Paul C. Rizzo Associates, Inc. (RIZZO) has been expanding its operations in the Sub-Saharan Africa. In 2004, RIZZO began a Feasibility Study for the Development of the Volobe Hydropower Project (VOLOBE) in Madagascar. During 2005, the authors of this paper began the works for a Feasibility Study to investigate the potential for development of small scale electric generation facilities for the Kenya Tea Development Agency (KTDA). The Feasibility Study is being performed under a grant provided by the United States Trade and Development Agency.

The authors ventured into the Kenyan river valleys without knowing about specific sites for optimum hydropower production, looking for potential sites both at the east and the west areas of the Great Rift Valley. The work began “from scratch,” at the site identification stages, so the experiences and encounters with the local population were somehow unique. A very challenging aspect of the project is the number of sites that needed to be identified. In this case, the authors needed to find six to eight feasible sites, each in the order of magnitude of 1 to 6 MW. To do so up to twenty sites were identified and mapped at the field.

This paper describes the particulars of small hydropower development in Kenya, and its economic, political, social, and environmental implications.

1 Paul C. Rizzo Associates, Inc.
2 Kenya Tea Development Agency
BACKGROUND

Paul C. Rizzo Associates, Inc. (RIZZO), under a grant provided by the United States Trade and Development Agency (USTDA), carried out efforts to investigate the feasibility of implementing small hydropower projects throughout the tea production areas in Kenya. The plants will provide energy for the tea production operations of the Kenya Tea Development Agency (KTDA, the Grantee). The power from the hydroelectric projects will positively impact the production by adding reliability of operation and lowering the cost of electricity.

The work of Reconnaissance is one of three main investigations that have been assigned to RIZZO, the other two being a Sustained Forestry Development Study, and an Energy Audit. The three investigations will integrate into a final study that will provide KTDA with a strategic approach to deal with energy consumption.

RIZZO developed a methodology to select the most favorable sites for hydropower generation from a vast region in Kenya. Prior to performing the economic or cost-benefit analysis, it was required to build and follow a methodology to eliminate the less advantageous sites from those that are more promising.

The Republic of Kenya is located on the Eastern Sub-Saharan Africa. The country borders with the Indian Ocean at the East and the Equator running through the midland (Figure 1). Kenya occupies an area of almost 600,000 km² and borders Somalia (East), Ethiopia (North), Sudan (North-West), Uganda (West), and Tanzania (South).

Kenya became a British colony in 1919 and since then organized African political activity began to develop, being KANU (Kenya African National Union) the most prolific (1944). Jomo Kenyatta became KANU's President in 1947; after lengthy periods of civil war, Kenyatta became the Prime Minister of a 1963 independent Kenya. The country became a Republic in 1964. The official languages are English and Swahili, with the later being preferred. Jomo Kenyatta died in 1978 and was succeeded by Daniel Arap
Moi. Today, Kenya maintains remarkable stability despite changes in its political system and crises in neighboring countries. Particularly since the re-emergence of multiparty democracy, Kenyans have enjoyed an increased degree of freedom.\(^1\) In December 2002, Kenyans held democratic and open elections, which were judged free and fair by international observers. The 2002 elections marked an important turning point in Kenya’s democratic evolution in that power was transferred peacefully from the single party that had ruled the country since independence to a new coalition of parties.

Nairobi continues to be the primary communication and financial hub of East Africa. It enjoys the region's best transportation linkages, communications infrastructure, and trained personnel, although these advantages are less prominent than in past years. A wide range of foreign firms maintain regional branch or representative offices in the city. In March 1996, the Presidents of Kenya, Tanzania, and Uganda re-established the East African Cooperation (EAC). The EAC’s objectives include harmonizing tariffs and customs regimes, free movement of people, and improving regional infrastructures. In March 2004, the three East African countries signed a Customs Union Agreement.

**THE KENYA TEA DEVELOPMENT AGENCY (KTDA)**

The tea industry in Kenya is the largest player in the economy, even over coffee and tourism. The quality of the Kenyan tea is outstanding and its prices highly competitive. Currently, tea exports account for about 20% of the total export earnings and the sector contributes about 4% of the Gross Domestic Product (GDP).\(^2\) In addition to the approximately 400,000 tea farmers, it is estimated that about 3 million Kenyans are somehow involved with the tea production activities.

