Underground dams: a practical solution for the water needs of small communities in semi-arid regions

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Introduction

Locating of potable groundwater aquifers within areas underlain by crystalline basement rock is a difficult task. But in semi-arid regions where surface water is not always available it is an ongoing and necessary struggle. The underground dams of Northeastern Brazil offer an unique solution to this problem.

Underground dams (Fig. 1) are an ingenious Brazilian method for storing water during wet periods for dispersal during dry times. Essentially, they are similar to above ground dams except that their reservoirs are full of sand to prevent evaporative loss. Water is stored in the porosity of the sand and extracted when needed during dry periods.

Underground dams are constructed in alluvial valleys. A long trench is dug perpendicular to water flow direction within the alluvial sediment down to bedrock, or at least as deep as the available equipment will allow. The downstream wall and the bottom of the trench are lined with plastic and then the trench is backfilled with the alluvium. When it rains, intermittent streams and rivers that are naturally channelled into alluvial valleys percolate into the alluvium and this water gets trapped behind the subterranean dam preventing it from escaping downstream. If rainfall is sufficient the alluvium behind the dam will become saturated with groundwater to the surface and spill over. During dry weather the groundwater behind the dam remains because it is trapped by the plastic barrier and sheltered from evaporation by the alluvium. Water is extracted through a large diameter well emplaced a meter or so upstream of the dam. In some cases, salt extracting plants are grown in the alluvium immediately upstream of the dam. Regular removal of these plants helps prevent salinity from building up in the groundwater.

Underground dams are relatively easy to make and very cheap to construct. The cost of constructing the dam in Figure 1 is estimated to be R$1,500 – around Cnd$600 at 2002 currency exchange rates. Assuming a porosity of 30 to 35% for loose sandy alluvium, the stored water volume for a typical underground dam is around 2,000 cubic meters but can be much larger. In semi-arid regions, these volumes are a significant resource and can supplement the water supply of a small village or supplement

small scale agricultural irrigation to preserve important crops during periods of drought.

In Northeastern Brazil, notorious for droughts that can last years, the Geological Survey of Brazil (CPRM) estimates that perhaps 400 underground dams, similar to the one shown in Figure 1, have been constructed, and most of these are in the state of Pernambuco. What makes them especially attractive is that, outside of community water wells, underground dams are the most "ownable" technology for the poorer communities and require essentially no external resources and little external expertise to run or maintain. This reduces dependence on volatile political cycles and the goodwill of regional governments and makes the dams a very viable water management solution for the communities most impacted by drought.

Underground dam construction and long term considerations

Generally, these dams are very inexpensive to install and can be quite effective in providing stored water during periods of drought. However, in some cases, dams leak or they don't provide expected water volumes or the water quality is poor. These types of failures are probably largely preventable but clearly illustrate that there are important issues that need to be better understood before a large number of these dams can be sustainably placed within a given alluvial valley. For example, surface topography, alluvium thickness, and sediment type are often not strongly considered in dam site placement and construction at the local scale. This is not surprising as no guidelines exist to address these concerns and so it is left up to each community to try their own methods.

Regionally, there are perhaps more serious and long term concerns. For example, the interactions between two or more dams in the same alluvial valley have not been studied and essentially nothing is known about the extent of potential impacts from these interactions. In addition questions such as "How close can dams be without negatively interfering with each other?" and "How many dams can a watershed reasonably accommodate?" cannot currently be answered. Basic information required to effectively extract the water from the dams is also lacking and may lead to long term problems. For example, the rate of groundwater evaporation from the dams is not known. And there is currently no consideration or knowledge of how to best maintain an underground dam over short or long terms.

Maintenance mainly needs to deal with the major problem of salinization. Over several usage cycles salts build-up due to incremental evaporation. As mentioned above, salt extracting plants can help combat this problem if they are harvested and taken off site. In fact this is beneficial because they are fed to cattle that require the salt and so these plants also act as a source of nutrition. But the balance between the amount of salt the plants extract and the amount they introduce by increasing transpiration is unknown – they may not provide as much desalinization as is currently believed. Effective control of salinization will require a deeper understanding of its formation. Keeping water levels too near the surface of the alluvium, for example, may exacerbate long term salinization issues because of increased evaporation. Appropriate flushing protocols required to minimize salinization and ensure long term sustainability of the dams currently do not exist.

And so, although these dams are an ingeniously simple invention and have great potential to improve water supply and quality for drought stricken communities, maximizing their potential requires further study of their hydrogeology and hydrogeochemistry. These studies are required to ensure that effective solutions to the problems outlined above can be found and that useful criteria for the construction, operation and maintenance of underground dams can be developed at the community level.

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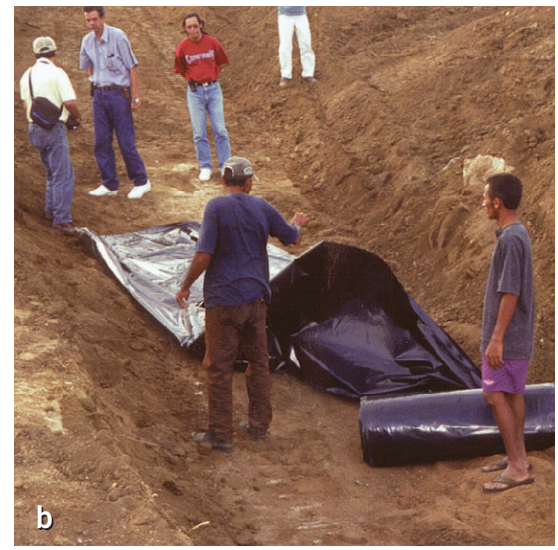

Figure 1: Construction of an underground dam;
(a) a trench perpendicular to flow in an alluvial valley is dug down to bedrock;
(b) the bottom and wall of the trench is lined with plastic;
(c) an extraction well is emplaced in the trench and then the trench is backfilled;
(d) salt extracting plants are grown in the alluvium immediately upstream of the dam to reduce salinity build-up – these are harvested and fed to cattle offsite.

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