Barry Lewis

Small Dams

Planning, Construction and Maintenance









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Disclaimer

This book is intended for use as a guide to owners and operators of small dams. It suggests prudent approaches to normal surveillance and maintenance practice with a view to enhancing the long-term safety and survival of small dams. It is not intended as a source of detailed information to cover all possible eventualities. In the event of any suspected imminent or potential failure condition, expert advice should be sought immediately.

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Preface

Farmers are well aware of the need to boost productivity. In the face of greater competition for domestic and overseas markets, the farmer who wants to succeed has to take a business person's approach to increasing efficiency, reducing costs and improving output. In this environment, water becomes an economic factor and its provision a matter for careful deliberation.

This book is designed as a guide for small dam owners, engineering students, Government agencies, developers, and earthmoving contractors who are responsible for designing, building and using the majority of water storages constructed. It is also designed for engineers who have not specialised in small earth dam design for agricultural hydrology, but who may be called upon, from time to time, to design small water storage schemes. It is not intended to replace standard procedures currently used by those specialised engineers who are engaged in farm water design, although many of the design methods described herein are based on their procedures. It does, however, attempt to provide such engineers with a comprehensive array of design data and a concise reference to basic design techniques that are not otherwise readily available.

To cover all aspects of water conservation and use in detail is not possible in a book of this size. However, it will give the landowner an insight to those aspects of planning which must precede the establishment of a feasible and economic water supply project.

The information for this book has come from a number of sources. One is a series of small dam pamphlets (which I wrote for the Rural Water Authorities in Australia over a number of years), another is data from papers that I have read and presented at conferences around the world.

Barry Lewis
May, 2013

Acknowledgments

There are many people who have supported and provided information, ideas and procedures in the collation of this book on small dams. Perhaps a major dilemma for me is the incorporation of sources of information, which are better explained in the anonymous quote:

> *How about the many ideas and procedures that one picks up from discussion with colleagues? After the passage of time, one can no longer remember who originated what idea. After the passage of even more time, it seems to me that all of the really good ideas originated with me, a proposition that I know is indefensible.*

It becomes clearer with time that nothing is new, but people forget the original sources and whether those sources were really original or were the result of slight modifications of other people's ideas. It is like the wheel. Nobody knows who conceived the idea, yet it is used universally. So, credit must be given to those who have gone before me in this area.

My family has been supportive in assisting in many ways. My wife, Marion, has typed and corrected a number of drafts. Richard, my son, has shown me some of the intricacies of the computer, whilst Janette, Helen and Kenneth have done their bit in other ways.

In the practical areas of planning, design, construction, maintenance and legal issues of small dams and other related areas I would like to thank all of those who have been instrumental in the completion of this book.

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Introduction

People have always gathered water during wet seasons so as to have enough for themselves, their animals and their crops in dry spells. The earliest known dams were in China in the sixth century BC. The ruins of ancient dams also exist in the Tigris and the Nile River Valleys. Some Roman dams built in Italy, Spain and North Africa are still being used today.

Today, dams are built to allow storage of water to give a controlled supply for domestic or industrial consumption, for irrigation, to generate hydro-electric power, or to prevent flooding. Large dams are built of earth, rock, concrete or a combination of these materials (for example, earth and rock fill). They are built as: gravity dams, where the stability is due entirely to the great weight of material; arch dams, where abutments at either side support the structure; or, arch gravity dams, which are a combination of the two.

Those who plan, design, construct, maintain, use and administer significant infrastructure developments which have a real potential to harm people and property if something goes wrong, are potentially subject to significant legal liabilities. These liabilities need to be taken into account when decisions are made in relation to such developments.

It is well known that Australia is a dry continent characterised by variable rainfall. It is less well known that, in response to widespread harvesting of water on the small and large scale, Australia has the highest water storage per capita in the world (Lewis and Perera, 1997; Lewis, 2001b). Small dam development has occurred in response to agricultural expansion, and to the need for a reliable source of water for stock, domestic and irrigation use, particularly during periods of drought. However, there is a growing belief in the community that small dams are impacting on water resources in many major catchments by reducing stream flow and flow duration. Potential and actual impacts of such reductions on the conflicting needs of the environment, agriculture and industry are cause for concern. These concerns are set against a background of changes including increased areas of intensive land uses such as viticulture and horticulture, and the development of farmland into rural residential subdivisions in commuter belts surrounding major cities and rural centres. These changes are associated with increased small dam development. In a significant proportion of cases, particularly where intensive land use changes have occurred, small dams are constructed that exceed the available water resource. Where this occurs, downstream impacts on stream flow will be the cause of conflict between users (including the environment). In addition, landowners may experience financial losses by constructing dams of a size inappropriate for the catchment.

In most countries around the world and in Australian States, provisions of the relevant *Water Act*(s) require that environmental consideration be taken into account in relation to new and renewed licences. These requirements apply to both regulated and unregulated waterway systems. Since unregulated waterways may not have large storage capacities from which environmental releases can be made, flow needs to be specified as a proportion of daily stream flow, or as a minimum daily flow. Many factors such as in-stream habitat requirements need to be considered when allocating an entitlement to environmental flows. In the case of regulated waterways, environmental flows can be released as part of the normal operating procedure.

Section 1

Planning

1.1 ASSESSING WATER NEEDS

Water is the most plentiful and vital liquid on earth. No life, as we know it, could exist without water as it provides the essential medium in which all things grow and multiply.

