The Future Water Supply of Växjö Municipality – Evaluation of different alternatives

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Abstract

The water supply in Växjö municipality has since 1887 been based on surface water from Lake Helgasjön. A water treatment plant was built in 1957 and was extensively reconstructed in 1969 but there are still problems to accomplish with drinking water quality, mainly related to temperature, smell and taste, manganese and aluminium rest. The present water consumption has periodically approached the water treatment plant maximum capacity. A performed risk analysis showed that catastrophic consequences for the water supply could occur due to an accident in a nearby traffic route or discharges from an industrial area. In 1997 Växjö municipality decided to perform a comprehensive investigation of different alternatives for future water supply. Seven alternatives were evaluated including remedial measures at the present water treatment plant. The chosen alternative was based on supply and conveying ground water from the Berga Esker in Ljungby municipality. Re-infiltration of ground water will be used to guarantee the required water quality and quantity and will be implemented in autumn 2008 with a planned supply of 200 l per second delivered to about 70,000 persons in the municipalities of Växjö and Alvesta. The article describes the different alternatives, motives for the chosen alternative and the evaluation procedure.

Key words – Ground water, infiltration, water supply, water treatment, Växjö municipality

Sammanfattning

Dricksvattenförsörjning i Växjö kommun har sedan 1887 baserats på ytvatten från Helgasjön. Ett vattenverk byggdes 1957 och en omfattande ombyggnad skedde 1969 men problem återstod med dricksvattenkvalitét med hänsyn till temperatur, lukt och smak, och mangan- och aluminiumrest. Nuvarande vattenförbrukning närmade sig periodvis vattenverkets maximala kapacitet. En genomförd riskanalys visade att katastrofala konsekvenser för vattenförsörjningen skulle kunna erhållas pga en olycka vid en närliggande traffikled eller utsläpp från ett industriområde.

Växjö kommun beslutade 1997 att genomföra en omfattande utredning av olika alternativ för framtida vattenförsörjning. Sju alternativ utvärderades inklusive förbättring av det befintliga vattenverket. Det valda alternativet blev utvinning av grundvatten från Bergaåsen, återinfiltration av grundvattnet och byggande av överföringsledning. Därmed kan säkerställas tillräcklig vattenkvantitet och vattenkvalitét och alternativet kommer att installeras hösten 2008 med planerad levereras av 200 l vatten per sekund till ca 70.000 personer i Växjö och Alvesta kommuner. Artikeln beskriver de olika alternativen, olika motiv för det valda alternativet och proceduren för utvärderingen.

Introduction

Regulations on drinking water are available in the National Food Administration "NFA" regulation SLV FS2001: 30. Drinking water has been classified as food since 1983 and is considered as fit, fit with remark or unfit, "unhealthy." Fit with remark implies that the water has a less satisfactory composition, for health, aesthetic, or technically based reasons, but is not expected to pose a health risk. The municipality should take immediate measures to meet the requirement of fit. To determine water quality, both microbiological and chemical analyses have been carried out. Chemical analyses also include colour, odour, test and turbidity examination. The water source is protected by the rules of the Environmental Code, which includes both wells and catchment area (Nordström, 2001).

The drinking water supply in Växjö municipality has been based on surface water from Lake Helgasjön since 1887. The present water treatment plant which is located at Sjöudden in the north-western part of Växjö was built in 1957 and the latest extensive renovation and extension was carried out in 1969. The intake of the water treatment plant is exposed to extensive risks as it is located at the eastern shore of Öjaby Inlet, which is surrounded by a traffic route, streets, buildings and an industry area.

The populated area of Alvesta municipality and Hjortberga village has been supplied since 1960 with drinking water from a groundwater source. Since then there have periodically been problems with water quality, mainly in form of high levels of humus, iron and manganese, but also bacteria, and it is therefore difficult to achieve a stable and adequate water quality with the current treatment facility. The Ljungby municipality urban area is today taking its drinking water from three different water sources. A reserve source for water supply is not available in Ljungby. In the late 1980s

Växjö municipality conducted studies of future water supplies and these resulted in two proposals, one with surface water and one with infiltrated water through artificial recharge as a raw water source. For the latter proposal further investigation was advocated, but the decision by the authorities gave a higher priority to the construction of a new sewage plant.

In 1997 Växjö municipality decided to conduct a new comprehensive investigation of the possibilities for the municipality's future water supply. Six different options were presented besides the option of investigating, rebuilding possibilities and suggesting measures for the present Sjöudden water treatment plant, which became the seventh option. Furthermore, in 1998 Växjö municipality together with many other unicipalities carried out a questionnaire investigation to form an opinion of how the municipality's residents experience the quality of their drinking water. The answers showed that the judgement of consumers in Växjö about their drinking water placed it at the second last position of all the contributory municipalities. The questionnaire also showed that the most satisfied consumers were in the municipalities whose drinking water was based on ground water.

The objective of this article is to describe the various options and clarify the reasons for the choice of the third one with the extraction of groundwater from the ridge at Hallsjö in Ljungby municipality and why this choice ensures water quality and quantity.

Problem description for the current water treatment plant

The existing water treatment plant is situated at the Sjöudden district in the western part of Växjö at the south bank of Öjaby Inlet, a part of the Lake Helgasjön, which in turn is a part of the Mörrum Ridge catchment area. A comprehensive status survey, conducted in specialist areas of processing, construction, machinery, plumbing and electricity, showed the following deficiencies: the raw water intake is located at Öjaby Inlet in shallow depth of 3 meters, and therefore the raw water periodically contains a relatively large number of heterotrophic bacteria. A number of coliforms bacteria occur in a range which requires three microbiological safety barriers, although today there are only two, namely chemical precipitation and chlorination.

The intake point is the most risky of the investigated area as the position of it is located so that all sources of pollution in the survey can affect this point. In addition there are a number of pollution threats at close range around Öjaby Inlet, such as stormwater outfalls, an airport and roads with a relatively high probability of an accident. In an accident the consequences may be serious, because the treatment plants today lack both a reserve intake and a reserve water supply (Scandiaconsult Bygg och Mark AB, 1998). It has also been estimated that the socio-economic consequences of an accident will amount to at least 100 million SEK if an effluent of hazardous substances is discharged into Öjaby Inlet. (VBB Viak, 1995). The manganese concentrations in raw water have had a tendency to increase during the 1990s. Since the current treatment process is not designed to remove manganese, which thus remains in the drinking water, this can lead to problems in the distribution network, particularly after the break-up of the ice and

Table 1. Raw water quality in öjaby Inlet 1988–1997
Source: (Vai och M&V, 1998).

Parameters		Raw water min–max	Limit Value of drinking water
Temp	(°C)	0.7–24.4	<12
pH		6.6–7.2	ca 8.2–8.5
Alkalinity	(mg/l)	10–15	ca 70
Aggr. CO2	(mg/l)	<1–15	0
Ca	(mg/l)	ca 7	ca 20–30
COD Mn	(mg/l)	5–11	2–<4
Colour	(mg Pt/l)	8 –10	5–15
Fe	(mg/l)	<0.05–0.49	<0.05–0.1
Mn	(mg/l)	0.01–0.79	<0.02–0.05
Turbidity	(FTU)		<0.5

during the following summer. (VAI, VA-Projekt AB, 1998).

