Understanding the Hydrology of (Kitui) sand dams

Short mission report

November 2005

within component 1 , Hydrological evaluation of Kitui sand dams, of

'Recharge Techniques and Water Conservation in East Africa; up scaling and dissemination of good practises with the Kitui sand dams' .

a project by the Acacia Institute Amsterdam and SASOL Foundation, Kenya

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INTRODUCTION

A short mission was carried out on the hydrology of sand dams as part of the ACACIA/SASOL project

'Recharge Techniques and Water Conservation in East Africa; up scaling and dissemination of good practises with the Kitui sand dams'.

Component 1 in this project is on the hydrological, environmental and socio-economic evaluation of Kitui sand dams, see project proposal August 2005. The component was funded by the Dutch Aqua for All Foundation.

Under component 1, a field study is carried out by hydrogeology students of the Free University of Amsterdam, Faculty of Earth and Life Sciences. A student from Nairobi University was added to the project through SASOL to support on geological aspects. Another part of the component 1 study is on the socio-economic issues, carried out by two other Amsterdam students

This mission report only deals with the hydrological and technical ('hardware') aspects of the sand dams concept.

The Amsterdam students took the sand dams of the Kiindu river (the stretch of the Kwa Kangesa-Kwa Ndunda- Kwa Langwa dams) as a case for a detailed hydrological field study. The facts and findings will be reported in their master's report [Borst and de Haas, to come out by February 2006]. This mission report is anticipating on the student's Masters and should be considered as a preliminary to their conclusions.

GOALS

The overall objective of the Acacia/SASOL project is to contribute to scaling up of community based small water conservation schemes, focussing on the concept of sand dams.
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The project will help to define best practises, best locations on the scale of catchments, regions and the opportunities in terms of water supply volumes. The project will recommend on the lessons learned, the main criteria for success or failure and main issues for up scaling and improvement of the sand dam concept.

The results will be used to disseminate the knowledge on the sand dams concept to other Sasol's in Kenya and other countries and to bring this kind of low cost groundwater solutions under the attention of regional and national water managers end decision makers.

MEANS

The Kiindu river and other Kitui sand dams are taken as a case to understand the hydrology of the sand dams concept. In particular it is tried to quantify the Kiindu hydrology to have proof of the various hydrological issues. From there, the results are used to extrapolate and to generalise on the potential of the sand dam concept for other areas and scales.

During the mission the various issues were intensively discussed with SASOL staff and SASOL board members. To compare different approaches of sand dam construction and sand dam hydrology, visits were paid to sand dams, wells and water/soil protection projects by SASOL and other NGO's. Further information came from handbooks and reports (e.g. the REAL project[1]). Several reports from this REAL project were made available through the Technical University of Delft, see references.

A mission itinerary is given in annex 1.

Details on the Kiindu dams and catchment area will be given in the student's master report.

[1] REAL: Rehydrating the Earth project by Delft Technical University, The Netherlands.

FINDINGS AND VIEWS

Siting of dams

General (and intensive) investigation methods to plan and pinpoint favourable areas and dam locations are given in handbooks like [Ake Nilsson 1988, chapter 4].
On local level the main discussion is how intensive the siting efforts should be and whether the community should have the deciding vote to determine the location of the dam.

In any case, when considering the building of sand dams the local community should be involved. From there, the water needs and the total water volumes are specified by the number of people in the community, deciding whether a dam makes sense anyhow and whether it is worth the investment.
The required siting effort highly depends on the experience of the NGO with the area and their knowledge on the local hydrogeology. SASOL for example, is based and working in Kitui area for many years. With their experience, wide scale and intensive surveys are not needed for each new dam; this would not be cost-effective anyhow. In this case, the rough planning of sand dam locations can be based on existing knowledge of local NGO's.

