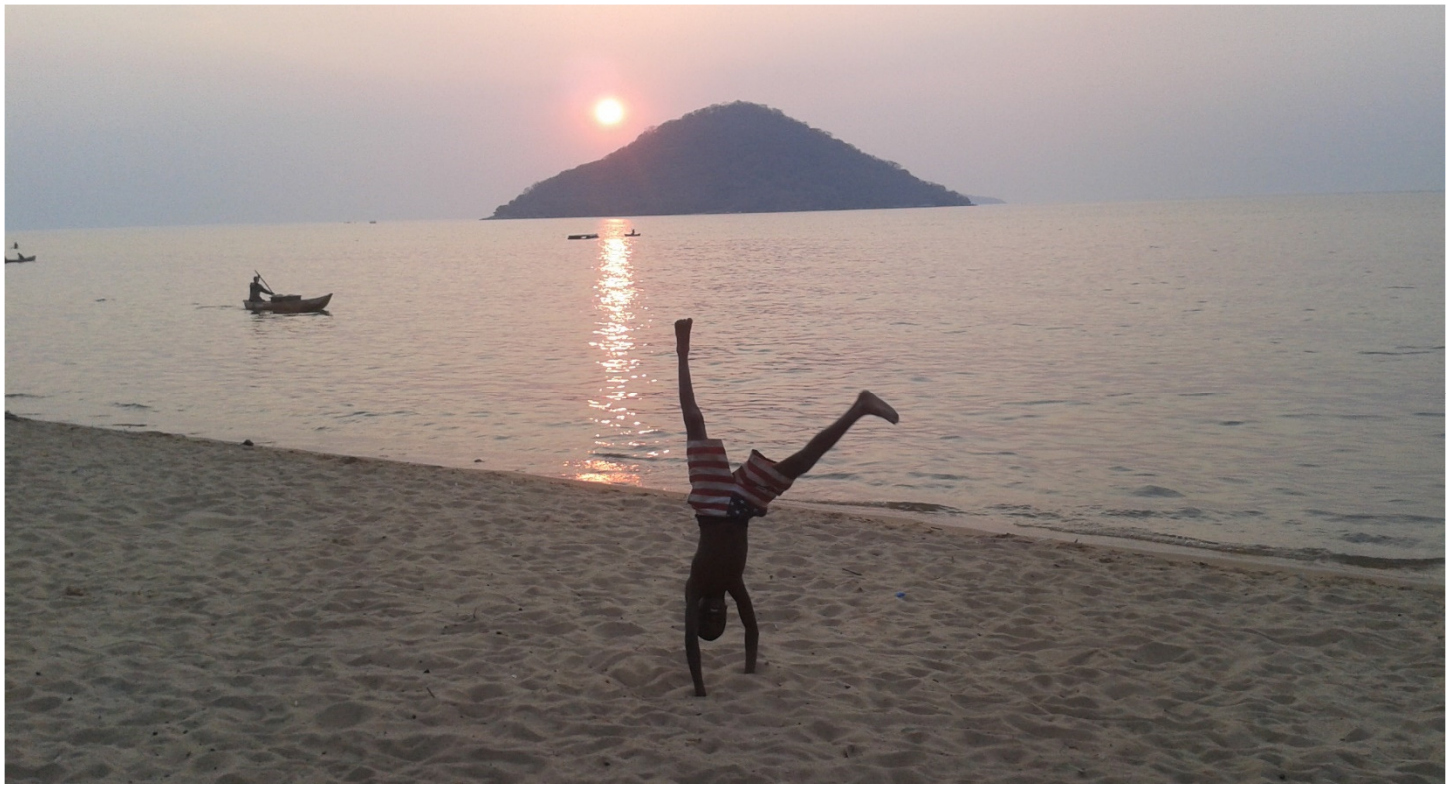


Imperial College London

Building Bridges 2015

An engineering expedition to Malawi, central Africa

26th July – 2nd August 2015

Contents

Appendices

1. Introduction

The Imperial College "Building Bridges" expeditions in 2006 and 2007 travelled to Uledi village in northern Malawi to construct a 36m suspended footbridge in collaboration with local people and the National Park authorities. Some time ago the expedition team were contacted by the local authorities and informed that the bridge had been vandalised. We had difficulty obtaining any details of the nature of the damage or the current condition of the bridge. One of this expedition's aims was therefore to visit the Uledi bridge site to carry out an inspection, and to develop a plan for any necessary repairs and maintenance alongside the local community and the National Park.

We felt that given the high cost of air fares, it would be uneconomic for us to travel to Malawi just to carry out repairs. We therefore contacted local NGOs working in Malawi to find other communities to visit during our trip. These communities have all identified a need for a footbridge, and we hoped to provide advice and information and perhaps even to identify a project for future construction.

When preparing our proposal for the Exploration Board, we intended to visit a site run by the NGO Bridges to Prosperity (B2P) in Rwanda. The aim was to learn more about their construction process as a first step to helping them develop a country programme in Malawi. Unfortunately we were unable to find dates which were convenient for all parties, so didn't manage to visit a B2P site; however, we found more than enough to occupy ourselves in Malawi, and are continuing to develop our relationship with B2P.

Instead, we established the following contacts:

- CCODE – an organisation working with informal settlements in the Blantyre region, and with particular contacts with the Federation of Rural and Urban Poor. Largely engaged in capacity building and support for settlement upgrading, such as improved sanitation. (See http://www.ccodemw.org/)
- Susan Reimer, who works independently in the Linthipe region with the aim of improving living conditions, for example through sustainable agriculture and support for infrastructure upgrades.

2. Aims & Objectives

The main aims of the 2015 Malawi expedition were:

- To visit the Uledi bridge, to carry out an inspection and to determine any repairs and maintenance required;
- To develop a strategy for these repairs and maintenance with the local community and National Park, and to determine how we can support them to carry out these repairs;
- If repairs are minor and can be carried out without significant cost and time investment, to carry out the repairs alongside the local community while in country;
- To visit up to three potential future bridge sites chosen with CCODE, to carry out site reconnaissance, discuss the project with the community and obtain information required for design;
- To visit a bridge site in the Linthipe region, to carry out site reconnaissance, discuss the project with the community and obtain information required for design.

3. Expedition Team

Harriet Kirk

Harriet graduated from Imperial College London in 2009 with a first class MEng in Civil Engineering. Since then she has been working as a geotechnical engineer, first with Ramboll in London and more recently with Atkins in Leeds. She is now a Senior Geotechnical Engineer and achieved chartered engineer status through the Institution of Civil Engineers in 2014. She has experience in geotechnical design and project management for a wide range of projects, including both offshore and onshore infrastructure, as well as a good understanding of health and safety and commercial issues.

Harriet led the engineering side of the 2007 Malawi "Building Bridges" expedition and was responsible for finalising aspects of the design and for quality control on site. She was involved throughout the design of the Uledi bridge so has a thorough understanding of the design and construction. In 2008 and 2009, Harriet went on to found the Imperial College Altiplano expedition, which designed and constructed a 25m steel truss footbridge in a remote Bolivian community. She once again led the engineering aspects of the project and was responsible for design, construction and health and safety.

Harriet is a keen rock climber and has organised independent expeditions to Morocco, Kenya, the Dolomites and the Alps, as well as regular trips within the UK. She also enjoys running, reading and cryptic crosswords.

Jumana Al-Zubaidi

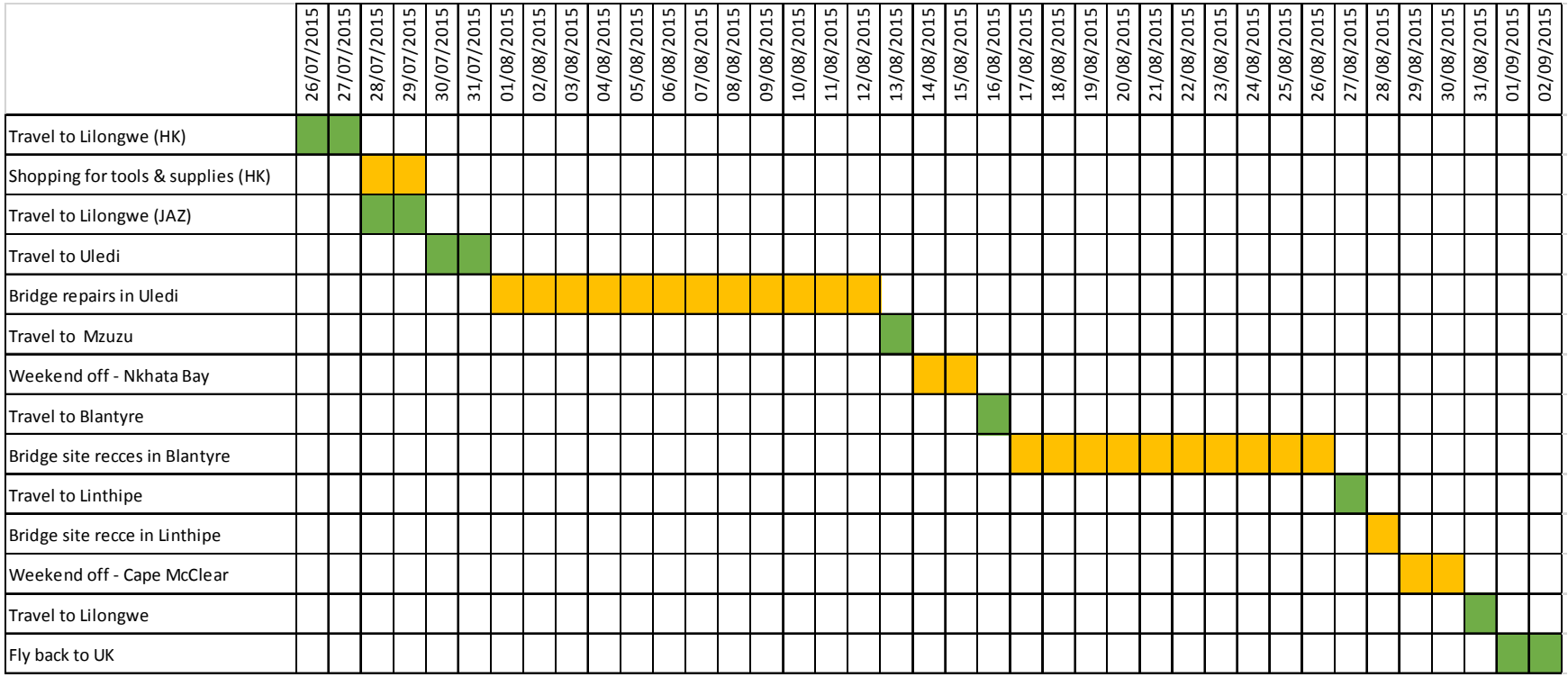
Jumana graduated from Imperial College London in 2009 with a first class MEng in Civil and Structural Engineering. She then began working as a Bridge engineer at Mott MacDonald in Croydon, carrying out the design, inspection and assessment of bridge structures. In 2010 she began a part-time PhD at the Aeronautics Engineering Department at Imperial College London in vibrations of long-span bridge structures. She splits her time 50:50 between her professional role at Mott MacDonald and her PhD. As well as significant experience in the design and assessment of bridge structures, she also has project management experience and a good understanding of resource management, health and safety management and commercial issues.

Jumana was a team member of the 2007 Malawi "Building Bridges" expedition and involved in the design and construction of the bridge. Through this project she learnt valuable lessons in designing and constructing a bridge in a poor country, with no electricity, using local materials and man power only. She also learnt a great deal about Malawian culture, especially in a remote village such as Uledi.

Jumana is very enthusiastic about developing networks amongst young professional engineers and researchers. She is on the executive committee of IABSE, the International Association for Bridge and Structural Engineers, where she is responsible for membership of the <35 yrs and developing a strategy to improve networks amongst young people. She hopes to use the networks and contacts she has developed through her work with IABSE to promote and recruit for future development work in Malawi.

Jumana enjoys go-karting, clay-pigeon shooting and running.

4. Expedition Timeline



5. Logistics

5.1. Travel

Travel to Malawi was by plane. Jumana flew out from Heathrow with Kenya Airways, via Nairobi, and back with Air France and South African Airways via Johannesburg and Paris. Harriet flew from Manchester with Lufthansa and South African Airways via Frankfurt and Johannesburg.

Within Malawi all travel was by road. To transport ourselves and all our kit, food, tools and materials to Uledi, we hired a 3-ton truck from Royal Function Car Hire. We also hired a driver, Wellington Chimtengo, who stayed with us in Uledi. We knew Wellington from the 2007 expedition, and once again he far exceeded his role as a driver, also acting as site foreman, translator, and general guide to Malawian life. The truck generally performed well although it did break down due to a blocked fuel filter on the way back from Uledi to Mzuzu. Luckily there was a mechanic nearby and we had the necessary spanners so were able to fix it within a few hours.

The road to Uledi was considerably better than on our previous trip as it is currently being regraded. On previous trips we had several punctures and got used to pushing the truck out of potholes. This time the road was in much better condition and we had no such problems.

Figure 1: With the truck on our way to Uledi

Once back in Lilongwe we hired a car, again from Royal Function Car Hire, which we drove ourselves to Blantyre and Linthipe. Vehicle hire in Malawi is very expensive and we were keen to economise, which resulted in paying $50/day (with one free day) for an ancient Toyota Funcargo which broke down regularly. However, the car hire company were good about getting it fixed when necessary.

Petrol in Malawi is expensive at around MK735/litre – almost the same price as in the UK. There are regular police road blocks, where police are likely to want to check your driving licence, car insurance and certificate of fitness (equivalent to the MOT). Insurance in Malawi is on the car rather than the driver, so as long as you have a valid licence you will be insured to drive the car. However, care should be taken to check that the insurance is comprehensive, as we found many vehicles have third party

insurance only. Speed limits are 50 km/h in towns and 100 km/h elsewhere, and there are lots of speed traps – this was not a problem for us as our car was reluctant to go over 40 unless going downhill.

Driving in Malawi feels like quite a risky experience, with minibuses cutting in all over the place, pedestrians wandering into the road, and cyclists wobbling along with unwieldy loads jutting into the carriageway. In the evenings, unlit bikes and pedestrians in dark clothing are very hard to see, and even many vehicles do not have working headlights. We tried to minimise the risk by avoiding driving at night and sharing the driving so that neither of us became tired.

5.2. Accommodation

When we first arrived in Lilongwe, we stayed with a friend of a friend in a suburb of Lilongwe. This was very comfortable. When passing through Lilongwe en route to Blantyre, we stayed at Korea Garden Lodge, and when returning to Lilongwe to catch our flights home, we stayed at Mabuya Camp, a backpacker hostel which we also used in 2007. Korea Garden Lodge is rather an executive option so we went for the cheapest room, which was very small and had a shared cold shower – but it was fine for one night. The hotel has a good Korean restaurant. Mabuya is much more relaxed and we stayed in a very comfortable A-frame. The food was good and there's a lively bar – but we found it a bit noisy when trying to sleep.

In Mzuzu, we stayed at Mzoozoozoo, a backpacker hostel with comfortable rooms, hot showers, good food and beer. At MK3000 a night this was very reasonably priced.

In Uledi, we slept in a brick building within the scout camp. The building had one large room where we stored food, and two small rooms, one of which Jumana and Harriet shared while Wellington slept in the other. We slept on the concrete floor in sleeping bags, which was uncomfortable for the first two nights until we became too tired to notice. The scout camp has been upgraded since our last visit, and now has a borehole for water, new (much cleaner) longdrop toilets and a small concrete building used as a washroom for bucket showers. As a result our stay in Uledi was more comfortable and hygienic than in 2007. We also noticed that the local people are able to use the borehole for water which has made the women's lives easier as they no longer have to carry water from the river.

Figure 2: The new borehole, and our luxurious bedroom in Uledi

In Blantyre, we stayed with our friend George Margesson in his rented house in the Namiwawa area of the city. This saved us lots of money as accommodation in Blantyre is expensive, and meant we could cook our own meals, do laundry and have the occasional hot shower (although the water and

electricity were rarely on at the same time!) George's landlords, Lois and Giorgio, are long-term Blantyre residents and introduced us to the city and to various influential people.

In Linthipe, we stayed with Susan Reimer in her house, which she has recently built. This was very comfortable, with electricity for lighting and cooking and water from the nearby borehole. We had mattresses on the floor and mosquito nets.

We had a couple of weekends off during the expedition. The first was spent at Nkhata Bay, where we stayed at Butterfly Lodge. This was extremely relaxing and a good place to meet other muzungus and feel normal for a while. The second was spent at Cape McClear, where we stayed at Malambe Camp, which was very cheap at only MK5,800 for a double room. However, Cape McClear is a 24-hour party resort and we felt very old and grumpy being woken up at 3am by revellers vomiting outside our room! Not recommended.

Figure 3: Lake Malawi at Nkhata Bay

In total we paid for accommodation for only 7 nights over the whole expedition.

5.3. Food

In general we managed to eat a fairly varied diet, quite cheaply. The only complication was Jumana being diagnosed as gluten-intolerant two weeks before the expedition, meaning she couldn't eat bread, pasta or biscuits (normally expedition staples). Luckily Malawians eat a lot of rice, and the national dish Nsima is made from maize.

5.3.1. In town

In cities, we cooked for ourselves where possible. A typical day would be:

Breakfast – cereal; toast or crackers with jam, peanut butter or honey; fruit; coffee
Lunch – bread or crackers with peanut butter; crisps; fruit; biscuits
Dinner – a variety of fairly normal meals, including meat or fish, rice, potatoes, and vegetables.

In town, shopping is quite easy, using a combination of supermarkets (Peoples and Chipiku were our favourites) and the fresh fruit and vegetables which are sold cheaply in supermarket car parks. Supermarket shopping is reasonably expensive, especially if you want to buy recognised brands. Cheaper alternatives are usually available in the markets but that takes longer.

We also ate out occasionally, and meals were much cheaper than the equivalent in the UK.

5.3.2. In Uledi

In Uledi, we cooked for ourselves over an open fire. All food and cooking equipment was bought in Lilongwe and taken in with us. At the start of the trip we had bread and fresh vegetables; these were eaten quickly before they went off and after that we relied on crackers and tinned vegetables. We took a lot of cheese which suffered in the heat, and we had to shave the mould off every day before eating. Dinners were flavoured with either curry powder or Italian herbs, which became a little monotonous towards the end.

Water for both cooking and drinking was collected from the nearby borehole and stored in plastic buckets. We drank the water without any treatment and suffered no ill effects.

Typical meals included:
Breakfast – porridge with honey and dried fruit; instant coffee
Lunch – bread or crackers with tinned fish, cheese or peanut butter; crisps; bananas or tinned/dried fruit; biscuits
Dinner – rice or potatoes; lentils, beans, chickpeas or soya mince; tinned or fresh veg; tomatoes (tinned or fresh).

We kept any food that might interest a mouse in large plastic buckets, which seemed to work well as we had no rodent problems. We burned any rubbish that could be burned, and took the rest out for disposal in town.

Cooking on the open fire was fun but requires care not to burn either the food or yourself.

At the end of our time in Uledi, we gave away some spare food and cooking equipment to the local workforce to thank them for their hard work.

Figure 4: Food storage solutions (watch out IKEA)

5.4. Healthcare

5.4.1. Preparation

Jumana attended a two-day Marlin led expedition first aid course. The course covered first aid treatment for common serious conditions, such as broken limbs or heart attacks when treatment is several hours away and included many practical hands-on sessions. In the end we didn't need any of this knowledge, but it made us more confident when we were two days' drive from the nearest healthcare facility.

We took a comprehensive first aid kit, the contents of which are listed in Appendix B. In the event, almost none of it was used.

We both had vaccinations as recommended by our GPs before travelling. These varied depending on previous vaccinations but included rabies, Hepatitis A and B, diphtheria, typhoid and meningitis. For malaria prophylaxis we took doxycycline, starting two days before entering Malawi and continuing for one month after returning. We also took precautions against mosquito bites including using a repellent containing DEET and covering up after dusk. Mosquitos were rarely seen in Uledi and Linthipe, but in Blantyre there were lots and we were glad to be sleeping inside mosquito nets.

The expedition risk assessment is included in Appendix C.

5.4.2. Expedition health

We suffered only very minor injuries during the expedition - one slight burn to the finger, sustained while cooking, and two minor cuts to the leg, caused by working with rebar on site. All were treated with antiseptic and dressings or plasters and healed well.

