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Appendix O: Groundwater Modelling Report (Water Supply)

Barrick Gold: Reko Diq Mine Water Supply

Fan Sediments Water Supply Modelling – Stage 2

17 May 2024

Groundwater Consulting Pty Ltd

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Table of Contents

Figures

Tables

Appendices

Executive Summary

Background

A 3D numerical groundwater model has been developed to assess the water supply potential of the Fan Sediments area and potential cross-border impacts of the proposed water supply abstraction in Iran and Afghanistan.

A staged approach to model development was adopted to incrementally develop an understanding of the key features and parameters controlling the groundwater movement in the Fan Sediments area. The GMDSI approach was used to develop Stage 1 and Stage 2 models. The GMDSI approach provides confidence intervals associated with predictions of management interest and provides assessment of potential risks associated with different courses of management action before critical decisions are made. The GMDSI models are stochastic in nature and simulate hundreds if not thousands of combinations of aquifer parameters and properties, providing a range of possible outcomes. The GMDSI approach is very useful when uncertainties in predictions that a model is tasked to produce are high. Difference between the "traditional", deterministic, approach and the GMDSI approach is that a traditional model would produce a single (deterministic) outcome or result. If uncertainties in the model are high, these results will never match the reality, and this is always a major risk for all parties involved in the project. The GMDSI approach is designed to produce a range of outcomes, all of which support the model calibration and conceptualisation. This range that falls under the Bell curve could be high in some cases. The GMDSI approach also provides guidance to modellers and non-modelers in relation what needs to be done to reduce this range (reduce model uncertainty) and where sources of uncertainty are. An example of this was the Stage 1 model developed in 2023 (GWC, 2023a and GWC, 2023b). The Stage 1 model takes into account available data and knowledge at that time. In summary, the Stage 1 model predicted that only a proportion of water demand for the Reko Diq mine could be sourced from the Fan Sediments area. The model also suggested that shortfalls could be sourced from the Patangaz area, or the entire water demand could be sources from the Patangaz area. The model was conservative in its setup, simulating a reduced depth to basement and no flow, or no connection, between the main aquifer in the Fan Sediments area and hydrostratigraphic units underlying the Gaud-i-Zirreh area in the east and west.

During the Stage 1 modelling, geophysical and hydrogeological site investigations were ongoing. They are documented in the SMEC, 2024 report. These investigations allowed the groundwater flow direction and gradients to be defined, increased the known saturated thickness of the sediments, provided monitoring points along the Afghanistan border, and allowed for better understanding of the aquifer properties including permeability distribution and conditions. They were used to refine the Stage 1 model in Stage 2. The aquifer extent in the Stage 2 model was expanded significantly to accommodate an updated conceptual model which extends beyond the Afghanistan border and encompasses Gaud-i-Zirreh. Due to an inability to collect field data outside of Pakistan, most of the required assumptions relate to definition of hydrostratigraphic units within Afghanistan. Although recent site investigations provided more refinements in terms of aquifer geometry and connections to Gaud-i-Zirreh, uncertainties in parameters used to describe aquifer storage and recharge remain. Therefore, the Stage 2 model was built using a conservative approach to avoid overpredicting the water supply potential of the Fan Sediments aquifer and to avoid underpredicting drawdown impacts resulting from the simulated water supply abstraction. Actions adopted in the current Stage 2 model were:

- Upper limit of aquifer storage in the model was capped at 5%.
- Aerial recharge in the model was not included.
- No flow boundaries were assigned across the model edges.

Results

The results of the Stage 2 model show that with the adopted approach described above, there will be no shortfalls in mine water supply over the simulated abstraction period of 46 years. That is, 142 simulated combinations of stochastic parameter fields show no discrepancy between the assigned and predicted abstraction from the simulated water supply borefield. In comparison with the Stage 1 model, which predicted shortfalls in simulated water supply, extended aquifer thickness in the Stage 2 model (delineated from latest geophysical investigations) and connection between the Fan Sediments aquifer and hydrostratigraphic units underneath the Gaud-i-Zirreh, provided additional storage and inflows that are predicted to support projected water supply for the project. Uncertainty remains in parameters adopted to represent hydrostratigraphic units in Afghanistan, in the Gaud-i-Zirreh area. With saturated thickness of these units of ~300m or more, they represent a significant aquifer in the model. Model water balance suggests that simulated lacustrine unit underlying the Gaud-i-Zirreh contributes up to 20% of predicted inflow in the borefield area. That is, the model predicts that more than 75% of water supply is sourced from aquifer storage of the main aquifer in the Fan Sediments area. The remaining 5% are inflows from Mirjawa Hills.

Uncertainties in predicted groundwater drawdown are significant at this stage and the current model is unable to reduce the range of predicted outcomes until more data become available. The results suggest that depressurisation of the lacustrine sediments underlying the Gaud-i-Zirreh will occur during operations. Most of all, this depressurisation is predicted to continue long after the water supply abstraction ceases. Uncertainties in this estimate lay in the water balance of Gaud-i-Zirreh. That is, amounts of water that can flow into and out of this system are unknown at this stage. The current model simulates no inflows on the Afghanistan side into the Gaud-i-Zirreh area. For that reason, it is likely that depressurisation predicted to occur in this area is overpredicted. These predictions could be refined further once more information related to water balance of the Gaud-i-Zirreh become available.

The proposed water supply borefield was simulated using 40 abstraction bores. Bores in the model were scattered inside the proposed borefield footprint provided by Barrick.

The number of bores was derived by dividing maximum projected water supply abstraction of 50.4 GL/year by the individual bore rate of 40 L/s. Distance between bores inside the proposed borefield footprint is around 1,500 m.

Recommendations

Our main recommendation is to update the Stage 2 model once more data become available. Predictive modelling will benefit from the ongoing collection of data from drilling, test pumping and the initial operation of the borefield. Monitoring scheme established in 2023 needs to continue and expand as additional monitoring bores become available.

Section 1 Introduction

1.1 Background

Barrick Gold Corporation (Barrick) are currently planning on developing one of the largest undeveloped copper-gold projects in the world, Reko Diq. The Reko Diq Copper and Gold project is located in western Balochistan, Pakistan in the Chagai District (Figure 1-1).

The main objective of this work is mine water supply. Several potential water supply areas near the mine have been identified and investigated in the past (Coffey 2005, 2008a, 2008b, SMEC 2009, Shomaker 2009). They are located to the northwest and southeast of Reko Diq. This work focused on water supply assessment of the Fan Sediments aquifer, located to the northwest of the proposed mine, in the Baghicha area (Figure 1-1).

Aquifers in the Fan Sediments area are derived from erosion by wadis of the Mirjawa Hills and their northward extension, from Saindak in Pakistan to Sefidabeh in Iran. The unconsolidated colluvial fans, sourced from the Mirjawa Hills, extend over 35 km northwards towards Afghanistan and Iran (north-west) and are part of the Helmand River Valley (SMEC, 2024).

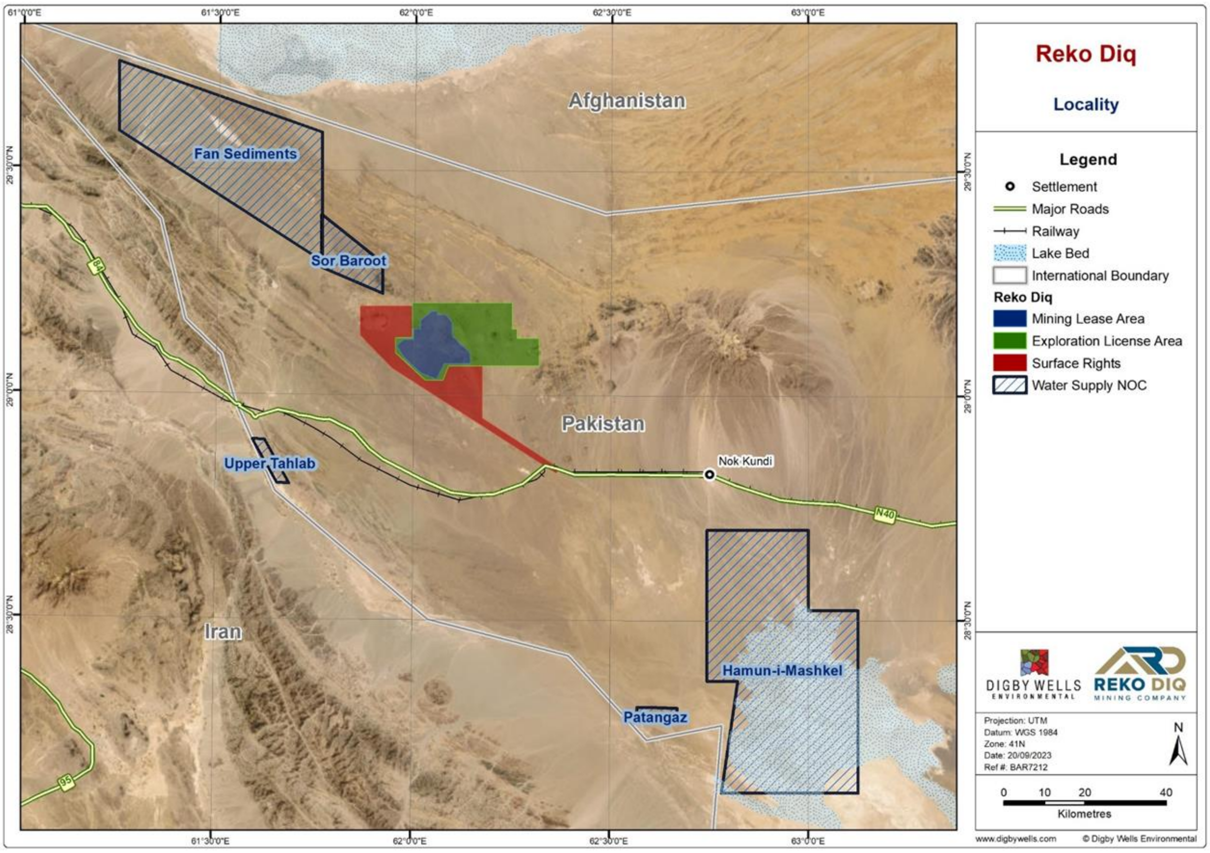

Figure 1-1 Map showing location of the Fan Sediments area relative to the Reko Diq Mine

The unconsolidated colluvial fans, sourced from the Mirjawa Hills, extend over 35 km northwards towards Afghanistan and Iran (north-west) and are part of the Helmand River Valley. The regional extent of sediment, hydraulic interconnection, and aquifer characteristics of the aquifers in the neighbouring countries are unknown (SMEC, 2024).

Within the Fan Sediments area in Pakistan, there is no groundwater extraction for domestic or irrigation purposes. There are no villages or date palm plantations within the proposed borefield.

The Fan Sediments aquifer has moderate permeability. Historical pumping tests and falling head slug tests were used to estimate aquifer storage and permeability. Aquifer permeability is estimated to range between 0.5 and 3 m/d. Groundwater is brackish with elevated temperature. Groundwater is 10,000 to 24,000 years old (SMEC, 2009).

Rainfall in this area is low and erratic, with a strong seasonal pattern. Average annual rainfall ranges between 16 and 87 mm/year (SMEC, 2009). January is the wettest month and September is the driest month. More than 85% of annual rainfall occurs between December and March. Almost no rainfall occurs during dry periods between May and October. The distribution of rainfall is also highly variable across the catchments which contribute to the Fan Sediments aquifer.

Groundwater level monitoring was undertaken during the 2007 to 2009 feasibility level assessment and continued until June 2011 when loggers were removed and stored at Reko Diq and the site closed. Manual water level measurements for Phase 1 commenced in March 2023.

Monitoring records collected to date display a steady state aquifer condition. That is, measured water levels across the site show no response to rainfall recharge or any other transient stresses. Since the Fan Sediments aquifer has not been significantly stressed in the past, aside from five short-term pumping tests, aquifer storage is only approximately known. Furthermore, it is unknown if its boundaries are pervious or not; hence unknown amounts of water can flow into and out of a local system from neighbouring areas.

Aquifer thickness and lateral extent were subject to different interpretations in the past. In Stage 2, aquifer thickness has been defined with greater certainty than previously through geophysical surveys.

The extent to which rainfall recharges groundwater storage is difficult to quantify. It is thought to be dominated by mountain front infiltration along the Mirjawa Hills with discharge at Gaud-i-Zirreh.

It follows that uncertainties in predictions of future groundwater availability are likely to remain until more data becomes available. The Stage 2 assessment of water supply security takes the most up to date knowledge of system geometry, properties, and recharge into account. Consistent with Stage assessment, a conservative approach was adopted to simulate aquifer units in the Fan Sediments area. That is, the main goal of this approach was to eliminate assumptions which were scrutinised in the past by the reviewers (WRA, 2017), and focus on factual data to primarily avoid outcomes that would overestimate water supply potential of this area.

1.2 Project objectives and scope

The objectives of this modelling study were centred around building a robust numerical groundwater model of the Fan Sediments area. This model was meant to provide a starting point for future refinements and upgrades and was designed to provide initial water supply and drawdown estimates for the study. The model will be refined in the future to include more details related to geology, hydrogeology, basin geometry and operational activities at Fan Sediments. Fine tuning details related to implementation stage of the project will be an ongoing process and will require model updates as new data become available.

The main objective of this study has been to develop a robust numerical groundwater model which is consistent with the latest conceptual understanding of the Fan Sediments groundwater system. The model has been used as a predictive tool to assess the following:

1. **Feasibility of Mine Water Supply** – The model was used to simulate mine water supply requirements for the proposed nominal 45MTPA life of mine (LoM). These results providing inputs into water management strategies and borefield designs.
2. **Water Balance** – The model was used to estimate the water balance for the LoM and to provide an assessment of likely range of water supply shortfalls over the LoM.
3. **Potential Impacts of Water Supply Abstraction** – The model was used to assess the potential magnitude of groundwater level drawdown resulting from long-term water supply abstraction.

Section 2 Groundwater Model

2.1 Introduction

The conceptual hydrogeology of the broader Fan Sediments area has been based on the conceptual hydrogeological model provided by SMEC (SMEC, 2024). The Leapfrog model that was used to construct the numerical flow model is described in Darkwater, 2024 report.

The key features of the conceptual model captured by the numerical model are:

- Unconfined aquifer conditions of the main Fan Sediments aquifer southwest of dunes.
- Superficial clay unit overlying lacustrine sediments in the Gaud-i-Zirreh area.
- Confined aquifer conditions interpreted to develop to the northeast, underneath the clay unit towards Gaud-i-Zirreh. Confined aquifer conditions are observed at Imtaz FC bore.
- Transition between colluvial sediments associated with the main aquifer and lacustrine/fluvial sediments northeast of dunes in the Gaud-i-Zirreh area.
- Interpreted shape and thickness of the main aquifer.
- Inflow via mountain front infiltration of runoff from the Mirjawa Hills.
- Vertical groundwater leakage to surface and evaporation at Gaud-i-Zirreh.

Modelling for this project was completed using the GMDSI approach described in the following section.

2.2 GMDSI Approach

The Groundwater Modelling Decision Support Initiative (GMDSI) is an industry-funded initiative focused on improving the role that groundwater modelling plays in supporting environmental management and decision-making. GMDSI has documented a number of examples of decision-support groundwater modelling. These documented worked examples attempted to demonstrate that by following the scientific method, and by employing modern, computer-based approaches to data assimilation, the uncertainties associated with groundwater model predictions can be both quantified and reduced. With realistic confidence intervals associated with predictions of management interest, the risks associated with different courses of management action can be properly assessed before critical decisions are made.

The decision-support challenges that can be addressed by the GMDSI approach include the following:

- Assessing water supply reliability.
- Protecting groundwater resources from contamination.
- Estimating mine dewatering requirements.
- Assessing the environmental impacts of dewatering or water supply, and
- Managing an aquifer threatened by saltwater intrusion.

In all cases the approach is the same. Management-salient model predictions are identified. Ways in which model-based data assimilation can be employed to quantify and reduce the uncertainties associated with these predictions are reported. Model design choices are explained in a way that both modellers and non-modellers can understand.

2.3 Model Setup

2.3.1 Background

A numerical model has been developed to assess whether proposed water supply abstraction for the 45MTPA plan could be sustained over the proposed abstraction period of 46 years. The model was also used to predict potential drawdown impacts associated with the proposed water supply abstraction.

The numerical groundwater flow modelling package Modflow-USG was used to develop the model operating under the Groundwater Vistas graphical user interface. As discussed in Section 1.1, a conservative approach was adopted to simulate aquifer units in the Fan Sediments area. That is, the main goal of this approach was to mainly avoid outcomes that would overestimate the water supply potential or underestimate drawdown impacts of the proposed water supply abstraction. In summary, the conservative approach adopted for this study has assumed the following:

- The extent to which rainfall recharges a groundwater storage was difficult to quantify; so too was the ability of a groundwater system to gain water from rainfall events.

  Action: Aerial rainfall recharge was not included in the model.

- Contribution of other groundwater systems to the greater Sistan Depression/Gaud-i-Zirreh water balance is uncertain.

  Action: They have not been included as not to introduce additional uncertainty and potentially overestimate the water supply potential and underpredict the impact of abstraction.

- Aquifers in the Fan Sediments area have not been significantly stressed in the past, aside from five short-term pumping tests. Storage parameters of hydrostratigraphic units across the site is only approximately known.

  Action: Upper limit of aquifer storage was capped at 5% although laboratory analyses completed to date suggest it could be much higher.

- The volume of inflow that aquifers within the model domain receive is assumed to match by the discharge to evapotranspiration as the system is in steady state (SMEC, 2024). Specific discharge at Gaud-i-Zirreh was estimated to be around 4.6×10^{-6} m/d (SMEC, 2024).

  Action: Depending on the size of the evaporation area within the model domain (the entire area within the model domain or just the lowest points) discharge at Gaud -I -Zirreh in the model is estimated to range between 3 and 5 GL/year. To be on the conservative side, the model assumes 3 GL/year of discharge at Gaud-i-Zirreh. To balance the outflow, inflow from the Mirjawa Hills was also assumed to be 3 GL/year.

It is recognised that in order to avoid overpredicting the water supply potential of the Fan Sediments aquifer and to avoid underpredicting drawdown impacts from prolonged abstraction, actions adopted in the current model might lead to underpredicting the amount of water that could be extracted from the Fan Sediments and overpredicting drawdown impacts. With aquifer storage being capped at 5% it is reasonable to state that the current model is likely to produce results that could fall into the so called “worst case” category.

2.3.2 Model Extent and Boundary Conditions

The model domain covers an area of 106 km east to west and 84 km north to south. The model extent is presented in Figure 2-1. Coordinates of the four corners of the model domain are detailed in Table 2-1.

Table 2-1 Model Domain

	Easting (m)*	Northing (m)*
Northeast	400,750	3,315,029
Northwest	294,750	3,315,029
Southwest	294,750	3,231,029
Southeast	400,750	3,231,029

* WGS84 UTM Zone 41N

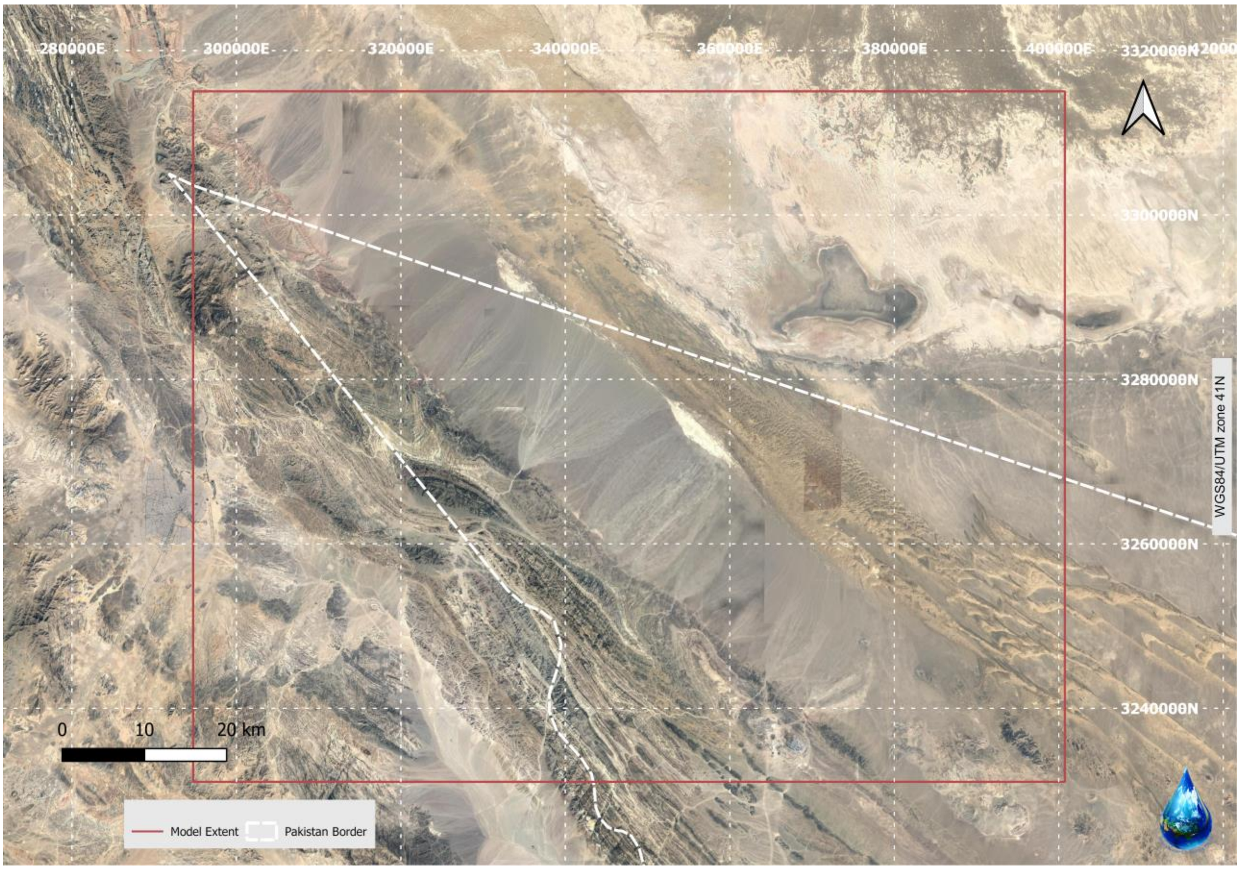

Figure 2-1 Model Extent

The model grid has the greatest spatial resolution in the immediate borefield area, where the minimum cell size is 62.5 m by 62.5 m. The grid was refined to provide appropriate grid size at the proposed water supply bore locations and to capture drawdown curvature expected to develop around the proposed borefield. Model cell size increases to a maximum of 1,000 m by 1,000 m at the model boundaries. The model employs a quadtree-refined grid to represent the 3 layered aquifer system displayed in Figure 2-2.

The model grid is defined by 52,933 active model cells over three model layers.

The model and all associated data are specified using the WGS84 UTM Zone 41N coordinate system.

Figure 2-2 Model Grid

The model layer 1 is designated as "unconfined"; hence transmissivity can vary with water table elevation. Layers 2 and 3 are simulated as a "convertible", meaning that water level elevation is checked at time step level. If the simulated water level is below the top of the layer, that layer is treated as unconfined and vice versa, if the simulated water level is above the top, that layer is considered confined.

Simulated boundary conditions are shown in Figure 2-3. As discussed in Section 2.1, the conceptual hydrogeological model suggests that the main aquifer unit in the Fan Sediments area receives inflow via mountain front infiltration of runoff from the Mirjawa Hills and Sor Baroot in the southeast. This is simulated using the Recharge package of Modflow-USG, located along the contact between the main aquifer and the bedrock outcrop in the west. Also, the conceptual hydrogeological model suggests that outflow from the system is via evaporation in the Gaud-i-Zirreh area (playa). This is simulated using the Drain package of Modflow-USG as presented in Figure 2-3. Drains were set 0.5 m below the surface to simulate the extinction depth of evaporation in this area. Outcrops associated with the Mirjawa Hills, located in the southwest, are simulated as a no flow zone or inactive cells. Along the model edges, aside from inflow boundary associated with Mirjawa Hills and outflow boundary associated with Gaud-i-Zirreh, no other inflow or outflow boundaries were adopted in the model.

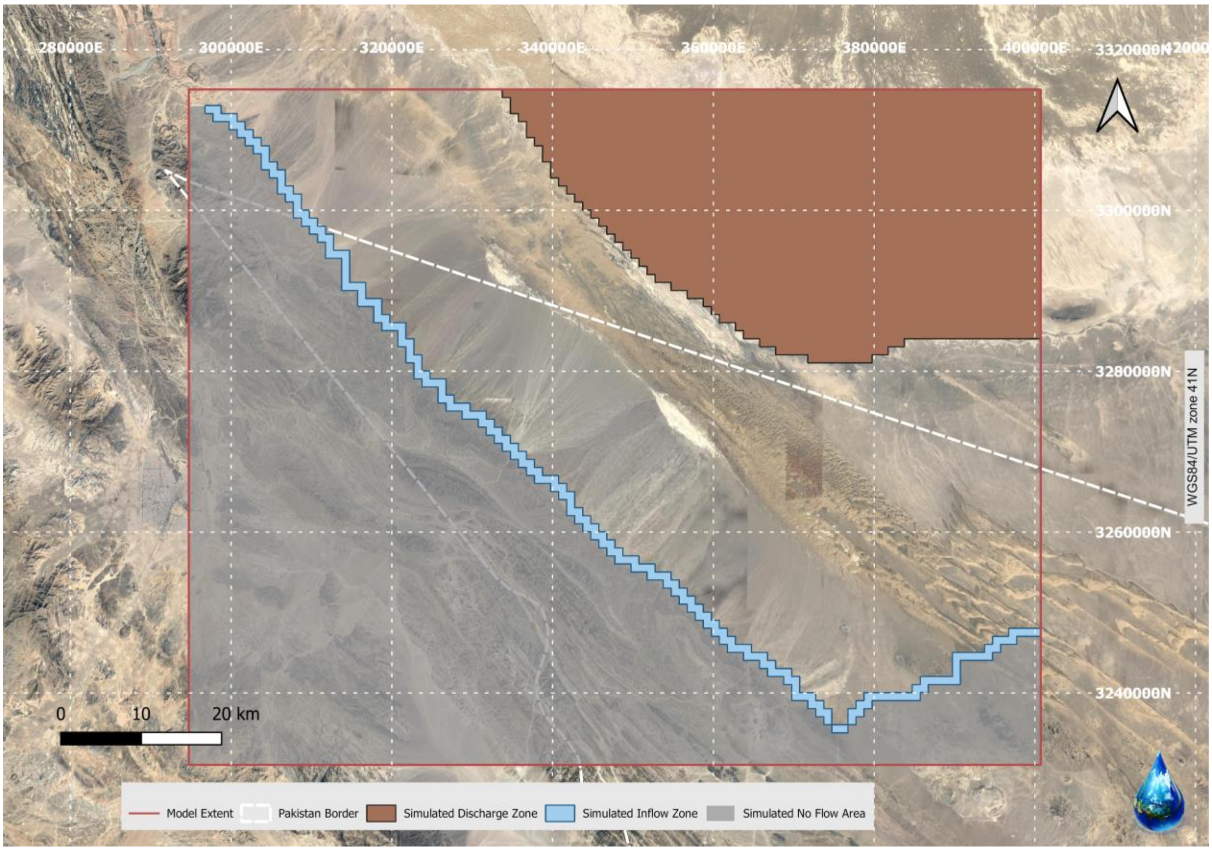

Figure 2-3 Model Boundary Conditions

2.3.3 Model Geometry and Parameters

The current model consists of three layers. Counting from the top, layer 1 in the model was used to simulate the superficial clay unit overlying lacustrine sediments in the Gaud-i-Zirreh area. In model layer 1, all cells located outside of the simulated clay unit were "pinched out" and simulated as "pass-through" cells. The other two layers in the model were used to simulate the underlying aquifer units and low permeability bedrock respectively. Layer elevations and thicknesses were assigned consistent with the Leapfrog model developed by Darkwater Consulting. The base of model was set to a uniform value of -200 mASL.

The spatial distribution of aquifer hydraulic conductivity within the model domain is presented in Appendices A1 to A3 [The Hydraulic conductivity and storage distributions in the model were simulated by generating stochastic parameter fields using pilot points. Minimum and maximum bounds used for the pilot points were set consistent with ranges presented in Figure 2-4. The conceptual model divides the main aquifer into three conductivity zones (Zones 1 to 3 presented in Figure 2-4). Zone 4 is associated with the lacustrine/colluvium northeast of dunes, underneath the Gaud-i-Zirreh. Parameters assigned to these four zones are summarised in Table 2-2. Hydraulic conductivity of the Clay unit in model layer 1 was assumed to consistent with Zone 1. Permeability of the Bedrock unit was assumed to be low (0.0001 m/d).

Table 2-2 Hydraulic Conductivity Assigned to Modelled Hydrostratigraphic Units

Unit	Model Layer	Minimum (m/d)	Maximum (m/d)
Clay	1	0.001	0.1
Main Aquifer (Zone 1)	2	0.001	0.1

Unit	Model Layer	Minimum (m/d)	Maximum (m/d)
Main Aquifer (Zone 2)	2	0.1	1
Main Aquifer (Zone 3)	2	0.5	4
Lacustrine / Colluvium (Zone 4)	2	0.1	1
Bedrock	3	0.0001	0.0001

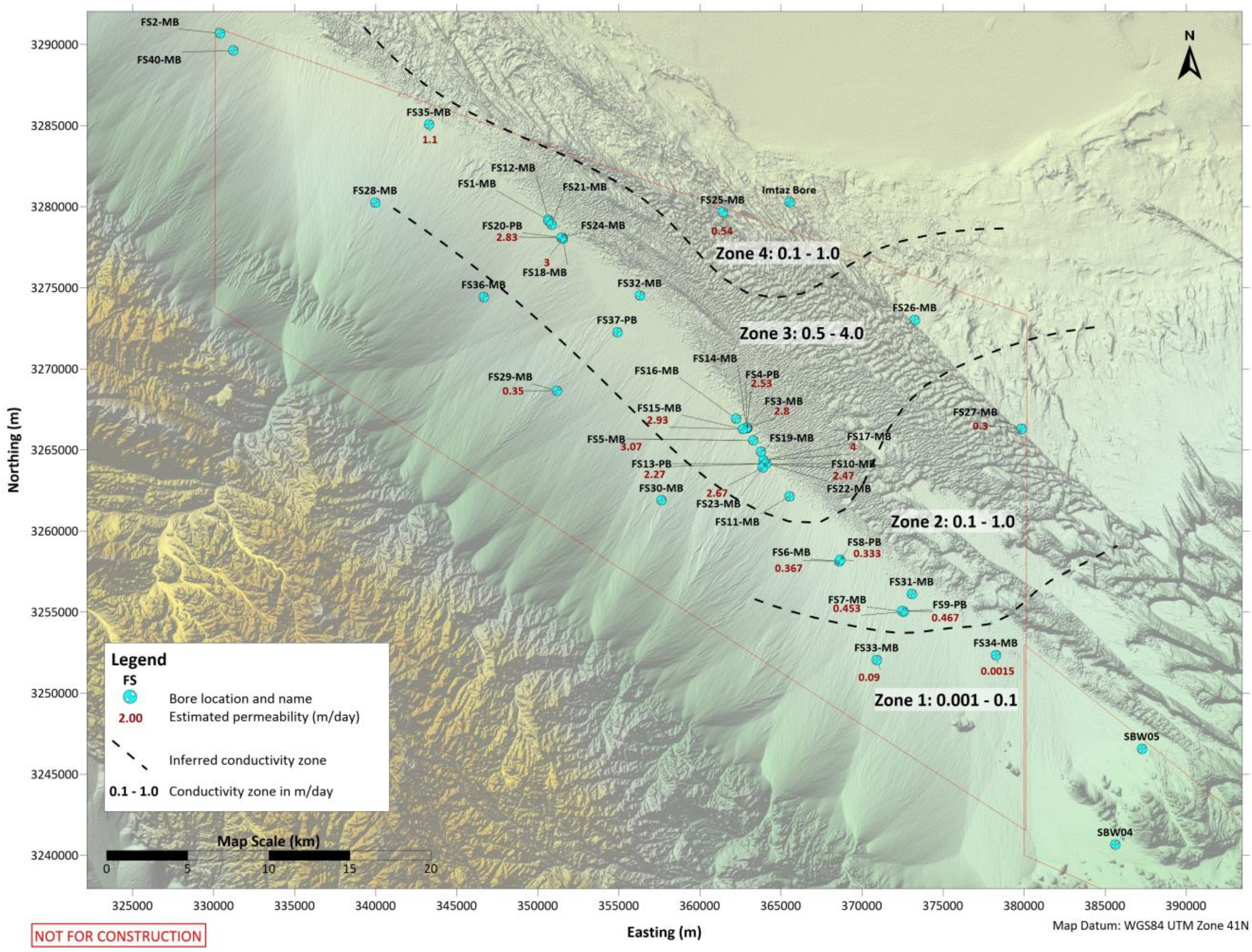

Figure 2-4 Hydraulic Conductivity Distribution in Model Layer 2 (Conceptual Model)

The conceptual model divides the main aquifer into two storage zones (Zone 1-2 presented in Figure 2-5). This aquifer property represents one of the key uncertainties in the model. Unconfined aquifer storage of the main aquifer to the southeast and southwest of the proposed water supply borefield is assumed to range between 0.1% and 3%. In the immediate borefield area, unconfined aquifer storage of the main aquifer is assumed to range between 1% and 5%. As discussed in Section 2.3.1, aquifer storage was capped at 5% although some investigations completed to date suggest it could be much higher. Northeast of dunes, unconfined aquifer storage associated with the lacustrine sediments underlying the Gaud-i-Zirreh was also assumed to range between 1% and 5%.

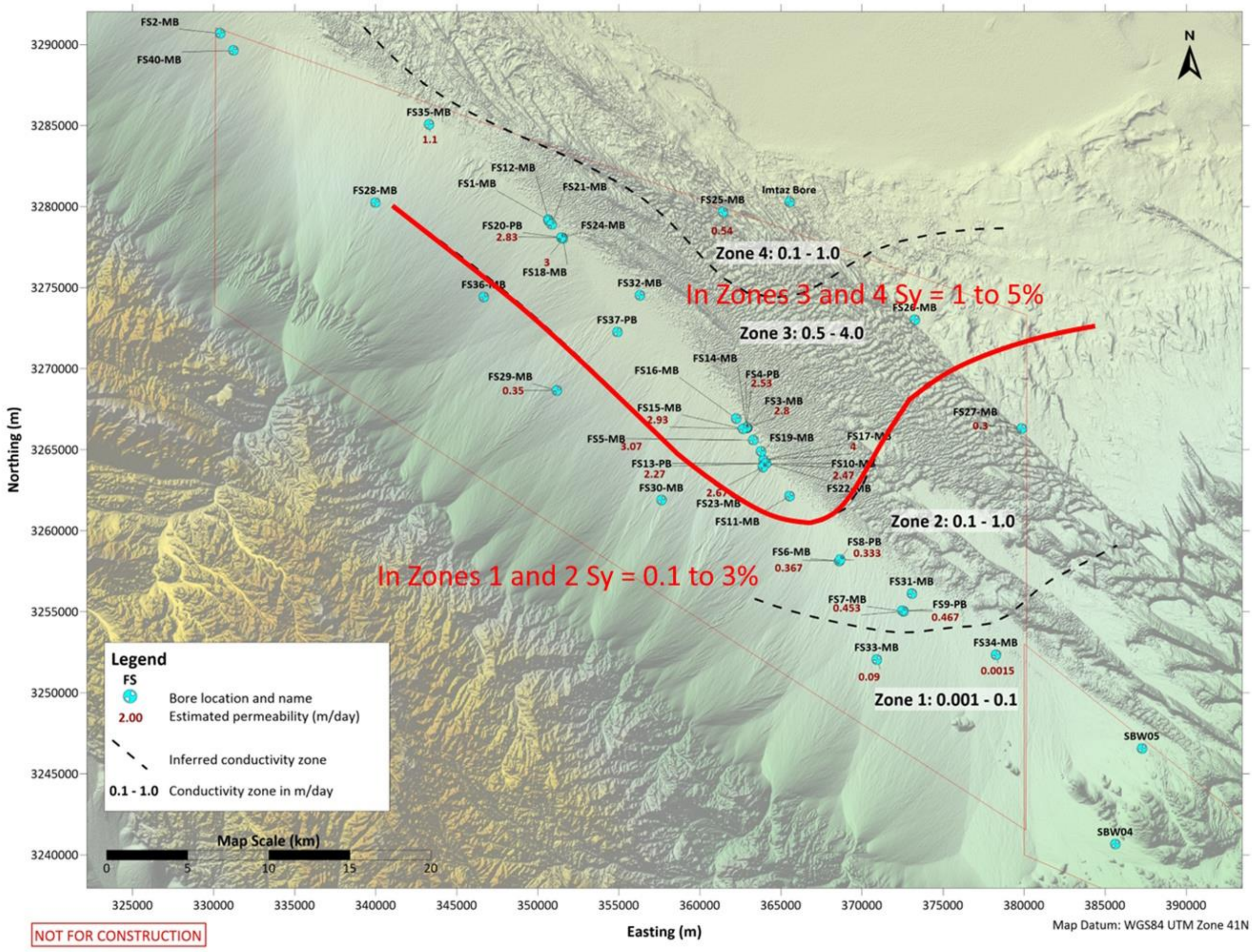

Figure 2-5 Unconfined Aquifer Storage Distribution in Model Layer 2 (Conceptual Model)

2.4 Model Calibration

2.4.1 Introduction

Model calibration is the process by which parameters of a numerical model are adjusted, within realistic limits, to produce the best match between simulated and measured data (normally groundwater levels obtained from monitoring). Those limits are presented in Figures 2-4 and 2-5 and summarised in Table 2-2. This process typically involves refining the aquifer properties and boundary conditions of the model to improve the match between the observed and simulated water levels.

