Water developments and their impact on runoff in the Upper Tisa catchment

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The 157 200 km^2 large catchment of the River Tisa[1] is situated in the eastern part of the Carpathian Basin, also known as the Central Danube Basin. The upper catchment down to the village Záhony is 32 782, that down to Tokaj 49 449 km^2 la rge.

The origin of the name Tisa is still unclear, some linguists trace it back to an Indo European root supposed to mean muddy, or silty. In Roman documents the river is mentioned under the names Parsiou, Pthirus, Tigas and Tisianus, while in the mediaeval Latin chronicles in the forms Tisia and Tysia.

Keywords: hydrology, Upper Tisa, Carpathian Basin

The Upper Tisa and her tributaries in the Ukraine

The headwaters of the Tisa are in the Maramuresh Alpine Mountains, the name Tisa is used downstream of the confluence of the Chorna Tisa and Bila Tisa. Of her 962 km total length, the mountain section is only 200 km long. From the confluence of the Chorna Tisa and the Bila Tisa down to the mouth of the Vişeu the average slope of the valley floor is very steep, 6.33 m/km, between the Vişeu and the Tereblja 2.28 m/km, flattening down to Tiszabecs to less than l m/km. Over the mountain section the valley is narrow, the river having carved her up to 50 m wide bed between steep banks. The normal depth is a few decimetres. Beyond her emergence into the plains at Hust the Tisa becomes a typically lowland river meandering in a spreading valley.

The Ukrainian part of the Tisa catchment (Zakarpatia) upper of Tokaj is drained by the right hand tributaries, the Chorna Tisa (564 km^2), the Bila Tisa (487 km^2) the Teresva (1224 km^2), the Tereblja (766 km^2), the Rika (1240 km^2) and the Borzhava (1418 km^2). The only major left hand tributary over the Zakarpatia section is the Bătar/Batár[2] Creek, the 54 km long valley of which crosses three countries: Her origin is in Romania in the Oaş Mountains, her longest section is in the Ukraine, she forms

1 The Hungarian name of the river is Tisza.

2 The first name of common streamflow is Romanian the second Hungarian

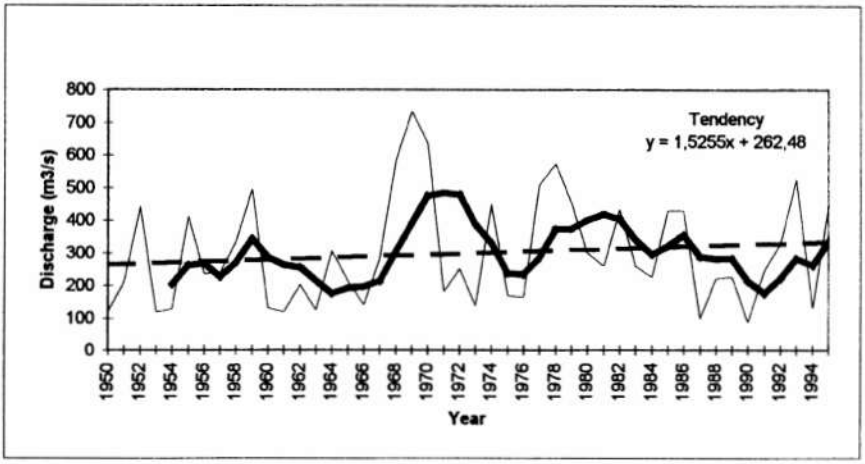

Figure 1. Annual peak streamflows (annual data, five year moving average, linear trend) past the Rahiv station on the Tisa (1950—1994)

the boundary between the Ukraine and Hungary to discharge at Tiszabecs into the Tisa. Of her 396 km^2 large catchment only 10 km^2 are on Hungarian territory. The mean streamflow in the Tisa is 13.8 m^3/s, which corresponds to a unit runoff of 23.0 l/s km^2. The mean streamflow at Vilok is 210 m^3/s. The annual mean streamflow fluctuates between rather wide limits, the maximum (39.0 m^3/s in 1970) being three times as high as the lowest (12.6 m^3/s). The highest streamflow of 734 m^3/s was recorded on June 8, 1969, the lowest (1.14 m^3/s) on February 2, 1963. The ratio of the tow is thus 1:644. The highwaters show a rising trend (Figure 1.).

Reservoirs

The theoretical water power potential in Zakarpatia is 10.2 thousand million kWh, of which a small part alone is developed. There are three water power stations, the largest of which is the 29.5 MW Olsoni hydropower station fed by the Tereblja and Rika rivers. The net storage volume is some 20 million m^3 only.

Flood defences

Embankments of some 230 km total length were built in the Ukraine along the Tisa and her major tributaries, further of some 220 km length along the minor streams The toal length of the bank linings amounts to some 40 km. The right hand embankments of the Tisa were strengthened over the section between Vinogradiv and Vilok bridge in recent years. The embankment section was designed to safely withstand the 1% flood. The Bătar/Batár Creek presents no flood hazard, but her highwaters back up the Tisa over several kilometres upper of the confluence. As a control measure a 9.6 km long embankment with 4.0 m crest width and 1.5 m safety freeboard was built between Tiszabecs and Magosliget in Hungary.

In the boundary zone high capacity runoff lift stations were built at the mouth of the Csaronda main canal discharging to the Latorica in the areas of Yavorovo and Solovka and elsewhere with over 40 m^3/s aggregate capacity. These pumping stations are large enough to lift at times of high stages in the recipients the entire surface runoff from the Ukrainian part of the Bereg lowlands and some of it on the Hungarian part. The Kovács stream, the Szipa, the Mosztok and the Déda-Mitz principals convey the runoff towards Hungarian territory, while the Kaszony-Botrágy, the Barabás, the Szipa-Csaronda and the Egercse canals carry the runoff from Hungarian territory towards the Ukraine. The runoff conveyed in the Déda Mitz canal is lifted by means of a 2.2 m^3/s pumping station into a storage basin, whence it is released over a 1.0 m^3/s capacity sluice to the Hungarian side of the border.

The water arriving from Hungary in the Szipa-Csaronda principal is divided to the Csaronda-Tisa and the Csaronda-Latorica canals, which discharge into the Tisa and Latorica, respectively. The tailworks of the Csaronda-Tisa canal include a 37 m^3/s sluice and an 8.4 m^3/s lift station, wile that of the Csaronda-Latorica canal a 60 m^3/s sluice and a 15 m^3/s lift station. At times of coinciding flood waves on the Tisa and the Latorica and when the capacity of these two lift stations is inadequate to pump the collected surface runoff, the 6.2 m^3/s Solovka pumping station is also started. The New Batár canal and tailgate were built on the low land secton of the Bătar/Batár Creek in the Ukraine by which most of the water is conveyed to the Tisa over a shorter route. In the Hungarian catchment of Bătar/Batár Creek 616 hectares of farmland were provided with land drainage between 1985 and 1990, of which 143 ha have underdrains.

Groundwater

The groundwater supplies available for use amount to 7 m^3/s. The major aquifers in Zakarpatia are Pliocene Quaternary sediments. The sands and gravels in the thick Pliocene and Quaternary formation under the Chop-Mukacheva basin hold 90% of the groundwater supplies in the entire region. In the alluvial layers the groundwater table is situated at depths between 0.5 and 7 m below the terrain. The yield of the wells ranges from 6 to 20 l/s. The 15 m deep shaft wells of the Mukacheva water works yield 10-20 l/s at 2.5 m drawdown. The deep aquifers are developed by 150m deep wells, in the interior of the basin by means of 250 m deep wells. The well yields range from of few thousands to 8.5 l/s. The groundwater supplies in the Chop-Mukacheva basin have been estimated at 6.1 m^3/s. In the Tyachiv-Hust-Vinogradiv basins the groundwater supplies are substantially smaller.

In contrast to these, the adjacent mountain areas are relatively poor in groundwater. In the volcanic range running parallel to the Carpathian sandstone belt to the north of the Uzhgorod-Mukacheva line, the main aquifers are the recent volcanic rocks, the Pannonian and alluvial layers in the valleys being of inferior importance. The groundwater in these areas is abstracted from depths ranging from 5 to 300 m. The yields vary between 1 and 15 l/s and are thus of an order comparable to that of the natural springs.

In the largest communities Uzhgorod and Mukacheva 85 and 87 %, respectively, of the population are served with piped water. In the other towns the percentage is lower, whilst a few villages only have water works. In the aforementioned towns the water works draw on the phreatic aquifer. The per capita consumption is approximately 200 l/day. Hardly over one half of the urban population and 10% of the population in the major villages live in sewered areas.

The quality of surface waters is good over the upper sections, especially in terms of the oxygen parameters, but farther downstream recurring phenol and hydrocarbon discharges, high concentrations of suspended solids and total iron cause pollution concerns.

Water quality in the Upper Tisa is still good relative to that in the River Someş/Szamos and the River Crasna/Kraszna. This is in part attributable to the absence of major industrial centres in the catchment. The major sources of pollution in the Ukraine are the communal discharges at Rahiv, Tyachiv, Hust, Vinogradiv, Irshava and Beregove. In Romania the towns Sighetu Marmaţiei, Borşa along the Vişeu, Vişeu de Sus and the non ferrous metal ore mines and dressing plants at Borşa are the potential sources of pollution. Although the volume of industrial production has declined generally in recent years, the number of pollution accidents has increased. The solution of the Stretter Phelps set of equations describing the oxygen balance in streams for the state corresponding to the critical streamflow of 80% duration in August has implied that the low in the oxygen curve occurs at approximately 40 km from the point of discharge to the Tisa River. As a consequence of the still considerable logging and timber industry considerable amounts of organic enter the streams and the sediment load has increased.

The Upper Tisa and her tributaries in Romania

In the north western part of Romania the tributaries of the Upper Tisa are the Vişeu, the Iza, the Săpânţa, the River Someş/Szamos and the Crasna/Kraszna.

