# METHODOLOGY FOR IDENTIFICATION OF LAKES DESTINED FOR LIQUIDATION IN THE REPUBLIC OF MOLDOVA

*Vasile GRAMA, Assoc. prof., Technical University of Moldova, gramavasile@yahoo.com*
*Ana VLASENCO, Lecturer, Technical University of Moldova, ana.vlasenco@gcg.utm.md*
*Agostino AVANZI, Hydraulic Engineer, Beta Studio srl, avanzi.agostino@gmail.com*
*Tommaso DOMINATO, Hydraulic Engineer, Beta Studio SRL,*
*tommaso.dominato.LP@betastudio.it*

***Abstract**: In the RM more than 6000 ponds and reservoirs have been built. The lifespan of them is usually 40-50 years. Considering that most of them were built in the years 1960-1980, many of them have an expired exploitation period and the others are at the limit of the exploitation period. Estimates show that, due to siltation the volume of reservoirs have decreased by an average of 0,50% per year. In result the ecological flow for the rivers, in special for the small rivers is critical. The purpose is to define the Criteria and a repeatable Methodology for lake liquidation and strengthening the capacities of the Moldovan Institutions to achieve a better management of the water and sanitation of the key stakeholders, improving their performance in implementing water and sanitation services in a sustainable, efficient and equitable manner. Based on the knowledge of the territory of the whole Republic of Moldova the following list of Criteria is used: lake size; safety condition; socio-economic development; ecology and environment. The methodology is mainly based expert judgment on GIS modelling involving geoprocessing of some specific parameters criterion by criterion. A Multi-Criteria Analysis is used to transform in "accumulated scores" the assessment done for each criterion in order to identified the possible lake to be liquidated.*

***Keywords**: ecological flow; lake liquidation; Multi-Criteria Analysis; GIS modelling;*

## 1. General introduction to dams and reservoirs

In the Republic of Moldova more than 6000 ponds and reservoirs have been built. Ponds are water storages of up to 1 million m³. Storages of water which have a volume bigger than 1 (one) million m³ are called reservoirs (**lacuri** de acumulare). [GD no. 977 of August 16, 2016].

The vast majority of ponds/reservoirs were built between 1960 and 1980, and their exploitable water volume has considerably reduced. In 1995, an inventory on the state of 1253 ponds/reservoirs was realized. As a result, the degree of risk was determined for settlements located downstream of dams in the case of failure (dam break). In the framework of *EPTATF 2013-2016, Management and Technical Assistance Support to Moldova Flood Protection Project - Service contract No TA2011038 MD EST* (TA-MDFRM 2013-2016), an assessment of dam break for several reservoirs have been also performed.

Important is that many of the ponds/reservoirs have been built with deviations from the standard construction rules (СНИП), with about 40% (visual inspections) of them creating a real risk to the population in case of dam break. The predominant height of the dams varies from 5 to 7 m. All ponds / reservoirs in the Republic of Moldova are designed and built for seasonal water regulation. The technical parameters of the hydrotechnical facilities should ensure the evacuation of the storm water discharge with the probability of 5% and 1%,

depending on the reliability of the construction. Dams were built mainly with clay situated, as a rule, in the immediate vicinity of the dams. Ponds/reservoirs were designed for irrigation, fish farming, potential water supply, power generation, soil erosion control and recreation purposes.

At the same time, it is established that the density of ponds and reservoirs in the Republic of Moldova is higher than the optimal one (depending on the intrinsic characteristic of the river catchment), as well as the density of ponds/reservoirs is uneven on drainage basins. The high density of ponds / reservoirs in a drainage basin in many cases reduces water flow in small rivers. Reducing the watercourse discharge means not ensuring the ecological flow, which in turn does not ensure the stable development of the river’s biodiversity.

The examinations of the current state of the hydrotechnical facilities of reservoirs/ponds (dam, spillway, bottom outlet) as well as their passports. The analysis showed the following:

- a large number of hydro-technical constructions of ponds/reservoirs are damaged;
- the lifespan of the ponds/reservoirs is usually 40-50 years. Considering that most of them were built in the years 1960-1980, many of them have an expired exploitation period and the others are at the limit of the exploitation period. Estimates show that, due to siltation the volume of reservoirs have decreased by an average of 0,50% per year [source World Bank].

Thus, the development of a methodology for assessing lakes/ponds appropriate to the situation in the Republic of Moldova becomes a priority, which can be a good contribution to the assessment of risks, the development of protection measures and the improvement of aquatic resources and rural development.

