CZECH UNIVERSITY OF LIFE SCIENCES PRAGUE

FACULTY OF ENVIRONMENTAL SCIENCES

Management of new water sources in TPCA factory

Diploma Thesis

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CZECH UNIVERSITY OF LIFE SCIENCES PRAGUE

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DIPLOMA THESIS ASSIGNMENT

Martin Hrbek

Land and Water Management

Thesis title

Management of new water sources in TPCA factory

Objectives of thesis

Evaluate options (economic, balance, feasibility) of the alternative water sources for TPCA factory. This project is particularly dealing with groundwater and rainwater use for manufacturing purposes.

Methodology

1)Introduction

2)Goals

3)Literature search

4)Methodology

5)Description of the area

6)Proposal

7)Discussion

8)Conclusion

The proposed extent of the thesis

60 pages

Keywords

water management, groundwater, rainwater, water recycling, factory

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Recommended information sources

BINNIE, Chris, Martin KIMBER a George SMETHURST. Basic water treatment. 3rd ed. London: Thomas Telford, 2002. viii, 291 s. ISBN 0-7277-3032-0.

ČIHÁKOVÁ I., 2005: Očekávaný vývoj v zásobování a distribuci pitné vody v České republice, ČVUT v Praze

CHEREMISINOFF, Nicholas P. Handbook of water and wastewater treatment technologies. Amsterdam: Elsevier, ©2002. xii, 636 s. ISBN 978-0-7506-7498-0.

MOSSET A., BONNELYE V., PETRY M., SANZ M. A., The sensitivity of SDI analysis: from RO feed water to raw water, 2007

NOVÁK J. a kol., 2003: příručka provozovatele vodovodní sítě. Medium, Líbezníce

RAM, Manoj Kumar, ed., Silvana ANDREESCU, ed. a Hanming DING, ed. Nanotechnology for environmental decontamination. 1st ed. New York: McGraw-Hill, ©2011. xviii, 430 s. ISBN 978-0-07-170279-9.

SPANNRING, Michael. Die Wirkung von Buhnen auf Strömung und Sohle eines Fliessgewässers: Parameterstudie an einem numerischen Modell. München: Technische Universität, 1999. 186 s. Wasserbau und Wasserwirtschaft Nr. 86 ISSN 1437-3513.

Technologies for Upgrading Existing or Designing new Drinking Water Treatment Facilities. 1st Ed. Lancaster: Technomic Publishing Co., 1994. 209 s. ISBN 87762-824-6.

TESAŘÍK I., 1987: Vodárenství. Nakladatelství technické literatury, Praha

TUHOVČÁK L. a kol., 2003: Sborník přednášek z odborného semináře: Ztráty vody ve vodárenských distribučních systémech. Akademické nakladatelství CERM, Brno

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Declaration:

I hereby declare that the entire diploma thesis represents my own work, and has been completed with the use of cited literature and according to the recommendations of my supervisor.

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Thanks:

I would like to thank all people who contributed with any comments or ideas relative to my topic. Big thanks to the employees of TPCA factory, especially to my supervising manager Petr Čížek and all technicians working in facility. In addition, I will always be grateful to Mr. Martin Guth, RNDr. from G-Servis Praha company who patiently cooperated on the groundwater project and willingly answered all my questions. Furthermore, I would also like to thank my supervisor Mrs. Ing. Marcela Synáčková, CSc., for valuable advices and supervision. And on the whole I want to thank my parents because without their support my university studies would not be possible.

Abstract

Subject of this diploma thesis is a project named “Management of new water sources in TPCA factory” assigned by a car making factory TPCA in Kolín. Purpose of this project is to evaluate possible options of the alternative water sources for the factory.

At the beginning is described the current condition of water management in TPCA and how facility is processing the water. I also depict how water management works in French Toyota and evaluate its possible implementation for TPCA´s purposes in spite of different conditions. Furthermore, the process of water pre-treatment and function of reverse osmosis are explained. Water from other sources is meant to be used as a supplement source of water for reverse osmosis unit. During my internship I have been consulting many fractional parts of these projects with the external companies. Results, reflections and thoughts of these meetings are also presented throughout this thesis. On the whole, proposals of groundwater and rainwater projects containing feasibility evaluation and economic balance are presented.

Key words:

Water management, groundwater, rainwater, water recycling, factory.

Abstrakt

Předmětem této diplomové práce s názvem "Hospodaření s novými vodními zdroji v TPCA" je projekt zadaný automobilkou TPCA v Kolíně. Účelem tohoto projektu je vyhodnocení možnosti vybudování nových zdrojů vody pro továrnu.

V úvodu práce je popsán současný stav vodního hospodářství v TPCA a to, jakým způsobem se na facility zpracovává voda. Dále take popisuji, jak funguje vodní hospodářství ve francouzské Toyotě a zvažuji možnou implementaci tohoto procesu do TPCA za rozdílných podmínek. Také je vysvětleno, jakým způsobem se upravuje voda a k jakému účelu se v TPCA využívá reverzní osmóza. Voda z jiných zdrojů by se používala jako pomocný zdroj vody pro napájení reverzní osmózy. Během své stáže jsem konzultoval mnoho dílčích částí těchto projektů s externími společnostmi. Výsledky, návrhy a postřehy těchto jednání jsou prostoupeny celou mou prací. Závěrem představuji projekty na využití podzemní a dešťové vody spolu s vyhodnocením proveditelnosti a ekonomickou rozvahou.

Klíčová slova:

Vodní hospodářství, podzemní voda, dešťová voda, recyklace vody, továrna.

1. Contents

2. List of abbreviations

$Al_2(SO_4)_3$ – Aluminium Sulfate
AniP - Polymer Anion
BOD5 – Biochemical Oxygen Demand over 5 days
BWT – Biological Wastewater Treatment
C_{10}, C_{40} - Hydrocarbons
$Ca(OH)_2$ – Calcium Hydroxide
CHMI – Czech Hydrometeorological Institute
CNS – Czech National Standard
CO_2 – Carbon Dioxide
COD – Chemical Oxygen Demand
WWT – Wastewater Treatment
CZK – Czech Crown
$Fe_2(SO_4)_3$ - Ferric Sulfate
H_2O_2 – Hydrogen Peroxide
H_2SO_4 – Sulfuric Acid
m.a.s.l. – Meters above sea level
NaOH – Sodium Hydroxyde
NH_4 – Ammonium
NTU - Nephelometric Turbidity Units
PAC - Poly Aluminum Chloride
PSI - Pound Per Square Inch
PVC - Polyvinyl Chloride
RO – Reverse Osmosis
SDI – Silt Density Index
SO_2 – Sulfur Dioxide
SO_4 - Sulfate
SSR - Shallow Seismic Reflection
TMMF - Toyota Motor Manufacturing France
TOC – Total Organic Carbon
TPCA - Toyota Peugeot Citroën Automobile
UV-Ultraviolet

3. Introduction

3.1 About TPCA

In 2000 started a process of consideration of a mutual project between Japanese Toyota and French PSA Peugeot Citroen. Subsequently, in 2002, was signed an agreement between these two companies and the foundation stone was laid in Kolín - Ovčáry. In the framework of territorial plans was defined 370 ha of land for the construction of an industrial zone. The actual construction of engineering and transport infrastructure began in May of that year. In 2003, negotiations with other potential investors started. To date there are four companies located in the industrial zone whose activities are linked to the TPCA. Those are LEAR, GEFCO, Toyota Tsusho Europe SA and NYK Logistics. TPCA itself occupies an area of 124 ha and car production was started in 2005. Production is based on the use of the system JUST IN TIME, which allows the production without the storage of material. The process works on close cooperation between the supplier and the assembly line, for example when the car seat is manufactured in the company LEAR then it goes directly to the production line to TPCA. Total TPCA´s investments from the beginning of construction to the various grant funding to develop Kolínský region has exceeded 26 billion. According to official information, the TPCA total production was 203 105 cars in 2014. Almost all manufactured automobiles (99%) are intended for export. Three types of cars are produced here in the ratio of 3 x 1/3, namely: Toyota Aygo, Peugeot 107 and Citroen C1. Total number of employees in TPCA is around 3 000.

In the areal of TPCA are several sections of production. If we start chronologically from the development of "life" of the car, the first section would be a press shop. From rolls of plate of different thicknesses and with different surface treatment are pressed sidewalls, roof, doors and floors. One mold weighs up to 30 tons. These intermediates then go to the welding shop, where by using welds are firmly connected to each other. This part of the production is largely automated, because the machines can work with accuracy of a tenth of a millimeter. Welded parts continue to the paint shop, in which all the people must adhere to very strict rules. Every person in this building must wear a special suit and pass through an air chamber, where all the dust and dirt is blown away. Bodywork is cleaned and protected against corrosion and only then the paint is applied. Lacquer is burned at 190° C in the furnace. Following is final assembly, where workers install all necessary components. Each post on the production line must be governed by the so-called tact time. This means that every worker has to perform their work on one car within a given time (55s), during which he must be able to perform all the tasks that belong to his post. The manufacturing process ends with quality control operators, who must check whether everything is as it should be. If they detect any abnormality, car is returned until the problem is resolved.

3.2 Water management in TPCA

The demands on water quality in the industry vary by field and method of manufacture. The automotive industry demands are relatively high but not that high as for instance electrical or pharmaceutical industry. Conductivity limit in TPCA from the first reverse osmosis (RO) is <100 μS / cm^2 and the second RO, which is located in the paint shop, has limit only <10 μS / cm^2. The most prone section of the production to water quality in TPCA is paint shop. Demineralized water is used for mixing of colors, which are then applied on the metal parts of cars.

Requirements for the amount of water are large, because production of one car takes 1.17 m^3 of water (2014). In 2006 water consumption of TPCA was nearly double the amount than as it is nowadays. The amount of water needed for manufacturing 1 car used to be 1.7 m^3, and the annual car production was exceeding current production by nearly one third. So far, all water being used in TPCA comes from only one source and that is municipal water system managed by Vodos company. Aim of this thesis is to assess any possible alternative options of new water sources.

In 2014 TPCA consumed 237 364 m^3 of water. If we compare this value with table on the next page, we can notice that almost 15 000 m^3 of water are missing. That could be caused by losses, leakage or by inaccurate measurement tools. Consumption varies within all production segments. The biggest share goes to the facility where the raw municipal water is used by reverse osmosis for production of demi water to paint shop. The amount of water needed to supply RO represents 78% of total water consumption of TPCA. Table no. 1 shows the water consumption of the individual shops:

Table no. 1 – Water consumption in the TPCA for individual segments (year 2014):

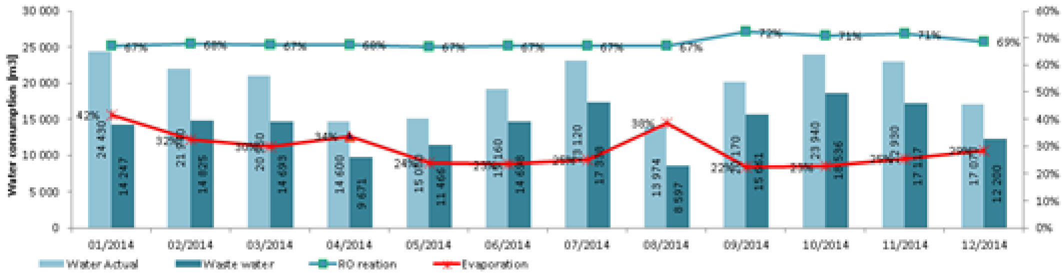
Shop	**Consumption [m^3/year]**	**Share [%]**
Assembly	2 828	1.27
Welding	62	0.03
paint	2 276	1.02
Press	722	0.32
Quality control	32	0.01
Facility	201 506	90.44
Aramark	5 128	2.30
601+ 602	10 251	4.60
total	**222 804**	**100.00%**

Source: Internal data of TPCA

Comment: Aramark is a company operating the canteen, building 601 + 602 are administrative buildings.

Even though water consumption in the facility represents 222 804 m^3, the paint shop then receives only 127 504 m^3 of demineralized water. That is because the total water consumption in the facility includes also water for the facility itself (water cleaning processes, water for compressor cooling, water for maintenance of tanks etc.). Furthermore, the average effectiveness of the RO is only 68.4%. This means that 186 385 m^3 of water is processed into 127 487 m^3 of demineralized water for the paint shop and the rest is waste. Figure no. 1 shows the water consumption, the amount of waste water, evaporation and efficiency of RO 2014:

Figure no. 1 – Water balance per year 2014:



Source: Internal data of TPCA

4. Goals

The main goal of this project in TPCA is to analyse whether any of the suggested proposals containing rain, waste and groundwater is feasible or not. Moreover, if the theoretical analysis proves that any particular project would satisfy the condition of <2.5 years payback time, then formulate specific design. The result of my work in TPCA should consist of creation of an A3 report which would serve for a presentation for the higher management. The report consists of several parts:

1) **Problem description** - Briefly describe how the actual situation looks like and what the alternative options are.
2) **Background -** Show how the current processes work.
3) **Desired outcome -** Present the theoretical result of the proposal.
4) **Proposal** - A detailed explanation of the proposal (where, how, costs, risks).
5) **Economical evaluation** – Compare the costs between current situation and the proposal. Evaluate the benefits and calculate payback time.

In my diploma thesis I am not limited with the actual feasibility and my proposals may remain on a theoretical level. I will also describe water management of this factory and all related processes. Moreover, I will provide the literature review related to these topics.

5. Literature search

The biggest challenge in the first half of the twentieth century was to meet the increasing water demand. Water management can be undestood as a management of a non renewable source. This source can also be considered as a limited factor for human life, developement of cultures, economy and agriculture. Lack of water causes conflicts and poor quality of water results in suffering and deseases. After the Second World War there has been a substantial increase in population and its water supply demands. Moreover, in this time there was a huge improvement of standards of home furnishings, increasement in the efficiency of economies, resulting in growing consumption of water for population and for industry needs. The two leading organisations on a global level in water supply and water treatment filds are International Water Supply Association and American Water Work Association. In the 80´s and 90´s was a noticeable decrease in water consumption as a result of economical and ecological pressure. After the year 1990 there was another significant decrease in water consumption in countries of Middle and Eastern Europe due to the change of pricing policy. Another water decreasing factor was the change of economy sector, which contributed to the closure of factories with too high water consumption. Economical, political and ecological changes reduced water consumption by 30-45% in comparison with the end of 80´s. This very positive fact implies new challenges in management of drinkable water, its distribution and monitoring water quality in the distribution network (Čiháková, 2005).

5.1 Greywater

„The most alarming of all man's assaults upon the environment is the contamination of air, earth, rivers, and sea with dangerous and even lethal materials. This pollution is for the most part irrecoverable; the chain of evil it initiates not only in the world that must support life but in living tissues is for the most part irreversible" (Carson, 2002).

