Recycling of Water from Thar Coal Mines

Engr. Nadeem Arif,

MD, EMC Pakistan Pvt Ltd, Karachi.

What we shall Discuss ?

- **Part 1 : An Introduction to Thar**
  Geography, Climate, Physiography and Social Context
- **Part 2 : Mining in Thar and Dewatering**
  Coal Mining in Thar, Aquifer Hydrogeology & Mine Dewatering
- **Part 3 : Utilizing Mine Effluent of Thar**
  Recycling Mine Effluent Water for Water Supply to Blocks and Local Settlements, Disposal of excess water and other avenues of reuse.

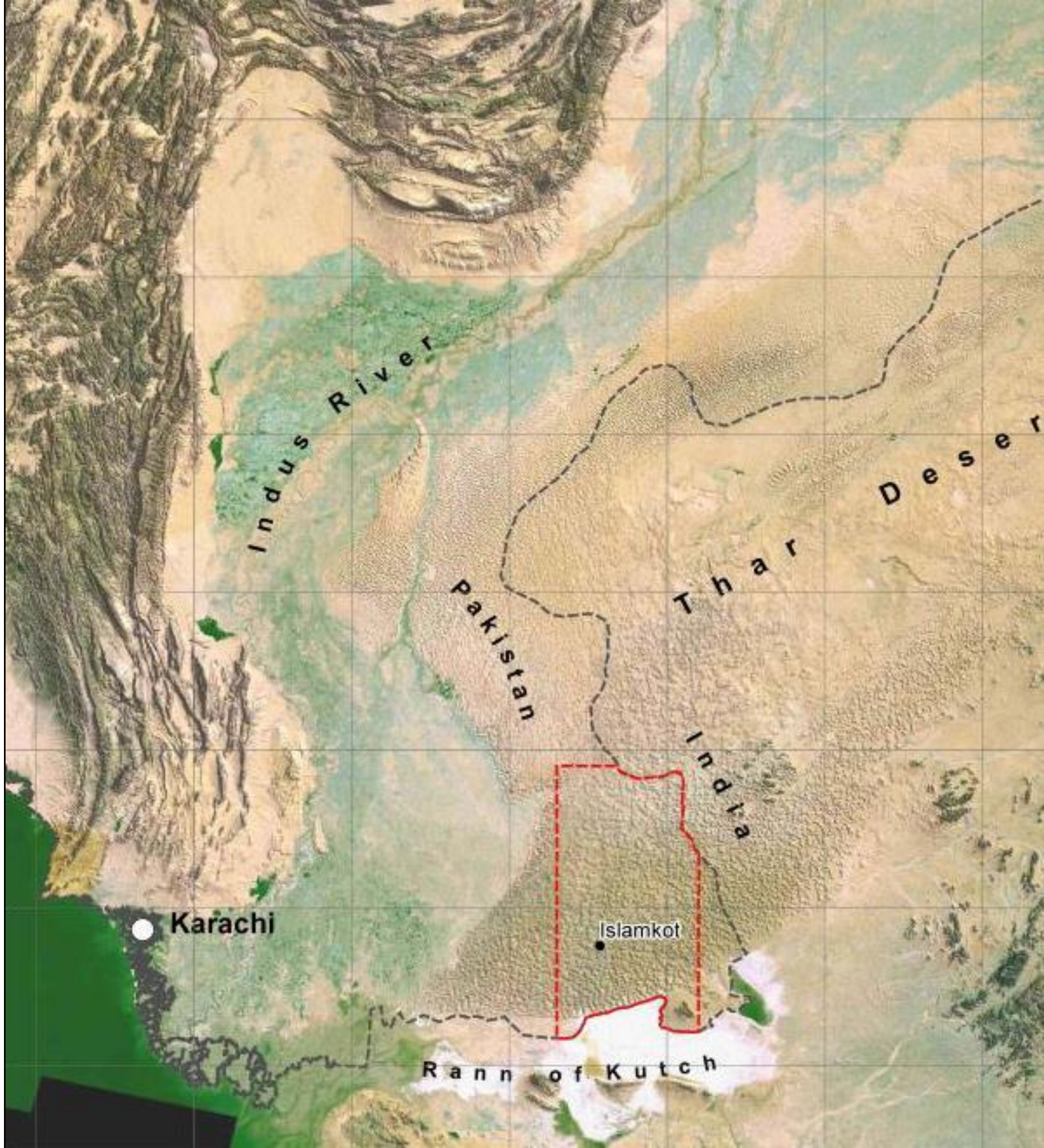
Part 1: An Introduction to Thar

Geography, Climate, Physiography and Social Context

Thar Desert

Geography of Thar Desert »

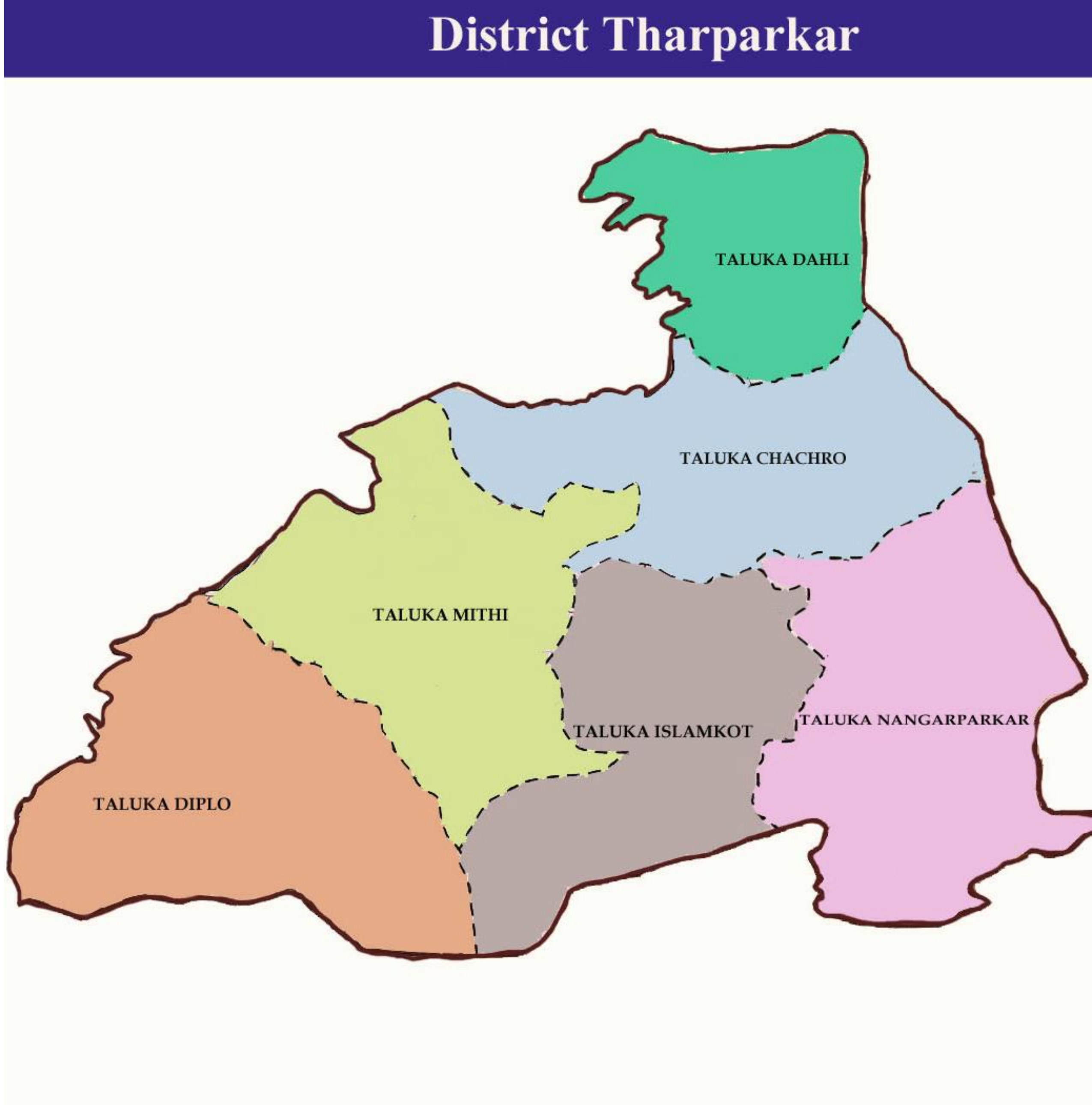
- The Thar desert covers an area of approximately 320,000 km^2, with dimensions of approximately 800 km by 400 km.
- It extends across northwest India and southeast Pakistan.
- The desert is bounded by the **Indus River** on the East and floodplains to the West, the **Sutlej River** and its floodplains to the North, the **Aravalli ranges** to the east and the seasonal salt marshes of the **Rann of Kutch** to the south.



Thar District

Thar District and its composition »

- The **Tharparkar District** is located in the south-eastern corner of Pakistan in the province of **Sindh**.
- The District derives its name from Thar and Parkar. The name Thar is from **Thul**, the general term used locally for a region of sand ridges and Parkar literally means "to cross over".
- The Tharparkar District comprises six Talukas (sub-districts) i.e. **Diplo, Mithi, Islamkot, Chachro, Dahli and Nagarparkar**. A seventh Taluka called **Kaloi** has been very recently added.
- It covers an area of 19,638 square kilometres (km^2).



Climate of Thar

Temperature

- In summer, the mean average temperature varies in between 24°C to 26°C.
- Winter are milder with average temperature varying from 4°C to 10°C
- The peak daily temperature in summer can reach ~52°C

Precipitation

- The precipitation pattern is irregular in this semi-arid to arid region of the Thar Desert.
- Droughts are cyclic with return periods of every three to four years.
- The Thar receives its highest precipitation in the months of July to August.

Wind

- In general, wind speed is highest during the summer when the prevailing monsoon brings high winds which blow southwest to northeast.
- During the cooler winter period (December-January), the wind direction changes to blow at a lower speed from the northeast.

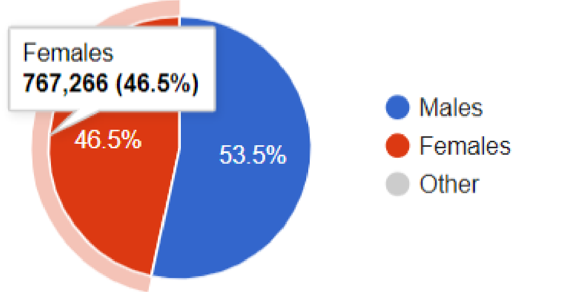
Physiography and Soil

Physiography and Soil »

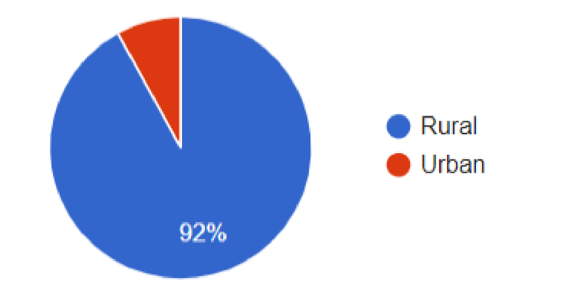
- Thar is a desert region dominated by **aeolian dune sand** topography.
- Elongated dune ridges separated **by interdunal valleys** provide the primary relief characteristics of the region. The ridges are long, irregular and roughly parallel to each other.
- The valleys and inter-dunal depressions provide a drainage flow in the monsoon season that also drains the silt / clayey silt and accumulates in these low-lying depression that are used **for cultivation** by the local population.
- These patches of silty clays not only provide an impervious base for **ponded rain-water** to stay for considerable time to support vegetation, but also prove to be of reasonable fertility to **support agriculture**.