However, still some of SASOL dams suffer from bad siting, leading e.g. to leaking dams that are build on sand or dams that are destroyed by peak runoff events. So, the decision to build a dam should not be solely based on the desires of the community and a haphazard field trip but also on sound technical data. No dam should be build when the hydrogeological conditions are not suitable.
In my view a minimum siting survey should contain at least:

- share the long-time experiences of the community. They know the best spots to find even the last drop of water in their scoopholes. The existence of scoopholes as such indicates low-permeable underground and/or natural underground dikes.
- steel-rod probing or test boring at the proposed dam location, examining the geology of the river bed foundation (bedrock, low permeable layers clays,..).
- study the nature of the sand/silt profile in the existing river bed, the future profile of the mature dam will be a look-a-like this. Make at least one borehole to estimate the effective porosity.
- The (difficult) estimation of (peak) river runoff from catchment area- and rainfall data to design the dam properties.
- estimate the dam storage from by leveling the upstream area and compare the expected storage with the water needs.

downstream effects

A point of discussion often heard is whether sand dams (or integrated systems of multiple 'cascading' dams in one single river, as they are built by SASOL) have significant negative effects on the areas down stream in terms of water supply. To respond to these questions it is important to know the fraction of the river runoff that is stored in the sand dams.

Calculations in the Kiindu/Kitui area prove that sand dams only take some percentage (1 to 10% approx.) of the total runoff. This will generally be true when building sand dams also in other semi-arid ephemeral rivers. Also there will be no negative effect on the river water quality since these are directly related to river discharge.

dam construction

In general, construction of sand dams is described in handbooks e.g. [Nissen-Petersen 1982 and 2000 and Nilsson 1988]. Also SASOL is preparing a report on the construction of sand dams [SASOL foundation, 2004, in prep.]. Also the REAL project is dealing with many of the construction issues [REAL project reports].
During the years, SASOL has build up a lot of experience in building sand dams and underground dams, meanwhile improving their technical concept. Mistakes are still being made. But as a 'learning organisation' SASOL became an expert-organisation in the community-based construction of sand dams.

Major (but well known) construction requirements are:

- well-designed spillway
- proper (geo-technical and hydraulic) foundation to bedrock or impervious material.

- proper wing walls
- still being prepared for extreme runoff events in the changing climate, planting Napier grass or other erosion protecting species on outside and downstream alluvial banks;
- being alert to rivers changing its bed, flowing around the dam.

There is a sensitive and difficult dilemma in maximizing the crest-height of the dam (to create maximum storage) and minimizing the risk of dam scouring and collapse. Proper monitoring of rainfall and runoff data is essential to solve this. However these data are missing in most cases.

A striking thing in the SASOL practise is that they build the dams at their final height at once. Handbooks advise to build the dams in stages, to prevent major deposits of silts upstream of the dam. Building the dam only in one stage is a great advantage because the NGO and the community don't need to be re-mobilised over years. The costs of building the same dam in stages could be 3 times higher (SASOL estimate).

SASOL claims that the assumed major siltation upstream the dam does not occur in the Kitui situation. This is proved in the case of the Kiindu dams: in the field study only minor, very thin layers of silt are found in the profile. This was also found by the student's investigation in the REAL project [Beimers e.a., 2001, page 30]. The silts are discharged by the river and building in stages is not necessary. The most likely process of this surprising process of silt discharge is explained in the section on siltation.

Hydrological system

The hydrological system works as follows.

When the first rains fall on the valley-catchment alongside of the river, a minor part of the rain water is infiltrating, moistering the clayey soils. A major part of the water runs off over the bad-protected farmlands and barring soils and from there into eroded (uncontrolled) drainage channels and gullies, carrying massive silts and some coarse sands. The gullies finally discharge water, silts and sands into the river bed.
Once in the river, the water spreads over the river bed. The silts and sands are deposited in depressions and the water recharges the sand profile. Observations show that this recharge is almost immediate and groundwater level is raised almost to ground surface, just after one night of rainfall. It might be that the existing scoopholes play a significant role in the recharge process.

Consequently the rise of the groundwater level in the bed induces a sideward flow of groundwater from the bed into the riverbanks and groundwater levels in these banks rise, almost without delay.

