Case Study Groundwater Dams

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See also the **Hydrogeology of Ethiopia** and **Hydrogeology of Kenya** pages.

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Contents

Summary

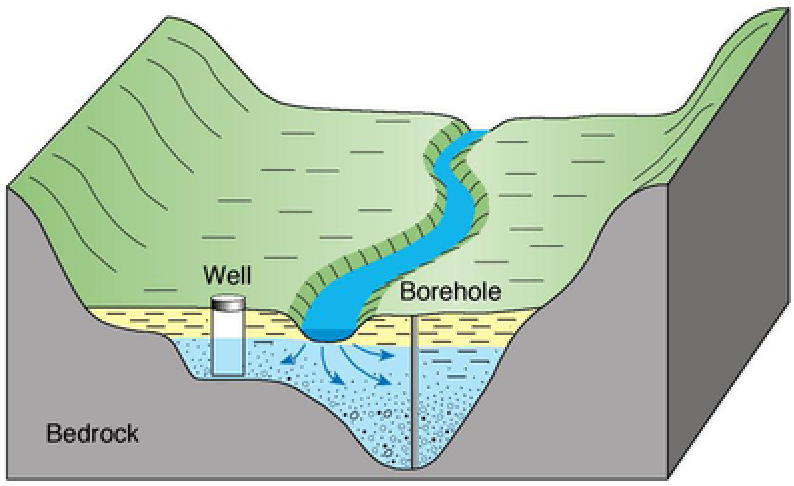
Storing water so that it can be used by people when and where they need it is a perennial problem. Storing surface water in tanks and reservoirs is a common solution, but has many disadvantages, especially in semiarid and arid climates: for example, water losses through evaporation; contamination from livestock and other polluting activities; and the fact that surface reservoirs take up large areas that could be used for other economically productive activities such as agriculture. Groundwater dams – also known as subsurface, underground or sometimes sand dams – are not new technologies, but in recent years have seen a resurgence of interest. Part of the reason for this is because of the potential for water user communities to be involved in their construction, ownership and management.

What is a groundwater dam?

Groundwater dams – also known as subsurface or underground dams, or in some cases sand dams – prevent or slow down the lateral flow of groundwater away from an area and store it below the surface so that it can be abstracted for use over longer periods.

Groundwater dams are constructed underground in aquifers – permeable rocks or sediments that can store and transmit groundwater. These aquifers usually store groundwater naturally, recharged from rainfall and sometimes from rivers flowing over them. Under natural circumstances, the groundwater recharged to the aquifers flows away over time, towards lower ground. Immediately after a rainy season, therefore, such aquifers can be full of groundwater, with a shallow water table; but as the dry season continues, the groundwater that people don't abstract naturally flows away and the water table falls, until eventually there may not be enough groundwater locally to meet people's needs. A groundwater dam stops this flow of groundwater so that it is kept in the area where people want to use it – just like a surface dam is used to create a surface water reservoir.

Groundwater dams are often built in river valleys, where permeable but narrow and shallow sand and gravel aquifers exist that are clearly bounded to each side and below by lower permeability bedrock. In this situation, it is relatively easy to construct a dam that crosses the whole aquifer and prevents groundwater leaving the dammed area.

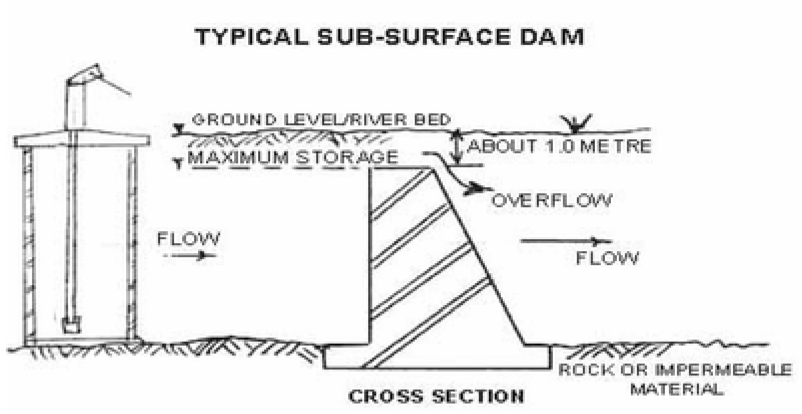


A schematic cross section of an alluvial aquifer in a river valley. Image credit: British Geological Survey

Constructing groundwater dams

Groundwater dams must be constructed in aquifers that have high enough storage and permeability to provide for the required use, and ideally that are laterally restricted (e.g. narrow) enough so that a dam can be built right across them. Hydrogeological testing of the aquifers may be needed to gather the data needed to decide where to construct a dam. Dams are also usually installed where the surface gradient is shallow, usually 2-4%.

