Sustainability of Water Resources under Increasing Uncertainty (Proceedings of the Rabat Symposium S1, April 1997). IAHS Publ. no. 240, 1997.

Conjunctive water use in an African river basin: a case study in poor planning

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Abstract A number of water related projects have operated, independently and at various times, over the River Rokel (Seli) basin in Sierra Leone, West Africa. These include a hydroelectric power scheme and mining and agricultural projects. It has not been adequately determined what the consequences of conjunctive water use within the basin are in terms of quantity and quality. Poor water management practices, however, are evident from a review of methodologies employed by the various operations. The need for effective project monitoring and evaluation through data collection and compilation is well recognized. The problem lies in overcoming the many identified factors preventing the achievement of these goals. This paper basically describes the schemes and highlights some of the limitations to sound river basin management as evident from this case study. Some recommendations are made for future basin planning.

INTRODUCTION

The ability to extract and utilize natural resources is often dependent on the level of development and management of available water resources. The harnessing of hydropower, for example can lead to the establishment of agro-based and mining industries. Clean drinking water prevents diseases and provides an able workforce.

The country of Sierra Leone, West Africa experiences a humid tropical climate with annual rainfall averaging 3000 mm. Nine main river basins are found, ranging in size from 14 145 to 2979 km^2. As such, water availability is not a major problem. Water resources planning at basin level, however, taking into account the conjunctive use of water is generally not done.

The varied bodies involved with water often have overlapping terms of reference as regards water use and hydrological data collection. Policy on the compilation and dissemination of data is not effectively implemented. Further, poor communication and coordination between government departments, research institutions and the mining and geotechnical sectors is a common situation that precludes widespread accessibility to technical information.

Despite recommendations to this end, made in national development plans (Carney, 1964; GOSL, 1974) and by the establishment of a national committee of the UNESCO International Hydrological Programme, this goal has not yet been fully achieved. Consequently, water related projects continue to operate independently within basins.

RIVER ROKEL BASIN

General

The 10 622 km^2 Rokel (or Seli) basin provides an interesting case study in basin management. The tectonically controlled river rises in the 900 m high interior plateau and hill ranges of Sierra Leone. It flows southwesterly, traversing geological formations of Precambrian, Infracambrian and Pleistocene Age, entering the Atlantic Ocean via the Rokel estuary.

The Gbengbe and Kabala granitoid hills to the west-northwest and the Sula mountains to the southeast form the drainage divide. Rapids and knickpoints frequently occur in the upper reaches of the river caused by outcrops of more resistant rock and the river cascades 15 m over the edge of the Sula mountains at the Bumbuna waterfalls. Available discharge data on the River Rokel basin are given in Table 1.

Table 1 Available discharge data on the River Rokel basin in Sierra Leone.

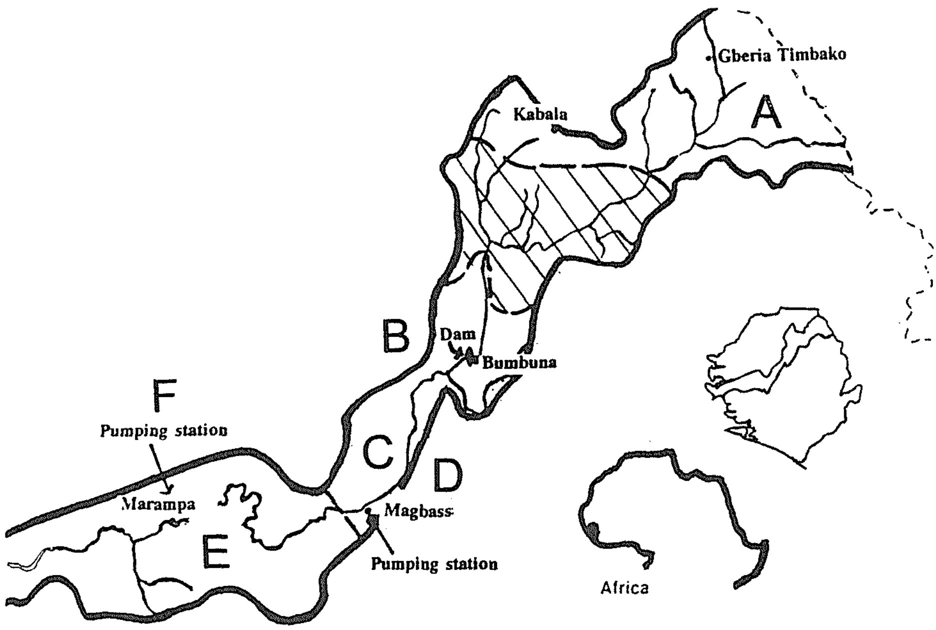
Basin	Area (km^2)	Gauge location	Area above gauge (km^2)	Flow ($m^3 s^{-1}$) min	Flow ($m^3 s^{-1}$) max	Average annual discharge (mm)	Number of years of data
Rokel	10 622	Badela	2525	1.2	503	546	5
		Bumbuna	3990	0.4	1052	888	9
		Magbass	4700	2.0	1905	-	-

