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Evaluating Highway Drainage Systems for Flood Mitigation: A Case Study of the Benin-Auchi Expressway in Esan West, Edo State

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Abstract Flooding poses a significant threat to highway infrastructure by weakening the structures, making them unsafe, and reducing how long they last. This research looks at how well the drainage systems along the Benin-Auchi Expressway in Edo State, Nigeria, prevent flood risks. The area studied is between Ikhirolo Road Junction and Ukpenu Road Junction in Esan West Local Government Area. This area has a low-lying landscape made worse by many streets coming together at the expressway, causing frequent flooding during heavy rain. The main goal of this study is to design an optimised drainage system that can efficiently manage surface water runoff and prevent flooding on the road, protecting the highway's strength and ensuring continuous traffic flow. The methods include detailed analyses of the region's rainfall patterns, terrain features, and water behaviours. Field surveys and data collection assess the existing drainage, identify flood-prone zones, and evaluate soil absorptivity. Using Geographic Information Systems (GIS), mapping hydrological features, rainfall intensity, and flood risk areas guide where to put the proposed drainage solutions. Local and regional communities, relevant policymakers, and environmental professionals are the best people to give feedback as the strategies meet various needs and capabilities.

Hydraulic design analysis is presented with Manning's equation, which supplies the ideal open channel dimensions, slopes, and construction material for water flow optimisation particular to the region. The drainage system includes trapezoidal channels BRC mesh along the road guard, which accelerates, including pick-up water. The design provides intake and outflow to regulate water speed and lessen erosion to create a nice flow into the streams and rivers around. The design solutions are based on an accurate calculus of flow rates, discharge capacity, excavation dimensions, and concrete volume requirements addition, which will guarantee that the system can handle the current level of water flows and the future, which might be up to 20 years. The research will contribute to the body of civil engineering knowledge by presenting a comprehensive procedure for flood management in highway planning. Its application may be sought for coastal regions experiencing floods as it addresses the demanding task of sustainable infrastructure development in such a setting.

Keywords Flooding, Highway drainage, Mitigation, Benin-Auchi Expressway, Esan West, Hydrological analysis, Meteorological analysis, Trapezoidal channels, Reinforcement, Catch pits, and Culverts.

1. Introduction and Background

1.1. Introduction

The intensity and durability of the highway infrastructure are highly correlated with the effectiveness of the drainage systems, which debar the harmful effects of water buildup. Suppose hydro-meteorological disasters, especially floods, are to be considered as another major peril to the roadway system that could worsen their structural stability and endanger safety and efficient operation. In that case, it is something we must become more aware of. The hazardous effect of excess moisture on the weight the soil can lift highlights that achieving robust highway drainage practices at a high rate is a key indicator of the soundness of the road structure and embankments. Permanent submergences in paved surfaces have been well-recognized as one of the most intricate components in the construction of the infrastructure to date. Puddles on the road surface restrict the traction of tyres and reduce visibility due to water spraying. This illustrates the critical necessity of effective drainage systems to keep the roads safe and resistant to ice buildup. Last but not least, flooding event randomness factors built around heavy rainfall, melting snow, and, e.g., bursting water storage installations underline the necessity of adjusting the dutiful engineering solutions to counteract floods caused by the destructive flows of decontrol water. Flooding is common in areas with a high risk of flooding. Therefore, constructing highways demands a careful consideration of flood risks and the addition of measures to prevent materials blocking downstream flow, as well as flow control structures to keep the storm runoff out of the highway.

The primary target of this study is to assess the options for drainage that are already being used along the Benin-Auchi Expressway and improve on the plans that will tackle the activities of flooding. The method points out an integral location analysis, a prerequisite for comprehending the region's precipitation patterns, terrain features, and water movement. Field surveys and data gathering do essentially the same: evaluate the Imperviousness of current drainage facilities, detect flood-threatened areas, and asses soil permeability capability of soils. Spatial mapping through GIS shows where water features, rainfall intensity, and flood risk are according to that location, which is the principal guide to the exact placement of proposed drainage projects. Collaborations with nearby citizens, legislators, and emergency planners help to pursue community-specific flood mitigation tactics accordingly. The hydraulic design determines Manning's equation to maximise open channel dimensions, slopes, and construction materials by the specific conditions of the region so that optimal flow resistance is accomplished. The proposed ditch uses trapezoidal channels lined with BRC mesh and is set at an angle so that they may facilitate efficient removal of run-off water from the surface. We applied deceleration and balancing pits and ditches into the design for flow speed control, force mitigation, and seamlessness to neighbouring streams or rivers. The objective of this study is to create a sustainable and comprehensive drainage system which can manage surface water runoff and keep highway flooding from the Benin-Auchi Expressway, thus protecting the roads from harm and keeping traffic on the roads uninterrupted.

1.2. Research Background

The problems connected with road networks due to floods have been a serious matter for a long time, and everyone interested in urban planning and engineering must be concerned about it. Functional drainage systems of highways help to mitigate the dangerous water accumulation conditions on roads, preventing possible road destruction and endangering the safety of motorists. Nevertheless, a design and an implementation of those systems have to be a posteriori fitted for a set of site-dependent hydrometeorological patterns and particular topographic features, which results in flow patterns that aim at the most appropriate height of water surface projection possible. In the Benin-Auchi Expressway in Edo State, Nigeria, the Esan West Local Government drift from flooding stands out, affirming the importance of thorough drainage networks' evaluation and optimisation. Regularly used as a distribution road for goods and as a reliable way to move people around, this vital local transport is an essential element in the town's economic development. The junction where all streets move onto the expressway, plus the area's hilly terrain, leads to the creation of what might be described as a perfect storm when it rains heavily. As the old drainage system has proved powerless in this case, replacing it with a system able to process precipitation adequately becomes essential for avoiding the risk of highway breakage, environmental worsening, and threats to commuters and residents.

For civil engineers, as long as the history exhibition is held, flood control and water flow management will be the primary objectives almost everywhere. In old civilisations, just as the Egyptians and Mesopotamians, the commanding of water flow and flooding were learnt through the development of compound irrigation and drainage systems, showing how practical this engineering challenge is even in the current days. With ever-growing technological innovations, more complicated hydrological and meteorological analyses could be applied to understand spatial features, rainfall patterns, and the dynamics of water movement. Their results further the knowledge about creating and applying drainage systems that are more context-conscious and practical than ever. Additionally, it is difficult to overestimate the extent of the significance of the integration of GIS (Geographic et al.), which changed the nature of spatial cartography altogether. Now, it allows engineers to visualise and analyse the interactions between hydrological features, the influences of rainfall intensity, and flood risk areas. In this regard, spatial data is a key factor in identifying the best sites for engineered solutions and providing an informed decision. Another inevitable fact is that stakeholder engagement and involvement have become a cornerstone of successful flood management. The inclusion of local community members, policymakers, and environmental experts can improve the functioning of engineers. The engineers can then easily find answers to questions prioritising technical, cultural, and social criteria.

The specification of hydraulic design of drainage systems has drawn a great deal of scientific research. Hence, engineers keep coming up with solutions to the ongoing problems posed by urbanisation, changes in climate, and land use. Subject to principles such as Manning's equation and the means of channels's open areas, gradients and making out of the materials are the key factors in designing the civil engineering field. In this context, the research to be conducted is intended to be an addition to the work in progress at reducing the existing flood hazards and enhancing the resilience of the transportation network. Innovating with the top tech solutions, sound engineering fundamental rules and the support of interested parties, the research work will design an effective strategy that will tackle the flooding problems along the Benin-Auchi road and, consequently, the sustainable livelihoods, commuters and local businesses.