In recent years the steady growth in the numbers of agricultural businesses, including viticulture, aquaculture, irrigating crops and grazing animals, has increased the demand for water supplies. No longer can the small, muddy small dam or the small bore with windmill provide adequate supplies of clean water for these uses.

Landholders are lucky if their property can be serviced from a local water trust or authority. In most cases, the only option is to utilise on-farm water resources and this requires careful planning prior to costly construction. In a majority of cases farmers use roofs of buildings to collect rainwater for domestic and farm purposes. Rainwater is the main source of high quality water for human consumption, providing that guttering and tanks are kept in good order. In some cases underground water is used, but it may require treatment to remove or neutralise the minerals it contains. Where the terrain permits, rainfall and run-off gravitating to various categories of dams (for example, off-stream and on-stream catchment dams), provide the farm water supplies.

1.1.1 Planning water supplies

When deciding the most appropriate source of water for a farm, the following steps should be taken:

- determine the purpose for which the water is to be used (for example, household, garden, irrigation, stock, aquaculture, viticulture or a combination of all of the above);
- determine the quantity of water required for the different purposes, time of year and seasonal use and conditions (for example, summer, winter, flood or drought);
- ascertain whether the source of water supply is regulated (controlled from a reservoir that releases flows subject to availability) or unregulated (for example, bore water, rainfall or combination of both) and can be maintained when supplies are needed.

These factors are a guide to planning and they differ with almost every property. The most likely base can be established by calculating the average daily or average annual requirements for each proposed use of the dam. It is only after these facts are established that harvesting, storing and distributing the water resource can be planned (Lewis, 1993).

1.1.2 Water quality

In project planning the quality of water can determine success or failure of a small dam for several reasons. First, the quality of water available from a farm water system will determine the use to which that water can be put, and hence govern the overall feasibility of the system. Many natural waters have impurities that can make them directly harmful to crops. Therefore, knowledge of the quality of the water supply is essential.

Second, water quality is a factor in determining storage capacity. For example, if saline water is intended for irrigation use, additional quantities of non-saline water must be applied from time to time to avoid damage to the irrigated crops or soils.

Third, the presence of certain mineral constituents (such as calcium, potassium, magnesium and/or sodium cations) in stored water may cause tunnel erosion in some soil types. Therefore, the quality of water to be stored in a small dam must be considered in the design and construction of the impounding embankment.

Finally, overland flows mobilise and transport nutrients, fertilisers and silt which can contaminate the dam water supply. Precautions need to be taken to minimise the risk of this occurring, as algal blooms and weed infestation could result (see Section 7.4.1).

When planning for farm water supply, the presence of minerals, sediments, nutrients, agricultural chemicals, biota or bacteriological contamination needs to be considered, according to whether the water is to be used for:

i Water for consumption for humans and animals

- Micro-organisms and other harmful organisms which may produce illness or disease.
- Soluble minerals and other substances which give the water an unpleasant taste or make a person unwell.
- Silts, suspended impurities or algae which may cause discolouration, odour or taste problems and in some cases are toxic to both humans and animals.

ii Water for household, dairy or general farm use

- Suspended minerals and compounds which cause problems with clothes washing and the build-up of scale in equipment such as pipes, hot water systems and cooking utensils.
- Impurities which can cause water discolouration and associated staining and odour problems.
- Acids, dissolved minerals and gases which corrode pipes and equipment.

iii Water for irrigation

- Dissolved minerals which can alter water and soil chemical and physical properties. For example, an altered pH may inhibit plant growth.

iv Water to be stored behind small dams

- Dissolved and suspended particles can affect the soil structure of a dam, which can lead to tunnel erosion.

The testing of water samples to determine the presence and likely effect of these impurities requires laboratory facilities (see Section 7.2).

1.2 ASSESSMENT OF CATCHMENT YIELD

The initial question to be asked when considering the development of any storage dam on a property is how much water can be harvested in a catchment from overland run-off.

1.2.1 Factors controlling catchment yield

Estimating catchment yield by the methods described needs to be done within the context of a full understanding of the run-off process, so that the limitations of the method can be appreciated. Catchment yield is the volume of water that flows from a catchment past a given point (such as a stream gauging station) and is generally calculated on an annual basis (Beavis and Lewis, 1999). It comprises surface run-off and base flow (discharge from shallow and deep groundwater). Catchment yield will vary according to a number of hydrological and physical factors, which control how much water is delivered to, retained by and transported from a catchment.

i Hydrological factors

Run-off may be regarded as the residue of rainfall after losses due to interception by vegetation, surface storage, infiltration, surface detention and waterway detention. There is always a time lag between the beginning of rainfall and the generation of run-off. During this time lag, rainfall is intercepted by vegetation, infiltrates the soil, and surface depressions start to be filled. Run-off occurs when the infiltration capacity is exceeded, or the precipitation rate exceeds the rate of infiltration. Thus the depth of water builds up on the surface until the head is sufficient to result in run-off. As the flow moves into defined waterways, there is a similar build-up in the head with volume of water, and this is termed waterway detention. The water in surface storage is eventually diverted into infiltration or evaporation pathways (Beavis and Howden, 1996; Beavis and Lewis, 1999).

Rainfall duration, intensity, and distribution influence both the rate and volume of run-off. Infiltration capacity normally decreases with time, so that a short storm may not produce run-off, in contrast to a storm of the same intensity but of long duration. However, an intense storm exceeds the infiltration capacity by a greater margin than a gentle rain. Therefore, the total volume of run-off is greater for an intense