A German Guideline for small Dams and small Flood Control Reservoirs

V. Bettzieche[1] and R. Pohl[2]

[1] Ruhrverband, Kronprinzenstr. 37, D-45128 Essen, Germany

[2] Institut für Wasserbau und Technische Hydromechanik, Technische Universität Dresden, D-01062 Dresden, Germany

E-mail: vbe@ruhrverband.de

Abstract

In Germany the technical rules for dams and reservoirs are published in the standard DIN 19700 Part 11 and 12. A classification into large, medium, small and very small basins is made, to enable owners, operators, consultants, contractors and authorities to assess appropriate analysis as well as operation rules to the works of different size and risk level.
Uncertainty often exists in practice how to deal with small plants. In the realization of the regulations it is often necessary to take into account the above two parts of the standard. Allowable simplifications are often not described or not specified detailed enough.
Therefore the DWA (German Association for Water Management, Waste Water and Waste) has decided to elaborate and publish a technical bulletin about the planning, construction and operation of small plants. This guideline is numbered M 522 and will be entitled "Small Dams and small Flood Control Reservoirs".
This paper covers the most important points of the upcoming guideline. These are the calculation of the hydrological parameters, the safety and stability of these small dams as well as the construction, the appurtenant works and the consideration of ecological aspects.

Introduction

In July 2004 an updated version of the German standard DIN 19700 was published, postulating the technical rules for dams and reservoirs in Germany.

Part 10 of DIN 19700 [4] contains the general specifications for all kinds of dam plants. The parts 11 through 15 specify various regulations for special kinds of reservoirs as dams, weirs, flood retarding basins. In the former German Democratic Republic (DDR) the Standard TGL (Technical Guideline) classified dams concerning to their importance and risk-level into three classes which was used in West-Germany only for flood retarding basins.

The new DIN 19700-11 "dams" [5] distinguishes two classes of dams according to the reservoir storage and the height of the dam. Dam class 1 is valid for large dams with a height of the dam of over 15 m or a volume of the reservoir from more than 1.000.000 m³. Dam class 2 seizes together medium and small dams which do not fulfill these criteria. Further distinctions are not officially given, but in principle possible.

Even DIN 19700-12 „Flood retarding basins“ [6] assigns these plants according to their storage volume and dam height into different classes. However four classes are used for the basins: large, medium, small and very small.

Using these guidelines for practical applications, uncertainties often arise when using both parts (11 and 12) of the DIN 19700. Additionally the guidelines in principal allow reductions of the specifications if the reservoirs are of lower risk. Unfortunately these reductions are not explicitly explained.

The new guideline from the German Association for Water, Wastewater and Waste (DWA) M 522 „Kleine Talsperren und kleine Hochwasserrückhaltebecken“ (Small Dams and small Flood Control Reservoirs) gives practical instructions for the planning, construction and maintenance of small dams and small flood control reservoirs.
It is the objective of the guideline (under discussion) to provide facilitations for small plants as against large and medium dams and to use the scope of interpretation of the DIN to fulfill the technical and operational requirements.

The DWA-Working-Group WW-4.5 „Kleine Stauanlagen“ (small dams) and the DWA-Committee WW-4 "Fluss- und Talsperren" (weirs and dams) would like to address owners and operators of the plants, dam inspecting authorities, water management and flood protection federations as well as consulting engineers and contractors with this guideline.

Scope of the Guideline

The new guideline covers small reservoirs which have a natural inflow. It refers to dams and flood retarding basins in accordance with the definitions of the DIN 19700-11 and DIN 19700-12.
On the other hand it does not cover sedimentation basins. The corresponding use of the guideline for these plants is recommended. For natural retention areas such as lakes as well as flood areas, which developed in consequence of road or railway embankments or similar constructions, the usage of the guideline could be proved. Culverts and other hydraulic crossing structures are specified in the German DIN 19661-1 [3].
Furthermore this guideline is focused on embankment structures. Masonry dams or concrete dams are not included. The similar use of DIN 19700-11 is recommended.

The guideline is restricted to small and very small plants. In accordance with the German dam standard and the legislation of the federal states the upper limits for the definition of small dams are

- a height of less than 6 m (above foundation) and
- a storage capacity of less than 100,000 m³.

