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RESEARCH ARTICLE

REVIEWING THE LITERATURE ON DAM-BREAK INVESTIGATIONS AND FLOOD MAPPING THROUGH THE USE OF HYDRAULIC MODELS AND GIS

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Abstract

Nowadays, it is essential to store water to meet the demands of human consumption and to mitigate flooding, which reduces the risk of inundation downstream of the river. The failure of dams can result in disastrous consequences in the surrounding areas downstream. Causing loss of human lives and properties valuedfrom millions to billions. Therefore, it is crucial to conduct dam break studies to understand the behavior of floods generated from such incidents and to identify the areas that may become inundated. This information can be utilized to prepare emergency plans for the evacuation of residents and to minimize property damage. While the floods themselves cannot be prevented, proper evacuation methods can help to minimize losses. This paper reviews various literature on dam break studies that have utilized numerical models to create inundation maps, and also discuss some hydraulic models commonly used in such studies.

Introduction:-

Dams are man-made hydraulic structures built across bodies of water to create upstream reservoirs that serve multiple purposes. These include supplying water for irrigation, generating hydropower, providing domestic and industrial water supplies, as well as serving as flood control and drought mitigation structures Dams also act as storage sites for sediment capture [1]. When human activities in the upstream catchment area cause changes in land use, it leads to a greater volume of soil erosion, which ultimately deposits in the reservoir.Siltation levels have been progressively rising each year, which has led to a decrease in the useful lifespan of the reservoir and a reduction in its storage capacity. During periods of high flooding, the limited space in the reservoir is insufficient to attenuate the approaching flood, causing excess floodwaters to overflow the dam section. This overflow can lead to a scenario in which the dam breaches, resulting in the generation of a massive flood wave that inundates downstream areas. Although the dams and reservoirs have many uses, the damages resulting from the failure of the dam exceed the damages caused by all other disasters combined. Dam breaks can be described as partial or catastrophic failure leading to uncontrolled release of enormous flood to the downstream [2].The flood resulting from a dam break is significantly more severe than the flood caused by heavy precipitation. Various reasons can lead to dam failure, including seepage failure overtopping, foundation failure, construction failures, and the use of poor-quality materials. Dam failure can occur gradually or suddenly. A concrete dam typically experiences sudden failure due to overtopping, whereas an earthen dam may fail due to erosion of material and piping action.

The high flood created by the dam break travel downstream of the dam creating damage to life of human beings and properties along the reach of flood wave [3],[4]. Additional problems created by the extreme flooding are socio-civil

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conflicts, environmental problems and economic losses [5],[6],[7].Despite the availability of advanced technologies for design methodologies and construction techniques, dams fail. Studies conducted on various dam failures in India and around the world have indicated the hazards caused by such occurrences. Hence emphasis to be given on better management of the flood by preparing emergency action plan to minimize the hazards of the flood in the floodplain rather than prevention of the flood. Before proposing flood management measures, it is essential to analyze flood behavior, which can be achieved by studying observed floods. Numerical models simulate the dam break and flood event based on the various parameters, hence numerical models are the very important tool to analyze the flood event.

Literature Review:-

For a long time, dam engineers have been concerned with studying dam breaks in order to minimize the hazards of flooding. The Dam Rehabilitation and Improvement Project (DRIP) aims to develop guidelines that cover flow charts, emergency situations, inundation maps, hazard evaluation and classification, and implementation methodologies, for the preparation of an emergency action plan. Dam break study includes detailed study on analyzing the reasons for cause of dam breach, studying the parameters responsible and study of high flood wave generated and impacts of flood waveon downstream reaches.

In this paper, a literature review of previous dam break studies is conducted to comprehend and analyze the most recent methodologies employed by different authors on various dams worldwide. This review assists in selecting the appropriate methodology and numerical model for conducting a dam break study.

Horritt & Bates (2002) [8] have tested both 1D and 2D flood hydraulics models such as HEC-RAS, LISFLOOD-FP and TELEMAC-2D on 60 km downstream reach of River Severn, U.K. The extent of flooding in the years 1998 and 2000 was determined through the use of radar remote sensing satellites, which were then calibrated using these numerical models. These models utilized data obtained from the floodplain and channel friction as independent parameters, and were compared against observed flood depth from the inundated area and discharge data in the downstream river reach. According to the study's findings, the researchers concluded that the HEC-RAS and TELEMAC-2D numerical models can be calibrated using observed inundated area and downstream reach data to achieve dependable results. On the other hand, the LISFLOOD-FP model must be calibrated against independent inundated area parameters to obtain satisfactory results.

