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city on the wave

Assistance to the Development of the Mykolaiv Masterplan

Future Sustainable Raw Water Source

Note

Final

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List of Abbreviations

BOD	Biological oxygen demand
COD	Chemical oxygen demand
EIB	European Investment Bank
GFA	GFA Consulting Group
ICRC	International Committee of the Red Cross
MCA	Mykolaiv City Administration
MFA	Ministry of Foreign Affairs
MVK	Mykolaivvodokanal
PS	Pumping station
RO	Reverse osmosis
TA SP	Technical Assistance Support Provider
TEM	Transient electromagnetic
UMIP	Ukraine Municipal Infrastructure Programme
WTP	Water treatment plant
WWTP	Wastewater treatment plant

Summary

In addressing the critical need to fortify Mykolaiv's water supply, a comprehensive assessment of seven viable options has been conducted.

Option 1 proposes establishing a new water intake at the 40km mark of the Pivdennyi Buh River. While this option offers proximity to a water treatment plant, potential upstream wastewater discharge from Nova Odesa poses a risk.

Option 2 suggests a similar intake location but with water directed to the Zhovtneve Reservoir for purification and emergency reserves. This option adds redundancy and emergency supply capacity, but comes with increased infrastructure costs.

Option 3 proposes drawing water from the 51km mark of the Pivdennyi Buh River, offering high-quality water but at higher capital and operational costs.

Option 4 suggests a similar intake location on the right bank, providing a route around protected lands but requiring additional infrastructure for water supply.

Option 5 explores a new intake 5km upstream from Mykolaiv, utilizing reverse osmosis treatment for high-quality water. This option presents higher capital and operational costs due to the technology involved.

Option 6 advocates for the rehabilitation of the existing Dnipro River water intake, utilizing the established infrastructure but facing potential risks from its proximity to the war zone.

Option 7 underlines the rehabilitation of Zhovtneve Reserviour as the preferred solution to secure water provision in Mykolaiv.

It is imperative to emphasize that the first five options necessitate significant investments, estimated to be in the range of 240 to 410 million EUR. Meanwhile, the reconstruction and use of the existing water intake from the Dnipro River, as mentioned in Option 6, located in the Kherson Oblast, are subject to substantial risks due to military actions. Additionally, historical incidents demonstrate that this singular water intake can be vulnerable to destruction by missile attacks, as witnessed in 2022, leaving the half-million city entirely without a source of potable water.

Based on consultations with MVK and the extensive efforts undertaken by EGIS on water supply in Mykolaiv and considering the pronounced water supply challenges in the city stemming from persistent damage to the current water intake from the Dnipro River, specialists from COWI assert that the paramount objective is to fortify the city's water supply reliability. This objective can be realized by establishing a substantial reserve of drinking water in close proximity to the city, ensuring a supply during periods when the primary water source is unavailable or compromised. The identified reservoir for this purpose is the Zhovtneve Reservoir, rendering Option 7 the highest priority, warranting implementation as an initial step. However, it is imperative to note that the execution of this option, which involves the reconstruction of the reservoir, does not preclude the simultaneous or subsequent implementation of any of the other six remaining options.

1 Introduction

This note has been prepared within the framework of the project “Technical advice to the Danish Ministry of Foreign Affairs regarding Mykolaiv - Denmark partnership” financed by the Danish Ministry of Foreign Affairs (MFA). The project, which has been entrusted COWI, is a framework contract, which, among others, includes assistance to the Mykolaiv City Administration (MCA) in developing the Mykolaiv Masterplan in close cooperation with an Italian company, One Works. COWI has been entrusted the development of contributions to the masterplan regarding water, energy and solid waste. The masterplan concerns the Mykolaiv City and its development in the period till 2050 (throughout this note Mykolaiv City and Mykolaiv are used synonymously).

Unsurprisingly, the Mayor of Mykolaiv City Mr Oleksander Senkievych has demonstrated a keen interest in ensuring the long-term sustainability of water supply to the citizens of Mykolaiv City. In light of this, he has kindly requested COWI providing its recommendations on this critical matter.

The current note provides these requested recommendations taking into good account recent works and studies being carried out in this field by the Mykoliavvodokanal (MVK) and others.

The note provides a set of thoroughly analysed recommendations regarding the future sustainable raw water source of Mykolaiv City. The time horizon is 2050. However, it takes into consideration the present situation in the city and addresses the issue of water supply with a view to the present challenges and threats. The reason being that urgent is because action is needed, and that actions to be taken in the near future should fit into the city's development strategies for the future.

In order to ensure that recommendations provided actually take into account relevant works and studies caried out, COWI has had consultations with experts from the MVK and also he French consultancy company EGIS, acting as Technical Assistance Support Provider (TA SP) to Mykolaiv City under the Ukraine Municipal Infrastructure Program (UMIP), a program, which was launched in 2016 by the Ukrainian Government and the EIB. MVK has for many years been dealing with the water supply challenge in question. As for EGIS, it has since 2022 been conducting a project on raw water sources in Mykolaiv City and Oblast and options that have been identified by EGIS in the framework of the project. The work of GFA financed by ICRC that has launched its research mission in water sector in Mykolaiv, has been assessed as well. COWI also collaborated with the Danish utility company to perform the analysis of the available options of raw water sources.