Social Context of Thar

Name	Status	Population Census 1972-09-16	Population Census 1981-03-01	Population Census 1998-03-01	Population Census 2017-03-15
Tharparkar	District	359,357	540,985	914,291	1,649,661



Gender (C 2017)	
Males	882,365
Females	767,266
Transgender	30



Urbanization (C 2017)	
Rural	1,517,590
Urban	132,071

Part 2 : Mining in Thar and Dewatering

Coal Mining in Thar, Aquifer Hydrogeology & Mine Dewatering

Coal Mining in Thar

186 Billion Ton

Pakistan's Coal Reserve

175 Billion Ton

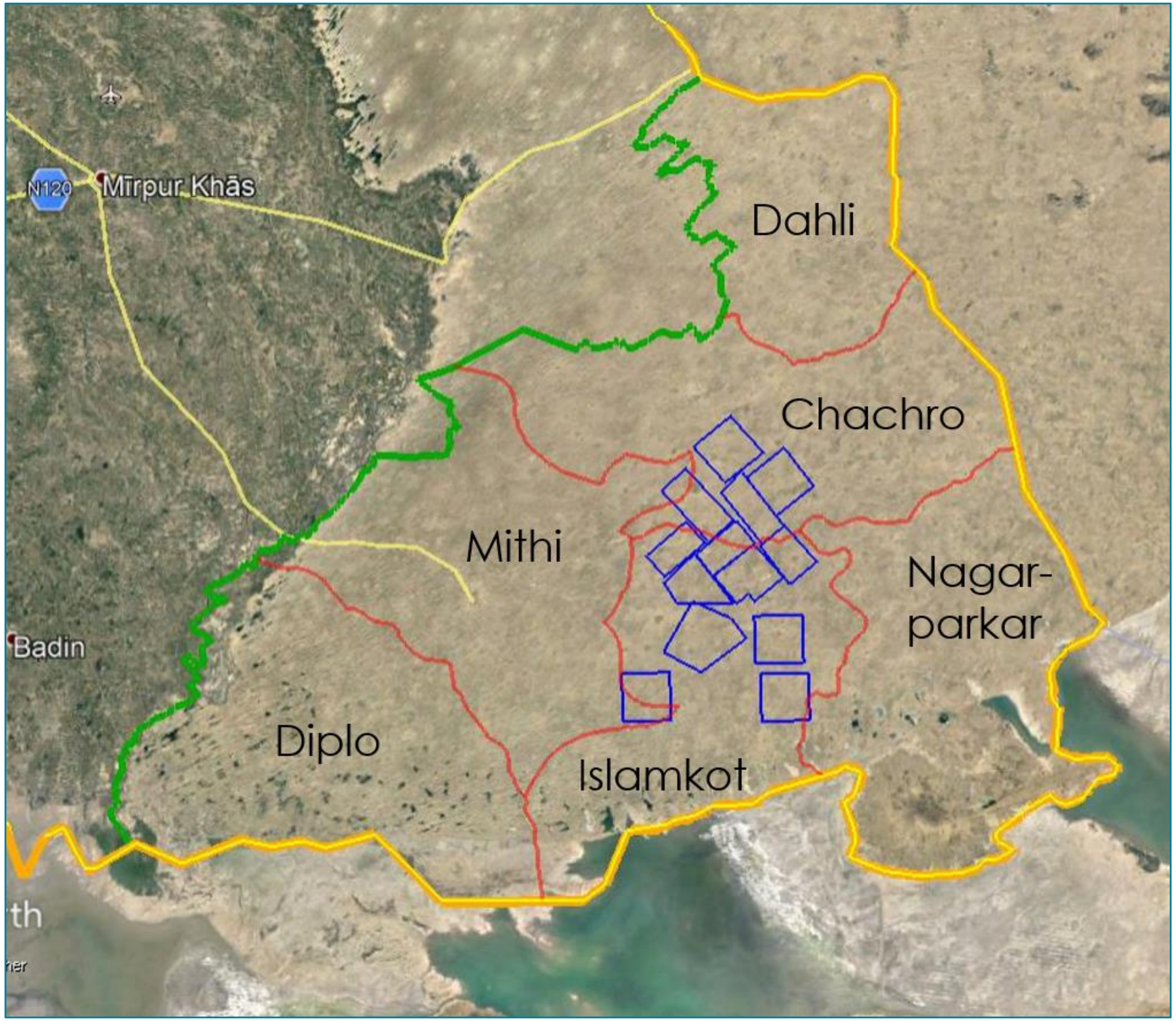
Total Thar Coal Reserve

50 Billion TOE *

More than Saudi Arabia &
Iranian Oil Reserves

2000 TCF **

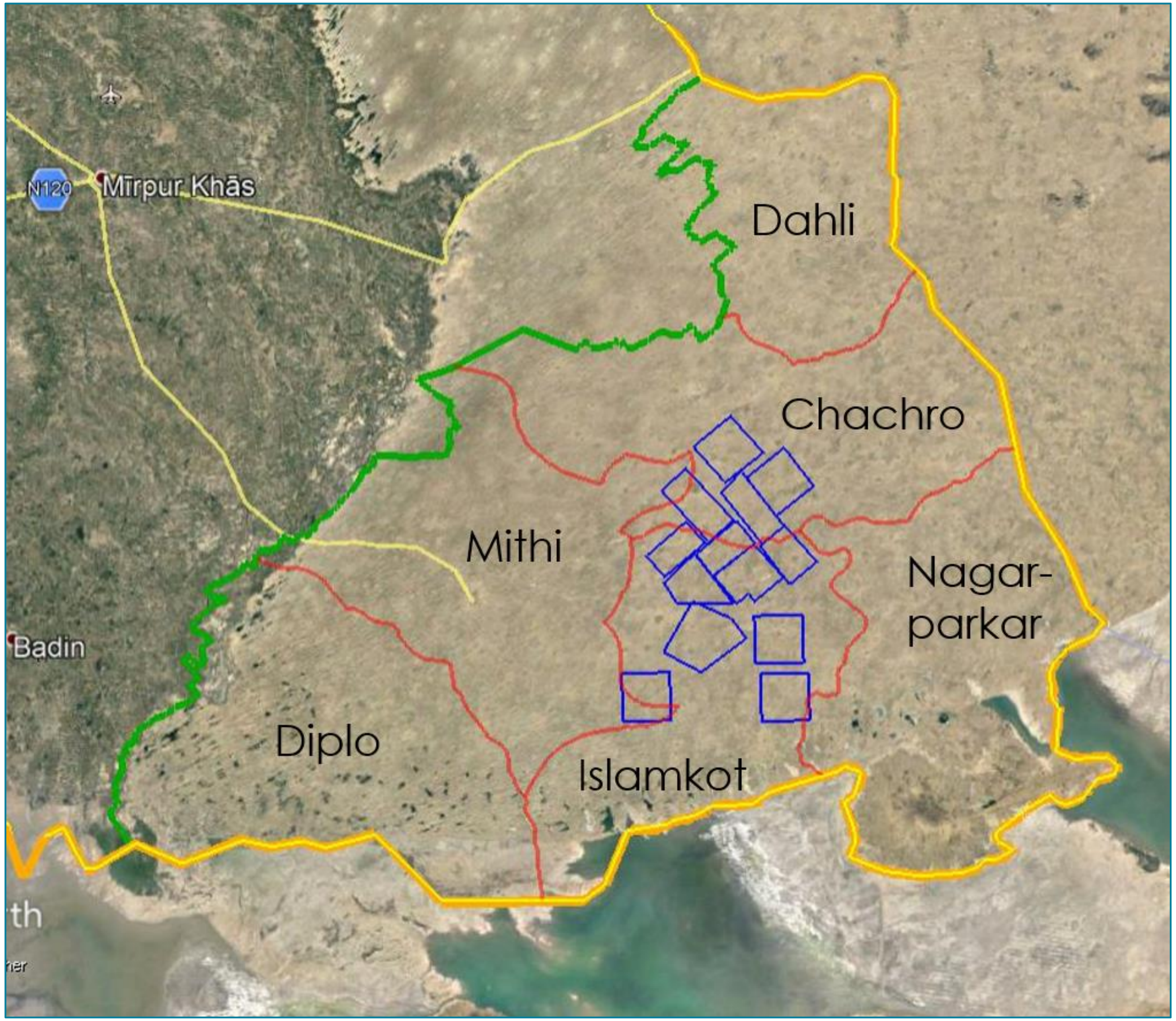
68 Times higher than
Pakistan's total gas reserves



**TOE : tonne of oil equivalent*
***TCF: Trillion Cubic Feet*

Coal Mining in Thar

- Coal Deposits are spread out over a **9,100 sq.km** area.
- **13 Coal blocks** have been identified by the Coal Authority
- Mining is underway in Block-II, with the other blocks (Block I, Block III & Block VI) in different stages of operations.
- Mining method for all active blocks is **open-cut/open-cast mining** (with the exception of Block V, which is focusing on Underground Coal Gassification).
- A power generation output of **10,000 MW** is envisaged for the near future.



