CHAPTER 2

REVIEW OF LITERATURE

2.1 GENERAL

A literature review is the core of any research work. The literature reviews help to identify and frame the new problem statement and assisted in the solution with the earlier work of the researchers and scientists. River engineering is challenging, and understanding its complexity is an essential assignment. The whole world is struggling for freshwater. The river water is the primary source of fresh water. Therefore, river basins, sediment transport, and pollutant management are essential to keep the entire river system safe. Literature related to the present study is given in the following sections.

2.2 INTRODUCTION

According to purposes in the literature review, the following focused parts are covered:

a) Watershed sediment modelling

b) Identification of sediment transport study

c) Sediment transport modelling, and

d) Pollutant dynamics

Watershed management is essential for available lands and proper drainage patterns. Sedimentation and erosion significantly affect the drainage pattern in the watershed. The process of sedimentation and erosion constantly changes the profile of riverbeds. There are some reasons observed for changes in the watershed like the slope of the area, soil property, flood condition, water body, canal system, river system, land use and land cover, pollutant discharge, rainfall intensity, anthropogenic activity, etc. Among all these reasons, the sediment transport capacity of the river flow discharge is an important reason for changes in the watershed. Therefore, the sediment transport capacity of the river plays a vital role in the transformation and construction of the watershed. For any large city situated on the riverbanks, the river system must manage its watershed.

2.3 WATERSHED SEDIMENT MODELLING

Soil erosion and sediment deposition is a continuous process of the river basin, and therefore, it is essential to understand and solve its complexity. In this regard, Land Use and Land Cover (LULC) study help to better understand the soil erosion and sediment yield problem. Land use and land cover have contributed to global climate change during and onwards few earlier decades. Various researchers closely observed the effects of global warming from the change in land use and land cover. It changes surface albedo and impacts energy balance and the regional climate (Stephen et al. 1973, Otterman 1974 and Carl et al. 1979). Foody (2002) examined the accuracy of the thematic map with the help of remote sensing techniques. The confusion matrix method was used to verify the original ground conditions. It is reported that the mapping of a large area is challenging, and correct results can be found only by proper ground-truthing. Therefore, the confusion matrix method becomes an advantageous technique in this case. Tong and Chen (2002) correlated the land use and surface water quality by statistical and spatial analyses using a modeling tool named Better Assessment Science Integrating Point and Nonpoint Sources (BASINS). Water quality changes regionally due to the mixing of fertilizer in agricultural land water. The statistical analysis exposes that there is a significant relationship available between land use and surface stream water. The spatial analysis revealed the intermixing of water from agricultural and urban land. The BASINS tool gives satisfactory results for these types of problems. Yang et al. (2003) studied the global soil erosion condition based upon the GIS-based Revised Universal Soil Loss Equation (RUSLE) model. Lambin et al. (2003) analyzed land use and land cover complexity near the tropical region. The study covers different impacts due to cropland change, irrigation land, tropical area, deforestation, urbanization, and barren land and provided an idea of how the soil is being eroded due to different changes. The tropical region also has considerable erosion from climate change.

Although, the extraction and detection of data were not done correctly in the early decades. The remote sensing and analytical technique provide correct detection and activation of land use and land cover change data (Rogan and Chen 2004). The basin's water quality is influenced by land use and land cover as a large basin area is a combination of sub-basins. Ahearn et al. (2005) estimated the total suspended sediment (TSS) and the nitrate –N level of a stream. The nitrate-N concentration majorly comes from the agricultural land area as compared to the human habitat. Therefore, the lowest sub-basin becomes a sink for the TSS and nitrate-N. The soil erosion significantly increased due to crop productivity and reveals the change of land cover. The crop production was observed to be reduced sometimes due to more soil erosion (Bakker et al., 2005). Logistic regression was applied with a depth of soil, slope, and soil erosion. The result predicted that continuous soil erosion would reduce agricultural activity in times to come.

