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4.2 Climate

4.2.1 National climatic conditions

Due to the landlocked location of the RA and the extent of mountain ranges within its borders, the climate is generally dry and continental; however, significant regional variations do occur.

The Köppen-Geiger climate classification groups the RA climate as "*Dfb*", meaning that the country has a Warm Summer Continental climate. In this designation, the *D* represents the Continental/Microthermal climate group, which has an average temperature over 10^{o}C in the warmest months with a coldest month averaging below -3^{o}C. This climatic type usually occurs in the interiors of continents or on their east coasts, and north of 40^{o}N in latitude. The *f* indicates that there is significant rainfall throughout all seasons and the *b* indicates that the warmest month averages below 22^{o}C; however at least four months average above 10^{o}C.

Regional climate variation across the RA is pronounced, with lower altitudes having longer and hotter summers, averaging around 25^{o}C, with winter temperatures in the foothills dropping to around -5^{o}C rather than the -12^{o}C which can be recorded in the mountains.

Annual rainfall variations occur across the RA and are influenced by topography. The Lesser Caucasus Mountains prevent humid air masses from reaching the inner areas of the country. Elevations between 1400 m and 2000 m above sea level (asl) tend to receive around 800 mm of rainfall per year, with the inland plains only receiving 200 mm to 400 mm.

4.2.2 State Meteorological Stations

Historical climate data have been obtained by Geoteam from the two State meteorological stations nearest to the Project – one located on the Vorotan Pass and another located in Jermuk. Distances of these two meteorological stations from the main components of the mine are identified within Table 4.2.1. The location of these meteorological stations in relation to the Project is shown on Figure 4.2.3.

Table 4.2.1: Geographical data for the Vorotan Pass and Jermuk meteorological stations			
Mine Component	**Approximate Elevation of mine component (m asl)**	**Vorotan Pass**	**Jermuk**
Artavazdes Open Pit	2,975 m	3.7 km	11.9 km
Tigranes –Open Pit	2,925 m	4.4 km	11.1 km
Erato Open Pit	2,900 m	5.6 km	9.8 km
BRSF	2,625 m	7.5 km	6.5 km
HLF	1,800 m	9.2 km	10.0 km
Elevation of met station (m asl)		2392 m	2066 m

As Table 4.2.1 details, the Vorotan Pass station is located at an elevation of 2,392 m asl, which is between the heights of the main Project components and is more representative than the station at Jermuk, which is at a lower elevation. The Vorotan Pass station lies on the northern edge of the Vorotan Pass, within the Zangezur mountain range. The station itself has a south-facing aspect, situated on the exposed footslopes of Mount Amulsar (Figure 4.2.1). This station provides a period of 51 years of continuous data for the majority of measurements (gaps are encountered for the snow dataset) from a proximal location to the Project. The dataset can be considered to provide representative climatic data, albeit lacking the more extreme weather patterns that will be experienced at the higher altitude of Mount Amulsar.

The Vorotan Pass climate data has been analysed for the continuous period from January 1962 to April 2013, at the onset of the Project design. Since the meteorological station remains operational and annual analysis can be maintained during the Project, the baseline climatic dataset can be compared to future weather data from the same meteorological station.

Figure 4.2.1: Vorotan Pass meteorological station, looking south onto the southern Zangezur mountains

The state meteorological station located at Jermuk is situated at an elevation of 2,066 m asl, a much lower elevation than many of the main components of the Project (Table 4.2.1). The station lies on the northern edge of the Jermuk airstrip, which is unexposed flat land, between mountainous areas to the east and west of Jermuk and the airstrip (Figure 4.2.2). Its location is therefore less representative of the more exposed conditions experienced by the Project. Analysis of this data displays trends which are similar to those obtained from the Vorotan Pass dataset. This analysed data is presented in Appendix 4.2.1; however, it is not considered to be ‘climate data’.

Figure 4.2.2: Jermuk meteorological station on the northern edge of the airstrip

Vorotan Pass Weather Station

Monthly averages for precipitation and temperature were combined to produce Figure 4.2.4, showing an average of the annual temperature and precipitation rates over the period 1962-2013. Peak rainfall is recorded in May, with an average of 94mm, with September having the lowest rainfall levels at an average of 27mm. Maximum temperatures are in August, with an average of 17°C, while minimum temperatures in January average -14°C. These temperature trends correspond with the monthly averages for evaporation.

Wind data from the Vorotan Pass weather station is available for the period 1966-2013 and Table 4.2.2 illustrates the summary of these results and provides an indication of the mean wind direction.