When the rains continue the overland flow from the valleys into the river bed continue. Once the sand profile is fully saturated, the runoff on the river bed surface increases. The increasing water velocity is once more working around the sands and silts, the silts go into suspension and are discharged over the dam.

After the rainy period the overland and river bed runoff stops. Groundwater flow however still continues: part of the rain water has infiltrated into the upland valley soils. The moisture in these soils is only partly used for evapotranspiration; the other fraction is recharged down to the underlying bedrock as saturated groundwater. This groundwater slowly flows downwards to the riverbed, replenishing the sands of the river in the dry season. It is important to quantify the amount and the delay time of this groundwater baseflow because it could make up a significant part of the total water supply. This component of groundwater baseflow could be extended significantly by water retention and additional Artificial Recharge measures in the upland catchment area.

SASOL tends to build a system of multiple ('cascading') dams, for instance in the Kiindu river. One of the advantages of doing this is that small leakage losses through the dams are no problem because they are recharging the next downstream dam.

An interesting phenomenon is reported several times in the multiple Kitui sand dams: downstream of the last dam people observe (and SASOL says it is proved by observations in boreholes) that there is still water flowing from the river during the dry season, more than ever before. This could be explained by leakage through the last downstream dam, either trough fissures in the dam foundation or by local groundwater flow around the abutments of the dam.

There might however be another process that could explain this. The layers underlying the river bed are never 100% impermeable: weathered or fissured rocks will allow groundwater flow to some (or large?) extend. Consequently the raised water level in the river bed induces vertical groundwater recharge into these deeper layers. This groundwater may slowly flow down-gradient in the longitudinal direction of the river and seep up in downstream areas. In a multiple dam system this longitudinal baseflow is kept in storage and is available for water supply. This is another major advantage of these multiple 'cascading' dam systems. To prove the existence of this baseflow component sampling on isotopes in combination with ground water modelling would be very helpful.

Summarizing, the water balance in the dry period is influenced by:

- abstraction of water from the river bed by scoopholes and wells
- evaporation of water from the river bed
- evapotranspiration of water from the soils in the river bank
- loss of water due to (horizontal) leakage through the dam construction and (vertical) leakage to deeper aquifers

and (incoming):

- delayed groundwater baseflow from the river valley, slowly trying to re-fill the system.
- (multiple dam systems) leakage through the upstream dam and induced longitudinal baseflow from upstream dams (through deeper layers underlying the bed floor).

This all leads to the conclusion that the total resource of water not only consists of the one-time storage of water in the river bed. Under the right conditions water is also stored in the river banks and the system may be replenished considerably by delayed groundwater baseflow components, particularly in a multiple-dam system.

Sand profile, sediments and siltation

The grading of the sand profile is a determining factor for both the total effective storage and the recharge velocity. In the siting process of new dams it is therefore essential to investigate the deposits in the profile of the existing river, this profile will be a look-alike of the future profile in the mature dam.

In the Kiindu case, high permeable coarse sands with only minor, very thin layers of silt are found all over in the river bed profile. There is a very distinct difference in coarse sand and extremely fine silts (clays). The effective yield and the total effective capacity will be estimated in the Amsterdam student's report.
In the Kitui case it is proved by water level observations that the bed fills up with water completely in just only one or a few days of rainfall, even when the first rains show a lot of siltation on the top of the profile
It is believed that these silts are removed quickly when the rains continue, the profile is filled up with water and the water starts to runoff over the dam. The 'first-rain-silts' are found in minor depressions in the bed and former scoopholes. In some parts of the bed silts are overlain by coarse sands, sedimented during these first rains.

So in the Kiindu case recharge is fast, almost immediately. Both recharge velocity and effective storage capacity are not influenced by silt. In this ideal case no recharge improving measures are needed. Also there are no problems with air-locks, preventing recharge.

