Environmental and Social Impact Assessment – Part 7

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GEO: Adjaristsqali Hydropower Project

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Adjaristsqali Hydropower Cascade Project

Shuakhevi HPP Climate Change Impact Assessment

January 2014

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Contents

1 Introduction

1.1 Introduction

Following successful award of concessions from the Government of Georgia in May 2010, Adjaristsqali Georgia LLC (AGL) is developing a 331 MW hydropower project known as the Adjaristsqali Hydropower Cascade, on the Adjaristsqali River in the Autonomous Republic of Adjara, south-west Georgia (the Project). The Project consists of the Shuakhevi and Koromkheti hydropower cascade schemes, of which only the Shuakhevi scheme is subject to the current round of financing. Detailed design for the Shuakhevi scheme has been completed and preparatory ground works have commenced. Full construction is due to follow in Quarter 1 2014. This report addresses the Shuakhevi scheme only.

The feasibility study for the Project included a technical appraisal of the ability of each design and layout option to manage likely changes in climate. However, a formal climate change risk assessment was not included in the Project Environmental and Social Impact Assessment (ESIA) as this was not required by the financing parties at the time of issue (August 2012). The Asian Development Bank (ADB) has subsequently become a financing party and its 'Guidelines for Climate Proofing Investment in the Energy Sector' are now applicable to the Shuakhevi scheme.

This Climate Change Risk Assessment (CCRA) has been produced to meet the requirements of the ADB Guidelines and is intended as a supplement to the Project ESIA. The CCRA formalises the assessment carried out at the feasibility stage and confirms the measures that have been adopted to mitigate these risks, including with regard to the resilience of the Shuakhevi scheme and its potential impact on the wider environment's vulnerability and capacity to adapt to climate change.

1.2 CCRA Process

The main stages that have been followed in carrying out this CCRA are summarised below:

- Chapter 2 describes the historical climate data as available at the time of the Project Feasibility Study;
- Chapter 3 also presents a review of future climate baseline data and potential long term climate impacts are identified according to data available at the time of the Project Feasibility Study;
- Chapter 3 outlines the design of the scheme and some of the principle design considerations relevant to climate change;
- Chapter 4 identifies the potential risks posed by the potential changes in climate within the study area and the resilience of the scheme to these risks;
- Chapter 4 then considers mitigation measures which are included in the scheme which address the potential risks associated with climate change;
- Chapter 4 concludes by identifying any residual risks to the Project; and
- Chapter 5 provides a summary of the assessment.

2 Baseline and projected meteorological, hydrological and climate data

2.1 Overview

A full overview of the current and predicted future baseline meteorological, hydrological and climate data used to characterise the project area in the feasibility study is provided in Appendix A. This data has been considered alongside the scheme infrastructure presented in Section 3 to determine potential risks. A summary of the key data is provided in Sections 2.2 to 2.7.

2.2 Temperature

2.2.1 Current baseline

Average annual temperature for the Adjaristsqali River basin ranges between 10.4°C (Khulo) and 12.7°C (Keda). Average maximum summer temperature is currently 23.8°C and maximum temperature has been recorded at 39°C. Average maximum winter temperature is currently -1.4°C and minimum temperatures have been recorded at -18°C.

2.2.2 Predicted future baseline

Over the 21st century temperatures are projected to increase (See Appendix A.1.2 and A.2).[1] Average summer maximum temperatures are expected to rise to 28.8°C, with a projected maximum recorded temperature of 42.4°C. Average winter minimum temperature is expected to move above 0°C to 2.9°C, with a projected minimum recorded temperature rising to -14.6°C.

2.3 Precipitation

2.3.1 Current baseline

The River Adjaristsqali inflows are provided by snow, rain and groundwater with a proportion of 26%, 44% and 30% respectively. There are no glaciers in the catchment.

Across the catchment total annual precipitation ranges from 1034 mm (Purtio) to 1979 mm (Makhunceti). Summer is predominantly the driest season (67.7mm to 139mm), while autumn and winter are the wettest seasons (106.7mm to 229mm).

2.3.2 Predicted future baseline

The climate model data suggests that annual precipitation is likely[2] to decrease (-1.9%). Seasonally, total spring (-2.4%), summer (-25.3%) and autumn (-8.8%) precipitation is projected to decrease, although total winter precipitation is projected to increase (18.8%).

[1] Median values provided

[2] Direction of change associated with the Median value

There is some uncertainty as whether the increased winter precipitation would be in the form of rain or snow; however due to the potential changes in winter temperature it is likely that it would fall in the form of rain.

2.4 Run-off

2.4.1 Current baseline

Run off data was collected for the period of 1980 to 1991 due to the lack of data on temperature and flow data outside of these periods. It was concluded that the calibration of the rainfall-runoff model achieved was not good enough, particularly at Shuakhevi, to justify attempting extended modelling of these records to later periods. The climate data available for parts of the basin is quite restricted with Goderdzi Pass the only station representing the higher elevations within the catchment. Therefore it is difficult to model sub-catchments downstream of the two headwater sub-catchments selected for the modelling trial.

It was therefore concluded, given the availability of around 50 years of hydrology data from a number of gauges within the project area that the rainfall-runoff modelling should not be taken further.

2.4.2 Predicted future baseline

The consequences of climate change for the runoff regime depend on whether the winter increase in precipitation manifests primarily as snow or rain. If an increase in winter snow cover is experienced the spring snow melt flood season may produce higher flows. Conversely an increase in temperature and higher rainfall may result in a shorter melt season.

2.5 River hydrology

2.5.1 Current baseline

The River Adjaristsqali experiences two flood seasons; the first during spring and a second in the autumn. The autumn floods tend to be flashy and result from high rainfall during this period.

After November temperatures are lower and much of the precipitation falls as snow, reducing runoff rates. During spring the snow melts and produces a long period of high baseflow. High rainfall during this period then results in flood events.

2.5.2 Predicted future baseline

The projected climate data suggests that winter may see significantly more precipitation whether falling as snow or rain, but that precipitation may be reduced over the rest of the year, particularly in summer.

The consequences for the runoff regime are very dependent on whether the winter increase will be largely manifested as snow or as rain. If winter snow cover is increased the spring snowmelt flood season may produce higher flows but the increased temperature may mean that the melt season gets shorter as more of the winter precipitation will have fallen as rain and run-off at the time of rainfall events rather than being stored up as snow.

2.6 Landslides

2.6.1 Current baseline

A geological and geotechnical analysis was undertaken as part of the feasibility study for the scheme. The study considered each section of the project and undertook a mix of historical data, site investigation and desk based assessment to determine the potential risks associated with landslides. Detailed landslide hazard mapping was also undertaken.

Areas which were susceptible to landslides were identified through this study, noting that there are some previous landslide events in the past. There are several fault lines within the study area. The study identified the following current risks:

- Negligible to minor risk of landslide at the Chirukhistsqali weir site;
- Minor risk at the Skhalta dam and reservoir site;
- Slopes at the Didachara dam and reservoir had minor risk, but a short distance downstream, risks were noted to be increased but not considered to significantly affect the scheme;
- Minor risk at the Didachara – Shuakhevi headrace tunnel
- Minor risk at the Shuakhevi powerhouse

2.6.2 Predicted future baseline

The risk of landslides is increased with prolonged periods of wet weather, snow melt and freeze thaw cycles. The climate data suggests that precipitation would increase in the winter months while decreasing in other month, against a general decrease in annual precipitation. The potential effect on the landslide hazard is dependent on whether the increased winter rainfall is in the form of snow or rainfall, and future risks may be slightly increased as a result.

2.7 Data gaps

Within the study areas, there was a lack of data with high enough confidence to be able to develop a full rainfall-runoff model for this scheme. However, this is mitigated by the availability of around 50 years of hydrology data from a number of gauges within the project area.

There is a lack of baseline and predicted baseline data in relation to wind speed and wind direction with only a limited amount of data available for wind speed. However the design parameters and assessment in the feasibility study have accounted for potential wind loading.

3 Scheme infrastructure

Risks associated with changes in meteorological and hydrological conditions as summarised in Section 2 depend on the type of scheme being developed and the nature of its infrastructure. An assessment of climate risks and mitigations in place is provided in Section 4.

The Shuakhevi scheme will have a total installed capacity of 181 MW and will comprise the following components:
- Dam and reservoir on the Adjaristsqali river at Didachara;
- Dam and reservoir in the upper reaches of the Skhalta River;
- One weir to allow abstraction and sediment basin on the Chirukhistsqali River;
- Transfer / headrace tunnel between Chirukhistsqali weir and small capacity Hydro Power Plant (HPP) at the Skhalta dam HPP (6 MW);
- Transfer tunnel between Skhalta dam and Didachara reservoir; and
- Headrace tunnel from Didachara dam to the main HPP unit near Shuakhevi village (175 MW).

To support the main works the following activities will also be required for construction and / or maintenance:
- Land acquisition associated with temporary and permanent structures;
- Development of borrow pits to provide aggregate for road building;
- Excavation of temporary and permanent access portals (known as adits), initially to construct underground infrastructure including tunnels and subsequently during operation for maintenance;
- Erection of temporary worker accommodation;
- Creation of temporary storage and work sites at dam and powerhouse locations;
- Disposal of significant amounts of spoil material from tunnel excavations;
- Installation and operation of concrete batching plant for the production of concrete to support foundation works;
- Upgrade of existing access roads to support delivery of equipment to site;
- Construction of new permanent access and maintenance roads; and
- Construction of temporary access roads for construction.