The KTDA operates over 50 tea factories throughout Kenya. The Agency began in the colonial era as the Special Crops Development Authority (SCDA), promoting growing of tea by Africans under the direction of the Ministry of Agriculture. After independence, the Kenya Tea Development Authority took over the liabilities and functions of SCDA to promote and foster the growing of tea in small farms. The authority experienced a tremendous growth from 1964 to 2000 and it was prudent to privatize the organization and form the now established KTDA Limited. KTDA’s success is based on the premise that tea production can, in fact, be managed by a small-scale enterprise, even though production depends on crop plantations. KTDA’s mission is to provide effective management services to the tea sector for efficient production, processing, and marketing of high quality tea for the benefit of farmers and other stakeholders. RIZZO’s professionals have witnessed that farmers are indeed benefited from the current strategic management of KTDA. The KTDA has over 54 factories distributed both throughout the East and West of the Great Rift Valley. The location of these factories is schematically shown in **Figure 2**.

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\(^1\) US Department of State (www.state.gov)

\(^2\) CJ Aron and Associates, Definitional Mission
There are two regions that exist for identification of tea zones, KTDA denominates East of the Rift Valley (East) and West of the Great Rift Valley (West). The Great Rift Valley is the result of the rifting and separation of the African and Arabian tectonic plates that began around 35 million years ago in the north, and by the ongoing separation of East Africa from the rest of Africa along the East African Rift, which began about 15 million years ago. It runs in a North-South direction through east Africa from Mozambique to the Dead Sea in Jordan.

Farmers gather their crops and collect payment through a zonal society. Payments are distributed by KTDA through the societies one month from the delivery date. The money collected by farmers is then used in local markets in exchange for goods of basic needs such as food and clothing. Overall, there is water supply all year long, though for the most part, it is untreated. In general, tea farmers are able to make ends meet and cover their basic needs. Electricity does not reach most of the population, though some homes do have diesel generators.

Conditions at the West and East of the Rift are quite different in many aspects, such as weather, economy, geology, soil types, social development, and land use. At the West, heavy rainfall interacts with human developments, tea crops, and other economic
activities to generate extensive soil erosion. The surface soils consist mainly of red silts that are continuously washed away, transported and placed on adjacent locations. Topography is of mild and regular slopes forming low elevation hills. Economic activities are uniformly spread out throughout the region. Even though there are two major urban centers, Kiisi and Kericho, most of the population prefers to live right on their farming land. During the site investigation at the West, RIZZO did not encounter uninhabited areas. Unequivocally, the development of hydropower projects requires significant efforts to settle land disputes between locals and KTDA, especially for the construction of canals and forebays.

The conditions at the East of the rift are quite different. The land is defined by the presence of Mount Kenya, with weather ranging from the warm lowlands to typical alpine regions. Mount Kenya is actually one of the few places near the equator on Africa with permanent glaciers. The minimum temperatures at Mt. Kenya are lowest at valley floors between 4,000 m and 4,270 m ranging between -4°C and -8°C. These temperatures are lower than those at the top due to the cold breezes that descend down the valleys during the night. Vegetation at the skirts of Mount Kenya, at elevations between 1,700 m and 2,200 consists of cultivated or pastoral lands and sporadic instances of rain forests of evergreen hardwood trees and some conifers. The forests become extensive at higher elevations. The forests are the main source of water for the rivers and streams that are under consideration for hydropower development. The tea plantations and factories are at the skirts of Mt. Kenya.

**OBJECTIVE**

The objective of the study was to identify feasible sites for the development of small-scale hydropower projects. RIZZO needed to pinpoint about twenty (20) sites to later select six to eight of the most favorable. Overall, the site search was performed with the following criteria in mind:

- Small-scale, run-off river projects with minimum or null storage capacity;
- Intake implementation without large dams or dams requiring a height of over 5 m;
- Avoid projects highly dependable on favorable weather conditions; in other words, maximize site head potential;
- Minimize length of water conveyance systems (canals and penstocks);
- Avoid environmental constraints, especially project inclusion into forest reserve areas;
- Avoid major visual impact effects on waterfalls and other environmentally appealing sites;
- Distance to tea factories; and
- Favorable political and social conditions.