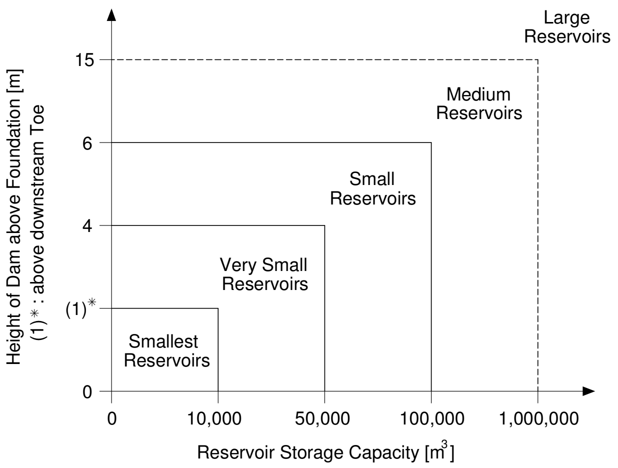

Figure 1: Classification of small Dams

The height of the dam refers to the technical foundation. At some old existing dams the foundation can not exactly be identified. In this case alternatively a maximum height of 5 m of the crest above the lowest point at the downstream dam toe may be used.

As shown in Figure 1, small dams and small flood control reservoirs are divided into small reservoirs and very small reservoirs.

Reservoirs with a dam height of less than 1 m and a storage capacity of less than 10,000 m³ are called “smallest reservoirs” and are not explicitly considered. Remarks for these smallest plants are given.

Based on risk analysis studies additional criteria for classification may be used. The DIN-regulations allow the classification of these plants in an upper or lower class, if the risk of the dams is on a corresponding level.

Figure 2: Small Dams: Reservoir as a part of a cascade of small dams in East Thuringia, Germany, with combined wooden Intake/Shaft Spillway (Photograph: Pohl)

Selected Points of the Content

In the course of this paper only some selected items of the new guideline can be discussed. Furthermore the following main points are included in the full guideline:

- hydrological and hydraulic design
- soil investigations
- dam construction
- design requirements
- geotechnical and stability analysis
- sediment
- operation, maintenance and monitoring
- ecological aspects
- selected examples of small plants

Hydrological and hydraulic Design
The German design concept (also for small and very small reservoirs) is clearly divided into three design cases: design flood 1 (BHQ_1) is for the design of the spillway, design flood 2 (BHQ_2) for the dam safety and design flood 3 (BHQ_3) for the flood protection referring to a certain objective of protection (s. Fig. 3).

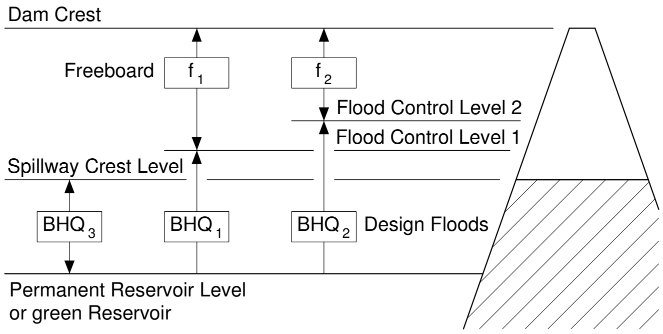

Figure 3: Design Concept of the German Standard DIN 19700 for small and very small Dams

Estimation of the Design Flood

According to the German standard DIN 19700-10 the estimation of the design flood should be carried out with different methods because the consideration of extreme events is subjected to uncertainties. The results have to be compared. The DVWK-report 124 „Flood Discharges“ [9] gives an overview of this topic including several methods of design flood estimation.

For small dams in small catchment areas there are often no or not enough hydrologic data available. This makes it difficult to carry out an appropriate statistical analysis. Flood peak discharges can be derived from reliable gauge data by means of regional transmission. Short gauge data series, extreme flood events etc. can cause misinterpretations. Therefore the data should be compared and adjusted with data from gauges with similar characteristics and similar watersheds. But even for small catchment areas this procedure is uncertain too due to the scarceness of data on one hand and to the local deviation from the average area behavior on the other hand.

If such influences cannot be excluded safely, additional considerations by means of a precipitation-runoff model are necessary. This model is normally based on regional parameters too but a sensitivity analysis can help to investigate specific regional properties and its influences in more detail. If flood discharges can only be yielded from a precipitation-runoff model due to insufficient data availability the plausibility of the results should be checked in comparison with similar watersheds.