In terms of illness we were remarkably healthy during this expedition, with a notable absence of stomach problems. We suffered one mild case of sunstroke, treated with rest and fluids, and one possible urine infection, treated with antibiotics. Both were recovered from quickly.

One of the women working for us in Uledi sustained a small cut to her shin while sieving gravel in the river. We cleaned and dressed the wound and it caused no further problems.

While in Uledi one of the scouts brought his four-year-old daughter to us having badly burned her arm while cooking. We dressed the burn and gave the father some dressings to keep it covered after we had left. We also taught the father how to cool a burn using cold water, for future accidents.

Figure 5: Four-year-old Julieka with her arm dressed

5.5. Communication

On arrival in Malawi, a simple mobile phone was purchased with a pay-as-you go SIM. Calls between different networks were much more expensive than calls within networks, and most Malawians have SIM cards for all the major networks. Credit was bought in MK500 amounts throughout the expedition as needed. During the time in Uledi, we required friends in towns to purchase credit and text the activation codes to us, as no credit was available locally. In Uledi the phone was charged using a solar charger at one of the scout's houses. We also took a satellite phone out from the UK as a precaution. In the end this stayed in its box throughout the expedition, since mobile phone coverage was so good (better than the UK in remote areas). This was a major change from the 2006 and 2007 expeditions, where mobile phones were not available and we had no way of communicating with the outside world whilst in Uledi.

Whilst in Uledi, communication with the scouts was in English. The scouts had a fairly good level of understanding and spoken English and with patience could communicate with the expedition team. The local community, including the labourers and chiefs mostly spoke little to no English, although some members had a basic level of understanding and spoken English. All formal communication was through Wellington, the expedition driver who spoke very good English. On site, communication was through demonstration and words in English and Tambuka picked up by the labourers and expedition team respectively.

In Blantyre, Chichewa is the most commonly spoken language. Communication was through a Rosina, an intern at CCODE and student at the Blantyre Polytechnic who had a very good level of English. Some of the village headmen and teenagers within the Chiwembe communities had a good level of English but for the most part the communities spoke little to no English.

In Linthipe we were introduced to the community by Susan Reimer, our contact. A teacher from the nearby school and two local young men provided translation.

5.6. Kit

5.6.1. Group equipment

We took quite a lot of equipment out with us from the UK – mainly safety equipment which we would not have been able to source within Malawi. As we only had a 23 kg weight limit each on the flight,

this was quite a challenge and meant we had to minimise our personal baggage. Group equipment is listed in Appendix D.

5.6.2. Clothing

During our time in Malawi temperatures were reasonably warm and the weather was dry, so no specialised clothing was required. We essentially took one set of clothes for site work and another to wear in town, with a few extra t-shirts. A full list of personal kit is given in Appendix D.

Figure 6: Harriet modelling a chitenje (traditional wrap skirt)

Malawi is quite a conservative country and it is rare to see a woman wearing trousers - although on this trip, we did see a couple of women in jeans in the major towns. Out of respect for local customs, we kept our knees and upper arms covered. We never felt that we suffered any negative reaction for our unusual dress. While in Linthipe, Susan recommended that we should wear a local wrap skirt over our trousers while visiting the remoter villages, to avoid giving offence. This was fine while sitting in meetings with the local people but was fairly impractical when trying to survey a bridge site. In the end we gave up and removed our wraps, whereupon the local people told us there was no problem with how we chose to dress.

5.7. Photography

We started the expedition with a Canon Powershot A480, which was around 8 years old but seemed perfectly serviceable. However, after a couple of days in Uledi the camera stopped working due to a faulty light sensor. Looking back over the photographs taken over the few days beforehand, it seems that the light sensor was gradually failing as the quality of the photos deteriorates. After this we used our smartphones to take photographs. This led to Harriet dropping her phone and smashing the screen, after which we were quite nervous about taking photographs, particularly near the river. Unfortunately this means the expedition photographic record is somewhat lacking in both quantity and quality.

6. Finances

Expedition funding and expenditure are summarised in Appendix E.

The expedition returned to find itself in the unexpected position of having a budget surplus. The remaining funds will be kept for future work to be carried out in Malawi. At present there are a number of potential options, including pursuing some of the projects visited in conjunction with Imperial College or Engineers Without Borders. Some of the funding may also be used to facilitate training with Bridges to Prosperity, which was one of the expedition's original aims.

7. Engineering Report

7.1. Uledi Bridge

7.1.1. General

We returned to Uledi to inspect the bridge, and if possible, to repair the damage and return it to a useable state.

Before travelling to Uledi, we met with the head of the National Park in the northern region, George Nxumayo, and Sam Banda, an engineer who heads up work programmes within the national park. Sam had visited the bridge and told us that the handrail cables had been completely removed. We agreed that the team would visit the site and carry out a full inspection. The team would then propose the works to be done and agree them with the national park; the national park would then purchase the materials required and transport them to Uledi.

After completing the works as far as possible, we again visited the national park authorities to give a full handover. Since returning to the UK we have produced a report detailing the works carried out and the works still remaining to be done; this has been provided to interested parties in Malawi, and is included in Appendix F.

7.1.2. Workforce

A total of 27 people from the Uledi community were hired to work on the project, with a maximum of 25 on site at any one time. 13 of the workforce were female and 14 male. The minimum working age was 16. The inclusion of women in the workforce was suggested by the local people and was a welcome change from our previous expedition when the workers were all men. The workforce was selected by the village chiefs after a general meeting where volunteers were called for. We requested that as many as possible of the men should be those who had worked on the project in 2006-07.

Figure 7: The expedition team with some of the workforce and National Park scouts

The working day was from 7 am to 4.30 pm, with a lunchbreak from 12 to 1.30 pm, and a ten minute break mid-morning and mid-afternoon. This was agreed with the workers as it gave them enough time to cook their lunch, and finishing at 4.30 meant that everyone was out of the river and dry before the cool of the evening.

Figure 8: Skilled builders re-pointing the towers

On the advice of the national park, we originally proposed to pay the workers MK 550 per day for a labourer and MK 800 per day for a skilled worker (carpenters and builders). After one day's work the workforce petitioned for a pay rise, so we agreed to pay MK 600 (£0.80) and MK 880 (£1.20) per day.

The workforce were supervised by the expedition team and by Wellington. Some tasks such as constructing new anchor blocks and embankments required close technical supervision, while others such a collecting materials just needed to be kept an eye on to make sure they were running smoothly. Wellington's help was invaluable here, as he was able to communicate easily with the workforce. Since the expedition team was only two people, it would have been very difficult to supervise the workers without Wellington's help.

There were many occasions when workers requested the day off in order to attend funerals or take relatives to hospital – this seemed to be much more frequent than in 2007. We allowed this as long as they provided a suitable replacement to work for the day, which never seemed to be a problem.

As on previous trips, working alongside the local people was one of the most rewarding aspects of the expedition. In particular it was good to have the chance to get to know some of the women, as in previous years we had very little interaction with the women. In 2006 and 2007, the workers were mainly unskilled, and we taught them basic construction skills such as mixing concrete and laying bricks. This time around, it was noticeable that the workers were more skilled. Several told us that after building Uledi bridge, they were able to use their construction experience to get work at the Uranium mine at Karonga and on smaller local jobs. One man, Hyson Kawonga, was part of the concreting team in 2007 and has since gone on to qualify as a builder. He is now able to find regular work in the local area. These changes demonstrate that although the bridge is not an unqualified success, there has been real benefit for the local people by improving their employability.

Figure 9: The teams working on gravel collection were mainly female

We were surprised that the villagers suggested employing women, although a few men did grumble that the women were lazy and wouldn't be able to work hard enough. There was a clear gender division in terms of which tasks were considered acceptable for women. The women generally did unskilled tasks such as collecting sand, gravel and rocks, carrying water and soil, and compacting the embankments. The men also did most of these tasks, but also did the more glamorous and skilled jobs such as carpentry, concreting and decking replacement. The men saw it as beneath them to carry water or soil in a bucket and would refuse to do so if there was a woman available who could do it instead.

It was noticeable that the women were more willing and able to negotiate with us, despite generally being less educated and facing a bigger language barrier. When small disputes arose over wages or working hours, it was the women who agreed a solution that was acceptable to everybody.

7.1.3. Tools

We bought some essential tools in Lilongwe to take to Uledi. We were keen not to spend too much on tools so just bought the bare minimum, and made it a condition of employment for workers to bring their own tools to site. One man secured his reputation by turning up on the first day with a 14-pound hammer, which made him very popular and earned him the nickname "Mr Hammer Man".

7.1.4. Summary of work carried out

More detail on the inspection and repair works are included in Appendix F.

7.1.4.1. Inspection

Our first task was a detailed inspection of the bridge. This took a full day and included all elements above ground. We did consider excavating the backs of the anchor blocks to inspect the cables – however, this is potentially dangerous and would be very labour intensive and time consuming, and the risk of any damage to the cables in this location was small, so we decided against it. We did however carry out some probing to confirm the extents of the anchor blocks below the embankments. The inspection showed that the handrail cables had been cut through just above embankment level and removed, along with the hanger cables. The decking was completely rotten, and this in combination with the lack of handrails meant that the bridge was very flexible and was quite terrifying to attempt to stand on! Other than this, the bridge appeared to be in good condition. In particular the walkway cables showed no signs of damage or corrosion.

Figure 10: The bridge as we left it in 2007, and as we found it in 2015

7.1.4.2. Planning and design

On the basis of the inspection, we determined a list of tasks required to return the bridge to good working order, and prioritised them (see Appendix F). We decided that the most important tasks for us to complete were reinstating the handrails and replacing the decking, since these were the most technical tasks and would involve working at height. The remainder of the works were less urgent and could be left for others if necessary.

A review of the bridge design before leaving the UK showed that the walkway cables alone have sufficient capacity to carry the full design load of the bridge, and therefore the handrails would only need to provide stability and to take the accidental load of a person falling against them. We therefore decided that either stiff rope or light chain should be suitable.

Working out how to install new handrails was not straightforward. The old handrails are connected to the large anchor blocks below ground level, and concreted in along with the walkway cables. Connecting new handrails to the same anchors would involve lots of excavation and breaking out concrete, and would risk damaging the anchor blocks and the walkway cables. However, the load transferred from the handrails to the anchor will be much smaller than that from the walkway cables, so we decided the best option was to construct new, smaller anchor blocks behind the existing anchor blocks on each side. These were designed to resist the horizontal and vertical forces from the self-weight of the handrail and live loading. For the anchor block design, we assumed it was possible for ground water to be at ground level, which would significantly reduce the capacity. In reality this is extremely unlikely, since there is no evidence of the river overtopping its banks.

The final design involved embedding a length of train track within a concrete block. A piece of chain was connected around the train track and protruded out of the anchor block, allowing the handrails to be connected. The embankments were to be built out above the new anchor blocks, both to protect the anchors and to provide additional resistance.

Once we had decided upon the solution, we then planned out our time on site. We had only hired our truck for three weeks, and couldn't afford any more time as it was so expensive. We also needed to make sure we left enough time to visit other project sites. This meant we could spend a maximum of 12 days in Uledi. The most important factor was to ensure that the concreting was done as early as possible, so that it could cure for as long as possible before any load was applied.

7.1.4.3. Communication problems

Unfortunately at this point our communications with the national parks began to break down. Despite having agreed that the materials needed would be brought to site by a particular date, we began to hear that the national park authority was having cash flow problems, and they were asking us to return to Mzuzu to pay for the materials ourselves. We were unwilling to do this for a number of reasons. Firstly it would take three days out of our construction programme, which we planned to spend doing preparatory works while waiting for the materials. Secondly it would mean paying for an extra tank of fuel for the truck; and thirdly and most importantly, we thought it was important for the national park to demonstrate commitment to the future of the bridge by

Figure 11: Jumana in despair after a difficult phone call

contributing financially to the repairs. In the context of Malawi's widespread corruption problems in local and national government, we were unwilling to hand over cash.
On the evening of 4th August, we received a phone call from the national park saying that they would not be able to provide the materials and we should do what we could without and then close the site. Very disappointed, we made a last ditch phone call to the Minister for the national parks in Lilongwe, to see if he could exert any influence. We then wrote up a simple document explaining the works that remained to be done. The following day, we spent the morning walking round the site with a small team of the local workforce who had proved themselves to be capable and engaged, explaining how the works should be completed if and when the materials were provided. In the afternoon, we held a meeting with the village chiefs and the local people to explain why the work could not be completed. They were understandably disappointed and angry with the national park. We then paid our workforce for the work done and prepared to leave the following day.

Just after the meeting, we heard again from the national park authorities – clearly our phone call to the Minister had worked and the materials were now on their way to Uledi! Relieved and annoyed in equal measure, we re-engaged the workers and prepared to start again the following day.

7.1.4.4. Construction tasks

This section provides a summary of the different tasks performed.

Collecting sand and gravel: Sand and gravel were collected from the river for use in concrete. The national park had arranged for some material to be collected before we arrived, but not in the quantities we required. Sand was collected by a team of 12 women over half a day, by shovelling from the river bed and carrying up to the bridge site in buckets. Gravel collection was a much slower task as it had to be sieved to remove material that was too small or too large. Sieves were made from sheets of corrugated iron with holes punched in them, held in a wooden frame. The gravel collectors worked in teams, with two people holding the sieve, two shovelling, and others transporting the material in buckets. Gravel collection was very unpopular, because it involved standing in the river for hours at a time.

Collecting large rocks: Large rocks were collected from the river banks, for use in bank protection and for breaking up to use as fill in the anchor blocks. These were gathered by hand.

Excavation: Excavation was required for the new anchor blocks. The required excavation was marked out using pegs and string, and a benchmark was set up to check the excavation depth. Each excavation was dug by a team of four men. Material was stockpiled at a safe distance from the excavation. Timber was on hand in case support was required, but this was considered unlikely given the strength of the soil and its unsaturated condition. There were no signs of instability during the excavation. (It is interesting to note that in 2007 we used an area away from the site as a borrow pit for material used in the embankment construction, and left an almost vertical cut in the clayey soil. This appeared to still be standing at the same angle, despite having been through 7 rainy seasons.)

Figure 12: Compacting embankment material using a homemade rammer

Collecting embankment material: Material for embankment construction was dug out from suitably positioned borrow pits on each side of the river and stockpiled in a convenient location.

Constructing embankments: Soil was placed in layers around 100 mm thick. While the soil was being shovelled and spread over the embankment area, it was sprinkled with water to make compaction more effective. It wasn't possible to do any testing to work out the optimum moisture content for compaction, so an appropriate amount of water was determined by trial and error. Each layer was then compacted by people stamping and jumping, and using homemade rammers. Compaction was another unpopular job and the workforce needed a lot of encouragement to compact the soil sufficiently.

Figure 13: Stockpiling soil for embankment construction

Concreting: A mortar pad was prepared in advance to provide a base for mixing concrete. All of the materials required were put ready the day before. Concrete was mixed by hand by a team of 6 men, using shovels. A concrete mix of 1:3:6:1.6 (cement : sand : gravel : water) was adopted. The materials were measured using buckets. Initially the dry materials were thoroughly mixed, and then the water was slowly added using a volcano method. The concrete was then carefully placed into the excavation using buckets and vibrated using rebar pokers to compact it. Where possible, we ensured that the men wore shoes while concreting to avoid contact with the skin, but this was difficult to enforce when people only have one pair of shoes and are used to doing construction work barefoot. We made sure that everyone washed thoroughly after concreting.

Once concreting was complete, the anchor blocks were protected with sacking and were kept wet to encourage curing.

It was noticeable that concreting was much easier than on the previous expeditions, because the workforce now knew what was required. One of the workforce is now qualified as a builder and was able to act as foreman and to supervise the concrete placement.

River bank protection: Large stones were placed into the washout on the left bank. The stones were placed carefully to make sure that they interlocked, with larger stones at the front to provide more protection.

Building decking units: New decking units were made by two skilled carpenters, working in the camp. The old units were used as templates. Making the new units went smoothly except for the difficulties of working out the most efficient way of cutting the required lengths from the available timber with the minimum wastage, which tested our algebra more than it should have!

Replacing decking units: The first two decking units could be removed from the bank, and the new ones lifted into place on the cables without getting onto the bridge. After this, the units could not be reached from the bank. We developed a system as follows:

- One of the expedition team clips into the safety ropes (see below) and walks out over the new decking to the nearest old decking unit
- Working from the safe platform of the new decking, the old unit is dismantled in situ using hammer and crowbar, and the pieces dropped into the river for collection by a team waiting a safe distance downstream
- The team member walks back over the new decking to the bank
- A team on the bank push the new decking units forward along the cables, into the space left by the old unit which has just been removed
- A new unit is lifted into the space now available by the bank.

This was repeated until the units reached the middle of the bridge, and then carried out in the same way from the opposite side. This meant the units never had to be pushed uphill over the cables.

Figure 14: Lifting a new decking unit into place

7.1.5. Health and safety

A construction site is an inherently risky environment, and this one was a long way from help if anything did go wrong. We spent a lot of time assessing the various risks before leaving the UK to ensure we took all the necessary equipment out with us. Safety equipment taken from the UK is listed in Appendix D.

7.1.5.1. Safety systems

In order to inspect the cables and replace the decking units, it was necessary to walk out over the bridge. To do so safely, we implemented a safe system of working:

- Only the expedition team (Jumana and Harriet) was permitted onto the bridge, one at a time.
- When someone was working on the bridge, the river bed below the bridge was out of bounds to the workforce, in case tools or pieces of decking were dropped.

- A system of safety ropes was installed across the bridge, and the person working on the bridge was clipped in at all times. This person carried extra equipment to rescue themselves in the event of slipping off the bridge.

Installing safety ropes: Two safety ropes were rigged over the bridge, one over each tower. One of the ropes was a DMM worksafe low stretch rope, which the other was a dynamic climbing rope. The low stretch rope proved more effective as it stretched less under load. The ropes were attached to steel stakes driven into the soil on either side. In order to ensure the stakes had sufficient resistance, two stakes were driven in at an angle, one behind the other, and were connected by a sling which was then tensioned to ensure the load was shared between the stakes. This is a method used by cliff rescue teams in the UK. The rope was then connected to the front stake, carried over the river, and tied off on the opposite side. While tensioning, the rope was held using a system of prussik cords to ensure it was always held securely and couldn't slip.

Figure 15: Safety ropes attached to stakes

Working at height: While working on the bridge, we were always clipped in using two DMM "buddy" devices with fall arrest lanyards. These were positioned to prevent us sliding along the ropes if we should fall off the bridge. We carried two ascender devices with us in case we needed to pull ourselves back to the bank along the rope. While working at height we also wore climbing helmets, as it's always much easier to rescue a conscious person.

Figure 16: Walking out onto the bridge

Originally we thought we might need to walk over the old rotten decking which would have carried a high risk of breaking through the decking units. It turned out that the wood was much too rotten to do this, and so we only stood on new decking units which were much more stable. The safety ropes became more like stabilising handrails which allowed us to move confidently along the bridge.

7.1.5.2. General health and safety

Attitudes towards health and safety in Malawi are very different to those in the UK, perhaps because in general people are used to being exposed to a much greater level of risk in their daily lives. According to the local people, the only consequence for us in the event of one of our workforce dying on site would have been an expectation that we would pay for the funeral (around £20-30). However, we felt a strong sense of responsibility towards our workforce and took measures to make sure that tasks were carried out as safely as possible.

Planning: Our time on site was carefully planned to ensure we could carry out the tasks safely, without rushing or overworking people. Working hours were set so that people could walk to and from work in daylight. Method statements were prepared for all construction activities, which helped us to consider the risks associated with each task and plan accordingly.

PPE: We took a number of basic items of PPE (donated by Atkins) out from the UK. These included gloves, glasses and goggles, and were provided to the workers when required by the task. The orange tinted safety glasses were very popular!

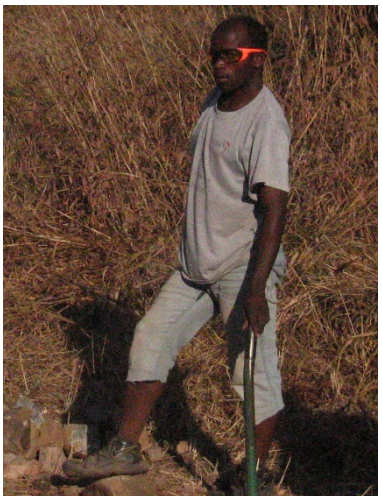


Figure 17: People are always happier to wear PPE if it makes them look cool.

