RESEARCH ON STRUCTURAL AND FUNCTIONAL STATUS OF SUPPLY CHANNELS IN IRRIGATION SYSTEMS

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Abstract

Irrigation systems in Romania were built 40-60 years ago, and those that are still in operation have varying degrees of infrastructure degradation. The degradation of the structural components of the irrigation system determined the appearance of water losses and the decrease of the exploitation efficiency. Research conducted over about 15 years has shown the state of advanced degradation of the supply channels and a significant decrease in their operating yields up to 40-60%. The absence of maintenance, repair and rehabilitation works determined the structural degradation of the canals. The degradation phenomena are represented by clogging, compaction, erosion of the slab sealing joint, cracking - breaking - movement of the slabs on the perimeter of the canal, etc. Important degradations are highlighted in the constructions on the canals: hydrotechnical derivation nodes, underpasses of roads, water intake of the pumping stations, etc. All this causes a large part of the volume of water transported by the canals to be lost through infiltration. The current structural and functional state of the irrigation canals requires the immediate application of rehabilitation works.

Key words: hydraulic efficiency, flow section, water leaks, waterproofing

Irrigation systems in Romania were created to supplement the moisture deficit and ensure the development environment of agricultural and horticultural crops in the climate conditions specific to Romania. In 1989, Romania had irrigation facilities with a technical level corresponding to the existing technologies and execution materials at national and international level.

Before 1989, a wide range of watering methods were used: sprinkler watering, furrow watering, bivalent watering, drip watering, etc. Irrigation systems consisted of irrigation plots, which was the basic unit of the system. Each system had a general infrastructure for capturing, transporting and supplying water to irrigation plots (Cazacu E. *et al*, 1982). Irrigation water is taken from surface sources (mainly the Danube River, rivers and lakes) and underground sources (Blidaru V. *et al*, 1982).

Much of the irrigation systems were dismantled after 1990 due to changes in land ownership and government decisions. At present, a small number of irrigation systems built before 1989 are in operation. Most of these systems were built in 1970-1985. In general, the infrastructure of large irrigation systems (catchment, basic pumping stations, pumping stations, supply channels, discharge pipes, etc.) is operated by the territorial administrations of land improvements. The exploitation of irrigation plots is done by private units that own the irrigated lands (Nicolaescu I. *et al*, 2005).

Irrigation systems built before 1990 were structured on the following components: water intake construction, pumping stations (basic, re-pumping) for raising water at various heights, water transport channels (supply, distribution), water stations pumping and commissioning of the pipeline network, hydrotechnical nodes with constructions and water diversion installations, protection and control installations of the exploitation process, etc. (Cazacu E. *et al*, 1982, Pleșa I., Burchiu V., 1986). The predominantly current watering method is sprinkler watering (Cismaru C., 2004, Luca M., 2012, Luca M. *et al*, 2016).

Research conducted in the last period of time has highlighted the state of advanced degradation of the network of channels (supply, secondary and, distribution channels). The state of degradation of the canals causes large water losses through infiltration and a significant decrease in operating yields (Luca M., 2015).

The objective of the paper is the synthetic analysis of the current state of degradation of the network of canals with the role of supply and water supply of irrigation plots from irrigation systems in operation in the eastern part of Romania.

MATERIAL AND METHOD

The study and research material is represented by the irrigation systems located in the

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eastern part of Romania. The research considered the irrigation systems located in the meadow area of the Prut River and located in the counties of Iaşi and Vaslui (*figure 1*).

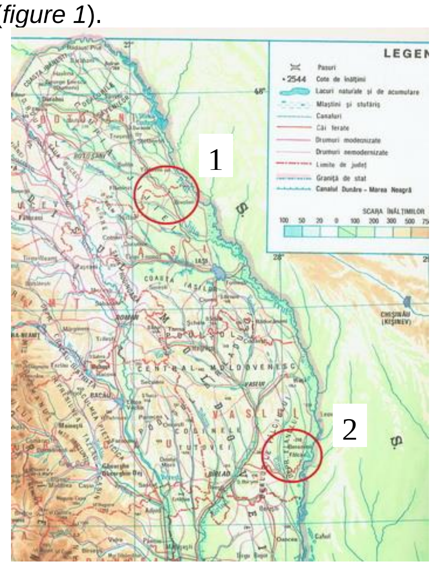

Figure 1 **Areas of study and research: 1 - South Soloneţ irrigation system; 2 - Complex Irrigation and Drainage Development Albiţa - Fălciu.**

The current paper presents the results of research conducted in irrigation systems in the structure "Complex Arrangement of Irrigation and Drainage Albiţa - Fălciu". The first analyzed systems are located in the meadow area of the Prut River (*figure 2*).