Meritt et al (2003) [9] reviewed various Empirical, conceptual and physical models which use explicit consideration of either sedimentgeneration or transport process such as AGNPS, ANSWERS, CREAMS, EMSS, GUEST, HSPF, IQQM, HEC-RAS, LASCAM, LISEM, MIKE-11, PERFECT, SedNet, SWRRB/SWRRB-WQ, TOPOG and WEPP and the suggestion put forward was that empirical and simple conceptual models can be used when there is limited availability of input data since they do not require a large amount of input data and are computationally simple. The use of physical models is challenging as they demand a substantial amount of input data and their complexity often makes them difficult to use. Furthermore, experts acknowledge that the data required by such models often surpass the data available for the area being studied, and there is a lack of simplified and distributed process-based models that can be applied in conditions where data is limited.

Hicks & Peacock (2005) [10] conducted flood forecast study using two-step procedure, first step is flood routing is conducted using the hydrological model and resulting peak floods are converted to water level forecasts using hydraulic models. In this study, HEC-RAS steady flow model is used. Extending floodplain delineation in flood forecasting applications can offer great convenience. This approach has the potential to enhance the accuracy of flood forecasting and simplify the process into a single step, resulting in significant time savings.According to the study, the HEC-RAS model can function effectively without requiring calibration of Manning's n, but it is recommended to assess the sensitivity of the parameters. The study suggests that flood routing and flood level forecasting can be easily accomplished using the HEC-RAS model. Using this model can result in time-saving during model calibration and eliminate the requirement of running a second model to predict the flood level.

Yang et al (2006) [11] developed a direct processing approach for delineating the river floodplain on a section of the South Nation River System in Ottawa, Ontario, Canada. The processinvolves integration Geographic Information system (GIS) with HEC-RAS to create floodplain maps. A series of numerical model simulations were conducted to produce water surface profiles for six distinct design storm events. To create a terrain model and floodplain zones, geo-referenced maps were combined with Digital Elevation Model (DEM) data to construct a Triangular Irregular

Network (TIN). By overlying the integrated terrain model with the appropriate water surface, the floodplain zones for each of the six design storm events were replicated. According to the authors, the HEC-RAS river network model was validated using the 100-year flood zone of the Bear Brook sub-watershed. The study's findings indicated that the model offered improved simulations through better computational routines, the ability to import and export GIS data, and the visualization of river reach and cross-section data. The research was primarily focused on the integration of hydraulic data and GIS maps to identify inundation floodplain zones.

Yochum et al (2008)[12] developed a one-dimensional unsteady numerical model using HEC-RAS to simulate Big Bay Dam embankment failure which happened on March 12, 2004 and to predict the behavior of flood wave generated caused by dam breach through the downstream valley. The HEC-RAS model was created based on the breach geometry observed, and its result were relatively accurate when compared with the water marks recorded shortly after the failure. However, the study found that although there was some random error in the model's projected peak water surface elevation when compared to the measured water marks, this was mostly due to the small amount of error introduced by 10m DEM-generated geometry. Therefore, the researchers concluded that to eliminate such errors, high-resolution data such as LiDAR or other advanced techniques should be generated when carrying out breach inundation studies.

Kalyanpu et al (2009) [13] presented paper for the evaluation of inaccuraciesresulting from LULC utilization in estimating Manning's roughness coefficient within a hydrological model on a watershed scale. A study was carried out on a 23 km2 watershed, where the researchers estimated Manning's n 'y utilizing the National Land Cover Dataset.From the study, it was discovered that a 50% difference in Manning's n was observed in 90% of the study area. The study suggested that an increasing trend deviation of the hydrograph peak would result in a corresponding increase in the Manning's n deviation. Consequently, the researchers concluded that the use of Manning's n values from NLCD datasets was acceptable for medium to large watersheds.