The note consists of six sections, including the current introduction. Section 2 in brief highlights the background for request of Mr Oleksander Senkievych. Section 3 informs about data collected when preparing the note, paying particular attention to data provided by EGIS. Section 4 puts forward the options for the provision of safe water identified and defined. Section 5 presents the analysis of the options defined. Last, but not least, Section 6 presents the recommendations of COWI on what to do to obtain the long-term sustainability of water supply to the citizens of Mykolaiv City.

COWI would like to use this opportunity to thank, especially, the MVK for always being ready to make clarifications and for kindly providing information and data and all sorts of questions. Nevertheless, COWI and only COWI is responsible for for the recommendations made.

2 Background

The provision of safe water supply to the citizens of Mykolaiv has been on the agenda for many decades. Before independence Soviet engineers paid much attention to this due to the lack of raw water sources in required amounts and requested quality in the city and the oblast.

The Russian invasion has made the situation with safe water supply in the city catastrophic and highlighted the need to do whatever possible to ensure water security in future.

Since February 2022, Mykolaiv has been permanently challenged with the safe water supply sources in the city. The city is seeking for the sustainable raw water source solutions and in long run that can satisfy as the population as well as the industries. The following sequencies of the destruction happened in the water supply system in Mykolaiv caused by Russian invasion to Ukraine has boosted the necessity to search for the reliable water source or sources:

- On April 12, 2022, amidst hostilities in the Kherson Oblast, the village of Kiselyvka witnessed the destruction of the vital "Dnipro-Mykolaiv" water transmission main. This transmission main served as the sole source of drinking water for Mykolaiv City, home to approximately 300,000 residents at that time. Consequently, the city found itself teetering on the brink of a humanitarian crisis, as the centralized supply of drinking water became severely compromised.

- In response to this dire situation, the Mykolaiv City authorities, in conjunction with the municipal water utility company, MVK, made the decision to restore a centralized water supply system. However, the only available option at the time was to utilize technical brackish water from the Pivdennyi Buh River estuary. While this decision alleviated some of the most pressing sanitation concerns faced by the local population, it was not without its challenges and consequences.

- To address the immediate need for drinking water, a combination of temporary emergency measures was implemented. This included the importation of water, borehole drilling, and the deployment of mobile RO stations, with support generously provided by the Government of Denmark.

- Regrettably, these temporary emergency solutions have taken a toll on the integrity of the water supply and wastewater systems, as well as the surrounding environment. The adverse impact is primarily attributed to the elevated salt concentrations found in the groundwater and the Pivdennyi Buh River, particularly in the P. Buh estuary.

As a response to the emergent situation with water supply in Mykolaiv City, during the summer of 2022, the MVK sought assistance from the EIB to establish an alternative water supply source for the city. That request was prompted by the city's existing water intake location at Dnipro River in Kherson Oblast falling under Russian occupation, coupled with the damage to the transmission pipeline due to the ongoing conflict. The EIB responded positively to this request, and EGIS conducted a Multi-Criteria Analysis report as part of a feasibility study. That report aimed at evaluating the current situation, assessing raw water source availability, identifying potential alternative water supply options for the city, and performing a multi-criteria assessment of each option, ultimately recommending the most suitable solution. MVK began to explore various options for establishing a new water intake, including the potential utilization of underground sources.

However, by the end of 2022 the situation changed significantly. The previously occupied water intake area (Dnipro River water intake) in Kherson Oblast was liberated, making it feasible to resume water supply to Mykolaiv from this source. MVK promptly initiated the restoration of water supply from the existing Dnipro River water intake, which was successfully completed.

Nevertheless, as the conflict continued, the situation evolved. In June 2023, the Kakhosvka Dam was destroyed, leading to flooding in the Kherson water intake area (at Dnipro River water intake), including the water intake pumping station (PS0), first-lift pumping station (PS1) and pre-treatment facilities. As a result, the respective facilities are currently inoperable that has caused again a significant impact on water supply in Mykolaiv following the missile attacks on the water main in 2022. These challenges renewed the alerted need to consider searching for the long-term sustainable raw water source (or sources) in Mykolaiv to be applied after the war.

3 Data collected

To collect the data COWI reached out to the MVK and EGIS. In pursuit of identifying a sustainable, long-term water supply solution, and within the framework of the Ukraine Municipal Infrastructure Program (UMIP) financed by the European Investment Bank (EIB), MVK, in collaboration with EGIS, conducted in 2022-23 a comprehensive assessment of available ground and surface water sources within a radius of approximately 100 km from the Mykolaiv City.

The data has been collected and taken into very good account when developing this note.

The outcomes of the EGIS hydrological analysis yielded the following results:

In terms of water quality:

- The water from the Pivdennyi Buh River (at the 40km mark) generally meets standard requirements, with exceptions noted in chemical oxygen demand (COD) and biological oxygen demand (BOD). The existing WTP can maintain the required drinking water quality, contingent on adherence to prescribed filter load parameters and the utilization of effective oxidizers as specified in the technological regulations.

- Water from Inhul River exhibits several indicators that significantly exceed regulatory thresholds, including COD, BOD, hardness, dry residue, sulphates, magnesium and sodium. Ensuring its suitability for drinking purposes would necessitate either the overhaul of the water treatment process with the introduction of water demineralization facilities or the construction of a new water treatment plant.