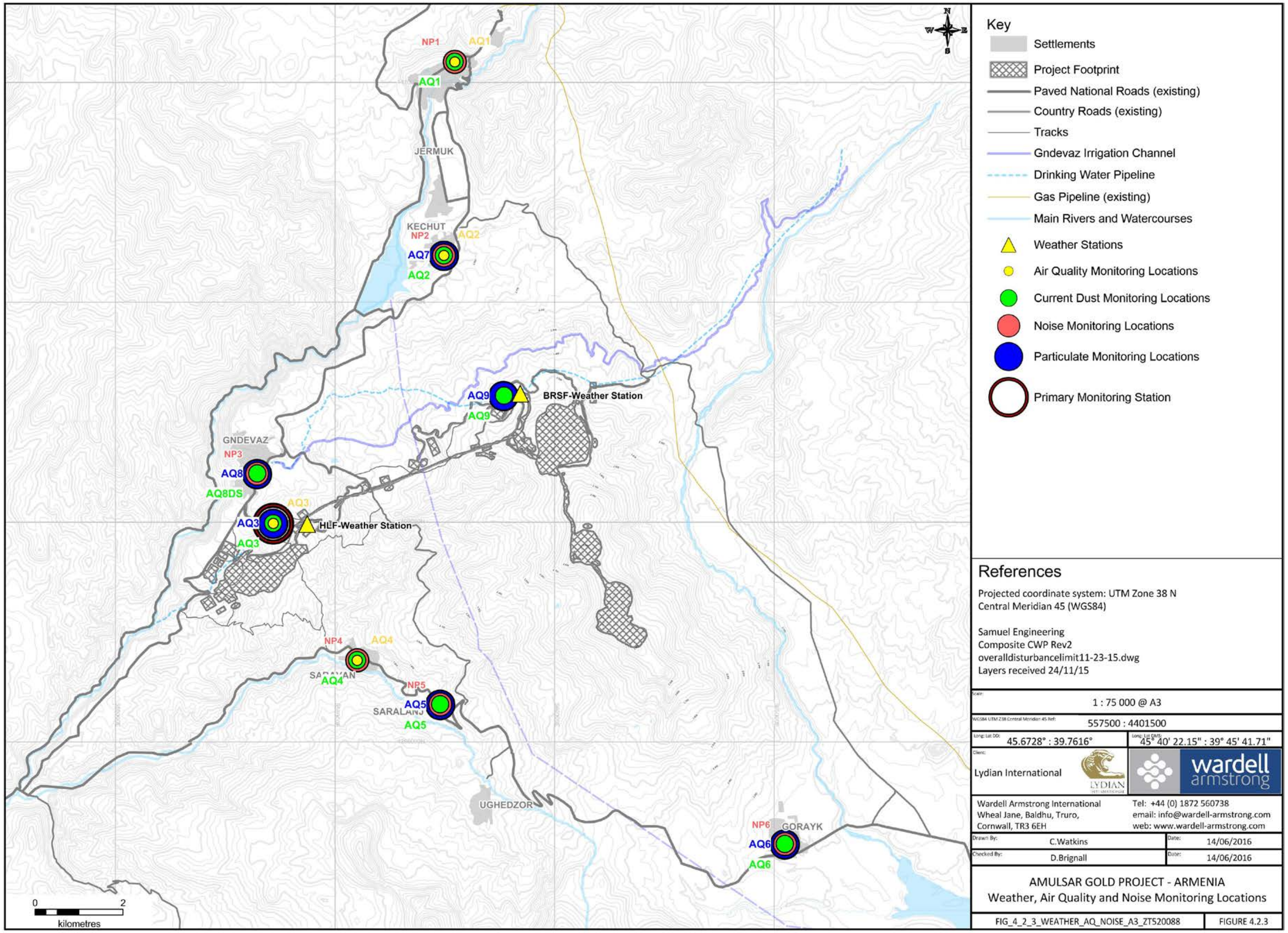

Figure 4.2.3: Weather Station and Air Quality Monitoring Locations

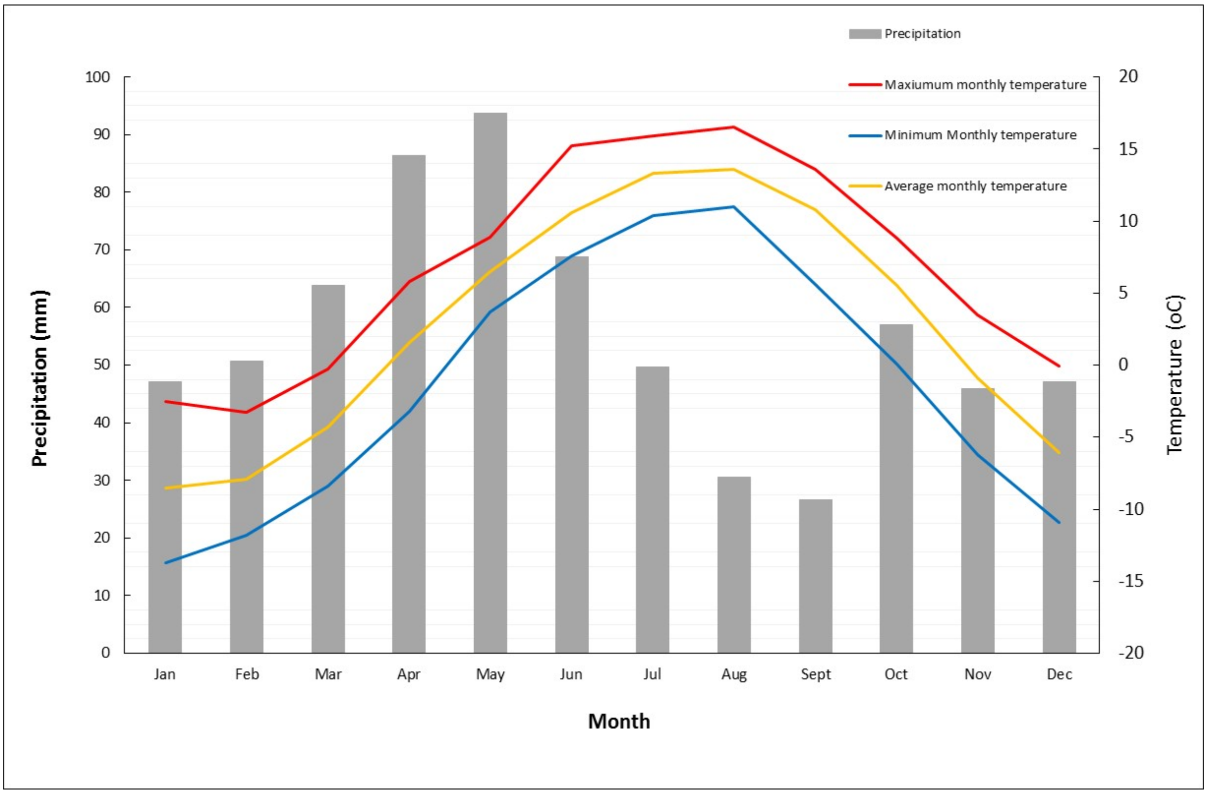

Figure 4.2.4: Summary of Average Precipitation and Temperature Data from the State Weather Station at Vorotan Pass

