Rural road crossings:

A vehicle for water investment

in drylands.

Transport plays an essential role in countries' economic growth, competitiveness, balanced and liveable spatial development, access to water and energy, and food security; it is also critical for social inclusion and improved quality of life. Ensuring adequate and better targeted funding and innovative financing for sustainable transport will be critical to deliver on this potential.

United Nations Secretary General
High-Level Advisory Group on Sustainable Transport
Addis Ababa, July 2015.

What's the big idea?

Incorporating the principles of sand dam technology with low volume road crossing designs will deliver a more robust and cost-effective rural roads infrastructure.

Sand dam road crossings will:

- Minimise costs of repair and reconstruction.
- Improve reliable access to markets and services.
- Reduce local flooding and erosion.
- Recharge groundwater.
- Supply millions of litres of safe water for multiple use.
- Contribute to climate change resilience.

What's the problem?

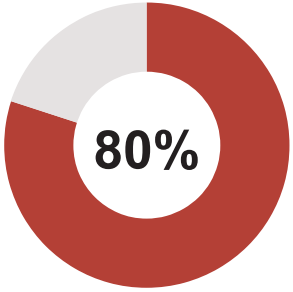
80% of damage to unpaved roads is caused by water. In rural drylands, the prevailing practice is to channel rainwater through low volume culvert bridges. Yet culverts in drylands are inherently flawed, because they cannot cope with the peak floods associated with intense and highly variable seasonal rains. As a result they are regularly damaged, causing local flooding, water logging and erosion. This results in high maintenance, repair and replacement costs for the managing authority, and diminished access to important markets and services for rural communities.

Poor rural roads infrastructure is directly linked to poverty. It isolates rural communities and increases the amount of time spent travelling for basic human essentials, such as water and fuel. This burden falls particularly heavily on women and people for whom access to water is already severely limited. 1 billion people are living in rural areas totally disconnected from basic services and markets.

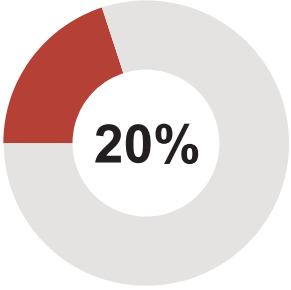
Across Asia and Africa, 80% of the road network consists of rural roads. In Africa alone, there are 5.5 million kilometres of rural roads, with an estimated 200,000 – 300,000 low volume road crossings. The annual investment in this sector is $1-2 trillion per year, less than 40% of which is spent in developing countries where water stress and physical isolation is often the greatest. Despite up to 80% of public works' budgets in developing countries being spent on emergency roads repairs and reconstruction, many rural roads are still in need of repair.

Given the financial constraints many low-income countries operate under, there is a pressing need to design rural roads, and especially road crossings, that are less prone to flood damage, require less routine maintenance and support the realisation of water development goals.

Global investment in roads required by 2030.



Of road budgets spent on roads maintenance.



Optimum percentage investment of road budgets on roads maintenance.

Culvert bridges don’t work in drylands.

Low volume culvert bridges are inherently unsuitable for dryland environments because they do not cope with the peak floods caused by variable seasonal rains. As a result, they suffer from three common problems:

1. They overflow and/or get blocked by debris in the river.
2. They cause flooding and/or wash away, reducing access for rural communities.
3. They widen or divert the river, causing erosion of nearby land.

A blocked and damaged culvert bridge. Rajasthan, India.

What's the opportunity?

The principles of sand dam technology can be integrated with Low Volume Rural Road (LVRR) crossings for a similar initial investment to traditional culvert bridges. However, the significant reduction in continual maintenance, repair and replacement costs, as well as the groundwater recharge function, makes them a much more cost-effective long-term solution. In Makueni County, Kenya, road drifts are already being implemented by the rural roads authority as an improvement on the ubiquitous culvert designs.

Sand dam technology offers the opportunity to maximise the cost/benefit ratio of improved rural road crossings by capitalising on their rainwater harvesting potential.