The Romanian section of the River Tisa

The Upper Tisa crosses the northern part of the Maramuresh Basin in E W direction, forming over 60 km length the boundary to the Ukraine between the mouth of the Vişeu and Teceu Mic. Between the Vallea Vişeului and Lunca the river flows in an 8 km long gorge. From the viewpoint of flood safety the section between Remeţi below the mouth of the Teresva and Teceu Mic causes the greatest concern, where the river meanders, forming several densely overgrown abandoned beds. Some 270

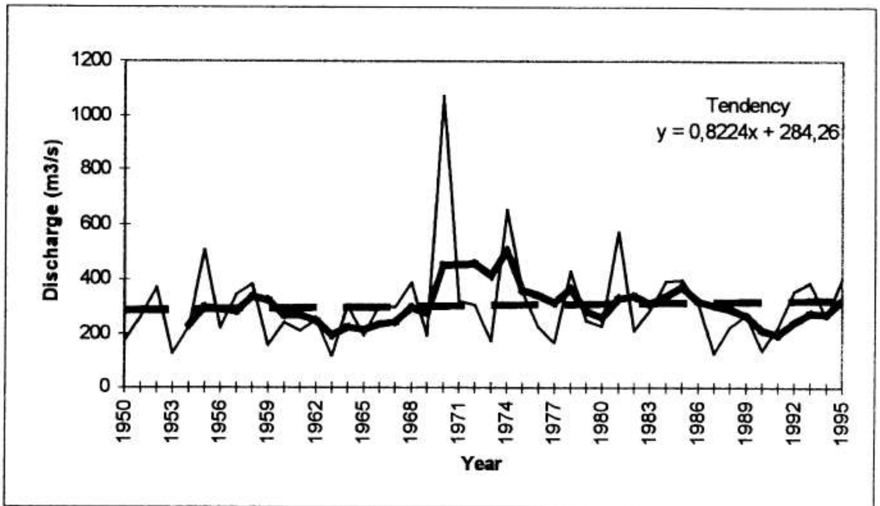

Figure 2. Annual peak streamflows (annual data, five year moving average, linear trend) past the Bistra station on the Vişeu (1950—1994)

hectares of the flood plain downstream of the Iza mouth are covered by a forest of phreatic trees.

Over the Romanian river section rock bank linings were built in 48 km length. The town of Sighetu Marmației is protected by a 4.6 km long flood embankment and also the water works drawing on bank filtered supplies are protected by a 1.4 km long ring dyke. Further flood defences are on the left hand bank at Bocicoiu Mare, Sarasău, Câmpulung la Tisa and Remeți.

The first and the largest tributary of the upper Tisa section in Romania is the Vişeu, the headwaters of which emerge from the Prislop saddle between the Rodna and Maramuresh Alpine mountains. The 80 km long river drains an 1580 km^2 large, asymmetrical catchment, the right hand feeders emerging from the Maramuresh Alpine Mountains, the Cisla, Vaser and Ruszkova/Ruscova, surpassing greatly in both catchment size and streamflow those entering from the left hand side (the Sebeş, or Repedea). The normal annual mean stremflow at Bistra is 32.0 m^3/s, the highest streamflow recorded during the May floods in 1970 was 1072 m^3/s (Figure 2.). The total length of the bank linings and flood embankments along the Vişeu is some 15 km, most of these protecting the communities Borşa , Vişeu de Sus, Leordina, Petrova and Bistra.

The second largest tributary, the Iza emerges from the Rodna Alpine Mountains and crosses the Maramuresh Basin in S N direction over 70 km length. The catchment drained is 1305 km^2 large. The normal annual mean flow past the Vadu Izei hydrographic station situated between the mouth to the Tisa and the entrance of the Mara stream is 15.9 m^3/s, while the 1% peak flood discharge is 780 m^3/s.

River training works and flood embankments were built of some 20 km total length in the Iza Valley: in the areas of Săliştea de Sus, Dragomireşti, Rozavlea, Bârsana and Sigethu Marmației.

On the upper section of the Mara stream construction work is under way on the dam of the Runcu reservoir. The 90.5 m high dam will create a storage space of 28 million m^3. A tunnel drilled into the volcanic rock of the Gutâi mountain will transfer a flow of 1.5 m^3/s to the Strâmturi, or the Frizia reservoir on which the towns of Baia Mare and Sighetu Marmației, further the villages in the Mara Valley will rely for their water supply. The reservoir will serve also flood control purposes and after the completion of the two underground power stations Runcu and Frizia will generate 28 mW of power.

Săpânța Creek is the third left hand tributary of the Upper Tisa. At a length of 20 km she drains a 135 km^2 large catchment with a mean flow of 3.80 m^3/s. The valley of 15 m/km average slope is cut into andesite rock.

Water uses

Water to the towns Borşa, Vişeu de Jos and Sighetu Marmației is supplied from groundwater resources, withdrawn from 9-12 m deep wells and springs at the rate of 0 363 m^3/s, of which 0.190 m^3/s are used for domestic purposes. The present demands are met, but assuming economic growth over a longer period this supply will prove inadequate. Water distribution networks have already being built in the villages Budeşti, Čalineşti, Ocna Şugatag, Dragomireşti, Săcel and Sâliştee de Sus, in other communities piped water projects are under construction or in the planning stage. However, in the majority of the communities water is still obtained from wells and springs.

Water quality is generally high along the headwater, mountain sections of the streams, deteriorating gradually to acceptable farther downstream. Zinc of natural origin in elevated concentration was observed on some stream sections.

The non ferrous metal ore mines at Baia Borşa, further the towns Borşa, Vişeu de Sus and Sighetu Marmației are the major sources of pollution. The wastewater treatment plants at these communities were built with mechanical and biological stages of the necessary capacity, but the removal efficiency is poor and should be improved by more careful operation. The mine drainage waters from the non ferrous ore mines at Baia Borşa , situated in the catchment of the Cisla stream are discharged over three settling ponds without any further treatment to the recipient. The villages are unsewered and have no sewage treatment facilities.

The Tur/Túr catchment

The 1 261 km^2 large catchment is bounded on the northern side by Tisa catchment, on the souther side by the catchment of the River Someş/Szamos. Of the total catchment area the share of Romania is 944 km^2 (75%), that of Hungary 317 km^2 (25%).

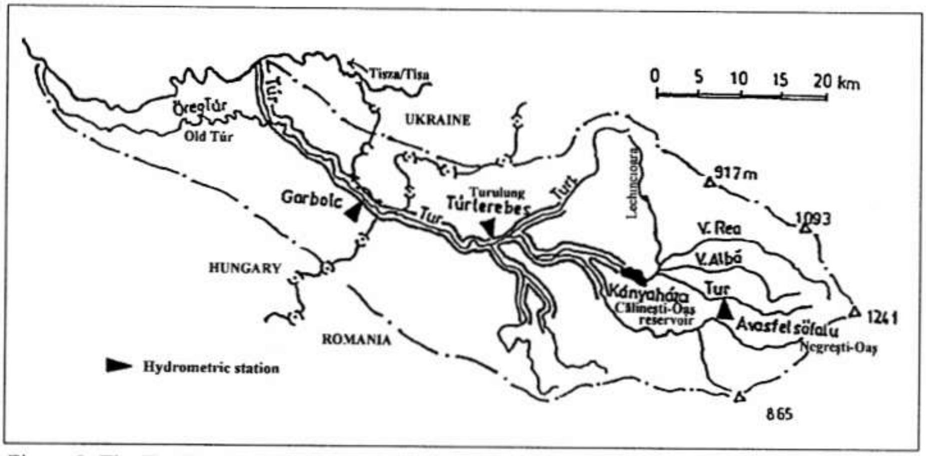

Figure 3. The Tur/Túr catchment, flood embankments, reservoir, key gauges

The Tur/Túr emerges in the Gutâi Mountains at an elevation of 989 m. The tributaries along the upper section, the Valea Rea, Valea Albă, Lechincioara, and Târşolţ drain to the Oaş Basin (Figure 3.).

Downstream of Călineşti Oaş the river sope becomes flatter, the mountain character changing successively to that of a lowland stream. The left hand tributaries Talna and Racta, further the right hand tributary Turţ enter in the lowlands already.

The mountain parts of the catchment have relatively abundant precipitation and owing to the favourable runoff conditions the unit runoff is high, over 20 l/s km^2.

The flood and runoff control system in the Tur/Túr catchment consists of the following components:

- The flood embankments along the flood plains the section of the Tur/Túr between Călineşti Oaş and the national boundary, further the donwstream sections of the Turţ, the Talna Mare and the Egher creeks.
- The Călineşti Oaş reservoir, which serves also flood control purposes upper of the flood defences.
- The drainage canals built to remove the surface runoff from the areas behind the flood defences.
- The runoff lift stations.

Prompted by the losses caused by the floods in May, 1970 in the Romanian part of the Tur/Túr catchment, the Călineşti Oaş reservoir was built in 1972, which serves besides flood control, the purposes of fish farming and power generation. Following the first trial impoundment in June, 1974, the reservoir was commissioned definitely in 1979.