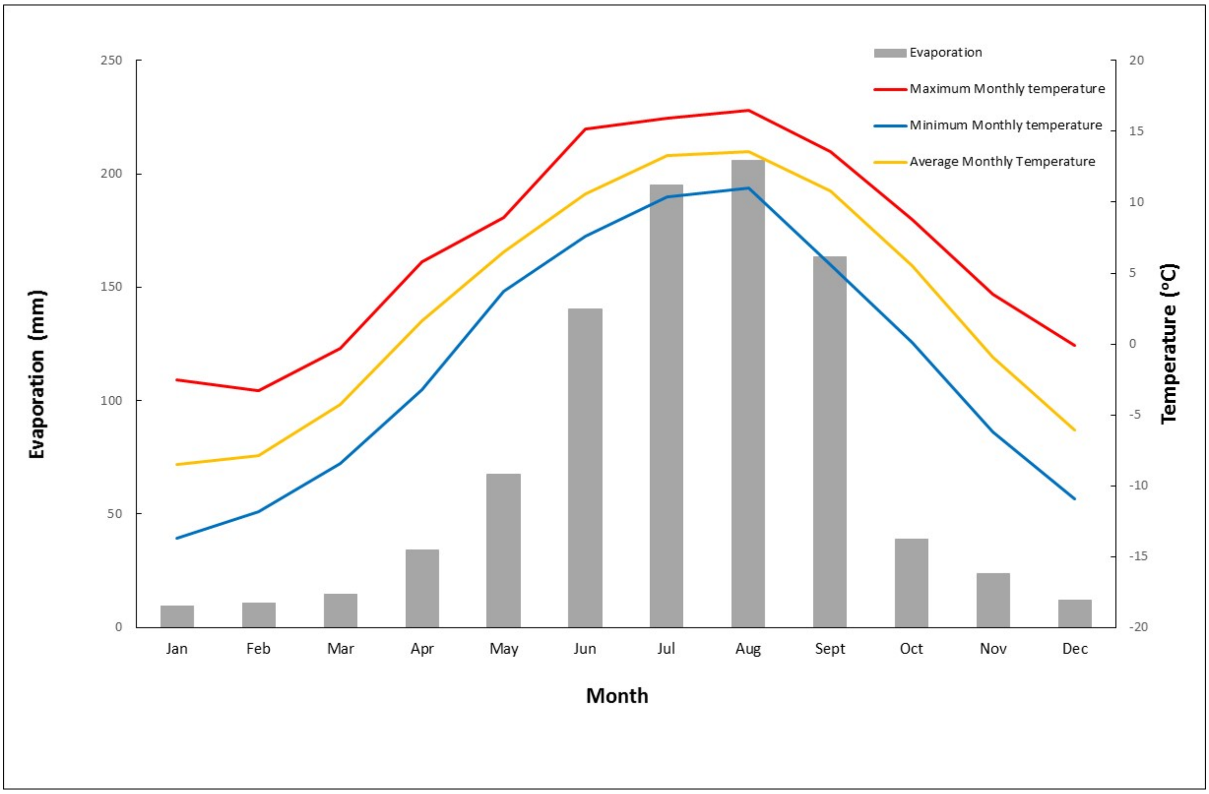

Figure 4.2.5: Summary of Average Evaporation and Temperature Data from the State Weather Station at Vorotan Pass

Table 4.2.2: Monthly Dry Wind Summary 1966-2013												
Mean Wind Direction, shown as a percentage of time												
Month	**346° to 15**	**16° to 45**	**46° to 75**	**76° to 105**	**106° to 135**	**136° to 165**	**166° to 195**	**196° to 225**	**226° to 255**	**256° to 285**	**286° to 315**	**316° to 345**
Jan	13.6	0.6	1.8	16.6*	3.0	2.0	1.8	1.2	2.2	17.5*	21.2*	18.6*
Feb	14.2	0.6	2.1	20.3*	4.2	1.8	2.2	1.0	1.9	16.0*	19.7*	15.9*
Mar	15.7	0.6	2.7	21.4	6.1	2.4	2.6	1.5	3.2	16.8	14.1	13.1
Apr	14.1	1.2	4.0	24.2	6.3	3.3	5.2	2.1	4.3	16.6	9.9	8.9
May	11.8	0.5	3.8	34.0	7.3	3.5	3.6	1.6	2.7	13.3	9.3	8.5
Jun	7.6	0.2	3.8	51.6	9.8	2.8	3.0	1.0	2.0	8.2	5.9	4.0
Jul	2.5	0.2	4.5	67.0	14.3	2.6	1.9	0.7	0.8	3.4	1.5	0.8
Aug	2.5	0.3	4.1	65.0	15.3	2.2	2.1	0.6	1.0	4.1	2.0	0.8
Sep	7.8	0.5	4.0	49.7	9.4	1.8	2.8	1.3	2.3	11.4	5.7	3.2
Oct	17.6	0.5	2.6	29.5	7.0	1.5	2.7	0.9	2.2	14.0	12.3	9.3
Nov	17.8	0.5	1.6	19.9	4.0	1.4	2.7	0.9	2.0	17.8	18.9	12.6
Dec	15.4	0.5	1.9	17.6*	3.7	2.4	2.5	1.4	1.8	19.6*	17.3*	16.0*
Notes: * Indicates the values used in the assessment of the winter seasonal wind speed pattern												

The data has also been analysed for the annual average wind direction and speed (see Figure 4.2.6), which shows the prevailing wind direction from the east (highlighted in orange in Table 4.2.2), with the majority of wind speeds <11.0 m/s. The data also shows that the easterly prevailing wind has a greater proportion of high wind speeds.

The lowest percentage of winds are from a north-north-easterly direction (highlighted blue in Table 4.2.2). This also has the lowest wind speeds with the majority <6.0 m/s. Mean wind speed in all directions is 4.7 m/s.

The data also identifies seasonal wind patterns in the winter months (December through to February), where there is an equal or greater proportion of time in which the wind blows from the east as it does from a westerly/west-north-west to north west direction (indicated by * in Table 4.2.2). This is likely due to the winter westerly winds associated with the North Atlantic Oscillation, which are directed into Eurasia by the Arctic Oscillation.