- The Inhulets River, in accordance with key water quality indicators, can serve as an additional water supply source if the mining wastewater from the Svystunova mine is effectively treated. Furthermore, a significantly higher water quality can be achieved through a reverse flow effect when the Inhulets River is blended with Dniper River water by activating a sufficient number of pumping units at the irrigation system's pumping station.

- Despite the negative impact on water quality resulting from the destruction of the Kakhovska Reservoir in the summer of 2023, the Dnipro River presently aligns with standard requirements for a drinking water source. Recent water quality tests indicate a gradual improvement in water quality, rendering the Dnipro River a viable option for drinking water supply.

- The Pivdennyi Buh Estuary, as per the primary indicators, falls short of the criteria for a water supply source. However, its utilization becomes conceivable following the implementation of desalination measures, such as RO technology.

- Groundwater within the city's vicinity fails to meet the stringent criteria for drinking water, necessitating the installation of Reverse Osmosis systems at all city boreholes. There is one exception, a fresh groundwater source supplied by an alumina refinery, which boasts relatively high quality but lacks the total yield required to meet the city's water demands.

In terms of water quantity:

- The Pivdennyi Buh River (at the 40km mark) possesses the capacity to meet the water demands of Mykolaiv City.

- The Inhul River's water volume is inadequate to satisfy Mykolaiv City's water requirements.

- The Inhulets River can only be considered for seasonal water supply, as the operation of the irrigation system and open distribution channels is restricted to the warm season. This usage is contingent upon the treatment of mining wastewater from Svystunova village.

- The Dnipro River offers a substantial water supply quantity.

- The Buh Estuary also provides sufficient water volume.

- The currently explored reserves of fresh groundwater in the region fall short of serving as the primary water supply source. However, a more extensive exploration of underground water sources using modern technologies, such as airborne geophysical surveying incorporating transient electromagnetic, magnetic, and radiometric data, is warranted. The potential advantages of such additional exploration may include a significant reduction in the cost of securing an alternative source of fresh water.

4 Options defined

As mentioned in the previous sections, the options of raw water sources in Mykolaiv have been identified in the framework of UMIP by EGIS.

Before exploring the primary options for establishing a new surface water intake, it's essential to consider the inability to rely on underground water sources. In Mykolaiv Oblast.

The majority of groundwater operational reserves are situated within the Pivdennyi Buh River Basin, accounting for 79.6 thousand m3/day (77.37% of the total reserves in the entire Oblast). There are six sources (nine sections) of groundwater in Mykolaiv Oblast, located across various districts. Throughout the entire Mykolaiv Oblast, only 12 explored groundwater fields (with 16 sections) are suitable for centralized water supply to settlements and industrial use, making it one of the lowest figures among Ukrainian regions.

Within the city itself, the MVK possesses a total of another 12 explored groundwater fields. Out of these, permits for subsoil use and special water use are currently in place for 10 wells, while the necessary documentation is unavailable for the remaining 2 wells. In May 2022, 10 of these wells were successfully recommissioned, with a combined estimated flow rate of 18 thousand m3/day.

Furthermore, it is key highlighting that the projections for the water balance in the years 2033 and 2050 made by EGIS were formulated by taking into account various factors. These include status of the water supply facilities, development plans provided by the city administration, population growth forecasts, and statistical data from MVK. However, due to the uncertainties arising from ongoing military activities, which hinder the ability to make well-founded projections regarding the city's development and related urban planning.

As a result, in coordination with MVK, the EGIS has agreed on the following design horizons:

- Phase 1: Year 2033 (10 years from the Feasibility Study)
- Phase 2: Year 2050 (27 years from the Feasibility Study).

The designed water intake max. daily capacity to meet Mykolaiv city's needs has been estimated at 160,000 m3/day for the year 2033 and 230,000 m3/day for the year 2050.

Given these considerations, it becomes evident that the available underground water sources are insufficient to adequately supply the city with drinking water. Therefore, it is necessary to establish a long-term water supply strategy for the city that takes into account the current difficulties related to the partial or complete inability to fully utilize the existing water intake from the Dnipro River in the Kherson Oblast due to military actions and the risk of damage to the water pipeline or pumping station due to shelling, as has already occurred in 2022. This will require identifying a new water source and the construction of a new water intake.

As part of its assignment as TA SP, EGIS has prepared a Multi-Criteria Analysis Report where six main options are identified, five of which involve using water from the Pivdennyi Buh River with the construction of a new water intake, and sixth involve the reconstruction of an existing one. These options differ in the location of the water intake, and consequently, in water quality and the corresponding treatment technologies.

Option 1 - New water intake from Pivdennyi Buh River at the 40 km mark upstream from Mykolaiv, a bit downstream from Nova Odesa. The main drawback of this option is that the water intake is located downstream from the wastewater treatment facilities of the city of Nova Odesa. Therefore, there is a risk of water pollution from the untreated wastewater of the city. Consequently, the option includes the reconstruction of the existing drinking water treatment plant in Mykolaiv to include additional chemical treatment in case of uncontrolled upstream wastewater discharges. Estimated cost of the option is 240.7 million EUR (including 21 million EUR for rehabilitation of the existing WTP).