Training: When introducing workers to a new task, we carefully explained how it should be done and any risks involved. It is not always easy to convince a rural Malawian that something is potentially dangerous, since they probably take bigger risks every day of their lives. For example, several people wanted to walk out onto the bridge without clipping into the ropes to dismantle the decking, and others wanted to stand directly underneath to catch the pieces of decking as they fell. In cases like this explanation didn't always work and we sometimes had to issue direct instructions on pain of dismissal.

Site access: One of the major risks was that the site was very close to the village and of course not fenced off as it would be in the UK, so we often had interested children wandering around as we were working. We had to keep a close eye to make sure that they weren't putting themselves in danger.

Figure 18: Village children keen to see what the Muzungu were up to

7.1.6. Outcomes

When we left the site, we had constructed anchor blocks for the new handrails, built the embankments, replaced the decking and re-pointed the towers. However, we were not able to replace the handrails themselves. The national park had provided some rope which we had attempted to install, but it was too stretchy to provide the stability required. We removed it from the bridge as we did not want to create an illusion of safety, and recommended that chain should be installed instead as this will be axially much stiffer.

We learned a lot from our time on site in Uledi. We gained confidence in our decision making ability from being responsible for all aspects of the design and construction, and developed our problem-solving skills. However, the main lessons were learned from our interaction with the various stakeholders. When leaving the site in 2007, we believed that both the local community and the national park felt a sense of ownership of the bridge, and therefore would be responsible for its

maintenance and for preventing vandalism. Returning in 2015 it was apparent that this was not the case. Politics surrounding the bridge are complex, since there is longstanding ill-feeling between the local community and national park over a range of issues. Both sides appear to expect the other to take responsibility for the structure. We attempted to mediate between the two groups, and to encourage the national park to take on more responsibility since they have greater financial resources and also get the most benefit from the bridge. Ultimately, we feel that if the national park are not prepared to contribute to the bridge's upkeep, this suggests that they do not really need it. We are maintaining communication by email in order to provide technical support if required, and hope to hear that they have been able to install the handrails before the rainy season begins in November – but we don't hold out much hope.

Figure 19: Uledi bridge as we left it, with decking replaced but no handrails

We also met up with Carl Bruessow, CEO of the Nyika-Vwasa Trust, a UK-led organisation which seeks to preserve the wildlife and habitats of northern Malawi. The UK trust withdrew funding from the area in 2014 following corruption problems and since has been less active in Nyika. However, they are planning to restart involvement in February 2016. We hope that the Nyika-Vwaza trust will be able to help by keeping an eye on the bridge and may be able to provide technical assistance to the national park if required.

7.2. Chiwembe feasibility assessments

7.2.1. General

We spent around a week visiting informal settlements near to Blantyre in the south of Malawi. We worked with CCODE, a Malawian non-profit organisation working to empower poor Malawians to improve their own lives. CCODE works closely with the Federation of the Rural and Urban Poor (FERUP), and focusses mainly on capacity building. They help communities to gather information on living conditions, plan and implement improvements, and seek funding.

Alongside CCODE and FERUP, we visited three communities in the Chiwembe district. We have summarised our work and findings in a report which has been provided to CCODE, and is presented in Appendix G.

Figure 21: Women in Chiwembe Macheso

This part of the expedition was very different to that in Uledi, as no construction work was carried out. Instead we were gathering information and providing advice to the communities on the options for improving their infrastructure. It was very interesting for us to see how Malawians live in a more urban setting, and to understand some of the problems they face. Although the people in Chiwembe are arguably more prosperous than those in rural areas such as Uledi, and certainly have better access to services such as healthcare and education, in some ways their lives are more difficult. Population density in Chiwembe is relatively high and houses are cramped into a small area, so sanitation and rubbish disposal are big problems. There is also less space for growing food so people are more likely to be dependent on buying food at the market. That said, people in Chiwembe clearly have more opportunities for economic activity.

7.2.2. Outcomes

As discussed in Appendix G, we decided that none of the bridge sites visited warrant a visit from a UK-based team to construct a bridge. However, we identified a significant problem in all of the communities with drainage control and erosion during the rainy season, and believe that the communities' resources would be best directed into dealing with this issue. This is an area where further engineering input will be of benefit. It may be a good opportunity for an Engineers Without Borders placement, and we will be contacting EWB to discuss this. We will also be presenting our findings to the Civil Engineering department at Imperial to see whether the department can provide support to an ongoing project.

We are continuing to work with CCODE to provide technical support and advice where possible, particularly with reference to the Chiwembe Macheso site.

7.3. Linthipe feasibility assessment

7.3.1. General

At the end of the expedition, we spent one full day on site at Linthipe, as well as two evenings with our host, Susan Reimer. We would have liked to spend more time on this part of the project but we had difficulty getting in contact with Susan to begin with, so we had to fit it in right at the end.

Susan Reimer is a Canadian now living in Edinburgh, who has independently decided to spend part of her year in Malawi trying to improve quality of life in the Linthipe district. She has a small amount of financial support from her church group, and is focussing on small scale initiatives such as improving food security, sponsoring education, and basic health education. Through spending time with communities in the Linthipe region since 2009, Susan has become aware of the need for a footbridge across the Linthipe River.

Figure 22: The traditional crossing point, which is impassable during the rainy season

Susan wanted us to carry out an initial assessment of the feasibility of constructing a footbridge, and if possible, to recommend a site and construction method. We spent time speaking to local people to gain a better understanding of the situation, and then carried out a site walkover.

As with the other sites, we prepared a report for Susan and the local community summarising our findings – this is included in Appendix H.

7.3.2. Outcomes

We fully appreciated the need for a bridge at Linthipe. There is a significant population cut off from schools, healthcare, markets and other services during the rainy season, for up to four months at a time. When the river is in flood, the only option is to take a detour which roughly doubles the journey time, and can be risky for solo travellers, women and children owing to criminal gangs.

Unfortunately, the technical aspects of constructing a bridge across the Linthipe river are not straightforward. The river is wide (around 40 m in the dry season, and considerably wider during the rains) and there are a variety of constraints which will limit the placement of abutments. We had hoped to find a site which would be suitable for a suspended or suspension footbridge. However, the

only potential site we found (which is also the traditional crossing point) has limited space available on the left bank, meaning it would not be possible to construct the tower and anchor block. Other more traditional options such as concrete, masonry or steel truss construction would require intermediate piers within the river for a span of this size. Intermediate piers are likely to be difficult to construct because the river is never dry.

For now, we have advised the communities that while a bridge would clearly bring significant improvements to their quality of life, design and construction will be technically difficult and is likely to require significant financial outlay. We will be pursuing potential avenues with Bridges to Prosperity and Imperial College London to consider whether there is a feasible and affordable solution. We have also recommended that Susan supports the community in gathering additional information which will support their need for a bridge.

Figure 23: Walking through one of the villages on our way to view the site

8. Lessons Learnt

We learned a lot on this expedition, some of which is summarised here.

- As there were only two of us in the expedition team, we didn't formally divide up tasks or roles, either when preparing for the trip or when in-country. In hindsight, things would have been easier if we had had defined responsibilities. Perhaps one of us could have led the expedition/logistics side, and the other could have had responsibility for the engineering.
- The most difficult aspects of the expedition were all to do with negotiating how far we should try to help by giving something for free, and how far people or government bodies should be expected to contribute themselves. We believe that the failure of the local community and government to look after the Uledi bridge stems in large part from the fact that it was freely given to them, so they feel no sense of ownership. The fact that we turned up again to fix it once it was broken probably hasn't helped with this.
- It is important to build a long term relationship so that the community can be supported in finding their own solutions where possible. In future projects, we are keen to take things much more slowly rather than helicoptering in and trying to solve the immediately obvious problem. In this, local NGOs and people working on the ground to build capacity are likely to provide the key.
- The relationships we built with people we worked alongside were one of the most rewarding aspects of the expedition. It was great to go back to Uledi and see how people's lives have moved on in the last eight years. We learned a lot about Malawian life through conversations with Wellington. Unlike in 2007, many of the people we met now have mobile phones and email addresses, so we will be able to keep in touch.
- A Toyota FunCargo with almost 200,000 km on the clock probably won't make it from Lilongwe to Blantyre and back.
- You can never buy too much peanut butter.

9. Acknowledgements

Thank you to our expedition sponsors, without whom this trip would not have been possible:
Imperial College London; Institution of Civil Engineers; Atkins; Mott MacDonald; DMM; S3i.

The local people who formed the Uledi bridge workforce:
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We would also like to thank the following people who helped us both before and during the expedition:
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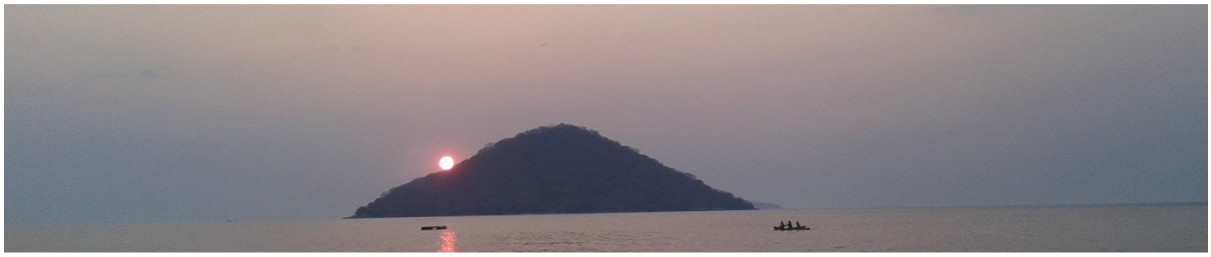
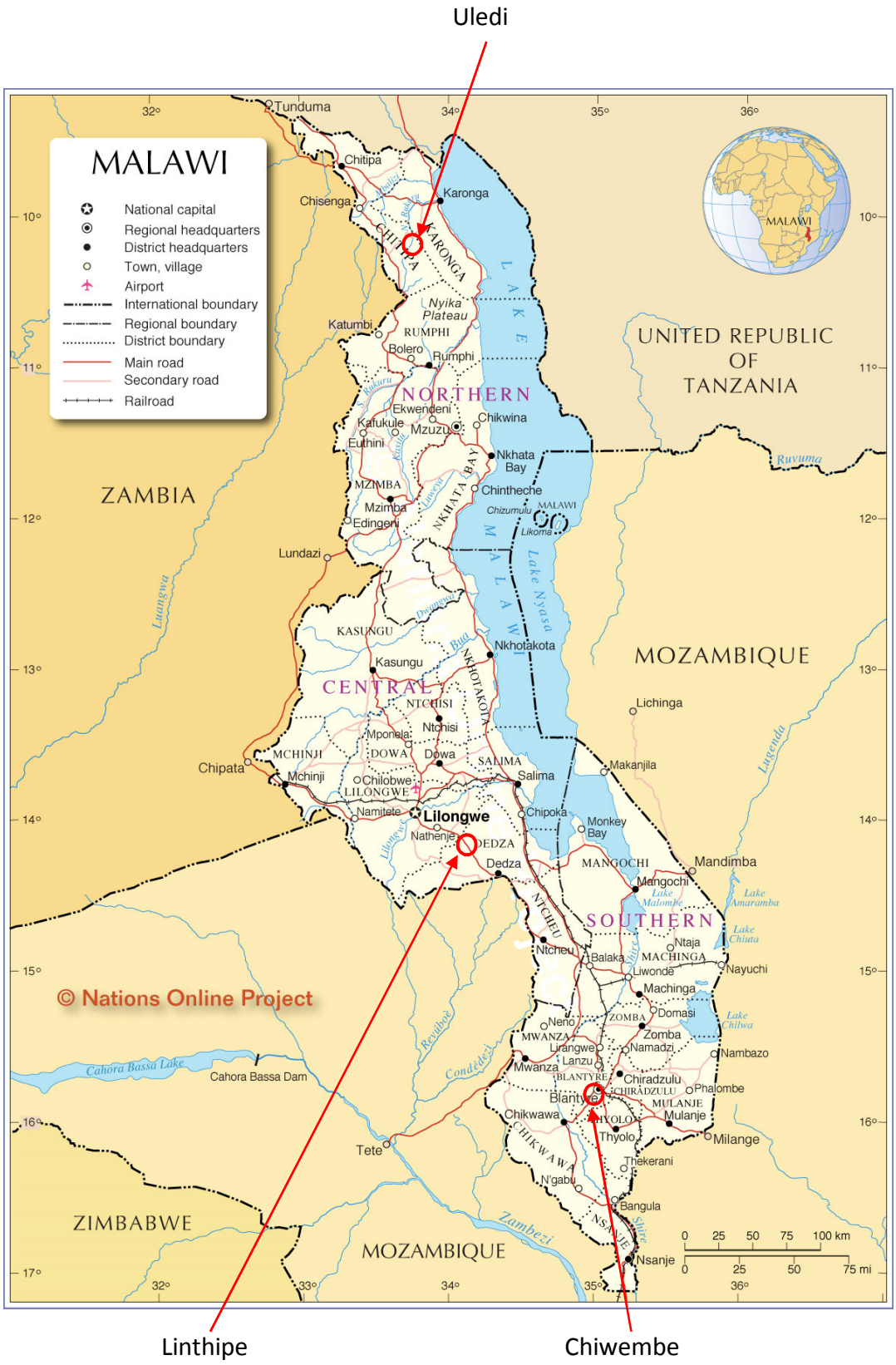


Figure 24: Final sunset over Lake Malawi

Appendix A
Maps


Uledi
MALAWI
National capital
Regional headquarters
District headquarters
Town, village
Airport
International boundary
Regional boundary
District boundary
Main road
Secondary road
Railroad
Tunduma
Chitipa
Chisenga
Karonga
CHITIPA
KARONGA
LAKE MALAWI
Nyika Plateau
Katumbi
RUMPHI
Bolero
Rumphi
NORTHERN
Ekwendeni
Mzuzu
Chikwina
Kafukule
Euthini
Nkhata Bay
NKHATA BAY
MZIMBA
Chintheche
Mzimba
Edingeni
Chizumulu
Likoma
MALAWI
ZAMBIA
UNITED REPUBLIC OF TANZANIA
Ruvuma
Lundazi
Luangwa
KASUNGU
Nkhotakota
Kasungu
CENTRAL
NTCHISI
Ntchisi
NKHOTAKOTA
MOZAMBIQUE
Lichinga
Mponela
DOWA
Dowa
SALIMA
Salima
Makanjila
Chipata
MCHINJI
Mchinji
Chilobwe
LILONGWE
Namitete
Lilongwe
Chipoka
Monkey Bay
Nathenje
DEDZA
Dedza
MANGOCHI
Mandimba
Mangochi
Lake Malombe
Lake Amaramba
Lugenda
SOUTHERN
Lake Chiuta
Ntaja
Ntcheu
NTCHEU
Balaka
MACHINGA
Liwonde
Nayuchi
Machinga
ZOMBA
Domasi
Lake Chilwa
Neno
MWANZA
Zomba
Lirangwe
Namadzi
Nambazo
Mwanza
Lanzu
BLANTYRE
Chiradzulu
CHIRADZULU
Phalombe
Blantyre
MULANJE
Chikwawa
THYOLO
Mulanje
Thyolo
Milange
Thekerani
CHIKWAWA
N'gabu
Bangula
NSANJE
Nsanje
Shire
Zambezi
Revubue
Condédezi
Cahora Bassa Lake
Cahora Bassa Dam
Tete
ZIMBABWE
MOZAMBIQUE
© Nations Online Project
0 25 50 75 100 km
0 25 50 75 mi
Linthipe
Chiwembe

Appendix B
First aid kit

Appendix B – First aid kit

4 x calico triangular bandages.
2 x Traumafix Dressings, for major bleeding.
1 x Blizzard EMS blanket.
1 x iSplint flexible "Sam" type splint.
2 x medium HSE dressings.
2 x finger bandages.
2 x Eye dressings.
20 x assorted fabric plasters.
1 strip wound closures.
2x 5x5cm Non-adherent pad.
2x 10x10cm Non-adherent pad.
1 x roll Relifix tape.
1 x Tweezers with magnifying glass.
1 x Tuff-cut shears.
2 x large crepe bandages.
2 x eye wash pods + 300ml eye wash bottle.
1 x resuscitation face shield.
2 x pairs nitryl gloves.
10 x wound wipes.
4 x Hydrocolloid blister plasters.
2 x 3.5g sachets Burn gel.
Sterile set, including various needles, syringes, cannulas and scalpel blades.
Rehydration sachets.
Immodium.
1 x Hydrocortisone cream.
Antihistamine tablets.
1 x Betadine.
Antibiotics: 1 course amoxicillin - broad spectrum
Antibiotics: 1 course MacroBID - urinary tract, bladder and kidney infections
Anti-inflammatory: 1 course Naproxen
Painkillers: Paracetamol, ibuprofen and diclofenac.
1 x digital thermometer

Appendix C
Expedition risk assessment

Health and Safety Risk Assessment

			Pre-mitigation				Post-mitigation		
Activity	**Hazard**	**Outcome**	**Severity**	**Likelihood**	**Risk**	**Mitigation**	**Severity**	**Likelihood**	**Risk**
Travel	Road traffic accident	Injury or death of member of expedition team or member of public. Damage to vehicle.	4	3	12	Ensure vehicle is road worthy. Ensure driver is qualified and sober. Know the route in advance. No driving at night. Wear seatbelts.	3	2	6
	Mugging	Injury to team member	3	3	9	Always travel together or with someone who can be trusted. Don't have valuables on display. Don't walk around in town at night.	3	2	6
	Car jacking	Injury to team member. Loss of vehicle.	3	3	9	Take local advice and avoid known trouble spots. No driving at night. Do not resist.	3	2	6
	Hit by car	Injury or death of team member.	4	3	12	Don't walk around town at night. Use designated crossings.	4	2	8
General	Food/water related illness	Upset stomach. Dehydration. May require hospitalisation in severe cases.	3	4	12	Sterilise or boil water before drinking. Wash hands or use antibactial gel before eating. Good food hygiene. Caution with bought food.	3	2	6
	Insect borne disease	Malaria, dengue fever, yellow fever.	4	3	8	Take antimalarials. Avoid insect bites – insect repellent, long sleeves and trousers around dusk, mosquito nets.	4	2	8
	Contagious disease	Illness / death	4	3	12	Vaccinations as recommended by NHS.	4	2	8
	Vermin	Disease	3	4	12	Keep food off the floor in sealed containers.	3	2	6
	Snake / scorpion bite	Illness / death	4	2	8	Wear closed shoes and long trousers at night and use a torch. No walking around alone at night.	4	1	4
	Cooking	Burns	3	3	9	Care with stoves and open fires. Care with boiling water.	3	1	3
	Mammals	Rabies – death	4	2	8	Rabies vaccine before leaving. Do not approach dogs or other mammals.	3	1	3
	Sun / high temperatures	Sun burn, heat stroke, dehydration	2	4	8	Use sunscreen and a sunhat. Cover skin with light clothing. Drink plenty. Stay in the shade where possible.	2	2	4
	Water snails	Bilharzia – illness or death	4	2	8	Avoid slow flowing rivers and lakes, particularly around reeds.	4	1	4
Site work	Working at height	Falls- injury or death of a team member. Dropping equipment which may cause injury.	4	3	12	Wear a harness and remain attached at all times. Caution with tools. Keep area below clear.	3	2	6
	Bridge unstable	Damage to bridge may mean it is unsafe to cross- risk of death or injury.	4	2	8	Thorough inspection of towers, cables and anchors before stepping onto bridge.	4	1	4
	Slips, trips and falls	Major or minor injury.	3	4	12	Care when walking on uneven ground. Wear appropriate footwear. No working at night.	3	2	6
	Manual handling	Back or other muscular injuries. Cuts and bruises.	2	3	6	Care when lifting. Use appropriate technique. Ask for help if necessary. Wear gloves.	2	2	4
Customs	Gender politics	Unwanted attention, assault	3	2	6	Dress appropriately – cover knees and shoulders. Ensure someone knows where we are. No travelling alone.	3	1	3

Appendix D
Kit lists

APPENDIX D - KIT LISTS

Personal kit list

Item	Notes
Sleeping bag & liner	Lightweight, 1 or 2 season
Roll mat	
Head torch	
Jacket	Light windproof jacket for cool evenings - not often used
Fleece/jumper	For cool evenings
Long sleeve top/shirt	For sun protection and for formal occasions e.g. meeting officials
T-shirts x 3	
Trousers x 2	
Socks	
Underwear	
Sunhat / cap	Essential when working on site
First aid kit	Small personal kit for minor injuries and any pre-existing conditions
Rucksack or kitbag	For carrying kit
Day rucksack	For taking out on site, and as hand luggage on the plane
Sunglasses	
Sun cream	
Travel towel	
Water bottle x 2	
Shoes / boots	For wearing on site. Both team members wore lightweight approach shoes which dried quickly after crossing the river.
Hand sanitiser	
Book	Essential for the long dark evenings in Uledi
Mosquito repellent	
Bio-degradeable soap	Run-off goes straight to ground water and river without treatment

Group kit list

Category	Item
Safety rope system	60m rope x 2
	15m static rope
	Climbing helmet x 2
	Climbing harness x 2
	Locking karabiners x 12
	Dyneema slings x 6
	Rated 6 mm cord x 20m
	Belay plate x 1
	Prussik loops x 4
	DMM Ropeman ascenders x 2
	Anchor rings x 2
	DMM Buddy 200 x 2
	Selection of pulleys
General	10l water carrier
	Resealable plastic bags x 30
	Steripen
	Whistle
	Compass
	Road map
	Guide book (Brandt guide to Malawi)
	Solar battery charger
	Satellite phone
Site surveys	Notebooks x 4
	Scale ruler
	Protractor
	Marker pens
	Survey book
	5m tape measure
	30m tape measure
Tools	Socket set

Appendix E
Finances

APPENDIX E – FINANCES

E.1 Expedition Income

Organisation	Details	Amount (£)
Imperial College London	John Lever Memorial Award [1]	5,320
Institution of Civil Engineers	Eloise Plunkett Award	1,500
Institution of Civil Engineers	QUEST Travel Award	1,500
Mott MacDonald [2]	-	1,000
Atkins	-	500
	Total income	**9,820**

[1] Awarded to Harriet Kirk and Andras Szollar in 2009
[2] In addition, Mott MacDonald provided Jumana with paid leave for the duration of the expedition.