Patrol et al (2009) [14] conducted a comprehensive analysis was provided regarding the challenges and drawbacks of hydrodynamic modeling for flood prediction in countries with inadequate data and substantial rivers susceptible to flooding. The research employed a one-dimensional (1D) hydrodynamic model to investigate river flow in the delta region of Mahanadi river with limited data availability. The study scrutinized SRTM DEM and contrasted it with elevationdata obtained from topographical maps and precise river cross-sections gathered through meticulous surveys. The X-section obtained from SRTM DEM is refined and incorporated into a hydrodynamic model, resulting in the development of a one-dimensional model. This model is calibrated using the x-section derived from SRTM DEM and measured x-section, discharge, and depth of water at various gauging stations during the 2004 monsoon season. The one-dimensional simulation of the river is conducted, and the valuesof discharge and water level obtained from the model simulation are highly similar to the observed values. This study demonstrates that x-sections derived from SRTM DEM can be effectively used hydrodynamic modelling studies in data-scarce regions.

Salajeghah et al (2009) [15], a study was conducted on the polasjan river basin located in Iran's central plateau to analyze floodplains, using HEC-RAS and GIS. The researchers introduced a direct approach for processing the outputs of HEC-RAS in the ArcGIS platform. Based on the obtained results, they concluded that GIS is a highly effective tool for floodplain mapping and analysis. Furthermore the integration of HEC-RAS and ArcGIS was founded to be an effective approach for floodplain mapping and analysis. According to the statement, the integration of HEC-RAS and ArcGIS in the model offers several benefits, including ease of use, digital output, resource conservation, and broad coverage of various structures like buildings and infrastructures. Moreover, this menu-based software doesn't require a high level of expertise, and the digital output can be compared with other digital data. This methodology saves time and resources when revising and updating floodplain maps, especially in response to changes in hydrologic and hydraulic conditions.

Xiong (2011) [16] conducted a dam break analysis of the Foster Joseph Sayers dam, which is situated across the Susquehann river and has a height of 100ft and a length of 1.3 miles. The analysis was performed using the HEC-RAS numerical model, and three scenarios were considered, namely "no dam break", and "without dam". The author of the study stated that the dam break process is complex and comprehensive, and the actual mechanics of failure are difficult to comprehend. Neither physical nor empirical models could fully illustrate the various scenarios and impacts of a dam break. The study found that dam break caused by piping prolongs the time during which water surface elevation remains high, thereby increasing the duration of the associated risk. However, downstream maximum water surface elevation does not increase due to dam break instead, dam break results in a longer period of elevated water surface and reduced flood protection capacity of the dam. Without a dam,the downstream reaches are at even greater risk. The author also conducted a sensitivity analysis, which revealed that changes in dam break parameters would not significantly affect the downstream maximum water surface elevation or boundary conditions.

Timbadiya et al (2012) [17] developed a Hydrodynamic model of the lower Tapi River was created using HEC-RAS to account for unsteady flow conditions. The model was developed by utilizing surveyed data for the stream, as well as appropriate downstream and upstream boundary conditions. The simulated floods were compared with observed floods at various stations, and it was discovered that the simulated flows were quite similar to the observed flows. As a result, the developed model has been validated for flood forecasting purposes in the lower Tapi River.

Qi & Altinakar (2012) [18] developed a GIS-based decision support system for managing dam break floods at Sinclair Damin Milledgeville,Georgia, USA. The system relied on realistic two-dimensional flood simulations that were generated using classified remote sensing images. According to the author, the Monte-Carlo method was employed to account for uncertainties in different variables and parameters. The study's outcomes were confirmed using HEC-RAS and HEC-FDA software, demonstrating that the new system is highly adaptable and dependable in estimating flood damage, which could aid decision –making in future flood prevention designs.

Yerramilli (2012), [19], created a hybrid hydrodynamic model for the city of Jackson, MS using HEC-RAS. This model was utilized to identify flood hazards and assess the region's vulnerability by integrating the numerical model with GIS. The combination of a hydraulic model that employs the HEC-RAS one-dimensional flood simulation model and a GIS tool demonstrates the ability flood events and visually represent the level of exposure or vulnerability of a region to a hazard events in items of the extent of inundation, water level, and depth. The HEC-RAS model simulation outcomes were consistent with the observed inundation depth record at the respective locations.

Lai et al (2013) [20] conducted a study on Yangtze river basin since it is experiencing rapid changes due to human activities and climate changes in the catchment. They have created a hydrodynamic assessment model that is coupled to simulate a vast water system containing intricate river-lake interactions. The model consists of an unsteady one-dimensional (1D) and two-dimensional (2D) hydrodynamic model using a novel algorithm designed for large-scale water systems. This model has the capability to accurately replicate the primary physical processes that occur during seasonal wetting and drying that are controlled by intense river-lake interactions, as per their research.

