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BEHAVIOR OF SĂCELE DAM FROM BRAŞOV COUNTY IN PERIOD 03.2018 - 05.2020

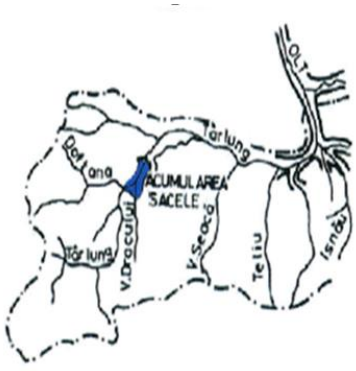
Vasile MĂNĂILĂ [1] Albert Titus CONSTANTIN [1] Marie-Alice GHIȚESCU [1]

Abstract: The paper has as objective the analysis of the behaviour of the Săcele Dam from Brașov County in the period 03.2018 - 05.2020, [11,12,14,15,16,17]. During the analysed period, two events were registered in operation, namely: the flood from March 13 to 16, 2018, which led to an increase in the level in the reservoir to 745.82 maSL; and the flood during June 24 - July 5, 2018, when the maximum level was registered as 745.91 maSL (July 1, 2018). The overall behaviour of the work, throughout the operation was in accordance with the nature and size of the requests and were within the limits of evolution below the accepted values. The visual observations did not reveal any elements that would lead to a reduction in the safety of the objects or restrictions on operation. The operation restrictions are due to the non-achievement of the DN1A national road overhang. The hydro-mechanical equipment in the retention front of the arrangement had a normal behaviour during the analysed period, without major events or accidents. The planned tests were performed. By processing the photographic images collected during the visual observations, an attempt was made to highlight the evolutionary phenomena of the work.

Keywords: dam behaviour, measurements, flood events

1. GENERAL CONSIDERATIONS

The Săcele accumulation is made by a dam made of earth fillings with a clay core with a height of 50 m. Other objects of the arrangement are: the large water drain located on left bank and the outlet tower that controls access to the bottom drain and gallery, both located on the right side.



B.H Târlung (F = 166 km²)

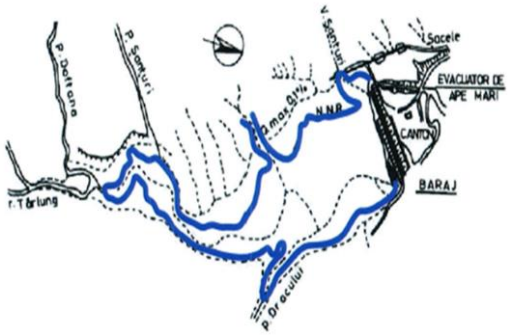


Figure 1. Dam displacement and plan view in Brașov County

Săcele reservoir has been designed to perform the following main functions, [1]:

-industrial and drinking water supply of Brașov municipality (ensures the delivery of 1650 l / s for the canopy Level 745.00 maSL)

-flood wave attenuation.

As a secondary function, the dam also ensures the production of electricity through Small Hydropower (SHP) Târlung I, which turbines the water of the treatment plant. Due to the rapid development of the Municipality of Brașov as well as other settlements in the area, the water requirement exceeded the initial provisions, and it was necessary to raise the dam according to some schemes that had been provided by the initial design. According to STAS 4273/83, at the initial design, the dam was classified in the 1st class of exceptional importance, for which the calculation flow $Q_{0.1\%}$ = 406 m^3/s and the verification flow $Q_{0.01\%}$ = 575 m^3/s resulted.

At the date of publication of Normative Technical Regulation NTLH-021/1998, [4], an associated risk index RB = 0.69 was calculated according to which the Săcele dam falls into category A of exceptional importance, for which the legislation in force requires a special monitoring of behaviour. The follow-up project developed together with the general project corresponds to the requirements of the current legislation for this category of importance. The implementation of the uplift project made it necessary to update the existing monitoring project.

As a result of this consideration, the dam is equipped with measuring and control devices for

[1] Politehnica University of Timișoara, Department of Hydrotechnical Engineering, Spiru Haret Street, no. 1A, 300022, Timișoara, Romania, vasile.manaila@student.upt.ro , albert.constantin@upt.ro

external loads, respectively for the supervision of constructions and their foundation.