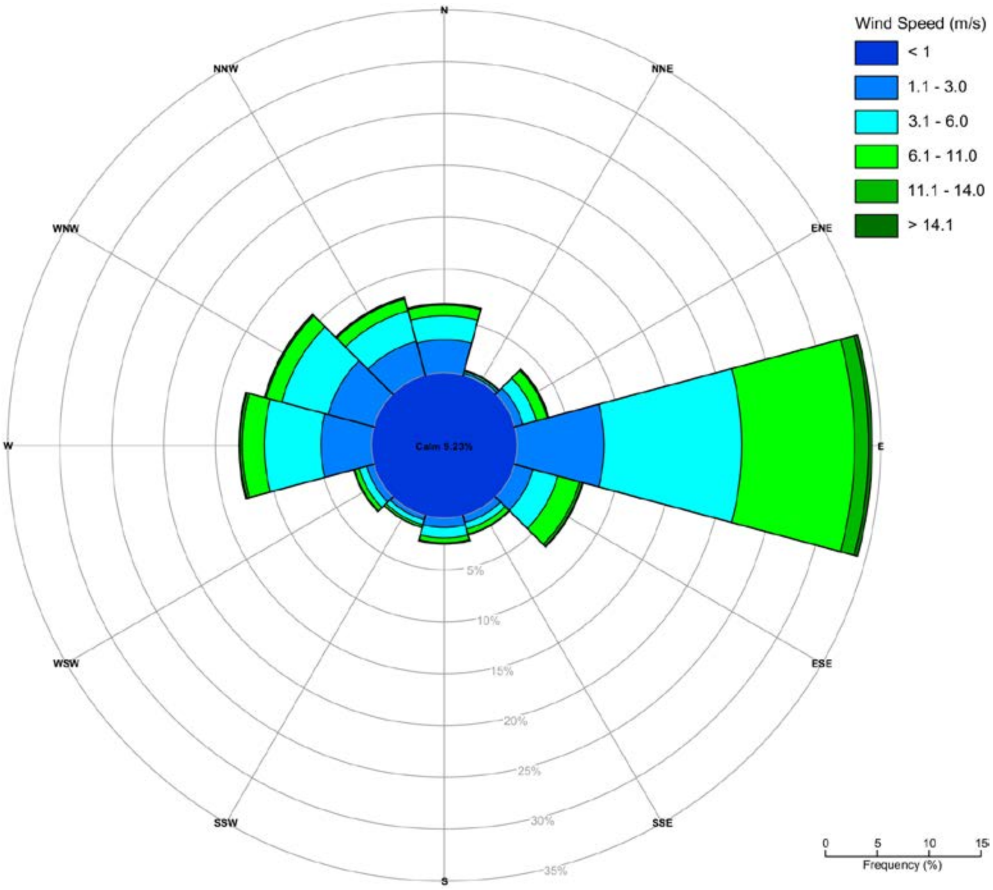

Figure 4.2.6: Average Wind Direction - Vorotan Pass Data

Table 4.2.3 and Figure 4.2.7 present the average monthly snow depth data, based on available information from the Vorotan weather station. This identifies snow accumulation periods between September to March [1], and snowmelt periods between the months of April to June [2], which results in increased runoff and localised flooding. As highlighted in the table, during July and August, the Vorotan Pass weather station is devoid of snow [3].

Table 4.2.3: Snow depth data for the Vorotan Pass Weather Station water year

Month	Minimum Monthly Average (cm)	Average Monthly Average (cm)	Maximum Monthly Average (cm)
October	2	4.2	35.5
November	2.3	14.5	59.4
December	10	34	86.7
January	10	55.9	102.1
February	10	74.2	131.1
March	10	88.1	156.6
April	10.8	62.7	133.5
May	2.5	12.6	66.6
June	2.5	2.9	62
July	0	0	0
August	0	0	0
September	2	5.3	18