By harvesting rainwater and slowing river flows, sand dam road crossings reduce the erosion associated with road flooding and provide a more robust, climate proof infrastructure. Sand dam road crossings can be built in many dryland regions, which make up 40% of the world's land surface, support 70% of the world's poor, and where the need for cost-effective and sustainable water management solutions is greatest.

In drylands, most LVRR crossings cross seasonal rivers and are therefore potential sites for sand dams. Because they are specifically designed to cope with the intense and variable rainfall associated with drylands, sand dam road crossings would increase year-round accessibility to markets and services for people in rural areas.

The volume of road building in drylands is enormous. Planning and designing rural road crossings with the principles of sand dam technology would enable the recharge and retention of groundwater on a major scale, creating a buffer against drought and climate variability, and providing improved access to water in water-scarce environments at no or little additional cost.

A 2005 study* on the contributing factors to poverty reduction in China during the previous 30 years demonstrated that, while the rapid development of major roads played an important role in economic growth, small rural feeder roads were even more critical, with a benefit/cost ratio about four times greater than major roads investment.

***International Food Policy Research Institute.**

A raised rural road drift built by the Kenya Rural Roads Authority acting as a sand dam and enabling nearby farming. Makueni County, Kenya.

Principles of sand dam technology.

Sand dam technology is inherently suitable for low volume rural road crossings in drylands because it is designed to cope with intense, highly variable seasonal river flows, while at the same time storing a large amount of safe, abstractable groundwater.

There are three prerequisites to building sand dams:

1. They must be built in a seasonal river.
2. The river must have a sufficient sandy sediment.
3. There must be accessible bedrock in the riverbed.

There are two guiding principles of sand dam design:

1. They must be built on bedrock at least 1.5 metres wider than the flood width of the river. This prevents water seepage that would undermine the dam's foundation and/or divert the course of the river.

2. They must enable the river to follow its previous course. This minimises the risk of flooding and erosion of adjacent land.If built in a location with a sufficient sandy sediment, sand dam road crossings provide up to 50m^3 per day of safe water for rural communities.

Makueni County, Kenya:

A case study.

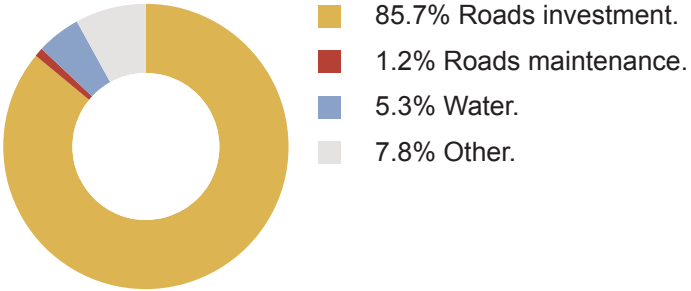
Makueni County, south east Kenya, is typical of many rural drylands in that poor physical access and water availability are two of the most important constraints to development. In such conditions, sand dam road crossings present the opportunity to improve connectivity to markets and services and increase access to water at no additional cost to current capital roads investment.

In Makueni there are 7,640 km of unpaved rural roads with 483 culvert bridges, costing an estimated $12.4M to build. The International Labour Office (ILO) recommends a 6% investment of budget to maintain rural road crossings. Yet, the total maintenance budget for Makueni County is just $1.1M, which falls short of the ILO target. This is reflected in the fact that, despite 85.7% of the county development plan budget being spent on roads, 25% of road crossings are currently in need of reconstruction after being washed away and 75% are in need of routine maintenance.

Either an increase in investment is required to maintain the infrastructure, or a more cost-effective solution is required to satisfy the budget limitations. The Kenya Rural Roads Authority has already identified the inherent flaws of culvert bridges and is beginning to move away from this design.