Figures 2 and 3 show the arrangement of significant measuring and control devices (MCD) for the plan view of the dam, respectively from its cross section.

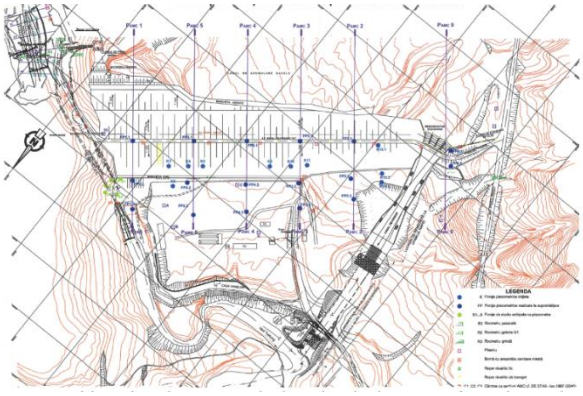


Figure 2. Plan View of the Dam and MCD Displacement.

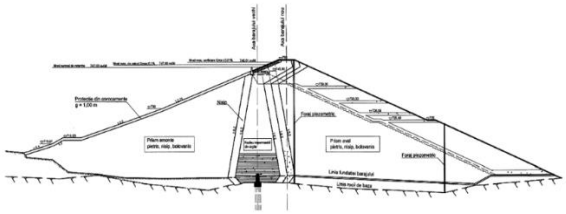


Figure 3. MCD Displacement in Main Dam Cross Section

The measurements performed on the measuring and control devices of the dam are analysed and interpreted by means of known mathematical methods. The interpretation of the data collected through the system of monitoring and direct inspections is necessary to assess the safety of the work. The basic models used for the interpretation of data obtained from dam surveillance are currently of several types: deterministic, statistical, based on neural networks, hybrids, etc [5].

2. FOLLOW-UP BEHAVIOUR IN TIME

Both, during the operation and during the elevation works, a series of changes took place which have repercussions in the follow-up of the behaviour of the works [3,4,6]. The current special monitoring project has the role of including in a single documentation the situation of the constructions after the elevation works, the existing tracking system and the necessary completions, the way of carrying out the tracking during the transition to the new Normal Retention Level (NRL). When compiling the documentation, the provisions of the legislation in force were taken into account and in particular the provisions of normative P130 / 1999, respectively of chapter 4 "Special monitoring of construction behaviour", Article 11, which establishes the content norm of the special monitoring project.

Because the necessary measuring devices have already been provided in the DE projects of the various component objects (including the specifications required for installation), the documentation emphasizes the tasks of the supervisory operating staff: collecting, storing, processing and interpreting information to behaviour of the work, [8].

All these modifications of the time tracking system of the Săcele dam have been analysed and approved by the Construction Behaviour Monitoring Commission attached to National Administration of Romanian Waters (ANAR) and do not change the character of "special tracking" of the work.

2.1 CONSTRUCTION RESPONSE TO LOADS

Infiltrations through the foundation ground and through the dam body. Increasing the level of under-pressures influences the stability of constructions or slopes. Infiltration currents can cause internal erosion, suffusion. Both the piezometric level and all the sources of water filtered or drained at both the dam and the slope are monitored. Deformation of the dam and the slope can be a signal of instabilities. Particular attention is paid to the movements of the right slope. A knowledge of the actual volume of the reservoir is required in order to be able to establish the operating regime. Clogging at the tail of the reservoir can influence the eddy and eventually lead to flooding of land during floods. The monitoring of the clogging as well as the eventual erosions of the riverbed will be done by bathymetrical surveys.

2.2 EXTERNAL SHEAR STRESS

-level in the reservoir: whistle probe at the tower;
-air temperature: thermometer;
-precipitations: rain gauge;
- inflows measured at Babarunca gauging station, where an analyser from the DESWAT program was installed. DESWAT system is short for DEStructive WATers. WATMAN - National Informatic System for Integrated Water Management, Stage I. is a national project whose goal is to protect the population by offering a modernized and appropriate infrastructure to prevent floods, in order to mitigate their destructive consequences, [9].

Through the DESWAT program in the intake tower was installed the data analyser that instantly displays the water level in the reservoir, temperature, Ph, conductivity, salinity and dissolved oxygen in the water in the reservoir. Communications are made by UHF and GSM radio to the Brașov Water Company and Water Management System (SGA) Brașov.

