Novi Sad (Republic of Yugoslavia): How the water supply of the town was affected by the NATO campaign of 1999

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Introduction

Novi Sad is the second largest town in the Federal Republic of Yugoslavia, with a population of slightly more than 300,000. During the NATO aerial campaign the town was bombed many times. The main targets were the refinery, the television station and the bridges. All the bridges across the Danube were destroyed between the 1st and the 24th of April 1999, and other targets suffered extensive damage. The chronology of the main events concerning Novi Sad during the Kosovo crisis is given in the following table, which has been adapted from that given in the UNEP/UNCHS Balkan Task Force report.

March 1999	
24	Beginning of the aerial operation against the Federal Republic of Yugoslavia (FRY)
April 1999	
1	Missiles strike the bridges between Novi Sad and Petrovaradin. Main water pipeline is badly damaged, leaving much of the town without water
5	Thermoelectric power station/boiler plant in Novi Sad hit. Oil refinery in Novi Sad is hit, along with store of bitumen
7	Garages and warehouse at an oil refinery in Novi Sad are destroyed
11	A Novi Sad residential area is hit
12	NIS oil refinery in Novi Sad suburb is hit
16	Oil refinery in Novi Sad is hit again
20	Novi Sad oil refinery reported struck
23	Zezelj Bridge in Novi Sad is attacked again
24	Oil refinery in Novi Sad is hit again
25	Strike at an oil refinery in Novi Sad
26	Novi Sad attacked
28	Novi Sad oil refinery is hit during the day Further bombardment of the oil refinery in Novi Sad
May 1999	
2	The RTS television building and oil refinery in Novi Sad are hit again
16	Beginning of the UN Inter-Agency Needs Assessment Mission to FRY
June 1999	
10	NATO suspends “Operation Allied Forces”

Table 1
Chronology of main events concerning Novi Sad from Ref (I)[4]

The Task Force was established in early 1999, when the conflict was still going on. Its first UN Inter-Agency Needs Assessment Mission was carried out between 16 and 27 May and the first specifically technical mission took place between 17 and 21 June, mainly to assess the consequences of the conflict on the environment and on human settlements in several key areas, including Novi Sad.

Figure 1
Varadinski Bridge

Of particular importance among the other targets chosen during the campaign because of their geographical location and their potential impact on the quality of the water used to supply the town’s inhabitants were the oil refinery of Novi Sad and the crude oil and chemicals storage tanks.

Figure 2
Liberty Bridge

[1] The opinions expressed in this paper are those of the author and do not necessarily reflect the views of the ICRC, of Vodovod, (Novi Sad Water Board) or any other institution quoted.
[2] Vodovod I Kanalizacija, Public Utility Company, Novi Sad
[3] International Committee of the Red Cross’ engineers
[4] The Kosovo conflict. Consequences for the Environment and Human Settlements, UNEP/UNCHS, 1999

The destruction of the bridges had an immediate consequence: the areas located on the right bank of the

Figure 3
Concrete Bridge

Danube, with a population of about 50,000 people, were completely deprived of potable water and it was feared that spillage of dangerous substances could contaminate the aquifer. The authorities were very worried about the lack of drinking water and the consequences to the public health of such a situation, knowing that it would take months to rebuild a passage between the two banks of the river, and emergency measures were immediately studied to find a solution.

In this report we describe how the water supply of the town was affected, the chronology of the emergency measures taken during the bombing campaign by the engineers of the public utility (Vodovod), and the assistance provided by the ICRC to restore at least minimum access to potable water until more permanent solutions could be found. Other projects to restore the water supply to the right bank, launched in 1999 after the end of the NATO campaign, will also be outlined, as well as those implemented since, completed only in mid 2001. The possible long-term consequences for the health of the inhabitants of Novi Sad due to the spillage of dangerous substances into the aquifer, are discussed. Finally, some considerations regarding the NATO campaign and its choice of bridges and areas containing dangerous substances as legitimate targets will be outlined in relation to the provisions of the 1949 Geneva Convention and its additional Protocols of 1977.

The water supply of Novi Sad

The general water supply scheme of the town is shown in the next figure. The situation of the primary distribution network both before the war and now is presented schematically. The exact chronology of the damage inflicted to the bridges and the interventions of Vodovod's engineers will be presented later.

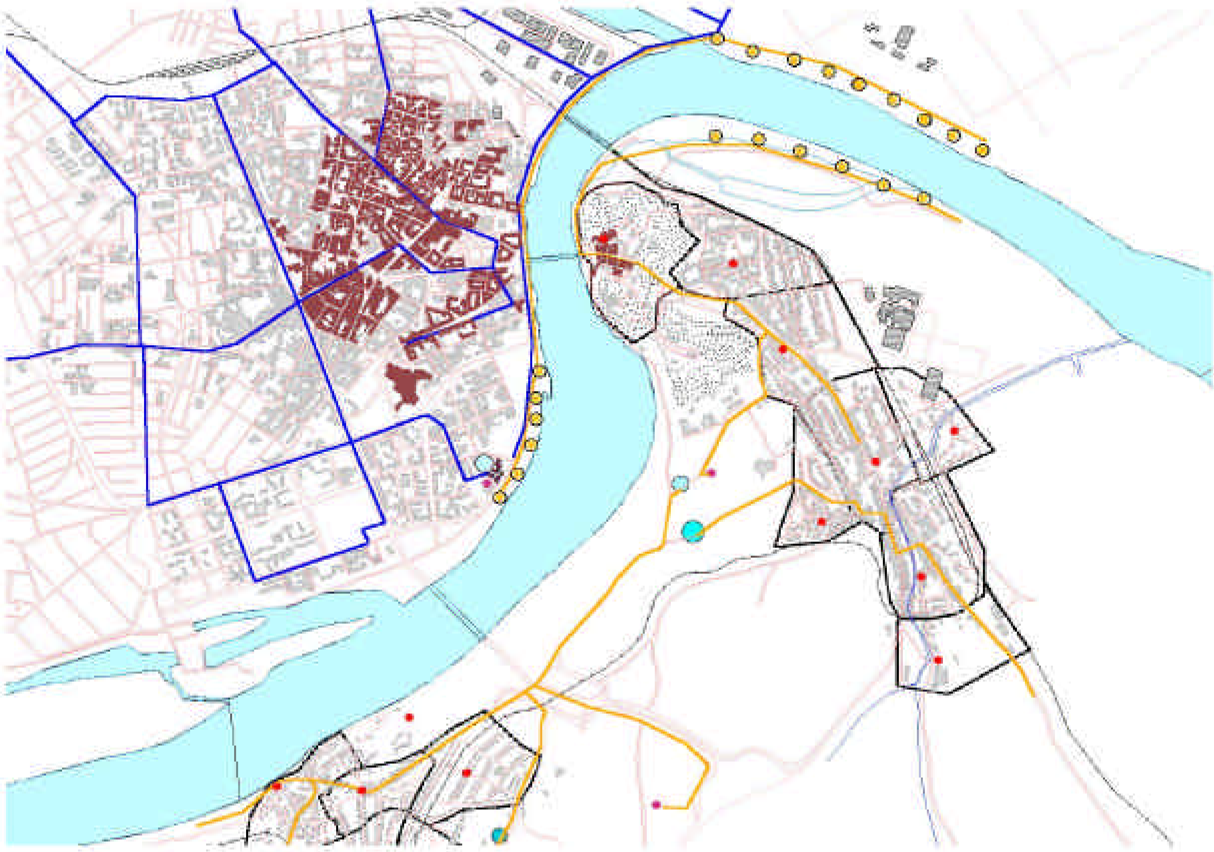

Figure 4
Layout of the conveying lines and primary network of the town

Raw water is obtained from several well fields located on both banks of the Danube. The oldest well field is located on the left bank and has the capacity to provide between 25,000 and 30,000 m3/day. Also located on the left bank are eight Renney wells in the immediate vicinity of the refinery, at Ratno. They have the capacity to provide roughly 65,000 m3/day. Six other wells are located on the right bank, in Petrovaradin Ada, and are capable of supplying about 50,000 m3/day. The well fields are equipped with different types of submersible pumps that pump the raw water to the treatment station located on the left bank, close to the Strand well field. This station has a capacity of about 130,000 m3/ day and a storage reservoir of 10,000 m3. The main problem is the high concentration of iron in the raw water, up to 3-4 mg/l, requiring aeration and filtration to remove oxidised particles.