To date they have built over 60 drifts, which provide a more robust road crossing than culvert bridges and in some cases act as sand dams. However, the opportunity remains to maiximise the cost/benefit and rainwater harvesting potential presented by integrating the principles of sand dam technology.

Makueni County Development Plan Budget 2002-2008.



A cost/benefit estimation.

Based on detailed data from the Kenya Rural Roads Authority in Makueni County, and known assumptions about drylands infrastructure and populations, we estimate that the benefits of integrating sand dam technology with rural road crossings in the world's drylands would be enormous. In dryland Kenya alone there are 137,000 kilometres of rural roads with an estimated 8,700 road crossings.

The cost of maintaining a 100% operational infrastructure is $23M per year – 10% of the capital investment cost. Replacing culvert bridges with sand dam road crossings could reduce this cost to $3M per year – a $20M annual saving. If this was scaled up across Africa's drylands, savings could reach $354M. An additional $528M could be saved if it was implemented in Asia, giving an estimated total global saving of $882M per year.

Key assumptions:

1. Kilometres of roads in drylands based on percentage drylands land cover (UNSO/ENDP, 1997).
2. Number of road crossings based on Makueni County, Kenya average per kilometre.
3. Culvert bridge capital investment costs based on Makueni County, Kenya actuals.
4. Culvert bridge maintenance, repair and replacement costs are derived from actual costs in Makueni County, Kenya.
5. Sand dam road crossings maintenance and repair costs are assumed to be the same as the actuals for culvert bridges in Makueni County, Kenya.
6. Asia excludes South East Asia and East Asia (but includes China and Mongolia).
7. Water supply per person per year is based on a conservative estimated average of 2,750m^3 per sand dam.
8. Based on dryland soil type maps (FAO 2004), 65% of road crossings would be sand dams instead of check dams.
9. Based on dryland populations of 34% in Kenya, 41% in Africa and 42% in Asia (UN, 2012).

Drylands stats	**Kenya**	**Africa**	**Asia [6]**	**Total**
Population [9]	15M	455M	1.4B	1.9B
Number of road crossings [1,2]	8,685	156,459	233,394	398,853
Culvert bridge costs				
Current capital investment costs [3]	$223M	$4B	$6B	$10B
Annual maintenance costs required [4]	$23M	$403M	$608M	$1B
Benefits of sand dam roads crossings replaced				
Water supplied annually [8]	15.5M m^3	280M m^3	417M m^3	697M m^3
Amount of water supplied per person per year [7]	1,029 litres	614 litres	292 litres	370 litres
Annual operations & maintenance cost saving [5]	**$20M**	**$528M**	**$354M**	**$882M**

Well managed rural roads are vital for economic development, environmental sustainability and social inclusion. Yet, 31% of the world's rural population remain isolated from markets and basic services.

Sand dams are the most cost-effective method of rainwater harvesting in drylands. They have almost no maintenance costs and can last over 100 years.

A sand dam road crossing in Makueni County, Kenya, which provides 50m^3 water per day, supplying 10 village kiosks, three secondary schools, three primary schools and a health centre.