The "Complex Arrangement of Irrigation and Drainage Albiţa - Fălciu" currently has a landscaped area of 16,973 ha. The entire surface arranged with irrigation and drainage systems is located in the Prut river meadow. The arrangement was designed by the I.S.P.I.F. Bucharest in 1977 and was executed between 1977 and 1978 (Luca M., 2015). After 1990, the irrigation infrastructure of the arrangement (water pumping stations taken from the Prut River, supply and distribution channels) is operated by the Territorial Branch of Land Improvements South Moldova. The irrigation plots were taken over and managed in a private system by OUAI in the location area. The arrangement contains a number of irrigation plots / blocks equipped with pressure pumping stations (SPP) and monofilament pumping stations (SPPM). All pumping stations are powered by a network of channels.

For each irrigation system considered in the analysis, a technical documentation was prepared. Technical expertise was performed for a series of irrigation plots. Through documentation, the state of the structural components was analyzed based on known and accessible data. The data obtained through the technical expertises allowed the analysis of the current state of the constructive structure of the canals and the hydrotechnical constructions related to them (socket of the pumping stations, hydrotechnical derivation nodes, bridges, etc.).

It should be mentioned that the network of channels has been in operation for about 40 years.

The research method is the one used to carry out technical expertise for land improvement objectives and in particular for irrigation systems with water distribution at pumping stations using a network of canals.

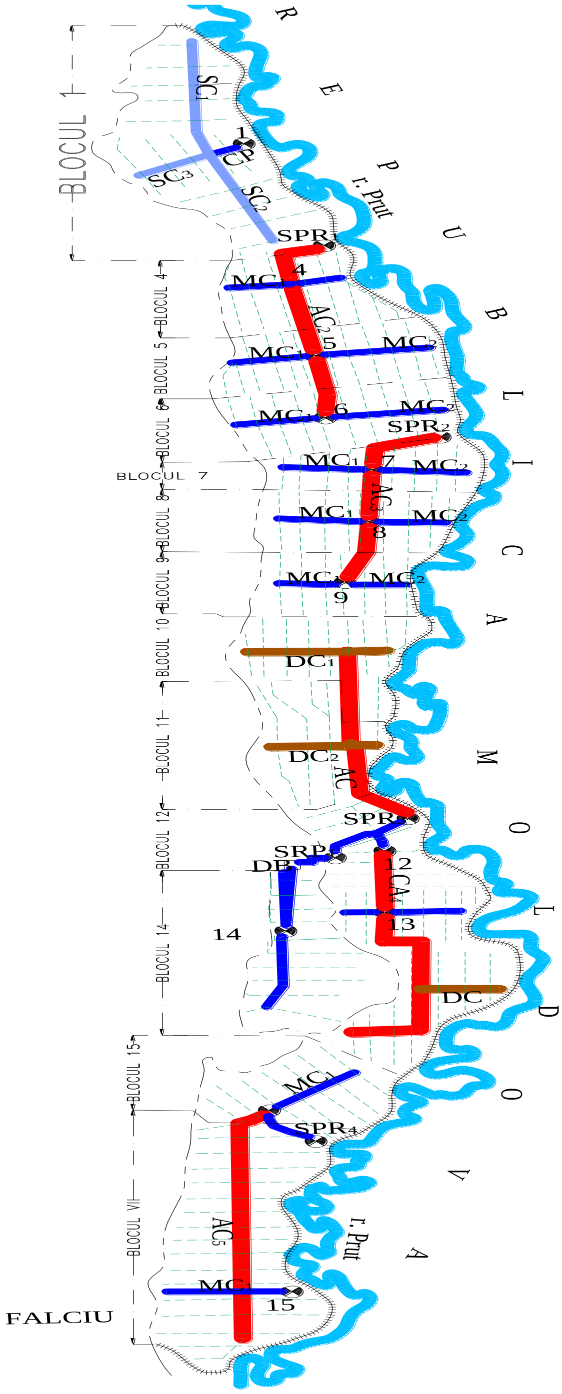

Figure 2 **Complex Irrigation and Drainage Development Albiţa Fălciu (meadow area): AC - supply channel; DC - distribution channel; CS - Secondary channel; CP - main pipe; SPR - basic pumping station; SPP - pumping and pressurization station; BR - discharge basin (Luca M., 2020)**.