Potential climate impacts have been considered in the Feasibility Study, the Geotechnical and Geological Report and the Tender Design Report for the scheme. A summary of the key considerations in these reports is presented below.

Flood events - The scheme infrastructure has a 50-60 year design life taking account of the climate data available (including the degree of uncertainty in the available hydrology data) and best practice in hydropower design has been followed throughout. The dam spillways are designed to allow for a 1 in 10,000 year safety check flood and 1 in 1,000 year design flood. The design is therefore considered sufficient to accommodate changes in flood frequency arising from climatic changes. In the unlikely event that design parameters are exceeded, the concrete dam structures can be over-topped.

Sediment loading - Changes in sediment loading were considered in detail during the project design, including within the Feasibility Study and the Tender Design Report. There is little historical monitoring of sediment loads, and therefore a conservative approach was taken in the design of the scheme. Sediment traps, sediment flushing arrangements and other aspects of the design that could be affected by debris and sediment loads have been studied in detail and have been designed to accommodate the type and volumes of debris and sediment anticipated, including during flood events. Sediment analysis was undertaken to identify whether any abrasive materials may be found, and this determined that there was some potential for these types of materials although it was not considered necessary to coat the runners. Sediment will also be periodically flushed to prevent the build-up of materials and the scheme is designed so that these materials can be returned to the river.

Landslide risks - Landslide risks have also been subject to detailed technical appraisal which has included consideration of changes in precipitation rates and drought. Changes were made to the scheme design at the feasibility stage to accommodate identified risks. During scheme development, geomorphological and landslide hazard mapping recommended the Skhalta reservoir terminate at a point upstream where slopes on the left bank are considered less stable. In other areas, such as the Didachara dam and reservoir, some slopes will be partially excavated to stabilise the land.

Materials - Materials are selected for Project infrastructure based on their appropriateness for the design, which takes account of potential climatic changes. This includes the use of abrasion resistant concrete, for example.

The Project will also require transmission lines for transmitting the generated electricity to substations for eventual use by consumers. It is proposed that a new 220 kV transmission line will be constructed connecting into existing national grid at Batumi and Akhaltsikhe substations. The development of the transmission line is not included as part of the activities for which AGL is seeking finance and risks are therefore not considered within this CCRA. Please refer to the Transmission Line ESIA for discussion on associated risks.

4 Risk analysis

4.1 Overview

Potential risks to the scheme have been identified through analysis of the available climate data and scheme information presented in the preceding sections. In order to determine the scheme's resilience to climate change risks, the following process has been adopted:

- the potential changes in climate parameters are considered based on the summary presented in Section 2;
- the potential elements of the scheme that might be affected by these changes have been identified, based on the project as described in Section 3.
- measures to manage these risks for this scheme are identified; and
- any residual risks are identified,

The findings of the risk assessment are presented in Table 4.1.

4.2 Included measures

Certain actions have been taken which have built in resilience to potential changes in climate variables. Table 4.1 identified which of these measures have been used to manage each of the potential risks. It should be noted that mitigation for climate change risks is referred to as adaptation and can involve measures that perform two primary functions:[3]

- **Measures that build adaptive capacity.** Initiatives that build capacity to adapt, creating the information (research, data collecting and monitoring, awareness raising), supportive social structures (organisational development, working in partnership, institutions), and supportive governance (regulations, legislations, and guidance); and
- **Measures that deliver adaptation actions**. Direct actions are delivered that help to reduce vulnerability to climate risks or to exploit opportunities.

The following list presents an overview of the measures that have been included within the scheme that build and deliver adaptation capacity and action. The measures applicable to each of the identified risks are identified in Table 4.1.

- Planning and design measures:
  - **Design standards and materials selection** – The scheme infrastructure has been appropriately designed as described in Section 3, taking into account available climate data. In addition, key potential risks including precipitation changes (including drought) on landslide risks and the types and effects of sedimentation have been fully integrated within detailed geotechnical and sediment studies and effective mitigation embedded in the scheme design.
  - **Building flexibility into responses** – Effects of climate change are uncertain and appropriate project level responses may require a change of direction in the future, as vulnerability, knowledge, experience and technology evolve. Effective adaptation measures will be informed by ongoing monitoring of key parameters. An Adaptive Management and Monitoring Programme for the effects of changed river flows on ecology and habitats has been instigated. Please refer to the Project

[3] http://www.ukcip.org.uk/essentials/adaptation/adaptation-types/

ESIA, Biodiversity Action Plan (BAP) and Environmental and Social Management Plan (ESMP) for further details.

  - **Resilient construction** – A Construction Environmental Management Plan (CEMP) is in place for the Project. The CEMP provides guidance on mitigating measures that must be adopted by the contractor team during construction to avoid impacts on the environment, including from extreme weather events that may be associated with climate change. The CEMP suite of documents includes an emergency response plan covering environmental incidents.
  - **Environmental impact mitigation** – The Project ESIA has identified a broad range of mitigation measures to reduce the effects of the Project on the environment and people, including on environmental media that could be affected by changes in climate.

- Operation and maintenance measures:
  - **Monitoring and evaluation** – As established in the Project ESIA, BAP and ESMP an environmental monitoring programme has been developed and monitoring is taking place as established in these documents.
  - **Resilient asset management/maintenance** – The maintenance of structures and surfaces and the removal of sediment build-up for example, provides a degree of resilience to climate risks. The Project design has considered O&M requirements including sediment flushing arrangements. In addition, whilst the details of the O&M regime are not fully worked up (as is normal for a project not yet constructed) AGL has identified budget for an appropriately robust O&M regime, including planned maintenance activities and through the course of operations will be able to identify any maintenance issues of concern that may be linked to changes in climate.
  - **Risk response procedures** – Practices for the operation and maintenance of assets, including reservoirs, are being developed taking account of climate risks and changes in these risks over time. This process will continue as the Project progresses.

Table 4.1: Climate risk analysis

Climate parameter	Potential risks	Adaptation measures	Residual risk
Temperature (extremes Summer and Winter)	Potential for structural damage through expansion, buckling and stresses to structures and surfaces	**Design standards and materials selection, Resilient asset management/maintenance, Risk response procedures.** Given some of the uncertainties in the available data, the project has been developed with conservative assumptions. It is considered that the structural design elements are appropriate to any potential change in temperatures that might be expected. The O&M regime will be used to account for any potential risks to infrastructure.	Managed through ongoing monitoring and maintenance regime.
	Increased river water temperature effects on aquatic ecology.	**Environmental impact mitigation Building flexibility into responses Monitoring and evaluation** Comprehensive monitoring plans are in place for the scheme as established in the Project ESIA and BAP which will include potential changes in the aquatic environment.	Managed through ongoing monitoring
	Damage to road surfaces such as asphalt due to extreme temperatures,	**Design standards and materials selection Resilient construction Resilient asset management/maintenance Risk response procedures** The project has been designed to withstand potential changes in temperatures through the appropriate selection of surfacing materials and specifications. The O&M regime will be used to account for any potential risks to infrastructure.	Managed through ongoing monitoring and maintenance regime.
Precipitation, run off and river hydrology	Subsidence and slope instability in embankments and cuttings as a result of increased precipitation or drought. Structural damage resulting from slope instability.	**Design standards and materials selection Risk response procedures** These were key issues considered in the Feasibility Study and a comprehensive geotechnical review was undertaken. Design was modified to account for areas where major risks were identified including limiting the extent of certain features of the project or including additional works to strengthen structures.	Managed through ongoing monitoring and maintenance regime.
	Increased sediment loads from slope instability. Could result in increased reservoir sedimentation and turbine abrasion (in cases where the sediment is abrasive), which if left unmanaged could	**Design standards and materials selection Resilient construction Monitoring and evaluation Resilient asset management/maintenance Risk response procedures** This is a potential issue where sediment is abrasive. The Tender	Managed through ongoing monitoring and maintenance regime.

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Climate parameter	Potential risks	Adaptation measures	Residual risk
	reduce operational efficiency and storage capacity [4].	design report has identified this as a potential issue and has put in to place mitigations to manage this risk. This includes the use of appropriate materials and technologies which have been included in the design.	
	Snow and ice accretion could result in loading of structures causing damage or failure	**Design standards and materials selection** **Resilient asset management/maintenance** **Risk response procedure** The scheme has been conservatively design to withstand loading scenarios. Appropriate materials and standards have been applied. Climate data suggests that risk will not increase over present day due to warming. The O&M regime will be used to account for any potential risks to infrastructure.	Managed through ongoing monitoring and maintenance regime.
	Snow and ice could impair site access for operational activities as well as reactive and planned maintenance works.	**Building flexibility into responses** **Resilient asset management/maintenance** The scheme has been conservatively design to withstand loading scenarios. Appropriate materials and standards have been applied. Climate data suggests that risk will not increase over present day due to warming. The O&M regime will be used to account for potential difficulties in working due to snow and ice events.	Managed through ongoing maintenance regime
	Changes in precipitation patterns over time are likely to affect river hydrology and flows, particularly in mountainous catchments.[5] This could affect the production capacity and design requirements of the scheme over time	**Design standards and materials selection** **Building flexibility into responses** **Monitoring and evaluation** **Resilient asset management/maintenance** **Risk response procedures** Based on the data presented in the feasibility study, there is some uncertainty in the flow data which determines energy produced by the scheme. This uncertainty could have a negative or positive effect on the project. The feasibility study took a conservative approach to the data that was available to determine flow based on available data and appropriate operating conditions were determined. Flows are not expected to vary enough to affect the operation of the scheme.	Managed through ongoing monitoring.
	River flows above plant and reservoir capacity could reduce scheme operability through increasing spillway flows and/or	**Design standards and materials selection** **Monitoring and evaluation** **Resilient asset management/maintenance** **Risk response procedures**	Managed through ongoing monitoring

[4] IPCC (2011): Hydropower. In IPCC Special Report on Renewable Energy Sources and Climate Change Mitigation

[5] Schaefli, B, Hingray, B and Musy, A, 2007. Climate change and hydropower production in the Swiss Alps: quantification of potential impacts and related modelling uncertainties. *Hydrology & Earth System Sciences*. 11, pp. 1191-1205.