ShahiriParsa et al (2013) [21] carried out a study to simulate the flood zoning on Kota Tinggi district of Johor state in Malaysia using HEC-RAS one-dimensional model by adopting various flood return periods and with different roughness coefficients. In order to improve the flood zoning results generated by the numerical model, a sensitivity analysis was conducted by varying the roughness coefficient, the coefficient of narrowing and opening, as well as that energy slope. By modifying the roughness coefficient, a water surface profile was generated. The research findings suggest that the sensitivity and recurrence of the flood are governed by the physical characteristics of the area, such as the reservoir water volume, upstream surface runoff area, and stream flood conditions.

Asnaashari et al (2014) [22] developed two hypothetical dam breach studies on Pinaus Lake dam near Version and Cold Spring Creek dam in Fairmont, Canada using HEC-RAS numerical model in combination with GIS tool. A study was carried out to determine the outflow hydrograph following a dam break, which involved routing the hydrograph through the river reach and floodplain downstream. The goal was to calculate the depth and durationof inundation, and maps were generated to depict the worst-case scenario, indicating the maximum possible area the could be flooded. Subsequently, incremental consequence analysis was conducted to evaluate the level of hazard and classify the dam. The findings of this study could be beneficial in enhancing dam breach analysis.

Benjankar et al (2014)[23] conducted study on three river systems in central idaho, specifically the South Fork Boise River, Bear Valley Creek, and Lower Deadwood River, using both 1D and 2D hydrodynamic models developed by DHI (MIKE 11 and MIKE 21). The researchers found that finer cross-sections (around 5m) in 1D modeling provided better results for hydraulic variables such as water depth, water surface elevation, velocity, and bed shear stress compared to 2D modeling. However, when coarser cross-sections were used, hydraulic variables varied both longitudinally and transversely in 2D modeling, whereas they remained the same for the entire cross-section in 1D modeling.

Piper (2014) [24] conducted study on Lower Thames flood risk management strategy which gives ideas about balancing flood risk and development in the flood plain. The basis for his study is the severe flood that mainland Europe experienced in 2000, along with the policy developed by the UK government with the aim of achieving the greatest benefits for the environment, society, and economy in terms of sustainable development. The policy applies to the most significant risk-prone and unprotected flood plain inn England which encompasses 21,000 properties and 50,000 individuals and has a flood risk exceeding 0.5% annual exceedance probability. The aftermath of a flood of this magnitude is severe, with flooding lasting up to two weeks, causing disruption in highways, and disturbing the supply of drinking water in London. The damages caused by flooding have doubled due to the worsening impacts of climate change. The main objective of the Lower Thames Strategy is to find a sustainable solution that can reduce the risk of flooding to both human beings and properties. To achieve this goal, the strategy aims to minimize disruption to infrastructure, protect the location of nature conservation and biodiversity,and maintain the quality and sediment level of rivers.

Dottori et al (2016) [25] have developed high resolution flood hazard models which is suitable at continental and global scale level helping the developing countries and data scarce regions to increase their preparedness to flood event and reduce the flood impacts. A model was developed using daily river discharge data from long-term simulations of the Global Flood Awareness System 9GloFAS) hydrological model. The dates were adjusted to match the high-resolution river network and used as input for flood inundation simulations conducted in a two-dimensional hydrodynamic model. In this paper, the authors have identified flood prone areas and generated flood hazard maps for different return periods at a lower resolution. They evaluated the performance of their methodology in several river basins around the world by comparing the simulated food maps with official flood hazard maps created using satellite images. Additionally, they studied the sensitivity of their flood models to various parameters as well as the strengths, limitations, and potential improvements of their methodology.

Zope et al (2016) [26] conducted research on the effects of land use and land cover alterations on urban flood patterns in the Oshiwara River of Mumbai, India. They employed HEC-HMS hydrological models in conjunction with the HEC-GeoHMS GIS module to conduct their study. To achieve this objective, the study utilized topographic maps and satellite images to conduct land use change analysis for the years 1966, 2001, and 2006. The findings indicate a 74.84% increase in the built-up area and a 42.80% decrease in open space. Furthermore, the impact of these land use changes on flood hydrograph for different return periods was assessedusing a hydrological model. Results showed that for a 100-yer return period, there was an increase in peak runoff and runoff volume by 10.4% and 12.2% respectively. According to the flood hazard analysis, the highly hazardous zone area has increased by 64.29%, while the less hazardous zone area has decreased by 32.14%. As a result, there has been an overall increase in the flood hazard area by 22.27%. The authors propose that these findings from the model can serve as a basis for developing flood mitigation and early evacuation management plans, as well as criteria for insurance policies offered by insurance organizations on properties located in the affected area.

