Evaluation of the permitted risk level for aged dams during survey and expertise

by

MIKHAIL GONCHAROV, EVGENY GONCHAROV

Higher School of Economics — National Research University,
University of Cambridge
mgoncharov@hse.ru

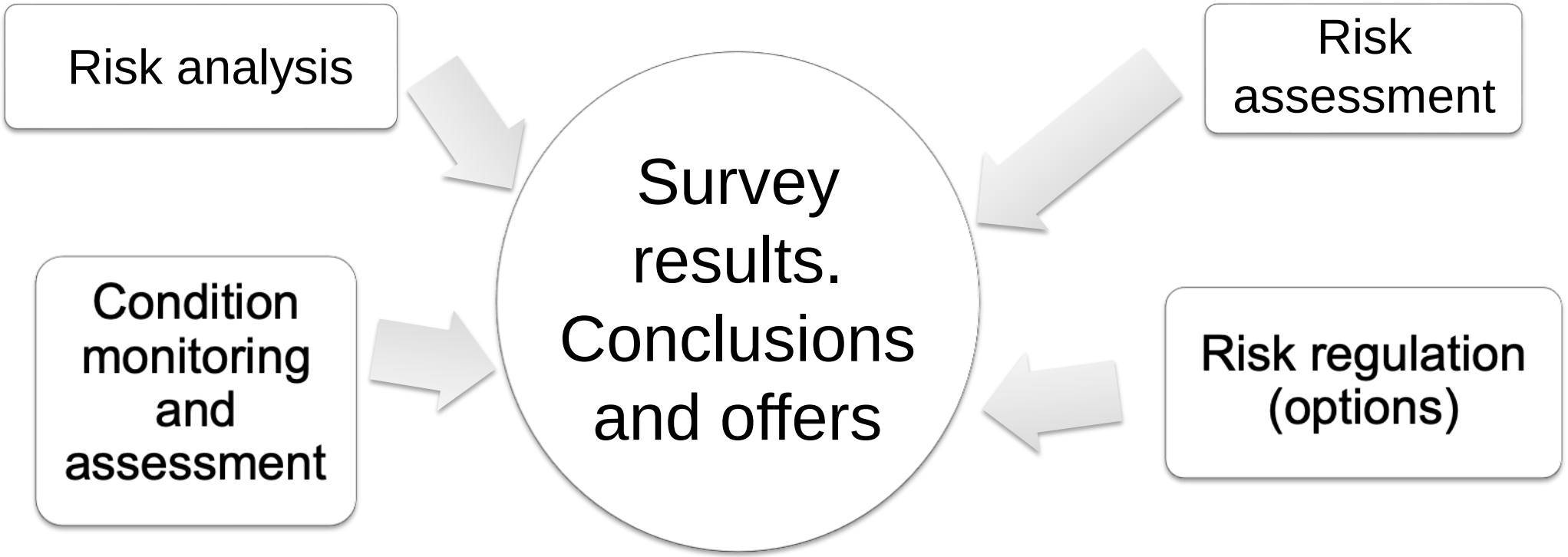
Risk management stages

Two main stages of risk management can be highlighted:

- stage 1 is performed during the survey (planned or extraordinary, caused by any serious damage);

- stage 2 is performed in the process of declaring safety and fulfilling the requirements of declaration

