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Especially in the summer dry season there was very often a drinking water shortage in the coastal area of Slovenia. For the future there is a further development of tourism in coastal areas expected and rising needs of drinking water supply as well. The water supply of the coastal area of Slovenia is accomplished by three main water sources. The main water source of drinking water supply is the Rižana River with a yearly mean coverage 70%, which is decreasing in the summer period to 40%. The seasonal deficits are compensated by hinterland water sources and by supply from Croatia. Several possibilities were discussed in last years to use additional water resources to compensate the shortage in the summer period for the drinking supply in the coastal region. The most appropriate solution was found to build a new water reservoir on Suhorka stream in the neighboring catchment area of the Reka River in the hinterland of the coastal area. The construction of a dam of 57m height and an impoundment of 13.1 hm^3 is planned on the Suhorka stream. The new water reservoir Suhorka with the water source Rižana River is expected to fulfill the rising needs of drinking water in the coastal area for the next 50 years. An important aspect in planning of the Suhorka reservoir is to prevent the adequate low discharge of the Reka River for the protection of downstream karstic caves park Škocjanske jame.

drinking water supply, ecological state, Reka River, Škocjan caves, Slovenia

Block 5
Saal 5

1 Introduction

Slovenia as a whole is relatively abundant in drinking water for undisturbed supply of its population. However, occasional shortages do occur in some areas. The Slovenian Coast and Karst region is the largest water-deficient region, especially during prolonged dry seasons that usually coincide with the tourist season and the resulting significant rise in drinking water consumption. The region is among the most propulsive regions in Slovenia, and is especially successful in advancing its tourism, logistics and services. The growing demand for drinking water due to the population increase and economic development has made the provision of sufficient volume of drinking water a pressing issue. In the past dry periods the operator of the regional water supply system was several times confronted with major water shortages, which were successfully overcome by supplying water from neighbouring water supply systems, especially from Croatia. However, due to Croatia's own increased demand in water during the tourist season the availability of surplus water has become an issue. Due to the significance and complexity of implementation, the drinking water supply of the region is one of the priorities of programmes implementing national projects of state infrastructure. In Slovenia a decision was made to approach this issue by finding a new independent regional water source that would provide a long-term solution to drinking water supply in the Coast and Karst region.

2 Starting points

The Coast and Karst region covers 2,080 km², representing 10.2 percent of the total Slovenian territory. The area has a permanent population of approximately 150,000 inhabitants. The drinking water supply is ensured by three regional water supply systems, which have the following capacities:

- The largest water supply system is situated on the Coast supplying drinking water to 80,000 inhabitants, and as much as 120,000 during the tourist season. The consumption peaks of drinking water during the tourist season are up to 500 l/s, that is, 16,667 m^3/day. The available water sources in the region (the largest being the Rižana with a capacity of approx. 240 l/s) during consumption peaks are not sufficient and the missing volume has to be imported. The consumption peaks in the region will continue to grow, and the expected consumption peak in 2040 will be around 700 l/s.

- In the area of Karst 17,000 inhabitants are being supplied by the regional water supply system, with daily consumption peaks of up to 110 l/s. The drinking water supply from the existing water sources (the largest being Brestovica with a capacity of approx. 250 l/s) is satisfactory throughout the year. During the summer months the water supply system of the Coast is being recharged from the Karst region. In the future, the trend of increased consumption is expected to remain, due to the growth of the water supply system, with an expected peak consumption of approx. 150 l/s in 2040.

- In the Notranjska region the regional water distribution system caters to 10,800 inhabitants with daily peaks of up to 70 l/s. The drinking water supply from the existing water sources (the largest being Bistrica with a capacity of 145 l/s) is estimated as satisfactory throughout the year. In the future it is foreseen that by widening of the water supply system there will be approx. 13,000 inhabitants included into the system with expected peak consumption of 90 l/s in 2040.