Long-term monitoring in the Fan Sediments area has only recently re-commenced. Therefore, the model was calibrated to interpreted steady state or predevelopment groundwater levels presented in Figure 2-6. In some areas multiple bores were clustered in a relatively small space, or within a single cell in the model. Those clusters were filtered to have one monitoring bore per cell, leaving 21 head target locations that were used for model calibration. Simulated head targets are presented in Appendix A4.

The PESTPP-IES ensemble smoother was used to calibrate the model against water level measurements presented in Figure 2-6 and Appendix A4. The parameter assembles provided to PEST-IES comprises hydraulic conductivity pilot points and drain conductance term assigned to drains at Gaud-i-Zirreh. Inflow from Mirjawa Hills remained fixed at 3 GL/year during calibration, predictions and aquifer recovery phases. Drain elevations at Gaud-i-Zirreh remained fixed at 0.5 mBGL (Below Ground Level) during calibration, predictions and aquifer recovery phases.

Instead of estimating/calibrating vertical hydraulic conductivity (Kz), a vertical anisotropy ratio was simulated by writing anisotropy values into the LPF package of Modflow-USG instead of Kz. Adopting this approach the estimated vertical conductivity was constrained to not exceed the estimated horizontal hydraulic conductivity across the model domain. Bounds assigned to pilot points that simulate vertical anisotropy, which represent the ratio of Kx/Kz, were set between 1 and 100.

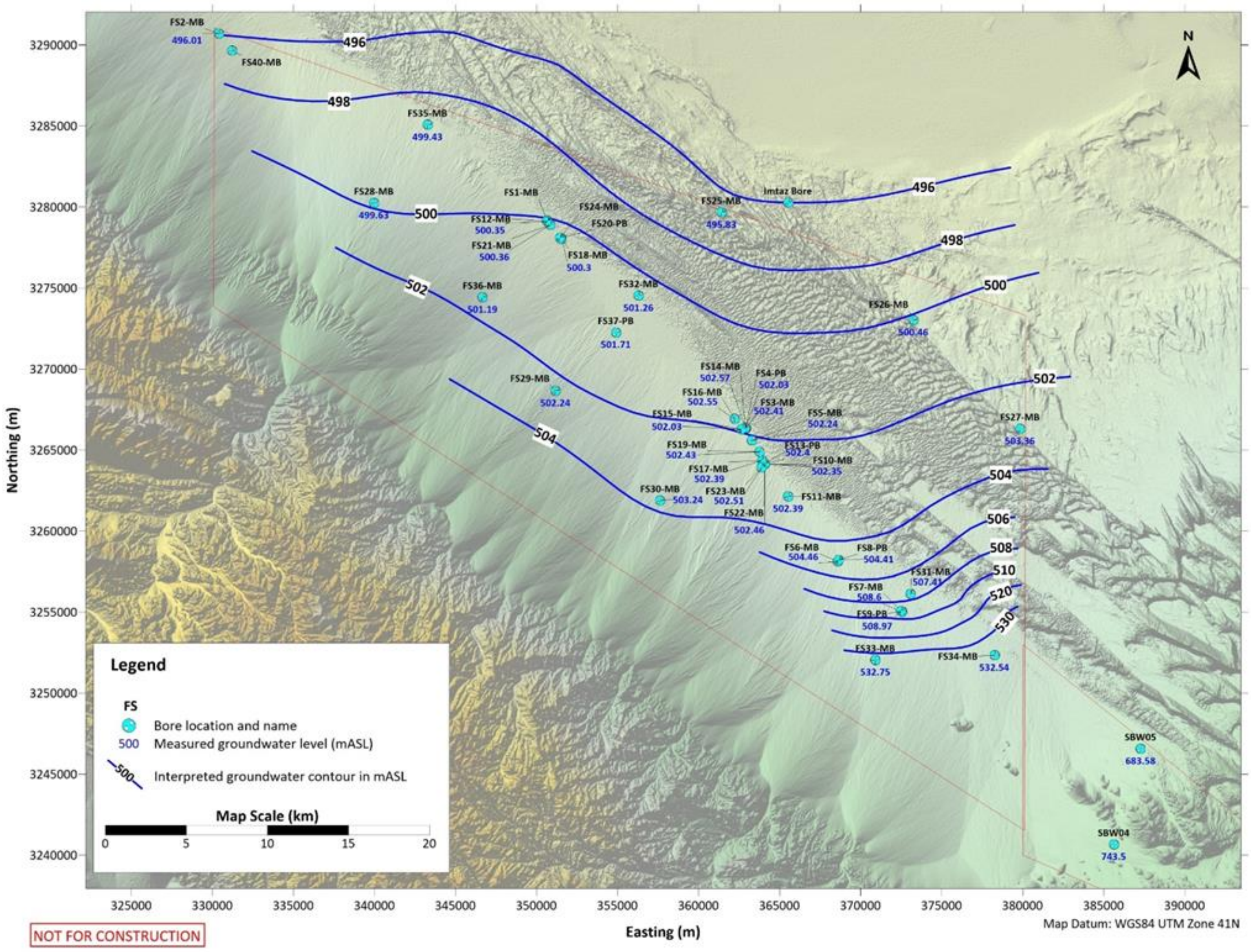

Figure 2-6 Interpreted Pre-development Water Levels

Pilot points were employed for parameterisation of hydraulic conductivity in the top two layers. Hydraulic conductivity of Bedrock, simulated in model layer 3, was fixed at 0.0001 m/d. Parameterisation of hydraulic conductivity relies on 339 Kx and 339 Kz pilot points. Their locations are shown in Appendices A5 and A6.

2.4.2 Model Calibration Performance

The steady state or long-term average calibration provides:

- A distribution of water levels that reflects the groundwater system prior to any development.
- Initial conditions for model predictions.
- Quantification of the groundwater flow through the model domain, under average inflow/outflow conditions prior to any development.
- Parameter fields that calibrate the model.

PEST-IES ran 200 realisations producing 142 parameter fields in iteration 14 with sum of weighted squared residuals (phi) between 1 and 45 (Figure 2-7). It should be noted that weights applied to all head targets were set to 1. This means that PEST-IES treated all head targets equally important and attempted to calibrate the model at each target location across the domain.

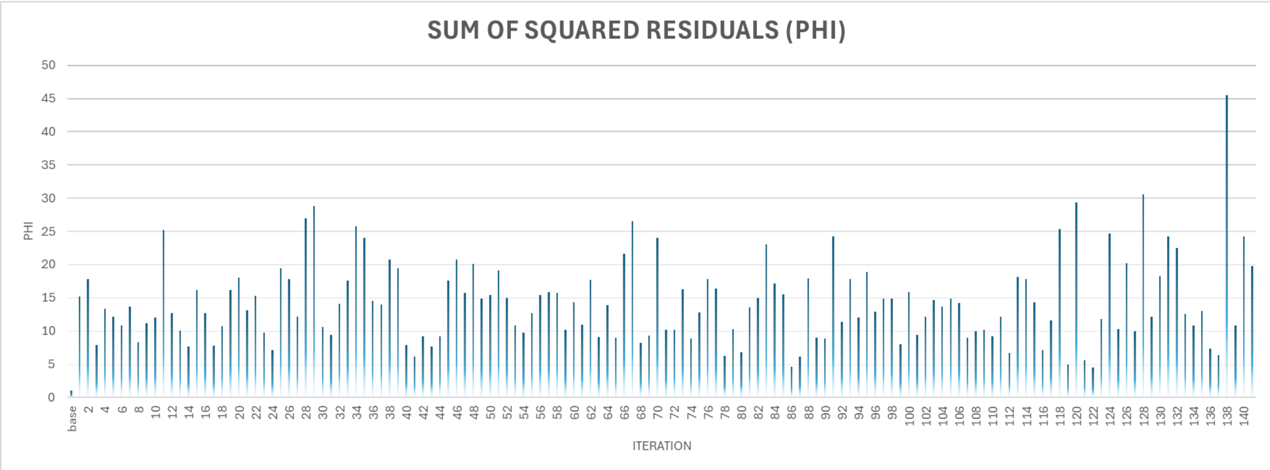

Figure 2-7 Steady State Calibration - Phi

Reasonable fits between model outputs and field measurements were attained by adjusting hydraulic conductivities in different parts of the aquifer and other simulated units in layers 1 and 2. Figure 2-8 shows difference between measured and predicted water levels at monitoring locations across the model.

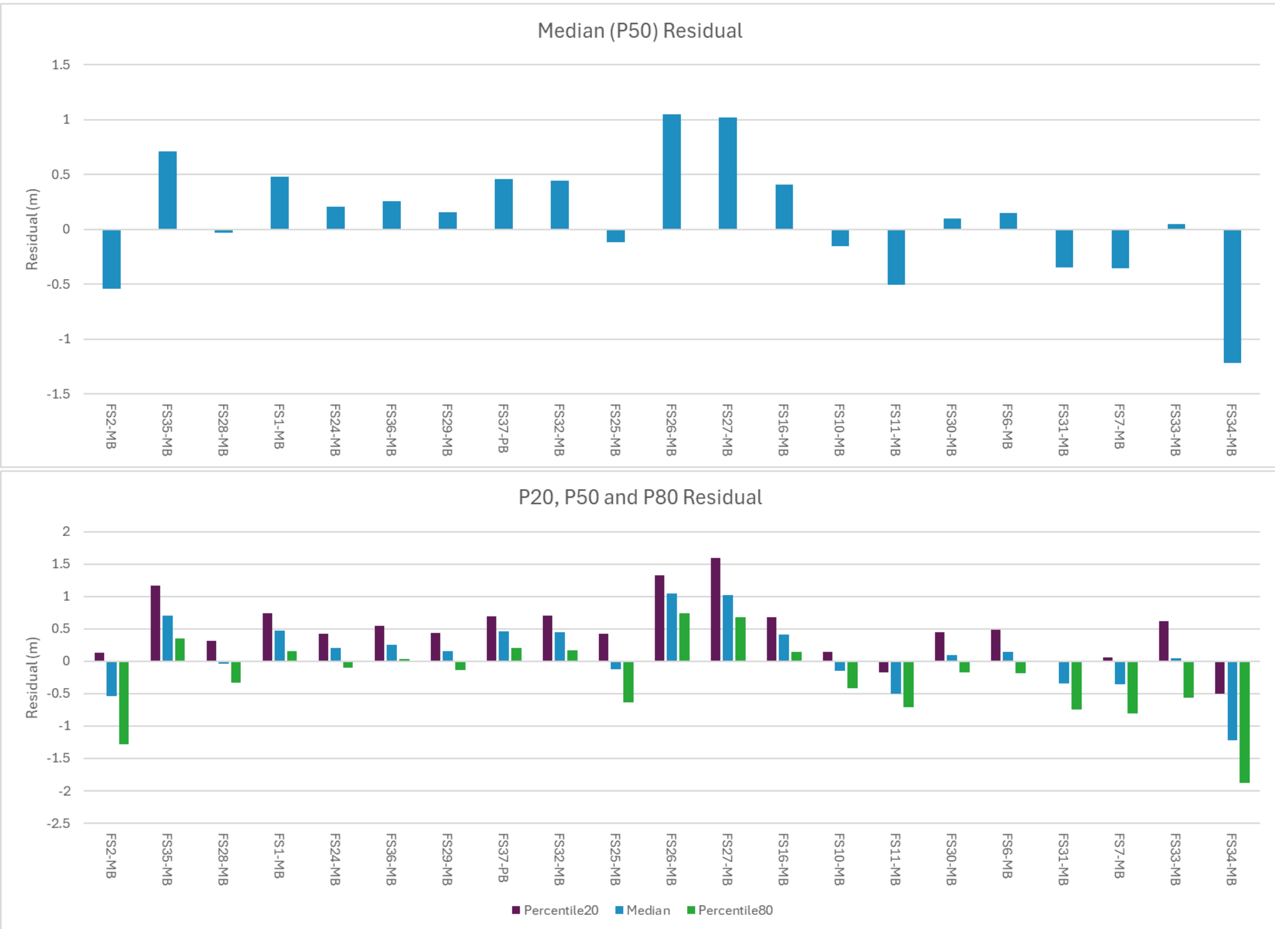

Figure 2-8 Steady State Calibration – P20, P50 and P80 Residuals

Median (P50) error between measured and predicted water levels (residual) is generally less than 1 meter. Only at bore FS34-MB, median predicted residual is 1.2 meter (Figure 2-8).

On a broader scale, between P20 and P80, residuals are generally below 1.5 meters, again except at FS34-MB where the predicted P80 residual is 1.8 meters (Figure 2-8).

2.4.3 Hydraulic Parameters

Initial spatial parameterisation of hydraulic conductivity was based on zones presented in Figure 2-4 and Appendices A1-A3. The adopted pilot point approach means that PEST-IES was not tasked to estimate a single value of hydraulic conductivity for simulated conductivity zones in the model; it provides a range of conductivity values for those zones within the bounds described in Table 2-2. Calibration-estimated hydraulic conductivity fields are displayed in Appendices A7-A10. Distribution of parameters in each of the zones presented in Figure 2-4 is shown in Appendices A11-A15 and summarised in Table 2-3. In zone 3, where the proposed water supply borefield will be installed, estimated mean (P50) horizontal conductivity is 1.6 m/d (Figure 2-9). That is, although modelled conductivity distribution is higher in some areas of this zone (see Appendix A9) mean value of hydraulic conductivity within this zone is significantly lower than the assigned maximum bound of 4 m/d. The results show that only 22% of the Zone 3 area has conductivities higher than 3 m/d (13% higher than 3.5 m/d).

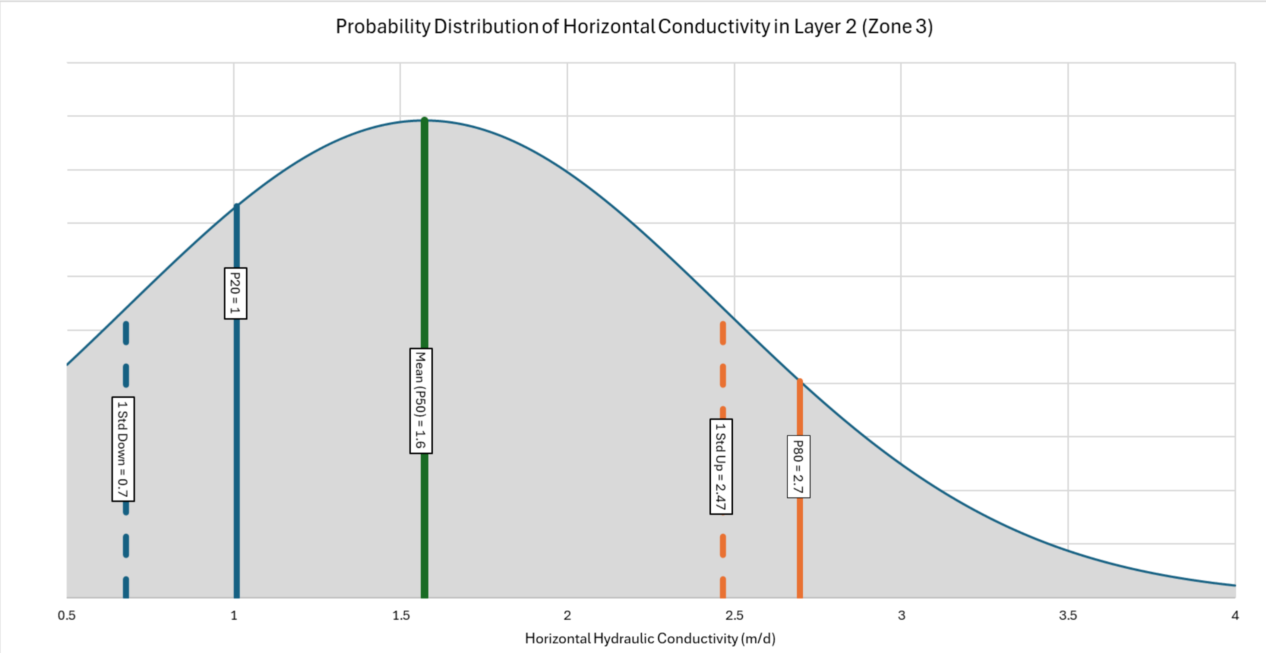

Figure 2-9 Hydraulic Conductivity Distribution in Zone 3 (Main Aquifer)

Table 2-3 Hydraulic Conductivity of Modelled Hydrostratigraphic Units and Zones

		Assigned Bounds		Estimated Conductivity		
Unit	Model Layer	Min (m/d)	Max (m/d)	P20 (m/d)	P50 (m/d)	P80 (m/d)
Clay (Horizontal K)	1	0.001	0.1	0.002	0.008	0.06
Clay (Vertical K)	1	0.00001	0.1	0.0002	0.0008	0.005

		Assigned Bounds		Estimated Conductivity		
Unit	Model Layer	Min (m/d)	Max (m/d)	P20 (m/d)	P50 (m/d)	P80 (m/d)
Main Aquifer (Zone 1) Horizontal K	2	0.001	0.1	0.004	0.036	0.08
Main Aquifer (Zone 1) Vertical K	2	0.00001	0.1	0.001	0.007	0.013
Main Aquifer (Zone 2) Horizontal K	2	0.1	1	0.24	0.7	0.96
Main Aquifer (Zone 2) Vertical K	2	0.001	1	0.04	0.09	0.12
Main Aquifer (Zone 3) Horizontal K	2	0.5	4	1	1.6	2.7
Main Aquifer (Zone 3) Vertical K	2	0.005	4	0.11	0.13	0.18
Lacustrine / Colluvium (Zone 4) Horizontal K	2	0.1	1	0.12	0.21	0.66
Lacustrine / Colluvium (Zone 4) Vertical K	2	0.001	1	0.016	0.03	0.064
Bedrock (Horizontal and Vertical K)	3	0.0001	0.0001	0.0001	0.0001	0.0001

2.4.4 Predevelopment water balance

With the adopted conceptualisation, the predevelopment water balance of the current model is straightforward. The only source of inflow in the model is inflow via mountain front infiltration of runoff from the Mirjawa Hills, simulated using the Recharge package (see Figure 2-3). The only source of outflow from the model is groundwater discharge to surface at Gaud-i-Zirreh simulated using Drain package (also presented in Figure 2-3). The predevelopment water balance is presented in Table 2-4:

Table 2-4 Simulated Predevelopment Water Balance

Water Balance Component	In (GL/year)	Out (GL/year)
Infiltration of runoff from the Mirjawa Hills	3	-
Groundwater discharge to surface at Gaud-i-Zirreh	-	3
TOTAL	**3**	**3**

The simulated inflow into the system of 3 GL/year is on the conservative side, consistent with the overall modelling approach. In fact, the amount of inflow on monthly or annual basis that this system receives is not well understood at this stage and future investigations and monitoring will address this aspect. Adopting a relatively low amount of inflow in the current model prevents overestimation of the amount of water available for water supply. It also prevents underestimation of potential drawdown impacts related to the proposed water supply abstraction.

As discussed in Section 2.4.2, 142 model runs produced good calibration against measured water levels across the main aquifer and inferred hydraulic conductivities across the model domain. Figure 2-10 shows that all 142 calibration runs matched the water balance estimates presented in Table 2-4. That is, in all 142 model runs, inflow to the model remained at 3 GL/year, which could be expected with the adopted approach to simulate inflow from Mirjawa Hills (using the Recharge package). Also, in all 142 runs outflow at Gaud-i-Zirreh remained at 3 GL/year as well. The model achieved this by modifying the conductance term assigned to drains at Gaud-i-Zirreh. As presented in Figure 2-11, simulated drain conductance is estimated to range between 0.3 and 0.7 m^2/day. Mean (P50) predicted drain conductance across all runs is 0.5 m^2/day.

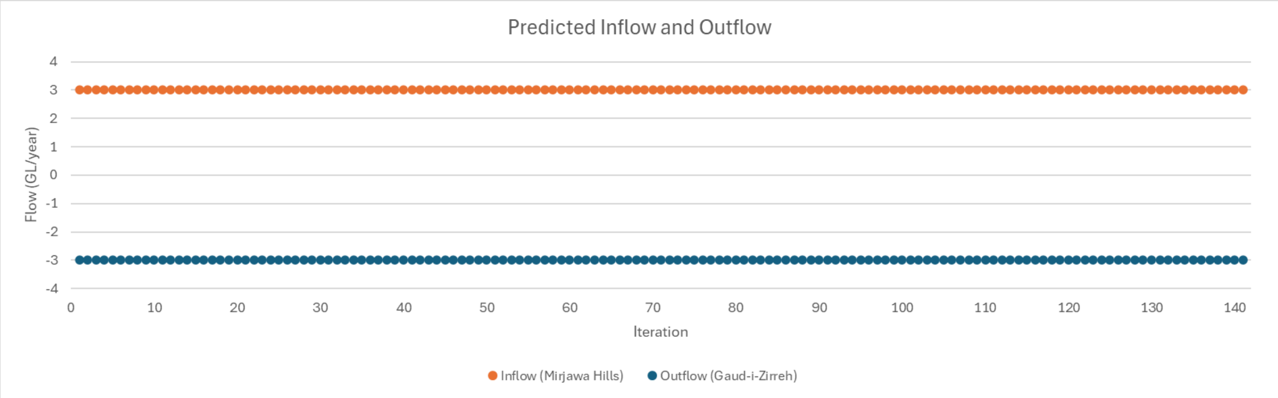

Figure 2-10 Predicted Inflows and Outflows of the Predevelopment (Steady State) Model

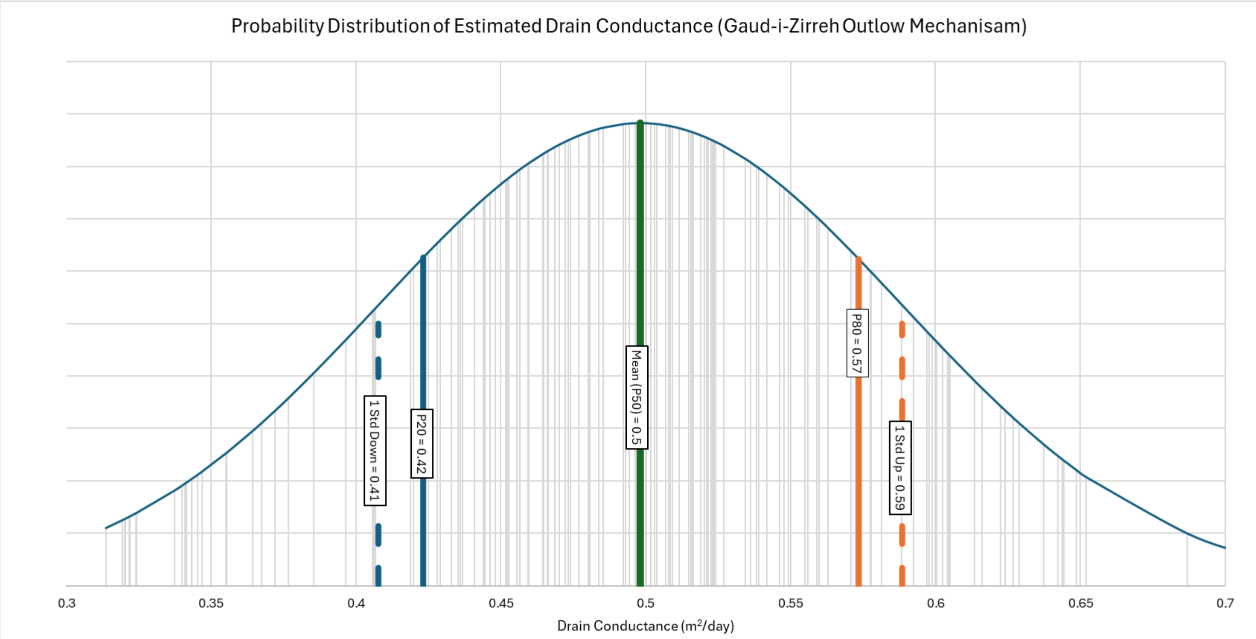

Figure 2-11 Estimated Drain Conductance Assigned in the Gaud-i-Zirreh Area

2.5 Model Predictions

2.5.1 Prediction Setup

The simulation of groundwater abstraction to meet mine water supply in the Fan Sediments area takes place over 11 stress periods in the model. The first stress period in the simulation is steady state and simulates predevelopment conditions. Nine of the other stress periods represent times over which the proposed water supply borefield operates. The last stress period in the model simulates aquifer recovery.

During operations, the maximum stress period length is 30 years (stress period 8), and the minimum stress period length is 1 year. Stress period length was dictated by the projected water demand. That is, if projected water demand in GL/year is constant over a period of 10 years, the length of the stress period was set to 10 years or until the water demand changes.

Stress period 2 in the model simulates three years of construction water supply, while stress period 10 simulates mine closure requirements. Maximum simulated water supply abstraction was 50.4 GL/year over a 30-year period simulated in stress period 8. Stress period 11 simulates aquifer recovery. In this stress period, the model was used to assess the water level rebound across the catchment. The length of this stress period is 1,000 years and abstraction during this stress period was assumed to cease.

Modelled stress period setup is presented in Table 2-5 below:

Table 2-5 Stress Period Setup

Stress Period	Type	Phase	Duration (years)	Simulated Abstraction (GL/year)
1	Steady State	Predevelopment	-	-
2	Transient	Construction Water Supply	3	1.6
3	Transient	Phase 1	1	2.1
4	Transient	Phase 1	1	19.9
5	Transient	Phase 1	3	25.2
6	Transient	Phase 2	1	27.3
7	Transient	Phase 2	1	45.2
8	Transient	Phase 2	30	50.4
9	Transient	Phase 2	1	41.4
10	Transient	Closure	5	1.6
11	Transient	Aquifer Recovery	1,000	-

Consistent with the model calibration approach, PEST-IES was used for model predictions. It was tasked to simulate water supply potential of the Fan Sediments aquifer and provide estimates of potential drawdown impacts associated with simulated water supply abstraction.

As described in Section 2.4, PEST-IES produced 142 hydraulic conductivity fields that provided a good calibration against measured water levels. Those 142 conductivity fields, as well as drain conductance terms estimated in the calibration task, were supplied to a PEST control file for predictions. That is, during predictions PEST-IES was not tasked to estimate aquifer parameters – it was instructed to use estimated conductivity fields and drain conductance to simulate extraction of the requisite water supply.

Since aquifer storage could not be estimated during the model calibration task, PEST-IES was asked to produce 142 random aquifer storage fields for model layer 2, consistent with current storage estimates described in Section 2.3.3 and presented in Figure 2-5. Aquifer storage was simulated using zones in the current model. Aquifer storage of the Clay unit in model layer 1 remained fixed at 1%. Aquifer storage of the Bedrock unit in model layer 3 also remained fixed at 0.1%. Aquifer storage distribution simulated in the predictive assessment is summarised in Table 2-6.

Table 2-6 Aquifer Storage Assigned to Modelled Hydrostratigraphic Units

		Unconfined Storage		Confined Storage	
Unit	Model Layer	Minimum (%)	Maximum (%)	Minimum (1/m)	Maximum (1/m)
Clay	1	1	1	-	-
Main Aquifer (Zone 1)	2	0.1	3	1E-6	1E-6
Main Aquifer (Zone 2)	2	0.1	3	1E-6	1E-6
Main Aquifer (Zone 3)	2	1	5	1E-6	1E-6
Lacustrine / Colluvium (Zone 4)	2	1	5	1E-6	1E-6
Bedrock	3	0.1	0.1	1E-7	1E-7

The proposed water supply borefield was simulated using 40 abstraction bores. Bores in the model were scattered inside the proposed borefield footprint provided by the project team. Bores were placed in a staggered (zigzag) pattern within the refined grid area to increase the distance between the bores. Guiding principles used to setup the proposed borefield are summarised below:

- Bores were placed in the highest conductivity zone (Zone 3 presented in Figure 2-4).
- Bores were placed in an area where the measured depth to water was lowest.
- Maximum abstraction rate per bore was 40 L/s (rate provided by Barrick).
- Bores were assumed to be screened 50 m above the base of the main aquifer.

The number of bores was derived by dividing maximum abstraction of 50.4 GL/year by individual bore rate of 40 L/s. Distance between the bores that could be fitted inside the proposed borefield footprint, presented in Figure 2-12 (nominally named the “Borefield March 2024 Zone”), was around 1,500 m (Figure 2-13).

Water supply bores were simulated using the Well package. As mentioned above, the proposed water supply bores will be installed 50 m above the base of the main aquifer. This constraint was not directly applied to the Well package. Postprocessing using Python was instead undertaken to check if this constraint is breached by checking predicted bore water levels against the base elevation of the main aquifer for all 142 model runs.

Water supply abstraction was monitored using a flux target. Results were recorded on annual basis. The weight applied to this target was set to zero. Through this the flux target is prevented from interfering with the PEST run.

Drawdown propagation was monitored at 8 monitoring locations (Figure 2-14). Seven of these are nominal bores located along the border between Pakistan and Afghanistan (4 nominal bores labelled as BC#1 to BC#4), two in the Gaud-i-Zirreh area, and one in the middle of the proposed borefield. One of these bores is a “real” bore, currently used and monitored (the Imtiaz FC bore). Although the objective behind setting up these targets was to monitor water table drawdown resulting from the proposed water supply abstraction, these targets were set as head targets. Since they were set to record the predevelopment heads as well, predicted drawdown at these locations was processed by subtracting predicted heads during or at the end of operations from the predevelopment heads. Weight applied to these targets was also set to zero.

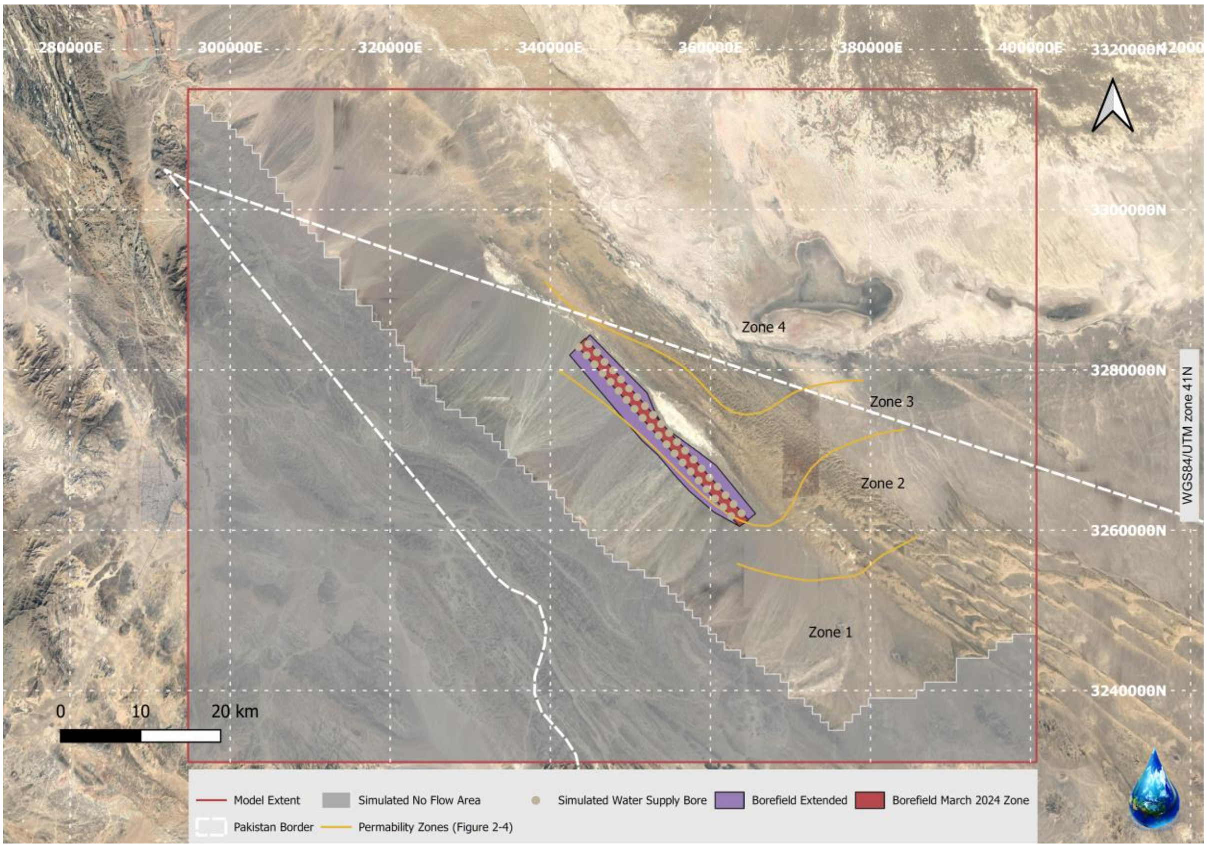

Figure 2-12 Borefield Layout

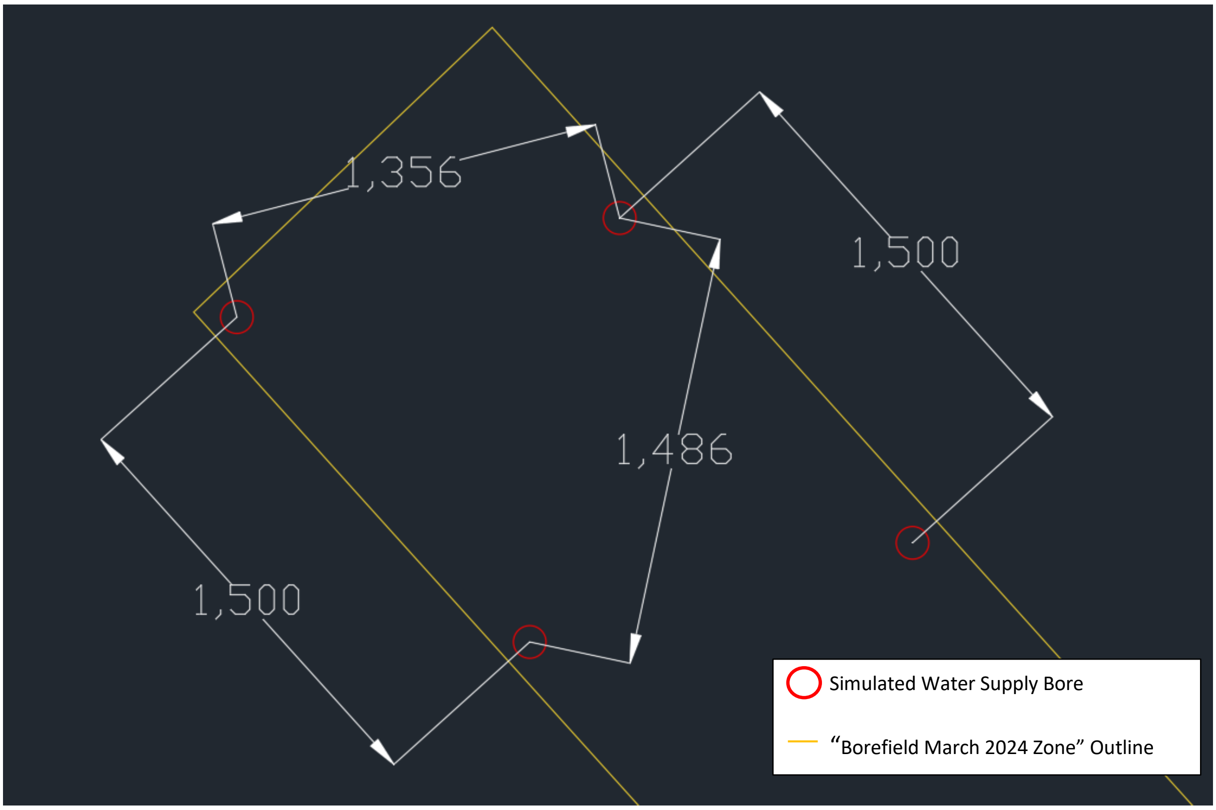

Figure 2-13 Borefield Spacing (presented in meters)

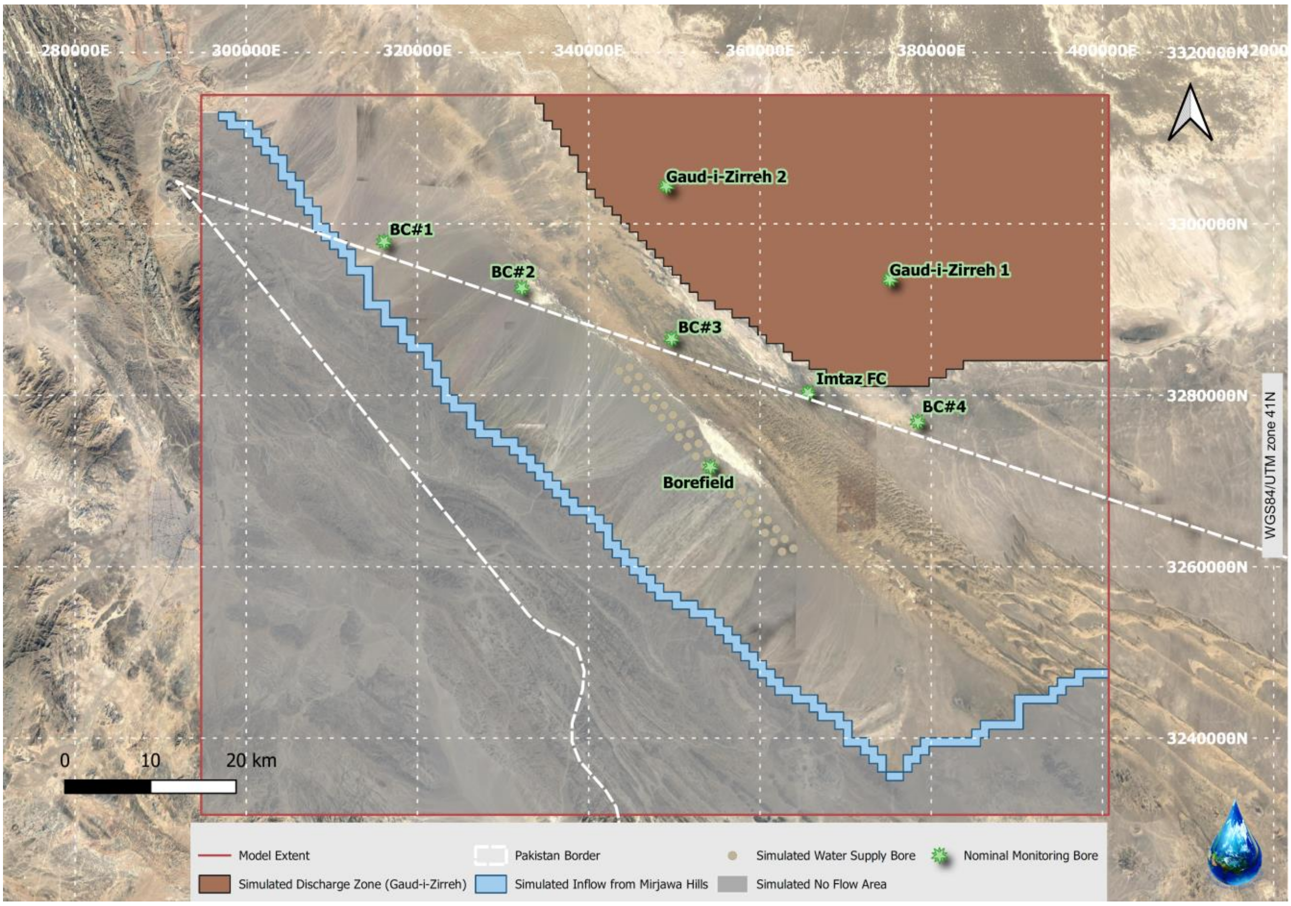

Figure 2-14 Nominal Monitoring Bores used for Drawdown Predictions

2.5.2 Prediction Results

Comparison between the water demand and model predictions is presented in Figure 2-15. The results show that all 142 model runs were successful in meeting the projected water demand. The results show that over the LoM shortfalls in water supply are unlikely to occur.

