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DAM SAFETY REGULATION IN SOUTH AFRICA: 32 YEARS DOWN THE LINE

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1. INTRODUCTION

South Africa is the 30th driest country in the world. This is due to low levels of rainfall (relative to the world average) and high variability (60% of river flow arises from only 20% of the land area) as well as high levels of evaporation. Of the total mean annual runoff of 49 000 million m^3 per year, only 10 000 million m^3 is annually available as assured yield (98% assurance) [1]. As a result, South Africa has been one of the major dam building countries in the world. It is the country with the seventh most large dams (more than15 m high) on the ICOLD register of dams [2]. It also has a significant number of small dams (less than 15 m high).

Of the total available water resources 67% is currently allocated for irrigation while the rest is made up of domestic and industrial use (22%), mining (5%), afforestation (3%) and power generation (mainly thermal power) and transfers between catchment basins (3%) [1].

This paper not only summarize the history of Dam Safety implementation in South Africa from its earliest humble beginnings in the 1970s to the implementation of Dam Safety legislation in 1980s [3] and the update of the relevant regulations in

2012 [4] but also provide insight into the required regulatory processes during the lifespan of a dam.

A summary is provided of the lessons learnt in the implementation of the legislation including the positive influence of effective dam safety legislation and the fact that it takes time and significant resources to implement a dam safety regulatory system. It is also important to note that these lessons learnt were used to help some other African countries starting with the implementation of Dam Safety regulatory systems in their countries [5][6].

2. LEGISLATION

2.1. HISTORY

Legislation on the safety of dams was formally introduced in 1984 in South Africa (after earlier attempts dating back to the early 1970s was not successful). It is interesting to note that initially the political decision makers in South Africa considered dams to be inherently safe. This was obviously not correct considering the failure statistics of dams before the 1970s. A visit to the US, UK and several European countries by a team of officials from the Department of Water Affairs in the 1980s lead to the first attempts to introduce dam safety principles in South Africa based on the experiences gained during their visit.

Apart from defining the structures subjected to control, authority has been given to the Minister of Water Affairs (and Forestry) to promulgate dam safety regulations in which conditions and requirements for the design, operation, maintenance, inspection and even decommissioning of dams are prescribed. This was done for the first time in 1986. It is important to note that these regulations initially did not specifically take into account any environmental aspects with regards to dam safety.

Although the Constitution of South Africa of 1996 [7] drawn up after the advent of democracy in 1994, is primarily human centered, it also highlights the protection of the environment. Subsequently a National Water Act was promulgated in 1998 that includes a section on dam safety [8] that also included environmental aspects pertaining to dam safety (impacts). As a result, revised dam safety regulations were promulgated in 2012 [4] which for the first time included the potential impact of a dam on the resource quality downstream of the dam.

2.2. DAM SAFETY LEGISLATION

The National Water Act [8] as well as the Dam Safety Regulations of 2012 [4] aim at “improving the safety of the new and existing dams with a safety risk so as to reduce the potential harm to the public, damage to property or to resource

quality". It is important to note these only pertain to dams with a safety risk. A "dam with a safety risk" is defined as a dam with a storage capacity of more than 50 000 m^3 and a vertical height of equal to or more than 5 m. This definition of height differs from the ICOLD definition – the height is measured from the lowest natural bed level at the downstream toe of the dam wall to the non-overspill crest. Smaller dams that do not satisfy these requirements do not form part of the dam safety legislation. It is of extreme importance to note that these dams, however, still have to comply with water use and environmental legislative requirements.

The authority of dam safety lies with the Minister of Water and Sanitation (DWS). The Minister is assisted with the regulation of the dam safety legislation by the Dam Safety Office (DSO) which forms part of DWS (as designated by the Director-General of DWS) – one could call the DSO the regulator in South Africa. The Minister is also assisted by the Engineering Council of South Africa with the approval of appropriately qualified and experienced professional persons (Approved Professional Persons - APPs) to perform tasks at dams with a safety risk. The mandatory involvement of APPs for all tasks carried out at certain categories of dams is one of the important principles of the dam safety legislation in South Africa.