These data indicate that the regional water supply systems in the regions of Karst and Notranjska have sufficient drinking water for local supply even taking into consideration the growing consumption. However, at the time being there is no water source in place to replace the drinking water shortage in case of failure of the main water source. The connection of the Coast and Karst water supply systems has made it possible for the Coast to be supplied from the Karst water source Brestovica (up to 130 l/s). However, this is not the case in reverse. For a continuous drinking water supply of the Coast the whole year through the water source Rižana is not sufficient. In the decade between 1997 and 2006, which was characterised by an above-average occurrence of dry periods, the water sources of the Rižana and the Sečovlje were able to cover 68% to 86% of the drinking water demand on the Coast, while it should be taken into account that since 2001 the Sečovlje water source (capacity of 50 l/s) has no longer been available. The rest of the water in the period under question was provided from the Brestovica water source (6% to 14%) and imported from Croatia (8% to 23%), which provided the main replacement of water after abandoning the water source Sečovlje, Figure 1. The supply becomes most critical in August when the capacity of water sources is smallest, while, due to the tourist season, the consumption is largest. In the period, the water source Rižana was enough to cover just over a half of the needs for drinking water. The missing quantities were mostly obtained from import (16% to 44%) and the Karst source of Brestovica (10% to 26%). It should be emphasised that during the dry years the major part of the missing water was obtained by importing the drinking water from Croatia, Figure 2.

All available water resources in the region are the result of leakage from Karst geological formations, which are characterised by the small capability to retain water. Underground water storage from the Karst formations is being emptied relatively quickly, and the sources, after one or two months without precipitation, often dry out. There are no natural surface reservoirs or geological formations with intergranular porosity in the region available, so a possible solution is the building of a surface reservoir big enough to provide sufficient water during dry periods.

It is to be expected that the need for drinking water will increase especially due to population growth and the expected development of tourism. Optimistic scenarios indicate that for drinking water supply in the region in 2040 there will be a demand for additional water quantity from other water sources, next to the Rižana water source, that is up to $4hm^3$ (30% of all water) in a wet year, and up to 6 hm^3 (47% of all water) in a dry year. In 2060 additional $5hm^3$ (36%) will be needed in a wet year, and up to $7hm^3$ (51%) in a dry year, respectively, from other sources.

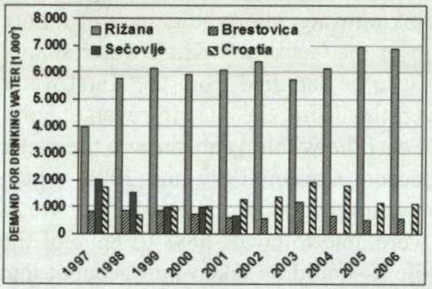

Figure 1: Drinking water supply in the Coastal region

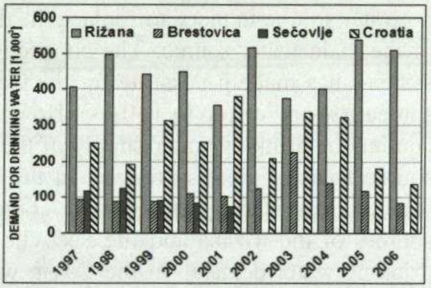

Figure 2: Availability of water sources in August

Due to its significance and complexity, the supply of population of the Coast and Karst region with drinking water is among the priorities of the programme implementing national projects of the state infrastructure. The project of water supply of population was, due to its broad regional and national significance, listed as one of the environmental projects to be nominated for financing from the EU Cohesion Fund. The Republic of Slovenia has decided to address the issue by proposing a new independent regional water source that would provide a long-term solution to drinking water supply in the region. The starting points in defining the source for drinking water supply in the region were:

1. To ensure a strategic, long-term and safe water source for drinking water supply of the population
2. The areas under water source protection and the transport pipelines must be situated in the territory of the Republic of Slovenia

3. In line with the Water Framework Directive the water source must be situated in the watershed area of the water consumption
4. The quantity must enable a long-term supply of population with drinking water, at least for a period of 50 years
5. The permanence of the volume and quality of raw water must be ensured
6. The water source must be acceptable to all stakeholders
7. The water source must provide a reserve during the failure of other water sources for all included water supply systems

3 Analysis of water resources

When deciding on the strategic water source, in the final selection all possible water sources in the region were considered and analysed (in terms of technical feasibility, environmental aspects, developmental aspect, economic acceptability), Figure 3. The acceptability study of the possible use of water sources revealed the following:

The Kubed reservoir in the Rižana catchment

In terms of its capacity, in a normal hydrological year the Rižana water sources covers up to 8 months of yearly consumption. The applicable water management consent regulates that the total abstraction at the spring is 350 l/s, out of which 110 l/s is for minimum flow of the Rižana and 240 l/s for drinking water supply. The average annual flow of the Rižana is 4 m^3/s, however, during summer, being the critical period; the flow can be as low as 0.11 m^3/s. The building of the reservoir would enable the accumulation of the water from the Rižana during the wet period (with flows above 1 m^3/s) and the use of the stored water during the dry period, that is, in the time of increased drinking water consumption. For this purpose the building of an approximately 50-m high earth-fill gravity dam with a useful volume of 4 hm^3 is designed on the Rakovec stream, in the Rižana river basin, and a linking pipeline (∅ 900 mm) in a length of 1.4 km, pumping (80 m) water to the existing drinking water treatment plant. The advantages of the Kubed reservoir are:

- it is situated close to the water consumption area
- it is entirely situated in the territory of Slovenia, including its water protection zones
- the occupancy of space with facilities is relatively small
- the operating costs and investment costs are relatively small

The disadvantages are:

- the size of the reservoir, which is constrained by space, does not suffice to cover the missing quantities of water in the region during extreme conditions even today, let alone to cover the expected increased water demand
- due to complex geological conditions (flysch/karstified limestone) there is the issue of sealing the reservoir space
- the reservoir is linked to the Rižana water source and does not allow for an alternative in case pollution of the water source occurred
- the reservoir is not a strategic water source by failing to address the problem of water supply of the entire Coast and Karst region

The Malni water source

This variant is designed on the Malenščica water source; karst springs on the south-western edge of Planinsko polje karst field. The most permanent spring is in Malni where hydrological data indicate that even during low flow, after prolonged drought, the flow does not drop below 1270 l/s. The technical solution provides for water withdrawal at the Postojnski vodovod water supply company abstraction point (capacity of 200 l/s) up to 800 l/s, covering the needs for drinking water supply in the Coast and Karst region for a period of 30 years. The link with the existing water supply system is designed by using a 37-km pipeline (∅ 800 mm), pumping (250 m) to the existing water storage in Rodik. To address the growing needs for drinking water supply after 2040 the water source of the Padež reservoir is to be linked into the water supply system and a parallel pipeline is to be built (∅ 500 mm) in a length of 17 km connecting Rodik with the existing treatment plant. The advantages of the Malni water source are:

- it is a strategic water source and it is entirely situated in the territory of Slovenia, including the protection zones
- in case of pollution of the water source there is still the alternative of the Rižana water source
- the building of the regional water distribution system enables an improved water supply in the region

The disadvantages are:

- the water source is located in a different catchment than the region to be supplied, thus failing to meet the conditions to obtain financial contribution from EU funds
- the investment costs are great due to the lengthy linking pipeline

- large abstractions have too significant impact to the hydrological regime of low flows of the Unica and the Ljubljanica

The Reka water source

This solution is based on a synchronous exploitation of the Rižana and Reka River water sources. During low flows of both rivers the missing water needed for water supply is ensured from the existing reservoirs of Klivnik and Mola in the Reka river catchment, whose primary function is the provision of flood safety and recharge of the Reka river during low flows. The total volume of both reservoirs is 8 hm^3, where 1.5 hm^3 is intended for flood wave prevention, while 6.5 hm^3 of the useful volume is intended to recharge the low flows of the Reka. The technical solution provides for the building of an abstraction facility on the Reka river and a small safety reservoir with a volume of 0.6 hm^3 in the location of the confluence with the Padež stream, intended for retaining the weekly quantity of water in case of pollution of the Reka. During the Reka low flow the reservoirs of Klivnik and Mola are exploited, by transporting the water through the natural river bed, or alternatively, through a linking pipeline. A 9.2-km pipeline (∅ 800 mm) is foreseen for transport of water by pumping (250 m) from the abstraction point on the Reka to the existing water storage in Rodik, which is to be upgraded with a parallel pipeline (∅ 500 mm) of 17 km in length connecting Rodik and the existing treatment plant, in order to meet the needs for water after 2040. The advantages of the Reka water source are:

- it is a strategic water source and it is entirely situated in the territory of Slovenia, including the protection zones
- it enables the use of the existing facilities with smaller alterations due to the building of a safety reservoir
- in case of pollution there is the alternative of the Rižana water source

The disadvantages are:

- the size of the existing reservoirs is not sufficient to cover the missing volume of water in the region under extreme conditions even today, let alone to cover the expected growing needs for water
- the surface of protection zones in the catchment area where protection measures are necessary, is extremely vast
- the problem of biologically acceptable flow of the Reka and environmental conditions in the catchment area of Škocjan Caves, which are under the protection of Unesco
- the investment costs are relatively high due to the reconstruction of the existing dams and operation of the system

The Padež reservoir in the Reka River catchment

This solution aimed for the exploitation optimisation of the Rižana water source by building the Padež reservoir in the Reka river catchment. The technical solution includes the building of a 45-m earth-fill gravity dam at the confluence of the Padež and Suhorka streams with a reservoir of 14.3 hm^3, where the useful volume of 11.4 hm^3 is as a priority intended for water supply. From the abstraction point in the reservoir a 10-km pipeline (∅ 800 mm) is designed to transport water by pumping (250 m) to the existing water storage in Rodik, which should be upgraded with a parallel pipeline (∅ 500 mm) in a length of 17 km connecting Rodik and the existing treatment plant to cover the needs after 2040. The reservoir also enables the abstraction for irrigation and recharging of low flows of the Padež and the Reka, having economic (tourism, fisheries) and major ecologic significance for the Reka and the Škocjan Caves. The advantages of the Padež water source are:

- it is a strategic water source and it is entirely situated in the territory of Slovenia, including the protection zones
- it is a long-term water source with a reservoir sufficient to meet the expected growing needs for water in the region for the next 50 years with the possibility of extension of the reservoir
- it lies at the juncture of three regional water supply systems providing a reserve for all the water supply systems
- due to low population density of neighbouring areas the risk of water source pollution is small

The disadvantages are:

- there is a relatively large surface area under permanent occupancy of land, which is significantly affecting the environment
- it is situated in the influence area of the Škocjan Caves, which are under Unesco protection
- the investment costs due to the building of the reservoir and system operation are relatively high

The Brestovica water source

The solution includes the upgrading of the pumping capacity of the existing water source Brestovica from the current 250 l/s to an estimated maximum of 1,000 l/s. The abstraction from the Karst aquifer is right before the outflow into the sea. A 47-km connecting pipeline (∅ 900 mm) from the pumping site is designed, in order to transport the water by pumping (640 m) to the existing water storage in Rodik, which should be upgraded by a 17-km parallel pipeline (∅ 500 mm) running from Rodik to the existing treatment plant, in order to cover the needs after 2040. The advantages of the Brestovica water source are:

- in case of pollution of the water source there is still the alternative Rižana water source
- the building of the regional pipeline enables an improved water supply in the region

The disadvantages are:

- based on the hydrological studies the capacity of the source in long-term ensures an estimated maximum of 350 l/s, thus failing to cover the missing volume of water in the region even in extreme conditions of today, let alone to cover the expected growing needs for water
- it does not meet the basic criterion of a strategic water source: the protection zones reach into the neighbouring Italy and the control over implementation of the required measures in the protection zones is thus not possible
- high investment costs due to the long connecting pipeline
- high operation costs due to the large height of pumping