For some irrigation plots, the updated topographic plans of the irrigation systems in operation were used. The field research took photographic surveys and video images. The data processing followed the methodology used in the technical and scientific analyzes developed for irrigation systems with canal and pipeline networks.

RESULTS AND DISCUSSIONS

Irrigation systems in Romania were realized in the years 1970 -1980 based on well-developed standard projects. Irrigation systems located in the meadow and plain area have an infrastructure based on a network of canals with different sizes depending on the flow transported. Pumping stations take water from the source (rivers, streams, lakes) and pump it into the adduction channel and further into the main and secondary channels (Cazacu E. et al, 1982).

The networks of canals located in the plain area are made in excavation and semi-embankment (*figure 3*). The channel flow section has a trapezoidal shape. The watered perimeter is waterproofed with large reinforced concrete slabs, or small plain concrete slabs. The joint between the tiles is filled with cement mortar or bituminous mastic (Nicolau C. et al, 1977).

Figure 3 **Irrigation canal made in semi-embankment with water intakes for pumping and pressurization stations, SPP (Ghelase I., 2000)**

The irrigation plots in Romania were designed for watering an area of 500 - 2500 ha. The pipeline network of the plot is supplied by a pumping and pressurizing station (SPP), or by a number of monofilament pumping stations (SPPM). The supply of the pumping stations (SPP, SPPM) is made from a channel (Stăncescu L. *et al*, 1984).

The canal network of the irrigation systems in operation has a long service life. The absence of maintenance and repair works and the obsolete life of the materials determined the degradation of the structural components of the canals, the hydrotechnical derivation nodes and the hydraulic installations on the canals (Luca M., 2016).

The irrigation plots in the „Albiţa - Fălciu Complex Irrigation and Drainage Development" are fed from the Prut River through four basic pumping stations (SPR1 Pogănești, SPR2 Săratu, SPR3 Bumbăta, SPR4 Berezeni). Pumping stations discharge water into adduction channels that supply irrigation plots / blocks. The adduction channels have the code CA2, CA3, CA4 and CA5. The distribution channels (CD) are fed from the adduction channels. Some of the adduction and distribution channels were analyzed within the available data and field investigations.

The CA2 adduction channel is fed by SPR1 and distributes water to the SPP4, SPP5 and SPP6 irrigation plots. The CA2 channel was put into operation in 1977 and has the following characteristics (Luca, 2020):

1. Structural characteristics: total length: 8,060 m; trapezoidal section in the excavation with width at the bottom b = 1.0 m, construction height H = 2.20 m, slope inclination 1: 2; channel bottom slope, i = 0.01%; surface with large reinforced concrete tiles, S_d = 60,410 m^2.

2. Functional characteristics: transported flow, Q = 1.35 m^3/s.

3. Constructions on the canal: four bridges.

The CA3 supply channel is fed by SPR2 and distributes water to SPP7, SPP8 and SPP9. The CA3 channel was put into operation in 1977 and has the following characteristics:

1. Structural characteristics: total length: 8,630 m; trapezoidal section in the excavation with width at the bottom b = 1.0 m, construction height H = 2.20 m, slope inclination 1: 2; channel bottom slope, i = 0.01%; surface with large reinforced concrete slabs, S_d = 56,420 m^2.

2. Functional characteristics: transported flow, Q = 1.60 m^3/s.

3. Constructions on the canal: four bridges and a dam.

The AC adduction channel takes water from SPR3 and distributes the water to two distribution channels CD1 and CD2. Channel CD1 supplies the single-wire irrigation block 10. Channel CD2 supplies the single-wire irrigation block 11. The AC adduction channel was put into operation in 1977 and has the following characteristics:

1. Structural characteristics: total length: 4081 m; trapezoidal section in the excavation with the width at the bottom b = 1.0 m, construction height H = 1.66 m, slope inclination 1:1.50; channel bottom slope, i = 0.02%; the perimeter of the canal is waterproofed with large tiles.

2. Functional characteristics: transported flow, Q = 1.35 m^3/s.

3. Constructions on the canal: bridges.

The distribution channel CD1 carries a flow Q = 1.15 m^3/s and has the characteristics: L = 2750 m, trapezoidal section in the flow with b = 1.0 m, H = 1.66 m, i = 0.03%, slope inclination 1:1.50. Bridges and a dam are located on the canal.