Biodiversity is a harmful effect due to rapid change in land use and land cover. Falcucci et al. (2007) suggested that more soil conservation should maintain for saving biodiversity and traditional agriculture practice. Schilling et al. (2008) stated that land use and land cover change would affect the region's water balance for the more extensive agricultural area. The crop conditions taken for the study are an annual crop, perennial, and both annual and perennial. The Soil & Water Assessment Tool (SWAT) tool was used for the estimation and given promising results. The Mediterranean environment is also not shielded from soil erosion due to agricultural land needs, and thus, increased the soil erosion conditions in the 16th and 19th centuries. The entire LULC was dependent on crop demand. Meanwhile, the land was abandoned, and therefore, the soil erosion is reduced during the 20th century (Garcia 2010). However, the increased orchards of almond and olive are started the soil erosion again.

Tefera and Sterk (2010) identified the soil erosion problem and influencing factors and provided the Soil Water Conservation (SWC) measures. The researchers collected the data in various seasons, interviewed almost 50 farmers, and concluded that the soil erosion was regular, and every farmer was aware of it. However, adopting SWC is not leading to success because it is laborious and intensive, takes much time, has a long-term plan, and even unavailability of free grazing area.Nunes et al. (2011) measured hydrological and soil erosional data. It depends entirely on the type of land cover area. He concluded that small crop agricultural land with coniferous forest area was most prone to soil erosion and runoff compared to the shrub cover with recovering oak less runoff and soil erosion.

Baker and Miller (2013) evaluated the impact of land cover on the water resource covering Kenya's Rift Valley as a study area for the hydrological change. The automated Geospatial Watershed Assessment (AGWA) tool was used with the SWAT tool, and the study was continued for seventeen-year in this area with three subdivisions. The authors concluded that the increased runoff lowered the groundwater recharge.

Sajikumar and Remya (2014) conducted a study of the watersheds, namely Manali and

Kurumali, using the SWAT because the Soil and Water Analysis Tool (SWAT) is one of the most helpful watersheds modelling tools compared to other watershed simulation tools. The reduction of forest area in Manali and Kurumali's watersheds is 60% and 20%, respectively. The increased runoff was observed to be smaller than the decreased forest area and was about 20%. The deviation is due to the farming pattern of Kerala because the rubber trees is planted in place of deforestation.

The study of any watershed management system can be analyzed when the present, past, and future data are interpreted correctly. Butt et al. (2015) used Earth Resources Data Analysis System (ERDAS) imagine to detect the LULC. The whole watershed was divided into five sub-watersheds and concluded that the increased population and agricultural land changed the LULC, creating higher soil erosion. Grafius et al. (2016) analyzed the impact of LULC comparing the urban images of two different resolutions as the urban ecosystem was closely settled in the area. The 5 m resolution image was compared with the 25 m resolution image, and the 5 m resolution image was observed to provide more precise results.

Yohannes et al. (2018) studied the effect of LUCL on the landscape. Twenty-five years of data were taken in Abaya-Chamo Basin and observed a rapid reduction in shrubland and natural grassland and increased arable land. Further, the authors concluded that more soil erosion and sediment yield ignited and lowered water resources due to reduced shrub and grassland. Dunne T. (1979) presented local relationship between sediment yield and their control. More attention was paid by researchers initially to the climatic change and landforms and somewhere more attention to LULC. Although, the sediment transport and sediment yield affected by the land use of that area. However, the wet period of the tropical region also contributes to higher sediment transport. Van et al. (2001) worked over the calculus of segment delivery applying the RUSLE (Revised Soil Erosion Equation) approach first to measure the annual mean soil erosion rate. The sediment yield values obtained from SEDEM (SEdiment DElivery Model) were more accurate than a lumped regression model. The gradual deposition of the sediment was observed due to the higher sediment transport than the routed local sediment transport capacity. The other mathematical models were also used to estimate soil erosion. Sediment Assessment Tool for Effective Erosion Control (SATEEC) is one of the models capable of calculating sediment yield with the help of RUSLE. Lim et al. (2005) enhanced the SATEEC modeling tool to estimate the effects of sediment retention basins and sediment yield from a single storm event and prepare input parameters for the Web-based sediment decision support system. Ndomba et al. (2008) estimated that the SWAT model capacity according to the availability of input data. Total six-year data were used to calibrate the model. The SWAT model can predict long-term sediment catchment yield. The result reveals that one can substitute the sediment rating curve where the sheet erosion is taking place.