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The criteria were jointly developed between RIZZO and KTDA. Given the local topographic and hydrologic conditions, it was expected, before the site reconnaissance, that 1 to 2 MW capacity projects would be feasible. This document shows that this expectation was surpassed.

**PRELIMINARY WORK**

Prior to advancing into site reconnaissance efforts, we performed a preliminary investigation of the local conditions that typically affect the development of hydropower projects, especially in the following areas: political, geologic, topographic, and hydrologic. Economic and financial analyses should be reserved for later stages, once a first alternative selection process is finalized.

The local political and social conditions of the area influenced our work throughout our investigation. Local production managers of the factories were very involved in the process and it was imperative to keep them involved in order to receive the local support that is required to access the remote sites. It would have been impossible to reach some of the locations without the guidance and friendliness of the Kenyan people.

Even though small-scale hydropower projects do not require large hydraulic structures that may possess an inherent geotechnical, structural, or seismic risk, it is still imperative to carry out a comprehensive geological investigation. The geological characterization is fundamental to understand the hydrologic behavior of multiple watersheds and the changing conditions of the soils and their use.

Topography and hydrology are obviously essential and we cannot stress enough the importance of the availability of good topographic maps. During these types of investigations, 1:50000 topography is required to identify the approximate location of a potential site. Hydrology can only be assessed through a combination of site reconnaissance, descriptive research of climate and vegetation, geology, and the availability of flow measurements. Fortunately, Kenya does have the basic information readily developed.

To assess the political and social conditions, we visited the areas and interviewed with local production managers at the tea factories. This allowed us to get an insight of the power requirements of the KTDA operations and the involvement of the factories. We then obtained 1:50000 scale topographic maps from the survey of Kenya, and hydrologic records from the Water Authority. With the information, prior to doing any site reconnaissance, it is recommended to develop a profile of the rivers and streams under consideration, and to perform a hydrologic analysis, including watershed characterization and statistical analysis. This information will considerably shorten the length of the site visits.

During this investigation, of particular interest were the conditions at Mt. Kenya (*Figure 3*), the extinct and collapsed volcano that has the highest peak elevation in the country.
Mt. Kenya is a large (partly denuded) volcano of the Vesuvian type, and peaking at El. 5,200 m. The volcanic pile is approximately 120 km wide at the base and it is about 4,000 m thick.

Originally, the crater must have been at a height exceeding 6,100 m since the volcano is now on the first stages of dissection. Figure 4 is an interesting graphic representation of the volcano varying slopes and the original slope profile. The highest portion has suffered the greatest erosion, having been subjected to at least two periods of glaciations. The geologic, topographic, and climatic conditions of Mt. Kenya were of particular interest for the identification of sites in the region.

**FIGURE 3 - VIEW OF MOUNT KENYA**

**FIGURE 4 - MOUNT KENYA PROFILE AND RAINFALL**

**RECONNAISSANCE**

On-site recognition is basically aimed to verify the geologic and topographic data, and to identify any possible obstacles that might hinder the development of a project, including

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4 B.H. Baker, 1966
technical aspects, as well as environmental, social, and political. The on-site reconnaissance efforts began at the West of the Rift along the Gucha River Valley, near the town of Ogembo. They continued at specific sites at the Eyaka and Menyeya streams, then to the lengthy Kipsonoi Valley, and finally at the Itare-Kiptiget system and the Chemosit River. At the East, Projects were identified at the Kiringa, the Thiba, the Rupingazi, and the Thuci Rivers. During the site recognition efforts, particular attention was placed to establish the feasibility of building intake structures and water conveyance systems (canals and penstocks). Intakes need to be located at zones where it is possible to divert the amount of flow required and they must be designed such that sediment is controllable. Intakes should be resistant to floods, and should sit on good foundation conditions. From a hydraulic point of view, the intake should be capable of diverting the flow to conveyance structures, in particular canals. The shape and topography of the valley at the site in which the intake is placed must allow for the diversion to occur without major civil works.

Canals must avoid landslide prone slopes and geologically unstable zones. Otherwise, maintenance cost will be high and interruption in power production frequent. If possible, the right-of-way of the canal should not interfere with economic activities or other rights-of-way, such as roads, railways, pipelines, or transmission lines. Unfortunately, and especially at the West, this is unavoidable and KTDA will need to incur into negotiations with land owners to acquire right of way for canals.