The Ministry of Environment and Sustainable Development provided the SĂCELE dam within two programs for the implementation of an integrated information system that would allow an operational operation of the accumulation in the "Romanian Waters" Administration that takes into account the hydrological and hydro-meteorological forecast (DESWAT and WATMAN), [10].

2.3 STRUCTURES REPLAY TO THE EXTERNAL SHEAR STRESSES

Dam

Existing piezometers are free-level piezometers equipped with a PVC pipe and a filter area protected with geotextile. Their location is shown in plate 2.

Out of the total of 33 boreholes, a number of 7

remained from the old piezometers, 5 pieces from the bottom emptying area are study boreholes transformed into piezometers, and the rest are new piezometers, which were executed in stages, together with the elevation dam works.

The piezometers in operation in July 2010 are listed in the table. The order is from the right slope to the left and from the crown to the downstream. The study boreholes, grouped downstream around the bottom emptying are passed separately, at the end of the table. Drillings that are currently dry (where the water level is below the bottom) are kept under observation because it is possible that with the rise of the accumulation level, the water level in the borehole will appear. Most piezometers have water at depths below 30 m. With a water level over 30 m there is only 1 piezometer, located on the canopy of the dam, in the riverbed area.

Ex-filtrated flows

There were three water springs downstream of the dam, on the right bank of the rapid channel where the flows were measured during the first period of operation. The origin of the accumulation could not be highlighted. The rehabilitation works of the rapid canal also include the capture and arrangement of these springs, thus ensuring the possibility of resuming the measurements.

The gutters at the base of the downstream slope together with the respective manholes are intended to collect and evacuate water from precipitation. It is not necessary to perform flow measurements. However, observations are needed. If permanent flows are found, measuring points will be arranged.

Dam movements

The geodetic tracking network of movements includes both the dam and the intake tower and the right slope. Following the reshaping works of the slope, some of the terminals and landmarks were destroyed. The network will have to be redone and the determinations restarted with the expected frequency. We emphasize that level measurements are mandatory for all types of structures, even in the case of current tracking.

Reservoir's behaviour and downstream diversion

Bathymetrical measurements will be performed to monitor the evolution of the clogging and the volume available in the accumulation reservoir. At present, due to the facilities offered by GSM, it is not considered necessary to materialize the lifting profiles in the field.

No bathymetrical survey has been carried out so far. In view of the completion of the elevation works, it is necessary to decide before increasing the level of accumulation.

Periodic lifts of characteristic downstream riverbed profiles are also required.

The right slope. Infiltrated and drained flows

All sources of infiltrated or drained flows are monitored by weekly observations. The drains executed in the galleries have very low flows, which are activated during precipitation. Flow measurements will be made at all sources where a continuous flow of water is noticed.

There are 14 drains at G1, 12 drains at G3 and 12 at G2. Flow measurements were made only at gallery G1, both individual flows and total flows.

The horizontal drains performed at the base of the steps are also included in the program of measurements and observations if they flow: on stage II, on stage III (out of 9 completed they debit 3) and on stage IV (out of 25 completed they debit 6).

The gutters at the base of the slopes are made to take over the rainwater. They are followed by observations. No flow measurements are made.

Displacements measured with rock-meters. To follow the movements on the right slope there are the following rock meters (in order of installation):

-Rock-meter from the access walkway to the intake tower, next to the walkway support at elevation approx. 746.00 maSL. It has 3 invar rods with lengths of 9, 24 and 36 m;

-Rock-meter from the G1 drainage gallery, with 2 invar rods with lengths of 42 and 48 m;

-Rock-meter on the anchor beam, near the G1 gallery, with 4 fiberglass rods, with lengths of 15, 30, 45 and 61.3 m.

Displacements measured with dilatometric clamps in the joints of the concrete rings of the G1 gallery. There are 5 dilatometric clamps mounted in the joints of the G1 gallery in which movements were observed in 2001. After the rehabilitation of the G1 gallery the clamps were reassembled.

Geodetic measured displacements in the geodetic slope tracking network, require rehabilitation to complete the terminals.

The World Bank-funded program on "hazard risk - landslide component" provides for the following measuring devices.

