Name of scholar:	AZHAR HUSAIN
Name of supervisor:	PROF.MOHD SHARIF
Name of co- supervisor:	PROF.MOHD SHAKEEL
Department:	CIVIL ENGINEERING

Title of Thesis: Optimal Operation of Satluj River Basin System under Future Climate Scenarios.

Abstract

Climate change represents an additional stress on ecological and socioeconomic systems in India that are already facing tremendous pressures due to rapid urbanization, industrialization and economic development. With its huge and growing population, a 7500-km long densely populated and low-lying coastline, and an economy that is closely tied to its natural resource base, India is considerably vulnerable to the impacts of climate change. Two out of three people are dependent upon agriculture and allied activities for their survival. Any changes in the patterns of rainfall are likely to result in the reduction of crop yields. The carbon emissions from transportation sector which are currently at 15% are likely to increase to 25 % in the next 10 years due to rapid growth in the transportation sector. This is likely to increase emissions of greenhouse gases which would ultimately result in the increase in temperatures. Due to increased temperatures, demand of water for agricultural activities is likely to increase.

There are several indications that climate change is indeed taking place in India. The recent droughts in northern India and unprecedented floods in parts of Southern India are seen as a manifestation of ongoing climate change in India. The year 2005 was the hottest year in the recorded history, and 10 out of the last 12 years have been the hottest. Recent drought in northern India is an indication of what changes in the patterns of monsoon could do to the country's agriculture in the coming years. A major impact of climate change is on the occurrence of extreme precipitation events leading to increase in the frequency and magnitude of extreme events such as floods and droughts. In view of the ongoing climate change, the temporal and spatial distribution of water availability is likely to be impacted.

The increasing gap between the demand and supply of water in most parts of the world has made it imperative to optimise the utilisation of available water resources. The importance of optimal operation and planning of hydrological systems has increased, particularly in view of the recent climate change. Maximum benefits, which are usually defined in some economic terms, need to be achieved without reducing the reliability of the system, thus making the whole process even more complicated. Reservoir operation models invariably use streamflow as an input. The optimal policies derived using such models are based upon the assumption of stationarity of streamflow. However, the assumption of stationarity of streamflow data cannot be justified in the context of climate change. The operation of reservoir systems is, therefore, likely to be more reliable if the impacts of potential climate change on inflow sequences are considered. Therefore,

the main objective of this research is to derive optimal storage trajectories for the Kol reservoir in Satluj River Basin for four different inflow sequences. The Satluj River is a major river of the Indus system, which originates from Mansarowar lake in Tibet. The catchment of river upto Bhakra Dam site lies between North latitudes 30^0 and 33^0 and east longitudes 76^0 and 83^0. It enters India near Shipkila at an elevation of about 2530 metres and continues to flow in Himachal Pradesh through Wangtoo and Kian before reaching Bhakra Dam. The objective of operation was to maximize the revenues from power generation subject to constraints on storages and releases from the reservoirs. The optimal storage trajectories for the Kol reservoir have been obtained for four different series of inflow sequences reflecting diverse set of climatic conditions using dynamic programming model. Reservoir operating rules have been obtained corresponding to a dry year, a wet year, a hot year and a cold year. The intent was to create an ensemble of reservoir operating rules that would correspond to diverse climatic conditions, and therefore assist reservoirs managers in decision making. The analysis of derived storage trajectories led to the conclusion that the climate change has potentially important implications for the operation of the Kol reservoir.

To put the work carried out in this thesis in context, trend analysis of hydro-meteorological data has been carried out using linear regression and non-parametric Mann-Kandall test. Also, linkages of large scale climate indices with several extreme flow measures have been investigated. Six climate indices have been examined in this research to identify linkages with extreme flow measures. The El Niño-Southern Oscillation (ENSO) is one of the best known climate signals for which teleconnections have been found with a variety of hydrological variables including precipitation (Kahya and Dracup, 1993) and streamflows (Cayan et al., 1999). The ENSO is an important source of inter-annual variability in weather and climate with a periodicity of 2–7 years. The other climate indices that have been considered include Pacific decadal oscillation, Arctic oscillation, North Atlantic oscillation, North Pacific index, and Atlantic Multidecadal Oscillation. A composite analysis approach (Hoerling et al., 1997; von Storch and Zwiers, 1999) was used to identify linkages between extreme flow measures and climate indices. Results of the composite analysis clearly indicate that changes are occurring in the flood regime for the sites examined, both in terms of the flood magnitudes (generally decreasing) and the timing of flood events (generally occurring earlier).

The present thesis also describes the estimation of design flood for the Kol Dam and Rampur sites. The design flood has been estimated for the Kol Dam site using the hydro-meteorological approach, the frequency analysis and the empirical formula. The estimation of design flood for the Rampur site has been carried out using the frequency analysis and the empirical formula as the hydro-meteorological approach could not be applied due to non-availability of physiographic data at the Rampur site. Using the design flood values, the risk of failure of a structure during various construction periods has been computed and presented in the thesis.

The analysis presented herein is likely to lend credibility to recent climate change modelling efforts for a basin fed by Himalayan rivers that are anticipated to experience potentially serious impacts of climate change. Finally, implementation of models developed in this work is straightforward due to the ease of interfacing.