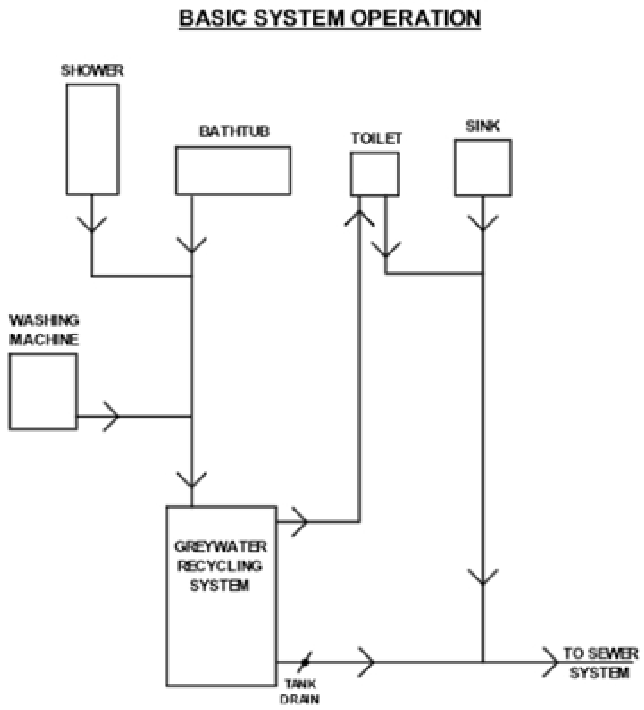
Greywater is defined as wastewater that originates from household activities, such as dish water, shower, and laundry, but does not include inputs from toilets (Ghaitidak, 2013). Unlike drinking water, greywater does not have to meet the requirements written in the Water Act. That means that the greywater does not meet the hygiene requirements consisting of microbiological, biological, physical or chemical indices. Simply written, greywater is washwater. We can say that it is all wastewater except toilet wastes and food wastes derived from garbage grinders. There are significant distinctions between greywater and toilet wastewater called blackwater. These distinctions tell us how these wastewaters should be treated or managed and why. In the interests of public health and environmental protection, they should not be mixed together. However, if the greywater is exposed to waste materials or urine, it will be regarded as blackwater. The level of bacteria inside blackwater is higher because it has a concentration of organic matter and Escherichia coli. Both greywater and blackwater are definitely not for human consumption. Greywater may be reprocessed and employed for farming purposes. Although greywater possesses microbe activity, it is far less polluted in comparison to blackwater. Re-using greywater for agricultural purposes considerably minimizes water use and acts to help the environment. Every household, using recycled water, must first ensure that both greywater, as well as blackwater, are let out by means of separate sewage systems, to prevent mixing up of the two. When mixed, greywater turns into blackwater and cannot be used for intended purposes anymore. Greywater itself is of two types, treated and untreated. The crude water can be used for irrigation purposes, depending on legal methods that are applicable for the specific region. The treated greywater can be used e.g. for toilet flushing or clothes washing (Hallandbaum, 2015).

Human waste can be identified as a critical threat to human and animal health as well as ecosystem functions. Addressing increasing sanitation needs is an important challenge facing growing urban areas worldwide but it is particularly critical issue in impoverished regions. It is predicted to only become worse with population growth over the next 30 years projected to occur dominantly in urban areas, particularly in Asia and Africa, creating extraordinary pressure on already insufficient infrastructure (Cohen, 2006).

Disposal of greywater is an increasing environmental challenge in congested urban areas and has largely been neglected with development focus directed at improving excreta disposal and provision of clean water (Imhof, 2005).

More and more often we can hear about the increasing lack of drinkable water and its quality. Even though water belongs to the renewable sources, it is crucial to reduce its consumption. There are many processes where the usage of drinkable water is unnecessary and could be replaced with worse quality water (eg. toilet flushing). To be able to easily determine different types of water, colour naming has been developed (Hlavínek & kol., 2007). In the figure no. 2, we can see a simple scheme how greywater recycling can be managed:

Figure no. 2 – Simple scheme of greywater use:



Source: www.grey-is-green.com

5.2 Rainwater

Throughout the history of mankind, countless different techniques have been developed to collect or store water for consumption, irrigation, and many other purposes. One of these techniques is rainwater harvesting, the practice of capturing stormwater runoff, usually from a rooftops and storing it in a tank for later use.

Historical evidence suggests that sophisticated rainwater collection systems were bulit before 3000 BC in Jordan (AbdelKhaleq and Alhaj Ahmed, 2007). Even though historically used in areas where water supply was limited by climate or infrastructure, the practice of rainwater harvesting has recently been used in humid and well developed regions. The main reason why is this happening can be explained by increasing public awareness about topics like droughts, increased water demands, and increased interest in green building practices, which support smart water use (Jones, Hunt, 2010).

While water supply is usually the primary concern in arid regions or locations where water supply infrastructure is lacking, also implementation of rainwater harvesting systems in humid and well developed regions offers a unique advantages and challenges. There is a big number of water uses around a household or business that do not require drinkable water, such as irrigation, car washing, and toilet flushing. Despite the fact that a high level of treatment is not necessary, drinkable water is typically used to meet these demands because it is readily available even though it is not cheap. When drinkable water is used to meet these demands, sources such as energy, money or chemicals are effectively wasted in treating and distributing the water. This treatment can result in increased infrastructure demands as well as increased costs for the water user (Gleick, 2000).

Since municipal water supplies are generally prevalent in the southeastern United States, companies usually do not seek any alternative options such as rain water harvesting systems (Jones, Hunt, 2010).

Hygienically safe water must be used only on those places, where a person comes to personal contact with it. That does not apply for watering gardens, car washing, laundry or toilet flushing. For these activities, the use of drinkable water is not ecological or economical. Moreover, it is convenient to use rainwater instead of drinking water in areas with hard water, because rainwater is very soft and can much easier dissolve soap powder and even does not cause limescale (Hlavínek & kol. 2007).

As we can see in the Figure no. 3, rainwater harvesting system can easily be bulit in almost every building:

1) Rainwater is collected through guttering

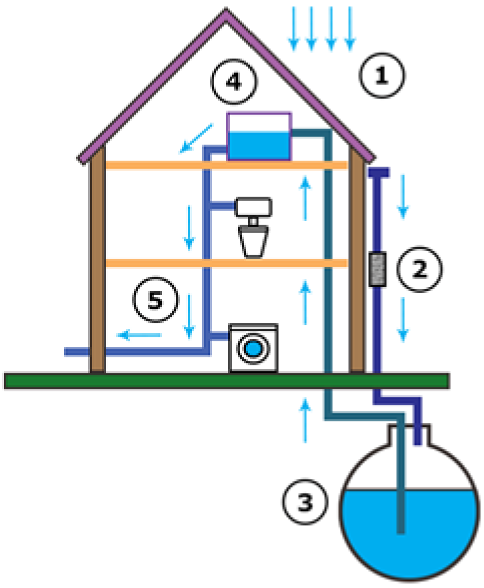
2) Water is filtered

3) Stored in (underground) tank

4) Transfered to high level tank

5) Fed to non-potable application by control system

Figure no. 3 – Rainwater harvesting system in a household:



Source: www.durkenergy.co.uk

According to (Durkenergy, 2015) benefits of collecting rainwater consist in many aspects:

- Provides free water supply and reduces water bills
- Reduces flooding, erosion and storm drain overflow
- Reduces the energy used in water supply
- Reduces environmental damage to rivers and lakes due to flooding

- Can be used to recharge groundwater
- Garden plants thrive on it
- Good for laundry and reduces the amount of detergent required
- Is beneficial to washing machines as it does not produce limescale
- Promotes self – efficiency
- Simple to install and easy to maintain

5.3 Groundwater

Kopáč (2016) clarifies the procedure of realization of own groundwater source as following:

Basic legal aspects of the establishment of groundwater resources:

Underground water source (well or borehole) is in accordance with current legal standards called water work and must follow the regulations. Basically, there are two possible approaches:

- Realisation of a well as a pre-approved water work.
- Realisation of a well as an exploratory work.

For the pre-approved water work it is necessary to formulate a project by authorized person, and submit permits for water withdrawal and well realization. Moreover, an official Municipal Authority approval needs to be executed as well as Water Management Office approval. After the construction works are done the builder can ask for legal approval.

The second option is more common and consists of construction of an exploration well in a first step. Retrospectively, after the construction works are done and the tests prove usable quantity of water the builder can ask for municipal authority approval and Water Management Office approval. Usually it is not necessary to have Water Management Office approval in advance of the exploration work.

Procedure for the establishment of an individual groundwater resource:

According to the Act 62/1988 Coll. (about geological work) realization of a well or borehole is considered as an interference to the land property and can only be done with an approval of the owner. The actual works must be supervised by a person with a certificate of qualification issued by the Ministry of the Environment. Procedure of the authorized person for the well construction consists of following steps:

1) Processing of all available documents (archives, maps etc.).
2) Inspection of the area, identification of potential sources of groundwater pollution and identification of the position of exploration well based on the field survey.
3) Elaboration of the project of exploration works.
4) Contractor is also obliged to conclude a written agreement with the owner (or tenant) of the plot for the geological exploration works (admission to the plot, conditions for implementing exploration works etc.).
5) Contractor is required to notify the municipality of realization of geological works.
6) Register geological works at the Czech Geological Service.

All the steps above are sufficient to begin drilling work with the following exceptions:

7) In case of 30m< deep borehole is necessary to obtain affirmative approval of the municipal office (Department of the Environment).
8) In case of 30m< deep borehole is also necessary to notify the Mining Office.
9) If the territory is protected in accordance with other regulations (protected landscape area, national park, buffer zone of water resources etc.) you must obtain permission of the authority concerned (eg. PLA and NP administrator or water source manager).

Deadlines for filling a notification of geological work are determined by appropriate legislation.

5.3.1 Legalization of groundwater resources

If the hydrogeological borehole reveals sufficient quantities of groundwater, exploratory borehole will therefore not be destroyed but protected. To ensure that the exploration well becomes water work and could be used as well for individual supply, further steps are needed to be followed for its legalization:

1) Territorial authorities - permit of placement of the borehole (the request is submitted to the competent Construction Authority).
2) Construction and Water Management authorities - permission to set up exploratory well and put the water work into operation (application is submitted to the competent Water Management Office).

Subsequent legalization of the work is therefore possible only if it does not conflict with the approved spatial Plan and zoning decisions. An integral part of the construction project is a hydrogeological survey or report of work that was done. In these documents should not be missing hydrogeological assessment of the drilled well with respect of the hydrogeology of the area and details of the intended operation of the well, including the basic technical parameters. These data are obtained by field tests of underground water resources (eg. pumping test) and laboratory analysis of groundwater samples (eg. assessment of basic physico-chemical parameters of groundwater).

5.3.2 Location of groundwater resources

Decree no. 501/2006 Coll. describes distances of wells from potential sources of contamination. The §24a defines minimal distances of wells for individual water supply from local sources of pollution as following:

Table no. 2 – Minimal distances of wells from sources of pollution:

Sources of possible pollution:	**Shortest distance [m]**	
	Low-permeable environments	Permeable environments
Cesspools, septic tanks and sewers.	12	30
Tanks of liquid fuels for individual heating located in a building or a separate auxiliary building.	7	20
Sheds, liquid manure tanks and manure heaps for individually housed livestock.	10	25
Public roads	12	30
Separate washing areas for motor vehicles and their drain pipes and ditches	15	40

Source: Decree no. 501/2006 Coll.

The decree permits in justified cases exceptions to the statements above. The exceptions are not automatic and must be justified and also must be asked by the Building Authority. Official act of issuing the exemption is usually charged an administrative fee of up to 5 000 CZK.

Not only possible sources of pollution are affecting the location of wells and boreholes. The input explorations of sites identify anomalies suitable for the installation of water sources. At this stage, not only the study of archival materials is applied, but also geophysical surveys or application of sensitive methods. Digging groundwater resources in more permeable zones of the geological environment gives a better chance of securing the required quantities of water. Finally, it is necessary to take into account the position of surrounding wells and deploy its own source of groundwater in a proper way. The well must be positioned so that its implementation and its future use would not adversely affect the yield or quality of surrounding water resources. Specific distances from nearby water sources are not determined by any rule, since each site depends on many factors. They are derived mainly from the hydrogeological conditions of the site and the technical and operational parameters of future wells (especially the size of future consumption). Minimum distance of the future wells from the surrounding water resources should be assessed by an authorized hydrogeologist. In very simple cases (e.g. a well-known hydrogeology of the site or greater distances between surrounding water sources) can assessment of future wells to nearby water sources be done by using empirical formulas for calculation of the range of so-called depression cone. In other cases, it is necessary to perform hydrodynamic tests (Decree no. 501/2006 Coll.).

5.3.3 Design parameters of water collecting objects

In many cases, the decisive criterion for the technical design of tube wells is their price. According to Kopáč (2016) it is a common problem that many wells are missing backfill kits (transient filter layer) and the sealing layer. Such technical executions of the pipe wells do not prevent the influx of fine particles of soil and contaminants from the surface into the borehole. Tap water of house or cottage includes sand and clay sediment, groundwater quality is abruptly aggravated by increased levels of nitrogen compounds (nitrates, nitrites) and microorganisms (eg. Coliform bacteria).

For a common user it can be impossible to recognize whether the well contains increased concentration of unsafe substances. Especially if water does not smell or the water table is absent of any layer from e.g. oil products (gasoline, kerosene, Diesel fuel). There are three most common solutions:

1) Frequently take water samples to the laboratory and determine the actual contents of selected indicators of groundwater quality.
2) Preventively install water treatment plant that removes any unwanted substances.
3) Create water source in cooperation with a specialized firm to assess the possible negative indicators of groundwater quality and optimally locates the construction of a borehole.

Construction of a well or a borehole, as a water work must follow certain requirements. Requirements for the structural design of wells or pipe wells (boreholes) governs the standard CNS 75 5115. The sealing layer should be provided at the top of the well to a depth of at least 2.5 to 3 meters. The parameters of the filter layer (backfill) depend on the type of geological environment, hydrogeological conditions of the site, selection of drilling profile and other requirements of the technical solution of groundwater resources (Kopáč, 2016).