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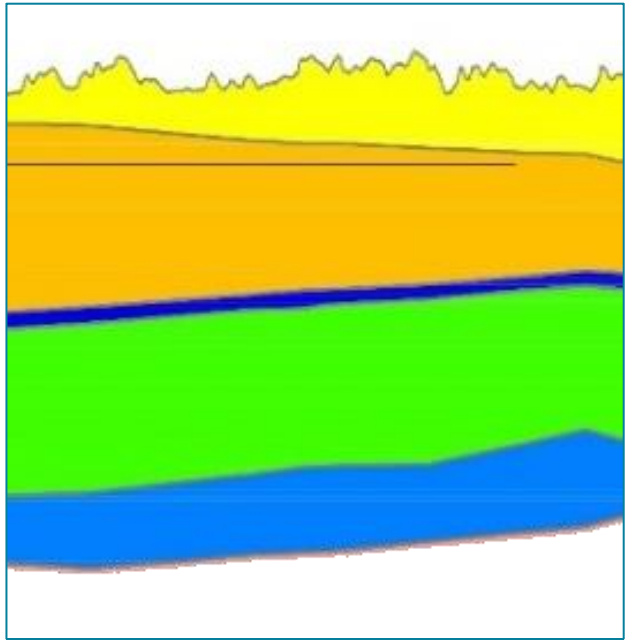
Hydrogeology of Thar Coalfield Mining Area

Key Hydrostatigraphic units of Thar »

Model layer	Hydrostratigraphic units represented	Period/Formation	Description
1	Dune Sand aquifer	Quaternary/Recent	Shallow, discontinuous (unconfined) aquifer
2	Sub-Recent alluvium	Neogene-Quaternary / Alluvial Deposits	Aquitard (leaky confined) with minor perched sand/sandstone layers
3	Coal Seam Roof aquifer	Neogene-Paleogene	Middle confined aquifer
4	Coal/lignite Bearing strata	Paleogene (Paleocene - Early Eocene) / Bara Formation	Aquitard/leakage layer
5	Coal Seam Floor aquifer		Deep confined aquifer

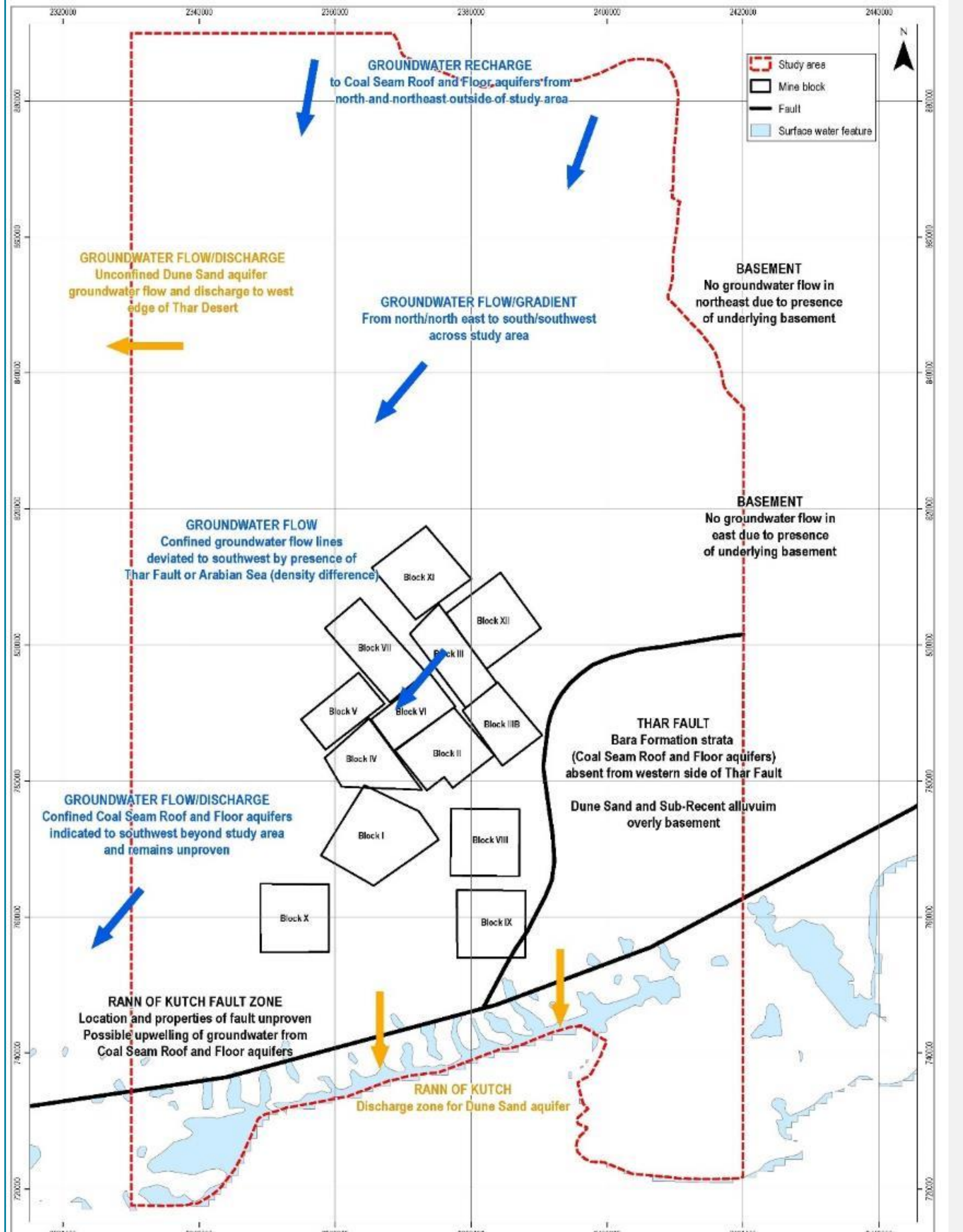


The lower aquifer is underlain by **impermeable basement** which is **not** considered to form part of the active groundwater system.

Hydrogeology of Thar Coalfield Mining Area

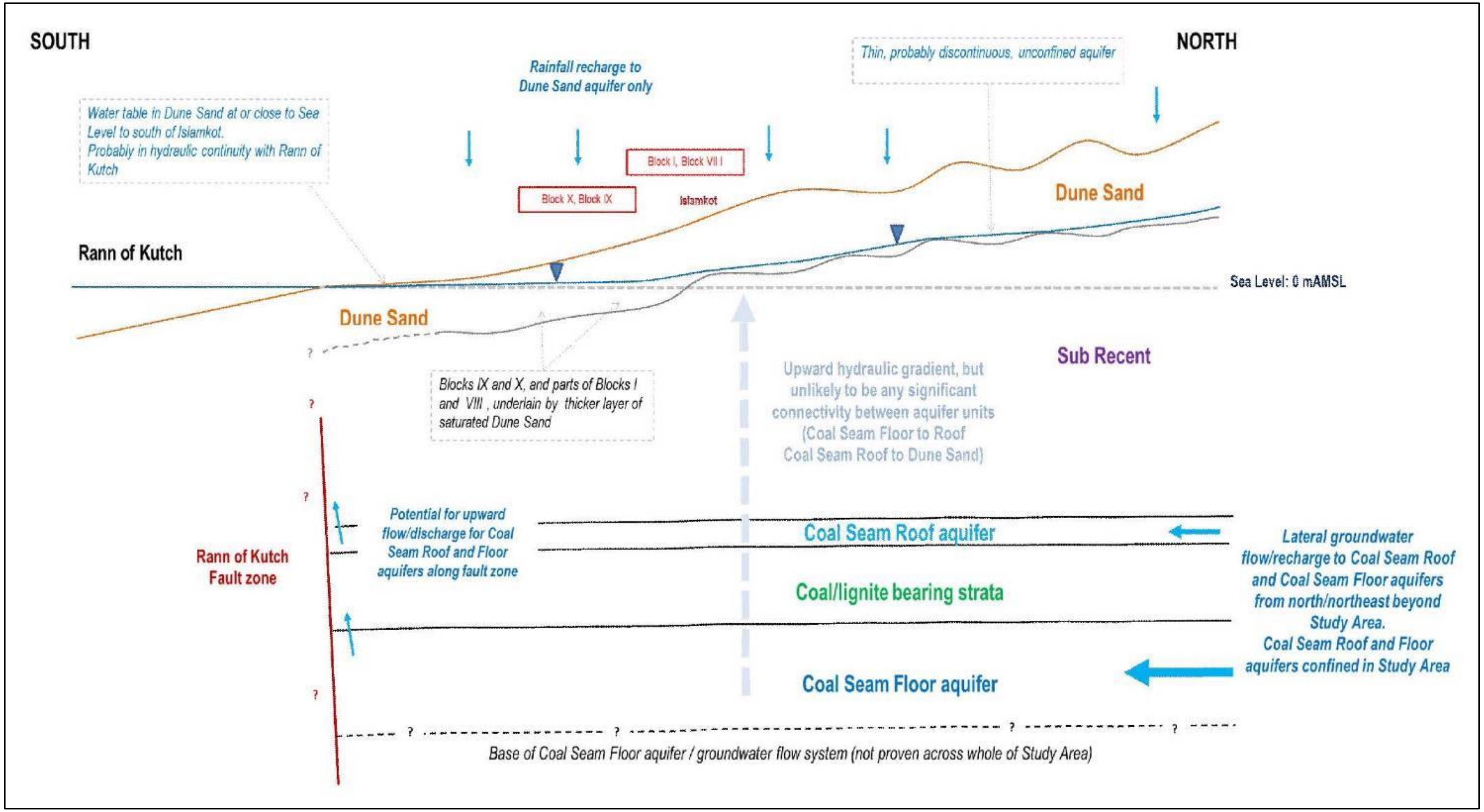
Coalfield conceptual hydrogeological model plan »

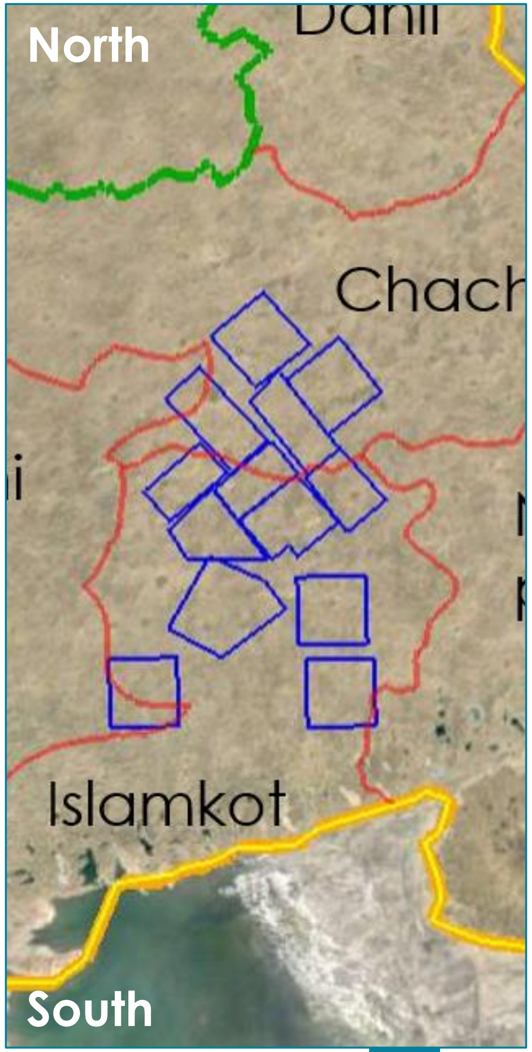
- The **direction** of groundwater flow in the three aquifer units is generally from the **north/northeast to the south/southwest**.
- Direct rainfall recharge occurs only to **the unconfined Dune Sand Aquifer**. The annual recharge rate is poorly defined but likely to be extremely low.
- Groundwater inflow to the middle and lower aquifers **(Coal Seam Roof and Coal Seam Floor respectively)** is from horizontal flow from outside, and to the **north**.
- The water that is abstracted from tubewells in and around the main mining area is classed as '**paleo-groundwater**' that occurred as rainfall recharge probably between **20,000 and 50,000 years ago**. This is supported by both **isotopic data** and extremely shallow groundwater hydraulic gradients.
- The **gradient** from north to south in the Coal Seam Floor aquifer is around **10 – 15 m over a distance of 120 km** (0.00008 – 0.00012) and the rate of groundwater flow is estimated to be between **less than one metre** to up to 10m per year.
- The main mining area is therefore located at the down gradient end of a **very slow moving groundwater** system.



