IMPACT OF CLIMATE CHANGE ON HYDROPOWER PROJECTS IN NORTHERN REGION OF PAKISTAN

THESIS RESEARCH PROPOSAL
For
M.SC IN WATER RESOURCES ENGINEERING
DEPARTMENT OF CIVIL ENGINEERING

SUBMITTED BY:
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S.No	Subjects	Completed/IP
1	Surface Water Hydrology	A
2	Water Resource Engineering	A-
3	Open Channel Flow	A-
4	River Mechanics	A-
5	GIS in Water Resource Engineering	Result Awaited
6	Introduction to Bridge Engineering	B
7	Statistical Hydrology	A
8	Dam Engineering	A
9	Climate Change in Water Resources	B+
10	Research Methodology	In Progress

CGPA= 3.67

SECTION # 1 IMPACT OF CLIMATE CHANGE ON HYDROPOWER PROJECTS IN NORTHERN REGION OF PAKISTAN

1.1 Introduction

Global warming induced impact of climate change on water resource distribution in the form of variability in intensity and volume are increasingly being witnessed around the globe including South Asia (Khalid, Qasim, & Farhan, 2013). Hydropower projects are direct recipients of climate change in-terms of altering river hydrology and water availability which indirectly transcends to increased greenhouse gas emissions by relying more on alternate non-renewable sources of energy (Berga, 2016). Pakistan's climate is diversified by virtue of its large latitudinal extents and significant variations in its geography resulting in many feasible sites across the region for Hydropower generation. Its Northern Region consists of three mountain ranges collectively known as the Hindukush-Karakoram-Himalaya (HKH) regions the predominant source of fresh water resource and plays a vital role in the water, energy and food security of the country (Hussain et al., 2016). The recent Intergovernmental Panel on Climate Change (IPCC) report ("Climate Change 2014 Synthesis Report Summary Chapter for Policymakers," 2014) clearly indicates the likelihood of considerable warming over sub-regions of South Asia, with greater warming in winter than in summer . The analysis of climatic trends using representative regional climate models (RCM's) coupled with different scenario outcomes (RCP4.5 and RCP8.5) for assessing the impact of changing climate on the current and future hydropower schemes in the country's extreme north is crucial for accurate planning, adaptation and mitigation strategies.

1.2 Problem Statement

The adverse impact of changing climate manifesting itself in the form of unpredictable fluctuations in the hydro-meteorological variables i-e precipitation, maximum temperature and minimum temperature; and its likely effect on hydropower schemes in the northern region of Pakistan.

1.3 Aims & Objectives

To assess:

1- Impact of climate change on the fluctuations of hydro-meteorological variables i-e precipitation, max temperature and min temperature on HPP's with the help of representative Regional Climate Models (RCM's) coupled with IPCC AR5 recommended scenarios (RCP4.5 and RCP8.5) using World Climate Research Programme (WCRP) project on Climate Variability and Predictability (CLIVAR) Expert Team on Climate Change Detection, Monitoring and Indices (ETCCDMI) recommended Climate Indices Approach.

2- Provide a set of recommendations based on above analysis for better planning, utilization, adaptation and mitigation strategies in the medium to long-term operations of the most-likely effected HPP's.

SECTION # 2 LITERATURE REVIEW & CONCEPTUAL FRAMEWORK

Surface water availability is largely dependent on the snowmelt from the Hindukush-Karakoram-Himalaya (HKH) region in the north of Pakistan. (Ul Hasson, Böhner, & Lucarini, 2017) while studying the prevailing climatic trends, found warming and drying of spring and increasingly early melt season flows from most of the sub-regions, likely due to a rapid snowmelt. However, in most of the central Karakorum sub-regions significant cooling phenomenon within the monsoon period (particularly in July and September) coinciding well with main glacier melt season was observed; indicating dominance of nival but suppression of the glacial melt regime. (Immerzeel, Droogers, de Jong, & Bierkens, 2009) observed that the snow and glacier melt runoff's from the HKH region together constitute around 70% - 80% of the mean annual water availability from the upper Indus basin (UIB). (Archer & Fowler, 2004) found an insignificant trend through the analysis of long-datasets from 1895 but a significant trend for 1960-1999 period was found for precipitation at seasonal and annual scales at several meteorological stations, with a positive correlation observed for winter precipitation over the entire Upper Indus Basin. For the same period, (Fowler & Archer, 2006) observed increase in winter mean and maximum temperature and decrease in summer mean and minimum temperature over the Karakoram and Hindu-Kush mountains, aptly supported by the increase in diurnal temperature range. (Islam, Rehman, & Sheikh, 2009) documented increase in daily minimum temperature during summer season as compared to maximum temperature whereas for winter season maximum temperature change was greater using PRECIS RCM with 1961-1999 as recent climate and 2071-2100 representing future climate. (Res, Khattak, Babel, & Sharif, 2011) found significant increase in maximum temperature during winter and spring season with almost insignificant precipitation trend over the UIB for 1967-2005 period. It is noteworthy that these findings are based upon at least a decade old data records. Analyzing updated data for the last three decades (1980–2009), (Bocchiola & Diolaiuti, 2013) suggested that winter warming and summer cooling are less general than previously thought, and can be clearly assessed only for Gilgit and Bunji stations. They found a mostly insignificant precipitation increase over the Chitral–Hindukush and northwest Karakoram but a decrease over the Greater Himalayas. Analyzing temperature record for recent six decades (1952–2009), Río et al. (2013) also reported dominant warming during March and pre-monsoon season.