The secondary channel CS38 is fed by SRP3 and SPR1, and the water is distributed to the irrigation plot SPP14. The secondary channel

CS38 carries a flow Q = 0.75 m^3/s and has the characteristics: L = 1190 m, trapezoidal section in the excavation with b = 0.50 m, H = 1.35 m, i = 0.03%, inclination slope 1:1.50. Bridges and a dam are located on the canal.

The CA4 adduction channel is fed by SPR3 and distributes water to the SPP12 and SPP8 irrigation plots, as well as to a CD distribution channel. The CD channel feeds the single-wire block 15. The CA4 and CD channels were put into operation in 1977. The CA4 channel has a trapezoidal section with a bottom width b = 1.0 m and is made of excavation.

The CA5 adduction channel is fed by SPR4 and distributes water to the SPP16 irrigation plot and to the SPPM17 / VII single-wire block. The CA5 channel was put into operation in 1977 and has the following characteristics (Luca, 2016):

1. Structural characteristics: total length: 11,850 m; trapezoidal section in the excavation with the width at the bottom b = 2.0 m, construction height H = 2.85 m, slope inclination 1:2; channel bottom slope, i = 0.01%; surface with large reinforced concrete tiles, S_d = 60,410 m2.

2. Functional characteristics: initial transported flow, Q = 2.0 m^3/s.

3. Canal construction: bridges and dams.

After 1990, there were exchanges of land, but also of property, through which the structural components of the irrigation systems were modified. The surface of the plots, the length of the channels and pipes, the supply flows, etc. they have changed continuously over time.

The canals in the structure of an irrigation system need a series of annual maintenance and repair works, which are highlighted (Pleşa I., Burchiu V., 1986, Ghelase I., 2000):

- unclogging the flow section;
- cleaning and restoring the structure of the joints between the waterproofing tiles of the flow section;
- structural restoration of the slabs by removing the broken ones and assembling / pouring new concrete slabs;
- repair works on the structure and hydraulic installations of the dams;
- restoration of the entrance, flow and exit sections of the bridges;
- canal canopy restoration works, etc.

The research was carried out between 2014 and 2020 by field analysis of the structural condition of the components of irrigation systems in operation (Luca M., 2015, Luca M., 2016, Luca M., 2020).

The current constructive and functional state of the supply channels of the irrigation plots for the study area is represented by the supply channel CA3 from „Albiţa - Fălciu Complex Irrigation and Drainage Development". The research conducted on this channel in 2019 highlighted the following aspects (Luca M., 2019):

A. General data on the operating process: structural and functional conditions

- the CA3 adduction channel has been in operation for about 43 years, during which time it underwent a complex of natural and anthropic actions differentiated in time;
- since 1990, the ownership regime over the structural components of the irrigation system has changed; the basic pumping stations and the canal network remained in the state administration; irrigation plots were taken over by companies / private associations;
- before 1990, annual maintenance and repair works were carried out regularly (clearing, restoration of joints between tiles, structural restoration of tiles, repair of dams, restoration of bridge drainage sections, etc.);
- the pace of application of maintenance and repair work on canals after 1990 has decreased considerably, and in some canal sectors they have completely disappeared.

B. Current structural condition of the canal and hydrotechnical constructions:

- the channel shows a degradation of the structure in length by settlements, collapses and swellings of the slope, modification of the geodesic slope, etc. (*figure 4*);

Figure 4 **General structural condition of the CA3 channel between the SPP8 and SPP9 pumping stations (Luca M., 2020)**

- the cleared alluvium was deposited on the canopy of the canal, a situation that determines the return to the section of the canal under the action of climatic factors;
- large reinforced concrete slabs used to waterproof the channel flow section are degraded in a proportion of 80 - 100%; this situation changed the geometric and hydraulic parameters of the channel flow section;
- the joint between the slabs filled with cement mortar was completely destroyed, which

favoured the penetration of water under the slabs and the destruction of the support layer; in the joints a vegetation developed that increased the roughness coefficient (*figure 5*);

Figure 5 **General structural conditions of the joints between the tiles of the CA3 channel (Luca M., 2020)**