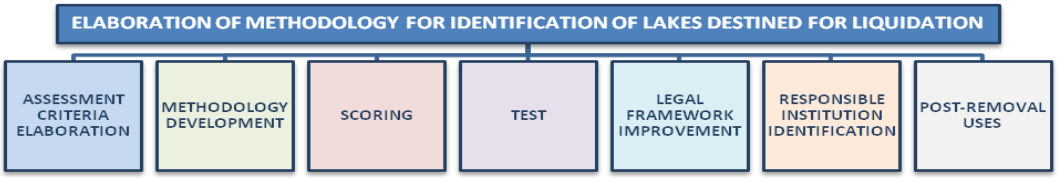



Fig. 1. Steps to flollow for elaboration of methodology for identification of lakes destined for liquidation

The overall purpose of the assignment is to define the Criteria and Elaborating a soundly based **repeatable methodology** to identify the **lakes** and **reservoirs to be liquidated**, enabling the Moldovan Institutions to regularly update criteria and methodology based on new needs (figure 1).

## 2. Legal Framework

In order to develop the methodology, it is necessary to identify the national legislative framework with direct or tangential involvement, which would allow the elaboration of the adjustment instruments, as well as the identification of the institution and the human resources responsible for the liquidation activities and the elaboration of the adjustment instruments of the national legislative framework.

At present, the field of water bodies management is regulated by a series of normative acts (laws and Government decisions). These normative acts do not directly or indirectly regulate the procedures of liquidation of the lakes but only have indirect applications. Preliminary analysis of the provisions of the normative acts listed below allows us to affirm that the legislation of the Republic of Moldova does not contain specific rules, regarding the liquidation of lakes, although such legislation, according to art.3, paragraph 2, letter b) that

the safety of the dams and other hydro-technical structures must be regulated by special laws. Which means that the construction, maintenance and, possibly, the liquidation of the dams and other hydro-technical structures must be subject to the regulation of an ordinary law. Currently, the rules regarding the protection dams are regulated by Government Decision no. 433 of June 18, 2012 "*For the approval of the Regulation on flood protection dams*". Also, the Government Decision no. 977/2016 regarding the approval of the Regulation for the exploitation of the accumulation lakes/ponds regulates the way of drawing up the regulation of the accumulation lakes/ponds and establishes the general criteria for exploiting the water accumulations, but its provisions are refer to lakes/ponds already built and put into operation. Thus, the construction and liquidation procedures are not regulated by ordinary special law.

The water law also states that when developing river basin management plans, consideration must be given to the assessment of flood risk and dam failure (art. 19) and classifies hydro-technical constructions into dams, flood protection dams, etc. and it produces the obligation to register and record the hydro-technical constructions through the Register of hydro-technical constructions, part of the State Cadastre of Waters.

According to the provisions of art.4 of the Water Law: "*The accumulation lake and the ponds are considered indivisible water bodies made up of the following goods: the land on which the water body is located, the river water protection strips and the hydro-technical constructions*". This means that when elaborating the regulations/methodology for the liquidation of the lakes, the complexity of the problems raised by the interconnection between the ownership of these goods, the fate of the protection strips and the hydro-technical constructions must be taken into account. However, without a complex approach to the normative framework, which is required to be amended, the achievement of the objective of liquidating the lakes cannot be achieved.

## 3. Criteria for lake liquidation

The main investigation is the definition of the set of Criteria for lake liquidation. The data and information collected on this domain refer mainly, as stated in the technical proposal, to the ones collected under the *Management and Technical Assistance Support to Moldova Flood Protection Project* funded by the EIB (2013-2016). By way of relevant sample were collected more than 11,700 very small/small/medium and large lakes (including pools and ponds) on the whole territory of the Republic of Moldova by digitising the water surface on ortophoto. The latter one layer was used and processed for hydraulic purposes verifying its consistency with the actual situation on the ground. An assessment of the data quality was also carried out and obtained from the data owner. The result of this assessment was recorded to ensure that data quality is taken into account when using the data to undertake tasks.

Additional information has been captured by *Moldova Map* (https://moldova-map.md/mapstore/#/) featured by INGEOCAD and by the "*"The Institute of Designs for the Organization of the Territory*" – IPOT (http://soluri.md/adapt/dist/#/layers). Based on the studies and the knowledge of the territory of the whole Republic of Moldova given by the involved national experts and, of course, by the aforementioned available data and information, the following list of Criteria is propose:

1. **Lake Size;**
2. **Safety condition**;
3. **Socio-Economic development**;
4. **Ecology and Environment**;

The Criteria cover a wide range of aspects and are being proposed in order to be as much objective (tangible) as possible. Each criterion has been then split in a set of sub-criteria deemed necessary for a better development of the subsequent methodology and in order to reach the sought results (*Table 1).*