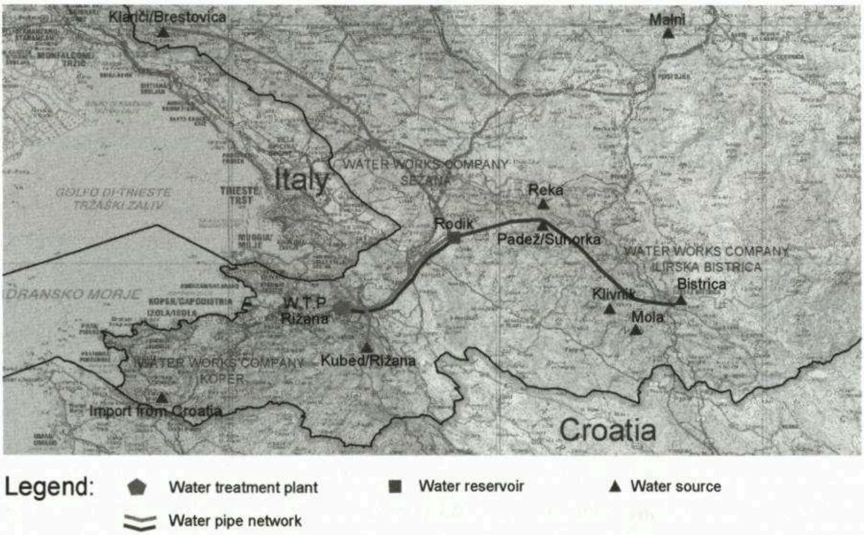

Figure 3: Overview of water sources

When comparing the possible water sources the following conclusions were made:

- the water sources Malni and Brestovica fail to meet the key conditions being exclusion criteria in selecting the strategic water source

- drinking water supply must be based on at least two water sources from different river basins in order to ensure greater operation safety during the failure of one of the water sources
- the abstraction must be performed in a way to ensure the proper ecological conditions in the stream
- during summer both the Rižana and the Reka lack sufficient water for drinking water supply in the Coast and Karst region
- it is reasonable to build a reservoir covering the needs for water during summer in the Reka river catchment, due to its higher drainage capacity

4 Proposal of a long-term solution to drinking water supply

Based on the comparative analysis of the possible water sources for the needs of the Coast and Karst region the following technical solution was proposed. Because of the diversification of water sources and operation safety the water supply in the region is based on exploitation of two water sources, the Rižana River and the Reka river recharge area. The primary water source is the Rižana, and during low flows the shortage is replaced by building a reservoir on the Padež/Suhorka, the tributary of the Reka river. The reservoir is a strategic water source that could in the long term (until 2060) provide the necessary drinking water for the Coast and Karst region.

The reservoir on the Padež/Suhorka site ensures sufficient quantity of water for seasonal (annual) adjustment of water, and the pumping from the Reka river is planned as an additional source of water. For a proper drinking water supply the reservoir must be filled by end-May of each calendar year. In the period from May to October the useful volume of the reservoir would be used for drinking water supply. Three variants of possible locations were considered (Figure 4):

- Variant 1 – the Padež reservoir with a dam on the Padež stream, 48 m in height, with a reservoir volume of 12.1 hm^3 and the reservoir surface area of 64 ha,
- Variant 2 – the Suhorka reservoir with a dam on the Suhorka stream, 57 m in height, with a reservoir volume of 13.1 hm^3 and the reservoir surface area of 60 ha,
- Variant 3 – the Veliki Padež reservoir with a dam on the Padež stream below the confluence with the Suhorka, 43 m in height, with a reservoir volume of 14.9 hm^3 and reservoir surface area of 83 ha.

