Hydrologic analysis in a region with Cascade of Hydropower Plants- A Review Paper

Anaz. A[*], Tamilselvan. K[+], Sudharsanan. R[@] Dr. Ravikumar. G[#]

[*] PG student in HWRE, CWR, Anna University, Chennai-25, India, anazahameed@gmail.com.

[+]Ph.D. Scholar in HWRE, CWR, Anna University, Chennai-25, India , tamilselvank40@gmail.com

[@]Assistant Professor of Civil Engineering,Velammal Engineering College, Chennai-66, India, civil.sudharsanan@velammal.edu.in

[#]Professor of Civil Engineering, CWR, Anna University, Chennai-25, India, grk6617@gmail.com.

***Abstract*— Hydropower is one of the dominant renewable sources of energy. It is a clean and Eco- friendly. An efficient Hydropower production system could be run by knowing the complete details of the surface water flow around the system and their contribution towards the river stretch in which the system is built. The study is carried out in a region around which Series of barrages are put in place for every 9m fall of head downstream of Mettur dam along a 100 kilometre stretch in the Cauvery river in Erode District, Tamil Nadu, India. Most of the Barrages failed to obtain the required head for the power production due to the insufficient heading up of water in the barrages and obstructions in the tail race of the channel against the free flow. The thesis aims a hydrologic analysis in and around the system to optimise the power production by obtaining the required head in each Barrage. In this study, Rainfall-Runoff contribution towards each Barrage from the surrounding watershed were evaluated using SWAT and GIS Interface along with the constant discharge through each Barrage and also the estimate of Return flow from the Command area surrounding the Barrages will helps to suggest some optimisation strategy for the proper allocation of water in both wet and dry seasons in the Barrages. The literatures were reviewed in such a way that to get the understanding about the Hydrologic study around cascade Hydropower plants to optimize the Hydro power production by using different strategies of water allocation and management. Most of the paper, the study was done by using some numerical hydrological models. The main aim of the study was to improve the margin of hydropower production.**

***Keywords*— Barrages. Command area. Return flow. Surface flow .Cauvery river**

I. Introduction

Hydro power is one of the dominant renewable sources of energy. It is a clean and Eco- friendly energy which is not only used for the social development and human welfare but also acts as a catalyst for development in the New Millennium. They tried to improve their development in hydropower by constructing cascade of hydropower plants, but the scenario remains unchanged with inefficient reservoir operations, poor management techniques, improper designs and insufficient water in the reservoir during drought times.

An efficient Hydropower production system can be run by knowing the complete details of the surface water flow around the system and their contribution towards the river stretch that the system built.

Some papers were reviewed based on the Hydrologic Study done in different parts of the world including India. Most of the paper illuminating how to use the water in a sustainable manner. Different type of numerical models like SWAT, HEC-HMS, FREQ2000 where used for the Study. Neelakantan, *et al* did a Study in Cauvery basin to restore the tanks in an economical way by doing mining operation in tank. Bansode S, *et al* and Wu Kangsheng, *et al* did some water balance study using SWAT model aided with some GIS Interface. Both of them analysed the water stresses in their region and how the parameters like Precipitation, Evapotranspiration etc are varying in their particular regions. Yadav, *et al* did some study in Beri Babi river, how to maintaining minimum water depth/flow in Bheri river and minimizing decreased water temperature in Babai river after diverting water from Bheri to Babai River through a tunnel. From the above studies, it is clear that we needed a replica(Model) of the system which may be a Physical or Numerical for the Hydrologic analysis study in my region. We choose Quantum GIS Interfaced SWAT Model for the Hydrologic

ISSN 2229-5518

analysis of the region and going to do a Return flow analysis Study apart from the above Studies using the SWAT Model itself.

II. OBJECTIVE

- To study the hydrology of watersheds around the Hydropower Plants.
- Performance analysis and Optimization of Hydropower Plants (HPPs) in Cascade using a Water balance and management approach.
- To estimate the average annual return flow from the command area after irrigation.

III. EARLIER RESEARCH

The literatures were reviewed in such a way that to get the understanding about the Hydrologic and hydraulic study around cascade Hydropower plants to optimize the Hydro power production by using different strategies of water allocation and management.