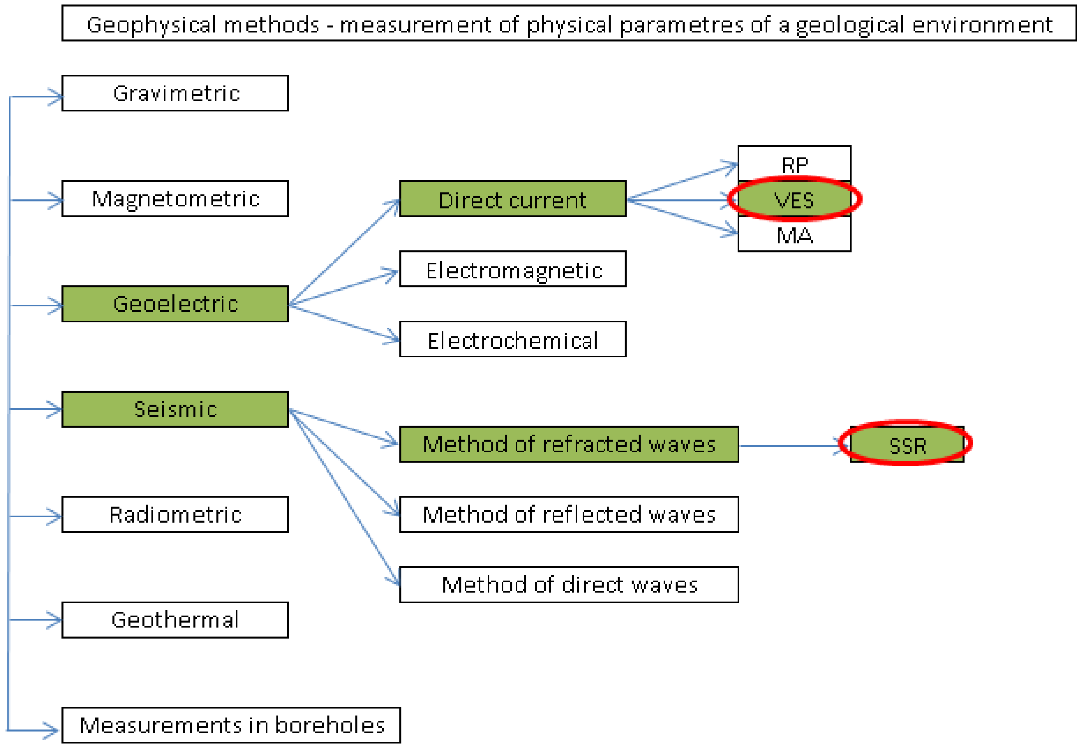
<u>Summary</u>

Kopáč (2016) claims, that establishment of individual groundwater resources require according to current legal standards series of steps and procedures. Installation of wells and drillings consist of geological work interfering with the land. Such work is necessary to project, announce and register. In some cases is also necessary to obtain permissions from Regional Authorities. Construction works are managed by a responsible person with a certificate of qualification. For groundwater abstraction is necessary to have a hydrogeological report. Included in the hydrogeological report (reports, project) is a description of the structural design of well or borehole, hydrogeological assessment of well in relation to the potential (or proven) sources of pollution and to the surrounding wells. Report also assesses the operating parameters of well, quality of groundwater and more. Improper construction design of wells and boreholes significantly shortens their lifespan and increases the cost of their operation. In many cases it is not possible to withdraw more groundwater after just a few years of operation of the object.

5.3.4 Geophysical methods

Applied geophysics deals with the physical fields of the Earth. Geophysical methods follow the physical field and appropriate physical parameters that allow you to characterize the physical state of rock mass (Jančovič et al., 2014). According to the monitored physical parameter and a character field geophysical methods are divided into several groups (Mareš et al., 1979):

Figure no. 4 – Geophysical methods

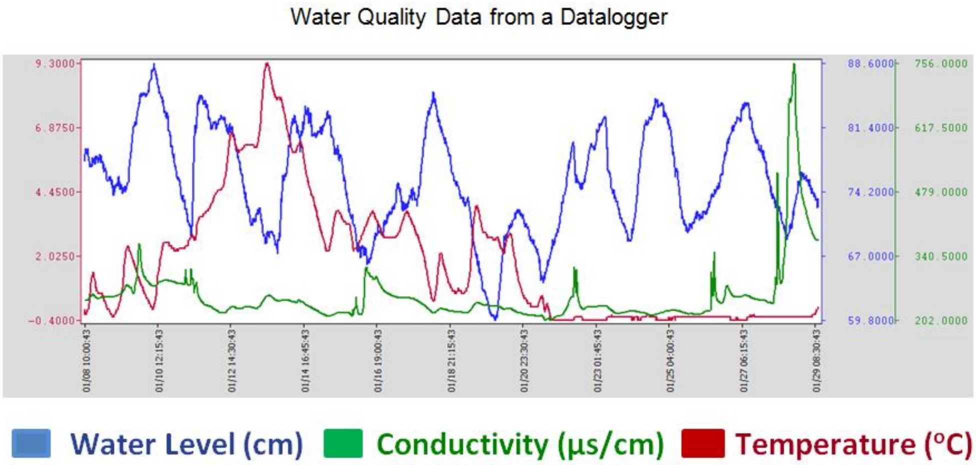


Source: Úvod do užité geofyziky (1979)

Shallow Seismic Reflection (SSR)

This is the surface geophysical method based on the evaluation of arrival time of the first deployment of reflected seismic wave. The wave moves from the source to genofons mostly by the surface of deeper, seismically faster medium (such as the surface of the bedrock or ground water level). Seismic energy is caused by repeated seismic impact of hammer on the fixed plate and by summarization of these shots is possible to reduce the proportion of noise and significantly increase measurement accuracy (www.sihaya.cz).

Figure no. 5 – Sample data output from the data logger:



Source: http://accdpa.org

Vertical Electrical Sounding (VES)

Electrical resistance is the most common principle of direct current method. Basic detected parameter is resistivity ρ [Ωm]. Resistivity of rocks depends on many factors. Among the most important belong mineralogical composition, porosity, water saturation, concentration of solutions filling the pores, structure and texture of the rock and the degree of weathering. During the measurement of the electric field are used electrodes to secure galvanic connection with the ground. Resistance methods use artificial electric fields that arise after installation of direct current "I" into the ground using current electrodes (designated with the letters A, B).

Potential "Δ U" is measured by the grounded (potencial) electrodes M, N. By using modified Ohm's law is determined apparent resistivity: ρz = k. Δ U / I, where "k" is a variable dependent on the geometry of the layout of the electrodes. The apparent resistivity corresponds to a total resistive state of environment to a certain depth and is influenced by the actual resistivity of the layers at a given depth interval.

Intervals between the possition of the electrodes determine the dimensions of the arrangement. Modification of the interval length change the depth reach. The larger dimension of the AB arrangement, the greater the depth range (Jančovič et al., 2014).

5.4 Water treatment

Engineering dealing with water supply is large, sophisticated and fastly growing field. But it was not always like that. Up until the second half of the twentieth century water supply was just a basic field following only elementary standards. Water was pumped mostly from reservoirs or wells with a good water quality. These sources were preferably protected, but it was not always possible to use any of these. Some supplies were taken from rivers where the quality of water was worse or fluctuating. Water from these kinds of sources needed to be treated before its further use. The most common cleansing method was to provide extensive storage prior to treatment, to allow self-cleansing processes. After that the sand filters were used in order to filter the water. Distribution systems were simple as well.

In the United Kingdom they generally pumped water to water towers and reservoirs and from there the water was gravitationally distributed. According to Binnie (2002) there was no flow measurement except for the treatment works and leakage rates was not a major concern because leakage rates could not be determined. Water quality requirement was simple, the water must be wholesome. The only monitored water quality standards were microbacteria. Universal chlorination of public drinking water was introduced after the Croydon typhoid outbreak in 1936 (Binnie, 1885).

Demands for sufficient clean water are expected to increase rapidly in the future years. Membrane technology provides sufficient solutions in the cleansing processes and treatment of groundwater, wastewater and saline water, such as required for environmental reasons, industry and in agriculture (Hoover, 2011).

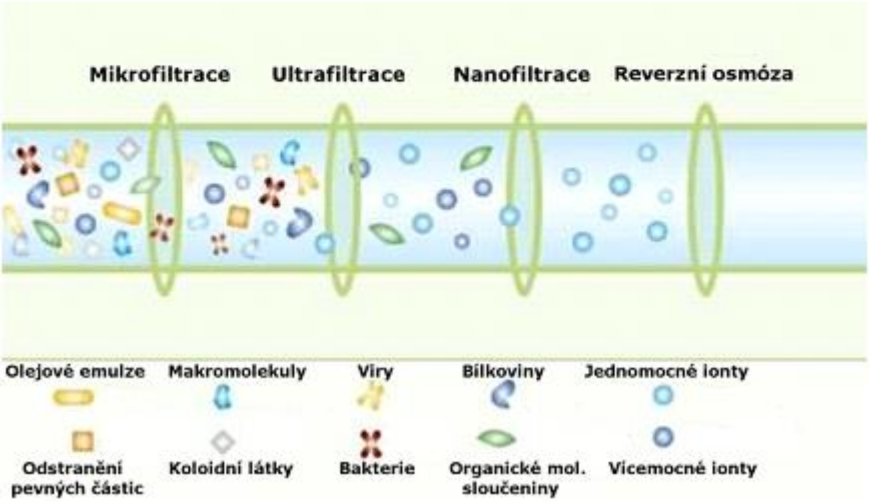
5.4.1 Pressure membrane processes

Pressure membrane processes usually refer to four types of separation techniques: microfiltration (MF), ultrafiltration (UF), nanofiltration (NF) and reverse osmosis (RO).

The common feature of these techniques is the use of semi-permeable membranes as the separation element and the pressure difference as the driving force of transport through the membrane. Mutual difference is in the amount of the pressure, properties of the membrane and prevailing transport mechanism. Pressure-driven membrane processes are used to concentrate or cleaning solutions and dispersions. The size of separated particles or molecules and chemical properties of the solvent are the determining factors for selecting a suitable type of membrane.

The driving force, i.e. pressure difference above and below the membrane causes molecule movement through the membrane, respectively low molecular compounds, while the larger molecules or particles are captured by the membrane. By proceeding from MF to UF to NF and to RO, the size of separated particles (or molecules) decreases and thus the pore size of the corresponding membranes must be smaller. This also means that membrane resistance is increasing to mass transfer and for securing the same intensity of permeate flow is necessary to increase the pressure. . Between the pressure membrane processes, however, there is no sharp boundary (www.czemp.cz, 2016). Principles of pressure membrane processes are shown in figure no. 6.

Figure no. 6 - Principles of MF, UF, NF and RO:



Source: www.czemp.cz

Table no. 3 – Translation of the scheme :

czech	**english**
olejové emulze	oil emulsions
makromolekuly	macromolecules
viry	viruses
bílkoviny	proteins
jednomocné ionty	monovalent ions
odstranění pevných částic	removing solids
koloidní látky	colloidal substances
bakterie	bacteria
organické mol. sloučeniny	organic mol. compounds
vícemocné ionty	multivalent ions

Information about basic pressure membrane processes are provided in the Appendix no. 4.

5.5 Silt Density Index (SDI)

SDI is a very important tool to evaluate water quality and its capability for further use. To be able to determine whether the water is acceptable or not can be crucial especially in big facilities. There are several parameters influencing membrane fouling: pH, conductivity, specific salts, turbidity, SDI, particles, TOC, UV absorbance, redox, chlorine, residual coagulant, algae counts and chlorophyll (Mosset et al., 2007). Silt Density Index (SDI) is a parameter that represents fouling tendency of water toward membranes. It is depending on the amount of micro particles and also on other specific fouling compounds. This test consists in filtration a liquid through a 0.45 μm membrane at a constant pressure (30 psi). SDI is then calculated according to the following calculation:

$$SDI_T = \frac{\%P_{30}}{T} = \frac{\left[1 - \frac{t_i}{t_f}\right] . 100}{T}$$

, where: $\%P_{30}$ = percent at 30 psi pressure, T = total elapsed flow time (usually 15 min), t_i = initial time required to collect 500 mL of sample s, and t_f = time required to collect a 500 mL of sample after test time T (Mosset et al., 2007).

Fouling potential is then described as *SDI 15min<5*. Disadvantage of this method is its sensitivity. The result can be influenced by operator´s techniques. According to Mosset et al. (2007), the main precautions should be followed during the SDI preparation:

• Equipment flushing

• Air purge (to avoid air going at the surface of the membrane)

• Membrane wetting (for a 100 % grip of membrane to the holder)

• Avoiding contact membrane/hands, especially outside of the joint’s place

6. Methodology

At the beginning of my work I was trying to collect all the available information and data. That is why I started writing with the description of the area. After understanding all the background of water management in TPCA, I went to France to see how they process rainwater. Additionally, I started to consult possible options with water treatment companies like Asio, s.r.o., BKG Úprava vody, s.r.o., WATERA CZECH, s.r.o., Dekonta, a.s., Milvit Water, s.r.o., Eurowater, s.r.o., Vodos, s.r.o. and G-servis Praha, s.r.o. I also made several business trips to many different cities like Valenciennes, Kouřim, Praha, Ústní nad Labem, Kolín and Kutná Hora.

In order to be able to propose any solutions, it was necessary to analyze water from various sources – retention basin, sedimentation basin and wastewater from TPCA. We also performed SDI test on the waste water leaving facility. For the groundwater project it was essential to work with available historical data (Czech Geological Service database) and old hydrogeological surveys and reports.

I gathered information from related articles and many professional websites. It is also important to mention that significant part of my work is based on personal discussions and meetings, which have enriched my work significantly. Process of this work was continuously discussed with my supervisor Mrs. Ing. Synáčková, CSc.

The outcomes of my work are proposals consisting of groundwater and rainwater projects. Moreover, economical balance is calculated in order to meet the condition of < 2.5 years payback time. I presented these projects according to the TPCA´s internal standards as an A3 reports. These reports are described in my thesis in detail and are provided with explanation and description of all related data.

7. Description of the area

7.1 Waste water

The discharged waste water from TPCA per year 2014 represented 144 817 m^3 of process water. All the discharged process water from many different sources of pollution comes to facility. Here, the incoming water is accumulated in reservoirs called operational tanks. If the expected inflow of water quality is poor, or it is weekend water, then the water is accumulated in so-called batch tanks. If a very dirty water that greatly exceeds the internal limits is coming to facility, then this water is stored in the manipulate water tank. Thus, highly polluted water is then treated by small portions in order to reduce limits to the desired threshold. The incoming waste water is divided into three groups: fluoride water (F), metal water (M) and oily water (O). Water M + O is not separated and is treated as a whole.