The temperature in summer amounts at most to about 24°C, while the temperature during winter can be just below 0.7 °C. Follow-up studies of the water temperature show that the limit value of 20 °C is exceeded annually. Despite the installation of carbon filters in the '80s consumers have been affected by odour and taste problems periodically. The raw water has a certain smell and taste, which are often experienced as "evident". The presence of odour and taste occurs throughout the year. The raw water content of organic matter (COD.Mn) is estimated at an average of 7 mg / l, which meets the limit value. The guideline value is 10 mg/l. Parameters of raw water have been compiled in Table 1.

The water consumption at times approaches the plant maximum design capacity, which is 1000 M^3/h (278 l/s). Based on anticipated population growth the need for capacity expansion can be expected shortly. As many parts of the plant are very old and many temporary parts were installed without taking into account its entirety, the plant is difficult to operate with the result that the working environment and the safety of the staff are poor, i.e. it cannot today meet the requirements of a modern functioning plant regarding operation and maintenance (VAI VA-projekt AB, 1998)

Possible raw water supplies for Växjö, Alvesta and Ljungby

Water supply can originate from surface water a well as from groundwater, which means that possible water resources include lakes, watercourses, and water conveying sand and gravel formations. An inventory has shown that there are four lakes which could be judged as suitable raw water resources for surface water or for artificial infiltration: Lakes Allgunnen, Helgasjön, Vidöstern and Örken. Four sand and gravel formations have also been deemed possible as ground water resources with or without artificial infiltration. These lake and gravel formations are shown in Figure1.

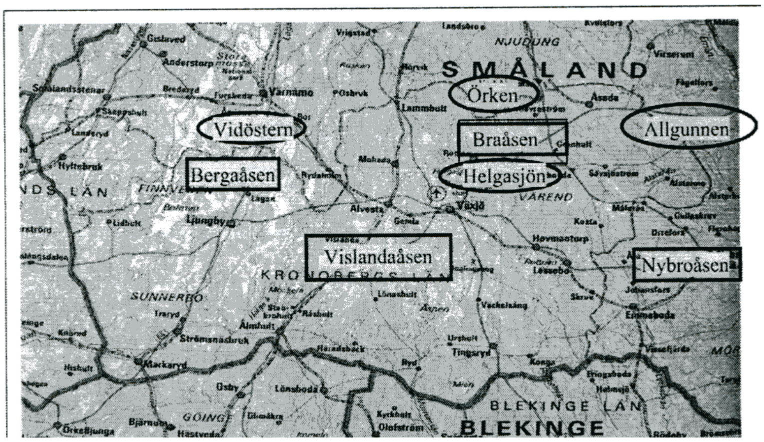

Fig. 1. Lakes and ridges in the Växjö & Alvesta area.

Four lakes have been judged possible raw water Sources

Four sand and gravel formations have been

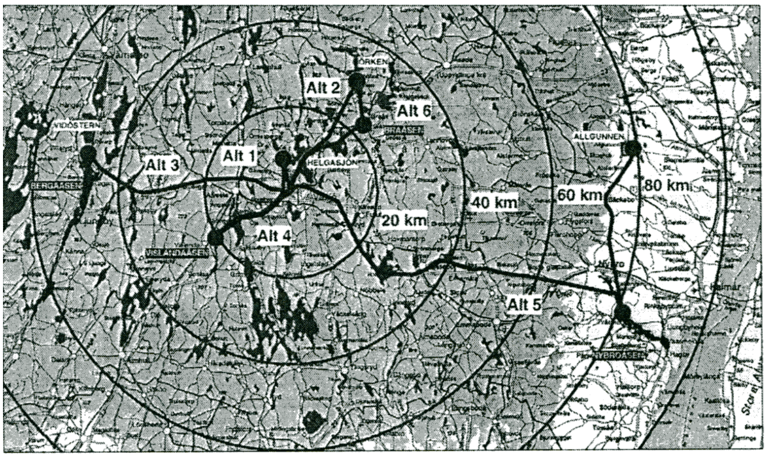

Fig. 2. Water supply Alternatives 1 to 6.

The Geological Survey of Sweden, SGU, has in its answer to the extended consultations noted that there is a lack of geological formation in the region in which the conditions exist for the extraction of groundwater for large-scale drinking water production. Furthermore, SGU considers that the requisitioning of the Bergaåsen ridge area for drinking water production is entirely in line with the EU Framework Water Directive and its proposed environmental quality objective Good- Quality Groundwater".

Possible future water supply alternatives.

The project group presented in the 1998 report, based on the inventory made, six possible water supply alternatives. A further alternative was added involving remedial measures within the present Växjö WTP – hence called Alternative 7.

The geographic location of all the alternatives is shown in Figure 2 and described below. Estimated investment costs are shown for 1998 (except for Alternative 6) and also for 2001 for Alternatives 1-3 and 7. For the finally chosen Alternative 3 the estimated costs for 2004 and 2007 are presented in (Table 3).

Surface water based supply:

- Alt 1: Surface water treatment plant WTP with intake in Örviken Inlet in Lake Helgasjön. 160/217 mil SEK
- Alt. 2 : Surface water treatment plant WTP with intake in the north part of Lake Örken 225/315 mil SEK

Alternatives 1 and 2 entail building an entirely new waterworks close to the existing water treatment plant at Sjöudden. The raw water is taken from Örviken Inlet and Lake Örken, respectively, and pumped to Sjöudden. The treatment will include manganese treatment, chemical precipitation, carbon filtration, alkalinization and disinfection.

Ground water based supply:

- Alt. 3: Ground water from the Bergaåsen ridge. 220/280 mill SEK.

Bergaåsen is a part of Ljungby Ridge. This alternative is based on ground water from a large sand and gravel formation between the river Lagan and the village of Dörarp. To remove iron and mangan re-infiltration of ground water through the ridge is planned. The ground water is then pumped up from wells. After pH adjustment and alkalinisation the 220/280water is pumped to Sjöudden in Växjö, where it is distributed to consumers. Because of the effect of the current water on the present distribution net, the new water is disinfected before being pumped to the consumers to prevent the growth of bacteria.

Ground water with artificial infiltration:

- Alt. 4: Vislandaåsen ridge infiltration with water from Örviken Inlet. 270 mill SEK
- Alt. 5: Nybroåsen ridge, infiltration with water from Lake Allgunnen. 500 mill SEK.

Alternatives 4 and 5 utilize water from Örviken Inlet and Lake Allgunnen for artificial recharge through Vislanda Ridge or Nybro Ridge. To protect both ridges in the long term, the water pumped from the lake is pre-treated through chemical precipitation prior to infiltration. The groundwater is then pumped from a large number of groundwater wells in the ridge. After pH adjustment and alkalinization the water is pumped to Sjöudden in Växjö, where it is distributed to consumers.

Vislanda Ridge is part of Alvesta Ridge, while Nybro Ridge is a large ridge formation between Nybro municipality and Vassmolösa comunity. Municipalities of Nybro and Kalmar have currently their water sources in the ridge.

Combination alternatives

- Alt. 6 : Braåsen with surface water from Lake Örken which is infiltrated through a natural slow filter in the formation (Braåsen) within Braås WTP.