Climate parameter	Potential risks	Adaptation measures	Residual risk
	deposition of additional sediment.	These issues have been addressed in the design of the scheme. Given some uncertainty in the available data, the dam structures have been designed for a 1 in 10,000 year safety check flood and a 1 in 1,000 year design flood. This is considered to adequately address any potential risks associated with changes in flooding with in the study area. Potential changes in the rainfall regime leading to were considered in the Feasibility Study in detail to provide resilience. The scheme can also accommodate over-topping of the dam structures.	
	Large sediment and debris loads carried by floodwaters could block dam spillways and powerful masses of water could damage important structural components.	**Building flexibility into responses** **Resilient asset management/maintenance** **Risk response procedures** The design has recognised potential risks from sediment abrasion. Materials have been selected to withstand potential abrasion from any sediment. The reservoirs will be periodically flushed to remove sediment and ensure their storage capacity is maintained. This flushing will also help meet the environmental flow requirements and will continue throughout the operation of the scheme The spillway is also expected to provide a “flushing” facility through the use of flood gates to reduce the risk of sedimentation.	Managed through ongoing maintenance regime
Landslides	The risk of landslides could increase as a result of changes in precipitation, particularly in the winter months.	**Design standards and materials selection** **Resilient construction** **Building flexibility into responses** **Monitoring and evaluation** **Risk response procedures** Landslide risk has been considered in detail as part of the Geotechnical study. Some areas of risk were identified and these have been managed through changes to the design, and intervention during the construction phase. Remaining landslide risks were determined to be minor. Potential changes in precipitation have the potential to lead to some landslides in certain areas, however the project has been designed to manage these risks. Ongoing monitoring will be undertaken to continually manage this risk.	Managed through ongoing monitoring regime
Wind and storms	Wind storms or gales could damage structures as a result of windborne debris and the loading of structures.	**Design standards and materials selection** **Resilient asset management/maintenance** The primary project infrastructure including dams, tunnels and powerhouse will be naturally resilient to wind due to the amount of loading the structures can take.	Managed through ongoing monitoring regime

5 Conclusions

This report presents a climate change risk assessment for the proposed Shuakhevi scheme as part of the Adjaristsqali Hydropower Cascade Project as a supporting document to the Feasibility Study and ESIA. The report summarises information provided in other reports to outline how climate change has been considered through the design of the scheme.

During the feasibility study, available climate data was assembled to determine some of the design parameters. Some data gaps in observational historical data were noted, and a conservative approach to scheme design was taken.

Projected climate data has demonstrated that the regional climate may be changing. The available climate models suggest that the nature of annual precipitation could be expected to change with an overall slight decrease and more seasonality to rainfall levels.

A number of risks associated with changes in climate were addressed during the design of the scheme, taking in to account the inherent uncertainties. The scheme has been designed to withstand variations in climate thorough a number of direct actions to address specific risks (for example those assumed with landslides and sediment loading) and by committing to a range of ongoing monitoring and maintenance.

Based on the actions included and committed to, risks associated with the scheme have been addressed. Given the uncertainty surrounding changes in climate, the ongoing monitoring, adaptive management and maintenance regime once the scheme is in operation will provide sufficient resilience to the project.

Appendices

Appendix A. Climate profile

A.1 Overview

This section summarises background meteorological and climate projection data used to characterise the project area in the feasibility study.

This assessment is based on an observational climate data set and the accompanying climate projections. Modelled data for the future are not predictions of climate, but simulations of future climate under a range of hypothetical emissions scenarios. Any further research, analysis or decision-making should take account of the accuracies and uncertainties associated with these projections. It is also important to note that the analysis is based on chosen observed data, the results of climate model ensemble experiments and a selected range of existing climate change research and literature at the time. Any future decision-making based on this analysis should consider the range of literature, evidence and research available and any recent developments in these.

A.1.1 Climate Stations Considered

The baseline climatological regime is based on an analysis of the historical records at the stations shown in Table A.1. Each of the important variables is presented based on the data available from seven climate stations that best represented the study area.

Table A.1: Details of Climate Stations

Station	Elevation m	Start Year	Comment
Khulo	923	1936	
Shuakhevi	650	1942	
Merisi-Sikhalidzeebi	550	1942	
Keda	256	1937	
Goderdzi Pass	2025		
Purtio	565	1926	Published averages only
Makhunceti	138	1928	Published averages only

Source: NEA, GEG

Historical records for precipitation are available at the stations shown in Table A.2.

Table A.2: Details of Precipitation Gauges

Station	Elev masl	Start Year	Snow Depth	Comment
Didachara	940	1941		Data obtained 1966-92
Khulo	923	1940	✓	Data obtained 1966-2010
Shuakhevi	650	1942	✓	Data obtained 1980-87, 1998-2005
Merisi-Sikhalidzeebi	550	1942		Data obtained 1966-92

Station	Elev masl	Start Year	Snow Depth	Comment
Keda	256	1937	✓	Data obtained 1966-92, 98-99, 2002, 06-10
Goderdzi Pass	2025		✓	Data obtained 1966-2006
Purtio	565	1926		
Makhunceti	138	1928		
Khikhadziri				

Source: NEA, GEG

There is no data on the water equivalent of the recorded snow depths.

A.1.2 Climate projections

The potential climate change impacts in the Adjara Region are described here on the basis of findings presented in The Second National Communication (2009) published by Georgia under the Kyoto Protocol.

Dynamic research has been made on climate parameters (mainly temperature and precipitation) for the several regions of Georgia in order to evaluate climate change and conclusions were made on the trends. The evaluation was performed in two phases: 1) current climate change evaluation based on existing static data and 2) long term forecast of social-economic changes considering various scenarios.

Current climate change of Georgia has been evaluated using the static method. Air average annual temperature, precipitation average annual data and humidity regime change trend have been studied primarily for the period of 1955-1970 and 1990-2005. Also trends in air temperature and precipitation data totals haves been analysed. The study revealed rapid increase of average annual temperature for the last 20 years (in three regions – Poti, Lentekhi, and Dedoplistsqaro). As for the trend of precipitation average annual data totals, it varies for western and eastern part of Georgia (decrease is observed in western part).

From the prediction of future changes to the climate parameters two regional models have been used PRECIS (definition 25km x 25km) and static program MAGICC/SCHENGEN (definition 600km x 600km).

Climate parameters have been evaluated based on three different boundary conditions: ERA40 (Georgia), HadAM3P (Armenia), ECHAM4 (Azerbaijan). Validation of the results was performed in comparison with the real time observation data received from the Georgian meteorological stations. The differences found during the validation process have been used for corrections of future projections.

Table A.3: HadAM3P (Armenia)

Region	Season	Spring		Summer		Autumn		Winter		Annual	
	Climate Unit	T	Q	T	Q	T	Q	T	Q	T	Q
		^{0}C	mm	^{0}C	mm	^{0}C	mm	^{0}C	mm	^{0}C	mm
West Georgia	1961-1990	9.1	372	19.3	463	10.5	566	-0.6	573	10.9	1554
	Expected changes Δ	-1.0	50	4.0	-175	2	-50	2.0	100	1.8	-30
	2100	8.1	422	23.3	288	12.5	516	1.4	673	12.7	1524

Note: 3-months per season; Spring defined as months III, IV and V.

Table A.4: ECHAM4 (Azerbaijan)

Region	Season	Spring		Summer		Autumn		Winter		Annual	
	Climate Unit	T	Q	T	Q	T	Q	T	Q	T	Q
		^{0}C	mm	^{0}C mm		^{0}C	mm	^{0}C	mm	^{0}C	mm
West Georgia	1961-1990	9.1	372	19.3	463	10.5	566	-0.6	573	10.9	1554
	Expected changes Δ	3.5	-9	5.0	-54	4.0	-9	4.5	108	3.4	36
	2100	12.6	363	24.3	409	14.5	557	3.9	681	14.3	1590

Table A.5: MAGICC/SCHENGEN

Region	Season	Spring		Summer		Autumn		Winter		Annual	
	Climate Unit	T	Q	T	Q	T	Q	T	Q	T	Q
		^{0}C	mm	^{0}C mm		^{0}C	mm	^{0}C	mm	^{0}C	mm
West Georgia	1961-1990	6.6	189	17.7	234	8.8	216	-3.9	180	7.3	840
	Expected changes Δ	5.6	-72	7.7	-36	4.1	-99	4.3	-27	5.2	-110
	2100	12.2	117	25.4	198	12.9	117	0.4	153	12.5	730

A.2 Temperature

Average annual temperature for the Adjaristsqali River basin is above zero and varies between 10.4°C and 13.1°C. The coldest month (January) air average monthly temperature is also above zero and varies between 0.9°C and 3.2°C. The coldest months are considered to be December to February. In those months average monthly temperature does not exceed 6°C. The warmest months are July and August, with average monthly temperature between 18°C and 22.3°C.

