Integrated energy and water resource management in support of sustainable development in South-East Europe and Central Asia

Case study on the application of UNFC in energy and water resources in Kazakhstan

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Executive summary

In Kazakhstan, for the classification of reserves and resources of solid minerals, energy raw materials and groundwater, the GKZ state-local system operates, which establishes uniform requirements for the classification of reserves and resources, and their state registration in the subsoil according to the degree of study and development.

In addition, the adoption of Kazakhstan by the tenth member of CRIRSCO (2016), and the new Code of the Republic of Kazakhstan "On Subsoil and Subsoil Use", introduced in 2018, the Kazakhstan Code of Public Reporting on the Results of Geological Exploration, Mineral Resources and Mineral Reserves (KAZRC Code), developed in accordance with the CRIRSCO template, received the right to be officially used in the Republic.

The current classification of the State Reserves Committee of the Republic of Kazakhstan reflects the results of a phased geological study of the subsoil. A step-by-step study of the subsoil is carried out by the implementation of relevant projects. Each project has goals, timelines, quality requirements and certain levels of risk.

Similar principles for the stage-by-stage subsoil study and project management are laid down in the UNFC.

In accordance with the objectives of the project, the South Inkai uranium deposit, located in South Kazakhstan, and a groundwater deposit combined with it in the subsoil - the explored area for water supply to the Taikonyr village and production facilities of the South Inkai mine, were taken as the objects of research In the area of the uranium deposit, no sources of surface water suitable for use have been found, therefore, groundwater is the only source of water supply [1].

This example shows the effective use of groundwater, which is widespread in the subsoil together with uranium mineralization, to supply fresh water to the population of the village and mine personnel, and process water to the production process of the South Inkai mine (Fig.1).

Thus, in the area of the uranium deposit South Inkai, in the semi-desert region of South Kazakhstan, the issues of water supply to the local population and the production process have been effectively resolved, in this connection, this project is of great socio-economic importance for this area of Kazakhstan.

Uranium resources and reserves of the South Inkai deposit were estimated in 2018 in accordance with the CRIRSCO standard (NI-43-101), for submission on the Toronto Stock Exchange [1]. The assessment of groundwater reserves was carried out in accordance with the requirements of the State Reserves Committee of the RK.

In accordance with UNFC, the estimated uranium resources of the South Inkai deposit as of 01.01.2018 can be classified as E2, F2, G1,2,3, and reserves as E1.1, F1.1, G1,2, and groundwater resources of this site as E1.1, F1.1, G1,2.

South Kazakhstan is one of the most densely populated regions of Kazakhstan. In this regard, the creation of new industries oriented for a long period provides a large number of additional jobs for the long term. The large deficit in this area of surface water can be successfully compensated for by exploration and use of groundwater, which occurs directly together with uranium ores, which are involved in mining. These waters are already being successfully used for both production and supply of the local population. Extraction and production of uranium products is accompanied by constant environmental monitoring. The best practices of safety assurance recommended by the IAEA have been implemented in production.

The systems for assessing resources and reserves used today in Kazakhstan (GKZ RK and KRIRSCO) do not allow government bodies to present a complete picture of the development priorities of mining projects, due to the lack of an assessment of their socio-economic and environmental significance. The implementation of the UNFC will allow government agencies to obtain a comprehensive assessment of not only individual projects, but also, on their basis, plan

the development of regional infrastructure, taking into account all the aspects that need to be taken into account in such planning.

The development of uranium mining in South Kazakhstan, in conjunction with the use of groundwater co-occurring with uranium ore, is absolutely consistent with the acceleration of the achievement of 6, 7 (and 13) UN SDGs.

1. Introduction

Energy resources of Kazakhstan

Energy resources play a critical role in Kazakhstan. Kazakhstan possesses the richest resources of oil, gas, coal and uranium.

According to BP Statistical Review of World Energy, in terms of proven oil reserves at the end of 2017 (3.9 billion tons), Kazakhstan possesses 1.8% of world oil reserves, ranking 12th in terms of both reserves and production [2]. The total oil reserves in the Republic of Kazakhstan are 4.8 billion tons. The overwhelming majority of them are concentrated in Western Kazakhstan. The state balance takes into account recoverable oil reserves in 277 fields. Of the 263 balance deposits, 256 objects with reserves of 4745.0 million tons were in subsoil use. More than 90% of oil reserves are concentrated in the 15 largest fields.

Projected oil resources are about 18 billion tons, including in the Kazakh part of the Caspian Sea - 10 billion tons of free gas and dissolved in oil - about 11 trillion. m3. The main part of gas condensate reserves is concentrated in the largest field Karachaganak - 74%. According to British Petroleum estimates, at the end-2017 level of gas reserves, the “Reserves-to-production (R/P) ratio”, the coverage is 42.2 years [2].

Explored coal reserves of Kazakhstan amount to 34.1 billion tons, of which 21.1 billion tons of hard coal (including 12 billion tons of coking coal) and 13 billion tons of brown. In terms of the amount of reserves and the volume of annual coal production, the Republic of Kazakhstan occupies, respectively, 8th and 10th places in the world [3]. In the aquifers of the Cretaceous-Paleogene structural-facies complex, epigenetic bed-infiltration uranium deposits of the regional zones of bed oxidation of the Shu-Sarysu and Syrdarya uranium provinces are located, which make up one of the world's largest East Turan mega province. Numerous large-scale deposits located in this province contain 73% of all uranium resources in Kazakhstan and 65% of confirmed uranium reserves [4].

The total identified uranium resources (reasonably assured and inferred) as of 1 January 2017 amounted to 10, 652,900 tonnes of uranium metal (tU). Kazakhstan ranks second in reserves (1,690,000 tons) after Australia and first in production (about 40 thousand tons). This situation is ensured thanks to the unique uranium ore province, which is located in South Kazakhstan, the deposits of which are of the roll-front deposits, which are processed by the ISL method [5].

The main region of distribution of the uranium roll-front mineralization of South Kazakhstan is shown in Figure 2 and 3 [5,1]. The current dominance of ISR is mainly due to increased production in Kazakhstan [1]. ISL continues to dominate uranium production, accounting for approximately 48 per cent of world production as of 2017. Underground mining (31.9 percent), open pit mining (13.7 percent) and co-product and by-product recovery from copper and gold operations (5.8 percent), heap leaching (<1 percent) and other methods (<1 per cent) accounted for the remaining uranium production shares. *In situ* bio-leaching using CO_2 and O_2 is now substituting for more environmentally invasive acid and alkaline leaching, a trend likely to grow [5].

Water resources of Kazakhstan

The sustainable development of the economy, and the socio-political situation in the state, largely depend on the availability and quality of water resources, which, in Kazakhstan, should be given strategic importance. At the same time, when assessing water supply, mainly surface waters are considered, which are almost half transboundary, and therefore depend on the state of water

consumption in other countries (Russia, China, Kyrgyzstan and Uzbekistan). The total resources of surface waters are estimated at an average of 100.8 cubic km/year, of which 56.84 km/year are formed in Kazakhstan, and 43.9 km3/year come from adjacent territories.

The provision of local surface water resources per inhabitant is very low - 3.2 thousand m3/year. For comparison, in Russia, there are 27.8 thousand m3/year per one inhabitant, in Kyrgyzstan - 12.7 thousand m3/year.

Groundwater is extremely unevenly distributed throughout the country, and the variable quality prevents exploitation of part of groundwater resources for economic activity. Groundwater is available in almost all the mountainous regions. About half groundwater resources (about 50 per cent) are concentrated in southern Kazakhstan. Significantly fewer of these resources (up to 20 per cent) are formed within western Kazakhstan. About 30 per cent of all groundwater resources are located in central, northern and eastern Kazakhstan (UNDP, 2004). A total of 626 groundwater fields have been explored with total reserves of 15.93 km3/year (43.38 million m3/day); probable reserves with a salinity rate of up to 1 g/litre are an estimated 33.85 km3/year and reserves of groundwater with salinity rate up to 10 g/litre are an estimated 57.63 km3/year (UNDP, 2004). Annual renewable groundwater resources in Kazakhstan are an estimated 33.85 km3/year, of which 26 km3/year corresponds to the overlap with surface water resources. Total actual renewable water resources (TARWR), including agreements, can thus be estimated at 107.48 km3/year (=99.63+33.85-26) [6].

With a large deficit of surface water, the total groundwater resources are 64.28 km/year, and 40.44 km/year of them are freshwater. Groundwater, which is essential, is underutilized. That is, it is quite obvious that it is the widespread use of groundwater that can guarantee all the country's needs for water resources.

South Inkai deposit

The South Inkai deposit in South Kazakhstan was selected as an example of a possible application of the UNFC for the assessment of an energy project (uranium) and groundwater resources associated with a uranium deposit and located in the same subsoil space.

This Mine is located in the western part of the Chu-Sarysu basin in the Suzak District of the South Kazakhstan Oblast and the Shieli District of Kyzyl Orda Oblast, approximately 360km north-northwest of Shymkent, Kazakhstan, and 170km east of Kyzyl Orda, Kazakhstan (Fig. 1,2). The South Inkai deposit is being successfully exploited using ISR techniques.

The Inkai orefield was discovered in 1978. The exploration programs identified three uraniferous horizons, the Inkuduk, Zhalpak, and Mynkuduk. The Inkai orefield was split into four licences for development, with the present South Inkai Mine being the No. 4 deposit or South Inkai deposit (Fig.3).

Fig.1 Location of the South Inkai deposit

Betpak Dala LLP drilled 429 exploration holes in 2006-2007, the next phase of exploration occurred from 2008 to 2009, when 572 holes were drilled. Between 2010 and 2011, 447 holes were drilled [1]. The exploration phase of 2008 to 2011 corresponds with Uranium One's interest in the project. There was no exploration on the property in 2012-2013 (Fig.4).

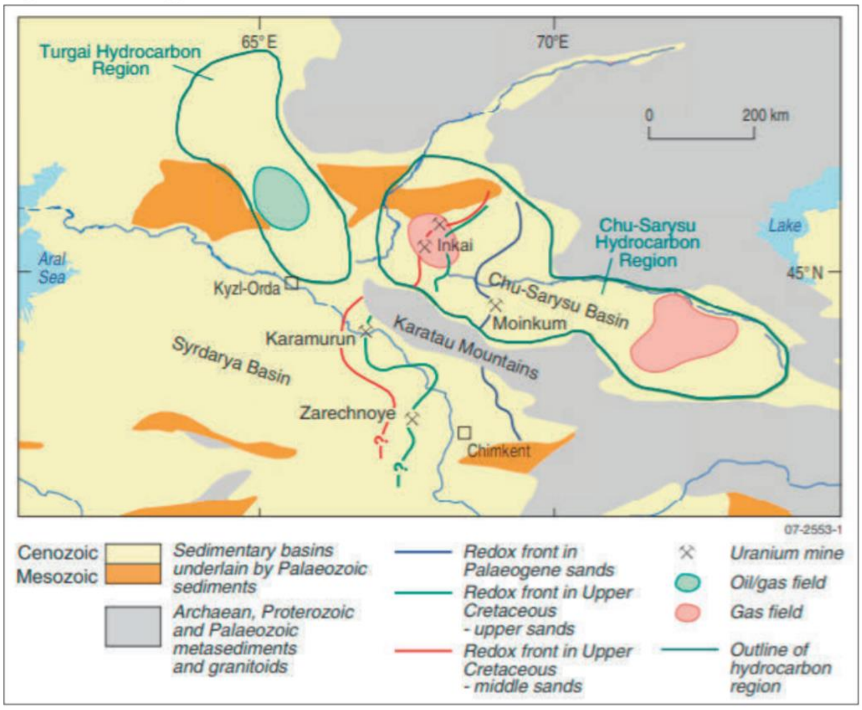


Fig.2 Energy Basin Kazakhstan

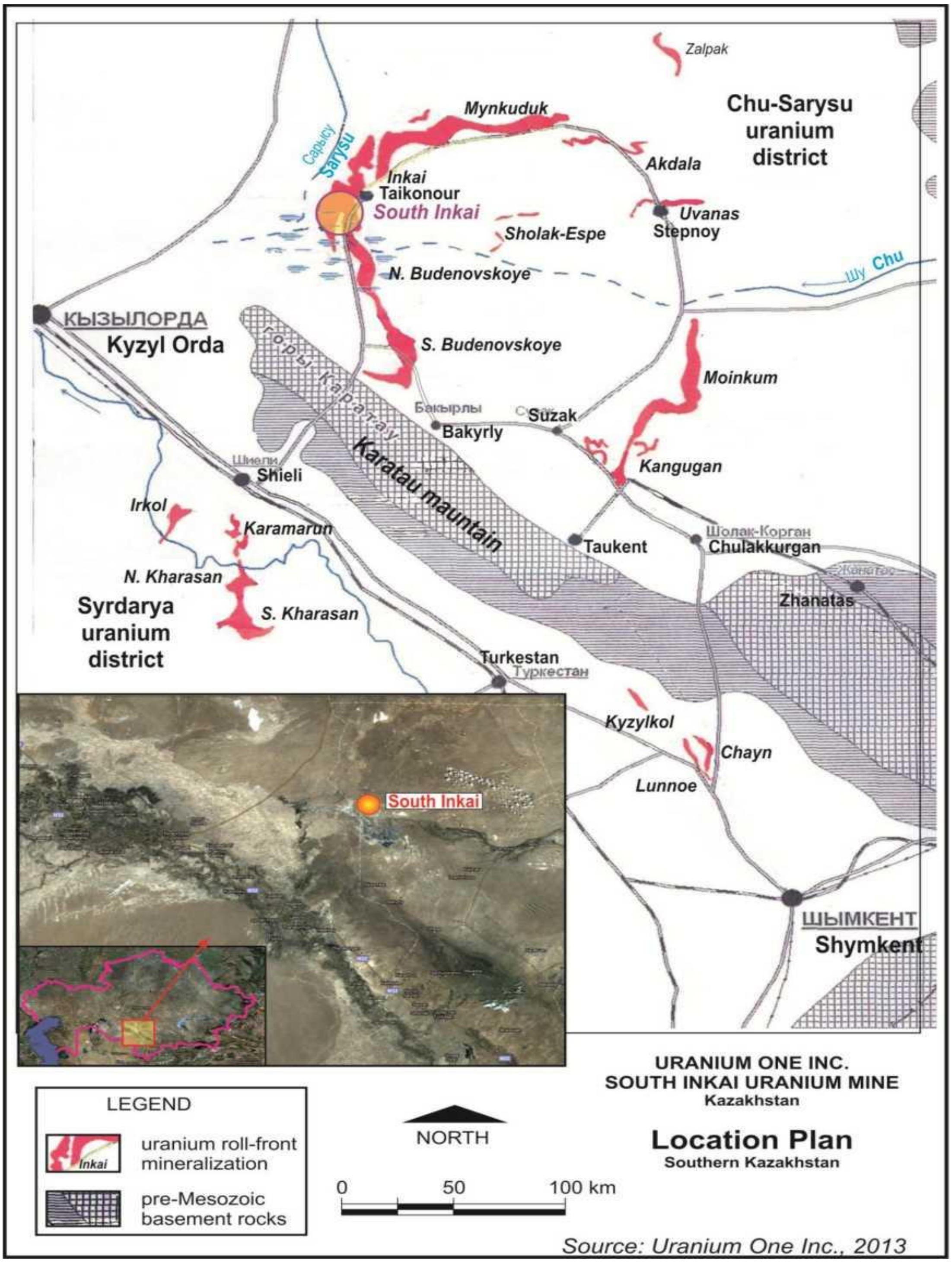


Fig.3 Location Plan of South Inkai Deposit in Southern Kazakhstan Uranium District