1.3. Research Questions

1. What are the primary causes of water accumulation on the Benin-Auchi Expressway, and how do they contribute to structural damage and deterioration?
2. How effective are the existing drainage systems in preventing water accumulation and protecting the road pavements along the expressway?
3. What are the optimal design specifications for an open channel drainage system to efficiently manage water flow and prevent flooding along the expressway?
4. How can integrating hydrological and meteorological data improve the design and implementation of flood control measures for the Benin-Auchi Expressway?
5. What are the potential consequences of insufficient drainage on the soil strength, stability, and longevity of the Benin-Auchi Expressway infrastructure?

1.4. Research Objectives

1. **Water Management:** To implement effective drainage solutions that prevent water accumulation on the road surface, thereby mitigating the risk of structural damage.
2. **Public Health:** To eliminate potential health hazards by preventing the formation of stagnant water bodies along the highway, which serve as breeding grounds for mosquitoes.
3. **Road Integrity:** To protect the road from damage, such as potholes and sub-grade erosion, thereby reducing the risk of accidents and enhancing safety.
4. **Functional Sustainability:** To ensure the road is running to its intended mission, the optimal load bearing and durability, along with other quantitative physical standards, must be kept as essential.
5. **Design Challenges:** Highway drainage systems design and efficiencies will be recognised, and solutions will be provided for the factors and challenges.

Community Benefit: My objective is to bring about this result through an elaborate design incorporating durable and long-lasting materials that would fit the community's requirements both in the present and future.

1.5. Scope of the Study

This study seeks the design and implementation of a system of drainage that will reduce the rate of flooding and secure the structural performance during the buildup of vehicles driving between Ikhirolo road and Ukpenu junction on the Benin-Auchi expressway. The study will consist of a full review of the current drainage infrastructure to address shortcomings based on the nature of drainage and tailor it to the local surface water and terrain. The project aims to build a drainage system design featuring trapezoidal drains, ditches, and catch pits, providing runoff with minimal buildup on the roadway surface. The design will be rooted in a detailed analysis

of water flows and movement, employing methods such as Manning's formula and experience-based equations to find the optimal denationalisation, slopes and materials for each drainage system component.
The evaluation would also include analysing weather data, rainfall items like intensity, and how often extreme rainfall happens to ensure that the suggested drainage system will withstand severe events and adapt to future climate change. During this session, we will do field surveys and gather data to tell how fast and how saturating water absorption is, what the terrain characteristics are, and how effective ongoing flood control schemes are. The area of consideration comprises assessing a suite of flood management solutions, both structural and non-structural, and eventually identifying the ultimate strategy for the study area. All these will be done together, including but not limited to cost-benefit, environmental impact assessment, and input from people whom this will affect so that the solutions are area-specific and meet the needs, means, and sustainability goals of the local people. This research also assesses the social, economic, and environmental effects of ineffective warning systems that destroy infrastructure and cause health and economic downside to the environment. The results and suggestions of this study will add to the general discourse on maintaining the sustainability of infrastructure and flood hazard management, where it might serve as the blueprint for many similar future initiatives.

2. Literature Review and Research Design

2.1 Definition of Flood

Floods form part of natural disasters classified as overflowing that much water before its typical boundaries, ultimately leading to land submergence and great magnitude of destruction (Hirabayashi et al., 2022). The word "flood" is derived from the Old English word "flood" and shares usage in other languages in the Teutonic group. This is important across cultures and histories (Kundzewicz et al., 2017). The term flood includes river overflows that are caused by excessive rainfall, melting snow, or a combination of all, and the term also extends to sea floods, which may be of different forms, such as storms, tsunamis and deeper harbours (Vousdoukas et al., 2018). Floods are not expected to be caused by the usual enlargement of the water area through the growth of tides, as they result in a complete water spillage and a breakdown of the holding capacity of water bodies (Keeling & Hernández Ayala, 2019). This character of Icis has been portrayed in two aspects as being destructive while, on the other hand, bringing some gains to the soil, such as replenishment for agriculture due to its flowing with the River Nile (Taye et al., 2018).
Flooding is categorised into extreme variations like de-containment of water bodies, a breach of river banks, and eventually overflows of water beyond the ordinary confines of the water bodies (Wilby & Keenan, 2022). This complexity stresses the demand for robust engineering interventions, starting from structural defences to strategic water management practices, to adapt infrastructure to the events of water overflow (Vousdoukas et al., 2020). Flood-prone regions in which highways are likely to get affected by floods demand careful planning and construction of highway infrastructures, considering flood risk and installing systems to facilitate flood run-off (Yin et al., 2020). This study addresses the intricacies of highway drainage and flood control in the approach to sustainable infrastructure in areas prone to flooding (Pregnolato et al. Sustainable Infrastructure in flood-prone Areas, 2017).

2.1.1. Factors causing Flooding

Floods, undoubtedly among the natural disasters category, refer to the overflowing of much water before its boundaries and eventually lead to land submergence and a great magnitude of destruction (Hirabayashi et al., 2022). "The word "flood" is derived from Old English "flood", and "The word "flood" is the same as the Teutonic word "flood". This means that water is an issue in every culture and even is the same throughout different histories (Kundzewicz et al., 2017). The term flood embraces an overflow of rivers that is attributed to either a mass of rainfall or snow melting, and this is commonly abbreviated to simply "flood," this term covers not only overflowing of the sea waters but also different forms such as storms, tsunami or even deep harbours (Vousdoukas et al., 2018). Interestingly, floods cannot be exactly accounted for by the inland expansion of water area through tide increase because it results in a full spillage of the water bodies and a collapse of the holding capacity of dams and other dams can hold water (Keeling & Hernadez Ayala, 2019). This particular part about Icis being depicted as both destructive and catastrophic and having aftermath effects such as replenishing for agriculture because of its flowing with the River Nile (Taye et al., 2018) also shows how she is a complex character.

Many forms of flooding mainly diverge into categories such as lakes, rivers, or ponds that exceed their limits and flow above their normal boundaries. The latter type is referred to as over-banking or bank-full floods. This variety highlights the need for effective engineering solutions de jour, including structural defences and enhanced water management strategy, to cope with the unfolding of water overflow (Vousdoukas et al., 2020). In areas subjected to flooding and with the probability of getting the highways engaged in those floods, it takes highly thoughtful planning and construction of infrastructures considering the issue of flood risk and installing systems to facilitate flood run-offs (Yin et al., 2020). This investigation reveals the sophistication of highway drainage and flood control mechanisms in the context of resilient communities in the actual flood zones (Pregnolato et al., 2017).

2.1.2. Human Activities

Human impacts, such as deforestation, arable farming, and urbanisation, exacerbate the risk as they interrupt the natural water flow (Taye et al., 2018). They also block natural water absorption processes and reduce soil integrity causing the major infiltration capacity decline and rapid runoff in the water flow (Wilby & Keenan, 2022). The fact that only such actions prove their effectiveness makes one realise the crucial significance of land-use and urban development methods, which do not raise flood risks (Vousdoukas et al., 2020). Regarding urbanisation, the natural water conveyance has largely changed because of the small porosity of paved surfaces like roads, buildings, and parking lots (Yin et al., 2020). These might become problems because street flooding, building collapses, and the excess of water surface runoff will cause other water-related hazards. (Pregnolato et al., 2017). Besides this, the construction plantation of crops and the compaction of soil during construction measures worsen this menace (Hirabayashi et al., 2022).

Furthermore, the conversion of seasonal wetlands and floodplains to human agriculture activities has also affected the extent of flooding in some areas (Kundzewicz et al., 2017). This region used to have some areas that worked as a buffer zone for durations of heavy rain and floods. However, since it can’t absorb an extra amount of water as it used to, excessive flood swamps in its surrounding areas. Besides the land clearing and massive machinery utilisation, which mechanises the earth's substructures and reduces the soil's capability to absorb water, these factors are also responsible for compacting the soil, which affects its water absorption power (Keeling & Hernández Ayala, 2019). In the first place, it is essential to realise the part performed by human activities in increasing flood risk, which is of great importance in developing breakthrough strategies that can reduce flooding (Taye et al., 2018). To achieve this, we propose the use of sustainable land management, incorporating urban green designs, and the restoration of natural flood plains and wetlands so that they function to increase water absorption and storage (Wilby& Keenan, 2022).