The creeks carrying abundant water drain a 375 km^2 large part of the catchment (30% of the total) to the reservoir. The 798 m long, 9.5 m high gravity dam was built of local rock Of the total 23.09 million m^3 reservoir space 20.34 million m^3 serve flood control purposes. At the normal retention level the surface area of the 4.7 km long and

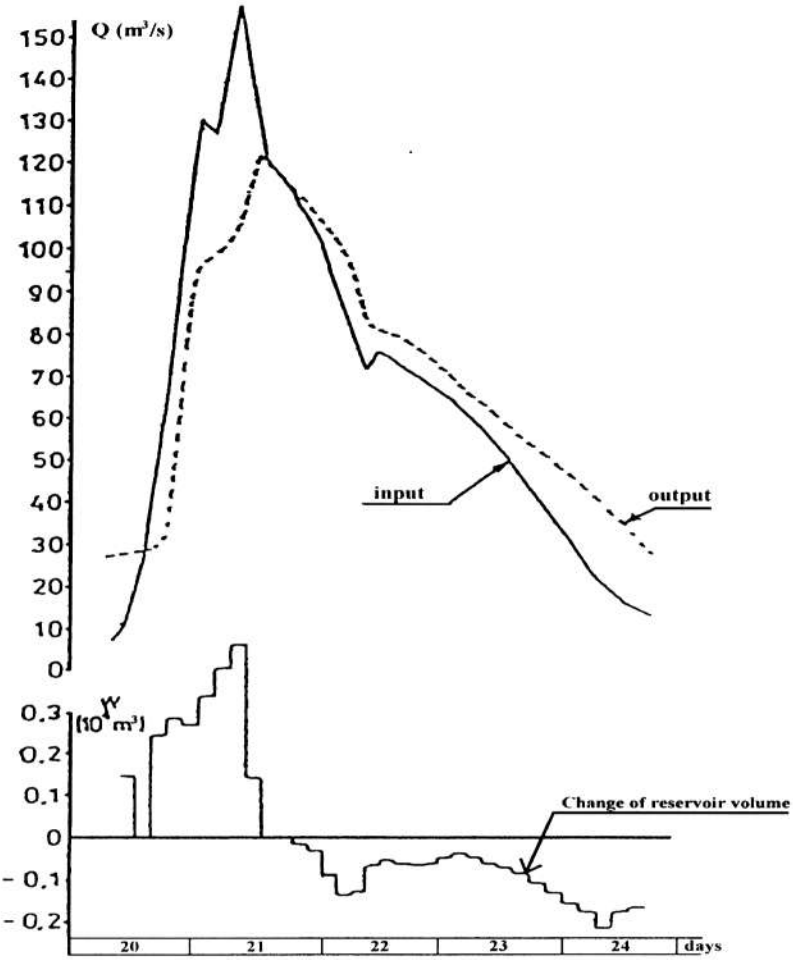

Figure 4. Attenuation of the 1993 December flood by the Călineşti Oaş reservoir on the Tur/Túr river

1.2 km wide reservoir is 382 ha. Under emergency conditions the bottom outlet, the gates and the spillway weir are capable of releasing a discharge of 200 m^3/d. The two turbines installed in the powerhouse at the toe of the dam have a combined capacity of 1.4 mW at 13.8 m^3/s discharge.

The feasibility of diverting the Talna Creek into the Călineşti reservoir has been studied. This transfer scheme would expand the catchment above the reservoir to 599 km^2, or to 50% of the total area.

The impacts of the Călineşti Oaş reservoir on the monthly and annual flows

The annual mean flows past the Negreşti Oaş gauging station upper of the reservoir, that is uninfluenced by storage, during the 1979-1994 period were lower by approximately 9% than over the 12 years (1963-1978) before commissioning the reservoir, while the mean flows past the downstream gauging stations Turlung and Garbolc on the Tur/Túr river the mean flow has increased by 10 and 6%, respectively, under the equalising impact of the reservoir (Konecsny, Sorocovschi 1996).

The annual highest flows in the Tur/Túr will be seen from the records of the Negreşti Oaş gauging station to have diminished by 9% on the average, while the avereage decrease thereof was 67 and 74% on the Turulung and Garbolc stations, respectively. The reservoir has thus reduced significantly the flood peaks and consequently the flood hazard. The falling limb of the flood hydrographs has become at the same time longer than under natural conditions (Figure 4.).

On the Turulung and Garbolc gauges peak flows higher than 200 m^3/s were recorded in five years over the 16 year period (1963-1978) prior to commissioning the Călineşti Oaş reservoir, whereas between 1979 and 1994 such event has occurred on a single occasion only, in 1980 (Turulung 220 m^3/s, Garbolc 195 m^3/d).

The annual low and the lowest monthly mean flows were found to have diminished by 9 and 17%, respectively, on the Negreşti Oaş gauge upper of the reservoir in the second half of the dry period 1979 1994. In contrast thereto, the low water flows have increased by about 10% on the gauges Turulung and Garbolc downstream of the reservoir.

In addition to the beneficial impacts outlined in the foregoing (flood peak reduction, augmentation of low flows), the adverse impacts of abnormally high heavy metal pollution in the Tur/Túr could also be reduced, thanks to the diluting and flushing effect of the flows released from the Călineşti Oaş reservoir at times of low water.

Runoff lift stations with a total capacity of 28 m^3/s are situated along the river section downstream of Turulung on both banks. These are. Drăguşeni left hand bank, 17+328 km, 3.1 m^3/s, Micula left hand bank, 9+115 km, 5 0 m^3/s, Mesteacăn right hand bank, 5+200 km, 7.41 m^3/s, Porumbeşti right hand bank, 1+050 km, 2.40 m^3/s, Cer left hand bank m 0+760 km, 2.10 m^3/s, further on the Egher canal Bercu left hand bank, 8.06 m^3/s.

Water quality in the Tur/Túr was excellent a few years ago, the oxygen level was high, organic and total dissolved salt concentrations were low (70-334 mg/l). The high values were registered during the summer low flow periods.

In recent years sewage bacteria have been detected at growing frequency, turning water quality to acceptable in terms of the coliform counts. Organic pollution in the river has scattered widely and displayed a growing trend. The ammonium content tended to decrease gradually from spring to late summer, although considerable fluctuations were registered periodically. In some samples ammonium ion was present in concentrations surpassing the classification criteria of good water (Konecsny,A. 1995). High iron (1 mg/l) and manganese (0.4 mg/l) concentrations were registered. Elevated zinc concentration (0.61 mg/l) was registered first in 1985. This was considered sporadic, but further heavy metal data have prompted frequent sampling and analyses necessary. These have revealed that the presence of zinc and other heavy metals is caused by continuous discharges to the river network.

The very high zinc concentrations in the Tur/Túr were traced back to the Turţ Creek. Owing to careless operation of the wastewater treatment plant of the non-ferrous metal ore mine along the creek, the effluent discharged represented a source of continuous heavy metal pollution. The peak concentrations of copper, lead, nickel and chromium remained below the limit set for excellent water quality, but the concentrations of cadmium, mercury and zinc have prompted a classification into the polluted and highly polluted categories. Sediment analyses have shown high accumulations of zinc in the deposits.

The groundwater aquifers are situated below the phreatic groundwater relatively close (2-3 m) to the surface, at depths of 15-80 m (Upper Pleistocene), 50 170 m (Lower Pleistocene) and 180 m (Upper Pannonian).

The Crasna/Kraszna catchment

Of the 3142 km^2 large catchment 2253 km^2 (72%) are in Romania, while 889 km^2 (28%) in Hungary. The Crasna/Kraszna emerges at El. 997 m below the Măgura Priei peak rising between the Meseş and Rez Mountains in the southern part of the Şimleu Silvaniei Basin.

Over her headwater reach she collects several minor streams, the more important ones of which, the Poniţa valley, the Banului Creek, the Mărtăuţa and the Şomoş Creek, drain the larger, left hand slopes. The mean unit runoff over this section is little above 6 l/s km^2. The river has carved her bed into sedimentary rocks with a wide loop around the crystalline shale block of the Măgura Şimelului (579 m). Notwithstanding the fact that this is the upper part of the catchment, the river slope is relatively flat at 10.2 m/km.

Down to Supuru de Jos the river meanders in the rolling Sălaj country between relatively recent Piemont type Pliocene Quaternary formations. Extending to the lowlands, the deep valleys provide ready drainage to the groundwater. The more important tributaries include the Zalău, the Corund, the Cerna and the Maria creeks, which drain the right hand catchment (Figure 5.).

Over the middle reach the river slope diminishes from 5.0 to 3.2 m/km down to the area of Moftinu Mare Ghilvaci. Upon her emergence into the lowlands, the river has deposited an alluvial fan which contributed to filling the Ecedea/Ecsed depression.

The eutrophic marsh known as the Ecedea/Ecsed Bog developed along the lower reaches of the Crasna/Kraszna during the last glaciation period. Before the reclamation drainage project, the Crasna/Kraszna has fed regularly the Ecsed/Ecedea Bog, while according to Benedek (1973) at times of major floods the inundation have extended between Acâş and Mihăieni as far as the Ier/Érmellék, which belongs to the catchment of the River Barcău/Berettyó. Depending on the alternation of wet and dry periods, the area of the marsh varied continuously. Reclamation, which involved the construction of drainage canals and embankments, has brought about profound changes in the original, natural stream network.