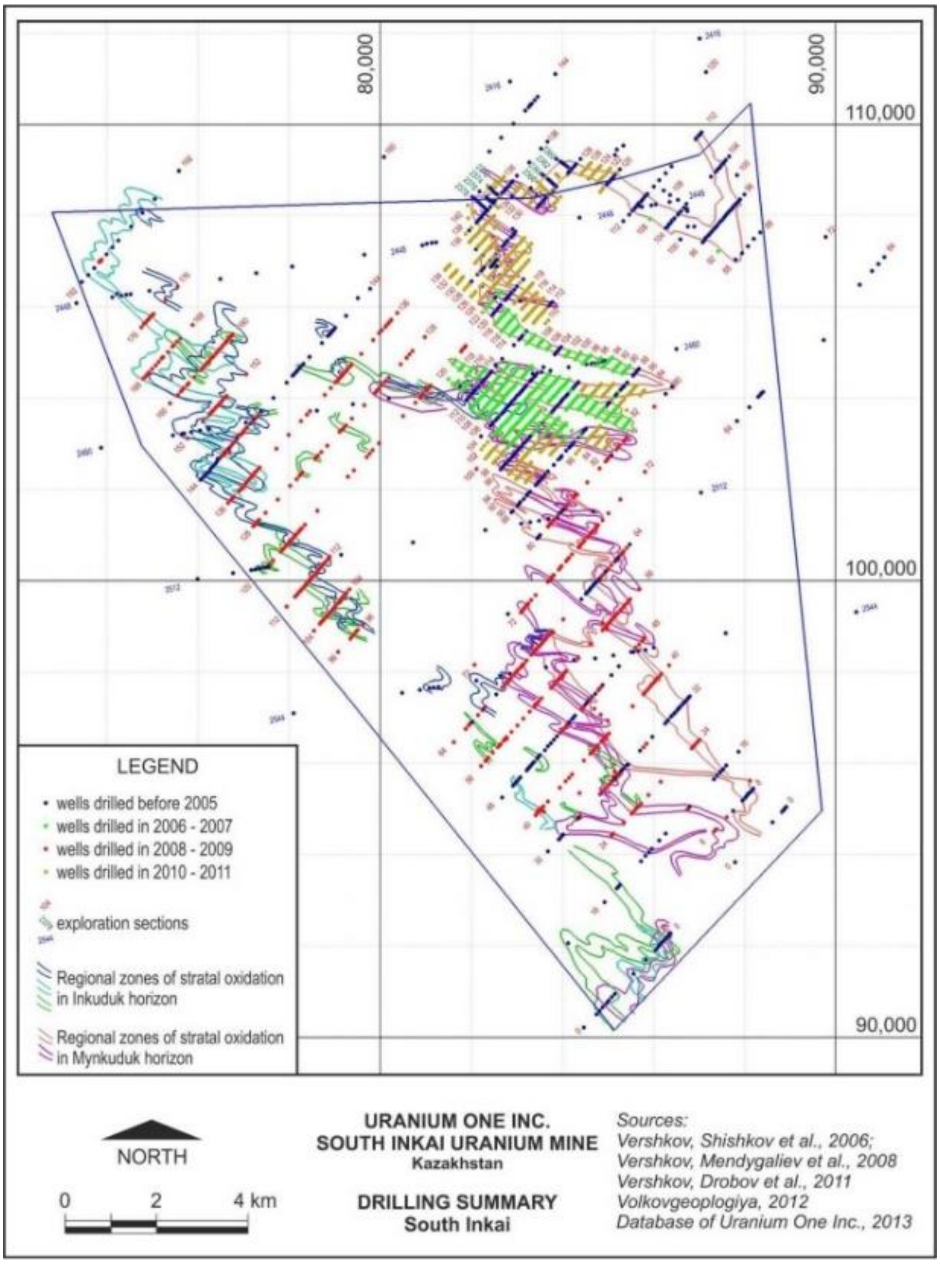


Fig.4 Drill collar plan for the South Inkai deposit

In 2018, the company CSA Global (Australia) prepared a public report on Uranium Mineral Resources and Uranium Mineral Reserves for Cameco company, a subsoil user of the South Inkai field, for submission to the Toronto Stock Exchange. The results of the Mineral Resources and Uranium Mineral Reserve estimates published in this report are presented in Tables 1 and 2 [1]:

Table 1: Summary of Mineral Resources of the South Inkai deposit – as of January 1, 2018

Category	Total tonnes (x1,000)	Grade, % U	Total M Kg U
Measured	36,680.9	0.022	8.2
Indicated	21,132.2	0.020	4.1
Total Measured & Indicated	57,813.2	0.021	12.3
Inferred	116,394.6	0.025	29.0

Table 2: Summary of Mineral Reserves of the South Inkai deposit – as of January 1, 2018

Category	Total tonnes (x1,000)	Grade, % U	Total M Kg U
Proven	214,104.1	0.030	64.7
Probable	166,913.0	0.024	39.4
Total Reserves	381,017.2	0.027	104.1

Reported mineral resources do not include amounts identified as mineral reserves.

This mineral resources & mineral reserves may by converted to UNFC (Table 3):

Table 3 South Inkai Mineral Resources and Mineral Reserves - CRIRSCO and UNFC Categories Correlation

Category NI-43-101 (CRIRSCO)	Category UNFC	Total tonnes (x1,000)	Grade, % U	Total M Kg U
Resources:				
Measured	E2F2G1	36,680.9	0.022	8.2
Indicated	E2F2G2	21,132.2	0.020	4.1
Inferred	E3F2G3	116,394.6	0.025	29.0
Reserves:				
Proven	E1.1F1.1G1	214,104.1	0.030	64.7
Probable	E1.1F1.1G2	166,913.0	0.024	39.4

Conversion of Mineral Resources and Mineral Reserves according to the NA-43-101 standard into the UNFC was made on the basis of the Bridging document between CRIRSCO and the UNFC, and the approximate relationship with the categories of reserves and resources of the GKZ RK, for solid minerals and groundwater (Table 4).

The reserves and resources of the South Inkai field, which were estimated according to the standard NI-43-101 in 2018, were in previous years estimated according to the GKZ RK system.

2. National Classification system for energy and groundwater resources and bridging or mapping to UNFC

2.1 Description and details of the national classification and management system?

Predicted resources of solid minerals according to their degree of geological knowledge are divided into categories P3, P2, P1. Each of these categories clearly indicates the degree of reliability of the calculated values.

Reserves of solid minerals according to their degree of knowledge are divided into two groups:

1. Pre-estimated reserves of category C2;
2. Confirmed (explored) reserves of categories C1, B, A.

For groundwater, during hydrogeological mapping of a small scale, predicted resources of category P are determined, at the stage of prospecting and appraisal work, reserves of category C2 are calculated, at the stage of exploration, reserves of category B and C1 are determined, at the stage of operation (operational exploration) of categories A and B.

The principles for applying the classification of forecast resources and reserves solid mineral and groundwater are given in Fig.5 [8,9].

<table>
<tr><td rowspan="5">Exploration Stage and Substage</td><td colspan="7">Solid minerals</td><td rowspan="5">Ground water</td></tr>
<tr><td colspan="7">Exploration Results</td></tr>
<tr><td rowspan="2">Forecast potential</td><td colspan="6">Field Reserves and Forecast Resources</td></tr>
<tr><td colspan="3">Forecast Resources</td><td colspan="3">Reserves</td></tr>
<tr><td>P</td><td>P3</td><td>P2</td><td>P1</td><td>C2</td><td>C1</td><td>B+A</td></tr>
<tr><td>Stage 1 Regional geological exploration of mineral resources</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Substage 1
Consolidated and survey (1: 500000 and smaller) geological mapping</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Substage 2
Medium (1: 200000) geological mapping</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Substage 3
Large-scale (1: 50,000) geological mapping</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td rowspan="2">P</td></tr>
<tr><td>Stage 2
Search work</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Stage 3
Search and assessment work</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td>C2, C1</td></tr>
<tr><td>Stage 4
Geological exploration</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td>C1, B</td></tr>
<tr><td>Stage 5
Operational exploration, production</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td>B,A</td></tr>
</table>

Fig.5 – Application of classification of reserves and forecast resources according to the GKZ RK standard for the solid minerals and groundwater

Groundwater reserves are classified by stage of work in the same way as solid minerals, while the classification of groundwater resources is much simpler than for solid minerals.

Both reserves and forecast resources, their definitions and application are fully consistent with the classification in force in the former USSR.

2.2 Overview of UNFC system

The 2019 Update of the United Nations Framework Classification for Resources (UNFC) is an update of the United Nations Framework Classification for Fossil Energy and Mineral Reserves and Resources 2009 incorporating Specifications for its Application (ECE Energy Series 42 and ECE/ENERGY/94) that was issued at the end of 2013. In September 2017, the ECE Committee on Sustainable Energy at its twenty-sixth session approved the change of name of the United Nations Framework Classification for Fossil Energy and Mineral Reserves and Resources 2009 to the United Nations Framework Classification for Resources (UNFC) [9].

The Expert Group on Resource Management at its tenth session (Geneva, Switzerland, 29 April – 3 May 2019; report of session: ECE/ENERGY/GE.3/2019/2) recommended that the language in UNFC be revisited to be inclusive of the full spectrum of the various commodities and stakeholders of UNFC.

The UNFC is a principles-based system in which the products of a project, resource-related are classified based on three fundamental criteria - of environmental-socio-economic viability (E),

technical feasibility (F), and degree of confidence in the estimate (G) - using a digital coding system. Combinations of these criteria create a three-dimensional system (Fig.6). Categories (e.g. E1, E2, E3) and in some cases subcategories (for example, E1.1) are defined for each of the three criteria.

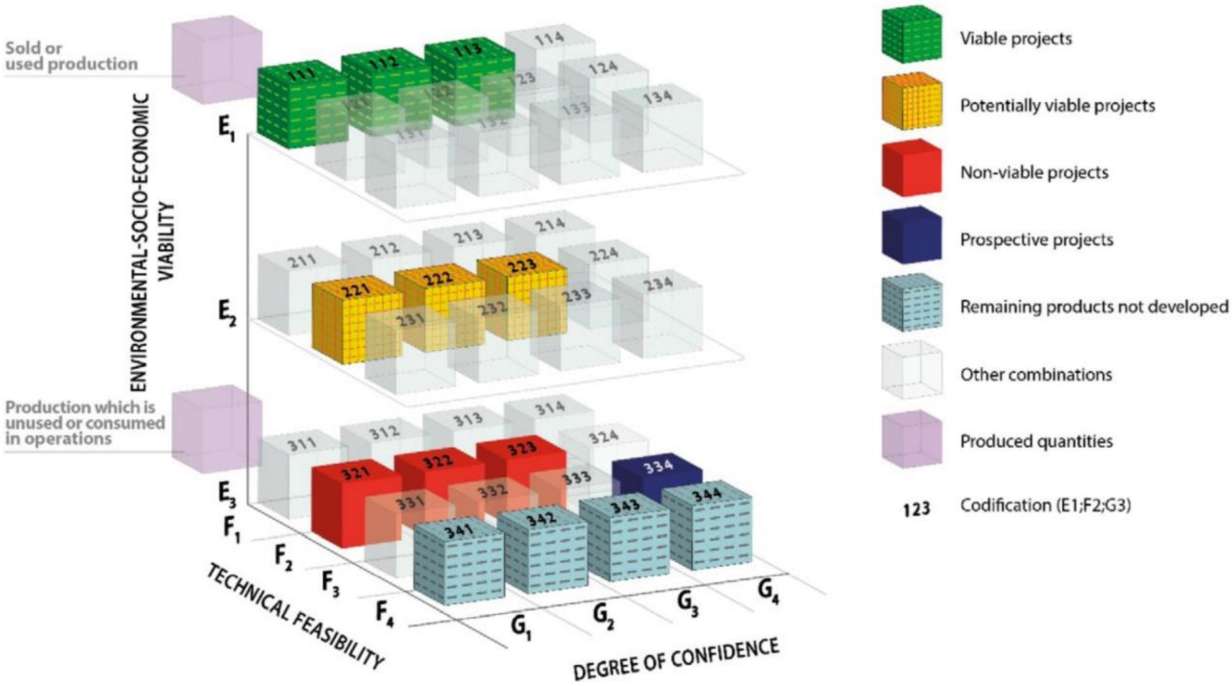


Fig.6 UNFC triad

While there are no explicit restrictions on the possible combinations of E, F and G Categories or Sub-categories, some may be more useful than others. For the more important combinations (Classes and Sub-classes), specific labels are provided as a support to the numerical code, as illustrated in Figure 7.

Total Products	Produced	Sold or used production			
		Production which is unused or consumed in operations[a]			
		Class	Minimum Categories		
			E	F	G[b]
	The project's environmental-socio-economic viability and technical feasibility has been confirmed	Viable Projects[c]	1	1	1, 2, 3
	The project's environmental-socio-economic viability and/or technical feasibility has yet to be confirmed	Potentially Viable Projects[d]	2[e]	2	1, 2, 3
		Non-Viable Projects[f]	3	2	1, 2, 3
	Remaining products not developed from identified projects[g]		3	4	1, 2, 3
	There is insufficient information on the source to assess the project's environmental-socio-economic viability and technical feasibility	Prospective Projects	3	3	4
	Remaining products not developed from prospective projects[g]		3	4	4

Fig.7 Abbreviated Version of UNFC, showing Primary Classes

As shown in Figure 7, the total product available for development, or on production, is classified at a given date. Quantification of the product may require consideration of the project

lifetime/limit (such as for renewable energy projects). Classification is done in terms of the following:

(a) Produced quantities that have been sold or used. This would include direct domestic use of a solar home installation, or non-sales domestic supply of a product to a local market.

(b) Produced quantities which are unused or have been consumed in operations.

(c) Quantities of a known product that may be produced in the future. Technical and environmental-socioeconomic evaluation studies based on projects constitute the basis for the classification.

(d) Remaining quantities of product not developed by any project.

(e) Quantities of a product that may be produced in the future from prospective projects. Technical and environmental-socio-economic evaluation studies based on prospective projects constitute the basis for the classification.

(f) Remaining quantities of product not developed by any prospective project.

For further clarity in global communications, additional UNFC Sub-classes are defined based on the full granularity provided by the Sub-categories. These are illustrated in Figure 8.

UNFC Classes Defined by Categories and Sub-categories						
Total Products	Produced	Sold or used production				
		Production which is unused or consumed in operations				
		Class	Sub-class	Categories		
				E	F	G
	Known Sources	Viable Projects	On Production	1	1.1	1, 2, 3
			Approved for Development	1	1.2	1, 2, 3
			Justified for Development	1	1.3	1, 2, 3
		Potentially Viable Projects	Development Pending	2[b]	2.1	1, 2, 3
			Development On Hold	2	2.2	1, 2, 3
		Non-Viable Projects	Development Unclarified	3.2	2.2	1, 2, 3
			Development Not Viable	3.3	2.3	1, 2, 3
		Remaining products not developed from identified projects		3.3	4	1, 2, 3
	Potential Sources	Prospective Projects	[No sub-classes defined]	3.2	3	4
		Remaining products not developed from prospective projects		3.3	4	4

a. Refer also to the notes for Figure 7.
b. Development Pending Projects may satisfy the requirements for E1.

Fig 8 UNFC Classes and Sub-classes defined by Sub-categories[a]

2.2.1 Nuclear fuels Bridging document

A bridging document between the UNFC and the IAEA was approved by the Expert Group on Resource Classification at its fifth session from April 29 to May 2, 2014, with the possibility of further minor revisions following a review by the Expert Group's Technical Advisory Group [10].

It aligns UNFC with other widely used resource classification systems for nuclear fuels, notably the "Red Book", co-published every two years since first appearing in 1965 by the Nuclear Energy Agency (NEA)5 of the Organization for Economic Cooperation and Development (OECD)6 and IAEA.

Two international systems are used to classify and report uranium and thorium deposits. These two systems include the International Mineral Resources Reporting Standards Committee (CRIRSCO) Standard Model and the Organization for Economic Cooperation and Development (OECD) / International Atomic Energy Agency (IAEA) Nuclear Energy Agency (NEA) Resource Reporting System (Fig.9).

Exploration results and mineral resource and reserve data prepared for uranium and thorium deposits using a set of agreed CRIRSCO codes and standards can be compared with UNFC digital codes using a document linking the CRIRSCO Standard Model and UNFC- 2019.