As in other countries that also had their major dam development in the 20th century, South Africa is experiencing a rapid decrease in the number of available APPs as the majority have either reached and are close to retirement. This is a major area of concern.

One of the founding principles of Dam Safety in South Africa and the rest of the world is that dam owners are responsible for the safety of their dams (the term "dam owners" also includes operators). It is therefore the responsibility of dam owner/s to register their dam with a safety risk with the DSO (including all new or planned dams). Once the registration information is received, the DSO would then classify the dam into one of three categories which determines the required level of control at that particular dam. The classification is based on the size and the hazard potential rating of a dam. The size class is determined by the maximum wall height. The size classification is given in Table 1. It is important to note that in many cases the classification date could be different from the registration date.

Table 1
Size classification (using the South African definition for height)

Size class	**Maximum wall height (m) (from the river bed level to the highest point of the dam)**
Small	< 12 m
Medium	≥ 12 m but < 30 m
Large	≥ 30 m

The hazard potential is based on an assessment of the potential loss of life (PLL), potential economic loss (PEL) (with respect to downstream development) as well as the potential adverse impact on resource quality (PIRQ) that may result from failure of a dam. In determining the hazard potential rating the PLL, PEL and

PIRQ are considered separately and the highest rating obtained, is accepted. The hazard potential classification is given in Table 2.

Table 2
Hazard potential classification

Hazard potential rating	Potential loss of life	Potential economic loss	Potential adverse impact on resource quality
Low	None	Minimal	Low
Significant	≤ 10	Significant	Significant
High	> 10	Great	Severe

The structural condition of a dam does not influence its category classification (only the size of the dam and its hazard potential are taken into account). There are three categories in the category classification (Category 1, 2 and 3). The relation between the category classification, size class and hazard potential are given in Table 3.

Table 3
Category classification of dams with a safety risk

Size class	Hazard potential rating (*)		
	Low	Significant	High
Small	Category 1	Category 2	Category 2
Medium	Category 2	Category 2	Category 3
Large	Category 3	Category 3	Category 3

(*) Highest level as determined by separate consideration of the potential loss of life, potential economic loss and potential adverse impact on resource quality downstream of the dam

To perform any task at a dam (including construction, enlargement, alteration, repair or decommissioning), the owner needs to obtain a licence for construction from the DSO. This normally includes the completion of an application form accompanied with the required design reports and engineering drawings as well as evaluation of the safety of the existing development. For Category 2 dams all tasks must be carried out under supervision of an APP whereas for Category 3 dams, an APP must be assisted by an approved professional team of experts. For Category 1 dams the involvement of an APP is not required but the dam owner has to fulfil the requirements of the dam safety regulations which includes completing an official application form, submitting design reports and engineering drawings and an evaluation of the safety of the existing development. Most of the small dams in South Africa are classified either as Category 1 or 2. In certain instances dam owners have decided to make use of a panel of experts over and above the APP and the accompanying professional team. This in certain circumstances leads to uncertainty regarding professional responsibilities.

Once construction is completed for Category 2 or 3 dams, the owner needs to obtain a licence to impound water (this is not required for Category 1 dams).

This includes the completion of an application form accompanied by a construction completion report and associated as-built drawings, an operation and maintenance manual, emergency preparedness plan and an affidavit from the owner stating that all residential areas and buildings in the dam basin have been vacated.

With regard to dam safety evaluations, the involvement of an APP and/or supporting professional team are similar to the other tasks (Category 2 dams only require an APP while Category 3 dams require an APP and supporting professional team). Depending on the category and the hazard potential, dam safety evaluations are required at intervals between 5 and 10 years (5 years for Category 3 dams and longer intervals for Category 2 dams).