Hydrogeology of Thar Coalfield Mining Area

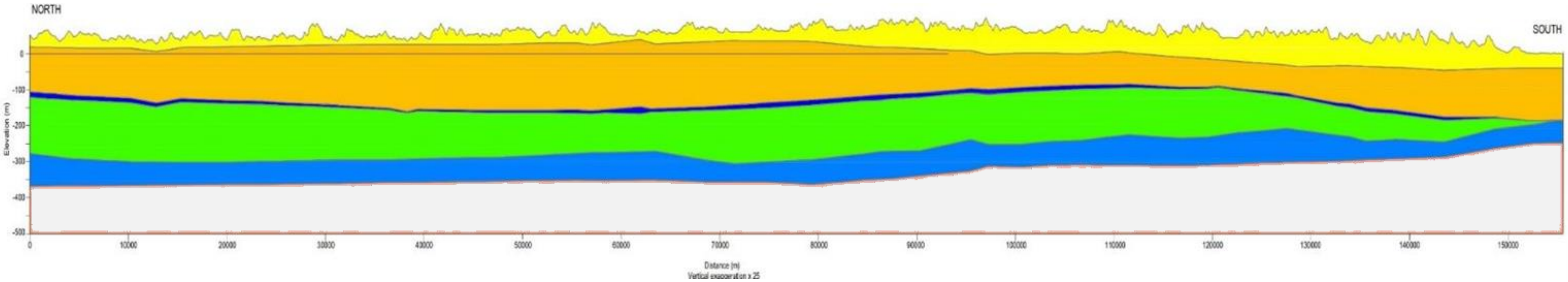
Coalfield conceptual hydrogeological model section »

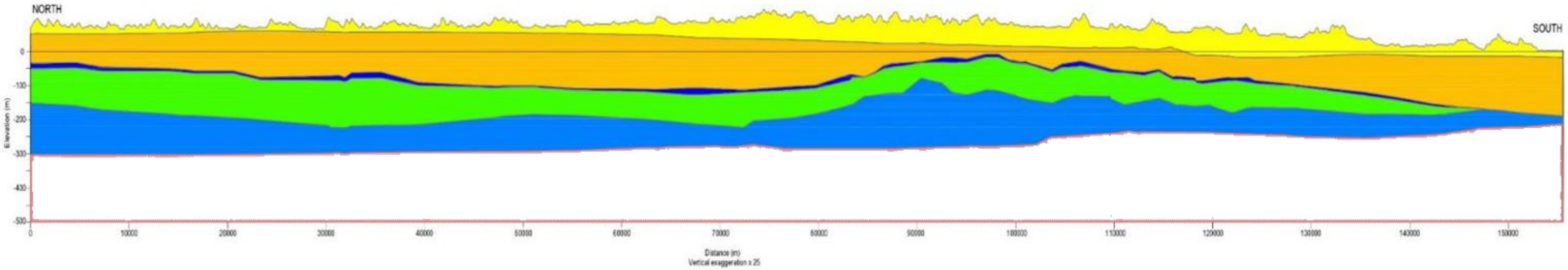


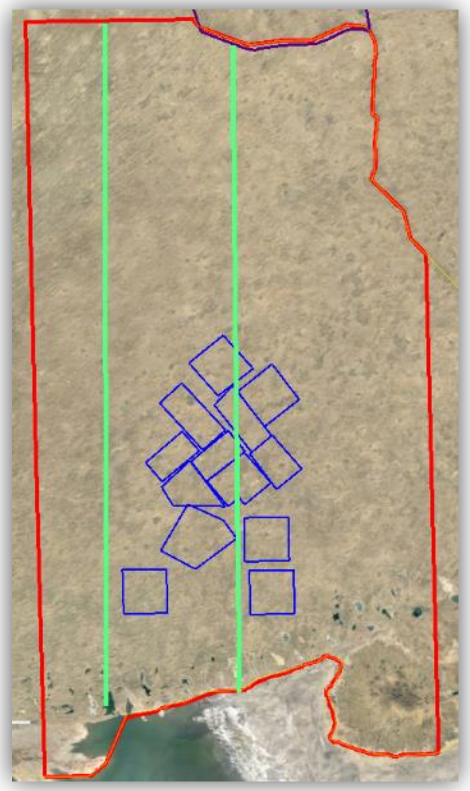


Hydrogeology of Thar Coalfield Mining Area

Cross section North-South





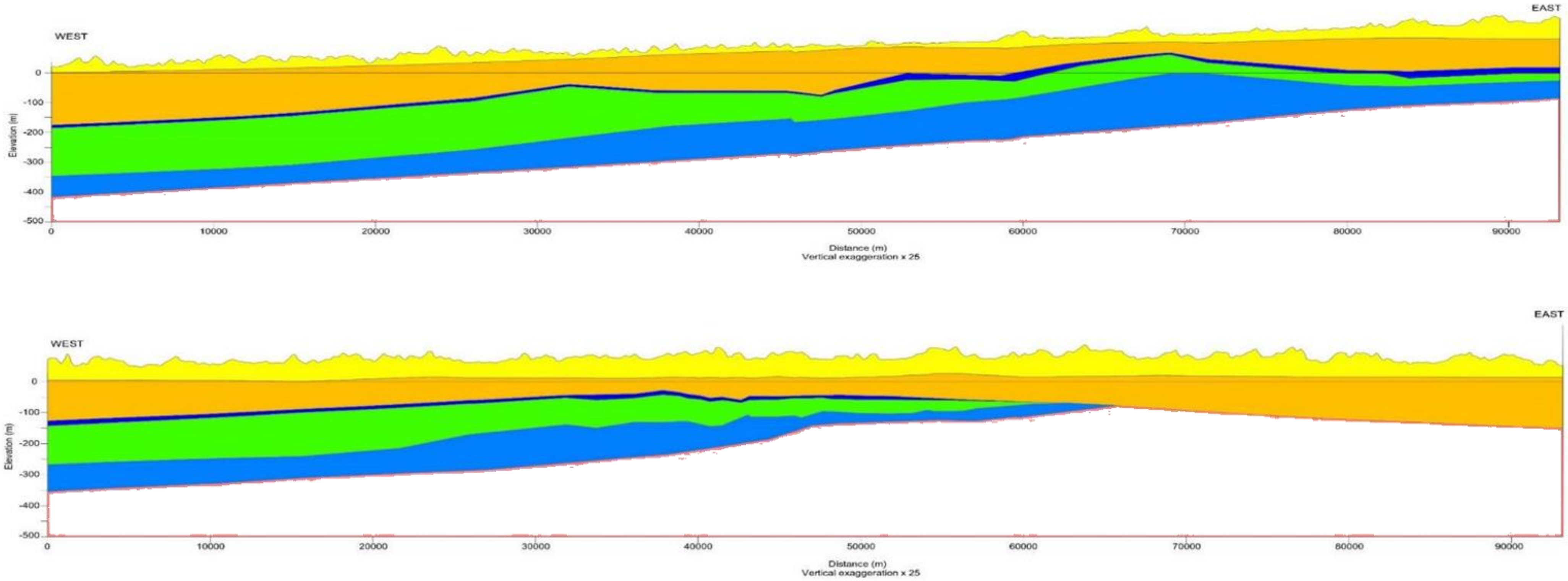


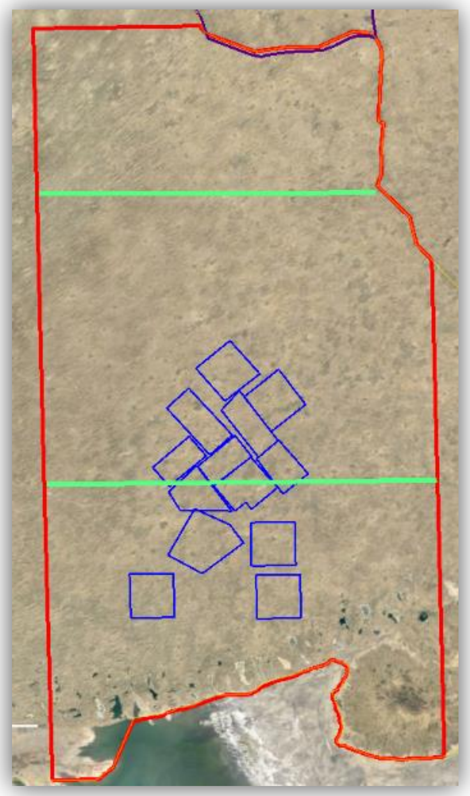
Dune Sand Aquifer : Highly discontinuous. Thickness ~ 3-10 m
Coal Seam Roof Aquifer: Thickness ~ 5 – 25 m
Coal Bearing Strata: Thickness ~ 30 – 100 m.
Coal Seam Floor Aquifer: Thickness ~ 25-150 m

- Vertical exaggeration: x25

Hydrogeology of Thar Coalfield Mining Area

Cross section West-East





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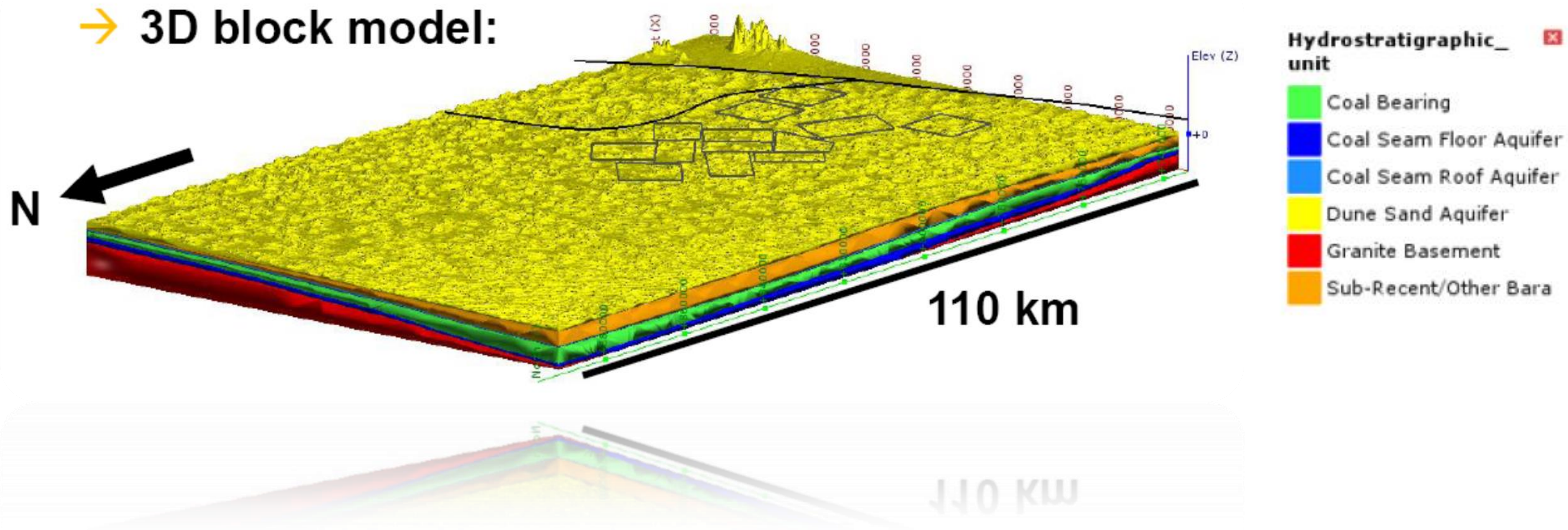
3-D Geological Model