UNFC-2009 Classification					NEA/IAEA Classification		
UNFC Classes and Sub-classes		UNFC Categories					
Class	Sub-Class	E	F	G	IAEA-NEA Categories		Status
Commercial Projects	On Production	1	1.1	1	Identified Resources	Reasonably Assured Resources (RAR)	Existing
				2			
	Approved for Development	1	1.2	1			Committed
				2			
	Justified for Development	1	1.3	1			Planned
				2			
Potentially Commercial Projects	Development Pending	2	2.1	1	Identified Resources	RAR	Prospective
				2			
				3		IR*	
	Development On Hold	2	2.2	1		RAR	
				2			
				3		IR*	
Non-commercial Projects	Development Unclarified	3.2	2.2	1	Identified Resources	RAR	Unclarified
				2			
				3		IR*	
	Development Not Viable	3.3	2.3	1		RAR	Not Viable
				2			
				3		IR*	
Exploration Projects		3.2	3.1	4	Undiscovered Resources	Prognosticated Resources	
		3.2	3.2, 3.3	4		Speculative Resources	

Fig.9 Relationship between the UNFC and the NEA/IAEA classification

The purpose of this bridging document is to facilitate the comparison of results obtained under UNFC-2009 and the NEA / IAEA Resource Reporting System [10].

2.2.2 U and Th guidelines

Many companies in different countries report uranium/thorium quantities in accordance with the CRIRSCO Template. UNFC-2009 provides a valuable opportunity to understand the relationship between the NEA/IAEA Classification and the CRIRSCO Template.

As many countries use their own systems, which are approximately mapped to the NEA/IAEA Classification, this mapping to the CRIRSCO Template does not necessarily mean that each of the national systems is fully in alignment with the CRIRSCO Template. The mapping of the NEA/IAEA Classification to the more granular UNFC-2009, through the CRIRSCO Template, may be treated with the same confidence as a bridging that exists between two aligned systems.

A Mineral Reserve, defined under the CRIRSCO Template, corresponds to a Commercial Project under UNFC-2009 and a Reasonably Assured Resource under NEA/IAEA (Fig.10).

Under the CRIRSCO Template and UNFC-2009, Mineral Reserves and estimates on Commercial Projects may be compiled as quantities delivered to the process plant (tonnage and grade or quality), or as saleable product (tonnage and quality). Most mineral deposits disclose Mineral Reserves at a "plant feed" reference point while most industrial mineral, coal, uranium and thorium reserves are reported as "saleable product". The Competent Person must clearly state the "reference point" used to prepare the estimate. Under the NEA/IAEA system, Reasonably Assured Resource estimates are always expressed in terms of recoverable tonnes of uranium or thorium ("saleable product"). When results are transferred from either UNFC-2009 or the CRIRSCO Template into the NEA/IAEA system, the transfer must account for any change in reference point which may occur.

UNFC-2009 Classification					CRIRSCO Template		NEA/IAEA Classification		
UNFC Classes and Sub-classes		UNFC Categories			CRIRSCO Classes and Sub-classes				
Class	Sub-Class	E	F	G	Class	Sub-Class	IAEA-NEA Categories		Status
Commercial Projects	On Production	1	1.1	1	Mineral Reserves	Proved	Reasonably Assured Resources (RAR)		Existing
				2		Probable			
	Approved for Development	1	1.2	1		Proved			Committed
				2		Probable			
	Justified for Development	1	1.3	1		Proved			Planned
				2		Probable			
Potentially Commercial Projects	Development Pending	2	2.1	1	Mineral Resources	Measured	Identified Resources	RAR	Prospective
				2		Indicated			
				3		Inferred		IR*	
	Development On Hold	2	2.2	1		Measured		RAR	
				2		Indicated			
				3		Inferred		IR*	
Non-commercial Projects	Development Unclarified	3.2	2.2	1,2,3	Inventory (not defined in Template)	Development Unclarified (not defined in Template)	Identified Resources RAR IR*		Unclarified
	Development Not Viable	3.3	2.3	1,2,3		Not Viable (not defined in Template)			Not Viable
Exploration Projects		3.2	3.1	4	Exploration Target		Undiscovered Resources	Prognosticated Resources	
		3.2	3.2, 3.3	4				Speculative Resources	

Fig.10 Mapping of UNFC-2009, CRIRSCO Template and NEA/IAEA Classification

A Mineral Reserve, defined under the CRIRSCO Template and Reasonably Assured Resource under NEA/IAEA, always correspond to UNFC-2009 Categories E1 and F1. Optionally, Mineral Reserves may be further sub-classified on the F axis into F1.1, F1.2 or F1.3, which correspond to "Existing", "Committed" or "Planned" production centres under NEA/IAEA and

“On Production (E1F1.1)”, “Approved for Development”(E1F1.2) and “Justified for Development” (E1F1.3) under UNFC-2009.

Mineral Reserves defined under the CRIRSCO Template are subdivided into Proved and Probable categories, which correspond to UNFC-2009 Categories G1 and G2. Since NEA/IAEA Classification does not subdivide Reasonably Assured Resources based on geological confidence, UNFC-2009 G1, and G2 categories and corresponding CRIRSCO Template Proved, and Probable Mineral Reserve classes are aggregated under NEA/IAEA (Fig.10).

The definitions used in the NEA/IAEA system are not strictly comparable as the criteria used in the various systems are not identical. “Grey zones” in correlation are therefore unavoidable, particularly as the resources become less assured. Nonetheless, Fig.11 presents a reasonable approximation of the comparability of terms [11].

<table>
<tr><td></td><td colspan="3">Identified resources</td><td colspan="3">Undiscovered resources</td></tr>
<tr><td>NEA/IAEA</td><td colspan="2">Reasonably assured</td><td>Inferred</td><td>Prognosticated</td><td colspan="2">Speculative</td></tr>
<tr><td rowspan="2">Australia</td><td colspan="2">Demonstrated</td><td rowspan="2">Inferred</td><td rowspan="2" colspan="3">Undiscovered</td></tr>
<tr><td>Measured</td><td>Indicated</td></tr>
<tr><td>Canada</td><td>Measured</td><td>Indicated</td><td>Inferred</td><td>Prognosticated</td><td colspan="2">Speculative</td></tr>
<tr><td>United States (DOE)</td><td colspan="2">Reasonably assured</td><td colspan="2">Estimated additional</td><td colspan="2">Speculative</td></tr>
<tr><td>Russian Federation, Kazakhstan, Ukraine, Uzbekistan</td><td>A + B</td><td>C1</td><td>C2</td><td>P1</td><td>P2</td><td>P3</td></tr>
</table>

Fig.11 Approximate correlation of terms used in major resources classification systems

2.2.3 Uranium best practices

In August 2019, UNECE published an extensive study - Redesigning the Uranium Resource Pathway: Application of the United Nations Framework Classification for Resources for Planning and Implementing Sustainable Uranium Projects (ECE ENERGY SERIES No. 57) (August 2019) [5]. This publication examines uranium in the context both of its contributions to climate action as a low-carbon, small-footprint energy material and of the value of applying the United Nations Framework Classification for Resources (UNFC) to planning and implementing transparent, sustainable uranium projects.

Uranium resources fuel 452 reactors with a total net capacity of 399 GigaWatt (electric), which represents approximately 10 per cent of global electrical generating capacity. This capacity has an availability factor of 80 per cent or more. Global nuclear capacity has the potential to increase significantly by 2030. China, for example, is putting a new nuclear reactor into operation every two months. New nuclear unit construction is also progressing in other countries, including in Belarus, France, Finland, Russian Federation, Turkey, United Kingdom, India and the United Arab Emirates. It is quite obvious that the expansion of the use of uranium in the energy sector will continue to grow more and more in the future.

A very important result of this case study is the consideration that the conventional model of uranium as a mineral commodity needs to give way to a new model of uranium as a “critical energy material” for meeting the global sustainability objectives on energy and climate action.

Due to the special properties of uranium, the expansion of its use in the energy sector (with strict adherence to safety measures) will contribute not only to the successful achievement of SDG 7 but also SDG 13.

2.2.4 Previous case studies

In 2015 and 2019, the ECE conducted studies in several countries on the application of the UNFC for the assessment of various minerals, including uranium (Argentina, Brazil, China, India, Malawi, Niger, United States, Egypt) serve to demonstrate how UNFC could be applied to assure sustainable resource management [12,13].

These studies have shown, that UNFC-2009 is an effective tool for reporting and management of uranium at regional and national levels. Higher granularity is important when reporting individual projects, and the information at this level of detail is important when addressing socio-economic issues at a regional level. The scheme also allows aggregation of the total quantities for comprehensive understanding. UNFC-2009 is particularly important for national reporting where data is assimilated from different company sources, both from public reports as well as direct communications to the Government. In comparison, most of the public reporting is done under international schemes suitable for the respective companies. Many companies that do not need public reporting could communicate quantities of uranium and other commodities to the Government under UNFC-2009—for example, the project (Egypt), where phosphate and uranium could be produced as co-products. Using UNFC for classification and reporting brings greater clarity to the reporting and demonstrates that phosphate and uranium projects are critical to the food and energy security of Egypt. This will vastly aid the management of natural resources and their timely development for the socio-economic development of Egypt.

2.3 Relationship with UNFC (either through one of the existing Bridging Documents or a proposed self-developed Mapping Scheme)

In 2016, Kazakhstan became the 10th member of CRIRSCO. With the introduction of the new Code “On Subsoil and Subsoil Use” (2017), the practical implementation of the KAZRC Code, which fully complies with the CRIRSCO template, began.

In accordance with the Code of the Republic of Kazakhstan "On Subsoil and Subsoil Use" (2017), the GKZ standard operates in parallel with the KAZRC code until 2024. Starting from 2024, only the KAZRC code will be used to assess resources and reserves (Table 4).

Table 4. The approximate ratio of resources and reserves according to the GKZ and UNFC.

CRIRSCO Template		**UNFC "minimum" Categories**			**UNFC Class**	**GKZ RK**	
						Solid minerals	**Groundwater**
Mineral Reserve	Proved	E1	F1	G1	Viable Projects	A, B	A, B
	Probable			G2		B, C1	B, C1
Mineral Resource	Measured	E2	F2	G1	Potentially Viable Projects		
	Indicated			G2		C1, C2	C1, C2
	Inferred			G3		C2, P1	P
Exploration Resalts		E3	F3	G4	Prospective Projects		
						P2, P3	

3. Background information on the energy project (s) and groundwater utilization in South Inkai

3.1 Previous work on energy and groundwater resources

Energy resources (Uranium resources)

The Inkai deposit was discovered during drilling campaigns conducted in 1976 – 1978 by Volkovskaya Expedition. By that time, prospecting and exploration programs had also resulted in the identification of the Uvanas, Zhalpak, Kanzhugan and Mynkuduk deposits. Together with the Inkai deposit, they formed a large new uranium mineralization prospect in the Shu-Sarysu depression. Exploration drilling progressed until 1996.

The Inkai uranium deposit is a roll-front stratiform system. Roll-front deposits are a common example of stratiform deposits that form within permeable sandstones in localised reduced environments. Microcrystalline uraninite and coffinite are deposited during diagenesis by oxygenated and uraniferous groundwater, in a crescent-shaped lens that cuts across bedding and forms at the interface between oxidized and reduced lithologies. Sandstone host rocks are medium to coarse-grained and were highly permeable at the time of mineralization (Fig.12).

The unconsolidated Upper Cretaceous sediments provide an excellent groundwater-storing reservoir, some 250 to 300 m thick. This reservoir is regionally confined by the underlying Palaeozoic rocks and the overlying thick Palaeogene marine clays (Intymak, Uyuk and Ikan aquitards). To varying degrees, there is local confinement created by the sedimentation cycles, with each cycle including fine sands to silts and occasional clay seams at the top.

The Upper Cretaceous groundwater regime exhibits a layered sequence of aquifers due to gravity separation by different salinity levels, or TDS. At Inkai, from youngest to oldest, top to bottom these are:

- Uvanas & Betpak Dala freshwater (0.6 – 0.8 g/L TDS) aquifer
- Zhalpak brackish water (1.1 – 1.5 g/L TDS) aquifer
- Inkuduk salt water (2.3 – 3.6 g/L TDS) aquifer
- Mynkuduk salt water (2.7 – 4.5 g/L TDS) aquifer.

The confined Upper Cretaceous aquifers produce artesian conditions where the topography is depressed below the piezometric surface of about 135 – 140 m above sea level. The general water table is at a depth of eight to ten metres at Inkai.

The Inkai deposit includes the lower hydrogeological sub-stage (Paleocene and Upper Cretaceous). The hydrogeological conditions for the Quaternary-Upper Eocene sediments are not described here because aquifers of the upper sub-stage are not hydraulically connected to the Inkai deposit (Fig.12).

Available hydrogeology information is summarized below for the entire South Inkai deposit with references for different blocks as specified.

Groundwater resources

Hydrostratigraphy plays key roles both in the formation of the uranium sandstone deposits and in mining them using the ISR method. The Inkai deposit is located in the north-western part of the Suzak artesian basin that comprises two hydrogeological stages, an upper platform stage and a lower basement stage. The upper platform stage is related to Quaternary-Neogene and Palaeogene-Cretaceous deposits. The hydrogeological section of the platform stage reveals two hydrogeological sub-stages. The upper hydrogeological substage is the Betpak Dala aquifer (fine-grain sands) and other aquifers of sporadic occurrence. In general, these aquifers contain brackish and saline water not suitable for drinking [1]. These upper aquifers are hydraulically isolated from the lower hydrogeological sub-stage aquifers by the regional Intymak clay aquitard of the Lower and Upper Eocene which is about 100 to 150 m thick. The lower basement stage contains groundwater in fractured rocks of Palaeozoic age. It contains four aquifers within Palaeocene and Upper Cretaceous strata, listed from top to bottom as follows (Fig.12,13):

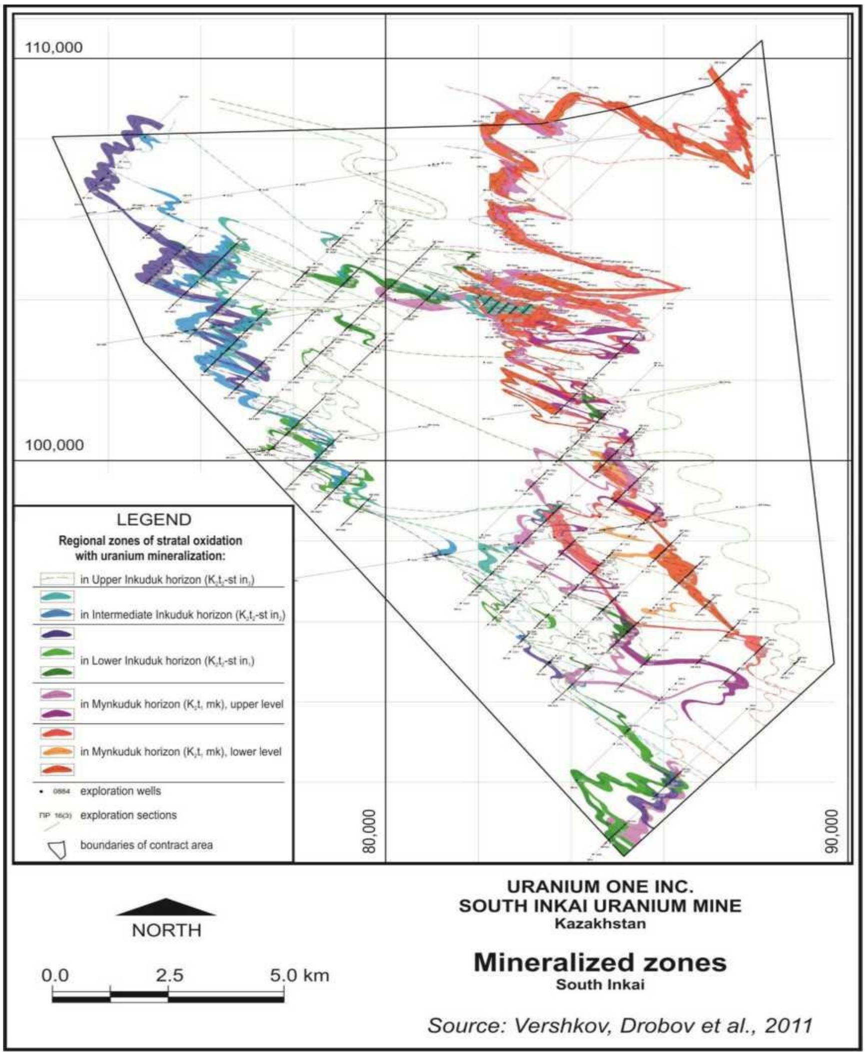


Fig.12 Regional zones of stratal oxidation with uranium mineralization

- Uvanas aquifer: contains fresh groundwater suitable for household and drinking purposes. The Uvanas aquifer is widely used in the region for domestic and livestock water supply. In the nearest vicinity of the deposit, in the town of Taikonur, there are six domestic water supply boreholes operated on the Uvanas aquifer. Additionally, outside Inkai, but in its vicinity, there are a few free-flowing artesian boreholes tapping groundwater from the Uvanas aquifer for livestock watering;
- Zhalpak aquifer: contains slightly brackish water which can be used for watering livestock. The aquifer is accessed by wells in proximity to Inkai. Groundwater from the Zhalpak aquifer is used for industrial and partial drinking water supply in the vicinity of the deposit site;
- Inkuduk aquifer: contains brackish and slightly brackish water not suitable for drinking
- Mynkuduk aquifer: contains brackish and slightly brackish water not suitable for drinking. Groundwater movement in the Chu-Sarysu Basin is towards the north-westerly discharge areas [14].