A. HYDROLOGIC ANALYSIS AROUND HYDRO POWER PLANTS

Neelakantan *et al,* Delta region of the Cauvery river in India is well known for paddy cultivation for centuries. Due to increased competition on river water sharing over the past century, availability and reliability of water in this region is dwindling. Changes in management practices, which caused the deterioration of traditional tank (relatively small reservoir) irrigation systems, and the difficulties in reviving them are discussed in this paper. Increasing the storage capacity of irrigation tanks for augmenting water availability for irrigation is discussed in detail. Managing the huge cost involved in deepening the heavily silted tanks in a sustainable manner is suggested through allowing mining activities in the tanks. Sample study on the suitability of soil for commercial uses indicates the possibility of mining in the tanks.

Bansode *et al*, The factors influencing decrease in water level are related to one another, such as scanty rainfall, excess evaporation, landuse changes, deforestation and smaller amount of groundwater recharge which fall out into inadequate supplies in most parts of Maharashtra. To meet the demands of the area; proper planning for judicious use of limited resources is essential. The study has been carried out to determine the availability of resources in small watershed which lies in Gangapur District, Maharashtra. The analysis has been carried out by using QSWAT 1.2 for time period of 33 years from 1979 to 2012. Daily data of precipitation, temperature, radiation, wind velocity and solar radiation has been processed on monthly time scale. After proper watershed delineation; the graphical and numerical summary of the simulated results for hydrological parameters such as Actual Evapotranspiration, Groundwater Contribution, Potential Evapotranspiration and Surface runoff are represented**.**

Kangsheng *et al*, Hydrology is critical to evaluate interactions among climate change, water cycles, and aquatic ecosystems. Complexity of hydrologic cycle makes modeling approaches necessary. In this study, a spatially-distributed hydrologic model--Soil & Water Assessment Tool (SWAT)--was examined for its applicability in a Northern Michigan watershed, a 3,460 km2 drainage basin to Lake Superior. Daily stream flow records were used for model calibration (1969-1971) and validation (1972-1973). A deviation of total stream flow and Nash and Sutcliffe coefficient values were 0.46 % and 0.94, and 8.34 % and 0.83 during calibration and validation periods, respectively, indicating a satisfactory simulation and capability of the SWAT model in the snow melting-dominated watershed. The study found that two hydrologic parameters were critical to the snow melting algorithm. The results suggest that accuracy of the SWAT model and snow melting algorithm could be improved by reducing spatial variations of daily air temperature and precipitation measurements.

Hongbo *et al*, The Taoer River, a representative ecologically sensitive area in Northeast China, has undergone great climate changes and rapid social developments since 1961. Subsequently, a substantial alteration of the stream flow regime was observed and severe eco-environmental problems were becoming prominent. To provide decision makers the scientific basis for effective resource management and sound future planning, it is crucial to understand and assess the impacts of the climate variability and human activities on stream flow in this region. In this study, they combined an observation-based statistical analysis and physical modeling experiments to address this broad question. An abrupt change point was identified in 1985 for the basin outlet station at Taonan. Accordingly, the stream flow was divided into baseline and changed period for attribution analysis. To investigate the impacts of climate change and human activities on annual stream flow, they applied a distributed hydrological model and six Budyko-type functions during the two periods. The results indicated that climate change and human activities accounted for about 45 and 55 % of the changes in stream flow, respectively

Yadav *et al,* "Hydrological analysis for Bheri-Babai hydropower project Nepal." Unpublished M. Sc. Thesis, Norwegian University of Science and Technology, Department of Hydraulic and Environmental Engineering, Norway (2002).The main objective of the study was to produce about 48 MW of electric power by diverting water from Bheri to Babai River through a tunnel of about 12.7 km. The key issues includes, attaining increased water depth in Babai river, maintaining minimum water depth/flow in Bheri river and minimizing decreased water temperature in Babai river. There are 17 rainfall-gauging stations in the Bheri and Babai river basins. Daily rainfall data from these stations were collected from Department of Hydrology and Meteorology. Precipitation gradient was plotted for these basins and gradient curve showed that the least rainfall occurs at the Dunai Station, which is located at upper reach in the Bheri river basin while the highest annual rainfall takes place at Nayabasti station, which is located in the Babai river basin. The estimated mean annual rainfalls for the Bheri and Babai river basins are 964 mm and 1156 mm respectively. Run-off data from gauging stations were used as input data to develop flow regimes in Bheri and Babai river basins. Flood frequency analysis is carried with the help of software FREQ2000 developed by A. Killingtveit. Different theoretical distributions – Normal, Lognormal and Gumbel were fitted to the data. The estimated flood values for different return periods obtained from each distribution for each gauge are obtained. Double mass curve analysis also carried out to find out some deviation in the data in a station.