Options 1 and 2 suggest a new water intake at the 40 km mark from Mykolaiv, differing in water treatment methods, but both risk poorer water quality due to upstream sewage treatment facilities in Nova Odesa

Option 2 - New water intake at the same 40 km mark as for Option 1, but with water not being pumped directly to the treatment plant; instead, it is initially pumped into the Zhovtneve Reservoir. The reservoir will serve the dual purpose of purifying the water from biological contaminants and will play a crucial role as a reserve of fresh water for the city in case of emergencies, such as pipeline damage. Further distribution from the reservoir to the WTP would occur through an additional pumping station with an estimated cost of 254 million EUR (including 21 million EUR for rehabilitation of the existing WTP and 52 million EUR for rehabilitation of Zhovtneve Reservoir).

Option 3 - Supplying water from from Pivdennyi Buh River at the 51 km mark upstream from Mykolaiv, a bit upstream from Nova Odesa, to the existing water treatment facilities. This would allow for the acquisition of the highest quality and cleanest water. However, it would significantly increase capital costs for laying pipelines and operational costs for water pumping. Estimated cost of this option is 276 million EUR (including 21 million EUR for rehabilitation of the existing WTP).

Option 4 - Establishing a water intake at the very same 51 km mark as for Option 3, but on the right bank of the Pivdennyi Buh. The advantage of this option is that the water pipeline can be routed around protected lands, simplifying the permitting process. However, a duiker transition would need to be arranged for supplying water to the existing water treatment facilities, which increases the overall cost of this option to 294 million EUR (including 21 million EUR for rehabilitation of the existing WTP).

Options 3 and 4 suggest a new water intake at the 51 km mark from Mykolaiv, differing in routing. Both options provide good water quality but require significant investments due to the high distance from the city.

Option 5 - Establishing a new water intake 5 km upstream from Mykolaiv, followed by water treatment using Reverse Osmosis technology. The advantage of this option is the minimal length of pipelines and potentially the highest water quality delivered to residents. However, the downside of this option is the highest capital expenditure for purchasing reverse osmosis equipment and high operational costs. Reverse osmosis stations require a significant amount of electricity for water purification, making this option the most vulnerable in terms of system reliability under conditions of constant stress on the power infrastructure. This option is estimated to cost 411 million EUR (including construction of a new WTP).

Option 6 - Rehabilitation of the existing Dnipro River water intake. This option stands out as the most suitable when considering various project aspects, such as technical, financial, and environmental factors. However, it's important to underline that this option faces a significant drawback: its proximity to the current war zone poses a potential threat to the sustainability of the

water supply process. The estimated cost of this option, which involves restoring the Dnipro inlet and pumping stations and utilizing the fully functional pipeline to supply the water treatment plant, amounts to 25 million EUR.

Despite the extensive work and analysed data, none of the options was selected as the primary choice for several reasons. Firstly, none of the new sources significantly increase the reliability of water supply since they remain vulnerable to missile attacks. Secondly, five out of six options require a substantial amount of investment, which neither the city nor MVK can afford. Additionally, options involving costly additional treatment, such as options 1 or 5, would lead to a significant tariff increase, negatively impacting the population.

Taking these factors into account, specialists from COWI, in collaboration with EGIS and MVK, have proposed a new option that would significantly enhance the city's water supply reliability – **the reconstruction of the Zhovtneve Reservoir.**

Option 7– Reconstruction of Zhovtneve Reservoir, located 2 km south of Mykolaiv City; currently, not in operation. Despite the fact that the reconstruction of the reservoir, which had been out of operation since 2007, doesn't essentially provide a new water source for the city, it excels in fulfilling the primary goal – ensuring a stable city water supply. This is made possible by its useful capacity of 26.8 million cubic meters, which should suffice for six months of regular city water supply even without imposing any constraints.

The reconstruction of the Zhovtneve Reservoir is of paramount importance as it not only enhances the city's water supply resilience but also provides a potential additional water source, offering a much-needed safeguard against water supply disruptions and the use of saltwater as an alternative.

Moreover, the reconstruction cost of the reservoir is estimated at 52 million EUR, making it the most attractive option among all, considering the advantages it offers.

An additional advantage is that the reservoir can be filled from any currently available source, whether it's the existing Dnipro River water intake or a new intake constructed as part of options one through four.

In the event that the Dnipro River water intake is non-operational, the reservoir can be filled from the existing and functional Inhulets Irrigation System, as it did when the reservoir was active.

Given the current uncertainty regarding the status of the Dnipro River water intake and its usability due to ongoing military actions, along with the fact that the construction of a new intake from the Pivdenyy Buh River is both time-consuming and prohibitively expensive for the city, the situation appears such that the reconstruction and commissioning of the reservoir is the fastest and most cost-effective way to ensure the city's stable water supply.

Furthermore, the reservoir also provides additional water purification, especially from biological contaminants, which is particularly relevant in the case of establishing a new intake at the 41-km of the Pivdenny Buh River or sourcing from the Inhulets Irrigation System.