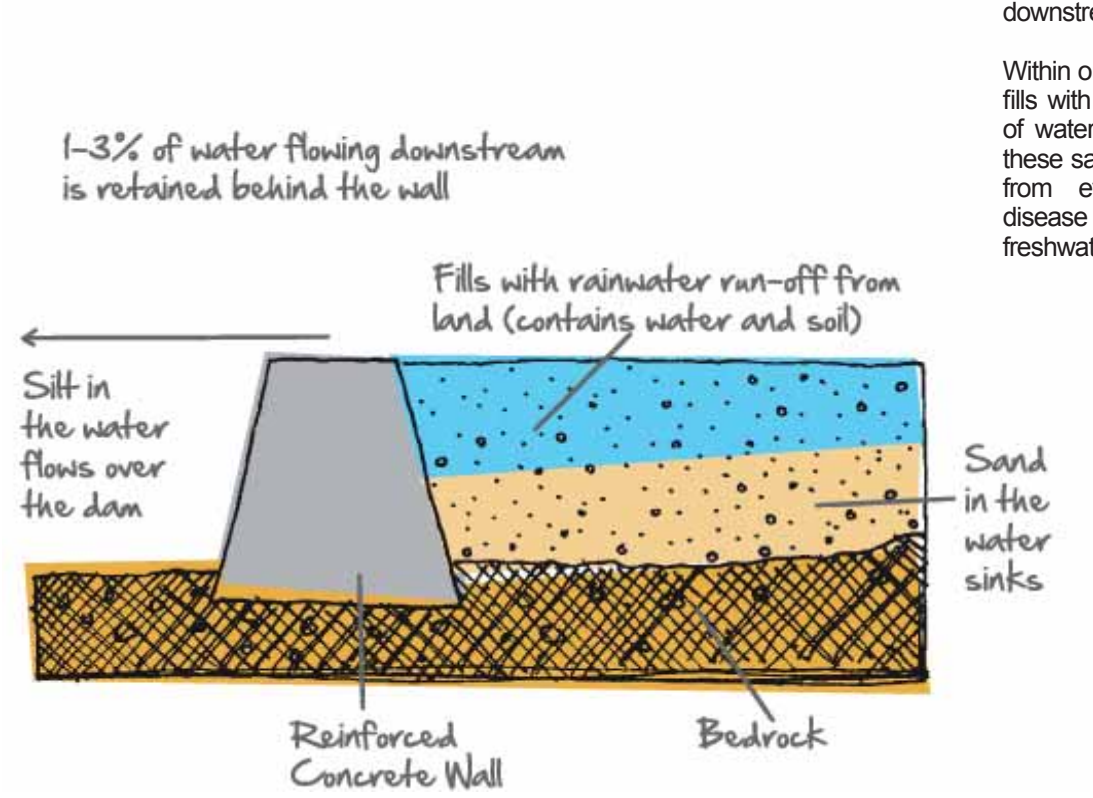
The water benefit.

Sand dams provide a year-round water source in water-scarce environments. This saves time – up to 12 hours a day – for women and girls to invest in other activities, such as agriculture or going to school.

By recharging groundwater they create a buffer against drought and enable dry season small-scale irrigation of vegetable and tree nurseries, as well as providing a vital water source for livestock and wildlife.

In addition, growth of vegetation along riverbanks increases, which stabilises the banks and allows for greater absorption of rainwater into the soil. Normalised Difference Vegetation index (NDVI) studies demonstrate that areas with sand dams sustain vegetation much further into the dry season than those without.

How sand dams work.



Seasonal rains fill the dam with sediment-laden water. The heavy sand is deposited behind the dam, while the light silt is carried downstream. 97-99% of the water flowing in the river continues downstream for use by downstream users.

Within one to four rainy seasons, the dam fills with sand. But, up to 40 million litres of water is stored in the pores between these sand particles, where it is protected from evaporation, contamination and disease vectors, such as mosquitoes and freshwater snails.

A sand dam chain in Kitandi village.
Makueni County, Kenya.

Sand dams store up to 40 million litres of safe, abstractable water for year-round use by people, livestock and wildlife.