Water Quality of the Mine Effluent

Item	Unit	Analysis result					
		Quaternary	Roof of coal seam	Floor of coal seam	disposal water index	disposal water of power plant	Amount of mixed water
Water quantity	m^3/d	1.5	2.2	9.9		2.10	10.70
PH	SU	7.59	7.34	7.56	7.52	9.00	7.81
Electric conductivity	ms/cm	5.16	13.83	8.47	8.97	35.89	14.25
Na+	mg/L	1017.49	2506.60	1505.90	1613.91	6455.65	2564.16
Mg^{2+}	mg/L	58.12	210.33	114.11	123.50	493.98	196.21
Ca^{2+}	mg/L	81.82	387.00	171.00	196.10	784.42	311.57
K+	mg/L	18.03	30.79	22.00	22.99	91.95	36.52
SO_4^{2-}	mg/L	248.50	285.00	168.67	196.29	785.16	311.86
Cl-	mg/L	1546.52	4478.52	2487.13	2705.52	10822.09	4298.49
F-	mg/L	0.66	0.97	1.53	1.34	5.38	2.14
HCO^{3-}	mg/L	317.50	427.00	379.33	380.22	1520.90	604.09
Hardness	mg/L	445.75	1838.20	894.33	997.54	3990.17	1584.88
SiO_2	mg/L	18.33	14.90	16.64	16.55	66.19	26.29

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		Quaternary	Roof of coal seam	Floor of coal seam	disposal water index	disposal water of power plant	Amount of mixed water
Mineralization degree	mg/L	3303.90	8341.19	4892.44	5275.12	21100.48	8381.03
S^{2-}	mg/L				0.00	0.00	0.00
Fe	mg/L	0.42	0.58	0.41	0.44	1.77	0.70
Al	mg/L		0.02		0.00	0.01	0.00
As	mg/L	0.00	0.00		0.00	0.00	0.00
Cd	mg/L				0.00	0.00	0.00
Cr	mg/L	0.05	0.07	0.06	0.06	0.25	0.10
Co	mg/L				0.00	0.00	0.00
Cu	mg/L				0.00	0.00	0.00
Pb	mg/L				0.00	0.00	0.00
Soluble Fe	mg/L				0.00	0.00	0.00
Mn	mg/L	0.08	0.22	0.05	0.08	0.33	0.13
Hg	mg/L				0.00	0.00	0.00
Ni	mg/L	0.23	0.22	0.22	0.22	0.89	0.35
Se	mg/L	0.00			0.00	0.00	0.00

Hydrogeology of Thar Coalfield Mining Area

Groundwater Modelling Conclusions

- The aquifer is of significant areal extent and has a large storage capacity. After 30 years of mining operations, models predict a regional cone of depression of similar size and magnitude that extends beyond the model domain to the west and north.

- Dewatering requirements for the Dune Sand and Coal Seam Roof aquifers are minor in comparison to the abstraction rates needed to depressurize the Coal Seam Floor.

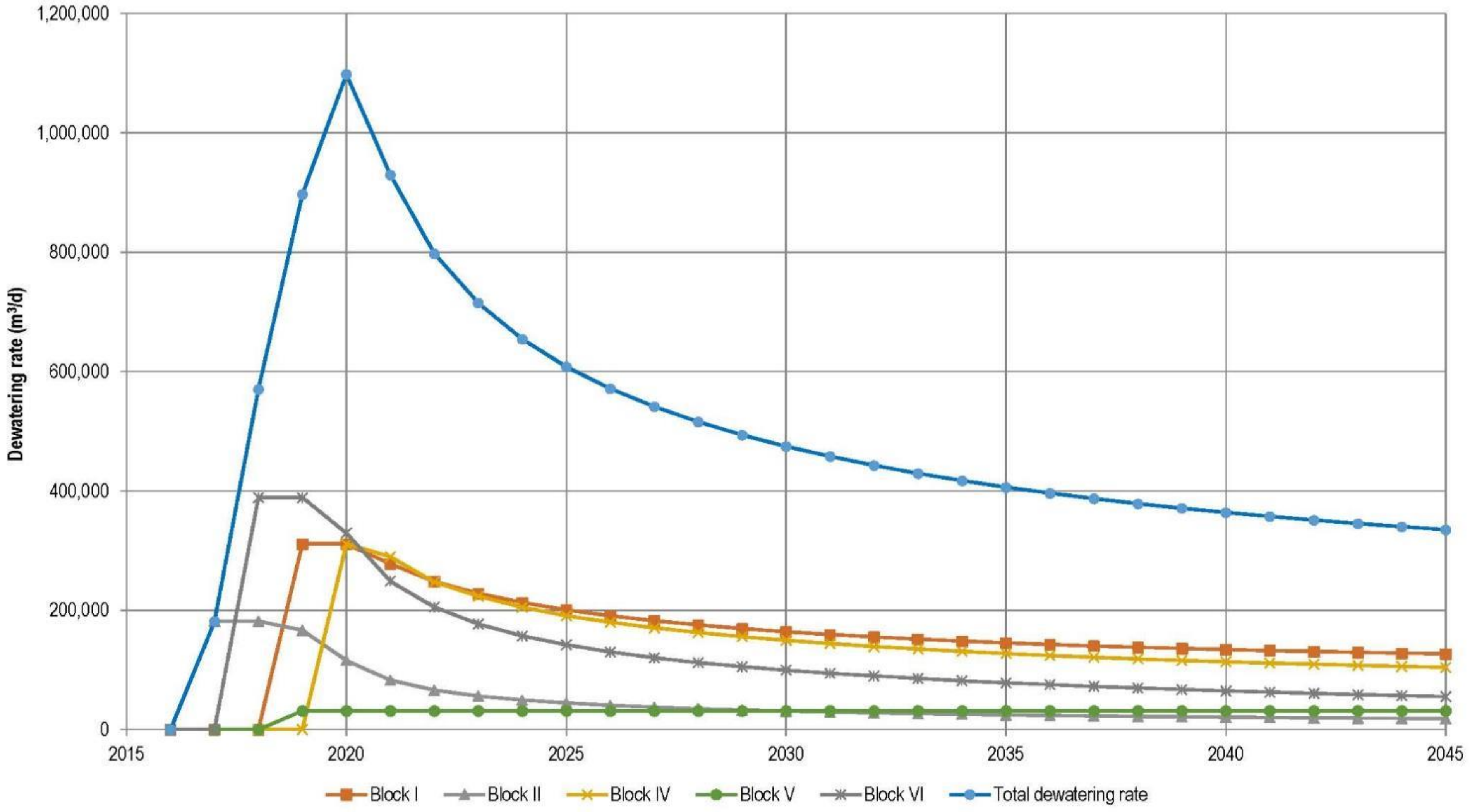
- The Thar Fault forms a significant barrier to groundwater flow which causes the propagation of the cone of depression to the west and north away from the mining area. It significantly impacts dewatering operations in adjacent mining blocks.

- The amount of water that will be pumped will depend on:
  The location of individual Blocks in relation to the Faults, thickness of Aquifer and Pumping operations in adjacent mine blocks.

- Groundwater level in the coal mining area is currently about 30 – 35 m above sea level. It will be necessary to draw this down to 70 – 120 m below sea level to depressurize the bottom aquifer.

Dewatering of Coal Mines

Predicted rate of abstraction in each mining block during each annual time step



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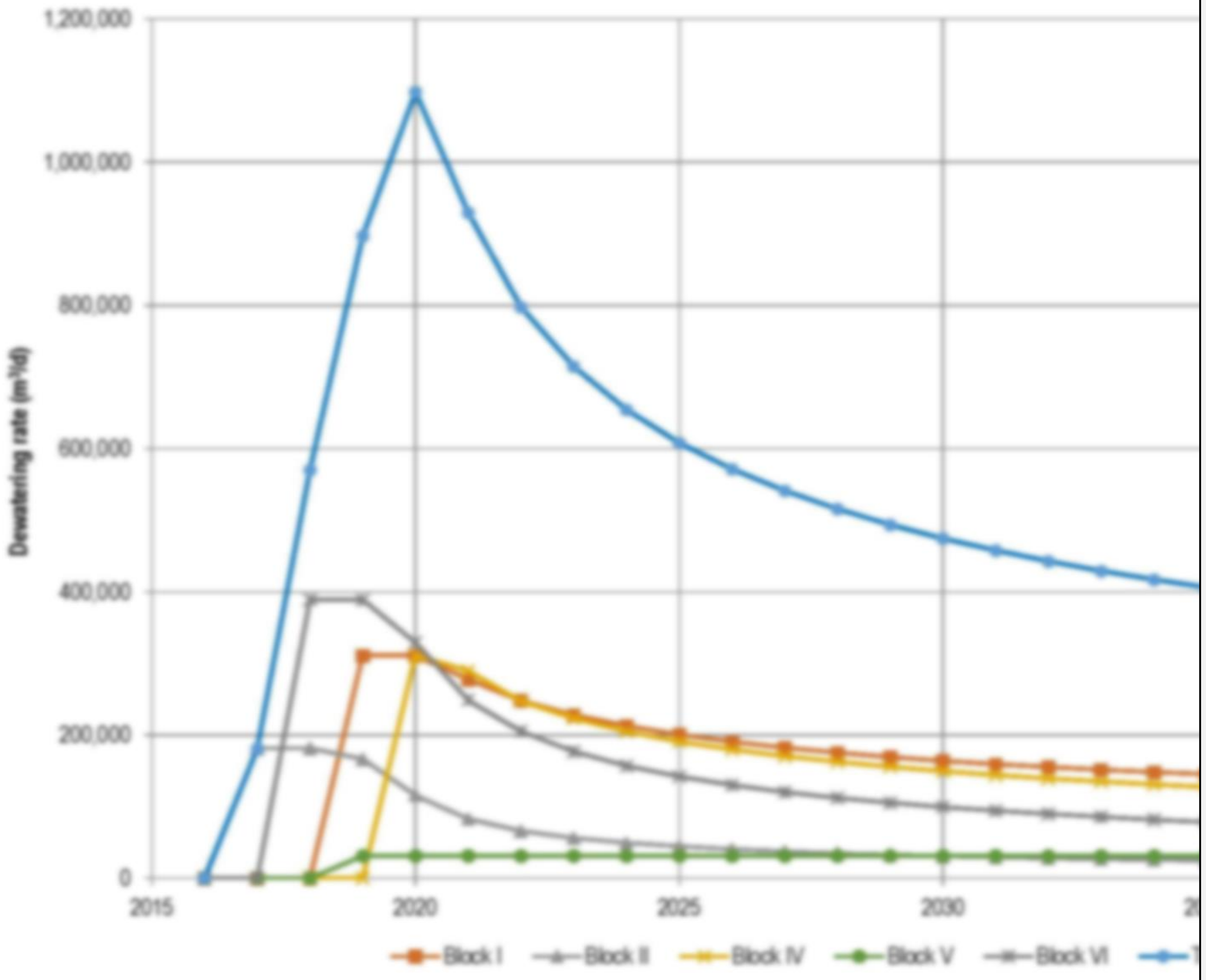