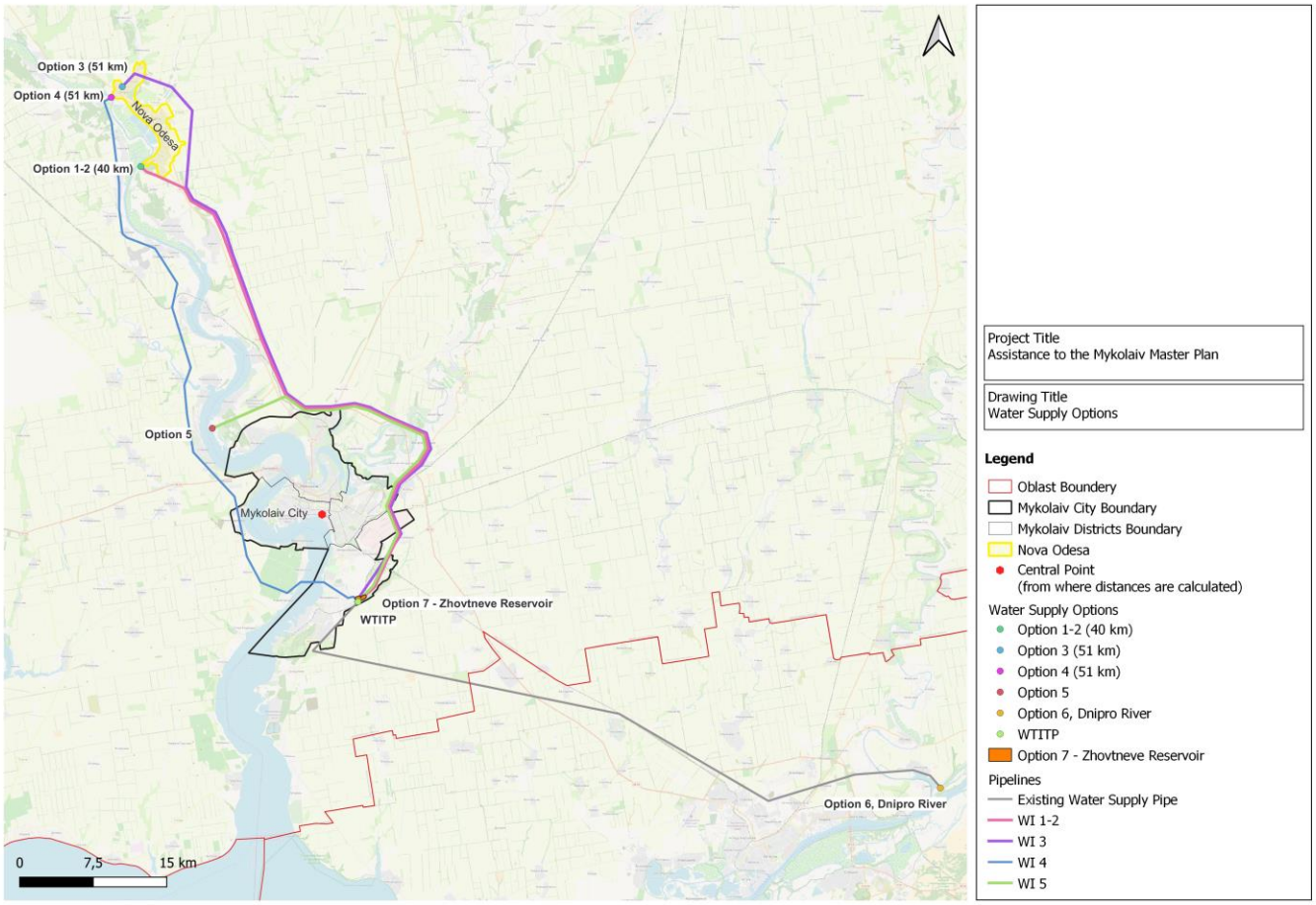
It's worth noting that the implementation of Option 7 does not preclude the implementation of any of the other six remaining options, whether it's the development of a new intake or the reconstruction of an existing one.

While this option has its challenges due to the seasonal nature of the irrigation system, which remains inactive during winter months and receives pollution in spring from mine water and industrial discharge, resulting in compromised water quality until late spring, it's essential to note that during peak operation of the pumping station, its production rate exceeds the Inhulets River's flow. This causes the downstream river to reverse, enabling a blend of water from both the Dnipro

and Inhulets rivers to enter the Zhovtneve Reservoir. This mixing positively influences water quality, as Dnipro River water is considerably cleaner than that from the Inhulets River.

The described options are presented at the map below.

Feature 4-1 Map of the available options of raw water sources in Mykolaiv



5 Analysis of options

In the previous chapter, a total of seven options were presented, including one further option identified and defined compared to the six options identified by EGIS. All the options are for the provision of water to Mykolaiv. In this section, these seven options are analysed. This analysis and, not least, comparison of these paves the ground for the recommendations provided in Section 6.

Estimates for demand and capacity for water abstraction have been provided by the MVK. These seem very high, even higher than the figures given in the EGIS analysis, which also reflect quite high demands in comparison with EU Member States in Central Europe, such as Poland. However, since this analysis options defined addresses the pros and cons between different options, the high demands will not affect the comparison seriously. That is, the comparison will result in same findings as for lower water demands. This, because all options identified and defined except for Option 7 are based on a possible provision of water from one source location. With regard to Option 7 it is envisioned that a second supplementary provision could be from a reactivated Zhovtneve Reservoir. The reservoir could be fed from either the Dnipro River water intake, Inhultes River or from one of the intakes along the Pivdennyi Buh River.