In case of the Jhelum river basin, (Mahmood & Jia, 2017) performed trend analysis of 21 historical climate stations data and observed increasing trends in maximum and minimum temperature in the basin, with the trend in maximum temperature being relatively stronger and statistically significant than minimum temperature. The western parts of the basin observed significant warming phenomenon compared to the other parts of the basin. As for the precipitation, non-significant trends were observed spread evenly throughout the basin; with only 5% - 10% of the stations disclosed significant trends. Collectively, precipitation showed decreasing trends in the basin with the exception of winter season. Additionally, the seasonal and annual streamflow's showed a dominant decreasing trend in the basin aptly showcasing the prevailing rising temperature and falling precipitation trends. (Azmat, Uzair, Huggel, & Hussain, 2018) while examining the impact of climate change in the Jhelum river basin using carefully selected four CMIP5 GCM projections, observed intra-annual rise in precipitation during monsoon periods using RCP4.5 projection scenario and a rise in maximum and minimum temperature during the pre-monsoon periods for RCP8.5 ; consequently resulting in an expedited and increased snowmelt runoff's. Overall, the pre-monsoon period is most affected under scenario projections with has the potential of altering the precipitation of Jhelum river basin due to significant early snow- and glacier melt.

(Khalid et al., 2013) studied the impact of changing climate on Chitral basin by analyzing hydro-meteorological trends by computing 5-year and 25-year means of temperature, precipitation and river flows of 1976-2000 period. A clear increasing trend in river discharge rate from 1976 to 2000 revealed strong influence of mean maximum temperature and relatively small impact of precipitation on discharge since most of the precipitation fell during winter season (Dec-Feb) to pre-monsoon season (April-May). Similarly, (Ahmad et al., 2018) observed that the Snow Cover Area (SCA) in the Chitral basin is more sensitive to changes in temperature as compared to precipitation over 1967 – 2013 period. A decreasing trend in the mean temperature along with a constant trend in the precipitation over the same period resulted in an increased SCA.

SECTION # 3 APPROACH & METHODOLOGY

3.1 Data collection

The study region is extended between 71 – 82 degree's longitude and 31 – 37 latitude comprising of three gigantic mountain ranges with Himalaya at lower western latitudes, Karakoram in further north, and Hindukush in the west of Karakoram-Himalaya ranges. A network of meteorological stations is present throughout the northern region which for ease of identification could be divided into upper Indus basin, Chitral Basin, Jhelum Basin and Swat basin stations; maintained and recorded by two public sector entities namely the Pakistan Meteorological Department (PMD) and Water and power development authority (WAPDA). The meteorological observations from these stations include values of precipitation, maximum temperature and minimum temperature on a daily time-step for at least 30-years of period so as to substantiate impacts of climate change in this region of study.