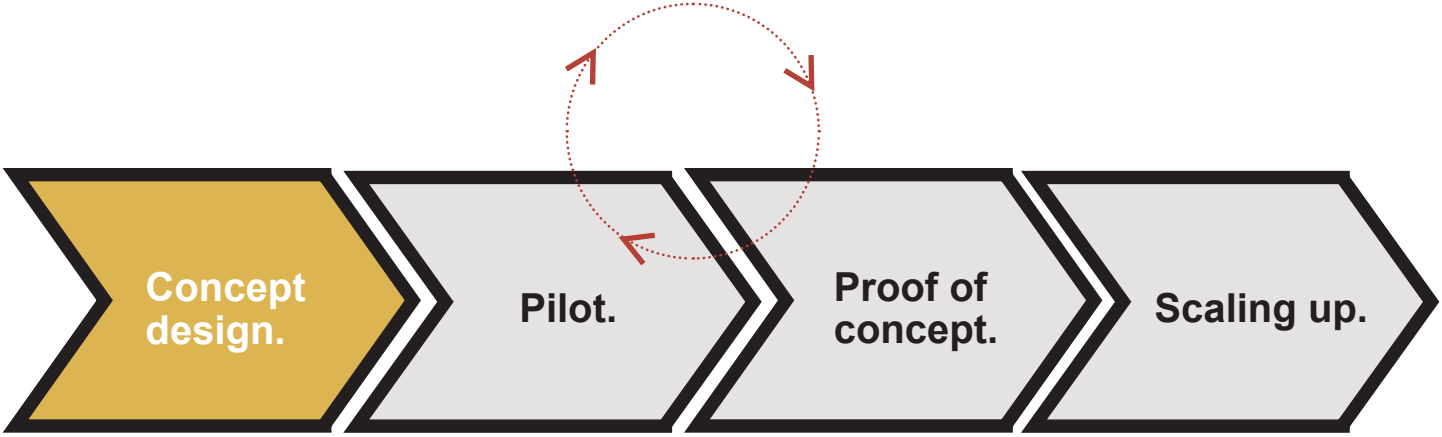
Water abstraction.

There is a long tradition of digging scoop holes to collect water from sandy riverbeds in drylands. Water can be abstracted from sand dams in this traditional way. Or, infiltration galleries can be built into the dam during construction to supply taps, pumps or animal water troughs.

An infiltration gallery is a horizontal perforated pipe built behind the dam wall. The pipe is surrounded by gravel to filter out any large particles. Increasing the number of infiltration galleries increases the water yield from each dam.

A large sand dam road crossings would supply year-round water for domestic and livestock use or the irrigation of small to medium-sized farms.

The route to scale.



Concept design outputs achieved.

Proof of sand dam technology:
848 sand dams have been constructed, enabling improved access to safe water for 838,571 people in rural drylands.

Initial concept testing:
Over 60 sand dam-like drifts have been built by the Kenya Rural Roads Authority in Makueni County, Kenya.

Pilot outputs needed.

- A range of pilot designs tested.
- Designs tested in a range of contexts.
- Evaluation of designs.

Proof of concept outputs needed.

- Standardised designs and decision matrices.
- Cost/benefit analyses:
    - Capital investment.
    - Five-year life costs (maintenance and repair).
- Opportunity cost (lost and gained).
- Additional benefits:
    - Groundwater recharge.
    - Vegetation regrowth.
    - Climate change resilience.
    - Disaster risk reduction.
- Environmental impact assessments.
- Road access assessments.
- Road safety assessments.
- Social impact assessments.

Scaling up requirements.

- Finalised designs.
- Training manuals.
- Mechanism for government engagement.
- Mechanism for investment funding.

About us.

Excellent Development is a UK based not for profit organisation that specialises in drylands rainwater harvesting.

We enable dryland communities, NGOs, institutions and governments to implement sand dams for the benefit of some of the world's poorest people.

In 13 years, we have enabled the construction of 848 sand dams in 10 countries, bringing safe water close to home for 838,571 people.

Excellent Development is accredited by the UN Convention to Combat Desertification and the UN Framework Convention on Climate Change, as well as being the only UK NGO member of the World Water Council.

Excellent | Pioneers of Sand Dams

Contact us.

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A large road bridge crossing a seasonal sandy river.
Namibia.

Another opportunity.

For large paved road crossings, where the cost of building big bridges is justified, design standards could be modified to integrate large sand dams. The potential for rainwater harvesting would be enormous, with only a small percentage increase required in overall infrastructure investment.

Because the sand dams would be integrated with major and rural roads networks, they would enable adjacent farming and easy access to sell surplus harvests at markets.

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