The ridge in the Braås area is largely broken and only a small portion of it which is connected to Braås water treatment plant can be used. The raw water is transferred from the northern part of Lake Örken to Braås area waterworks where it is pre-treated with chemical precipitation prior to infiltration into the ridge. The small ridge formation means that the retention time for the infiltrated water is only from a few hours to a couple of days and therefore the ridge function is considered to be equivalent to a slow filter in a waterworks. During investigations additional studies in Braås Ridge have shown that the formation capacity is limited, which means that the prognosticated water demand cannot easily be produced. This means that Alternative 6 is not feasible.

The present WTP in Växjö

- Alt. 7: the rebuild and extension of the present Växjö WTP to be in function in a 15-20-year perspective by changing the intake to Örviken Inlet of Lake Helgasjön. 130/179 mill SEK.

For each option the investigation of 1998 calculated a capital cost based on rough principal sketches. The calculations have thus been made with a 20% uncertainty up and down. Investigation costs of about 10 million SEK have been added to the costs of 1998. In the mean time until the new water supply was estimated to be in operation, the existing plant had to be kept in operation and therefore emergency measures for several million were carried out for the management of chemicals and electrical safety during 1998-2001.

Investigative and decision-making process

During 1997 Växjö municipality decided to carry out a comprehensive study of the possibilities for the future water supply in Växjö. In October 1998 Alternative 3 "Ground water from Bergaåsen ridge at the Hallsjö area in Ljungby municipality" was considered the most interesting of the seven presented alternatives.

The Växjö Municipality Technical Services Committee decided in January 1999 to continue the effort to investigate the feasibility of this option and the possible location of the transferring pipes to Växjö. The results of the first part of this work were presented in the reports "Feasibility study of conditions of groundwater production from Bergaåsen", dated October 31, 2000, and "Feasibility study on transferring water between Bergaåsen and Växjö", dated September 15, 2000. Subsequently system documents were set up dated April 25, 2001, which describe how the groundwater production will be carried out and how the water will be transferred to Alvesta and Växjö, as well as the facilities required.

The City Council of Växjö decided in August 2001 to realize the implementation of the water supply project and establish the documents for permission application. A project of this size requires an environmental court decision and the Government's trial for permit. A 1300-page application for a decision according to the Environmental Code was submitted to the Environmental Court in Växjö in December 2001. The processing time was estimated at a maximum of 1.5 years, but the proceedings were conducted in late October 2003. In an environmental assessment the Environmental Court scrutinizes the application, requests additional information and conducts the main proceedings. Then a statement is issued to the government. The government makes a trial for permit, i.e. ensures that the project is consistent with other national interests, etc., such as the E4 Highway. The government's decision then forms the basis for the environmental court decision. The Environmental Court expressed its opinion on January 13, 2004, and handed over the issue to the government for trial. In its statement to the government the Environmental Court supported the municipality's application on all essential points. The government commented positively in February 2005. When Växjö municipality finally received the environmental court decision on October 13, 2005, the court proceedings had lasted almost 4 years without there being any significant conflicting interests.

After the decision, the National Land Survey – NLS – carried out the utility easement procedure to provide the opportunity to lay the water conveyance pipelines from the Bergaåsen area to Växjö. Figure 3 is a schematic presentation of the decision-making process.

Choice of water supply opptions

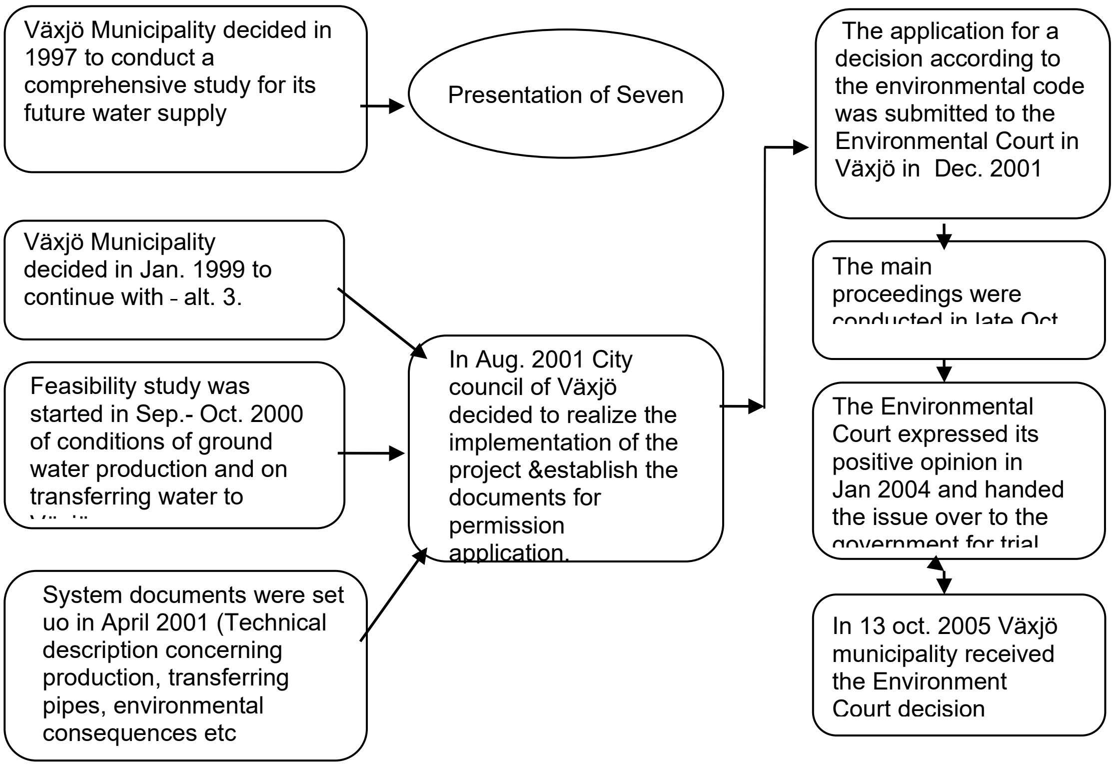

Fig 3. A schematic presentation of the decision-making process.

In the comparison Alternative 6, "Braås", is not included, as it was not deemed to have sufficient capacity for the future water supply of Växjö. Due to the high investment costs which in 1998 were calculated for Nybro Ridge (alt. 5) and Vislanda Ridge (Alt. 4), respectively, these were judged not to be interesting to study again.

With Alternative 1 the received drinking water will meet the current requirement for all parameters. But the temperature will for a few weeks in the summer exceed the benchmark, 12 ° C., and therefore the water treatment plants should be complemented with a refrigerating system to reduce the water temperature to the benchmark level throughout the year. This will cost 7-8 million SEK and give an operating cost of 0.1-0.2 SEK/ m^3.

In a comparison between Örviken Inlet for the intake of Alternative 1 and Lake Örken for the Alternative 2 intake as raw water resources it could be observed that the quality of Lake Örken's water is better and has lower and more even temperatures and a lower content of organic matter and manganese than Örviken Inlet. But the long distance means that the investment costs of transferring pipelines will increase by approximately 85 million SEK compared with using Örviken Inlet. Lake Örken has furthermore a significantly lower degree of exposure to risk and environmental impact than Örviken Inlet, which in the long term may mean that Lake Örken retains a very good water quality.