Table 1. List of Criteria and sub-criteria for each criterion

| CRITERIA | SUB CRITERIA |
|---|---|
| **LAKE SIZE** | RESERVOIR'S SURFACE |
| **SAFETY CONDITION** | DAM CASCADE EFFECT RISK |
| | SEISMIC INDUCED DAM BREAK RISK |
| | FLOOD STORAGE VOLUME (for flood risk reduction) |
| | DAM RELIABILITY |
| **SOCIO-ECONOMIC DEVELOPMENT** | IRRIGATION |
| | AQUACULTURE |
| | WATER SUPPLY |
| | RECREATION |
| | HYDRO POWER POTENTIAL PRODUCTION |
| | ROAD CONNECTION |
| **ECOLOGY & ENVIRONMENT** | EVAPOTRANSPIRATION |
| | LAKE SILTATION DUE TO CATCHMENT EROSION |
| | ECOLOGICAL FLOW |
| | PHYTOREMEDIATION |
| | RIPARIAN RESTORATION |
| | AQUIFER RECHARGE |

Given the ecological importance and implications of riparian areas, and stated that many of the constructed dams in Moldova have changed the natural habitats, restoring ecosystems, especially in the natural protected areas of the country, should be pursued through dam removal. In this perspective, dams that are located within protected natural areas or ecologically important zones should be liquidated, leaving riparian vegetation the possibility of restoring.

## 4. Methodology for lake liquidation

This represents a "*desk study and analysis*". The methodology is mainly based expert judgment on GIS modelling involving geoprocessing of some specific parameters criterion by criterion. Nevertheless, the GIS based approach is commutable and switchable to a manual approach as the methodology has been thought to be easily repeatable enabling the final users of the Moldovan Institutions to regularly update criteria and methodology based on new needs.

The important aspect is criteria assessing and scoring. As is mention, the criteria cover the physical aspect of the lakes, the safety condition of human being, proprieties and goods, the socio-economic issue and the ecological and environmental aspects. The methodology intends to undertake the assessment by scoring each sub-criterion for each lake. The overall scores will then be sum ("accumulated") and properly weighted by means of the Multi

Criteria Analysis (MCA). The lower the score for a lake for each sub-criterion, the higher the tendency to be liquidated.

A Multi-Criteria Analysis is used to transform in "**accumulated scores**" the assessment done for each criterion in order to identified the possible lake to be liquidated. The Consultant believes that this is the best way to approach the evaluation because it permits the assessment of all benefits and impacts including those that are difficult to quantify or are intangible, by means of weights. This approach also has the benefit of offering greater transparency to the decision-making process. The MCA process is carried out as follows:

1. determine a proper weighting of each criterion;
2. calculate the total score for a lake and undertake sensitive analysis;
3. interpretation of scores and final analysis.

Relative numerical weights will be assigned to the criteria. There is a risk that this could become very subjective, and it is therefore important to ensure that stakeholders agree with the proposed weightings and understand the implications. The weight can be adjusted region by region. The criteria have been chosen on the basis of their completeness, consistency and no-redundancy so that they constitute a coherent whole, resulting in plausible and non-disputable findings.

Table 2. Proposed weights for the MCA criteria.

| ***Criteria*** | ***Weight*** |
|---|---|
| Lake Size | **1** |
| Safety condition | **4** |
| Socio-Economic development | **2** |
| Ecology and Environment | **3** |

The weighted scores for each sub-criterion obtained in the methodology will be aggregated in next step of the MCA in order to obtain a single score for each lake taking account of the weightings for each of the criteria. This is done through adding the scores of each sub-criterion belonging to the same main criterion and then weighting the sum by means of the main criteria weights (Table 2). The weighted scores for each main criterion are then added ("accumulated"), obtaining the final score for the reservoir.A further step will be a sensitivity analysis that will examine the impact of modifications to the weights applied for each criterion. This will identify how robust the results are to changes in assumptions. The sensitivity analysis will be particularly important when the data are uncertain. In this final stage the following will be evaluated: whether the results are stable and reliable / whether the differences in scores are significant / and the meaning of the results. After the MCA calculation, the lower the final accumulated score for a lake, the higher the tendency to be liquidated.

The MCA method is a high level way of identifying the best scoring for the lakes to be liquidated. It creates the methodological base in order to promote a regionalised approach. However different weights options may be preferred for individual districts within a river basin. The results from the analysis should, therefore, be considered as a guide to the best weighting. Indeed, the methodology is based on tangible objectives and define the grade of liquidation of a lake. The procedure and the institutional engagement for the liquidation is not part of the methodology but is part of the institutional and legal aspects coming next.