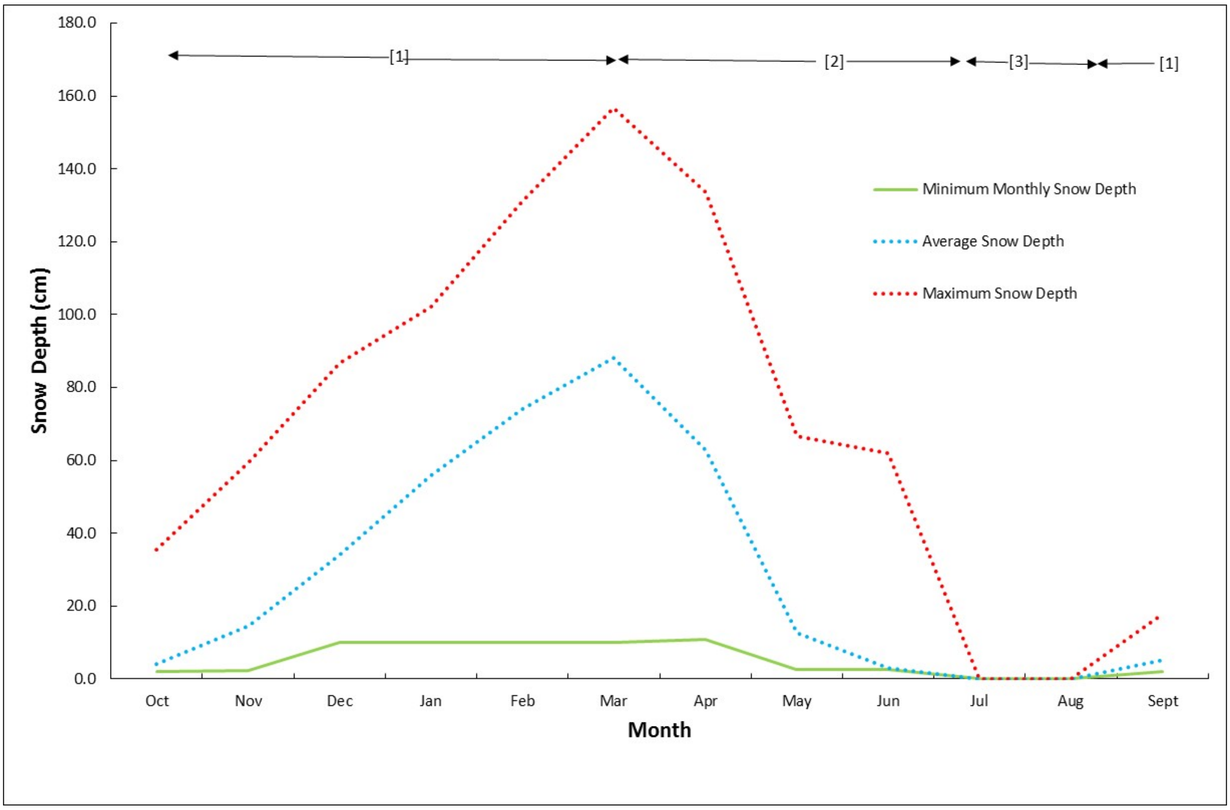

Figure 4.2.7: Monthly Snow depth data for the Vorotan Pass

Jermuk Weather Station

Data from the Jermuk weather station has similarly been analysed. This indicates that peak rainfall is recorded in April, with an average of 133mm, with August having the lowest rainfall levels at an average of 25mm. Maximum temperatures are in August, with an average of 18^{o}C, while minimum temperatures in January average -6.5^{o}C.

The results show differences in the patterns and extent of weather between the two meteorological stations, however no statistical differences have been identified. The Jermuk station shows higher amounts of precipitation (approximately 30% higher) which occurs earlier in the year than that of the Vorotan Pass dataset, and overall warmer temperatures. This is due to its lower elevation and less exposed location on the northern edge of the Jermuk Airfield. As the Vorotan Pass station lies on the exposed footslopes of Amulsar Mountain at an elevation closer to the high terrain of the Project, and provides climate data that is representative within the footprints of the main Project components, it is more appropriate to use this dataset for modelling and design. Consequently, the Jermuk dataset has not been used further within the project design or ESIA.

4.2.3 Capricorn-Colombia on-site weather station (CCWS)

The on-site weather station data has been collected during the period 2009-2011, after installation in 2009 at the exploration camp (see Figure 4.2.3). The CCWS is approximately 4 km from the proposed Erato open pit and lies on the south eastern edge of the BRSF; however, it was subject to a suspected lightning strike which caused technical problems during the downloading of data. As a result, the dataset from the CCWS is incomplete and thus is not included in design or impact assessment calculations. Furthermore, as the data only spans 2 years, it cannot be used as climate data.

The data that has been collected from the CCWS has been analysed (Appendix 4.2.2) and indicates comparable data to that of the Vorotan Pass. This supports the use of Vorotan Pass data for design criteria.