The annual natural groundwater movement averages one to four metres, depending on the various permeabilities of the different sand horizons. The lower aquifers have a common recharge area (the Karatau ridge and the Tien-Shan Mountains) and discharge into topographic depressions of the region-saline lands of Ashikol, Askazansor, and Lake Arys. Regional groundwater flows north-north-west. Permian claystones and siltstones underlay Mynkuduk aquifer and appear to be a regional aquitard. Elsewhere in the region, the groundwater is tapped by numerous boreholes for livestock watering. The groundwater of lower aquifers is not used at Inkai or in the surrounding area [15].

In order to identify the potential for developing a deposit that can be exploited using ISR, it is extremely important to study the hydrogeological parameters.

Hydrogeological studies include the following:

- The conditions of leaching solution filtration within mineralized-hosting rocks;
- Hydrogeological parameters of water-bearing horizons;
- Internal structure of the mineralized-bearing horizon;
- Assessment of possible changes of hydrogeological conditions likely during production; and
- Assessment of the influence of production and exploitation on ground water intakes.

Depending on their purpose, hydrogeological holes drilled on the site are divided into test (pilot) holes, central holes and observation holes drilled in a cluster for hydrogeological study.

Drilling was performed by JSC Volkovgeologia and Rusburmash-Kazakhstan LLP using ZIF-1200MR rotary drill rigs mounted on BPU-1200u mobile units designed by JSC Volkovgeologiya. D50mm tool joint drilling pipes were used for drilling. A GBR-132 MG water jet stepped spear borer was used with water flush in clay intervals or mud fluid in sand intervals. The core was recovered using an 89 mm core barrel with M-1 112 mm bit. Reaming was performed using T type 151mm and 190mm rolling cutter bits.

3.2 Current Status of energy and groundwater resources

Energy resources

South-central Kazakhstan geology is comprised of a large relatively flat basin of Cretaceous to Quaternary age continental clastic sedimentary rocks. The Chu-Sarysu Basin extends for more than 1,000 km from the foothills of the Tien Shan Mountains located on south and southeast sides of the basin and merges into the flats of the Aral Sea depression to the northwest. The basin is up to 250 km wide, bordered by the Karatau Mountains on the southwest and the Kazakh Uplands on the northeast. The basin is composed of gently dipping to nearly flat-lying fluvial-derived unconsolidated sediments composed of interbedded sand, silt and local clay horizons [1].

The Cretaceous and Paleogene sediments contain several stacked and relatively continuous, sinuous “roll-fronts” or redox fronts hosted in the more porous and permeable sand and silt units. Several uranium deposits and active ISR uranium mines are located at these regional oxidation roll-fronts, developed along a regional system of superimposed mineralization fronts.

The overall stratigraphic horizon of interest in the basin is approximately 200 to 250 m in vertical section. The Inkai deposit is one of these roll-front deposits. It is hosted within the Lower and Middle Inkuduk horizons and Mynkuduk horizon which comprise fine, medium and coarse-grain sands, gravels and clays. The redox boundary can be readily recognized in core by a distinct colour change from grey and greenish-grey on the reduced side to light grey with yellowish stains on the oxidized side, stemming from the oxidation of pyrite to limonite. The sands have high horizontal hydraulic conductivities. Hydrogeological parameters of the deposit play a key role in ISR mining. Studies and mining results indicate Inkai has favourable hydrogeological conditions for ISR mining.

Mineralization in the Middle Inkuduk horizon occurs in the central, western and northern parts of the MA Area. The overall strike length is approximately 35 km. Width in plan view ranges from 40 to 1,600 m and averages 350 m. The depth ranges from 262 to 380 m, averaging 314 m. Mineralization in the Lower Inkuduk horizon occurs in the southern, eastern and northern parts of the MA Area.

The overall strike length is approximately 40 km. Width in plan view ranges from 40 to 600 m and averages 250 m. The depth ranges from 317 to 447 m, averaging 382 m. Mineralization in the Mynkuduk horizon stretches from south to north in the eastern part of the MA Area. The overall strike length is approximately 40 km. Width in plan view ranges from 40 to 350 m and averages 200 m. The depth ranges from 350 to 528 m, averaging 390 m.

Mineralization comprises sooty pitchblende (85%) and coffinite (15%). The pitchblende occurs as micron-sized globules and spherical aggregates, while the coffinite forms tiny crystals. Both uranium minerals occur in pores on interstitial materials such as clay minerals, as films around and in cracks within sand grains, and as replacements of rare organic matter, and are commonly associated with pyrite.

The South Inkai is an operating ISR uranium mining project which uses a sulphuric acid leach and produces a dried intermediate (approximately 40% U) yellowcake product. Commercial operations followed a pilot plant testing program that commenced in October 2007. Production has increased each year since the test mining program.

South Inkai is an operating ISR uranium mine that began operating in 2009. South Inkai's land position is contiguous with, and south of, Inkai. It is owned 100% by the Southern Mining and Chemical Company (SMCC) joint venture and operated by SMCC, in turn, owned by Uranium One Inc. (70% interest) and Kazatomprom (30% interest). The mineralization hosted in the Middle and Lower Inkuduk and in the Mynkuduk horizons extends from Inkai's MA Area onto the South Inkai property. The source of this information, not verified by the QP responsible for this section, is from Uranium One's "Operating and Financial Review – Quarter Ended June 30, 2016" and their technical report on South Inkai published in 2014. This information is not necessarily indicative of the mineralization in the MA Area that is the subject of this technical report.

As part of the Restructuring, JV Inkai is in the process of returning portions of Blocks 2 and 3 to the Government of Kazakhstan that is not part of the MA Area.

Groundwater resources

The area is confined to the northwestern part of the Sozak artesian basin of the third order, which is part of the larger Western Shu-Sarysu basin of the second order.

The West Shu-Sarysu basin is a semi-closed structure with a submerged central part and raised marginal ones, conjugated with mountain neotectonic structures framing the Shu-Sarysu depression, and are the area of formation of regional groundwater flows.

The border of the Sozak artesian basin of the third-order runs in the east along the Ulanbel-Talas shaft, in the north - along with the Tastinsky uplift, in the west - along the Bugudzhil salient and in the south - along the foot of the Karatau ridge.

In hydrogeological terms, two hydrogeological levels are distinguished in the vertical section of the Sozak artesian basin. The lower floor is represented by Paleozoic deposits with reservoir-fissured and fissure-vein accumulations of groundwater. In the upper hydrogeological level, stratal-porous groundwater is formed in the Neogene-Quaternary loose-detrital formations, in the sediments of the Paleogene and Upper Cretaceous. In the section of the upper hydrogeological stage, a thick stratum of dense, water-resistant clays of the Eocene age is distinguished (Uyuk, Ikan, and Intymak horizons). This stratum divides the upper floor into two parts: in the upper part, mainly groundwater is formed, and in the lower, high-pressure groundwater.

The hydrogeological conditions of the work area are illustrated by a hydrogeological map at a scale of 1: 200000 and an accompanying hydrogeological section along the line I-I (Fig.13).Freshwater use (Uvanas & Betpak Dala freshwater (0.6 – 0.8 g/L TDS) aquifer). Currently, the drinking water supply of the v.Taikonur is carried out from two wells No. 520g and No. 536g drilled during the exploration of the Inkai uranium deposit in 1983. and in 1989. The operation started from well # 520 in 1984.

In the period from 2003 to 2005, at the water intake site, exploration work was carried out to assess the operational reserves of groundwater for the purpose of household and drinking water supply to the village of Taikonur.

The modern water withdrawal in 2019 amounted to 648 m3 / day or 7.5 l / s, which is 100% of the total approved groundwater reserves in category C1.

Water intake (Zhalpak aquifer) of the mini-plant for the primary processing of radioactive raw materials (OPV-2 site of JV Inkai LLP)

Production well No. 544g was rotary drilled and had a depth of 238 m. When performing 10-day pumping from well No. 544g in 2003, its flow rate was 10.7 dm3/s with a decrease in the water level by 12.9 m. The static level lay at a depth 15.1 m below the surface of the earth.

3.3 Outlook

Energy resources

Based on the estimated reserves and resources of uranium and groundwater, it is planned to continue development of the South Inkai deposit for another 25 years.

Mine life. The production plan presented in this technical report is based on Inkai mineral reserves from which production of an estimated 88.6 M Kg U is forecast. The projected mine life extends until mid-2045.

The LOM Plan details the Ramp-up, with production increasing to 4.0 M Kg U per year; variations of plus or minus 20% from the levels in the LOM Plan are allowed. The LOM Plan is partially based on inferred mineral resources [1].

Therefore annual production levels will be dependent on results of further delineation drilling and market conditions. There is no certainty that the LOM Plan production will be realized. With continued delineation drilling, it is reasonable to expect that the majority of inferred mineral resources could be upgraded to indicated mineral resources. The reserves-based production profile and economic analysis supporting the reported mineral reserves do not include the inferred resources and their associated extraction costs and revenues.

Groundwater resources

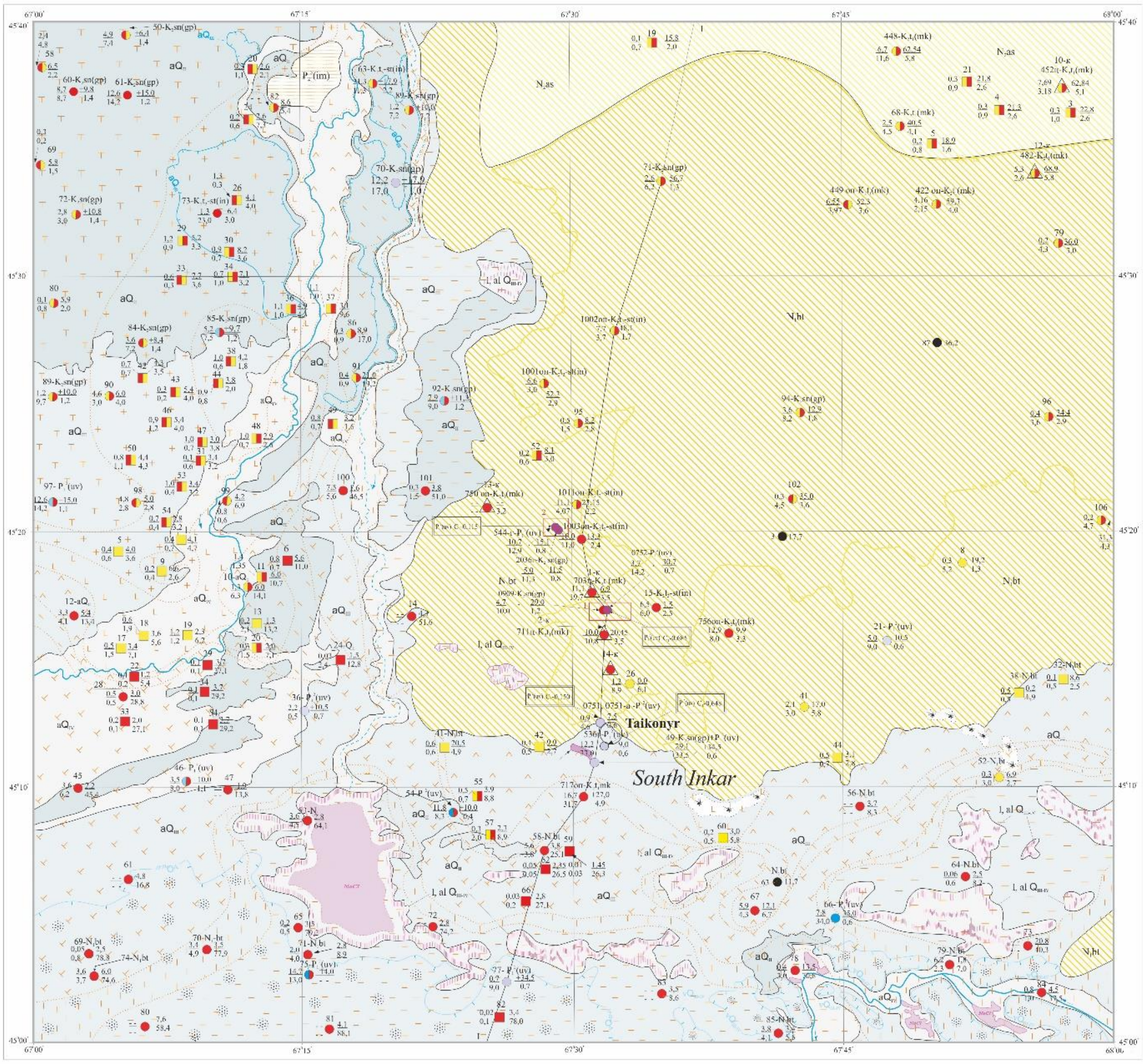
Zhapak aquifer is spread over tens of kilometres in all directions. Therefore, this horizon is schematized for design purposes as an unlimited reservoir. When assessing groundwater reserves, the impact of the group of water intakes of JV Katko LLP in the area under consideration is not taken into account. These water intakes are located at a distance of 130-140 km to the southeast of the water intake at section South Inkai. The radius of influence of water intakes of JV Katko LLP does not exceed 100-120 km. Therefore, the impact from the group of water intakes of LLP JV "Katko" on the considered water intake will not occur.

The water intake for technical water supply operating the Zhapak aquifer will operate in a continuous operation mode for 10,000 days with a capacity of 220 m3 / day. Groundwater reserves are calculated in an amount equal to the actually achieved flow rate at self-flowing through the production well No. 6289 - 8.8 dm3 / s (760.3 m3 / day). In addition, a check calculation was made for the same amount of reserves for reserve well No. 6288 [16].

Thus, according to the above estimate, the provision of groundwater reserves will be 27 years. Since, at the same time, the groundwater resources will not be exhausted; subsequently, it will be necessary to recalculate the reserves and continue the operation of this water intake.

After the completion of the development of the South Inkai uranium deposit, the operation of the water intake of the Uvanas aquifer will continue to provide drinking water to the Taikonyr village for several decades.