Figure 5
Aeration room to remove iron at the WTS

Aeration is performed at the treatment station. Fe (II) is oxidised to iron (III) by atmospheric oxygen and the particulate precipitate is removed by rapid filtration. The water is then pumped into the network at a flow rate of about 2 m3/s via pipelines varying in diameter from 900 mm to 700 mm. The treated water was brought to the right bank through a 900 mm pipeline via the upstream bridge, and a 450 mm pipeline via the middle bridge. Several intermediate storage reservoirs were located on the right bank and water was pumped from them to the different localities by several booster stations. Water was then distributed by gravity from the 15,000 m3 elevated storage reservoir (Institut), located at a height of 140 m, the mean elevation of the town (left bank) being about 80 m. The other storage reservoir, Transzament, with a capacity of 4,000 m3, supplied by the 450 mm pipeline via the middle bridge, is also located at an elevation of about 140 m. This reservoir was not connected to the Srem network and was used as a balancing tank for the left bank network.

Bridges were therefore essential to guarantee a normal supply of water to the town. The right bank is particularly vulnerable as the water must first be pumped to the treatment station, treated and then pumped back via the bridges to the distribution network. The destruction of the bridges also disrupted the supply to the left bank of the town, having cut off the supply of raw water from the well fields in Petrovaradin as well as the main equilibrium reservoir, essential to maintaining normal pressure on the right bank (4-6 bars).

Interventions during the aerial campaign

By the Water Board

The Water Board engineers reacted quickly. After the destruction of the Varadinski Bridge (the central steel bridge) they tried immediately to restore the potable water network of the right bank by reconnecting the secondary and primary pipelines to the main system supplied via the Liberty Bridge (farthest upstream).

The pumping station that supplied Kamenica was stopped and the pipeline used to feed the Transzament reservoir, which would have supplied the area of Petrovaradin. Kamenica was supplied by an improvised pumping station that was fed from the Institut reservoir. The work was completed on 3 April and the makeshift system was scheduled to become operational. All these efforts were undermined a few days later, when this supply was also cut off by the destruction of the Liberty Bridge.

On 6 April only one bridge was left, with a 600 mm pipeline supplying raw water to the treatment station from the wells located on the right bank. The only possible solution was to close down this supply of raw water, convert the line into a potable one and reconnect it to the distribution network of the right bank, thus reducing the source supply to about 50,000 m3/day with a total production of drinking water down to 35,000 m3/day. A 500 meter long linking pipeline of 500 mm diameter, with all the necessary valves and fittings was laid on the left bank, and a 1,100 meter long 500 mm diameter pipeline was laid on the right bank to reach the existing network, close to the Varadinsky Bridge. The construction was completed in about ten days. The Sremska Kamenica pumping station was restored to its former operation and the supply became relatively normal, with some interruptions due to damage to the remaining bridge, until 24 April, when the bridge was completely destroyed.

The right bank was left without drinking water.

By the ICRC

The ICRC responded quickly on 24 April, after the destruction of the last bridge, putting at the disposal of the municipal Water Board (Vodovod I Kanalizacijia) two tanker trucks (15 m3 each) and 8,000 l of diesel fuel to start water distribution to the inhabitants of the right bank, estimated at close to 50,000.

Reconnection of the raw water supply to the right bank network

Despite the problems caused by the destruction of the bridges and the losses in the supply of raw water, the situation on the left bank remained acceptable. There were some problems related to the difficulty of pressurising the network as before, because of the equilibrating role that had been played by the main reservoir located on the right bank and because of power cuts. The supply of electricity was not as critical as in other towns as Novi Sad could be supplied from two different grids. There was some disruption, but it was not considered, at that time, as having a significant impact on the health of the population.

Production data from Vodovod[5] show that there was a significant decrease in water production during the months following the destruction of the bridges. The total quantities produced decreased from a monthly average of roughly 3,000,000 m3 to a low of 1,800,000 m3 in May. In fact, the figures from April through December include “technical water” pumped into the right bank network, roughly 15-17,000 m3/day (450-510,000 m3/month), reducing the production of drinking water to about 40 % of the normal amount.