2.2. Principal Types of Floods

The diversity of flood phenomena and the need for established procedures should be understood to develop successful management plans (Vousdoukas et al., 2020). The principal types of floods are periodical floods, such as seaside floods, riverine floods, estuarine floods, and flash floods, including disastrous floods (Yin et al., 2020). Periodic floods are a usual phenomenon that characterises river floodplains, and they may be caused by (i) a long run of rainfalls and (ii) the melting of snow, which overloads riverbeds (Pregnolato et al., 2017). Such a flood is called along the river where water flows during the season. It is, above all, a matter of floodplain areas adjacent to the rivers (Hirabayashi et al., 2022).

Coast floods that have arisen due to severe sea storms, high tides or underwater earthquakes during the last few years have affected some areas close to the sea residing on the shoreline (Kundzewicz et al.,2017). Though inland areas might be a part of overall regional flood risk, it is of great importance to extensively understand coastal flood dynamics in order to comprehensively estimate regional flood risk (Vousdoukas et al., 2018). Depending on the speed and duration of the inundation of the river flow, the action of floods can be considered to be fast (fast floods or flash floods) or slow (extended or Keellings & Hernández Ayala (2019). Flash floods are known by their fast onset, which may lead to the wash-away of materials by consequently [resulting] from intense thunderstorms or surges from dam breakages, and these cause extreme risks to areas with variable topography and hydrology because they are sudden and without warning (Taye et al., 2018). Unlike a sudden deluge, which is buttressed by torrents from heavy rainfall or slide off from mountains, a slow river overflow occurs when a river cannot drain at a high flow rate, and it is commonly experienced in monsoon regions or areas with water accumulation that has exceeded the drainage limit (Wilby & Keenan, 2022).

2.2.1. Estuarine Floods

Estuarine flooding can be attributed to the fact that the waters from the sea rise as a result of high tides and storm-driven winds. Estuarine zones are those where rivers meet the sea (Vousdoukas et al., 2020). Though it may depend more on coastal environments, the interrelation between riverine and estuarine dynamics can also influence the overall hydrological system (Yin et al., 2020). These high tides can be caused by powerful winds and low atmospheric pressure that lift the sea levels, resulting in water forcing its way through estuarial and coastal areas with minimum elevation. When SEMSW is combined with heavy rains, it can result in floods, the effects of which are intensified, making the inundation widespread. (Hirabayashi et al., 2022).

Flooding in estuaries may have a terrible effect on settlements located in the proximity of such areas, causing infrastructure damage and spoilage, economic base distortion, and pollution (Kundzewicz et al., 2017). An effective way of dealing with the issue of estuarine flooding generally involves a mix of relieving measures like sea walls and dykes along with nonstructural approaches like railing systems and well-distributed land planning. One of the most catastrophic climate-change-driven impacts is rising sea levels. Residents who live near estuaries will be more vulnerable to floods as the risk of inundation increases in response to rising water levels (Keellings & Hernández Ayala, 2019). The fact that the global population increases vigilance on proactive adaptation activities, including the inclusion of flooding by estuaries in management plans of coastal zones (Taye et al., 2018).

2.2.2. Flash Floods

Floods, which are characterised by sudden onset and rapid development, have caused massive casualties and destruction (Wilby & Keenan, 2022). Besides this, floods can result from aggressive rainfall, dam failure, or fast snowmelt, and the disaster may strike without either warnings or any advanced notifications (Vousdoukas et al., 2020). Unfortunately, flash floods are very powerful because they can generate huge amounts of water in a short time, even maybe carrying with them sand and stones, which can also destroy property. (Yin et al., 2020) Areas with slopes, narrow gorges, or urban vicinities, which would include poor drainage systems, are at the top of the list for flash flood risk (Pregnolato et al., 2017).

Successful management of flash floods is a multi-pronged process which incorporates advanced early warning systems, community preparedness, and structural solutions like retention ponds and reservoirs (Hirabayashi et al., 2022). Furthermore, urban planning, which includes drainage systems covering flood protection and green infrastructure outfitments, will be helpful against floods in urban areas (Kundzewicz et al., 2017). According to the forecast estimates on climate change, we may expect an increase in the number of occasional and vigorous rainfalls, and as a consequence, the risk of flash floods can be higher in many areas (Vousdoukas et al., 2018). In this case, the implementation of multipurpose flash flood management practice plans that take into account the expected changes in climate is an important requirement for the sustainability of the society and the reduction in the occurrence of setbacks as well as the loss of lives and property (Keeling & Hernández Ayala, 2019).

2.2.3. Catastrophic Floods

Heavy floods mainly occur as a consequence of the occurrence of a very unusual event, such as a dam burst or a great natural disaster (Taye et al., 2018). Wider destruction and severe loss of life are the main negative effects of severe floods; risk assessment and preparation will help to understand and plan for such events (Wilby & Keenan, 2022). Damages, such as structural failure that could result in outtopping or the deliberate breaching of dams, release immeasurable amounts of water in short periods and then carry these waters downstream (Vousdoukas et al., 2020). The effects of events like this could be catastrophic, which can wipe out the whole region and usually critical infrastructure that is sensitive enough to be damaged or destroyed.

Combining human-driven processes (e.g. floods made as a consequence of deforestation) and natural disasters (e.g. floods made as a consequence of volcanic eruptions, landslides, etc.) could also trigger catastrophic floods (Pregnolato et al., 2017). To illustrate one example, the 2004 Indian Ocean tsunami was accompanied by heavy flooding and deaths in various nations, as reported by scientists (Hirabayashi et al., 2022). A multidisciplinary strategy consisting of structural measures and emergency planning, as well as awareness of the public, is necessary for reducing risks due to catastrophic floods (Kurdzewycz S., 2017). This may involve the adoption of early warning systems, the development of evacuation plans, and supporting the strengthened building of the critical infrastructure against the tremendous force of the catastrophic water level (Vousdoukas et al., 2018).

2.3. Consequences of Flooding

Flooding carries enormous environmental, economic, and health risks with irreversible and cumulative impacts that demonstrate the imperativeness of developing a strong flood management program (Keeling & Hernández Ayala, 2019). This part highlights the varied implications of flooding involving, for example, single-place observations and themes discussed by researchers such as Taye et al. (2018). From the ecological and health standpoints, floods can cause water problems because they increase the chance of cholera and typhoid transmissions. The water can be polluted with human excreta (Wilby & Keenan, 2022). This point depicts the urgent need for waste management and clean water systems in flood-prone areas that would help mitigate this challenge. Truly, the dangers posed by floods are immediate and physical, consisting of loss of life and injury, even to the extent of catching populations unawares if the situation is that of a flash flood (Vousdoukas et al., 2020).

Flood-induced economic effects can also be great if we consider the huge amount of money spent on repairing public infrastructure, medical aid and provision of essentials such as food and water (Yin et al., 2020). The community and businesses with the adverse impact of flooding, such as aquaculture farming and disrupting the normal flow of daily processes, are considered to have a physical impact in losses like property and sales (Valentine et al., 2017). This would include social and environmental damages of flooding, which include loss of people's lives, health issues, and unstable environment of society (Hirabayashi et al., 2022). The two most susceptible sectors, infrastructure and agriculture, to the flood's effects, according to Kundzewicz et al. in 2017. During floods, Telecommunications and electricity services might be disconnected; this will also hinder how the emergency response is being managed or how a recovery strategy is being implemented. Another consequence of the agrarian sector's direct impacts from the water surge constituted the food security of farming communities, which adversely affected their economic stability (Vousdoukas et al., 2018).