In Alternative 7 a major rebuild and expansion of the existing water works would be necessary to meet the required capacity and quality demands as well as the demands on the working environment and personal safety. The proposed actions have an expected lifespan of 15-20 years, after which new reinvestments must be implemented. To ensure a safer, more stable and better quality of raw water it is proposed that its present intake point should be moved to Örviken Inlet. The previously carried out risk investigation shows that Örviken Inlet, is safer overall than Öjaby Inlet despite its proximity to Highway 30 and the airport. A new water pumping station with signal box and power supply equipment has been estimated to be needed to ensure the delivery of water to consumers

Several parts of the plant are 30-50 years old and require a reinvestment in a 15-20-year perspective. The cost of emergency measures amounts to about 6 million SEK added to the cost of the drinking water pumping station of about 20 million SEK. A complete rebuild and expansion of the existing water treatment plant in the long run will amount to approximately 110 million SEK (VAI, VA-Projekt AB, 1998).

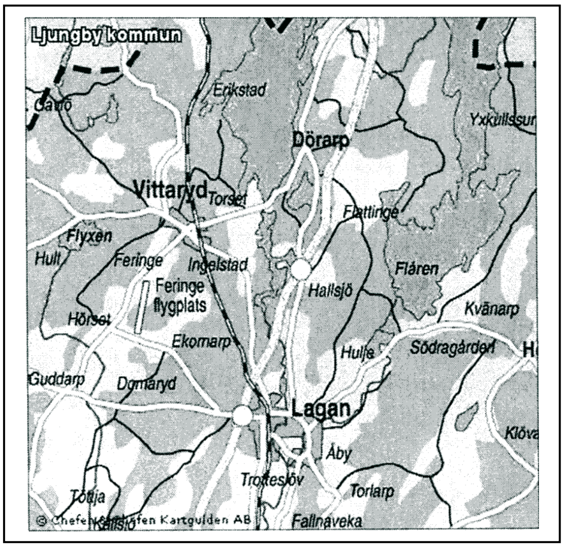

Fig. 4. Project area "Bergaåsen"

As the knowledge of Alternative 3, Bergaåsen, has grown in the project, this option has become more and more interesting for Växjö's future water supply. The completed feasibility study and development of systems of action with deeper studies (1999-2001) confirm that, in accordance with the synoptic assessment in 1998, the ridge can supply Växjö with good quality drinking water in a sufficient quantity. The continuing investigations showed that Ljungby municipality is positive to an implementation of the Bergaåsen option, and it was also considered a feasible option from the land owners' point of view. From all the studies conducted and from the test pumping it emerges that an extension of the withdrawal capacity beyond a 30-50-year perspective is possible.

Description of the Bergaåsen ridge area

Bergaåsen can be described as a very large and thick sand and gravel formation. It is located all along the east shore of Lake Vidöstern and continues southward to the municipalities of Ljungby and river Lagan. It is a part of the extensive ice river formations (boulder ridges and their side formations) all along the valley of the river Lagan, which extends from Jönköping municipality in the north to Markaryd municipality in the south (Fig 4).

The part of Bergaåsen which is of interest to be used for municipal water supply is an area located between the Lake Vidöstern outflow into the river Lagan in the north and the E4 flyover across the river Lagan in the south, about 15 km to the north of the city of Ljungby. The area is bounded to the west by the Lagan and to the east by the new and the old E4 highways. The area, which is just over 3 km long and 1 km wide, is divided into three parts: North Hallsjö, Central Hallsjö and South Hallsjö. The formation in the area is up to 50 m thick and the water conveying part rises up to 35 meter.

The quantity of water in the area between the E4 flyover across the Lagan river in the south and in Lake Färsjön in the north is estimated at about 20 million m^3, which is equal to three years of water consumption in Växjö and Alvesta. In the east, where the formation is thin and moraine begins, the water levels are approximately +155.0 meters. In the aquifer the water table is +143.0 to 144.0 meters above sea level. A level change in the aquifer indicates that there is a good hydraulic connection between the aquifer and the river Lagan.

Assessment criteria for the ridge capacity

It was necessary to collect enough data as a basis to estimate the capacity of the ridge and to have a sufficient basis for the application for an environmental court decision. Figure 5 below shows schematically the steps performed to prepare the required basis for the environmental court decision.

The adjusted rainfall for the area is on average about 880 mm / year. Runoff and groundwater recharge are estimated at about 11 l / s km^2. The precipitation that falls within the area flows either through a watercourse or is drained through the aquifer to the river Lagan. The area which is drained to the Lagan (through the aquifer) is about 7 km^2. The area is covered by North, Central and South Hallsjö, the part to the south and west of Lake Färsjön as well as smaller areas to the west of the river Lagan. The groundwater recharge through rainfall amounts to about 80 l / s (2.5 million m^3/year). The natural recharge does not cover the need for a water production of the planned order, but supplements are needed either through artificial recharge or through induced infiltration. In the event that the groundwater recharge is done by infiltration, the term re-infiltration is used. The basic water quality in the area is characterized by naturally low alkalinity and low hardness. It is therefore