The options involve new intakes at three different locations, all at the Pivdennyi Buh River, at 5, 40 and 51 km upstream from Mykolaiv. They all present different challenges regarding water quality, treatment requirements, pipeline trace and consequently economy. Two existing intakes are also proposed which seems more economically friendly alternatives, these do however have other challenges.

Key issues assessed when analyzing the options defined and major findings are presented below.

Water quantity and location challenges:

- The intake at 5 km upstream has a water quality that would demand a new WTP with advanced technologies and a greatly increased OPEX. It might also possess a risk for further urbanisation near the intake bring water quality at risk.

- The intake at 40 km is downstream or inside the city of Nova Odessa. This is a smaller city, the pollution risk might be small, but further there can be issues regarding access to land. These issues make it slightly less attractive than the 51 km mark intake.

- The intake at 51 km is upstream from Nova Odessa and there is no other large settlements upstream from intake.

- Intake from Dnipro through the existing Kherson main. Giving the fact that the water quality in Dnipro is improving and can be considered for drinking water, it becomes a significant option in this supply scheme. Also, as a huge part of infrastructure already are established the CAPEX will be significantly reduced. But it’s proximity the warzone can possess a potential risk to the state of the water quality and installations when the war is over.

- Intake from the Inhulets river through the irrigation system, possesses many challenges concerning the transportation through the open channels, local pollution from industries, and the potential risk of freezing over during winter. However, the installation is present and fully operation.

Water quality and treatment:

- For options with intake at the 40/51 km mark. The water quality is good, only elevated levels of COD and BOD. This is traditionally treated with coagulants (alum) and is assumed to be part of the existing WTP. However, intake at the 40 km mark is located downstream from the Nova Odessa and there is a risk of pollution by wastewater. Treatment at the intake to address this risk is included in option 1, in option 2 this risk is ignored. The water quality of the Dnipro is increasing and is assumed suitable for further treatment at the WTP. Water from the Inhulets mixed with Dnipro will also have a sufficient quality, however the risk of contamination in the open channels, needs to be considered. Dilution at settling in the reservoir can contribute to a better water quality, for all options, but especially for the supply by the irrigation channels.

Pipes and Zhovtneve Reservoir:

- It is assumed, that all transmission pipes are double to obtain redundancy. For option 1-3 the pipeline trace is the same and on the left side of the bank. Option 4 is on the right side of the river. Option 5 will have a shorter pipeline in the same trace as 1-3. The pipeline traces on both sides will have to pass elevations of approximately 70 meters, hence the energy consumption for pumps will be similar for option 3-4. The left bank trace opens up for connecting pipes from other of the possible sources, Inhult, Inhulets and boreholes. For option 1-2 the transmission pipe is shorter and therefore a slightly reduced energy consumption. For options including the reservoir, where there will be additional pumping to the WTP, this estimated to increase energy cost with approximately 10 %. If the reservoir is used, it is recommended to make a by-pass to the WTP for direct emergency supply.

- Reestablishment of the reservoir will greatly increase the overall robustness of the water provision. The reservoir will effectively be working as a buffer for peak-periods or during maintenance or breakdown at the inlets. The buffering capacity will also ensure that the inlet-pumps can operate at a ~fixed flowrate, operating at the highest possible point of efficiency. Furthermore, the reservoir will participate in settling of solids and dilute eventual pollutants. Concerning future supply sources, other sources of water can be led to the reservoir in combination with the proposed options. Using groundwater will most likely be attractive, both in the perspective of CAPEX and OPEX. But using ground water can only be as a supplement to other resources, however it can highly increase the robustness of the water provision.

CAPEX

- There is no realistic chance for estimating the cost of the different options, they all seem high though. In the ranking, the cheapest and plus 10 % is given score 1, plus 20 % score 2 and above that score 3.

OPEX:

- The following parameters affect the OPEX: Treatment cost for traditional surface water treatment plant, (Options 1-4 and 6), treatment for extra difficult water as wastewater discharge, (option 2), membrane filtration, (Option 5), pumping of water from intake, which will be a significant amount, increasing with distance, see also comments under “pipes” and extra pumping if pumping to and from the reservoir. But being able to address fluctuations in consumption in a reservoir can reduce the pumping expenses in certain periods. It is not known to us, if clean water reservoirs at the WTP is available and with a sufficient volume to address this situation.

- Using membrane solutions has high OPEX. If RO this requires high expenses for pumping, a significant water loss in the form of brine, (20-30%), replacement of membranes approximately every 7 years. Nano filtration implies at least half pumping expenses and water loss compared to RO. But it cannot be used for water quality in Option 5. Can maybe be used for water from Inhultes or Ihult intakes.

Robustness of water provision:

- The most important aspect of securing robustness in water provision is to have access to more than one water resource. Having a reservoir is important to securing a reserve quantity. Important is also, to be able to address or avoid changes in water quality due to, for instance, industrial activities. The passage of pipes over the Buh River from the right bank, flexibility.

Results of the analysis are summarized in Table 5-1 below.