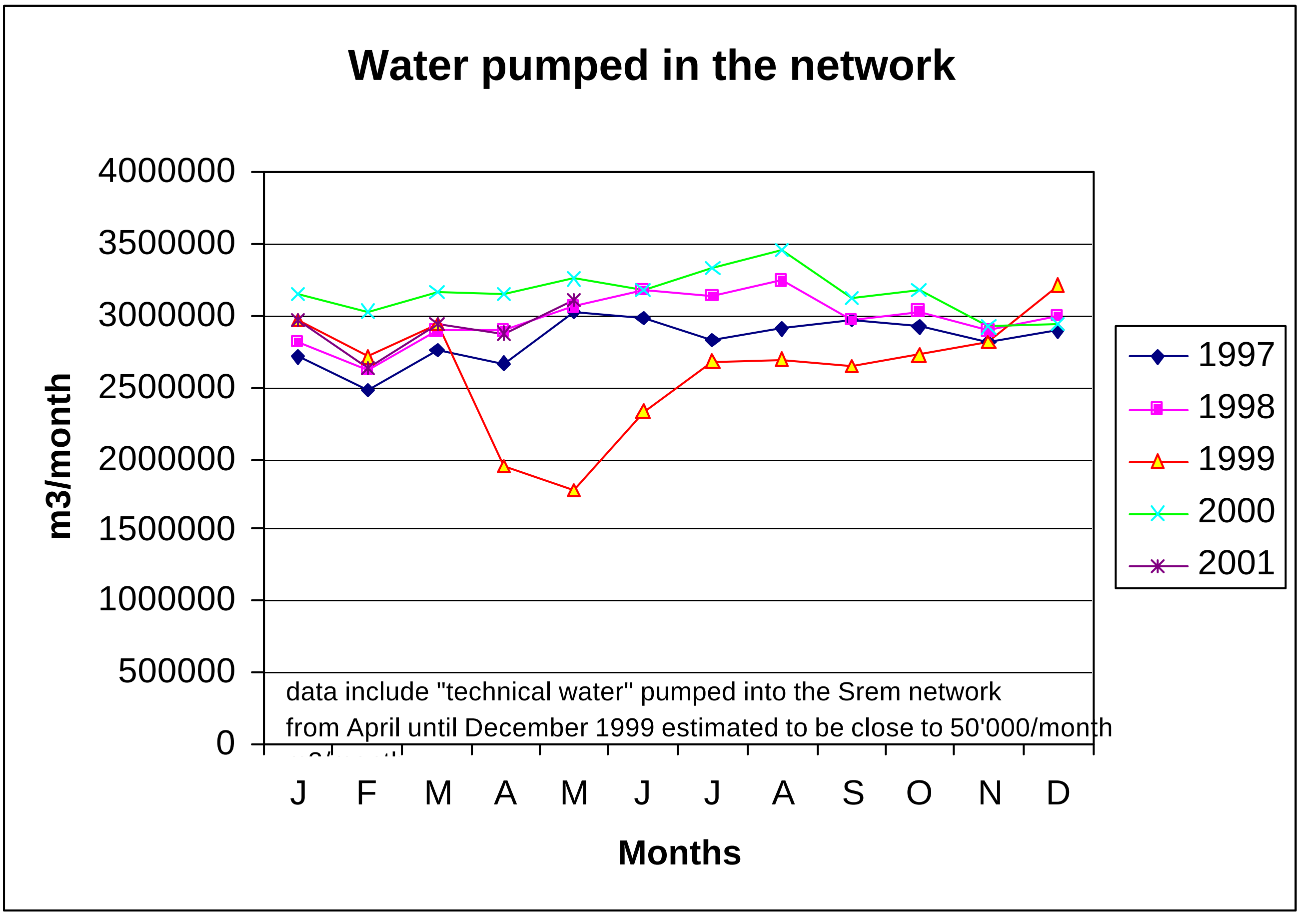

Figure 6
Average monthly production of water for the last five years, from 1997 to 2001

[5] Monthly production of water (pumped into the distribution network) from 1991 until 2001, Slavko Kulacin Vodovod, personal communication, September 2001

The situation on the right bank was more serious, albeit not dramatic. Vodovod decided to connect the raw water supply line to the treated water network and to distribute untreated water for domestic use, i.e. toilet flushing, personal hygiene, cleaning and laundry, although the latter was not recommended because of staining due to the high concentration of iron. The following figure (*Figure 7*) shows the new configuration of the network, with raw water distributed throughout the right bank. Apart from the concentration of Fe (iron, up to 3-4 mg/l) and Mn (manganese, up to 0.5 mg/l) the quality of the water made such a decision possible, even if this solution had to be considered as temporary. Drinking water guidelines recommend that the concentrations of the two metals should be less than 0.3 mg/l.

Water distribution by tankers

Drinking water requirements appeared to be covered by tankers. A wealthier minority was still able to purchase bottled water but supplies were running low and prices increasing sharply. The cost of a litre of bottled water was close to DM 0.4 and customers of Vodovod generally paid DM 0.16 DM/m3. In normal times, a family would spend, on average, DM1/month for water. A quick evaluation of the water distribution, carried out jointly by Vodovod and ICRC engineers on 10 May 1999, showed that the situation was far from satisfactory. The tankers sometimes had to drive 40 km south to Ruma to refill. They were generally allowed to refill in Beocin, which was closer at about 20 km from the town. The access to water was erratic, as it was not clear where the tankers would be at any given time.

Figure 7
Raw water distribution: the primary network after the destruction of the last bridge on 24 April 1999

Projects to improve the situation on the right bank

The Hidroinvest Project

On 16 April, Hidroinvest, a consulting company, submitted to the relevant authorities a proposal for a permanent solution to the situation. The proposed project was then submitted to the Vojvodina Red Cross, which finally handed it to the ICRC on 4 May. Hydroinvest had gained experience in the laying of pipelines across rivers and canals. They had successfully completed a number of smaller projects of up to 100 meters in length. On 6 May, a video of these operations was shown to the ICRC's engineer, at a briefing session held in the company offices in Novi Sad. The operations to be carried out were concisely described in a letter of intent given to the ICRC.

Several depth profiles of the river had been made. According to the engineers, the best location was 100 m downstream of the middle bridge (Varadinski), where the width of the river is about 300 m. It would be possible to lay two pipelines under the bottom of the river and not too difficult to connect them to the network. The steel pipes were already available at Vodovod. The operation was planned as follows:

- preparation of the working platforms on one side of the river
- preparation of two segments of pipeline about 150 m long and 450 mm in diameter
- positioning of six barges equipped with cranes across the rivers. The barges would have to be anchored at the remaining structures of the bridge and on the shores
- digging of an underground channel to host the pipelines
- preparation of the river bank infrastructures (connections, other installations, protection of the dikes, etc.)
- transfer of the two segments onto two boats and positioning on the barges with the cranes
- welding of the two segments
- laying of the whole pipe in the underground channel
- connection of the pipeline to the network

The total cost of the operation was estimated at about 10,000,000 dinars (DM1 Million at the prevailing exchange rate).

It was clear that the operation was rather more complex than those carried out previously. The segments of pipe were up to three times longer than any in the company's records, they were larger, they had to be more rigid and, last but not least, they had, in this specific case, to deal with a flowing river and not with canals, where the water is relatively still.

The profiles showed that the river had different flows, up to 1.5 m per second on either side and close to 0.5 m/s in the middle, apparently due to the destroyed bridge structures, which had modified the flow in the middle part. This had already resulted in an accumulation of sediment in the middle section due to the lower velocity of the water. Moreover, the channel dug on the bottom of the river to host the pipeline would be quite rapidly refilled where the flow of water had been reduced. Anchoring the barges and maintaining them at their exact positions, even if they were fixed to the bridge with steel cables, would also be more difficult. The transport and laying operations would require extremely precise coordination and the transfer from the carrying barges to the fixed ones would also be delicate.

The particular nature of the embankments, which protect the city from spring floods, was also of concern, and would require extensive civil engineering, difficult to foresee at the time. All the service installations are located in the embankments and care would have to be taken to avoid any damage to the sewage network, telephones lines, etc. The project would have to be initiated during low water periods and completed before the high waters. The need for a precise feasibility study was recognised by all the participants. It was also clear that nothing could be started while the NATO bombing campaign was under way and nobody knew, mid May, when the hostilities would stop.

The ICRC's involvement

After several meetings in Novi Sad with the engineering department of Vodovod on 6 and 7 May, several options were discussed:

- Improve water distribution by installing storage reservoirs at strategic locations. This would decrease the trucks' unloading time and improve access to drinking water but would also increase water consumption and, in turn, fuel consumption if the tankers increased their rotations. The use of both trucks would have to be optimised anyway as distribution would probably go on for some time, at least six months or more. Basically, the two trucks would be required full time and diesel fuel would have to be supplied.

- Improve the quality of the raw water distributed as drinking water. The main problem was the concentration of iron. Several compact units capable of removing the iron and adding the chlorine disinfecting solution would have to be installed at strategic locations and the water could then be consumed directly. The advantage of this solution, if feasible, was evident. Raw water was already distributed in the network and the units would make it possible to decrease the tanker operation and eventually stop it altogether. Removal of iron is in principle quite simple and only requires aeration to oxidise iron (II) to iron (III), followed by filtration. The only problem was that such compact units were not available in the market and would have to be designed specifically. Normal compact units remove suspended solids with the addition of a coagulant (aluminium), followed by filtration, but are not specifically designed to remove iron.

- Install a pipeline across the Danube, as per the tentative project presented by Hydroinvest or even

- Consider reconstructing a bridge and installing the necessary pipeline on it.

The bridge option, which was rejected by the different stakeholders, would still have to be considered as this is the universally accepted method of crossing a river with a pipeline, at least when a bridge exists. The ICRC decided not to get involved with this project and to concentrate its efforts on improving water distribution. People on the right bank would in any case face several months of deprivation, at least six, before any project was completed.