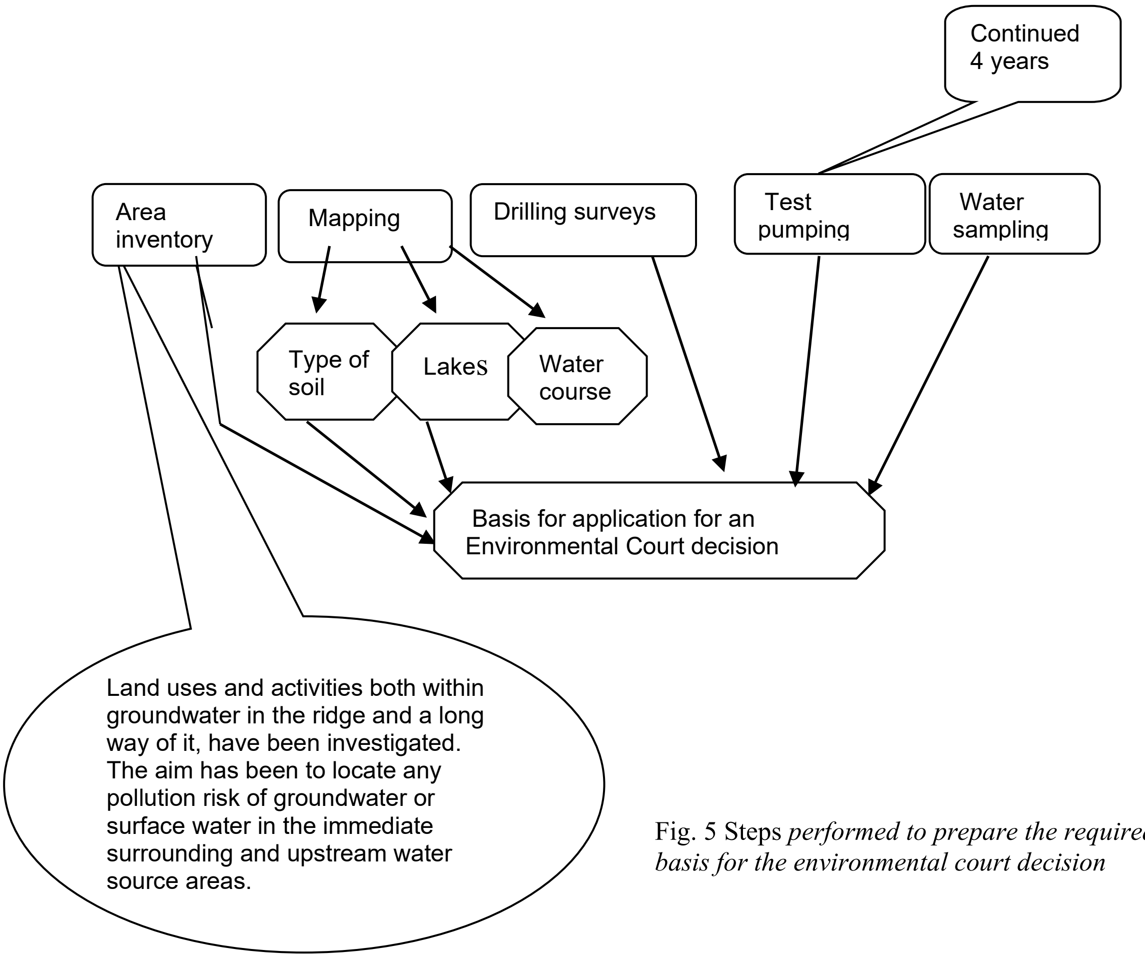

Fig. 5 Steps *performed to prepare the required basis for the environmental court decision*

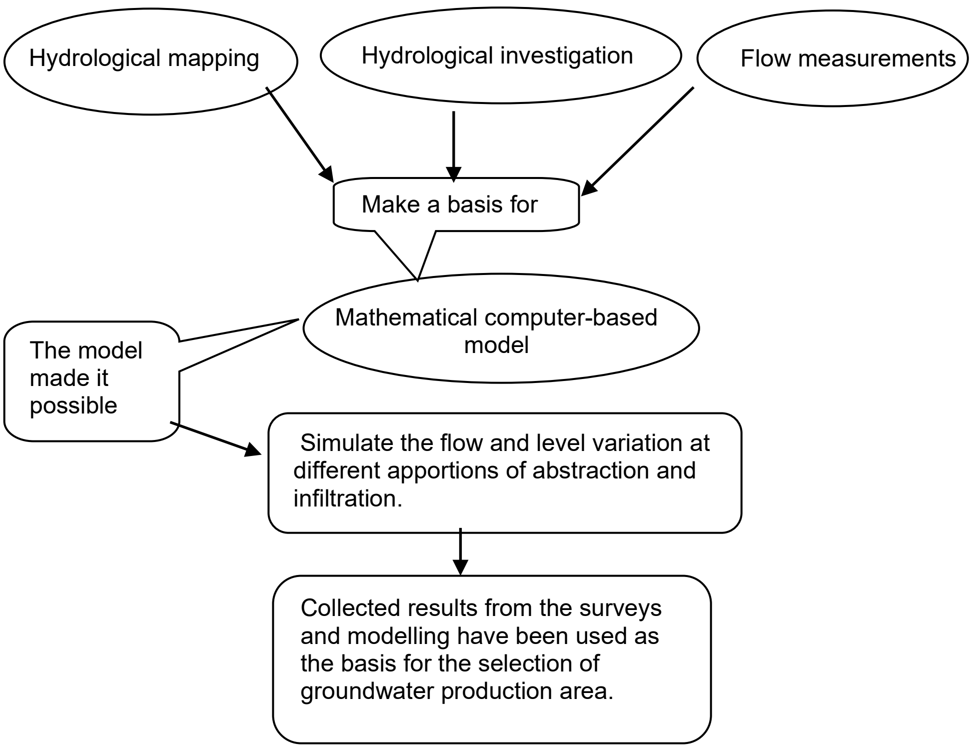

Fig. 6: *A schematic basis for the development of a mathematical model for assessing the ridge capacity.*

necessary to increase these parameters so that drinking water quality is achieved.

To assess the ridge capacity for supplying groundwater and what is happening in the aquifer if the needed amount is taken for Växjö and Alvesta, a large number of studies have been conducted, including about 140 drilling surveys conducted since 1998 to map the earth's geological structure and the aquifer extension. Furthermore, extensive test pumping programs, including long-term test pumping, have been implemented. With results from these surveys and test pumping as a basis, a special computer-based groundwater model of parts of the ridge has been constructed. With the help of this model it has been possible to simulate the flow and level variation at different apportions of abstraction and infiltration. Figure 6 shows schematically the basis for the development of a mathematical model for assessing the ridge capacity.

Water supply system

The water production area of the ridge covers a distance of 3 km with a width of about 1 km. It has been divided into 8 production areas as shown in Figure 7. Production zones 1, 2, 3 and 4, arelocated in North and Central Hallsjö, normally operate for raw water production.

Production area 5, which is located in Central Hallsjö, is a future reserve area for raw water production. Area 6, located in South Hallsjö, is the main production area for drinking water. Area 7 is a future reserve area for drinking water production, possibly within a 30-years perspective, depending, among other things, on the full participation of Ljungby municipality. Area 8 is a future reserve area for drinking water and possibly raw water production, seen in a longer perspective.

Raw water is pumped up from wells in North and Central Hallsjö and transmitted after treatment to the southern area to be re-infiltrated in open infiltration ponds. So that's why the net withdrawal from groundwater formation in South Hallsjö become small, thus minimizing the inflow from the Lagan River (Fig. 8).The pumped water is gradually replaced by so-called induced infiltration of water from the Lagan through the water banks and river bottom. The water residence time between the Lagan and the abstraction wells is estimated to exceed 1 month.

The pumped raw water from North and Central Hallsjö is pH adjusted and alkalinized through the addition of carbon dioxide and chalk. This is done at the pumping station at Hallsjö, which is located between the old and the new E4 highways. The water is led from there to infiltration ponds in South Hallsjö in which the water is slowly infiltrated through an approximately 40-m-thick gravel layer to reach the aquifer. The water is then pumped up into clean water wells. The residence time for the re-infiltrated water is expected to exceed 14 days.

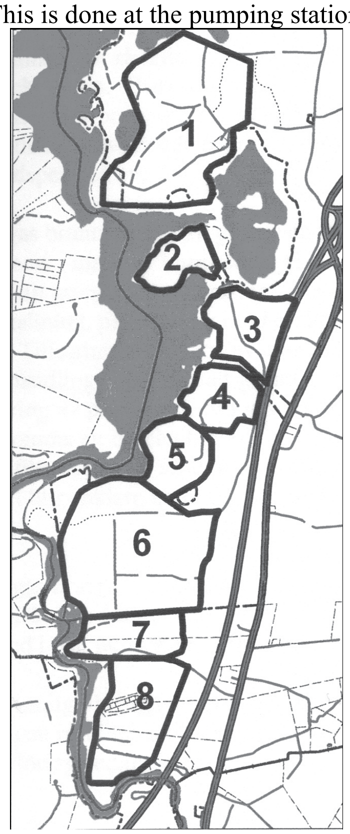

Fig. 7. Production area

The natural ability of the soil to turn surface water into a groundwater character is utilized in three steps:

- In the first step the water flows directly into the groundwater zone.
- The second step involves re-infiltration in the elevation tableland.the water here passes through a ca.15-m aerated zone before it reaches the aquifer.