Shen et al. (2009) compared the soil erosion data of the Water Erosion Prediction Project (WEPP) and SWAT models. Both models were applied to simulate runoff and sediment yield for the Zhangjiachong Watershed. The WEPP model was observed influential in determining the soil loss of every type. Jain et al. (2010) simulated sediment yield and runoff of the great Himalayas. ArcView GIS software used for the SWAT simulation. Two-year data were used for the calibration, and three years of data were used for the model validation. It was observed that the value of coefficient R2 is very satisfactory for the daily data of sediment yield and runoff compared to the monthly data set. Ouyang et al. (2010)

estimated the relationship of vegetation regarding soil erosion and sediment yield using the SWAT model. The SWAT simulation gave a similar spatial distribution of annual sediment yield and soil erosion pattern, but the monthly spatial distribution of sediment yield and soil erosion were different. It was revealed that Normalized Difference Vegetation Index (NDVI) vegetation zone controlled the sediment transport; however, it partially contributed to the soil erosion for the Yellow river basin.

Betrie et al. (2011) developed a sediment yield model for the upper Nile River basin considering four scenarios for modeling. The first scenarios were maintained with the original condition, the second scenarios introduced with filter strips, the third scenarios introduced with stone bund, and the fourth scenarios present reforestation. The result shows that the second, third, and fourth scenarios helped reduce soil erosion and sediment yield. Phomcha et al. (2012) tested alternatives for reducing soil loss with the help of the SWAT modeling technique considering the 350 km2 watershed area of Thailand for the intensive study. The model was calibrated and validated for streamflow using time series. The SWAT model gave satisfactory results and identified that approximately forty percent of watershed areas faced high sediment yield.

Singh et al. (2012) also compared the sediment yield modeling tools as SWAT and multilayer perceptron (MLP) artificial neural networks. Ten years of data were used for the calibration, and three years of data were used to validate the model development. The coefficient of determination (R2) value showed that the MLP artificial neural network model is the best model compared to the SWAT model. Much software for sediment modeling is available in the open literature; however, it is crucial to know and understand which software is accurate. De Vente et al. (2013) tested 14 models over 700 watersheds to evaluate the respective model's accuracy and precision. A group of 14 models was observed to estimating precisely with fewer data supplies by the SPADS and WATEM–SEDEM model.

Yan et al. (2013) evaluated the impact of land-use change on sediment yield and streamflow using SWAT and the least square regression method and tried to understand the influence of land-use change on the streamflow and sediment yield condition. Thirty years soil map was used for the model development. Both models have much change in the streamflow and sediment yield in areas where forest land has been converted into agricultural or urban areas. Bonuma et al. (2014) estimated landscape sediment transport capacity for the watershed of Brazil. The Modified SWAT Model was used for the testing and estimation. The study revealed that 60 percent of mobilized soil was first deposited to the landscape then go to the river stream. However, the Modified SWAT model gave a more accurate estimation in the slopy watershed area.

Son et al. (2015) calculated the impact on runoff discharge and sediment yield due to changes in the land use pattern. The SWAT model was used using SUFI-2 for calibration and validation. The land cover area of the watershed had changed from 1995 to 2005. The extensive forest area was now gradually converted into agricultural land or vegetable land and caused a gradual increase in runoff discharge and sediment yield yearly. Briak et al. (2016) assessed the sediment yield of Morocco's Kalaya watershed using the GIS and SWAT model for the forecast. Whatever preventive majors were taken to avoid the sediment yield and runoff of the watershed can be taken only based on a model. The models were calibrated and validated for monthly time series data using Sequential Uncertainty Fitting 2 (SUFI-2, version 2) and observed limited sediment yield and runoff in the entire watershed.