From operational tanks water is entering into the process, where chemicals are added: AniP, $Ca(OH)_2$, H_2SO_4, $Fe_2\ (SO_4)_3$, PAC and NaOH. Subsequently, water enters into sedimentation tanks where sludge is separated. This sludge then passes through the filter press where excess water is separated from solids. From the sedimentation tanks the purified water is overflowing into a mixing tank where F and M + O water is mixed and the resulting parametres are checked. If the limits are not met, it is possible to pump this water back and repeat the cleansing process. In case that the limits are met, water is collected in the very last discharging tank before leaving treatment plant and then is discharged from TPCA to a biological WWT.

As the greatest polluter of water can be considered paint shop, especially after cleaning the color tank walls. In the presence of large amount of highly polluted water the paint shop submits this information in advance to the facility in order to prepare for this water. Such heavily polluted water needs to be retained and gradually handled by smaller batches. Then, during the discharging is not violated any of the monitored parameters. Workers in facility are doing water abstraction and analyzes of wastewater two times per shift.

Sanitary water passes through the fat and oil separators and along with pre-treated process water goes separately to biological waste water treatment plant (biological WWT), where water is mixed and subsequently cleaned. Treated waste water from biological WWT flows into the retention tank, where is mixed with rain water. Furthermore, this water is drained by Sendražická stream and continues to the river Elbe.

7.2 Process of demiwater production

Raw water flows into the water storage tank with the volume of 436 m^3. Operating water level of this tank is defaultly set between 255 to 366 m^3. The system works in the way that if water level falls below the lower limit, raw water begins to fill up again to the upper operating level. Next to this storage tank stands the same identical tank, which collects produced demineralized water from RO. The paint shop is directly connected to this tank with demineralized water and water is pumped according to their needs. If the level in the tank with demineralised water falls below 255 m^3, RO turns on and sucks up water from the raw water tank in order to start the process of production of demineralized water. Water consumption is therefore batching, when 2 RO units are simultaneously working and each takes 45-50 m^3 / h of water. This is how RO is operating two or three times per shift. Although there are four unites available, only two of them are in use and the other two have a backup function. The RO was dimensioned for water quality stated in the Table no. 4.

Table no. 4 – Parametres of supplied raw water:

		units:
Ca hardness	100	mg/l
Mg hardness	10	mg/l
Total hardness	303	mg/l
pH	7.7	
Conductivity	687	$\mu S/cm^2$

Source: Internal data of TPCA

RO performance was designed to be possible to produce 111 m^3/h of demineralized water (2610 m^3/day) and the processing time was 24 h/day. Furthermore, the effectiveness of the RO should be at least 75%, which now after more than ten years is not true anymore (average effectiveness for 2014 was 68%). In order to maintain the greatest lifetime of the RO membranes and filters, it is necessary to treat the inlet water and follow the requirements for water quality:

Table no. 5 – Quality requirements of inlet water for RO:

		units:
Ca hardness	60	mg/l
Total hardness	100	mg/l
pH	6-8.8	mg/l
Conductivity	100	$\mu S/cm^2$
M-Alkalinity	60	mg/l
Insoluble compounds	200	mg/l
Cl	10	mg/l
SO_4	30	mg/l
SO_2	30	mg/l
Fe	0.3	mg/l
Mn	0.3	mg/l
Turbidity	2	NTU

Source: internal data of TPCA

These values are crucial for design of any water treatment technology prior to RO.

Before raw water enters to RO, water must be treated to ensure the best possible life time of the filters and membranes. That is ensured by the use of antiscalant, pH adjustment with sulfuric acid (H_2SO_4) and dechlorination with sodium sulfite (Na_2SO_3). Water goes through two sand pressure filters with the volume of 12 m^3, which are connected in parallel. The last step of this treating process is water filtration before entering the RO. Two cartridge filtres are connected in series with porosity of 20 microns and 5 microns. Although the conductivity requirement of demineralized water is up to 100 $\mu S/cm^2$, average value is usually around 33.6 $\mu S/cm^2$. The second RO unit is located on Paint shop, which (connected in series) is capable to produce demiwater with values up to 10 $\mu S/cm^2$. In the event of increased values of observed parametres in produced demineralized water, facility must immediately inform the Paint shop.

7.3 Toyota Motor Manufacturing France (TMMF)

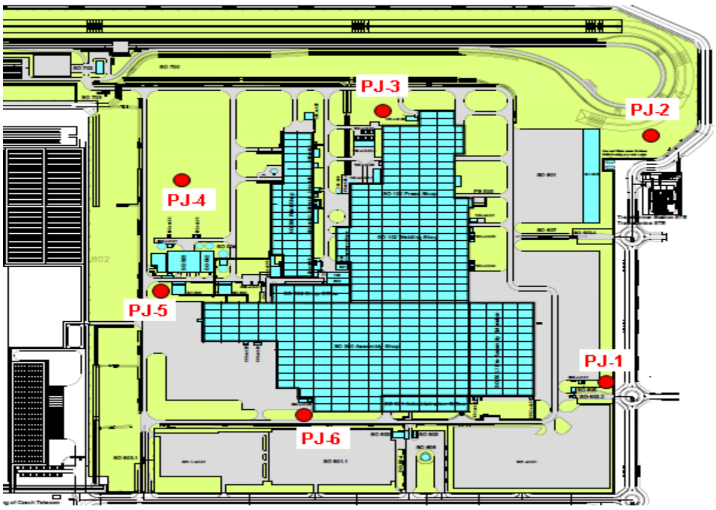
In June 2015 I took the opportunity to go on a business trip to French Toyota in Valenciennes. Within Production Working Group event representatives from TMMF presented water management process of their factory. Rainwater is collected in two ponds with volume of 6209 m^3 and 10 thousand m^3, where rainwater is drained by gravity force from a huge parking area of 280 000 m^2. The annual average precipitation is supposedly 723 mm. In general, we can say that the conditions for collecting rainwater in France are better, because of the larger collecting surface and higher annual precipitation. The tank labeled TK 13 is a mix of treated wastewater (with an average pH of 8), along with rain water (pH 8.5) at a ratio of 4 : 6. This ratio changes automatically in dependance of the quality of wastewater. Furthermore, in this tank is added a biocide (chlorine) and sulfuric acid to adjust the pH to the optimum values of 6 to 7. In TK 16 tank, as a flocculant is added aluminum sulphate $Al_2(SO_4)_3$. In order to ensure a good lifetime of the membranes, sodium bisulfite ($NaHSO_3$) is added to remove residual chlorine. On the whole, this water can be filtered through a sand filter and finally through a cartridge filter of 10 micron. The last step before the actual use for RO is a step called "remove T.H.TAC", which I unfortunately have not been able to understand to.

Before this business trip, I consulted the possibility of using rainwater as an alternative source of water for the RO with Eurowater Company. I was told that unless the input water quality is guaranteed, it is not possible to guarantee the quality of the output diluate and a good life time of membranes or filters. Simplicity of the principle in French Toyota where they use both waste and rain water astonished me, because according to Eurowater Company nothing like that should be even possible. According to local employees, they did not have any problems with either filters or membranes. They have already been using water from these sources for more than three years. We can say that although some circumstances may be different than in TPCA, in principle the volumes and parametres of water are similar.

7.4 Ground water

There are six monitoring wells in TPCA to monitor the quality of groundwater. Every five years is necessary to carry out water abstraction, but according to internal rules of Toyota, monitorings are done every year. The depth of the monitoring wells is in the range of 5 to 7 meters. Indicators to be checked are C10 - C40, benzene, toluene, xylene, COD-Cr, BOD5, TOC, pH, phosphate, nitrite, nickel, zinc, tin, lead and arsenic.

Figure no. 7 – Existing monitoring wells in the area of TPCA (PJ-1 to PJ-6) :



Source: Internal data of TPCA

From the groundwater usage point of view the monitoring wells do not have any predictive value, because they are too shallow and do not reach our considered layer. In 2008, TPCA ordered a hydrogeological report, carried out by Mr. Miloš Mikolanda, RNDr. from the company GEOLOGICKÁ SLUŽBA s.r.o.

7.5 Geological conditions

TPCA factory is located northwest of the village Ovčáry and directly over Kolín city. This flat territory was created during the Cretaceous Period and only a few ridges occur here, such as Na Kuklách or Horka. The average altitude in this area is 202 meters above sea level. Geological structure is made of a horizontally mounted stack of Czech Cretaceous basin, which is covered by Quaternary terraced sediments . The area's geological evolution belongs to the Kolín region, which is in the north closer to Elbe region. Thickness of the terrace sediments is reaching up to 2 meters in the western region and further to the north is decreasing to 0.1 to 0.3 meters. Sediments are composed of light brown to brown-grey sands of medium to coarse grain. Furthermore, they are made of gravel, or fine ingredients. Terrace sediments may also be covered with eolian deposits such as loess and sands. Pre-Quaternary base is made up of rocks from Mid-Turonian Age. In particular, there are deposited gray marls and brown-gray silty marls, locally with calcareous additives (Jizerské souvrství). In the zone of 3 to 7 meters below the surface the marls are strongly fractured with fissures. The intensity of fracturing decreases with the depth below the surface. Toward the surface the marls are then transferred into reddish-brown colour, with thickness of 1-2 meters. Turonian marls or mudstones were encountered with the archival borehole HJ-100 to the depth of 104 meters below the surface. In their baserock was discovered basal Cretaceous level - 28 meters thick Cenomanian horizon. The complex consists of Cenomanian strata and mostly fine grained, calcareous sandstones and sandy-silty claystone. Crystalline core in his basement is a complex made of Proterozoic gneisses, amphibolites and serpentinites. Towards the north of the TPCA complex (Na Kuklách, Horka) this area is undergone with major tectonic structure, system of “Železnohorský zlom”. Along this structure has been apparent a movement of rock blocks with a height difference of tens of meters (Mikolanda, 2008).

7.6 Hydrogeological conditions

On this site a total of three groundwater collectors can be recognised, its existence was proven by drilling surveys.

The collector of Quaternary sandy sediments:

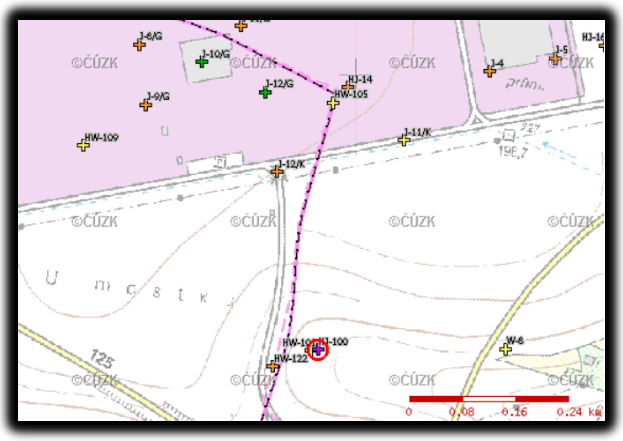
It occurs in only one part of the area and from the Cretaceous collector is separated by insulating marls and eluvially distributed marls. It is bound to sandy sediments terraced and eolian origin. The groundwater in the interstitial collector is with free surface, at a depth of about 0.8 to 1.6 meters below the ground surface. Thickness of saturated quaternary collector is 1 to 1.5 meters. Saturation outside sand collector is only temporary, dependent on the intensity of precipitation and in terms of solving this task its significance is minimal.

Collector of the surface zone of weathering and fracturing of marls:

This collector is located in the whole area of interest within the exploration drilling in the area of TPCA. This is a collector created by a fissure, with a slightly artesian groundwater level (especially in the northern part of the territory). The water level is pressured by an impermeable layer of eluvially distributed marls. Significant flow of groundwater can be expected in the not too abundant open fissures and fissure zones. Water yield of this collector was validated by hydrodynamic tests and was different depending on whether the test borehole was or was not encountered with saturated fissure structure. Coefficient of transmissivity was detected in two-row dissipation in the range of $6x10^{-4}$ to $2x10^{-6}$ $m^2.s^{-1}$, coefficients of filtering in the range of $1x10^{-4}$ to $3x10^{-7}$ $m^2.s^{-1}$. The most intense fracturing can be expected in a depth of 4 to 10 meters. With the increasing depths fracturing usually decreases.

Collector the Cenomanian horizon: The most significant water horizon at the site and is bound to Cenomanian sandstone bedrock. If the bedrock is bounded with kaolinitic sandstones with contact cement, they have excellent interstitial permeability. Water inputs to the Cenomanian structure are located mainly in the eastern edges of the field but also can be caused by interstitial water from the Turonian overlaying structure. The overlying impermeable marl pelvic structures are causing tension of the Cenomanian artesian aquifer. Cenomanian horizon was proven by archival exploratory borehole HJ-100 in year 1965 and was located south of today's complex of TPCA.

Figure no. 8 – Location of archival HJ-100 borehole (Czech Geological Service – Geofond, 2009):



Source: Česká Geologická Služba – Geofond, 2009

Stratigraphic interface Turon - Cenomanian was encountered in a depth of 104.4 meters. Negative discharge groundwater level was detected in a depth of 192 m.a.s.l. (approx. 8 meters below ground level) with the indicatively determined yields about 1 liter per second with water level decrease of 32 meters. According to Mikolanda (2008) this task has two solutions. One option is to create a drilling into the interstitial systems of Turonian layer or to the basal Cenomanian structure.

Turonian aquifer:

Is tied to the water-bearing fissures and fissure zones that have been identified by both: 1) zone of the surface disengagement (depth of 5-10 meters, with a water level 4-5 meters below the surface), and 2) by the HJ-100 in a depth of 62.5 -69.5 meters with upwards levels. Depending on the reachable fissure aquifer structures, depth of potential drilling would be within first tens of meters. Water yields in such resources can be expected at most about 0.2 to 0.3 liters per second. Water will be quite hard, of hardness carbonate type and with increased iron content.

Cenomanian aquifer:

We can expect even higher water yields, but the estimated depth of the pumping object (drilled artesian well) should be ca. 140 meters. We can assume that not only Cenomanian structures will be reached but also a partial breaks. Water yields can realistically be expected about 1 liter per second. Archival laboratory test results showed a very soft water, sodium bicarbonate- chloride type, with a pH of about 7.5 and with a source temperature of about 16° C.

7.7 Hydrodynamic Tests

Generally, hydrodynamic tests are used to determine the yield and quality of the underground source. It serves as a basis for determining the optimal and maximum amount of groundwater abstraction from the source. Hydrodynamic tests consist of two parts - pumping test and recovery test. Based on the output of hydrodynamic tests, it is possible to design the optimal method of pumping water.

Pumping test:

When the pumping is tested in a borehole (well), submersible pump is hanged down to a predetermined depth. From the well is pumped a constant amount of underground water at specified time intervals and decrease of water level in the pumped well is monitored. When there are other water sources like wells, boreholes, ponds, streams etc., they are usually measured too. These measurements are input data for mathematical calculation of the yield of water source. For water yield measurement is usually used calibrated meter and water is pumped into a calibrated measuring container. If the wells are constructed with the intent to use them as a source of drinking water, sampled water is taken for analysis to an accredited laboratory.