• In the third step the water flows through the aquifer to the clean water wells. This step contributes to a further increase in quality.

A complete reduction of bacteria, protozoa and pathogens can be expected by the long residence time until the water reaches the clean water wells. The total transmission time i.e. the time that the groundwater transport takes in the aquifer from the Lagan to the raw water wells, through infiltration ponds, and then as groundwater transport in the aquifer up to the clean water wells, will exceed 100 days (Mark & Vatten Ingenjörerna i Växjö, 2001).The final alkalinization is made in the final step, possibly also a hardness increase and, if necessary, disinfection before the water is transferred to Växjö and Alvesta. This is also done at the pumping station in Hallsjö (Fig.9).

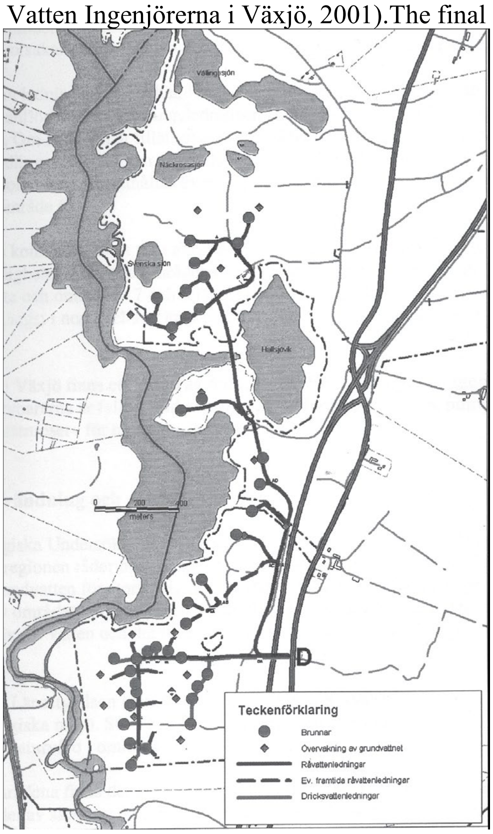

Fig. 8. *Wells and pipelines*

In order to transfer the water 50km to Växjö by two 500-mm-thick water pipes, the pressure should be raised twice in two booster stations on the way. The first is located near the lay-by next to Lake Fenen beside Trunk Road 25. The second is at Lekaryd and also has the function to provide the connection point for Alvesta. The water is disinfected with UV or chlorinated, if necessary, before distribution to Alvesta water networks. The transmission pipelines run along the north side of Trunk Road 25 to the Långstorp district, where they cross the road and go up to the treatment building in the Kvälleberg district. It also contains UV filters and chlorine equipment for distribution to Växjö's water network. Adjacent to the treatment building at Kvälleberg there are two high reservoirs with a total volume of 22,000 m^3, which corresponds to the daily water consumption for Växjö and Alvesta (Fig. 10).

Connecting Alvesta and Ljungby municipalities

Alvesta has an agreement with Växjö municipality to join the water from the Bergaåsen ridge . The water resources as well as the transferring pipe lines have therefore been designed for the water requirements of both Växjö and Alvesta in 2030. Ljungby municipality has also signed an agreement with Växjö municipality to secure a portion of its reserve water from Bergaåsen. At a later stage Ljungby municipality may wish to be able to completely replace its current water production from Bergaåsen. This will then involve a water demand of 55 l / s for the mean daily and 75 l / s for the maximum daily consumption. This entails that the plant needs to be expanded with more wells, ponds and pipelines. The pipelines have been partially up-dimensioned to be able to carry the increased flows.

Water demand in Växjö, Alvesta and Ljungby

The timescale for the design of the Bergaåsen water project has been set at approximately 30 years. Today around 54,000 people are connected to the Sjöudden water treatment plant. The population connected in 2030 is estimated to be 62,000-72,000 people, with an estimated annual increase of 200-500 (according to the municipal population prognosis for 2010). An additional few thousand affiliated persons from other parts of the municipality may be added if these are connected to Växjö's drinking water supply. The specific water consumption (270 l / pd), i.e. the total water consumption including industrial consumption, etc. divided among the number of connected people, is not expected to change to any great extent.

With 72,000 people connected by 2030 the mean daily drinking water consumption is estimated at 19,400 m^3 / d and the maximum daily at 25,300 m^3/d. This represents an annual consumption of around 7 million m^3. The estimated water need in Alvesta amounts to

3,200 m^3 / d (36 l / s) and for both Växjö and Alvesta together the maximum daily consumption is estimated to reach a total of 28,500 m^3/ d (329 l / s). For Ljungby municipality the water need for reserve water is estimated at 35 l / s for maximum daily consumption (Table 2).

The water source as well as the transferring pipeline have been designed for both Växjö's and Alvesta's requirements for the year 2030.