E.2 Expedition Expenditure

E.2.1 Pre-expedition

All of the following expenditure was in GBP.

	GBP
Transport	
Flights	2,359.31
Subtotal	**2,359.31**
Health	
First aid kit	237.31
Vaccinations	385.00
Water purification	14.38
Anti-malarials	75.50
Subtotal	**712.19**
General equipment	
Solar charger	79.80
Water container	5.00
Subtotal	**84.80**

	GBP
Communications	
Satellite phone	115.20
Subtotal	**115.20**
Construction	
Vernier callipers	6.52
Safety rope equipment	302.00
Socket set	19.98
30 m tape	12.99
Subtotal	**341.49**

Total pre-expedition spend	**£3,612.99**

Appendix E
Finances

E.2.2 Expenditure in Malawi

Most items were paid for in kwacha (MK), with the exception of truck hire, which was paid in US dollars, and car hire, which was paid partly in dollars and partly in kwacha.

The average exchange rate obtained was MK735 to £1.

	Currency used		Cost
	MK	USD	GBP
Communications			
Mobile phone	15,000		21.10
Sim card	500		0.70
Top up	3,000		4.22
Phone charger	3,500		4.92
Internet	1,800		2.53
Subtotal	**23,800**	**0**	**33.47**
Accommodation	**67,000**	**30**	**112.98**
Subsistence			
Food shopping	280,043		393.87
Eating out	192,201	8	275.32
Subtotal	**472,244**	**8**	**669.20**
General equipment			
Cooking equipment	20,920		29.42
Stationary	2,000		2.81
Sacks * 10	1,100		1.55
Jerry cans	450		0.63
Subtotal	**24,470**	**0**	**34.42**

	Currency used		Cost
	MK	USD	GBP
Transport			
Truck hire		2,520	1,575.00
Driver hire		525	328.13
Car hire	214,000	300	488.48
Fuel	232,892		327.56
Repairs	11,200		15.75
Parking	550		0.77
Airport transfer	12,000		16.88
Subtotal	**470,642**	**3,345**	**2,752.57**
Construction			
Tools	125,188		176.07
Materials	55,400		77.92
Wages	136,800		192.41
Subtotal	**317,388**	**0**	**446.40**
Misc			
Visa extensions	10,000		14.06
Shoe repair	250		0.35
Toiletries	9,388		13.20
Entertainment	41,000		57.67
Gifts			150.00
Subtotal	**60,638**	**0**	**235.29**

Total expenditure in Malawi	**£4,284.32**

E.3 Expedition Financial Status

Total income = £9,820

Total expenditure = £7,897.30

Balance = £1,922.70

Appendix F
Engineering Report - Uledi Bridge

Imperial College Building Bridges Expedition
Malawi 2015

Uledi Bridge

- *Summary of works carried out August 2015*
- *Summary of works required*
- *Inspection and maintenance schedule*

1. Introduction

1.1.Background

The Uledi footbridge was designed and constructed in the summers of 2006 and 2007 by a team of students from Imperial College London. More information on the original project can be found in the expedition reports here:

https://www.imperial.ac.uk/media/imperial-college/be-inspired/exploration-board/public/2006NorthernMalawi.pdf
http://www.imperial.ac.uk/media/imperial-college/be-inspired/exploration-board/public/42633717.pdf

The footbridge was built for and in association with the Nyika National Park. The bridge crosses the North Rukuru River, which is impassable at Uledi during the rainy season. A National Park scout camp exists at Uledi and the scouts are unable to cross the river during the rainy season to patrol the National Park and prevent poaching. The bridge was also intended for use by the local community to access schools and markets during the rainy season.

The footbridge is a 37m span suspended bridge, constructed of walkway and handrail cables, connected by cable hangers, with masonry towers and buried concrete anchor blocks. The decking is made from wooden units. Drawings and photographs showing the bridge as constructed in 2007 are included in Appendix A.

We understand that post 2007, the bridge was used by the National Park scouts and the local community. At some unknown date the bridge was vandalised by a member of the local community, who cut the handrail cables as they emerged from the ground and removed them along with the hanger cables. The bridge was left without any handrails and impassable. We were made aware of the damage in 2014 and returned to Uledi in August 2015 with the aim of returning the bridge to use.

The works carried out from 1st August 2015 to the 12th August 2015 consisted of an initial inspection of bridge elements, and maintenance and repair works.

1.2.Roles and responsibilities

Before visiting Uledi in August 2015, we met with Georgo Nxumayo (Division Manager, Northern Region) and Sam Banda (Works Supervisor, Nyika TFCA Project) at the National Parks office in Mzuzu. The key outcomes of this meeting were:

- It was agreed that we should carry out an inspection of the bridge in order to determine the extent of the damage, and should then determine whether the bridge could be repaired and what resources would be required.
- The National Park Authority agreed to contribute financially towards materials required for repairs, and provided 10 bags of cement as an initial contribution. It was agreed that Sam Banda would transport the materials required to Uledi to minimise time spent in travelling by the authors.
- It was agreed that the National Park and the local community must take on joint responsibility for ongoing inspection and maintenance of the bridge following handover, and that the authors would provide sufficient information to allow them to do so safely.

Once in Uledi, discussions were held with the local community, through the village Chiefs, and the National Park. Once again it was agreed that the local community and the National Park would hold joint responsibility for the bridge once repaired. A document was drawn up to explain the key limitations of the inspection, design and construction of remedial measures, and to clarify responsibility for the bridge in the long term. The document was signed by the authors and by representatives of the National Park and the local community, and is included in Appendix B.

A further meeting was held at Mzuzu on 14th August 2015 with George Nxumayo and Sam Banda. During this meeting the inspection findings and the work done so far were discussed, and the work still required was explained. It was agreed that the National Park would take on responsibility for completing the works. This meeting served as a formal handover to the National Park of responsibility for the bridge.

1.3.Report aims

The aims of this report are:

- to provide details of inspection and repair works carried out on Uledi bridge during August 2015;
- to give recommendations for further works required to return the bridge to service;
- to provide a recommended inspection and maintenance schedule for the bridge.

1.4.Contact details

Contact details for the bridge design team are:

Harriet Kirk: hkirk777@gmail.com
Jumana Al-Zubaidi: jumana.al-zubaidi@imperial.ac.uk

Please contact the design team for advice if unsure about any aspect of the bridge.

2. Inspection and Maintenance carried out August 2015

2.1.Scope

This section of report details the work carried out by Jumana Al-Zubaidi and Harriet Kirk from 1st August 2015 to 12th August 2015 at the Uledi footbridge in north Nyika. This included the inspection of elements of the footbridge and some construction works to maintain the structure and return it to viable use.

2.2.Inspection

The following bridge elements were inspected:

- Masonry abutments and saddles
- Steel cable where above ground only and not below decking units
- Embankments
- Decking
- River banks

The following bridge elements were not inspected:

- Steel cable below decking units
- Steel cable below ground
- Concrete anchors
- All other elements below ground

The findings of the inspection are summarised below. Photographs showing important findings are included in Appendix C.

Masonry abutments

- No major cracking, indicating no significant differential settlement
- Some mortar loss all over; repointing needed
- Saddles appear to be in good conditions. Plates are rusted but grease still present
- No major section loss
- No major spalling of brickwork

Walkway cables

- At the locations inspected the cable is in good condition, with no loose or broken wires, corrosion or section loss visible.

Handrail cables

Handrail cable has been cut at ground level and removed.
Hanger cables have been removed.

Embankments

The full height of the embankments remains at the centrelines of the bridge, but some erosion has occurred on the side slopes, and some of the sacks which formed a retaining structure appear to have been removed. The side slopes need to be built up to protect the embankment and anchors.

Decking units

The wooden decking units have become completely compromised by wet-dry cycles. The wood has little strength remaining and in some places planks are broken or missing. All decking units should be replaced.

River banks

- The right hand side (RHS) bank looks in good condition, with no significant sign of undercutting and erosion by the river.
- The left hand side (LHS) bank shows signs of substantial undercutting at the tower location.

Bridge elements below ground

No bridge elements below ground were inspected as such significant excavation was not thought wise. These include, but are not limited to the cables below ground, the anchors and the towers below ground. The advice, design and all following statements and recommendations are based on an assumption that subterranean elements are in good condition.

General condition of bridge

The bridge had no handrails and was not useable. The decking units had degraded significantly and combined with the loss of handrails and hangers, caused the bridge to be highly flexible in sway. The LHS bank was compromised, with significant undercutting from river erosion. The side slopes of the embankments behind both abutments had been eroded by the rain.

2.3.Maintenance and Repair

Following the inspection, we identified a number of works required to return the bridge to a useable state.

1a	Construct new handrail anchors	Completed August 2015
1b	Install new handrails	To be completed – see Section 3
2	Rebuild embankment slopes	To be completed – see Section 3
3	Protect LHS bank from further undercutting	Completed August 2015
4	Repoint both masonry towers	Completed August 2015
5	Replace all wooden decking units	Completed August 2015

Items 1a, 3, 4 and 5 were completed in August 2015 by the authors and workforce from the local community. Details follow. The handrail remains to be attached, as well as the rebuilding of the embankment slopes behind both abutments.

Drawings and photographs showing the as-built condition following the repair works are included in Appendix D.

2.3.1. Handrail Anchor construction

Anchors were constructed to take the load from the new handrails. These were placed below ground level and behind the original anchors built in 2006 and 2007 on both banks. There are two handrail anchors on each bank, measuring 1.2m wide by 0.4m deep by 0.8m long (as shown in the schematic below). On each bank a single excavation was made to 1m below ground level. The handrails were designed to be placed in their original positions and to run over the tower saddles, with a separation distance of 1.6m. The space between the two anchors was infilled with rocks that had been broken to have jagged edges and which were placed interlocking each other.

Within each anchor, a 0.9m length of railway track was placed with a length of chain attached around it and running up a trench excavated leading towards ground level and the towers. A

minimum of 100mm cover concrete was aimed for. Concrete was mixed using cement and aggregate, sand and water collected from the river bed in the ratios 1:3:6:1.6 (cement : sand : aggregate : water). Each anchor was poured using 2 mixes and poked using rebar to remove air. Curing was allowed for three days before refilling each excavation with earth in compacted layers.

The embankment above the anchors was rebuilt to 0.5 m above original ground level, to provide additional resistance and protection for the anchors. This was done slowly and carefully in layers of about 100mm thick, and compaction by jumping and stamping. Slopes of 2 (horizontal): 1 (vertical) were built on three sides.

2.3.2. Bank Protection

The river bank on the LHS was significantly eroded, leaving an undercut at the base of the bank, around 4 m below the tower. Large rocks were placed in an interlocking fashion in the undercut. The strength of the river flow during the rainy season is unknown, and therefore it is not clear how long these rocks will remain in place. It is recommended that the banks are inspected before and after each rainy season to determine if the banks require more protection or if the bank is becoming unsafe.

2.3.3. Repoint Towers

Both masonry towers were repointed with a mortar mix. The work was done by a local builder and an assistant.

2.3.4. Decking Replacement

New decking units were constructed from soft wood provided from Chelinda plantation by the National Park. The units were of the same dimensions and design as the 2006 and 2007 units and were built by local carpenters. All units were replaced. Replacing the decking units had a very positive effect on the bridge stiffness.

3. Future work

Unfortunately the expedition team had to leave the bridge unfinished due to lack of time and suitable materials being made available. This section details the remaining works required to return the bridge to a useable condition.

All works should be carried out by a competent and experienced person. We recommend that an engineer employed by the National Parks should be present throughout.

The new handrail anchors have been designed to take a force based on rope handrails. However, after installation of a rope handrail it was observed that the rope was too flexible relative to the walkway. A large gap between the handrail and the walkway could develop, potentially allowing a person to fall through. A stiffer material such as chain should reduce this gap sufficiently, but this must be judged by the installer.

Installation of the handrails and hangers is potentially dangerous because of the risk of falling from height. A system of safety ropes should be set up to ensure that a person cannot fall while working on the bridge. No one should be allowed to walk below the bridge while the handrails and hangers are being installed, in case something is dropped.

The work required is summarised below.

1. Install chain handrails
    - 6 mm chain is recommended.
    - Chain is to be connected to the chain sections emerging from the new anchors and run over the saddle points at the top of the towers.
    - Chain should be connected using a shackle or similar connection, with strength equal to or greater than the chain. The shackle should be tightened according to manufacturer's instructions.
    - The chain should sag at the same curve as the walkway cable and be connected to the cable with rope hangers.

2. Install rope hangers
    - The hangers must be the weakest part of the system to limit the force transferred to the handrails and anchors.
    - Synthetic rope up to 10 mm diameter is recommended.
    - Natural fibre rope is NOT recommended since this is likely to shrink and extend.
    - Chain or cable hangers are NOT recommended since this will transfer too much force to the handrails.
    - Hangers should be placed vertically and tied with a suitable knot around the chain at the top and cable at the bottom.
    - Hangers should be placed at 1 m intervals along the full length of the bridge, on both sides.

3. Excavate and concrete trenches
    - The trenches containing the chains below ground and connected to the anchors should be excavated and the chains concreted in. This will protect the chain from corrosion.
    - Allow a minimum of 3 days of curing. Do not use the bridge during this time.

- After 3 days the trenches may be backfilled with soil, which should be compacted in 10 cm layers.

4. Install side protection
    - Side protection should be provided between the handrail and walkway cable to prevent people falling.
    - Fishing net or chicken wire should be suitable.

5. Rebuild embankments
    - Additional soil should be placed along the sides of the embankments to repair erosion damage.
    - A 2 (horizontal) : 1 (vertical) slope is required.

4. Inspection and Maintenance Schedule

4.1.General

Uledi Bridge was constructed in 2007 with a design life of 15 years. In order to achieve this design life, regular inspections and maintenance are required. It is the responsibility of the National Park and local community to ensure that this is carried out.

This document outlines the minimum inspection and maintenance requirements for Uledi Bridge. Inspections should be carried out by an appropriately qualified and experienced person, preferably an engineer with experience of trail bridge construction. Much of the maintenance work can be carried out by unskilled workers, under supervision from an experienced engineer.

Depending on the condition of the bridge, additional work may be required to make the bridge safe for use. This is the responsibility of the National Park and local community.

If users are uncertain about the best course of action, please contact the bridge design team for advice, using the following email addresses:

hkirk777@gmail.com
jumana.al-zubaidi@imperial.ac.uk

4.2.Safe use of the bridge

ONLY ONE (1) PERSON SHOULD CROSS THE BRIDGE AT A TIME.

Regular users of the bridge (local community and scouts) should be aware of the main bridge components. All bridge users should be responsible for reporting any defects or problems as soon as they occur – don't wait for the next inspection!

If you are unsure whether the bridge is safe for use, contact the bridge design team.

4.3.Inspection schedule

Bridge component	Inspection frequency	Key points
Main anchors	-	Buried – no inspection possible.
Handrail anchors	-	Buried – no inspection possible.
Embankments	Before and after rains	Inspect for signs of erosion or deliberate damage (e.g. holes dug). Repair any damage by compacting soil in 10 cm layers. Vegetation should be allowed to grow on embankments.
Towers	Annual, before rains	Inspect for cracking. If towers are cracked, photograph and send to bridge design team. CRACKING MAY BE A SIGN OF TOWER MOVEMENT – DO NOT USE THE BRIDGE.

Bridge component	Inspection frequency	Key points
		Inspect condition of mortar and brickwork. Repoint if required.
Main cables	Annual, before rains	Inspect full cable length, taking great care when examining cables in centre of bridge. Inspect for rust, fraying, cuts, bends or kinks. **DO NOT USE BRIDGE IF MAIN CABLES ARE DAMAGED. TAKE PHOTOGRAPHS AND SEND TO BRIDGE DESIGN TEAM FOR ADVICE.**
Handrail chains	Before and after rains	Inspect full length, taking great care when examining handrails in centre of bridge. Inspect for rust, cuts or other damage. Replace chain if damaged.
Decking	Before and after rains	Inspect for missing nails, missing planks or rotten wood. Repair or replace unit if necessary. DECKING CONTRIBUTES SIGNIFICANTLY TO BRIDGE STABILITY. IF DECKING UNITS ARE ALLOWED TO DETERIORATE, BRIDGE IS LIKELY TO BECOME UNSTABLE AND UNSAFE TO USE.
Hangers	Before and after rains	Identify missing or frayed hangers and loose knots. Replace as necessary.
River bank protection	Before and after rains	Ensure that large rocks are still in place and that undercutting of the river bank is not getting worse. Compare to photographs provided by design team. Replace rocks if necessary. Extend bank protection up and downstream if necessary.
Firebreaks	Every 2 weeks during dry season	A firebreak should be maintained around the bridge to prevent the structure being damaged by bush fires.

4.4.Recommended maintenance schedule

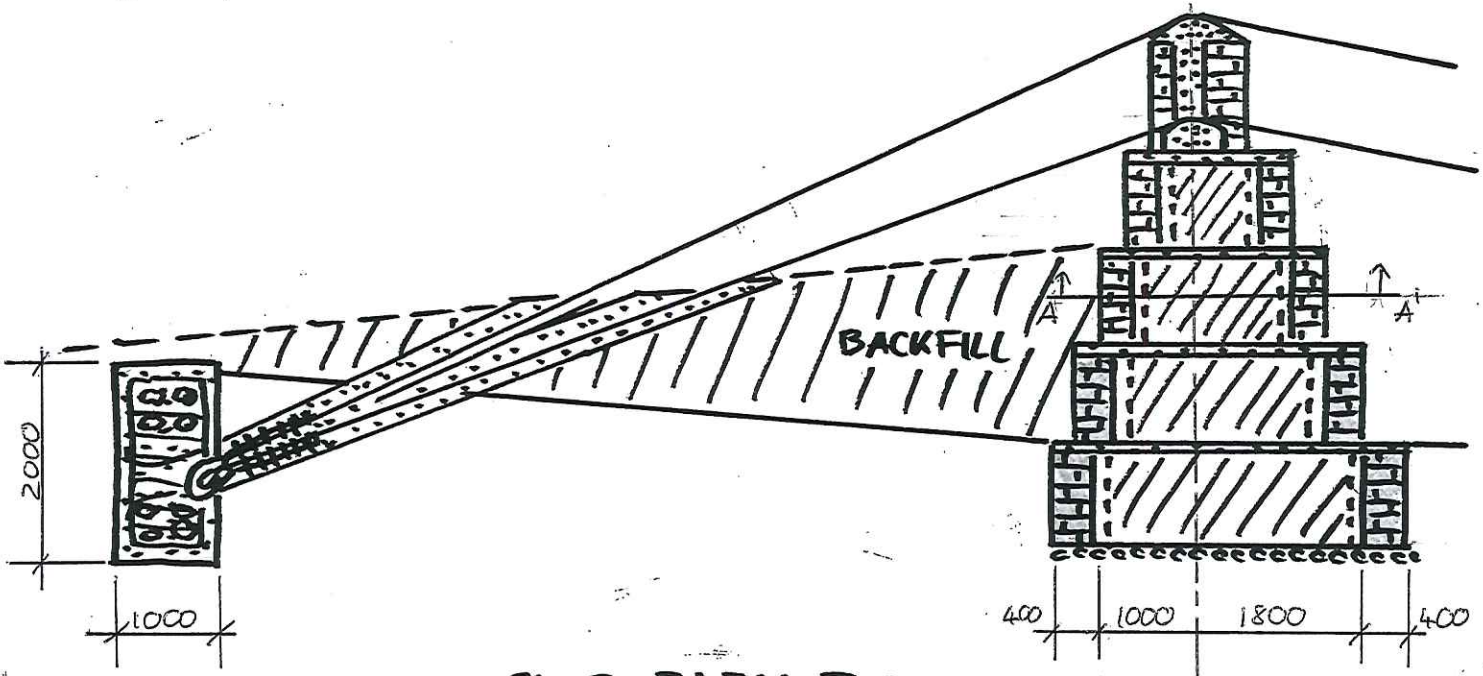
The following regular maintenance is recommended to keep the bridge in a safe condition.