Khattak et al(2016) [27] have carried out floodplain mapping study for part of Kabul river in Pakistan using HEC-RAS hydraulic model. The study team used conventional methods such as log-normal, Log-Pearson type-III, and Gumbel's methods to determine extreme flows in the river for varying return periods. After performing the kolomogorov test, they concluded that Log-0Pearson type-III was the most appropriate for their study area. The obtained results were then utilized as input in the HEC-RAS model to determine the anticipated flood level in the river reach stretching from Warsak dam to Attock. The obtained outcomes were exported to ArcGIS software, which was utilized to prepare floodplain maps for various periods. By scrutinizing the floodplain maps, areas susceptibleto flood hazards were identified, and it was determined that the flood could potentially inundate 400% more area than the regular river flow. The researchers concluded that the combination of HEC-RAS and ArcGIS is an effective method for floodplain mapping, providing more accurate outcomes that can be employed in decision support systems.

Moya Quiroga et al (2016) [28] conducted a 2D simulation on the vast plains of Lianos de Moxos in Bolivian Amazoniawhich was continuously being flooded by Mamore river. Anew version of HEC-RAS, version 5, wasutilized the February 2014 flood in Bolivian Amazonia. This version incorporates Two-dimensional (2D) capabilities, enabling the solution of either the full 2D Saint Venant equation or 2D diffusive wave equations. A new version of HEC-RASA, namely version 5, was utilized in the simulation of the February 2014 flood in Bolivian. This updated version includes Two dimensional (2D) capabilities, enabling the solution of either the full 2D Saint Venant equation or 2D diffusive wave equations. The performance of the HEC-RAS 2D hydraulic model simulation was evaluated by comparing its results with the event's satellite images. The researchers found that the simulation displayed good performance as it closely matched the observed inundation from satellite images. Additionally, the simulation provided extra information on flood depth, flow velocity and flood duration. The study found that the Mamore River is particularly dangerous during floods, exhibiting larger extents, deeper depths, and longer durations. Based on these findings, it was concluded that the HEC-RAS Ver.5 is a valuable tool for analyzing and understanding flood events, and its application may aid in developing effective flood management strategies. According to the conducted study, it was noted that both the 2D Saint Venant equation and the 2D diffusive wave equation yield identical outcomes. However, solving the 2D diffusive wave equation simulation is quicker than solving the 2D Saint Venant equation simulation. HEC-RAS Version 5 offers two modeling options: a fully 2D modelor a hybrid 1d-2D model. Specifically, the main river reach can be simulated as a 1D model, while the flood plain can be simulated as a 2D model. Additionally, it has been suggested that the hybrid 1D-2D model is faster than the 2D model.

Hydrodynamic Models:-

The study of dam breaks and flood routing relies on numerical models, which can be either one-dimensional, two-dimensional, or a combination of both. However, when the channel width widens or the flow losses its channelization, the accuracy of one-dimensional models decreases. As a result, two-dimensional models are more dependable when conducting floodplain studies. The majority of hydrodynamic models utilized for calculating dam breach hydrographs and flood routing are parametric models, which can be classified as either hydrologic or hydraulic models. Hydrologic models, such as HEC-HMS, solves the equation of continuity, and they offer the advantages of simplicity, user-friendliness, and computational efficiency. The models can generated a weakened flood hydrograph at a specific location, but they cannot offer precise outcomes for water surface elevation and flow velocity. As a result. Unsteady flow and dynamic routing methods are commonly used for dam break flood mapping studies due to the limitations of the hydrologic models. The approach known as transient flow or hydraulic routing involves solving the equations of continuously and momentum, which makes it well-suited for forecasting the development and downstream spread of a flood resulting from a dam breach. In hydrodynamic modeling, Barre De Saint Venant's equations from 1871 are employed. These equations consist of two differential equations, namely the Continuity equation, which deals with the conservation of mass (eqn.1), and the Conservation of momentum (eqn.2) equation.