The dam safety legislation and regulations clearly set out the steps required to satisfy dam safety practice, but within the legislation or regulations there are no specific norms or standards prescribed. The APP has the responsibility to determine appropriate standards for a particular dam and the legislation provides for a review of such standards by the DSO. The appropriate norms are considered to be current acceptable dam engineering practice for site-specific conditions. This is significantly different to a number of other countries in the world where specific norms and standards are applicable. There are, however, a number of guidelines available for use in South Africa including these on Dam Break Floods [9], Safety in Relation to Floods [10] and Freeboard for Dams [11].

Again, it is important to note that the legislation is as such that the owner/s of a dam is at all times responsible for the safety of their dam – South Africa's common law responsibility is applicable in addition to the dam safety responsibility. Included is the responsibility for the implementation of the recommendations of the dam safety evaluations by the owner. The DSO may instruct the owner to implement the recommendations. Failure of the DSO to give such an instruction does however not take the responsibility away from the owner.

2.3. WATER USE AND ENVIRONMENTAL LEGISLATION

In addition to the dam safety requirements of the National Water Act of 1998 [8], a dam owner is also required to satisfy the water use requirements of the act by applying for a water use licence when wanting to construct any new dam or increase the storage capacity of an existing dam (Section 21 of the Act). No construction work may be carried out before a water use licence or written authorization has been obtained from the DWS.

For so called "dirty water" dams (or dams for water containing waste), a dam owner must also comply with the Regulations on the "Use of Water for Mining and related Activities aimed at the protection of Water Resources" promulgated in 1999 [12].

A dam owner must also satisfy the provisions of the National Environmental Management Act and its accompanying regulations [13] with regards to activities which may have a detrimental effect on the environment (construction, enlargement, alteration, repair or decommissioning of a dam or storage of "dirty water" in most cases may be listed as such an activity). This normally requires an

environmental impact assessment (EIA). One of the conditions of the water use licence is the environmental authorization. In other words, no listed activity at a dam may take place before receiving the necessary environmental authorization.

3. LESSONS LEARNT FROM LONG TERM IMPLEMENTATION OF DAM SAFETY LEGISLATION

According to the latest database of the DSO [14] a total number of 5 462 dams with a safety risk according to the Dam Safety Regulations were registered in South Africa at the end of February 2018 (see Table 4). The large majority of these dams (more than 75.3%) can be classified as small (less than 12 m high) while only 3.46% can be classified as high. The rest is classified as medium dams. When comparing the number of dams with the ICOLD definition of a small dam it is evident that there are 458 dams between 12 m high and 15 m high.

Table 4
General dam statistics (using the South African definition for height)

Height of dam (from the river bed level to the highest point of the dam) (m)	**Number of dams**
Less than 12 m	4 158
12 m to < 15 m	458
15 m to < 30 m	672
30 m and higher	174
Total	5 462

It is important to note that of the 5 462 dams registered, 5 434 dams have been classified by the DSO. Of these 5 434 dams, 57.3% are Category 1 dams that does not require any further regulatory actions other that registration and classification. The remaining classified dams consist of 36.3% Category 2 dams and 5.4% Category 3 dams - both Categories requiring the involvement of an APP and a supporting professional team (for Category 3 dams) and 0.9% dams that does not warrant a classification. In other words, a significant portion of small dams are classified as Category 2 dams due to their adverse hazard ratings.

Fig. 1 provides a graphical presentation of the number of dams registered as well as classified annually since the inception of dam safety regulations in 1986. As expected a large number of dams were registered within the first 5 years (2 632 dams in total). What is however interesting to note is that although the number of dams registered per year has decreased since, the number of annual registrations basically stayed constant since 2000. An increase is evident since 2012 – this could be attributed to the implementation of the revised dam safety regulations in 2012 with an increased focus of the so-called dirty water dams. It has taken another

27 years of dedicated registrations by the DSO to double the amount of registrations to the current 5 462 dams.

However, when considering classification, it is clearly evident from Fig. 1 that all the effort in the beginning was spent on the registration of dams and the classification of dams lagged significantly behind especially the first 2 years after implementation. So, in comparison only 1 692 dams were classified within the first 5 years. This lag was basically eliminated in 2012 with the implementation of the revised dam safety regulations in 2012 with an increased focus on the so-called dirty water dams as the lag was mostly made up of the so-called dirty water dams.