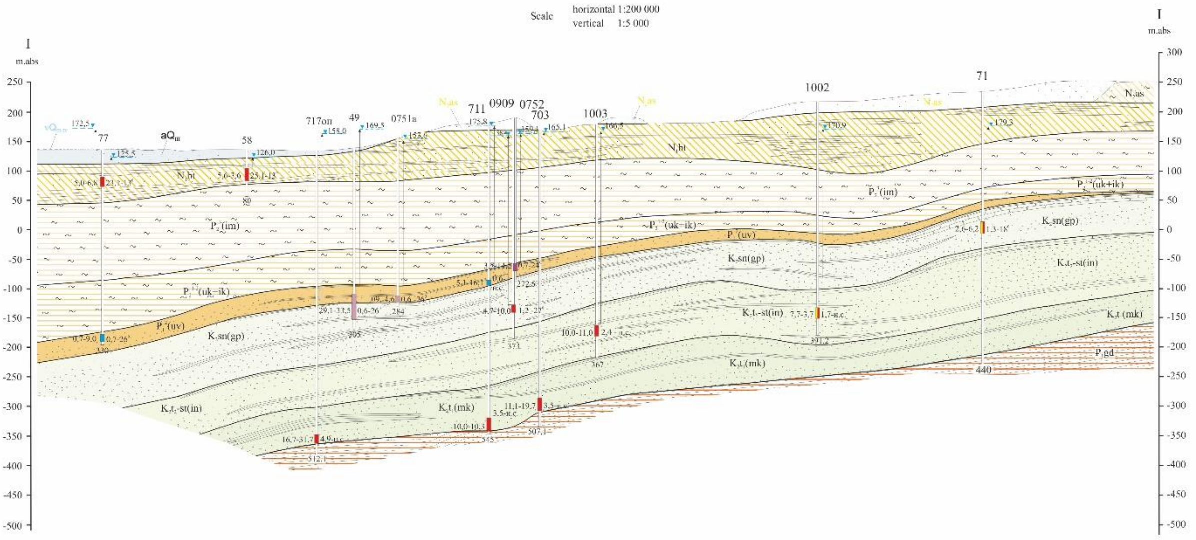
HYDROGEOLOGICAL MAP



Scale 1:200 000

Hydrogeological section along the line I-I

Scale horizontal 1:200 000
vertical 1:5 000



LEGEND

1. Distribution of aquifers and complexes

aQ_{IV}	Aquiferous modern alluvial horizon. Sands, pebbles and gravels interbedded with sandy loam and loam
$l,al\ Q_{III-IV}$	Aquiferous Upper Quaternary-modern lacustrine and alluvial-lacustrine horizon. Fine-grained and fine-grained clay sands and sandy loams, occurring among loams and clays
aQ_{III}	Upper Quaternary alluvial aquifer. Interlayers of sands, less often gravel and pebbles among loams and clays
aQ_{II}	Mid-Quaternary alluvial aquifer. Sands, gravels, pebbles, sandy loam
N_2as	Locally aquiferous Pliocene Askazansor horizon. Interlayers and lenses of sands with gravel and sand and gravel deposits among loams and clays
N_1bt	Locally aquiferous Miocene Betpak-Dala horizon. Interlayers and lenses of sands with gravel, sand and gravel deposits among dense carbonate clays
$P_1^2(uv)$	Upper Paleocene aquifer (Uvanassky) horizon. Sands greenish-gray quartz-feldspar fine-grained and medium-grained with the inclusion of gravel, (only in the section)
$K_2sn(gp)$	Aquifer Senonian (Zhalpak) horizon. The sands are variegated and green fine-grained. In the lower part of the section, there are sands of varying grained and medium grained. At the top of the horizon there are dense massive clays, variegated silts (only in the section)
K_2t_2-$st(in)$	Aquiferous Upper Turonian-Santonian (Inkuduk) horizon. Fine-grained and medium-grained sands with gravel and pebbles with interlayers and horizons of dark gray dense clays, (only in the section)
$K_2t_1(mk)$	Lower Turonian (Mynkuduk) aquifer. Sands are whitish and light gray, fine-grained and medium-grained; in the lower part of the section - mixed-grained sands with the inclusion of gravel and pebbles; at the top of the horizon - dark gray and gray-green massive dense clays (only in the section)
(line)	Borders of various aquifers and complexes

2. Distribution of permeable, but practically waterless (drained) and water-resistant rocks

vQ_{III-IV} (line)	Non-aquifer permeable (drained) Upper Quaternary-modern Aeolian horizon. Sands
aQ_{III} (line)	Non-aquiferous permeable (drained) Upper Quaternary alluvial horizon. Sands
N_2as (line)	Non-aquiferous permeable (drained) Pliocene Askazansor horizon. Quartz sands of various grains with lenses and interlayers of gravelstones, sandstones, less often clays
vQ_{III-IV}	Non-aquifer permeable (drained) Upper Quaternary-modern Aeolian horizon. Sands (cut only)
N_2as	Non-aquiferous permeable (drained) Pliocene Askazansor horizon. Different-grained quartz sands with lenses and interlayers of gravelstones, sandstones (only in the section)
$P_2^3(im)$	Water-resistant Upper Eocene (Intymak) horizon. Dark gray, green-gray, green dense clays with horizontal discontinuous bedding (only in the section)
$P_2^{1-2}(uk+ik)$	Water-resistant Lower-Middle Eocene (Uyuk-Ikan) horizon. Greenish-gray and dark gray dense massive clays (only in the section)
P_1gd	Non-aquiferous fracture zone of the Lower Permian deposits of the Zhidelisay suite. Siltstones cherry-brick-red, brown, gray cross-bedded (only in the section)

3. Water points

78-N_1bt $\frac{0,4}{3,0}$ ● $\frac{13,5}{70,8}$	Well	Figures: Above - the number and index of the geological age of the water-bearing rocks. Left: in the numerator - well flow rate, dm^3/s; in the denominator - the decrease, m. Right: in the numerator - the depth of the established water level, m; denominator - water salinity, g/dm^3
N_1bt 87 ● 112	Without well	Above - geological index of rocks at the bottom of the well; left - number; right - waterless well depth, m
38 N_1bt $\frac{0,5}{0,5}$ ■ $\frac{0,2}{1,9}$	Well	The designations are the same as for the well
1-к 703-ц-$K_2t_1(mk)$ $\frac{11,1}{19,7}$ ▲ $\frac{6,9}{3,5}$		Experienced cluster of hydrogeological wells. Above is the number of the bush and the well in the bush The rest of the designations are the same as for the well

4. Chemical composition and mineralization of groundwater in water points

- With the predominance of the hydrocarbonate anion
- With the predominance of the chloride anion
- With the predominance of the sulfate anion
- Sulfate-chloride
- Chloride-sulfate
- Hydrocarbonate-chloride
- Mixed anionic composition, three-component

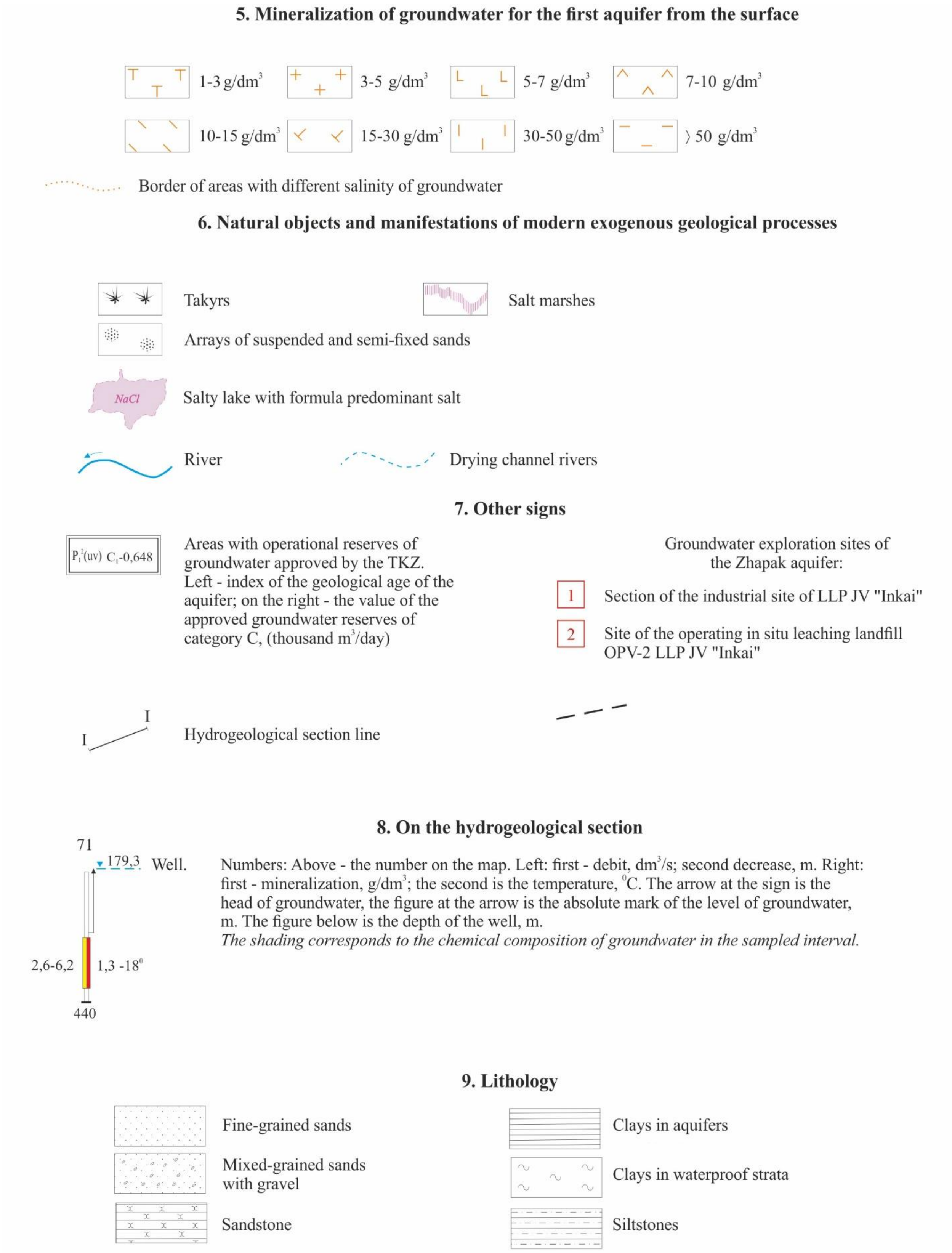


Fig.13 Hydrogeological map of the region and hydrogeological section [16]

4. Social-economic including social and environmental aspects of the projects

4.1 Economic aspects of energy resource development and its impacts on groundwater resources

Energy resources

The South Inkai mine is a major project and is therefore of great economic importance to the region.

Capital costs for Inkai are estimated to be $1.064 billion over the remaining life of the current mineral reserves. The remaining capital costs, as of January 1, 2018, includes $811 M for wellfield development, $149 M for construction and expansion, and $104 M for sustaining capital. It is assumed that wellfield development costs will trend with the production schedule. Capital for construction and expansion is heavily weighted to 2018 to 2020 due to the capital required for the Ramp-up, as well as upgrades planned for existing facilities.

Estimated operating expenditures, excluding taxes and royalties, for ISR mining, surface processing, site administration and corporate overhead for Inkai from 2018 to 2045 are estimated to be $17.86/kg of U over the remaining life of the current mineral reserves.

Mining costs consist of annual expenditures incurred at Inkai to extract the uranium from the ore zone and pump the pregnant solution to the surface for further processing. Surface processing costs are expenditures incurred to turn the pregnant solution from the wellfields into the product. This includes IX (adsorption and elution), precipitation, thickening, drying, and packaging circuits. Site administration costs consist of general maintenance, health, safety and environment, camp and catering costs, along with charges for additional functions performed at the mine site office, such as geology and supply chain management. Corporate overhead costs consist of the marketing and transportation of the finished product, along with additional charges due to the administration functions at the Shymkent office, such as the finance and legal departments.

The economic analysis results in an after-tax NPV (at a discount rate of 12%), for the net cash flows from January 1, 2018, to mid-2045, of $2.2 billion for JV Inkai mineral reserves. Using the total capital invested, along with the operating and capital cost estimates for the remainder of the mineral reserves, the after-tax IRR is estimated to be 27.1%.

The main economic indicators of the project from 2018 to 2045 are (CAD M) [1]:

- Sales Revenue - 14,786.1
- Operating Costs - 2,188.5
- Capital Costs - 1,063.5
- Mineral Extraction Tax - 383.5
- Corporate Income Tax - 2,245.5
- Net cash flow - 8,905.1

As can be seen from the above indicators, the South Inkai project is economically very important both for the company and for the region.

Groundwater resources

Capital expenditures for the exploration of underground water and water supply, as well as operating costs, are fully assumed by JV Inkai LLP, due to the fact, that the bulk of the explored underground waters will be used for the needs of the company.

Under the terms of subsoil use, on the basis of an agreement concluded between JV Inkai LLP and local government agencies, water supply to the local population is also fully provided by JV Inkai LLP. Accordingly, the subsoil user assumes these costs. The costs of water supply (capital and operating) are included in the capital and operating costs of uranium production. These costs represent 1.5% of the total operating costs of uranium production.

4.2 Social aspects of energy production and groundwater utilization

Energy resources

Social and community factors JV Inkai operates in the Suzak district of the South Kazakhstan region. The territory of the district is about 41,000 km2, and its population is over 50,000. The town of Taikonur, with a population of about 680, is in this district and the Inkai deposit is located nearby. A major part of Kazakhstan's uranium deposits are in the district. The district also has deposits of gold, silver, coal and other minerals. Meat and dairy products production is a leading agriculture industry in the district. In accordance with JV Inkai's corporate responsibility strategy and to comply with its obligations under the Resource Use Contract, JV Inkai finances projects and provides goods and services to support the district's social infrastructure. Under the Resource Use Contract, JV Inkai is required to finance the training and development of Kazakhstan personnel. The Resource Use Contract imposes local content requirements on JV Inkai with respect to employees, goods, works and services.

Mining and production of uranium are directly related to the radiation hazard. Therefore, ensuring the radiation safety of the personnel of the enterprise and the local population is the primary task of the subsoil user. Radiation safety rules are governed by the laws of the Republic of Kazakhstan (Law on use of atomic energy, Law on radiation safety of the population, Law on licensing, Ecology Code), and Technical rules "Nuclear and radiation safety", adopted by the Government Provision [17].

In turn, these laws are fully coordinated with the international rules defined by the IAEA. To ensure safety at the enterprise, as well as in nearby settlements, constant radiation monitoring is carried out, which ensures continuous monitoring of the radiation situation.

The implementation of the necessary safety measures is monitored by state bodies represented by the Atomic Energy Committee of the Republic of Kazakhstan as a regulator, and Nuclear Technology Safety Centre. Taking into account the specifics of uranium deposits, subsoil users of Kazakhstan constantly train and retrain production personnel, in many specialities, at the universities of Kazakhstan and Russia. In addition, a specialized Nuclear University has been created in the national company Kazatomprom, which regularly organizes refresher courses for industry specialists. At the same time, given the large population of South Kazakhstan, local residents have the preferential right to be employed in uranium production.

At the international level, uranium mining and production in Kazakhstan is monitored in accordance with IAEA (the program of technical cooperation) – "Supporting Radioecological Monitoring", and European Regional projects of IAEA, such as Introducing and Harmonizing Standardized Quality Control Procedures for Radiation Technologies, Strengthening Education and Training Infrastructures and Building Competence in Radiation Safety, Strengthening the Inspection Capabilities and Programmes of the Regulatory Authorities [17].

Groundwater resources

The State manages water resources in Kazakhstan, an authorized state body the Water Resources Committee, manages water use and conservation, local representatives and executive bodies (maslikhats, akims or oblasts, cities, districts, auls/villages), and other state bodies, manage aspects of water use within their competencies. For example, groundwater management is carried out by the WRC in cooperation with the state body for geology and conservation of mineral resources. Other specialized authorized state bodies involved in water use and conservation include those dealing with environmental protection, mineral resources, fishery, flora, fauna, and state sanitary and veterinary supervision. The relationships between state management bodies concerning the rational use and conservation of water is regulated by Kazakhstan's legislation (UNDP, 2004) [18].

The WRC of the Ministry of Agriculture carries out state management and protection of water resources at the national level; participates in the development and implementation of state policies for use and protection of water resources; develops programmes for the development of

the water sector; plans complex use and protection of water resources; issues licenses for special water use; allocates water resources between territories and sectors; adopts standard rules for water use and cooperates with neighbouring countries on water relations and other functions.

The basin water management units are territorial subdivisions of the WRC and provide integrated management of water resources and coordination between water users in the basin (UNDP, 2004). They carry out integrated management of the use and protection of water resources at the basin level, coordinate activities concerning water relations within the basin, perform state control of use and protection of water resources and compliance with water legislation, conduct state accounting, Kazakhstan 17 monitoring and public water inventory in conjunction with the environmental bodies and agencies for geology, protection of natural resources and hydrometeorology, issue licenses for special water use and other functions.