4.2.4 Meteorological Data Used for Design Criteria

Based on the observed trends of the climatic data from the Vorotan Pass provided for the project, the precipitation and evaporation data was manipulated for use in the three water balance model cases performed for the HLF, which are the average climate year case, the typical wet year case, and the typical dry year case. The manipulated climatic data is provided below; the monthly precipitation data and definitions are provided in Table 4.2.4, and the monthly evaporation data and definitions are provided in Table 4.2.5.

Table 4.2.4: Manipulated Precipitation Data for Use in Water Balance Calculations

Month	Extreme Dry Year (mm)	Typical Dry Year (mm)	Average Climate Year (mm)	Typical Wet Year (mm)	Extreme Wet Year (mm)
January	11.8	47.1	47.1	47.1	81.5
February	11.7	50.7	50.7	50.7	132.3
March	4.5	63.9	63.9	110.6	158.0
April	17.1	86.4	86.4	180.4	180.8
May	26.5	93.7	93.7	213.7	213.7
June	2.0	2.0	68.7	199.7	199.7
July	0	0	49.6	49.6	196.0
August	0	0	30.6	30.6	154.8
September	0	0	26.6	26.6	158.5
October	2.2	2.2	57.0	57.0	172.8
November	0	0	45.9	45.9	100.3
December	5.3	47.1	47.1	47.1	117.6
Totals:	**81.1**	**393.1**	**667.3**	**1,059.0**	**1,866.0**

Notes

1. Extreme dry, average climate and extreme wet year precipitation data reflect the minimum, average and maximum monthly precipitation amounts recorded at the Vorotan Pass weather station over the period of record 1962 – 2013 with gaps.
2. Typical dry year precipitation data includes the minimum precipitation amounts recorded in the six months of June through November, and the average precipitation amounts recorded in the other six months.
3. Typical wet year precipitation data includes the maximum precipitation amounts recorded in the three months of April, May and June, 70% of the maximum precipitation amount recorded in March, and the average precipitation amounts recorded in the other eight months.

The evaporation data in Table 4.2.5 was used in the three aforementioned water balance model cases.

Table 4.2.5: Manipulated Evaporation Data Used in Water Balance Calculations					
Month	**Extreme Dry Year (mm)**	**Typical Dry Year (mm)**	**Average Climate Year (mm)**	**Typical Wet Year (mm)**	**Extreme Wet Year (mm)**
January	18.2	9.4	9.4	3.9	3.9
February	23.4	10.5	10.5	2.6	2.6
March	28.6	14.6	14.6	5.2	5.2
April	53.3	34.1	34.1	22.9	22.9
May	79.5	67.4	67.4	55.2	55.2
June	172.7	172.7	140.3	96.0	96.0
July	252.2	252.2	194.9	194.9	138.0
August	292.4	292.4	206.1	206.1	160.7
September	218.2	218.2	163.6	116.2	116.2
October	46.2	46.2	39.1	32.1	32.1
November	44.3	44.3	23.6	9.7	9.7
December	27.3	12.2	12.2	5.2	5.2
Totals:	**1,256.3**	**1,174.2**	**915.8**	**750.0**	**647.7**

Notes:
1 Extreme dry, average climate and extreme wet year evaporation data reflect the maximum, average and minimum monthly evaporation amounts recorded at the Vorotan Pass weather station over the period of record 1964 – 2013 with a gap.
2 Typical dry year evaporation data includes the maximum evaporation amounts recorded in the six months of June through November, and the average evaporation amounts recorded in the other six months.
3 Typical wet year evaporation data includes the minimum evaporation amounts recorded in the ten months of September through June, and the average evaporation amounts recorded in July and August.

Considering the available precipitation data for the period of record 1962 – 2013 that was used in the water balance calculations, the return period for the annual typical wet year precipitation of 1,059.0 mm was statistically estimated to be 100 years.

Based on the available precipitation and snow depth data, spring snowmelt effects were simulated in the water balance model as described below, and effective monthly precipitation values were estimated and used in the water balance calculations.