The use of precipitation-runoff models enables the estimation of the inflow hydrograph and the calculation of the peak reduction due to flood retention. If only peak discharges (without hydrograph) are used for the calculation of the design flood, higher values would be yielded. The design floods (outflow) that have been calculated in this way normally refer to medium probabilities of exceedance only. For extreme flood discharges the required extreme precipitation values can be derived from PEN (Extreme Precipitation Values for practical Application [18]). But these values are available only for two recurrence intervals(1,000 a and 10.000 a) and for 5 duration levels (6 h through 72 h). For other conditions e.g. in Baden-Württemberg the KOSTRA-catalogue [19] can be applied.

Using extreme precipitation in precipitation-runoff models should be taken into account if the considered catchment has the same hydrologic behavior also at very small exceedance probabilities. Therefore it is recommended to extrapolate the very rare flood peaks from more frequent peaks by a coefficient. Kleeberg & Schumann [17] suggest a procedure for the estimation of extreme values on the basis of gauge observations from several German regions using the formula

$$HQ_n = MHQ + (HQ_{100} - MHQ) \times cn \qquad (1)$$

with the coefficient cn for the recurrence period n (Table 1). In this way the design flood peaks BHQ_1 and BHQ_2 can be estimated where the mean flood MHQ can be set equal to.

TABLE 1: COEFFICIENTS BY KLEEBERG/SCHUMANN

n	100	200	500	1.000	5.000	10.000
cn	1.0	1.3	1.6	1.9	2.5	2.8

Due to DIN 19700-11 an increase of the exceedance probabilities of the design floods is allowable if a dam failure would produce downstream consequences with lower impact.

Freeboard

Regarding the freeboard design a simplification is planned to allow for dams with normal wind conditions and an altitude of less than 400 m a.s.l. the freeboard heights from table 2 including wind set-up and wave run-up.. A calculation according to DVWK guideline 246 [10] is in this special case not necessary but will be recommended in general.

TABLE 2: FREEBOARD AT SMALL AND VERY SMALL DAMS

	Small Dams		Very small Dams	
Upstream Dam Slope	1 : 2	1 : 3	1 : 2	1 : 3
Lawn on the upstream Slope	0.80 m	0.60 m	0.70 m	0.50 m
Rockfill on the upstream Slope	0.65 m	0.50 m	0.60 m	0.40 m

Operational Devices

Small dams must possess operational devices to convey the inflowing water during normal flow periods, to release incoming floods and to withdraw the water according to the purpose of the reservoir. Also for small dams the workability of the operational devices is essential. Especially at dams that are inspected in longer intervals reliable, overloadable spillways are necessary. They should not tend to clog and should not be gated. However the experience shows that especially dams below the dam classification threshold for small dams sometimes are not operated by skilled personnel, are not sufficient inspected and have maintenance imperfections.

For intakes it is allowed to arrange only one gate or valve respectively in each waterway if an upstream revision gate or stop log can be provided on demand.

For small dams the following types of construction have often been built :
a) overtopable embankment section (e.g. spillway in Figure 4)
b) ungated weirs; also with chutes,
c) gated weirs (e. g. fish shaped flap),
d) gated openings below the spillway crest,
e) permanent openings (culvert, gallery)

The spillways of types a) and b) and to a certain extend also c) are overloadable and relatively insensitive to clogging Therefore they should be preferred at small works without frequent inspection. For the same reason bridges over the spillway should be avoided. If this is not possible the minimum distance between the elevated flood water level and the lowest point of the bridge construction must be 0.5 meters (s. a. DIN 19661 part 1).

Figure 4: The Members of the technical working Group visiting the Spillway Section and Bottom Outlet of the small Dam of the Flood Control Reservoir Hainteichstraße/ Gellershagener Bach in Bielefeld (green reservoir, storage volume < 30,000 m³, Photograph: Pohl)

Spillways at small dams are often a part of the barrage. But they can also be individual structures or can be joint structures with the intake works.
Ungated spillways should be preferred. If gates are installed (s.a. DIN 19704-1 [7] and DIN 19704-2 [8]) there should be at least two openings that can be operated separately (n-1 rule, redundancy). In the case of a low downstream hazard potential also a scheme with only one opening can be allowed.
If all available gates and valves had been included in the hydraulic calculation for conveyance of the design flood at the elevated reservoir level z_{H1}, a consideration of the downstream risk (failure probability x failure consequences) is recommended.
It might be advantageous to design dams with a scheme that allows a later increasing of the spillway capacity (widening, deepening) to make possible an adaption to higher design floods in the future (e.g. due to climate change). Dams with regular permanent spillway overflow operation should have a mean-water gully on the spillway crest.