State water management in Kazakhstan is based on the principles of recognizing the national and social importance of water resources, sustainable water use, separating the functions of state control and management and basin management. Based on these principles, in 1998, the government began a structural reorganization of the water system, aimed at the clear assignment of responsibilities at national and local levels. According to Government Resolution No. 1359 of 30 December 1998, oblast committees for water resources were reorganized into "republican state enterprises for water", charged with technical maintenance of hydrosystems, water headworks, mains systems, pumping stations, group water pipelines, i.e. the facilities that provide consumers with water [19].

In the context of limited and vulnerable water resources and dependence on transboundary flows, SDG 6 is relevant for Kazakhstan. The country is a party to the UN Convention on the Protection and Use of transboundary watercourses and international lakes. It due to the fact that Kazakhstan depends on transboundary water resources. Access of the population to clean water is a strategic priority of the country [6]. Despite constant work in this direction, the provision of the population access to water, including quality drinking water, remains an acute problem in the country.

A very important social aspect is that the underground waters, which occur together with the uranium deposit, can be used by the local population for economic and drinking purposes.

4.3 Environmental issues of energy production and groundwater utilization

Energy resources

Socio-environmental-economic viability and impact assessment

The long-term profitable mining and processing of uranium at the South Inkai deposit, as well as the strategic plan, calculated until 2045, to continue the profitable operation of the enterprise, testifies to the economic and socio-ecological viability of the project. When mining and processing radioactive uranium ores, environmental safety issues are of particular importance. For this reason, government and subsoil users pay great attention to the environmental safety of production and health protection of production personnel and the local population [20].

In accordance with the Environmental and Water Codes of Kazakhstan, before the start of the development of the South Inkai field, all necessary studies were carried out.

The Ecological Code requires that the subsoil user obtain environmental permits to conduct its operations [21]. A permit certifies the holder's right to discharge emissions into the environment, provided that it introduces the "best available technologies" and complies with specific technical guidelines for emissions as set forth by the environmental legislation. Government authorities and the courts enforce compliance with these permits and violations may result in civil, administrative and/or criminal liability, the curtailment or cessation of operations, orders to pay compensation, orders to remedy the effects of violations and orders to take preventative steps against possible future violations. In certain situations, the issuing authority may modify, renew, suspend or revoke the permits. JV Inkai has applied for and received a permit for environmental emissions and discharges for the operation that is valid until December 31, 2022.

Pursuant to the Water Code, JV Inkai is qualified as a primary water user and is entitled to extract water directly from water sources for its own use. JV Inkai has obtained special water use permits, which have various expiry dates. Water usage under the permits is limited to the purposes defined in the permits.

Observations of the operating mode of the water intake are carried out to control the development of the dynamics of groundwater in order to adjust the operating conditions. These observations are carried out on production wells and include measurements of the volume of water production once a day, dynamic level, groundwater temperature - 3 times a month. The results are recorded in a special journal. Observations are carried out by the service that operates the water intake.

The water intakes at the newly assessed sites will operate with a slight decrease in the groundwater level.

A decrease in the piezometric level in the productive aquifer during the operation of the water intake will not have any effect on vegetation and subsidence of the earth's surface. Therefore, special measures for environmental protection are not required.

As an industrial company, JV Inkai has developed programs to reduce, control or eliminate various types of pollution and to protect natural resources. JV Inkai actively monitors specific air emission levels, ambient air quality, nearby surface water quality, groundwater quality, levels of contaminants in soil and the creation of solid waste. It must also submit annual reports on pollution levels to Kazakhstan’s environmental, tax and statistics authorities. The authorities conduct tests to validate JV Inkai’s results.

If JV Inkai’s emissions were to exceed the specified levels, this would trigger additional payment obligations. Moreover, in the course of, or as a result of, an environmental investigation, regulatory authorities in Kazakhstan have the power to issue an order reducing or halting production at a facility that has violated environmental standards.

The Ecological Code and the Resource Use Contract set out requirements with respect to environmental insurance.

Radiation protection

There is a radiation protection program that is based on international standards for exposure (International Atomic Energy Agency, "IAEA") that monitors worker health and safety. Key elements of the program include good housekeeping, and monitoring of gamma radiation exposures through the use of worker thermoluminescent dosimeters ("TLD"s) (reported and posted quarterly) and periodic radon measurements at selected areas of the plant.

Small quantities of sand may accumulate in the process ponds. This material may contain radioactive materials and is planned to be disposed of in an approved waste disposal area off-site.

No material issues of concern became evident, and no fatal flaws from an environmental perspective were identified.

The South Inkai project is operating and has obtained the necessary permits for the production operations currently underway.

The community of Taikonur is approximately 10 km from the South Inkai site. There are no residents in the immediate mine area.

In view of the depth of the zones being mined and the relative isolation of the aquifer, there is no aquifer remediation planned as part of the closure. The surface disturbances will be reclaimed, and process facilities will be removed.

Under the subsoil use contract, South Inkai is required to contribute to a reclamation fund. As of December 31, 2013, the Uranium One portion of the asset retirement obligations (on an undiscounted basis) has been estimated at US$7.8 million for the successful decommissioning, reclamation and long term care of the surface and wellfield facilities. The total asset retirement obligation is estimated to be US$11.1 million.

Closure plans

The liquidation of uranium production is carried out in accordance with the requirements "Rules for liquidation and conservation of subsoil use objects", on the basis of which the following should be true: on the basis of the liquidation Project (five years before the completion of the development of the deposit) - dismantling of equipment, liquidation of technological wells (except for the monitoring system), restoration of disturbed lands, provision of a set of radiation safety measures for personnel and the local population, elimination of the environmental consequences of industrial activities. All liquidation measures take into account not only the requirements of the legislation of Kazakhstan but also, without fail, the requirements of the IAEA.

JV Inkai is subject to decommissioning obligations which are largely defined by the Resource Use Contract. JV Inkai has established a separate bank account and has made the required contributions to the account as security for decommissioning Inkai. Contributions are set as a fraction of gross revenue and are capped at $500,000 (US). The account has been fully funded by JV Inkai in this amount. The estimated decommissioning cost in 2016 was $10 M (US) on a 100% basis and is in the process of being revised [1].

Groundwater resources

Socio-environmental-economic viability and impact assessment Groundwater resources that meet the needs of production and local population water are an important and integral part of uranium production. As an integral part of ensuring the social sphere and economy of the project, water resources are undoubtedly socially and economically viable. Considering that after the liquidation of the uranium mine, water resources will meet the needs of the local population in water for decades, their social significance is obvious.

Radiation protection

The radioactive safety of groundwater during the operation of the uranium production is ensured by the production monitoring system. After the completion of production, the monitoring system will continue to operate; its financing will be carried out at the expense of the state under a special monitoring project.

Closure plans

After the completion of production activities, water consumption will sharply decrease, in connection with which the term of supply of groundwater resources will become unlimited, and in the foreseeable future, the elimination of water intake is not planned.

4.4 Resource depletion aspects and Groundwater depletion or contamination.

Energy resources

The South Inkai deposit has been secured with reserves and resources for over 25 years. The prospects for discovering new uranium mineral resources in the area of this deposit are very significant. Due to the fact that uranium deposits of the roll-front type are always associated with groundwater, including fresh, in the future, when exploring new reserves of uranium, new reserves of groundwater will be explored.

Taking into account the experience of geological exploration for uranium for many decades in this area, it is highly likely that new discoveries of large uranium and groundwater deposits can be expected.

Groundwater resources

The depletion of groundwater is a natural process due to its regular use. Pollution can occur only in case of violation of design decisions and environmental regulations, as well as in the event of emergencies at the production facilities of the South Inkai mine. Therefore, monitoring the state of groundwater is mandatory in accordance with the requirements of the Environmental and Water Codes of Kazakhstan.

Compliance with the technology of uranium production, as well as design safety measures, with constant monitoring, will ensure the exclusion of groundwater pollution. Field project status and feasibility for energy production and groundwater utilization

5. Technological feasibility aspects for energy resource production and groundwater utilization

Energy resources

Mining at Inkai is based upon a conventional and well-established ISR process. ISR mining of uranium is defined by the International Atomic Energy Agency as: "The extraction of ore from a host sandstone by chemical solutions and the recovery of uranium at the surface. ISR extraction is conducted by injecting a suitable leach solution into the ore zone below the water table; oxidizing, complexing and mobilizing the uranium; recovering the pregnant solutions through production wells; and finally, pumping the uranium-bearing solution to the surface for further processing."

There is ongoing wellfield development to support the current production plan.

As a result of extensive test work and operational experience, a very efficient process of uranium recovery has been

The process consists of the following major steps:

- uranium in-situ leaching with a lixiviant
- uranium adsorption from solution with IX resin
- elution of uranium from resin with ammonium nitrate
- precipitation of uranium as yellowcake with hydrogen peroxide and ammonia
- yellowcake thickening, dewatering, and drying

-packaging of dry yellowcake product in containers.

According to the project for the development of the South Inkai field, profitable production with high efficiency will be carried out until 2045. Most of the processes in the mine and uranium production plant are computerized. All data is received and processed online. Both summary information (obtained as a result of processing) and primary information are sent to the head office of the company.

- Recovery factors
- Technological developments, SMART mining, Big data etc
- Detailed studies done (pre-feasibility, feasibility studies)

Groundwater resources

Groundwater, which occurs with uranium ores in the same geological section, is explored in detail and is used for drinking and technical water supply to the local population, the production process and the mineworkers. Two water intakes (for industrial water and for drinking water) have been built at the groundwater deposit, which for many years have been providing water for production, production personnel and the local population.

6. Level of knowledge/confidence in estimates

6.1 Geological or other relevant aspects

Energy resources

The stratigraphic sequence at Inkai ranges from Cretaceous to Quaternary sediments. Neogene-Quaternary sediments of continental origin form the uppermost cover. They do not host significant uranium occurrences. These are underlain by 100 to 150 m of Palaeogene clay-dominated marine sediments. Elsewhere in the basin, these display a lower facies transition zone of brackish sediments that host the uranium deposits of Tortkuduk and of the Taukent area

(Kanzhugan and Moynkum). The underlying Upper Cretaceous strata are divided into three horizons, listed from youngest to oldest: the Zhalpak horizon; the Inkuduk horizon; and the Mynkuduk horizon (Fig.11).

The Zhalpak horizon is Campanian-Maastrichtian in age and is generally comprised of medium-grained sand, with occasional clay layers.

The Inkuduk horizon is Coniacian-Santonian in age and is typified by medium to coarse-grained sands, with occasional gravels. In the Inkuduk horizon, there are three sub-horizons representing indistinct transgressive alluvial cycles composed of several incomplete elementary rhythms. Lower and middle sub-horizons are composed mainly of coarse clastic sediments of channel facies while the upper sub-horizon is made of floodplain channel formations. The thickness of the Inkuduk horizon is up to 120 m, and the depth to the bottom varies from 300 to 420 m at the Inkai deposit, being a function of both basin architecture and the topography.

The Mynkuduk horizon is Turonian in age, uncomfortably overlying the Permian argillites and dominated by fine to medium-grained sands. These sands are generally well sorted, reflecting a probable overbank environment. Sediments of the Mynkuduk horizon represent an alluvial cycle of the first order where several (up to ten) elementary rhythms with a thickness up to several metres can be identified. Each of them begins with coarse, poorly sorted gravel, inequigranular sands with gravel and pebble and ends with small, clastic rocks, sometimes interbeds (up to 20 cm) of dense sands with carbonaceous cement. In some areas in the basal part of the horizon, mottled sandy clays and siltstones of floodplain facies are developed. The dominating colour of the rocks is greyish-green to light-grey for the channel sand-gravel sediments. The total thickness of the sediments of the Mynkuduk horizon in the area is 60 to 80 m. The regular alternation of channel sediments with floodplain sediments is characteristic of lateral direction, where initial mottled and green sand-clay formations in floodplains and watersheds are replaced by channel midstream, grey bars and rocks.

Different lithologic and geochemical types have been studied for the content of their organic carbon, total iron, and iron contents. The zone of uranium mineralization is located along the geochemical barrier marked by the contact zone of the incompletely oxidized rock and the primary grey-coloured rock. Iron oxides are nearly absent in this zone. Organic carbon content is decreased. Some associated pyrite, and sometimes carbonates, are observed. Four geochemical host rocks types can be identified at the deposit:

- diagenetically reduced grey sands and clays containing coalified plant detritus
- green-grey sands and clays, reduced both diagenetically and epigenetically by “gley” soil (anaerobic organic) processes
- non-reduced initially mottled sediments
- yellow-coloured lithologies that underwent stratal epigenetic oxidation.

The initial colours are typical of the channel of flood-plain facies. Diagenetically reduced grey sands and gravel of channel facies are more favourable for uranium deposition compared to greenish-grey or grey-green sands. The morphological types of uranium mineralization in the vertical section are shown in Figures 12 and 13.

Groundwater resources

Groundwaters of various uranium-bearing horizons, taking into account geochemical factors, ensure the formation of uranium ores.

Since groundwater has a decisive influence on the formation of uranium mineralization, much attention is paid to their study at all stages of prospecting and exploration of roll-front type uranium deposits. Practically at all uranium deposits of this type, water supply for production and personnel is provided at the expense of associated explored groundwater.

The possibility of using these waters for production and technical purposes and for drinking has been agreed with the Department of Public Health of the South Kazakhstan region.

Radiologically safe waters. The content of heavy metals and other harmful micro-components does not exceed the established standards, which is confirmed by the analyzes carried

out by the Center for Sanitary and Bacteriological Expertise of the South Kazakhstan region. Toxic elements and harmful substances in the groundwater of the water intake area are contained either in negligible concentrations or not found.

Organoleptic characteristics (colour, smell, taste, turbidity) also comply with drinking standards.

The absence of pollution is due to the geological and hydrogeological conditions of the territory of the location of the water intake - the deep occurrence of the operational aquifer, isolated from the surface by powerful aquicludes.

Thus, the quality of groundwater generally satisfies the goals of industrial, technical and drinking water supply of uranium production and the local population.