2.4. Flood Defense, Planning, and Management

Proper flood management activities need local solutions, and the great variations in flood control measures in different climatic zones should be born in mind (Keellings & Hernández Ayala, 2019). This is an issue of quite an importance in Ekpoma's Esan West Local Government Area. This is because specific local parameters often drive the best practices for mitigating flood damage. By transferring and adapting global flood defence technologies, we will get valuable lessons relating to flood risk management (Wilby, Keenan, 2022). An example of such a case is the Thames Barrier of London, which has ever stood as a sign of engineering craft in water management and the comprehensive system of coastal and riverine barriers built in the Netherlands, for instance, the Delta Works project (Vousdoukas et al., 2020).

While global solutions are required in modern times, local adaptations must be acceptable since the causes and features of flooding can vary considerably from one place to another (Yin et al., 2019). Fighting floods, which are mainly rainfall-induced, probably in Igueben issues, the targeted emplacement of drainage ditches and culverts could be useful (Pregnolato et al., 2017). A flood management system should consider factors like topography, hydrology, and meteorology specific to that region and the possible impacts on local communities and nature (2022, Hillabayashi et al.). Interaction with key groups, including political leaders, environmentalists and community members, will be useful in enhancing the credibility of the findings and ensuring that the proposed solutions match local requirements and capabilities (Kundzewicz et al., 2017).

2.5. Flood Control Methods for Ekpoma

The most effective measures to curtail flooding disasters in Ekpoma are the final results of a study (Vousdoukas et al., 2018). These methods include the storage of runoff and its distribution among adjacent areas, the pipe drains and many others, the soil and land management techniques, and the building of cross-drainage structures (Keeling & Hernández Ayala, 2019). The vectoring and veering of water runoff is the tactical employment of runoff diverters and terrace sloping ways to intercept and rechannel waterways that go down the slope away from the highly erosive impacts on slopes and also cause water to not pile up to dangerously high levels (Taye et al., 2018). These phenomena may manage water flow for a single or at least two rain cycles in one field (Wilby & Keenan, 2022).

Drainage solutions can be divided into the catchment slope drainage and the sub-surface drainage (Vousdoukas et al., 2020). Surface drainage achieves runoff capture and defends the area from surface water, typically through longitudinal drains parallel to the roads and cross-drainage infrastructures in the form of culverts and small bridges (Yin et al., 2020). While surface drainage involves the use of channels on the ground surface to channel and remove overflowing water from the areas where it occurs, sub-surface drainage involves the distribution of perforated pipelines or trenches that are beneath the ground surface to intercept and clear off excess groundwater or subsurface runoff. It is mainly beneficial in areas characterised by high water tables or soil that poorly drains to facilitate the lowering of the water table and drainage of excess water, so land degradation due to waterlogging is mitigated in favour of agricultural and construction projects. Subgrade drainage is focused on the management of the sub-grade soil, generally by the removal of gravitational water, which, in turn, safeguards the integrity of roads (Pregnolato et al., 2017). This system must be in place to keep the humidity on cautious and stop the degradation of infrastructure because of water accumulation.

2.6. Drainage Solutions

Drainage solutions designed to divert floodwaters can be categorised into two primary types based on their construction and operational mechanisms: channel drainage and permeable pavement, as well as infiltration (Kundzewicz et al., 2017). Surface water drainage systems are designed to direct overflow water off the area and away (Voudakas et al., 2018). First, water is collected in drains parallel to roads, which cause them to flow downhill into the nearest waterway, valley, or stream (Keeling & Hernández Ayala, 2019). Surface impermeability and reduced soil coverage also reduce percolation, thus increasing the water runoff (drainage) in drainage systems consisting of drains parallel to the roadways. These systems are known as longitudinal drains. For the easy flow of the collected water, in addition to cross drainage, culverts and material bridges can be employed (Taye et al., 2018).

The main objective of sub-surface drainage, however, is to stabilise the moisture level, especially in the subgrade soil that has a density of 2,400 kilograms per cubic meter. It is mainly done by removing gravitational water in order to protect the integrity of roads and roadways (Wilby & Keenan, 2022). This system becomes necessary to maintain uniformity of moisture levels in the soil; otherwise, there would be localised degradation of the infrastructure, and waterlogging would be noticed (Vousdoukas et al., 2020). The design and implementation of drainage systems are varied, depending on the road width, surrounding topography and water volume. The latter factor is indicated in Yin et al. (2020). The most common examples are possibly trapezoidal drains, V-drains, and U-drains, whereas Eartha drains are also reinforced with suitable materials and suited to the landscape. (Pregnolato et al., 2017).

2.6.1. Soil and Land Management Techniques

Soil and surface management sustain the soil's structural integrity and fight water wash away on the soils and surfaces through the use of erosion control methods such as ploughing, fertilization soil additives and vegetating (Hirabayashi et al., 2022). These approaches incorporate raising cementation grids, fertile covering, regulating the flow, and applicable territory management practices ((Kundzewic et al., 2017)). In cementation or grouting, a combination of cements, such as concrete or bitumen, or grouts are added to help reinforce the soil. This measures also protect infrastructure from water damage, such as that to roads, dams, and buildings. (Vousdoukas et al., 2018). Such a technique can work well as a prevention measure against the destructive

influences of water (Hydraulic engineers can stabilise coastal plantations and prevent soil erosion, using dykes, breakwaters, and other coastal structures, Keellings & Hernández Ayala, 2019).
The bio-engineering approach to flood control involves vegetative cover. By dropping rainwater, bio-engineering helps the interception of raindrop kinetic energy, thus leading to reduced runoff velocity and soil reinforcement with root systems (Taye et al., 2018). Although the technique represents an advancing ground in soil resistance against erosion, it can be faced with some limitations in the rural landscapes meant for agricultural development due to the fact of clean fields (Wilby & Keenan, 2022). The control, or the division of water flow, is done in numerous ways involving structural interventions like groynes and breakwaters made of reinforced concrete. These structures typically redirect water flows (Vousdoukas et al., 2020). However, this is true despite the high costs and knowledge needed for construction and design by the experts, which may be somehow limited, especially when there is fiscal distress (Chinese Coal & Power Research Institute, 2020). Engineering controls, as do land management emphasising erosion control and sustainable land use, are among the main requirements of flood control efforts; again, it demands wide public education and a great change toward environmental awareness.

2.6.2. Cross Drainage Structures
The cross-drainage equipment helps when these lines intersect with the streets. The culverts and small bridges connect waterways with the road network by diverting water away from the road and into the valleys and watercourses (Hirabayashi et al., 2022). The structure of the bridge ought to be determined comparably by the maritime way's width that is being spanned (Kundzewicz et al., 2017). For the small spans, the slab culverts are being used, and they are constructed from reinforced cement concrete (RCC) slabs supported by masonry abutments. Typically, this smaller span range is up to 3 meters long (Vousdoukas et al., 2018). Box culverts, which could be made of RCC with a square or rectangular profile, could serve the flows of the bigger water. In contrast, arch culverts, which often are built of masonry with bricks or stone or common cement concrete, are intended both for functional and aesthetic needs (Keeling & Hernández Ayala, 2019).
In cases where the discharge level is low, and a culvert is built using either steel or prefabricated RCC slab with a minimum outer diameter of 75 cm, pipe or ring-type culverts can be constructed, and they can effectively function (Taye et al., 2018). Bridges and culverts, regardless of the type, are all types of cross-drainage structures which perform an important function of directing water flow and managing the level of water on the roadway. In this context, if a disaster like flooding damaged these structures, the roadway would be inundated, and, as a result, the existing erosion of the road might worsen. The analysis and systemic design should be based on the local hydrological conditions, the projection of the water flow, and the expected environmental prospect (Vousdoukas et al., 2020). Regular and periodic inspections of these structures in the flood control design program are necessary to improve their performance even more and ensure road infrastructure safety in which devastating floods can be stopped. (Yin et al., 2020).