Projects in the basin

Project areas within the basin that utilize the river are shown in Fig. 1. Iron ore and alluvial gold mining ventures initiated in the late 1920s and early 1930s were under the Ministry of Mines. Ongoing agricultural ventures such as the Integrated Agricultural Development Projects (IADPs) swamp scheme and the Magbass irrigation scheme are coordinated by the Ministry of Agriculture and Forestry. The Bumbuna Falls hydroelectric power project liaises with the Ministry of Energy and Power.

Iron ore mining at Marampa A pumping station on the Rokel and associated pipeline system were built to facilitate opencast mining of iron ore deposits lying in the Masaboine and Gafal Hills by the Sierra Leone Development Company (DELCO) from 1933 to 1975 and by Austro Minerals in 1983. Large scrapers and mechanical shovels were used to work the soft grey specular schistose haematite overlain by a cap of hard red ore with 47% and 38% iron content respectively. The powder was concentrated in spiral concentration plants.

In 20 years, one of the hills was lowered by 24.4 m and at the peak of mining operations, over a million and a quarter tonnes of ore were produced. The Rokel River Water Rights Agreement (Ratification) Act was drawn up for the benefit of this company. It granted them the "exclusive and preferential right to the use of the Rokel River waters by special agreement" for a period of 89 years starting on 1 January 1938



Legend: A – Kionadugu IADP area; B – *Bumbuna Falls HEP Project, * gold mining area; C – Northern IADP area; D – Magbass irrigation scheme; E – Magbosi IADP area; F – disused iron ore mine; cross-hatched area – non project area.

Fig. 1 Map showing project areas within the River Rokel basin.

(Caponera, 1979). The company was expected to ensure that users downstream had a continuous and adequate supply of water. No rehabilitation or environmental management efforts were carried out by either of these companies as evidenced by waste water pools and tailings still present at the abandoned mine site.

Gold mining in the Sula Mountains Gold deposits derived from arsenopyrite bearing quartz lodes, amphibolites and pyrite pegmatites intercalated with schists have been mined intermittently since their discovery in 1929 in the Sula Mountains and Kangari Hills. As MacFarlane *et al.* (1981) have shown in Fig. 2, gold was extensively worked in the Rokel and its tributaries.

Arsenic derived from breakdown of arsenopyrite was used as a pathfinder for gold during mineral exploration, so detailed studies on its concentration in stream sediment, soils, weathered material and bedrock cores taken from depths between 40 and 330 m were carried out (Wilson & Marmo, 1958; SLGS, 1963; Elliot, 1966; and others). Altogether a total of 4000 arsenic determinations were carried out in the laboratory (SLGS, 1963) and an arsenic anomaly in excess of 800 ppm in soil was measured.