Kumar *et al,* "Environmental flows for hydropower projects–a case study." In International conference on small hydropower-hydro Sri Lanka. 2007.In this paper, a methodology comprising of hydrological and ecological studies has been applied to assess environmental flows in Nathpa-Jhakri reach of Satluj river in the context of Nathpa Jhakri Hydroelectric Project (NJHEP) in Himachal Pradesh. There are almost negligible direct water uses of river due to highly inaccessible terrain. River bank, being rocky, does not support much vegetation up to 100 m height. The main affected phenomenon is river bed ecology. Hydrological (river mapping), hydraulic (cross section, water depth and velocity) and ecological features (river bed and bank flora and fauna) in the study reach have been determined. In addition hydraulic habitat analysis has been carried out. A minimum release of 7.0 cumec from the dam is recommended. Higher rainfall is received in lower parts compared to upper part. Seasonal as well as annual rainfall in the study area is highly erratic creating situation of meteorological drought as per criteria of India.

Arsić *et al* "Modeling of Flow in River and Storage with Hydropower Plant, including the Example of Practical Application in River Drina Basin. Goal of the mathematical modelling and simulation of a physical system is to provide the user with the relevant information used in design and/or management decision-making. Calculation of the inlet hydrograph transformation along the river section and storage was exercised by virtue of the hydrological methods that are actually a simplified solution of the fundamental differential equations of flow. Calculation of discharge through hydro-technical structures, such as spillways, foundation outlets etc., are shown in hydraulic equations or water level-discharge relations. Storage management includes direct or indirect planning of the hydropower plant operation, as well as meeting other water management requirements. Efficient numerical algorithms provide for processing of input event series and initial values that describe the state in the river and storage, resulting in the series of events on all important locations of the physical system. An example illustrates the application of the mathematical models of flow in the river, wave transformation in the storage and electricity generation calculation. The example covers the part of the River Drina basin between the profiles of "Zvornik" HPP and "Bajina Bašta" HPP.

1) *Summary Based on Hydrologic Studies.*

The above papers were reviewed based on the Hydrologic Study done in different parts of the world including India. Most of the paper illuminating how to use the water in a sustainable manner. Different type of numerical models like SWAT, HEC-HMS, FREQ2000 where used for the Study. Neelakantan, *et al* did a Study in Cauvery basin to restore the tanks in an economical way by doing mining operation in tank. Bansode S, *et al* and Wu Kangsheng, *et al* did some water balance study using SWAT model aided with some GIS Interface. Both of them analysed the water stresses in their region and how the parameters like Precipitation, Evapotranspiration etc are varying in their particular regions. Yadav, *et al* did some study in Beri Babi river, how to maintaining minimum water depth/flow in Bheri river and minimizing decreased water temperature in Babai river after diverting water from Bheri to Babai River through a tunnel. From the above studies, it is clear that we needed a replica(Model) of the system which may be a Physical or Numerical for the Hydrologic analysis study in my region. We choose Quantum GIS Interfaced SWAT Model for the Hydrologic analysis of my region and I am going to do a Return flow analysis Study apart from the above Studies using the SWAT Model itself.

B. HYDRAULIC ANALYSIS AROUND HYDROPOWER PLANTS.

Karthikeyan, *et al*, "Hydraulic Design of Headrace and Tailrace Channel for a Low-Head Hydro Power Plant Using Partial Analysis. The main objective of this study was to achieve the required head of 6.5 m and 9.0 m for maximum and minimum discharges respectively through different model studies, for that a physical model of low head hydro power plant is constructed by designing the tailrace and headrace of channel. In order to minimize the modifications in the physical model because of the time consumption, design and analysis is carried out using HEC-RAS Software and the results obtained is implemented on the physical model. Series of barrages are put in place for every 9m fall of head below the Mettur dam in the river Cauvery in Tamil Nadu. The sixth in this series called Bhavani Kattalai Barrage-2 is the study area. Trial and error method is used in Designing Headrace of the channel using HEC-RAS. By doing some alteration in the alignment of channel, finally designated head is obtained. The reason for the observed deviation in the results between the HEC-RAS and the physical model is due to the inability of HEC-RAS to consider the 3-dimensional surfaces into account.

