# ROAD-SIDE BORROW PITS AS PONDS FOR OFF-SEASON SMALL-SCALE IRRIGATION

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## Background

AFRHINET was a three-year project which focused on fostering the knowledge and use of rainwater harvesting technologies for off-season small-scale irrigation in rural arid and semi-arid areas of sub-Saharan Africa. As part of this project, best practices on collecting and storing rainwater for off-season small-scale irrigation have been documented and evaluated.

This case study discusses the systematic conversion of borrow pits as rainwater harvesting ponds for off-season small-scale irrigation. The overall goal of this case study is to contribute to the replication and scaling up of borrow pits for off-season small-scale irrigation in arid and semi-arid areas. The technical sheet has been developed in cooperation with the Roads for Water Learning Alliance (http://roadsforwater.org/) and the Flood-Based Livelihoods Network Foundation (http://spate-irrigation.org/).

## The technology

Borrow pits provide the source material for the construction of road embankments, which depending on the local area are: gravel/aggregates, silica sands, laterite sands and calcite. Borrow pits can become major assets in local water security. Thus, as soon as the pits are no longer used for the mining of building materials, the excavated structure can become an important and valuable water supply source. More specifically for rainwater harvesting irrigation management, rather than backfilling the pits or leaving them unattended, borrow pits can be systematically converted into sources of off-season small-scale irrigation.

**Figure 1:** Road-side water harvesting in a borrow pit in Ethiopia. Photo: MetaMeta.

During wet periods, borrow pits can store rainwater and runoff from roads, and/or act as a recharge pond everywhere. In addition, in areas with high levels of shallow groundwater, borrow pits may also serve as a seepage pond, which are constantly recharged with seeping shallow groundwater from adjacent areas. Either way, borrow pits may serve as source of stock water, irrigation, fishery and with proper treatment even drinking water.

However, borrow pits for rainwater harvesting and off-season small-scale irrigation are currently used without planning. As a result of this, some borrow pits are unsafe and/or not reusable and/or sources of contaminated water. Due to this, there is a need to systematically approach the ‘second life’ of borrow pits as roadwater harvesting ponds for off-season small-scale irrigation. This requires to look at the following 4 factors:

1. Siting of borrow pits.
2. Shaping of borrow pits.
3. Special protection measures.
4. Management of borrow pits.

**Box 1: Two types of borrow pits**

There are two types of converted borrow pits. Different considerations apply as to the siting and shaping of these two types of borrow pits.

**(1) Borrow pits in dry areas**
These are supplied by run-off water, including water from road drainage. They serve to store surface water and/or act as a source of recharge of groundwater. This depends on the soil formation, where the borrow pit can contain water or whether water percolates, preferably to usable groundwater source, depending on the local hydrogeology. The period that the converted borrow pit stores water in the dry season depends on many factors, such as the size and depth of the pond (if the pond is deeper less water is lost to evaporation), the permeability of the bed material (determining how much water seeps away) and the surrounding measures (tree planting for instance around a borrow pit may reduce the evaporative effect of wind). Several of these factors can be made part of the design of a borrow pit – in particular depth. The preferred depth of a borrow put is seven meter – as this still allows lifting with centrifugal pumps but also reduce evaporation. The borrow pits may be filled several times a year, depending on the rainfall.

**Figure 2:** Borrow pit collecting and storing surface runoff in Tigray region, Ethiopia. Photo: MetaMeta.

**(2) Borrow pits in areas with high shallow groundwater tables, such as in flood plains**
In such areas the borrow pit is filled with the surrounding shallow groundwater and depending on the area may provide a (nearly) perennial source of water. The depth of the borrow pits is less critical but should be within the level where groundwater is available even in the driest period. The location of such borrow pits usually best on the river side of the road as these have the most reliable supply of seepage water.

**Figure 3:** A borrow pit filled with seepage from high shallow groundwater in South Sudan. Photo: MetaMeta.

**1. Siting of borrow pits**

The siting of borrow pits is guided by the availability of source material for road construction, the proximity to the road and the arrangements for acquiring the borrow sites. Yet when there is choice a number of considerations should be applied:

a) Borrow pits (for conversion) should be close to areas where people reside or where there is interest in irrigation. Care should be taken to balance different possible uses. In some pastoralist areas there is for instance concern that the converted barrow puts may invite the inflow of non-pastoralists. In pastoralist areas in general it is useful to plan the location of water resources taking into account the grazing resources.

b) There is a choice to be made – to either have one relatively large borrow pit or to have several smaller ones. The choice for more but smaller borrow pits is often preferable in areas with dense population as it will create more local storage at shorter distance. A larger borrow pit may be a secure source of irrigation, water particularly if combined with

c) In general, it is important to position the borrow pits in the direction of the available water. The preferably location of a borrow pits in dry area is often downslope of the road. This has a number of reasons:

- Downslope of the road the borrow pit may be supplied by run-off from culverts and other road drainage. Upslope there are less opportunities to direct flows into the borrow pits from the road drain. In some dry areas however water impeded from a highway road embankment may be guided to an uproad storage pond, such as a converted borrow pit.