-2 piezometric boreholes with depths of 50 m, equipped with cells for level monitoring.

-2 sloping boreholes with depths of 60 m, equipped in the lower half with borehole inclinometers.

The results of the measurements are transmitted directly wirelessly to Water Management System (SGA) Brașov and to the Ministry. It is necessary for the dam owner to complete the necessary protocols to ensure the inclusion of the results of these tracking systems in the information circuit regarding the behaviour of the dam.

3. SĂCELE DAM BEHAVIOUR FOR THE PERIOD MARCH 2018 - MAY 2020

The report includes a summary of observations, measurements between March 2018 and May 2020, as well as an interpretation of the results in terms of the safety of the Săcele dam. The report is prepared according to the "Framework content of the annual report" (Annex 2.a. to the Regulation on the organization and functioning of the activity of the tracking behaviour of constructions over time (UCC) Commission - Decision no. 22 / 12.01.2006).

During March 2018 - May 2020, [11,12,14,15,16,17] 2 events were registered in operation, namely:

-the flood from March 13 to 16, 2018, which led to an increase in the level in the reservoir to 745.82 maSL;

-the flood during June 24 - July 5, 2018, when the maximum Level was registered was 745.91 (July 1, 2018). During the analysed period (March 2018 ... May 2020), the minimum registered Level was 736.56 (January 23, 2019), the maximum Level was 745.91 (July 1, 2018), and the registered average was 740.98 maSL.

The maximum annual variation was approx. 8.73 m in 2018, 7.05 m in 2019 and 4.91 m in January - May 2019.

The annual rainfall in 2018 and 2019 (919.3 - 2018, respectively 826.8 - 2019) was above the average measured at the site (798.3 l / m^2).

Precipitation over 40 mm / day was recorded in March 2018 (47.9 mm / day) and June 2018 (50.1 mm / day).

At the transit of the flood from March 13 - 16, 2018, it was observed:

At the setting tower, the exfoliation of the plaster on the outer face was reported when the platform level was exceeded at the level of 745.50 maSL.

On the fast channel of the high-water discharger, at the upstream end of the rehabilitated area, at the discharge, some existing super concrete plates detached upstream from the old area with increased roughness. Under the detached slabs remained the concrete surface of the original screed. It is finished and there are no bare fittings.

At the transit of the flood from June 24 - July 5, 2018, it was observed:

-the measurements undertaken on UCC, used to monitor the right bankside, included in the WATMAN program, demonstrated a good behavior of the slope and allowed the exploitation of the reservoir advantageously to facilitate the intervention of the SHP outlet cofferdam. From the analysis of the piezometric level in the MCD 6 and 7 WATMAN profiles, located in the vicinity of the bottom outlet from the right bankside, it resulted that between June 28 and July 7 2018 they had a normal evolution, in accordance with the external demand, given by the reservoir level.

On June 30, 2018, a large flow of water over the top of the reinforced concrete wall of the rapid canal was observed on the left bank of the fast canal from the large water drain. The source of the leak was the downstream end of the SHP Târlung 2 pipeline (approx. 50 m downstream of the gutter at the foot of the homogeneous dam) with a regressive erosion upstream. The area was monitored, as the level in the reservoir was rising.

In emergency mode, on first of July 2018, after the decrease below the level of the overflow threshold, the intervention works started.

Simultaneously with the intervention works, the level in the reservoir was lowered.

It should be noted that during this incident, the operational safety of the Săcele dam was not affected.

Between June 28 and July 7, 2018, the sensors installed through the WATMAN program were particularly useful for monitoring the behaviour of the Săcele Dam, because they allowed quick access to the information needed to make correct and quickly decisions.

According to the hydrological study from 2018, conducted by the Hydrology service within the Romanian Water Authority, Olt Basin Management (A.B.A.), [7], (volume of the flood with the probability of 1% is $W_{1\%}$ = 22.7 hcm), it results that the flood from June 29 - July 5 2018 corresponds to a maximum flow with the probability of occurrence of approx. 1 %.

The measurements performed on the measuring and control equipment used to monitor the right slope, included in the WATMAN program, demonstrated a good behaviour of the slope, and allowed the operation of the reservoir advantageously to facilitate the intervention of the SHP.