Paddocking methods employing hand labour, used in alluvial gold mining as described by Fowler-Lunn (1938) were environmentally destructive. Forests in the valleys were cleared and large tree stumps burned. Manipulation of the hydrological regime was necessary to channel water to where the gravels were being washed. In her own words:

"The complete removal of payable gravels was started at the lower end of the valley and gradually progressed upstream leaving great boulder heaps and desolation

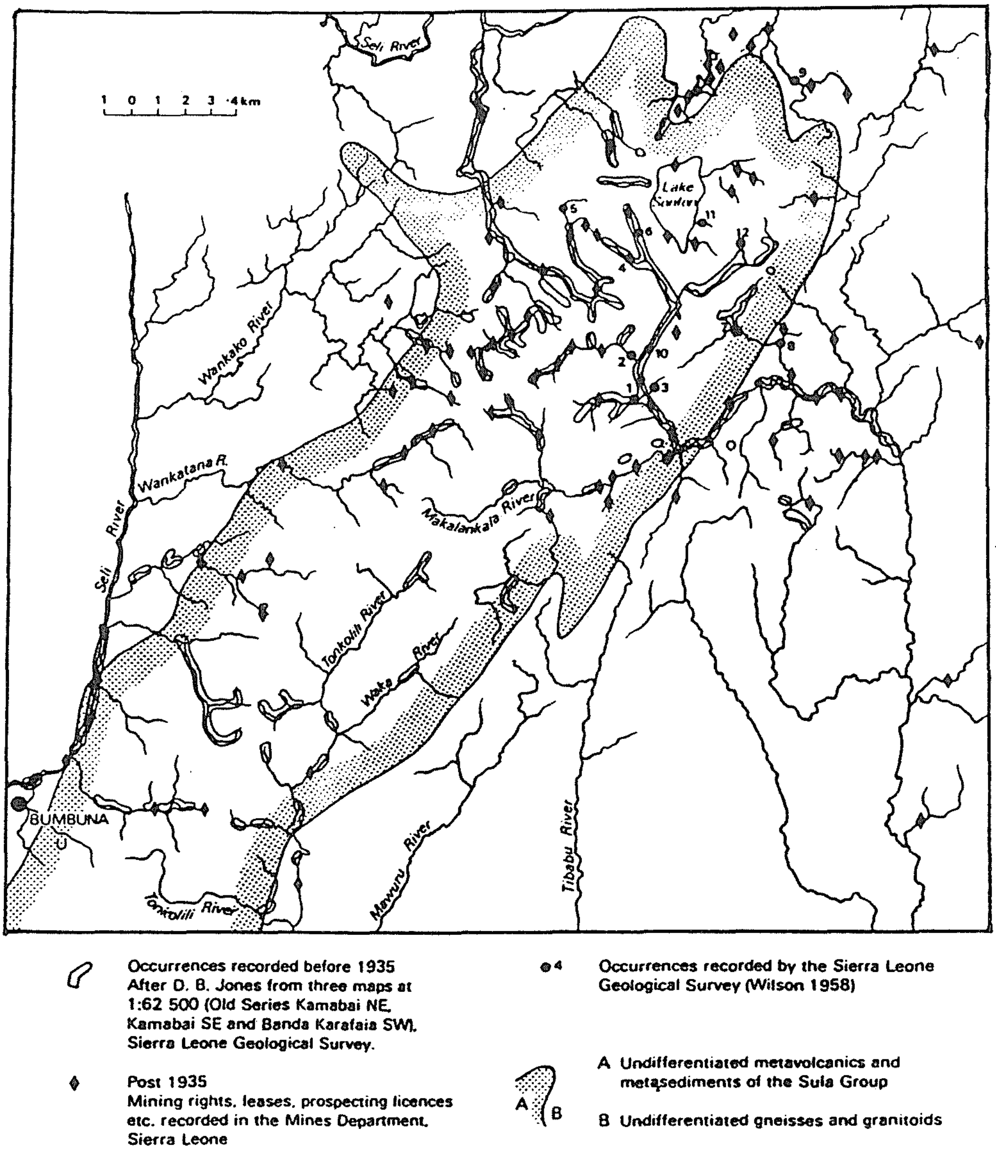


Fig. 2 Gold in the Sula Mountains/Lake Sonfon area (MacFarlane *et al.*, 1981).

behind... Trenches extended for miles winding in and out of valleys bringing the water from distant streams...Trenches, trenches and more trenches!"

Further, the toxic element mercury was used to collect gold particles associated with arsenic and then the ores were roasted in the middle of populated mine camps.