Source of silts

The silts are mainly eroded from the clayey soils of the valleys alongside of the river. The first big showers of the rainy season took place just at the day the mission arrived in Kitui. Big showers are discharged overland and through eroded drainage gullies into the river bed. You can observe the silts in the endings of these channels. Just behind these silts coarse sands are transported into the river bed. Obviously, in a later stage when the river starts flowing, these silts go into suspension and are removed with the runoff over the dam.

Siltation at the dam site

In the area just upstream of the dam the profile shows almost no silts. This is surprising because the dams are directly built to their final hight and not in stages as is advised in handbooks. This could be explained by the following process.

At the initial stage after building the dam the sands are transported over the bed surface. With the water running off, the silts are in suspension. In the area just upstream of the dam the water depth is much greater. Obviously in this area the water velocity is still so high that the silts stay in suspension. Maybe this is only true in the case of big showers (as they often occur in the Kitui area). While the silts are in suspension, the coarse sand is trapped at the bottom and the main fraction of the silts is discharged over the dam. Once the runoff has stopped (zero velocity), the silts that stay behind in the water will slowly settle on the top of the coarse sands. With each shower and runoff this process is repeated. As a result, the silt layer will always be on top of the coarse sands: the silt layer is 'growing upwards' until the dam is mature.

For this process high peak runoff (by big rain showers and fast runoff) is required and there should be a distinct difference between the coarse sands and the fine silt particles. It would be very helpful to quantify this process scientifically.

Erosion

The sedimentation in the mature dams of Kiindu show that massive erosion is still going on in the river valley. To have a sustainable natural resource situation proper soil conservation measures should be integrated in the further development of the catchment area. In an ultimate and ideal situation the runoff from the drainage channels should consist of clean and clear water only.

SASOL started to take this up by training the communities on water harvesting and soil protection in their Natural Resource Management training programme [SASOL 2003]. However the action is left to the initiative of community land owners, terracing their plots. There are no actions taken to prevent erosion from the barring, unused soils.

Of course, erosion protection is not just the responsibility of SASOL. It should be addressed by Kenyan Government.

Water use and abstraction

The water from the river bed is mainly used for household and livestock water and small scale bucket-irrigation in the river banks and watering cattle in the river bed.

The community still take most of the water from scoopholes that are digged out in the river bed. The water is put in jerry cans and is carried upland by donkeys. In the older SASOL dams (such as the Kiindu dam system) no wells were constructed. SASOL claims that they are now constructing sealed, handpumped wells just upstream of each the dam as standard procedure. These wells are used, owned and should be maintained by 'well-members' of the community. These are people who actively contributed in the construction.

Some large diameter open wells were digged and masoned by the community at their own initiative. During the student's field work such a well was constructed by very active community members just in a period of some days.

At other dam locations (Ithimani river) appropriate hand-pumped wells were seen, constructed through AMREF. These wells were nicely sealed, with special care on the apron and a double acacia fencing to keep the animals out. Unfortunately at one of these Ithimani dams (build already in 1985) the river tends to break out in the outer corner within some years. This will flush away the sands and the AMREF well will soon be without water.

Handbooks advise gravity pipes through the dam as an extraction option. SASOL does not use these pipes. One of reasons for not doing so is that the dam construction will be weakened. Also it is found too expensive and complicated.

Several alternative practical options for extraction are given by [Erik Nissen-Petersen, 2000] including construction details and costs.

As far as we know there is no management of water demand or water abstraction. Apart from the water levels that can be seen in the scoopholes there is no regular observation of the underground water level. This underground water level would be a good measure to manage the amount of water that is left in storage.

The Amsterdam student's report will give details on stored water volumes in relation to the water needs of the community.

Water quality and safe water supply

A lot of the water is still taken from scoopholes. This water definitely is not safe for drinking water and will lead to water related diseases.

Although some of the scoopholes are protected by acacia branches, cattle (donkeys) is often seen close by, leaving their droppings at a distance of only 1 or 2 metres from the scoophole. Faeces and dropping from cattle and humans within such a short distance can and will lead to serious contamination of the water by humane pathogen viruses and bacteria. This will happen particularly in the wet season and when the groundwater level in the bed is close to surface.

