# EMERGENCY REPAIR & RECONSTRUCTION OF THE JAHORINA-BRUS GRAVITY LINE SUPPLYING SARAJEVO FROM 1994 TO 1996

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## History of the Jahorina Gravity system

This system was designed and constructed in the austro/hungarian period at the beginning of the century. Its completion took more than 15 years. Several springs are supplying water to the main line: the Bistrica spring connected to the system in 1917, the Praca spring, completed in 1921 and the Stansko catchment, completed in 1923. In the year 1917 the Vlahovici source was connected to the system with the help of a pumping station. Nowadays it is used as a back-up system when the yield of the other three mentioned sources decreases below the designed maximum output of 160 litres per second (l/s) during the dry periods. Since 1970, part of the water from the Praca source is used to supply the Olympic sports centre of Jahorina and the villages around the Jahorina area. A schematic view of the whole system is given in *Figure 1*.

The Jahorina Gravity system was one of the first, and probably the most sophisticated, water supply system for Sarajevo. Planned as a long-term solution, its design, layout and construction were exemplary. It has secured Sarajevo's water supply for a long period, becoming less important when new resources, like the Bacevo well field, were developed and supplied the town with a much larger amount of water (over 1000 l/s). In the course of time the Jahorina system had literally been raped, and most of the difficulties which are presently experienced are 'man-made'.

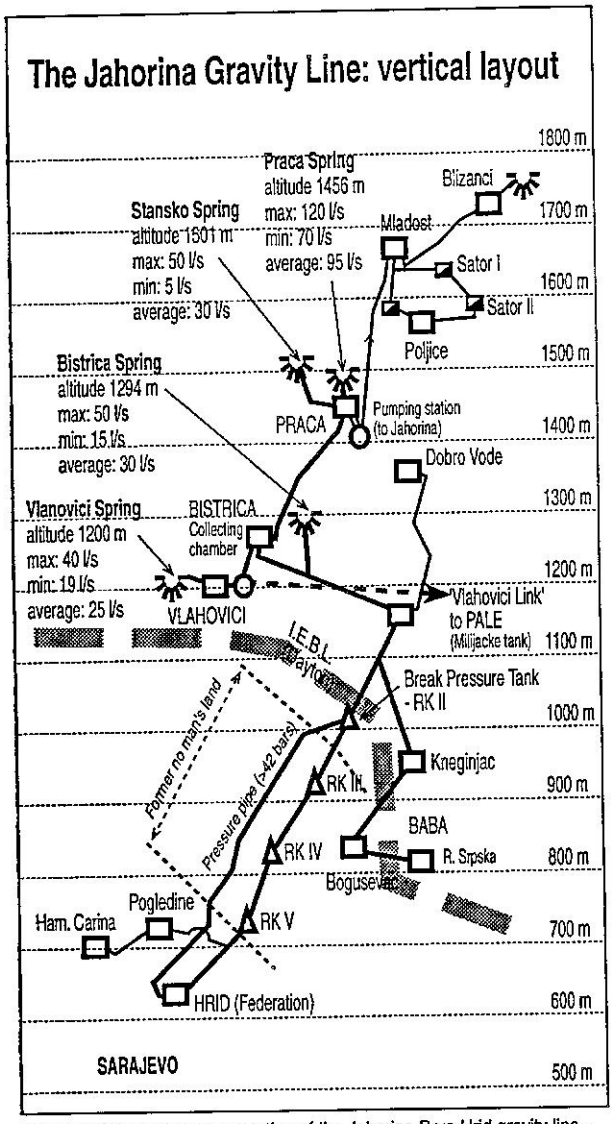


Figure 1: Schematic representation of the Jahorina-Brus-Hrid gravity line – main springs with respective yields.

The Jahorina system became of interest again when the main water supply for Sarajevo, the Bacevo well field, was cut off during war time, being located in the no man's land between serbian and muslim positions and dependent on the erratic power supply.