## 5. Pilot river basins – Test

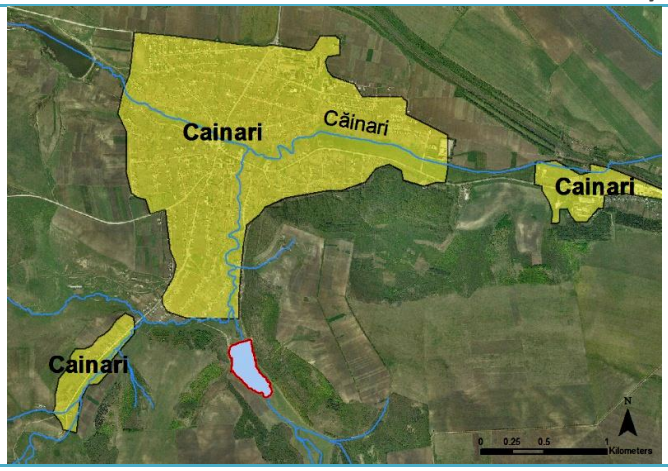
A list of lakes all around the country of Republic of Moldova was selected in order to test the methodology. Together with the test results, that will be exposed in this document,

excel files related to each particular pond/reservoir analysed will be part as well of the deliverable.

The methodology's procedure is really easy to apply and it reduces the subjectivity in the analysis of the positive and negative aspects of each lake, as the criteria and sub-criteria have been chosen on the basis of their completeness, consistency and no-redundancy. The only possibility to make the analysis more subjective is to change the weights of the criteria in the final score assessment. This could be done if a different approach, based on changed needs or conditions, is preferred for a particular river basin or district.

The main difficult that was found during the methodology's test is related to the availability of dam's information. In fact, most of the dams don't have a passport, or if they do it is not known whether it is updated or not. The same consideration can be done for the dam's condition, as the information in the database provided by "Apele Moldovei" are not comprehensive. In such perspective, gaps related to data's availability can be filled through detailed topographic surveys of the dam's body that are already being carried out by a private company. Some examples for real reservoirs is presented below.

| DISTRICT | BASIN - SUB BASIN - RIVER |
|---|---|
| Causeni | **Nistru - Botna – Tributary of Căinari** |



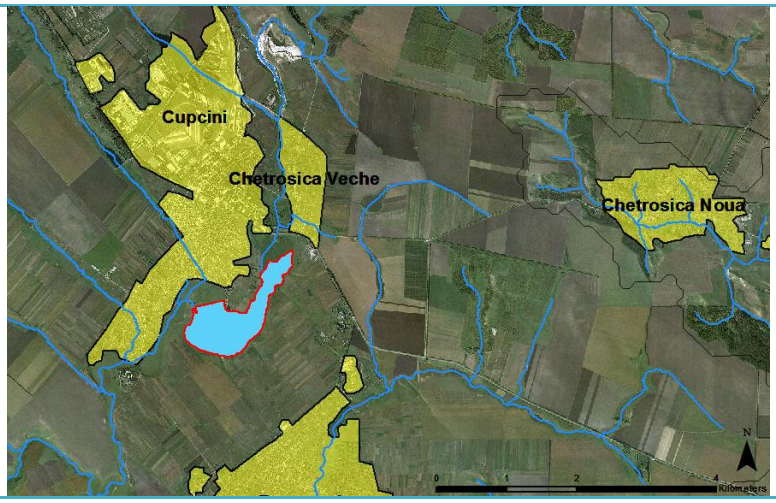

| Lake surface [ha] | Average Depth [m] | Passport / Dam condition / Operating Rules* |
|---|---|---|
| 7.5 | **3.15** | **Not existing / Satisfactory / Not existing** |

** Source of information Apele Moldovei Database*

| CRITERIA | SUB CRITERIA | WEIGHTED SCORE |
|---|---|---|
| **LAKE SIZE** | RESERVOIR'S SURFACE | -1.5 |
| **SAFETY CONDITION** | DAM CASCADE EFFECT RISK | -1 |
| | SEISMIC INDUCED DAM BREAK RISK | -1 |
| | FLOOD STORAGE VOLUME (for flood risk reduction) | 3 |
| | DAM RELIABILITY | -4 |
| **SOCIO-ECONOMIC DEVELOPMENT** | IRRIGATION | 3.75 |
| | AQUACULTURE | 5 |
| | WATER SUPPLY | 0 |
| | RECREATION | 2.5 |
| | HYDRO POWER POTENTIAL PRODUCTION | 0 |
| | ROAD CONNECTION | 1 |
| **ECOLOGY & ENVIRONMENT** | EVAPOTRANSPIRATION | -3 |
| | LAKE SILTATION DUE TO CATCHMENT EROSION | -5 |