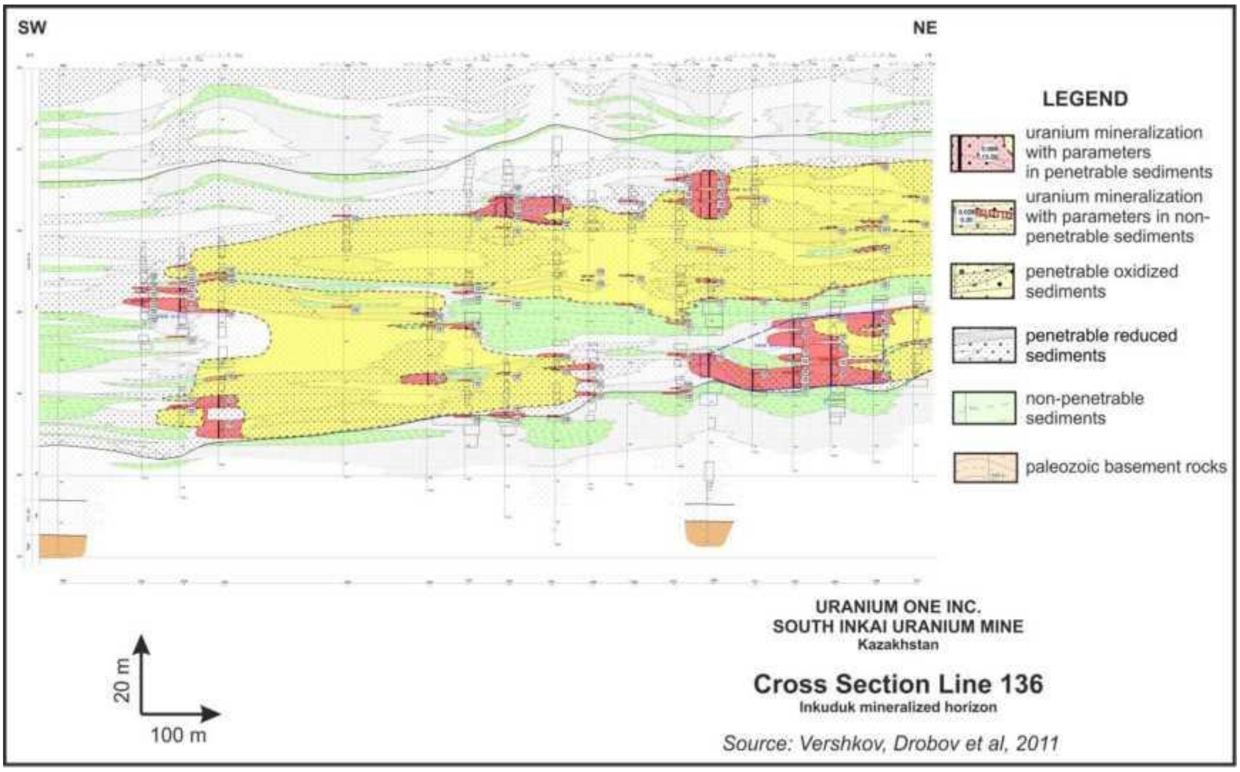
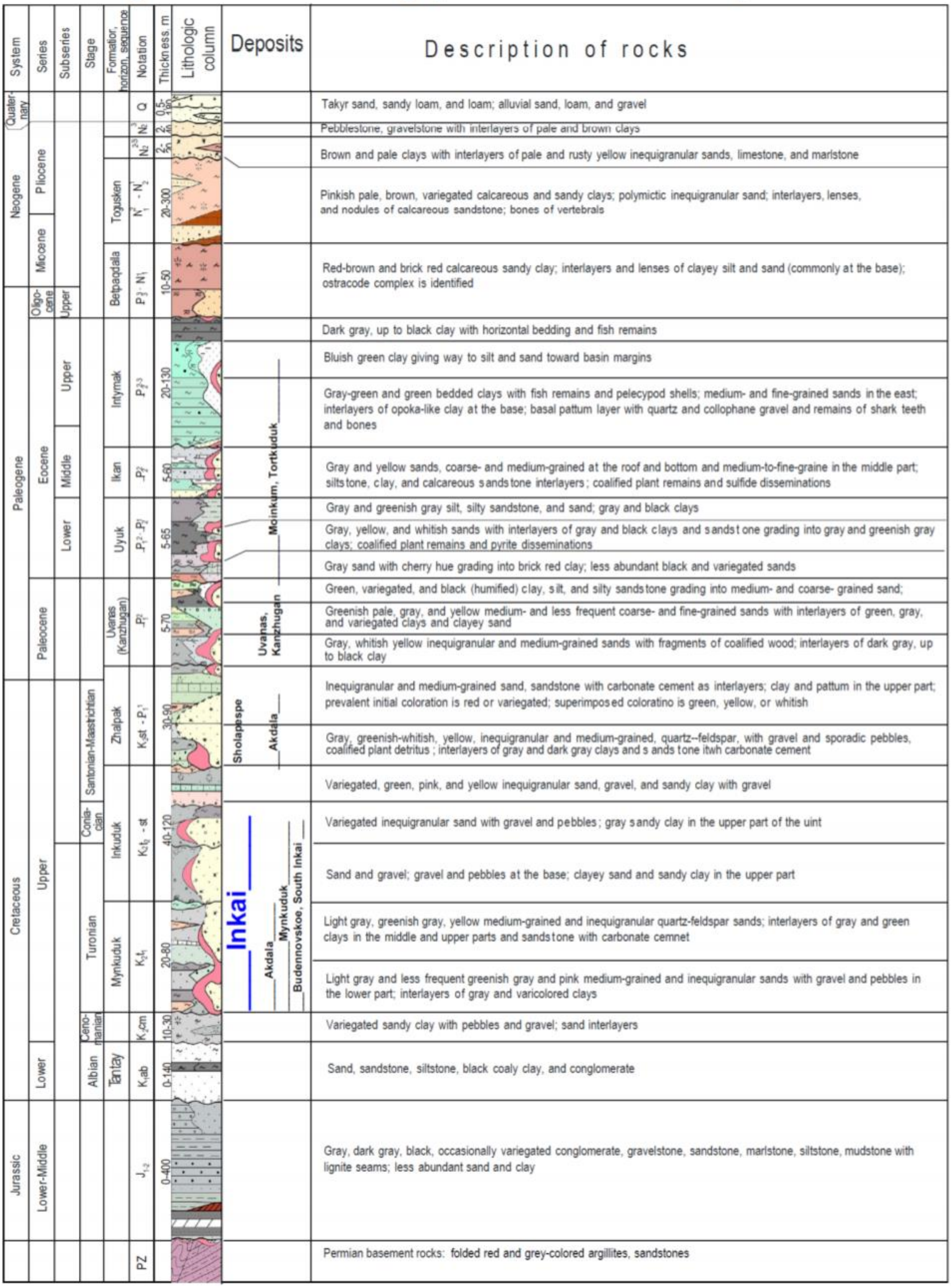


Fig.14 Cross-section [1]



(Source: Kislyakov and Shetochkin, 2000; modified by Cameco in 2016)

Fig.15 Schematic Stratigraphic Column for the Chu-Sarysu Basin [4,1]

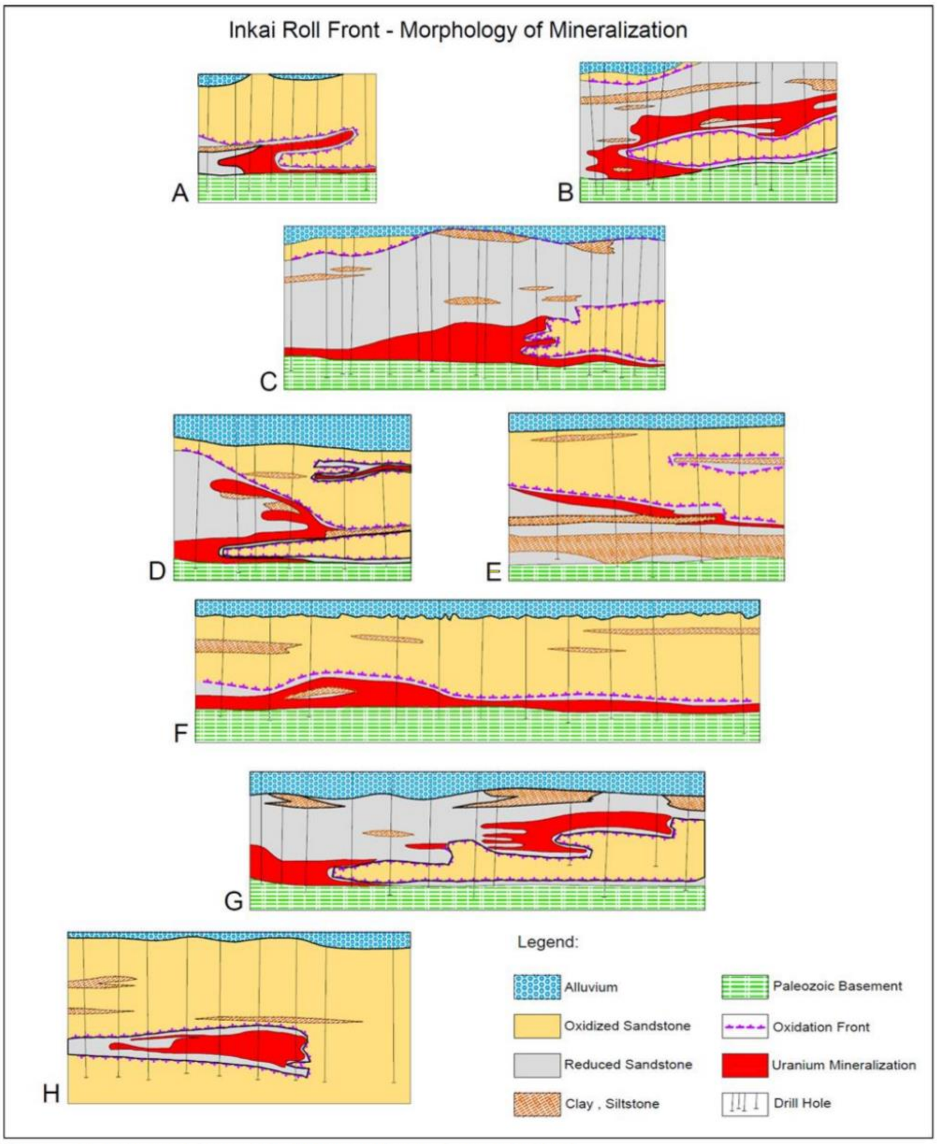


Fig. 16 Inkai Roll-Front morphology mineralization

6.2 Estimates of quantities and volumes of energy and groundwater resources

Energy resources

Uranium mineralization and groundwater are explored in detail and reliably identified.

The estimated mineral resources and reserves at Inkai are located in the Mining Allotment Area. The preparation of the resource models and estimates followed the SRC guidelines. The models and estimates for Blocks 1 and 2 MA were completed by Volkovgeology. 2K LLP completed the model and estimate for Block 3 MA. Volkovgeology is a subsidiary of Kazatomprom and is involved in prospecting, exploration and development of uranium deposits in Kazakhstan. The estimates were done using the GT estimation method on two-dimensional blocks in the plan.

In 2003, Cameco performed a validation of the Kazakhstan estimate for Block 1 and confirmed the estimated pounds of uranium to within 2.5% of the Kazakhstan estimate. The same Kazakhstan estimate was validated by an independent consulting firm in 2005. In 2007, Cameco and an independent consulting firm verified the Kazakhstan estimate for Block 2 and obtained results in agreement with the Kazakhstan estimate [7,22]. In 2016, Cameco reviewed the criteria to bridge the Kazakhstan mineral resources and mineral reserves classification system with the CIM Definition Standards. Previously the Kazakhstan C2 category was aligned with the inferred

resource category and the C1 category with the indicated resource category. Now the C2 category can be aligned with the inferred or indicated resource categories, and C1 to the indicated or measured resource categories.

The current mineral resources and reserves estimates are based on 2,352 surface drill holes. Summaries of the estimated mineral resources and mineral reserves for Inkai with an effective date of January 1, 2018, are shown in Table 5.

Table 5 South Inkai Mineral Resources and Mineral Reserves - CRIRSCO and UNFC Categories Correlation

Category NI-43-101 (CRIRSCO)	Category UNFC	Category GKZ	Total tonnes (x1,000)	Grade, % U	Total M Kg U
Resources:					
Measured	E2F2G1	C1	36,680.9	0.022	8.2
Indicated	E2F2G2	C2	21,132.2	0.020	4.1
Inferred	E3F2G3	P1	116,394.6	0.025	29.0
Reserves:					
Proven	E1.1F1.1G1	A, B	214,104.1	0.030	64.7
Probable	E1.1F1.1G2	B, C1	166,913.0	0.024	39.4

Groundwater resources

Exploration and assessment of the operational reserves of groundwater in the water intake of the village Taikonyr and technical water intakes of JV Inkai LLP will allow for uninterrupted water supply to both the Taikonyr settlement and industrial facilities for a long time (until 2045).

The water intake sites have been prepared for industrial operation, the groundwater resources have been approved by Yuzhkaznedra (protocols No. 907 dated December 22, 2005, and No. 971 dated December 05, 2006) in the following quantities by categories according to the GKZ standard (Table 6) [23,24]:

Table 6 Summary of Resources of the groundwater by categories according to the GKZ standard

Section	Category	Resource, m3/day
section 1 (wells 520g, 536g)	C1	648
section 1 (wells 520g, 536g)	C2	216
section 2 industrial site (well 0909)	C1	660
section 3 (well No. 0910)	C1	325
Total	C1	1633
	C2	216

The estimates of uranium and groundwater reserves and resources are very reliable, which is confirmed by the results of mining.

7. Classification of the mineral or energy projects using UNFC

7.1 Review of Socio-economic information including social and environmental (E axis)

Energy resources

The South Inkai uranium deposit is located in South Kazakhstan, a region with low employment, so the creation of such a large-scale production provides jobs for hundreds of local residents. The production is highly profitable, and therefore the local budget receives large amounts of taxes. The optimal performance of the uranium ore mining and processing plant ensures the profitable operation of the plant until 2045.

Mining and production of uranium are associated with radiological risks; therefore, the main attention is paid to environmental safety and health protection of personnel and local

population at the enterprise. Considering that one of the shareholders of JV Inkai is the Canadian company Cameco, the enterprise has implemented not only Kazakhstani, but also international environmental safety standards, for which monitoring systems have been organized to ensure constant monitoring of the radiation situation, both uranium production and used groundwater.

Therefore, the environmental-socio-economic viability of ore mining, production of concentrates and their marketing can be classified according to UNFC by sub-category E1.1 and category E2 (Table 7).

Table 7. Environmental-socio-economic viability of South Inkai (uranium) project

Category	**Sub-Category**	**Sub-Category Definition**
E1	E1.1	Development is environmentally-socially-economically viable on the basis of current conditions and realistic assumptions of future conditions. The actual results of the development of the South Inkai project (uranium) for many years confirm the validity of the assignment to the E1.1 sub-category.
Category	**Definition**	**Additional explanations**
E2	Development and operation are expected to become environmentally-socially-economically viable in the foreseeable future.	Development and operation are not yet confirmed to be environmentally-socially-economically viable but, on the basis of realistic assumptions of future conditions, there are reasonable prospects for environmental-socio-economic viability in the foreseeable future.

Groundwater resources

The study area is characterized by an acute shortage of surface water. In this regard, groundwater is the main source of water supply for both production and the population. There are several aquifers in the region with active water inflows, some of which can be used for technical purposes, and others as drinking water supply.

Exploration of underground waters and organization of water supply is carried out by the subsoil user. At the same time, the subsoil user provides water not only for their own needs but also for the water needs of the local population. The subsoil user takes the costs of providing water to the cost of uranium production.

The water used meets all sanitary and epidemiological standards; constant monitoring confirms this compliance.

Thus, the socio-economic feasibility of groundwater extraction to support the production of uranium and the population can be classified according to UNFC-20019 by sub-category E1.1 and category E2 (Table 8).

Table 8. Environmental-socio-economic viability of South Inkai (groundwater) project

Category	**Sub-Category**	**Sub-Category Definition**
E1	E1.1	Development is environmentally-socially-economically viable on the basis of current conditions and realistic assumptions of future conditions. The actual results of the development of the South Inkai project (groundwater) for many years confirm the validity of the assignment to the E1.1 sub-category.
Category	**Definition**	**Additional explanations**
E2	Development and operation are expected to become environmentally-socially-economically viable in the foreseeable future.	Development and operation are not yet confirmed to be environmentally-socially-economically viable but, on the basis of realistic assumptions of future conditions, there are reasonable prospects for environmental-socio-economic viability in the foreseeable future.

7.2 Evaluation of Project technical feasibility information (F axis)

Energy resources

The economic analysis, undertaken from the perspective of JV Inkai, is based on JV Inkai's share (100%) of Inkai mineral reserves, and results in an after-tax NPV (at a discount rate of 12%), for the net cash flows from January 1, 2018, to mid-2045, of $2.2 billion. Using the total capital invested, along with the operating and capital cost estimates for the remainder of the mineral reserves, the after-tax IRR is estimated to be 27.1%.

Capital costs for Inkai are estimated to be $1.064 billion over the remaining life of the current mineral reserves. The remaining capital costs, as of January 1, 2018, includes $811 M for wellfield development, $149 M for construction and expansion, and $104 M for sustaining capital. Capital for construction and expansion is heavily weighted to 2018-2020 due to the capital required for the Ramp-up, as well as upgrades planned for existing facilities.

Operating expenditures for ISR mining, surface processing, site administration and corporate overhead are estimated to be $17.8 per Kg of U over the remaining life of the current mineral reserves.

Taking into account the reliable technical and economic indicators of the South Inkai project, taking into account the long-term prospects of the enterprise, it is possible to unambiguously can be classified according to UNFC in sub-category F1.1, and category F2 (Table 9).

Table 9 Technical feasibility condition of South Inkai (uranium) project

Category	Sub-Category	Sub-Category Definition
F1	F1.1	Production is currently taking place (uranium).
Category	**Definition**	**Supporting Explanation**
F2	Technical feasibility of a development project is subject to further evaluation.	Preliminary studies of a defined project provide sufficient evidence of the potential for development and that further study is warranted. Further data acquisition and/or studies may be required to confirm the feasibility of development.