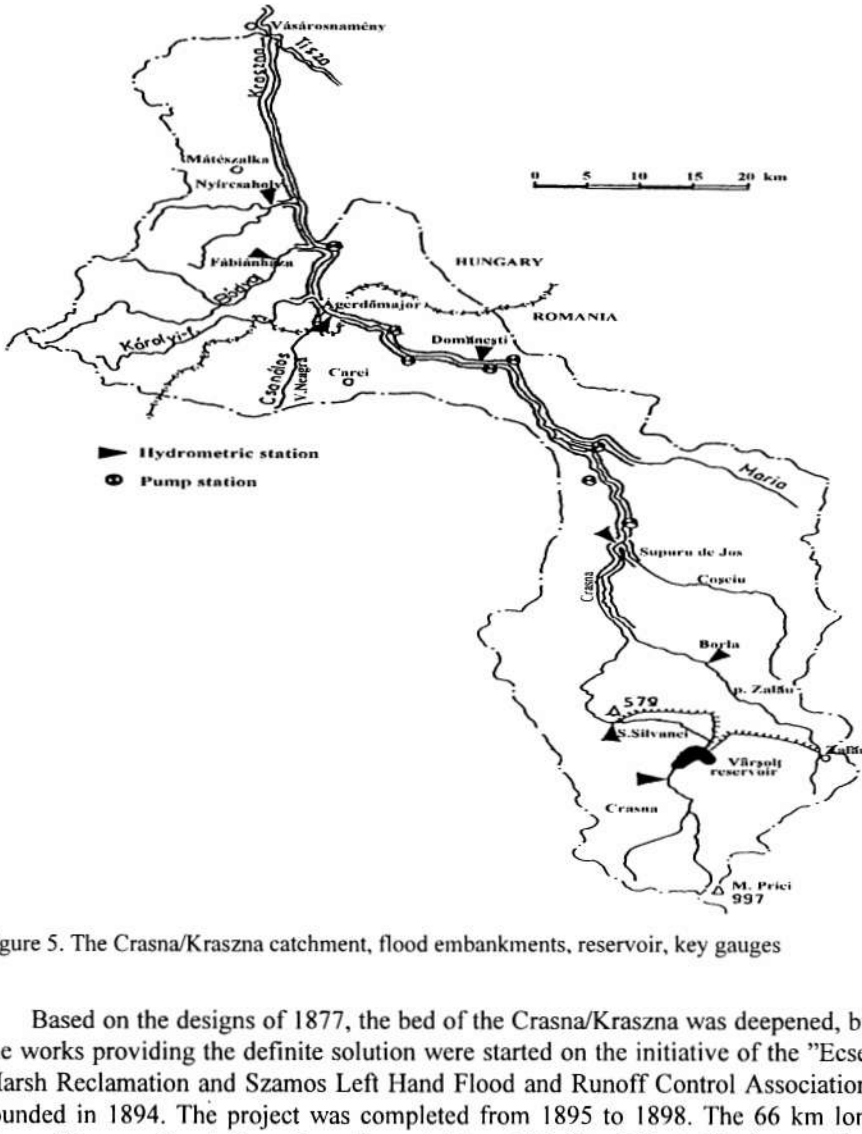

Figure 5. The Crasna/Kraszna catchment, flood embankments, reservoir, key gauges

Based on the designs of 1877, the bed of the Crasna/Kraszna was deepened, but the works providing the definite solution were started on the initiative of the "Ecsed Marsh Reclamation and Szamos Left Hand Flood and Runoff Control Association" founded in 1894. The project was completed from 1895 to 1898. The 66 km long Crasna/Kraszna Canal (from the railway bridge at Moftinu Mic to Vásárosnamény) was excavated and flanked by flood embankments. The canal by passed the marsh and discharged directly to the Tisa instead of the River Someş/Szamos. An embankment was also built along the left hand bank of the River Someş/Szamos, the small streams draining the Făget and the Nirului/Nyírség sand hills were trained, interrupting this way water supply to the marsh. The next step consisted of the excavation of the Boghiş/Keleti, the Északi and the Central/Lápi drainage principals. As a result of these measures the 9200 ha large Romanian part of the marsh retreated and dried up within a relatively short period of time.

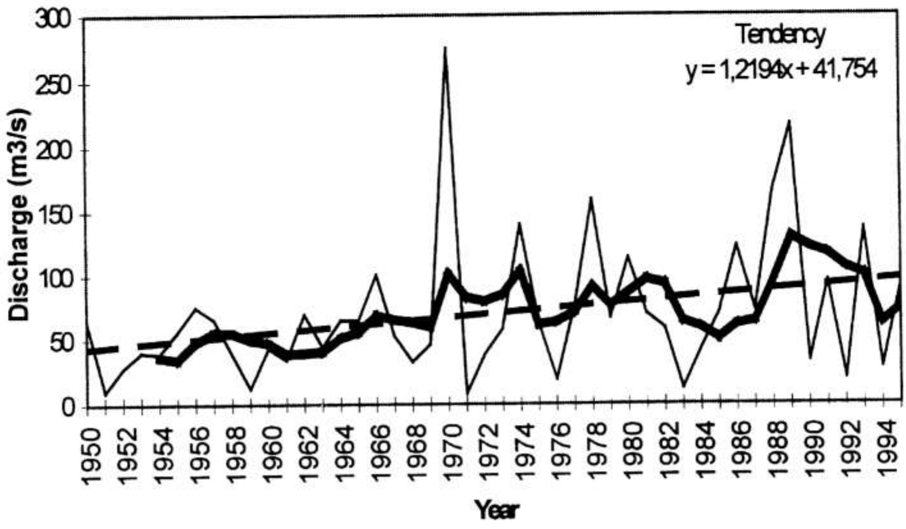

Figure 6. Annual peak stram flows (annual data, five year moving average, linear trend) past the Supuru de Jos station on the Crasna/Kraszna (1950–1994)

Flood embankments extend presently along both banks of the Romanian section of the Crasna/Kraszna from the mouth of the Zalău Creek to the national boundary and thence to the Tisa. On the tributaries embankments were built along short sections upper of their inflow to the recipient. The defences were strengthened in 1979-1985 to withstand floods of 2.5 10% probability. The embankments rise to 1.5-3.5 m above the terrain, the distance between the low water bankline and the embankments Arieş from 60 to 80 m. The mouth of the Maria Creek was relocated 3.5 m upper, increasing thus the size of the catchment pertaining to the Alsószopor hydrographic station.

On the 45 years long 1950-1994 record three periods can be distinguished. While there were no major floods from 1950 to 1964 and 1985 to 1994, major flood waves travelled down the river every second to fifth year between 1965 and 1984 (Figure 6.).

The aggregate capacity of the pumping stations built to lift surface runoff in the Crasna/Kraszna catchment is 72 m^3/s, of which that of the 14 stations on Romanian territory is 58.2 m^3/s. Three of these pumping stations (1.5 m^3/s) are upper of Supuru de Jos, seven (32.9 m^3/s) between Supuru de Jos and Domaneşti, while four (23.8 m^3/s) between Domaneşti and the national boundary. The largest pumping stations are those at Moftin (22.5 m^3/s) and Berveni (18.0 m^3/s) (Pandi 1992).

Although reclamation has eliminated open water surfaces, the groundwater table is still very close (0.5—1.0 m) to the surface locally.

Reservoirs

Following the large floods of the 70s, the 2160 m long and 14 m high earth dam was built between 1977 and 1979 at Vârşolţ, which created a 40.65 million m^3 storage space of 460 ha large water surface at normal retention level. The catchment area above the reservoir is 345 km^2 (11% of the total). Over one half (23.88 million m^3) of the reservoir space serves flood control purposes. The total capacity of the bottom outlet and the spillway weir is 263 m^3/s and thus considerably higher than the conveying capacity of the flood bed. The conservatively dimensioned storage space allows complete retention of 0.8% probability flood waves. Drinking water to the towns Zalău (0.5 m^3/s) and Şimleul Silvaniei (0.25 m^3/s) is supplied from this reservoir.

The Moftinu Mare emergency reservoir was built in 1980 on the right hand bank of the low land section of the Crasna/Kraszna. The reservoir is capable of retaining 6.8 million m^3 of flood flow (2.4 million in the first and 4.4 million in the second basin). The 274 ha large reservoir enclosed by a 3 m high embankment is 2.4 km long and 1.3 km wide. Water to the first basin can enter only at stages overtopping the 70 m long fixed weir, the maximum capacity of which is 115 m^3/s. After the flood the water is released through two 2.0 by 1.2 m vertical lift gates of 10 m^3/s combined capacity.

For the complete development of the flood control system two further emergency reservoirs are envisaged, one at the mouth of the Maria Creek to the recipient (catchment area: 240 km^2, or 11% of the total) and one at Rătești (catchment area 117 km^2, or 8% of the total).

Water transfers

Part of the Crasna/Kraszna flood flow can be diverted at Acâş into the catchment of the Barcău/Berettyó, specifically into the valley of the Ier/Ér Creek, provided that the latter carries no flood at the same time. In the upper part of the catchment, on the other hand, a flow of some 0.2 m^3/s is transferred from theBarcău /Berettyó catchment to the Vârşolţ reservoir to augment the relatively low flow available in arid periods. The meet the considerable demand of the industries in the Zalău region water is also imported from the River Someş/Szamos through the diversion at Jibou (0.8 m^3/s).

Construction of the Vârşolţ reservoir and other water resources projects have opened the possibility of transferring some 1 m^3/s to the Crasna/Kraszna catchment from the neighbouring River Someş/Szamos and Berettyó/Barcău catchments. The return flow appears in the Crasna/Kraszna as domestic effluent at Şimleul Silvanei, which is supplied with piped water from the reservoir, and farther downstream in the tributary Zalău Creek to which industrial effluents from the River Someş/Szamos and domestic effluent from piped water supply obtained from the Vârşolţ reservoir are discharged.

The flows entering the reservoir can be estimated from the records of the Crasna/Kraszna gauging station, at the village Crasna, while the released volumes from those of the gauging station at Şimleu Silvanei and Supru de Jos situated downstream of the Zalău Creek, further on the Ágerdőmajor gauge. The streamflow record of the guaging station at the village Crasna on the Crasna/Kraszna river reflects the natural runoff influenced little by human activities, while the flow registered on all gauges downstream of the reservoir are modified ones. The record of the Domaneşti and Ágerdőmajor stations is influenced by the operation of the runoff lifting stations in the lowlands and the impoundment of the Moftinu Mare emergency reservoir at floods higher than the Alert Level I.

The impact of the Vârşolţ reservoir on the monthly and annual flows

The annual mean flows before (1963—197) and after impoundment (1979—1994) were compared with the following conclusions:

- On the Crasna/Kraszna gauging station the flows during the first period were 8% higher than during the second, owing mainly to the sequence of 13 arid years after 1979.
- On the Şimleul Silvanei gauge impoundment has reduced the mean flow by 40%.
- On the stations downstream of the Zalău Creek (Supuru de Jos, Ágerdőmajor) the impact of impoundment was no more detectable.

The annual peak flows averaged over the 1979—1994 period

- have grown slightly on the Crasna/Kraszna gague upper of the Vârşolţ reservoir,
- have dropped drastically, to 22.5% of the former (from 72.6 to 15.9 m^3/s) on the Şimleul Silvanei gauge, and
- have dropped moderately from 96.4 to 78.1 m^3/s (19%) on the Ágerdőmajor gauging station.

The impacts of the Vârşolţ reservoir and the inter basin transfers are significant ones also in low water periods:

- The low flows past the Crasna/Kraszna gauge have increased slightly (10%).
- The low flows past the Şimleul Silvanei station have decreased following impoundment of the reservoir.
- The averages of the annual minima have doubled on the gauges Supuru de Jos (from 0.261 to 0.568 m^3/s) and Ágerdőmajor (from 0.366 to 0.771 m^3/s) (Figure 7.).