The location of the forebay and powerhouse is mainly driven by: (1) the optimum location for maximum power generation, (2) the minimization of the penstock length, and (3) the feasibility for the foundation and anchoring of the penstock supports.

The softly undulated nature of the region, especially near Kisii, is a condition that forces the design of new hydropower projects to use large canals in order to achieve reliable heads. Larger canals are required since tea producers are calling for economic and reliable power. With the hydrologic characteristics of the area and the demand requested by the tea production activities, it will not be possible to provide such power without the application of larger heads and the construction of conveyance canals and/or pipelines.

Given the economic and social conditions of the region, the biggest disadvantage of canals is safeguarding them against human interference, cattle raising, and other farmland activities. The lands are of low elevation and sparsely populated. The canals would run through generally accessible lands. A solution to overcome this obstacle is to implement canals by means of closed, half-buried conduits. The disadvantage is, of course, an increased capital cost, since the canals would require approximately a 1.0 to 1.5 m excavation given a trapezoidal cross section.

At the East of the Rift, topography is certainly more favorable for the development of hydropower projects. However, in the zones of investigation, some of the river valleys are very young, especially in the immediate skirts of Mt. Kenya, in the brinks of the forest reserves. This condition makes the projects feasible only where waterfalls are present. Further downstream, getting into the cultivated Mt. Kenya Belt, the river valleys
begin gaining age and more pronounced “V-shaped” form that facilitates the implementation of tailrace canals. Larger heads are achievable in short distances. The investigation focused on finding sites where facilities could be placed away from scenic places and forest reserves.

Flows are slightly lower than those of the West, with a base, dry-season flow provided by the controlling hydrologic conditions of Mt. Kenya and the forest reserves. There are two “wet” seasons, one running from March to June, and a second in October and November. The criteria to select the design flow for the projects in the East are equivalent to the procedure described for the case of the West. A higher percentage of the River flow is diverted. This is justifiable since canals are much shorter and therefore watershed impact is not as significant. However, visual impact on waterfall scenarios could be significant. We recommend that projects near these zones should be avoided. The overall organization of economic activities, housing, and land use is better organized in the East zones.

PROJECT SELECTION

RIZZO and KTDA jointly developed a preliminary comparison criterion for the investigated projects. It is required to select six to eight Projects for further investigation, which will include interconnection issues, cost estimation, economic analysis, financial analysis, and preliminary impact assessment. The preliminary criterion will compare the Projects based on capacity, possible environmental constraints, ease of development, estimated relative costs, estimated efficiency, location, and local conditions among others. The objective of the comparison is to aid the KTDA in the selection of those six to eight projects for which further investigations will be performed.

A preliminary comparison criterion assigns points, from 1 (unfavorable) to 5 (best) in each of the following categories:

- **Capacity** – Small hydroelectric projects usually have a high cost per kW installed. As capacity increases, it is expected to see improvements in such cost. Higher capacity projects will also be capable of supplying electricity to more than one tea factory. The Capacity category has 30% of the total score. In other words, the capacity points are multiplied by 30% and later added to the total points.

- **Environmental Impact** – Environmental impacts may increase the cost of development of the projects and as such these should be considered in the preliminary evaluation criteria. The environmental impact has 25% of the total score.

- **Intake Adequacy** – During the site reconnaissance, particular attention was placed to recognize favorable sites for the location of intakes. The intake of a small hydroelectric project might be one of the main cost drivers. A total of 10% of the scoring points are given to the intake adequacy category.

- **Canal Length** – The length of the canal is directly related to the capital and operation and maintenance costs. The canal length is assigned with 10% of the scoring points.
• **Location** – Preferred location is such that tea factories are nearby. However, the interconnection scheme that will be later recommended during the Feasibility Study might reduce the importance of the site placement. A 10% weight was given to the Location criteria.

• **Penstock Length** – The penstock length is an indicator of the adequacy of the topographic conditions and the required project investment (5%).

• **Access** – Overall, the sites were easily and readily accessible, due to the existent road infrastructure. Some sites did not enjoy this advantage. A 3% importance is assigned to this category.

• **Constructability** – This category is included to account for difficulties that might be encountered during construction, such as hard rock excavation, slope stability issues, or hydrologic and weather concerns (3%).

• **Development constraints** – Other issues that might complicate the development of the project. KTDA will assist RIZZO in the identification of such constraints (2%). At this stage, every project is assigned with a uniform average score of 3.