Table A.6: Temperature Statistics for Khulo and Keda (oC)

	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	year
Khulo													
Average	0.9	1.7	4.6	9.4	14.2	16.5	18.6	19.4	16.2	12.3	7.8	3.6	10.4
Average minimum	-2.4	-2.1	0.2	4.6	9.2	11.8	14.2	14.6	11.5	8.2	4.4	0.3	
Absolute minimum	-18	-18	-13	-9	-2	4	7	7	0	-3	-12	-13	-18

	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	year
Average maximum	4.8	5.8	9.4	15.3	20.4	22.5	23.9	25.0	21.8	17.7	12.4	7.6	
Absolute maximum	17	21	24	31	35	39	39	38	32	27	22	19	
Keda													
Average	3.1	4.0	7.4	12.1	16.1	19.1	21.3	21.5	18.4	14.2	9.8	5.3	12.7
Average minimum	0.1	0.7	3.3	7.0	11.4	14.4	17.1	17.3	14.0	10.0	6.0	2.0	
Average maximum	7.8	9.2	13.3	18.9	22.9	25.0	26.5	26.9	24.4	20.5	15.5	10.2	

The dates of the first and last coldest dates and duration of non-frosty days are very important for defining the construction period.

Table A.7: Dates for the Start and End of the Frost Season

Climate Station	Period						Frost Days
		Last			First		
		Average	Earliest	Latest	Average	Earliest	Latest
Khulo	1930-60	14/IV	5/III	12/V	6/XI	30/IX	6/XII
Keda	1934-60	21/III	5/III	24/IV	4/XII	1/X	12/I
Purtio	1926-35	7/IV			18/XI		
Makhunceti	1928-32	19/III			8/XII		