- a large part of the tiles are cracked, displaced or missing (*figure 6a*);
- the absence of tile maintenance and repair works determined the growth of vegetation of various species (grass, shrubs, trees, etc.) and dimensions in the flow section (*figure 6b*); vegetation contributed to the dislocation of the tiles, their movement and fracture;
- the canal areas where the irrigation water is captured by the pumping stations (SPP) is in a state of advanced degradation; the section of the channel is deformed due to the movement of the slabs and the hydrodynamic erosion (*figure 6b*);
- the water intake taps / pipes located in the canal slope are protected with gratings made of cast iron; the grills are displaced, corroded and unstable; this situation allows the access of large alluvium in the hydromechanical installation of the pumping station (*figure 7*);

a

b

Figure 6 - **State of structural degradation of the CA3 supply channel: a - geometric modification of the flow section by moving and fracturing the slabs; b - the presence of arboreal vegetation in the flow section (Luca M., 2020).**

a

b

Figure 7 **- The state of structural degradation of the CA3 supply channel in the SPP catchment area: a - general view of the catchment area for SPP8 Oţetoaia; b - the state of degradation of the grilles on the suction pipes (Luca M., 2020).**

- the channel in the area of the SPP pumping stations is equipped with a dam to create water levels for the sockets / suction pipes (*figure 8a*);
- the construction and installation of the dam is degraded in proportion of 80 - 90%, and its operation is deficient (*figure 8b*); the metal

constructions of the dam have exceeded the operating period and no longer provide functional parameters (tight closing, controlled flow transit);

a

b

Figure 8 - **Degradation state of the CA3 channel in the dam area from SPP8: a - general view of the channel section; b - detail regarding the condition of the dam (Luca M., 2020)**

- the bridges used at the intersection of the canal with the road of exploitation are degraded in proportion of 60 - 90%; the construction of the bridges was modified in time by the interventions for repair works (*figure 9*);

- the completely degraded bridges were replaced with temporary constructions (PREMO tubes);

- a part of the adduction channels of the irrigation plots from „Irrigation Systems Albița – Fălciu" are clogged in excess, and in time an abundant vegetation represented by reeds has developed (*figure 10*);

Figure 9 - **General view of the CA3 canal and a modified bridge at the intersection with an exploitation road (Luca M., 2020)**

C. Synthetic elements regarding the functional state of the supply channel:

- the current structural condition of the canal no longer allows the fulfilment of the functional parameters according to the technical execution project (SPP supply flow, water depths in the area of the suction pipes, irrigation water quality, limitation of water losses, etc.);

Figure 10 - **Condition of the CA5 adduction channel with clogged sections and the presence of reed vegetation (Luca M., 2020)**

- the transported flow is reduced along the length of the canal due to the large water losses by infiltration caused by the totally unsatisfactory condition of the waterproofing system;

- an important influence on the transported flow is presented by the increased value of the roughness of the wet perimeter of the canal; the value of the roughness coefficient after Manning increased from 0.014 - 0.015 to 0.030 - 0.045 depending on the degree of degradation of the concrete slabs and the presence of vegetation on the wet perimeter;

- the water losses allowed for the CA3 channel protected with reinforced concrete slabs jointed with cement mortar are of maximum 5%;

water losses at the current stage reach 40 - 60% and involve high costs to ensure the volume of water for irrigation;

- the operating efficiency of the canal has decreased significantly, from 90 - 95% at commissioning, to 55 - 60% at the current stage, due to the degradation of the waterproofing system;

- the efficiency of a canal in an irrigation system is determined by the relationship (Pleşa and Burchiu, 1986):

$$\eta_r = \frac{Q_i - Q_p}{Q_i}\ 100\ (\%),(1)$$

where where Q_i is the flow introduced into the network; Q_p - lost network flow; the use of the relationship requires the measurement of the water flow introduced into the network and the lost flows, an aspect that is not currently achieved in irrigation systems;

- on long-length canals, a clogging phenomenon differentiated in length was achieved; alluvium was deposited along the length of the channel depending on the diameter and specific gravity; the volume of alluvium decreased along the length of the canal, being influenced by their takeover by the pumping stations;

- the large amount of alluvium present in the water transported by the CA3 canal and in general in the irrigation systems from „Irrigation Systems Albița – Fălciu” is taken over by the pumping stations and deposited in the network of pipes that supply the irrigation equipment (Luca, 2020);

- the process of clogging the channels is particularly intense, but differentiated on sections; the analysis performed on CA3 showed the thickness of the alluvium layer of 0.30 - 1.20 m; the SPP operating personnel intervene in some situations to clear the section of the canal and ensure the suction quotas;

- transport of alluvium that influences the quality of irrigation water, which causes faster degradation of sprinklers in irrigation systems;

- the alluvium from the irrigation water generates a negative impact on the mechanical characteristics of the pumping units (accentuated wear of the rotor at the pumps) and determines the increase of the energy consumption at the pumping stations fed from the canals.