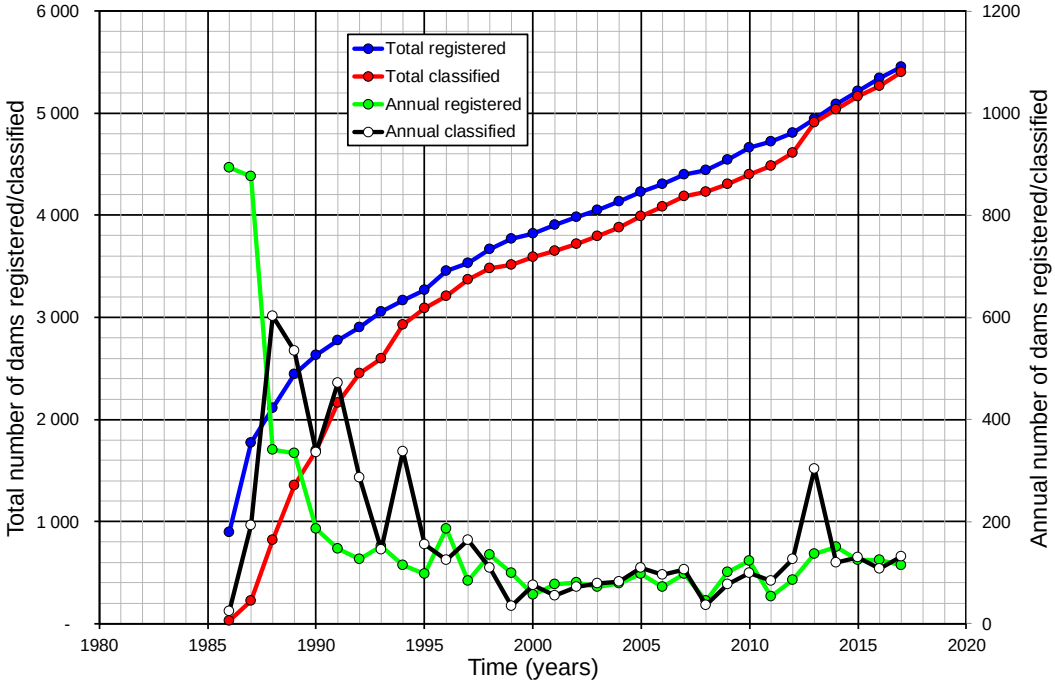

Fig. 1
Number of dams registered and classified since inception of dam safety regulations

Fig. 2 provides more detail on the distribution of completion dates of the dams registered during each year since the first implementation of dam safety legislation. It can therefore be concluded that to effectively implement a Dam Safety regulatory system takes time and effort even for the most basic things like registration and classification of a dam with a safety risk.

The building of dams in South Africa went through a boom period from the 1950's to the 1990's, peaking during the 1980's for both small as well as large dams. Since the 1990's the number of dams constructed has drastically reduced. One of the main reasons can be attributed to a change in the water related legislation in South Africa in 1998 [8]. The old system based on riparian rights changed to a system that recognizes water for the environment and for human consumption as a basic right. Authorization for all other water uses has to be

obtained from the DWS acting as custodian of water resources and responsible for distributing water in an equitable manner.