Year	Coalmine Blocks Demand	Settlement Demand	Total Water Demand	Abstraction of Coalmine Water	Surplus Brackish Water	Brine From RO Plants	Amount Of Effluent Water
	m³/day	m³/day	m³/day	m³/day	m³/day	m³/day	m³/day
2017	82,863.97	29,480.13	112,344.10	181,440.00	69,095.90	8,803.13	77,899.02
2018	254,042.59	30,392.65	284,435.24	570,239.91	285,804.67	9,076.88	294,881.55
2019	569,125.30	31,333.72	600,459.02	897,082.07	296,623.05	9,359.20	305,982.25
2020	**662,543.50**	**32,304.25**	**694,847.75**	**1,098,321.59**	**403,473.84**	**9,650.36**	**413,124.20**
2021	662,957.14	33,305.16	696,262.30	929,760.29	233,498.00	9,950.63	243,448.63
2022	663,383.72	34,337.39	697,721.12	797,579.30	99,858.18	10,260.30	110,118.49
2023	663,823.66	35,401.94	699,225.60	715,113.18	15,887.58	10,579.67	26,467.25
2024	664,277.37	36,499.80	700,777.17	654,518.31	-46,258.86	10,909.03	-35,349.84
2025	664,745.28	37,632.03	702,377.31	608,176.06	-94,201.25	11,248.70	-82,952.55
2026	665,227.84	38,799.70	704,027.53	571,448.02	-132,579.51	11,599.00	-120,980.51
2027	665,725.49	40,003.91	705,729.41	541,207.19	-164,522.21	11,960.26	-152,561.95
2028	666,238.73	41,245.82	707,484.55	515,707.56	-191,776.99	12,332.83	-179,444.15
2029	666,768.03	42,526.60	709,294.63	493,650.76	-215,643.87	12,717.07	-202,926.80
2030	667,313.90	43,847.47	711,161.36	474,505.32	-236,656.04	13,113.33	-223,542.71
2031	667,876.85	45,399.68	713,276.53	457,670.87	-255,605.66	13,578.99	-242,026.67
2032	668,457.42	46,804.52	715,261.95	442,699.59	-272,562.35	14,000.44	-258,561.91
2033	669,056.17	48,253.34	717,309.51	429,220.61	-288,088.90	14,435.09	-273,653.81
2034	669,673.65	49,747.51	719,421.16	417,129.00	-302,292.16	14,883.34	-287,408.82
2035	670,310.47	51,288.44	721,598.91	406,157.43	-315,441.48	15,345.62	-300,095.86
2036	670,967.21	52,877.61	723,844.82	396,157.42	-327,687.40	15,822.37	-311,865.03
2037	671,644.51	54,516.52	726,161.03	386,966.01	-339,195.01	16,314.04	-322,880.97
2038	672,343.01	56,206.72	728,549.73	378,553.15	-349,996.59	16,821.10	-333,175.48
2039	673,063.38	57,949.83	731,013.21	370,801.69	-360,211.51	17,344.03	-342,867.48
2040	673,806.29	59,747.49	733,553.78	363,649.36	-369,904.43	17,883.33	-352,021.09
2041	674,572.45	61,601.43	736,173.88	357,013.44	-379,160.45	[illegible]	[illegible]

Dewatering of Coal Mines

- The dewatering of the mines targets **the bottom coal seam floor (CSF) aquifer** that needs to be depressurized to allow mining to continue. **Dewatering wells** will target the CSF aquifer and **high volumes of water** will be abstracted.
- The highest dewatering volumes will be abstracted during the **first 4 to 8 years** after which a decrease in volumes is observed as the system reaches **equilibrium**.
- During year 4 the peak dewatering rate of **1,098,321 m3/d** is reached after which it gradually decreases down to **334,789 m3/d** in year 30 (2045). In total a volume of approximately **4 billion m3** will be dewatered over the **30 year period** cumulatively from the mines, as applied to the demand study estimates.
- This water should be used first by **all water users** in the Thar coalfield before any other source of water is considered. Due to the potential impact of mining on the tubewells supplying the **local communities** (potential reduction in yields and a risk of running dry) the community supply of water should be provided the same supply priority of the power plants to ensure their livelihood.

Part 3 : Utilizing Mine Effluent of Thar

Recycling Mine Effluent Water for Water Supply to Blocks and Local Settlements, Disposal of excess water and other avenues of reuse.

Existing Situation of Water Management in Thar

Water Supply

i. Dug Wells

ii. Hand Pumps

iii. Water supply from Naukot Branch to Islamkot City

iv. Small storage tanks

v. Local Reverse Osmosis (RO) Plants

Identification of Consumers

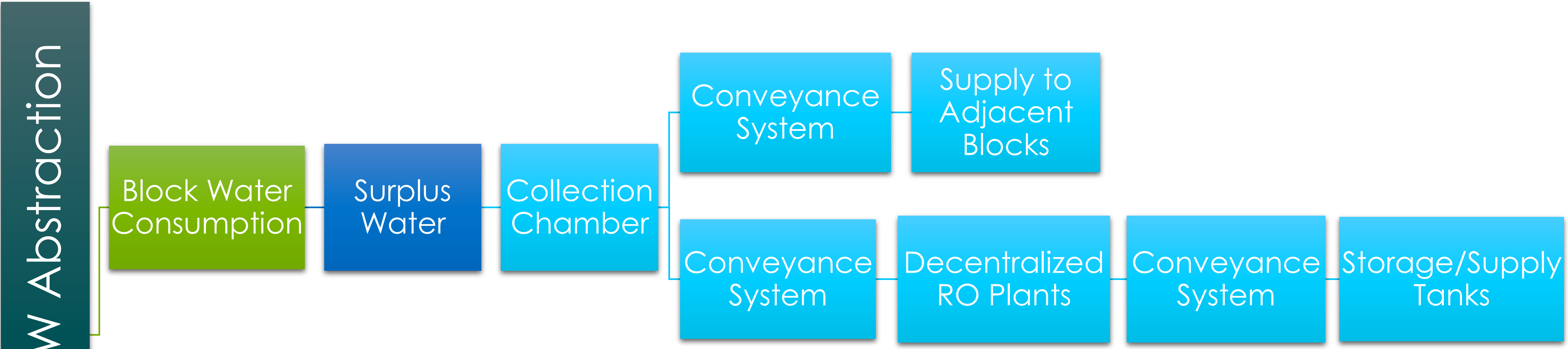
1. Power plant and Coalmine Blocks

- Power Plant and Coal mine workers
- Power plant operations
- Make up water requirement
- Dust suppression
- Fire Fighting Demand

2. Domestic Consumers

- Islamkot City (regional hub)
- Fire Fighting Demand (urban areas)
- Utility Facilities
- Villages outside coalmine blocks
- Villages within coalmine blocks
- Livestock

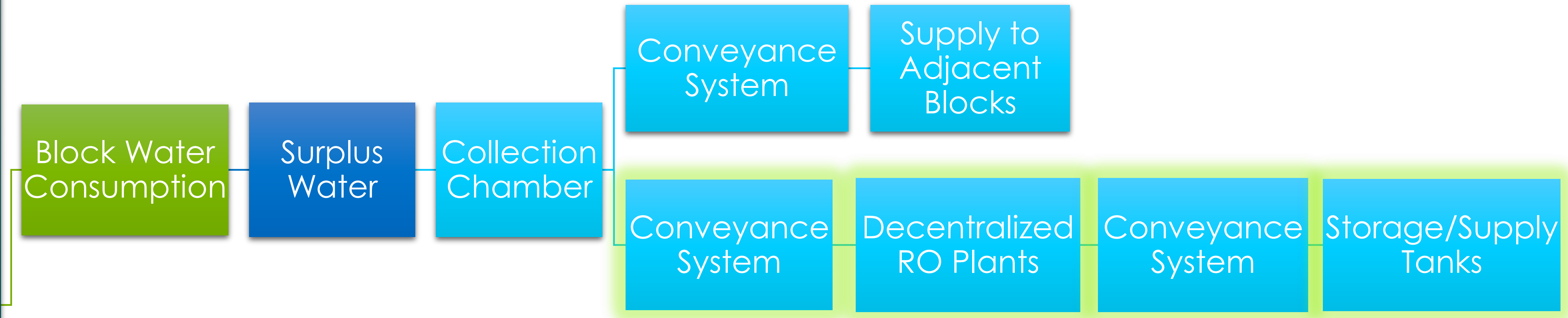
Water Supply From Abstracted Coalmine Water



- ❑ Conveyance system from Blocks to Reverse Osmosis (RO) Plants
- ❑ Laying of pipelines from centralized RO plants to different clusters
- ❑ Desalinated water will be supplied to all the villages spread over the cone of depression
- ❑ A storage tank for each cluster with maximum distance, from each village, will be 4km.
- ❑ Villagers will access water from the storage facility