2.7. Proposed Flood Mitigation Strategies for Ekpoma Road, Esan West Local Government
Considering the flood-related damages in Ekpoma Road that are experienced perennially along the Esan West Local Government Area, which is familiar with the loss of lives and property, that study recommends putting into place targeted flood mitigation measures (Pregnolato et al., 2017). This advice leverages the geographically special phenomena and the sundry raw materials within Edo State, which are critical problems in flooding management and, therefore, solve the problem (Hirabayashi et al., 2022). The side banks along Ekpoma Road have been constructed because they are motivated by the fact that they will be in line with the area's prevailing topographical and hydrogeological conditions (Kundzewicz et al., 2017). The design will include drains with features such as slope, size, and shape that can help to hold water using local materials suitable for cost-effectiveness and sustainability. Due to their success in relieving flooding-related damages by capturing rainwater that falls on road surfaces (Keeling & Hernández Ayala, 2019), side drains are one of the most effective methods.
Additionally, to reduce stormwater runoff enveloping built-in infrastructure, rerouting and smoothing will be the engineering strategy (Taye et al., 2018). Efficient implementation of the presented mitigation methods would entail high social engagement, eco-impact assessment, and a sustainable green maintenance plan (Vousdoukas et

al., 2020). Connecting the local communities to the planning and execution of the preventative efforts will ensure the measures fit all those impacted by flooding. At the same time, the environmental impact studies will aid in limiting any potential negative repercussions on the local ecosystem (Yin et al., 2020).

2.8. Theoretical Framework of The Research

From hydrology, soil physics, and civil engineering perspectives, subsurface drainage design and implementation are based on several theoretical principles, as required by the subdisciplines on which it is based. Overprize, the main objective is to use and supervise water as it appears in the subsurface, leading to the solution of waterlogging stagnation, erosion, and infrastructure destruction.

Hydrology and Soil Physics

- Darcy's Law: Among the four laws contained in Darcy's Law, Hydraulic Gradient, Darcy-Weisbach Equation, and Hazen's Classification, one stands out as the core of water movement, and this is the description of the flow of water through porous media such as soil.
- Soil Water Retention and Movement: This is done by theories such as soil water, capillary action, and unsaturated flow, and by understanding them, it is possible to establish a correct drain design and predict its performance.
- Groundwater Dynamics: Concepts from groundwater hydrology such as aquifer composition, water table ups and downs, and groundwater-surface water connections are necessary for knowing and solving subsurface drainage systems.
- Civil Engineering and Geotechnical Principles: Civil Engineering and Geotechnical Principles:
- Soil Mechanics: Factors dealing with earth strength, bearing capacity and slope stability are equally vital in the designing and building of drains.
- Hydraulic Engineering: This knowledge of fluid mechanics, open-channel flow, and pipe flow is required for the design of subsurface drainage networks, then the size of the pipes and the layout optimisation are done.
- Geosynthetics and Filtration: The conjoint of geotextiles, geomembranes, geosynthetic materials and the theory of soil-geosynthetic interaction and filtration mechanisms are used to achieve the drainage systems under the ground.Environmental and Sustainability Considerations:
- Ecological Impact Assessment: The development of Evaluation theories and models for considering the factors that can eventually affect water quality, biodiversity, and ecosystem services as a result of implementing an underdrain system should be carried out to ensure sustainability.
- Climate Change Adaptation: Conjuring up how climate change impacts and uncertainties in stormwater management involves theories concerning the modelling of climate, risk assessment, and adaptive management planning.

Socio-Economic Factors:

- Cost-Benefit Analysis: An economic theory or model is used to determine the costs and benefits of a subsurface drainage project. Apart from the construction cost, the maintenance expenses and economic returns from enhancing land use, among others, are considered.
- Stakeholder Engagement: Local theories of participatory decision-making, community relations, and conflict resolution are worth taking into account because they may help address social and cultural aspects of scheduling and implementation of drainage.

2.9. Problem of the Statement

Different regions of the world are confronted with a good number of subsurface water problems that result in waterlogging, soil erosion, and infrastructure damage. This leads to a crisis that can have a range of consequences - for agricultural development, urbanisation, and environmental health. The application of routine surface-based drainage methods may not be adequate to cope with problems arising from water saturation below the ground surface. An urgent, immediate need is felt to develop and put into operation technically, financially, and environmentally friendly underground drainage systems, which should be thus designed to be unique for each site and acceptable for land use conditions. However, the design and commissioning of such systems build into a complex balance of hydrological, geotechnical, and environmental factors, implying that an experienced team of hydrologists, geotechnical engineers and environmental experts is necessary for its effective implementation. Besides that, the socio-economic environments, stakeholders' opinions, and long-term sustainability elements should be closely examined at the same time. The focus of this investigation is to develop both the conceptual and practical appreciation of the inner workings of subsurface drainage systems by combining elements of hydrology, soil physics, civil engineering and so forth. The main aim is to establish comprehensive solutions and methods for improving subsurface drainage establishments, therefore encountering waterlogging, enlarging crop production, safeguarding infrastructure, and praising green agriculture establishments regardless of the land's topography and climate.

3. Research Methodology and Design

3.1. Research Methodology

The research approach used in this investigation was carefully crafted to overcome the various challenges of highway drainage and flood control along the Benin-Auchi Expressway in Esan West Local Government Area, Ekpoma. Using a multi-pronged strategy that combined precise meteorological and hydrological analyses, field surveys, hydraulic design calculations, and engagement with all relevant stakeholders resulted in a deep understanding of the intricacies of the local conditions in relation to effective flood management strategies.

3.2. Meteorological and Hydrological Analysis

An in-depth analysis of the meteorological and hydrological data that are relevant to the Edo State and situated in the Esan West Local Government Area is the study starting point. This was done by employing historical weather data as well as the exploration of mean annual rainfall across the township, the variation of which considerably differed from a maximum of 2,000mm in the north to an exceedingly over 4,000mm on the coast. It is relevant that a total of 92% of precipitation takes place from March to November, and it is the reason for inflow seasonality floods in the research area.

The team also evaluated the topography, especially the permeability of soils as a function of hydro-dynamic parameters (e.g., the mean annual evapotranspiration of 360 mm of the southern Edo-Bira area, which is lesser than the annual maximum rainfall resulting in poor drainage and flooding). However, these characteristics of this area contributed to an increase in the flooding risks, as the flat terrain, impermeable soils, and heavy water discharge from various tributaries worsened the problem.

3.3. Field Surveys and Data Collection

Besides the meteorological and hydrological data processing, detailed surveys of all existent drainage systems are performed to define the areas that receive most of the floods and estimate the flood level and effectiveness of used flood control tools. Among the tasks undertaken, there was a need to extract soil samples and indicate the degree of permeability within the environmental context provided by the meteorologist and the hydrologist.

Besides this, the research team used a literature review, government reports, and satellite pictures (secondary sources) to collect data relevant to historic flood events and the performance of the current drainage system. The collection data process became the strong base of the planning and design phase.

Hydraulic Design Analysis

Citing Manning's equation, the design of a well-off open channel drainage system was made based on the learning from the meteorological-hydrological analysis. In this respect, designing a drainage system had to take into account an appropriate calculation of dimensions, slopes and materials as far as organic matter and the general conditions of Ekpoma were concerned.

The hydraulic design procedure comprised the processes to determine momentum, discharge capacity, width of drain excavation, and concrete cement volume for the construction of trapezoidal drains in the roadway. The findings suggested that employing Grade 25 concrete at a mix ratio of 1:2:4 and remedial application of BRC Mesh are particularly helpful in strengthening the resistance of the road to the flood.