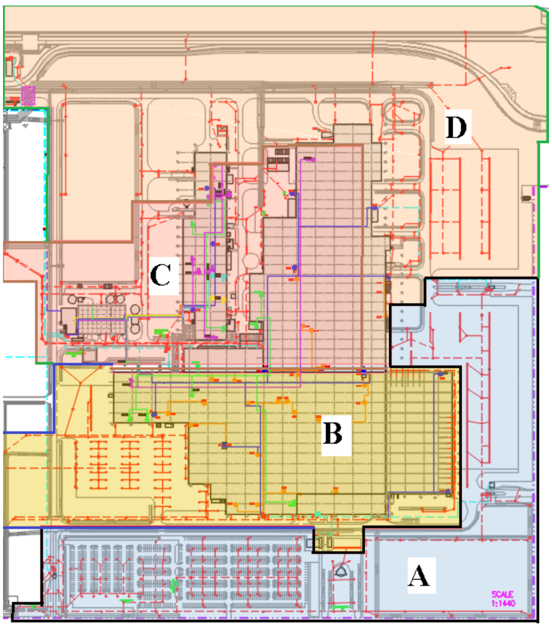
Recovery test:

Recovery test follows immediately after completion of pumping tests. After stopping the pump at regular intervals, recovery of the groundwater level is recorded. These measurements are then used for mathematical calculations of water yields. Measuring and recording of specific values (temperature, water level and amount of pumped water) is done manually or automatically by the manometer probe recorded into dataloggers. The outputs from the datalogger are individually measured values in a numerical form and a graphical representation from which is apparent a trend in the process of pumping.

7.8 Rainwater

The amount of water that falls on the area of TPCA in the form of precipitation is considerable. Only the roof areas occupy an area of about 120 000 m^2. Measured area of paved surfaces (parking spots, roads, sidewalks) occupies approximately 244 400 m^2. On the Figure no. 9 we can see rainwater drainage areas of TPCA: A, B, C and D - measured in AutoCAD:

Figure no. 9 – Rainwater zones:



A – 50 200 m^2

B – 57 500 m^2

C – 46 000 m^2

D – 90 700 m^2

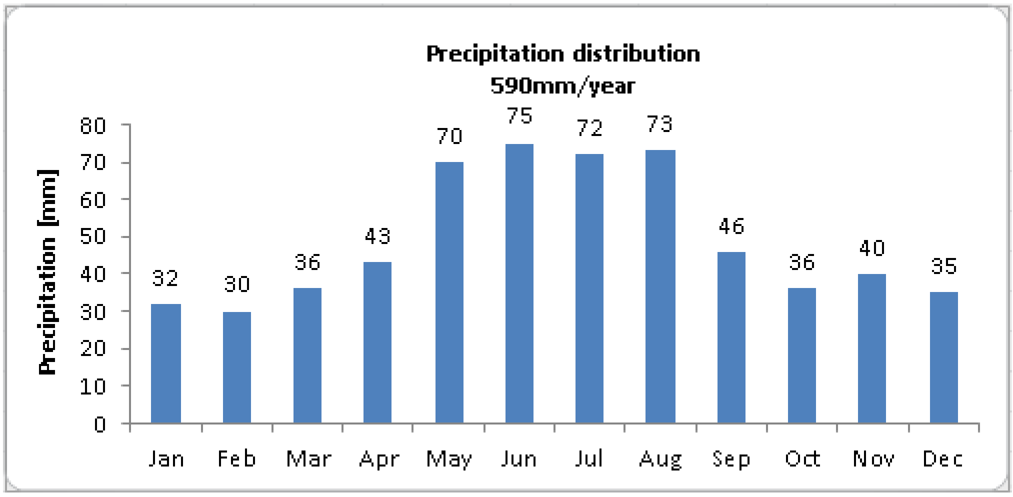
Comment: Most of the area D consists of grassland.

Source: Internal data of TPCA

Discharged rainwater from parking places goes through oil separators. Until now, all the outgoing rainwater from TPCA´s areal uselessly goes away to the sedimentation basin (ca. 1 km far away). Sedimentation basin and retention basin are connected with a special wall that is permeable due to holes and has also an overflow edge. In the retention water is mixing both rainwater and cleaned wastewater from BWWT. On the whole, this water leaves retention basin and continues as a brook called "Sendražická svodnice" to river Elbe.

The problem with the eventual collecting of water lies in the fact that the fallen rain water is drained by two open channels, which meet about 720 m far from the area of TPCA and conduct water into the sedimentation basin 1 km away. Therefore, in case that the pumping would not be used, it is necessary to determine the most appropriate place where it would be possible to accumulate water. Another problem is the ground level of the overflow channel, which is with its 197.86 m.a.s.l. more than two meters lower than eg. the ground level in the area of TPCA (200.22 m.a.s.l.) . For the theoretical rainwater use is therefore necessary to include pumping, since it is not possible to use only the gravity force. The advantage of rainwater use is minimum required pretreatment. From the table no. 10 is apparent the average distribution of rainfall during the year:

Figure no. 10 – Long-term precipitation standard from years 1961 – 1990:



Source: Czech Hydrometeorological Institute

Ministry of Agriculture Decree no. 428/2001 Coll., which implements Act no. 274/2001 Coll., about water supply and sewerage systems for public use (Act of Water Supply and Sewerage) Annex no. 16 provides formula for calculation of the amount of atmospheric water discharged into the sewer system:

Table no. 6 – Formula for calculation of the amount of atmospheric water:

Type of area	area [m^2]	runoff coefficient	reduced area [m^2]
A			
B			
C			
sum of reduced areas:			
Long-term precipitation standard*:……….mm/year, i.e. ……….m^2/year.			
The annual amount of discharged rainwater Q in m^3 = sum of reduced areas in m^2 times long-term precipitation standard* m / year.			

Source: Decree no. 428/2001 Coll. - Annex no.16

* Long-term precipitation standard is an average of a certain value (eg. annual rainfall) in a given location or area during a period of 30 years, current period of 30 years is between years 1961 and 1990. This value is then used for 30 years until 2020. This is the norm of World Meteorological Organization.

Runoff coefficient according to the types of surface:

a) Area A - hardly permeable surfaces, such as built-up areas, roofs with waterproof top layer of asphalt and concrete surfaces, tiles with grout joints, paving:
if discharged to the sewage system - runoff coefficient of 0.9.

b) Area B - permeable hard surfaces, e.g. gravel covered paved area, paving with the wider joints filled with material that allows infiltration:
if discharged to the sewage system - runoff coefficient of 0.4.

c) Area C - the areas covered by vegetation, grassed areas, e.g. parks, playgrounds, gardens, road from grass and infiltration blocks:
if discharged to the sewage system - runoff coefficient of 0.05.

In our case I will use this formula to calculate total annual amount of discharged water. Basically, TPCA consists only of types A and C. For this task it is necessary to perform additional accurate measurements in AutoCAD program. Total area of A type covers 156 475 m^2 and B type covers 71 000 m^2:

Table no. 7 – Calculation of the annual amount of discharged water:

Type of area	area [m^2]	runoff coefficient	reduced area [m^2]
A	173 400	0.9	156 060
B	-	-	-
C	71 000	0.05	3550
Sum of reduced areas [m^2] : 159 610			
Long-term precipitation standard*: 590mm/year, i.e. 0.59 m/year.			
The annual amount of discharged rainwater Q in m^3 = sum of reduced areas in m^2 times long-term precipitation standard* m / year.			

Source: Decree no. 428/2001 Coll. - Annex no.16

The annual amount of discharged rainwater Q = 94 170 m^3. This amount of water represents 43% of the annual TPCA´s water consumption worth of 3 098 193 CZK.

7.9 Recycling of wastewater

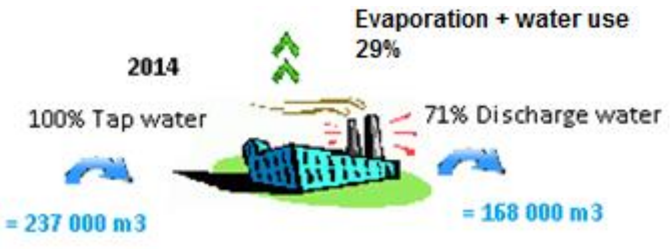
TPCA´s intention is to assess the possibility of recycling industrial waste water. The problem of this type of water is particularly its high value of biofouling that can not be reduced in TPCA. To recycle process water and utilize it for production of demineralized water is not possible.

If we want to consider the possibility of recycling of wastewater from TPCA, it would be necessary to use water from the retention basin. This water has already been processed in the BWWT and already has reduced parameters of organic pollution and subsequently is additionally mixed with rain water. Concentration of pollutants is thus significantly lower in comparison with waste water flowing out of TPCA. According to BKG Úprava vody s.r.o. company, it is possible to filter this water with UF and subsequently use this water as an input for RO.

8. Proposal

8.1 Problem

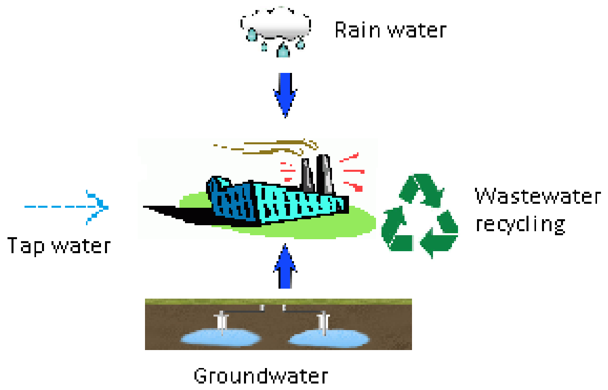
Figure no. 11 – Actual situation in TPCA:



Source: My personal production

As we can see on the picture, current condition is that TPCA factory is fully dependant on water supplier company Vodos.

Figure no. 12 – Alternative options:



Source: My personal production

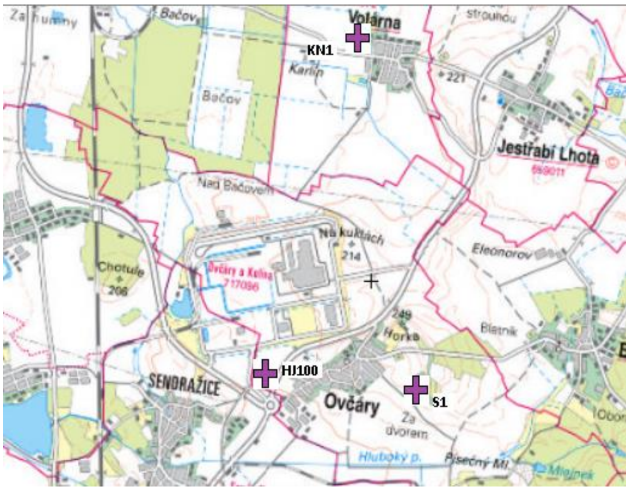
The TPCA´s intention is to evaluate any available sources of water that could partially supplement current drinkable water consumption.

8.2 Groundwater proposal

8.2.1 Background

First of all, I asked myself if there was any groundwater around TPCA that could be used. I wanted to analyse the situation and compare any available data. From the Czech Geological Service database it was clear that the only drillings around TPCA deeper than 100 meters were HJ100, S1 and KN1.

Figure no. 13 – Historical drillings HJ100, S1, KN1:

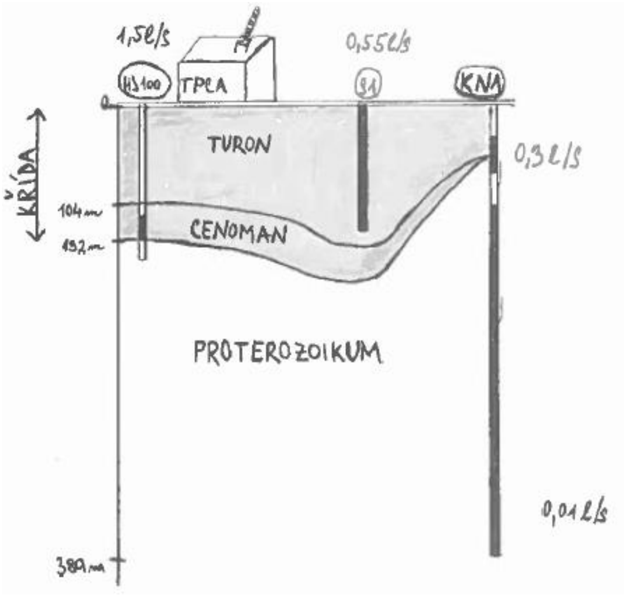


Source: www.geology.cz

<u>Historical drillings HJ100, S1 and KN1:</u>

HJ-100 from year 1965 declared 1.5 l/s from Cenomanian aquifer (130 meters), but neighbouring historical drills showed yields significantly smaller. Historical drilling named S1 (1962) showed yields 0.55 l/s from the depth of 120 meters. The problem was that unluckily they did not manage to reach the Cenomanian aquifer. We only can assume that if they had managed to reach Cenomanian aquifer the yields would have been much higher. As far as the KN1 drilling is concerned, record shows that bedrock under this location is unfavourable for the groundwater use, because aquiferous layer is in this case too shallow with only 0.3 l/s in 57 meters under the surface. On the figure no. 14 we can see a simplified theoretical scheme of the stratigraphical situation around TPCA.

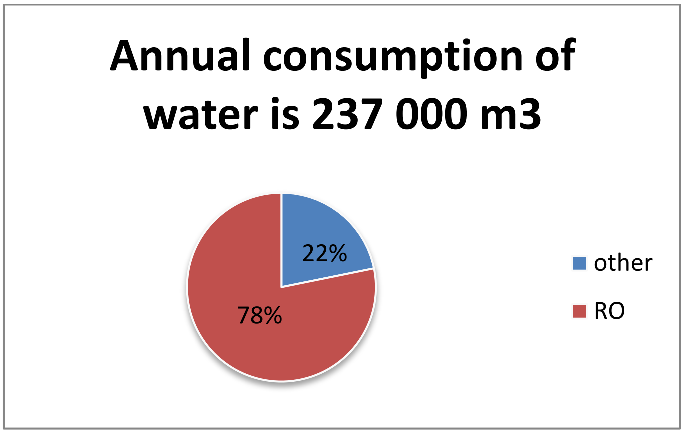
Figure no. 14 – Theoretical stratigraphical situation:



Source: My personal production

From this picture is obvious, that the geophysical survey is necessary to maximize water yields. Our goal is to reach the Cretaceous aquifer in its maximal width. Then I asked myself how could TPCA actually use this water. As we were not able to predict quality of the water in advance and we could not be sure that the water would meet the hygiene standarts for drinking purposes, I focused on the possibility to use this water for production purposes. The desired idea is to supplement input water for RO with the groundwater. Reverse osmosis is consuming majority of all the water used in TPCA as we can see on the figure number 15.