From the analysis of the piezometric level in the MCD 6 and 7 WATMAN profiles, located in the vicinity of the bottom drain from the right slope, it resulted that between June 28 and July 7, 2018, they had a normal evolution, in accordance with the external demand, given by the accumulation level.

It is also specified that during 2019 reinforcement works were carried out for the SHP Târlung II outlet.

Operating personnel check the operating condition of all hydro-mechanical equipment on a monthly basis. All manoeuvres, breakdowns, overhauls and repairs are recorded. The UCC system and the current safety assessment activity have undergone changes due to the dam lifting works. By implementing the WATMAN data acquisition and transmission system in 2015, it is considered that the UCC system is sufficient to assess the operational safety of the work.

The assessment of structural safety is based on data measured in the MCD system.

Piezometric levels. The piezometric level was tracked through a network of 33 piezometers to which another 12 piezometers were later added through the WATMAN program (8 equipped with interstitial pressure cells and 4 equipped with piezometric cells). There is a clear dependence on the level in the reservoir, observed at large level variations. The effect of precipitation overlaps with this dependence.

Infiltrated debts. The total flow drained by the G1 gallery was 52.1 l / min, maximum values recorded in June 2018.

Relative displacements. During the analysed period, no atypical variations were found for the dilatometric clamps from the G1 gallery, the annual deformation rate being between 0.2 - 1 mm / year.

The relative displacements of the right slope, measured at rock-meters, register insignificant variations. Measured displacements at the rock meter at the end of gallery G1 confirm that behind the breccia area, the rock is stable. The rocker on the anchor beams next to the G1 gallery, which came into operation in March 2011, shows a normal operation.

Absolute displacements are measured geodetically. The last series of measurements was performed in November 2019. The vertical displacements of the dam show a tendency to dampen over time. On the downstream slope the settlements have normal distributions, are proportional to the height of the fillings and almost stabilized. On the right side, even if they have low values, the measurements show clear movement trends.

In the area of the right slope, halfway between the dam body and the access walkway in the intake tower, near the last two prefabricated breakwaters, below the level of the access road to the right slope (elevation 750.00), there was a landslide of approx. 12 m long and approx. 0.5 m depth measured at the upper level. The landslide extends from the upper level to the depth, below the water level, and to visualize the base of the landslide it is necessary to lower the level in the reservoir. In the same area there was previously, at 743.00, the detachment of some rocks that stopped in the vegetation grown on the shore, tilting it towards the water. At the moment, the existence of vegetation below the water level is no longer observed.

Operating personnel check the operating condition of all hydro-mechanical equipment on a monthly basis. All manoeuvres, breakdowns, overhauls and repairs are recorded.

4. EVOLUTION OF THE MEASURED PARAMETERS

The March 2018 flood event was caused by heavy rains. The maximum tributary flow was 41.21m^3/s. The hourly evolution of the tributary flow and the outflows discharged through the bottom outlet and pumping station are illustrated in Table 1.

Table 1. Inlet and outlet flood flows – March 2018

Data	Reservoir level (maSL)		Q inflow (mc/s)	Q outflow (mc/s)	Q bottom outlet (mc/s)	Q pump (mc/s)
	8h	14h				
13	743.74	743.9	6.66	3.26	1.87	1.38
14	745.53	746.0	41.21	11.27	9.84	1.43
15	745.75	745.63	19.84	16.06	15.0	1.06
16	745.18	744.88	11.55	21.31	40.42	0.89
17	744.19	743.87	10.03	26.62	25.86	0.79
18	743.21	743.11	7.50	23.43	22.57	0.86
19	743.22	743.25	8.50	8.34	7.42	0.92

The Maximum Retention Level reached for the first time the 746.00 maSL. The discharge over the spillway (745.00 maSL) started through all four openings. The flooding volume was 18.6 mil. Cm. In Figure 4 are illustrated the March flood event hydrographs.

The S.G.A. Brașov report also mentions:

- At the electrical drive, malfunctions were found when starting the pumping units, due to the lack of voltage at the control buttons. An inspection was carried out to check all the contacts, tighten them and lubricate them with contact spray, following which the non-conformity will be accurately identified at the subsequent occurrence of the defect.