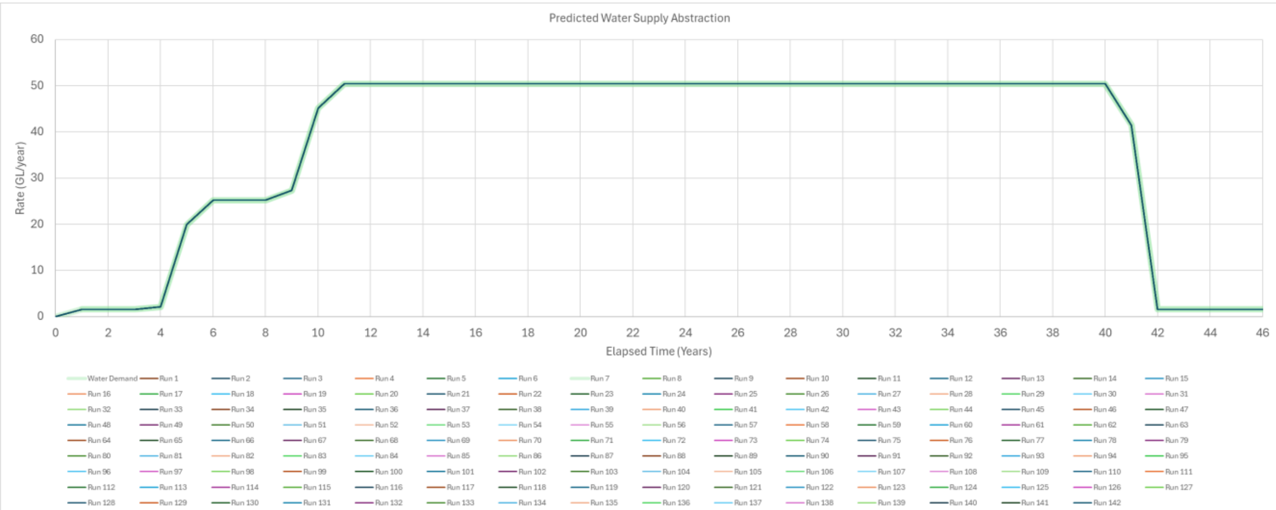

Figure 2-15 Predicted Water Supply Abstraction

Distribution of simulated aquifer storage is presented in Figure 2-16. The figure shows that random aquifer storage values produced by PEST were not tilted towards either end of the distribution curve. Mean simulated aquifer storage in Zones 1 and 2, south of the proposed borefield, was 1.1% and mean simulated aquifer storage in Zones 3, where the borefield is located, and Zone 4 north of the proposed borefield was 3.1%.

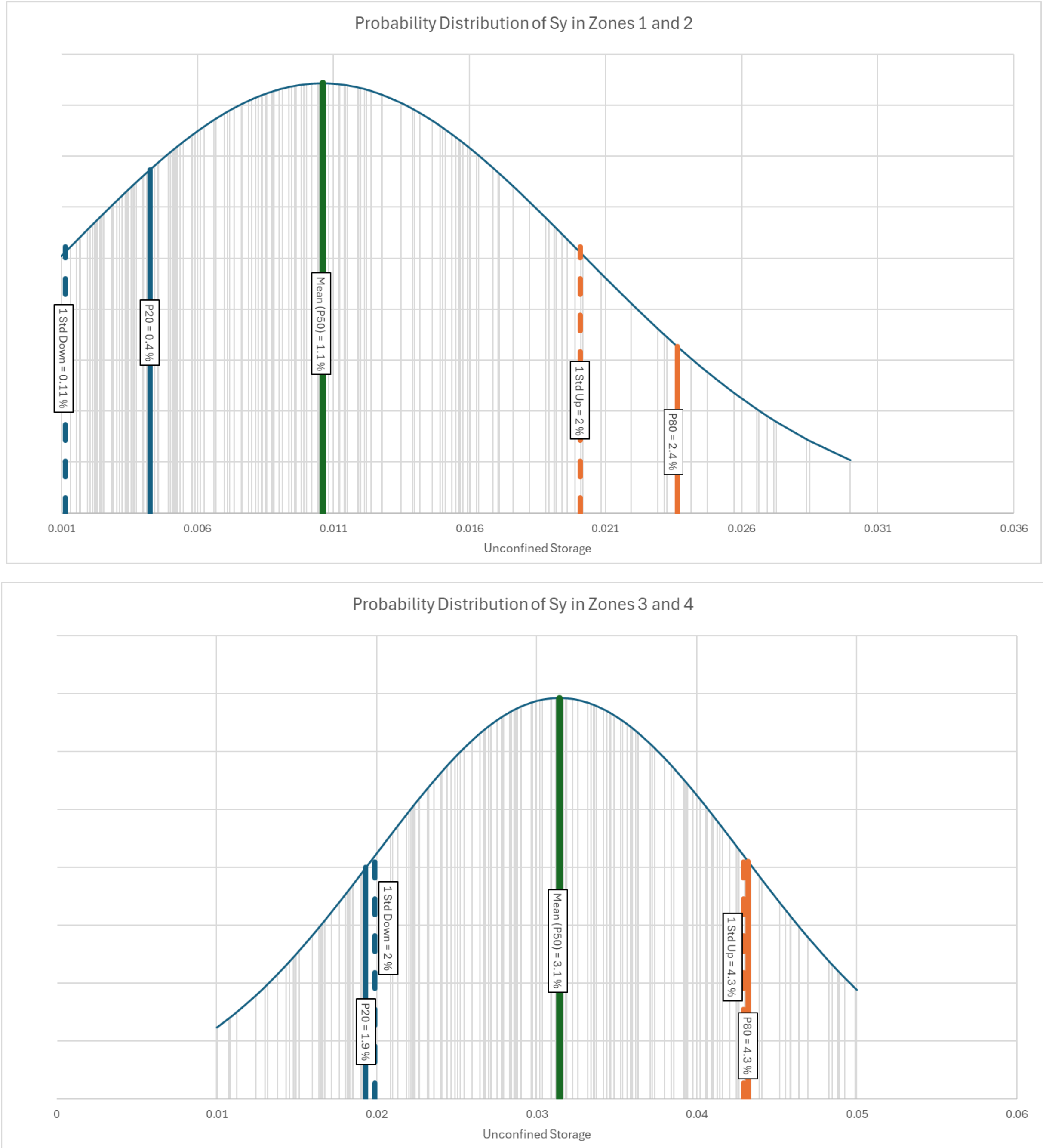

Figure 2-16 Simulated Aquifer Storage

The predicted impacts of simulated water supply abstraction on regional groundwater system are presented in Appendices A16 to A43. Drawdown for the nominal monitoring points is calculated by subtracting predicted water levels at the maximum abstraction period (year 40, stress period 8) from steady state or predevelopment water levels. Maximum drawdown is predicted in the immediate borefield area, with predicted drawdown reducing with distance from the borefield. Drawdown to the southwest was truncated by the low permeability outcrops of the Mirjawa Hills. Drawdown is predicted to spread in the southeast-northwest direction along the highest conductivity zone of the main aquifer (Zone 3). The simulated water supply borefield is predicted to cutoff throughflow from the Mirjawa Hills towards the Gaud-i-Zirreh within the borefield footprint, resulting in depressurisation of the confined aquifer associated with lacustrine sediments to the north of the proposed borefield. Probability distribution of predicted drawdown during operations is presented in Appendices A16 to A19. Probability distribution of predicted aquifer depressurisation at Gaud-i-Zirreh is presented in Figure 2-17. The results show that simulated water supply abstraction would depressurise this aquifer by 4.32m (Mean P50 result).

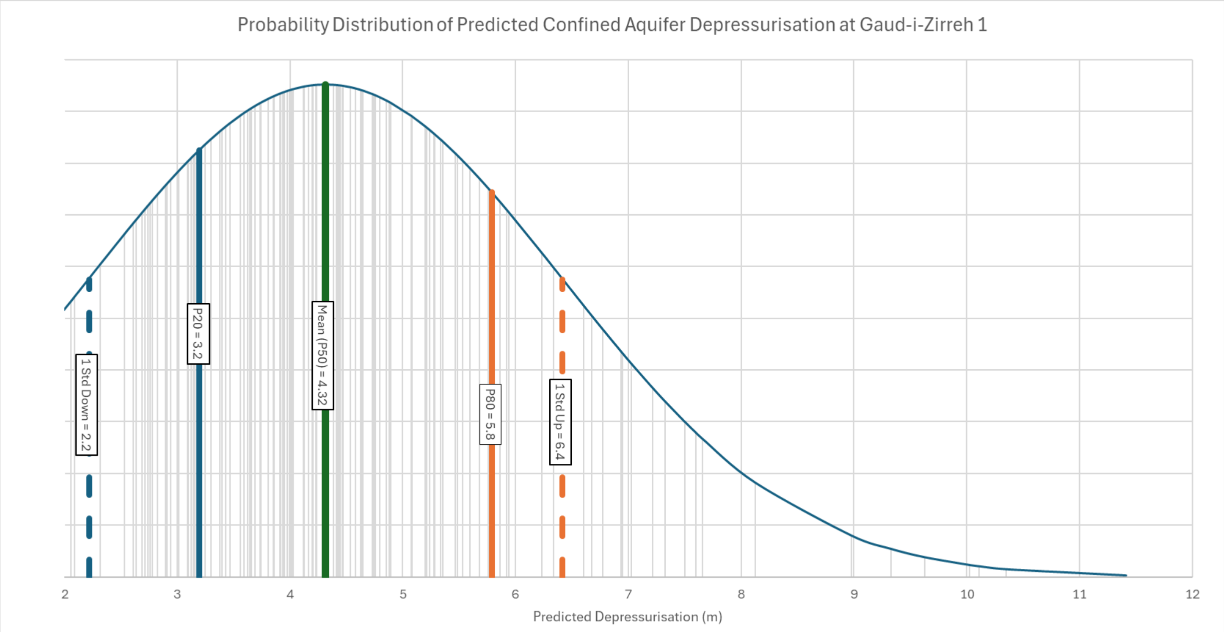

Figure 2-17 Probability Distribution of Predicted Confined Aquifer Depressurisation at Gaud-i-Zirreh 1

Time series of predicted drawdown during operations are presented in Appendices A20 to A27. Probability distribution of predicted drawdown during aquifer recovery phase is presented in Appendices A28 to A31. Contours of predicted drawdown are presented in Appendices A32 to A43.

Drawdown propagation is driven by both simulated hydraulic conductivity and simulated aquifer storage. If the simulated hydraulic conductivity is high and aquifer storage is low, predicted drawdown would extend further away from the simulated borefield, which is captured in the P80 drawdown estimates. On the contrary, if the simulated hydraulic conductivity is low and aquifer storage is high, predicted drawdown would not extend as far, which is captured by the P20 drawdown estimates. The current model simulates all combinations of those two parameters. The P50 results represent the mean predicted drawdown and, in most cases, could be designated as the "base case" results. It should be noted again that simulated hydraulic conductivity fields are derived from the model calibration task and are consistent with the current conceptual understanding. Aquifer storage on the other hand is not and remains the primary source of uncertainty in the current model. The model could not be calibrated against this parameter. Capping storage at 5% prevents any water supply overestimates. Analyses completed to date suggest that aquifer storage could be significantly higher.

As discussed in Section 2.3.1, the adopted model setup is likely to have produced the highly conservative estimates in terms of predicted drawdown. It is likely that once the proposed borefield reverses gradients in the Fan Sediments area, inflows might occur from other areas across the border. Inflows are likely to occur from the northwestern section of the Fan Sediments in Afghanistan. The current model simulates no inflow in this area (no flow boundary). Also, inflows could be expected across the northern and eastern model boundary that also sits across the border in Afghanistan. The current model also assumes no inflow in this area. These inflows could potentially reduce the amount of drawdown that the current model predicts in the Gaud-i-Zirreh area and to the northwest.

Results of the current model are summarised in Table 2-7 below:

Table 2-7 Predicted Drawdown and Aquifer Depressurisation at Nominal Monitoring Locations During Operations

Monitoring Location	P20 (m)	P50 (m)	P80 (m)
Borefield	92	105	128
Gaud-i-Zirreh 1	3.2	4.32	5.8
Gaud-i-Zirreh 2	2.8	4	6
Imtiaz FC	31	36	44
Border Control Point 1 (BC#1)	0.3	0.9	2.3
Border Control Point 2 (BC#2)	2.9	5.3	11
Border Control Point 3 (BC#3)	33	41	53
Border Control Point 4 (BC#4)	23	28	35.4

Predicted drawdown is also presented as time series in Appendices A20 to A27, as well as contour lines in Appendices A32 to A43. The results show that aquifer recovery will commence after 41 years of abstraction, or when the projected water demand reduces from 41.4 to 1.6 GL/year (stress period 10 in the model). During mine closure and aquifer recovery periods, drawdown predicted in the immediate borefield area is predicted to move away from the borefield in almost all directions, mainly towards the Gaud-i-Zirreh or towards the simulated discharge zone (Figure 2-18).

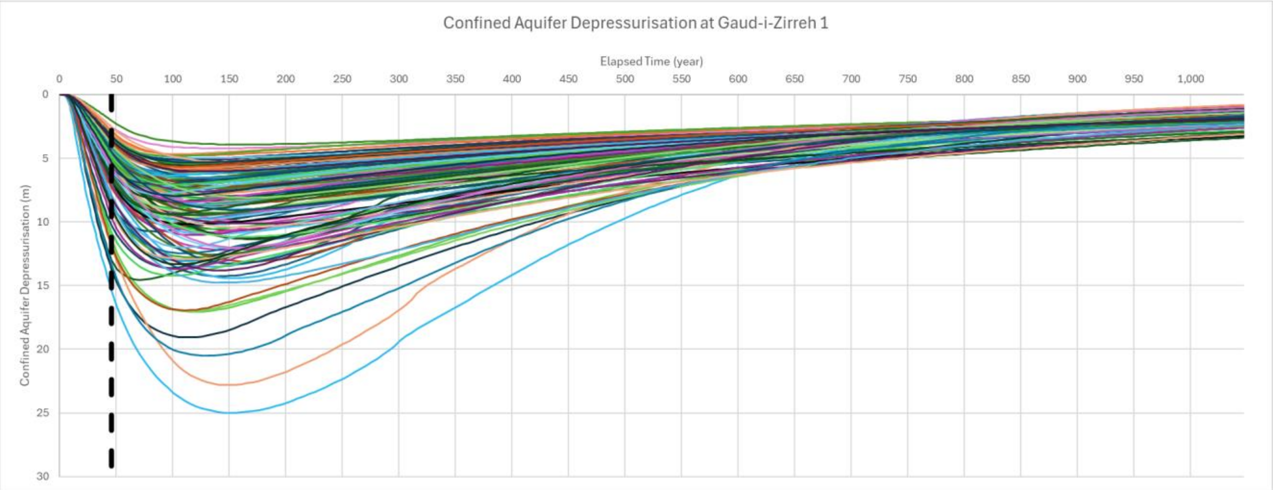

Figure 2-18 Time Series of Predicted Confined Aquifer Depressurisation at Gaud-i-Zirreh 1

The main aquifer zone between the borefield and Mirjawa Hills is predicted to start recovering immediately after abstraction reduces to 1.6 GL/year. Drawdown is not predicted to increase in this area during the aquifer recovery period due to simulated inflows from the Mirjawa Hills.

As presented in Appendix A35, 50 years into the aquifer recovery period, mean predicted drawdown (P50) in the Gaud-i-Zirreh was around 7 and 8 meters at Gaud-i-Zirreh 1 and 2 respectively. This area was not predicted to fully recover within the simulated aquifer recovery period (Appendix A28). The results are also summarised in Table 2-8.

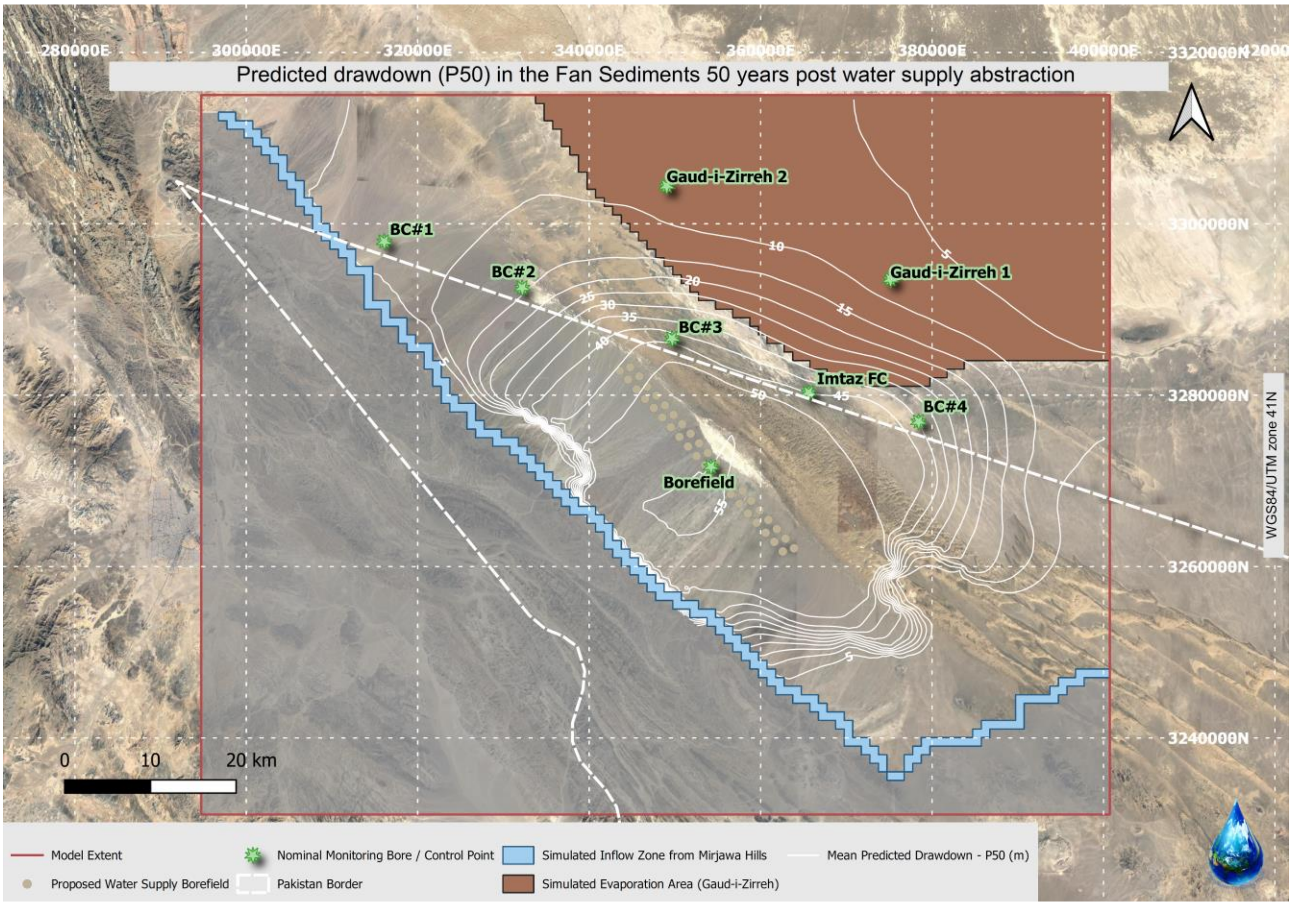

Figure 2-19 Predicted Drawdown in the Fan Sediments 50 Years Post Water Supply Abstraction

Table 2-8 Predicted Drawdown and Aquifer Depressurisation at Nominal Monitoring Locations 50 Years Post Abstraction (Aquifer Recovery)

Monitoring Location	P20 (m)	P50 (m)	P80 (m)
Borefield	49	55	65
Gaud-i-Zirreh 1	7	9	12
Gaud-i-Zirreh 2	6.5	7.5	11.5
Imtiaz FC	37	45	55
Border Control Point 1 (BC#1)	4	7.5	13
Border Control Point 2 (BC#2)	10	14	23

Monitoring Location	P20 (m)	P50 (m)	P80 (m)
Border Control Point 3 (BC#3)	37	42	50
Border Control Point 4 (BC#4)	28	40	48

As discussed, aquifers in the Fan Sediments area are not predicted to recover fully during the simulated aquifer recovery phase. This is also likely to be an underestimate as a result of the proposed modelling approach and it could be improved as the quantification of water balance (inflow, rainfall recharge, cyclones, evapotranspiration etc) outside of the immediate Fan Sediments area becomes available. The model predicts that at the end of the aquifer recovery period, borefield area, as well as Imtaz FC and Border Control Points 2 and 3, would reach ~86% recovery. The Gaud-i-Zirreh area was predicted to reach around 80% recovery. Predicted drawdown at the end of the aquifer recovery period is presented in Table 2-9.

Table 2-9 Predicted Drawdown and Aquifer Depressurisation at Nominal Monitoring Locations at the End of Aquifer Recovery Period

Monitoring Location	P20 (m)	P50 (m)	P80 (m)
Borefield	6.4	8	8.7
Gaud-i-Zirreh 1	1.5	1.9	2.1
Gaud-i-Zirreh 2	2.7	3.4	3.8
Imtiaz FC	5.4	6.6	7.3
Border Control Point 1 (BC#1)	5.7	6.8	7.3
Border Control Point 2 (BC#2)	5.7	6.8	7.3
Border Control Point 3 (BC#3)	5.5	6.8	7.2
Border Control Point 4 (BC#4)	5.6	7	7.6

The probability distribution of drawdown at the end of the aquifer recovery period is presented in Appendices A28 to A31.

The model predicted water balance (average water balance across 142 model runs) at the end of the maximum abstraction period of 50.4 GL/year (end of stress period 8 in the model) is presented in Table 2-10. Consistent with the adopted setup to simulate the Fan Sediments area, the main source of the water abstracted by the simulated water supply borefield comes from aquifer storage (94.3%). Inflow via mountain front infiltration of runoff from the Mirjawa Hills contributes to the overall water balance by 5.7%.

Further water balance breakdown was completed using the Zone Budget. It revealed that 75% of aquifer storage that contributes to the water supply abstraction is sourced from the main aquifer (Zones 1, 2 and 3 presented in Figure 2-4), and that aquifer storage associated with lacustrine sediments simulated in Zone 4, provides around 20% of water available for water supply.

Table 2-10 Modelled Water Balance at the End of Maximum Abstraction Period of 50.4 GL/year

Water Balance Component	Inflow (GL/y)	Outflow (GL/y)	Inflow (%)	Outflow (%)
Infiltration of Runoff from Mirjawa Hills	3	-	5.7	-
Discharge to Surface at Gaud-i-Zirreh	-	2.2	-	4.2
Borefield Abstraction	-	50.4	-	95.8
Aquifer Storage	49.6	-	94.3	-
TOTAL	**52.6**	**52.6**	**100**	**100**

Section 3 Summary and Recommendations

3.1 Summary

The Stage 2 model of the Fan Sediments area builds on conceptualisation, results and finding of the Stage 1 model and incorporates all available information to date. Work completed in 2023 and 2024 that was used to upgrade the Stage 1 model in Stage 2 is reported in SMEC, 2024 and Darkwater, 2024 reports. This work allowed the groundwater flow direction and gradients to be defined, increased the known saturated thickness of sediments, provided monitoring points along the Afghan border and allowed for better understanding of the aquifer properties including permeability distribution and conditions.

Long-term water level monitoring in the Fan Sediments area has only recently been established. Since aquifers in the Fan Sediments area have not been significantly stressed in the past, the size of a groundwater storage is only approximately known. The current model could not be calibrated against this parameter. To prevent the model from overpredicting the water supply potential of the Fan Sediments aquifer, aquifer storage was capped to 5% although investigations completed to date suggest that it could be significantly higher. Therefore, the current model was calibrated against inferred predevelopment water levels only.

Furthermore, contribution of other groundwater systems to the greater Sistan Depression/Gaud-i-Zirreh water balance is uncertain. Further work programmes need to address this aspect. Adopting the no flow boundary conditions along the edges of the Stage 2 model means that they have not been included as not to introduce additional uncertainty and potentially underpredict the impact of abstraction.

The aquifer extent in the Stage 2 model was expanded significantly to accommodate an updated conceptual model which extends beyond the Afghanistan border and encompasses Gaud-i-Zirreh. Due to an inability to collect field data outside of Pakistan, most of the required assumptions relate to definition of hydrostratigraphic units within Afghanistan. Although recent site investigations provided more refinements in terms of aquifer geometry and connections to Gaud-i-Zirreh, uncertainties in parameters used to describe aquifer storage and recharge remain.

The extent to which rainfall recharges a groundwater storage was difficult to quantify; so too was the ability of a groundwater system to gain water from rainfall events. Therefore, aerial rainfall recharge was not included in the current model. Monitoring scheme established in 2023 needs to continue monitoring water levels, rainfall, evaporation, and abstraction.

As uncertainties in parameters used to describe the system are significant, a conservative approach has been adopted to simulate aquifer units in the Fan Sediments area. It is understood that in order to avoid overpredicting the water supply potential of the Fan Sediments aquifer and to avoid underpredicting drawdown impacts resulting from the simulated water supply abstraction, actions adopted in the current model might lead to overpredicting drawdown impacts. With aquifer storage being capped at 5%, no aerial recharge and no flow boundaries assigned across the model edges, it is fair to say that the current model is likely to produce results that could fall into the so called “worst case” category.

The results of the Stage 2 model show that, even with the adopted conservative approach, there will be no shortfalls in mine water supply over the simulated abstraction period of 46 years. 142 simulated combinations of storage and conductivity fields show no discrepancy between assigned and predicted abstraction from the simulated borefield. Uncertainties in predicted groundwater drawdown remain significant at this stage and the current model is unable to reduce the range of predicted outcomes until more data become available.

The proposed water supply borefield was simulated using 40 abstraction bores. Bores in the model were scattered inside the proposed borefield footprint provided by the project team. Bores were placed in a staggered (zigzag) pattern within the refined grid area to increase the distance between the bores. Guiding principles used to setup the proposed borefield are summarised below:

- Bores were placed in the highest conductivity zone (Zone 3 presented in Figure 2-4).
- Bores were placed in an area where measured depth to water is lowest.
- Maximum abstraction rate per bore was 40 L/s (rate provided by Barrick).
- Bores were assumed to be screened 50 m above the base of the main aquifer.

The number of bores was derived by dividing maximum abstraction of 50.4 GL/year by individual bore rate of 40 L/s. Distance between the bores that could be fitted inside the proposed borefield footprint, presented in Figure 2-12 (nominally called Borefield March 2024 Zone), was around 1,500 m (Figure 2-13).

3.2 Recommendations

Our main recommendation is to update the Stage 2 model once more data become available. Predictive modelling will benefit from the ongoing collection of data from drilling, test pumping and the initial operation of the borefield. Monitoring scheme established in 2023 needs to continue and expand as additional monitoring bores become available.