In the following days an agreement was reached between the ICRC and the director general of Vodovod to improve water distribution. A strategy was prepared to improve the management of the tankers in order to cut down on fuel consumption and increase the quantities of drinking water provided to the population. A decision was made to install storage reservoirs at strategic locations, to be refilled by tankers, and plans were prepared with Vodovod's engineers.

Improving water distribution

Background

In mid May distribution of drinking water was not satisfactory. It barely covered the needs of the population. Many people were still able to purchase bottled water in the shops as there was still sufficient water and cash. The situation would become more precarious in the following months, because of the difficulty of transporting bottled mineral water from its place of production to that of purchase. At the same time, many people were jobless and bottled water was a luxury they could no longer afford.

The first survey

The survey was imprecise, and it was difficult to modify the timing, as several meetings had been scheduled and further attacks were feared. Unfortunately, it was not possible to obtain better data. What was clear was that the technical water could not be used for drinking purposes, due to its high iron content, up to ten times the WHO guideline values of 0.1 to 0.3 mg/l, which left a pronounced, characteristic metallic aftertaste. In fact, the iron concentration varied from well to well but in general reached its highest level when the Danube was low, i.e. in August and September. When the level of the water is high, some dilution occurs in the radial infiltration galleries of the deep (25 m) wells (Renney wells) and the iron (II) concentration decreases. In contact with the atmospheric oxygen the iron (II) is oxidised to iron (III) and precipitates as a red iron colloid, which stains everything.

Drinking water distribution in May 1999

Number of people

The population count of the different localities was not precisely known. Estimates were the following:

Petrovaradin	15,000
Kamenica	10,000
Karlovci	12,000
Bukovac	5,000
Displaced	5,000

Distribution

The two ICRC tankers were refilled at Beocin, about 26 km from the main distribution points. The capacity of the station was close to 35 l/s (i.e. 126 m3/h), with a storage reservoir of 2000 m3. There was sufficient water at that time of the year but in summer some problems would arise. The second best possibility was Indija, about 40 km from the distribution area.

The tankers began their route at 0700 or earlier but had to wait when the electricity was cut. In that case, they had to drive to another location (Banos). They then moved on to Petrovaradin, where they were stationed for about four hours. People collected the water from the distribution ramps affixed to the tankers at a rate of 6 l/minute/tap, i.e., taking into account the number of taps, about 1.5 m3/hour and a total of 6 m3/hour at any given point. The tankers also filled a fixed tanker cistern elsewhere in the locality. People were allowed to draw water continuously at that point. Then, the same ICRC tanker was refilled and provided water to a health centre.

One of the tankers provided water to Kamenica, but was on the move when the ICRC engineers looked for it. Another tanker belonging to Vodovod, with a capacity of 9 m3, was in operation and also supplied Kamenica and Petrovaradin, refilling twice a day. Every two days a tanker supplied Bukovac, but it was not clear which one. According to the authorities another 5 m3 tanker was operating in Karlovaci. Although the quantities were considered sufficient, being close to 90 m3/day, access to water was limited to specific points. People in the surrounding areas were supplied but others had to walk a considerable distance.

The purchasing capacity of some of the inhabitants was still sufficient and the situation was not dramatic, with the exception perhaps of Karlovaci, which was already experiencing some tension, according to the local Red Cross representative. The situation would worsen during the hottest months to come and there was a need to streamline the whole operation.

A new distribution strategy

Plans were prepared together with Vodovod. They were based on the local purchase of polyester reservoirs and on local construction of distribution ramps. This solution was welcomed by the authorities as it would provide some activity to the local industry, which was almost completely paralysed since the outbreak of the conflict. There was also the option of using ICRC storage tanks, located in ICRC's emergency stock. Administrative measures linked with the certification of the collapsible reservoir for potable water storage delayed their availability and the decision was quickly reached to build all the tanks in Novi Sad.
As far as distribution was concerned, the following objectives were set:

- A maximum walking distance of 500 m from a distribution point
- Between 1.5 and 2 l per person, i.e. a storage capacity of about 4,000 l per 2,000 people
- Two rotations per tanker to Beocin, with a total capacity of about 90 m3
- Each storage tank would be equipped with a distribution ramp fitted with six taps supplied by gravity
- Filling and emptying times should not exceed 20 minutes and 10 minutes respectively
- Hospitals and health centres had to be supplied with specific storage.

Figure 8
Areas covered by a distribution point in four suburbs on the right bank of Novi Sad

Figure 9 ICRC water tanker

The urbanised areas were tentatively divided into distribution areas where the 4,000 l storage tanks, equipped with distribution ramps, were to be located. A total of 22 distribution points were chosen, of which several were designated to respond to specific needs in case of overly heavy attendance at some points. The installation would have to be done gradually and would have to be stepped up according to consumption, which would have to be monitored. A transport schedule was prepared and the mileage of the trucks was to be monitored for fuel consumption control and to foresee future needs, as the distribution would last for at least three months, maybe six or more, depending on the kind of medium term solutions that would be found. The following map shows tentatively where distribution tanks were located.

Quotations for the production of the reservoirs were obtained quite rapidly and the implementation of the whole programme was planned to start in week 21 (24 May), if the emergency stock could be cleared and the proper papers obtained. The intention was to immediately install collapsible reservoirs and gradually replace with rigid ones, according to the pace of production, which depended on power availability and on the global security problems faced by the industrial area.

Constructing storage reservoirs

Most of the necessary equipment was generally available in Novi Sad and specific equipment would have to be supplied from the Belgrade Wat/Hab (Water and Habitat) emergency stock. Unfortunately, the initial installation of the collapsible reservoirs had to be dropped due to delays in obtaining the necessary clearances from the authorities. The timing of the construction, set at one reservoir every day, could not be met. The first reservoirs were installed beginning of June and the whole process was completed by the end of the month. A plan of the reservoir is shown in the previous figure. The initial roofing system was abandoned in favour of a simpler and cheaper one, as the whole operation was meant as a temporary solution.

Seven tankers were in use with a total capacity of 64,500 l. The ICRC maintained two tankers (33,000 l), Vodovod operated three tankers (16,500 l) and private owners the remainder (15,000 l). The ICRC supplied the fuel. Two rotations per day were made and the total daily quantity delivered was close to 130,000 l, in conformity with the initial objectives.

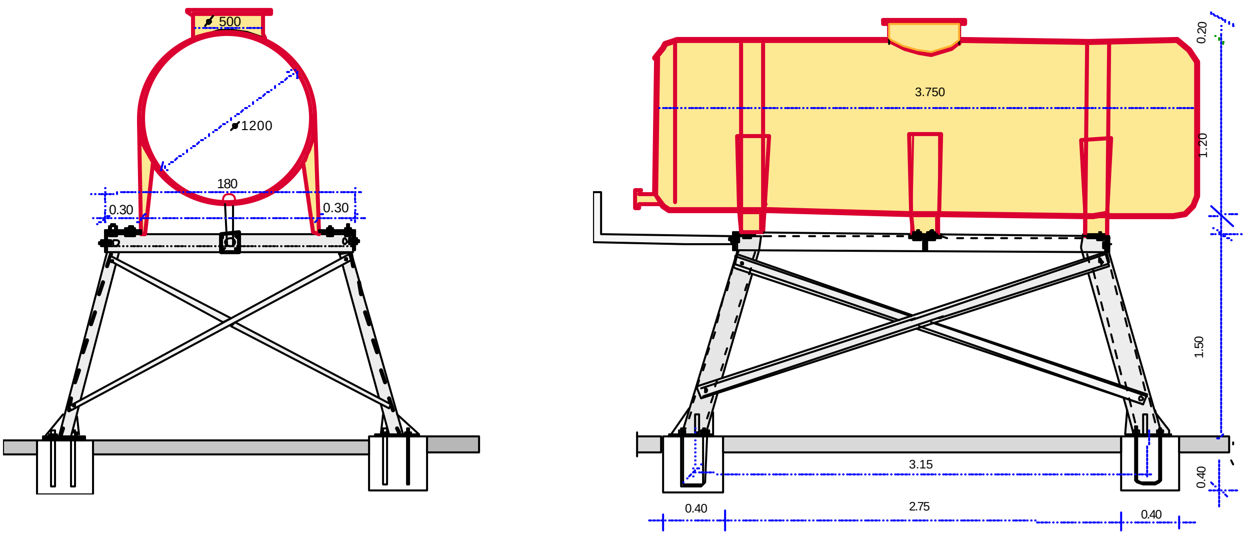

Figure 10
Front and side views of a distribution reservoir and support (Vodovod Novi Sad)