- The manoeuvre for lifting the valve from the bottom emptying carried out on 13 of March.2018, at 18:00, to supplement the discharged flow from 5.5 m^3 / s to 16.5 m^3 / s, provided that the quota in the lake it was 744.26 maSL, a level that had not been reached before, it was found after repeated maneuvers, that the valve does not rise more than 25 cm in the conditions in which all the procedures for performing the maneuver were fulfilled. After other maneuvers to completely close the valve and then lift it was possible to cross the 25 cm threshold to the set value. On the downstream side of the dam there are 3 beveled metal ribs at the top for a length of approx. 25 cm. Due to the pressure exerted on the valve at 744.26 maSL, these ribs reached the upper threshold of the window preventing the valve from being raised.

- The discharge of water from the lake was conditioned by the flow capacity of the downstream riverbed. Starting March 13, the AMC dam team conducted visual surveillance and measurements at the AMCs.

- At the setting tower, the exfoliation of the plaster on the outer face was reported when the platform elevation was exceeded from the elevation of 745.50 maSL.

- On the fast channel of the intake tower, at the upstream end of the rehabilitated area, at the discharge, some existing super concrete plates detached upstream from the old area with increased roughness. Under the detached slabs remained the concrete surface of the original screed. It is finished and there are no bare fittings.

- The level in the piezometers that respond to precipitation had important jumps. Between 2 and 17 m, most likely due to heavy rainfall that reached 55 l / m^2 on the day of the flood.

- The total flow at the springs on the left bank of the rapid channel reached a maximum of 3.67 l / s.

- On the right side, no significant displacements were reported at the terminals associated with the area of the sliding surface.

- Overall, the structural behavior of the dam was good.

The June-July 2018 flood event was caused by heavily rain through the river basin. The maximum tributary flow was 47.2m^3/s. The hourly evolution of the tributary flow and the outflows discharged through the bottom outlet and pumping station are illustrated in Table 2.

Table 2. Inlet and outlet flood flows – March 2018

Data	Reservoir level (maSL)		Q inflow (mc/s)	Q outflow (mc/s)	Q bottom outlet (mc/s)	Q pump (mc/s)
	8h	14h				
27jun	744.28	744.54	1.61	3.26	1.88	1.38
28jun	744.71	744.74	15.76	8.6	7.22	1.37
29jun	745.3	745.49	21.35	11.38	10.04	1.33
30jun	745.9	746.58	47.22	36.90	18.44	1.39
1jul	745.91	745.6	23.98	45.99	27.37	0.82
2jul	744.13	743.44	3.17	41.11	40.20	0.91

The Maximum Retention Level reached for the first time the 746.58 maSL for flood attenuation on Târlung watercourse, upstream of the dam. The discharge over the spillway (745.00 maSL) started through all four openings, overtopping the spillway maximum level with 98 cm. The flooding volume was 18.6 mil. Cm. In Figure 4 are illustrated the March flood event hydrographs.

The use of the spillway, in the floods of June 2018, led to the following phenomena:

- the slabs detached from the quick drain of the spillway channel were transported by the water discharged through the large water drain, during the

flood from 30 of June 2018 to the heat sink.

- downstream of the dissipating basin, due to the high flows discharged through the spillway openings, there was a re-profiling of the section between the dissipating basin and the bridge over the Șanțuri valley. The channel made downstream of the rock-bottom dissipation basin has been enlarged.

- on the left bank of the rapid channel, at the level of the crowning of the reinforced concrete wall, on the drainage area from the SHP pipe, there were small erosions of the wall and of some rock areas behind the wall.

- downstream of the protection threshold of the bridge over the Șanțuri valley, there was a strong erosion of the trough consisting of a very cracked rock, so that the foundation of the threshold was completely uncovered on the downstream side.

- the dissipation basin was filled with alluvium transported especially from the left bank of the rapid channel from the erosion produced.

- on the surface of the pouring concrete of the overflow profile, there are cracks appeared in the areas of interruption of concreting.