Sediment transport in the River Tur/Túr and Crasna/Kraszna rivers

From the data of the sediment observations in Romania it was noted that the rate of suspended sediment transport in the Crasna/Kraszna at the Domaneşti station (3.87 kg/s) was 2.5 times as high as that in the Tur/Túr at Turulung (1.45 kg/s), although the streamflows in the latter are appreciably higher.

A comparison of the records registered before and after the construction of reservoirs has lead to the unexpected result that rather than decreasing, the transport rate has increased upon impoundment by 57% on the Tur/Túr and 88% on the Crasna/Kraszna. The phenomenon is interesting enough to merit further study, but it appears obvious that the increase in the rate of suspended sediment transport is unlikely related directly with the commissioning of the reservoirs. In fact, the two reservoirs are

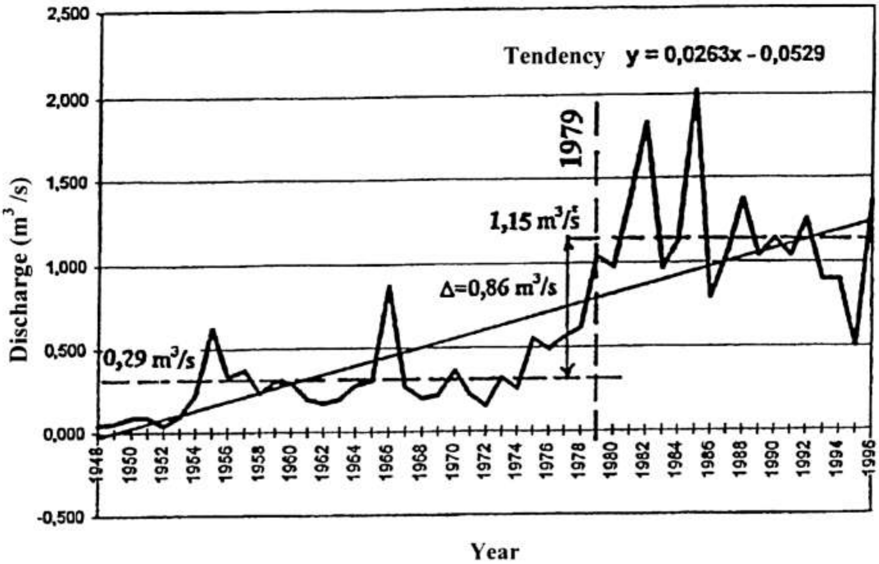

Figure 7. Increase of the annual minimum flows by the Vârşolţ reservoir after its commissioning in 1979, on the Ágerdőmajor gauge on the Crasna/Kraszna

on the upper reaches of the rivers, where owing to moderate erosion rates the sediment transport rates are relatively low. The distance between the reservoirs and the stations with sediment observation data is long and it is the middle reach of the rivers, where physico geographical conditions, precipitation, surface runoff and channel erosion, are conducive to sediment entertainment.

The Crasna/Kraszna is the stream with the poorest water quality in the region. In the boundary cross section the arriving flow is virtually sewage. The organic content is high, although the organic load in terms of the COD has diminished slightly relative to the level in the 80s. The high ammonia content is the result of the liquid manure discharges. Relative to the streamflow the ammonium ion flux is the heaviest. The TDS content is also high. The phosphate ion level originating from poorly treated effluents depends on the actual streamfow and is comparable in this respect to the other streams (phosphate removal being rare).

The DO content is consumed by the large amount of decaying organic, algal growth is triggered by the abundant nutrient supply and is the cause of secondary organic pollution. In this respect the worst (4.6 mg/l) month is May, when the water temperature starts rising and the decomposing activity of bacteria intensifies.

Prolonged oxygen deficient conditions in summer with DO levels as low as 0.9 3.0 mg/l are the result of high organic loads. Fibrous fungi (Sphaerotilus) appear in the water, while others are present in the form of fine floating flocs.

No higher animals can survive in the stream bed. The nitrogen and phosphorus content responsible primarily for eutrophication keeps growing and affect the aquatic ecosystem by extended exposure (Erdelics, Barta 1989).

The causes of poor water quality and organic silt deposits in the stream bed are the sources of pollution. like the poorly treated effluent discharges and the sugar refinery at Carei, and the untreated liquid manure from the Moftinu Mare pig farm.

Groundwater

The aquifers in the entire catchment yield generally little water. There are no more than six major water works drawing on groundwater, abstracting a total of 0.268 m^3/s, of which 0.226 m^3/s, pumped from depths between 50 and 400 m, are used for industrial and agricultural purposes in the lowlands around Carei.

The River Someş/Szamos catchment

The River Someş/Szamos catchment is shared by Romania and Hungary. The Romanian part of the is 15 217 km^2 large. The length of the river section in the catchment is 345 km. The two headwater branches, the Someşul Mare and the Someşul Mic join at Dej, downstream of which the river is called River Someş/Szamos.

The catchment enclosed by the 726 km long divide is drained by a dense stream network, which includes some major tributaries originating in areas of higher elevation and abundant precipitation, like the Someşul Mare, the Someşul Mic and the Lapuş.

Climate and hydrology are influenced basically by the geographic location of the catchment, which is 170 km long at an average width of 90 km. The mean elevation is 536, the average slope 170 m/km, the density of the stream network is 0.59 km/km^2. The mean discharge of the River Someş/Szamos at Satu Mare is 120 m^3/s, which carries a suspended sediment load of 136 kg/s. The variations of the annual peak flows is illustrated in Figure 8.

Flood embankments were built generally along the river sections in the mountain and hilly parts to protect major communities and where the channel is not embedded deep enough in the valley floor. Continuous embankments run along the Someşul Mare between Năsăud and Dej, along the Someşul Mic between Gilău and Dej, further in the plains between Berindan and the national boundary.

Reservoirs

The Colibiţa reservoir was built from 1977 to 1995 on the upper reaches of the Bistriţa, a tributary to the Someşul Mare, on the western slope of the Căliman Alpine Mountains. The 1.6 million m^3 of volcanic rock for the 92 m high, 252 m long valley dam were excavated in the vicinity. The upper slope was sealed with a special asphalt lining. The storage space created by the dam has a volume of 90 million m^3 at a water surface area of 300 ha. The flow of the Bistriţa and that of five creeks diverted via

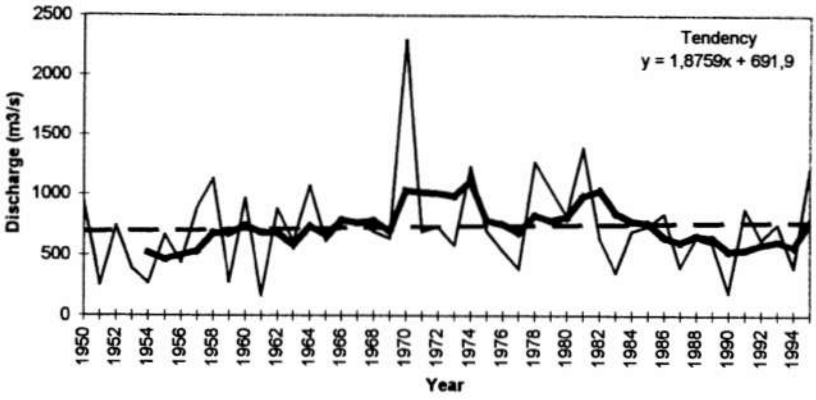

Figure 8. Annual peak streamflows (annual data, five year moving average, linear trend) past the Dej station on the River Someş/Szamos (1950—1994)

tunnels are impounded. The maximum release rate of 741 m^3/s is composed of the 6 m diameter glory hole spillway (550 m^3/s), the bottom outlet (104 m^3/s and the power station (87 m^3/s). The 21 MW underground power station is connected over a 6.2 km long tunnel.

The Someşul Mic water power and water management system project was implemented between 1969 and 1988. The scheme includes 16 dams of different size and serves to provide flood control to the Gilău-Dej section of the Someşul Mic, to save thus the costs of embankments, to supply drinking water to communities and to create welfare, recreation opportunities.

The 102 m high, at the crest 410 m (at the base, owing to the steep valley slopes only 270 m) long Mărişel gravity dam ios lined on the upper slope with r.c. slabs of 0.35-0.94 m thickness and 34 100 m^2 total surface area. The Fântânele (Beliş) reservoir is 13.5 km long and 815 ha large at normal retention level. At the highest storage level the volume is 250 million m^3, of which 48 million m^3 serve flood control purposes, so that the net storage space is 200 million m^3 (Figure 9.).The reservoir is fed by the 6.81 m^3/s mean flow of the Someşul Cald, the creeks (4.09 m^3/s) diverted from the Someşul Rece catchment and the Iara (1.78 m^3/s), a tributary of the Arieş. These flows are diverted to the reservoir through tunnels os 21 km total length. Under emergency conditions a maximum flow of 700 m^3/s can be passed over the spillway (Pop 1997).

The Mărişel underground power station was excavated in very hard metamophic rock to accommodate three Francis turbine generating sets of 220 MW total capacity (73.5 MW each). The power flow of 60 m^3/s is conveyed in a 8,75 km long, 4.4 m dia. tunnel from the reservoir under a head of 470 m.