Source: Climate Handbook

Figure A.1: Long term change in minimum temperature

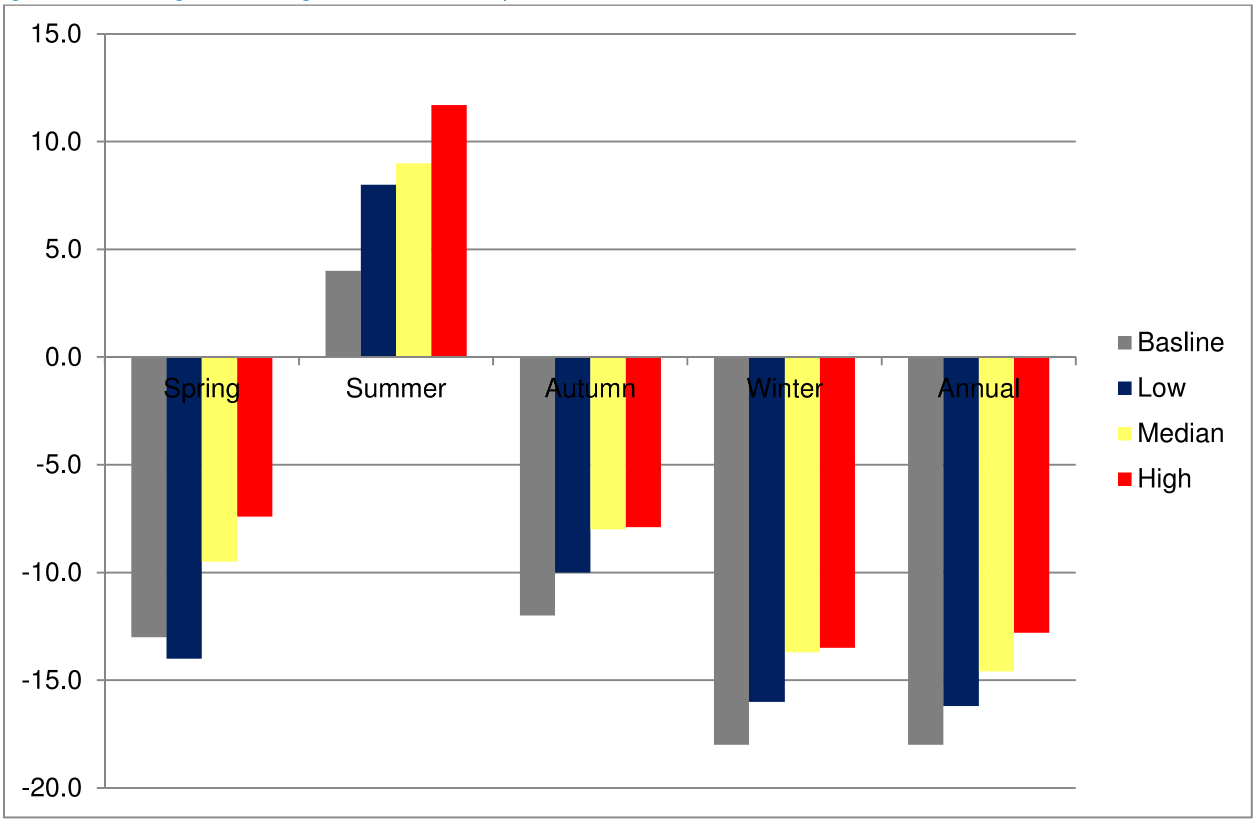


Figure A.2: Long term change in average minimum temperature

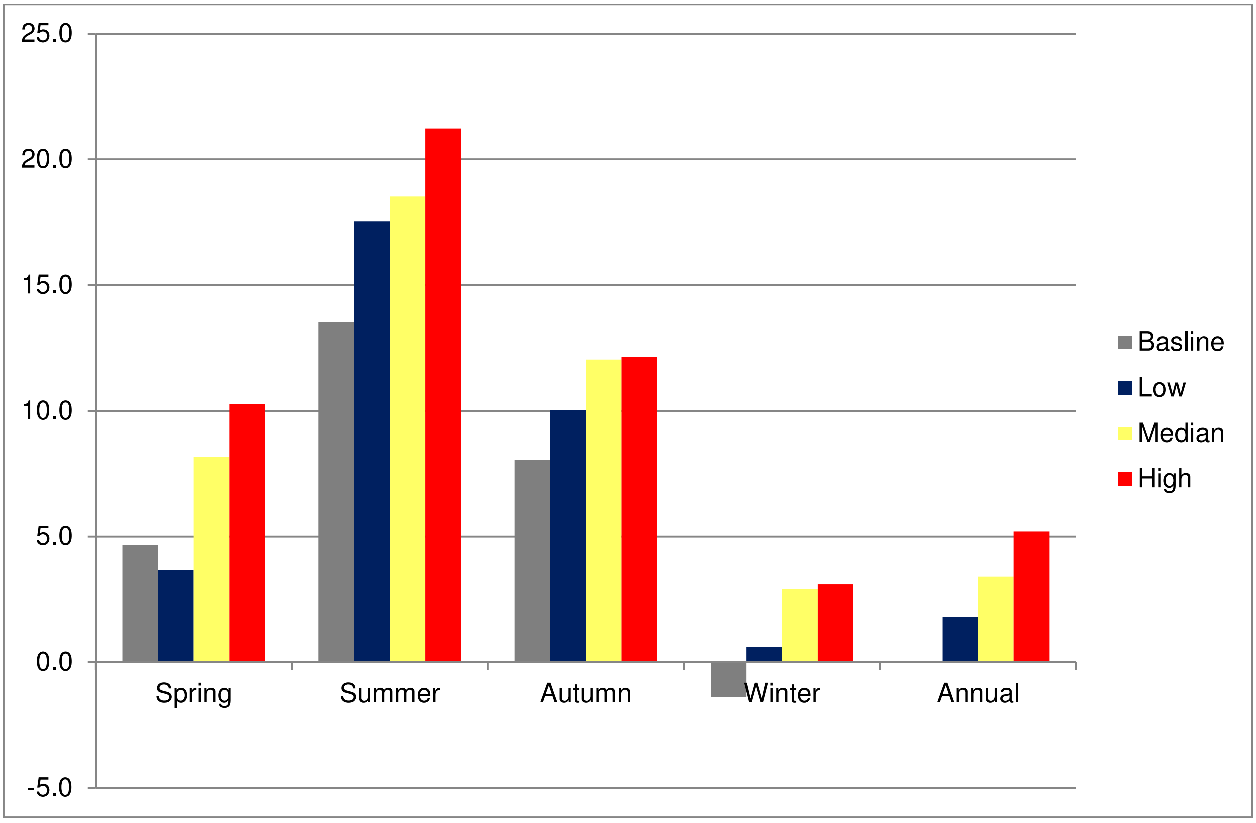


Figure A.3: Long term change in maximum temperature

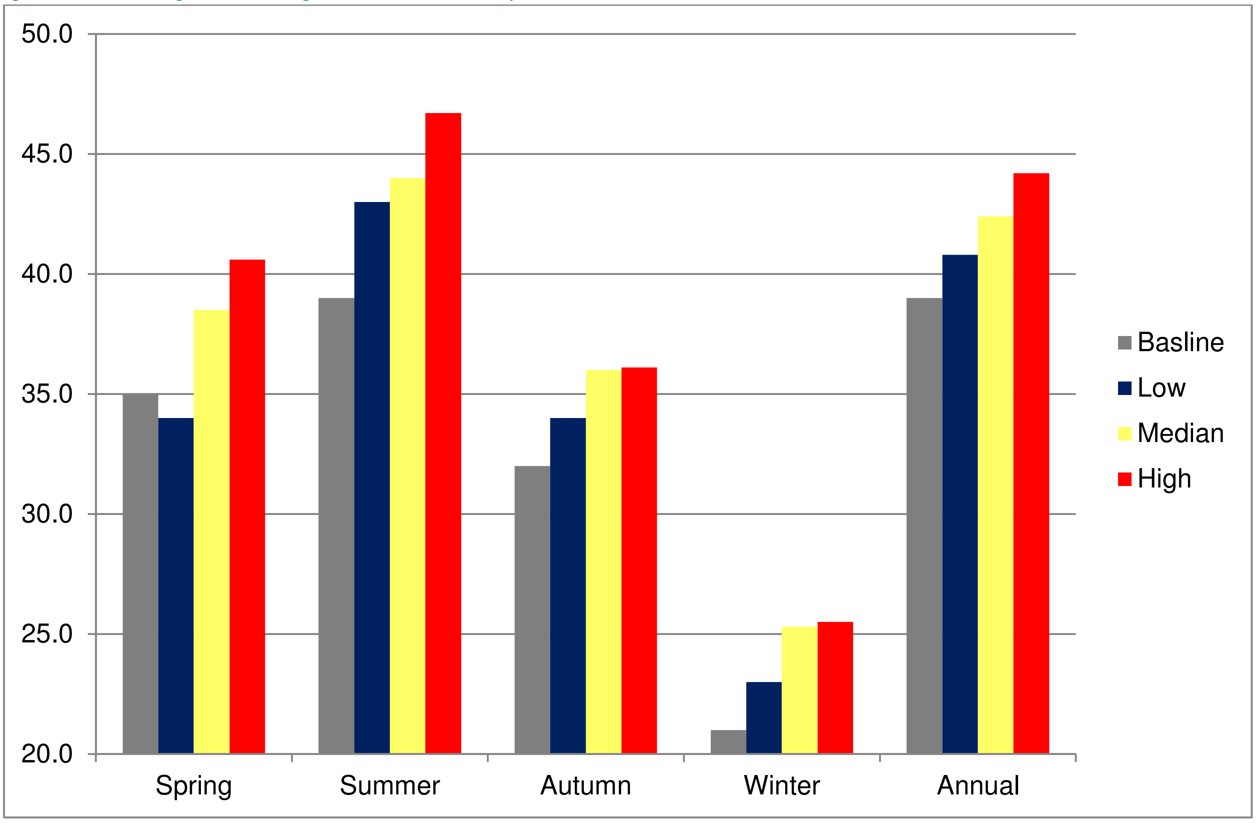
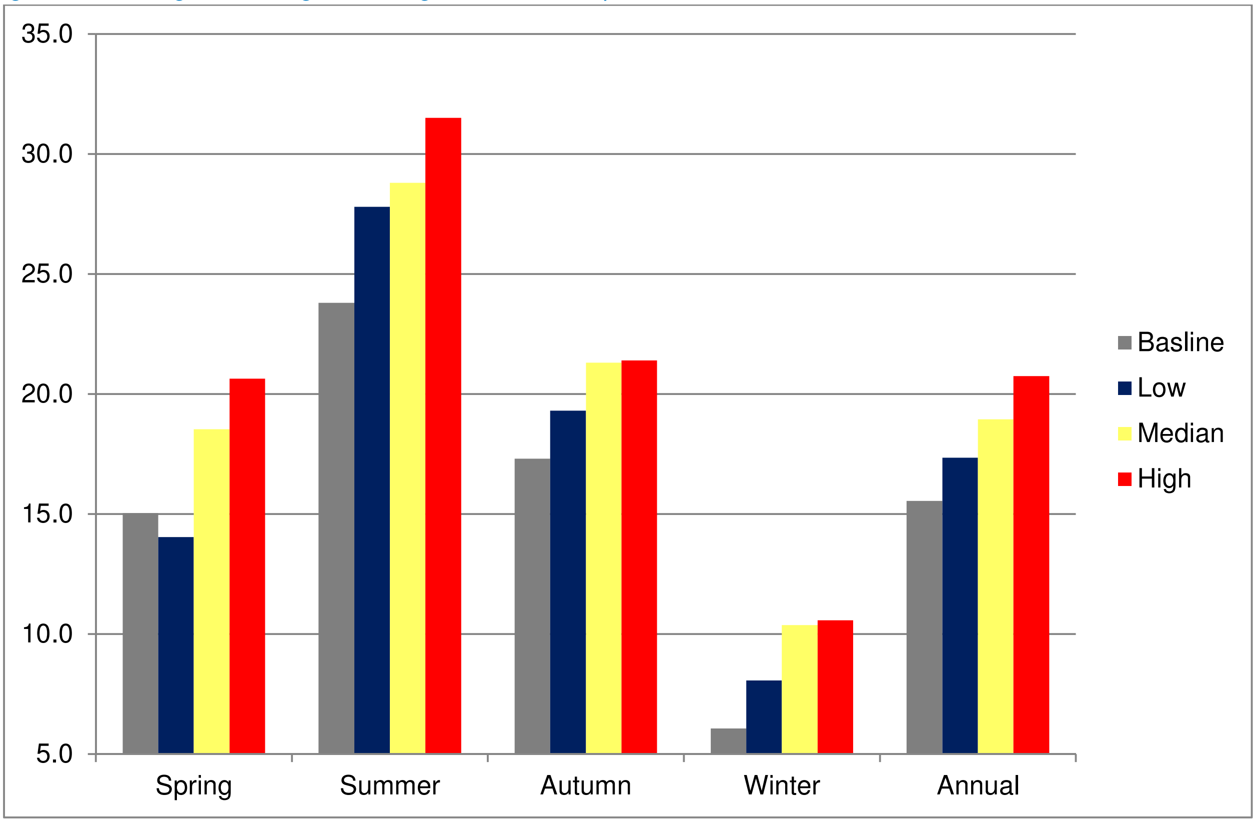


Figure A.4: Long term change in average maximum temperature



A.3 Humidity

Table A.8: Relative Humidity (%)

	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	year
Khulo	69	69	68	64	66	72	77	75	74	70	66	65	70
Keda	78	76	73	70	73	76	80	82	83	81	79	77	77

A.4 Wind

Table A.9: Wind Speed (m/s)

	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	year
Khulo	2.8	2.9	2.8	2.8	2.5	2.4	2.2	2.2	2.2	2.4	2.6	2.8	2.6
Keda	1.0	1.0	1.4	1.6	1.6	1.6	1.4	1.3	1.2	1.0	0.9	0.8	1.2

A.5 Evaporation

The Georgian Academy of Science, Vakhushti Institute of Geography has prepared and published (Author V.K.Gvakharia) a book entitled “Evaporation from the reservoir surfaces of Caucasus”, where the evaporation from a 20m^2 water tank is presented.

Table A.10: Evaporation Estimates for Khulo and Keda

	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	year
Khulo													
mm/month	46	45	68	95	125	125	126	149	116	98	73	58	1124
mm/day	1.5	1.6	2.2	3.2	4.0	4.2	4.1	4.8	3.9	3.2	2.4	1.9	
Keda													
mm/month	16	19	43	72	93	108	112	121	87	62	35	21	789
mm/day	0.5	0.7	1.4	2.4	3.0	3.6	3.6	3.9	2.9	2.0	1.2	0.7	

Georgian Academy of Science, Vakhushti Institute of Geography

A.6 Precipitation

During winter in the higher zones of the basin precipitation is in the form of snow. This Section describes rainfall and the next section snow.

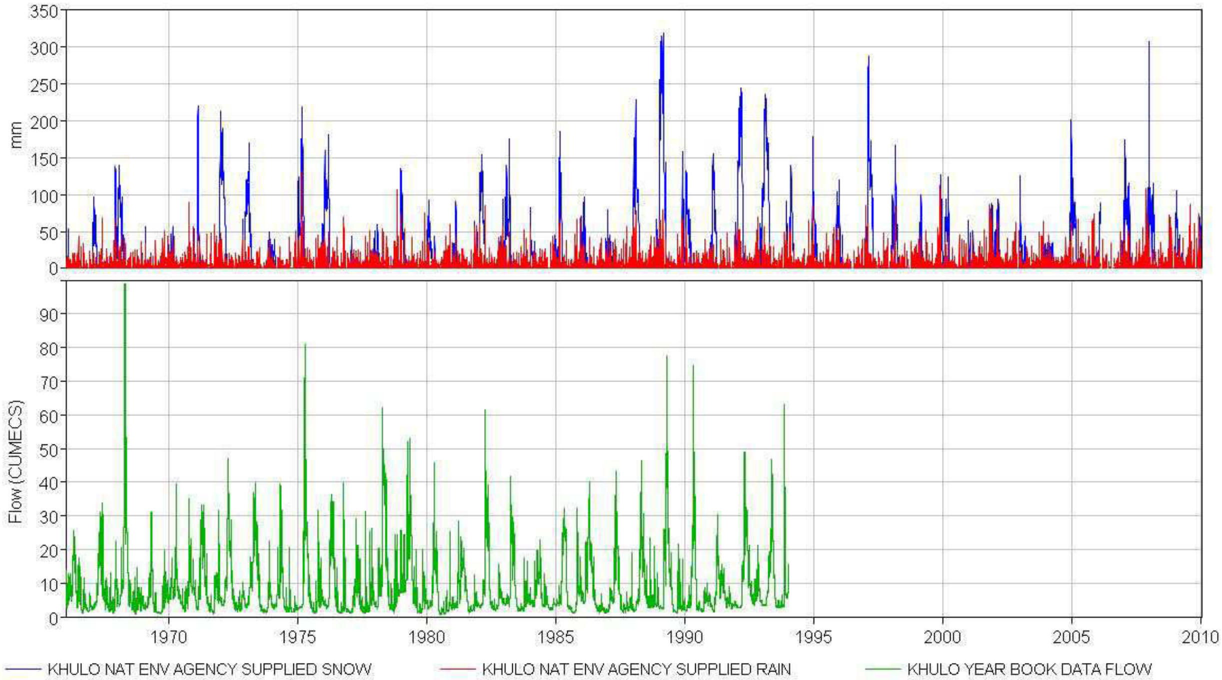
Table A.11: Long Term Average Rainfall (mm)