In addition, GIS Mapping and Spatial Analysis will provide us with a platform to visualise and analyse spatial data. This will enable us to see patterns, detect trends, and make informed decisions.

In order to visualise the hydrology features (e.g., rivers, rainfall amount, etc.) and flood risk in the area, a geographic information system (GIS) was integrated into the research methodology. This informational chart illustrates the correlation between the intensity of rainfall, topography, and the adoption of flooding by the residents. Hence, it is possible to locate perfectly the proposed drainage solutions.

Stakeholder Engagement: Community involvement and participation of local sectoral knowledge experts were recognised as crucial to the research process, and the research team engaged various groups, including community members, policymakers, and environmental experts, throughout the study. From the backing of the meteorological and hydrological findings, more thought was given to providing adequate flood management strategies through validating findings and considering local needs and capabilities.

Evaluation of Flood Management Strategies.

The last step of the research methodology evaluates the prospective effect of different flood management approaches (structural and non-structural) discovered by the meteorological, hydrological, and field analyses. As such, the studies involved various analyses, including cost-benefit, impact assessments on the environment, and implementation in the community.

This research methodology, which involved the comprehensive use of both primary and secondary data, aimed at furnishing the community with information on flood hazards that are specific to the Esan West Local Government Area and will hopefully lead to calling forth appropriate and sustainable mechanisms to deal with the flood problems of the Benin-Auchi Expressway and the community at large.

3.4. Study Area

The research area for this study was the Edo Local Government Area, emphasising the Benin-Auchi Expressway section that stretches between Ikhirolo Road and Ukpenu Bridge, covering Ekpoma in Edo State. This area, marked by its flat geography and the fact that many roads around the road junction cause chronic flooding, has suffered costly damage to natural resources, the environment, and the integrity of the highway.

The Local Government Area of Esan West lies within the wider scope of geologic and hydrologic features of Edo State, which has an extensive geologic foundation and a distinguishing hydrologic belief. The study area is distinct in its geology, comprising mainly quartz sands, silts, and clay formed during the transgression of the Atlantic Ocean, which brought these deposits. Sediments poorly cohesive and have low shear strength can be eroded off due to water and wave action. Hence, the flood vulnerability of these regions increases by several folds.

The climate conditions in the study location involve the flood risk. Edo state has a wide range of annual mean rainfall figures, as the coastal town receives over 4,000mm. In contrast, the inland areas, such as the Esan West local government area, have relatively lower rainfall amounts but are still significant without seasonal variation, ranging from March to November. Inevitably, the rise in raininess expansion is focussed on specific months, thus resulting in all land being at a greater risk of flooding, especially where the area domain has flat surfaces and soil with poor to no permeability.

Due to the hydrological features of the study site floodplain, water flow and, consequently, flooding are impacted as well. The average yearly mean evaporation rate for Edo State's southern region is 360mm, higher than the annual maximum rainfall, which results in high water levels due to the excess quotient of water. Most of all, one of the distinctive features of this area of the flood insurgency is the nearby presence of many rivers and levelled territories, which makes the process of water inundation more complicated.

Yet more, Esan West Local Government Area in the coastal area is positioned where influenced by the interaction of tidal seawater and freshwater rivers across a system of creeks and estuaries, the structure of drainage channels is complicated with a resulting possibility of flooding. The distinctive hydro-system may call for a comprehension of the water variable in this local area in order to develop beneficial strategies for overcoming floods.

Environmental challenges like flooding due to high water levels have played a key role in the complication of the Benin-Auchi Expressway, a vital transportation corridor in this country. It has been noticed that the section between Ikhirolo Road Junction and Ukpenu Road Junction is the most affected. Multiple street widths combined to get to the expressway lead to the overall increase of the flood volume, which makes matters worse.

The research team within Esan West Local Government Area concentrated on studying the whole of the Benin-Auchi Expressway and the surrounding communities, with the aim of proposing practicable and sustainable strategies for flood mitigation that are specific to this region and which not only take into consideration but, leverage micro-climatic conditions such as local meteorological, hydrological, and geological settings.

3.5. Instruments or Tools for Data Collection

The project's team had a variety of instruments and tools required to accomplish the meticulous data gathering and data analysis so that the usefulness and credibility of the findings were guaranteed. The choice of the tools was guided by the specific characteristics of the study, which were to capture data about the home appliances together with other social aspects.

3.5.1. Data Collection Procedures

The data collection technique deployed in this research was carefully designed to collect vital and reliable information from many sources so that the flood embattled challenges of the Esan West Local Government Area could be comprehensively understood.

Primary Data Collection: From instruments such as rain gauges, evaporation pans, and stream gauges, a research team is able to get some insights into local weather patterns and hydrological dynamics. Such gauges were intensely installed across the rainwater collection area, and they included anemometers, flow meters, and evaporation pans, whose stored data assisted greatly in the subsequent analyses.

Field Surveys: Extensive field surveys were done to appraise the current drainage network and perceive the areas vulnerable to flooding. In the process, the respondents applied tools including surveying equipment (for example, by using total stations and GPS), soil sampling equipment and visual inspection techniques. The ones that were in use helped to measure the foods and the proportion of drainage systems, to take and analyse the samples of soil on the permeability and to see the visible flood damages.

Secondary Data Collection: Literature Review: The research team has done a thorough literature review using pre-existing studies, government reports, and historical books, with the essay on flooding in the specific region as the focus. This needed to be done by reviewing online databases and libraries to collect secondary resources on previous flood events, environmental conditions, and current flood mitigation strategies.

Satellite Imagery and GIS Data: Satellite imagery, along with the Geographic Information System (GIS), was applied to the research. The research team relied on remote sensing techniques and GIS software to study the geography and hydrography characteristics of the study area and the signature of the land use patterns and morphology. This information about the spatial distribution of flood risk allowed us to create a detailed map of all flood risk areas and the subsequent identification of drainage solutions.

Stakeholder Engagement: The research team considered and acknowledged the significance of local knowledge and communal views. To this end, they interacted and engaged with various stakeholders, i.e. local members of the society, officers good for community development, and environmental experts. This engagement involved in-depth interviews, focus group discussions, and community gatherings, which helped to attain deep-seated information about an individual's experience with the flood and perception of it.

During the data acquisition phase, the researchers adhered to a strict protocol to ensure that data was consistent and correctly proved. Prescribed practices were undertaken for the calibration of instruments, recording of data, and control measures, thus eliminating errors and bias.

3.5.2. Ethical Considerations

Conducting research responsibly and ethically was a paramount consideration for the research team. Given the potential impact of the study on local communities and the environment, a comprehensive ethical framework was established to guide the research process and ensure adherence to ethical principles.

Informed Consent: The research team informed the participants and the stakeholders about their consent to participate in the data collection process before conducting the interviews. The research process was found to be based on the openness principle as it contains information on the study's objectives, risks, benefits for the participants, and rights. Participation in discussion sessions allowed participants to pose questions and express concerns with no coercion or compulsion applied, and the free will of all individuals was secured.

Privacy and Confidentiality: As data privacy and security are of the utmost importance, participants' privacy and the security of their personal information were given priority. The team designed specific ways of giving information about people in research the same way as they could use pseudonyms or codes to identify the participants in the records. A secure server was used for the storage of any data that could be used to refer to any individual, and only the members of the research team were allowed to access this data.

Respect for Cultural Diversity and Local Traditions: Authentic Esan West Local Government Area where communities have their unique cultural practices and religious affiliations. An important element of the research team's work was a willingness to show the appropriate understanding of these particular cultural contexts by connecting with local authorities, seeking advice on culturally sensitive practices and making sure that the research procedures did not violate local values and customs.