Decking – decking units should be replaced at least **every 4 years**. Replace more often if showing signs of damage or rot, or if the bridge starts to sway more when in use.

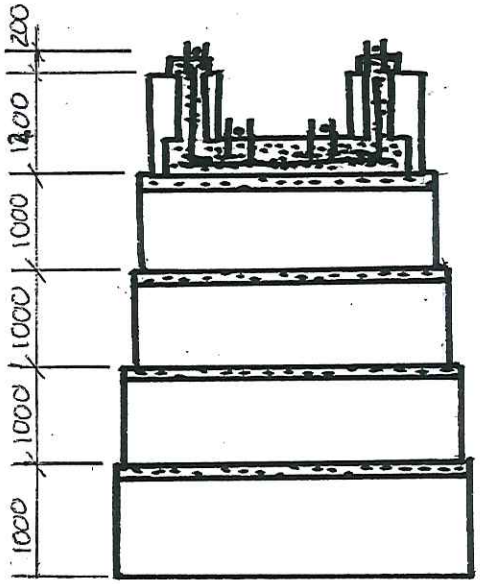
Hangers - replace rope hangers **every 2 years**. Replace more often if hangers are missing or showing signs of wear.

Additional maintenance may be required depending on the findings of regular bridge inspections.

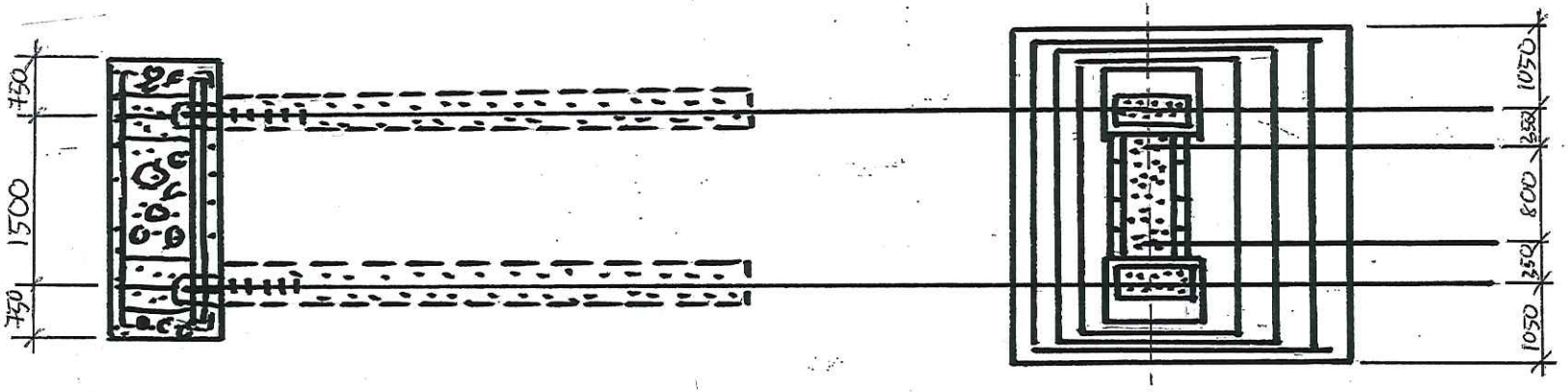
APPENDIX A
As built bridge information, 2007



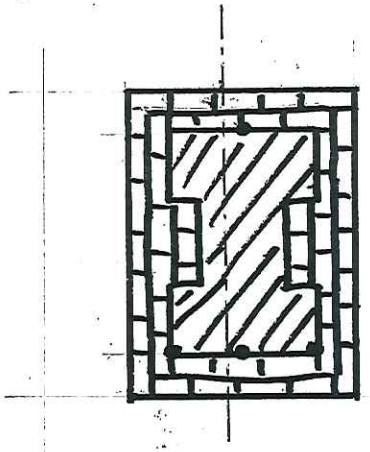
SIDE ELEVATION



FRONT ELEVATION



PLAN

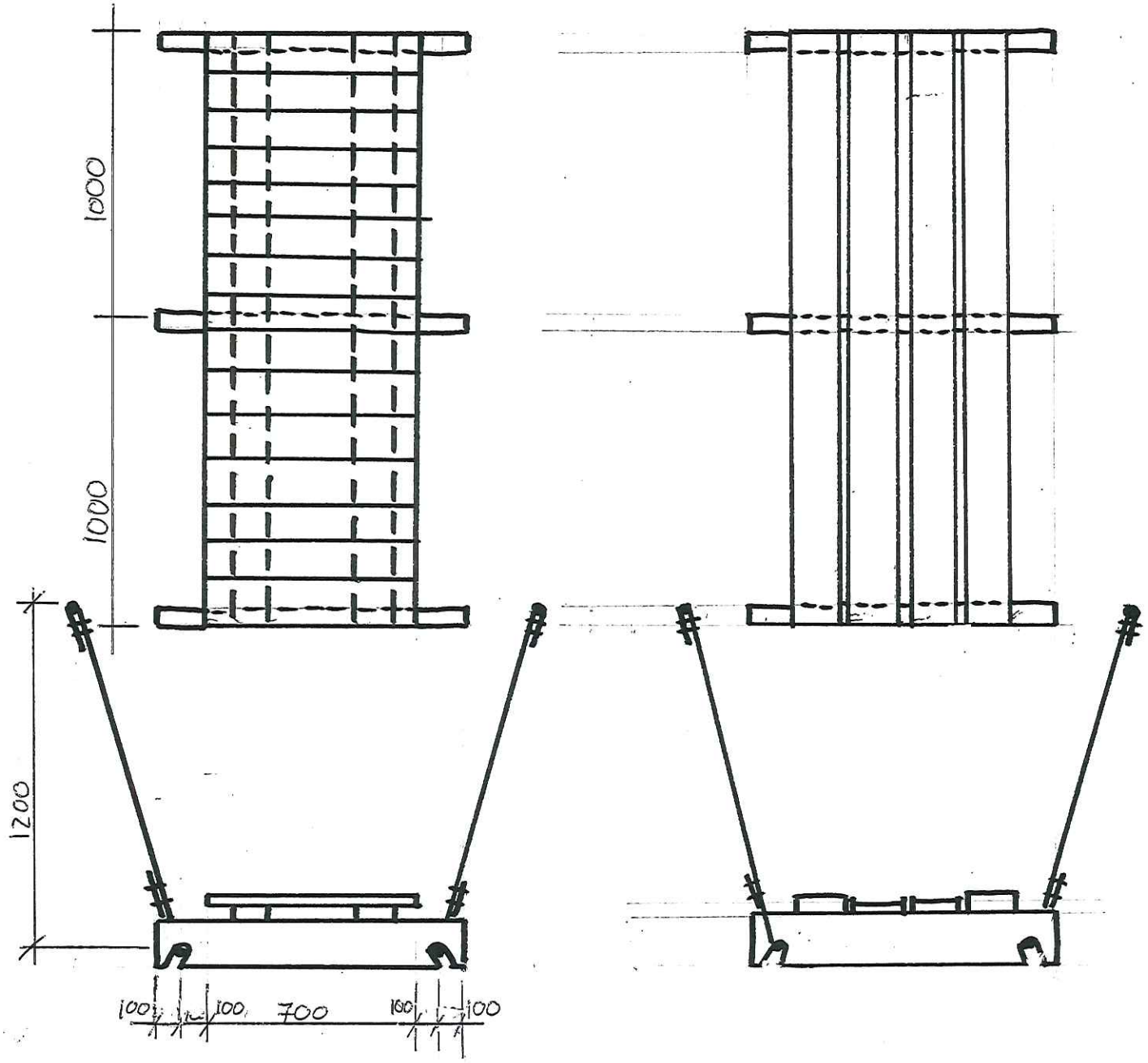


SECTION AA'

A TYPICAL CROSS-SECTION OF TOWER UNIT

ORIGINAL DESIGN

ALTERNATIVE DESIGN



The bridge as-built in 2007 – view from left bank

Tower and embankment in 2007

APPENDIX B
Agreement with National Park and Uledi community

Meeting with National Park + JAZ + HK
@ Uledi

7/8/15

Key limitations

Inspection:
- elements below ground (anchors, cables) not inspected.
- carried out during dry season - condition during rains unknown
- no testing (load testing, concrete cores etc) performed

Design
- strength of rope handrail unknown. Should be considered a temporary solution only.
- assumptions required on interaction of rope handrail & walkway cable, & how the load is shared.
- design life of 7 years will only be achieved if maintenance/inspection schedule is followed.

~~Construction~~

Construction

- We won't have time to complete all works - responsibility for remaining works lies with the National Park and Uledi community.

Maintenance

- Full maintenance schedule to be provided
- rope handrail is a temporary solution. Likely to deteriorate due to environmental conditions (sunlight etc)
- chain is currently in contact with soil. We recommend excavating & concreting to prevent corrosion.

Liability

- since we are not being paid for these works, we carry no design or construction liability for the structure once handed over.

- it is the responsibility of the National Parks to ensure the bridge is safe for operation.
& Ubedi community

Sam Banda
Work Supervisor
07/08/2015

SAMUEL KAOMBA
SQUAD. UBEDI
08-08-2015

WELLINGTON KHOZOMBA (P.W.A)
07/08/2015

JUMANA AL-ZUBAIDI
07/08/2015

HARRIET KIRK
07/08/15

Finlay Zimba (APWO)
8/08/15

APPENDIX C
Bridge inspection photographs, 2015

View of bridge from left bank – showing missing handrail cables and rotten decking

Handrail cable cut through just above embankment level

Appendix C – Bridge inspection photographs

Brickwork on left tower, in need of repointing

Tower generally in good condition

Appendix C – Bridge inspection photographs

Saddles in good condition

Main walkway cable in good condition

Appendix C – Bridge inspection photographs

Main walkway cable in good condition

Erosion below left tower

APPENDIX D
Maintenance work details, 2015

Decking units replaced

Handrail anchor before concreting

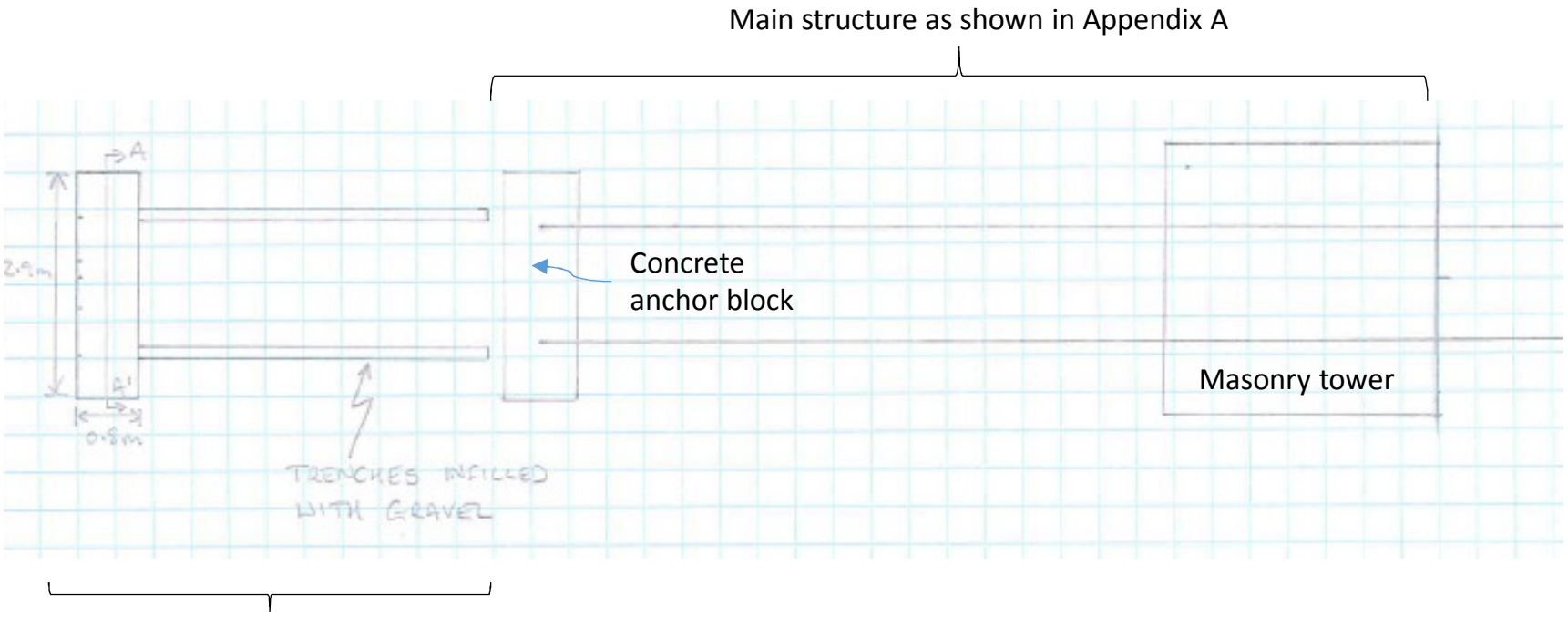
Replacement decking units

Compacting embankment to 0.5 m above ground level

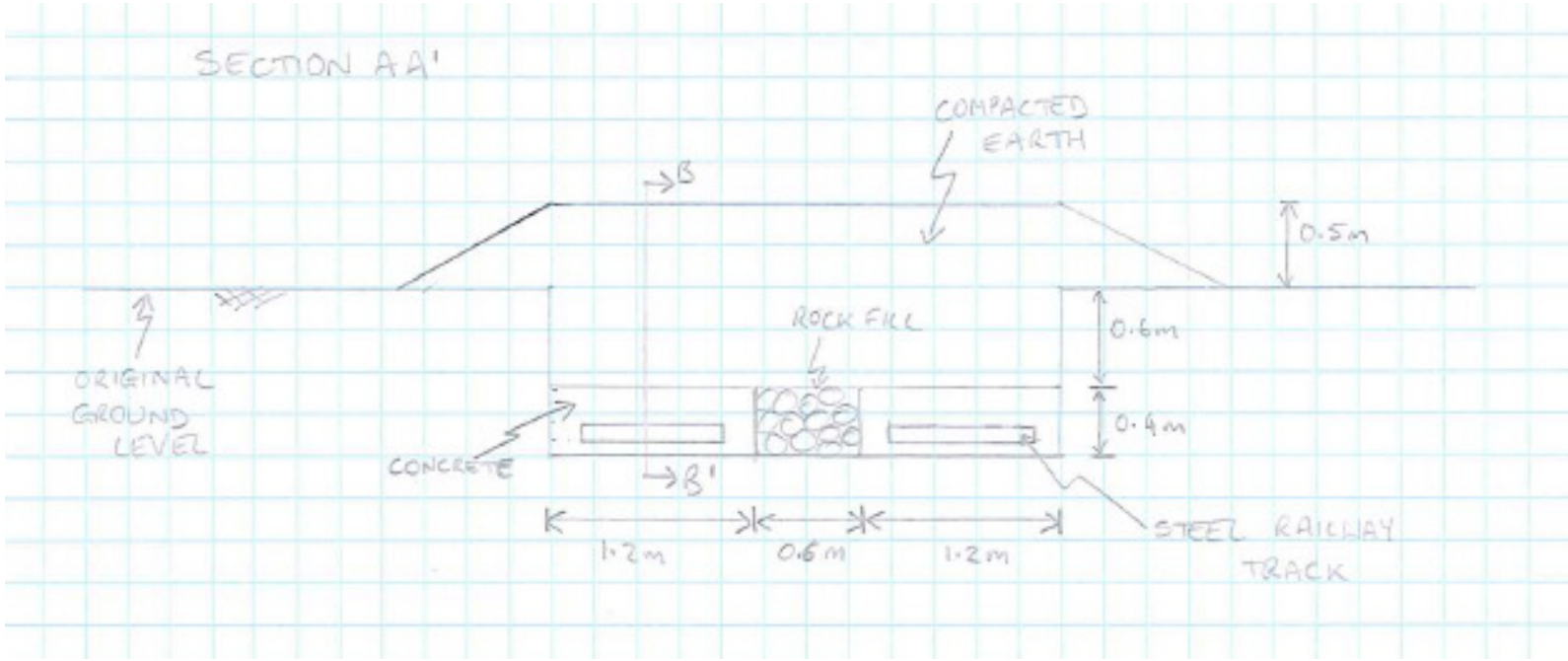
Tranches which will carry new chain handrails have been left infilled with gravel as a temporary measure.

River bank protection on left bank

Uledi bridge – details of repair works carried out August 2015



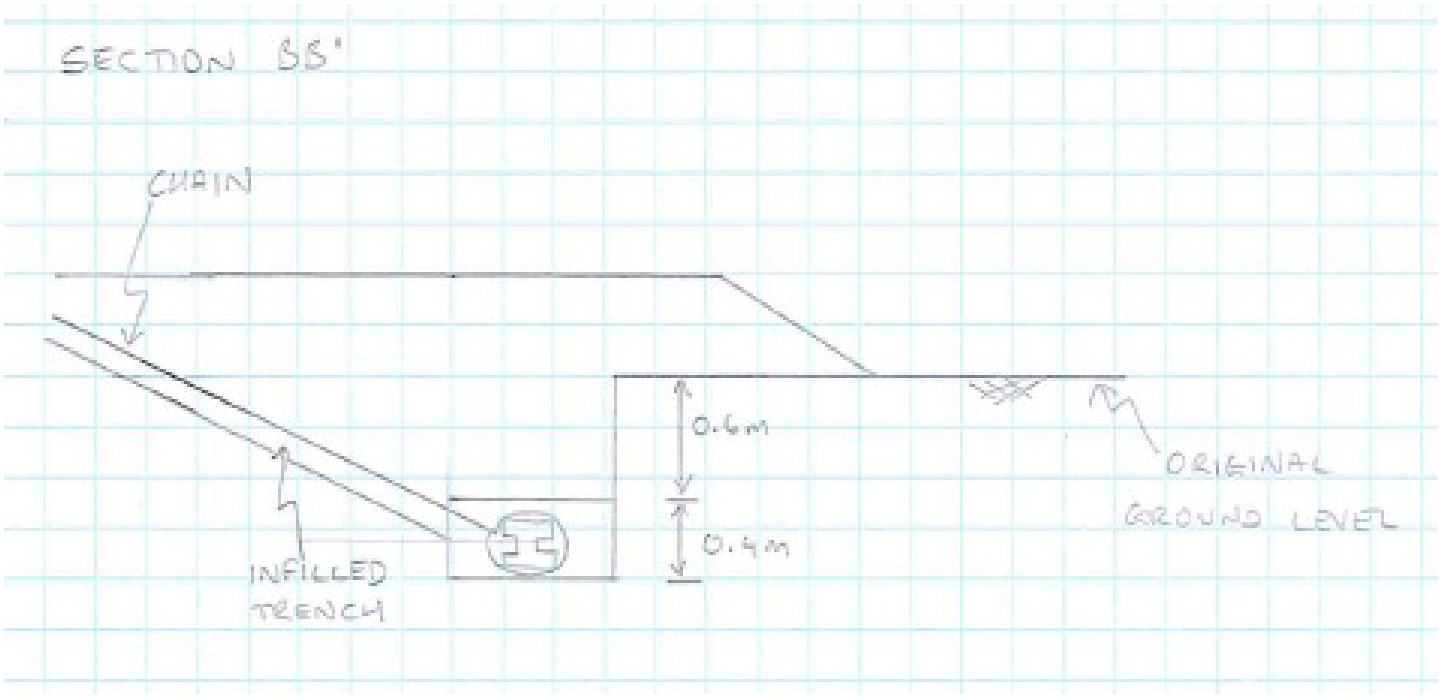
Uledi bridge – details of repair works carried out August 2015



Not to scale

Appendix D

Uledi bridge – details of repair works carried out August 2015



Not to scale

Appendix D

Appendix G
Engineering Report– Chiwembe Macheso, Chiwembe Village & Chiwembe Selemo

Imperial College Building Bridges Expedition
Malawi 2015

ENGINEERING REPORT–
CHIWEMBE MACHESO, CHIWEMBE VILLAGE & CHIWEMBE SELEMO

Engineering Report – Chiwembe Macheso, Chiwembe Village & Chiwembe Selemo

1. Introduction

From the 20th August – 25th August, an expedition team from the UK visited three communities in Chiwembe, South Blantyre. The expedition team consisted of two civil engineers: Jumana Al-Zubaidi and Harriet Kirk who were working with CCODE to research the potential for new bridge construction in these communities. CCODE already works with these communities on other projects, and knew that there was a want for bridges at each of these communities. In addition the Federation of Rural and Urban Poor has also worked closely with these communities to improve their quality of life. The expedition team was joined by Loveness from the Federation and Rosina from CCODE on days spent in the communities.