Due to improper management of land, soil erosion, runoff, and sediment yield are constantly increasing. Therefore, it is necessary to identify the watershed areas with maximum erosion and sedimentation yield to managed and improve. Ayele et al. (2017) determine the watershed's full streamflow and Sediment Yield area to be prioritized. The SWAT model was calibrated and validated using SUFI-2, GLUE, ParaSol, and PSOSWAT-CUP optimization algorithms. It was concluded that the soil was being eroded from the upper area due to high agricultural practice and transporting it to the reservoir catchment area. Himanshu et al. (2017) applied the SWAT model for the sediment yield, runoff discharge, and water balance. The large basin was divided into ten sub-basins. Hydrological response units were selected based on soil classification slop class and land cover area. Eleven years of data were taken for the calibration, and ten years of data were taken for validation of the model. The evapotranspiration was observed to be predominant in the basin area that receives approximately forty-four percent annual rainfall. The basin sediment yield was higher due to the higher soil erosion.

Duru et al. (2018) tested the SWAT modeling tool to predict sediment yield and streamflow for the Turkey watershed and develop a sediment model and erosional map. The seven-year data was used for calibration, and three years of information were used for the model validation. The model was evaluated based on various error measurement techniques for the accuracy of the model. The high erosion and sediment yield were observed in the urbanized and crop cultivated area. Melaku et al. (2018) assess the impact on the runoff and erosion process in a watershed of the hydraulic structures specially used to conserve the soil and water. A total of five years period were studied for the analysis. Daily data were used for the SWAT modeling and revealed that the soil water conservation structure (hydraulic structure) is 20 to 35 percent effective for the watershed.

2.4 REVIEW ON IDENTIFICATION OF SEDIMENT TRANSPORT STUDY

Sediment deposition and sediment erosion are a natural process of a river. The river creates a zigzag path in this process meanders. Horizontal and vertical erosion are the types of erosion in the river. Horizontal erosion contains riverbank erosion, and vertical erosion includes riverbed erosion. Colin et al. (2002) developed a technique to measure the bed-load velocity using Acoustic Doppler Current Profiler (ADCP). The technique is beneficial to know the movement of bed load and aware of how much bed load sediment is moving in the river. In addition, it is helpful to estimate the bed load transport capacity. The bed load movement can be assessed quickly using ADCP compared to the conventional technique.

Shams et al. (2002) analysed the computational method for sediment deposition and sediment transport modeling. The Reynolds stress transport model was used with the help of the FLUENT code. After the computational modeling, the simulation data was compared with the experimental data. The experimental data and simulation data were in close agreement in many ways and observed that the mean-flow quantities reveal some dynamic similarity; on the other hand, the turbulence parameters of the main river were not similar.

Rennie and Millar (2004) evaluated fluvial bed load transport velocity in the gravel and sandy bed rivers. ADCP supports river study to measure discharge, bed load movement, river velocity, and other parameters. The bed velocity was measured along with the depth and estimated the spatial distribution of the shear stress. Chakrapani (2005) observed the various factors that control sediment load carried by the river from the upper ridge and flushed into the Ocean. The various land formed through this steady process. The massive human intervention in the natural process of sediment transport creates many changes. The sediment transport depends on the topology of the river, land cover, human intervention. Parsons et al. (2005) suited riverbed morphology with flow field using high-resolution multi-beam echosounder (MBES) among the various available technique to explore 3-D dunes. ADCP was used for flow-field analysis with the high-intensity acoustic beam. The instruments were used insensibly in the area and estimated similar observations close to the experimental values.