At the beginning of 1994 the security situation in Sarajevo improved significantly and an emergency repair programme could be initiated with the aim to improve the amount of water supplies to some areas of the town which were difficult to reach. At the same time, a more regular exploitation of the wells in the Bacevo aquifer field, which had reached 70 per cent of their pre-war capacity, was possible. This water system had, however, suffered significant damage and had still not been repaired. Effective telemetry for the remote control of supplies to the different reservoirs was not yet possible. Electricity supplies, moreover, were still not regular and it would not have taken much for a shortage situation to return. This was apparent in fighting at the end of September 1994, when three pylons supplying power to Bacevo were hit by shells and the inhabitants had to go back to fetching their own water supplies.

In this paper we will describe what could have been done during the war to improve the transport of water to Sarajevo and what has been done recently to reconstruct the system, in order to insure a regular supply to about 20,000 people living in the old town of Sarajevo and the surrounding hills.

## Emergency repairs during the war

The difficulties of the work carried out from June to December 1994 are described by Parker.[1] At that time it was essential to maintain such a supply not only for its symbolic importance, but also because the system was almost independent of any fuel supply, and therefore possible power cuts, unlike the other systems supplying Sarajevo. Some rehabilitation work was also carried out in the pumping stations supplying some small agglomerations on the serbian side, but the main involvement of the engineers was to replace some damaged lines suffering from heavy leaks, linked with poor anchoring of the pipes and land sliding.

The main involvement of the ICRC/British Red Cross programme was in the upper section of the line, close to the Praca collection chambers and in its

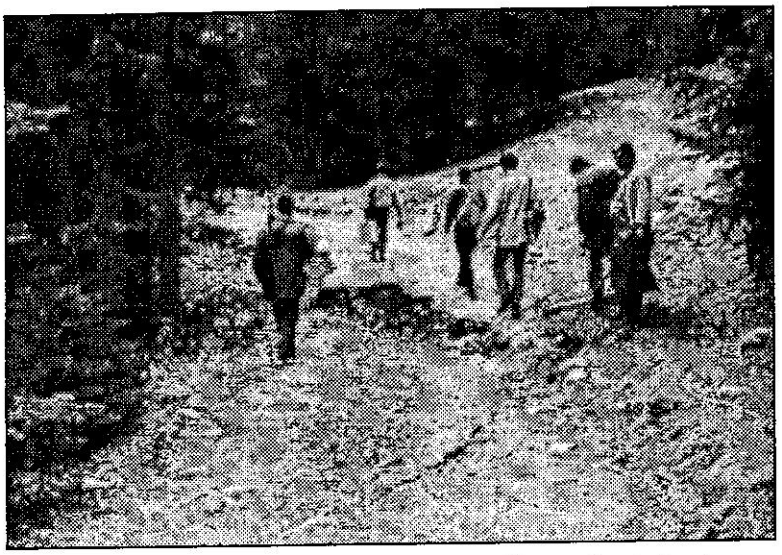

Figure 2: A survey team inspects a landslide caused by a leaking pipe.

lower part, located between the Bistrica collecting chamber and the Brus reservoir. Despite the numerous problems due to poor security conditions, and delays due to front line crossing, the emergency work carried out resulted in an increase of the flow from about 30 l/s to 60 l/s. This improvement was still far from the original design capacity, but was allowing for a minimum water distribution in the old town area, despite the leakage in the secondary distribution network (particularly difficult to repair, being located almost within the front line).

But it was also clear that more in-depth surveys and repairs would have to be carried out to restore the original capacity of the system.

## Results of the feasibility study for a reconstruction programme

In mid 1996, a complete survey on the Republika Srpska side of the system was carried out with the help of the serbian engineers of the Pale Water Board and the engineers of the serbian contractor. The survey team inspected the springs, the collecting chambers and the break-pressure chambers, the state of the line and the conditions of the air-valves, and performed several flow tests (6 locations) to estimate the losses of water due to leaks in the different sections of the transmission lines.