The 232 m long, 97 m high double curvature arch dam Tarniţa was built 16 km farther downstream and commissioned in 1974. The powerhouse at the toe of the dam

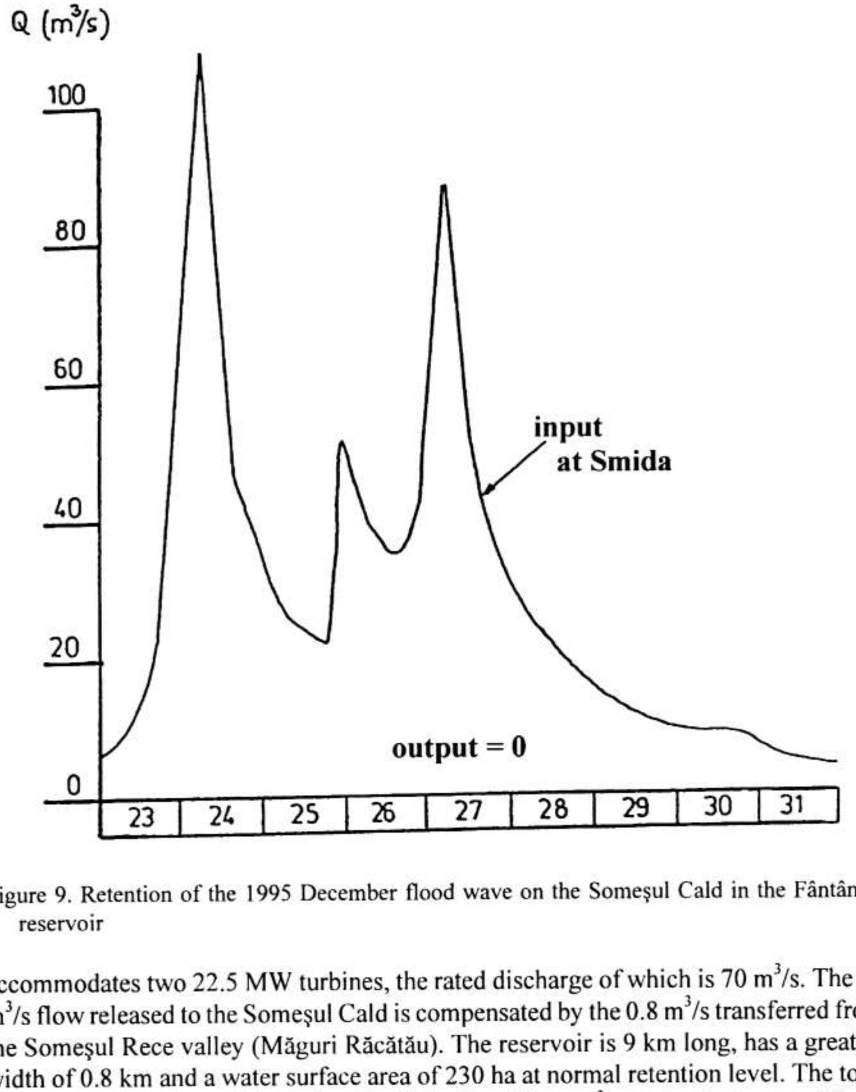

Figure 9. Retention of the 1995 December flood wave on the Someşul Cald in the Fântânele reservoir

accommodates two 22.5 MW turbines, the rated discharge of which is 70 m^3/s. The 15 m^3/s flow released to the Someşul Cald is compensated by the 0.8 m^3/s transferred from the Someşul Rece valley (Măguri Răcătău). The reservoir is 9 km long, has a greatest width of 0.8 km and a water surface area of 230 ha at normal retention level. The total storage space is 71 million m^3, of which 41 million m^3 are dead storage. Of the remaining 30 million m^3 net storage space 7 million serve flood control purposes.

The Someşul Cald reservoir was completed in 1983 with the main purpose of preventing the large volume of sediment transported by the Agârbiciu Creek from entering the Gilău reservoir (the source of water supply to the town Cluj). The 3.5 km long, 85 ha surface area reservoir created by the 130 m long, 33.5 m high concrete gravity dam is capable of impounding 10.8 million m^3 of water, which is used also for generating 12 MW of power by a Kaplan turbine.

The Gilău I dam was built between 1968 and 1971 on the Someşul Mic, downstream of the confluence of the Someşul Cald and the Someşul Rece. The 285 m long and 23 m high consists of a 117 m long r.c. secrtion, a 59 m long rockfill section and a 109 m long earth embankment of local materials. The 1.8 km long and 72 ha large water surface corresponds to a storage space of 4 million m^3. The design discharge of the three 6.3 MW turbines is 61 m^3/s. Drinking water to the towns Cluj, Gherla and Dej, further to a number of minor communities is supplied from the reservoir over an 80 km long pipeline.

The smaller Gilău II, Floreşti I, Floreşti II and Cluj I power stations were built downstream of the Gilău dam. The 7 km long power canal extending on the left hand side of the Someşul Mic between the Gilău I dam and the Floreşti II power station has a slope of 0.175% and is capable of conveying the 60 m^3/s discharge of the turbines in the Gilău power station for use at the Gilău II and Floreşti I power stations, each equipped with a vertical shaft 5.6 MW Kaplan and one horizontal shaft 0.65 MW EOS 1100 turbine.A weir with four movable gates was built in the bed of the Someşul Mic at the village Floreşti, which impounds the 2 km long, 31 ha large Floreşti reservoir of 1 million m^3 capacity. A flow of 25.8 m^3/s is released therefrom to drive the six 220 kW capacity EOS 1100 turbines in the Floreşti II power stations.

The last unit in the chain of of power developments is the 0.49 MW small hydro station Cluj I, where six turbines of the EOS 1100 type are mounted on a weir built formerly to divert a flow of 1 m^3/s for the Canalul Morii (millrace) crossing the centre of the town.

It should be noted that the Someşul Cald (the valley of which comprises the overwhelming part of the storage space and the power stations) contributes no more than 55.5% to the operation of the Someşul Mic hydropower scheme, 32.6% being contributed by the Someşul Rece and 11.9 by the Iara, a tributary of the Arieş river in the Maros/Mureş catchment. The chain of reservoirs built on the Someşul Cald is capable of retaining flood waves of virtually any size and to provide over year flow control.

On the small streams of the Câmpia Transilvanei region, especially in the Fizeş Valley there are a number of minor reservoirs used for fishing. The majority of these was created by Man. The number of ponds has diminished gradually since Meviaeval times. One century ago 150 of such ponds were mentioned in the documents, but presently no more than 13 are registered. Of these seven are on the Someşul Mic and the tributary Fizeş thereof, one on the Şieu (Săndulache 1970). These are as follows: Ţaga Mare 3.9 million m3, 220 ha; Sântejude 0.94 m^3, 38 ha; Lake Ciucaş 1.88 million m^3, 26 ha; Lake Cătina 1.40 million m^3, 56 ha; Lakes Tău Popii I, II 0.75 million m^3, 26 ha; Lake Geaca 0.54 million m^3, 38 ha, Lake Ţaga Mică 0.24 million m^3, 21 ha. Some distance away, in the valley of the Şieu (a tributary of the Someşul Mare) is Lake Brăteni 0.12 million m^3, 18 ha.

The Sălăţig permanent fish pond and flood control reservoir was built between 1982 and 1984 on the Mineu Creek (a tributary of the Sălaj Creek, which, in turn, is a left hand tributary of the middle reach of the River Someş/Szamos). The 265 m long earth dam rises to a greatest height of 11.1 m and the upper face is lined with concrete slabs. The reservoir created is 2 km long, 0.1 km wide and 23 ha large at normal retention level, and is capable of holding up to 3.4 million m^3. The highest discharge which can be released simultaneously is 114 m^3/s.

The Strâmturi or Frizia dam and reservoir was built 10 km to the north of Baia Mare, in the catchment of the Lăpuş, on the Frizia Creek between the years 1960 and 1964. The catchment above the dam site is 130 km^2 large, to which 82 km^2 must be added from the catchment of the Runcu Creek, a tributary of the Mara (which belongs via the Iza to the Tisa stream network). The reservoir serves three purposes, viz., water supply to Baia Mare, power generation and the attenuation of flood waves. The dam proper is 150 m long, but on the right hand side the local rock is concrete lined over 48 m length, so that the dam is actually 198.4 m long. The greatest height is 51.5 m. At normal retention level the water surface is 3 km long, 0.5 km wide and 113 ha large. The total storage space is 17.53 million m^3, or which 0.93 million m^3 are used for flood control purposes. In emergency situations up to 300 m^3/s can be released. The rated discharge of the 4.2 MW Kaplan turbine is 14.5 m^3/s.

Immediately (300 m) downstream of the Strâmturi dam is the 14.5 m high, r.c. concrete lined Berdu gravity dam, the reservoir behind which has a maximum capacity of 133 000 m^3 (at normal retention level 120 000 m^3). Mountain water of high quality is supplied from the reservoir to Baia Mare town over a 5.6 km long pipeline.

The Someşul Mic hydropower scheme with its 340 million m^3 of reservoir capacity has the greatest impact on the river regime. The normal annual runoff is 407 million m^3 so that theoretically, 84% of the annual runoff could be stored in the reservoirs.

N°	Stream	Reservoir	Net volume. million m^3	Purpose
1	Crasna /Kraszna*	Vârşolţ/Varsolc	41	water supply, flood control
2	Crasna /Kraszna	Majtény/Moftin	7	flood control
3	Tur/Túr	Călineşti-Oaş/Kányaháza	23	flood control, hydropower
4	Someşul Cald /Meleg-Szamos	Beliş/Béles	250	hydropower, flood control
5	Someşul Cald /Meleg-Szamos	Tarniţa/Tarnica	78	hydropower, flood control
6	Someşul Mic /Kıs-Szamos	Gilău/Gyalu	4	water supply, hydropower
7	Bistriţa/Beszterce	Colibiţa/Kolibica	78	water supply, flood control. hydropower
8	Firiza/Fernezely	Firiza/Fernezely	18	water supply
9	Talabor/Teresva	Olsoni/Olszoni	20	hydropower
Total			**519**	

* The first name is Romanian, and second Hungarian

Table 1. The main data of the major reservoirs

The reservoirs have changed considerable the flow regime of the Someşul Mic, in that the monthly mean flows during the late summer later winter low water period increased (4-82%), while the spring high flows decreased by 8 to 66%. The change in the ratio of the monthly highest and monthly lowest flows from 1:5 to 1:3 is considered significant.