Bumbuna Falls hydroelectric project The construction phase of the Bumbuna Falls hydroelectric power project is presently under way and the river has been obstructed by a 90 m high dam in the narrow valley at Bumbuna creating a 30 km long lake upstream.

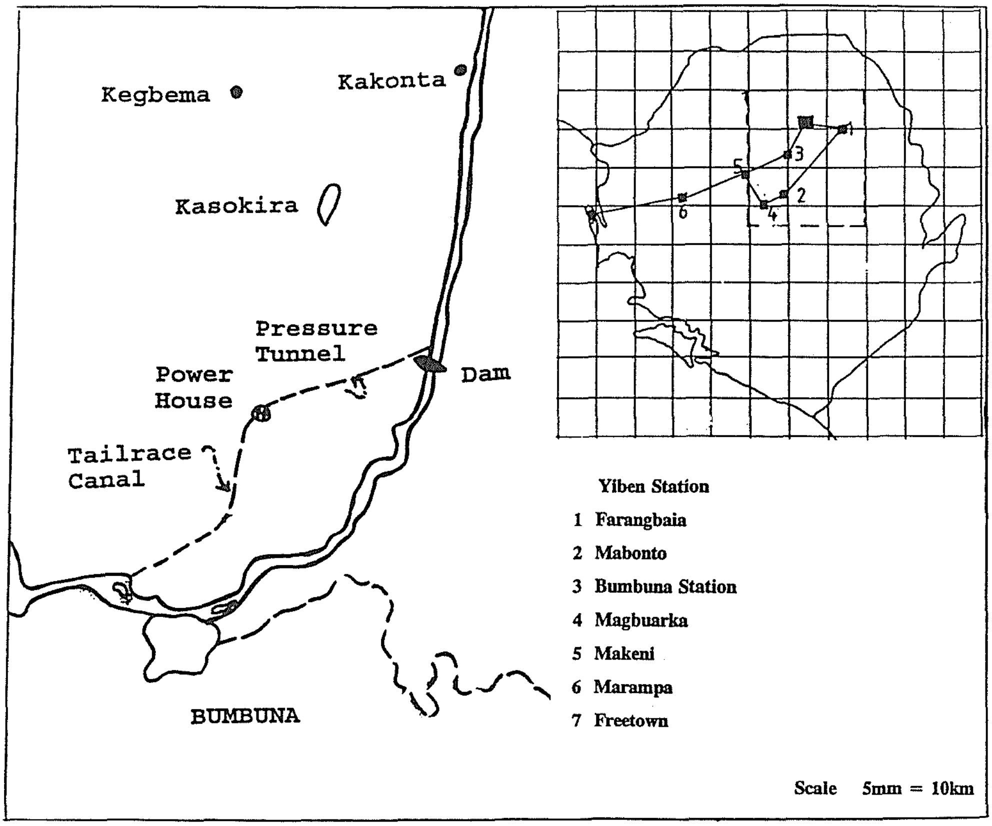


Fig. 3 Bumbuna Falls hydroelectric power project area showing proposed grid system (after Blyden, 1981).

According to EWI (1994) the dam has had apparently little negative impact on settlements and croplands.

The plan is to operate two hydroelectric power stations, one at Bumbuna with an installed capacity of 50.2 MW and the other at Yiben, 30 km to the north. The original proposed grid system is shown in Fig. 3, after Blyden (1981). Modifications involve the omission of transmission lines to Farangbaia and Mabonto.

An environmental impact assessment study funded by the World Bank and carried out by EWI-Switzerland and Techsult-Freetown in 1994, has recommended that the Yiben phase of the project be eliminated. This is due to the fact that approximately 800 km^2 of prime agricultural land and a long stretch of the major and recently completed Makeni-Kabala highway would be flooded.

Magbass irrigation scheme The Magbass irrigation system, funded by China, was constructed in 1980 adjacent to the River Rokel at Magbass in central Sierra Leone to irrigate a sugar cane plantation. The site is downstream of the dam at Bumbuna and the basin area between an installed gauge and the gauge at Bumbuna is 710 km^2.