At the downstream end of the aquifer to be dammed, a vertical cavity is dug into the ground, if possible down to the base of the aquifer – this could be an impermeable bed of clay below a gravel layer, or low permeability bedrock, below alluvial sands in a river valley.



Subsurface groundwater dam profile. Image credit: Onder and Yilmaz (2005)

A vertical impermeable wall is constructed in the cavity to form the dam. This wall can be made of clay, stone, brick or concrete, and may be covered with plastic sheeting or cement. Simple versions have been constructed with timber frames, which are then filled with impermeable materials including plastic, iron and clay, such as examples in Kenya.

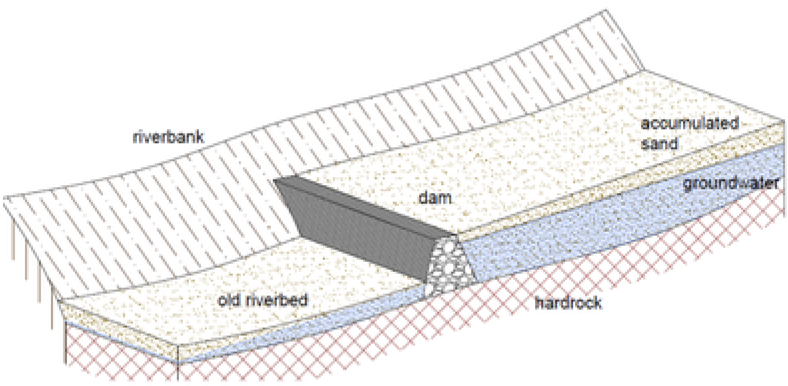

Constructing a groundwater dam in a sand aquifer. An impermeable wall will be built in this trench, preventing

groundwater from the upstream side from flowing away downstream as it would naturally do. Image credit: RAIN Foundation (2011)

A constructed sand dam in Tanzania. Here we can see only the top of the concrete dam, which extends below the surface. Image credit: The Mennonite Central Committee Sand Dam Project, Dodoma, Tanzania (2012)

Sand dams

’’Sand dams’’ is a term used generally to describe a particular type of groundwater dam constructed in sandy river beds, as described above. A slightly different type of ‘’’sand dam’’’ is where an impermeable dam is built in a river bed that doesn’t contain much permeable sediment, to trap sand when the river flow is high, and create an ‘artificial aquifer’. This artificial aquifer stores groundwater, also trapped behind the dam. A particularly effective method is to build the dam in stages: first a low wall designed to trap coarser sediment (gravels and coarse sand) that is more permeable, while allowing the lower permeability fine sand and silt carried in the river water to flow over the wall; this wall is then gradually raised to continue trapping only the most permeable sediment. This incremental method is, however, more expensive than building the whole wall on a single occasion.



Schematic cross section of a typical sand storage dam.
Image credit: RAIN Foundation (2011)

In practice, many groundwater dam schemes are hybrids of the above-ground sand dam and the below-ground groundwater dam. An existing permeable aquifer below the ground in a river valley is excavated until an impermeable layer is reached, and at the same time a wall is built to a certain height above ground level, to trap additional sediment and increase the volume of the aquifer, and therefore the amount of water that can be stored in it.

Abstracting groundwater from behind groundwater dams

Groundwater that accumulates in the aquifer behind the groundwater dam can be tapped using standard technologies. In aquifers away from active river valleys – where seasonal river flow will not damage them – permanent boreholes can be drilled or wells dug, and installed with suitable pumps to meet local conditions and requirements.

In river valley (alluvial) aquifers, where seasonal river flow means permanent surface structures can't be built in the valley, stored groundwater can be tapped by traditional means by digging seasonal pits or wells into the ground. However, like all open wells, these are highly vulnerable to contamination, and not convenient to use.