$$\frac{\partial Q}{\partial x} + \frac{\partial A}{\partial t} = 0$$

………………………..eq^n.(1)

$$\frac{1}{A}\frac{\partial Q}{\partial t} + \frac{1}{A}\frac{\partial}{\partial x}\left(\frac{Q^2}{A}\right) + g\frac{\partial y}{\partial x} - g(S_o - S_f) = 0$$

………..eq^n.(2)

DAMBRK MODEL was developed by NWS, USAin 1984 and it was updated by BOSS Internationals. This model predicts dam breach wave formation and its progression in downstream. DAMBRK's key attributes include its capacity to depict the dam's failure mode both temporally and geometrically, calculate the outflow hydrograph across the breached section, and direct the outflow through a downstream channel. This model is good in determining potential influenced area allowing users to input geometric and temporal data to accurately predict the initial breach wave. This includes both piping and overtopping failures. The updated BOSS DAMBRK has many improvements including faster calculations and it has graphic interface[29].

FLO-2D model developed in 1989 based on MUDFLOW model. The prediction of flood hazards, mudflows, and debris flows over alluvial rivers involves the use of a grid system to determine floodplains based on elevation and roughness coefficients. This method is highly effective in accurately predicting both the flow path and areas. According to the model, it is possible to simulate both sediment-laden and sediment-free flows. The model estimates the discharge by calculating the depth of flow over each sector and summing up the values for all sectors on the four sides of the grid. The accuracy of the model relies on the density of the grid system and the availability of data [30].

FLDWAV model was developed by the National Weather Services, USA as replacement to DAMBRK model. The model incorporates wave front tracking technology, which enhances its accuracy while reducing computational time. This enables it to predict dam breaches and calculate the potentially affected areas. The purpose of this model is to simulate fast flood incidents resulting from intense precipitation or dam breaches. It can predict the water flow in a single stream or a network of streams by employing advanced forecasting technology that takes into account the terrain and characteristics of the material at various time intervals, thereby adjusting the flow pattern. The model has a secondary function of predicting the flow in hydrological structures and river basins, as well as conducting dam break analysis, flood predictions, and rapid flow scenarios such as pumping stations. It has the ability to model the transition from subcritical to supercritical flow and vice versa based on location and time. Additionally, it can simulate one-dimensional unsteady debris flow [31].

SMPDBK, a model developed by National Weather Services (NWS), USA as simplified version of DAMBRK. This model is beneficial for acquiring dam classification and determining the potential risk of dam failure. In contrast to DAMBRK, this method is fast and straightforward, and it doesn’t demand multiple parameters, but it generates comparable outcomes with DAMBRK when applied to less complex scenarios. The SMPDBK model is capableof generating the necessary data for identifying downstream inundation zones, while also being efficient in simulating dam break scenarios and aiding in the creation of emergency action plans. Furthermore, this model can run on relatively low-spec computes without any issues [32].

Danish Hydraulic Institute (**DHI**) **MIKE11** is a new generation software of fully windows integrated graphical user interface. The application is availablein both 32-bit and 64-bit versions, and boastsa significantly faster computationspeed when compared to earlier iterations of MIKE and other software. It is a fully dynamic and user-friendly one-dimensional tool designed for break analysis, with the ability to simulate flood waves, sediment transportation, water quality in channels or water bodies, and more. MIKE 11 has distinguishing characteristic is its integrated modular architecture, which incorporates a variety of add-on modules such as hydrology. Advection-dispersion, water quality, cohesive sediment transport, non-cohesive sediment transport, hydrodynamics, rainfall-runoff modeling, and flood forecasting. Among these modules, the hydrodynamic component is a core feature of the MIKE 11 package, which simulates unsteady flow in open channels using an implicit finite difference method for simulation [33].

Danish Hydraulic Institute (**DHI**) **MIKE 21,** which is a two-dimensional modeling tool, was developed using MIKE 11 as a basis. It is designed for analysing 2D free surface flows, and can be used to study the behaviour of Newtonian fluids over dry terrain. The software is employed to simulate the flow in rivers and estuaries in two dimensions and forecast various floodplain scenarios. It can handle sub-critical, super-critical, and mixed flow conditions, making it useful for designing coastal and offshore structures, as well as modeling inland and overland flooding. When simulating floods that are steeply rising and have a large volume of water, it is important to exercise caution. The method used for solving the numerical solution of the shallow water equations is based on the finite difference approach. This involves integrating the depth of the incompressible Reynolds averaged Navier-Stokes equations in two dimensions. While accounting for the Boussinesq assumption and the hydrostatic pressure [34].