Section 4 References

Coffey, 2005	Hydrogeology of the Tahlab valley, Balochistan & Iran, and the potential for water supply for the Tanjeel project at Reko Diq. Reko Diq copper project, Balochistan, Pakistan (P6569.01-BF (Rev 5), 10 August, 2005)
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Coffey, 2008b	Reko Diq Project, Prefeasibility Groundwater Assessment, Groundwater Model Predictive Simulations (26 March 2008)
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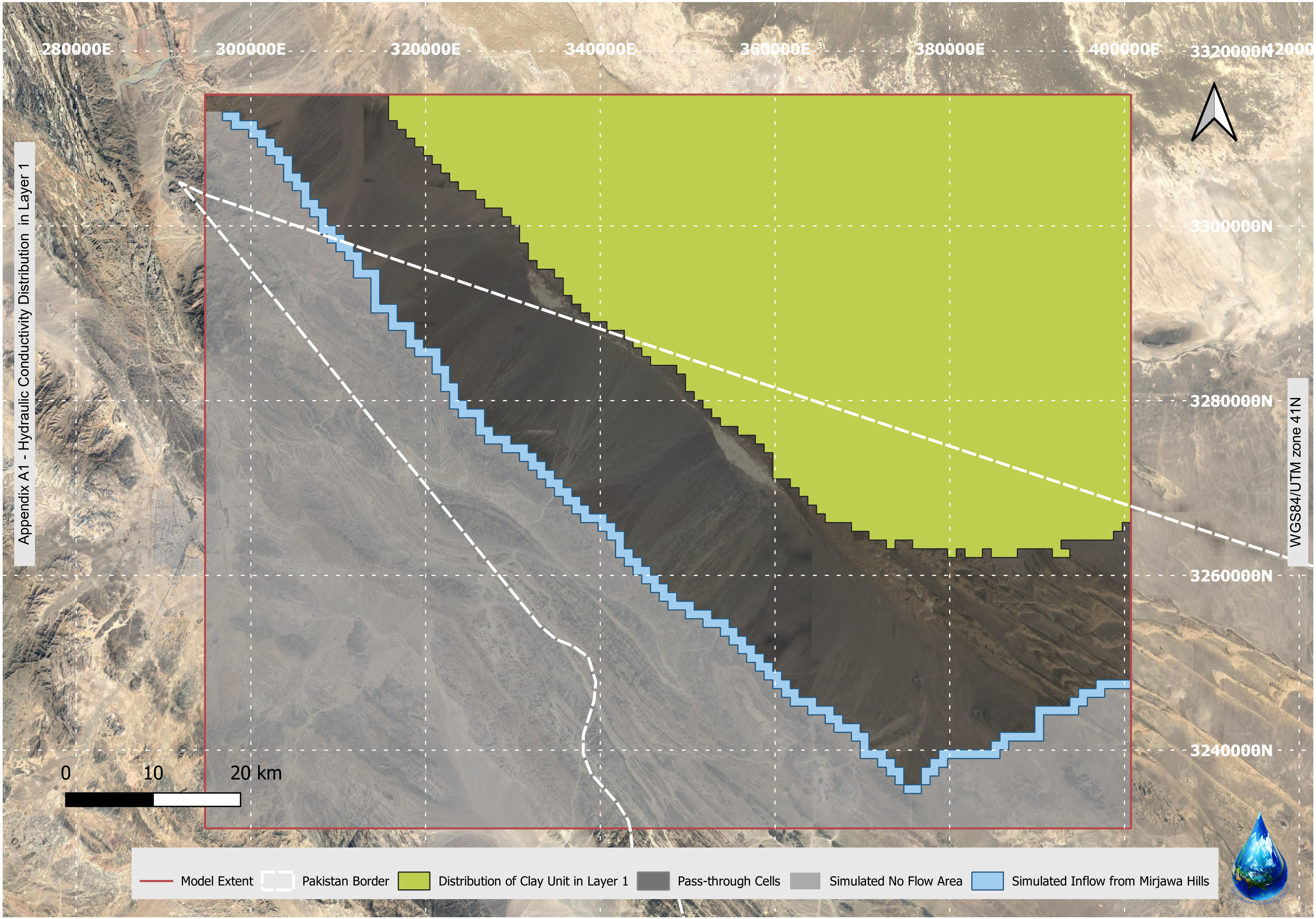
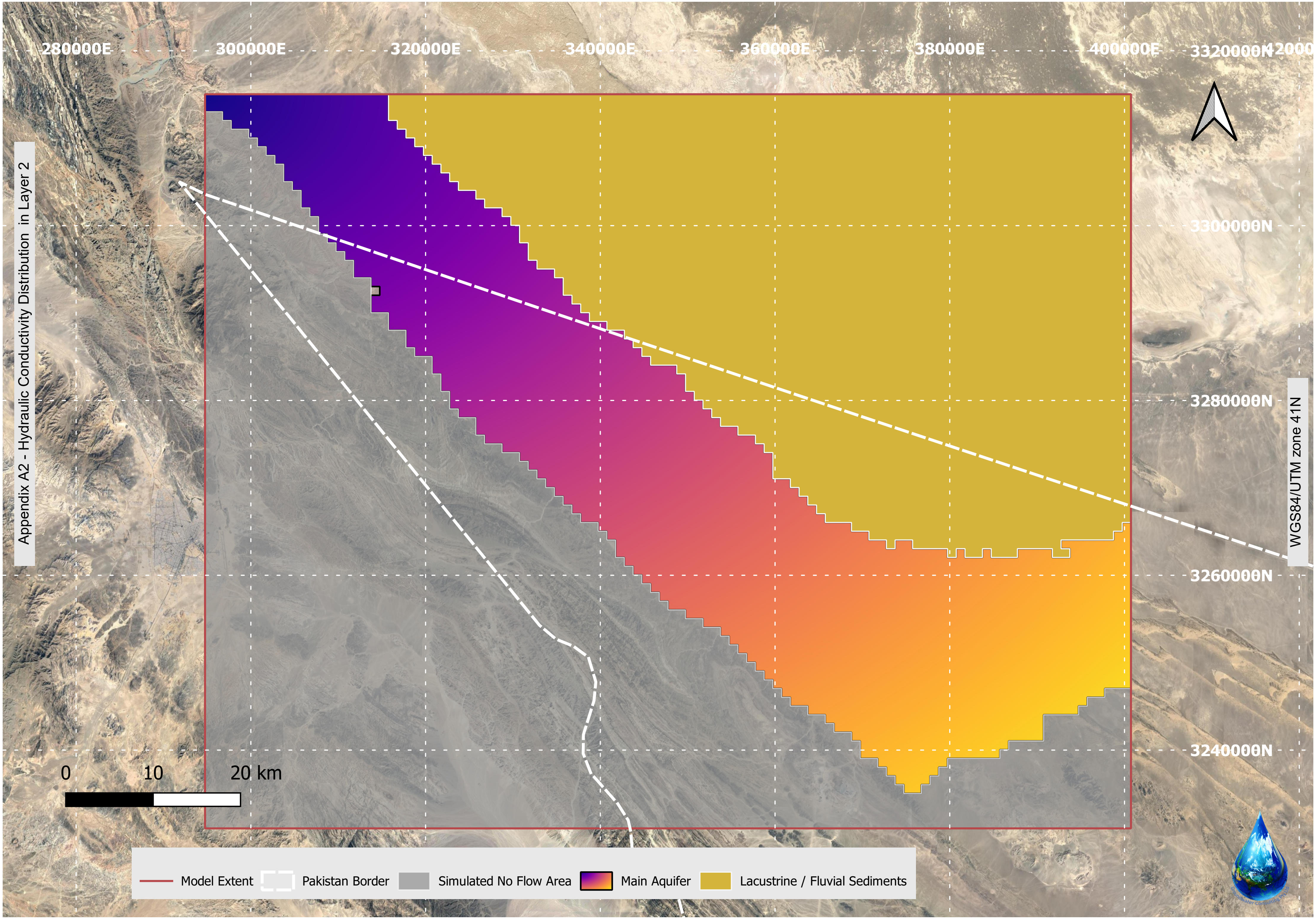
GWC, 2023a	Reko Diq Groundwater Modelling (Fan Sediments) - Technical Memo, Rev B GWC-TM025-2022, December 2023
GWC, 2023b	Reko Diq Groundwater Modelling (Patangaz) - Technical Memo, Rev B GWC-TM025-2022, December 2023
Shomaker, 2009	Ground-water model feasibility study Reko Diq project (20 February 2009)
SMEC, 2009	Reko Diq water resources assessment feasibility study (5065032.1y1, 21st December 2009)
SMEC, 2024	Fan Sediments Hydrogeological Factual and Interpretive Report – Phase 1, DRAFT (Prepared by SMEC on 13 February 2024).
WRA, 2017	Reko Diq mine, Pakistan; Review of hydrogeological, water governance and transboundary risks associated with the proposed water supply source (Expert Report, September 2017)

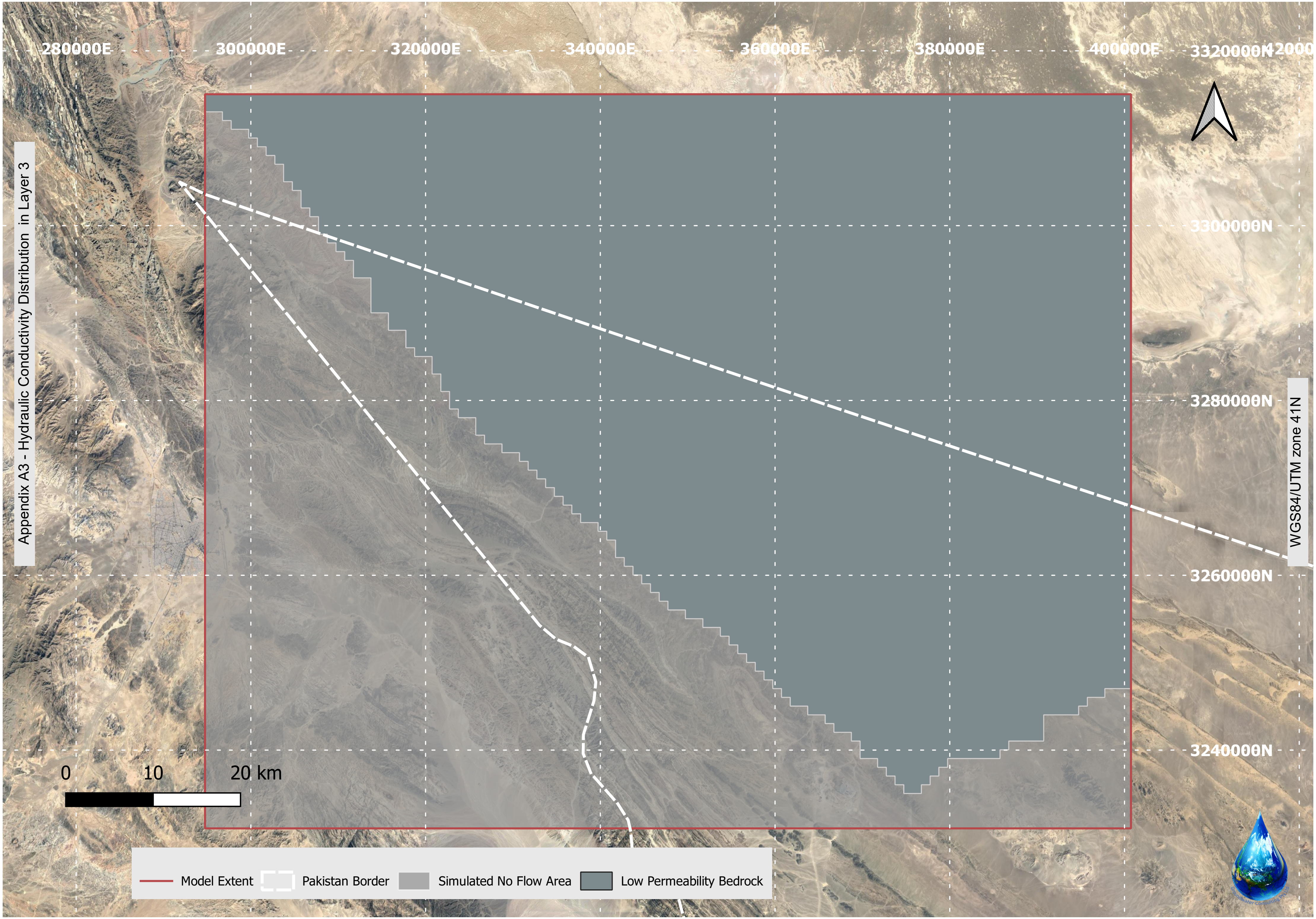
Appendix A



Appendix A1 - Hydraulic Conductivity Distribution in Layer 1
280000E
300000E
320000E
340000E
360000E
380000E
400000E
3320000N
3300000N
3280000N
3260000N
3240000N
WGS84/UTM zone 41N
0
10
20 km
Model Extent
Pakistan Border
Distribution of Clay Unit in Layer 1
Pass-through Cells
Simulated No Flow Area
Simulated Inflow from Mirjawa Hills



Appendix A2 - Hydraulic Conductivity Distribution in Layer 2



280000E
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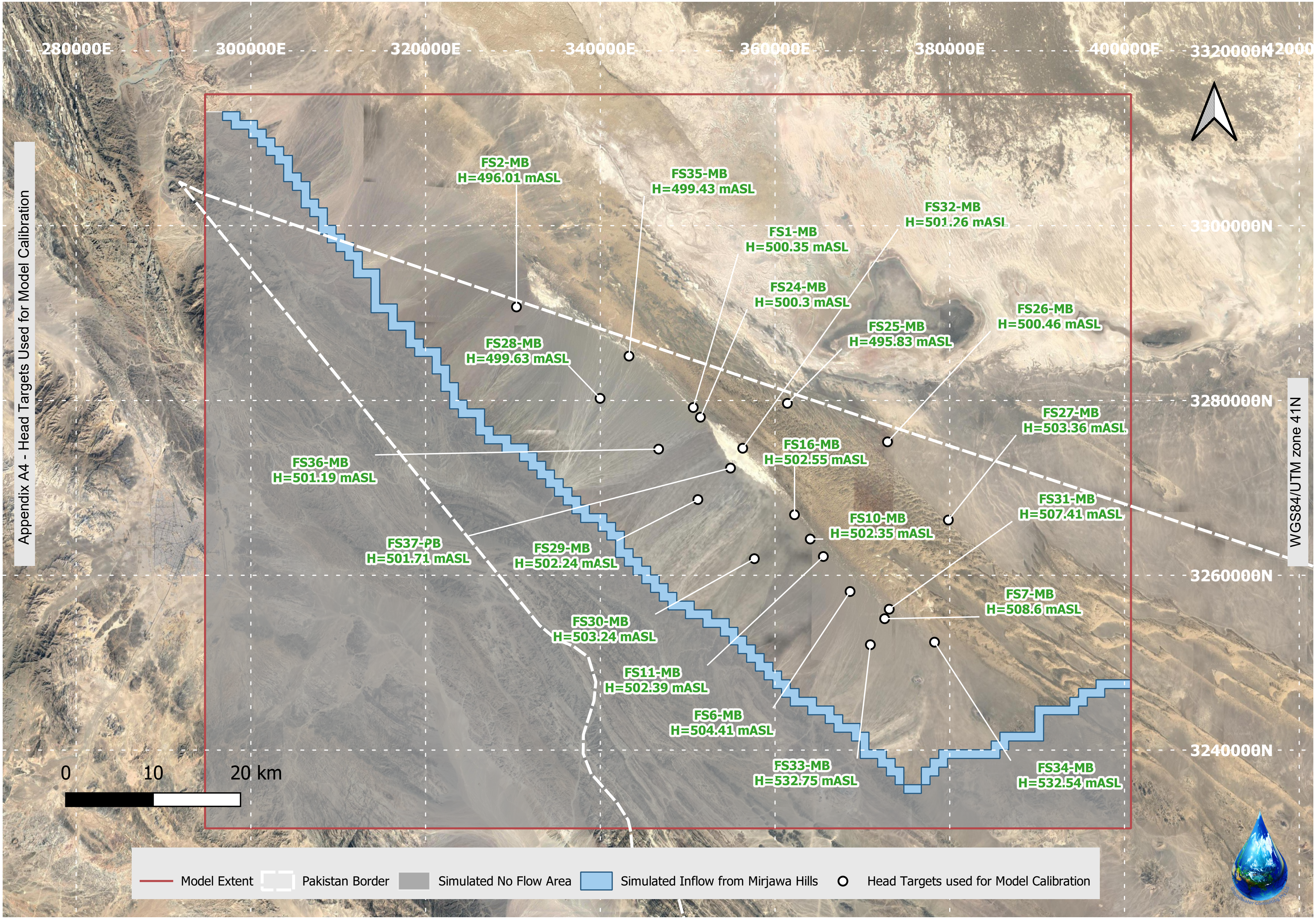
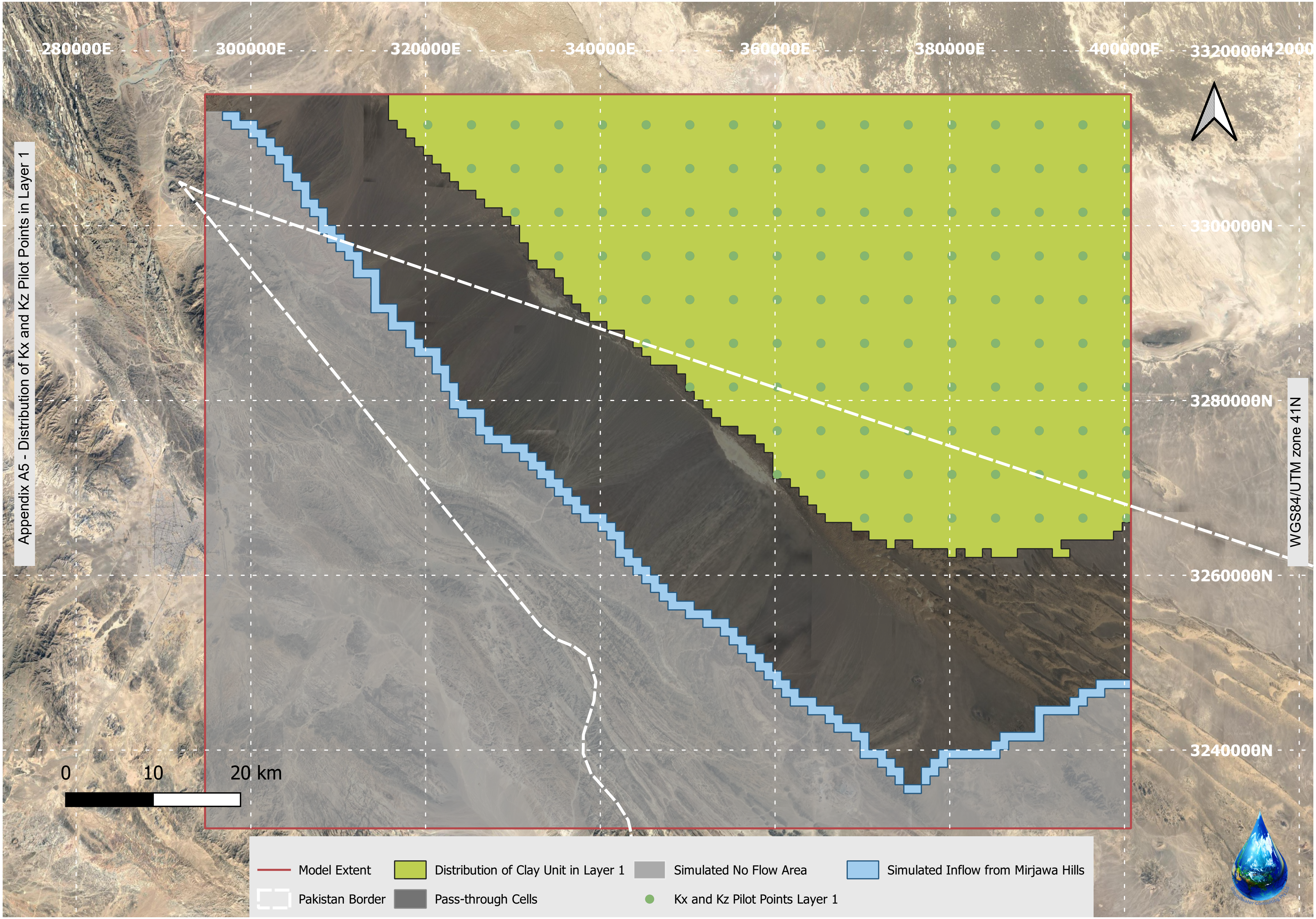
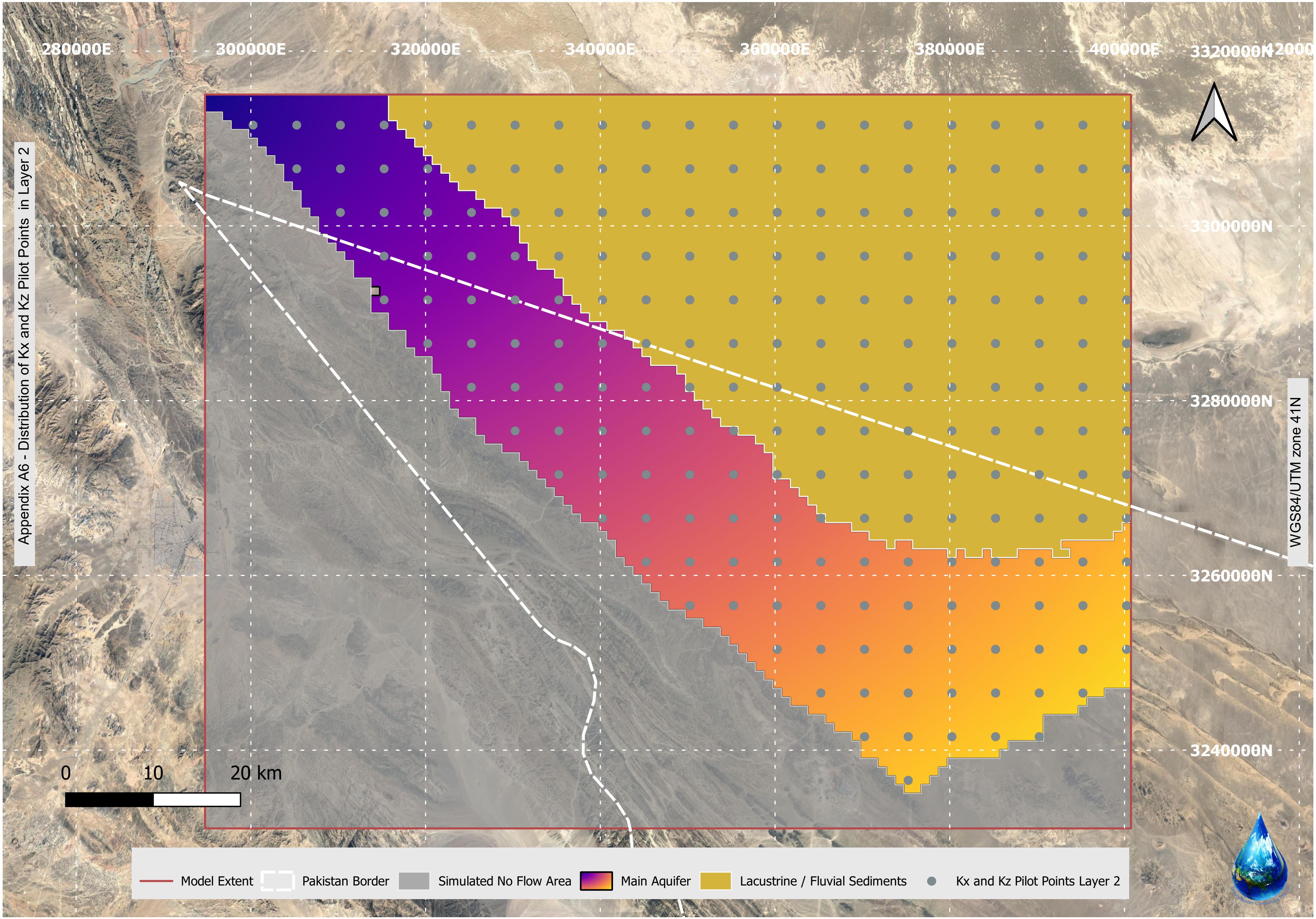
340000E
360000E
380000E
400000E
3320000N
3300000N
3280000N
3260000N
3240000N
0
10
20 km
Appendix A3 - Hydraulic Conductivity Distribution in Layer 3
WGS84/UTM zone 41N
Model Extent
Pakistan Border
Simulated No Flow Area
Low Permeability Bedrock

Appendix A4 - Head Targets Used for Model Calibration





Appendix A5 - Distribution of Kx and Kz Pilot Points in Layer 1



Appendix A6 - Distribution of Kx and Kz Pilot Points in Layer 2
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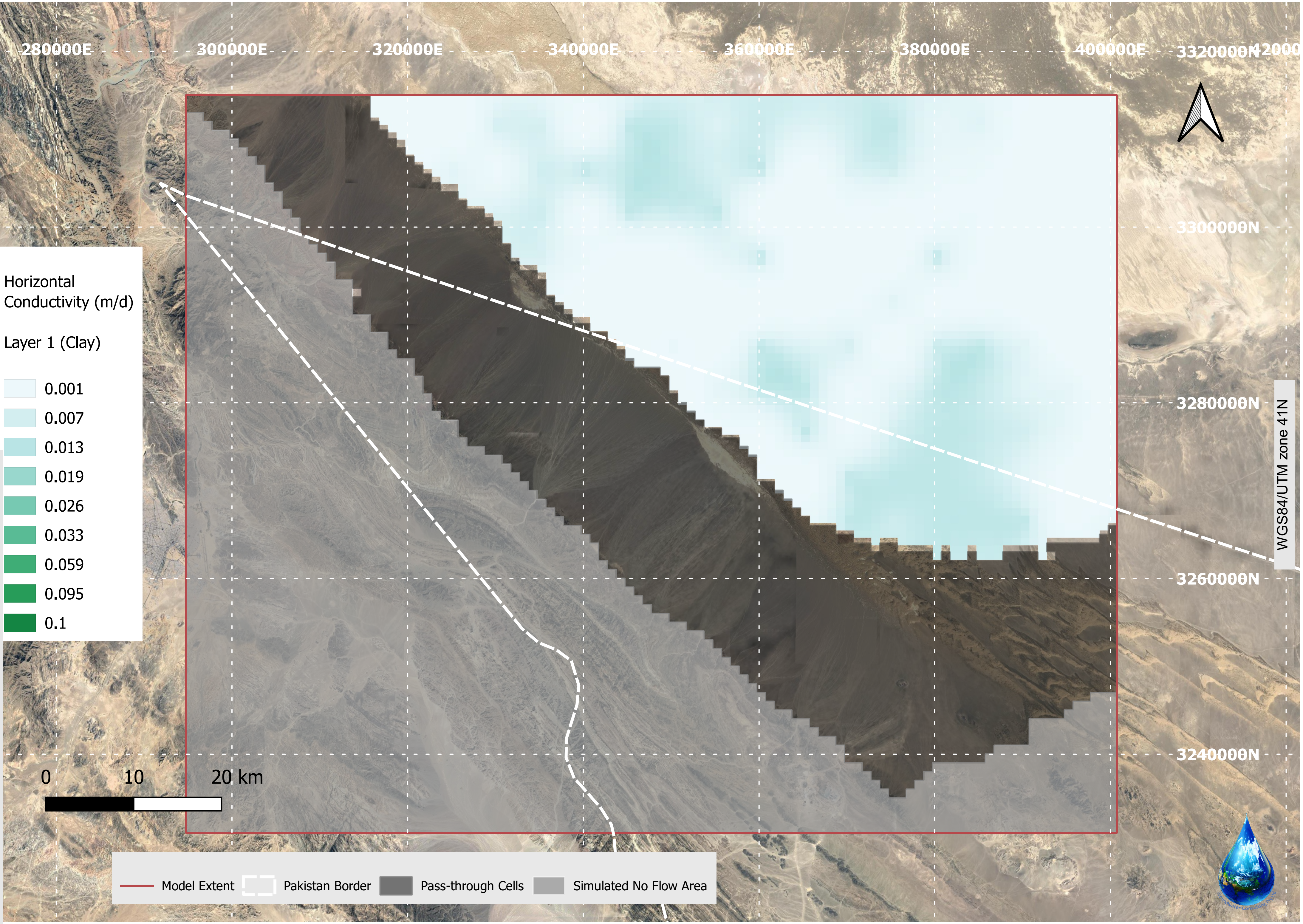
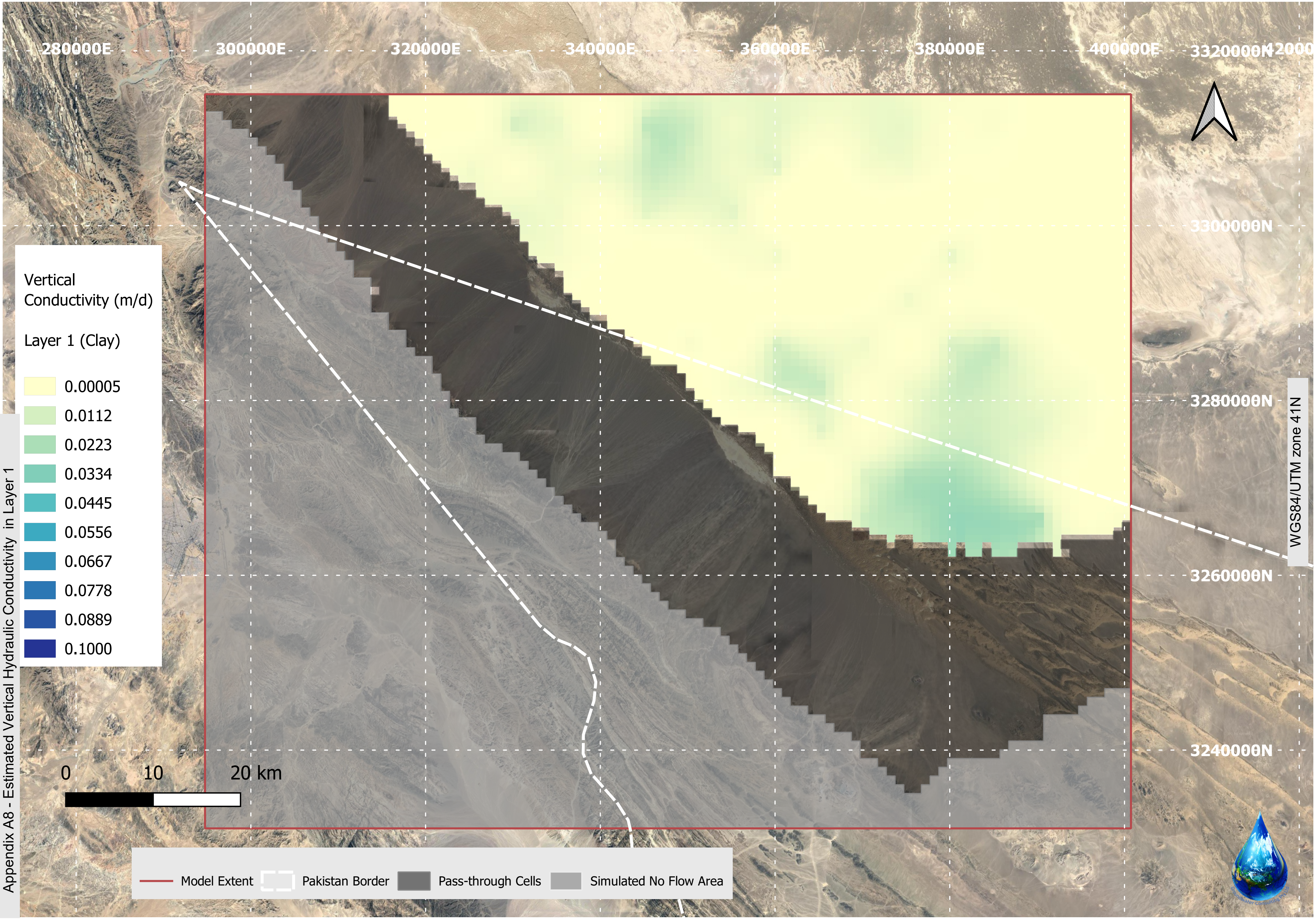
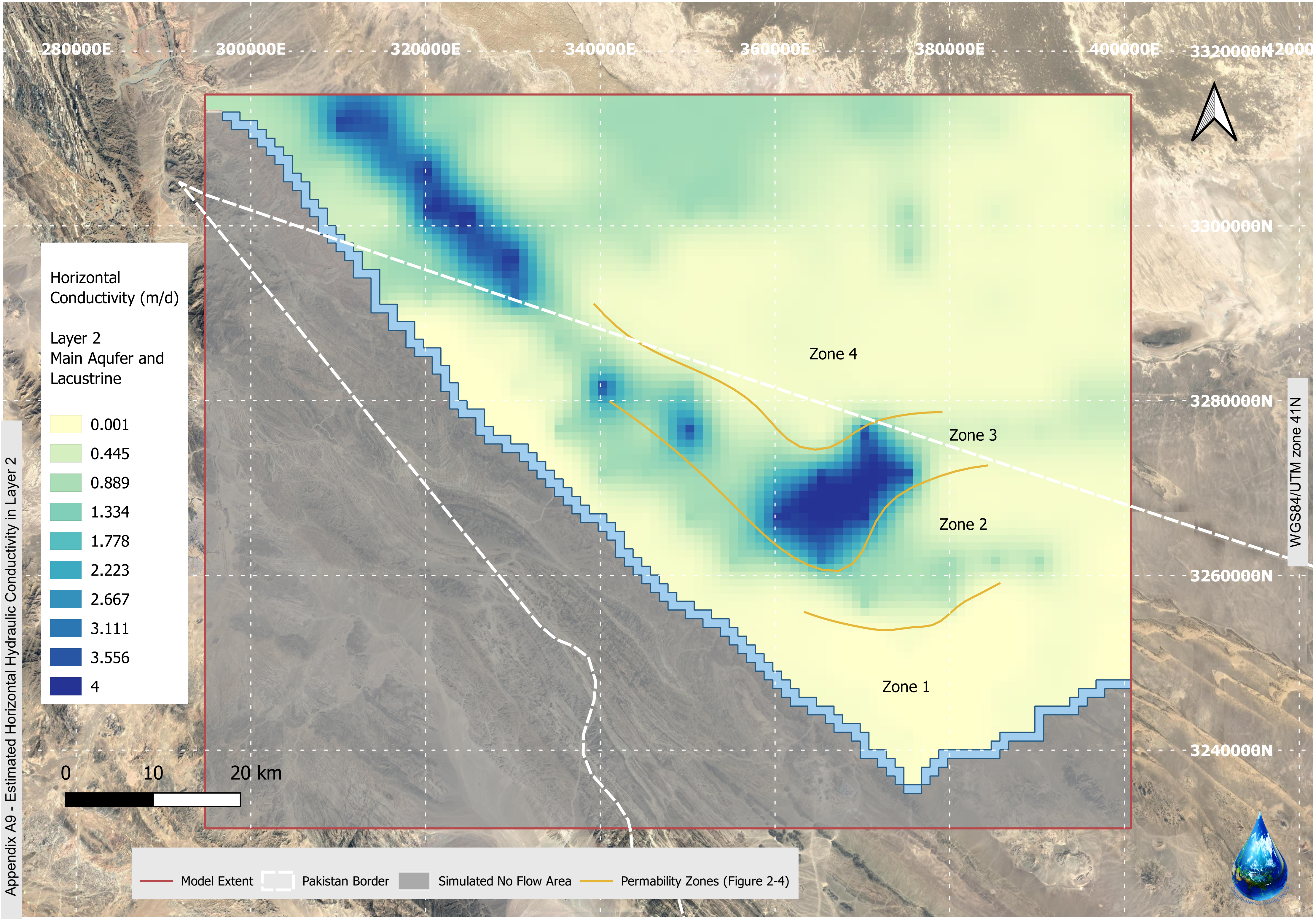
3260000N
3240000N
WGS84/UTM zone 41N
0
10
20 km
Model Extent
Pakistan Border
Simulated No Flow Area
Main Aquifer
Lacustrine / Fluvial Sediments
Kx and Kz Pilot Points Layer 2



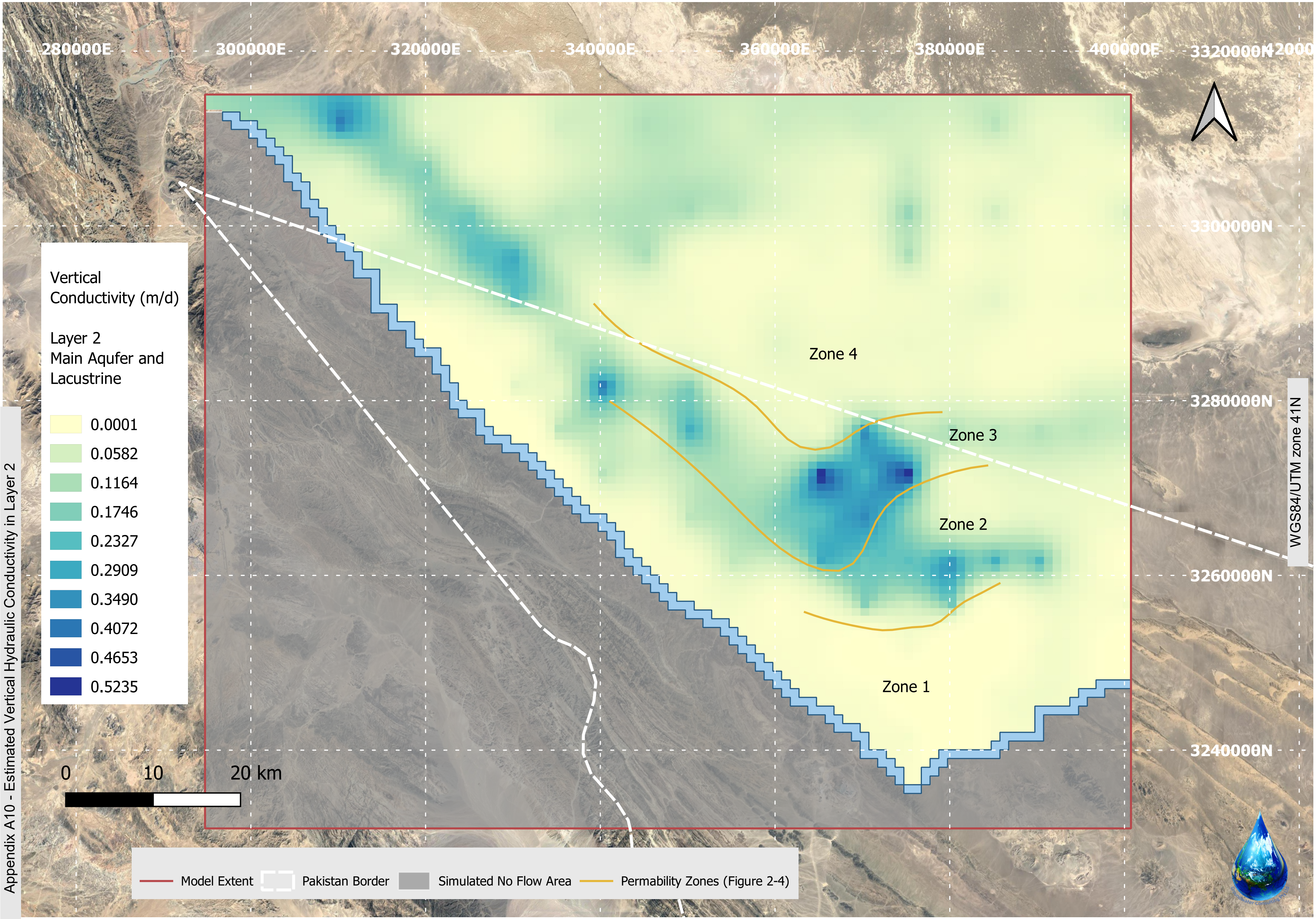
Appendix A7 - Estimated Horizontal Hydraulic Conductivity in Layer 1