- There is usually more and flatter land for productive use on the downslope side of a road. Also, if the borrow pit is located downslope of the road, there is less risk of human and cattle crossing the road to the drinking pond as the downslope area of a road tends to be quite large with cattle straying away from the road.

- If a borrow pit is supplied by seepage flows in area with high groundwater tables, for instance in flood plains, then the location on the riverside of the roads is in many case best as much of the water is supplied from this side and groundwater tables tend to be more secure. It is however always useful to investigate and consult the local population on the reliable availability of groundwater.

**2. Size and shape of borrow pits**

Size and shape of the borrow pits is important. Size and shape is partly ruled by the availability of material for excavation. When primarily used for the sourcing of the construction material shapes of borrow pits are often very irregular and unshapely.

The ideal shape of a borrow pit that is reused for water supply is:

a) **Properly landscaped:** Avoiding potentially dangerous heaps and sides and ensuring stable slopes (see box 2).
b) **Convex shape:** Convex shape is preferred for water storage ponds as generally they create maximum storage compared to the efforts of excavation and because they are inherently more stable than ponds with odd and square angles.
c) **Adequate depth:** Particularly where borrow pits are not constantly recharged from shallow groundwater seepage, but depend on surface run-off, depth is an important consideration. This is particularly relevant in dry and hot periods when evaporation from the borrow pits is high. The deeper the borrow pit the less loss to the evaporation. A depth of 7 meters or more is often preferred.
d) **Access ramp:** The borrow pit will be used by different water users and the shape of the borrow pit ideally should facilitate access to the water source. Access may be for human or for trucks to allow these to get near. There may also be special ramps to place small pumps to lift the water out of the borrow pit. In general it is not good practice however if livestock directly enters a converted borrow pit, as this will contaminate the water source. This can be prevented by special water troughs for livestock or sub-ponds and fences or trenches to prevent the livestock is in direct contact with the water.
e) **Room for spill way facility, if necessary and especially in sloping terrain:** As borrow pits collect water, they may also spill over the water once they are filled in, for instance after heavy rain storm. Particularly for large borrow pits in sloping areas the overspill from a borrow pit can be dangerous with breakage of the pond and unleashing of floods. In that case a spillway that can release excess water to a natural drain is important to consider in the layout of the borrow pit.

With regard to the size of the borrow pit, It is very important to give the pond the right dimensions. The size of the borrow pit and its usage are closely related. Borrow pits are meant as a source of water supply often where there is no alternative and so usage of the borrow pit. The pond should provide ideally provide enough water to carry over a large part of the dry period. In some areas, the pit may fill several times in a year. In addition, where the borrow pit primarily serves to recharge groundwater, the size should be big enough to accommodate a large part of the run-off (with some escaping from a spill ways or from overflow structures in the feeder canal). This expected run-off can be calculated for instance with the simplified rational method.

**Box 2: Slope of the converted borrow pit**

The preferred slope of the converted borrow pit pond strongly depends on the type of the soil. As a thumb rule the next values can be used:

- Clay 1:1 - 1:2
- Cay loam 1:5 - 2:1
- Sandy loam 2:1 - 2.5:1
- Sandy 3:1

The average slope of the pond can be calculated with the following calculation:

$$Y = \frac{100CI}{A}$$

Wherein

| | |
|---|---|
| Y = The average slope | % |
| C = The total contour length | cm |
| I = The contour interval | cm |
| A = Drainage area | $cm^2$ |

**Box 3: Calculating the size of the pond: the supply factor**

Generally the storage capacity of a pond is 0.4 times its maximum water depth. To calculate the exact capacity there are a number of things that should be taken in mind. First of all the supply of water is an important factor. To know the supply you should calculate the average rainfall of at least the last eight years. Rank the rainfall data on terms of months with high rainfall. Select the type and also determine the size of the catchment that will be available. When this information is collected the demand of runoff can be calculated with the following calculation:

$$Y = 10K \times R \times A$$

Wherein

| | |
|---|---|
| Y = Annual runoff | $m^3$ |
| K = Runoff coefficient | - |
| R = Annual Rainfall | mm |
| A = Catchment area | ha |

With this information the demand of water can be calculated with the following calculation:
We= Wb + Wr + Wh - Wet - Wd - Wf