Figure no. 15 – Total water use in TPCA:



Source: My personal creation

8.2.2 Desired outcome

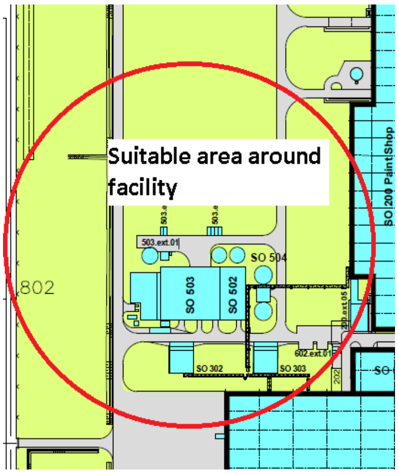
Goal of this project is a partial substitution of tap water by groundwater to produce demineralized water. Theoretical savings range between 8.5% and 25.5% of the total input volume of tap water for reverse osmosis. That depends on the actual yields. Partial substitution of the input water for RO would mean cost reduction of the demiwater production.

8.2.3 Groundwater project proposal

<u>Location</u>

Location to be determined, based on the geophysical survey. Then we will be able to choose the most suitable location and depth. Geophysical survey is also the very first item of the budget that needs to be approved. The price is 174 560 CZK and then TPCA can decide whether to continue with this project or not. The most suitable location for the drilling is around facility. I calculate with the maximum distance of 250 meters:

Figure no. 16 – Location of the drilling:



Source: My personal creation

Theoretical costs of the connection between facility and the drilling are 550 000 CZK in the worst scenario.

Construction:

This project meets the statutory standard ČSN 755115 „Jímání podz. vody". Technical parametres: Drilling diameter 430 mm up to 5 m; 381 mm up to 105 m and 254 mm up to 150 m - separation of Turonian and Cenomanian aquifer with steel layer and bentonite seal. The final seal is made of atested PVC which is environmentally friendly. Price for the technical work is 982 300 CZK.

Quality of water:

According to historical survey, mineralization of the ground water should be minimal. In the most optimistic scenario it will not be necessary to treat water before its usage for RO. However, water treatment technology is designed to be able to treat water with much worse quality (according to adjacent drillings). Projected price is 500 000 CZK and the operating costs are 47 304 CZK per year.

Documentation:

The final documentation is consisting of water use authorization, final report and construction project by authorized engineer. Furthermore, before the construction will be executed all the permits for water and building authorities.

Economic evaluation:

	Actual	Proposal
water rates	32.9 CZK/m^3 (year 2015)	3 CZK/m^3
operational costs	0 CZK	64 824 CZK/year
investition	**0** CZK	**2 330 000** CZK

Total costs of 31 536 m3 water:

	Actual	Proposal
	1 037 534 CZK	159 432 CZK

annual savings: 31 536 m^3..........878 102 CZK

payback time: **2.65 years**

Construction procedure of a borehole:

To ensure the most precise drilling and best water yields possible, it has been agreed with geological company that within the preparatory works will be carried out also a geophysical survey of the TPCA´s area using Shallow Seismic Refraction (SSR) and Vertical Electrical Sounding (VES).

By using these methods we will be able to verify with great precision deep embedding of the geological structures under the complex of TPCA. VES method serves for the most accurate of vertical deformation, which is an important element for assessing the appropriate location of the waterlogged zone. Prior to the initiation of drilling operations is needed to perform the survey to determine the most appropriate place.

The actual borehole will then have the following parameters: the drilling diameter of 430 mm to 5 meters, 381 mm to 105 meters and 254 mm to 150 meters. Separation of collectors will be ensured by using the protective steel isolation with diameter of 273 mm and in a depth ranging from 0 to 105 meters, sealed with bentonite. By using this method Turonian and Cenomanian structures will be safely separated. The final borehole reinforcement will be secured by using certified PVC with diameter of 165 mm and thickness of 7.5 mm. On the whole, the technical works will be ended with installing a pressure cell and establishing handling shaft at the wellhead.

Completion of the construction works will be followed by processing the permits for water use. Furthermore, examination of a long-term pumping test along with a recovery test for 24 days to monitor the behavior of the groundwater table by dataloggers.

Final acts of a project of building a borehole will be the final report about survey, including the expert opinion of person with competence and construction project of well will be approved by authorized engineer for water works. The last step then will be completion of the official permits and so-called "legalization of well" (approbation) (G-servis Praha, 2015).

After the pumping tests will be possible to say with certainty what is the amount of water yields. According to latter, further dimensation of the connection system will be done. Regarding water quality, it never can be assessed with certainty, because water analyzes need to be done after a borehole is constructed. However, expectations of water quality are based on assumptions according to archival records from the HJ-100 from 1965. Table no. 7 shows measured values of the archival borehole HJ-100 (Czech Geological Service - Geofond, 2015):

Table no. 8 – Water analysis of archival drilling HJ-100, 1965:

Chemický rozbor: 28.09.1965, Laboratoř: IGHP České Budějovice					
[mg/l]					
Na	258	Cl	87	COD-Mn	11.1
K	12	NO3	0.028	CO2 free	0
Mg	5.16	NO2	0	CO2 aggresive	0
Ca	8.58	HCO3	518.59	Total mineralization	740
NH4	1.05	SO4	20.98	Mn	0
Fe	0	CO3	36		

Source: Česká Geologická Služba – Geofond, 2015

8.2.4 Water treatment

According to G-servis Praha company, water softening process should not be complicated but the COD-Mn values showed relatively high organic pollution. Filters and RO membranes are very sensitive to water quality and increased content of organic pollution can significantly contribute to shortening of life of the membranes due to fouling (clogging of the membranes by different particles). However, according to expert opinion of Mr. Zdeněk Zýma, RNDr. and Mr. Martin Guth, RNDr. of company G-servis Praha it is unlikely that the water contains such high values of organic pollution. In their opinion, this is probably a mistake caused by misspelled transcription. The actual values will be detected after the laboratory tests. After that will be possible to propose the most appropriate water pre-treatment system before applying to the RO.

8.3 Rainwater

8.3.1 Background

Firstly, it is important to know how much rainwater gathers in the TPCA areal. To be able to determine rainwater volume, it is necessary to combine precipitation amount and total area according to its surface.

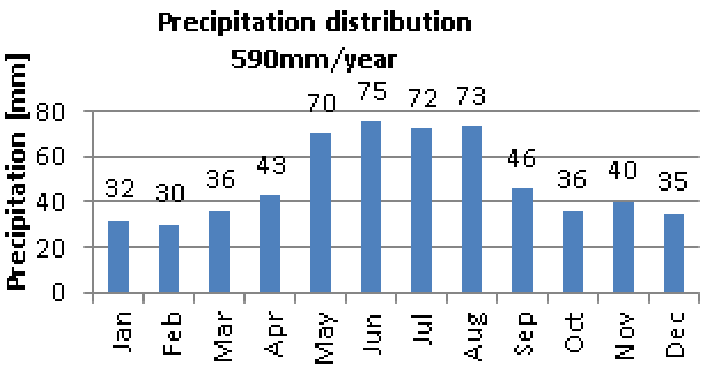
How much rainwater is available in TPCA:

From the CHMI portal we know that the annual precipitation amount is 590 mm. The problem might be during the occurrence of storm rainfall events. In those cases, either the basin or the dammed channel would not be able to catch all the water and part of it would uselessly go away.

Combination of the rainfall data (1) and the surface data (2):

1) Rainfall data:

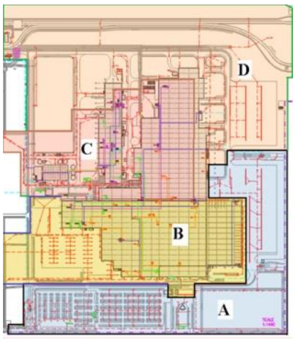
Figure no. 17 – Rainfall distribution throughout the year:



Source: Czech Hydrometeorological Institute

2) <u>Surface:</u>

Figure no. 18 – Rainwater zones A, B, C, D:



A – 50 200 m^2.........coeff. 0.9

B – 57 500 m^2.........coeff. 0.9

C – 46 000 m^2.........coeff. 0.9

D – 90 700 m^2 → 19 700 m^2...coeff. 0.9

→ 71 000 m^2...coeff. 0.05

Source: internal data

Roofs & build-up areas – 173 400 m^2 x 0.9 = 156 060 m^2.

Grassed areas - 71 000 m^2 x 0.05 = 3 550 m^2.

⇨ Total effective area: 159 610 m^2.

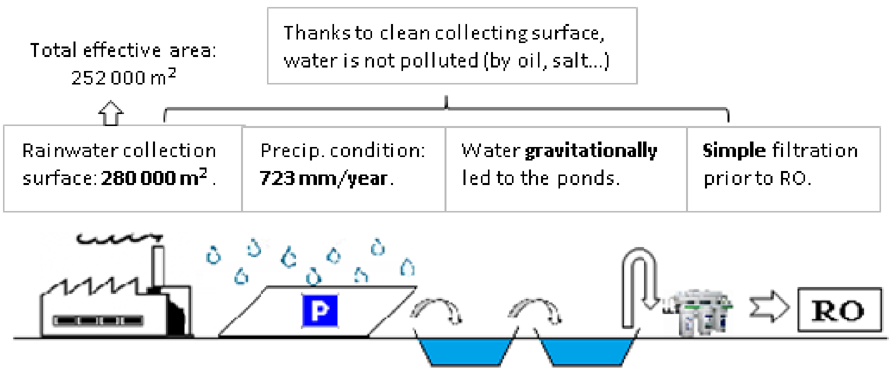
⇨ Total amount of discharged water: 159 610 m^2 x 0.59 = 94 170 m^3.

If TPCA would be able to collect at least 70% of rainwater, then the realistic amount of available water would be 65 919 m^3/y (worth of 2.17 million CZK).

8.3.2 Desired outcome

TPCA wants to use the potential of rainwater like e.g. in TMMF, where they collect rainwater and feed RO with it as we can see on a simple scheme:

Figure no. 18 – TMMF´s model of rainwater use:



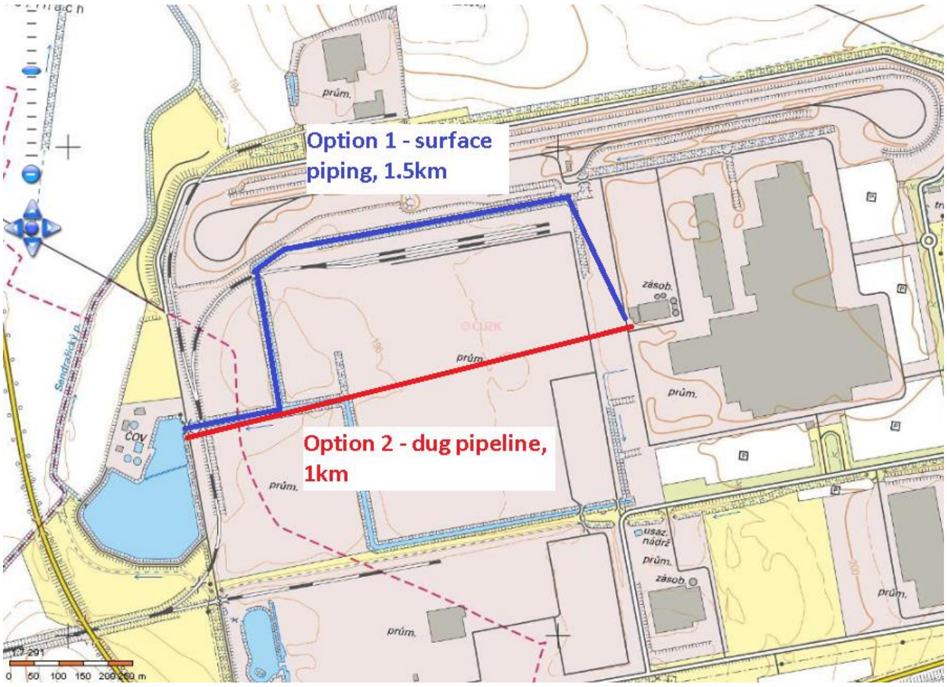
Source: My personal creation

The process does not necessarily need to be the same because the conditions are different.

8.3.3 Rainwater proposal

Potential use of rainwater seems like a viable option. The most feasible option seems to pump water from the already existing sedimentation basin for rainwater and pump it back to the TPCA as it is shown on a picture no. 19. Another advantage is that it eliminates the need of construction of the storage volume because it uses already existing sedimentation basin. On the other hand, there is a complication with pumping. Even though the pumping costs are low, this process could be used only at temperatures above zero degrees Celsius. An automatic sensor would have to be installed to stop the process of pumping if the temperature falls below zero. I case of dug pipe into the frost resistant depth the linear distance from facility to the basin is one kilometer. At a price of 2 200 CZK (According to TELSIG-servis, spol. s.r.o.) per meter the total costs would be minimally 2.2 million CZK.

Figure no. 19 – Pumping of rainwater from basin to TPCA:



Source: Map server Marushka

The biggest advantage of this option is that the rainwater is cleaner than water from retention basin and does not belong under the administration of Vodos company.

Water pre-treatment:

Part of the pre-treatment process in TPCA is the same like in TMMF (values of pH are regulated, water is dechlorated and goes through cartridge filters). The only missing parts of the process are:

1) Biocide use (chlorination)
2) Flocculant use – $Al_2(SO_4)_3$

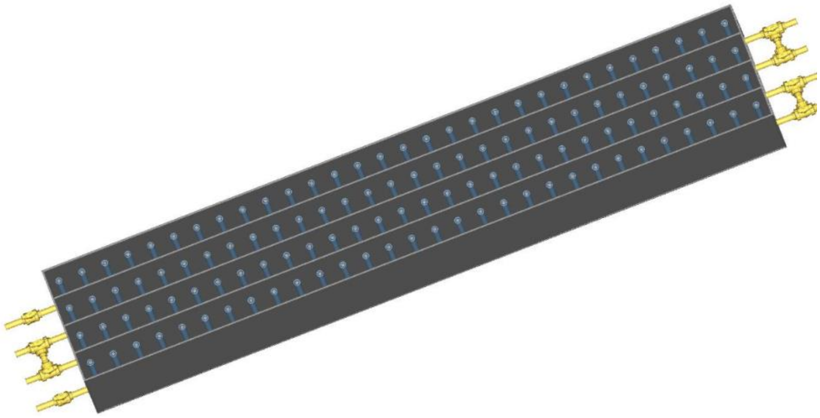
Total price for this treatment process remains unknown. Other important aspect is that quality of rainwater in TPCA is worse than in TMMF.