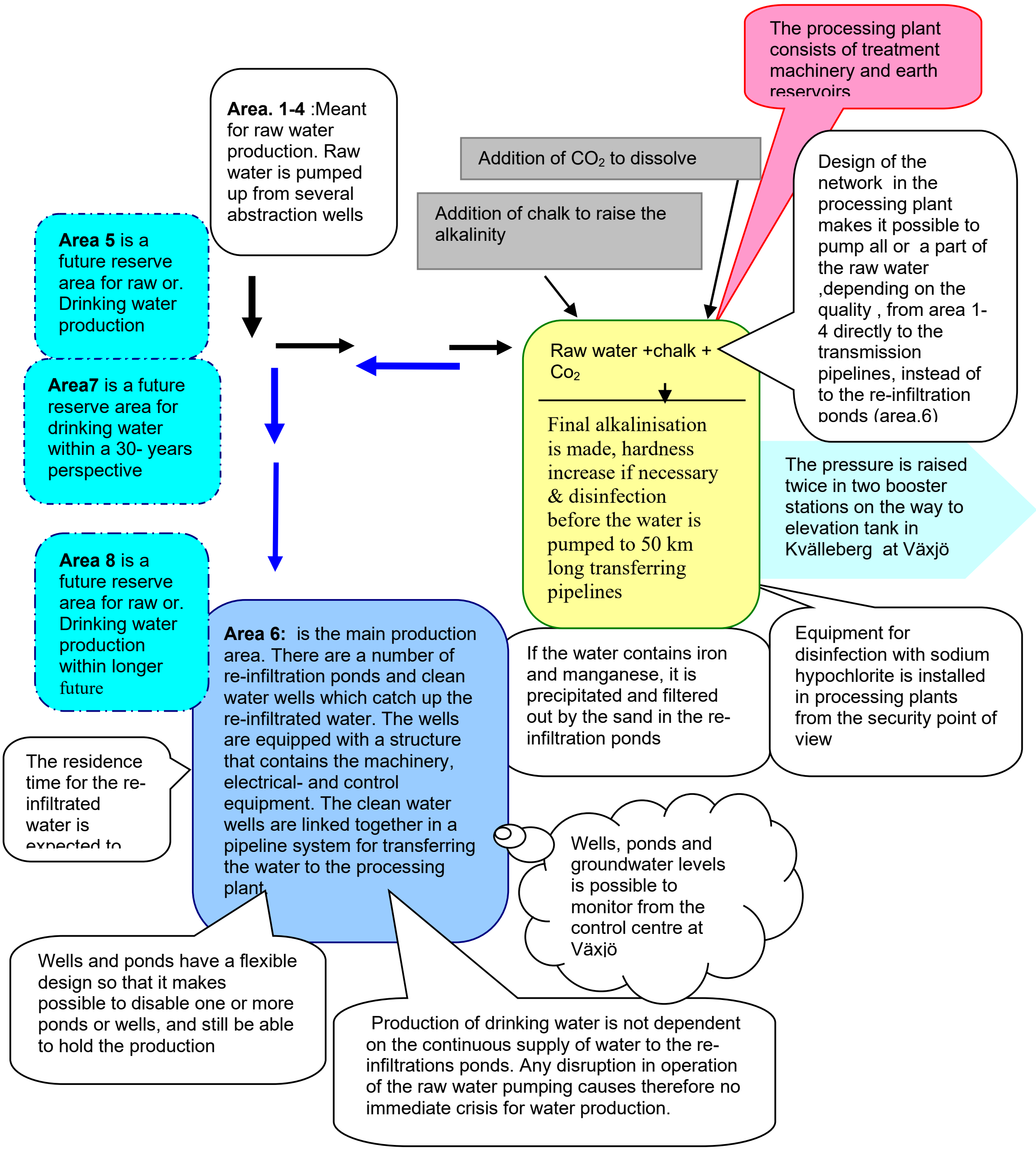

Fig 9 *Flow chart showing the water path and the process of water production in Bergaåsen*

Table 2. ***Future water demand in Växjö, Alvesta and Ljungby***

Water demand in	Mean daily consumption in l/s	Maximum daily consumption in l/s	Maximum daily consumption in m^3/d
Växjö	225 l/s	293 l/s	25 300 m^3/d
Alvesta	28 l/s	36 l/s	3200 m^3/d
Växjö and Alvesta	253 l/s	329 l/s	28 500 m^3/d
Ljungby (reserve)	25 l/s	35 l/s	

This means a water demand of 253 l / s for the mean and 329 l / s for the max daily consumption. Pipelines for the distance Alvesta -Växjö have been dimensioned for Växjö's maximum daily needs for 2030, i.e. 293 l / s.

Should Ljungby municipality at a later stage wish to take all its water needs from the ridge, the estimated need is 55 l / s for the mean daily and 75 l / s for the max daily. This then entails that the plant needs to be expanded with more wells, reservoirs and pipelines. The designed network has to some extent taken into account how to manage the increased flows.

Cost estimates for the remaining options

The costs presented as follows are estimated by the price level in January 2001. Price increases since the autumn of 1998 have varied between 5% and 20% depending on the investment type. In the comparison Alternative 6, "Braås", is not included, because it is not deemed to have sufficient capacity to supply Växjö with water in the future. As the investment costs which were calculated in 1998 for Nybro Ridge, Alternative 5, and Vislanda Ridge, Alternative 4, are high, these were judged not to be interesting to study again.

To achieve as comprehensive accounting as possible the costs of construction, investigations, planning, designing, permits, developer costs, land payment and emergency measures for existing water treatments plant have been included.

The Bergaåsen option includes the 20.2 million SEK used up to January 2001 for drilling, test pumping, investigations, etc., of which 4.4 million SEK concerned wells that can be used in full production if the Bergaåsen option is to be implemented. It should be noted that the costs for further investigations for the Bergaåsen option would have remained even if one of the other options should be chosen.

To account for what annual cost the four remaining alternatives will cause, the cost of capital for investment and re-investments has been calculated together with estimated costs for operation and maintenance over a 50-year period. The updated cost of 20.2 million SEK has been included in the calculation for all alternatives. The calculation has been made with straight-line depreciation and an interest rate of 6% at the 2001 price level. Figure 11 presents the annual estimated cost for operation and maintenance of straight-line depreciation for the four options.

Tabell 3. sammanställning över beräknade totala kostnaden för olika alternativ och tidpunkter.
Alt. Kostnadsnivå 1998 Kostnadsnivå 2001 Kostnadsnivå 2004 Kostnadsnivå 2007

	Kostnadsnivå 1998 , milj. Kr	Kostnadsnivå 2001 , milj. kr	Kostnadsnivå 2004, milj. kr	Kostnadsnivå 2007, milj kr.	Kostnadsnivå 2008, milj. kr
1) Ytvattenverk, intag i Örviken	160	217			
2) Ytvattenverk intag i Örken	225	315			
3) Grundvatten från Bergaåsen.	220	280	323-352	395	455
4) Vislandaåsen + ytvatten från Örviken	270				
5) Nybroåsen + ytvatten från Allgunnens	500				
6) Braåsen (är utbruten)	Ej aktuell, kvalitét och kvantitet	179			
7) Renov. av befintligt vattenverk + ny drickvattenSP	130				