Ranga Raju *et al* "Sediment management in hydroelectric projects. In this paper the basic equations concerning morphological changes in alluvial rivers are discussed with particular reference to computation of reservoir sedimentation. The hydraulics of lined canals carrying wash load is examined from the point of view of limiting transport capacity and changes in frictional resistance. Lastly, the methods of design of sediment extraction devices like settling basins and vortex chambers are presented. The estimation of the annual sediment yield from the catchment, determination of the fraction of this which would deposit in the reservoir based on a knowledge of its trap efficiency and computation of the deposition profile following a method like the Empirical Area Reduction method (Borland & Miller, 1958) from which the reduction in storage capacity at various elevations can be worked out. In this paper they used some equations to find the efficiency of the settling basin and also for assessing the friction factor, which is increasing or decreasing. By solving numerically the governing equations, they carry out more detailed analysis of the process of sedimentation in reservoirs as well as of degradation downstream of dams. The fully coupled model applicable to one-dimensional analysis may be described by some set of equations (Krishnappan and Snider, 1977).

ISSN 2229-5518

Dudhraj *et al*, "Design of Headworks in steep sediment loaded rivers: A model study case of Lower Manang Marsyangdi Hydropower Project." Headworks design in steep, sediment loaded rivers is challenging. The Physical Hydraulic Model study conducted at Hydro Lab focuses on intake hydraulics, sediment handling and trash removal along the intake. Velocity measurements were conducted at several cross-sections along the settling basins to evaluate the hydraulics. Turbulent Kinetic Energy (TKE) was calculated from the velocity measurements to assess the effect of secondary currents. A Three dimensional (3D) CFD-program, STAR CCM+, has been used to conduct the numerical model study of the intake hydraulics of LMM headworks. Use of numerical model has to a large extent been successfully able to replicate the hydraulics in the modelled head works of LMM HPP. The velocity range is comparable to the measured values in the laboratory. However, secondary currents and, thereby, the TKE values have not been reproduced properly in the numerical model. Thus, it is recommended for numerical model studies to be used in combinations with PHM study. Numerical model requires an initial validation by comparing simulated flows to measured flows from the laboratory. The validated numerical model can then be used to predict further effects of modification in the headworks design and to optimize the conceptual design.

Holmeset *et al*, "DEBRIS HANDLING AT SMALL HYDRO POWER INTAKES. In this study the handling of debris in small hydro power intakes is assessed by evaluating the concept of back flushing with a horizontally fixed trash rack. The concept of back flushing is to reverse the flow over the trash rack for a short period of time in order to detach and evacuate clogged debris through a flushing pipe or gate. In this study the concept of back flushing with a horizontal trash rack is evaluated for two different designs; a one chamber design and a two chamber design. The efficiency of back flushing as well as the hydraulic performance during normal operation is mainly evaluated using numerical modelling and a CFD-software. The demonstration model is built and tested for flushing efficiency and performance during normal operation. During normal production the length of the model and the height of the weir are important parameters affecting both the total head loss and TKE-values. The results achieved by the numerical modelling should be validated, as further research, on a scale model designed and built in the lab. The test program for the scale model is presented in this study.

Mulelid *et al*, "Mulungushi Cascade Hydropower Project: A Technical Economic Assessment Of Hydrology, Design And Power Production. Steadily increasing economic growth and population growth in Zambia implies that the need for electrical power will increase in the coming years. There are currently developed around 1788 MW of a potential of about 6000 MW. It is therefore expected a major development in the coming years.This will contribute to improved living standard for the natives. This thesis addresses the hydropower project “Mulungushi cascade”, which is to be built about 70 km. southeast of the town Kabwe in Zambia. An Italian consultant has outlined the major components in a sketch project, and this is the basis for this report. It is planned to construct two new hydropower plants in a cascade with respectively 300 and 143 meters of head. Data on local conditions are mainly obtained from a database with reports from the planning of a larger power plant 60 km. further east. This applies to both hydrology and costs for development, and has been supplemented by more traditional Norwegian costs basis and tools like TunSim. Hydrological models have been used to simulate the inflow to the ungauged catchments. Simulation of power production based on the overall technical specifications and the hydrological time series gave an average production of 370 GWh.

Jones *et al*, "Assessment and design of small-scale hydro-electric power plants. Appraisal and design of small-scale hydro power plants requires a knowledge of hydraulics, hydrology, civil, mechanical, and electrical engineering, and basic economics. Further, small hydro is site specific in nature and marginal from an economic view point. Methods of appraisal and design are required therefore that will keep engineering fees to a minimum and yet still achieve a reliable evaluation

ISSN 2229-5518

of scheme potential and economics. In this context it should be appreciated that small hydro is not large hydro scaled down, and that small hydro needs its own experts. This thesis considers techniques for appraisal of small hydropower schemes,. the selection and specification of scheme components, their costing and economic evaluation, it also draws on experience gained by the writer during short visits to India and Nepal, and during a six month design appraisal for rehabilitation of mini-hydro schemes in Sri Lanka.