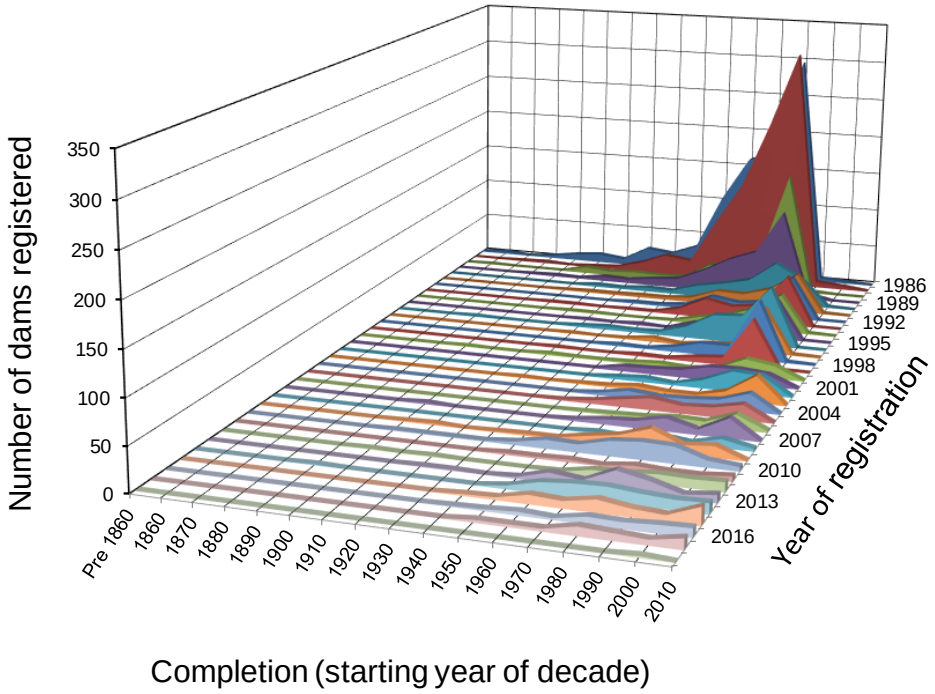

Fig. 2
Timeline of dams registered

So, where a land owner in an uncontrolled area could build a dam on his property up to 250 000m^3 without a licence before 1998, presently a licence is required taking into account the water resource situation in the relevant catchment as well as the possible redistribution of water resources. This process together with the scarce nature of the water resources in the majority of South African catchments has subsequently led to fewer dams being built during the last two decades (only 257 small dams were completed in the 2000s and 90 so far in the 2010s compared to a total of 1 303 dams completed during the 1980s). In many catchments the best dam sites have already been utilized and additional storage will not significantly increase the yield of the system.

Prior to the introduction of legislation on the safety of dams in the 1980s not a lot of attention was given to the recording of failures and incidents in South Africa. So much so that in an ICOLD publication on failures and incidents in 1973 [15], only 2 incidents at South African dams were described. Subsequent to the promulgation of the first dam safety regulations in 1986 and the formation of a “DSO” that acts as regulator, failures and/or incidents have been recorded in a “Catalogue of incidents” as part of the information system of the DSO. A number of publications were published with the majority focusing on failures and incidents of large dams. Hattingh and Oosthuizen published a paper in 2017 [16] that

provides a summary of both large as well as small dams. The most important conclusions are as follows:

- With regards to large dams, only earthfill and tailings dams (no large concrete dams) have failed in South Africa. With regards to small dams, the large majority of failures are earthfill dams although some smaller concrete weir structures have also failed.
- Overtopping due to inadequate spillway discharge capacity as well as piping and internal erosion make up the large majority of causes of incidents at and failures of small dams

4. CONCLUDING REMARKS

From the lessons learnt from the implementation of dam safety legislation in South Africa the following is of importance:

- It is of prime importance to convince political decisions makers about the necessity for Dam Safety implementation including the necessary legislative and regulatory environment.
- It takes time and significant resources to successful implement a dam safety regulatory system – for example after more than 30 years existing dams are still being registered in South Africa. It also takes time and effort to classify the dams as well as establish regulatory compliance;
- Dam Safety legislation, enforced by dedicated and experienced officials (in the DSO), has a positive correlation with the decrease in the number of incidents and failures of dams built since promulgation of dam safety legislation in South Africa. This has also ensured the formal recording of incidents and failures. Not all incidents and failure of especially small dams are however reported to the DSO as required.

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SUMMARY

This paper not only summarize the history of Dam Safety implementation in South Africa from its earliest humble beginnings in the 1970s to the implementation of Dam Safety legislation in 1980s and the update of the relevant regulations in 2012 but also provide insight into the required regulatory processes during the lifespan of a dam.

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REGULATION
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FAILURE