Risk management stages

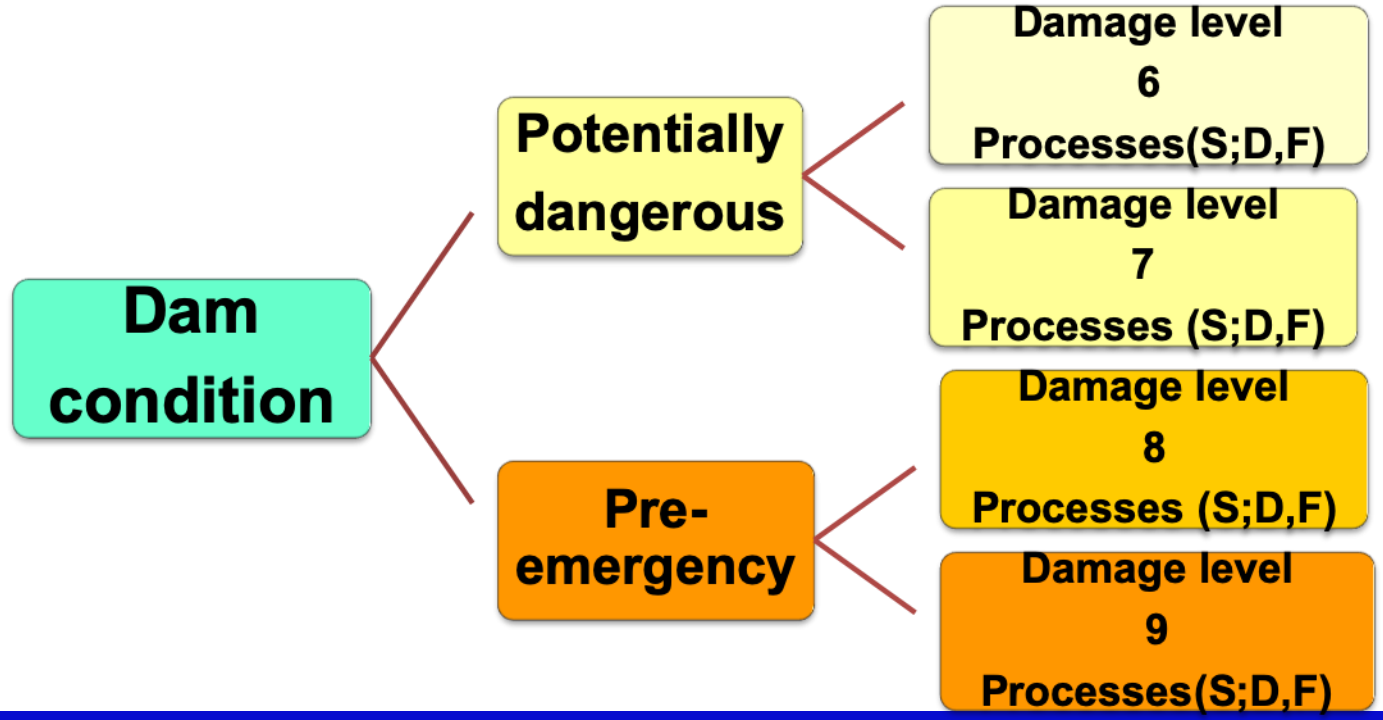


Methods presented in the report

The following methods are presented:

1) digitization of initial ordinal estimates of the dam condition;
2) formalized assessment of the condition for old dams;
3) assessment of the acceptable risk level.

Possible dam conditions (levels of damage and risk)



“Emergency" condition. Example

The achievement the level I = 5 corresponds to an "emergency" condition.

The process of transitioning the structure from the "pre-emergency" to the "emergency" condition clearly demonstrated, for example, by the recent (2017 year) accident at the 235-meter Oroville dam.

Database and the scale of damages

Dimensionless ordinal scale is used to assess the level of the risk in a deterministic approach.

A quantitative and qualitative assessment of both the initial information and the level of risk for the structure as a whole is carried out.

Condition Index I (from 0 to 6) is used as a deterministic measure of damage and risk.

Descriptive scale for assessing the condition of operating dams and damage levels (excerpt)

Potentially dangerous condition; Damage level: 8; Index Ie: 3,5–4,5

Achieving index I = 4 (criterion K2) by one or more diagnostic indicators.

S (filtration). Failure of a drainage system, concentrated exit of filtration water in local areas of the downstream slope or (and) side junctions of dams, signs of suffusion.

D (destruction). The lack slope stability, the development of processes of destruction of the crest and slopes of earth dams with the formation of numerous longitudinal and transverse cracks, local collapses and landslides. Wave processing of the upstream slope of the dams. Inadequate (below the design) excess of the dam crest or its anti-filter element over the normal top water. The presence of numerous damages, including associated with the pass of an off-design flow and excess of the verification calculated flow. Local slumping, erosion of the downstream slopes of earth dams, the formation of cracks, breaks approach floor and apron dam. The development of the process of reducing the effectiveness of cement curtain at the dam base.

F(flow) The need to pass the maximum design discharge at the level reservoir, exceeding the mark of the abnormal water level. End of the warranty period of service and the need to replace the lifting mechanisms of the gates. Limitation of the maximum design discharge due to partial failure of the spillways elements.