Figure 11 a, b
Water collection on the right bank of Novi Sad

Reducing travel distance

In order to reduce the distance travelled by the trucks and the burden on the production capacities of Beocin, two units capable of producing 10 m3/hour of potable water were built and installed in Petrovaradin and Sremski Karlovci. The units were connected to the network and used technical water to produce drinking water with an iron concentration under 0.1 mg/l. Both units were built using local expertise and supplied the tankers by gravity, through a filling gantry. On 21 July both units were operational. They were maintained in operation until the right bank was supplied from the new pipeline laid on the bottom of the river.

Emergency water supply for the hospital

The hospital for cardiovascular diseases located in Sremska Kamenica was left without water and could not be operational with the water distributed by tanker. The decision to equip it with an independent water supply was taken at the beginning of June and a local company was contracted to drill a borehole and equip it. The well was drilled to a depth of 140 m and equipped with a submersible electrical pump, delivering up to 5 l/s, thus covering the needs of the hospital. A small treatment station had to be installed to remove the iron and manganese, which were found at concentrations slightly above standard. The whole installation was completed in roughly two months and was operational on 30 August.

Figure 12
Treatment unit to remove iron concentration

Figure 13
Before and after iron removal

The pipeline under the Danube

When the hostilities ended, it was not clear when and where the bridges would be rebuilt. In order to create a more permanent solution for the town's water supply, the authorities decided in July to build a pipeline across the Danube. The initial project was abandoned and a new location and a new laying technique were chosen. Two fibreglass pipes 500 mm in diameter were pre-assembled perpendicular to the shores, laid over a metallic support and maintained in position with the use of sandbags. The whole assembly was then pulled into the river where a channel was dredged. Finally, stones were placed over the sandbags to maintain the whole system in position and to insure a minimum of protection. One pipeline was meant for raw water and the other to pump drinking water and resume the normal supply to the right bank. The whole operation was completed by the end of October. Several problems had to be solved: one of the pipes was damaged during construction and had to be repaired. Despite the intervention it was never possible to pressurise it again up to the required 7 bars. It was then irrevocably damaged by an anchor, and its use had to be discontinued.

Figure 14 - 16
Dredging the underwater canal and the shores. Preparing the pipeline assembly

As a consequence, the termination of the joint drinking water distribution had to be postponed twice and it finally ceased only at the end of December. The remaining pipeline was finally used to pump drinking water to the right bank, but the use of the water from the right bank well fields had to be temporarily stopped.

The new bridges

Immediately after the cease-fire a pontoon bridge was built to allow people to cross the river. Two other bridges were rebuilt. The new Zezelj Bridge is located about 70 m upstream of the former concrete one. The bridge is still considered as temporary and hosts the railway and a single carriageway on the same track, which is used as a one-way road. No pipes have been installed on this bridge. In May 2001 the new Varadinski Bridge, built at the same location as the old one, was opened to cars. Two pipelines 500 mm in diameter were installed underneath. One has been connected to the raw water supply and the other delivers about 200 l/sec to the right bank network, thus restoring the situation that prevailed before the war, at least as far as drinking water is concerned. The next figure gives the layout of the present situation. The highway bridge (Sloboda) is not shown and its reconstruction has not yet started.

As long as the bridge farthest upstream is not reconstructed the balancing tank located on the right bank will be out of use. Peaks in demand now have to be addressed with precise management of pumping capacities, but it is clear that the role of this tank will have to be restored. The present reservoir, Transzament, is used to cover the needs of the pumping stations that supply the various localities on the right bank and cannot be converted to a balancing tank for the left bank due to its limited capacity (3000 m3).

New and reconstructed bridges: May 2001

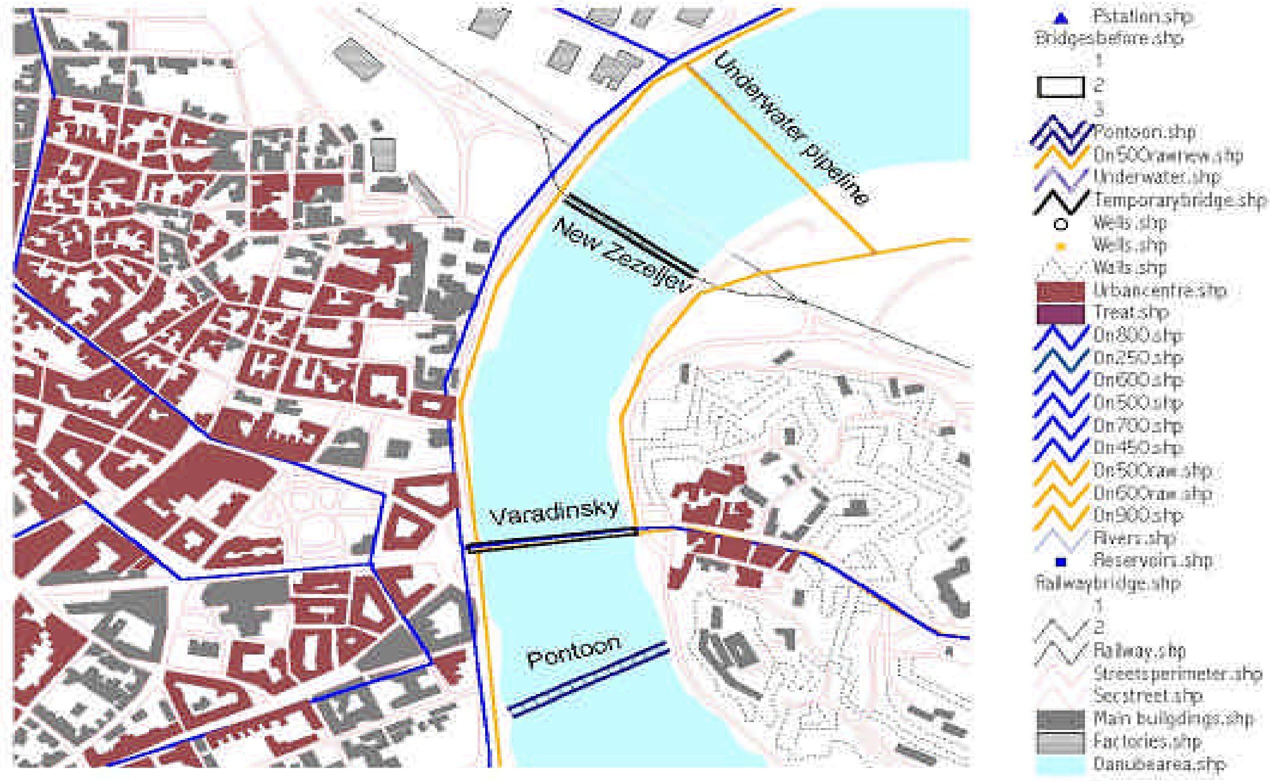

Figure 17
The situation of the bridges and of the main pipelines across the Danube

Specific problems

One would have expected a significant increase in losses due to the damage to the network during the bombing campaign. The total length of the network is close to 1000 km, with about 600 km for the primary network and 350 km for the connections. Unfortunately, the data from Vodovod do not allow for a distinction between losses in the network, illegal connections and other losses. Unaccounted for water (UFW) is recorded as the difference between the water pumped into the system and the quantity of water billed, as recorded by the meters. It is estimated at between 25 and 30%, with illegal connections representing roughly 10% of total production. In the next figure the data for 1998 are compared to those obtained in 1999.