Of course additional contamination will occur during transport of the water, but that could be prevented by sanitation and hygiene training. It was said that people boil the water before drinking; this however was mostly not the case at Kiindu.

In most areas there are special scoopholes for cattle. It is seen that people, when their own scoopholes get dry, start using the cattle scoopholes as their last source of water.

Water samples have been taken from wells and scoopholes. The results will be given in the students report.

Properly constructed sealed, handpumped wells can deliver an acceptable biological quality of potable water, provided that the water is taken from the deepest parts close to the river floor and provided that the surrounding area is protected from contamination. In its present practise SASOL is constructing a hand pumped well at each new dam location.

The student's report will deal with the hydrochemistry of the water in the Kiindu dams.

The water quality can of course be influenced negatively by pollution (e.g. latrines) or the uses of fertilisers/pesticides in the upland catchment area. It was said that the farmers mainly use 'natural' manure from animals to fertilize their lands.

One special issue is the salt content of the water. It was said that one of the handpumped wells was not used because of salt water by the end of the dry season. Apart from possible evaporation effects it might be so that this increase of salts is caused by the incoming baseflow of groundwater. At the end of the dry season the contribution of this groundwater inflow will be relatively high. This groundwater has flown a long way through the weathered rock zone, meanwhile taking up salts from these rocks. If so, it would prove the existence as such of a substantial amount of baseflow.

It would be nice if the water quality (approximated by the electrical conductivity) could be monitored over a whole cyclus of one rainy season and one dry season.

Location of wells

The handpumped wells are mostly constructed in the river bank, just upstream of the dam. On the other hand you see open wells being constructed by the local people at places elsewhere in the river, known as best spots from their long-term experience with the river.

It should be considered therefore to construct the wells at the deepest spots of the river bed, which is not necessarily the area close to the dam.

Of course it is also important that the yield of the well is sufficient. Provided that the well construction is ok, the yield should be no problem in the case of coarse sands. When the well is located in the riverbank, the profile should be checked on permeable layers and their connection to the river bed by making a test boring. In case of doubt the permeability should be tested before the digging of the well starts.

Innovation opportunities

There are several opportunities to make the concept of sand dams even more effective:

- Increase the availability of water by additional Artificial Recharge measures:
    - upstream in the catchment valley by water retaining- or specific AR structures.
    - AR structures (or small sand dams) in the drainage channels.

- Increase the storage volume by raising the dam-crest to the maximum. The extra water could e.g. be used for additional irrigation by pumping. Another option would be to supply water under gravity to downstream purposes (e.g. to recharge shallow wells at schools or to irrigate downstream lands). The latter option is being developed by Westerveld Conservation Trust in so-called 'Water Dispersion Units')[2]
- Use the (multiple) sand dam concept to recharge deeper groundwater aquifers.

Monitoring

Monitoring of hydrological variables like rainfall, groundwater level, water discharge and water quality would be very helpful to 1) manage the community water supply and demand 2) to evaluate the performance and effectiveness of projects and 3) to improve the general concept by learning and scientific proof.

In the Kitui case almost no regular monitoring is installed. Of course it is realized that monitoring is extremely difficult to organize in the communities.

At the Kiindu dams several temporary rain stations and observation wells are installed by the Amsterdam students. Groundwater levels are observed by hand and by DIVER data loggers[3]. Dedicated members of the community are involved in these observations. There is hope that this monitoring can be continued over a period of at least four months, up to the next rainy season.

Although not very realistic in the present situation, SASOL should consider installing at least one piezometer observation borehole at each dam location (just upstream of the dam or at the location of the abstraction well). Even scoopholes could be used for groundwater monitoring. These piezometers should be observed by the community and organised and checked by the implementing NGO. Ideally such monitoring should start even before the construction of the dam. Putting in more effort on regular and organised monitoring would very well fit SASOL's conceptual approach of 'learning by experience'.