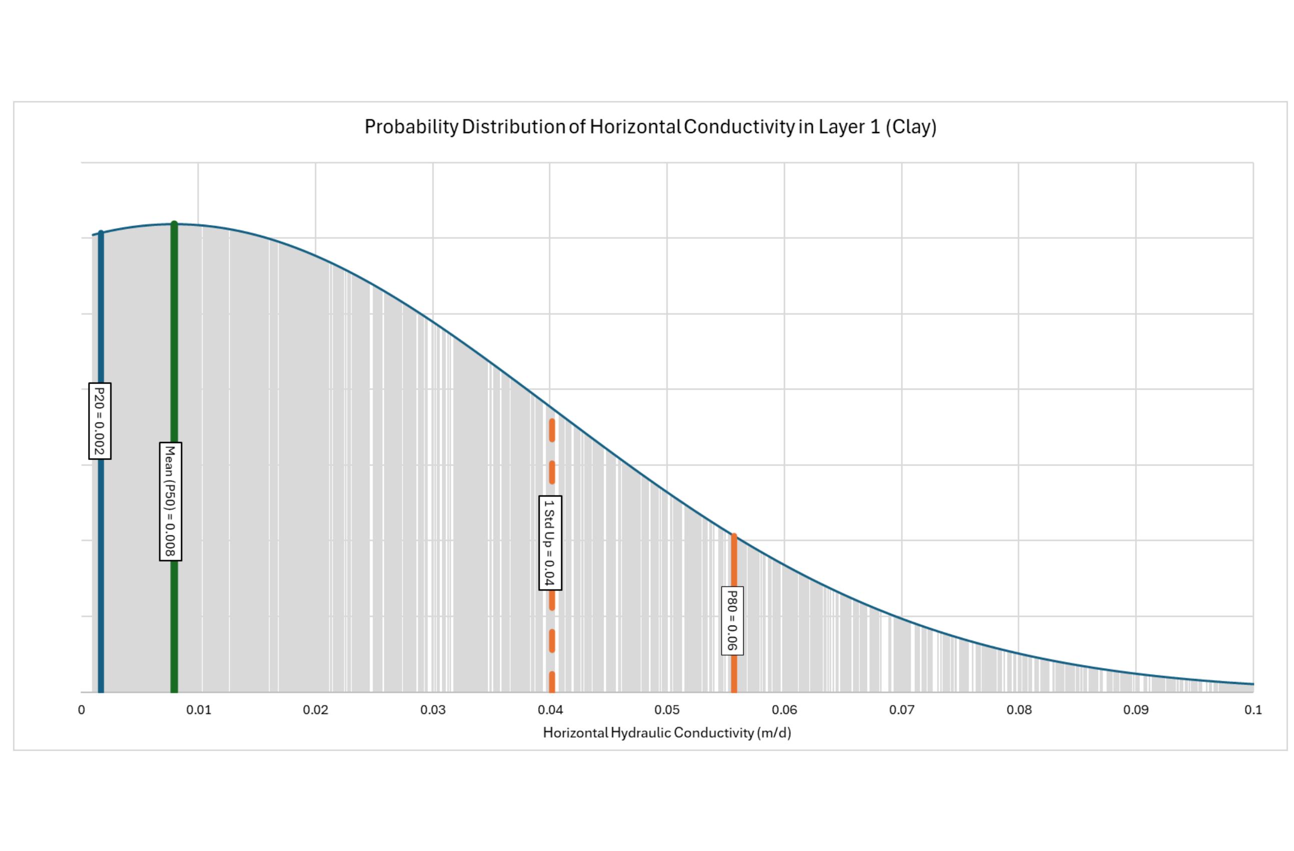
Appendix A8 - Estimated Vertical Hydraulic Conductivity in Layer 1



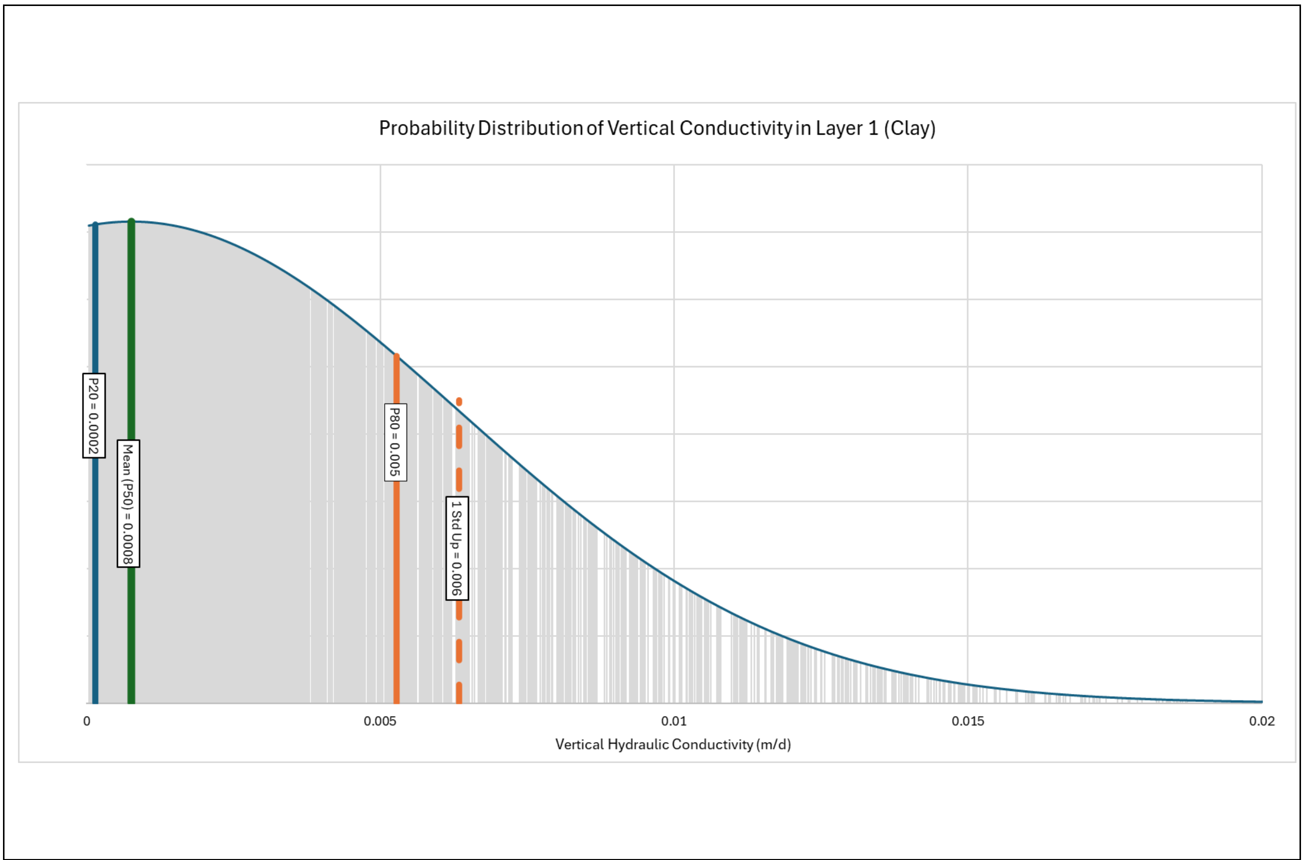
Appendix A9 - Estimated Horizontal Hydraulic Conductivity in Layer 2



Appendix A10 - Estimated Vertical Hydraulic Conductivity in Layer 2

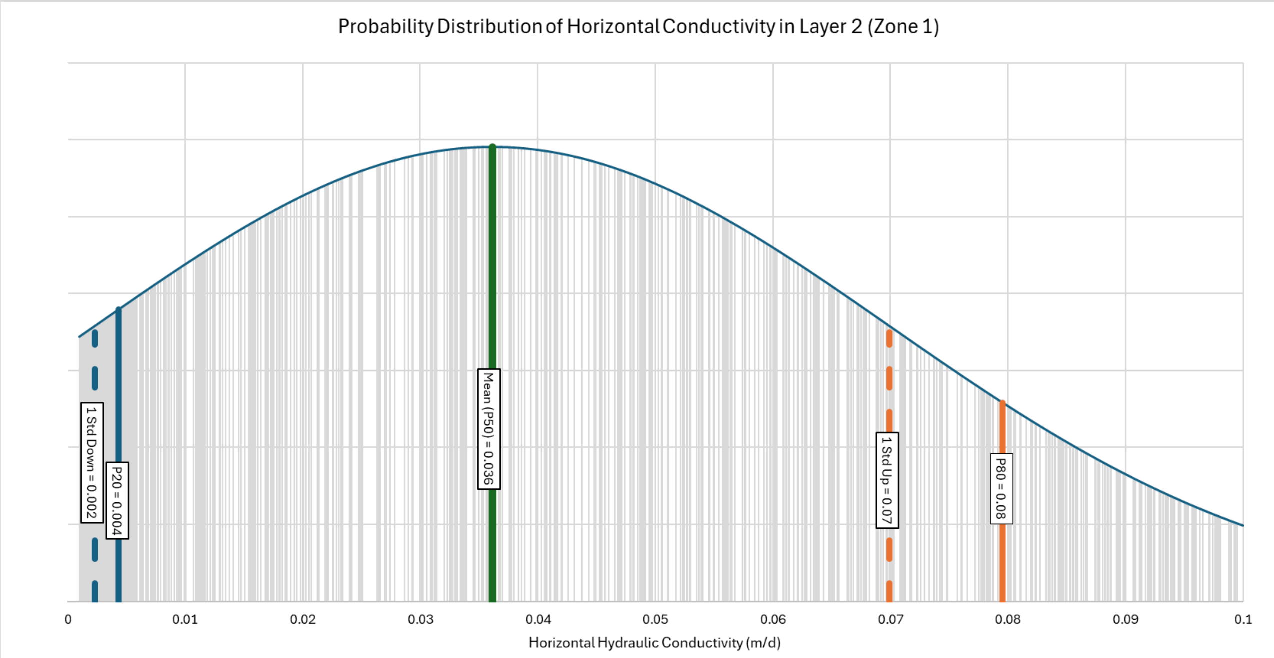


Probability Distribution of Horizontal Conductivity in Layer 1 (Clay) **Appendix A11a**

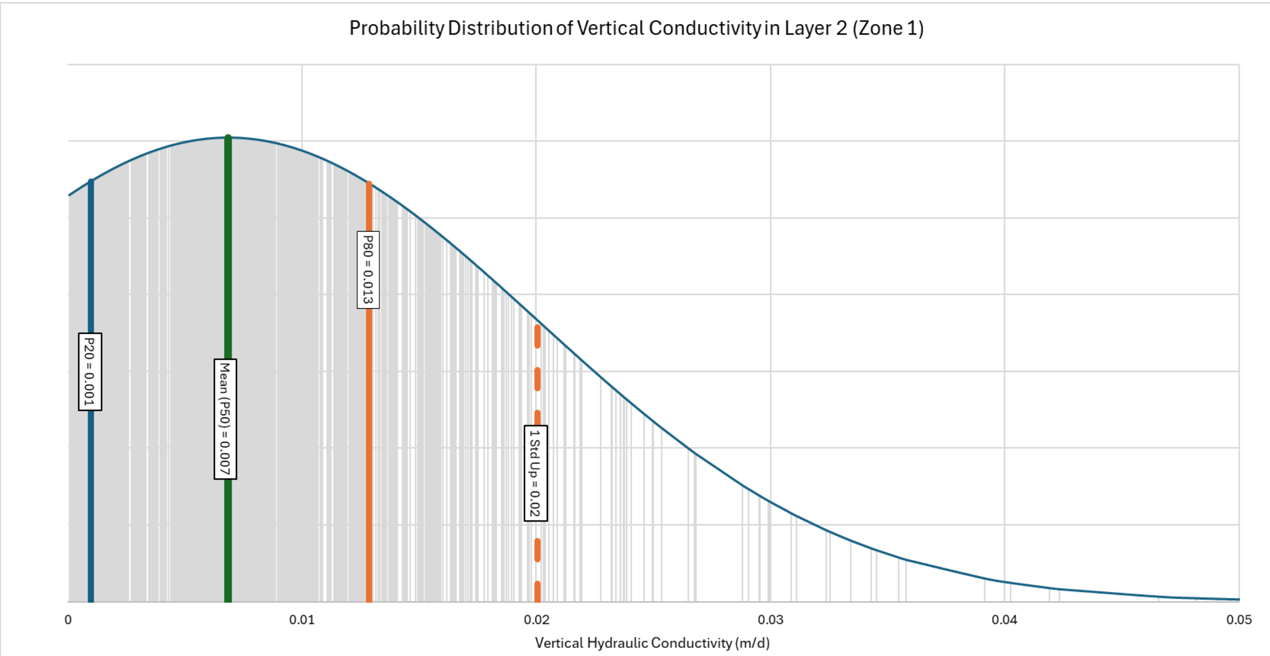


Appendix A11b

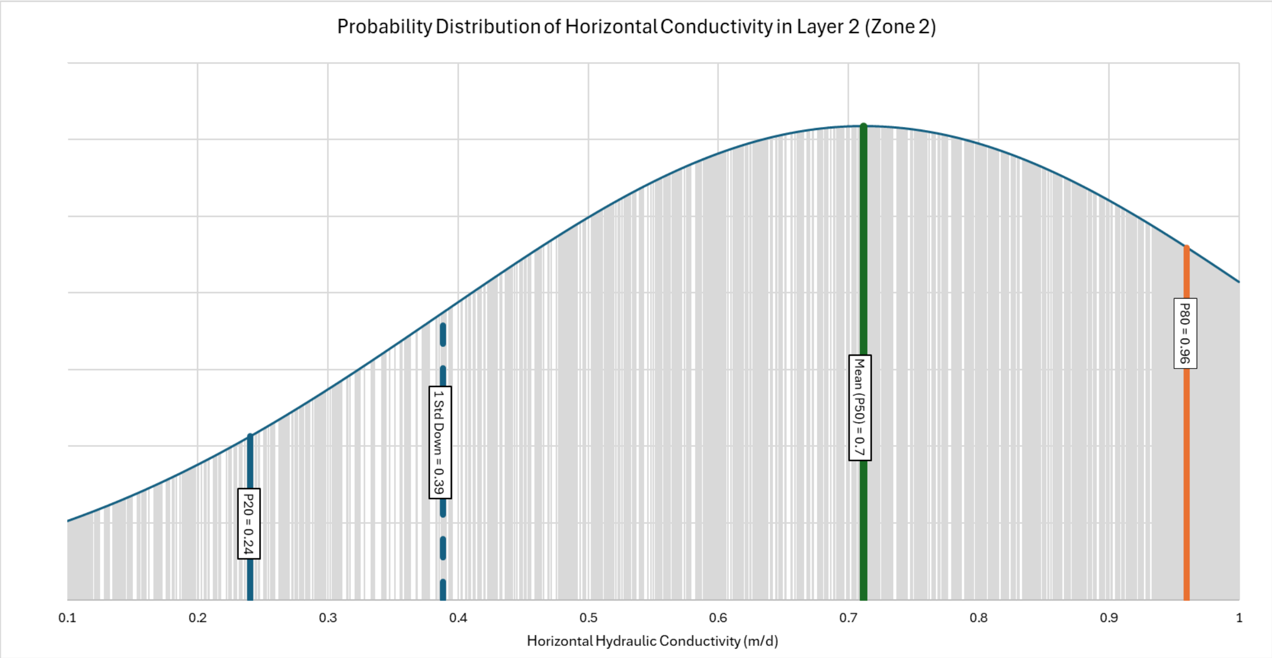
Probability Distribution of Vertical Conductivity in Layer 1 (Clay)



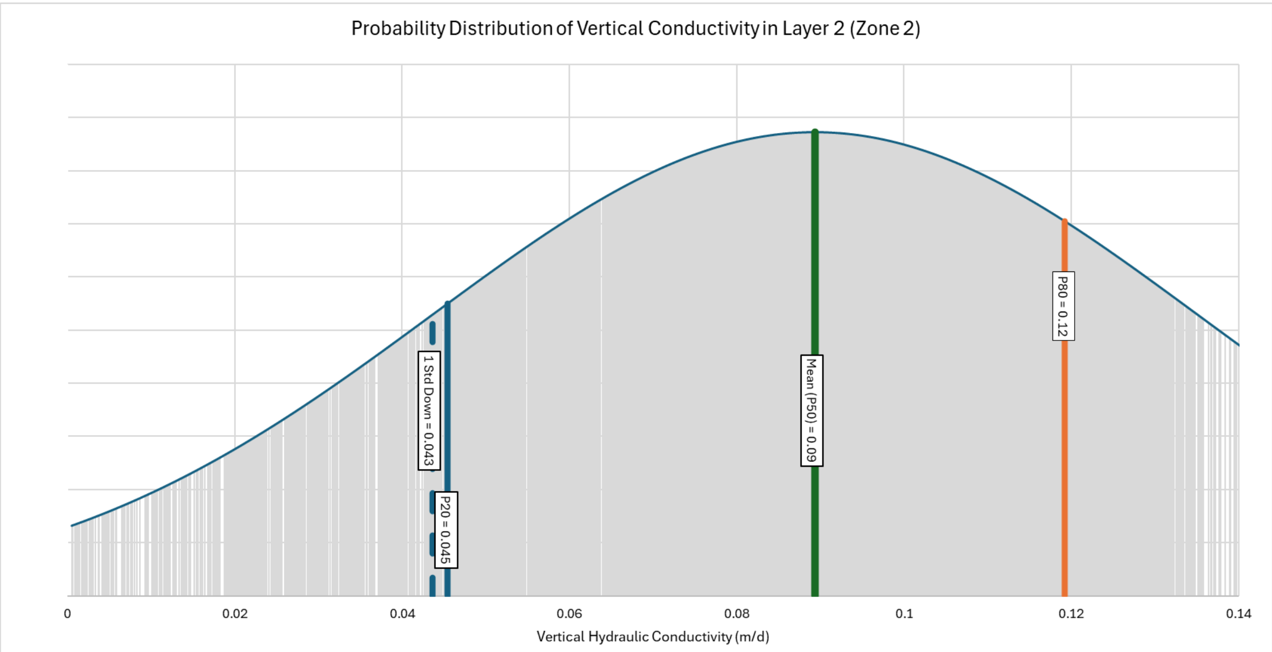
Probability Distribution of Horizontal Conductivity in Layer 2 (Zone 1) **Appendix A12a**



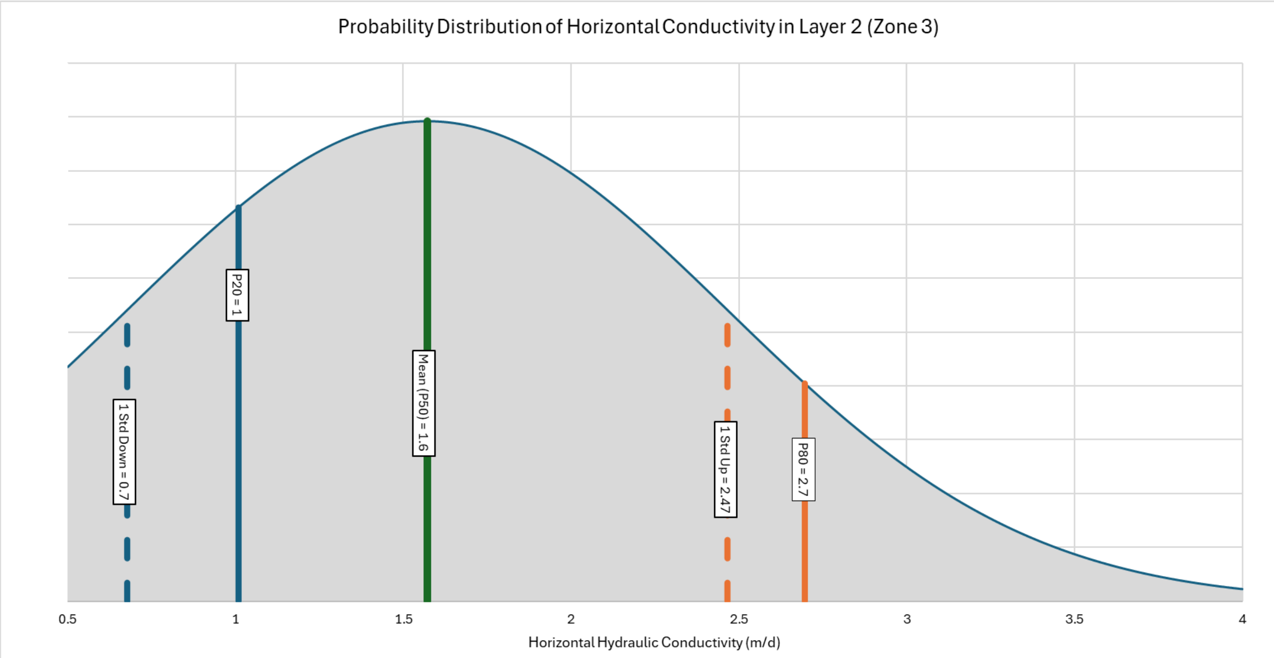
Probability Distribution of Vertical Conductivity in Layer 2 (Zone 1) **Appendix A12b**



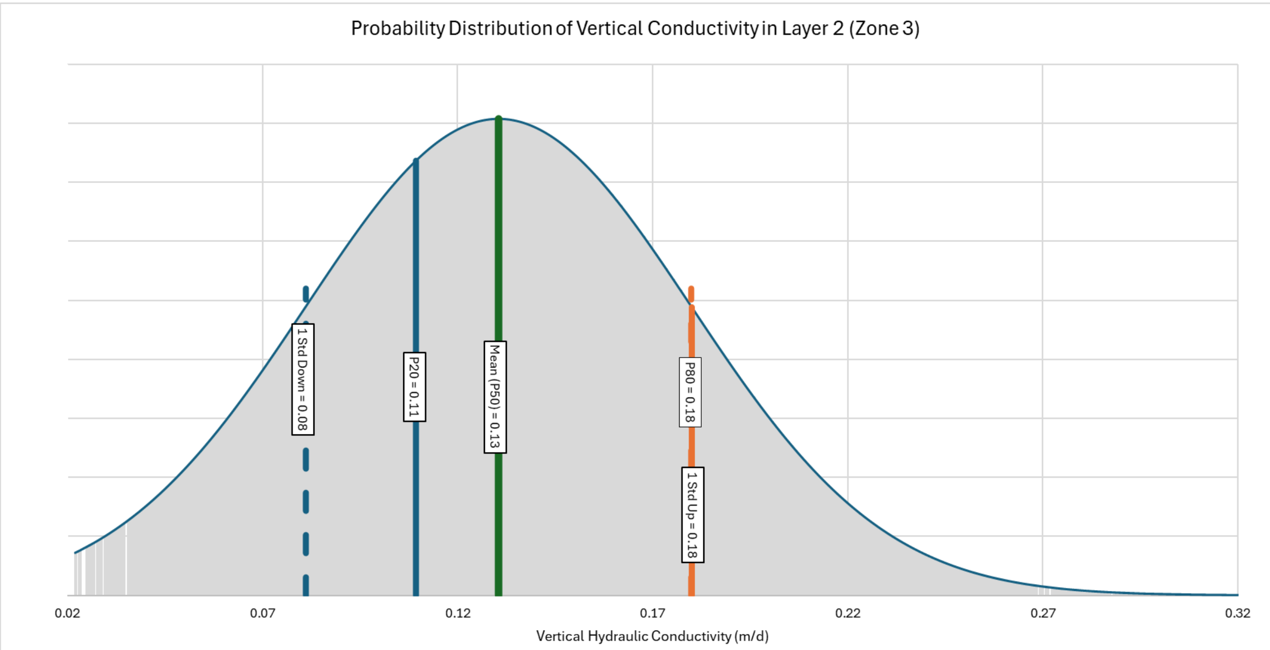
Probability Distribution of Horizontal Conductivity in Layer 2 (Zone 2) **Appendix A13a**



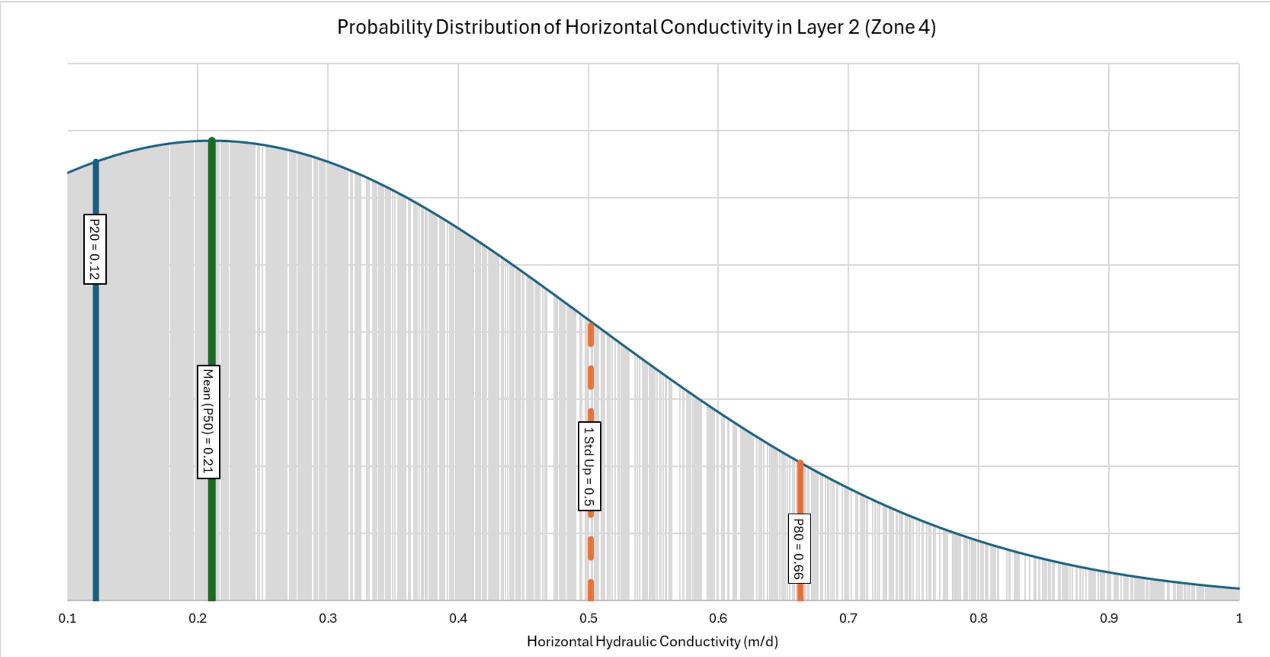
Probability Distribution of Vertical Conductivity in Layer 2 (Zone 2) **Appendix A13b**



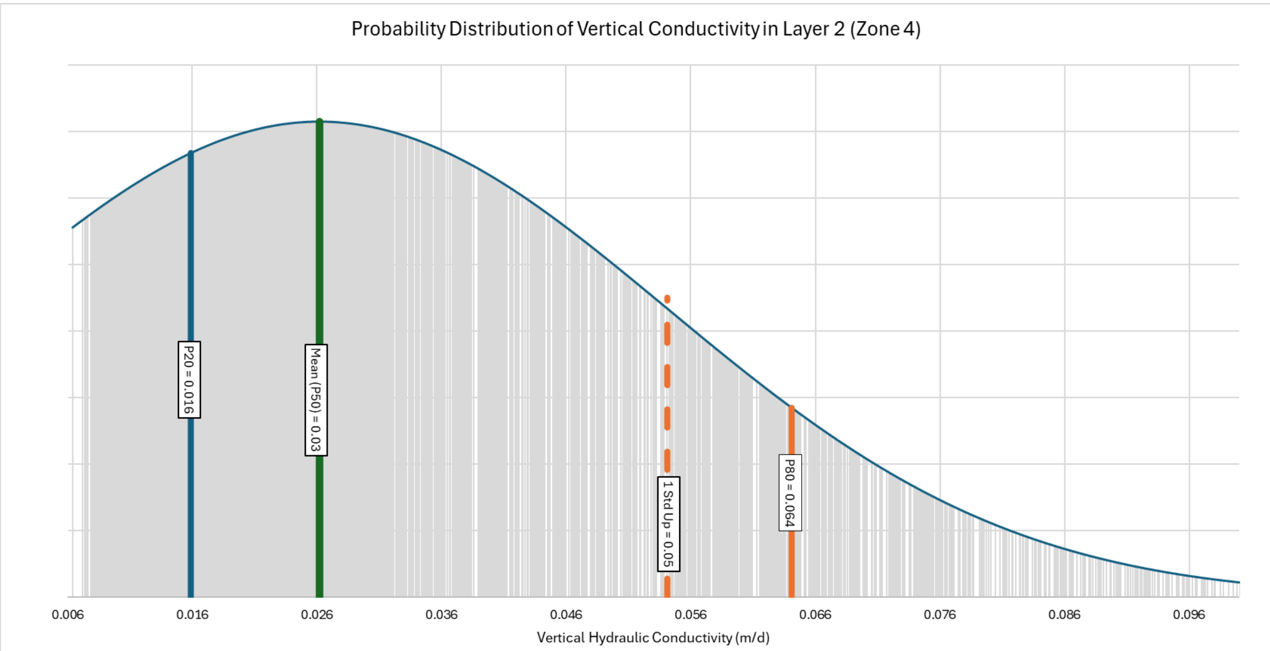
Probability Distribution of Horizontal Conductivity in Layer 2 (Zone 3) **Appendix A14a**



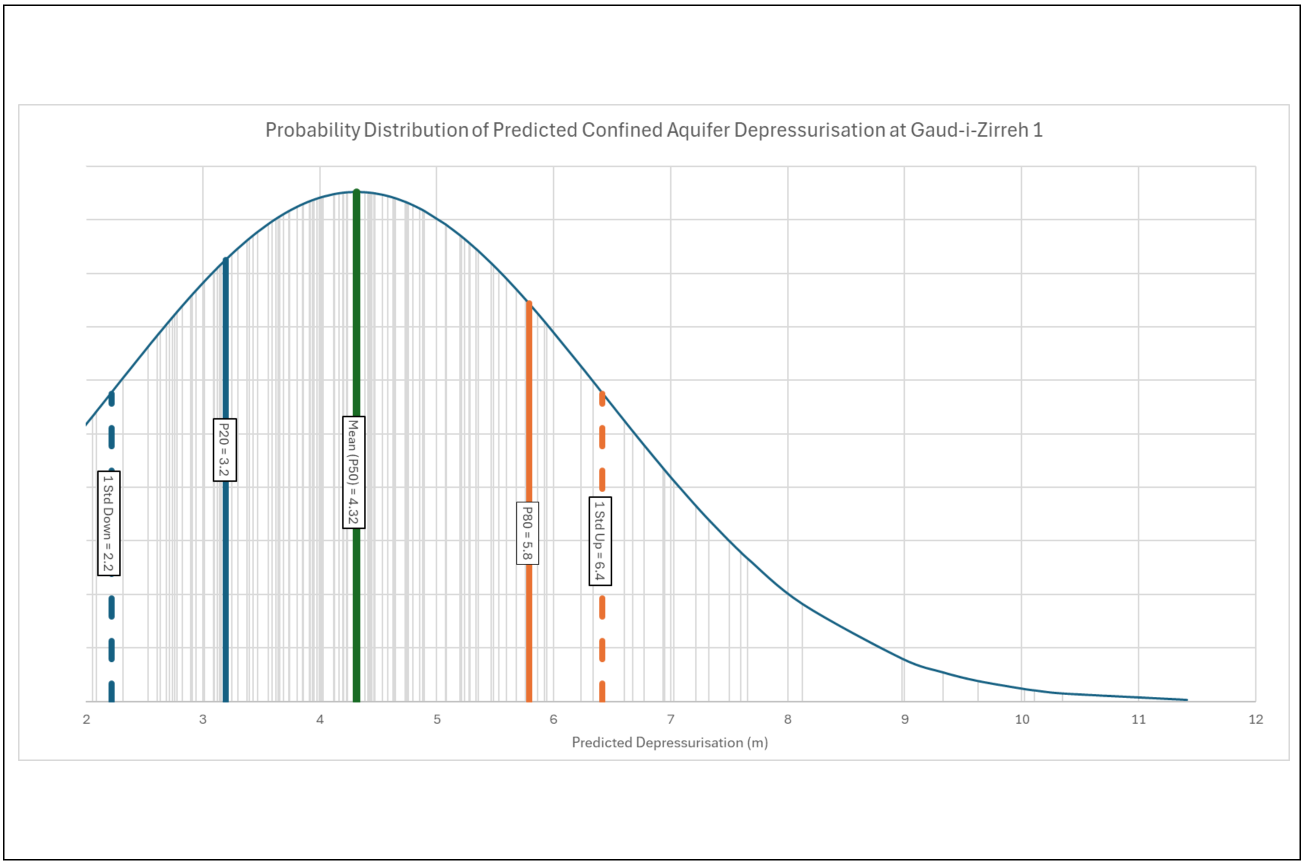
Probability Distribution of Vertical Conductivity in Layer 2 (Zone 3) **Appendix A14b**



Probability Distribution of Horizontal Conductivity in Layer 2 (Zone 4) **Appendix A15a**

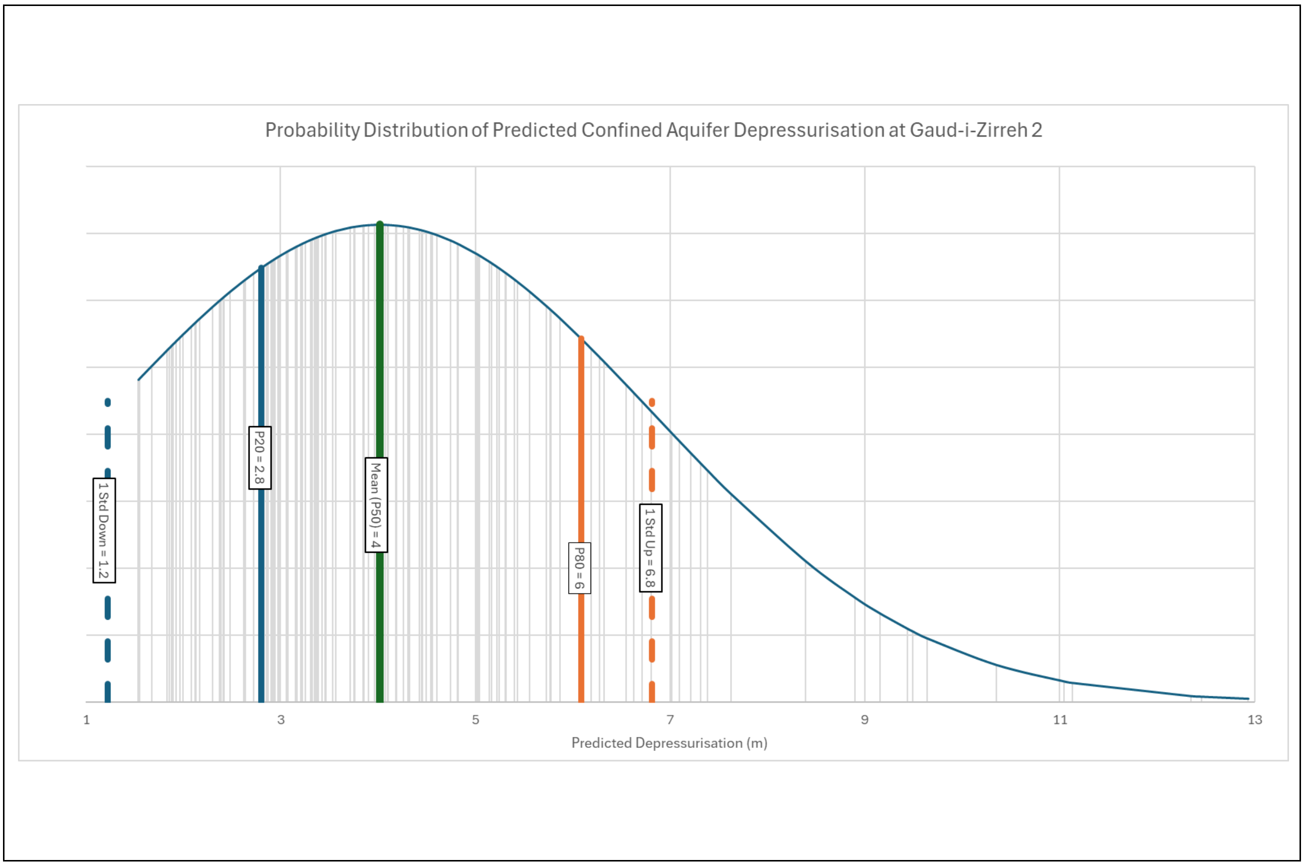


Probability Distribution of Vertical Conductivity in Layer 2 (Zone 4) **Appendix A15b**