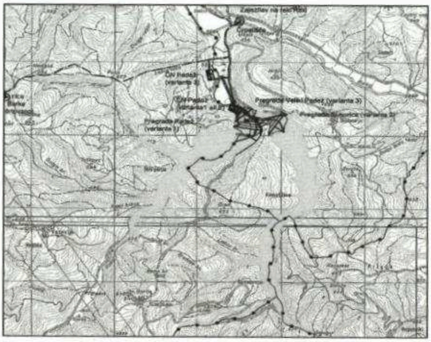

Figure 4: Variants of the reservoir site

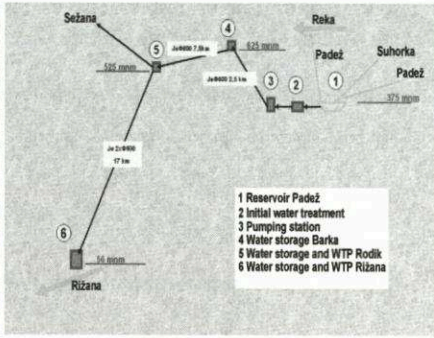

Figure 5: Technical design of the water supply system

In line with the conclusions of a comprehensive assessment of environmental impacts and technical/economic analysis, the building of a reservoir on the Suhorka stream has been recognised as the most appropriate and environmentally most acceptable solution for all stakeholders (Figure 5). From the abstraction point the raw water is transferred by the delivery pipeline to the treatment plant, pre-treating the water with gravitational settlers. The pre-treated water is then transported by pumping (height of 250 m) through the pipeline (∅ 800 mm) in a total length of 10 km to the existing water storage facility in Rodik, where there is an existing connection to the karst water supply system. In Rodik the connection of the Notranjska water supply system is also planned. Based on the expected dynamics of drinking water consumption in the coastal region until 2040, a new 17-km pipeline (∅ 500 mm) will be built in Rodik, parallel to the existing pipeline, connecting Rodik and the existing treatment plant in the Rižana valley, where the upgrading of capacity of the treatment plant will be performed using the same ultra filtration system that is already in operation in the existing facility.

At the Rodik site a junction of all three regional water supply systems is planned. This will enable the drinking water supply from the Suhorka water source to Karst and Notranjska in case of failure of primary sources, the Brestovica in Bistrica. The advantage of the Suhorka reservoir is its position in the gravitation point of supply of three regional water supply systems and, as the only existing source in the broader region, it meets all the criteria as a reserve water source in case of water shortage or failure of the existing water sources for all water supply systems in the region. By connecting the three water supply sources in the region greater operational safety is ensured; in this case the existing water sources are not mutually exclusive, but they keep the important role of reserve water sources during distress conditions, which is not the case today.

5 Analysis of water source capacity

One of the key questions regarding the design project was whether the capacity of water source Padež/Suhorica is big enough for the long-term supply of drinking water in the region. There is unfortunately a lack of data on past hydrological and climate conditions on the Padež/Suhorica catchment area. There are only shorter sets of direct hydrological and hydraulic measurements for the past periods available (for periods 1958–1973 and 2005–2007), which fail to give a reliable estimate of the parameters needed for the design of the reservoir. Because of the lack of sets of measurements the acquired meteorological and hydrological data were connected to the meteorological data from the Trieste climate station, where there was a continuous set of meteorological data for the period from 1851 to 2007 available. By using several statistical tools we reconstructed the data sets of meteorological and hydrological data in the catchment area. In this way we obtained the duration curves of average monthly flows in the streams for the entire reconstructed period and we identified the most critical dry period, which began in 2003. Figure 6 shows the runoff volumes from the catchment area of the Suhorka from October to May when the filling of the reservoir is planned, and for the hydrological year (October–September) in the entire reconstructed period. The lowest runoff volume in the entire time period set was calculated for 2006–2007, that is, 6.6 hm^3 (period October–May) and 8 hm^3 (hydrological year), when flow measurements were available. The reason for the lowest values in the observed time period can be the consequence of:

- the extremely dry autumn/spring period of 2006–2007, which can be seen from the comparison of monthly precipitation with longer periods of precipitation,
- a larger accuracy of measurements in the period 2005–2007 with 15-minute data capture in comparison with the previous period when the average annual runoffs were calculated based on one measurement per day and because of the fast hydrological response of the catchment area overestimated values of actual runoff volumes,
- the occurrence of precipitation peaks during summer when the losses on the mostly forested catchment area of the Suhorka were large.

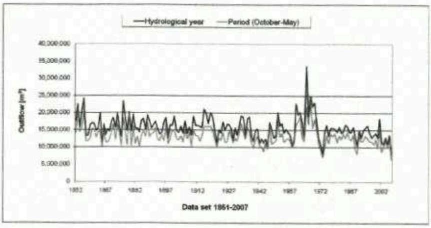

Figure 6: Runoff volumes for the set of 1851–2007

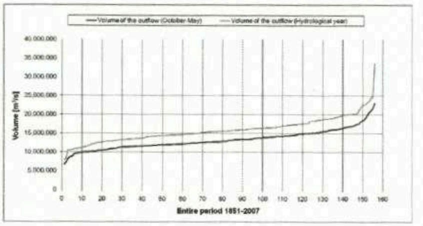

Figure 7: Duration curve of runoff volumes

The duration curve of runoff volumes from the Suhorka catchment area in the entire time set, Figure 7, shows that:

- for the period of October–May, the runoff volume smaller than 10 hm^3 occurs in a total of 12 years,
- for the hydrological year (October–September), the runoff volume smaller than 10 hm^3 occurs in a total of 2 years.