The yields of the springs are still high, close to the expected ones, with some fluctuations during the dry season. The average yields of the Stansko and the Praca springs are close to 125 l/sec with a maximum yield between 200 to 250 l/s. The Bistrica spring has been closed since 1992 due to a clogging of the sewage channel from the Jahorina sports centre passing nearby. The back-up system at the Vlahovici spring is not included in the gravity system, because the water must be pumped to the Bistrica collecting chamber and the pumping station is out of order and needs major repair works. The spring has also suffered from some contamination. After repair one can expect a further yield of 30 l/s from the Bistrica spring and a further 25 l/s from the Vlahovici one. The civil work of all these premises is in good condition, with the exception of the Vlahovici building which needs some repair. In June 1996 a complete survey along the line was carried out to inspect the condition of the transport line, the air valves, the washouts and section valves, and to locate bottlenecks such as sliding areas or river crossings. At the same time visible leaks were located and flow meter tests carried out. The main results are reported in *Table I.*

Losses are estimated from differences between flows measured at different locations along the line. The value of 127 l/s is the difference between the flow measured just after the Praca collection chamber (170 l/s) and the flow measured at the river crossing just after the Bistrica collecting chamber (43 l/s), where the losses are particularly important and were identified as one of the main bottlenecks of the system. The repairs carried out during the war by the ICRC/BRC emergency programme reduced some leaks in the upper section (attested by the measured flow at position 4, close to 109 l/s), but it is clear that the river/road crossing leaks have worsened since, reducing the amount of water reaching Sarajevo from about 60 l/s (end of 1994) down to the low value of 12 l/s measured during the recent survey.

Figure 3: A leaking air valve.

| Gravity main | Type of pipe Cl = cast iron St = steel DN in mm | Flow test (SEBA Ultra sonic UDM 100 portable flow meter Q = l/sec | Losses Q = l/sec | Visible leaks (nr.) and (estimated losses in l/sec) | No. of air valves and washouts AV | WO |
|---|---|---|---|---|---|---|
| Stansko - Praca (1) | DN 200 Cl | 18.7 | 2 (2-3) | | | |
| Praca - Bistrica (2) | DN 325 Cl | 170 | 127 | 9 (24.5-26.5) | 21 | 22 |
| Praca - Bistrica (4) | DN 325 Cl | 109 | (457m³/h) | | | |
| Praca - Jahorina (3) | DN 200 St | 17 | | | | |
| Bistrica - Brus (5) | DN 350 St | 43 | 31 | 25 (30) | 28 | 25 |
| Brus chamber (6) | DN 350 Cl | 12 | | | | |

Table I: Main results of the survey along the line (1-3 June 1996).
Location of flow tests: (1) at km 00 Stansko line; (2) at km 1.300 Praca-Bistrica line;(3) at km 1.300 Praca - Jahorina line; (4) at km 5.863 Praca-Bistrica line; (5) at km 0.130 ; Bistrica - Brus line; (6) at km 11.595 Brus chamber.

## Repairs and reconstruction work carried out

The main repairs and interventions to be carried out are listed in table II. The major rehabilitation works (1996/97) were divided into two phases, the first one implemented during the second half of 1996, the second one in 1997 on the basis of a further careful study. The financial involvement for the first phase is close to about $1 million.

Most of the work had to be subcontracted to a serbian company with the necessary manpower to complete the work before the winter. It was necessary to build or reconstruct 96 concrete chambers to protect valves (air valves, washouts), to repair numerous leaks, and in several locations the main pipe had to be replaced for a total length of 520 m due to landslides and river-crossings. Also a break-pressure chamber had to be rehabilitated and reconnected to the system, reducing the maximum hydraulic static pressure from 17 to 10 bars. The first phase of the reconstruction programme is nearly completed, increasing significantly the flow of water arriving to the Brus reservoir from 12 to 104 l/s.

**First Phase**
- replacement of air valves (single and double stages DN 50 PN 10/16), mud valves, section valves, repair of washouts;
- construction of 96 concrete chambers (protection of valves);
- construction of anchor blocks;
- repair of main leaks with new joints;
- construction of a new river crossing at KM 10.187;
- reinforcement of sliding areas;
- repair of leaking house connections (connected directly onto main line);
- rebuilt original hydraulic gradient at KM 9.300 by rehabilitating and reconnecting the old pressure chamber (reducing maximum pressure from 17 down to 10 bars).