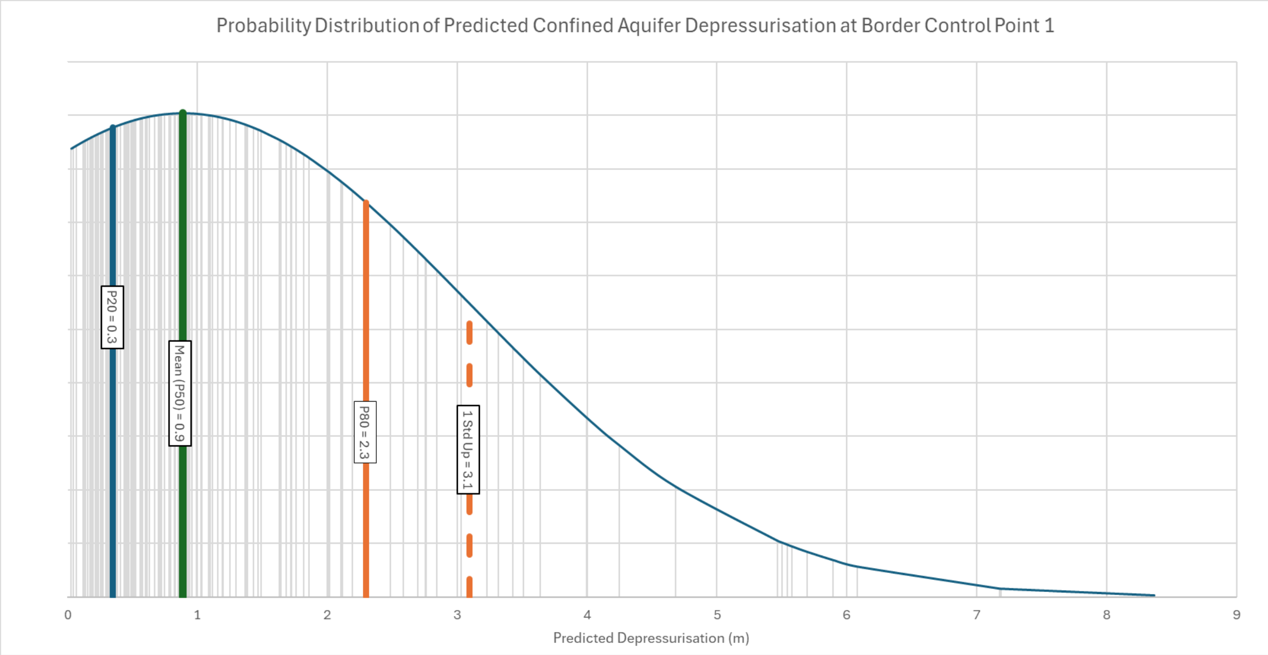
Probability Distribution of Predicted Confined Aquifer Depressurisation at Gaud-i-Zirreh 1 (End of Abstraction)

Appendix A16a

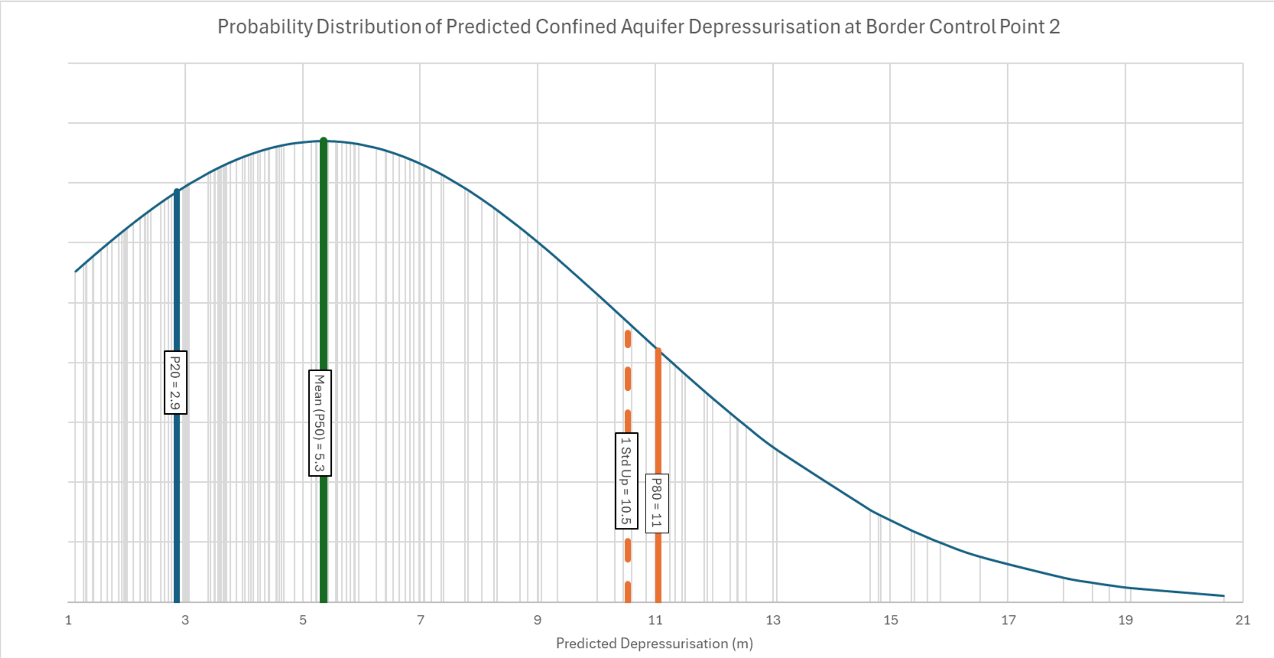


Probability Distribution of Predicted Confined Aquifer Depressurisation at Gaud-i-Zirreh 2 (End of Abstraction)

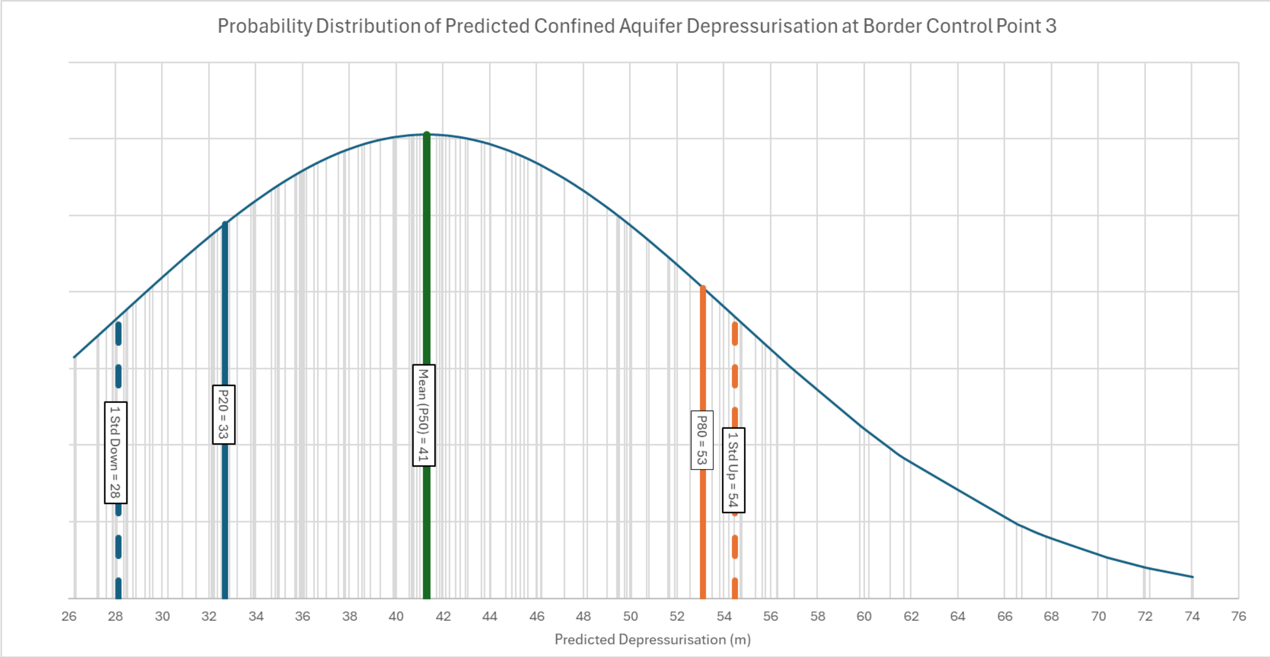
Appendix A16b



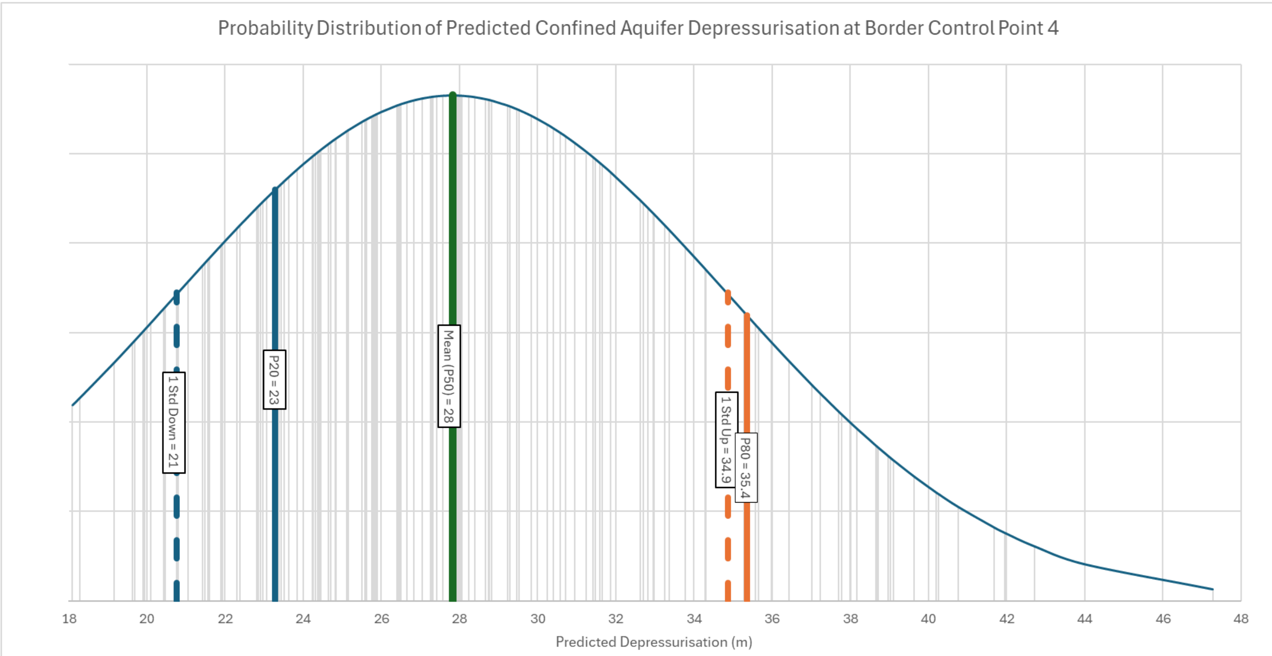
Probability Distribution of Predicted Confined Aquifer Depressurisation at Border Control Point 1 (End of Abstraction) **Appendix A17a**



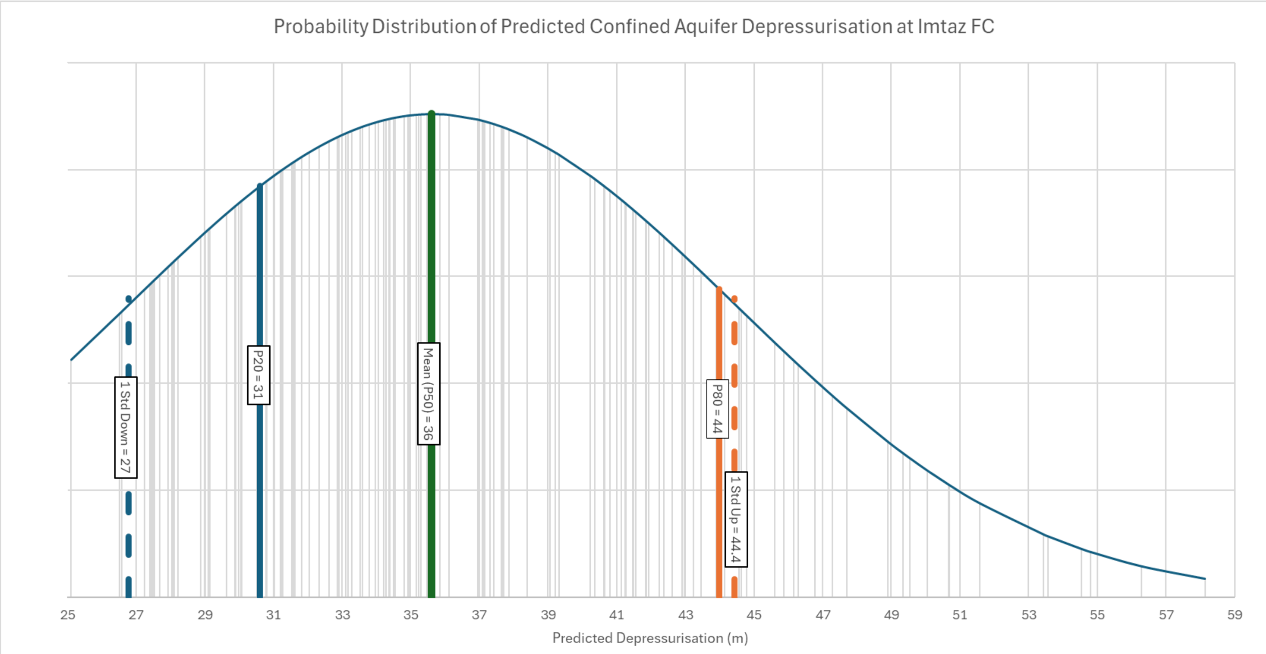
Probability Distribution of Predicted Confined Aquifer Depressurisation at Border Control Point 2 (End of Abstraction) **Appendix A17b**



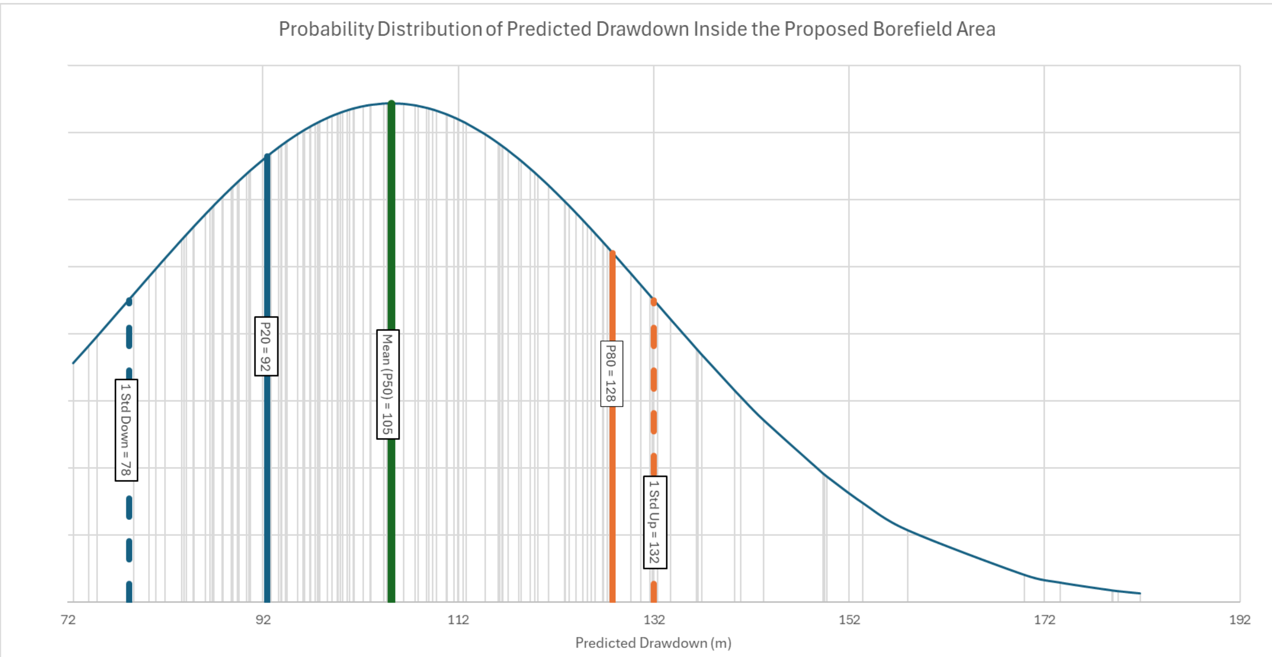
Probability Distribution of Predicted Confined Aquifer Depressurisation at Border Control Point 3 (End of Abstraction) **Appendix A18a**



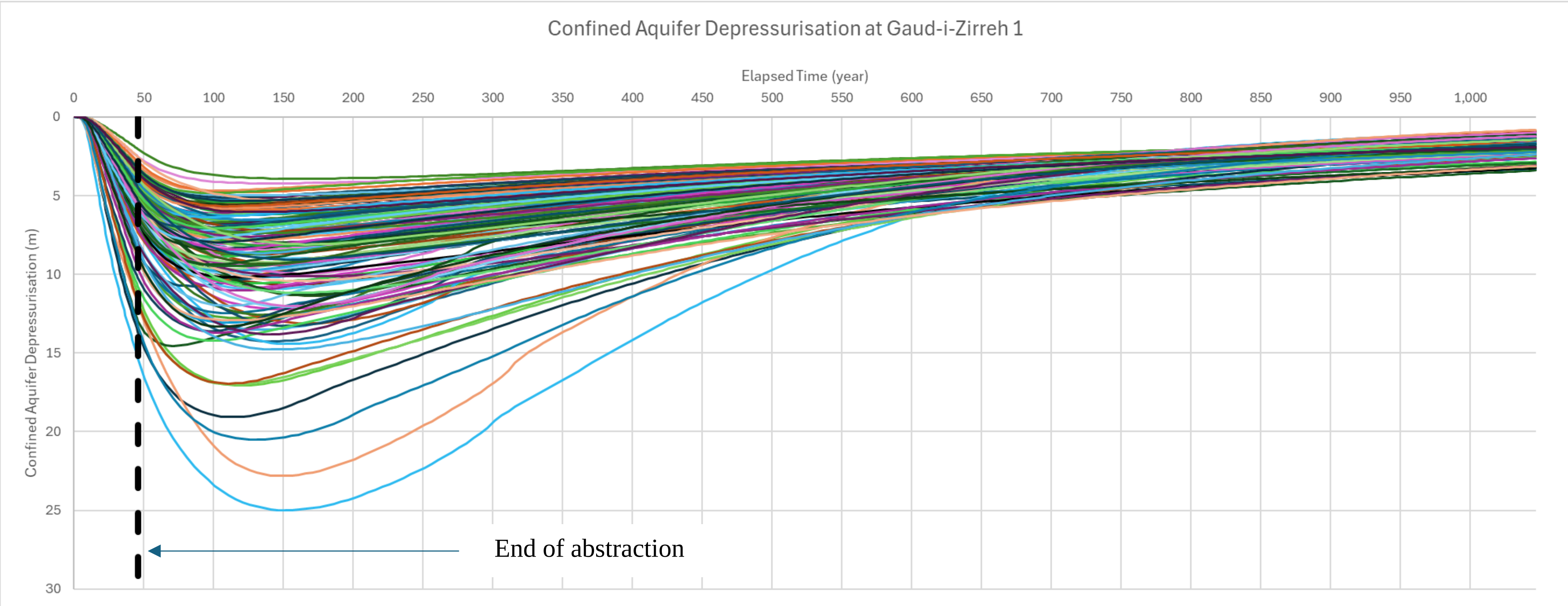
Probability Distribution of Predicted Confined Aquifer Depressurisation at Border Control Point 4 (End of Abstraction) **Appendix A18b**



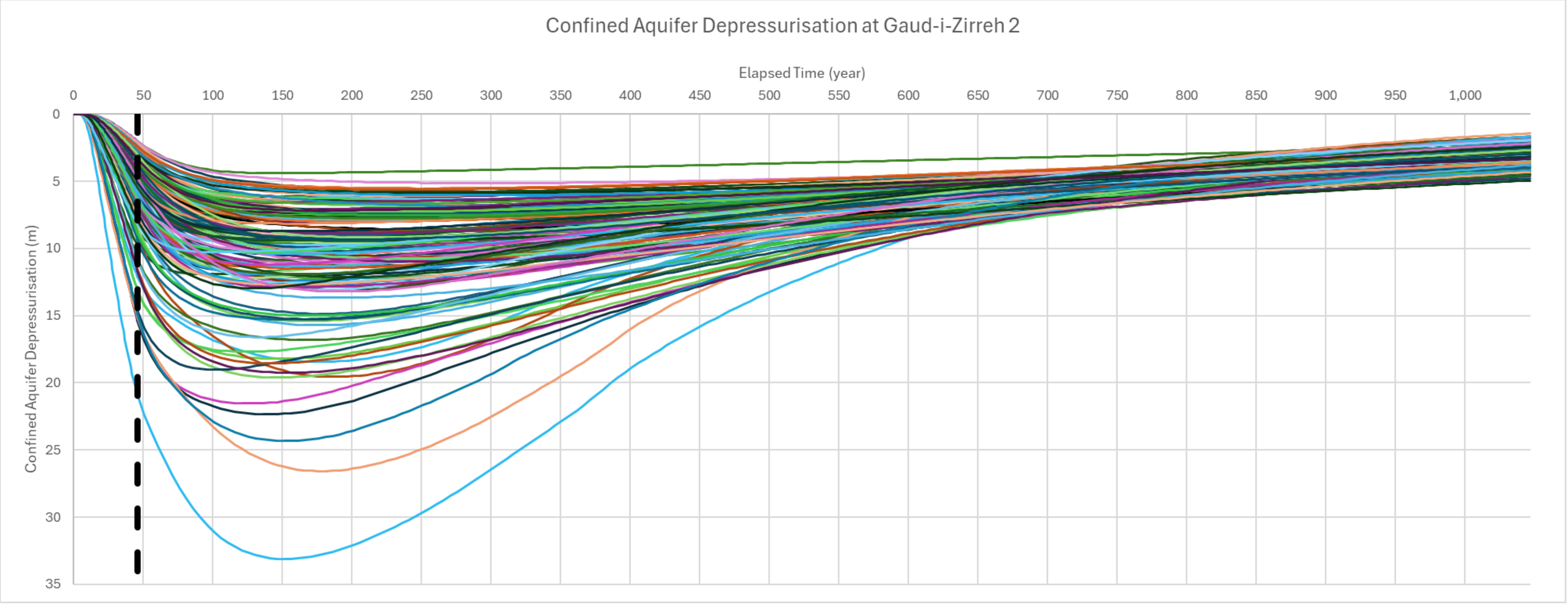
Probability Distribution of Predicted Confined Aquifer Depressurisation at Imtaz FC (End of Abstraction) **Appendix A19a**



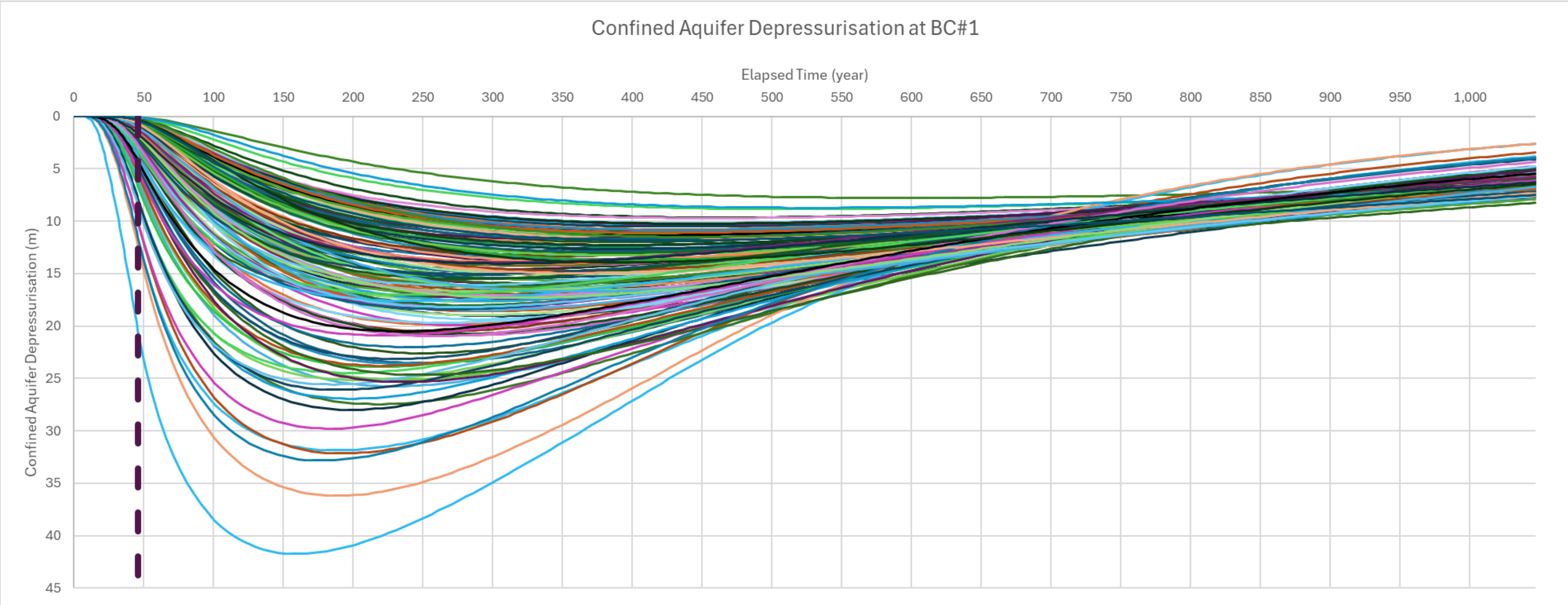
Probability Distribution of Predicted Drawdown Inside the Proposed Borefield Area (End of Abstraction) **Appendix A19b**



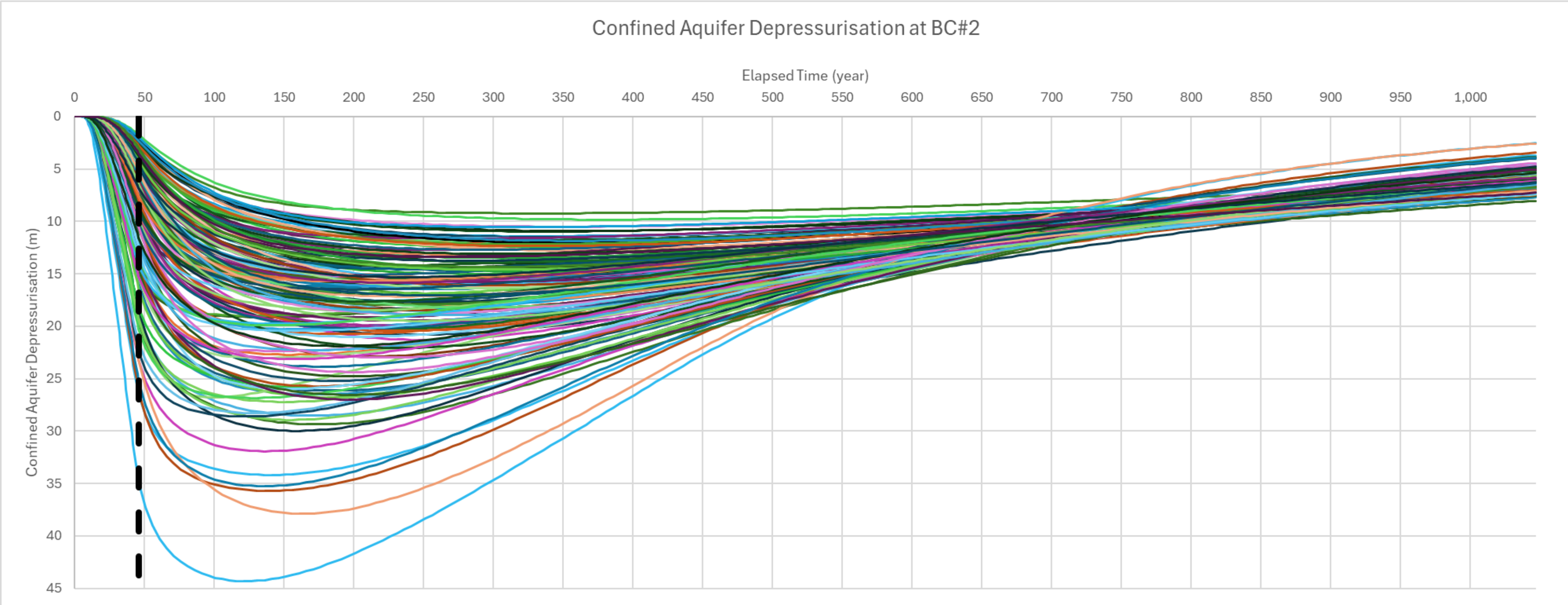
Confined Aquifer Depressurisation at Gaud-i-Zirreh 1 **Appendix A20**



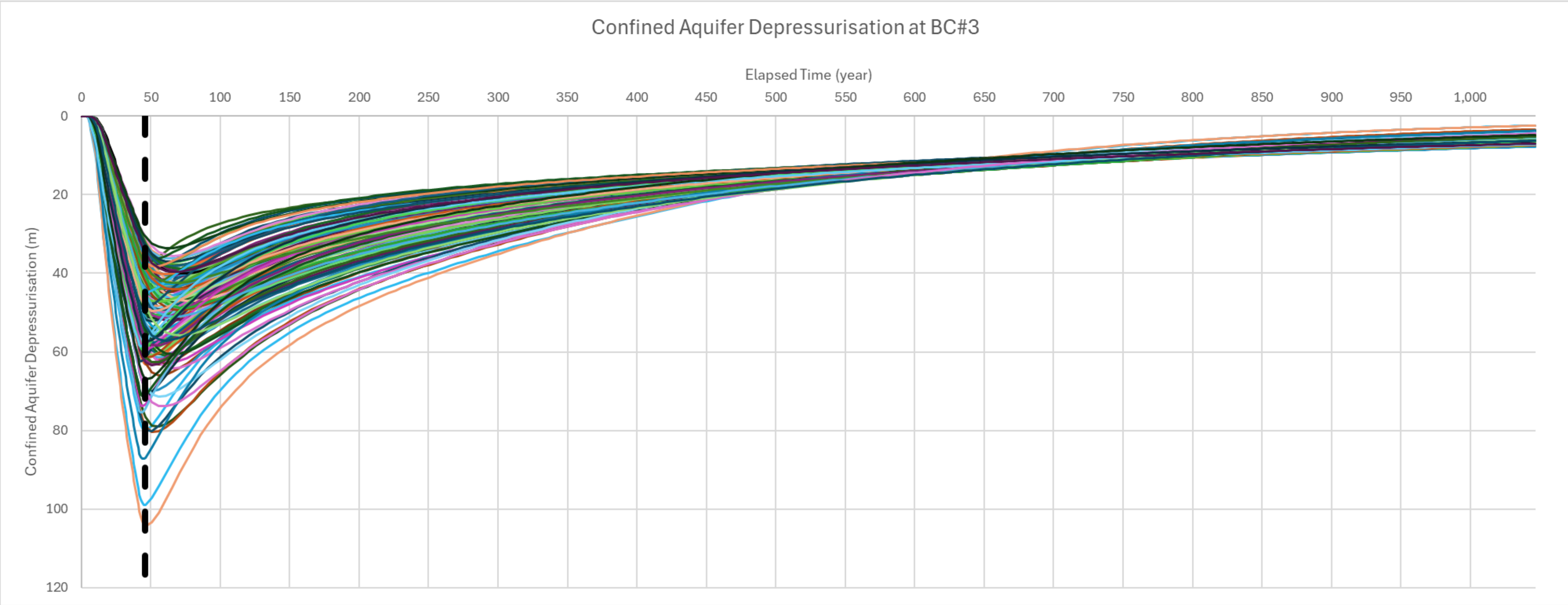
Confined Aquifer Depressurisation at Gaud-i-Zirreh 2 **Appendix A21**



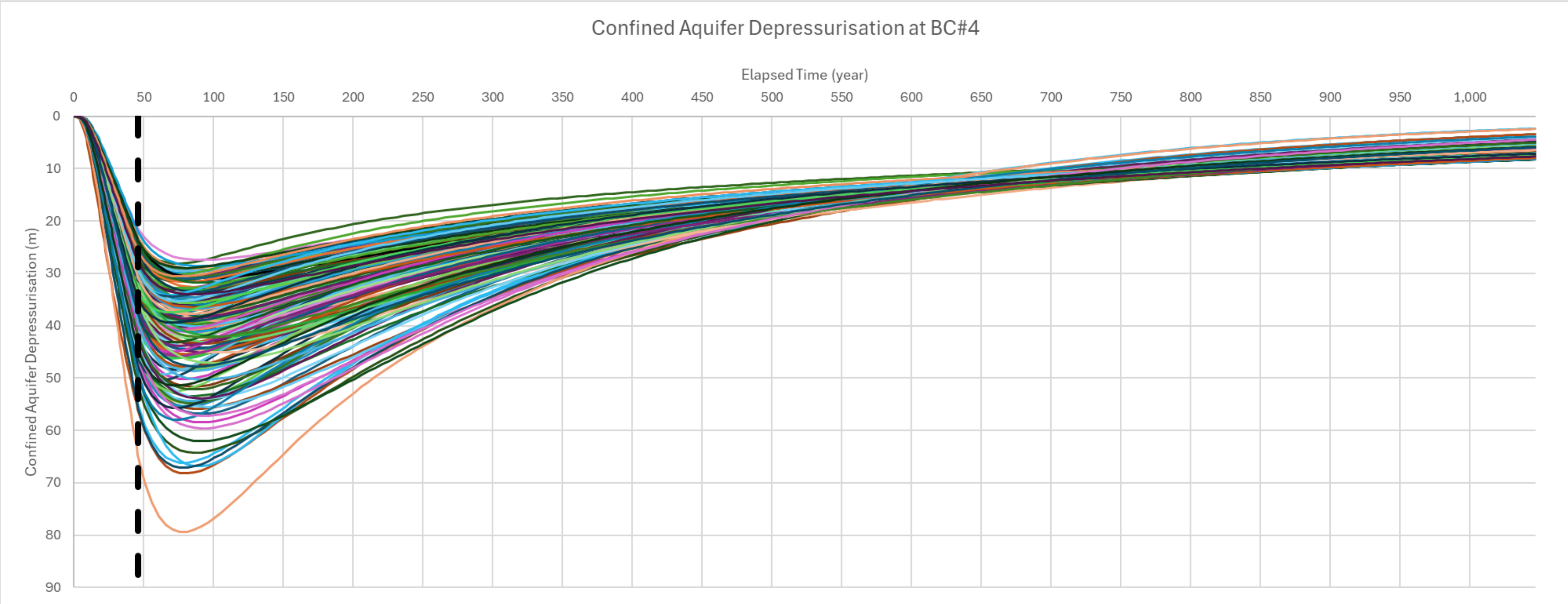
Confined Aquifer Depressurisation at Border Control Point #1 **Appendix A22**