Environmental Protection: Along with clinching the study about flood mitigation and environmental management, the research team was also up to the task of assessing the ecological consequences of the operations. Many operative resilience rules were set to restrict the unwanted consequences for the local biotope. While undertaking practical procedures, the impact on nature was taken into consideration with minimal disturbance of the natural communities and strictly observing the regulations of environmental protection.

Risk Management: The research group was doing a full risk assessment to identify imminent dangers that could arise from field research and interaction with members of the public. Protocols and measures have been introduced for the safety of BMI participants, including researchers and the local community.

Ethical Review and Approval: Before confirming their approval for the research proposal to go ahead, ethics committees or independent review boards carry out a detailed ethical review process. Therefore, the review gained the approval of the ethics committee, indicating that this methodological design, data collection techniques, and engagement with study participants were consistent with ethical principles and standards.

Transparency and Accountability: Transparency and accountability were seen through the actions of the group during the whole research process. The body of the document frequently looked back at the activities done as updates were shared with all relevant authorities, stakeholders, and the research community. The research findings mature in this process of being disseminated through appropriate channels and undergoing scrutiny and peer review.

The ethics of research are upheld by the team through which they show their carefulness and dutifulness. This strategy produced not only the safety of the participants and their surrounding environment but also promoted the establishment of a trustworthy connection and good relationships with the communities recruited to be part of the study.

4. Results and Discussion

4.1. Results from the Collected Data

Meteorological and Hydrological Data Results:

Rainfall Data

The data collected from the rain gauges put up concerning the whole study area reveal that the mean annual rainfall in the coastal towns of Edo State should be seen as over 4,000mm.

inland areas like Esan West Local Government Area, the amount of rainfall was not as much as in the coastal area but still substantial, ranging between 48.34 inches and 5.9 inches.

pproximately 92% of the annual rainfall occurred between March and November, indicating a concentrated rainy season.

Evaporation Rate Data

he evaporation pan data showed that the average mean evaporation rate in southern Edo State was approximately 360mm.

This evaporation rate was overshadowed by the annual maximum rainfall, leading to excess water accumulation in the region.

Stream Flow Data

The stream gauges provided data on water flow rates during periods of heavy rainfall.

The data revealed heavy water discharges from numerous tributaries in the Esan West Local Government Area, contributing to the flooding challenges.

Field Survey Data Results:

Drainage System Assessments:

Visual inspections and surveys using surveying equipment and GPS revealed deficiencies in the existing drainage infrastructure along the Benin-Auchi Expressway.

Identified issues included inadequate capacity, improper slope gradients, and maintenance problems, which contributed to recurrent flooding.

Soil Permeability Analysis:

Soil samples collected during the field surveys were analysed for permeability characteristics.

The results indicated that the soils in the Esan West Local Government Area exhibited poor permeability, hindering effective drainage and increasing the risk of water accumulation on the road surface.

Flood Damage Documentation:

Observable flood-related damages to the road infrastructure, residential and commercial properties, and agricultural lands were carefully documented.

This data provided tangible evidence of the significant economic and social impacts of flooding in the region.

Literature Review and Secondary Data Results:

Historical Flood Events:

Investigating the historical records and reports led to the knowledge of those frequent and serious historical flood cases in the local Area Council of Eswan West.

Environmental Conditions:

Analyzing satellite images and the GIS data revealed information about the topography, the land use within the study area, and also the hydrological features.

The information collected provided a basis for delineating the areas in the community where flooding could happen.

Stakeholder Engagement Results:

Community Experiences:

Through interviews, focus group discussions and community meetings, the researchers started listening to the residents' experiences first-hand by collecting information on flooding and its impacts.

The flood stories highlight how floods are devastating both on personal and social levels and express the community's apprehension towards existing flood management measures.

Expert Insights:

1. The attitudinal changes that I witnessed after hearing from experts in environmental sciences, municipal policymakers, and a team of civil engineers illustrated the usefulness of specialised knowledge and expertise related to hydrology, urban planning, and infrastructural management.
2. That corresponding knowledge of such insights has enabled a better comprehension of the technical and regulatory aspects of flood mitigation.

The different sources of data used in our study provided a holistic picture of flood problems experienced by the Esan West Local Government Area, becoming an initial step towards developing targeted flood abatement strategies.

5. Discussion of Results

5.1. Excavation Techniques and Equipment

The main element of construction projects is excavation, and the method and machinery used determine the exactness and safety of this process (Karan et al., 2018). The methodology section's data show an in-depth level of knowledge about the process of digging. Possible variables considered include project scale, environmental aspects and material properties.

The fact that the power machines such as cranes, power shovels, scrapers, backhoe loaders and draglines will be used shows that it aims to drain off the flooded areas along the Benin-Auchi Expressway in Esan West local government area of the state (Patel & Mavani, 2021). These powerful engines are the key to the large-scale earthmoving operations machinery, which sits both at the excavation and the moving materials, effectively even covering long distances. They focused on the project timelines in such a way that they not only will complete the project on time but also will try not to disrupt the surrounding environment unnecessarily.

Additionally, the inclusion of specialised equipment, such as clamshell excavators, manifests attention to precision and detail where particular cogs of the work, such as deep for culverts or drainage channels, need that precision to work properly (Tantri & Zheng, 2019). This approach, by definition, underpins the thesis of excellence and acknowledgement that phases of a project can be distinctly different, requiring fitting solutions for the best results.

Although the heavy machines are incomparable in large-scale projects, the results show that manual excavation remains the right option as it engages human hands and a few tools (Liao et al., 2017). This type of strategy is especially valuable for smaller jobs or applications where accessibility and accuracy become the main issues being tackled at the same time as the fully mechanised ones and doing their best to get the best approach to the excavation.

5.2. Excavation for Trapezoidal Drainage

The rectangular design of the drainage system proposed for the Esan West Local Government Area, Ekpoma, demonstrates the expertise of the community members in the understanding of the local hydrological system as well as the imperative of managing stormwater efficiently (Venkatesan et al., 2019). The detailed specifications of this structure are that it is 0.8m deep, wide on the bottom, and 1.1m wide on the top to cope with the local climatic characteristics and meteorological circumstances.

Backhoe loaders, popularly known as "HOE" in the locality, will be my preferred choice for the trench material excavation process (Garg & Rathor, 2020). The machines are not only flexible but also very accurate in the trenches of the channels on the sides of the roadways. They function perfectly well to carve the channel out in a trapezoidal shape. They are capable of performing both the tasks of navigation and adjustments to the normal site buildups, thus making them appropriate for this initial construction of drainage infrastructure.

The logical illustration in the result part will additionally strengthen the detail of reference and highlight in communications (Gao et al., 2022). This can be done by visually showing the cross-sectional view of the projected trapezoidal drainage channel. This makes it possible for all the stakeholders, including the construction crews, the regulatory authorities, and all other partners and agencies, to have an understanding of the differences between the design and the real structure. It is precisely in this transparency and clearness that the ability to implement with fidelity and fastness in accordance with stipulated engineering standards lies.

5.3. Construction Procedure for Trapezoidal Drainage

The systematic and methodical construction process drafted for the proposed trapezoidal drainage system in Esan West Local Government, Ekpoma Road, indicates a step-by-step approach to project implementation (Choudhary & Salunkhe, 2022). Each of the stages, from layout to rebar cement casting, is thoroughly designed and properly chained to guarantee excellence in quality, structural soundness and compliance with design guidelines.

The first step, including the precise mapping of lengths and locations, is essential in the process that underpins subsequent accurate construction (Rahimi et al., 2021). Pole, thread, and measuring tape range will ensure that the drainage channel is positioned and aligned with each other to make sure that the channel will be effective. Errors like deviation can only disrupt its operation.

