

M316F1

M437F1

M318F1

6F1

M347F1

M115F4

M332F1

M443F1

M175F3

M405F1

Group 3b

Group 3a

Group 1c

Group 1a

Group 2

M350F1

M350F2

M396F1

M382F1

M351F2

M360F1

M351F1

M387F2

M010F2

M387F1

M385F2

M377F1

M385F1

M367F1

M468F1

M011F2

M366F1

M397F2

M391F1

M011F1

M384F2

M384F3

M386F1

M182F3

M183F2

M182F2

M350F1

M350F2

M396F1

M382F1

M351F2

M360F1

M363

M387F2

M010F2

M387F1

M385F2

M377F1

M385F1

M367F1

M468F1

M011F2

M366F1

M397F2

M391F1

M011

M384F2

M384F3

M386F1

M182F3

M183F2

M182F2

F1

F3

**High
Mineralization
Group**

M437F2

M029F4

M301F2

M307F1

M334F1

M333F2

M310F2

M013F5

M402F1

M316F1

M437F1

M318F1

M347F1

M115F4

M332F1

M443F1

M175F3

M405F1

M115F3

M338F2

M405F2

M426F1

M315F1

M406F1

M319F1

M175F2

M403F2

M324F1

M411F1

M324F2

M442F2

M441F2

M322F1

M422F1

M334F5

M346F1

M424F1

M426F2

M165F2

M021F4

M418F1

M427F2

M311F1

M315F2

M120F4

M348F3

M421F1

M313F2

M330F2

M410F1

M336F4

M336F5

Group 1b

Group 1b*

M386F1

M386F1

M386F1

M386F1

M386F1

M388F1

M383F1

Appendix 13. TREE PLOTS - SEDIMENTS

Appendix 13. TREE PLOTS - SEDIMENTS

C. Carr, 1988

**High
Mineralization
Group**

M407F3

M407F2

M408F1

ell +

Appendix 9. TREE PLOTS - BEDROCK

Appendix 9. TREE PLOTS - BEDROCK

C. Carr, 1988

END

18.02.90

FIN