Hydraulic Engineering Centre’s- River Analysis System (HEC-RAS) is developed by USACE’s Hydrologic Engineering Center. Before February 2016, it was only feasible to model flow as one –dimensional in earlier versions of HEC-RAS by using the full Saint Venant equation. However, the updated version of RAS released in February 2016, introduced a new features allowing for two-dimensional hydrodynamic unsteady flow routing, utilizing either the Saint Venant equation or the Diffusion wave equation. The HEC-RAS model is capable of simulating the flow in both river channels and floodplains, and it has been deemed an effective tool for predicting downstream flooding resulting from an upstream event, such as a dam break. To simulate the dam break scenarios, the HEC-RAS model requires input on the breach information and geometry.The simulation model creates a flood wave that results from an upstream event and predicts downstream impacts through dam break studies. It can handle both on-channel and off-channel reservoir storage, perform dam break modeling, and conduct mixed flow analysis [35].

TUFLOW is a powerful and flexible software that supports a range of modeling applications including 1D, 2D, and 3D hydraulic modeling, floodplain mapping and stormwater management. TUFLOW is a hydraulic modeling software that was first developed by engineers at the Water Research Laboratory (WRL) at the University of New South Wales in Australia in the late 1990s. The software was substantially commercialized by the company BMT in 2002, and has since been continuously updated and improved by a team of engineers and developers.It uses a finite-volume numerical method to solve the governing equations of water flow and sediment transport, and includes a range of physical processes such as turbulence, sedimentation, and erosion. TUFLOW is capable of simulating the hydraulic behaviour of complex flows, including unsteady, non-uniform and rapidly varying flows, which makes it a useful tool for dam break modeling. TUFLOW has been used for dam break modeling in a number of studies, including for emergency action planning and risk assessment. The software can simulate the breach process by specifying the breach geometry, size, and timing, and can predict the resulting flood wave propagation downstream. The software is based on the Shallow Water Equations (SWE), which are a set of partial differential equations that describe the movement of water in shallow rivers, estuaries, and floodplains. They are commonly used in hydraulic modeling because they are well-suited to simulating the behaviour of shallow flows with low Froude numbers [36].

ISIS-Integrated Surface and Subsurface Hydrological Simulation, the hydraulic model was developed by the UK's Environment Agency. It is physically-based, distributed hydrological model that simulates the movement of water through the landscape. The model is governed by a set of partial differential equations that describe the conservation of mass and momentum of water flowing over the land surface and through the subsurface soil layers. These equations are based on the principles of fluid mechanics and are solved using numerical methods.The key equations used in the ISIS model include continuity equation, momentum equation, the infiltration equation and the groundwater flow equation. By solving these equations, the ISIS model can predict the spatial and temporal distribution of water flow, surface runoff, and groundwater recharge in a given catchment area. This information can be used to help manage water resources, assess flood risk, and plan land use activities. The ISIS model can be used for dam break simulation. The model is capable of simulating the propagation of flood waves resulting from a dam break event, and can be used to predict the extent and severity of flooding downstream of the dam. It is worth noting that the accuracy of the ISIS model's predictions for dam break events will depend on the quality of the input data and the assumptions made the behaviour of the water and the surrounding environment. Therefore, it is important to validate the model's results against actual observations and to use caution when interpreting its predictions. The ISIS model has been used for a range of dam break simulations, including the simulation of the Vajont dam disaster in Italy in 1963 and the Oroville dam crisis in California in 2017. These simulations have helped to inform emergency management plans and improve our understanding of the potential impacts of dam failure [37].

TELEMAC is a hydraulic modeling software developed by EDF (Electricite de France), one of the world's largest electricity companies. The TELEMAC system is designed to simulate the behaviour of water and fluid flows in rivers, estuaries, and coastal areas. The development of TELEMAC begins in the early 1980s for simulation hydrodynamic process in complex water systems widely used by engineers, researchers in the water management industry around the world. It uses finite element and finite volume methods to solve complex equations of fluid motion, and can handle 2D and 3D models with unstructured meshes. TELEMAC can simulate the propagation of the flood wave resulting from a dam break and the interaction of the flood with the surrounding terrain. To model a dam break event, the user would typically start by setting up a simulation of the dam and its surrounding area. This would involve creating a 2D or 3D model of the terrain, the water in the reservoir, and the dam itself. Once the model is set up, the user can simulate the failure of the dam and the release of the water into the downstream area. TELEMAC can provide valuable information for dam break studies, including the speed and depth of the flood wave, the extent of the flooding, and the areas that are most at risk. This information can be used to develop emergency response plans, to design mitigation measures, and to assess the [potential impacts of a dam break events [38].