Valuable conceptual information would be retained when a typical sand dam system could be intensively monitored over a period of several years. Such a pilot project could further demonstrate and prove the effectiveness of the concept and show more about the underlying hydrological and hydrochemical processes, in particular when the observations are integrated in a transient groundwater model.

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[2] WCT /REAL Sand Dams and soil conservation in the Tsavo river at Voi
A short visit was paid to three of these dams that were implemented by Westerveld Conservation Trust (WCT). The construction of the dams is up to standard. The water is used for irrigation and as a backup to the central water supply of Voi. However, in our short discussions with Peter Westerveld some questions raised on the concept of the contour trenching programmes that are being planned for the area (within the REAL project). One of these is the method of so-called 'water dispersion units' (WCT) is which peak flow water from the sand dam will be use to supply (under gravity) a large system of deep contour trenches.

[3] These DIVER dataloggers were made available by Van Essen Instruments, A Schlumberger Company (www.vanessen.com)

Upscaling

Since it is clear that the construction of sand dams is a low cost and sustainable way of water supply to local rural communities it is only surprising that the concept is not yet implemented on a wider scale in many other semi-arid lands with comparable hydrological and physiographical conditions. Governments, donors and implementing NGO's should take up this challenge.

On the scale of catchments it is effective to construct systems of multiple 'cascading' dams in one single river:

- the loss of water caused by the leakage through dams is minimized.
- a multiple-dam system may even recharge deeper, weathered rock aquifers, leading to additional groundwater baseflow in the longitudinal direction of the river. This groundwater will seep up in downstream compartments of the dam-system or even downstream of the last dam.
- The communities alongside of the dams will profit more; they can work and organize together in dam committees and go forward to organize additional activities to preserve their water- and land resources, while preventing conflicts on water.
- Building a series of dams is more cost-effective

CONCLUSION

General

The technical concept of sand dams proves to be clear and appropriate to supply safe water: it is cheap, sustainable, easy to construct and maintain with local means and well-accepted by the people.

There are no major technical hindrances to apply the concept on a wide scale to solve the immense water problems of the many people living close to “dry rivers” in hilly semi arid lands, lacking groundwater or perennial river resources.

In terms of natural resources the concept of integrated catchment development centred on sand dams is only sustainable when combined with proper soil erosion protection programmes. In the Kitui Province soil erosion is not yet seriously addressed.

Apart from clear technical conditions, the main factor for success of the sand dam concept is the involvement of communities during a longer period of time.

The main risks of failure are: bad siting, bad design and bad construction due to mere ignorance, lack of know-how or just insufficient finances.

Up scaling of the concept to a system of multiple ‘cascading’ dams in one single river has clear technical, financial and social advantages.

Sand dams have no negative effects on downstream areas since the amount of stored water is only some percentage of the total river discharge. People downstream are not being deprived of their water.

The availability of water could be largely increased by additional water retaining measures and artificial recharge structures in the upper catchment area.

Implementing agencies like SASOL should give more attention to water quality and safe drinking water issues.

More detailed, technical

DIVER data-logger observations of groundwater level prove that the recharge of the groundwater storage is fast and complete in the Kitui/Kiindu case, so there is no need for additional recharge improving measures.

The observations clearly indicate that groundwater is also stored in the river banks due to groundwater flow induced by the raised groundwater head in the river bed.

Groundwater baseflow from the catchment-valleys alongside of the river as well as (in the case of multiple dam systems) deep groundwater baseflow from upstream dams may significantly contribute to the available water supply.

The profile of the Kiindu dams shows extremely coarse sands and only very thin layers of silts. Apparently the massive amounts of silts that are eroding from the upper catchment-valleys are easily suspended and discharged by the river, even in the SASOL case where the dams are build at once at their final height.

Negatives on water quality:

- the older SASOL dams do not have proper wells.
- many people still use contaminated drinking water from scoopholes or open wells without boiling.
- cattle leave their dropping close to scoopholes and wells.
- awareness on water quality and hygiene is missing.