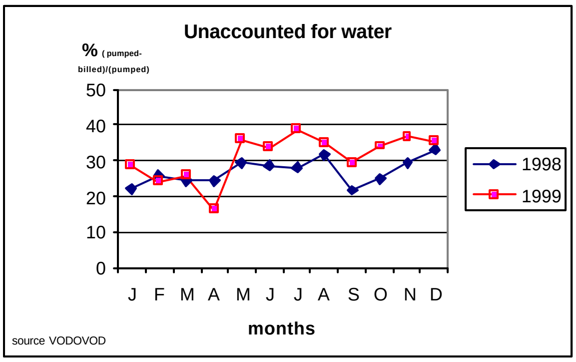

Figure 18
Unaccounted for water (UFW) in Novi Sad before and during the war

There is a significant increase in UFW in May, June, July, with higher figures up to December, which may be attributed to the effects of the war. But the low figure for May 1999 is difficult to interpret if a distinction cannot be made between leaks, illegal connections, faulty recording of the meters and other factors. According to Vodovod the network apparently did not suffer significantly from the bombing campaign and in the absence of more detailed information no conclusions can be drawn from these figures. Since 2001 KfW (*Kreditanstalt für Wiederaufbau*) is assisting Vodovod in rehabilitating the network. Fifty-one streets will be affected and a total length of 16 km of old pipelines will be replaced. A new billing tariff should also be introduced by the year 2004. On the right bank the use of technical water has damaged the mechanisms of the meters and all of the 8,000 mechanisms are scheduled to be replaced, at a cost estimated at close to DM 200,000.

Environmental problems: raw water quality and oil spillage from the refinery

The oil refinery of Novi Sad was attacked on several occasions between 5 April and 8 June 1999. More than 250 missiles or bombs hit the refinery facilities, with a total of about 230 during the nights of 2-3 May and 7-8 June. Damage was, of course, considerable and many oil storage tanks were completely destroyed, with a consequent massive leak of oil, hydrocarbons and semi-refined distillate sub-products and huge amounts of aromatic polycyclic-hydrocarbons (PHA). An aerial photograph of the refinery after the attacks, where the damaged tanks can be recognised, is shown in the next figure.

It has been estimated that more than 73,000 MT of oil and oil derivatives were lost. Ninety per cent of these huge quantities burned, causing significant air pollution but 9% were spilled on the grounds of the refinery, where quantities up to 42 g/kg of oil could be collected in ground samplings[6]. About 3,800 MT of crude oil, 480 MT of middle distillates, 4 MT of oil and 60 MT of gasoline were spilled into the ground.

The protection dykes were not sufficient to contain the leakage in the refinery compound and eventually the oil slicks reached the shores of the Danube via the storm-water collection network and its pumping station, located behind the well fields. Of about 300 MT which reached the pumping station, only about 100 could be recovered and confined to the refinery. Due to the high level of the river water these oil slicks were pushed toward the shores, polluting the areas surrounding the wells located downstream of the rainwater discharging pit. On 6 May the authors observed oil slicks on the ground at the wells located downstream of the discharge channel. The next figure shows the location of the affected wells and the path of contamination.

The use of an oil-binding water-repellent absorbent was envisaged. Detailed information on such materials was obtained immediately[7] and a suitable biodegradable compound selected. Unfortunately the necessary quantities could not be purchased, as the use of such substances was not authorised by the authorities. When the level of the water decreased the oil penetrated the soil surface. Fortunately, its penetration into the water-bearing layers was prevented by the quick removal of a 30 cm layer of soil surrounding the wells. Although the groundwater abstracted from the well fields did not show significant short-term contamination by derivatives of the oil and other spilled substances, the extensive pollution of the soil in the refinery threatens the future use of this water source.

Figure 19
Aerial view of NIS Novi Sad Refinery (courtesy of Prof. Bozo Dalmacija, Faculty of Science, University of Novi Sad)

[6] For detailed information on the contamination of the soil, of the type of pollutants and their migration, see Prof. Bozo Dalmacija, Faculty of Science, University of Novi Sad

[7] ELCOSORB R *Centre de documentation, de recherche et d'experimentation sur les pollutions accidentelles des eaux.* Plouzane, France.

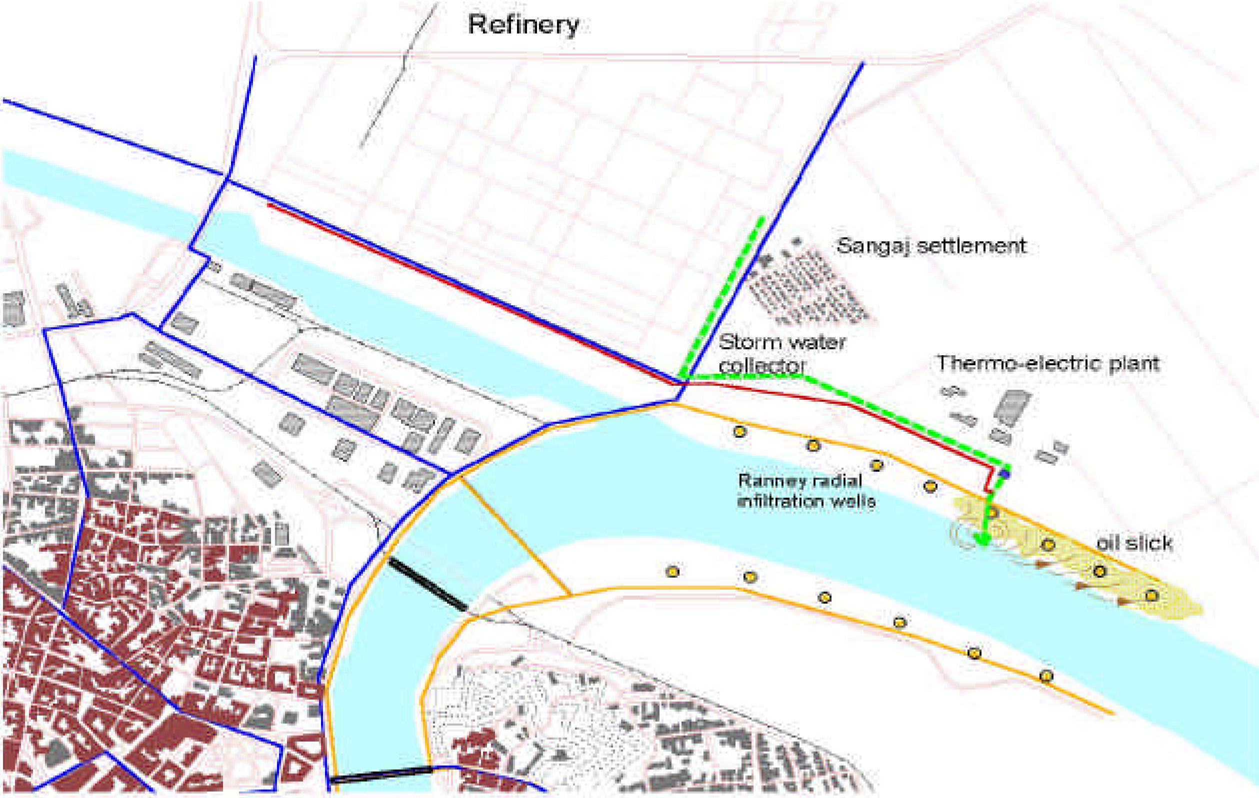

Figure 20
Wells on the left bank of the Danube affected by the oil spillage at the refinery

