Pilot Project: Construction of an experimental Geomembrane subsurface dam in Kenya

Prepared by: Kurt Klitten

Thematic area: Water for domestic use, for small-scale irrigation and for livestock.

Country and location: Mutendea riverbed at Syongila Village, 7 km northwest of Kitui, Kenya

Number of communities and Beneficiaries: Not known since the detailed location is yet to be identified, but expected to be at least 600 beneficiaries. However, in the long term the introduction of a Geomembrane linerfor construction of sub-surface dam can be a generally adapted method for hundreds of projects not only in Kenya, but in many other African countriesin which there are thousands of dry river beds suitable for subsurface dams.

Time Period:
The pilot project is estimated to have a duration of 18 months, including 12 months monitoring and final evaluation. The project includes five phases.
Phase I (Site Survey), II (Design) and III (Construction): Month 1-3.
Phase IV (Monitoring):Weekly for one year, beginning in month 3
Phase V (Implementation of water supply facility): Month 16-18.

Project Group:
The project is a joint collaboration between Engineers without Borders – Denmark (EWB-DK) and two Kenyan partners, lead partner Mr. Erik Nissen-Petersen, and sub-partner the South Eastern Kenya University (SEKU).

Rough estimate of funding:288.842 DK = Ksh4.852.560 incl. EWB-DK administration fees. (See budget for further details)

Background and objective:
The idea of using a Geomembrane liner for construction of subsurface dams (SSD) in dry riverbeds instead of clay dams came about during a EWB-DKfact-finding mission to Kenya in April 2013.

Geomembrane liner for construction of fishpondsis widely used in Kenya but *has never been used for subsurface dam construction* in riverbeds. The advantage of constructing a subsurface dam using the Geomembrane liner instead of clay is expected to be reduced construction cost because of significant less number of labourer working days and supervision days thus also less transportof labourer and supervisors. Furthermore, there are cases where useful clay or clayey soil is not available in the vicinity of the construction site. In these cases an alternative solution as the Geomembrane liner would be a welcome alternative.

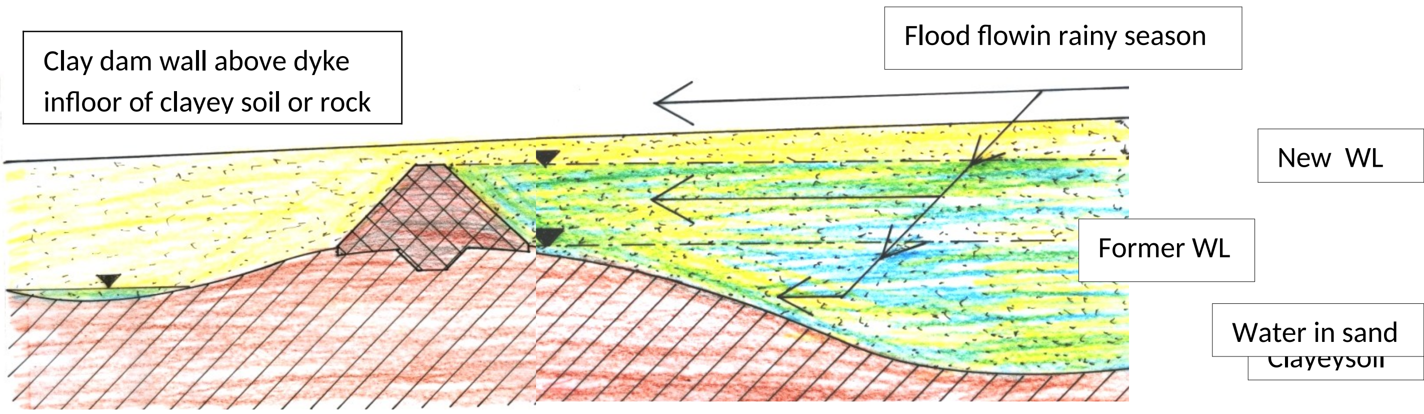
Principle of a subsurface dam built of clay or clayey soil:

The aim of constructing a subsurface dam in a riverbed is tostop and store part of the subsurface flow of floodwater in the voids between sand particles in the sand of riverbed upstream the dam.

As coarse sand has the largest voids up to 35% of water can be extracted from it, while only about 5% of water can be extracted from fine-textured sand. No water can be extracted from silt.

Accordingly, only riverbeds with sufficient thickness of sediments consisting of sand or gravel are feasible for storage of water.