	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	year
Didachara	152	114	98	67	77	78	64	61	89	144	150	130	1224
Khulo	164	125	105	71	83	85	69	65	97	155	162	140	1321
Shuakhevi	133	100	86	59	68	69	57	54	79	125	132	114	1076
Keda	186	166	132	76	74	83	94	98	161	217	202	163	1652
Purtio	123	90	86	57	67	68	55	52	77	124	128	107	1034
Makhunceti	202	173	144	80	69	120	132	165	222	256	209	207	1979
Sikhalidzeebi	174	131	112	78	89	90	75	70	103	165	172	148	1407
Khikhadziri	181	136	116	80	91	93	76	71	105	170	177	153	1449

Source Climate reference book, USSR, Edition 14, 1967

The higher rainfall at Makhunceti is related to influence from the Black Sea. Figure A.5 illustrates the relationship between snow depth and rainfall and between these two records and daily flow at Khulo.

Figure A.5: Rainfall, Snow and Flow at Khulo



Source: NEA data

Figure A.6: Projected change in annual precipitation (mm)

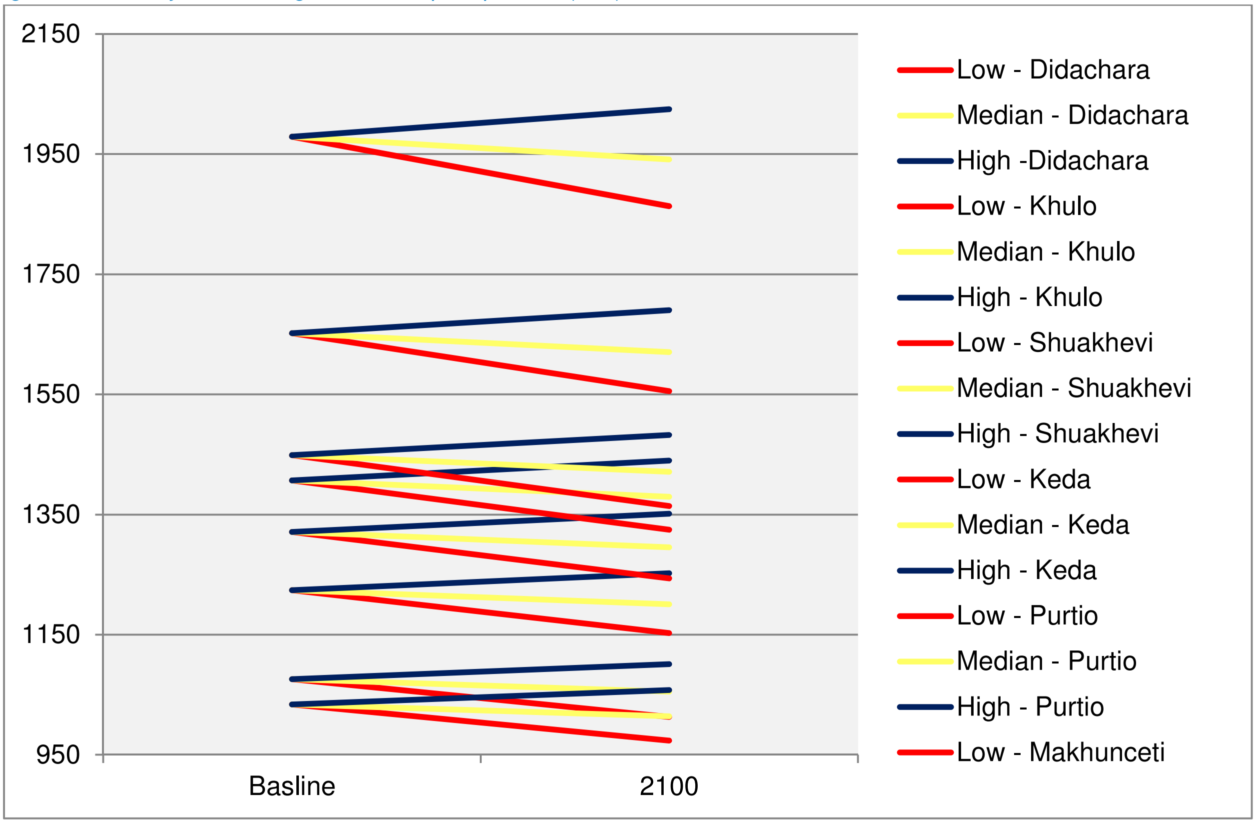


Figure A.7: Projected change in spring precipitation (mm)

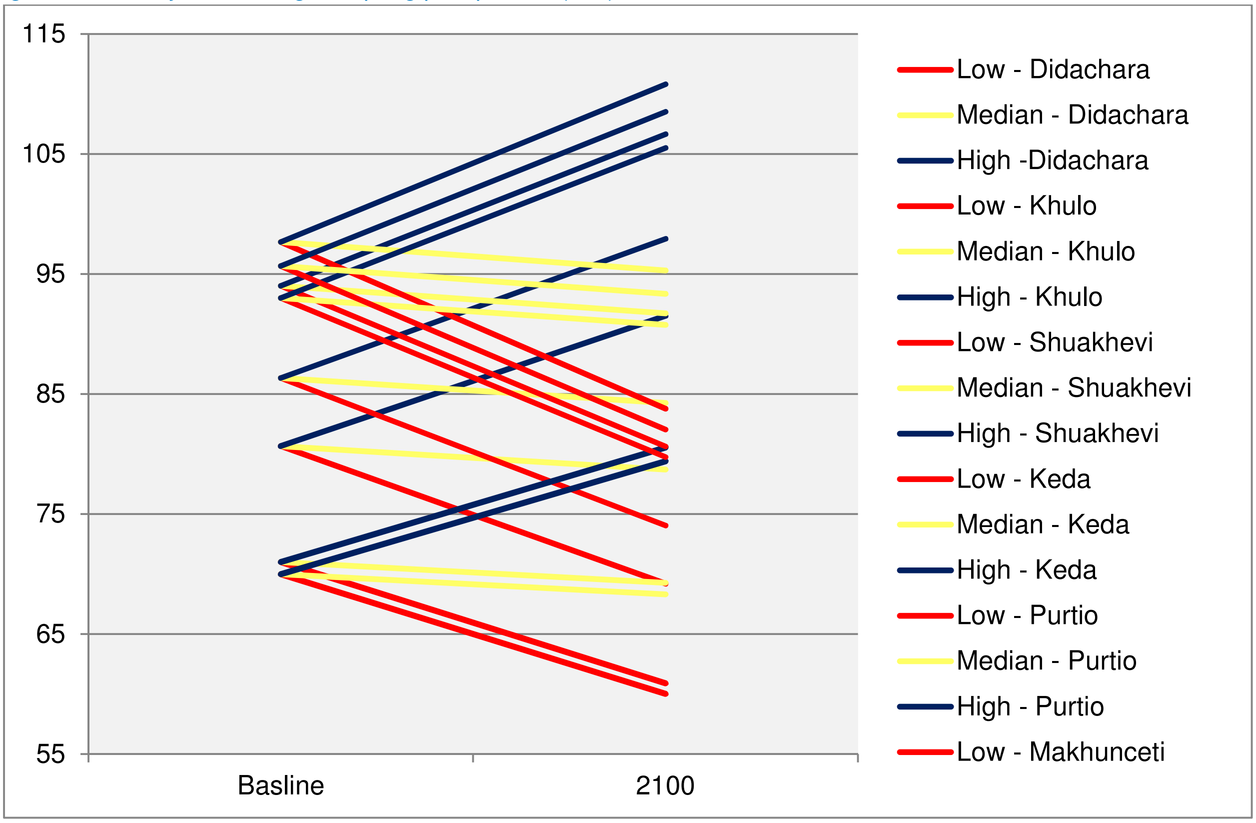


Figure A.8: Projected change in summer precipitation (mm)