Groundwater resources

The technical feasibility of using groundwater was demonstrated in the project for the development of the South Inkai uranium deposit. The costs of groundwater extraction are included in the operating costs of uranium production at the South Inkai deposit, which is highly profitable.

Therefore, the technical and economic feasibility of groundwater extraction for industrial and drinking use can be confidently classified according to UNFC in sub-category F1.1, and category F2 (Table 10).

Table 10 Technical feasibility condition of South Inkai (groundwater) project

Category	Sub-Category	Sub-Category Definition
F1	F1.1	Production is currently taking place (groundwater).
Category	**Definition**	**Supporting Explanation**
F2	Technical feasibility of a development project is subject to further evaluation.	Preliminary studies of a defined project provide sufficient evidence of the potential for development and that further study is warranted. Further data acquisition and/or studies may be required to confirm the feasibility of development.

7.3 Review of Geological knowledge / Confidence in estimated (G axis)

Energy resources

The long history of exploration of the South Inkai uranium deposit, and of co-occurring groundwater since the Soviet period, repeated resource and reserve assessments confirmed by the results of field development, testify to the reliability of the available data and high accuracy of the assessment to ensure for a long time profitable operation of the enterprise.

Since there are prospects for the discovery of new uranium resources in this area, it is advisable to continue geological prospecting and exploration in the adjacent territories, which may lead to the discovery of new uranium deposits.

Based on the obtained reliable data in the assessment of resources and reserves of uranium, in accordance with the UNFC classification on the G axis, the resources and reserves of uranium correspond to category G1,2,3 (Table 11).

Table 11 Degree of confidence in the estimate of the uranium resources of the South Inkai deposit

Category	Definition	Supporting Explanation
G1	Product quantity associated with a project that can be estimated with a high level of confidence.	Detailed study of geological structures and distribution of uranium mineralization, high confidence
G2	Product quantity associated with a project that can be estimated with a moderate level of confidence.	Detailed study of geological structures and distribution of uranium mineralization, medium confidence
G3	Product quantity associated with a project that can be estimated with a low level of confidence.	Previously studied geological structures and uranium mineralization, low confidence

Groundwater resources

The exploration of the groundwater deposit was carried out in parallel with the exploration of the South Inkai uranium deposit for a long time. The exploration work was accompanied by assessments of groundwater resources. The operation of the water intakes, for many years, confirms the reliability of the exploration data on the quantity and quality of groundwater. Therefore, the data is reliable. Groundwater resources can be categorized as UNFC the resources of groundwater correspond to category G1 и G2 (Table 12).

Table 12 Degree of confidence in the estimate of the groundwater resources of the South Inkai deposit

Category	Definition	Supporting Explanation
G1	Product quantity associated with a project that can be estimated with a high level of confidence.	Detailed study of higrogeological structures and distribution of groundwater, high confidence
G2	Product quantity associated with a project that can be estimated with a moderate level of confidence.	Detailed study of higrogeological structures and distribution of groundwater, medium confidence

7.4 Classification of the projects uranium and groundwater resources using the UNFC scheme

Energy resources

Based on the above review of the uranium project (subsections 7.1, 7.2, 7.3) can be of the UNFC classification as (Table 13):

Table 13 Classification of uranium mineralization of the South Inkai deposit in accordance with UNFC

Class UNFC	Categories, and Sub-categories UNFC	Total tonnes (x1,000)	Grade, % U	Total M Kg U
Viable Projects	E1.1F1.1G1	214,104.1	0.030	64.7
	E1.1F1.1G2	166,913.0	0.024	39.4
Potentially Viable Projects	E2F2G1	36,680.9	0.022	8.2
	E2F2G2	21,132.2	0.020	4.1
Non-Viable Projects	E3F2G3	116,394.6	0.025	29.0

Groundwater resources

Based on the above review of the groundwater resources (subsections 7.1, 7.2, 7.3) can be of the UNFC classification as (Table 14):

Table 14 Classification of groundwater of the South Inkai deposit in accordance with UNFC

Class UNFC	Categories, and Sub-categories UNFC	m3/day
Viable Projects	E1.1F1.1G1	1633
Potentially Viable Projects	E2F2G2	216

8. Alignment to Sustainable Development Goals Implementation

8.1 National approaches

UN program "Sustainable Development Goals (SDGs)" adopted at the 70th session of the UN on 25.09.2015. “Transforming Our World: The 2030 Agenda for Sustainable Development”, and as stated in the resolution, the program should be implemented at three levels: national, regional and global.

The UN Sustainable Development Goals (SDGs) program fully coincide with the priorities and tasks of Kazakhstan. For Kazakhstan, the implementation of the SDG methodology and indicators provides an opportunity for systematic adaptation of strategic planning and monitoring to world standards, taking into account the consonance of Kazakhstan's program documents, first of all, “Strategy 2050” and the sectoral programs arising from it, global development goals.

The mission of UNDP international experts for a rapid comprehensive assessment of Kazakhstan's readiness for the implementation and monitoring of the SDGs, held in November 2016, revealed a fairly high degree of inclusion of SDG targets in national and sectoral plans - 61% of the SDG targets are already covered by national strategic documents.

Kazakhstan is part of the High-Level Group for Partnership, Coordination and Capacity Building to Provide Statistics for the 2030 Agenda for Sustainable Development (HLG), composed of member states, including UN regional and international agencies as observers.

Kazakhstan hosted the first national technical meeting on SDG statistics with the participation of representatives of all government bodies, NGOs, research organizations, various trade unions and associations, national companies, UN agencies and international experts in various industries.

The main purpose of the meeting was to assess the readiness of the national statistical system to produce global indicators for monitoring the SDGs, as well as to identify additional national indicators that will be relevant for Kazakhstan.

A specially created interdepartmental Working Group on the implementation of indicators for monitoring the SDGs is developing a system of indicators that includes both global and national indicators, taking into account the priorities of Kazakhstan.

In general, the systematic implementation of the SDGs in Kazakhstan will undoubtedly have a positive multiplier effect, in particular:

- facilitating the process of becoming one of the 30 most competitive countries in the world by achieving the indicators of the Organization for Economic Cooperation and Development (OECD) through the implementation of the SDGs.
- giving additional impetus to such processes as increasing human potential, attracting foreign technologies and experience, improving qualifications in the field of processing big data arrays (Big Data).
- the implementation of the SDGs is becoming one of the factors of investment attractiveness for large international corporations, for which the model of socially responsible business and its compliance with the SDGs is an important component of their image.

In 2019, the Government of the Republic of Kazakhstan adopted the National indicators approved by the protocol of the Coordination Council.

The presentation of the Voluntary Review of Kazakhstan on the Sustainable Development Goals in the 2030 Agenda for Sustainable Development at the UN high-level political forum was made in August 2019.

For Kazakhstan, the presentation of the first survey is an opportunity to demonstrate the country's progress in achieving sustainable development goals, highlight the main challenges, get an external assessment, and also get acquainted with the experience other countries.

In three decades, Kazakhstan has made a huge socio-economic leap - entered the third wave modernization, entered the 50 most competitive countries. As a result, the GDP per capita in Kazakhstan has grown to almost USD 10 thousand. In the 2018 Human Development Report, Kazakhstan ranked 58th out of 189 countries of the world and entered the group of countries with the highest level of human development. 99.8% of citizens of Kazakhstan aged 15 and over belong to the population with a high educational level.

Through systemic reforms and effective strategies, Kazakhstan has successfully met the Millennium Development Goals and launched the implementation of the Agenda for Sustainable Development up to 2030.

At the same time, there is still a gap in poverty rates in urban and rural localities. The poverty level in rural areas is 2.7 times higher than the poverty level in cities.

Already 79.9% of the Sustainable Development Goals targets are reflected in strategic and program documents of the state planning system [18].

In the context of limited and vulnerable water resources and dependence on transboundary flows, SDG 6 is relevant for Kazakhstan. The country is a party to the UN Convention on the Protection and Use of transboundary watercourses and international lakes. It due to the fact that Kazakhstan depends on transboundary water resources. Access of the population to clean water is a strategic priority for the country.

8.2 Sectoral/industrial strategies

Energy resources

The economy of Kazakhstan is largely dependent on mining activities. Attracting private investment in subsoil use is one of the priority tasks in the extractive industries. The task of economic growth can be solved by sustainable development programs. So, for example, the subsoil users of Kazakhstan working in the fields of solid minerals, oil and gas deduct to the regional budget, in addition to tax payments, also targeted payments for infrastructure development, construction and repair of schools and preschool institutions [25].

During the development of new uranium deposits in South Kazakhstan, thousands of new jobs have been created. Many residents of the region, working at uranium deposits, received

special technical education at the expense of subsoil users. Subsoil user companies are constantly involved in projects that provide social support to the population.

In 2018, in Kazakhstan, a new Code on Subsoil and Subsoil Use came into force, which provides for significant liberalization of the mining industry. Thus, the new Code significantly simplifies the procedures for granting subsoil use rights, introduces public geological reporting according to CRIRSCO standards, and transfers from contracts to subsoil use licenses. The new Code provides for the termination of the application of the GKZ standard, starting in 2024, with a full transition to the CRIRSCO standards. The Code also abolished the controversial tax - a commercial discovery bonus, which caused many questions from subsoil users.

Groundwater resources

The current volume of river runoff in Kazakhstan seems to differ significantly from previous estimations and long-term averages. Reduced surface runoff could provide evidence of significant climatic and anthropogenic effects on water resources and reflects the strong tendency towards possible reduction of surface water resources in the country.

Groundwater is extremely unevenly distributed throughout the country, and the variable quality prevents exploitation of part of groundwater resources for economic activity. Groundwater is available in almost all the mountainous regions.

The total volume of exploitable groundwaters of Kazakhstan constitutes 42.306,44 thousand m3/day (equivalent to 15,44 km3/year) or approximately 24% out of the total resources with mineral content up to 10 g/l (176.105 thousand m3/day) and 38% out of prognostic resources with the mineralization up to 1 g/l (110.789 thousand m3/day) [26].

About half groundwater resources (about 50 per cent) are concentrated in southern Kazakhstan [6]. Therefore, large-scale use of groundwater in the research area (uranium deposits of South Kazakhstan) is a state strategic task, given the shortage of surface water in this area.

Study shows that in the process of water cycling, underground water is hydraulically interrelated to the surface water of river basins, forming a unified water resource potential. This is equivalent to a layer of moisture for the entire territory of Kazakhstan (2.7 million. km2) of about 50 mm per year [9] with an average value of 250 mm of precipitation per year and estimated evapotranspiration of 200 mm per year [14]. With the possible impact of the global climate and regional trans-border hydrological threats, the underground water resources may eventually decrease in Kazakhstan by 2020 by up to 40.8 km3 /year. A possible change of the underground drain water could be the value of ± (1–2)%, i.e. on ± (0.5–10) km3 /year. This equates to a modern selection of Kazakhstan's groundwater for economic-drinking water supply amounting to 0.84 km3 /year [9]. The increased environmental concern in Kazakhstan and worldwide is confirmed by the ecosystem restrictions in the use of water resources, i.e. regulation of the environmental demand for water resources. Sustainable water use is necessary.

Consequently, at the lowest estimate for groundwater in the volume of 1.5–2.0 km3 /year, the requirement would be 20 times the reserved water supply of Kazakhstan. The Ak Bulak programme is estimated to use 15.44 km3 of underground water per year [7]. Because of the surface and groundwater connection, the surface water level would be decreased to 5 km3 per year [27].

8.3 Case study project (s) and groundwater resource-specific aspects

Since the area of the South Inkai field has practically no surface water sources, groundwater is the only option for water supply for the needs of local residents and regional production. The spatial combination of uranium and groundwater deposits creates favourable conditions for the organization of water intakes, both for drinking and technical water supply.

The risks of these projects, associated, first of all, with the radiological conditions of uranium mining and processing, subject to a set of design safety measures and continuous monitoring, ensure the safety of production and the local population.

9. Conclusions on UNFC classifications of energy or mineral resource projects in Kazakhstan

9.1 Advantages of UNFC at national- and project-level decision making

An important task of the development of the mineral resource complex of Kazakhstan is to increase the resource base of solid minerals and hydrocarbons. UNFC can create the most favourable conditions for investors.

The special significance of UNFC is that this classification is based on three fundamental criteria – the environmental-socio-economic viability (E), technical feasibility (F), and degree of confidence in the estimate (G) – using numerical and linguistic independent coding schemes. It is noteworthy that unlike other (numerous) classification systems, the UNFC is applicable to any emissions of mineral raw materials, as well as to renewable energy sources and anthropogenic resources. This is due to the fact that the UNFC takes into account the maximum number of factors when evaluating any objects.

Given that in the modern world, the number of multi-resource companies operating in different countries is growing, the need for a unified classification system is obvious. UNFC is the first version of the Classification at a level where general principles are established, and which can serve as the basis for international research in the field of energy and minerals.

UNFC can be a tool for global accounting of mineral resources, which ensures the comparability and compatibility of various classifications used today in Kazakhstan and other countries. Of course, it will be advisable to use the UNFC at the level of state planning and subsoil management. In this case, taking into account national characteristics, it is necessary to take into account international experience in integrating the national system in the UNFC, in particular the experience of the Russian Federation, which was the first to implement the integration process in the UNFC, while they did not blindly copy and implement this system, but adopted the so-called transitional document taking into account its specifics and the unified internal system for estimating reserves already existing there.

During the last six months, Kazakhstan has been discussing the issue of changing the classification of resources and hydrocarbon reserves, and a possible transition to SPE PRMS or UNFC.

9.2 Constraints in the use of UNFC

Limitations in the use of the UNFC include the need for significant adjustment of national legislation both in Kazakhstan and in other countries. And this process, as you know, always happens very slowly.

A difficult question is the responsibility of the Competent Person for the results of his evaluations. There are unclear questions about the methods of verification of reliability, as well as the system of responsibility for inaccurate assessments of objects by Competent persons.

The legal provisions existing in Kazakhstan today, enshrined in the Constitution of the Republic of Kazakhstan, speak of the ownership of minerals, described as “the property of the people”. Therefore, for the implementation of the UNFC, it is also necessary to develop mechanisms of state control in this area.

In this case, it is necessary to take into account precisely the national interests of our country, first of all, to increase environmental and environmental requirements, as well as the norms of social responsibility of subsoil users.

Also, when introducing and unifying systems, it is desirable to establish the priorities of national legislation over the proposed international legal provisions in this area.

Given the lengthy work of state bodies in the field of improving legislation and creating a base of by-laws, the introduction of a new system may take a long period of time.

9.3 Benefits in using UNFC for alignment to SDGs

The advantages of using the UNFC to estimate mineral reserves include the possibility of using it to increase the investment attractiveness of our country in the eyes of the world community within the framework of common reporting standards.

It should also be noted that using the UNFC reporting system is able to ensure the transfer of stocks and resources from one system to another, for example, from the SCPC system to the SPE PRMS system.

The UNFC can also serve as the basis for harmonizing national valuation systems and national regulatory systems with international systems and help integrate the national system in the international market. Moreover, reporting on the basis of the principles of socio-economic feasibility will ensure the construction of rational consumption and production models.

Improving the level of scientific and technological development is achievable by introducing the best world experience in this area through the introduction and integration of the UNFC.

Also, in the context of globalization, the UNFC can serve as a system for harmonizing the global exchange of information, since, being an integral set of common rules, it will facilitate the paths of global communication, will lead to the revitalization of global partnership mechanisms for sustainable development.

General principles and reporting mechanisms will help to significantly increase the efficiency of development of the sphere of mining by increasing investment attractiveness.

All this should lead to a significant development of the exploration and mining sectors, and this, in turn, to the sustainable development of the country's economy, increase the level of employment and welfare of the population.

Thus, the benefits of using UNFCs are fully consistent with the Sustainable Development Goals. and will help ensure that four of the seventeen SDGs are achieved: on promoting sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all; on creating a solid infrastructure, promoting inclusive and sustainable industrialization and innovation; on providing rational patterns of consumption and production; on strengthening the means to achieve sustainable development and revitalizing global partnership mechanisms for sustainable development.

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