Application letters duly signed by the supervisor, post-graduate advisor and the respected chairman of the department shall be mailed to the above mentioned departments for the issuance of requisite data for research purposes. Following are the list of Meteorological stations maintained by PMD and WAPDA in the northern region of Pakistan

Serial No.	Station Name	Agency	Lattitude	Longitude	Altitude(m)	
1	Khunjerab	WAPDA	36.84	75.42	4440	
2	Naltar	WAPDA	36.17	74.18	2898	
3	Ramma	WAPDA	35.36	74.81	3179	
4	Rattu	WAPDA	35.15	74.8	2718	
5	Hushe	WAPDA	35.42	76.37	3075	
6	Ushkore	WAPDA	36.05	73.39	3051	
7	Yasin	WAPDA	36.4	73.5	3280	
8	Ziarat	WAPDA	36.77	74.46	3020	
9	Dainyor	WAPDA	35.93	74.37	1479	
10	Shendoor	WAPDA	36.09	72.55	3712	
11	Deosai	WAPDA	35.09	75.54	4149	
12	Shigar	WAPDA	35.63	75.53	2367	

Serial No.	Station Name	Agency	Lattitude	Longitude	Altitude(m)	
1	Chilas	PMD	35.42	74.10	1251	
2	Bunji	PMD	35.67	74.63	1372	
3	Skardu	PMD	35.30	75.68	2317	
4	Astore	PMD	35.37	74.90	2168	
5	Gilgit	PMD	35.92	74.33	1460	
6	Gupis	PMD	36.17	73.40	2156	
7	Balakot	PMD	34.55	72.35	995	
8	Chitral	PMD	35.85	71.83	1498	
9	Dir	PMD	35.2	71.85	1375	
10	Drosh	PMD	35.57	71.78	1464	
11	Saidu Sharif	PMD	34.73	72.35	961	
12	Kalam	PMD	35.83	72.98	2103	
13	Malam Jabba	PMD	34.75	72.90	2591	
14	Mir Khani	PMD	35.50	74.70	1250	
15	Garhi Dupatta	PMD	34.22	73.62	813	
16	Kotli	PMD	33.52	73.90	614	
17	Rawalakot	PMD	33.87	73.68	1677	
18	Muzaffarabad	PMD	34.37	73.48	702	

3.2 Data Analysis