**Second Phase**
- stabilisation of further potential sliding areas (due to deforestation);
- installation of pressure reducing systems and small reservoirs for numerous house connections connected directly onto main line;
- leakage repair on main line at Brus-Hrid-Sarajevo and Brus-Baba reservoir, including main leaks on secondary network;
- eventual further measures to correct hydraulic gradient (prevention of exhaustive pressure or vacuum).

Table II: Main interventions on the Jahorina gravity line necessary to resume the supply of water to the Brus main reservoir and finally to allow for a distribution of water to part of the population of Sarajevo (estimated at 20,000 people).

Figure 4: Rehabilitation of a break-pressure chamber.

The realisation of this project was only possible thanks to a joint effort and participation of the engineers of the British and German Red Cross, the Water Boards of Pale and Sarajevo and the Serbian contractor company under the overall supervision of the ICRC.

## Conclusion

This project will help around 30,000 people, left almost completely without a safe drinking water supply for years, to again have a regular water supply. The emergency work carried out during the war had only helped them for a while with some minimum distribution. The proposed project will

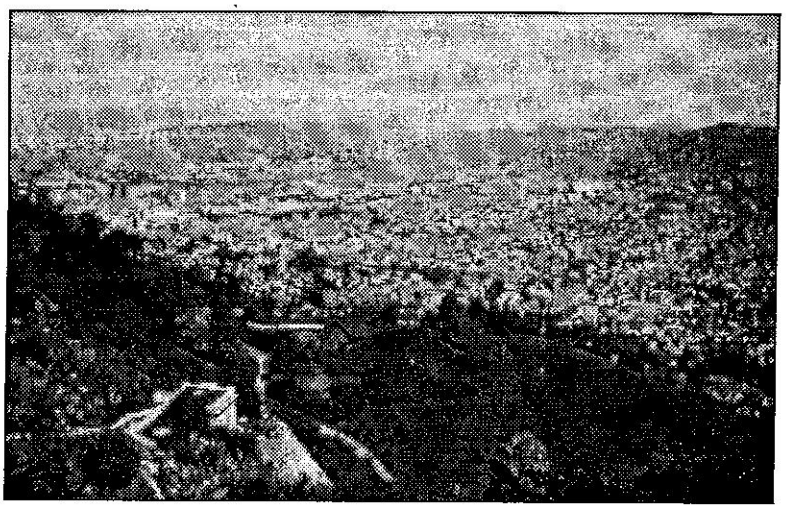

Figure 5: View to Sarajevo across former front lines. In the foregroung is one of the four break-pressure chambers on the Brus-Hrid section of the Jahorina system. *(see Figure 1)*

require the collaboration of the two Water Boards on both sides of the Dayton line (WB Pale and Sarajevo, already existing during the war), which must now be strengthened, bearing in mind the common interest they have in maintaining this line in working conditions.

For instance, the water distribution in Sarajevo will improve, as it will not be necessary anymore to pump water from Bacevo along a very complicated scheme (via several pumping stations and reservoirs) in order to supply a little amount of water to the old part of Sarajevo, and the same is true for the remaining serbian part of the town and the numerous houses situated along the pipeline.

The ICRC started to work on the Jahorina line at the beginning of 1994. Several projects have been carried out since that time and this should be the final contribution. The symbolic link between Pale and Sarajevo can be emphasised, as well as the fact that beneficiaries will be on both sides of the Dayton line.

#### References

Josephine Parker. Water supply for Sarajevo, emergency repairs of the Jahorina-Sarajevo gravity line. Waterlines 1995, December.

#### Acknowledgements

A particular thanks goes to K. Witek for invaluable work, and a thought to those who have built this system. We would also like to thank the British Red Cross for its financial commitment during the war; the German Red Cross for its present involvement; and all the people concerned from within ICRC and the two separate Vodovods.