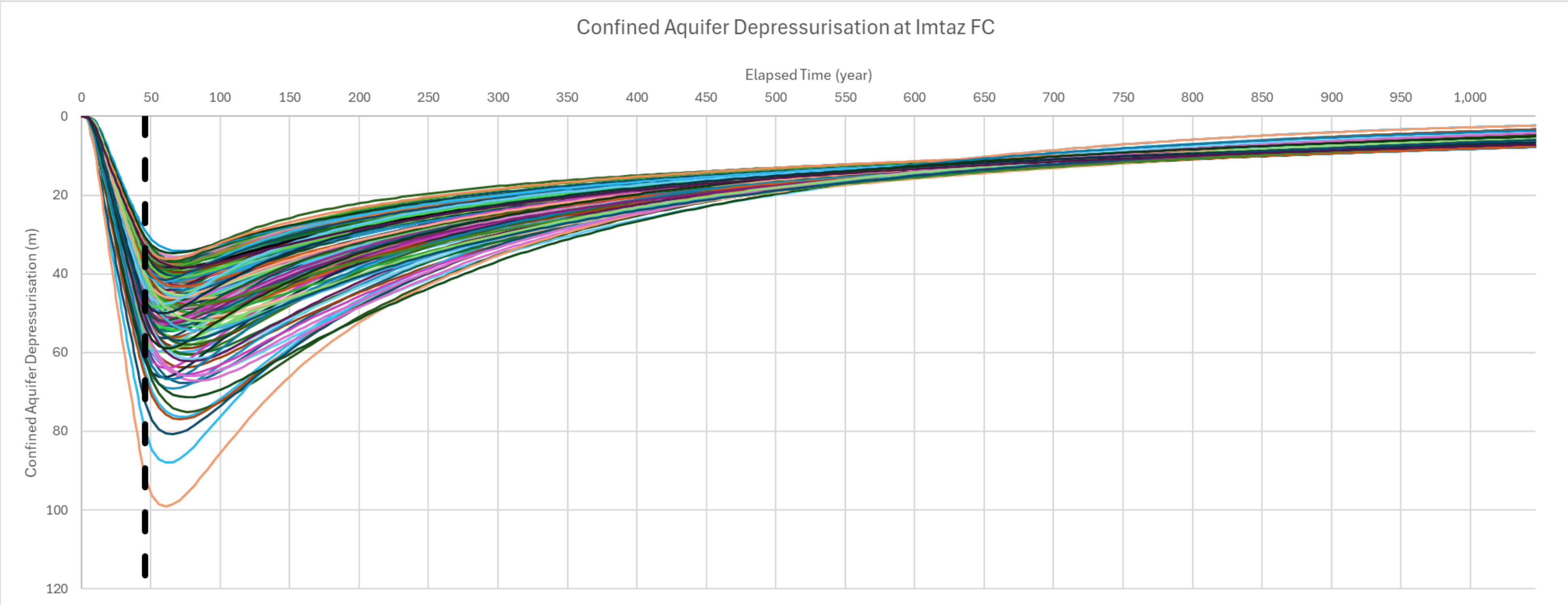
Confined Aquifer Depressurisation at Border Control Point #2 **Appendix A23**



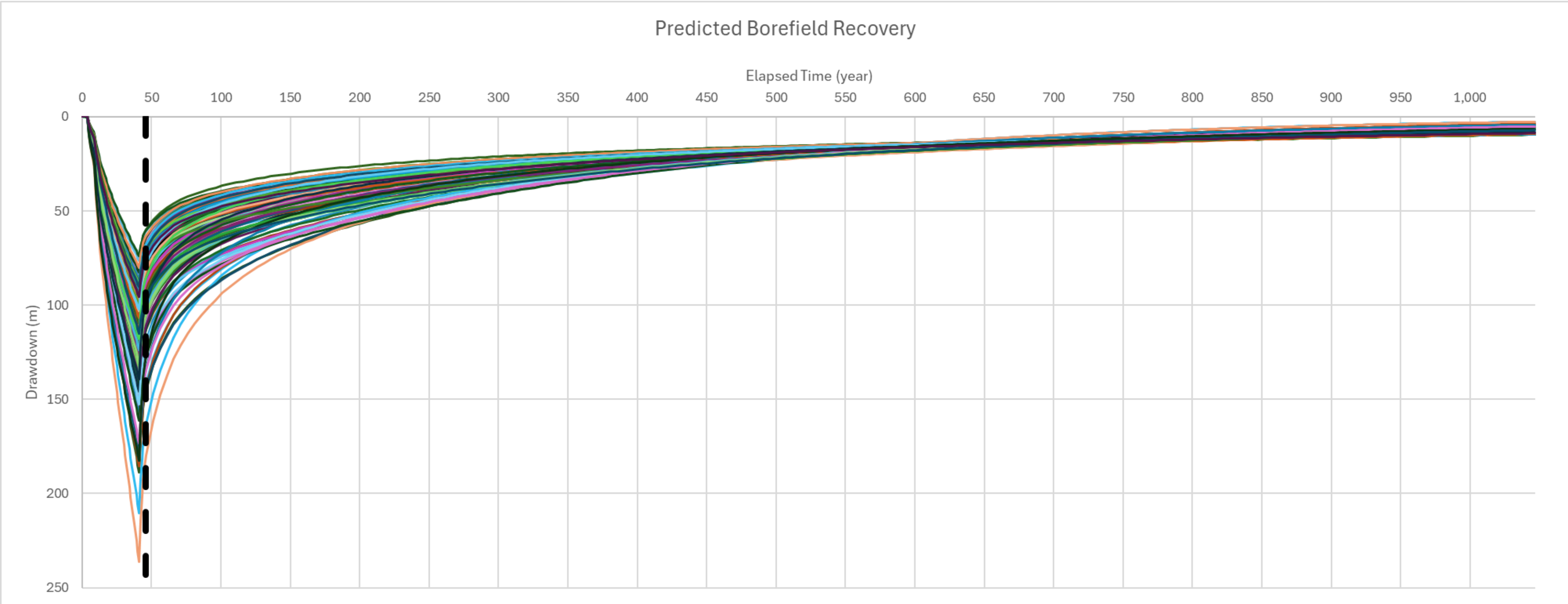
Confined Aquifer Depressurisation at Border Control Point #3 **Appendix A24**



Confined Aquifer Depressurisation at Border Control Point #4 **Appendix A25**

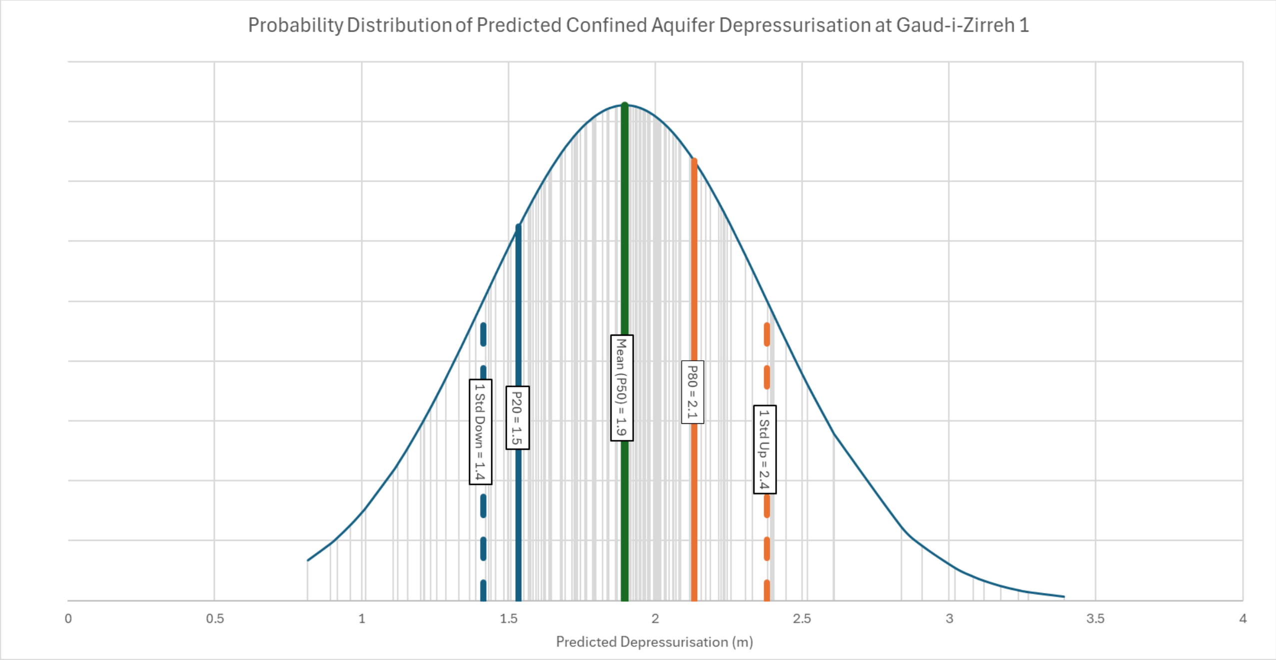


Confined Aquifer Depressurisation at Imtaz FC **Appendix A26**



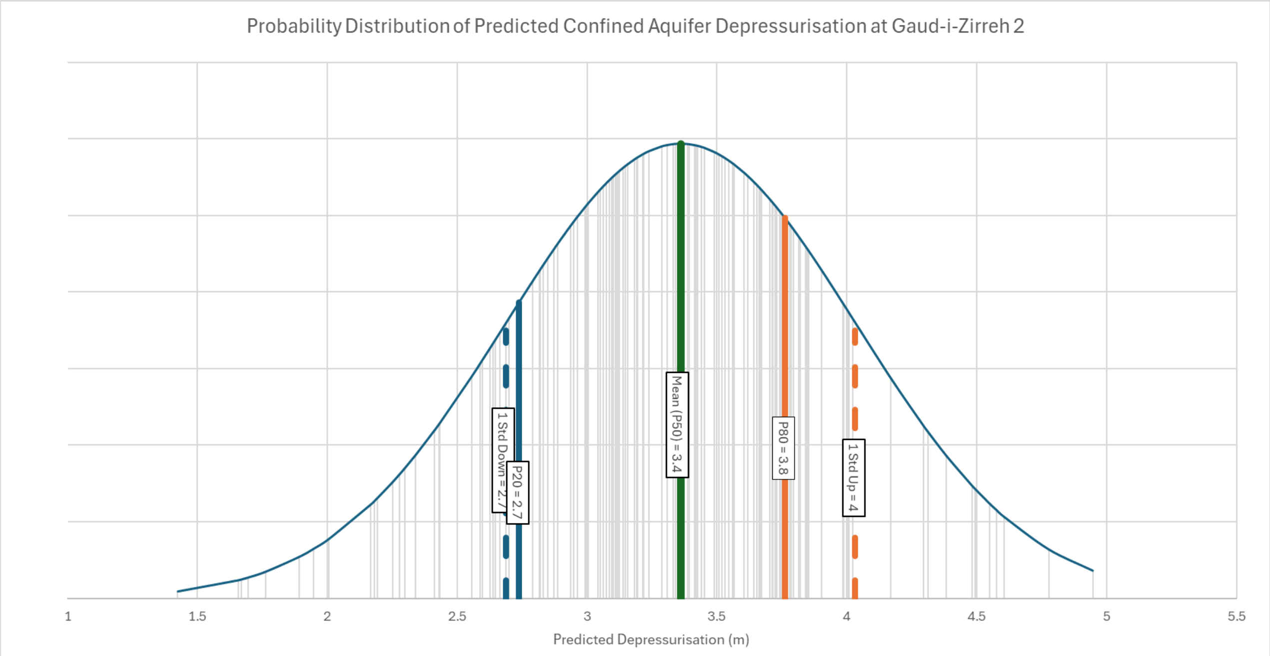
Predicted Borefield Recovery and Drawdown

Appendix A27



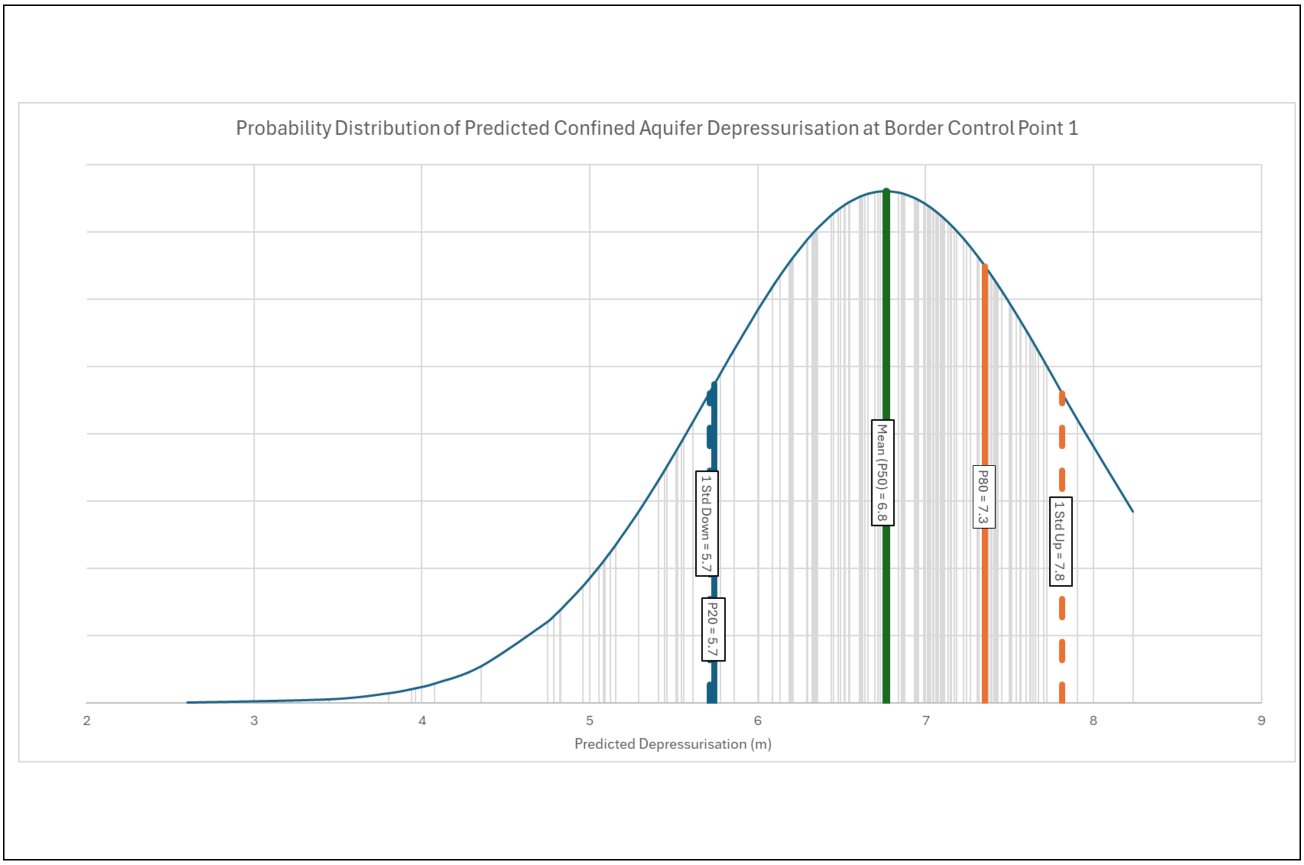
Probability Distribution of Predicted Confined Aquifer Depressurisation at Gaud-i-Zirreh 1 (End of Aquifer Recovery Period)

Appendix A28a

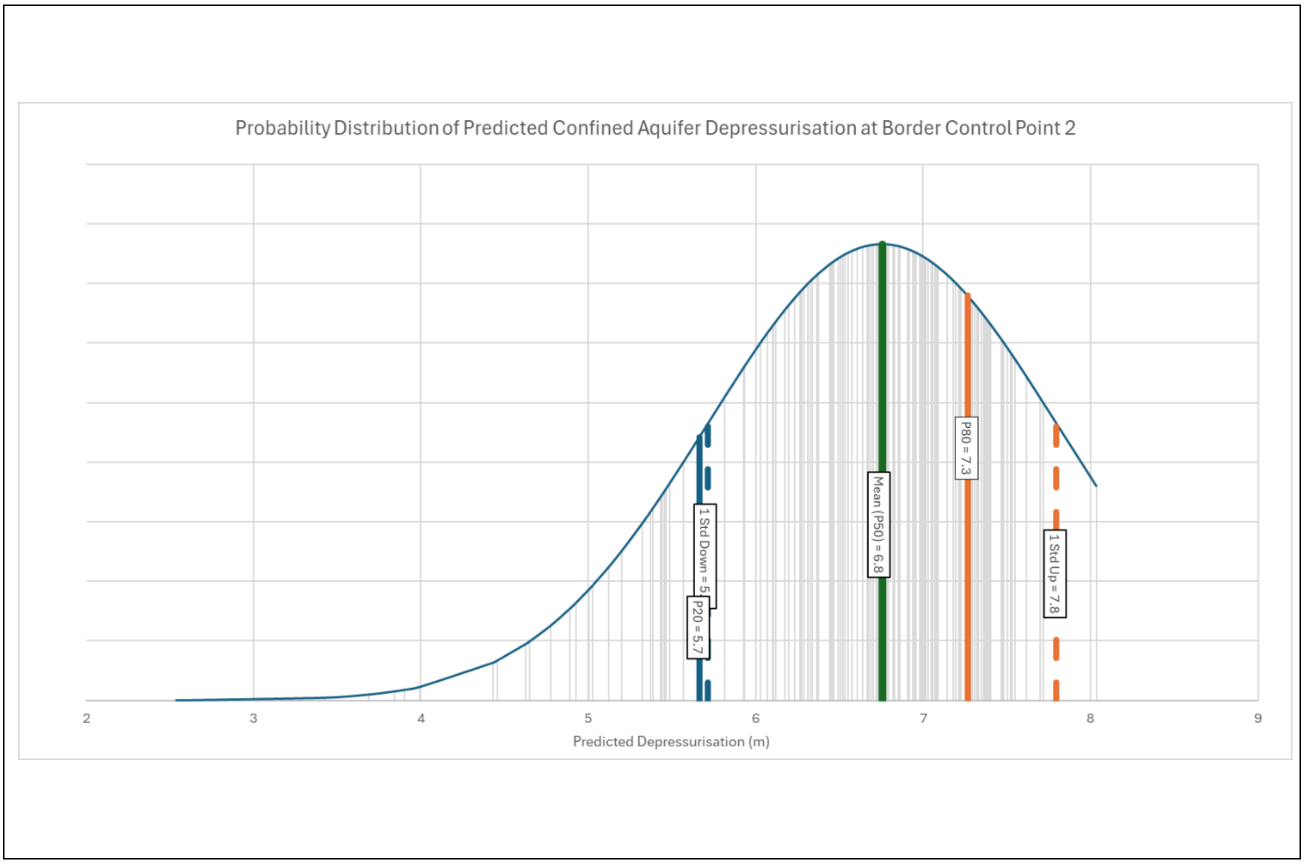


Probability Distribution of Predicted Confined Aquifer Depressurisation at Gaud-i-Zirreh 2 (End of Aquifer Recovery Period)

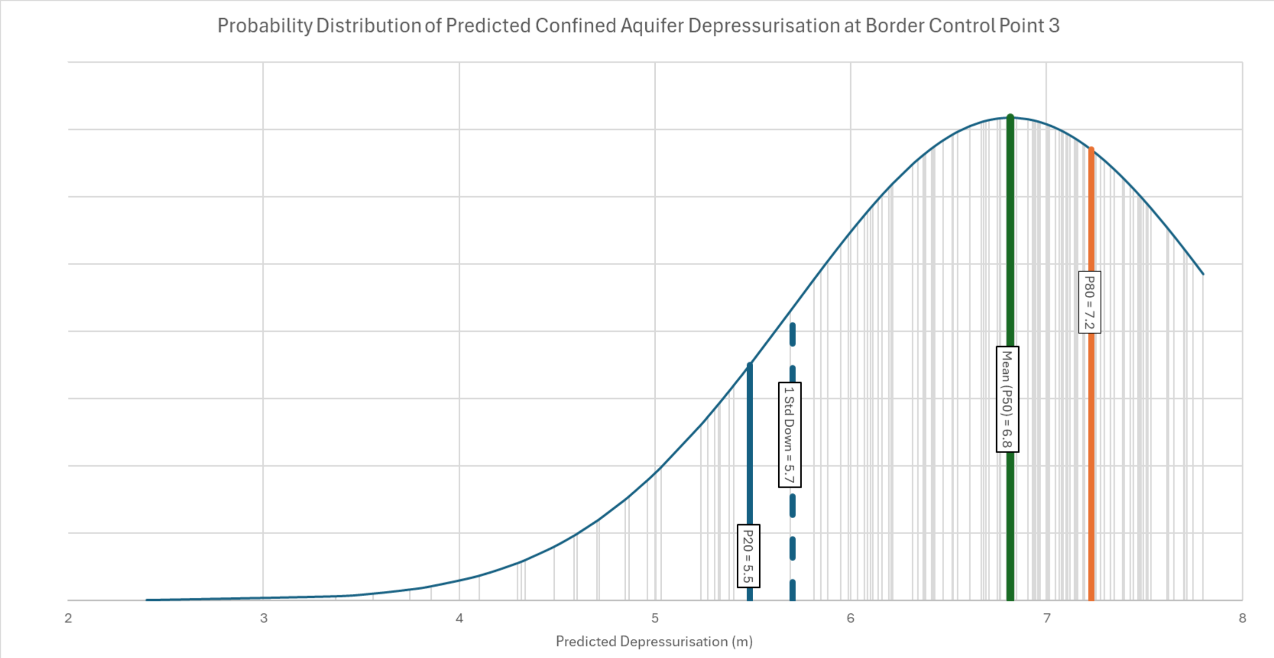
Appendix A28b



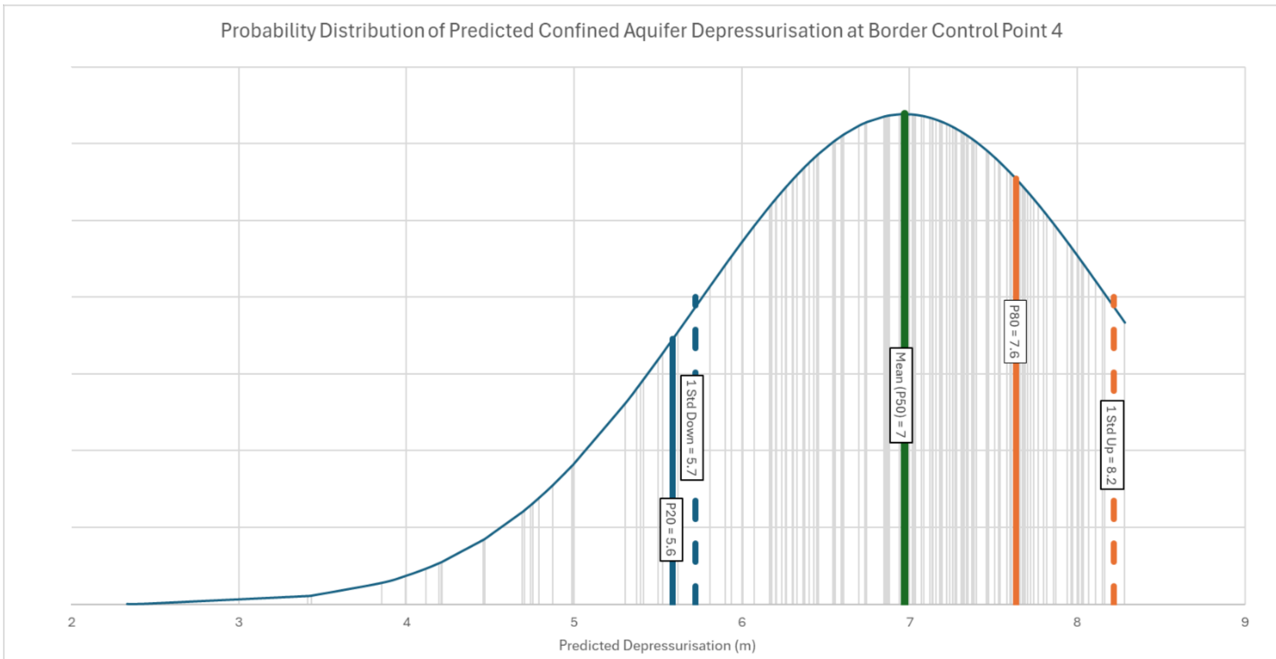
Probability Distribution of Predicted Confined Aquifer Depressurisation at Border Control Point 1 (End of Aquifer Recovery Period) **Appendix A29a**



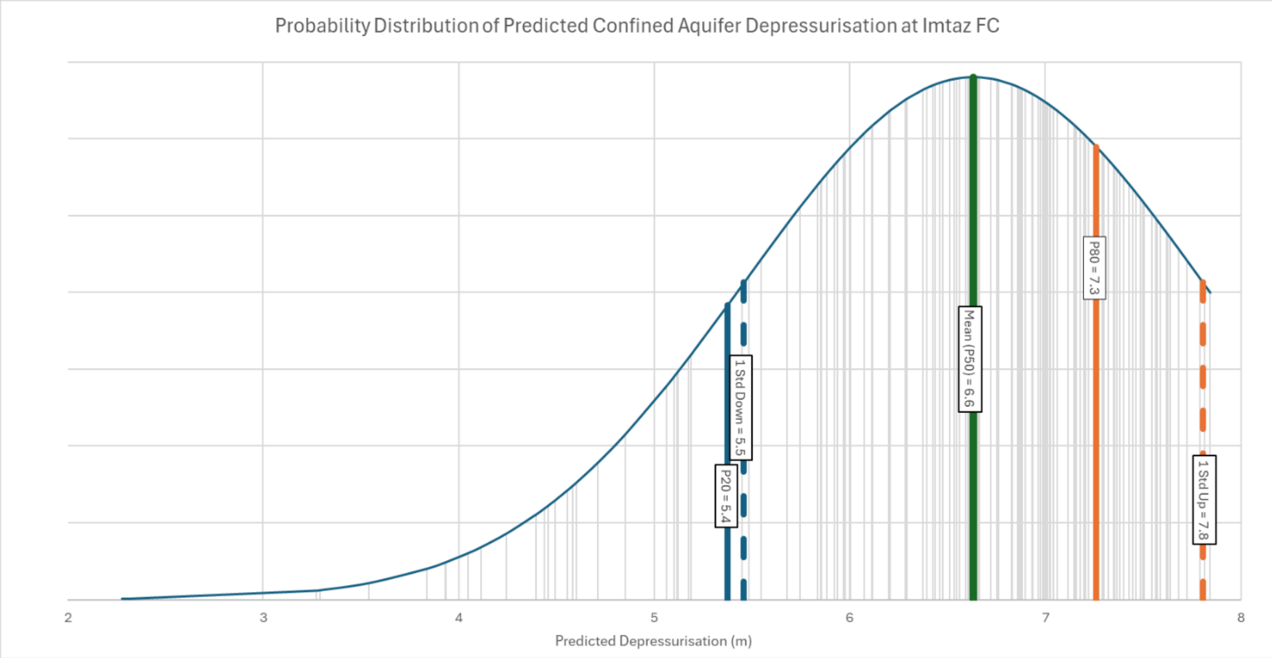
Probability Distribution of Predicted Confined Aquifer Depressurisation at Border Control Point 2 (End of Aquifer Recovery Period) **Appendix A29b**



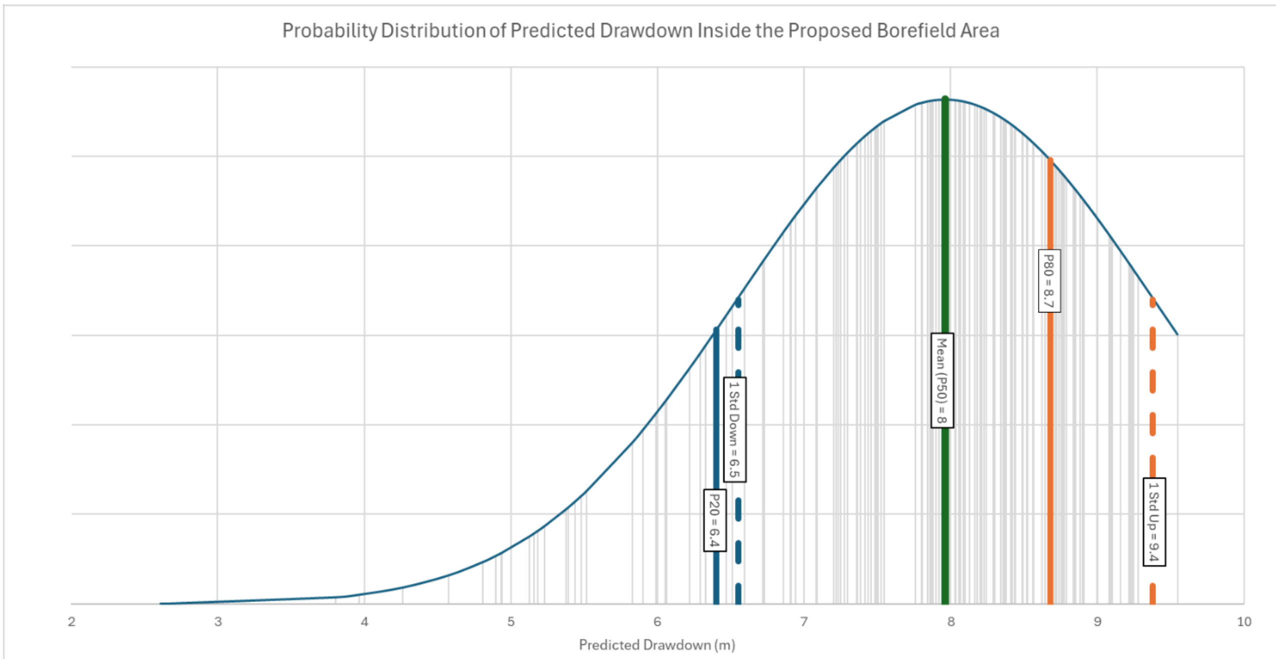
Probability Distribution of Predicted Confined Aquifer Depressurisation at Border Control Point 3 (End of Aquifer Recovery Period) **Appendix A30a**



Probability Distribution of Predicted Confined Aquifer Depressurisation at Border Control Point 4 (End of Aquifer Recovery Period) **Appendix A30b**

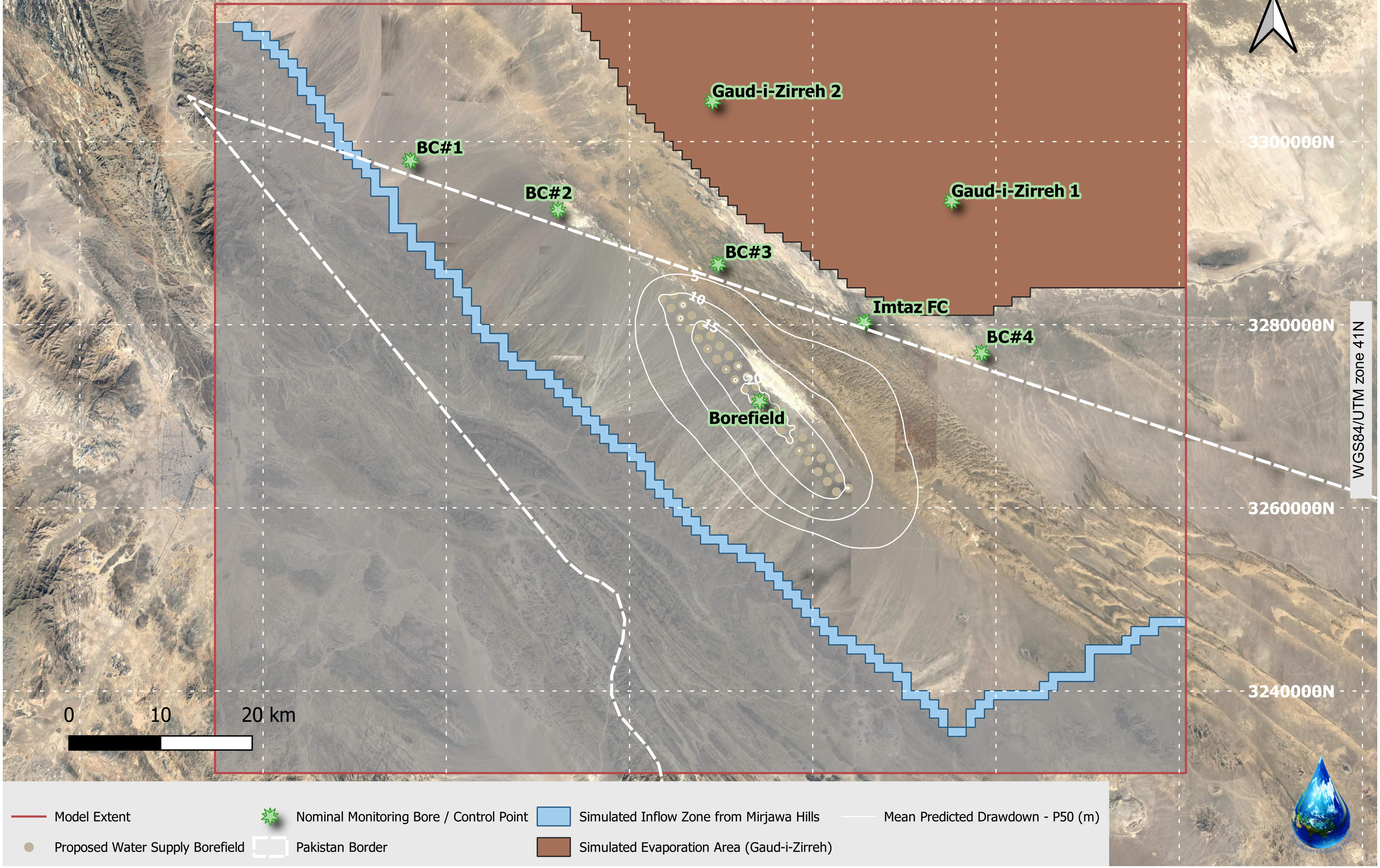


Probability Distribution of Predicted Confined Aquifer Depressurisation at Imtaz FC (End of Aquifer Recovery Period) **Appendix A31a**

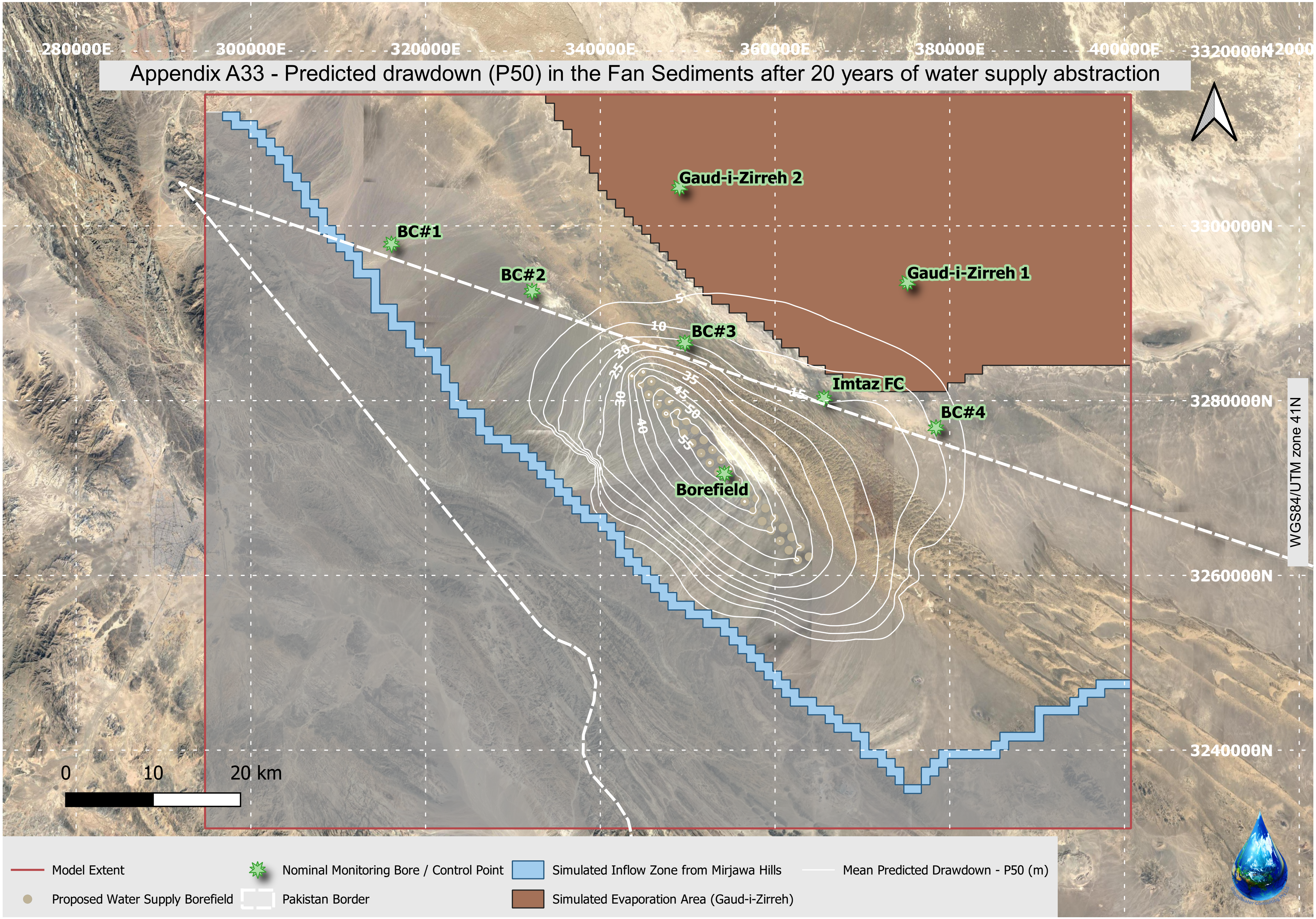


Probability Distribution of Predicted Drawdown Inside the Proposed Borefield Area (End of Aquifer Recovery Period) **Appendix A31b**