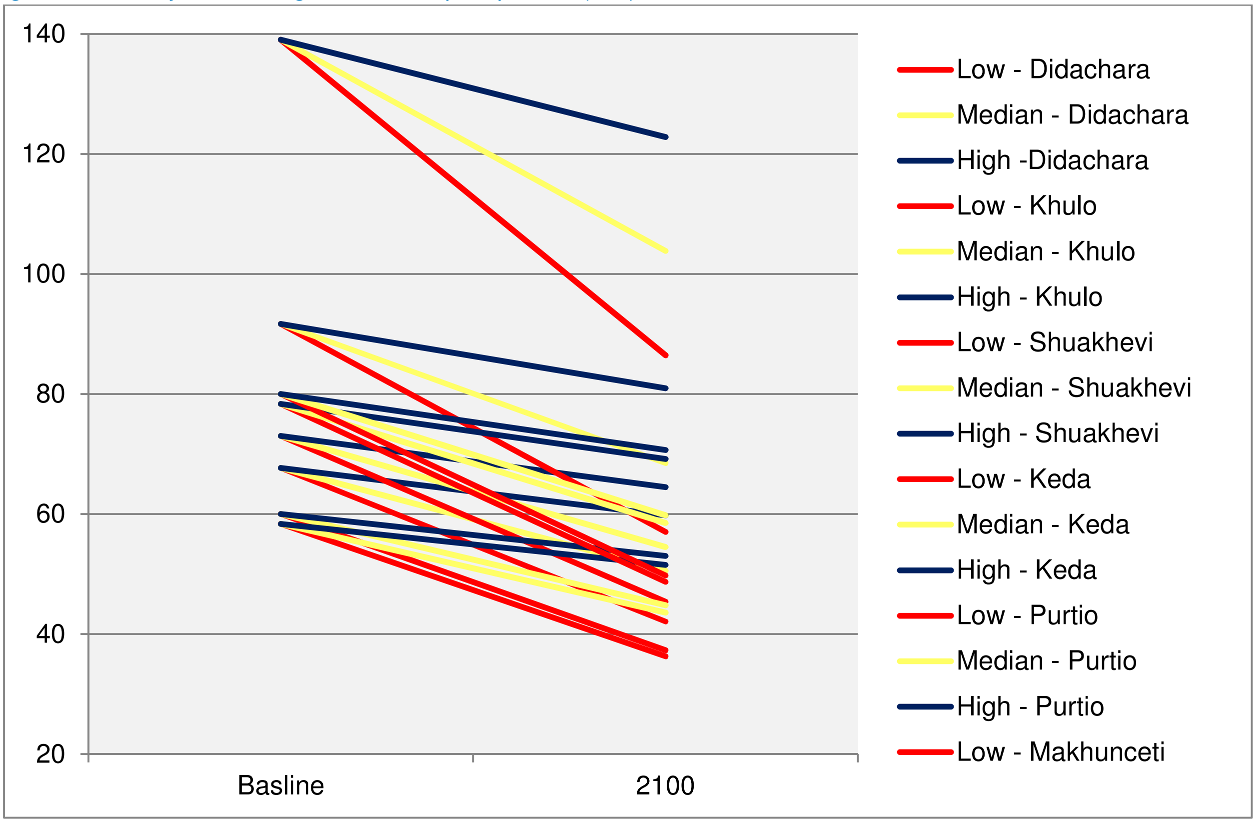


Figure A.9: Projected change in autumn precipitation (mm)

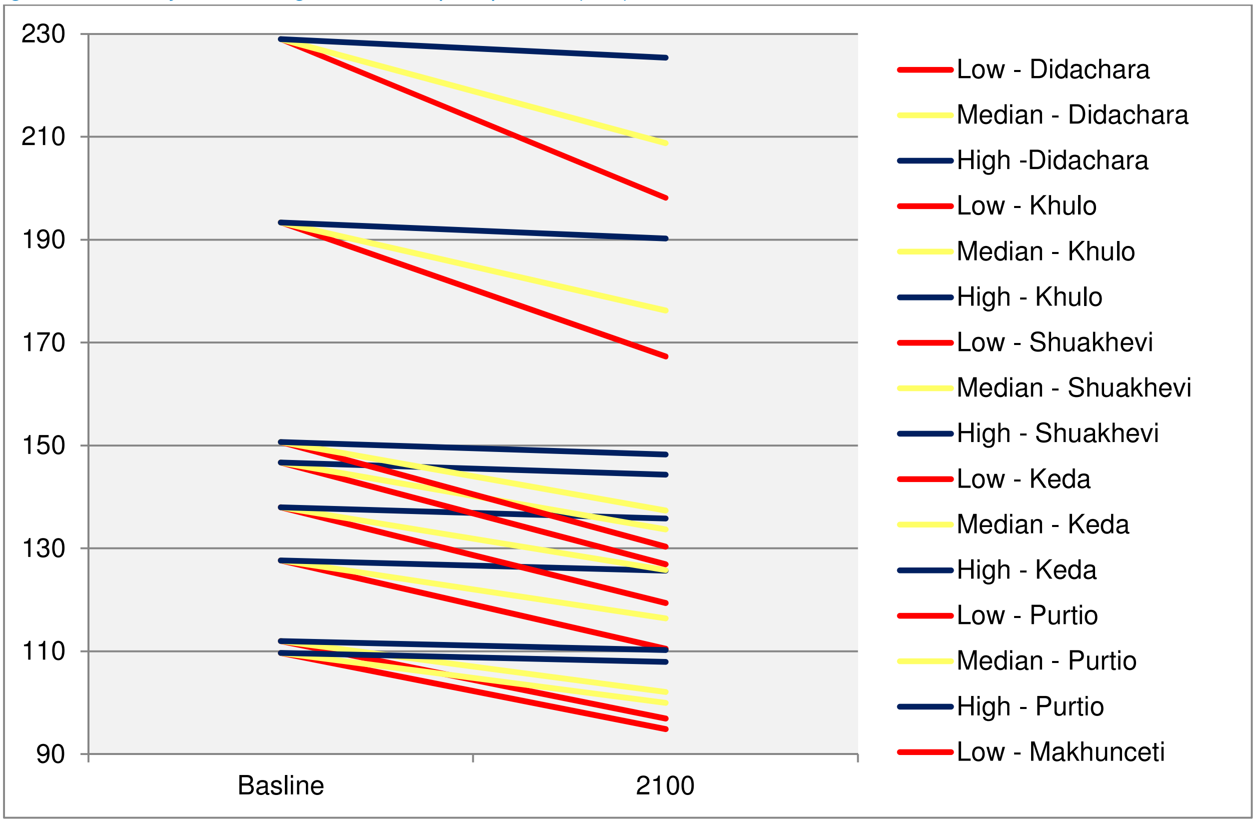


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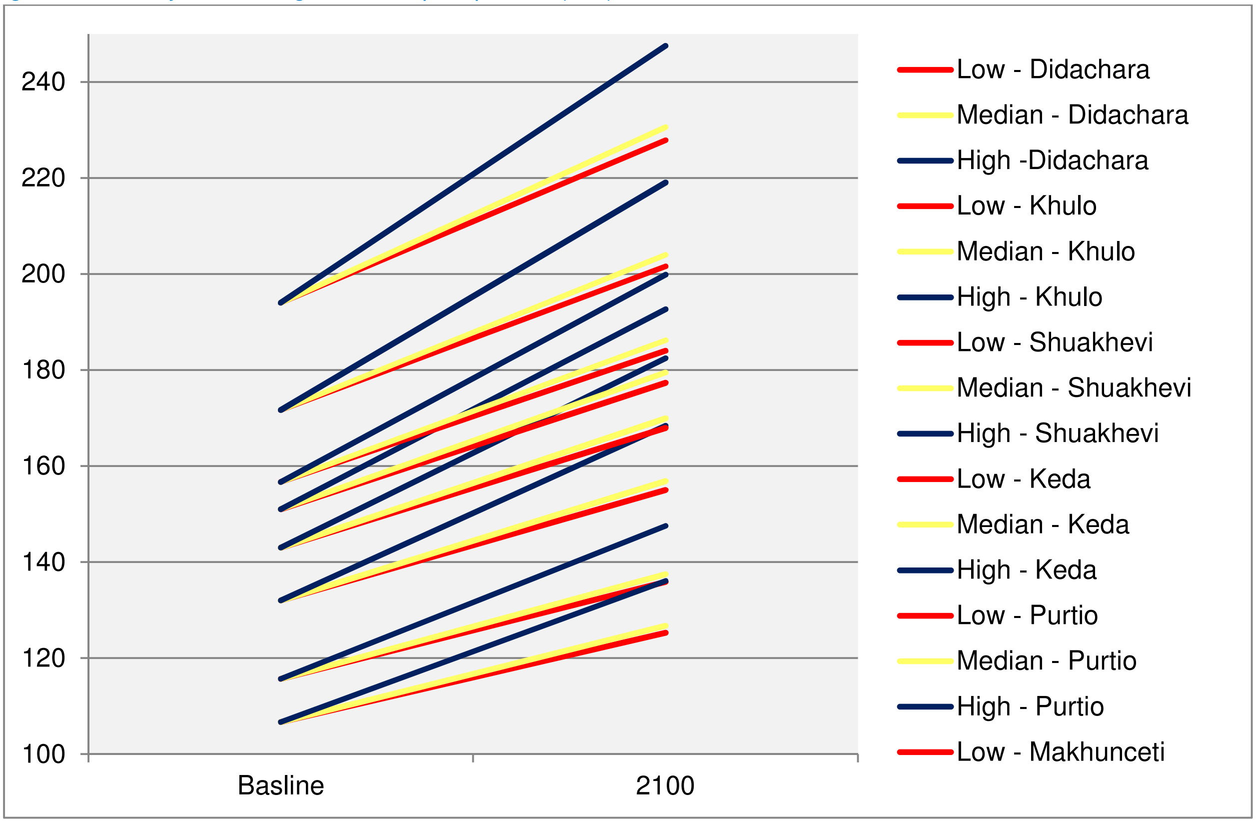
Figure A.10: Projected change in winter precipitation (mm)



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A.6.1 Snow

The average snow depth over 10-day periods (decads) varies between 52 and 82cm. The maximum depth observed in Khulo is 248cm and at Keda is 235cm, and the corresponding minima are 12cm and 11cm. The average number of days with snow in Khulo is 73 days, and in Keda 39 days. The earliest snow in Khulo is recorded in the beginning of October, the latest snow date is observed to be the first of May.