In order to gain free storage capacity and reduce the construction work, the dam should be constructed at a location where the “floor” below the sandy riverbed consist of almost impermeable soiland forms a sort of natural dyke or threshold with less depth to the “floor” than otherwise in the river bed as shown on the figure below.



Accordingly, by adding the dam on top of the floor dyke the volume of water stored in the sand upstream the dam will then be increased, though assuming the “floor” below the sand is sufficiently impermeable. The latter to be examined and verified by observing water-indicating trees and villagers water dug-holes as well as by probing with 6 m long iron rods hammered down through the sand. Sites, where fractured rocks and boulders can be observed within or around the riverbed, will most probably not offer suitable conditions for establishing a storage reservoir because of risk for drainage by leakage.

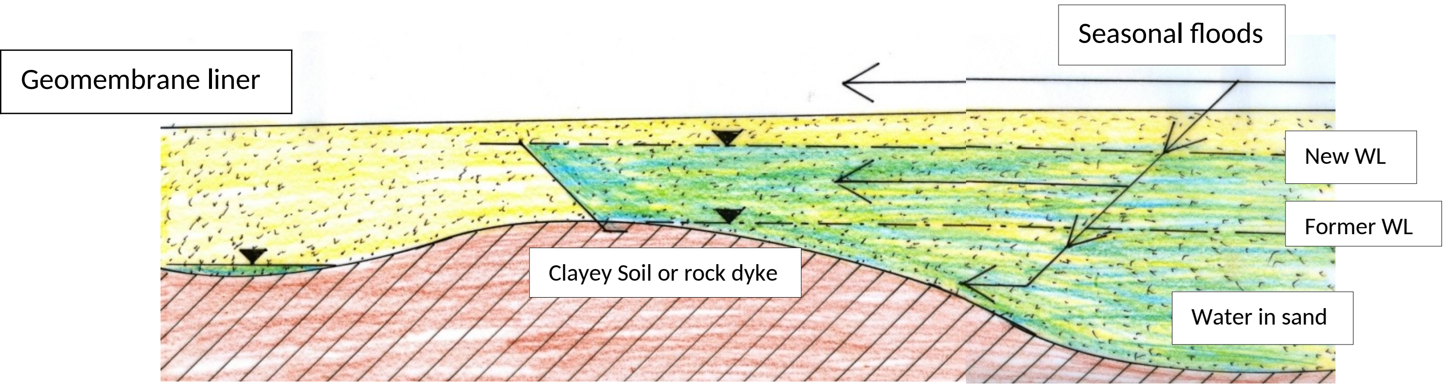
Photos: Probing with 6 m long iron rods.

The actual storage volume can be estimated from a longitudinal profile combined with cross sections showing the probing data as well as the measured elevation at each probing point, and taking in consideration that the maximum water level will be the elevation level of the top of the dam, and that the maximum extraction porosity of the sand is 35 % (to be determined by field test on sand samples).

Details of the design for dams built of clayey soilare: 1) Top of dam(crest)should be 1 m wide and kept 0.5 m below surface of riverbed to prevent evaporation andfunction as a spillway under the surface of a riverbed for water overflowing a full reservoiravoid; 2) Foundation of dam to be excavated 0.2 m into the “floor” material below the sand as well as into the riverbanks with a 1 m wide and 0.6 m deep key below central partof the dam wall; 3) The batter (slope) of the dam wall to be 1:1 in coarse sand and 2:1 in fine-textured sand; and 4) Suitability of clayey soil for construction of the dam to be verified by a saturation test.

SSDs are relevant only in non-perennial or seasonal watercourses (ephemeral streambeds named laggas and wadis in East and North Africa). Several clay subsurface dams have been constructed in East Africa: by Tanganyika Railways in the years 1905 to 1915, by ASAL Consultants Ltd. since 1990, and byTheVeterinaries Sans Frontièresand the Swiss Development Cooperation in northern Kenya during the last 4 years.

Experimental project with subsurface dam built witha Geomembrane liner:
The purpose of this pilot project is to build an experimental subsurface dam using a geomembrane liner instead of the traditional clay dam.The only differences to what is described above for a clay dam are some of the details of the design:
The bottom of the dam-liner should be as a minimum 0.3 m widebase and buried at least 0.2 m into the “floor” material as well as into the riverbanks.The top of the liner placed as a 1 m wide horizontal base and kept 0.5 m below the surface as with a clay dam.The batter (slope) of the dam liner should beas with a clay dam, e.g. 1:1 in coarse sand and 2:1 in fine-textured sand.The recommended dam-liner is a 1.0 mm Low Density Polyethylene (LDPE) Geomembrane Liner, which is available in widths of 6 m and 7 m and in rolls of 200 m length (e.g. from Linefix International, Nairobi).