Water Supply From Abstracted Coalmine Water

Coalmine GW Abstraction



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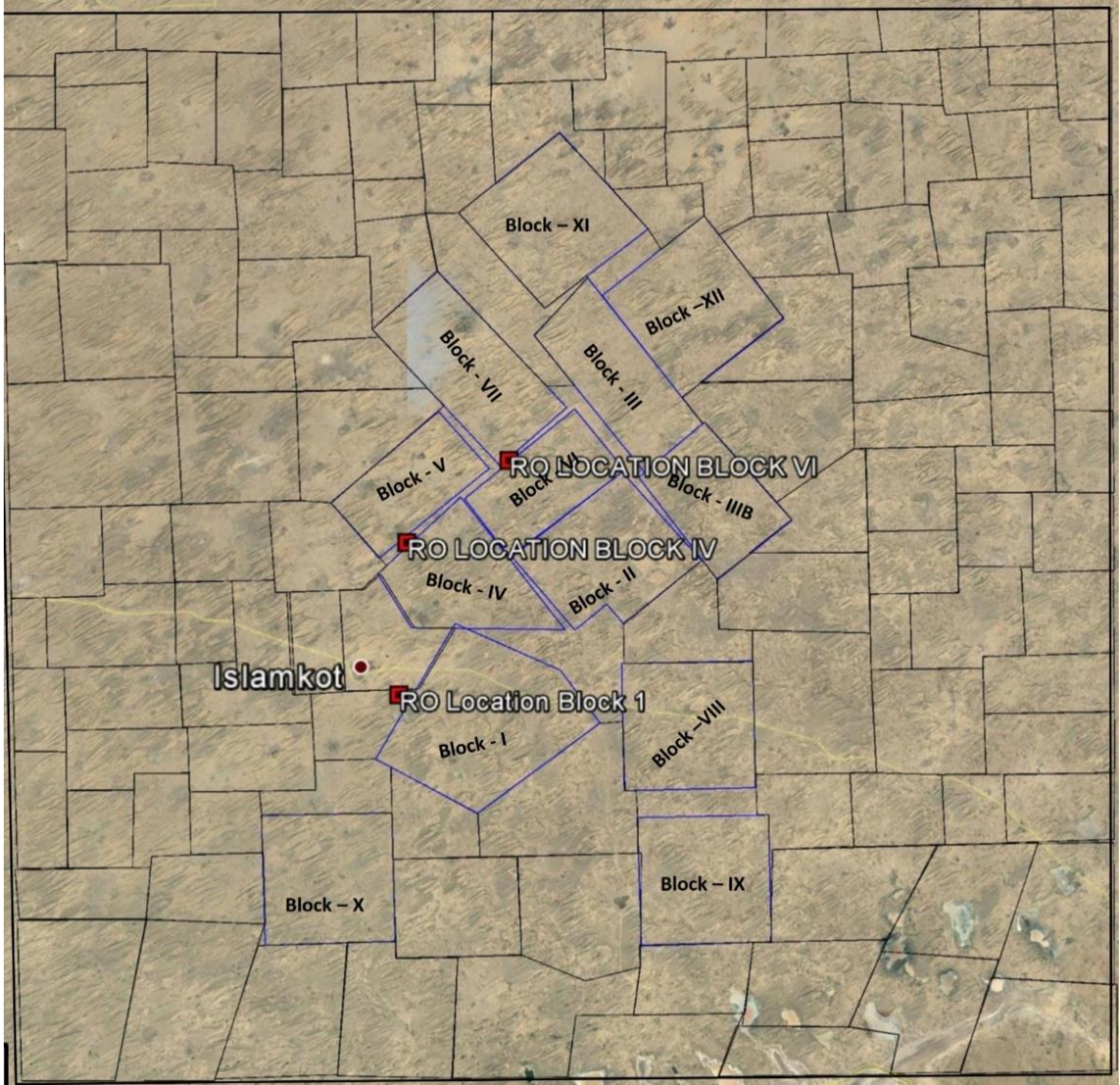
Water Supply, Treatment & Distribution Network

- Coalmine GW Abstraction
- Collection Chamber
- Conveyance System
- Decentralized RO Plants
- Conveyance System
- Storage/Supply Tanks



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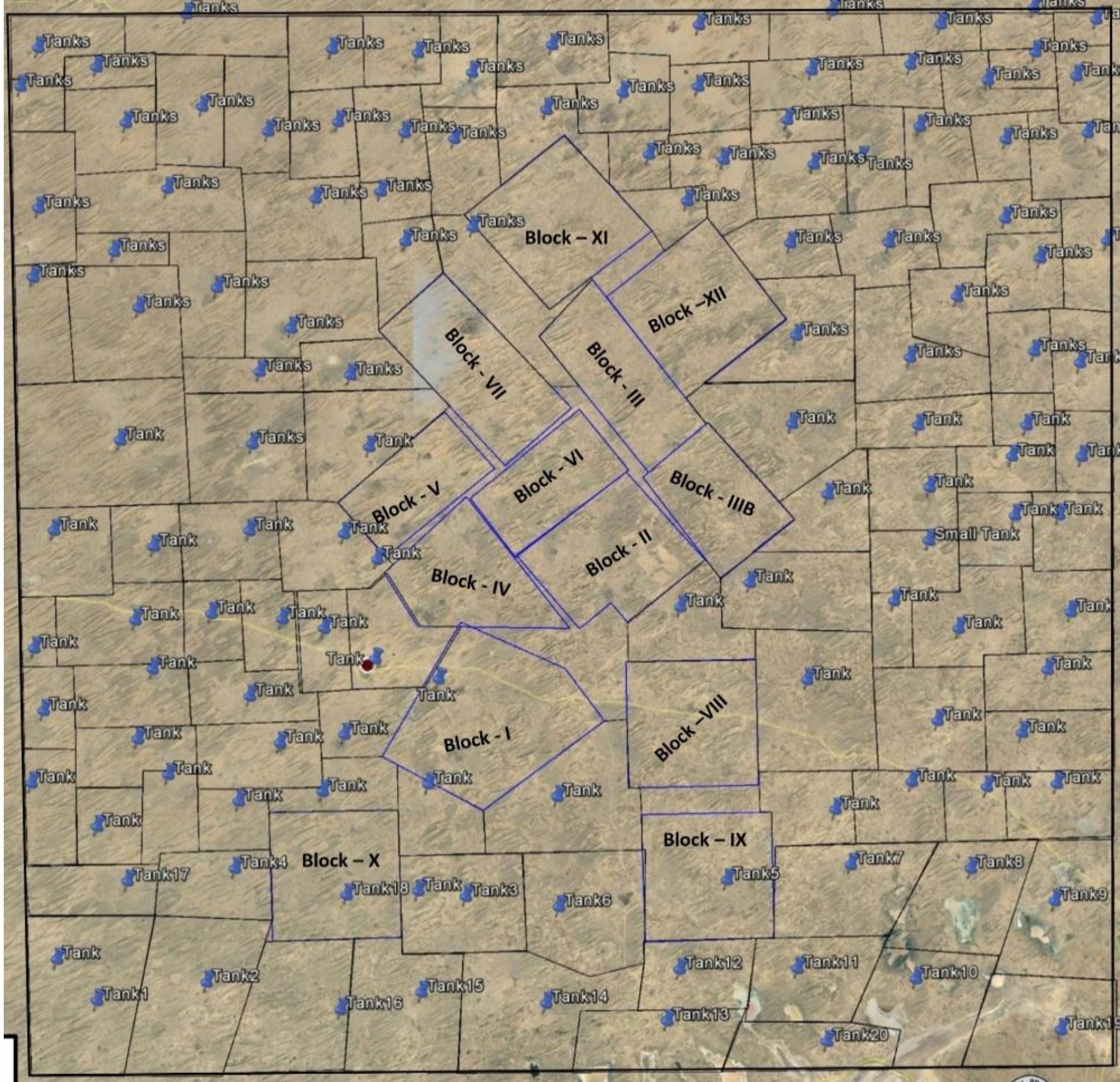

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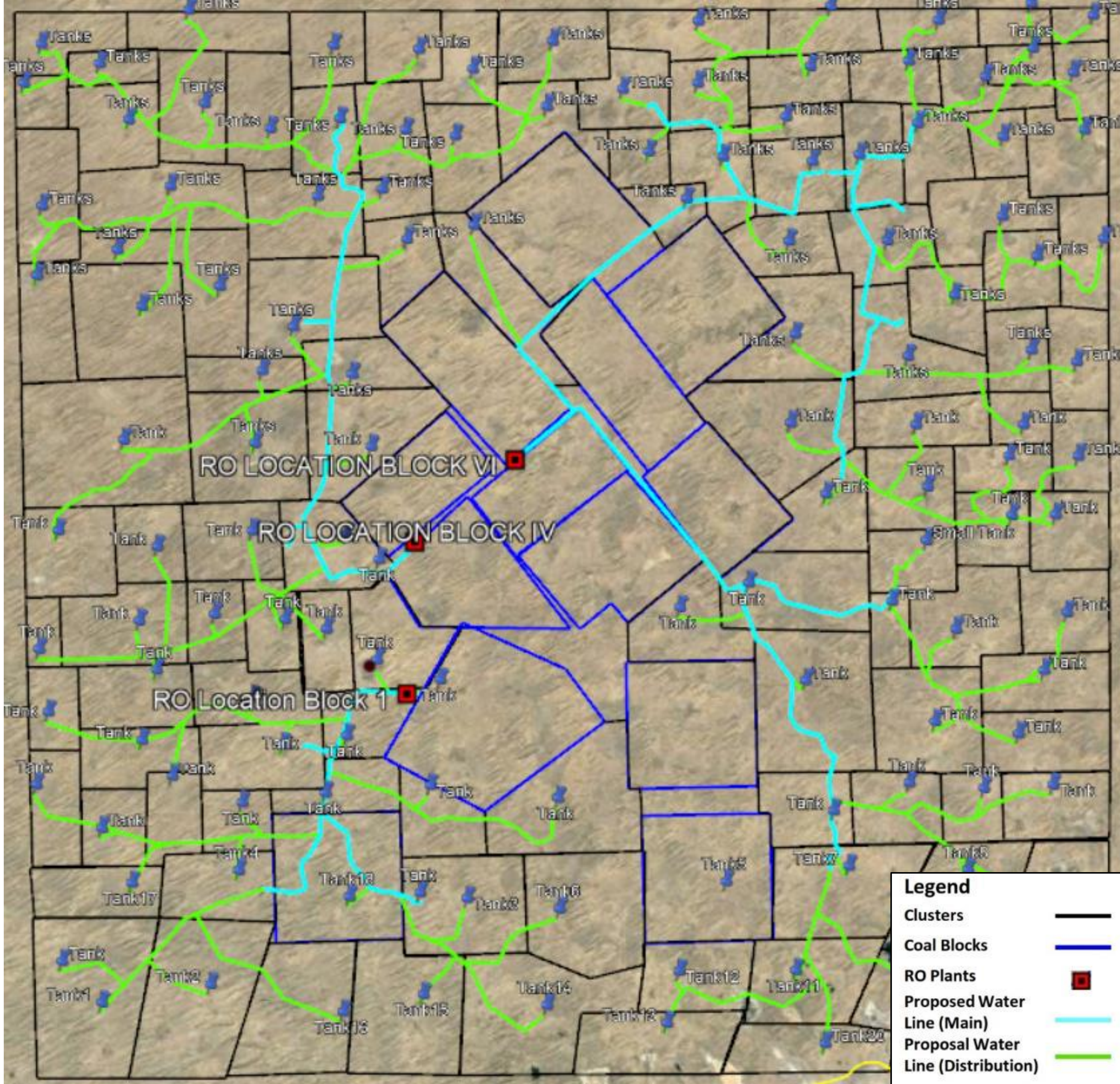
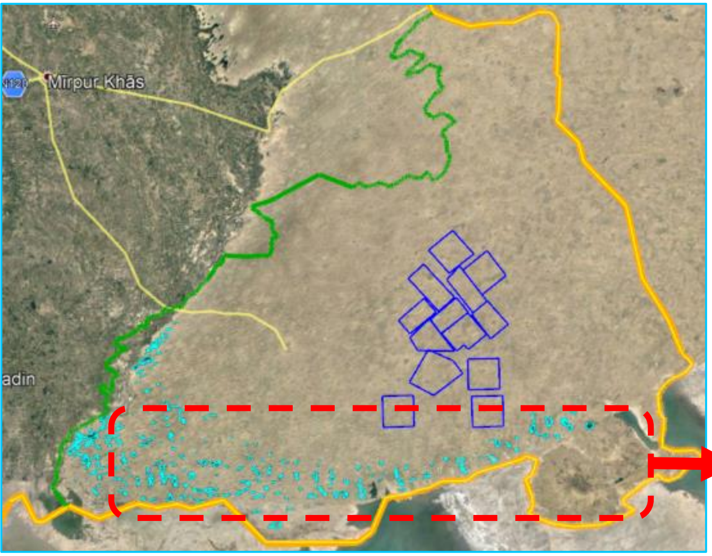