More complex technologies can also be used to drill laterally into the alluvial valley aquifer from the side of the valley which is dry year-round. Sometimes called ''horizontal wells'' or ''collector wells'', ''infiltration galleries'', or in some cases ''radial wells'', these are essentially horizontal boreholes, which tap groundwater in the alluvial valley aquifer and channel it to the valley side to an underground chamber (or a standard vertical borehole or well) installed with a pump.

Examples of groundwater dams

Ethiopia

In Bombas in Ethiopia, a village of around 500 people, the Ethiopian Water Works Construction Authority (EWWCA) constructed a hybrid groundwater-sand dam in 1981. In a project costing US$15,000, unconsolidated sediment was excavated to 3 m depth to the top of bedrock. A dam of solid concrete was built to 0.8 m above the original ground level. Boulders were paced downstream of this wall to combat erosion. Sand accumulated behind the dam, forming an artificial aquifer that trapped and stored groundwater. A small quantity of groundwater flowed downstream over the wall, but the majority was stored in the new aquifer for several months into the dry season. Horizontal pipes were dug into the new aquifer to tap the stored groundwater and transport it 300 m downstream to a steel tank, from where villagers collected it.

The pictures below show another groundwater sand dam being constructed in Benishangul-Gumuz region, Ethiopia, in 2007. The alluvial (river) sand of the valley aquifer is being dug out by mechanical digger and a brick/concrete dam wall built at the downstream end to prevent groundwater flowing downstream. Once built, the area behind the dam was refilled with permeable sand that stores groundwater for abstraction during the dry season. The picture on the right shows the concrete rings being used to construct a wide-diameter well at the edge of the valley, above river flood level, that will be used to abstract groundwater from the dammed aquifer.

Constructing a sand dam in alluvial (river valley) sands in Benishangul-Gumuz region, Ethiopia. Image credit: Brighid Ó Dochartaigh / BGS

Concrete rings in the alluvial sand aquifer being used to construct a well for groundwater abstraction. Image credit: Brighid Ó Dochartaigh / BGS

Kenya

Between 1995 and 2005, the Sahelian Solutions Foundation (SASOL) constructed around 400 hybrid groundwater/sand dams in Kitui district in Kenya, at 0.5 – 1.0 km intervals along the beds of various rivers and ephemeral streams. The aim was to promote the development of new, permanent sandy alluvial aquifers along these river beds, which would trap seasonal rainfall and store it as groundwater into the dry season. Additional benefits are changing ecology from the greater water retention.

The dams are mostly 2 – 4 m high and up to 500 m long. The stream bed and banks are excavated and the impermeable dams built across the valley. The dams are designed to last for 25 - 50 years. A 60 m3 dam cost approximately $7500 USD.

The advantages of the sand dams are that they facilitate the operation of additional water points: wells and scoopholes have been used upstream of the barriers to facilitate water collection, reducing the time people (mostly women) spend on water collection. The water provided is better quality for domestic purposes than unprotected surface water. It can also be used to enhance livestock and crop production: some communities claim that the dams have enabled them to maintain vegetable production and increase their income.

Community involvement and management

Experience has shown that groundwater dams are most successful when the water user community identifies a need for improved water management and agrees that a groundwater dam is an appropriate solution. The example of the SASOL project in Kitai district, Kenya, illustrates this.

The projects in Kitui district were directed and supervised by SASOL, with local organising committees from water user communities responsible for mobilising resources and contributing approximately 40% of construction costs. Community representatives have information and understanding on the needs of the community, and will be able to advise on land rights and access routes around the proposed site.

The community organising committees were also ideally involved in selecting the site of the dam. They are likely to have an understanding of which areas currently retain groundwater effectively, helping to screen potential sites. However, there may also be a need to collect new hydrogeological data to support successful siting and development of groundwater dams.

After completion, community committees operate and maintain the structures in Kitui, with SASOL staff providing advice.

Training community groups on maintenance is important. This includes sessions on water quality management, sanitation and hygiene. Avoiding contamination of the water source is paramount. For most training sessions, and especially hygiene training, it is helpful if community members other than the committee participate, and both women and men are involved. SASOL recommended that there should be some 'caretakers' as well as the water committee, and that management is done with the involvement of the local government as well. The organising committee and caretakers also need to be in contact with experts such as masons to do any exceptional repairs required.

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