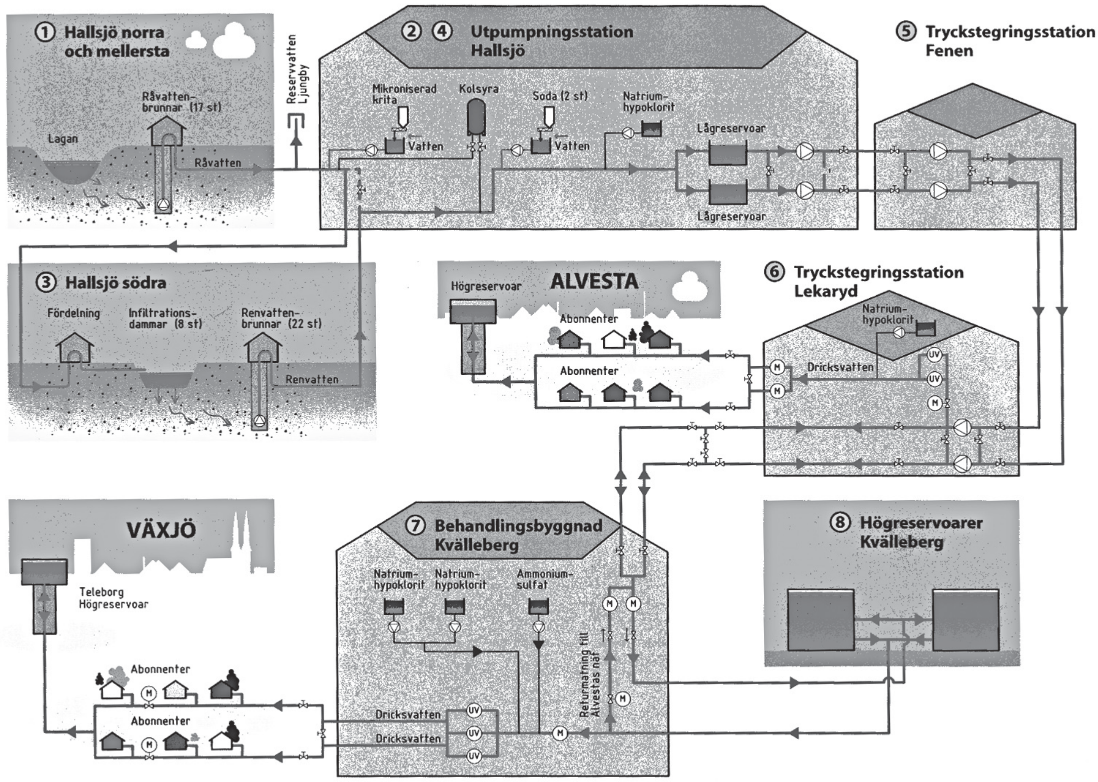

Fig. 10. Water supply system *(Source: Växjö municipality).*

Figure11 shows that Alternatives 3 and 7 go together in the first 15 years. After that Alternative 3, "Bergaåsen", is the cheapest option throughout the remaining period. The main reason is that this alternative contains a high proportion of investments with long amortization periods. If the above annual costs should be financed through the water tariff, without a sharp increase when the facility is completed, the tariff should continue to be increased gradually by 3.5% during the 2000-2005 period.

The cost level in January 2001 has been updated to the cost level in January 2004 to 323-352 mill SEK.

Cost estimates have been performed for three different pipeline options and for different levels of bedrock existence and supplements for Earth rocks. The calculation showed that the costs are very much dependent on bedrock existence. The total investment for the project was in the 2007 budget estimated at 395 million SEK. The consequence of the drawn-out environmental testing was that the construction of the project ended up in a cyclical boom and in a period of high oil prices, which affect the price of the pipes. In return, the interest rate has fallen, making the current water rate level sufficient to fund the project. Operating and maintenance costs of the facilities at the ridge, pumping station, the other pressure stations, pipelines, high reservoir, etc. have been calculated at 7.5 million SEK/ year (Bruch, mf. 2001, Rev. 2004) (Table 3).

Concluding discussion

Quantity, quality, chemical dependency, environmental impact as well as risk and vulnerability are important aspects for the selection of future water supply.

The water quality of groundwater-based alternatives is usually better, especially with regard to temperature and organic matter content as well as taste and smell. The groundwater, which is usually free of bacteria, also provides conditions for long-term avoidance of disinfecting water with chlorine if the network does not require it.

There may be limitations on water quantities in groundwater formations, while surface water resources usually have a higher capacity. The environmental impact of a water supply facility may be difficult to evaluate before more detailed plans have been developed for each option. Generally, a groundwater plant requires a large area, but the parts that are visible above ground are very limited. Long pipelines will obviously have an impact along the route during the pipe-laying phase. The higher chemical consumption of a surface water treatment plant will result in a greater environmental impact and resource consumption compared with a ground water treatment plant. A surface-based treatment plant is more exposed to risk and vulnerability regarding the direct impact of the water resource, but this can usually be resolved by the availability of a reserve water supply. Groundwater may be experienced as more secure, but if an impact occurs on the sand-gravel formation, it may be difficult to rectify the damage within a limited period of time. It is therefore important that aquifers are protected properly and that a sectioning is made to avoid that the whole water catchment is affected by an accident. A possible groundwater resource will be far away from Växjö, which means long pipelines that can fail. The safety issue for the pipes may be solved by a high level of repair preparedness and the Bergaåsen option has spare capacity in the elevation reservoir in the Kvälleberg district.

In conclusion, there are advantages and disadvantages of both surface and ground-based alternatives. A groundwater system needs more extensive measures during the planning and construction stage than a surface water treatment works, but the final product to consumers, drinking water, often tastes good with regard to both composition and temperature.

Bergaåsen is a large groundwater-carrying formation which allows for great flexibility in how the ridge can be exploited for the production of drinking water. The technique of re-infiltration has been chosen to ensure that good water quality can be achieved even in the long term. Since drinking water is a food, any risks and the vulnerability of supply water should be taken extremely seriously. If the water quality should deteriorate in the future, the existing treatment may be supplemented by, for example, oxidation or chemical precipitation of the possible infiltration water.

The existing groundwater quality is very good. However, it has a deficit of alkalinity and calcium and a low pH as well as containing some aggressive carbon dioxide (J &W and Mark & Vatten Ingenjörerna AB, 2001). When a certain flow from the river Lagan to the aquifer occurs, there is some risk that the groundwater may be affected by the Lagan waters, which may cause some increase in iron and manganese. Alternative 3 was chosen because it ensures long-term water quality through the re-infiltration procedure

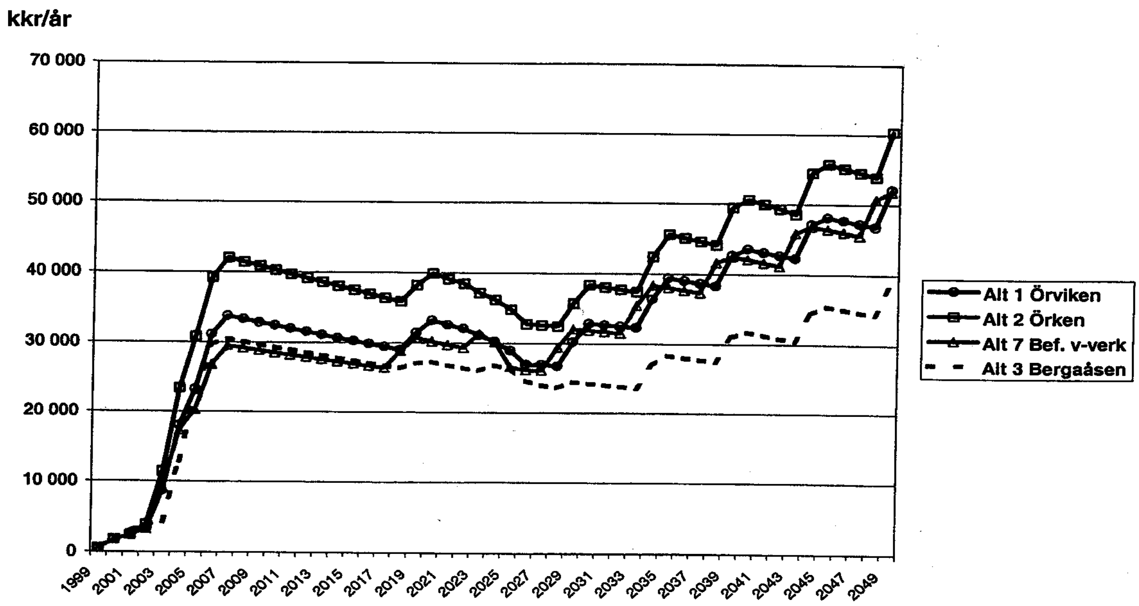

Fig 11. Annual estimated cost for operation and maintenance of straight-line depreciation for the four options (Source: Växjö municipality)

and because this option involves the greatest flexibility in the water production. The option may be introduced in the autumn of 2008 with the delivery of 200 liters of water per second for about 70,000 people in Växjö and Alvesta municipalities.

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water
production.
Raw water is
pumped up
from several

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