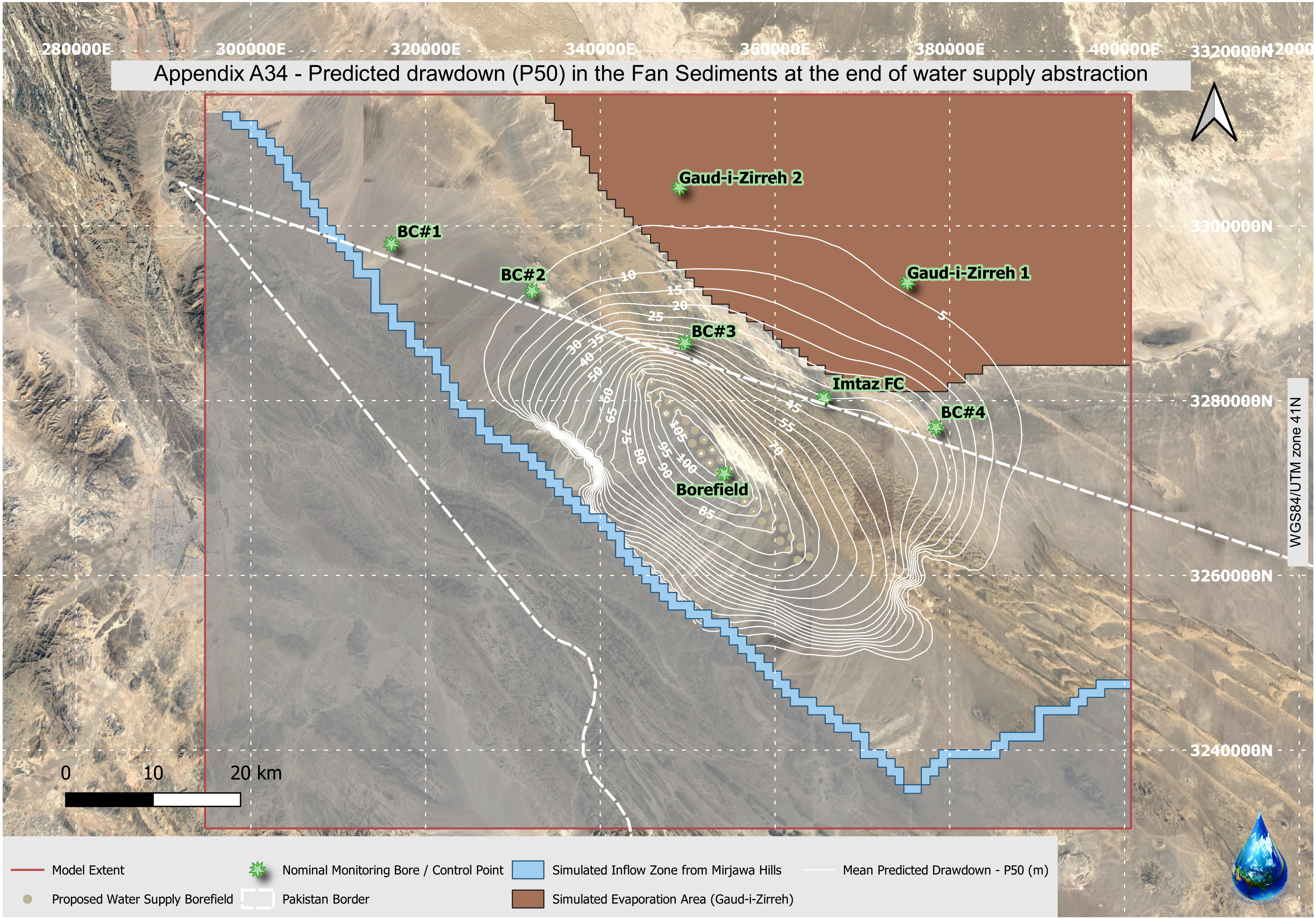
Appendix A32 - Predicted drawdown (P50) in the Fan Sediments after 10 years of water supply abstraction



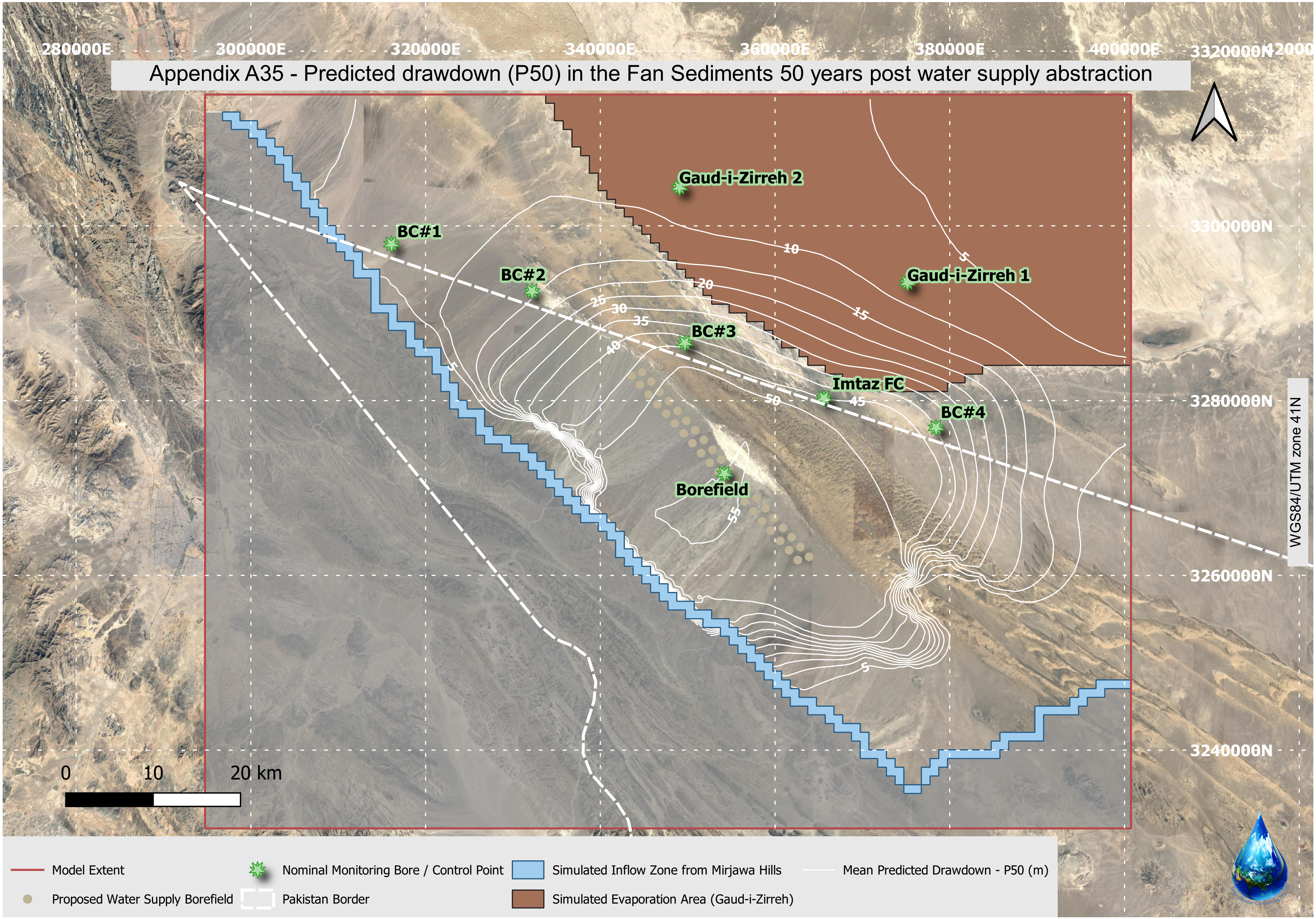
Appendix A33 - Predicted drawdown (P50) in the Fan Sediments after 20 years of water supply abstraction



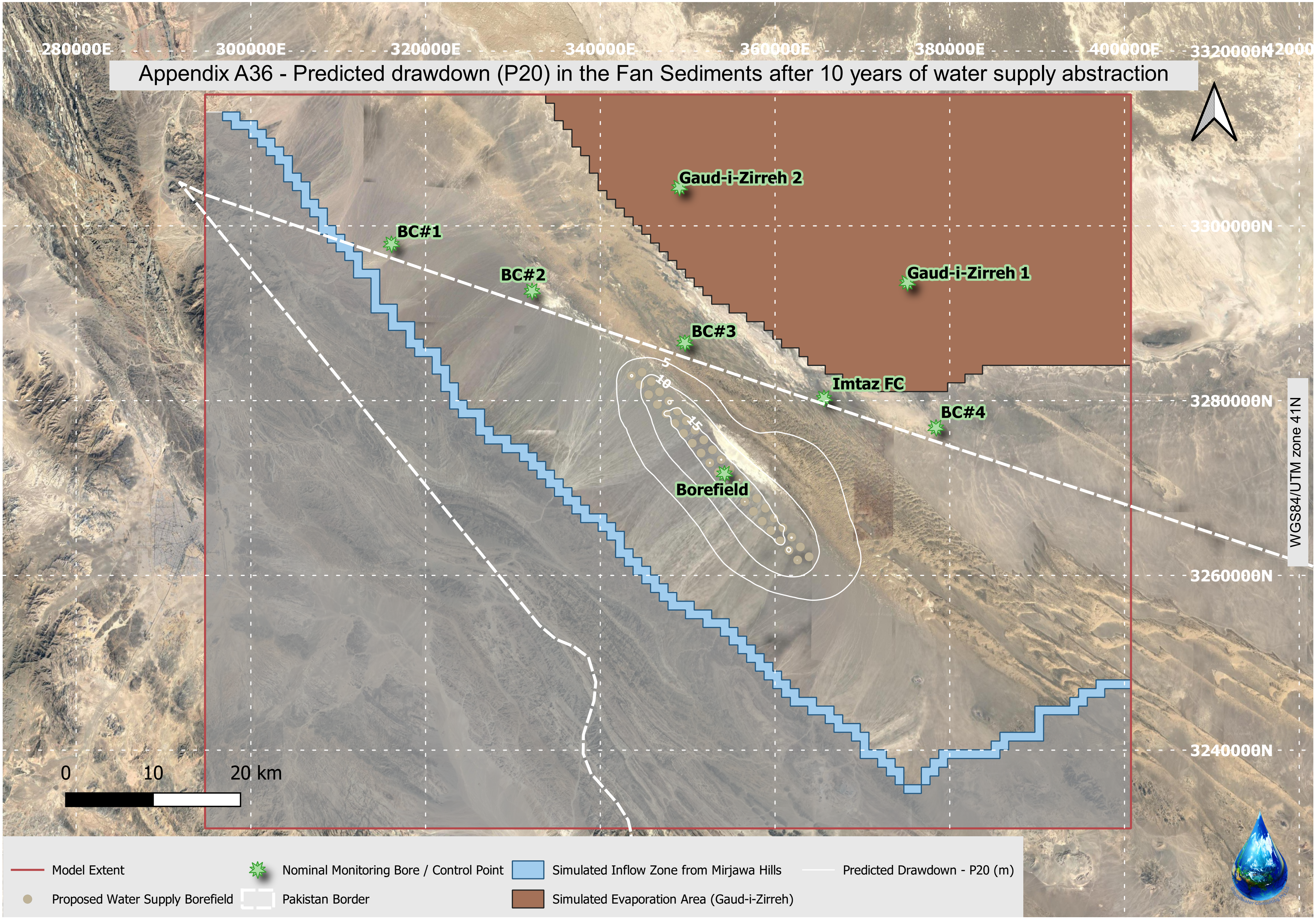
Appendix A34 - Predicted drawdown (P50) in the Fan Sediments at the end of water supply abstraction



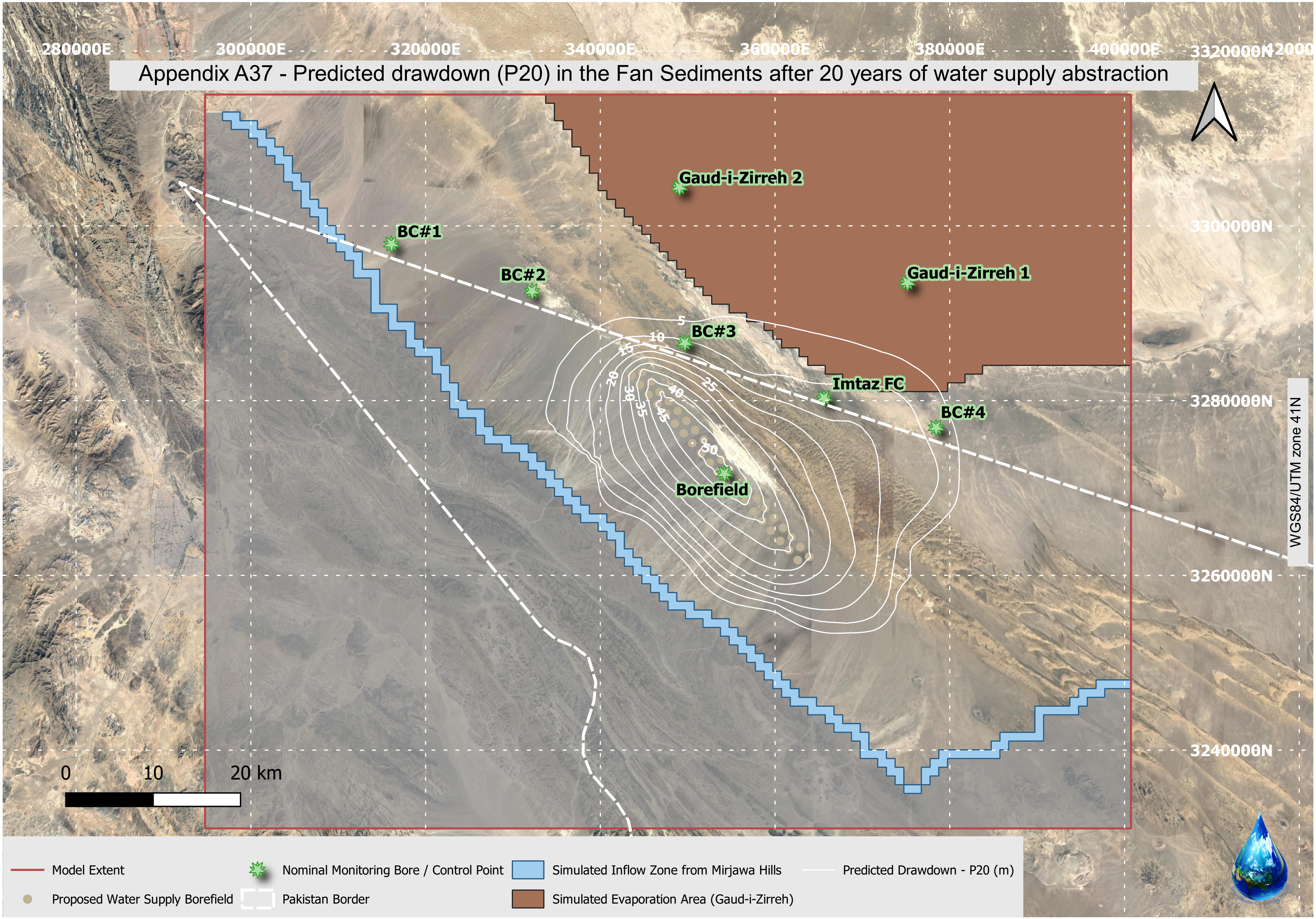
Appendix A35 - Predicted drawdown (P50) in the Fan Sediments 50 years post water supply abstraction



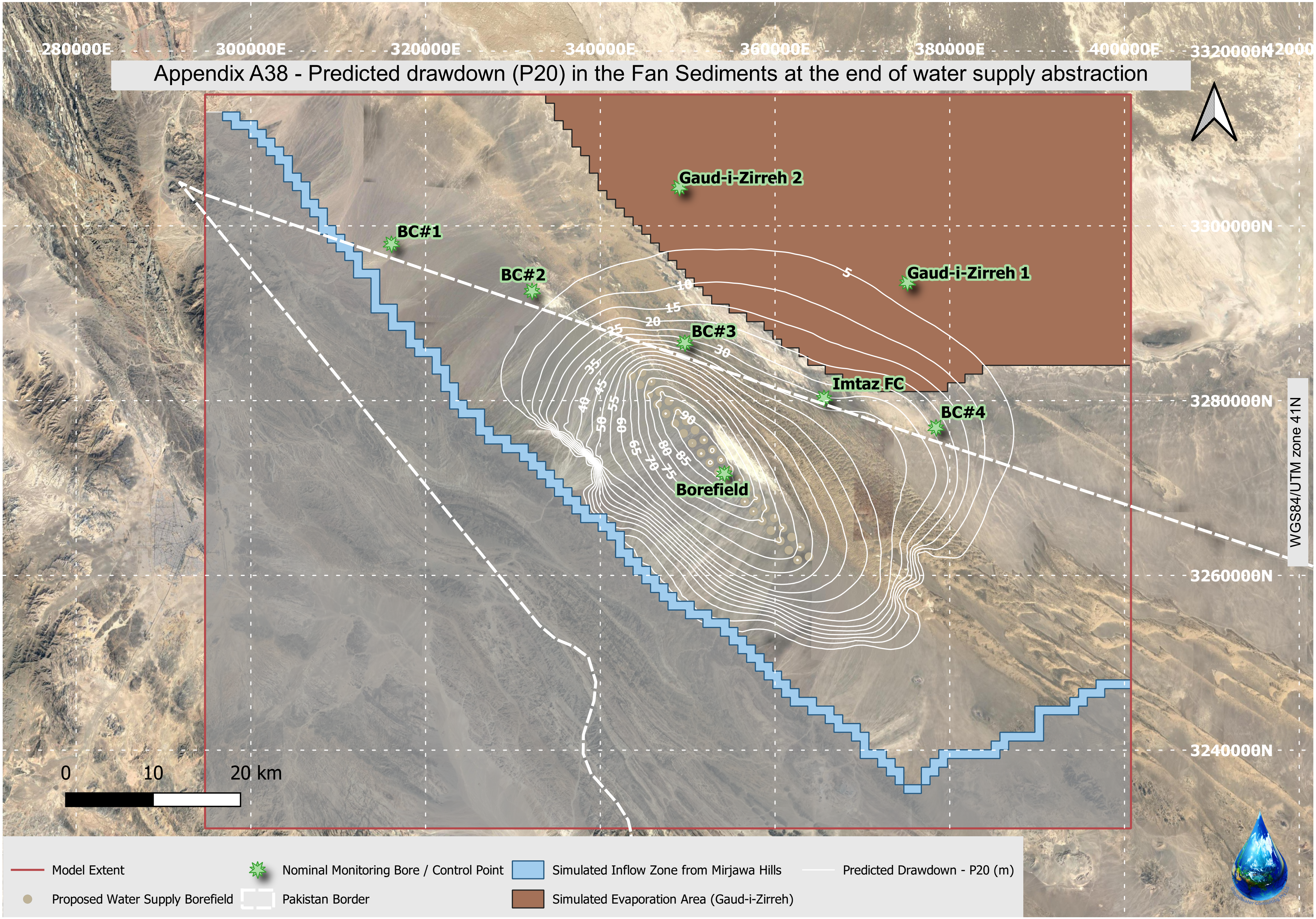
Appendix A36 - Predicted drawdown (P20) in the Fan Sediments after 10 years of water supply abstraction



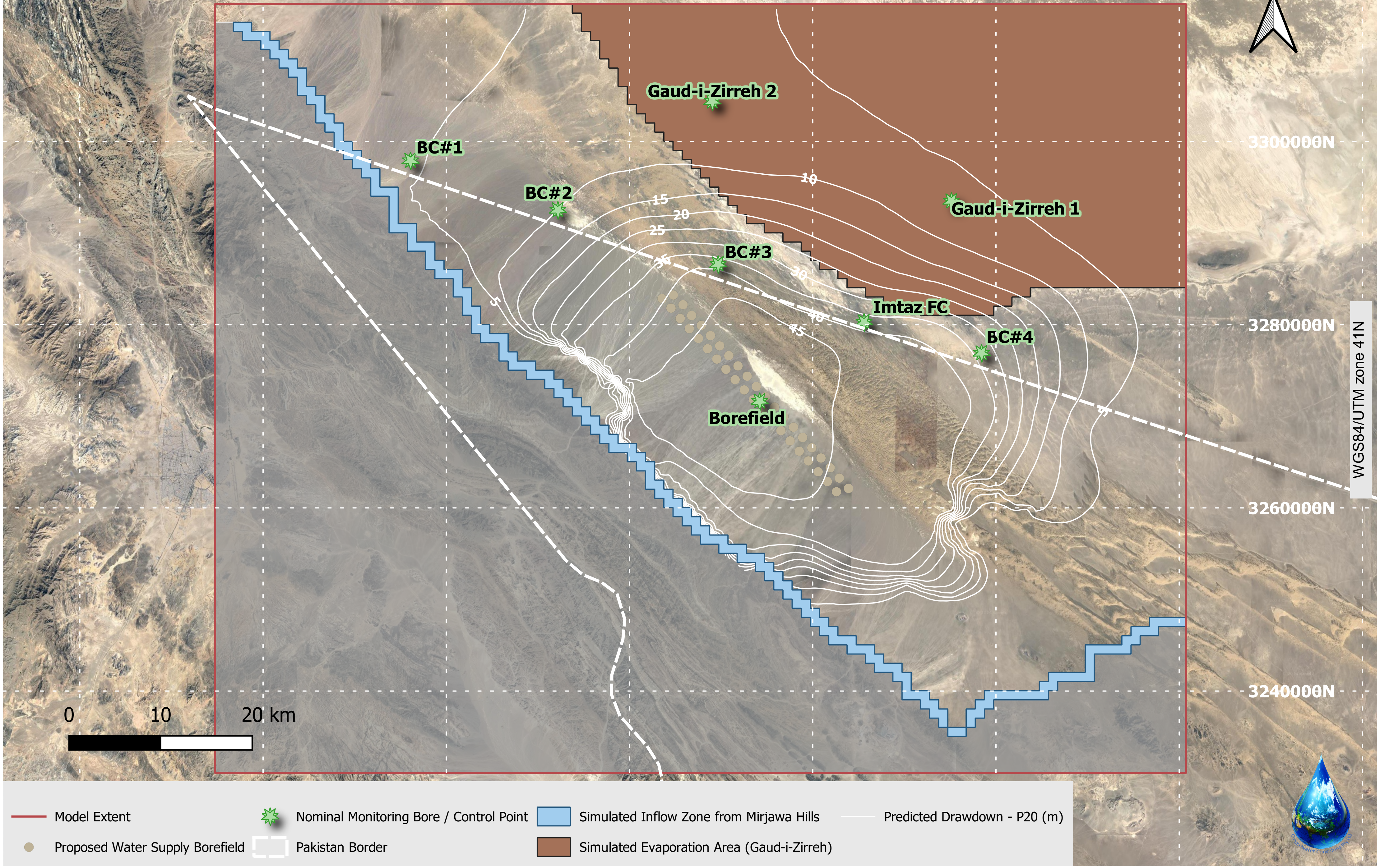
Appendix A37 - Predicted drawdown (P20) in the Fan Sediments after 20 years of water supply abstraction

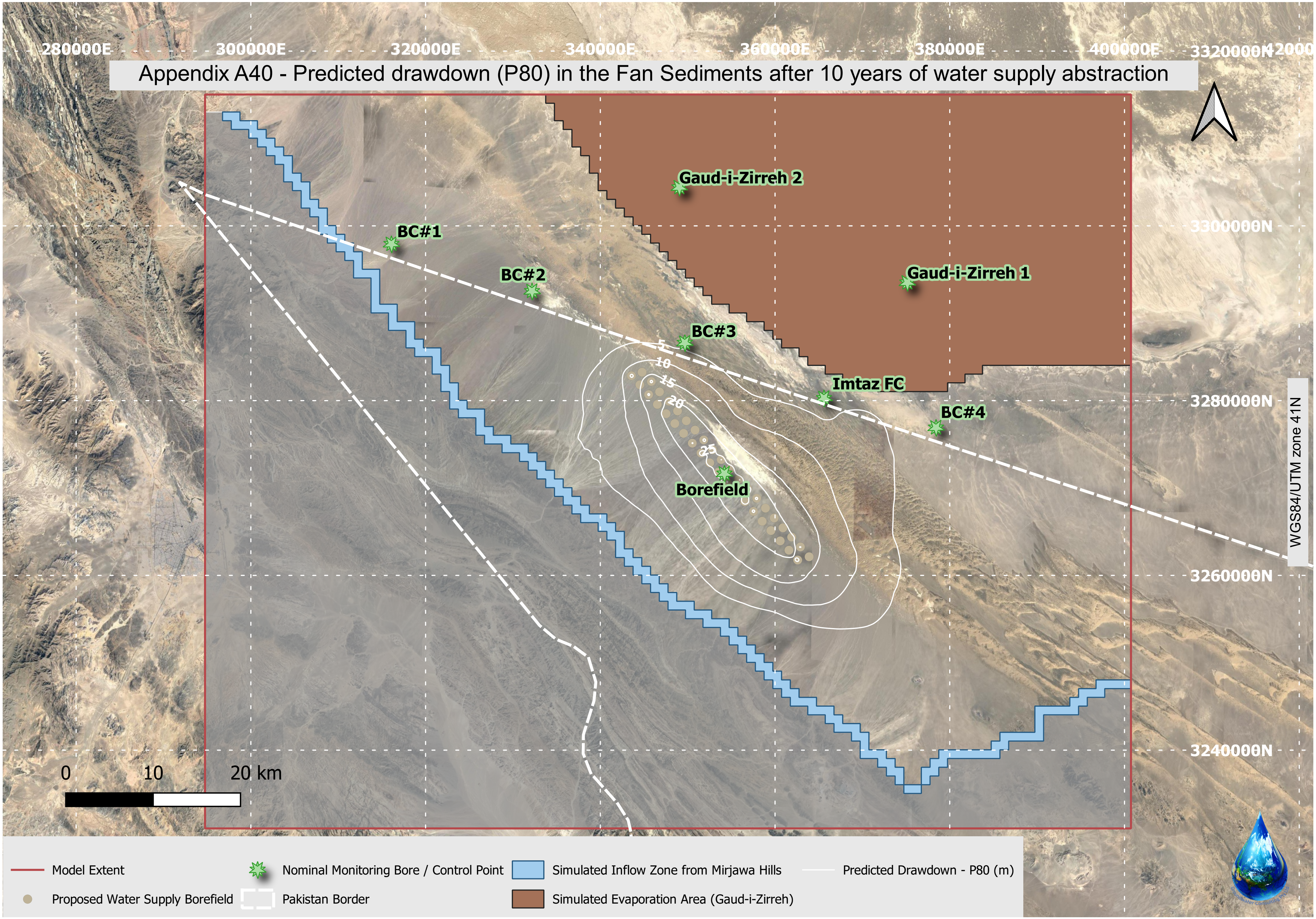


Appendix A38 - Predicted drawdown (P20) in the Fan Sediments at the end of water supply abstraction



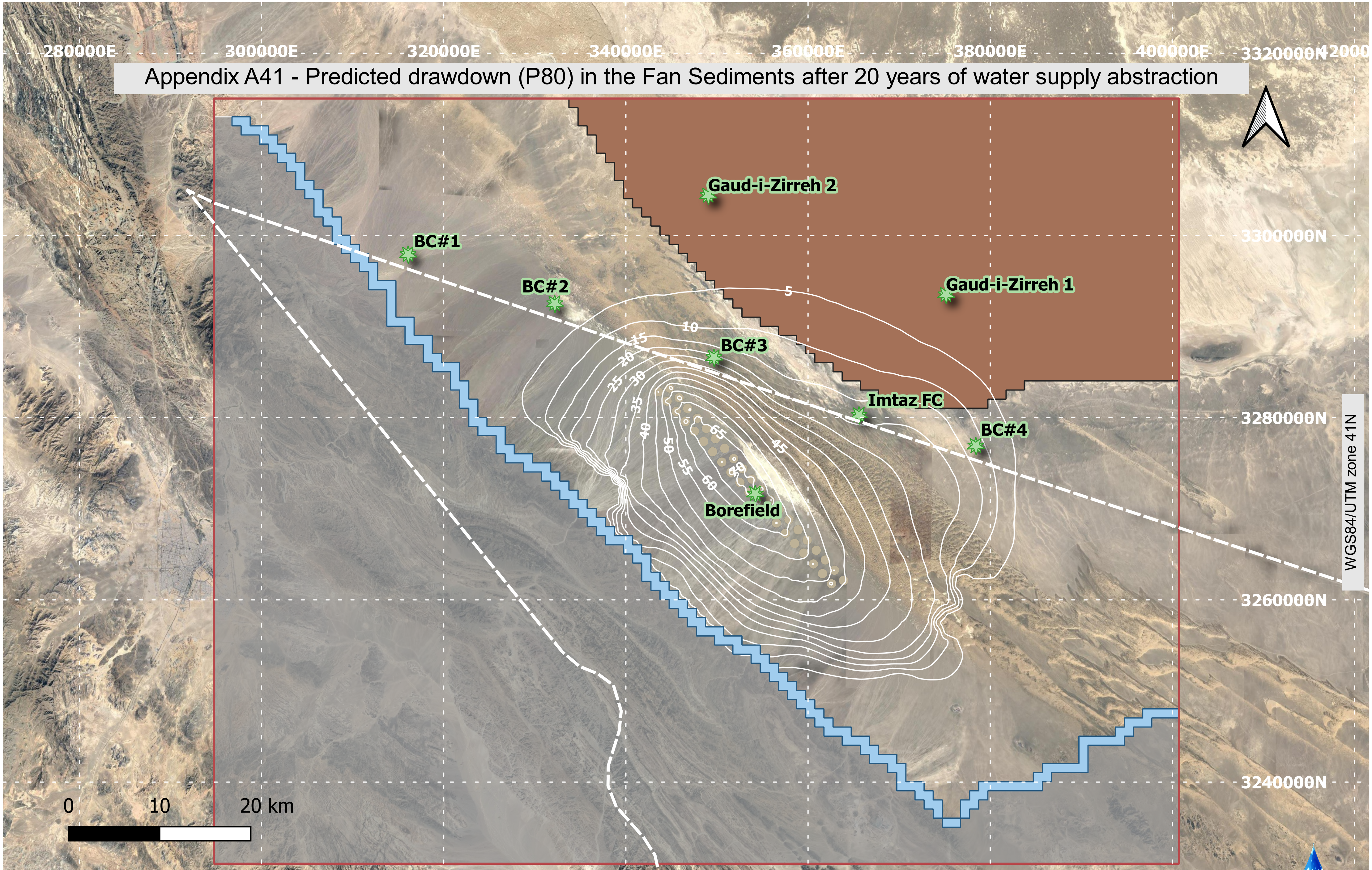
Appendix A39 - Predicted drawdown (P20) in the Fan Sediments 50 years post water supply abstraction





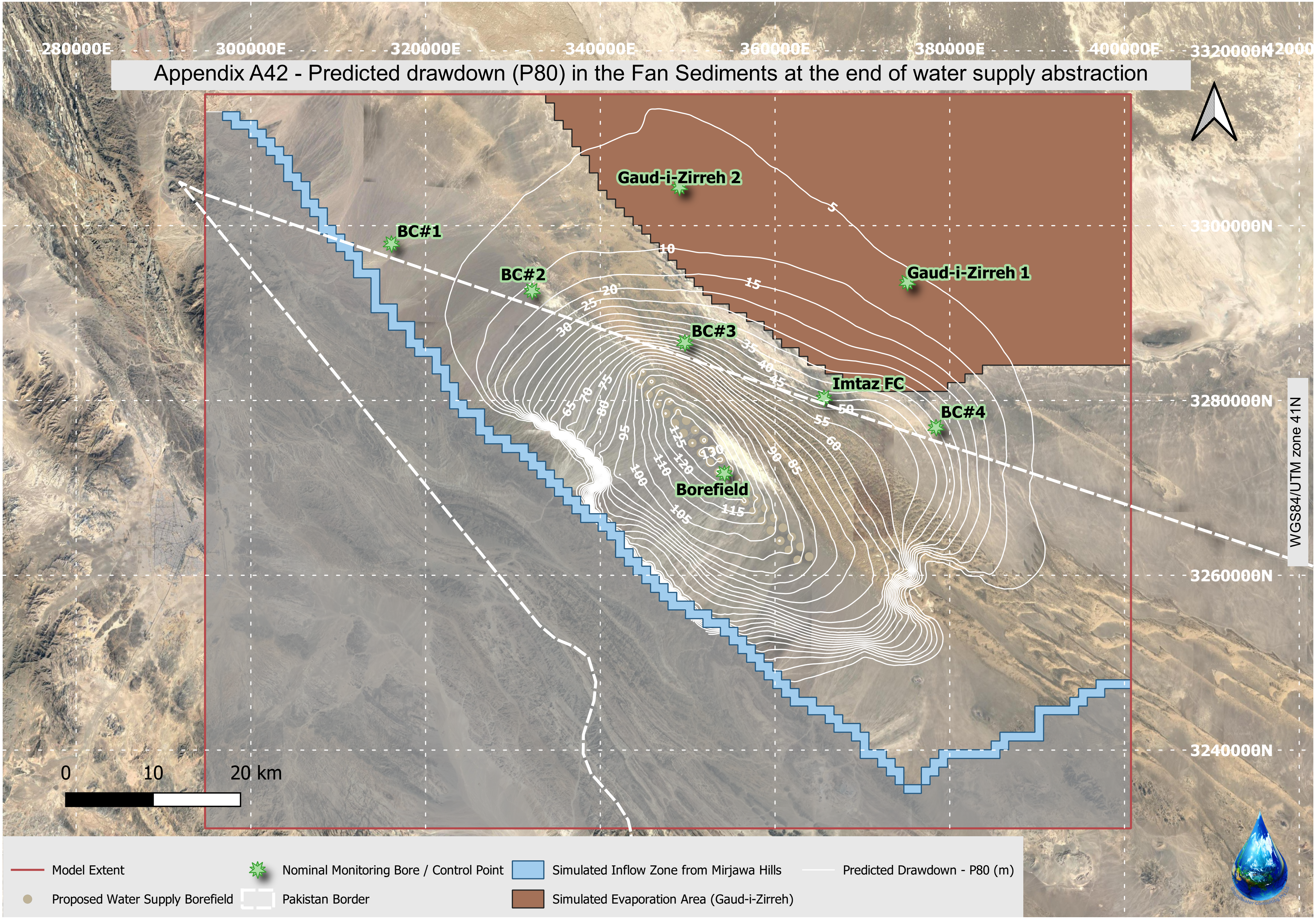
280000E
300000E
320000E
340000E
360000E
380000E
400000E
3320000N
3300000N
3280000N
3260000N
3240000N
Appendix A40 - Predicted drawdown (P80) in the Fan Sediments after 10 years of water supply abstraction
Gaud-i-Zirreh 2
Gaud-i-Zirreh 1
BC#1
BC#2
BC#3
BC#4
Imtaz FC
Borefield
5
10
15
20
25
WGS84/UTM zone 41N
0
10
20 km
Model Extent
Nominal Monitoring Bore / Control Point
Simulated Inflow Zone from Mirjawa Hills
Predicted Drawdown - P80 (m)
Proposed Water Supply Borefield
Pakistan Border
Simulated Evaporation Area (Gaud-i-Zirreh)

Appendix A41 - Predicted drawdown (P80) in the Fan Sediments after 20 years of water supply abstraction



Model Extent
Proposed Water Supply Borefield
Nominal Monitoring Bore / Control Point
Pakistan Border
Simulated Inflow Zone from Mirjawa Hills
Simulated Evaporation Area (Gaud-i-Zirreh)
Predicted Drawdown - P80 (m)

Appendix A42 - Predicted drawdown (P80) in the Fan Sediments at the end of water supply abstraction



Appendix A43 - Predicted drawdown (P80) in the Fan Sediments 50 years post water supply abstraction