The acquisition of observed data from the PMD and WAPDA will be checked against consistency for precipitation, maximum temperature and minimum temperature as the below zero precipitation, maximum temperature lower than minimum temperature need to be corrected. Additionally, (Wang & Feng, 2009) suggested the RHTestV3 to identify any number of change points in the time series.

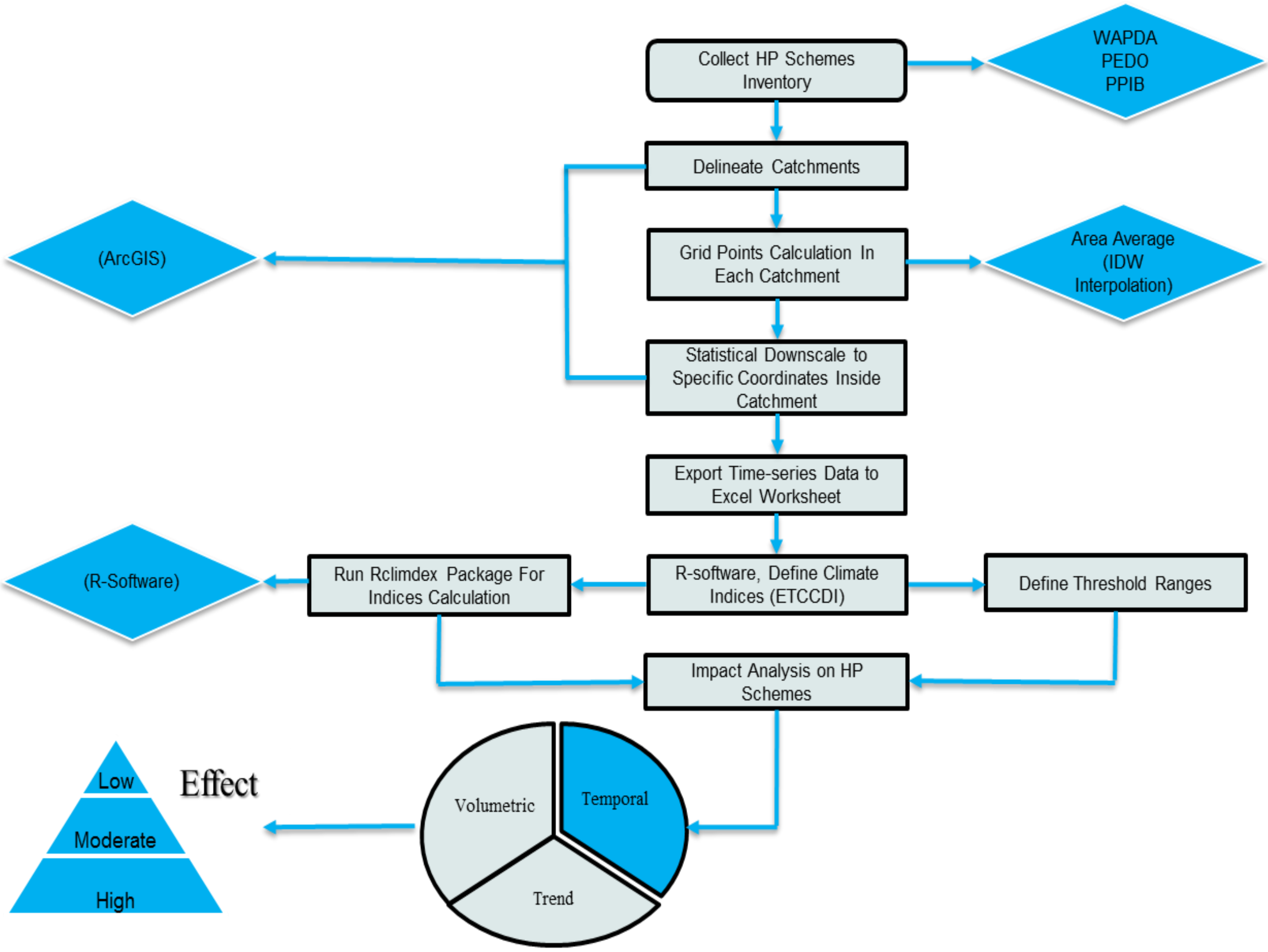
The output data of climate models for the period that is to be decided depending upon data availability of RCM datasets and its suitability to the geographical region under study. These RCM's will be used for the extraction of the time series of temperature and precipitation for the corresponding location of meteorological stations stipulated above. These data will be used to compare with observed station data for the purpose of correlation analysis and then used those RCM's that have correlation analysis greater than 0.5. The resolution of these RCM datasets is finer compared to their corresponding GCM datasets and resultantly provided much improved forecasts for a particular region as compared to GCM's, respectively. The climate model's output datasets are based on future emission scenarios of the Representative Concentration Pathways (RCP) RCP4.5 with 4.5Wm−2, and RCP8.5 with 8.5Wm−2 radiative forcing by 2100 are most often used as it incorporates the realistic and worst case scenarios for the most likely future forecasts.