1) Summary Based on Hydraulic Studies

The above papers were reviewed based on the Hydraulic Study done in different parts of the world including India. Most of the paper gave solutions for the Hydraulic problems encountered in the efficient working of Hydropower Plants . Karthikeyan *et al* did a study in Hydraulic Design of Headrace and Tailrace Channel for a Low-Head Hydro Power Plant Using Partial Analysis in the sixth Barrage called Bhavani Kattalai Barrage-2. Like that different people did Studt on their respective area aided with some Physical Models and Numerical Models like HEC-RAS, CFD-software , STAR CCM+ etc.

C. HYDRO POWER OPTIMISATION STRATEGIES.

Stojanović *et al*, "Hydropower Plants Cascade–Modeling of Short and Long-Term Management. Hydropower plants in a cascade that operate on their own had certain additional requirements and constraints than normal one.In this paper they develop special modes for the optimum management of such HPPs. They are Short term planning with hourly demand. (iterative method), Long term planning with daily demand, Optimization of revenue. (Genetic algorithm), Discharge at each unit specified with historical time series “Vlasinske hydropower plants” (that consists of the “Vrla 1” HPP, “Vrla 2” HPP, “Vrla 3” HPP and “Vrla 4” HPP) in Japan is the study area. For each barrages they uses different data like rated discharge, rated power, mean inflow from tributaries, volume of the reservoir, minimum and maximum water levels for their analysis and optimum management. In this paper, a large potential of the described models and algorithms for the design of new systems of Hydro Power Plants is demonstrated, as well as the possibility of application of modern numerical methods like genetic algorithms for the optimization of such systems.

Ngo *et al*, Optimising reservoir operation: A case study of the HoaBinh reservoir, Vietnam. Technical University of Denmark, Danmarks Tekniske University, Department of Hydrodynamics and Water Resocurces Strømnings mekanikog Vandressourcer, 2006.Application of optimisation techniques to reservoir operation has become a major focus of water resources planning and management. The thesis proposes a way for changing traditional reservoir operation into optimised strategies using the developments in the computational techniques. The main contribution of the thesis is the development of a framework in which a simulation model (MIKE 11) is coupled with a numerical search method for optimizing decision variables specifically defined for operation of the reservoir. AUTOCAL software is used for optimization. Hereby it has become possible to estimate the trade-off between the various objectives.

1) Summary Based on Optimization

The above papers were reviewed based on the Hydropower Optimization Study done in different Study Area. Most of the paper gave some optimization Strategies for the efficient working of Hydropower Plants. Stojanović, *et al* "Hydropower Plants Cascade–Modeling of Short and Long-Term Management, used some Iterative methods and Genetic algorithm for the Optimization of Hydropower production and Ngo *et al*, Optimising reservoir operation: A case study of the HoaBinh reservoir, Vietnam, used MIKE 11 andv AUTOCAL Software for the Optimization.

D. SUMMARY

From the literatures reviewed these are the points which could be taken for the Hydrologic studies to improve the performance of Hydropower plants. Rainfall Runoff Estimation towards each Barrage, Average Return flow Analysis, Water

Balance Study, Water management approaches in different seasons.

IV. Conclusions

An efficient Hydropower production system can be run by knowing the complete details of the surface water flow around the system and their contribution towards the river stretch where the system built. The above papers were reviewed based on the Hydrologic Study done in different parts of the world including India. Most of the paper illuminating how to use the water in a sustainable manner. Different type of numerical models like SWAT, HEC-HMS, FREQ2000 where used for the Study. Neelakantan, *et al* did a Study in Cauvery basin to restore the tanks in an economical way by doing mining operation in tank. Bansode S, *et al* and Wu Kangsheng, *et al* did some water balance study using SWAT model aided with some GIS Interface. Both of them analysed the water stresses in their region and how the parameters like Precipitation, Evapotranspiration etc are varying in their particular regions. Yadav, *et al* did some study in Beri Babi river, how to maintaining minimum water depth/flow in Bheri river and minimizing decreased water temperature in Babai river after diverting water from Bheri to Babai River through a tunnel. From the above studies, it is clear that we needed a replica(Model) of the system which may be a Physical or Numerical for the Hydrologic analysis study in my region. We choose Quantum GIS Interfaced SWAT Model for the Hydrologic analysis of my region and I am going to do a Return flow analysis Study apart from the above Studies using the SWAT Model itself.