For each community visit, a meeting with the Village Headmen was held, including a lengthy discussion about the local community, its needs and wants and the level of community involvement anticipated. Then the bridge site was visited, as well as nearby amenities and close crossings. This document includes the main findings of the meetings and visits. These findings have been discussed with CCODE and the Federation in a meeting on 26th August.

2. Chiwembe – general information

The three communities visited all lie close to each other within the Chiwembe district, south of Blantyre and about 4km south of Limbe town centre. They are Chiwembe Macheso, Chiwembe Village and Chiwembe Seremo and are under the Traditional Authority of Kapeni and Senior Group Headman Chiwembe.

Access to the communities is by a dirt road which is passable by car in the dry but likely only by 4x4 during the rains. Very few of the inhabitants have access to a car, so travel to Limbe is by bike, on foot, or occasionally by public minibus.

Most houses are constructed from mud bricks with tin roofs. A few houses belonging to wealthier members of the community are built using commercial bricks. Healthcare, markets and law enforcement are all accessed within Limbe. Primary schools are located within and close to the communities.

Much of the information within this report was gathered from residents during community interviews and should therefore be treated as anecdotal evidence. Numerical values such as population figures may not be accurate.

3. Chiwembe Macheso

Chiwembe Macheso is an informal settlement with around 1000 families. To the south, the community is bordered by the Limbe River. There is a shortcut pedestrian route to Limbe (around 2.5 - 3 km) which involves crossing the river; this appears to be the preferred route for most residents.

CCODE works regularly within the community, focussing mainly on settlement upgrading works including improved sanitation.

3.1. Economics

Most people in Macheso make a living either by working as labourers in Limbe, or by buying goods in Limbe market and selling on within their community. Some people also run small businesses, for example tailoring or making charcoal.

There appears to be a reasonably broad range of incomes within Macheso, with skilled labourers and those working in Limbe earning considerably more than those who resell commodities within the

community. From observations of the houses and general living conditions, the community appears to become poorer as you move downhill away from the road and towards the river.

3.2. Services

Chiwembe Macheso is connected to the electricity grid, and many houses have electricity (although may not be able to afford to use it). Water and sanitation are more problematic. The majority of latrines are pit latrines, which can only be used for a few years, and so space for new latrines is limited. There are two public boreholes within the community which provide fresh water, as well as a number of private wells which belong to individual houses.

3.3. Education

There are three primary schools attended by children from Chiwembe Macheso. Two are on the same side of Limbe River as the community, while the third, Misesa Primary, is on the opposite side, around a 20 minute walk away. Around 1000 students attend Misesa Primary, of whom perhaps half live on the opposite side of Limbe River in the Chiwembe Macheso area. There is an active Scout troop at Misesa Primary, attended by around 800 children.

Figure 1: View across Chiwembe Macheso

3.4. Macheso bridge

We met with three Village Headmen, who told us that there is a need for a footbridge to cross the Limbe River during the rainy season, since an existing bridge was swept away during the floods in the last rainy season. The main reason put forward for requiring the bridge was to allow school children safe access to Misesa Primary all year round. The bridge would also be useful for almost all community members since by crossing the river, a shorter pedestrian route can be taken to Limbe.

The previous bridge at Macheso was built 10 years ago and was a typical Malawian “tree trunk” bridge, constructed by laying cut trunks across masonry abutments and fixing planks as decking. The bridge

span is around 7 m. The tree trunks were swept away during the floods but the abutments remain and appear to be in good condition. However, the bridge is situated on a meander and there appears to be significant erosion around the abutments on both banks. During the dry season, the river can be crossed at the same point using stepping stones.

The existing bridge was built using funding from a shadow MP, Victor White Mbewe, during an election campaign. This is a fairly common tactic in an attempt to win votes. We were told that he promised the villagers that if elected, he would replace the bridge with something more permanent; however, since his election they have been unable to hold him to account on this promise.

Figure 2: Existing crossing point from left bank, showing stepping stones and right abutment

3.5. Chiwembe bridge

The nearest safe crossing point is around 1.5 km upstream at Chiwembe village. Walking at a slow pace between the sites took us around 35 minutes. This crossing point is in the direction of Limbe and would therefore not add significantly to journey time to Limbe. Using Chiwembe bridge to access Misesa primary school from Macheso would increase the distance, perhaps increasing the walking time from 30 minutes to 1 hour for some students.

Chiwembe bridge is sited just downstream from a dam, which was created to store water during the rainy season for use in the dry. The lake behind the dam has now become choked with vegetation and the water just runs straight out of the outlet due to lack of storage. The outlet structures are badly

damaged and the banks have become eroded, therefore the dam does not serve to control the river. The dam itself appears to be of earth construction and in reasonable condition.

Chiwembe bridge has a span of around 21 m. It has masonry abutments and two intermediate piers, one masonry and one steel, clearly retro-fitted. The superstructure comprises thick tree trunks laid longitudinally with wooden decking attached. The bridge was originally intended to carry vehicles but money ran out during construction so it was completed using a narrower deck for pedestrian traffic only.

Significant bank erosion was noted on both sides of the river, and in particular on the left bank the bridge will soon need to be extended because of erosion behind the abutment.

Figure 3: Chiwembe Bridge, viewed from the left bank

3.6. Community interviews

3.6.1. Village headmen

A formal meeting was held with the Village Headmen for Macheso, Moyo and Ntundu. Key outcomes were:

- Information on community provided, as outlined above.
- Headmen initially stated they would prefer to construct a bridge for vehicle use. We highlighted the additional cost that this would entail, as well as pointing out that roads on the right bank would need to be significantly upgraded to allow vehicle access. They then accepted that a vehicle bridge is unlikely to be practical. However, the bridge should be suitable for bicycles and animals (goats and cows).
- No NGOs other than CCODE currently work in the community.
- The community have had some contact with national and local government but find it difficult to access funding for infrastructure projects.
- The community will be able to provide contributions towards any bridge project. This will include both labour (skilled and unskilled) and financial contributions.

3.6.2. Senior Group Headman Chiwembe

A formal meeting was held with the senior headman. His approval and active participation would be required for any project to be a success, since he coordinates the village headmen.

- The community is actively looking for support to rebuild the bridge and ready to contribute to the project. The bridge is important for access to school, churches and markets.
- The community is used to collaborating with CCODE and have a good relationship with them, therefore organisation should be straightforward.
- A pedestrian bridge is the best option since most in the community do not have cars.
- The senior headman suggested setting up a committee to be responsible for the bridge and taking regular small financial contributions from the community to cover maintenance.

3.6.3. Community members

Informal interviews with community members were carried out while walking around the village.

- During the rainy season there are occasions when the river is too full to cross. It was difficult to ascertain how often this happens and how long it lasts; an estimate is once or twice a week, and unlikely to last for more than a day.
- Everyone interviewed said that their family would use the bridge, either for going to school or for visiting Limbe. Stated frequency of use ranged from twice a day to twice a week.
- One young man stated that the top priority for the village was sanitation, rather than the bridge.
- Everyone interviewed said that their family would be able to contribute something towards the bridge, ranging from MK 100 to MK1000.
- Several people employed in skilled trades suggested that more affluent members of the community, or those whose businesses would benefit from the bridge, could contribute more than poorer members.

List of community members interviewed:

- Mr Chigwenembe (dairy farmer)
- Samuel (Reverend)
- Betha Tembu (Mother, occupation unknown)
- Elisa Chigwani (small business buying commodities in Limbe and selling in Chiwembe)
- Christina Michael (small business buying firewood near Limbe and selling in Chiwembe; mother of 6)
- Ronald Fadwick (Tailor; father of 3)
- Daniel Sakanamba (young man employed in Limbe; no children)
- Esther Bonges (runs a small business buying firewood near Limbe and selling in Chiwembe; mother of 6)
- Benford Jackson (elderly man, working in Limbe as a cleaner; father of 3)
- Geoffrey Kapingi (shop owner, buying in Limbe and selling in Chiwembe; father of 1)
- Rex Brown (Chairman of Misesa Primary PTA)
- Christina Jaluluka (Headteacher, Misesa Primary)
- Charles Lewis (teacher and scout troop leader at Misesa Primary)
- Samuel Lunda (young man, occupation unknown)

3.7. Bridge site review

A site walkover was carried out close to Macheso to determine the most appropriate site for any future footbridge. A sketch map is shown in Figure A1 in Appendix A.

In general the river course is quite meandering and there is significant bank erosion. Several sites were discounted because they were too close to bends or to existing washouts. During the rainy season, the river may overtop its banks at times.

Geology appears to comprise limestone bedrock which outcrops within the river bed. The river banks are typically 1 -2 m high and comprise weathered limestone and residual soil, and river deposits of sandy clay. At places on the banks sizeable limestone boulders were observed, up to 3 m in diameter; these do not appear to be recently deposited. Boulders and shallow bedrock may cause problems for excavation during bridge construction.

The most appropriate bridge location identified during the walkover is shown in Figure 4. This is located on a reasonably straight stretch of river with less significant erosion than other locations. However, to maximise the bridge lifespan the towers would need to be located as far from the river as possible. A minimum span was measured as 19 m.

Figure 4: Preferred bridge site, downstream of existing crossing point

3.8. Recommendations

- Another bridge within Chiwembe Macheso would add to quality of life for the residents. However, in the meantime, there are bridges available for crossings required to the school and Limbe. It is recommended the community and school does not try to cross at the current crossing point when the rains are heavy and the river is unsafe to cross. Instead, the bridge upstream should be used where possible.
- A new bridge should not be placed at the existing crossing point. This site suffers from significant erosion and a bridge placed here will encounter erosion at the abutments sooner or later which will shorten its useful lifespan. Instead another bridge location has been identified at a downstream location, close to an existing crossing of the river. The community has also identified this position as somewhere they are happy for a bridge to be placed. This

crossing position still suffers from some erosion, and the bridge abutments would have to be placed some distance behind the banks. An approximate span of 20m is anticipated. This is a significant span and would require a technical design for the new bridge. It has been discussed with CCODE that local technical assistance is used for the design. The expedition team are happy to provide support and assistance to the design team as required.

- There is an active Scouts group at the Misesa primary school. A potential source of funding would be through collaboration with the international Scouts communities. The team will make enquiries in the UK.
- In order to demonstrate the potential value of the bridge, a crossing count should be carried out. This involves recording the number of people crossing the river at the traditional point and their reasons for crossing, and should be carried out over a minimum of 1 week. To capture representative data, the crossing count should be undertaken during school termtime and should include the morning and evening journeys. CCODE would be in the best position to perform this.

4. Chiwembe Village

Also within the Chiwembe district and bordering with Chiwembe Macheso and Limbe, this is a heavily populated community with approximately 15,000 inhabitants and seven to eight people per household.

There is little local or national government involvement. The community has tried to contact local government regarding their bridge request with no success.

4.1. Economy

People are employed as farmers, running small businesses locally buying products in Limbe and selling locally, and work in Limbe in shops or as labourers. Average household income was reported as 20,000MK/month ($40).

4.2. Services

Houses are closely packed on a steep hillside, some having electricity, others not. Access to water is via 2 boreholes and 16 water kiosks which are ‘pay as you use’. The boreholes were installed by a charity ‘Water for People’. The community is organising other projects, including constructing a new nursery school for orphans. The general impression was that the community is well-organised and motivated to improve facilities for themselves where possible.

4.3. The Bridge

A meeting was held with key community members:

- Senior Group Headman of Chiwembe
- Trouble – Counsellor to the chiefs, involved in strategic planning with CCODE
- Matipa (Edward) – Village Headman
- Rose Byekachere – Chair of some projects in the area

The proposed bridge location is used by members of the community to cross over the Bengwe River to access the primary schools either side, and to access the main road to walk or catch a bus to Limbe and where most shops selling food and goods are. Kapeni Demonstration school is at the top of the hill and is a fairly extensive government school with 7300 children. The school was built in 1961, with recent renovations funded mostly by government with some charity funding from the Netherlands and Blantyre Teaching Association and is rapidly growing with 6675 pupils enrolled in September 2014. Approximately half the pupils are female. There are 60 teachers, of which 53 males and 7 female.

Approximately 60% of the pupils cross the Bwenge River to attend school, with lots of problems in the rainy season, especially last year when the rains were heavy and bridges were washed away. Journey times are 25 minutes walking from the main road in Chiwembe Village. Misesa school is an hour walk away and another school Kapeni 2 is 30 minutes walk away from the same main road location. Kapeni 2 was not visited by the expedition. The community layout (based on our site walkover) is shown on Figure A2.

Figure 5: Typical view within Chiwembe Village

Discussing their expectations for a bridge, the community has few specific requests aside from a safe crossing. CCODE has been involved with a potential bridge at this site, including specifying materials and quantities for a concrete deck. However this project failed to begin because of a lack of funding. The community only want a pedestrian bridge with no heavy animals expected to cross.

The proposed bridge location is over the Bengwe River and a gully, that when visited were dry at the crossing, but with groundwater close to the gully's base at around 2m below ground level. There is a well located close by from which the groundwater level could be measured. There are reports of water reaching 2m above ground level but not above bridge level during the rains. The river was reported consistently full for 4 months. There is an existing bridge, built last year by the community and of approximately 5m span and made of traditional wooden pole and plank construction. The community contributed stones (about MK 40,000) and free labour for the bridge. This bridge survived the heavy rains last year. We heard reports that a few years ago, a child was washed away at this site before there was a bridge. The child was standing on a part of the bank that collapsed. A detailed plan of constraints at the bridge site is included as Figure A3.

The bridge site is located within an area of clayey soil which is friable when dry and appears to be easily eroded by water flow. No bedrock was observed during the site walkover.

There is significant erosion at this location, with the bridge abutments compromised as well as several properties. Some efforts have been made by the community to protect the banks of the gullies and the properties by placing tyres and sacks of compacted earth. Six nearby households donated MK 4,800 each to fund these works. The river is full of rubbish, dumped by the community, which will increase the water level during flooding.
The erosion problem is the key here. An expensive bridge is not required, since the traditional wooden deck bridges the community know how to build are suitable. Any funds and labour the community can contribute is better spent diverting rain water away from gullies running through the centre of the community. This will reduce the number of crossings required, the span of those crossings and erosion of footpaths and under houses.

There is an alternative and safer crossing point only 3 minutes' walk away, where there is another wooden bridge of approximately 5m span. This bridge is already used by those living close by or when the first bridge has problems. This site is less affected by erosion and the banks do not flood during the rains. The channel is used as a rubbish dump.

Figure 6: Existing bridge and adjacent gully, showing erosion protection

4.4. Community members interviewed: (in addition to village headmen, etc)

Doreen – a teacher at Misesa School.
Winston Gwiritsa - Headteacher at Kapeni Demonstration School (tel: 0882911161)
Joyce Mapeto – teacher at Kapeni Demonstration School and Girl Guide Leader.

There is a local scouts and girl guides group at Kapeni Demonstration school, with about 30 girls enrolled and 60 boys. Leaders are Joyce Mapeto for the girl guides and Blessings Banda for the scouts. There is no contact with international groups. Some of the guides and scouts live on the opposite side of Bwenge River and have problems attending meetings in the rainy season.

4.5. Recommendations

- The proposed bridge site is an extremely poor location for a crossing. There is significant erosion to the banks and this will endanger the nearby houses. The existing bridge may collapse in the next rainy season due to erosion at the abutments. It is recommended that permanent footpaths diverting pedestrian traffic to the nearby safe crossing point are built. CCODE can help organise the local community to do this.
- The nearby bridge should be well maintained. Erosion is much less here and the traditional wooden deck construction is adequate for pedestrian traffic over this short span.
- A long term holistic plan is needed to reduce the erosion through the community. This will increase in coming years and the retaining structures built by the communities will only help to a limited degree. It is strongly recommended that water is diverted away from gullies running through the centre of the communities and around it where possible. This could be a potential Engineers Without Borders (EWB) project. The expedition team will approach EWB in the UK.

5. Chiwembe Selemo

Also within the Chiwembe district and bordering with Chiwembe Macheso, this is another heavily populated community with approximately 8,000 houses and four people per household. The community lies on a hillside towards, but not reaching the Kapeni Demonstration school. Access to Limbe is along the main road, with some people travelling over Chiwembe Bridge. CCODE has worked in the community in the past, on ecosan toilets and producing manure from waste.

The village headmen identified the main needs of the community as improvement works on the main road leading to the community, which is difficult for minibuses to travel on during the rainy season and more river crossings for during the rainy seasons.

5.1. Economy

The economy is similar to that in the other Chiwembe communities visited. Members of the community earn a living by buying products from Limbe market and selling them locally. Others work in Limbe as labourers. There is some skilled work, such as building.

Meeting with:

- Matipa (Edward) – Village Headman
- Pearson Kapinga – Village Headman of Seremo
- Chipirio Cirisa – Representative of Village Youth (with very good English)

5.2. Services

Some, but not all houses have electricity. There is one borehole, paid for by political parties and 3 water kiosks. It was reported that an NGO was working in the community with the aim of installing wells, but nothing was built – the reasons are unknown.

5.3. Education

Most children in the community attend Kapeni school and Namami school. A few living further downhill attend Misesa school, on the opposite side of the Limbe river.

5.4. Bridge Sites

Two bridges were identified by the community as in need of replacement. Both are bridges of traditional wooden deck construction. The bridge sites are shown on Figure A4.

The first bridge is used by children attending Kapeni Demonstration school and people travelling to Limbe for work. It has main poles which have been there for some time, with the timbers being replaced recently. This bridge is in a poor condition and crossing it is not very safe. The river is getting wider and the community are concerned the bridge will not last much longer and want a more permanent replacement. They have concreted the base of the channel and are also considering building retaining walls to protect the banks and nearby houses from erosion. The community has contributed to the concreting of the base of the channel with 185 families contributing MK200 each for sand and cement and women volunteering their time to collect stones.

Alternatives to this bridge involve walking a slightly longer route – approximately 10 minutes longer.

The second bridge is further up the hillside. This is used by the 150 houses at the top of the slope. This bridge was built last year by political parties during campaigning.

When asked to prioritise, the first bridge was selected by the headmen as more important to the community since it is used by more people.

5.5. Recommendations for Chiwembo Selemo

- The first proposed bridge site is suffering from severe erosion. It is likely the bridge here will collapse in a few years from erosion at the abutments. Nearby houses will also be in danger from collapse. The community has concreted the channel base which will unfortunately aggravate the bank erosion, as the water will now be forced sideways and upwards. This will also cause more flooding.
- Similar to Chiwembo Seremo the main priority for this community is erosion prevention, more than a new bridge. Long term and large scale water diversion works are recommended to reduce the amount of water that runs through the centre of the community during the rainy season. If the volume of water running through the centre of the community is reduced, then erosion will be reduced. Traditional wooden deck bridges will then more than likely be adequate for the community needs. The expedition team will make contact with EWB in the UK to see if an EWB placement can be organised within the community.
- In the meantime, alternative crossing points are available during the rainy season.