Recommended ranges* of initial estimates for I^e index				
Dam conditions	**Potentially dangerous**		**Pre - emergency**	
Damage levels	**6**	**7**	**8**	**9**
Ranges index I^e	**2,5 – 3,5**	**3 – 4**	**3,5 – 4,5**	**4,5 – 5**

***Ranges of initial estimates are assigned based on the surveys of about 180 objects.**

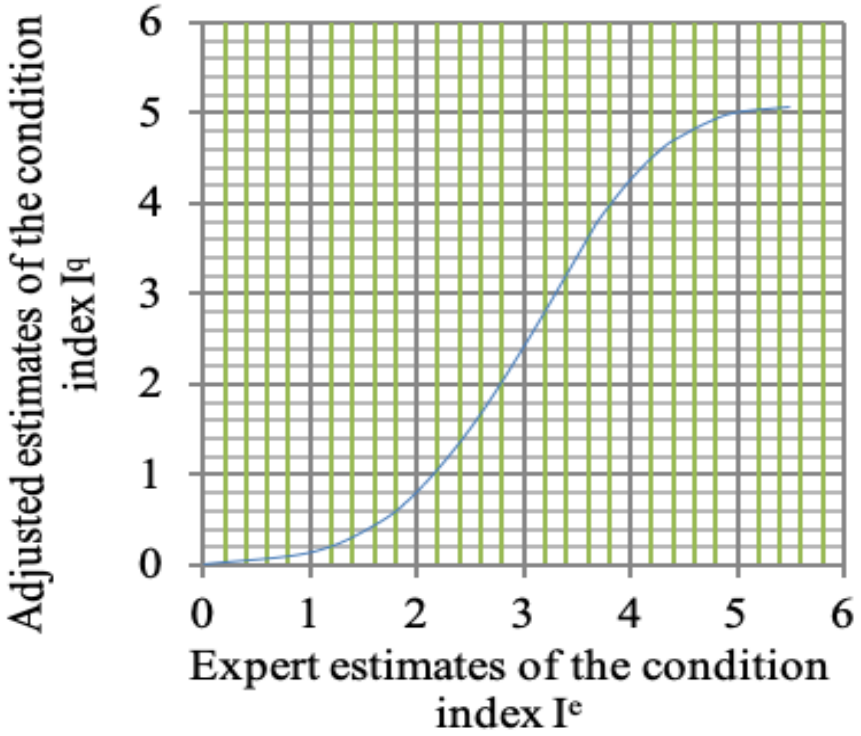
Digitization of initial ordinal estimates

The quantification (digitization) of the initial ordinal estimates of the index I is necessary, as is known, for performing mathematical operations. In this paper, the authors use a method of I.F. Shakhnov (Shakhnov, 2005) and his proposed formula:

$$V_p = \left[1 + \sum_{t=p}^{m-2} \prod_{k=t+1}^{m-1} \frac{1-r_k}{r_k}\right] * \left[1 + \sum_{t=1}^{m-2} \prod_{k=t+1}^{m-1} \frac{1-r_k}{r_k}\right]^{-1}$$

Digitization chart of expert assessments

The results of the calculation by the formula of I.F. Shakhnov are presented in the graph:



Combining initial information

The initial information is combined for condition indicators corresponding to the most “dangerous” of the entered states of the structure.

Within the same range, for calculating the index I, formula be used:

$$I = (I_{max} + q) - \prod [(I_{max} + q) - Ii] / [I_{max} + q) - I_{min}]^{n-1}$$

Examples of detailed assessment and classification of damage

Dam Damage	Possible dam conditions	Damage rank (level)	Average Assess ment index I	Damage code; description in the database of damage (destruction) or violation of the norm (project) requirements	Index I
Low Damage	Normal	2 - 5	1,22	3. Insufficient monitoring devices	2-2,8
				4. It is necessary to develop (specify) and approve safety criteria	2-2,5
Average Damage	Potentially dangerous	7	3,35	D.7.2.1*. Damage to the spillway: cracks, chips, shells (caverns), exposure of reinforcement on the picking beams, overflow face, gobies and apron	3,5-4
				F.7.3. Damage (low reliability) to gates and mechanical equipment of the spillway	3,8-4,2
Very severe destruction s	Pre-emergency	9	4,43	S.9.1. Outflows of water to the lower dam slope, sometimes with material removal	4-5
				D.9.1. High level and (or) increase in the intensity of deformation on base and crest of the dam	3,8-4,8
				D.9.3. Destruction of the fore apron and (or) downstream apron sections, breaks	4-4,6

