

# Furthering the Conceptual Groundwater Model for Sarcheshmeh Copper Pit, Iran

Ismail Mahomed<sup>1</sup>, Colleen Kessopersadh<sup>1</sup>, Mahmood Shams Alipour<sup>2</sup>

<sup>1</sup>SRK Consulting, 265 Oxford Road, Johannesburg. IMahomed@srk.co.za

<sup>2</sup>National Iranian Copper Industries (NICICO), 1019 Valy-e-Asr. Avenue, Tehran, Iran

## Abstract

A conceptual hydrogeological model is an essential tool for the interpretation of available data and its linkages to understanding the relationships between components of the groundwater system, and other variables in a given problem. The climate, structural geology, dyke emplacement and hydrothermal alteration in the vicinity of the Sarcheshmeh Copper Porphyry play important roles in determining the hydrogeological conditions at the Sarcheshmeh open pit mine. Inflows into the pit and pore pressure distribution around the pit will be dictated by these and other factors. Understanding these factors will help the mine operator's deal with its groundwater issues and optimise water management plans.

**Keywords:** Conceptual Hydrogeological Model, Sarcheshmeh Mine, Hydraulic Properties

## Introduction

The Sarcheshmeh Copper Mine (SCM) is located in the central Zagros mountain range in Iran. The area is characterised by incised watercourses and sparse vegetation of grasses and shrubs. Precipitation occurs as both rainfall and snow and varies with altitude (Figure 1). Rainfall averages between 120 mm to 400 mm per annum with snowfall usually occurring between November and February, but rarely exceeding 50 mm per season.

Mining operations at SCM began circa 1973. The pit floor as at the end 2015 was at approximately 2,337 mamsl, [approximately

200m deep], with the final pit planned to reach 1,852 mamsl, and hence establish a 700 m deep pit. The western highwall, which was developed into the adjacent mountain, is at present over 500 m high and will be approximately 1,000 m high at the end of the life of mine in 2043. Mine waste rock dumps are located across catchment valleys, damming up some of the tributaries.

A detailed conceptual hydrogeological model was developed in order to inform the groundwater management strategies for the planned pit expansion.

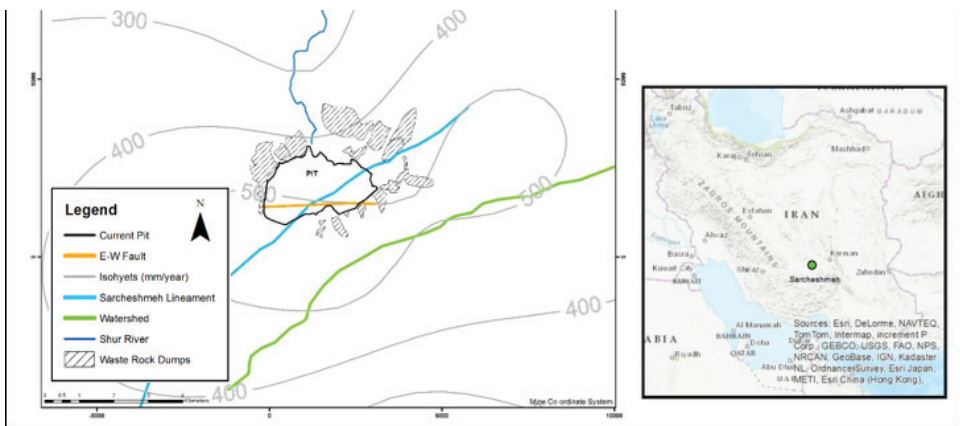


Figure 1: Locality and Isohyets Map



## Geology

The SCM is located near the centre of the Zagros mountain belt that is bordered to the south-west by a major thrust zone. The mountains are a complex of folded, faulted and metamorphosed rocks. The mine geology can be summarised as follows:

- The Sarcheshmeh Porphyry and the Late Fine Porphyry are the main intrusions which date from the late Tertiary; these units intruded the early Tertiary andesite host rocks (Figure 2);
- The andesite is flanked to the north by the granodiorite and the quartz-eye granite;
- Metamorphism generated by both porphyry intrusions can be divided into three main alteration zones at SCM; by decreasing intensity these alteration zones are as follows:
  - o High alteration: silicic zone and potassic zone, biotite zone, phillite-sericite-quartz or quartz-sericite zone ;
  - o Moderate alteration: quartz-sericite zone, porphyritic medium-strong and,
  - o Weak alteration: porphyritic weak.
- Three different vertical dyke generations intruded the Sarcheshmeh Porphyry with a general north-north-west to south-

south-east orientation. The thickness is variable but can reach up to 200 m. There are a number of dykes intersected by the open pit and they may represent at least a third of the volume of the pit;

- The strike-slip faults and dykes dip steeply, mostly between 60 and 80 degrees. The faults often have slickensides, are mineralised and altered (SRK, 2015).
- The fault geometry could in part be related to regional north-south directed transpressional right lateral orogeny. This has produced dominant north-west trending right lateral strike slip faults with conjugate north to north-north-east trending, left lateral shears (SRK, 2015).