The researches carried out on supply and distribution channels from the „Brăila Terrace Irrigation System” (Ghelase I., 2000) highlighted the negative impact of alluvium in the operation of SPP type pumping stations. The research showed the role and functional characteristics of alluvial access limitation installations in the pump suction line. Without works to stop the access of alluvium to the outlet of the base stations of the irrigation system, a favourable operating efficiency of the supply channels and pumping stations cannot be ensured.

For the efficient operation of the SPP pumps, as well as of the pipeline network within the irrigation plot, a series of installations are proposed that limit the access of alluvium in the suction of the pumping stations (Ghelase, 2000).

Every year there is a reduction of the irrigated area due to the degraded technical condition of the main infrastructure of the irrigation systems. The study found the state of degradation in various stages of the basic pumping stations (SPR1 Pogănești, SPR2 Săratu, SPR3 Bumbăta, SPR4 Berezeni) and the adduction channels CA2, CA3, existing CA, CA5, distribution channel CD1 and channel secondary CS38 etc.

Some canals are not waterproofed along their entire length, a situation in which water losses through infiltrations cause a decrease in efficiency. Also, the water losses from the canals cause a high consumption of electricity, with a share of about 80-90% in the irrigation water tariff.

In the last period of time, the importance of the rehabilitation works of the main infrastructure from the existing irrigation systems has been realized and attempts are being made, for the time being at a low pace, for the maintenance and rehabilitation of some components of it. Some private operators have approached the development of irrigation infrastructure on their own, although in other countries it is a government activity (Blidaru V. *et all*, 1982, Cismaru C., 2004).

The increase in operating costs and the low yields of the supply, distribution and secondary canals for the supply of irrigation plots necessitate the rehabilitation of the canal network.

The rehabilitation of the canal network of the irrigation system is done in the first stage by drawing up a technical expertise. This expertise substantiates the technical project; acre will be approved by a project verifier in the field of land improvements. The technical design may provide for a partial or total change of the duct waterproofing system by using modern solutions. The hydraulic systems on the channels must be completely changed, as their service life is exceeded (Luca M., 2020).

The absence of the complete rehabilitation of the canal network determines the intensification of water losses on the old canal sections, which have exceeded the exploitation period. The absence of the rehabilitation of the constructions on the network of canals (hydrotechnical nodes, bridges, water intakes, dams, etc.) determines the increase of the number of damages and implicitly of the water losses (Chirica St. *et al*, 2018).

The efficiency of the canal network is not currently assessed by the irrigation systems operation services. This activity should be intensified with the adoption of measures to reduce water loss and energy consumption.

CONCLUSIONS

The main infrastructure of irrigation systems still operating in Romania is the least rehabilitated and modernized component after 1990.

The research carried out in the „Complex Development of Irrigation and Drainage Albița – Fălciu" in the period 2014 - 2010 showed that the network of supply and distribution channels of irrigation systems must be rehabilitated in view of exceeding the service life of most components (construction structure, system waterproofing, dams, bridges, etc. catchment outlets, etc.) and large water losses recorded in the operation process.

The waterproofing system of the channels (large concrete slabs with joints filled with cement mortar) has an advanced state of degradation, a situation that causes high water losses, but also a high consumption of electricity to pump the volume of water required by operation of the irrigation system.

Hydrotechnical constructions and installations located on canals are in an advanced state of degradation, even unusable, given the exceeding of the service life.

The network of canals has a high degree of clogging, a situation that influences the value of the transported flow and the achievement of water levels on the canal imposed by the suction of pumping stations.

Irrigation water has a high degree of turbidity, a situation that causes a negative impact on the operation of pumps, the network of pipes and irrigation equipment.

The lowest hydraulic efficiency takes place on the network of transmission and distribution channels, where there are the highest water losses (about 40-60% of the water volume), given the absence of rehabilitation works in the last 30 years.

Bringing the infrastructure of the irrigation system to the level of current technology requires the realization of an extensive program of rehabilitation and modernization of the canal network, as well as the related constructions and installations.

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