6. Conclusions and further work

A meeting was held with CCODE to discuss the findings of the engineering assessments. The following actions were agreed:

Community	Action	Responsible
All	Provide engineering report with recommendations	JAZ / HK
	Report findings to communities	CCODE
Chiwembe Macheso	Conduct bridge site crossing count	CCODE
	Seek support from City Council to develop a technical design for an appropriate footbridge	CCODE
	Seek funding partnership through the Scouting movement	JAZ / HK
	Provide bridge design manuals	JAZ / HK
Chiwembe Village / Chiwembe Selemo	Contact Engineers Without Borders regarding placement options	JAZ / HK

APPENDIX A
Figures

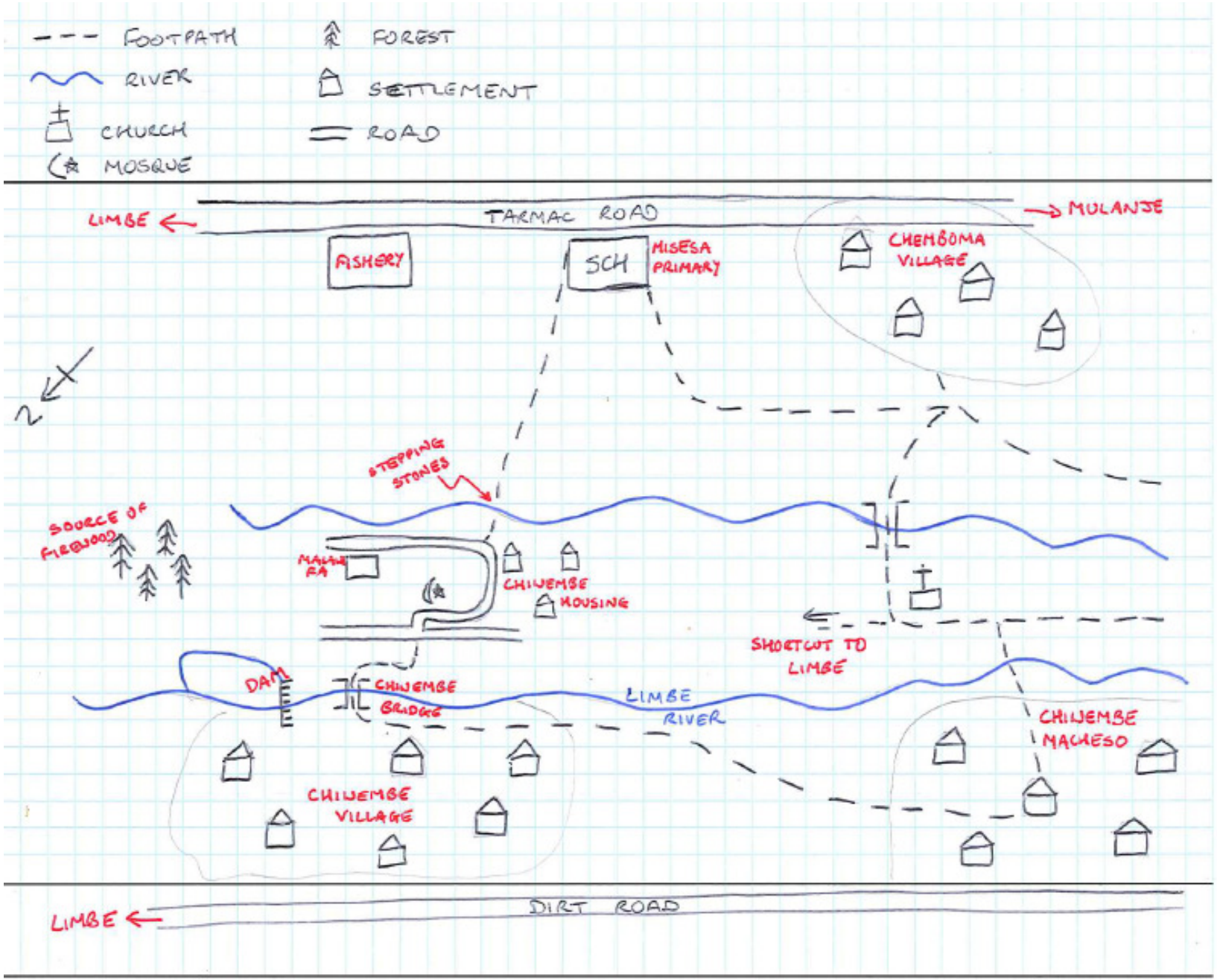


Figure A1: Chiwembe Macheso sketch map (NTS)

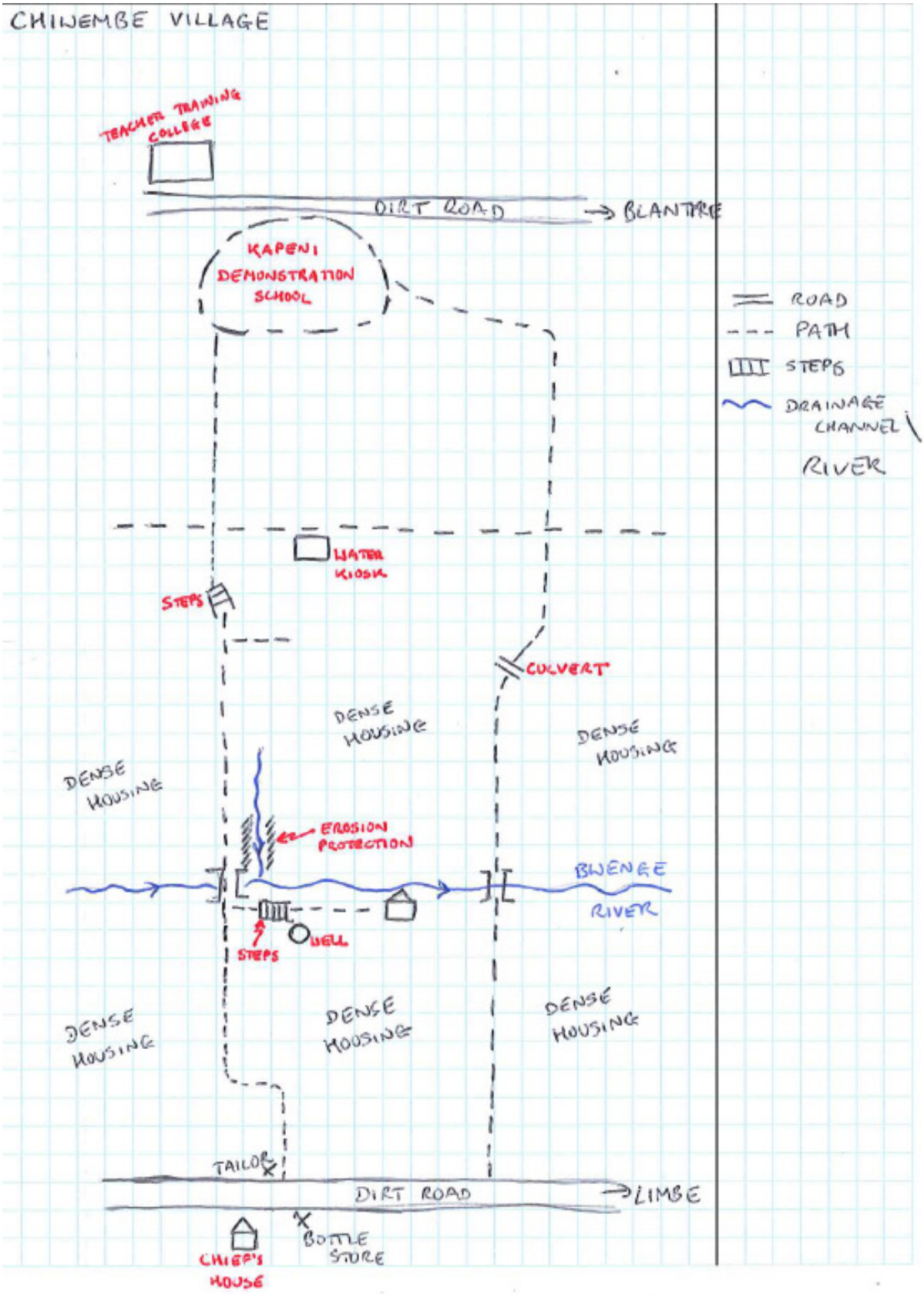


Figure A2: Chiwembe Village sketch map (NTS)

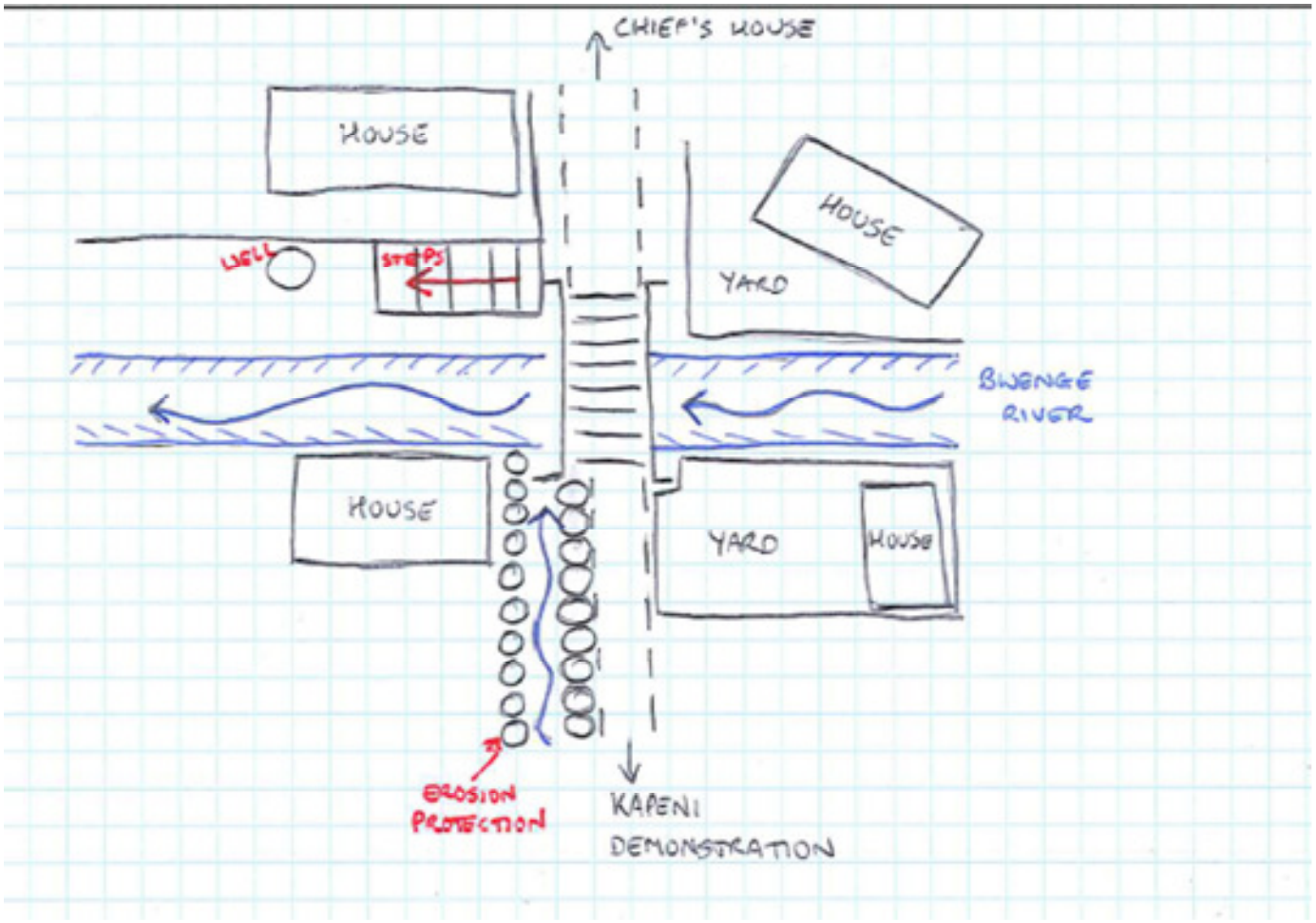


Figure A3: Chiwembe Village bridge constraints (NTS)

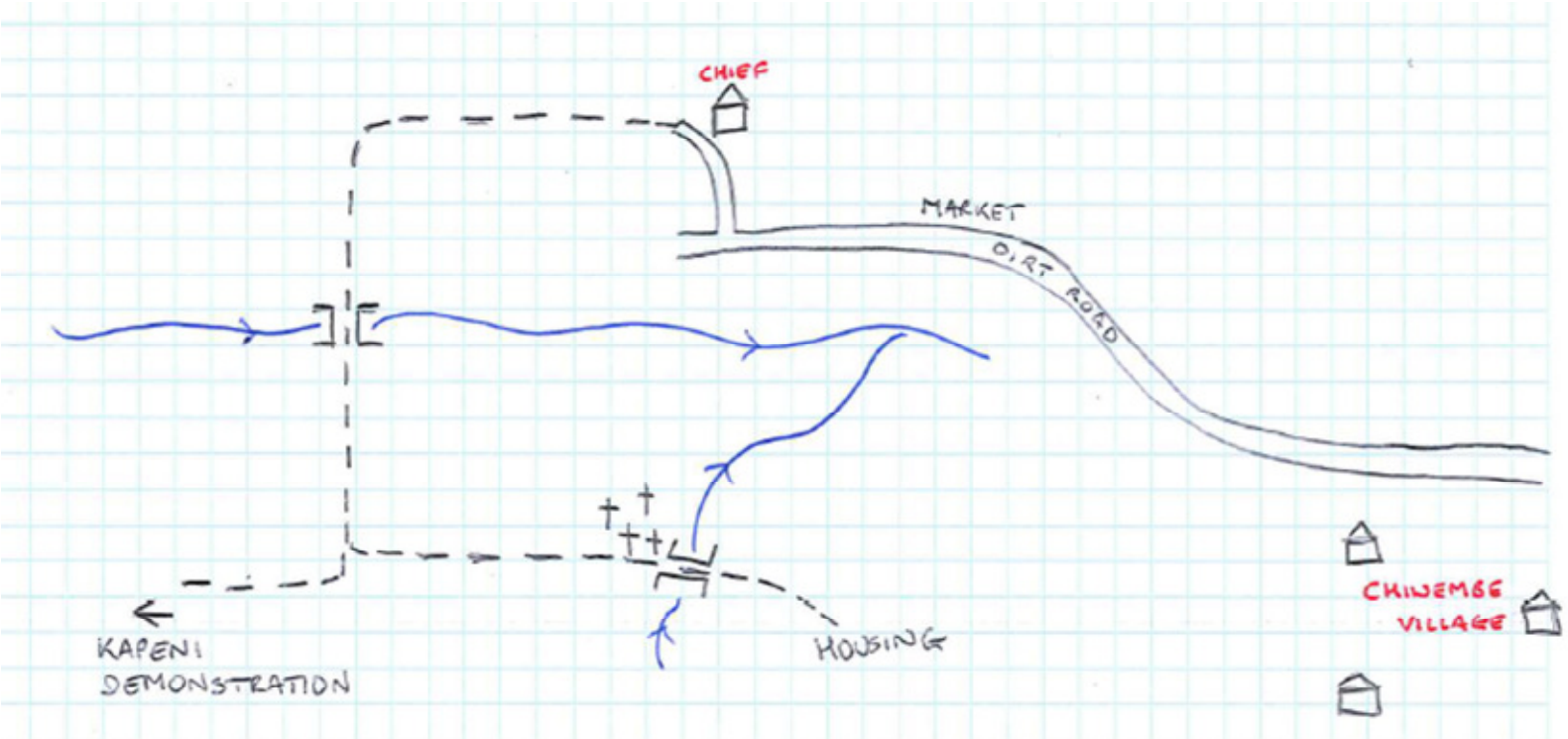


Figure A4: Chiwembe Selemo bridge locations(NTS)

Appendix H
Engineering Report – Linthipe Footbridge Feasibility

Jumana Al-Zubaidi
Harriet Kirk

Imperial College Building Bridges Expedition Malawi 2015

Engineering Report- Linthipe Footbridge Feasibility

1. Introduction

In August 2015, the authors travelled to Linthipe in Malawi at the request of Susan Reimer to assess the feasibility of a new footbridge. The authors spent 1 day gathering information from the community, Susan and potential bridges sites, as well as two evenings learning about the communities from Susan and discussing potential options. This report summarises the work carried out, the information gathered and recommendations for action going forward.

2. About the authors

Jumana Al-Zubaidi and Harriet Kirk are Civil Engineers who have studied and worked in the UK. Both have first class MEng degrees from Imperial College London. Jumana is a Bridge Engineer at Mott MacDonald and Harriet is a Geotechnical Engineer at Atkins. In 2007 they were part of a student-led team which planned, designed and built a suspended footbridge in Uledi, northern Malawi. Just before arriving at Linthipe, they had spent two weeks at Uledi, inspecting the bridge and making repairs. Harriet has also led an expedition to Bolivia to construct a steel truss footbridge.

3. History to the Linthipe Visit

In July 2014, at the Footbridge conference in London, Kayin Dawoodi approached the authors about a potential footbridge project in Malawi. Kayin was working for Bridges to Prosperity (B2P), a charity which constructs bridges in developing countries around the world, and had been approached by Susan to see if B2P would consider a footbridge project in Linthipe. As B2P do not currently operate in Malawi the authors were approached to see if they would be able to contribute. The authors were planning a trip to Malawi to inspect and make repairs to the Uledi Bridge they had built in 2007 and agreed to visit Susan at Linthipe to assess the feasibility of a footbridge.

4. About Linthipe and the surrounding communities

Linthipe is a small market town 30km south-east of the capital city Lilongwe on the main M1 road connecting Lilongwe to Blantyre. The River Linthipe is the major river in the region, running roughly north to south and shown in Figure A1 in Appendix A. In the surrounding region, there are several communities dispersed on both sides of the river. It was difficult to gain an estimate of the number of communities and their populations, but it is likely that several thousand people live in the region.

The communities visited by the team were rural, remote and clearly impoverished. The majority of houses are of mud construction with thatched roofs. There is no electricity and water is provided from boreholes. The villages are mainly served by footpaths and most journeys to and from Linthipe are on foot, although some people have bicycles. The livelihood of most people is farming, primarily subsistence, although some people also sell produce at Linthipe market.

Most of the facilities serving the communities are located in Linthipe, close to the M1 highway. These include a market and trading centre, police station, secondary school and the traditional court where disputes are settled. Aside from the main M1 road and a secondary road (S126) which intersects to the north of the proposed bridge site, there is no road infrastructure in the region.

Figure 1: One of the communities in the Linthipe Group

The communities have a similar hierarchal traditional government to much of Malawi, with Village Headmen representing and governing each community and Group Village Headmen being more senior and representing a group of communities.

5. Scope of Works

The team arrived at Linthipe on the evening of 27th August 2015 and stayed with Susan at her house. Work began the following morning. Susan had a satellite image of region from which the River Linthipe could be identified as well as the surrounding communities and the main road to Lilongwe.

At the team's request Susan had arranged a meeting at a locus point in the communities, between the team, the Group and Village Headmen and interested members of the communities. A local teacher named Thomas accompanied us to the meeting and acted as interpreter and community liaison.

Bicycle taxis were used to travel to the river, around a 20 minute journey. From here the team crossed the river and travelled on foot to the meeting, which took around 15 to 20 minutes. The meeting was attended by 11 Village Headmen, 3 Group Village Headmen and approximately 100 men, women and children from the surrounding communities. It was communicated that more people would have attended, however a funeral was taking place at the same time and many people were attending the service.

Following the meeting with the community, a site walkover and basic line and level survey were carried out.

6. Community meeting

After introducing the team and the objective of the meeting, which was to gather information about the need for a footbridge and the level of community participation, the community was asked questions. The following is a summary of the information gathered. Everyone who attended the

meeting was in favour of a footbridge crossing the River Linthipe. It is vital for the success of a development project that there is substantial community support so this was a positive sign. Most of the people attending were from communities on the west bank and regularly crossed the river to travel to facilities on the east bank. These facilities included a secondary school, hospital and police station. The training centre (shown in figure 2), and markets where people bought agricultural products such as fertiliser and took their maize to be ground were also on the east bank. Funerals regularly took place on both sides of the river. Many people also worked at the training centre. People would travel to the market on the east bank of the river to buy food. When asked about the frequency of journeys across the river, everyone present crossed the river at least once a week to visit the market, and many much more frequently. A third of the people attending travelled to the hospital and 15 people crossed the river to travel to the secondary school.