## Hydrogeological units

Groundwater is associated with joints, fractures and faults within the various lithological units. Alteration and weathering has enhanced the hydraulic conductivity of some lithological units. The dykes typically impede flow and are believed to be the cause of the artesian conditions encountered in some of the coreholes drilled in the western portion of the pit. An east-west fault is also presumed

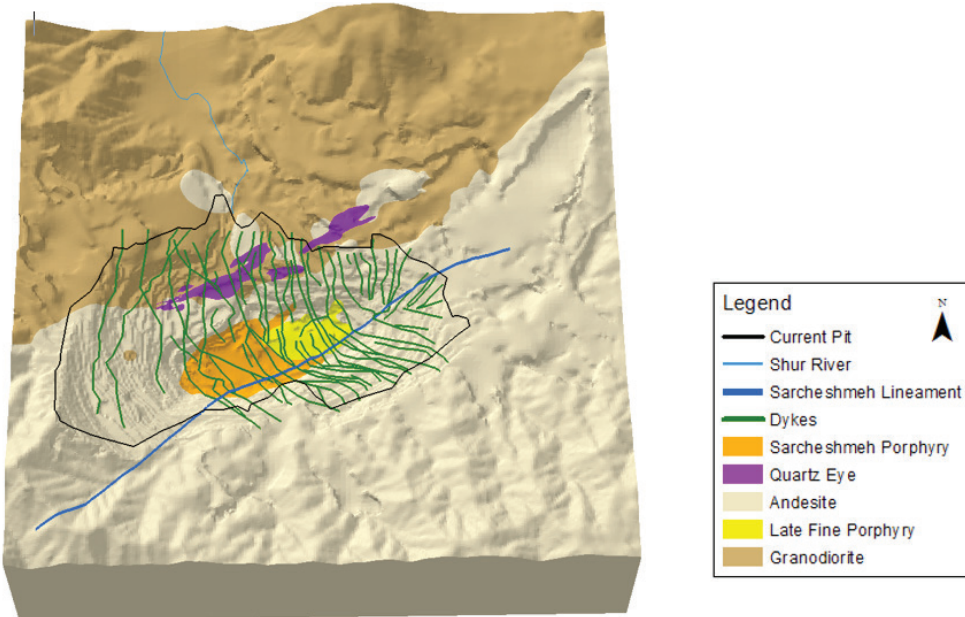


Figure 2: Geological Map



**Table 1: Summary of Hydraulic Test Results**

Rock type	Hydraulic Conductivity (K) in m/d			No. of tests
	Geometric mean	Minimum	Maximum	
Andesite	0.12	0.03	0.68	7
Granodiorite	0.11	0.02	1.04	16
Hornblende dyke	0.06	0.01	0.23	6
Quartz Eye	0.01	0.01	0.01	1
Sarcheshmeh Porphyry	1.65	1.60	1.70	2
Sarcheshmeh Lineament	3.64	1.07	12.35	2

to impede groundwater flow due to the steep water-level gradient measured across the fault. However the Sarcheshmeh Lineament which is orientated north-east to south-west was found to be a preferential groundwater conduit.

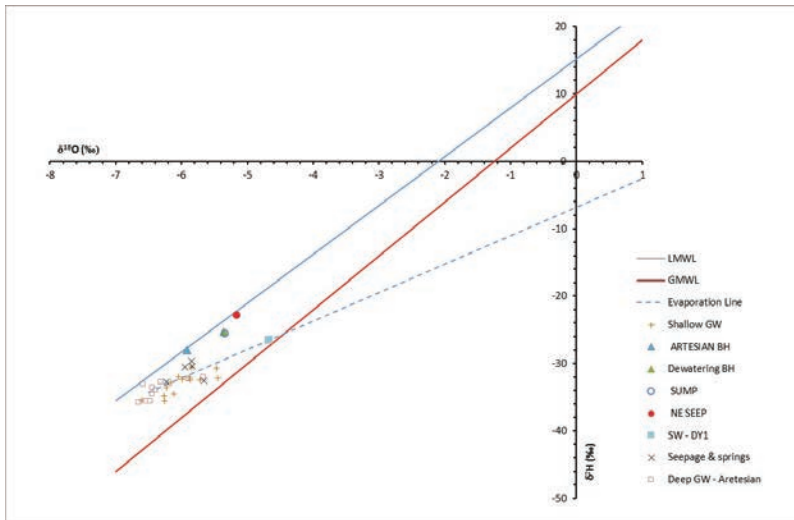
The granodiorite stock and possibly dyke intrusions into the andesite has caused some fracturing and weakening of the rock mass, potentially creating more permeable zones. The contact of the porphyry with country rock is not well understood, but field testing indicates that the porphyry itself is more permeable than the andesite and granodiorite.