The regular monitoring of the sediment and river flow of the large river is tedious, and the use of ADCP gives a better result than the other instruments in this case. The model predicted bed velocity with higher accuracy compared to the existing bed load theory. Szupiany et al. (2007) compared moving and fixed vessel flow efficiency using an Acoustic Doppler Profiler (ADP). The river cross-sections were selected for fixed ship flow measurement and for moving improved vessel flow measurement. Although both techniques observed different flow velocities, a satisfactory result was obtained for fixed ship flow measurement. Yilmaz (2008) estimated the sediment transport quantity in the laboratory using flume. The experimental result was like Einstein's approach. Kirincich et al. (2010) used the ADCP instrument to measure turbulent Reynolds stresses as the instrument can estimate the stress in various flow dimensions and best suited for the coastal study. Ghaffari et al. (2011) estimated SSC using ADCP. The bed profile of the river changes from time to time due to changes in sediment transport behavior. The SSC can be estimated very quickly using ADCP. The ADCP is also capable to faces future challenges. Sassi et al. (2012) studied the impact of suspended sediment on the backscattering sound attenuation of ADCP. The backscattering attenuation was observed to be varied due to the size of the sediment and the boat speed.

Baranya and Józsa (2013) estimated SSC in the Danube River using ADCP based on the intensity of backscattered sound. The data were collected with a fix and moving boat method and calibrated using the physical sampling method. Besides the uncertainty observed in the result that affected the outcome, the basic need for data smoothing for more precise results is fulfilled. Weiss et al. (2015) estimated the total suspended solids with the help of ADCP using the instrument in the ice cover and open water periods. The multiple linear regression of the backscatter data obtained improves the model performance and calculates total suspended solids (TSS) precisely. Khan et al. (2016) determined the factors responsible for the temporal and spatial water and sediment discharge. Ramganga river was taken as the study area. Ten years of daily data were used for the extensive study of the 642 km river stretch. It was observed that the river meanders in the plane area as the flow and sediment concentration changed due to the significant amount of water and sediment received by the river in the monsoon period.

2.5 REVIEW ON SEDIMENT TRANSPORT MODELLING

Rivers are one of surface water body which carries fresh water. The entire river system is as important to us as the blood in our bodies. The river brings many sediments with its flow and forms various landforms such as the oxbow lake, estuary, delta, etc. River access ocean through building the channels in its downstream as straight, meandering, and braiding channels. The changes in the sediment transport pattern create channels and generated differences in bed profile and morphology of the river. The continuous research work is going on for decades to understand the complex phenomenon of sediment transport as the sediment transport behaviour depends on various parameters and the clear understanding needed to manage the river system properly. It is challenging and time taking to carry out an accurate estimation of parameters affecting sediment transport. The various computational models and mathematical tools working in 1D, 2D, and 3D modeling are used to predict sediment transport accurately. Hydrologic Engineering Center's–River Analysis System (HEC-RAS) and Neural Network modeling tool is one of the most useful computational tools.

Stronach et al. (1993) tested different 3-D sediment transport models. The first model used a fine grid, and a coarse grid was utilized in the second model. Both models had nine layers vertically, and the three-directional velocity was measured with varying densities. The coarse grid model is not frequent and is used where a large simulation was needed. Whereas the extensive simulations can be done quickly using the small grid models. The estimated data was observed close to the predicted data after simulating for 69 days. Simons et al. (2000) estimated sediment transport using numerical modeling and measured the sediment mobility, trends, and channel morphology. The model results were observed to depend on the current software selection, initial data set, model calibration, and model validation. Sinnakaudan et al. (2003) explore the application of Geographic Information Systems (GIS) in the field of flood mapping analysis. The integrated GIS with the HEC-6 model was used to develop the area's flood map, collecting the required data from filled sampling. Flood risk models were tested and verified with the help of hydraulic and hydrological data. The GIS data were observed to be beneficial for the development of a flood risk map. Yitian and Gu (2003) developed a model for sediment transport and river flow with the help of an Artificial Neural Network (ANN). The model can be used for daily discharge and annual discharge data. The neural network was a very active tool as it required fewer input data and predicted accurate results with lowered time consumption.