** Decryption example damage code D.7.2.1: D* - violation of strength and stability*; 7- average damage level (rank) ; 2 - concrete (reinforced concrete) structures; 1 - spillway*

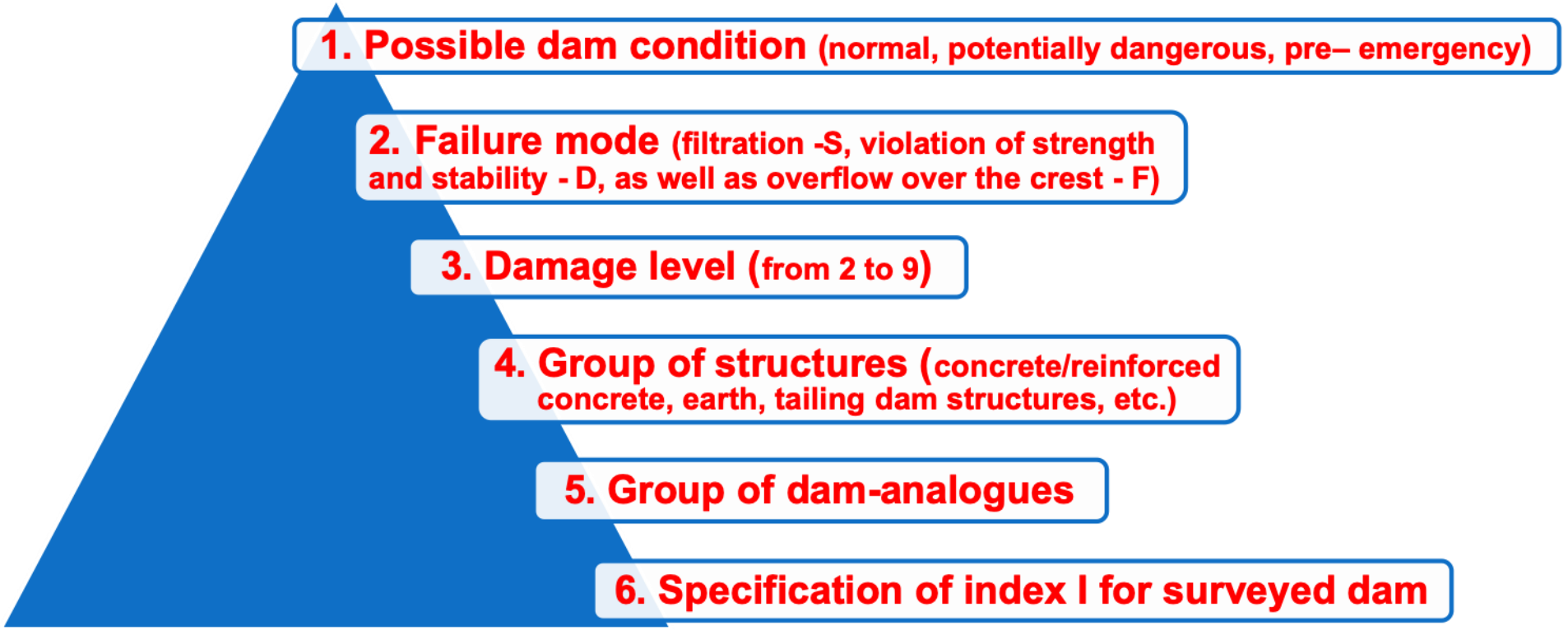
Options for estimating index I

Two options are possible for estimating index Ie for a specific dam.

Option A: damages of the surveyed dam are compared with descriptions of dam damages from the selected group and an analog dam is selected and the Ie index of the analog dam is assigned to the dam under investigation.

If it is not possible to select a suitable analogue, then option B is applied: a direct comparison of the dam condition with the aforementioned verbal description of the damages presented in the base.