Requirements for the Construction of small Dams
Small dams have to be designed by some different requirements than large dams. Small dams are more susceptible to damage caused by vegetation and voles. Sealings of the bedrock are often constructed in another way compared with large dams. The construction of an inspection gallery for monitoring and subsequent ground improvement is impossible already for geometrical reasons. Bedrock seepage is i.e. often prevented by an impervious blanket at the upstream side of the dam.

Even at small dams a geotechnical investigation is required. In Germany the depth of this investigation is defined in DIN 4020 [2] and classified in three geotechnical categories (GK). Dams that are “impacted by a water pressure difference of Δh > 2 m” are classified in GK 3, which is the highest category. Hereby Δh indicates the difference between the water level at full capacity and the ground surface at the downstream toe. The geotechnical investigations may include:

- outcrops for the assessment of the support capability and the stability against erosion,
- determination of the soil characteristics in the laboratory as the basis for the geotechnical calculations,
- determination of all relevant hydraulic parameters of the soil,
- if possible, exploration of the possibility for removal of materials in the reservoirs area.

For smallest reservoirs with a storage volume of less than 10,000 m³, a height of the dam of less than one meter above the downstream dam toe and without any specific exposure of the reservoir, the following minimum requirements have to be fulfilled:

- a freeboard of at least 0.30 m above design water level,
- a spillway or an overflow section,
- stability to be calculated according to DIN 1054, GK 1 [1].

For reservoirs with a storage volume of less than 500m³, only the stability analysis according to DIN 1054, GK 1 has to be calculated.

Category GK 1 of DIN 1054 allows the proof of stability by simplified procedures based on experience instead of an comprehensive engineering calculation of the stability in GK 2 and GK 3.

For small dams simple and robust construction schemes, methods and designs should be chosen. The proposed operation, availability of qualified personnel operating even in extreme conditions as well as the accessibility of the reservoir in such situations have to be taken into account. Already during the design process adequate account of local specificities (e.g. local construction methods and materials) and regional characteristics (terrain morphology, available dam materials) should be considered.

Vegetation on small Dams
Small dams have to be planted with a dense and durable turf.
Vegetation with trees and shrubs is in principle not permitted to small dams.
If the outer dimensions of a dam are larger than the statically required cross section, a growth of shrubs is allowed in these areas, if the statically required cross section is not affected by the rooting and the visual inspection is not hindered. Construction parts of the dam, like the drainage systems and the measuring or operating equipment must permanently not be affected in their function and must be verifiable.
It is well known, that in practice these construction requirements as well as visual inspection, maintenance and care are often ignored (s. Figure 5 and 6).

Figure 5: Trees rooting into the static Cross-Section of a small Dam (Photograph: Pohl)

Figure 6: Shrubs rooting into the static Cross-Section of a small Dam (Photograph: Pohl)

Next Steps

The work on the guideline will be continued and is assumed to take some other month. Further supplementations, specifications, coordinations and adjustments to other standards and guidelines will be required. After the completion of the guideline a draft will be made and published, so that the public is able to submit written objections, comments, remarks and proposals to the DWA. The paper of the drafts of German standards and guidelines is traditionally of yellow color. Therefore these drafts are usually named “yellow print”.
After the objections of the public have been processed, the rules will be introduced as a final “white paper”.

Acknowledgements

The authors wish to express their thanks to the DWA for the support of the project and to all members of the technical working group WW-4.5 for their contribution. The members of the group are:

Dr.-Ing. Andreas Bieberstein, Universität Karlsruhe, Dipl.-Ing. Klaus Flachmeier, Bezirksregierung Detmold, Dipl.-Ing. Matthias Groteklaes, Regierungspräsidium Freiburg, Dipl.-Ing. BOR Reinhard Klumpp, Bayrisches Landesamt für Umwelt, München, Dipl.-Ing. Lothar Knödl, Zweckverband Hochwasserschutz, Waibstadt, Dipl.-Ing. Jörg Koch, Ingenieurbüro Wald + Corbe, Hügelsheim, Dipl.-Ing. Jochen Mehl, Thüringer Fernwasserversorgung, Dipl.-Ing. Quent Mehlhorn, Thüringer Fernwasserversorgung as well as the authors: Dr.-Ing. Volker Bettzieche, Ruhrverband (Speaker /Chairman), Prof. Dr.-Ing. habil. Reinhard Pohl, TU Dresden (Vice Chairman).

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