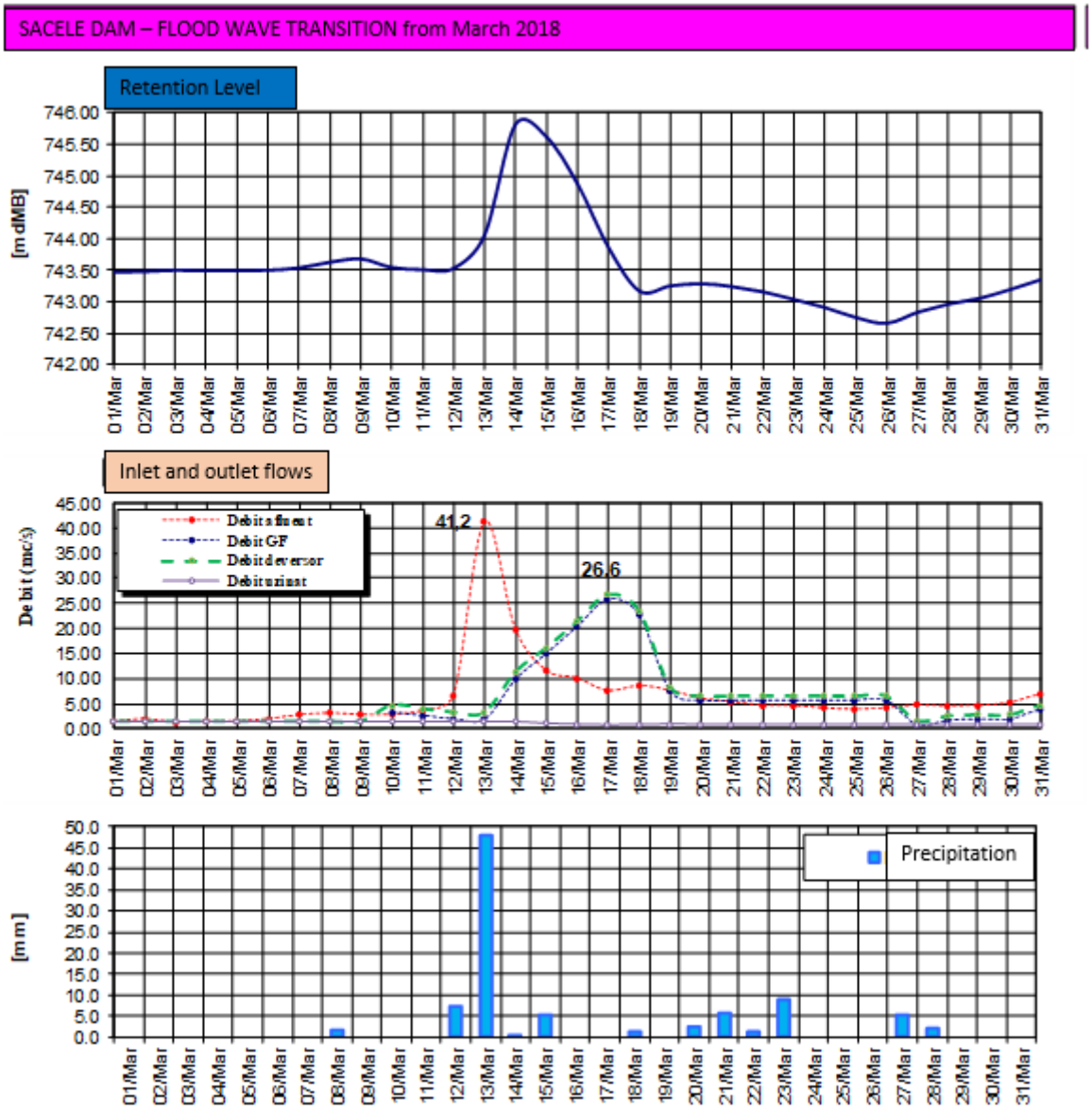


Figure 4. Flow hydrographs in March 2018

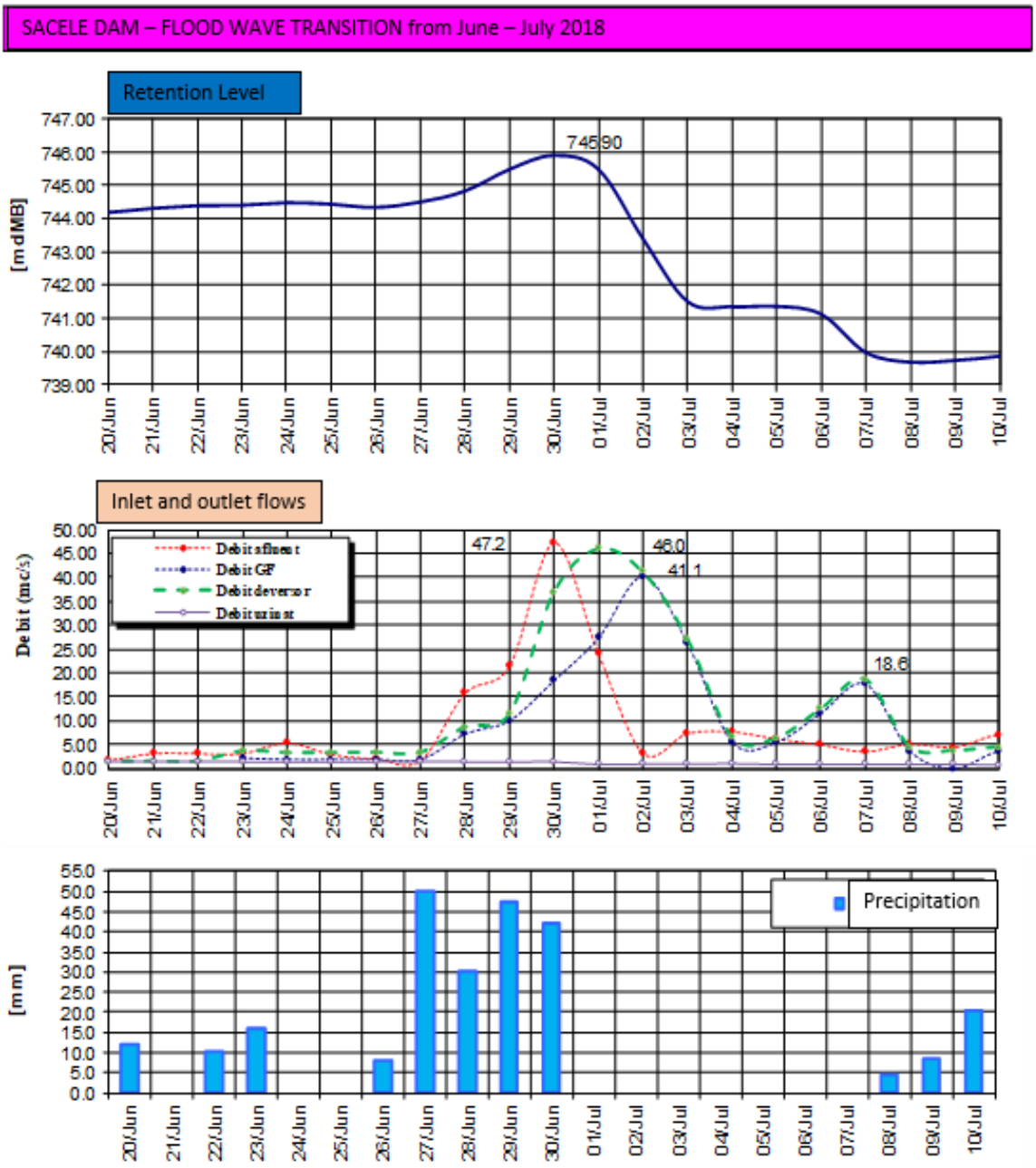


Figure 5. Săcele Dam- Flow hydrographs in June-July 2018

5. CONCLUSIONS

During the analysed period, 2 events were registered in operation, namely:

- the flood from March 13 to 16, 2018, which led to an increase in the level in the reservoir to 745.82 maSL.
- the flood during June 24 ... July 5, 2018, when the maximum Level was registered was 745.91 (July 1, 2018).

The overall behaviour of the work, throughout the operation was in accordance with the nature and size of the demands and were within the limits of evolution below the accepted values.

The visual observations did not reveal any elements that would lead to a reduction in the safety of the objects or restrictions in operation. The operation restrictions are due to the non-achievement of the DN1A national road overhang.

The hydro-mechanical equipment in the retention front of the arrangement had a normal behaviour during the analysed period, without major events or accidents. The planned tests were performed.

The activity of UCC, organized according to the legal regulations in force, managed to ensure the safe operation of the constructions.

Further emphasis will be placed on:

- pursuing the stability of the right bankside.
- maintaining the UCC system, including the one carried out under the WATMAN program.

For the maintenance program, the following will be considered maintenance work on the gallery MCD's.

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