Table A.12: Snow Cover Average Decad Depth (cm)

Month	XI			XII			I			II			III			IV		
Decad	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
Didachara	✓	✓	16	17	17	20	27	28	42	56	55	50	40	37	17	✓	✓	✓
Khulo (open)	✓	✓	✓	12	14	20	23	32	43	44	38	33	25	24	11	✓	✓	✓
Khulo (covered)	✓	✓	13	15	16	19	21	25	35	51	38	37	27	25	12	✓	✓	✓
Shuakhevi	✓	✓	✓	✓	✓	6	9	10	27	32	26	21	17	11	✓	✓	✓	✓
Keda	✓	✓	✓	✓	✓	6	14	17	25	29	25	21	13	11	✓	✓	✓	✓
Sikhalidzeebi	✓	✓	✓	✓	✓	10	15	16	34	43	40	32	22	19	✓	✓	✓	✓
Sindieti	✓	✓	✓	✓	✓	✓	✓	✓	28	39	29	28	18	12	5	✓	✓	✓

Note: ✓ indicates very low snow cover.

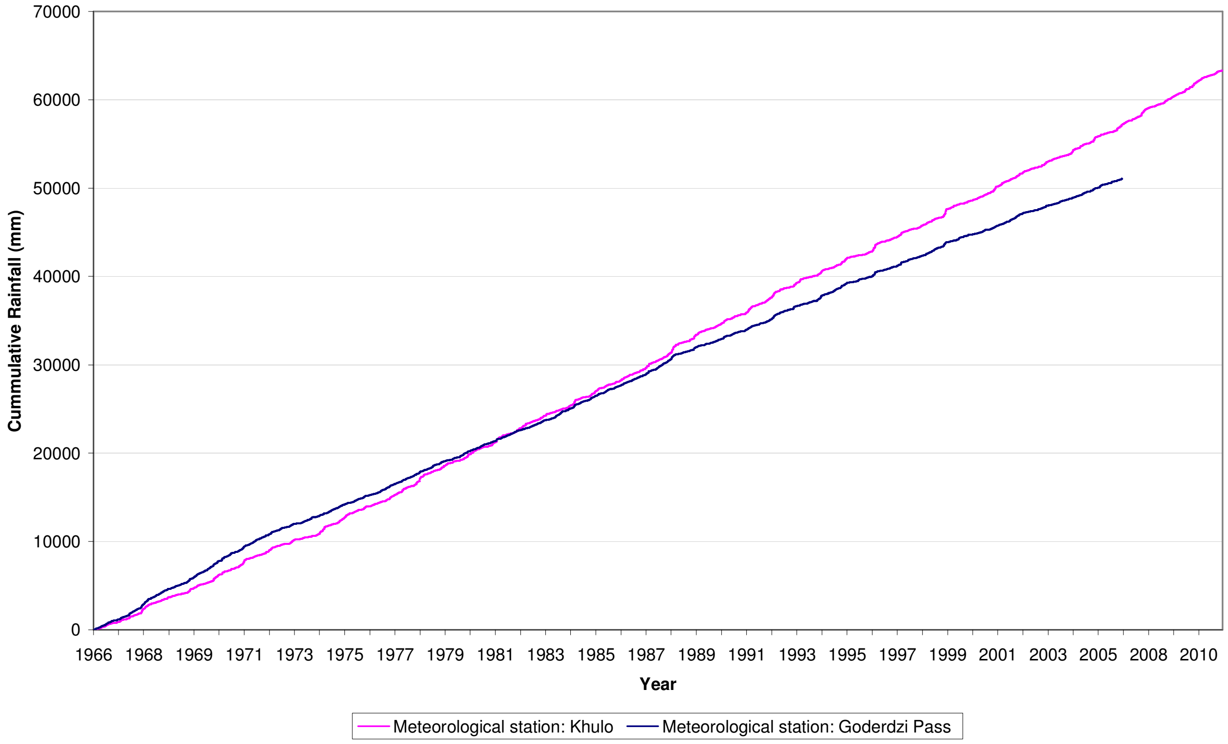
A.6.2 QA/QC of Historical Precipitation Data Series

Single mass and double mass analyses on the daily NEA data are illustrated below for the two key stations – Khulo which has the longest data set and Goderdzi Pass which is the only high elevation gauge in the Adjaristsqali River basin. The NEA data was sourced from the “Year Book” (1966-1992) supplemented by more recent data (1993-2010) provided by NEA.

The single mass plot indicates that while the record for Khulo appears to be consistent throughout the available period, the record at Goderdzi has inconsistencies which lead to changes in slope in the single mass curve. The first occurs in August 1973 and the second in March 1989.

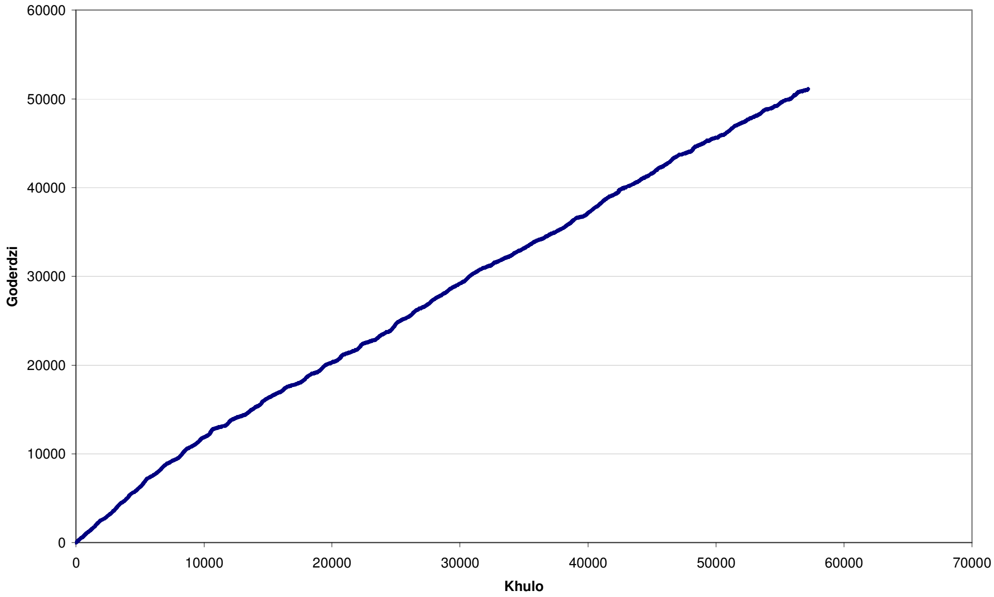
The inconsistencies in the Goderdzi record are also evident, but to a lesser extent, in the double mass plot.

Figure A.11: Single Mass Check – Khulo and Goderdzi Pass Rainfall



Source: NEA Data

Figure A.12: Double Mass Check – Khulo and Goderdzi Pass Rainfall



Source: NEA Data

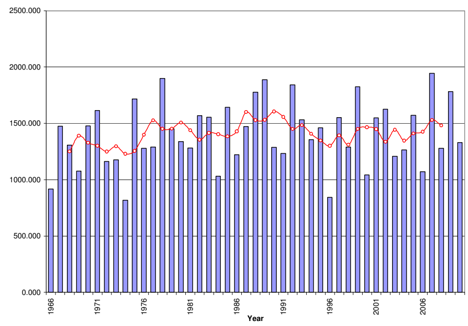
As for the flow records a review was carried out for consistency in the annual records including trend analysis.

A trend analysis on the Khulo and Goderdzi records gives conflicting results which may be due to data quality issues (Below).

The 5-year running mean of the annual rainfall at Khulo has a positive trend to around 1989 when it tends to level off. Three of the seven trend statistics tested gave a significant result indicating that the trend visible in the annual data (and its 5-year mean) is significant.

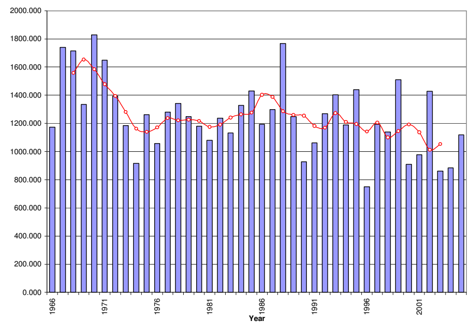
The trend analysis carried out for the Goderdzi record exhibits a visually more evident trend, although in this case it is a downward trend. However, only two of the five trend statistics tested gave a significant result as a result of the relatively short record period.

Figure A.13: Trends in Annual Precipitation: Khulo



Source: NEA, Year Book Data

Figure A.14: Trends in Annual Precipitation: Goderdzi



Source: NEA, Year Book Data

A.7 Flooding

Figure A.15: Range of projected change in maximum daily precipitation