RECOMMENDATIONS

Carry out a nationwide, GIS-based, study on the assessment of areas that are potentially suitable for the building of sand dams

On SASOL operations:

- give more attention to the issue of safe drinking water.
- spend more time (and money) in the evaluation, monitoring and administration of projects.
- go back to existing older dams and evaluate their performance and shortcomings and to fine-tune or re-habilitate dams and wells. Evaluation and optimization should be common practise.
- be more active to initiate proper soil and water conservation programmes.
- optimize procedures on the siting of dams and abstraction wells.
- establish community based operation and maintenance

On research:

Transient groundwater modelling on the Kiindu data would give additional - scientifically sound - insights in hydrological processes. These will help to set criteria for the concept of sand dams on the whole. Upon finishing of the model it can be used for demonstration purposes and to predict benefits of additional measures like water retention.

To protect the biological water quality, protection zones should be applied. Experts could help to advice on the width of these zones.

Experts should give their opinion on appropriate technology for soil conservation (terracing, trenching), water retention measures and artificial recharge opportunities.

Experts should quantify criteria on the sedimentation processes in relation to river discharge velocity and the composition of the sands and silts: under what conditions are silts completely suspended and discharged?

Experts should give their opinion on the risks of dam failure due to peak flow events as well as procedures to quantify these risks from incomplete rainfall and runoff data.

On information:

It is advised to select and adopt a pilot project in which the (multiple) sand dam concept is researched and demonstrated by intensive monitoring, modelling and reporting. This pilot should include training and agricultural practises.

Whenever thinking of anymore 'best practices' handbooks, it is essential to involve local experts and authors of existing handbooks e.g. Erik Nissen-Petersen as well as expertise from other countries.

Reports on sand dam experiences and research programmes (e.g. from India, South Africa, Zimbabwe…) should be disclosed and made available on the internet.

ANNEX 1

MISSION ITINERARY

Persons

Arjen de Vries	Acacia Institute Amsterdam, project coördinator
SASOL Nairobi:	
Mr. Pieter van Dongen	Board, Treasurer
Prof. G-C.M.Mutiso	Board Chairman
SASOL field office Kitui:	
Mr. Sam M. Mutiso,	Field manager
Mr. F. Katua	Board, vice chairman
Mr. Julius Munyao	Chief construction officer
Mr. Matthew Kitema	Community manager
Mr. Joseph Mutinda Munguti	………….
Students:	
Lucas Borst	Free University of Amsterdam (hydrogeology)
Sander de Haas	Free University of Amsterdam (hydrogeology)
Mr. Joseph M. Munyoki	Nairobi University (geology)
Wouter Rhebergen	Free University of Amsterdam (social-economy)
Ellen de Bruijn	Free University of Amsterdam (social-economy)
Peter Westerveld	Westerveld Conservation Trust

Itinerary

5/11 Amsterdam – Nairobi, Heron Hotel

6/11 Nairobi, discussion Pieter van Dongen

7/11 Nairobi – Kitui town, Tourist Hotel

8/11 field visit Kiindu river Kwa Ndunda, Kwa Kangesa and Kwa Langu dams

9/11 preliminary reporting, first discussions with Lucas and Sander, dinner with SASOL staff, Arjen and students

10/11 meeting and discussion Sam Mutiso, field visit 2 dams Ithimani river, discussion with Julius Munyao

11/11 transport Kitui – Voi, field visit 3 dams in Tsavo river and trenching activities, discussion Peter Westerveld

12/11 visit Tsavo West National park, Serena Lodge

13/11 transport Tsavo NP – Kitui, field visit Kisuna dam, just finished by Exchange students

14/11 field visit Kwavanza location, Kamulu dam, Kathara dam and Kilika Waani dam, final discussion with Sander, Lucas and Arjen

15/11 transport Kitui – Nairobi, Heron Hotel, meeting Prof. Mutiso and Erik Nissen- Petersen

16/11 reporting, discussion with Pieter van Dongen

17/11 transport Nairobi - Amsterdam

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