Figure 21
Air strikes caused heavy damage to the refinery, oil spillage and ground contamination, endangering the water sources located downstream of the pollution point. An oil slick covered the ground over the infiltration wells

Comprehensive studies carried out by the Faculty of Science of Novi Sad show that a migration of toxic substances is taking place from the contaminated ground in the refinery toward the areas surrounding the wells.[8] Soil samples collected at different locations, as well as regular analyses of water samples collected from piezometers located at relevant locations, show that substances such as toluene, xylenes, chlorinated hydro-

[8] Bozo Dalmacija, Study of the soild and ground water contamination of the surroundings of the Novi Sad refinery. Faculty of Science, University of Novi Sad. To be published, personal communication. 2001

carbons such as tri-chlorethane and di-chloroethane, and polycyclic aromatic hydrocarbons will reach the underground water to be pumped into the network in a lapse of time estimated at between 24 and 36 months, depending on the type of substances and the location of the gross contamination in the grounds of the refinery.

Plans have been made to build a hydraulic barrier that would allow soil decontamination and treatment of the underground water. A diagram of the system, located between the refinery grounds and the area behind the wells is given in the next figure. An extension of the storm-water collection channel to discharge the collected waters downstream of the well field is also envisaged. If no hydraulic barrier is built, toxic substances will reach the wells and this essential source, which supplies roughly 50 % of the present needs of the town, will be doomed.

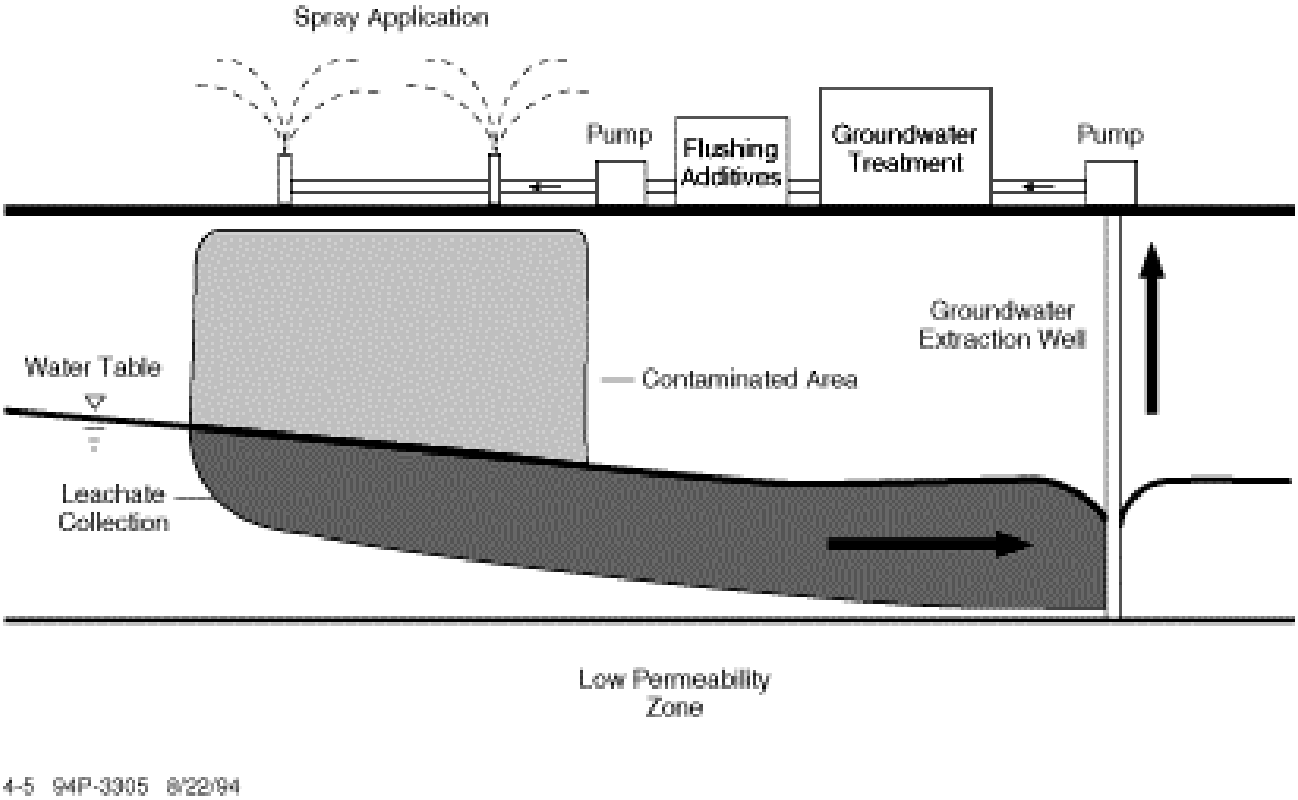

Figure 22
Diagram of the cleaning process (courtesy of Prof. Bozo Dalmacija)

Part II

Should bridges be better protected by International Humanitarian Law?

Are bridges always military targets?

In principle, bridges are built to allow people, vehicles and railway trains to cross a river or a valley. They are usually considered as military objectives as they enable the movement of troops and may be used to transport vital relief or fuel to allow an army to maintain its fighting capacity or positions. Bridges may be considered legitimate military targets under International Humanitarian Law (IHL). Bridges or means of transport were first included in the legitimate military objectives outlined in the list "drawn up by the ICRC with the help of military experts and presented as a model, subject to modification"[9] prepared during the drafting of the Protocols, between 1970-71, under the category:

"those of the lines and means of communication (railway lines, roads, bridges, tunnels and canals) which are of fundamental military importance." In this category the installation of broadcasting and television stations as well as the industries of fundamental importance for the conduct of the war were also listed, and, among others, "installations providing energy, mainly for national defence, e.g. coal, other fuel, or atomic energy, and plants producing gas or electricity mainly for military consumption". But in the final draft of Protocol I the definition of civilian objects which should not be attacked or those which could be considered military objects was dropped, and the article was finally drafted as follows:

Article 52 - General protection of civilian objects

1. Civilian objects shall not be the object of attack or of reprisal. Civilian objects are all objects which are not military objectives as defined in paragraph 2.
2. Attacks shall be strictly limited to military objectives. In so far as objects are concerned, military objects are limited to those objectives which, by their nature, location, purpose or use make an effective contribution to military action whose total or partial destruction, capture or neutralisation, in the circumstances ruling at that time, offers a definite military advantage".