In phase 1 of the project, a 70 km canal system was laid down over an area of 1222 ha under cultivation. Water is pumped into the canals from the Rokel and excess water is drained by gravity into a tributary running roughly parallel to the main channel. The pumping station on the Rokel has four pumps each with a total pumping output of 2.16 $m^3 s^{-1}$.

Sugar cane suckers are planted between December and March with a spacing of 1250 kg ha^{-1} and irrigation is carried out every 20 days for 15 h per day. The total cropping season is 150 days. In 1980-1981 and 1981-1982, 1200 kg ha^{-1} and 750 kg ha^{-1} of fertilizer were used, respectively.

Integrated Agricultural Development Projects (IADPs) The World Bank sponsored IADPs initiated in 1977 were intended to bring a variety of agricultural and infrastructural improvements to 22 chiefdoms in the country. Sixteen of these lie at least in part in the Rokel River basin. It was expected that 6070 ha of virgin inland valley swamps would be cultivated and 14 570 ha of partially developed swamps upgraded under the scheme.

Two methods of water control were used. Either irrigation water was diverted into peripheral canals and excess water allowed to flow into the main drain or the stream/river was dammed to create a reservoir from which water was drained by gravity during the dry season. Apart from poor water management leading to technical problems like clogged drains and subsequent iron toxicity, attitudes to swamp cultivation influenced by history and culture were major limitations to the success of schemes.

The IADPs also have a rural water supply component exploiting hand-dug wells in alluvial deposits and the weathered zone. Several hundred wide diameter wells have been constructed over the Rokel basin.

CONCLUSIONS AND DISCUSSION

Although little quantitative data is available on conjunctive use of the river, qualitative evidence of poor water management practices can be seen. Most important would be the effect of the dam at Bumbuna on downstream projects. River discharge data collection for the 3990 km^2 area upstream of this site was initiated in 1970. Data collection at Magbass was implemented in 1980. No gauging station exists at the basin outlet.

In the absence of long term data, basin hydrology could not be fully evaluated in terms of future water availability at the Magbass irrigation scheme and swamp development projects downstream. Further, if mining activities were to resume around Marampa or in the Sula Mountains where unworked reserves of iron ore still occur, water shortages might arise at certain times of the year.

Many potential water quality problems were created at a time when environmental consciousness was lacking and policy and legislation were weak. In the mining sector for example, early agreements between mining companies and the colonial government were made in the absence of substantive data on the extent and worth of ore deposits and their intricate relationship to water resources. Mineral exploration and exploitation were carried out concurrently.

A first step therefore towards risk assessment, would be to review available data and evaluate the nature of past and ongoing projects in the basin. Volumes of water abstraction at pumping stations should be tabulated. In addition, methodologies employed by mining companies can be indicators of likely environmental deterioration from geochemical contamination and siltation of surface water.

Comparative studies based on similar geological and climatological parameters and mining methods can also be useful. Osafo (1988), Adzaku (1993), Barnes *et al.* (1993), for example have verified high arsenic levels in water, flora and fauna (including humans) in the Ankobra basin of southwestern Ghana where gold found in rocks of like age are being mined using the same methods as those employed in Sierra Leone.

In spite of many well-meaning and sound policies laid down in national development plans and existing legislation, poor government planning and implementation strategies are root causes of problems in the water sector. According to Logan (1983), location of water supply facilities has been largely based on engineering and political considerations with little regard to population distribution, economic activity and social variables that affect water consumption. Further, projects are implemented simultaneously without determining effects on one another or the cost of duplication in data collection.

A lack of incentive stemming from poor economic conditions and hence logistical support creates difficulties with data collection and monitoring. The continued absence of a national water resources data bank is a major limitation. However, several positive steps have been taken towards the establishment of data bases and environmental monitoring. The University Research and Development Services (URDS) of the University of Sierra Leone, assisted by several international foundations, has established the Sierra Leone Science and Technology Information Network (SALSTINET). In addition, several environmental watch groups such as the Conservation Society of Sierra Leone (CSSL), the Sierra Leone Network of NGOs (SLANGO) and the Commonwealth Human Ecology Council for Sierra Leone (CHECSIL) have emerged over the last ten years, following in the footsteps of the inaugural Sierra Leone Environmental and Conservation Association (SLENCA) founded in the 1970s.

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