Eventually, after additional water analyzes from sedimentation basin and oil separators Dekonta company introduced possible technology of water purification based on H_2O_2/UVC process. Principle of this method is the decomposition of hydrogen peroxide induced by ultraviolet radiation in the UV-C with the wavelength of 254 nm. The generated OH radicals are very powerful oxidising agents that allow direct, highly efficient decomposition of a wide spectrum of organic compounds (polyaromatic hydrocarbons, chlorinated hydrocarbons, aniline, nitrobenzene, etc.).

The proposal works with the capacity of 7 m^3 of water per hour which represents the value 61 000 m^3 per year. The design will consist of 400 fluorescent tubes with 36 W of wattage each. That means the total power needed (pump included) would be 16 kWh. Annual energy consumption is considerably high – 280 320 CZK. Consumption of 30% H_2O_2 solution is estimated as 1 m^3 per 24 days at a price of 1 m^3 for 9 000 CZK. That gives us total annual costs for chemicals 136 875 CZK. In addition, charge for the use of surface water is unclear. According to Envigroup (2015) the average price for withdrawal 1 m3 of surface water is 4.64 CZK.

Payback time was calculated as 4.85 years, which does not meet the initial condition up to 2.5 years.

Figure no. 20 – Photochemical unit:



Source: Dekonta

Another option presented by BKG-Úprava vody company is supposedly capable of treating water from retention basin. That means water with much worse quality than just rainwater. Processing costs are based on energy and chemicals consumption. Power input is 15 kW and consumption of the chemicals is:

H2SO4 (40%)	53	kg/24h
PAC	10	kg/24h
HCl	2	kg/24h
NaOH	4	kg/24h
NaClO	1	kg/24h

If we use the same amount of rainwater as for the H_2O_2/UVC technology, we will get slightly better result from the economical balance.

Economic evaluation:

	Actual:		Proposal:
water rates	32.9 CZK/m^3		4.64 CZK/m^3
operational costs	0 CZK/year		122 065 CZK/y (energy,chemicals)
investition	0 CZK		**6 315 000 CZK**

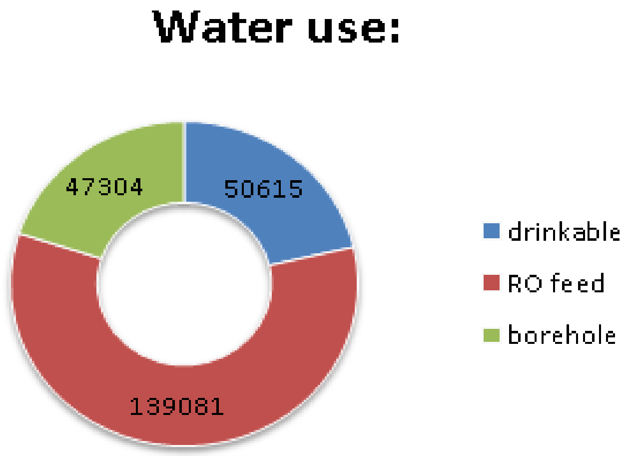
Total costs of 66 000 m3 water:

	2 171 400 CZK	vs	428 305 CZK
annual savings	1 560 698 CZK		
payback time	**4.05 years**		

Total investition includes: 3.5 million CZK for ultrafiltration technology, 2.2 million for pumping system, 115 000 CZK for pumping, 500 000 CZK for engineering. Moreover, the UF´s efficiency is calculated for the value 91.6%. Not even this technology meets the condition of payback time up to 2.5 years.

Since we are not able to decrease initial investment costs, the only option how to make this project economically feasible would be to increase the amount of available water. If we already calculate with better option of water yields from borehole and static drinkable water use, we receive the amount of water 139 081 m^3 that could still be supplemented with other sources, as is illustrated on the Figure no. 21.

Figure no. 21 – Water use [m^3/year]:



Source: My personal creation

Theoretically, if we cover all water demands for RO from water out of retention basin, we receive an excellent result:

<u>Proposal:</u>

investition: **6 315 000 CZK**

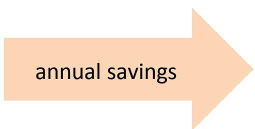
water rates 705 248 CZK

energy: 227 990 CZK

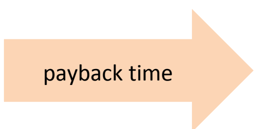
chemicals 53 116 CZK

<u>Total costs of 139 081 m^3 of water:</u>

4 580 535 CZK vs 986 354 CZK



3 594 168 CZK

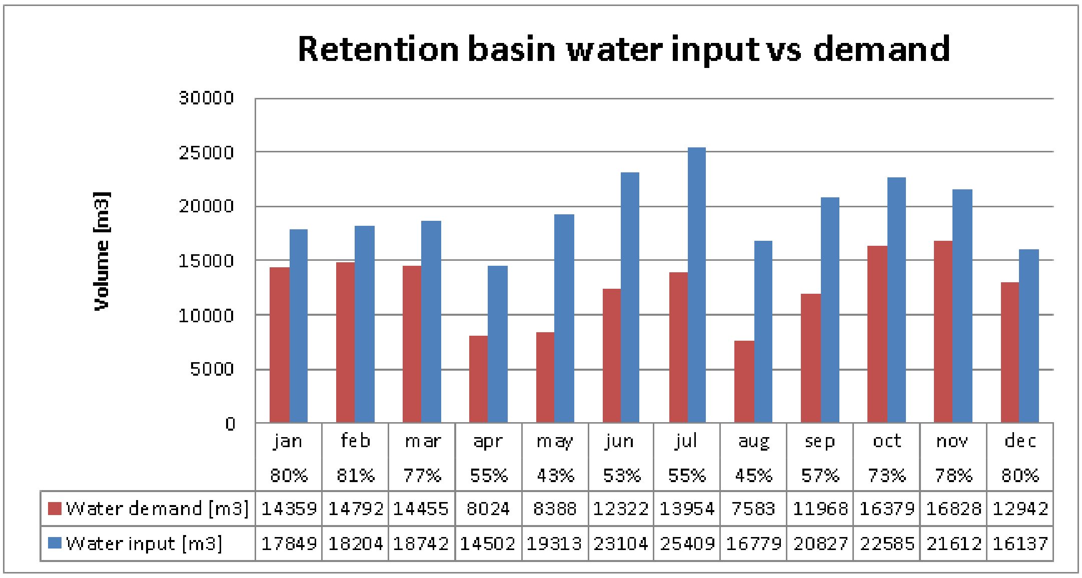


1.76 years

I am aware, that to fully supplement water demands for RO from retention basin might not be possible. I tried to compare water inputs to the retention basin with water demands for TPCA´s purposes. With the efficiency 91.6 % of UF, to be able to produce 139 081 m^3 of water for RO we need to take 151 993 m^3 of water.

On the figure no. 22 we can see the comparison and theoretical water balance of the basin:

Figure no. 22 – Retention basin water input vs demand:



Source: My personal creation

As we can see from the graph, it might not be possible to withdraw our desired amount of water during the whole year. I understand that it is necessary to maintain the minimal residual outflow or some other water management criterias for the basin. That is why we need to know water management statement of Vodos company.

To be able to meet the condition of 2.5 years of payback time, I calculated that the minimum amount of water for TPCA´s purposes is 107 000 m^3. If Vodos company gives the permission to use this amount, TPCA can initiate this project and start the process of implementation.

9. Discussion

Even though my proposal does not meet the condition of <2.5 years payback time, it still seems feasible. Total payback time is calculated from worse (overrated) option and I expect that the final payback time will be better than 2.65 years.

Rainwater project would be possible only if TPCA would be allowed to take more water than just 66 000 m^3. Next complication is that for the higher efficiency would be necessary to locate the ultrafiltration unit somewhere near the basin. This measure would ensure that only treated water would be pumped and could be directly used as an input for RO. Unfortunately, the unwillingness of Vodos company to cooperate can be expected.

During several months I had been trying to open a discussion about the alternative sources of water for TPCA factory with several leading employees from Vodos. Technical director of Vodos Mr. Ing. Nešpor has chosen a delaying tactics. To be honest, I cannot blame him. This project would work against their interests and probably would decrease their incomes. I had waited two months for an appointment and finally after promising of sending me required materials, he has never done that. Not even after several reminders from my side. Moreover, Mr. Ing. Tichý who was responsible for managing the operations of the biological wastewater treatment plant delayed my work significantly. Unfortunately, he was not able to answer most of my questions even though all the other employees were reffering to him. That is why I am not able to work with real numbers concerning reuse of water from retention basin. I did not receive any of the continuous analyzes, operating rules of the retention basin or even the information about the basin´s volume.

Theoretical values of the available water were easily calculated from available data of area and precipitation amount. It was quite surprising for me how the treating process for rainwater before the RO use could be difficult to design. I have been looking for the solution for many months without any satisfying result. There are many companies dealing with water treating processes in the Cezch Republic. But only several of them are able to work on a large industrial field. I have discussed this matter with companies Eurowater, Dekonta, Asio, BKG – Úprava vody and Watera Czech. Company BKG – Úprava vody presented the technology of ultrafiltration and this technology would supposedly be able to treat even the cleaned wastewater mixed with rainwater. Other proposals have never been presented.

On the whole, Dekonta Company has come with possible solution of the pre-treatment process based on photochemical oxidation using method H_2O_2/UVC. The question is if this technology is worth of applying because the initial costs are high and capacity is only 7 m^3 per hour. In comparison with ultrafiltration technology that is capable to process worse water quality with capacity of 20 m^3 per hour does not seem much feasible. Moreover, the UF technology would give the TPCA possibility to process even water from retention basin in case that they would be able to come to an agreement with Vodos company in future.

10. Conclusion

In the very beginning of my work on this project, I dedicated considerable amount of time to understanding the ongoing processes in TPCA. Technicians of facility took me under their wings and showed me what is going on in pre treatment section of input water for RO. They also showed me all the water cleansing processes and parametres they are monitoring on a daily basis. I also spent one whole day in the lab to see how the analyses work. Since the TPCA monitor only some selected indicators, it was not sure what does the pre-treated water leaving facility contain. In the Attachment no. 3 is analysis of wastewater from TPCA, which I had done retrospectively by laboratory ÚNS Laboratorní služby.

In addition, I was offered to go on a business trip to France. Within two days the French technicians described in detail their ongoing processes in facility and also showed me how the rainwater use and water recycling work. After the business trip I tried to consult this French solution with company Eurowater, provider and maintenance of TPCA´s RO, to see if it would be feasible to implement these methods here. Unfortunately, these discussions have been fruitless. Eurowater did not approve the French methods of water use and did not wish to participate on this project. On the other hand Mr. Ing. Heller agreed to perform SDI test on the TPCA´s discharge water from facility. Unfortunately it was not possible to finish this test correctly probably because the organic content was too high which made the filter impermeable after several seconds. From this moment I had proof that without an additional biological treatment process (like in TMMF) it is not possible to reuse the TPCA´s discharge water for other purposes.

In the meantime, I followed up on the hydrogeological survey carried out in 2008 by Mr. Miloš Mikolanda, RNDr., and discussed the project of construction of a borehole with him. The problem was that Mr. Mikolanda was dealing with the geological aspect only and did not deal with water quality. So I decided to contact company G-Servis Praha, which offered more comprehensive approach to this project. We discussed the potential risks and how to prevent it. On the whole, I was able to create final design for the construction of a borehole in cooperation with G-Servis Praha. Even though I was already done with the proposal at the end of November 2015, the approval process consisting of several presentations and defences took another three months to collect all the necessary signatures. I am really proud of myself, that I was able to bring this project to a successful end not only within my thesis, but also within the whole internal process in TPCA. My worries at the beginning of this work that the budget for the project will not be accepted proved wrong.

As far as the other alternative options are concerned, I was facing the problem how to treat the outgoing water from TPCA before its actual use. Since the analysis of the TPCA´s discharge water showed unfavorable results for any other use of this water, I tried to focus on water stored in retention and sedimentation basin. Thereafter I conducted another analyzes of this water.

Furthermore, I consulted these analyzes with Mr. Novák from BKG Úprava Vod s.r.o. company who presented their ultrafiltration technology. With this technology would supposedly be possible to use water from retention basin (rain + treated waste water) as an input for RO unit. I also contacted company Watera Czech with the same task to present a technology for the water treatment. Although we have conducted many meetings and discussed this matter thoroughly, they unfortunately never presented any solution.

As far as the rainwater project is concerned, I consulted this matter with Mrs. Ing Hnátková, Ph.D. from company Dekonta. Mr. Hnátková performed analysis of samples taken from oil separators. Location and some of the oil separators are stated in the Appendix no. 3. Mr. Hnátková suggested that there is a potential use of photooxidation unit to treat water with this quality before its use for RO. This technology should supposedly be even cheaper than the solution in TMMF. I mention this solution in my rainwater proposal where the H_2O_2/UVC technology would be used to treat the rainwater before its use for the RO. Since the economical feasibility proved this option unacceptable, I rejected this option and proceeded only with ultrafiltration technology.

The overall outcomes of this project are proposals of rainwater and groundwater projects with economical balance and its feasibility description. I am proud to say that I managed to finish the groundwater project. I was even able to collect all the necessary signatures from coordinators, general managers, vice president and president of TPCA, who approved the budget for 2.33 million CZK. Moreover, in the end of my internship in TPCA we were able to initiate negotiations with the Vodos company through the City of Kolín. After my presentation to the Head of the Department of Regional Development of Kolín City Mr. Ing. Martin Tichý, the Kolín City offered us their support and transferred our request for data to Vodos company. Even though my internship has already ended, I honestly believe that this project has a big potential to reduce drink water consumption of TPCA factory and I will stay in contact with my colleagues to help them realise this project.

Sources:

http://www.geology.cz/extranet, [online] - mapa vrtné prozkoumanosti (10/2015)

http://www.accdpa.org/wp-content/uploads/2014/04/Datalogger-Graph.jpg, [online]

- the output graph of the datalogger, 18.10.2015

http://www.sihaya.cz/vystupy_rft.html, [online]- popis metody SSR (Shallow Seismic Reflection), 18.10.2015

http://www.czemp.cz/cs/membranove-procesy/tlakove-membranove-procesy – Pressure membrane processes, CZEMP,[online],19.2.2016,

http://grey-is-green.com, [online]– scheme of greywater use, 26.12.2015

http://durkenergy.co.uk/img/rainwater_harvesting_system_diagram.png

- [online], rainwater harvesting scheme, 28.12.2015.

http://www.hallandbaum.com.au, [online] (30.12.2015).

http://www.geology.cz/,[online] - map outputs of the drilling survey

Kopáč, Jiří. G-servis Praha [online]. 18.1.2016, www.g-servis.cz/zajimavosti/jak-ma-vypadat-zdroj-podzemni-vody-pro-individualni-zasobovani-180.