• **Regional and Political** – Equivalent to the previous category, KTDA will assist RIZZO in the identification (2%).

RIZZO and KTDA identified 21 projects of which 3 were eliminated due to hindering environmental and/or political obstacles. Others were grouped into joint developments. Table 1 presents the rank of each of the projects according to the previous evaluation criteria. Table 2 presents the four (4) top ranked projects for the East and West of Rift Valley.

**CONCLUSIONS**

The methodology described and carried out during our work provided an efficient and economic way of identifying sites for small-scale hydropower production along a vast portion of land. This process requires a preliminary investigation of the geologic, topographic, and hydrologic conditions in combination with the involvement of local representatives. For the case of the KTDA some particular conclusions are:

1. It is suggested that the Gucha-Mogunga Project and the Kipsonoi 2 should be implemented into one interconnected system. The arrangement would have the capability of feeding power to the following factories: Ogembo, Nyamache, Kiamokama, Nyankoba, Tombe, Gianchore, Kebrigo, Sanganyi, Nyanzongo, Momul, and Tegat. This arrangement translates into approximately 600 kW of installed capacity per factory.

2. The Kipsonoi 1 and the Itare-Kiptiget should be implemented into one interconnected system to provide for the following factories: Tegat, Kapset, Rorok, Litein, Kaptatet, Mogogosiek, Kobel, Kapkoros, and Tirgaga. This arrangement translates into approximately 670 kW of installed capacity per factory.
3. In the East, the Thuci and Kiringa 3 Projects in Table 2, may be interconnected to provide power for Ndima, Ragati, Kangaita, Mununga, Kimunye, Thumaita, Kathangariri, Muganie, and Rukuriri. This would provide over 1 MW of installed capacity per factory. The Nyamindi development could later add to such capacity.

**TABLE 1- PROJECT RANK**

<table>
<thead>
<tr>
<th>Project</th>
<th>Design Capacity [MW]</th>
<th>Points</th>
<th>Rank E/W</th>
<th>Overall Rank</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gi-M</td>
<td>3.0</td>
<td>3.73</td>
<td>3</td>
<td>7</td>
</tr>
<tr>
<td>Gucha 2</td>
<td>3.4</td>
<td>3.66</td>
<td>5</td>
<td>10</td>
</tr>
<tr>
<td>Gucha 3</td>
<td>1.5</td>
<td>3.53</td>
<td>7</td>
<td>12</td>
</tr>
<tr>
<td>Eyaka</td>
<td>0.4</td>
<td>2.73</td>
<td>8</td>
<td>16</td>
</tr>
<tr>
<td>Kipsconci 1</td>
<td>2.5</td>
<td>4.21</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Kipsconci 2</td>
<td>3.7</td>
<td>3.83</td>
<td>2</td>
<td>6</td>
</tr>
<tr>
<td>Kip-Itare</td>
<td>3.5</td>
<td>3.83</td>
<td>2</td>
<td>6</td>
</tr>
<tr>
<td>Chemost</td>
<td>1.3</td>
<td>3.61</td>
<td>6</td>
<td>11</td>
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</tbody>
</table>

**TOTAL [MW]** 42.0

**TABLE 2 - TOP RANKED PROJECTS**

<table>
<thead>
<tr>
<th>Project</th>
<th>Design Capacity [MW]</th>
<th>Points</th>
<th>Rank E/W</th>
<th>Overall Rank</th>
</tr>
</thead>
<tbody>
<tr>
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<td>2.5</td>
<td>4.21</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Kip-Itare</td>
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<td>3.88</td>
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<tr>
<td>Gi-M</td>
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<td>3</td>
<td>7</td>
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<tr>
<td>Kipsconci 2</td>
<td>3.7</td>
<td>3.68</td>
<td>4</td>
<td>8</td>
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<tr>
<td>Nyamindi 1</td>
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<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Nyamindi 2</td>
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<td>3</td>
</tr>
<tr>
<td>Rubingizi</td>
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<tr>
<td>Ena</td>
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<td>2.95</td>
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<tr>
<td>Thuchi 1</td>
<td>5.6</td>
<td>3.92</td>
<td>2</td>
<td>3</td>
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</table>

**TOTAL [MW]** 27.7
REFERENCES

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