Singh et al. (2007) estimated the sediment transport quantity and dynamics of river Ganga. The sediment transport samples, including the bed load and suspended sediment load was collected at 63 locations through the 125 km stretch of the river. The sediment grain size was found to vary from start to the endpoint due to the connecting tributaries in the selected stretch of the river Ganga. The sediment transport capacity of the river was observed to be increased during the flood seasons, and the erosion was observed mainly from the hilly area. Papanicolaou et al. (2008) quoted that many sediment transports modeling tools have been developed in the last three decades working in 1-D, 2-D, and 3-D. Some of these used the traditional tools; however, the use of neural networks and fuzzy logic has proven effective for sediment transport predictions. Mirbagheri et al. (2010) used five different models for the estimation of SSC as ANN, neuro-fuzzy model (NF), wavelet analysis, neuro-fuzzy (WNF) model, and the conventional sediment rating curve (SRC). The wavelet analysis and neuro fuzzy (WNF) model gave precise predictions than other models. James et al. (2010) correlated the experimental data of sediment with the actual data of the river dividing the bed layers into four layers of non-cohesive. The model was further applicable in the field depending upon the bed shear stress, river water depth, and sediment particle size. Rajaee et al. (2011) predicted suspended sediment load with the help of ANN and Wavelet Conjunction Model. The multilinear regression (MLR) and sediment rating curve (SRC) models were used to study daily suspended sediment load data. The wavelet analysis with ANN was relatively new and provided noticeable results compared to the other models. Guerrero et al. (2013) used a multi-frequency acoustic device for monitoring the suspended sediment. The acoustic instruments were used at the same water column with different frequencies (600 and 1200 kHz). The maximum grain size was observed on the riverbed, fixing the acoustic device vertically.

Ebtehaj and Bonakdari (2013) evaluated sediment transport in the sewer using ANN. The lower flow velocity of the sewage significantly affected the sediment deposition, and heavy sediment deposited on the bed of shallow flow sewage and required a specific flow rate for the continuous flow of sewage. Kamanbedast et al. (2013) analyzed sediment transport using the CCHE2D model that was primarily used for developing the sediment transport model. It is imperative to understand the river's nature while meandering. The 50-year flood event was observed higher bed load, velocity, Froude number, and shear stress than the 25-year flood event. Zhang et al. (2014) estimated a sediment transport model for sediment deposition in the reservoir. The four years of field measurement data were collected for the model development, and three sections were used for the model validation. The model could predict the following seventy-year sediment deposition scenario.

Leon and Goodell (2016) controlled the HEC-RAS tool using MATLAB with new coding. Morianou et al. (2016) develop a sediment transport model with the help of the MIKE-21C tool. The 2-d model was developed for the study of sediment transport and the change of bed profile. The 1m X 1 m resolutions of the digital elevation model (DEM) were used to develop a 2-D map. Peixoto et al. (2017) developed a morphodynamic model for the sediment transport for cohesive soil. The model was focused on erosion and sediment flux. Dibike et al. (2018) estimated the impact of climate on the river's hydraulic and sediment transport property. The temperature of the study area was estimated to change in the future by approximately 2 to 7 degrees. The MIKE-11 software was used to assess the changes. Differences in sediment transport capacity were observed due to climate change, and these changes were also seen in the river's bed and banks. Ouda and Toorman (2019) estimated the sediment transport behavior of the river. The Open FOAM framework was introduced to estimate the hydraulic and sediment transport property based on multiphase mixture theory to create the interface between the water and sediment. The volume of fluid (VOF) method was used. The model was validated with actual data and estimated the bed load, sediment behavior, local scouring, and turbulent sheet flow.

2.6 REVIEWS ON POLLUTANT DYNAMICS

The rivers are the primary source of fresh water. However, a major part of the extracted freshwater from the river for various purposes is converted into sewage and discharged into the river after treatment in sewage treatment plants or sometimes without treatment. Thus, the sustainability of a river is a major problem and impacts human life directly. Future research is necessary to improved pollutant dispersion behavior to minimize the pollutant impact. The conventional technique required a large amount of water sampling and required more time and labor to estimate pollutant impact. Therefore, the mathematical modeling and computational fluid dynamics (CFD) are effective tools to assess pollutant dynamics. Liu et al. (2019) studied the contaminant flow dynamics for the Y shape channel developed in the laboratory, similar to the natural river. The study was based on the symmetric and asymmetric confluence channels. CFD was used for the analysis and observed that the high pollutant was available near the interaction point and diffused after the confluence point.