Assessment of index I on the scale of damages



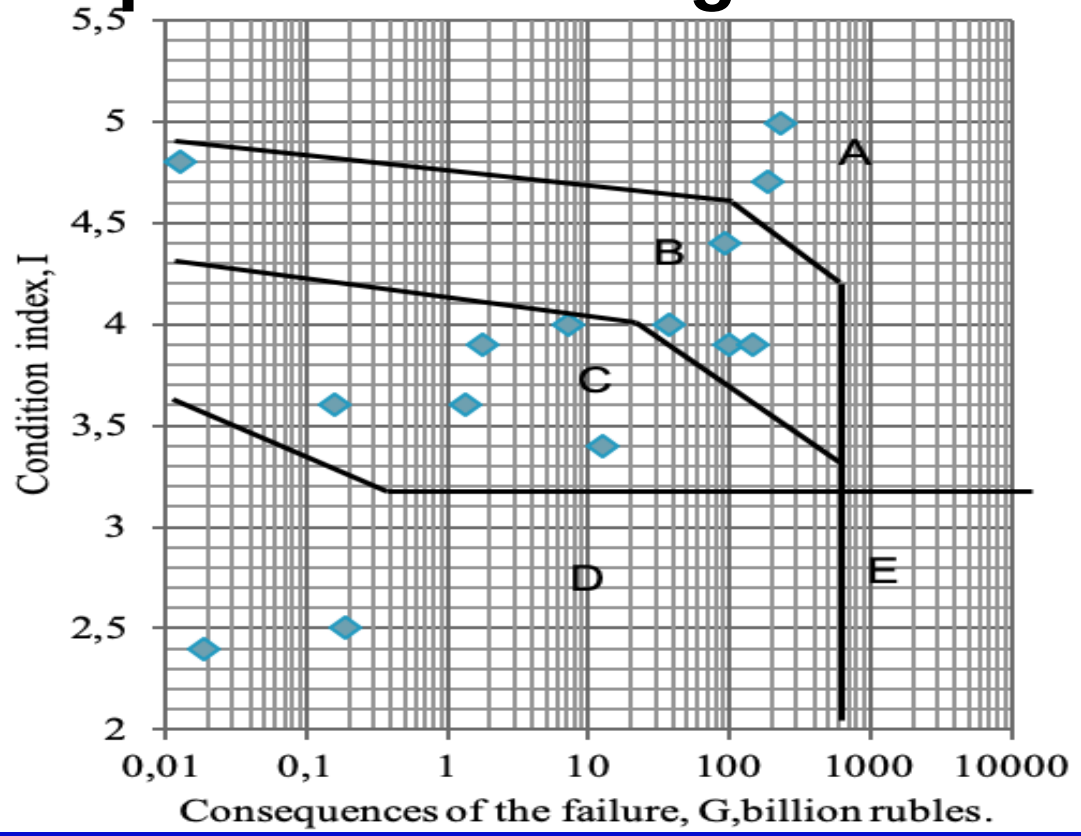
Dam condition and failure risk assessment

If the index is I > 3, it is necessary to analyze not only the dam condition, but also the consequences of a possible failure (G).

In this report, assessments of the acceptable level of risk are carried out on the basis of the “I - G” diagram.

When creating the chart, the results of surveys of 14 dams were used. (Estimates of damage from a possible hydrodynamic failure were made mainly by S.Ya. Shkolnikov).

Acceptable risk. Diagram "I - G"



Identification of risk areas

On the diagram "I - G", the experts identified the risk zones:

- unacceptable (A);
- elevated (B);
- conditionally acceptable (C);
- acceptable (D);
- acceptable for unique structures (E).

The boundary of the “unacceptable risk” zone is drawn through the “dangerous” zone, which presents data on I and G for the most damaged structures.

Application of the methodology

Practical application of the developed methodology is carried out in the course of the following types of work:

1. Commission inspection and monitoring of the operated dams' condition. The dam condition is assessed based on the application of the proposed condition index Ie and a descriptive database scale.

2. Expertise of project options and economic justification for the effectiveness of major repairs or reconstruction of the "old" structure.

CONCLUSION

1. A method is proposed for a formalized assessment of the condition and risk of old dams.

2. A ordinal scale is proposed for expert assessment of the dam condition I, and on its basis a database is formed.

3. The possibility of failures and possible damage to 14 dams was assessed. These data were used to illustrate the proposed methodology again to assess the acceptable risk of operated old dams based on for creating the "I - G" diagram ("failure possibility I - damage G").

ACKNOWLEGEMENTS

The authors are grateful
to
D.B. Radkevich and I.N. Ivashchenko
for providing initial information on the results of dam surveys.

Thank you for attention!