Table 5-1 Options identified, Result analysis (1 is the best, 3 is the worst)[1]

	Water quantity and location challenges	Water quality and treatment	Pipes and reservoir	CAPEX	OPEX	Robustness of water provision
Option 1	2	2	2	1	1	2
Option 2	2	2	1	1	2	1
Option 3	1	1	2	2	2	2
Option 4	1	1	2	2	2	2
Option 5	2	3	1	3	3	3
Option 6	2	1	1	1	2	2
Option 7	1	1	1	1	1	1

Note: 1) The following should be noted:

- Water quantity and location challenges: Score 1 - all options can provide the required quantity.
- There are only small differences between the scores 1 and 2 due to location challenges.
- Water quality and treatment: Only small differences for Options 1- 4. Option 5 needs extensive treatment and Options 6 and 7 comprise of water from Dnipro, which appears to be one of the best available qualities in the region.
- Pipes and reservoir: Very little difference between Options 1, 3 and 4. Option 2 is the most attractive, because of the inclusion of the reservoir. Option 5 with the short pipe and Option 6 and 7 have existing transportations possibilities available.

The following remarks are n place in connection with the above table:

- CAPEX
  - This is difficult to evaluate on the given background. Option 5 is though the least attractive, Options 1-4 are all close and score 2 cannot be disqualifying, option 6 and 7 have the lowest CAPEX.
- OPEX
  - Covers, energy to pumping, treatment and replacement of significant element in installations, (membranes in treatment plants). Chemical for treatment is an expense but assumed to very similar for all options except Option 5.
- Robustness of water provision:
  - Based on the scoring above, it is recommended to pursue a scenario including the existing provision from Kherson Oblast combined with a solution that mixes 2 and 3: Intake at the 51 km mark, pipe transport on the left bank, reestablishment of the Zhovtneve reservoir and treatment at the existing WTP. A preliminary and later secondary source could be the use of the irrigation channels for supplying the reservoir.

6 Recommendations

When selecting the most suitable options, several principles must guide the decision-making process. Among these, ensuring the most stable and secure water supply for the city's residents and financial considerations are of paramount importance. Thus, these recommendations are made considered the city's history of water supply vulnerabilities and the need for a strategic water reserve. It is crucial to consider both the quality and quantity of potential water sources, as well as to prioritize financial considerations. Applying the below mentioned three priorities – and implementing the actions therein - will significantly enhance Mykolaiv's water supply resilience.

The main priority is to establish a reserve of clean water to ensure stable and sustainable water supply, so reconstructing the Zhovtneve Reservoir is crucial to ensure this goal especially during emergencies, providing a half-year reserve of clean water.

COWI suggests not to consider any of the six options presented above as the first priority to take action on, but to ensure a stable and secure water supply for Mykolaiv City in the form of rehabilitation of the Zhovtneve Reservoir as the **first priority**. The reservoir is in close proximity to the existing water treatment plant and has a useful volume of almost 27 million cubic meters of water, which is sufficient for half a year of city supply under normal conditions, without any restrictions. It's important to note that the reservoir was taken out of operation, primarily due to the inundation of nearby lands. The estimated cost for its rehabilitation is 52 million EUR.

An undeniable advantage of this option is that the reservoir can be filled from various sources, such as the existing water intake from the Dnipro River, if it is in working condition, or from a new source built in accordance with the proposed options 1- 4, or even from the existing Inhulets Irrigation System or from groundwater - preferably, as many as possible at the same time to ensure water robustness. It´s important to find a source that have the quality and quantity sufficient for supplying Mykolaiv as it's extremely vulnerable to rely only on one raw water source.

The reservoir will serve multiple functions, including biological contamination purification and drinking water storage. Additionally, both the Pivdennyi Buh and Dnipro rivers are situated near nuclear power stations, namely the South Ukrainian and Zaporizhzhia plants, respectively. Having a water reserve can safeguard the city not only during times of conflict but also in peacetime, protecting against radiological contamination in case of an accident at one of the plants.

Consequently, the need to create a reliable source of clean water for filling the reservoir allows for the identification of the second priority for action - rehabilitating and reconstructing the existing Dnipro River water intake (estimated at 25 million EUR). This is proposed as the **second priority**.

Reconstructing the existing Dnipro River appears to be the most cost-effective and practical solution for a reliable drinking water source as the main infrastructure already exists.

Unfortunately, when the area around Dnipro River water intake in Kherson Oblast is in the state out of the active war activities is not known now. To back up the water intake from Dnipro River, the Inhulets irrigation system might be used. The irrigation channels are operational and so is the intake pumping station. There are, however, some water quality concerns from the open channels and also the question whether it freezes over during winter. If local pollutants are present at a given source, this could be dealt with locally at the source, by the implementation of various new technologies - Carbon filter, nano filter UV-disinfection and many more. Treatment locally at the