The hydraulic conductivity, particularly of the granodiorite, is expected to decrease with depth and to be anisotropic; with preferential flow parallel to the dykes in a north-south direction rather than laterally across the dykes in the east-west direction.

The hydraulic conductivity values range over several orders of magnitude, from  $6 \times 10^{-3}$  m/d to 12 m/d (Table 1). The higher values (those greater than 1 m/d) are associated with the Sarcheshmeh Lineament and Porphyry. There is no distinct hydraulic conductivity amongst the various igneous and metamorphic lithologies; however, values on the upper end of the scale represent the fractures within the rock, whilst values on the lower end represent the weakly jointed, less-fractured rock mass.

## Environmental Isotopes

Isotope data indicates that the groundwater originates as precipitation (rainfall and snowmelt) with some evaporation occurring prior to recharge (Figure 3 [includes data from Parizi and Samani, 2014]). The presence of Tritium ( $^3\text{H}$ ) in the shallow groundwater



**Figure 3: Plot of  $\delta^2\text{H}$  (Deuterium) vs  $\delta^{18}\text{O}$  (Oxygen-18) (Parizi & Samani, 2014)**



samples suggests that shallower groundwater has a residence time of less than two decades whilst the deeper groundwater, although also of meteoric origin, has a longer residence time of two or more decades (Parizi and Samani, 2014).

**Recharge and discharge zones**

Recharge is expected to vary in accordance with precipitation; however five percent of mean annual precipitation (MAP) was used as a recharge rate in a previous groundwater model developed by HATCH (HATCH, 2003). The NICICO numerical groundwater model estimated the recharge rate to be 20% of MAP using a mass balance approach. Stable isotope data indicates that most of the groundwater recharge in the mine occurs at elevations between 2,730 and 2,970 mamsl (Parizi and Samani, 2014).

Outside the mine pit, groundwater discharges into various drainage lines where it daylights as springs and then flows along defined drainage lines. Many of the drainage lines do not flow throughout the year, and it is likely that the groundwater seeps into the alluvial material and is not evident as surface flow.

**Groundwater levels**

Water levels around SCM are relatively deep (>100 mbgl). The groundwater level conditions can be described as follows:

- The regional groundwater divide is located south of the Zagros Mountain range. Under natural conditions it would be expected that the groundwater divide would be located at the Zagros Mountain range and would be coincident with the surface watershed. It is possible that the divide has moved to the south due to the expanding zone of drawdown around the pit (Figure 4);
- There is a steep groundwater gradient to the south of the pit area and also along the south-western wall; this gradient appears to be structurally and lithologically controlled and does not appear to be only controlled by the mountainous terrain;
- Seepage faces of between 100 m and 200 m in height are present along the eastern and western highwalls respectively (Figure 4), and this is probably due to reduced pumping capacity; and
- The dykes, particularly on the western side of the pit, act as barriers to flow and cause the groundwater gradients to steepen.