The following criteria have been applied for selection of a site for the experimental project:

- A seasonal watercourse with high probability for fulfilling the feasibility criteria described above.
- Felt need amongst the villagers in nearby communities for improvement of the supply facility for domestic water, for small scale irrigation and for livestock.
- As near Nairobi as possible in order to minimize expenses to transport and supervision of the project by local implementing partner Erik Nissen-Petersen.
- A watercourse, which is not target for exploitation of sand & gravel for construction work.
- As near a university as possible in order to provide "on the job" training of relevant students and involve them and their professor in the monitoring of the efficiency of the Geomembrane sub-surface dam.

Based on these criteria our local implementing partner, Erik Nissen-Petersen,has recommendeddetailed site investigations of 3 potentialsections ofthe Mutendeadry riverbed nearSyongila Village, 7 km northwest of Kitui Township which is located approximately 180 km east of Nairobi.Furthermore, Southeastern Kenya University (SEKU)is located approximately 20 km from the probable project site nearSyongila Village.
Professor Musimba of SEKU will be responsible for themonitoring of the effect of the dam on the groundwater level in dry riverbed upstream and downstream as well of the dam.The aim of the monitoring program (project phase IV) is to establish documentation of the efficiency of the dam after its completion. This will be done by conducting one year of weekly monitoring of the water level in each of the six water level monitoring pipes (1" GI) which will be installed (two downstream and near the dam, two upstream and near the dam and the last two also upstream but in the deepest part of the water reservoir).The water level recording will be done by students from SEKU under guidance of ProfessorMusimba and his assistant, Dr. Mwangi, who after completion of the monitoring programme will prepareamonitoring report.

Already during the site investigations (phase I) as well as during the design (phase II) and during construction of the dam (phase III)the same students from SEKU will be involved in the practical work under guidance of local implementing partner Erik Nissen-Petersen (on the job training).

After hopefully having documented a sufficient increase in storage of water upstream the dam and estimated the amount of water possible to exploit annually from the river bed it will be decided how to bestutilize the water for the benefit of the nearby villagers (project phase V). If the potentialwater volume is less than e.g. 2000 m^3/year or 5.750 liter/day the water supply facility to be implemented should be a protected dug-well constructed in the riverbank next to the deepest part of the reservoir to the riverbed, and provided with preferably a windlass.

If water storage is more than 2000 m^3/year equal to 5.750 liter/day it is recommended to invest in a solar driven submersible pump to bring the water from the dug-well through a pipeline and up to an elevated storage tank to be located as near as possible to the beneficiary community. In the budget for project phase V the latter water supply system is assumed, thus including construction of a protected dug-well, installation of aGrundfos SQF-12 volts submersible pump med accessories, solar panels with steel rack, a 6.000 l PVC-water storage tank, and 1000 m PVC-pipes (ø60mm).

The respective reports from each of the five phases will be compiled by EWB-DK into a comprehensive completion report, which will include experiences, costs, lessons learnt and recommendations for future similar projects based on GeomembraneSSDs. This report will be made accessible for the public via the internet in order to ensure that everyone can use the Geomembrane-method for SSDs.

The "Open Source" principle for the Geomembrane technique applied for SSDs is also maintained by involving the local university (SEKU) in the project and by providing "on the job training" for students from this university during all five phases of the project implementation, thus to ensure replication by experienced engineers.

Maintenance and sustainability:
For an SSD and for the sand reservoir upstream the SSD there should be no maintenance. For the protected dug-well eventually occurring cracks or fractures in the upper part of the lining as well as in the cover slab should be cement plastered. Therefore, a regular inspection of the physical status of the well inside and outside should be done annually followed by needed repair. The lower part of the well-lining will have tiny infiltration holes for recharge of water into the well.

Theonly maintenance needed for the solar panelsis a cautious cleaning, thus keeping them free for dust, dirt and leaves. If that is not done their productivity of power will decrease dramatically thus lowering the capacity of the pump significantly.

The most reliable submersible pump in the market is the Grundfos pump. A preventive examination and maintenance every five years is recommendable, or if its capacity has decreased and the latter is not caused by lack of cleaning of the solar panels. In order to avoid wear and tear of the pump caused by fine particles in the water the latter will be tapped from the sand reservoir by drainage pipes, which will direct it to the dug-well located outside but near the sand riverbed.