River/gauging station	$Q_{max.}$ with storage	$Q_{max.}$ without storage	$H_{max.}$ with storage	$H_{max.}$ without storage	$\Delta_{max.}$
Tisza-Tiszabecs	1900	1910	484	484	0
Tisza-Vásárosnamény	2650	2910	858	885	27
Tisza-Záhony	2800	3060	658	688	30
Szamos-Csenger	1220	1300	629	659	30
Kraszna-Ágerdőmajor	46	174	499	620	121
Túr-Garbolc	114	182	465	510	45

Table 2. Greatest potential impact of storage abroad on the peak stages and flood discharges in Hungary (Illés, Konecsny 1996)

The normal annual mean flow in the Someşul Mic at Cluj was 14.7 m^3/s. After the hydropower scheme was commissioned, the streamflows actually observed were 10.6% lower than those estimated without the scheme. For this fact the following explanations are offered:

Up to 4 m^3/s are diverted from the Someşul Mic at Gilău;

The total water surface area of the reservoirs is 1160 ha at normal retention level, which contributed perceptibly to evaporation and infiltration;

At the Cluj station on the Someşul Mic the errors of streamflow measurement in the water transfer from the Arieş catchment and in the water uses are probably superimposed upon each other.

Three runoff lift stations on the downstream reach of the River Someş/Szamos, in the border zone have a total capacity of 19.7 m^3/s. These are at Mărtineşti righ hand bank, 18+215 km, 9.43 m^3/s, Satu Mare right hand bank, 6+641 km, 3.55 m^3/s and Dara right hand bank, 2+070 km, 6.70 m^3/s.

Water quality

The River Someş/Szamos is polluted with organic, the DO level fluctuates rather widely, the dissolved substances (virtually mineral salts), just as the ratio of sodium ion have increased steadily over the recent decades.

The transport of ammonium ion (the bulk originating from sewage) has also increased. The high concentration of dissolved salts originates from the geological and geographical conditions in the catchment.

The high concentrations of chloride and phosphate ion affect adversely water quality. The high phosphate ion concentration is the main cause of the undesirable prolification of floating algae in the water, especially during the summer low water period. Rising water temperatures tend to dissolve the plant nutrients accumulated in the bottom sediment leading to several million counts of diatomaceous algae per litre. Biological studies under the microscope have shown the diatomaceous algae

(Cyclotella, Tabelaria) to predominate and a variety of green alga species to be also present in considerable numbers. Decaying algae deplete the DO and lead to significant secondary organic loading in the water.

Pollution accidents occur frequently. The heavy pollutant load arriving in the River Someş/Szamos in August, 1990, has depleted drastically the DO level in the water and destroyed part of the aquatic ecosystem. The heating oil spill at Satu Mare in autumn, 1993, has necessitated cleanup action lasting 20 days on the Hungarian river section, during which over 20 tons of oil were recovered.

The sources of pollution are situated downstream of Cluj on the River Someş/Szamos river. The water is clean over the mountain reaches, the Gilău reservoir supplying domestic water to Cluj and several other minor towns. However, downstream thereof treated industrial wastewater and the effluents of the communal sewage treatment plant are discharged to the river.

Large amounts of organic substance enter the river with the effluent of the paper mill at Dej. The heavy metals detectable originate from the mining activities and non ferrous metal ore processing at Baia Mare and are transported to the River Someş/Szamos by the Săsar stream.

Seini is a town with a small population but the untreated communal sewage thereof represents a heavy load of organic and bacteria on the River Someş/Szamos .

Water quality in the River Someş/Szamos is further deteriorated by the industrial waste waters and poorly treated communal effluents, further by the runoff from the pig farm at Satu Mare.

The untreated sewage from the cattle farm at Doroltţ village is discharged via a canal to the River Someş/Szamos . The stock of the pig farm at Vetiş has diminished recently, but represents still a major source of pollution.

Gauging station	Catchment area F_1 (km^2)	Drained to reservoirs F_2 (km^2)	F_2/F_1x 100 (%)	Normal annual runoff Vres mill.m^3/y	Net storage space Vres mill.m^3/y	S=ΣVres /Wx100 (%)
Tisza-Tiszabecs	9707	438	4,5	6898	20	0,3
Tisza-Vásárosnamény	29057	2093	7,2	1124	482	4,3
Tisza Záhony	32782	3675	11,2	12600	553	4,4
Szamos-Csenger	15283	1280	8,3	4095	439	10,7
Kraszna-Agerdőmajor	1974	1582	80,1	198	23	35,8
Túr Garbolc	944	375	39,7	313	71	7,3

Table 3. Main indices of runoff control on the Upper Tisa and her tributaries (Illés, Konecsny 1996)

Groundwaters

From the viewpoint of hydrogeology, the Intercarpathian Depresssion, that is the Transylvanian Depression, can be dividided into two areas. The active recharge areas in the foothills have a significant impact on all components of the water regime, whereas the groundwater supplies originate in the basin, which forms the central part of the depression (Ujvári, Makkfalvi 1994). Owing to the fact that the basin was filled by torrential streams, the aquifers at different depths are relatively small in area and highly stratified. This is the reason why deep aquifers yielding abundant water exist in the perimeter areas of the basin alone. The logs of several deep boreholes demonstrate that down to 2000-3000 m depths impervious, clay, pelitic sediments predominate. These are followed by the similarly impervious salt level of the Baden horizon, the base of which consists of Oligocene and Eocene Paleocene clays. The sediments in the Transylvanian Depression were therefore deposited in a marine environment which explains the high salts content (HCO_3, SO_4, Cl_2) of the deep groundwater. The salts were leached by freshwater from the top 10-30 m thick sediment layer only, the salt content of this groundwater ranging between 0.5 and 1.0 g/l on the average. On the other hand, the groundwaters in the mountain areas belong without exception to the $CaHCO_3$ and $MgHCO_3$ types, their level of mineralisation in the eruptive belts is extremely low, less than 50 mg/l. Owing to the scarce supplies of poor quality, hard water of high salts content, the Câmpia Transilvanei region is economically less developed, even in areas with favourable soil conditions.

Along the lower, plain part of the River Someş/Szamos, in the Pannonian Basin, four hydrogeological units are distinguished above the crystaline shale and Tertiary sediments:

- the Torton Sarmatian layers under major foothill areas,
- the deep Pliocene Pleistocene aquifers,
- the Pleistocene Holocene formations mainly in the foothill areas, and
- the Upper Pleistocene Holocene alluvial fans.

Thermal waters of 35- 88 °C temperature have been struck in several boreholes in the Pannonian and especially the Pontinian aquifers of 50-250 m total thickness at 500-1000 m depth.

The groundwater supplies in the River Someş/Szamos catchment down to the Hungarian border amount to 31.2 m^3/s, of which some 3.77 m^3/s are abstracted by 36 major water works. The groundwater supplies in the approximately 1300 km^2 large alluvial fan of the River Someş/Szamos in the plains have been estimated at 3.70 m^3/s (Cineti 1985, 1990), of which some 1.9 m^3/s are abstracted by nine major units. The most important of these is the Mărtineşti water works which supplies drinking water to the town Satu Mare from 53 wells extending down to 120 m depth, at the rate of 1.16 m^3/s.

The Tisa enters Hungarian territory at Tiszabecs and is called upper over the over 200 km long section down to Tokaj Rakamaz (Figure 10.). The fundamental aim of the channel training works on the Upper Tisa and her major tributaries was to provide flood control to the wide plains. The first attempts date back to the 16th 17th centuries, but the definite project initiated by Count István Széchenyi and designed by Pál Vásárhelyi was started in 1846 only, following the establishment of the Tisza Valley Association. Of the 63 cuts envisaged upper of Tokaj, 61 were completed (28 upper of Záhony) by 1875 already.

The training project launched in 1846 has changed the flow regime of the Tisa gradually, as reflected by the lower low water and rising high water stages. A new period in river life was introduced between 1872 and 1908, when the flow regime adjusted to the new situation controlled by the embankments and the cuts. The extremes were still less pronounced, owing to occasional embankment failures, which prevented the development of flood peaks (Vágás 1977). Downstream of Tiszabecs the widely meandering bed is accompanied by silting oxbow lakes.

The annual rainfalls over the Upper Tisa catchment vary over a very broad range (Figure 11.).

Over the Hungarian section of the Tisza and the Szamos the flood and low water levels differ by 10-12 m, while on the Kraszna and Túr by 6-7 m. The rivers originating abroad (Tisza, Szamos, Túr, Kraszna) carry an important runoff, which amounts to 1.7 km^3 per year. The runoff volume in Hungary is hardly 0.2 km^3.

N	Stream	Gauge	LLQ	LQ_{mean}	C_v	C_s	Probability %			
			m^3/s	m^3/s			80	90	95	99
1	Tisza	Tiszabecs	14,0	62,8	0,29	0,00	42,0	33,0	26,0	14,0
2	Tisza	Záhony	47,0	82,0	0,32	0,53	64,0	58,0	49,0	38,0
3	Szamos	Csenger	10,5	22,9	0,36	0,70	15,6	13,0	11,2	8,30
4	Túr	Garbolc	0,099	0,847	0,76	1,55	0,315	0,195	0,126	0,052
5	Kraszna	Ágerdőmajor	0,037	0,609	0,82	1,70	0,207	0,127	0,086	0,042
6	Bódvaj	Fábiánháza	0,000	0,032	1,06	2,00	0,006	0,002	0,000	0,000
7	III. sz.ff.	Kántorjánosi	0,000	0,018	1,02	1,90	0,004	0,001	0,000	0,000
8	IV. sz. ff.	Levelek	0,003	0,061	0,69	1,30	0,026	0,016	0,010	0,003
9	VII. sz. ff.	Nagykálló	0,000	0,048	0,90	1,20	0,011	0,001	0,000	0,000
10	Lónyay-főcs	Kótaj	0,090	0,873	0,63	0,10	0,300	0,120	0,080	0,020

Table 4. Annual low flows and their probability

The normal meanflow in the Tisa at Tiszabecs is 217 m^3/s, at Vásárosnamény 355 m^3/s, that in the Szamos at Csenger 129 m^3/s, in the Túr at Garbolc 9.83 m^3/s, in the Kraszna at Ágerdőmajor 5.52 m^3/s. The distribution of the flows over the year is highly uneven, in that the flood discharge in the Tisa may be up to 3000 4000 m^3/s, dwindling in the arid summer autumn season to 30 50 m^3/s, so that the difference may be wider