Figure 2: Community meeting, with the team and village headmen on chairs

People currently cross the river at an established crossing point. This crossing was the shortest route to reach facilities on the east bank. Using this route it takes approximately 1hr 30 to travel to the M1 at Linthipe. When the river is impassable, a longer route is taken with a journey time of around 3 hours. It was reported that pedestrians on this alternative route are often accosted by criminal gangs, and women in particular are threatened.

Between the communities and the River Linthipe there is another narrower river to cross. A span of approximately 12m is required to be above flood levels. The land on either side of both banks is in private ownership, and mostly used for farmland. The village headmen advised that land can be bought from the owners who will be reimbursed by the communities.

In the team's experience, communities often have an expectation for the type of bridge they want, which can lead to dissatisfaction if a different bridge design is constructed. It is important that these expectations are heard so that any withdrawal of community support is anticipated and addressed.

Some members of the community mentioned there is another bridge over another river a few kilometres away. This bridge has masonry piers and the community expressed that they thought this was a good idea for a bridge. Many of the community farmers would like to transport their animals and crop across a bridge to see at the market. These animals are goats, pigs and oxen pulling carts of crops.

There have been a few charitable projects in this community in the last few years. Concern Universal had drilled boreholes for drinking water. A local MP had funded the bridge with the masonry piers. (We found it to be common practice at election time for MPs and candidates to fund local bridge projects in poor communities. Outside of election time this was unheard of). The government had provided funding for the footpath from the river to the training centre. A conservation project had also taken place in 2014.

Everyone agreed that access to clean drinking water was the biggest problem facing people. There were not enough boreholes to supply everyone and this had been recently exacerbated by one borehole breaking in an accident. The local people were saving to replace the broken part and this would take time.

The community appeared committed to contribute towards the construction of a bridge and its maintenance and security. Several people suggested the community could provide free collection of local materials such as rocks and sand and voluntary labour in construction. The village headmen confirmed that there was skilled labour within the communities that could be used. One member of the local voluntary community watch said he and his colleagues would include the bridge in their patrols at night. He stated he had 45 colleagues.

7. Site walkover

7.1. Existing Crossing

The existing crossing, shown in figure 4 is at a bend in the River Linthipe, where the channel is relatively wide and shallow. Established footpaths approach it from both sides and connect the communities and the main road. The community had built an elevated stone footpath, which allowed users to cross on foot during the dry season when the water level was low without getting their feet wet. However, by creating a geometric blockage, during the rainy season this will increase the water level. The river upstream of this crossing was stagnant as a consequence of the blockage. The local community was advised this provided conditions for mosquito breeding and increased their risk of malaria and to introduce drainage channels in the footpath.

The local people advised that during the rainy season, flood events would happen a few times each season and last a day. During this time the water level would rise significantly and sharply but the water would have very low velocity. Outside of these flood events the rainy season water level would still be significantly higher than the dry season water level. It was reported that the river may be too high to cross safely for around three months at a time. A crossing span of around 46m would be required to cross this mean rainy season water level, with the possible submersion of the abutments during the flood events.

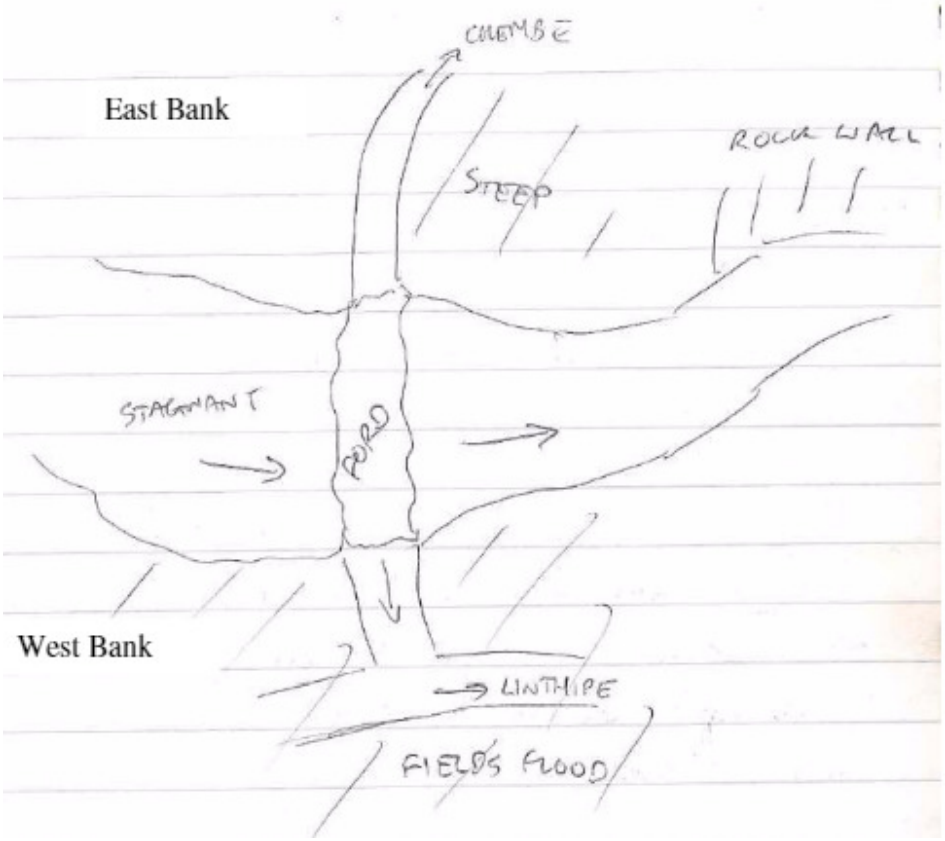


Figure 3: Hand sketch of River Linthipe, showing footpaths leading to the communities and to Linthipe town. The arrows indicate the flow direction and the stagnant water upstream of the ford and the steep rocky banks downstream of the ford.

Figure 4: Existing crossing showing line of level survey over raised footpath

The team carried out a simple level survey using a hose pipe filled with water and a tape measure. The results are in the table below. This method is useful for in the field measurements with very simple equipment and is very approximate. A more detailed survey using more accurate methods is recommended prior to any construction. The survey took place on a line between the proposed

locations of the abutments if they were to clear the mean rainy season water level and join the existing paths.

Distance from Linthipe Bank (metres)	Backsight (mm)	Foresight (mm)	Ground level change relative to Linthipe Bank (mm) +ve rise -ve fall
0			
2	400	810	-410
5.15	410	990	-990
6.77	200	410	-1200
7.98	490	490	-1200
10.83	480	620	-1340
14.20	330	690	-1700
17.32	660	550	-1590
21.07	380	390	-1600
23.42	450	480	-1630
26.2	430	460	-1660
29.57	450	230	-1440
32.87	570	350	-1220
34.71	900	680	-1000
37.61	1020	350	-330
39.93	950	170	450
41.18	800	320	930
42.31	1160	260	1830
44.61	820	400	2250

The survey suggests there is an approximate 2.3m difference in level between the proposed positions of the two abutments.

The surveyed levels are shown in Appendix B.

At the community bank, a few metres behind the proposed abutment location, a small tributary flows and converges with the River Linthipe just downstream. It is unknown how high and fast the water in this tributary is during the rainy season and whether it would invalidate the placement of a bridge abutment close by. The tributary can be seen in Figure A2.

7.2. Upstream of Existing Crossing

The team walked a few hundred metres upstream of the existing crossing to scope for other promising crossing sites. The river is very bendy in this location and does not narrow significantly. It is inadvisable to construct bridges on or close to bends in rivers, as erosion can be high at these positions and bridge lifespan may be shortened by erosion at the abutments.

The terrain is very rocky, with large boulders. The water depth is approximately 0.5m - 1m and the water at the centre of the channel is fast flowing.

7.3. Downstream of Existing Crossing

Further downstream the west bank of the river has very steep, almost vertical rocky banks. The slope above this rock face looks unstable and prone to slip. The height difference between the banks close to the river is more than 5m. The combination of unstable slopes and large height difference means this would not be a sensible bridge site.

Figure 5 Photos of downstream (left) and upstream (right) locations showing rocky terrain and stagnation upstream of ford

8. Conclusions and further work

This report serves to provide an initial assessment of the feasibility of a footbridge crossing the River Linthipe close to Linthipe town. The site walkover showed that it will be challenging to design and construct a suitable bridge for this location. The key findings are summarised below.

- An ideal bridge site is not immediately apparent. The river is very bendy in this location, making bank erosion a concern. Downstream of the existing crossing point the banks are steep with a significant height difference. Upstream of the existing crossing point the river is wider and more bendy. The existing crossing point seems to be the best location for the bridge, but the convergence of a local tributary close by possibly does not leave enough room for an abutment on the community bank.
- The span required will be significant – at least 46 m if it can be demonstrated that it is acceptable for the abutments to be submerged during flood events, and at least 70 m if the abutments must be kept above the flood level.
- The cheapest option for a footbridge of this span would usually be a suspended or suspension bridge. However, this is unlikely to be feasible owing to the limited space on the left bank for construction of the tower and anchor block. It would also not be the preferred

construction type for the local people, who were concerned about being able to take animals and carts across.

- Other options such as a concrete, masonry or steel truss bridge are likely to require intermediate supports within the river. These will be difficult to construct because the river is never dry.
- Access to the site is reasonable. It is likely to be possible to bring materials to the right bank using a 4 wheel drive vehicle. As such it may be possible to pre-fabricate elements off site to improve quality control.
- Significant labour is likely to be available from the local population, including skilled labour such as carpentry. It is unlikely that the communities would be able to contribute financially.
- Another bridge is required at a smaller river to the east of the River Linthipe. Most of the communities on the east bank, and most potential users of the footbridge at River Linthipe will need to cross this smaller river. The span required is estimated to be 12m. Any benefit gained from a new bridge over the River Linthipe will be reduced if no crossing over this smaller river is provided.

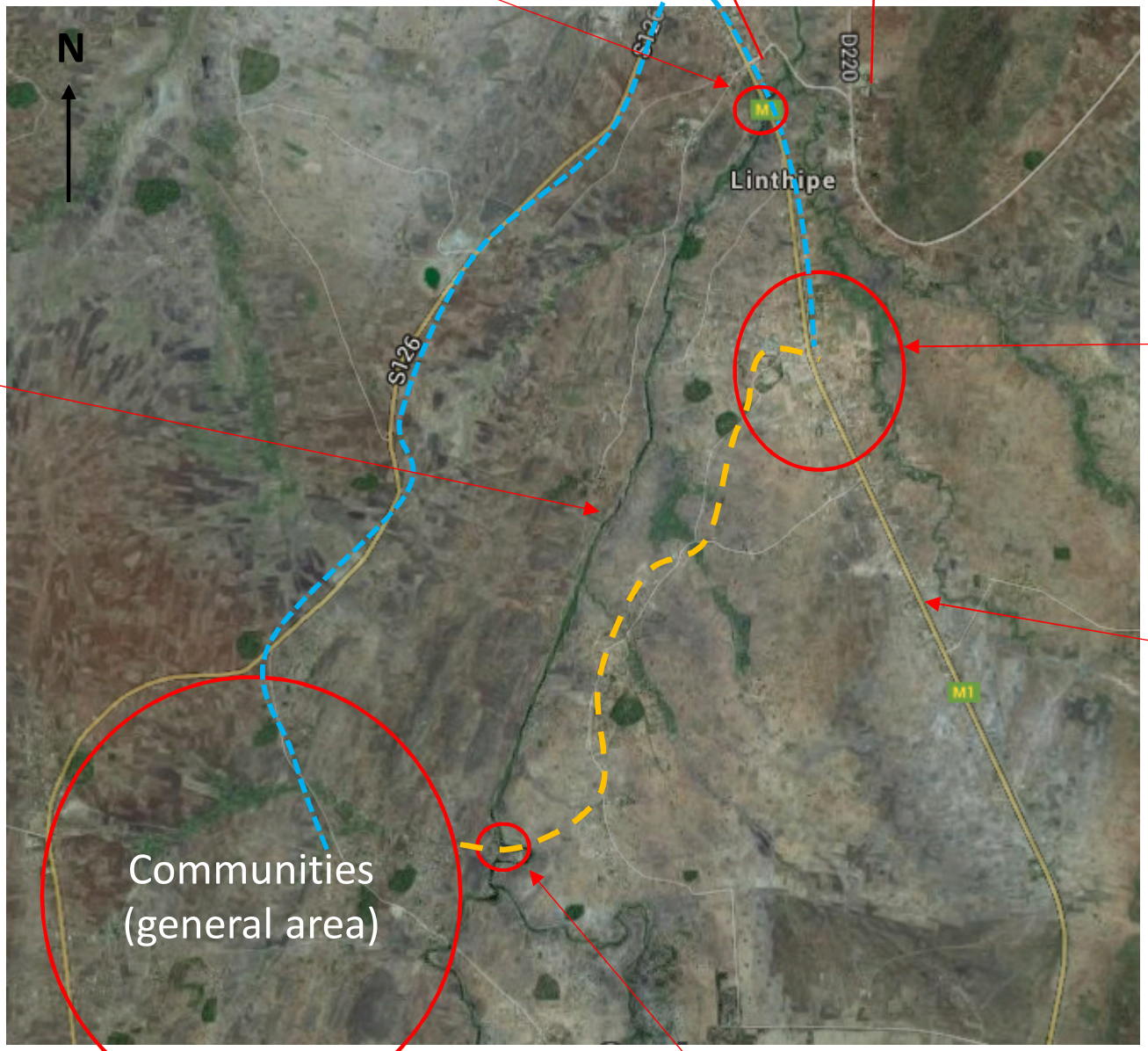
In order to fully assess the feasibility of building a footbridge, further technical information is likely to be required, including information on the soils and rocks, and a better understanding of river depth and flow volume during the rainy season. This information would need to be gathered during a longer visit to the site, and it would be beneficial for engineers to observe the river and tributary during the rainy season.

It is recommended that the community should compile further information to support their need for a crossing, which may also be used in seeking funding. This should include:

- A crossing count, to determine the number of people using the traditional crossing point each day. This should be carried out over a period of at least one week and should record the number of people crossing, the start and finish points of their journey, and the reason for their trip. It should also record bicycles, carts or animals being taken across the river.
- Photographs showing the river during the rainy season. These should be taken from both banks if possible (without putting the photographer at risk).
- Further information on the locations of the communities which would be served by the bridge, and their populations. This could be presented marked onto a map or a satellite image.

APPENDIX A
SATELLITE IMAGES

Figure A1: Area overview



Nearest alternative bridge

To Lilongwe

To hospital

Linthipe river

Linthipe 1 – market, police station, traditional court, schools

Main Lilongwe-Blantyre road (M1)

Preferred route to Lilongwe (c. 1.5 hrs)

Alternative route when river is high (c. 3 hrs)

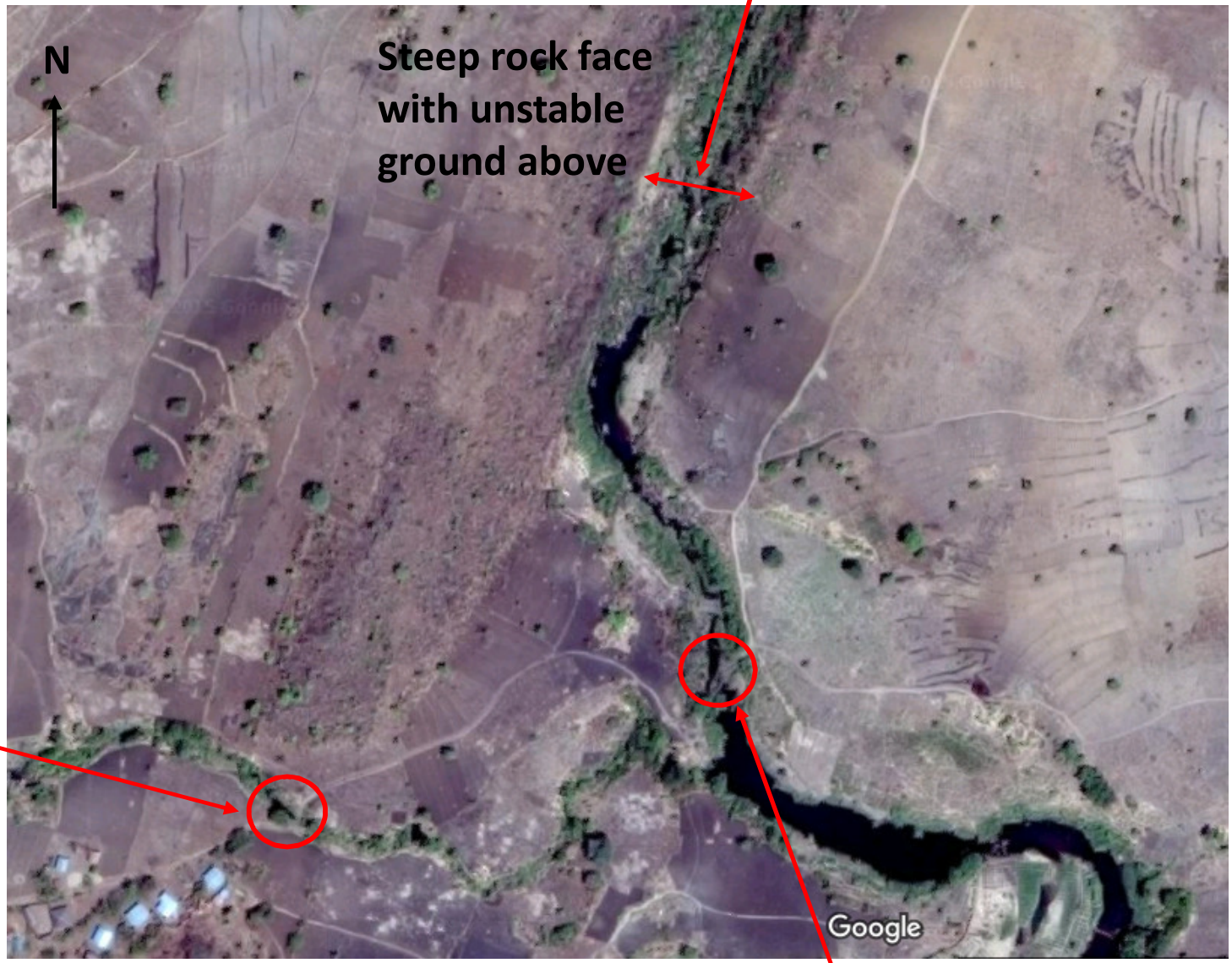
Communities (general area)

1 km

Traditional crossing point

Source: Google maps

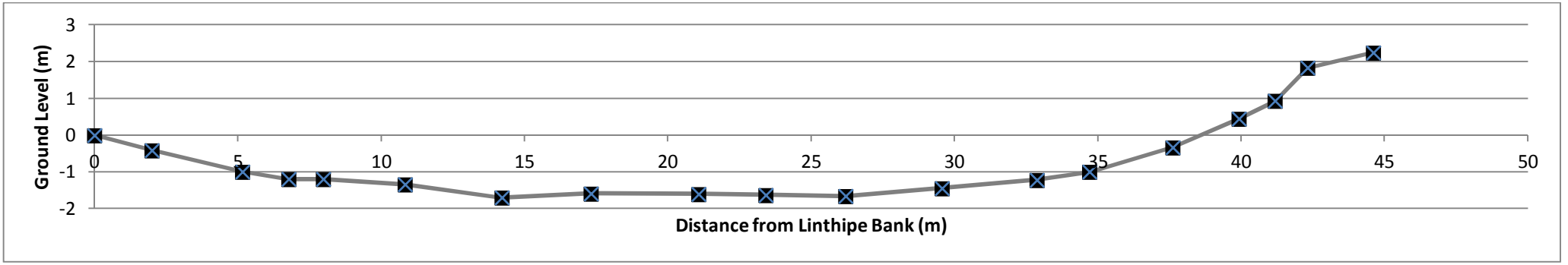
Figure A2: Site walkover detail



Source: Google maps

APPENDIX B
LEVEL SURVEY RESULTS

Indicative only as taken from a rudimentary survey – not to be relied upon for design



1 Elevation of existing crossing at River Linthipe, with east bank on the LHS and the west bank on the RHS. Levels are an approximation from a crude level survey.