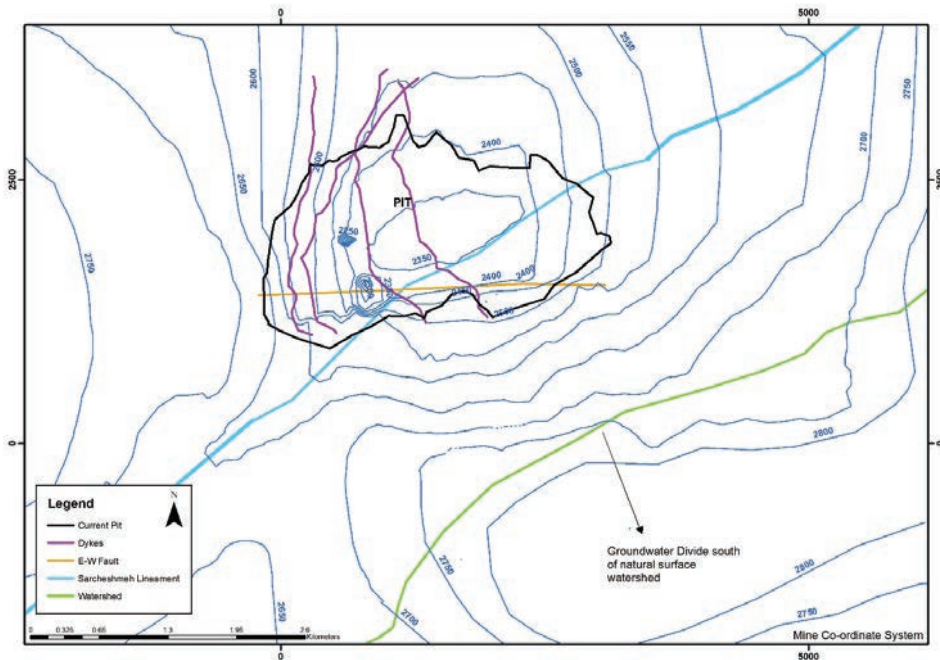


Figure 4: Piezometric Surface (2016 -2017)



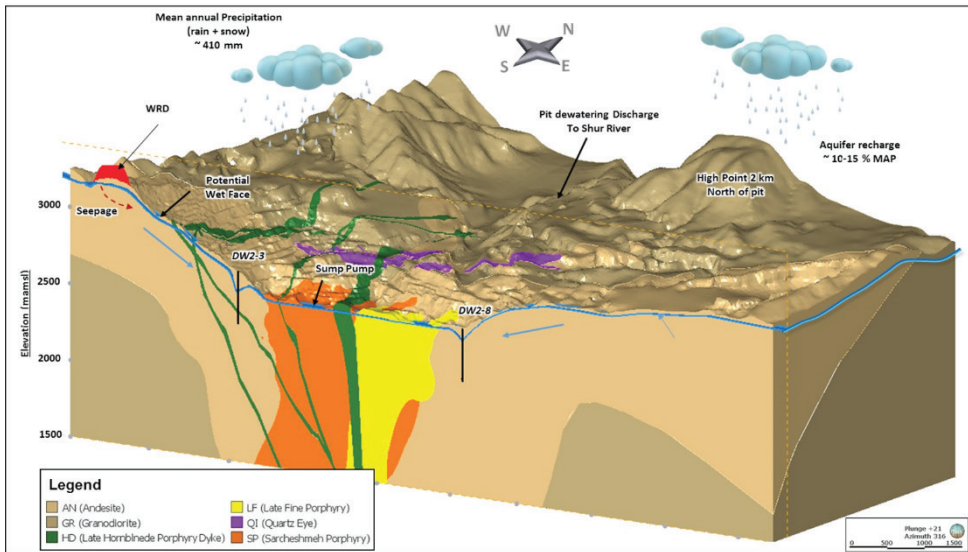


Figure 5 Conceptual groundwater model for the mine site

## Conceptual model

At SCM, the granodiorite porphyry stock intruded into an andesite country rock, leading to a hydrothermal alteration of the andesite. The granodiorite stock and possibly the network of dyke intrusions into the andesite has caused fracturing and weakening of the rock mass, potentially creating zones with a higher permeability. The structural geometry in the pit is dominated by steeply-dipping faults and a complex network of dykes. Groundwater is associated with joints, fractures and faults within the various lithological units. In particular, the Sarcheshmeh Lineament which is orientated north-east to south west is permeable and conveys groundwater into the pit. The dykes are typically barriers to groundwater flow, and this is particularly noticeable in the western part of the pit, where some coreholes are artesian on the floor of the pit. Similarly, some structural features such as the east-west fault system to the south of the pit appear to be barriers to flow. The Sarcheshmeh Porphyry itself is generally more permeable than the surrounding andesite host rocks. There is a sharp increase in rainfall from the plain to the mountain peaks, and recharge to groundwater increases with increasing elevation.

The conceptual groundwater model for the mine site is depicted in Figure 5 and

is a synthesis of current information. The groundwater controls are complex and have been simplified in the conceptual model. The key features of the conceptual groundwater model are:

- The Sarcheshmeh pit is located close to the surface watershed and is in the region of highest precipitation; hence it experiences higher recharge rates compared to surrounding areas.
- Groundwater recharge is from rainfall and snowmelt. Groundwater discharges directly into the Shur River, but in addition also to its tributaries, and to springs.
- The dykes, faults and Sarcheshmeh Lineament surrounding and within the pit control the flow of groundwater.
- The Sarcheshmeh Lineament will have to be actively dewatered in order to control inflows into the pit.
- The compartmentalisation of the groundwater indicates that dewatering infrastructure will need to be placed in an arrangement that ensures that zones in front of and behind the dykes are dewatered and depressurised.

## Conclusions

SCM is located in a complex geological region, with the complexity effecting the occurrence and flow of groundwater. Many other



mines in Iran are also located in complex geological settings. This case study emphasizes the need for a comprehensive conceptual model founded on good data, for effective mine water management. It also illustrates the need for multiple data sets from multiple disciplines.

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