This confirms that the capacity of the Suhorka water source is sufficient for covering the needs for drinking water supply in the region until 2060.

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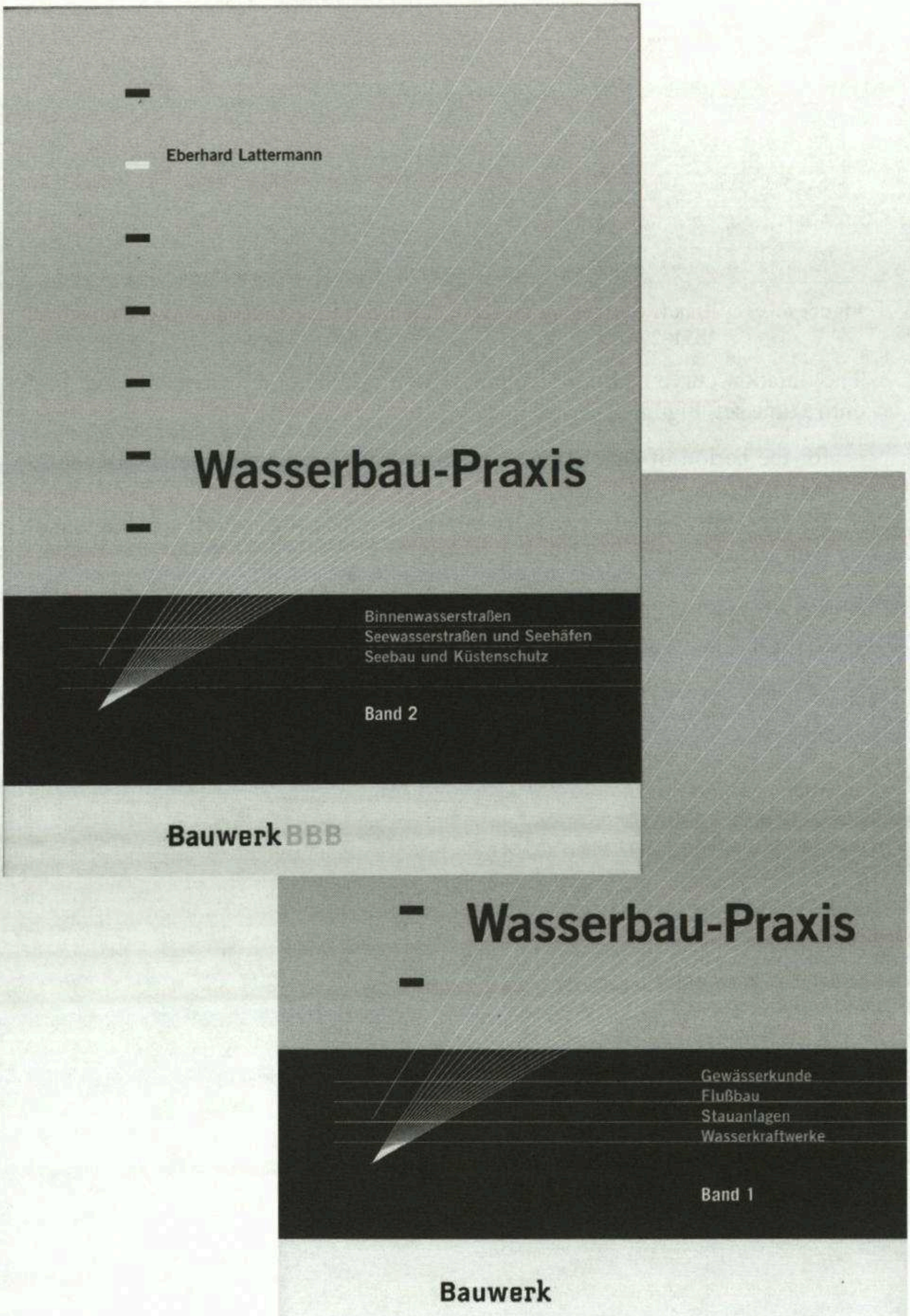
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