Czech Hydrometeorological Institute, 20.1.2016, http://portal.chmi.cz/historicka-data/pocasi/uzemni-srazky#, Long-term precipitation standard for Central Bohemian Region.

Cadastre map portal, company Geomap – Marushka portal, 27.1.2016, Industrial zone in Ovčáry, http://sgi.nahlizenidokn.cuzk.cz/marushka/default.aspx?themeid=3

EnviGroup, [online], 14.11.2015, http://www.envigroup.cz/mzp-planuje-zdrazit-odbery-podzemni-vody.html

Literature:

ABDELKHALEQ RA, ALHAJ AHMED I.: Rainwater harvesting in ancient civilizations in Jordan. Water Science & Technology: Water Supply 2007;7(1):85–93.

BINNIE, A.R., Bradford Corporation Waterworks: prevention of waste of water. Report dated 1 October 1885, Bradford.

CARSON, R., HARCOURT, H. M., Silent Spring: New York, USA, 2002.

ČIHÁKOVÁ I., 2005: Očekávaný vývoj v zásobování a distribuci pitné vody v České republice, ČVUT v Praze.

COHEN, B., Urbanization in developing countries: Current trends, future projections, and key challenges for sustainability. Technol. Soc. 2006, 63–80.

GHAITIDAK, D. M.; YADAV, K.D., Characteristics and treatment of greywater - A review. Environ. Sci. Pollut. Res., 2013, 2795–2809.

GLEICK P. H., The changing water paradigm: a look at twenty-first century water resources development. Water International, 2000, 25(1):127–38.

HLAVÍNEK, P. & kol. (2007): Hospodaření s dešťovými vodami v urbanizovaném území. ARDEC s.r.o., Brno, 164 s.

HOOVER, L.A. ET AL., Forward with osmosis: emerging applications for greater sustainability, Environ. Sci. Technol., 45 (23) (2011), pp. 9824–9830.

IMHOF, B.; MUHLEMANN, J. Greywater Treatment on Household Level in Developing Countries - A State of the Art Review; Department of Environmental Sciences at the Swiss Federal Institute of Technology (ETH): Zurich, Switzerland, 2005.

JANČOVIČ L., DOSTÁL P., FRÝBOVÁ P., 2014, Geofyzikální metody měření V geotechnice, ISBN 978-80-214-4910-7, Brno.

JONES, M. P., HUNT W.F., Performance of rainwater harvesting systems in the southeastern United States, Resources, Conservation and Recycling 54 (2010), 623-629.

MAREŠ, S. ET AL.: Úvod do užité geofyziky, Praha: SNTL, 1979.

MIKOLANDA, M., Posouzení hydrogeologických poměrů v prostoru průmyslové zóny TPCA, Poděbrady, 2008.

MOSSET A. ET AL., The sensivity of SDI analysis: from RO feed water to raw water, (2007), ScienceDirect: Desalination 222 (2008), p. 17 -23.

WIBISONO, Y., CORNELISSEN, E., R., KEMPERMAN, A., J., B., ET AL., Two-phase flow in membrane processes: A technology with a future, Volume 453, 1 March 2014, Pages 566 – 602.

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Appendix no. 1 - Analysis of water from retention basin:

VÝSLEDKY ANALÝZ

OZNAČENÍ VZORKU	VÝTOK-potok		ČÍSLO VZORKU	36611
UKAZATEL	VÝSLEDEK	ROZŠÍŘENÁ NEJISTOTA	JEDNOTKA	POUŽITÁ METODA
TOC	20,7	±3,0	mg/l	SOP66(ČSN EN 1484)
zákal	16,0	±1,3	ZF(n)	SOP3(ČSN EN ISO 7027)
NL-105	29,0	±2,3	mg/l	SOP18(ČSN EN 872)
RL-105	931	±36	mg/l	SOP17(ČSN 75 7346)
RL-550	807	±31	mg/l	SOP17(ČSN 75 7346)
chloridy	160	±10	mg/l	SOP94(ČSN EN ISO 10304-1)
fluoridy	0,752	±0,070	mg/l	SOP94(ČSN EN ISO 10304-1)
dusičnany	10,2	±0,7	mg/l	SOP94(ČSN EN ISO 10304-1)
sírany	326	±25	mg/l	SOP94(ČSN EN ISO 10304-1)
baryum	0,033	±0,003	mg/l	SOP57(ČSN EN ISO 11885)
vápník	107	±12	mg/l	SOP57(ČSN EN ISO 11885)
tvrdost celková	3,15	±0,20	mmol/l	SOP57(ČSN EN ISO 11885)
železo	0,229	±0,026	mg/l	SOP57(ČSN EN ISO 11885)
draslík	68,2	±6,3	mg/l	SOP57(ČSN EN ISO 11885)
hořčík	11,7	±1,0	mg/l	SOP57(ČSN EN ISO 11885)
mangan	0,015	±0,001	mg/l	SOP57(ČSN EN ISO 11885)
sodík	102	±9	mg/l	SOP57(ČSN EN ISO 11885)
křemík	6,79	±0,68	mg/l	SOP57(ČSN EN ISO 11885)
SiO2	14,5	±1,5	mg/l	SOP57(ČSN EN ISO 11885)
stroncium	1,27	±0,10	mg/l	SOP57(ČSN EN ISO 11885)
BSK-5	6,4	±0,7	mg/l	SOP5(ČSN EN 1899-1,2)
CHSK-Mn	24,1	±2,0	mg/l	SOP7(ČSN EN ISO 8467)
konduktivita	134	±4	mS/m	SOP22(ČSN EN 27888)
pH	9,3	±0,1	bezrozm.	SOP21(ČSN ISO 10523)
amonné ionty	0,555	±0,028	mg/l	SOP23(ČSN ISO 7150-1)
CO2 volný	0		mg/l	SOP38(ČSN 75 7373)
hydrogenuhličitany	82,4	±6,9	mg/l	SOP38(ČSN 75 7373)

Source: External analysis performed by ÚNS - Laboratorní služby, s.r.o.

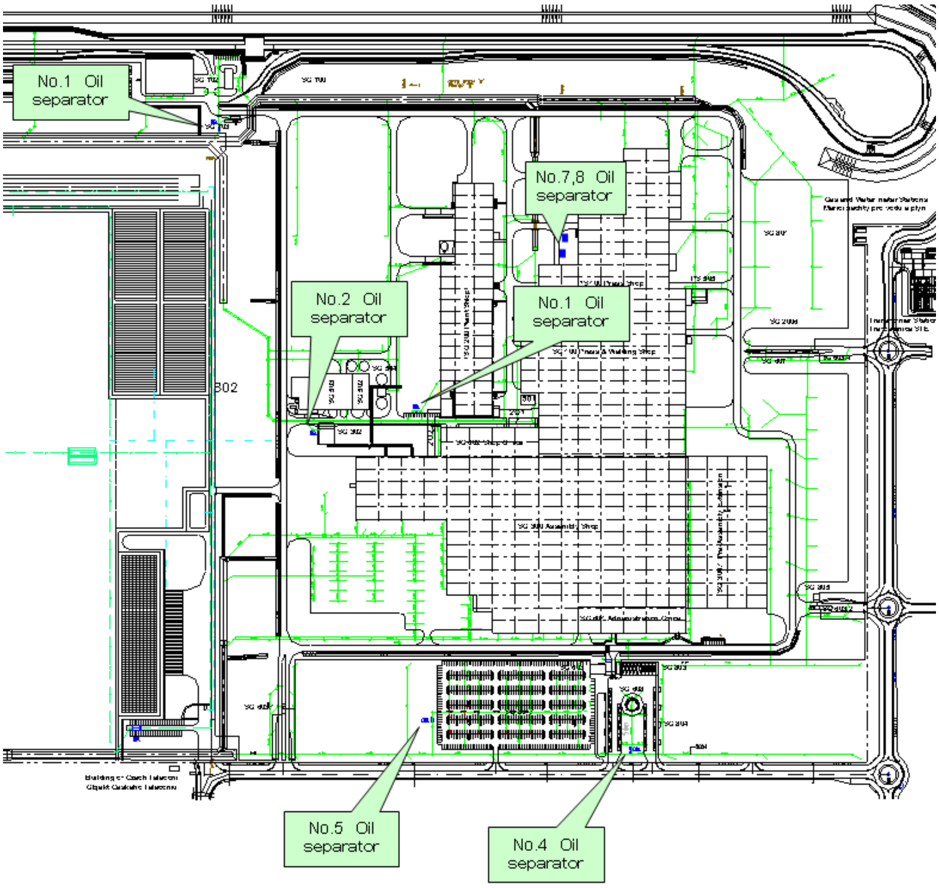
Appendix no. 2 - Analysis of water from sedimentation rainwater basin:

zkušební analytická laboratoř č. 1066 akreditovaná Českým institutem pro akreditaci, o.p.s.

OZNAČENÍ VZORKU	RET.USAZ-dešťová		ČÍSLO VZORKU	36612
UKAZATEL	VÝSLEDEK	ROZŠÍŘENÁ NEJISTOTA	JEDNOTKA	POUŽITÁ METODA
TOC	5,47	±0,80	mg/l	SOP66(ČSN EN 1484)
zákal	6,37	±0,50	ZF(n)	SOP3(ČSN EN ISO 7027)
NL-105	7,0	±0,6	mg/l	SOP18(ČSN EN 872)
RL-105	156	±6	mg/l	SOP17(ČSN 75 7346)
RL-550	111	±4	mg/l	SOP17(ČSN 75 7346)
chloridy	19,3	±1,2	mg/l	SOP94(ČSN EN ISO 10304-1)
fluoridy	0,056	±0,005	mg/l	SOP94(ČSN EN ISO 10304-1)
dusičnany	1,3	±0,1	mg/l	SOP94(ČSN EN ISO 10304-1)
sírany	20,2	±1,5	mg/l	SOP94(ČSN EN ISO 10304-1)
baryum	<0,030		mg/l	SOP57(ČSN EN ISO 11885)
vápník	13,4	±1,5	mg/l	SOP57(ČSN EN ISO 11885)
tvrdost celková	0,429	±0,027	mmol/l	SOP57(ČSN EN ISO 11885)
železo	0,500	±0,056	mg/l	SOP57(ČSN EN ISO 11885)
draslík	1,82	±0,17	mg/l	SOP57(ČSN EN ISO 11885)
hořčík	2,30	±0,20	mg/l	SOP57(ČSN EN ISO 11885)
mangan	0,015	±0,001	mg/l	SOP57(ČSN EN ISO 11885)
sodík	15,8	±1,4	mg/l	SOP57(ČSN EN ISO 11885)
křemík	2,38	±0,24	mg/l	SOP57(ČSN EN ISO 11885)
SiO2	5,10	±0,51	mg/l	SOP57(ČSN EN ISO 11885)
stroncium	0,261	±0,021	mg/l	SOP57(ČSN EN ISO 11885)
BSK-5	3,8	±0,4	mg/l	SOP5(ČSN EN 1899-1,2)
CHSK-Mn	4,41	±0,37	mg/l	SOP7(ČSN EN ISO 8467)
konduktivita	19,4	±0,6	mS/m	SOP22(ČSN EN 27888)
pH	7,8	±0,1	bezrozm.	SOP21(ČSN ISO 10523)
amonné ionty	<0,050		mg/l	SOP23(ČSN ISO 7150-1)
CO2 volný	4,8	±0,2	mg/l	SOP38(ČSN 75 7373)
hydrogenuhličitany	42,7	±3,6	mg/l	SOP38(ČSN 75 7373)

Source: External analysis performed by ÚNS - Laboratorní služby, s.r.o.

Appendix no. 3 – Location and analyzes of oil separators:



Source: TPCA internal data

Oil separators analyzes:

Sample	units	PM UV I/0	PM UV II/1	PM UV II/2	PM UV II/3	PM UV II/4
pH	-	7.68	7.71	7.68	7.72	7.77
conductivity	mS/m	65.5	105	106	106	106
COD $_{Cr}$	mg/l	20.2	< 12	< 12	< 12	< 12
Insoluble compounds	mg/l	< 2.0	< 2.0	< 2.0	< 2.0	< 2.0
Dissolved compounds	mg/l	445	762	762	735	750
Dissolved inorganic salts	mg/l	265	502	450	383	442
total alkalinity ($KNK_{4,5}$)	mmol/l	0.96	1.54	1.45	1.49	1.59

Source: Company Dekonta

Appendix no. 4 – Basic membrane filtration processes

Type:	Membranes:	Membrane thickness:	Size of pores:	Driving force:	Separation mechanism:	Membrane material:
Microfiltration	(a)symmetric porous	10 - 150 µm	0,1 - 10 µm	pressure difference (<4 bars)	sieve mechanism	polymer, ceramic
Usage: Removal of bacteria and yeast from beer, wine and milk; Cleaning and sterilization of fruit juices; Water treatment in the production of ultra pure water; Separation of fine crystals in the pharmaceutical industry; Thickening of oil from oil emulsions; Process prior to UF and RO.						
Ultrafiltration	asymmetric porous	150 µm	1 - 100 nm	pressure difference (1-10 bars)	sieve mechanism	polysulfone, polyacrylonitrile, ceramic
Usage: Processing of oil emulsions; Obtaining electrophoretic paint from rinsing water; Treatment of wastewater from the textile and paper industries; Thickening latex emulsions; Thickening of protein and whey processing; Hemodialysis; Prior to RO.						
Nanofiltration:	composite	150 µm + layer 1 µm	< 2 nm	pressure difference (10 - 25 bars)	diffusion	polyamides
Usage: Water softening; Elimination of nitrate ions from drinking water; Desalination products and intermediates in the chemical industry; Waste water from galvanic shops, textile and paper industries.						
Reverse osmosis	Asymmetric skin-type solution–diffusion membrane	150 µm + layer 1 µm	< 2 nm	pressure difference (15 - 80 bars)	solution and diffusion	cellulose acetates, polyamides
Usage: Desalination of sea and brackish water in the production of drinking water; Production of ultra pure water for the electronics and pharmaceutical industries; Wastewater Treatment of galvanic shops, textile and paper industry; Rinsing surgical and laboratory instruments prior to sterilization; Dialysis; Supply of high-pressure boilers.						

Source: Adapted from Wibisono (2014) and www.czemp.cz