An important factor in securing the success of this project and its sustainability is to ensure local involvement and commitment. In addition to the involvement of SEKU and their students, two main activities are planned:

1. As part of the site selection process, lead local partner Erik Nissen-Petersen will explore and secure the different communities' involvement in the actual construction of the SSD.
2. Shortly before implementation of phase V, a water committee representing the beneficiary community will be established and registered at the authorities. The committee will be responsible for selling the water from a water kiosk to the consumers for a reasonable price, and for saving the income in order to ensure funds are available for operations, maintenance and eventually repair of the water supply facility.A nearby (30 km) clay-based SSD was constructed by Erik Nissen-Petersen in Kisasi in 2005 and here a water committee was also established. It is therefore recommended that a study tour to Kisasi be arranged, during which the Kisasi Chairman will conduct a short practical training course.

Environmental Impact Assessment

EWB-DK considers the environment as an important factor when defining sustainability. As such, all phases of this project will involve environmental impact assessments (EIA) and consequent project authorization by Kenya's National Environment Management Authority (NEMA). An EIA will pinpoint both the positive and possible negative effects of the project. It will also provide detailed suggestions as how to minimize negative effects, if any.The work with the construction of the SSD will not begin before formal authorization of from NEMA has been given. As it is mandatory for traditional clay-based SSDs in Kenya to receive authorization from NEMA before construction and the only difference in this project is the use of a geomembrane liner instead of clay, it is expected that NEMA will also approve this approach.

Because the determination of the water supply facility depends on the results of project phase IV, local lead partner Erik Nissen-Petersen will get two separate EIAs prepared – one covering phases I, II and III and one covering phase V.

Implementation and responsibilities for the experimental project:

Project phases	***Responsible***
Phase 0:Funding	Engineers without Borders, Denmark (EWB-DK)
Phase I: Site surveying incl. report	Erik Nissen-Petersen, ASAL Consultants Ltd., Kenya
Phase II:Design incl. report	Same as above
Phase III: Construction incl. report	Same as above
Phase IV: Monitoring incl. report	Professor Musimba, South Eastern Kenya University
Phase V: Design and construction of water supply incl. report	Erik Nissen-Petersen, ASAL Consultants Ltd., Kenya
Completion report (compilation of reports I, II, III, IV and V.	Engineers without Borders, Denmark (EWB-DK)

Budget:

Main groups of work tasks	Ksh*	DKr
Phase I: Site investigations incl. report	420.000	25.000
Phase II: Design incl. report	168.000	10.000
Phase III: Construction incl. report, dam-liner, transport, wages, etc.	924.000	55.000
EIA consultancy for Phase I, II and III	67.200	4.000
On the job training of 10 students during phase I, II and II (14 days field allowances for students, Professor fees, transport)	168.000	10.000
Sub-total Phase I, II and III	***1.747.200***	***104.000***
Phase IV: Monitoring incl. report and allowances to students	420.000	25.000
EWB-DK site visit	235.200	14.000
Sub-total Phase I, II, III and IV	***2.402.400***	***143.000***
Phase V: Design and construction of water supply incl. Supervision and report		
EIA consultancy for Phase V	50.400	3.000
Construction of a 2 m diameter and 6 m deep well incl. Drainage pipes and materials and transport	168.000	10.000
Grundfos SQF 2.5-2 for capacity 2.500 litre/hour and 8 Nos. 80W solar panel incl. accessories, steel rack, transport and installation	620.000	36.905
1000 m HPDE-PVC pipe ø60 mm from well to water tank on elevated terrain near Syongila Village (digging done by villagers)	320.000	19.048
6.000 liter PVC water tank incl. Transport	88.200	5.250
Fittings, valves, taps etc.	58.800	3.500
Design and Supervision of phase V, inclusive training of water committee	168.000	10.000
On the job training of 10 students during phase V (14 days field allowances for students, Professor fees, transport)	168.000	10.000
Sub-total Phase V, Water supply facility	***1.641.400***	***97.702***
Total for Phase I, II, III, IV and V	***4.043.800***	***240.702***
EWB-DK overhead for administration, fund raising, project support, knowledge sharing/dissemination and compilation of reports I, II, II, IV and V to a Completion report	808.760	48.140
Grand total	***4.852.560***	***288.842***

* Exchange rate: 16,8 Ksh = 1 Dkr

References: Erik Nissen-Petersen, 2006: ”Water from Dry Riverbeds”. Danida funded traininghandbook. ASAL Consultants Ltd., Nairobi, Kenya. -Erik Nissen-Petersen, 2014:“Subsurface dams for water storage in dryriverbeds” uploaded to the Internet onwww.waterforaridland.com and 2015:“Survey of water sources using satellite images”.