Shahidi and Taghipour (2012) used M5' tree model for the predicted longitudinal dispersion of pollutants. The model used 149 field data of hydraulic and geometrical parameters. The model was validated with the actual data set and found suitable for pollutant dispersion analysis. Yuan (2010) done numerical simulation for flow and pollutant analysis in the river at the confluence. The sediment transport pattern and the pollutant dynamic were mostly affected near the confluence point. The secondary flow of the river is also involved in the process. The CFD was used to study the secondary flow and separation zone for model simulation. The result obtained from the CFD simulation was closer to the results obtained from the laboratory flume. Benkhaldoun et al. (2007) used the finite volume method for pollutant transport with the help of unstructured meshing. The shallow water flow on the uneven plain was considered. The method was observed to be beneficial in estimating the pollutant load transportation from one place to another place. The model could estimate the concentration of the pollutant also.

Mazumder and Bandyopadhyay (2001) applied the finite-difference method and the implicit method to solve the solute dispersion problem in open channel flow. The unsteady convection-diffusion was used. The mean velocity of flow was observed as a critical factor affecting pollutant diffusion. Bazilevs et al. (2011) used the volume of the fluid method to model the incompressible free flow. The two-phase problem was simulated based on mass conservation. The result of the study was in good agreement with other methods. Biron (2004) estimated lateral mixing of pollutants at the confluence of river. The river width was between 100 m to 300 m, and PHOENICS 3.4 was used for the 3D modeling. The RNG k-ε model was used for the model development. The 3D modeling results were validated with the laboratory experiment and observed that the dispersion of pollutants highly affected by the higher discharge compared to low discharge condition.

Huang and Wang (2013) used a 3-D numerical model to estimate the impact of pollutants in the river valley. FLUENT was used for model development. The Navier-Stokes equation and k- ε model were used. The effects of wind at various places were calculated from the

CFD technique. Khaldi and Bournot (2014) predicted pollutant dispersion in a two-phase model. The turbulent free-surface flow was tested. The predictive hydrodynamic model was developed for the dispersion of pollutants. The water velocity of 0.2 m/s was taken with a pressure outlet. The obstruction in the path of pollutant flows increased the pollutant dispersion reflecting through the mesh size in the model. Chao et al. (2013) developed the three-dimensional models for pollutant transport in the flooded area. The CCHE3D model was used for the model development based on the finite element method. The continuity and momentum equation were used as a governing equation. The pollutant in the flooded area was observed to be dispersed rapidly. The model was validated with the laboratory experiment. The model gave a promising result close to the experimental observation.

2.7 RESEARCH GAP

After the rigorous literature review, it may conclude that most researchers have performed laboratory investigation or numerical modeling to understand sediment transport behavior. The numerical modeling is validated by the data obtained from the model testing under laboratory conditions. Very few studies are done on the actual river sediment transport behavior. None of the studies was found to model the sediment transport behavior of river Ganga at Varanasi. River Ganga is the most important river of India and plays a crucial role in forming the northern plain through its sediment transportation process. Therefore, it is essential to develop an understanding of the sediment transport behavior of river Ganga.

The major cities are situated on the bank of river this river. The people of these cities are dependent on the water of Ganga for drinking and other various purposes. The change in the quality of water influences the utility of river water. The quality of rivers like Ganga gets affected due to the sewage discharge produced by human activities. For proper management of pollutants through sewage discharge and understanding the pollutant transport dynamics is essential. Most of the studies to understand the pollutant transport dynamics in river Ganga were performed through the sampling process, excluding the pollutant dynamics behavior of the river. Therefore, the objective of the present study is to investigate sediment transport behavior and pollutant transport dynamics through computational and physical modeling.