Wherein:

| | | |
|---|---|---|
| We = | Total depth of water in the effective depth. of root zone at the end of a selected period. | m |
| Wb = | Total depth of water at the beginning of the period | m |
| Wr = | Total depth of rainfall during the period. | m |
| Wh = | Total depth of water harvesting during the period. | m |
| Wet = | Total depth of evapotranspiration losses during the period. | m |
| Wd = | Total depth of deep percolation losses below the effective rooting depth of the crop. | m |
| Wf = | Total equivalent depth of surface runoff out of the cropping area. | - |

With this information the cumulative inflow and outflow can be calculated. After that subtract the smallest negative difference from the largest positive difference. The maximum difference between the highest value and subsequent lowest value of the accumulated difference in the required storage volume. Volume of water to be lost through evaporation +10% to adjust some unforeseen water losses.

## 3. Protection measures

### 3.1 Siltation and seepage

The lifetime of a borrow pit converted into a water storage may be severely curtailed if the borrow pit is filled with high sediment water flows. To avoid these, a number of measures are recommended:

- Have borrow pits in areas with protected watersheds and reduced silt contents of the run-off feeding the borrow pit. This may however often not possible – but in the location of borrow pits that status of the catchment may be a consideration.
- Take measure to trap sediments before they reach the converted borrow pits – in particular having sediment traps or using vegetative measures.
- Ensure the sediment traps and vegetative measures are maintained. In particular in sediment traps this is a practice that needs to be arranged as by their nature and function they fill quickly. The sediment is sand traps sometimes also represent a value as building material or agricultural soil and may be harvested and sold as such.

Another important factor is that much of the water in the pond may disappear because of seepage. In areas with fine sediment this effect may disappear over time as fine material seals the bottom of the pond. This is also an additional argument to control the filling of the pond with course sediment, as described below. Other low-cost measures recommended to reduce seepage from ponds are:

- Compacting the bottom of the pond.
- Clay lining or lining with thermite soil – provided either material is available nearby.
- Treatment with table salt.

### 3.2 Safety of the borrow pit

Several measures should be taken to safeguard the safety of a borrow pit. As it is an open surface body there are two dangers. First, the water may be easily contaminated and also become a source for mosquito breeding. Persons, especially children, but also animals may fall in the borrow pit. In order to improve the safety of the borrow pit a number of measures may be taken, in close cooperation with the group of people that manage the borrow pit:

- Fencing: The borrow pit may be fenced – either by vegetative material or by excavating trenches. This reduced the risk of people or animals straying into the storage pond. Tree fencing may contribute to reduced evaporation triggered from rains.
- Reducing incidence of mosquito: Mosquito infestation of ponds is often caused by standing water bodies. This is one reason to actively managed and use the water pond so that there is much movement of water. The risk of mosquito infestation can further be reduced by having tilapia fish in the pond or having the pond covered with a thin layer of non-harmful algae – which also help reduce evaporation. Also the management of vegetation around the borrow pit and the removal of small water filled depressions can reduce the malaria breeding places.
- In some areas there is no source of water but the borrow pit: Yet borrow pits by virtue of being open surface water bodies do not provide safe water for human consumption. This may be overcome by placing a hand pump and sand filter on the borrow pit or by household treatment of the water.

**4. Management of borrow pits**
As borrow pits often are opportunistically used for water storage, they are at the same time not well managed. This needs to be regulated however. Management of borrow pits is important to:

- Regulate who is using the borrow pit, particularly in times of scarcity.
- Balancing different uses (irrigation and others) avoiding contamination that make the water unfit for usage by other users.
- Undertake basic maintenance and protection – such as protecting vegetation and cleaning of sand traps or removing silts from the borrow pits (see also above).

One of the first things to regulate is the future ownership of the borrow pits cum storage facility. The land of the borrow pits may have been privately owned before the development of the borrow pit. It is important that ownership of the borrow pit is clarified and that the original land owner is compensated. In addition, the other important arrangement is to have a local committee or local government to look after the water source – taking care of access, protection and maintenance. There can be several arrangements for this:

- Charging for use.
- Dividing the work for maintenance with different users taking care of section of the pond.
- A combination of both.

Maintenance of borrow pits will also benefit from small mechanization or the use of draft animals using scrapers. Particularly the so-called Fresno scraper that is operated by draft animals and has a tipping facility is recommended for local maintenance. In addition, as much as possible such committee should not be ad hoc, but linked to legitimate local government.

## Efficient water use

The water stored in a pond is always relatively limited – and hence it is important to combine it with the use of water saving measures – so as to stretch the use of the limited volume of water and to get 'sufficient crop per drop' and not be faced with a water shortage before the end of the season.