Snow generally falls in the Project region in all months except for July and August. Snowfall in June and September/October is rare; during the 50 years of record described above, snow cover was measured in June and October in only five and eight years, respectively. The deepest snow on the ground generally occurs from December through April. Based on an evaluation of the available precipitation and snow depth data, spring snowmelt was simulated in the water balance calculations as follows:

- Since the snowpack will be light and the spring snowmelt effects negligible in a typical dry year, the typical dry year monthly precipitation values in Table 4.2.4 without snowpack effects were used for the typical dry year case for the entire year.
- For June through October when any snowfall will generally not accumulate, the average climate year and typical wet year monthly precipitation values in Table 4.2.4 were used in the model for the average climate year and typical wet year cases, respectively.
- For November through March in an average climate year and a typical wet year, when the snowpack is building and only a fraction of the snowfall is melting, the effective monthly precipitation values used in the model were considered to be 8% of the monthly snow depth water equivalent (SDWE) values, based on the rainfall and snowfall data patterns. The SDWE values are the snow depth values in Table 4.2.3 multiplied by the average snow density of 0.26 gr/cm^3. The average and maximum SDWE values in Table 4.2.3 were used for the average climate year and typical wet year cases, respectively.
- For April and May in an average climate year and a typical wet year, when most of the snowmelt occurs, the effective monthly precipitation values used in the model were considered to be the annual precipitation amounts in Table 4.2.5 for these two cases less the precipitation used in the model for the other 10 months as described above, with 60% of the difference applied in April and 40% in May.

Based on the above, the effective monthly precipitation values used in the three water balance model cases, which account for the spring snowmelt, are provided in Table 4.2.6.

Table 4.2.6: Effective Precipitation Data Used in Water Balance Calculations			
Month	**Typical Dry Year (mm)**	**Average Climate Year (mm)**	**Typical Wet Year (mm)**
January	47.1	12.0	21.2
February	50.7	14.9	24.6
March	63.9	18.9	32.6
April	86.4	227.7	354.4
May	93.7	151.8	236.3
June	2.0	68.7	199.7
July	0	49.6	49.6
August	0	30.6	30.6
September	0	26.6	26.6
October	2.2	57.0	57.0
November	0	2.2	10.0
December	47.1	7.3	16.3
Totals:	**393.1**	**667.3**	**1,059.0**

4.2.5 Long-Term Climate Trends

A climate change impact assessment on Armenia[1] was completed in 2009 by a team of experts from the United Nations Development Programme (UNDP) for Armenia and the Ministry of Nature Protection of the RA (MNPRA). The main focus of this report was socio-economic impacts in the context of different climate change scenarios.

This concluded that a low emission scenario (‘B_2’ in the IPCC 2007 report[2]) will result in an increase in temperature across Armenia of 3°C, and a precipitation decrease of up to 15% by 2070. The high emissions scenario (‘A_2’ in the IPCC 2007 report[2]) will result in a temperature increase of 3.4°C and a precipitation decrease of up to 17%.

Conclusions were also made specifically for the Vayots Dzor region, in which by 2070 under the A_2 emissions scenario, temperatures will increase by 3°C, and precipitation will decrease by up to 25%. This represents a significant impact to the region of Vayots Dzor and Armenia as a country, having a major impact upon agriculture, energy generation, biodiversity and water availability.

[1] UNDP et al., 2009, *The Socio-Economic Impact of Climate Change in Armenia*, Yerevan, Armenia, accessed on 03/07/2014 from http://www.undp.org/content/dam/armenia/docs/Report%20SOI%20of%20CC.pdf

[2] IPCC, 2007, *Fourth Assessment Report: Climate Change 2007 (AR4)*, can be accessed at http://www.ipcc.ch/publications_and_data/publications_and_data_reports.shtml

Additionally a Regional Climate Change Impacts Study for the South Caucasus Region was completed in 2011 by a team of international consultants and national experts from the RA, Azerbaijan Republic and Georgia[3]. This study was undertaken in cooperation with the MNPRA, the Ministry of Ecology and Natural Resources of Azerbaijan Republic and the Ministry of Environment of Georgia, with technical support from the in-country offices of the Environment and Security Initiative (ENVSEC) and the UNDP.

The report concluded that the whole of the South Caucasus area has demonstrated evidence of increased warming over the last century, with the RA, Azerbaijan Republic and Georgia all exhibiting statistically significant trends with an increase in mean annual temperature and mean daily minimum and maximum temperatures. No overall trends were established for mean annual precipitation or the number of wet days per year. Approximately half of the meteorological stations in the RA included in the study displayed statistically significant trends that verify an increase in annual temperature. This included the State meteorological station at the Vorotan Pass, in which analysis of the readings taken between 1935 and 2008 (the study period) there was sufficient data to indicate that the locality has been subject to an average increase of between 1.1°C to 1.9°C in the annual mean temperature over the 73 year period up to 2008.

[3] UNDP et al., 2011, *Regional Climate Change Impacts Study for the South Caucasus Region* , Tbilisi, Georgia, accessed on 19/09/2012 from http://www.envsec.org/publications/cc_report.pdf