SOBEK is a powerful hydraulic modeling software developed by Deltares, a leading Dutch research institute and consultancy firm specializing in water and subsurface management. SOBEK can simulate dam break scenarios by modelling the release of water from the dam and the resulting flood wave that propagates downstream. The modelcan take into account the characteristics of the dam, such as its size, shape and material properties, as well as the properties of the water and surrounding terrain. The governing equations used in SOBEK are based on the principles of conservation of mass, momentum and energy, which are describe by the Navier-Stokes equations. SOBEK also includes a variety of sub-models for simulating different processes related to water flow and quality, such as sediment transport, erosion and deposition, water temperature, and water quality [39].

OpenFOAM is a free and open-source computational fluid dynamics (CFD) software package that is widely used for simulating fluid flow and heat transfer in a variety of engineering applications. It was originally developed by OpenCFD Ltd in the UK, and is now maintained by the OpenFOAMFoundation.One of the key applications ofOpenFOAM is in hydraulic modeling, which involves simulating the flow of water or other fluids in hydraulic structures such as dams, spillways, and channels. This is important for a variety of reasons, including designing and optimising hydraulic structures, predicting and mitigating the impact of floods and other natural disasters, and assessing the environmental impact of hydraulic engineering projects.The governing equations that are solved by

OpenFOAM in hydraulic modeling are the Navier-Stokes equations, which describe the motion of fluids. These equations are solved using numerical methods such as the finite volume method, which discretizes the equations into a set of algebraic equations that can be solved using a computer. One of the key advantages using OpenFOAM for hydraulic modeling is that it allows for the simulation of complex geometries and flow conditions that are difficult or impossible to replicate in the laboratory or in the field. Forexample, OpenFOAM can be used to model the behaviour of a dam during a dam break, which is an important scenario to consider for dam safety and flood management [40].

HYDRO-4S-2D is a hydraulic numerical model used to simulate water flow and flood inundation in river channels and floodplains. It was developed by the Hydraulic Engineering Centre of the Netherlands (HEC-NL) in collaboration with Deltares, a Dutch applied research institute.

The model is based on the 2D shallow water equations, which describes the conservation of mass and momentum for a fluid in motion. These equations are supplemented by a bed resistance term, which takes into account the frictional resistance of the channel bed. The model also includes equations for the computation of lateral inflow, storage and discharge from floodplains. The HYDRO-4S-2D model is capable of simulating a wide range of flow conditions, from steady-state to unsteady flow, and can handle complex topography and boundary conditions. The model uses a finite volume method to discretises the equations and solve them numerically. The HYDRO-4S-2D model can be used to simulate the propagation of flood waves downstream of a dam breach, including the interaction of the flood wave with the river channel and floodplain. In addition, the HYDRO-4S-2D model can be used to evaluate the potential environmental impacts of a dam failure, such as erosion, sedimentation, and changes to water quality. This information can be used to inform decisions about the management of dams and the design of new infrastructures. The HYDRO-4S-2D hydraulic model can be integrated with GIS data to provide additional spatial information for the simulation. The model can read in elevation data, channel cross-sections, and other spatial data from GIS software, and use this information to define the computationaldomain, boundary conditions, and other input parameters for the simulation.

Conclusions:-

Dams are built across rivers to store water upstream and release it downstream as needed. Despite the numerous benefits of dams and reservoirs, dam failures can result in disasters for human life and property, including the loss of life, roads, railways, bridges and buildings. Hence it is necessary to carry out dam break analysis to study the behaviour of the flood wave generated from the dam break and to prepare the inundation maps as a part of emergency action plan to evacuate the population during the flood event. In a dam break study, choosing the right model is crucial. The selection process involves examining the study area, the available dam breached parameters, and the model’s precision. The review of the literature revealed that HEC-RAS is an efficient tool for conducting dam break studies and that the simulation model’s result can be exported to a GIS platform through GeoRAS to create inundation maps with greater reliability.

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