Figure 23
Much hardship was caused by the destruction of the two bridges farthest upstream (Varadinsky and Liberty Bridges. On 22 April, the concrete bridge was only slightly damaged)

[9] Commentry on the Additional Protocols of 8 June 1997 to the Geneva Convention of 12 August 1949, Article 52, General protection of civilian objects, quoting Article 7 of the Draft rules for the Limitation of Dangers Incurred by the Civilian Population in Time of War. (Commentry 2002, page 632, Protocol I)

Paragraph 3 introduces further protection as it recalls the principle of precaution outlined in article 51, as it is presumed that in case of doubt, objects normally dedicated to civilian purposes should be considered as such and not as contributing effectively to the military action.

In the specific case of Novi Sad it may be considered that the destruction of the bridges could result in a consequent military advantage and therefore nobody would be surprised to see these bridges included in the chosen targets. For instance it should, of course, be proven that these bridges were used by the FRY army, even if this is difficult to do, and that their destruction presented a definite military advantage. Unfortunately, this was not the case as other bridges were still in use, but their destruction caused considerable disruptions that particularly affected civilians accustomed to crossing from one bank to the other for their work (see picture).

However, once all the bridges were down it was still possible to travel from the left bank of Novi Sad to Belgrade and then farther on, as the main bridge over the Danube, located in the outskirts of the capital, was not damaged at all and the link between the right bank of the river and the city of Belgrade, located mainly on the left side, between the Danube and the Sawa, was still possible via the roads to Zemun, Novi Belgrade where the Sawa river could be crossed. Apparently, the bridges were regarded as merely a means of communication and the fact that they may have been important for other civilian uses was not taken into account.

Damage to civilian property and military advantage

The sequence of destruction is surprising. First the steel bridge was destroyed. This bridge was mainly used to allow small vehicles to cross the river and hosted the pipeline conveying potable water to the right bank. Attempts were immediately made to repair the damage to this bridge, as shown by the following photographs, taken on the day the bridge was destroyed.

But of course nothing could be done to restore to working order the 450 mm pipeline carrying potable water from the treatment station to the right bank. The only solution left to the engineers was to reconnect the 900 mm diameter pipeline conveying drinking water to the balancing tank, located on the right bank. It took them several days to link this line to the distribution network on the right bank, by installing several gate valves. On 6 April, when everything was ready, the Liberty Bridge was destroyed, along with the only remaining pipeline supplying the right bank. Again, a bridge carrying essential conveying lines was targeted and destroyed, thus depriving an estimated 50,000 people of any access to potable water.

Figure 24 a,b
Repairs are carried out after the destruction of the steel bridge (Varadinsky) to stop losses. The 450mm pipeline is out of repair and lies with the steel structure in the Danube

Figure 25
Valves are installed to reconnect the 900mm pipeline to the right bank network

Figure 26 - 27
The damaged Liberty Bridge and drinking water pipelines conveying water over the Danube

The last remaining bridge, which was used by the railway, resisted longer. Damage to both sides of the bridge rendered it unusable as a means of communication, but it was still possible to repair and reconnect a pipeline previously used to convey raw water. This line would be used, after proper flushing and cleaning, to pump water to the right bank. Almost immediately, construction began on a link between the valve box, located close to the concrete bridge, and the right side of the steel bridge, from where drinking water could be pushed into the elevated storage tank feeding the pumping stations. The line, 1km long and 500mm in diameter, was built in about ten days. All these efforts were reduced to naught when the bridge was again bombed, and destroyed, on 24 April.

Here, we find ourselves in a situation where NATO clearly inflicted on civilian objects damage that was excessive in relation to the concrete and direct military advantages to be gained by the destruction of the bridge, for the above-mentioned reasons. All these attacks fall, in principle, under Article 52, paragraph 2, even if they did not directly cause considerable civilian casualties, as was the case during attack on the Leskovac Bridge, where hundreds of people were killed and many more injured. This latter case has been widely commented on, not because of the destruction of the bridge as a civilian object but rather because of the high death toll involved in this particular attack [10,11] and nobody contested the choice of that bridge as a legitimate objective, the bridge, in principle, regarded as being important in maintaining a communication link between FRY and the Kosovo.

Figure 28 - 29
The destroyed concrete (New Zezelj) bridge and damaged pipelines

[10] Final Report to the Prosecutor by the Committee Established to review the NATO Bombing Campaign Against the Federal Republic of Yugoslavia, published on 13 June 2000
[11] N. Ronzitti, is the *non liquet* of the Final Report by the Committee Established to Review the NATO Bombing Campaign Against the Federal Republic of Yugoslavia acceptable?, International Review of the Red Cross, December 2000, Vol. 82 No. 840, pp. 1017 - 1027

Pipelines conveying raw and potable water under bridges

Bridges are important to the survival of the civilian population as they convey essential raw or drinking water. The term essential must include raw water, as raw water is used to produce drinking water, after treatment. In this case 50,000 people on the right bank of the town were left without drinking water or raw water during the first phase of the bombing campaign. Therefore, the pipelines located under the bridges fall under the protection not only of Article 52, as commented above, but also under Article 54, paragraph 2, which states:

"it is prohibited to attack, destroy, remove or render useless objects indispensable to the survival of the civilian population, such as foodstuffs, agricultural areas for the production of foodstuffs, crops, livestock, drinking water installations and supplies and irrigation works, for the specific purpose of denying them for their sustenance value to the civilian population or to the Adverse Party, whatever the motive, whether in order to starve out civilians, to cause them to move away, or for any other motive".

Paragraph 3 does not apply here as we are dealing with the supply of an entire town (280,000 inhabitants) and, as in all towns, the installations are used primarily for the inhabitants and not for the sole sustenance of the members of the armed forces. In this specific case, and in many other situations around the world, the destruction of bridges inevitably implies the destruction of conveying lines, which are part of the drinking water installation and supplies, and should therefore not be considered as legitimate targets, unless a definite military advantage can be obtained. We have seen above that this was not the case.

The new "smart bombs", laser-guided bombs or even more sophisticated missiles pose another difficulty that has to do with the precision of these weapons. They have increased the options open to the attacker[12]. But this precision has created a new responsibility in the choice of the targets, as once a target is chosen it will certainly be destroyed, even if some errors are bound to occur[13].

There is, in effect, some possible collateral damage, but in the majority of the attacks the targets were hit very precisely and the bridges were destroyed.The burden of responsibility now lies with those who gather the intelligence regarding the identity of the proposed target rather than with those who use the weapons. But can intelligence be more intelligent?

Figure 30
Zezelj Bridge is hit by a missile

[12] A.P.V. Rogers, Zero casualty warfare, International Review of the Red Cross, March 2000, Vol. 82, No. 837, pp. 177
[13] Ibid., page 171

New bridges

Since the end of the war, a pontoon bridge has been built and two bridges have been rebuilt. The new Varadinsky Bridge is located on the same site but has been engineered differently. The New Zezelj Bridge is located about 70m upstream of the old one and is still considered temporary. Only the new Varadinsky Bridge has been equipped with pipelines, namely two 500mm steel pipes, which supply the right bank as before with drinking water and the treatment station with raw water from the well fields located on the right bank. These well fields have acquired considerable importance because of possible future contamination of the groundwater if the hydraulic barrier is not built in time. In any case, they are important for the needs of the town.

Despite what happened, the decision to install water-conveying lines had to be made and water again flows under this bridge. The underground pipeline, probably built in a hurry and quite vulnerable, has only partially replaced the essential role of a bridge in conveying water across a river.

Figure 31
People crossing the pontoon bridge in September 1999

Figure 32
Conveying pipelines under the new Varadinsky Bridge

Figure 33
The new Varadinsky Bridge