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This Technical Brief is concerned with the typical small dam (up to about three metres high) which is built across a stream to form a reservoir. It provides guidance on planning, design and construction, but professional help should always be sought before building any dam whose failure could endanger lives, property or the environment. Care must also be taken to avoid the health hazards of reservoirs, including schistosomiasis and polluted water; and the rights of existing users of the water and land must be protected.

A reservoir is useful where the available flow in the stream is sometimes less than the flow required for water supply or irrigation, and water can be stored from a time when there is surplus, for example, from a wet season to a dry season. In addition to the simple earth dam, alternatives to consider are using the sub-surface (groundwater) dam (see *The Worth of Water,* pages 97-100) or using wells. These may be preferable for environmental and water-quality reasons.

Simple earth dams can be built where there is an impervious foundation, such as unfissured rock, or a clay subsoil. The channel upstream should preferably have a gentle slope, to give a large reservoir for a given height of dam. An

Construction

The materials should preferably be taken from the reservoir area; different parts of the side of the valley should be examined so that the most suitable soils are located (soil textures will vary according to position in the valley). The following materials should be avoided: organic material — including topsoil — decomposing material, material with high mica content, calcitic clays, fine silts, schists and shales, cracking clays, and sodic soils. Avoid material with roots or stones.

Other construction points to consider:

- Construct during the dry season.
- Divert the stream; block it with a temporary low dam, or divert it through a culvert (which could become part of the outlet works or spillway later).
- Strip topsoil because it contains organic matter (such as roots) which prevents proper compaction and may provide seepage routes (piping) once the organic matter has decayed.
- Pay attention to people's safety — avoid hazardous practices and dangerous equipment.
- Place material in the dam:

  i) in layers 100 to 200mm deep;

  ii) at the optimum moisture content — when material can be rolled to pencil thickness without breaking, and is as wet as possible without clogging the roller; then

  iii) compact with a heavy roller, or by driving across vehicles or animals.
- Cover the whole dam with topsoil:

  i) plant strong grass (such as Kikuyu grass, star grass or Bermuda grass) to protect against erosion;

  ii) maintain the grass (water in the dry season if necessary), but prevent trees taking root, and keep out animals such as rats and termites.
- Protect the upstream slope:

  i) lay a stone or brush mattress (for example bundles of saplings between 25 and 50mm long) on the slope, and tie it down with wire anchored to posts;

  ii) secure a floating timber beam 2 m from the dam — these need replacing every 10 years or so.

Settlement

Even with compaction, earth dams settle as the weight forces air and water from voids (consolidation) — allow for this settlement in the design.

For small dams, well-compacted settlement should be between 5 to 10 per cent of the height of the dam.

Seepage/filter

Some water will seep through the dam, even if it is constructed of good materials, and well-compacted. This seepage reduces the strength of the dam. Nelson recommends the crest width and slopes shown in Figure 2 to provide a stable, 3m-high embankment making extra seepage protection unnecessary. A safer, but technically difficult, solution is to include a rock toe drain (as shown), to collect seepage water. This should extend up to a third of the height of the dam, and a graded sand and gravel filter must be placed between the dam fill material and the drain to prevent fine clay particles being washed out. The filter must be designed according to the particle size of the dam material and the drain, following, for example, recommendations in Schwab *et al,* p488-490.

Extraction of water from the reservoir

A gravity outlet can be constructed, as shown in Figure 1, using a screened inlet on the bed of the reservoir, and a pipe in a trench below the dam. Problems can arise with seepage through poorly compacted material beside the pipe (reduced by placing seepage collars along the pipe to increase the perimeter by at least 25 per cent), and difficulty repairing a damaged pipe. Alternatively, water can be extracted by lifting or pumping, using some of the methods described in Technical Briefs Nos. 22 and 47, for example:

- a sump (well reservoir) in natural ground at the side of the reservoir, supplied by gravity from a screened inlet and pipe through the bed and side of the reservoir;
- a bank-mounted motorized or human-powered pump; or
- a floating intake.

Safety and management

National and local regulations on small dams must be checked and followed in design, construction, and maintenance.

A technically competent person (an engineer or technician) should be responsible for designing and supervising the construction of the dam. The level of expertise required will depend on the potential for failure. Particular technical attention should be paid to the selection of materials and the design of the filter and spillway.

The sizeing of the spillway is important for protecting the dam during floods, but it is difficult to design. It depends on the rainfall intensity and the size and characteristics of the catchment area, and technical advice should be sought on local standards and practice.

A system needs to be set up for checking the condition of the dam and spillway, and for arranging any necessary repair work. This will usually involve training a local caretaker, who has access to a technician who inspects the dam at an appropriate interval (e.g. before each rainy season).

The dam should be regularly inspected for signs of deterioration, such as cracks, gullies, damage by rodents or insects, seepage, and damage to structures, especially the spillway.

Spillways

A spillway is required to protect the dam from overtopping, for example during high flows. It passes surplus water downstream safely, preventing both the failure of the dam, and damage downstream.

Surplus water flows over a spillway crest at the top water level, and into an open channel around the side of the dam, discharging safely into the stream below the dam. It may be made from reinforced concrete, but a cheaper solution is a grassed spillway with a:

- vegetated earth channel
- protected crest at reservoir top-water level
- maximum velocity 2.5m/s

A grassed spillway requires regular inspection and maintenance, so that erosion can be repaired and a good grass cover is maintained. It is often used together with a trickle-pipe spillway so that small inflows into a full reservoir flow through the trickle pipe, and do not erode the grass spillway. Table 1 can be used to find the minimum inlet width for a given flood flow. These widths apply to well-grassed spillways. Poorly grassed spillways should be wider.

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