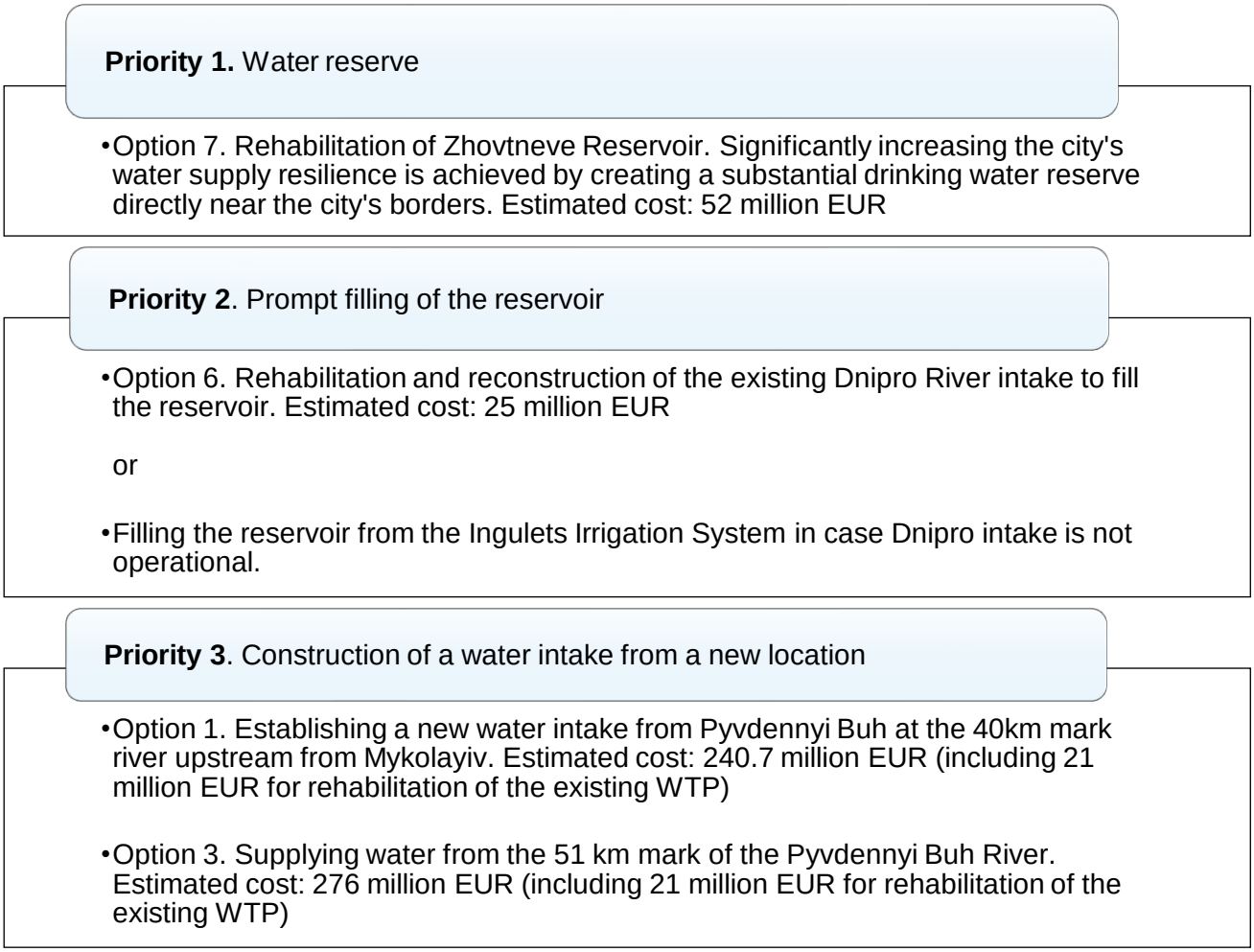
source, have the advantage that a pollutant doesn't contaminate the rest water, but also removes the pollutant completely from the source, thus reducing the risk of further contaminations of the source. Furthermore, the equipment for a local treatment is much smaller, as economically as well as physically.

Securing a new water source location from the Pyvdennyi Buh River may be introduced on a later stage when the financing is available.

Finally, the proposd **third priority** includes options for establishing a new water intake from the Pyvdennyi Buh River at the 40km mark upstream from Mykolayiv (estimated cost: 240.7 million EUR, including 21 million EUR for rehabilitation of the existing WTP) and supplying water from the 51 km mark of the Pyvdennyi Buh River (estimated cost: 276 million EUR, including 21 million EUR for rehabilitation of the existing WTP). This step is considered in the view of the time horizon 2050.

Figure 6-1 below summarizes COWI's recommendation on the three prioritized options that effectively serve the primary goal, which is to ensure a sustainable water supply for the city.

Figure 6-1 Towards sustainable water supply in Mykolaiv City



Five further recommendations are made:

- Open for new technologies
  - New technologies will emerge, no doubt. The MVK should continue being on the top of the technological development in Europe within water treatment and water supply.
- Address environmental issues
  - Environmental impacts are unknown. They may negatively affect some of the options (e.g. Options 1 and 2 since they are located downstream from Nova Odesa). Hence, it's important addressing these.
- Take into account population's opinion
  - It's important that the population is confident with the options pursued. Hene, it is recommended, one way or the other, to reveal population's opinion at an early stage.
- Ensure sustainable financing
  - It may be considered developing a water sector financing strategy since many of the investments are cost-heavy and may put a serious burden on the municipal budget if financing of these is not addressed in a holistic way.
- Reach out to IFIs and donors ASAP
  - The sooner it is possible attracting IFIs and donors to the investment projects aimed at ensuring safe water to the citizens of Mykolaiv, the better. It may enable IFIs and donors entering into a constructive dialogue with the Mykolaiv City Administration and MVK, conducting feasibility studies and preparing tender documents so that tenders may be carried out whenever possible.