These climate datasets have inherent biases which if not addressed or removed could lead to unrealistic results. The Best Easy Systematic (BES) estimator is used for both temperature and precipitation. Although the BES method is good for temperature, its performance is low for precipitation. The Mean Monthly Correction Factor (MMCF) method is another such method used for precipitation bias correction but Bias correction of projected datasets against the observed data should employ a process that preserves its future peaks and does not average out the extreme values (Ali, Li, Congbin, & Khan, 2015). One such method employed that does not alter the future peaks is Quantile Delta Mapping method that is most frequently used in hydrological forecasting and projections.

An inventory of Hydropower projects in the northern region is to be collected which are constructed, under-construction and at pre-construction phases. Freely available Shuttle Radar Topography Mission (SRTM) 1-arc second digital elevation model (DEM) is to be downloaded from United States Geological Survey Website for the whole northern region under study and mosaicked together in ArcGIS software. Delineation of watershed of all the hydropower projects is to be performed in the above mentioned software. Once the watershed areas for each HPP is determined, shape-files of meteorological stations of PMD and WAPDA will be made. RCM's are available in netcdf format for analysis, in the form of Grid Points and can be statistically downscaled to the Meteorological stations and compared with the observed data to check its correlation as well as consistency.

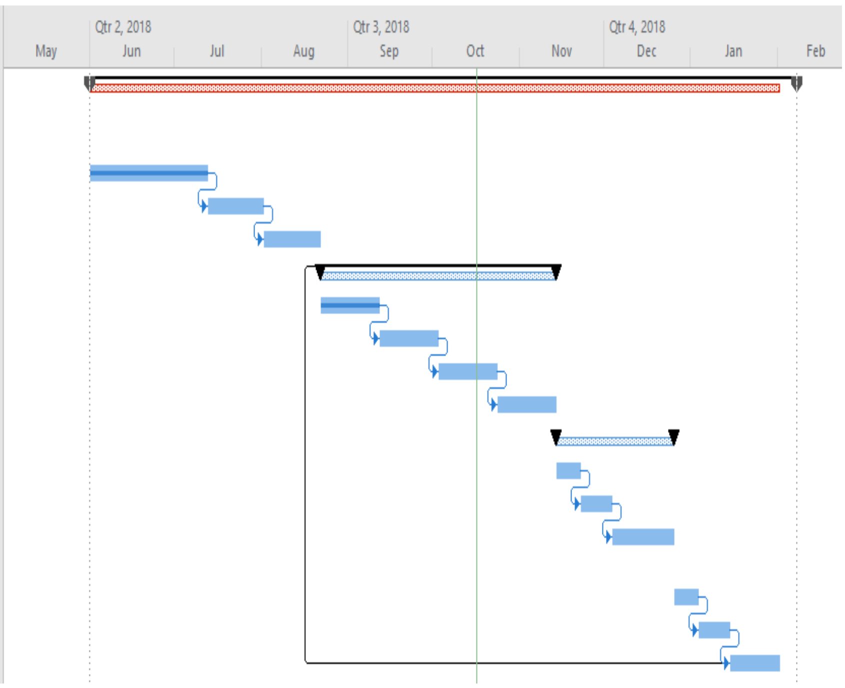
The most important step of analysis will be the introduction of climate indices approach for the climate change impact assessment on HPP in the northern region. To gain a uniform perspective on observed changes in weather and climate extremes, the joint CCl/WCRP-Clivar/JCOMM Expert Team on Climate Change Detection and Indices (ETCCDI) has defined a core set of descriptive indices of extremes. The indices describe particular characteristics of extremes, including frequency, amplitude and persistence. The core set includes 27 extremes indices for temperature and precipitation (World Meteorological Organization, 2017). Sixteen of the 27 indices recommended by the ETCCDMI are temperature related and eleven are precipitation related. They are derived from daily maximum and minimum temperature and daily precipitation. A full descriptive list of the indices can be obtained from http://cccma.seos.uvic.ca/ETCCDMI/list_27_indices.html. One of the indices has a user-dependent threshold which we have chosen not to analyze in this study. The indices were chosen primarily for assessment of the many aspects of a changing global climate which include changes in intensity, frequency and duration of temperature and precipitation events (Alexander et al., 2006). The set of climate indices from the Expert Team on Climate Change Detection and Indices (ETCCDI) will be calculated for the present and future climate under two Representative Concentration Pathways, namely, RCP4.5 and RCP8.5 (Dosio, 2016).

Finally, a powerful statistical software R will be used to compute these 27 core indices for the northern region using various RCM datasets with two IPCC emission scenarios namely RCP4.5 and RCP8.5. Xuebin Zhang and Yang Feng at Climate Research Division have developed and maintained a source code "RClimdex" that provides a friendly user interface to compute all 27 core indices in R-software. Once the indices are calculated, changes in temperature and precipitation patterns and trends will be assessed for likely impact of climate change on the HPP's in the northern region of Pakistan and subsequently its effect would be categorized under low, moderate and high depending upon the severity of climate change on HPP's.



Work Plan

The intended work schedule is as follows:



	Task Name	Duration	Start	Finish	% Co
1	Impact of Climate Change on Hydro-Power Projects In Northern Pakistan	180 days	6/1/2018	2/7/2019	26%
2	Literature Review	30 days	6/1/2018	7/12/2018	100%
3	Data Collection	14 days	7/13/2018	8/1/2018	0%
4	Data Preparation	14 days	8/2/2018	8/21/2018	0%
5	ArcGIS Simulation	60 days	8/22/2018	11/13/2018	25%
6	Catchment Delineation	15 days	8/22/2018	9/11/2018	100%
7	Grid Point Calculation	15 days	9/12/2018	10/2/2018	0%
8	Statistical Donscaling	15 days	10/3/2018	10/23/2018	0%
9	Bias Correction	15 days	10/24/2018	11/13/2018	0%
10	R-Software Simulation	30 days	11/14/2018	12/25/2018	0%
11	Climate Indices Calculation	7 days	11/14/2018	11/22/2018	0%
12	Trend Analysis	7 days	11/23/2018	12/3/2018	0%
13	Conclusion and Recommnedations	16 days	12/4/2018	12/25/2018	0%
14	Pre-Defence	7 days	12/26/2018	1/3/2019	0%
15	Defence	7 days	1/4/2019	1/14/2019	0%
16	Thesis Write-Up	14 days	1/15/2019	2/1/2019	0%

SECTION # 4 REFERENCES

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