| CRITERIA | SUB CRITERIA | WEIGHTED SCORE |
|---|---|---|
| | ECOLOGICAL FLOW | -0.5 |
| | PHYTOREMEDIATION | 0 |
| | RIPARIAN RESTORATION | 1 |
| | AQUIFER RECHARGE | 0 |
| | **FINAL ACCUMULATED SCORE** | **-11.5** |

| DISTRICT | BASIN - SUB BASIN - RIVER |
|---|---|
| Edinet | **Prut – Ciuhur – Ciuhur** |




| Lake surface [ha] | Average Depth [m] | Passport / Dam condition / Operating Rules* |
|---|---|---|
| 84.0 | **1.3** | **Not existing / Unknown / Not existing** |

** Source of information Apele Moldovei Database*

| CRITERIA | SUB CRITERIA | WEIGHTED SCORE |
|---|---|---|
| **LAKE SIZE** | RESERVOIR'S SURFACE | 2.5 |
| **SAFETY CONDITION** | DAM CASCADE EFFECT RISK | -1 |
| | SEISMIC INDUCED DAM BREAK RISK | -1 |
| | FLOOD STORAGE VOLUME (for flood risk reduction) | 3 |
| | DAM RELIABILITY | -5 |
| **SOCIO-ECONOMIC DEVELOPMENT** | IRRIGATION | 0.75 |
| | AQUACULTURE | 3.75 |
| | WATER SUPPLY | 0 |
| | RECREATION | 5 |
| | HYDRO POWER POTENTIAL PRODUCTION | 5 |
| | ROAD CONNECTION | 1 |
| **ECOLOGY & ENVIRONMENT** | EVAPOTRANSPIRATION | -1 |
| | LAKE SILTATION DUE TO CATCHMENT EROSION | -3 |
| | ECOLOGICAL FLOW | -1.5 |
| | PHYTOREMEDIATION | 2.5 |
| | RIPARIAN RESTORATION | 1 |
| | AQUIFER RECHARGE | 0 |
| | **FINAL ACCUMULATED SCORE** | **11.5** |

## 6. Conclusions

The methodology is mainly based expert judgment on GIS modelling involving geoprocessing of some specific parameters criterion by criterion. Easy to apply and it reduces the subjectivity in the analysis of the positive and negative aspects of each lake, as the criteria and sub-criteria have been chosen on the basis of their completeness, consistency and no-redundancy. The only possibility to make the analysis more subjective is to change the weights of the criteria in the final score assessment. This could be done if a different approach, based on changed needs or conditions, is preferred for a particular river basin or district.

## 7. References

1. *Eastern Partnership Technical Assistance Trust Fund (EPTATF) 2013-2016, Management and Technical Assistance Support to Moldova Flood Protection Project - Service contract No TA2011038 MD EST.*
2. *Official document from Institute of Geology and Seismology of Republic of Moldova, 2014.*
3. *Zubcov, E., Curcubet, G., Biletchi, L., Domanciuc, V., Usatii, M., Barbaiani, L., Kovács, É., Moth-Poulsen, T. & Woynarovich, A. 2013. Review of fishery and aquaculture development potentials in the Republic of Moldova. FAO Fisheries and Aquaculture Circular No. 1055/3. Rome, FAO. 93 pp.*
4. *William R. Sutton & Jitendra P. Srivastava & James E. Neumann & Ana Iglesias & Brent B. Boehlert. "Reducing the Vulnerability of Moldova's Agricultural Systems to Climate Change: Impact Assessment and Adaptation Options" World Bank Publications, The World Bank, number 16199, June 2013.*
5. *International Land Coalition, 2018. Promoting people-centred land governance, NES Republic of Moldova.*
6. *International Land Coalition. Training of water users associations for irrigation for more sustainable land and water management, Case Study Moldova.*
7. *THE WORLD BANK Sustainable Development Department Europe and Central Asia Region, May 2007. Rural Productivity in Moldova – Managing Natural Vulnerability.*
8. *Gheorghe Duca. Management of Water Quality in Moldova. Water Science and Technology Library, Springer, 2014.*
9. *Adrian Piticar, Dumitru Mihăilă, Liliana Gina Lazurca, Petruţ-Ionel Bistricean, Anatolie Puţuntică, Andrei-Emil Briciu. Spatiotemporal distribution of reference evapotranspiration in the Republic of Moldova. Theoretical and Applied Climatology, 2015.*