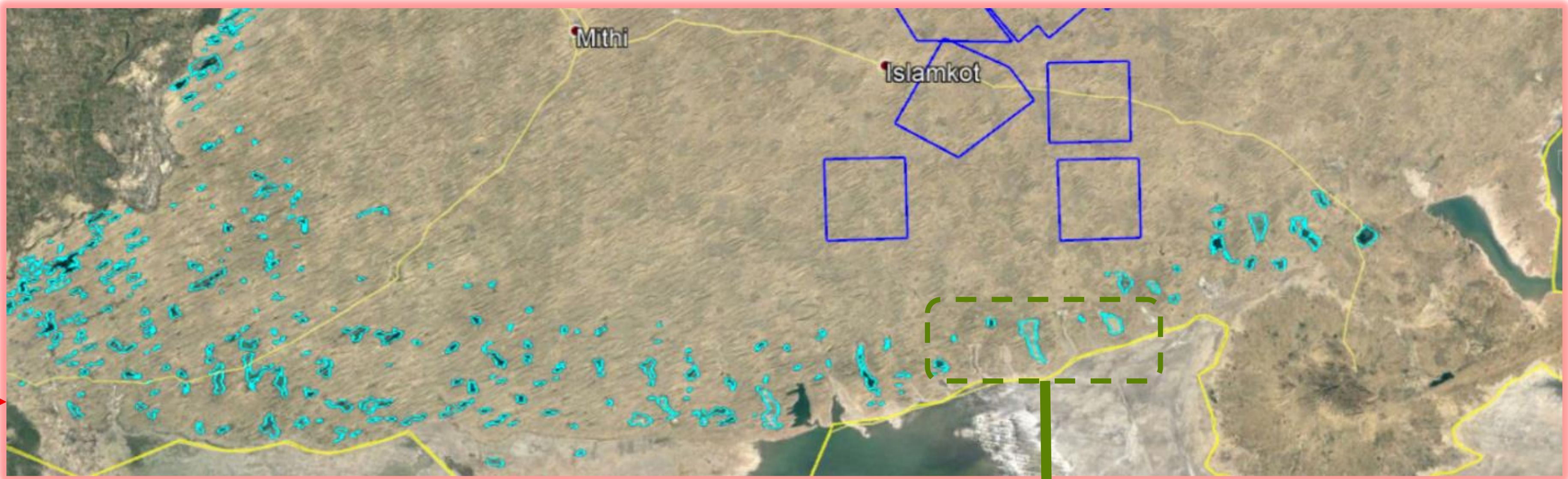
Possible Effluent Reuse/Disposal Options

Possible Effluent Disposal Options

Disposal into Salt Lakes *(Runn of Kutch)*	Disposal into a natural depression	Re-injection into Groundwater aquifer
De-notification of Runn of Kutch from Ramsar Convention (1976) to enable disposal into salt lake. No requirement for acquiring land. Economical. Conveyance system required. Less skilled labor required.	Land requirement. Conveyance system required. Possibility of groundwater recharge. Economical. Less skilled labor required.	Uneconomical (Cost of pumping, electricity & transportation). Land occupied for reinjection wells. Possibility of contamination of available ground water. Skilled labor required.

Possible Effluent Reuse/Disposal Options





Salt Lakes at the Rann of Kutch, South of the Thar Coal Mines

Possible Effluent Reuse/Disposal Options

Disposal into Salt Lakes (Rann of Kutch)

Trisingri Dhand, Rann of Kutch

No requirement for acquiring land.

Replenishes salt lakes

De-notification needed

Possible Effluent Reuse/Disposal Options

Disposal into Salt Lakes (Rann of Kutch)

Trisingri Dhand, Rann of Kutch

No requirement for acquiring land.

Replenishes salt lakes

De-notification needed

- A number of **saline lakes** containing salt deposits are present in the southern margins of the Thar. Generally concentration of such salt lakes usually exceeds the sea water concentration and the water is not fit for human consumption. These lakes form part of the Ramsar protected wetland area called the Rann of Kutch.
- The lakes provide suitable conditions for **discharge of brine** or **excess mine effluent** from the mining and power operations to allow evaporation to take over the process. This will leave behind salt deposits similar to the ones **already found** in these saline lakes. Due to this being a Ramsar site might also be an obstacle in getting **permission** for this option.

Possible Effluent Reuse/Disposal Options

Disposal into a natural depression

Gorano Reservoir

Land requirement

Conveyance system required

Inundation of Habitat

Possible Effluent Reuse/Disposal Options

Disposal into a natural depression

Gorano Reservoir

Land requirement **Conveyance system required** **Inundation of Habitat**

- Various shallow depressions exist in the sand dunes to the south of the mining blocks that can be utilised for this type of discharge and recovery. However, a lot of the rural communities rely only on the **shallow aquifers** for water supply with a lot of the villages in the area of the mining blocks and to the **south** having good quality ("sweet") water in the dune sand aquifers.
- The **infiltration of brine or saline effluent** into these aquifers can negatively affect the water quality.

Possible Effluent Reuse Options

Opportunity for Utilizing brackish groundwater for sustainable agriculture

"Salt-affected lands and brackish water should not be treated as waste: they are a precious resource available to mankind" – Ajmal Khan, TWAS Fellow.

Bio Saline Pilot Program, Block II

Biosaline Agriculture

- **Halophytes** - Plants that can live in saline conditions.
- SECMC + Institute of Sustainable Halophyte Utilization (Karachi University) + Local Farmers.
- Chinese Academy of Sciences' Xinjiang Institute of Ecology and Geography + Sindh Agriculture University, Tandojam.

Nurtures drought resistance in community

Cotton, Sunflowers, Melons etc.

Possible Effluent Reuse Options

5000 – 6000 TDS Brackish Water from Mine Dewatering

Opportunity for Biosaline Agriculture

Bio Saline Pilot Program, Block II

A Precedent for the future

- 15 Indigenous crops successfully harvested, including fodder species.
- 25% of irrigated land in Pakistan is affected by high salinity.
- Fish farming in Gorano Dam is also underway.

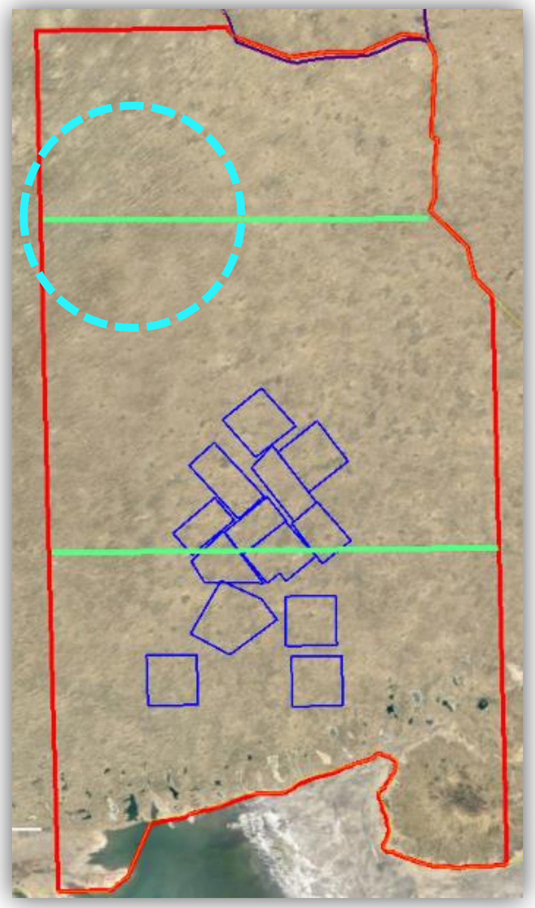
Nurtures drought resistance in community

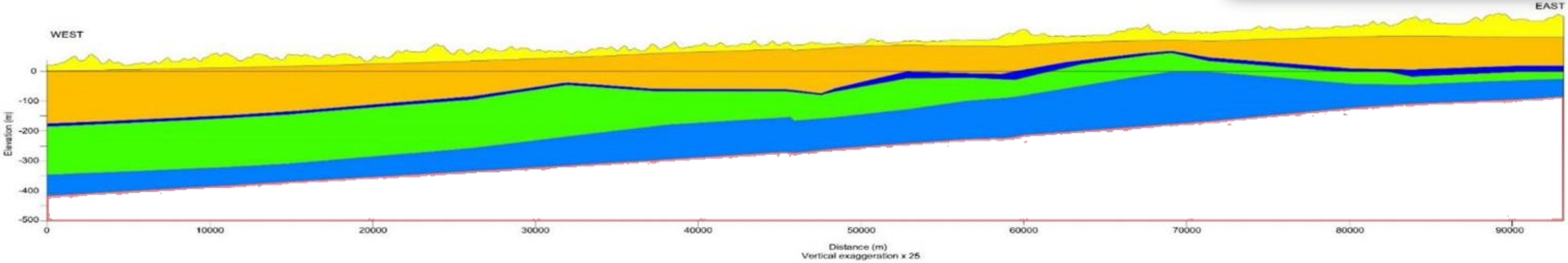
Round-the-year yields

Future Prospects

Well Field Development

- Despite an arid environment with low rainfall, large volumes of groundwater can potentially be abstracted. This has been proven by the dewatering volumes to be abstracted from the regions adjoining the main mining areas.
- Although this water is mostly from deeper aquifers with moderate to high salt content, it is an option to develop a **well field in the north-west** of the Thar Coal Mining area, for supply to the mining blocks.
- The abstraction of water north-west of the developed coalfield will also potentially aid the mining owners in underground water management and reduce the amount of water to be abstracted on site. The development of a water supply well field is however something that needs further investigation and modelling.






THANK YOU