**Figure 4:** Vegetable cultivation from a borrow pit in South Sudan. Photo: MetaMeta.

There are two main complementary strategies:

1. Having a cropping plan that is line with the limited water availability: Using crops with low water requirement or crops that respond well to water saving measures and are still profitable.
2. Use a broad range of water saving measures (Table 1): Improved field irrigation techniques generally save water but they also introduce precision farming. With this higher yields can be achieved and better more uniform product quality. Many water saving measures also make it possible to be more prudent in the use of other farm inputs. Box 3 gives the overview including impact on access to farming for women and additional job opportunities created.

**Table 1**: Innovative complementary technologies to enhance off-season small-scale irrigation. Source: [http://afrhinet.eu/materials/viewcategory/65-regional-best-practices.html](http://afrhinet.eu/materials/viewcategory/65-regional-best-practices.html).

| Technology | Description | Yields | Water saving | Reduced inputs | Product quality | Security | Employment |
|---|---|---|---|---|---|---|---|
| Low-cost water storage ponds by animal-driven excavation | Animal-driven dozers can accelerate the development of storage ponds in a variety of settings: The most appropriate is the Fresno scraper that has a tipping bucket and gliders. | x | x | | | x | x |
| Water storage with sealing agents | Sealing agents have been developed to make impervious and weather-proof low volume roads. The same technology can be used as a sealing agent for water ponds. This is an alternative to clay or geotextile. | x | x | | | x | |
| Hydroponics in greenhouses | Affordable greenhouses and hydroponics with specialist nutrient supply. The greenhouses have self-regulating temperature control and safe up to 80% of power and water, whereas the nutritious value of the grown products is up to 140% of the commonly grown crops. | x | x | | x | | |
| Biodegradable plastic mulch | Plastic films can come in different colours (transparent, black, white) to control soil moisture evaporation, soil temperature and suppress weed growth. | x | | | | | |
| Reel farming | Strips with nutrients and plant seeds to be introduced for school farming and homestead farming. | x | x | | | | |
| Compost | Different types of compost to improve soil structure, water holding capacity and increase nutrient availability. | x | x | x | | | |
| Vermicomposting | With the use of earth worms, organic waste materials can be converted in high quality compost that improves fertility and moisture holding capacity. | x | x | x | | | |
| Sanitation link | Reuse of human manure and struvite in agriculture. | | | x | | | |
| Bokashi | Biofertilizer with good water holding capacities can add micronutrients. | x | | x | x | | x |
| Rock dust biofertilizer | Biofertilzier mixed with rock dust or zeolite increases the supply of micronutrients and fertiliser, and (though modestly) moisture holding capacity. | | | x | x | | x |
| Tal-ya dew plates | Plates made of a special plastic that concentrates runoff and causes dew formation (in altitude areas) and suppresses the growth of weeds. | x | x | | | | |
| Water pads | Combination of water absorbing polymers with layers of jute and paper that creates a localised water buffer for plants, increasing chance of survival of young trees and plants. | x | x | | | x | |
| Groasis waterboxx | Water storage and dew collection device especially for water-stressed areas. | | | | | x | |
| Buried diffuser | Pressure system to be connected to a drip system in order to bring water into the root zone. | | x | x | | | |
| Subsurface irrigation | Root zone irrigation though buried drip lines. | x | x | | | x | |
| Lay flat hoses | Polyethylene hoses connected to groundwater systems to reduce conveyance losses and increase extra head. | | x | | | x | |
| Mulchers and harrowers | Different techniques to improve the water absorption capacity of soil, regulating soil temperature and soil evaporation. | x | x | | | x | |

Publisher Hamburg University of Applied Sciences, Hamburg, Germany. Financed by the ACP-EU Cooperation Programme in Science and Technology (ACP-S&T II). A programme implemented by the ACP Group of States, with the financial assistance of the European Union.

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May 2017.

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**Partnership** The AFRHINET consortium comprises of 8 organisations located in Ethiopia, Kenya, Mozambique, Zimbabwe and Germany. The contents of this technical sheet have been developed in cooperation with the Roads for Water Learning Alliance and the Flood-Based Livelihoods Network Foundation (MetaMeta, the Netherlands).

| Ethiopia | Ethiopia | Kenya | Kenya | Mozambique | Zimbabwe | Zimbabwe | The Netherlands |
|---|---|---|---|---|---|---|---|
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Implemented by the ACP Group of States

Funded by the European Union

The AFRHINET Project is funded by ACP-EU Cooperation Programme in Science and Technology (ACP-S&T II).A programme of the ACP Group of States, with the financial assistance of the European Union.