References

1. Arsić Miomir, Vladimir Milivojević, DejanVučković, Zdravko Stojanović, and D. Vukosavić. "Modeling of Flow in River and Storage with Hydropower Plant, Including The Example of Practical Application in River Drina Basin." Journal of the Serbian Society for Computational Mechanics/Vol 3, no. 1 (2009): 127-153
2. Bansode Shruti, and Kailas Patil. "Water Balance Assessment using Q-SWAT." *International Journal of Engineering Research, Volume* 5 (2016): 515-518Neelakantan, T. R., C. R. Suribabu, and R. Selvakumar. "Opportunity to restore irrigation tanks in the Cauvery delta by mining and deepening."*Environment, Development and Sustainability*: 1-10.
3. Holmeset, Fredrik. "DEBRIS HANDLING AT SMALL HYDRO POWER INTAKES." p.11-45. (2013).
4. Jones, Ian David. "Assessment and design of small-scale hydro-electric power plants." PhD diss., University of Salford, p.11-90. 1988
5. Karthikeyan.M, B. V. Mudgal, G. Ravikumar, and K. Karunakaran. "Hydraulic Design of Headrace and Tailrace Channel for a Low-Head Hydro Power Plant Using Partial Analysis." In International Conference on Small Hydropower-Hydro Sri Lanka, vol. 22, p. 24. 2007.
6. Kumar, Pradeep, Umesh Chandra Chaube, and Surendra Kumar Mishra. "Environmental flows for hydropower projects–a case study." In International conference on small hydropower-hydro Sri Lanka. 2007.
7. Li, Bin, Hongbo Su, Fang Chen, Haibin Li, Renhua Zhang, Jing Tian, Shaohui Chen, Yongming Yang, and Yuan Rong. "Separation of the impact of climate change and human activity on streamflow in the upper and middle reaches of the Taoer River, northeastern China." *Theoretical and applied climatology* 118, no. 1-2 (2014): 271-283.
8. Melesse A.M, Nangia V. and Wang X., "Hydrology and Water Balance of Devils Lake Basin: Part 2-Grid-Based Spatial Surface Water Balance Modeling", Journal of Spatial Hydrology Springer, Vol.6 (1), 2006, pp.133-144.
9. Mulelid, Simon. "Mulungushi Cascade Hydropower Project: A Technical Economic Assessment Of Hydrology, Design And Power Production." p.8-40 (2014).
10. Neelakantan, T. R., C. R. Suribabu, and R. Selvakumar. "Opportunity to restore irrigation tanks in the Cauvery delta by mining and deepening."*Environment, Development and Sustainability*: 1-10.
11. Ngo, Long le, Dan Rosbjerg, and Henrik Madsen. Optimising reservoir operation: A case study of the HoaBinh reservoir, Vietnam. Technical University of Denmark Danmarks Tekniske Universitet, Department of Hydrodynamics and Water Resocurces Strømnings mekanikog Vandressourcer, p.11-50, 2006.
12. Raju, KG Ranga, and U. C. Kothyari. "Sediment management in hydroelectric projects." Int. J. Sediment Res. 20, no. 1 (2005):p. 52-61.
13. Stojanović, Zdravko, D. Vukosavić, D. Divac, Nikola Milivojević, and Dejan Vučković. "Hydropower Plants Cascade–Modeling of Short and Long-Term Management." Journal of the Serbian Society for Computational Mechanics/Vol 3, no. 1 (2009): 210-227.
14. Wu, Kangsheng, C. A. Johnston, Christine Cherrier, Scott Bridgham, and Boris Shmagin. "Hydrologic calibration of the SWAT model in a Great Lakes coastal watershed." *Coastal Hydrology and Processes. Water Resources Publications: LLC, Highlands Ranch, Colorado* (2006): 15-28.
15. Yadav, ShyamKishor. "Hydrological analysis for Bheri-Babai hydropower project Nepal." Unpublished M. Sc. Thesis, Norwegian University of Science and Technology, Department of Hydraulic and Environmental Engineering, Norway. p.42 (2002).
16. SWAT Website: http://www.swat.tamu.edu/
17. Soil Data : https://soilgrids.org/
18. Landuse and Land cover data: https://landcover.usgs.gov/
19. CARTOSAT Data: http://bhuvan.nrsc.gov.in/bhuvan_links.php