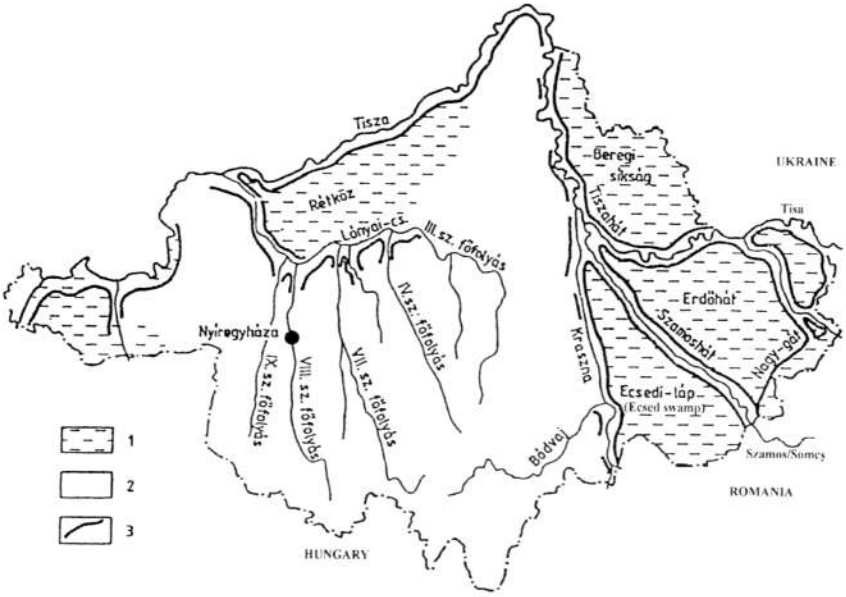

Figure 10. Reclaimed flood plains and major flood embankments in Szabolcs Szatmár Bereg County. 1 reclaimed flood plains, 2 terrain rising towards the flood plains with drainage canals, 3 flood embankments (Frisnyák 1993)

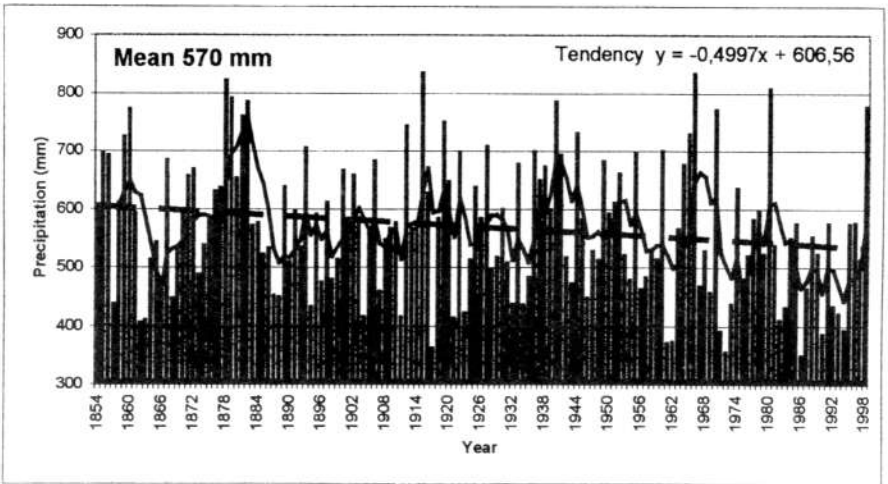

Figure 11. Annual rainfalls (mm) on the Nyíregyháza station (1950—1996)

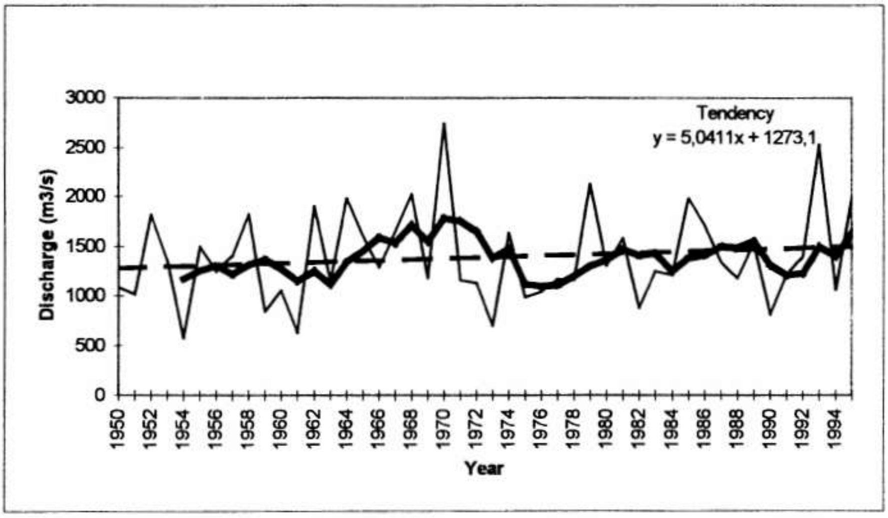

Figure 12. Annual peak streamflows (annual data, five year moving average, linear trend) past the Tivadar station on the Tisa (1950 1994)

than 100 fold (Figure 12.). On the Tisa three floods occur typically: in early spring, in early summer (the green flood) and in late autumn (Figure 13.).

The reservoirs built in the Nyírség Region and at Szabolcsveresmart in the 1960s and 1970s reduce the gap between the demand and supplies but slightly, the total storage capacity in the region being 37 million m^3 only.

Water quality over the Hungarian Tisa section

Under normal conditions the DO level is high along the entire river section, even the lowest levels observed at the stations meeting the criteria of good (Class II) quality. During algal blooms in the summer months the water may become over saturated with oxygen. The concentration of organic in terms of oxygen consumption increases slightly below the entrance of the tributaries, but does not surpass the limit value of the acceptable category at any of the stations. The peak oxygen consumption levels measured by the dichromate method which indicate a high organic load, Class IV V water quality coincide with the passage of flood waves.

The oxygen parameters show a slight improvement at the Záhony and Balsa stations.

The average and maximum concentrations of ammonium nitrogen are below the limit values of good water quality at all sampling stations. In terms of the average nitrite nitrogen parameters the water is of excellent quality and acceptable in terms of the peak values. Not even the highest nitrate nitrogen levels exceed the limit value of good water quality. The concentration of inorganic nitrogen is typically low in Tisa

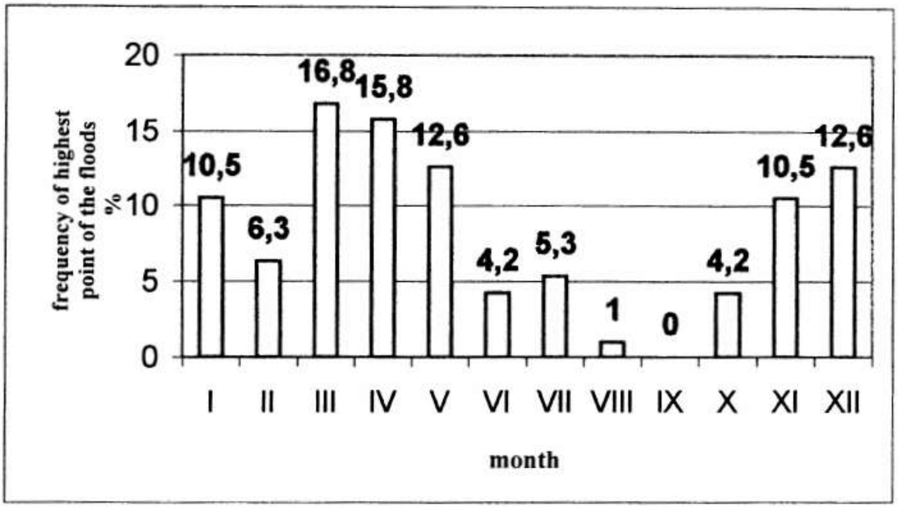

Figure 13. Frequency of high stages within the year (%)

water. The levels of total nitrogen hardly surpass those of the inorganic nitrogen, implying that the amount of nitrogen present in organic forms is insignificant.

In terms of the average orthophosphate content readily available to the plants, the water was of Class II quality, in terms of the peak levels of Class III quality at the border station, while of Class IV „highly polluted" at Balsa. The total P concentrations show and even poorer situation. Both the average and the peak levels increase with distance from the border station, the level at the border being acceptable, but „polluted" farther downstream.

Primary production depends basically on the amount of inorganic nitrogen and phosphorus form present and is described most simply in terms of the chlorophyll a levels. The average concentrations do not surpass the limit value of the acceptable quality class. The peak concentration is low at the border station, but increases more than seven fold below the tributaries, turning the water of Class IV „polluted" quality.

Bacterial pollution in the Tisa indicates very poor conditions. The coliform counts per millilitre are typically those of the polluted highly polluted quality classes. In terms of the average counts of faecal coli and streptococci the quality is acceptable. The peak values at the border station and below the tributaries indicate Class IV, polluted quality, while a slight improvement, lower counts were noted in the samples taken farther downstream.

The concentration of the various organic trace pollutants, such as phenoles, detergents, hydrocarbons is very low, close to the detection limit in Tisa water. In terms thereof the water is of excellent, Class I quality.

Of the inorganic trace pollutants, neither the average, nor the peak concentration of copper, arsenic, lead and chromium surpass the limit values of the quality classes I-II.

In most samples nickel was present in low concentrations, but the peak at the Tiszabecs station attained the limit of the acceptable category.

In terms of the peak zinc concentrations the water was classified „polluted" at the border station, but improved to „acceptable" farther downstream. In terms of aluminium the water was highly polluted, but the concentration diminished in the direction of flow and the quality improved to acceptable at Balsa. The concentration of heavy metals was found depend decisively on the quality of flow past the border station.

The peak pH levels indicated slightly alkaline water but remained below the limit of „good" water quality. Electric conductivity, as a measure of total dissolved substances, has met the criteria of excellent good water quality.

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