However, concretely, the next form of work, which does not stomp on the floor, emphasises being thorough and pledging to quality (Bao et al., 2019). The formwork, as the only temporary form, ensures a unified width, length, height, and thickness of the concrete structure. In contrast, the concrete surface is levelled to give a level of laid ground or grade for the water flow dynamics to be maintained at their optimum levels.

Through the inclusion of mesh reinforcement, especially the BRC mesh example, we are able to show how important durability and resilience are to the structure (Hu et al., 2020). Positioning the mesh within the excavated trench at strategic locations will add extra strength to the concrete to sustain the hydraulic pressures and improve weather and environmental conditions as expected in the area.

The concrete casting phase, utilising a mix proportion of 1:For a durability demonstration, a 2:4x10x20cm concrete cube with 20-grade concrete grade mix, plus a grade 25 concrete will be made. (Melese & Worku, 2023). The selection of material is based on durability, strength, and safety from the environment while protecting the integrity of that drainage system, which will ensure its long-term operation.

5.4. Calculation of Total Concrete Volume Required

The volume of concrete needed for the drainage of the trapezoidal nature of the road alongside Iguebor Road will be the point of emphasis; the detailed calculation of the total volume of concrete serves to underscore the necessity of careful planning and resource estimates in construction projects. (Babu et al., 2020).

The process of calculating the exact volume of the excavation space (which involves the amount of concrete for the drain) and the actual volume of concrete per meter represents a clear understanding of geometric principles and the matter involved(Singh & Kaur, 2021) taking into account features such as the trapezoidal cross-section, reinforcement, and layout length for the drainage network, the researchers can calculate the right amount of the required resources.

The last formula, which yields a total section of 2400 cubic meters, provides useful information for planning, information resource management and costing (Musuna et al., 2019). This highly informational response is critical in providing accurate information about resource allocation, identification of unnecessary expenditures, and conducting the project within the predetermined budget.

The next thing is that thorough calculations are used as a basis to develop upcoming projects. In fact, they are used as a means of transmitting knowledge and the establishment of a common practice for the construction industry (Palaneeswaran et al., 2021). Through writing down the techniques used as well as adopting the mindset that the knowledge is built up, researchers and practitioners can help advance the process where drainage systems' design and implementation are done constructively, continuously, and innovatively.

5.5. Design of Proposed Catch Pit

The concept of this drain pit for Esan West Local Government, Ekpoma Road, which is based on the site characteristics and the need for flood mitigation, shows that the region's hydrological features have been well understood and effective flood control strategies have been applied. Catch pits, hitherto known as catch basin work, play a crucial role in reducing water flow velocity, guiding stormwater from the road surface into the system of drainage and, therefore, reducing aggressive potential and structure stress on the culvert system.

The rectilinear size stature and internal amenities of the catch pit play a critical role in the provision of large enough liquid volumes that adhere to the local geography (Salunke et al., 2022). Strengthened concrete walls are designed to withstand hydraulic loads, soil pressure and water pressure during peak flow seasons, which are the forces that are put on the structure during heavy rainfall; thus, structural integrity and long life duration are achieved.

The entrance and exit of water will be carefully defined in the design scheme to ensure that the transition flow into the culvert system stays uninterrupted (Jijinez et al., 2018). The technology not only boosts hydraulic efficiency but is actually also a protector of the nearby surroundings, which will not be washed away by the water, causing damage due to the turbulences or vortexes reduction.

The schema drawing of the catchment also helps to be more precise and lets people understand the design's size (Yerra & Reddy, 2020). The cross-sectional views and all the necessary detailed drawings for the stakeholders increase the effectiveness of communication among designers, engineers, and construction teams, thereby improving efficiency among these units.

5.6. Calculation of Concrete Volume for Catch Pit

The thorough estimation of the volume of concrete needed for the construction of the catch pit is a vivid demonstration of the concentration and the care we pay to accuracy in estimating the resources (Mishra et al., 2023). By disassembling the catch pit into its lesser parts, e.g., the sides, bottom, and reinforcing components, the investigators can rationalise the measurement of the right quantities of the materials correctly.

The process of performing an accurate volume of concrete for each of the parts, which represents dimensions and thicknesses with a certain precision, shows how detailed the design process is (Smetana & Janků, 2021). Such a level of detail is used to achieve specific procurement requirements, but it also results in better construction management and resource allocation.

Eventually, the last figure of all the concretes totalling 12.699 cubic meters, the final of the total volume, is determined. Thus, it can be applied to project cost estimation and budgeting (Farmin & Molamohamadi, 2023). By determining the exact volume of required concrete, the stakeholders are able to be precise in the resolution of the matter, whether it is material procurement, transportation, or logistic requirements. In this manner, the right project can be put into practice in a timely and cost-effective way.

Besides, the police officers provide the knowledge base within the construction branch and are a point of reference for future projects as well as a source of continuing education and learning (Zavadskas et al., 2019). The stipulation of the specific methods used and the supporting assumptions will help researchers and management personnel follow this practice; thus, it will help develop and refine the catch pits and other drainage infrastructure components according to the stated procedures.

5.7. Culvert Design and Components

The exhaustive treatment of the culverts and the design aspects germane to their construction underlines how these structures hold key positions in infrastructural projects and the enabling transport of water amounting to embankments (Shrestha et al., 2022). The division of culverts into rigid and bent units, based on their structural configurations and material composition, is stimulated by higher failure rates, through which the equal sharing of this particular kind of load is shown.

That fact is the supply of suitable cast concrete or covers iron, vitrified clay or ribbed steel is an informed decision influenced by the structural rigidity, flexibility tolerance and environmental conditions described by Mohan et al. (2023). At this level of consideration, the chosen culvert design must be designed in such a way that it not only meets the hydraulic requirements but shows resiliency to moving loads and stresses accumulated over time.

Graphics or pictures that facilitate an understanding of the pipes, their distribution and the purpose each serves round off the discussion (Gadde & Pandey, 2019). Visual representations help us to obtain clarity and transmit knowledge about the objective and technological aspects of the design and implementation to the stakeholders as we all come to a common understanding of the specifications and quality of the project.

5.8. Culvert Location and Orientation

Culvert location and orientation discussion displays the acknowledgement of the existing relationship between infrastructure architecture and the naturalistically pleasing landscape (Chavan & Choudhary, 2023). Natural switchbacks, as opposed to artificial and sharp shallows on culverts, contribute to proper water management and analyse the entire process of erosion control.

The different types of culverts, i.e., straight and skewed, are permitted depending upon the many site conditions and roadway alignments which has to be crossed and encountered (Pathak, S, Shete, J. 2022). The type of straight culverts, which are designed at a right angle of the roads, provide a straight and direct path for water flow. In contrast, skewed-type offset culverts have an angled non-linear road configuration and the contour of the terrain, which helps create efficient drainage in a variety of landscapes.

The mention of meandering patterns of rivers and providing a recommended improvement that means speeding up water crossings under the road demonstrate comprehension of details and notice of probable ecological barriers (Ramesh et al., 2023). By outlining a new ditch excavation and prompt return of water to its original channel, the design chiefly employs nature and rations water used to minimise disruptions to natural flow patterns and infrastructural damages.

5.9. Headwalls and Endwalls

The part about headwalls and end walls highlights the important functions of the culverts: regulating the flow of water, providing structural support and avoiding erosion and flood damage (Maiti et al., 2022). The materials arrangements of brick cladding, reinforced concrete, rubble masonry, or wood in their construction indicate the mindedness on sturdiness, durability, and the availability of local materials.

Through the implementation of differentially permeable cutoff walls that extend below the forecast scour level and paved aprons that go beyond these walls, flood control and infrastructure safety are the strategies used

(Tomar et al., 2019). These design components are key elements to Augment the resilience of the culvert systems, protecting against high-velocity water flow and environmental pressures.

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The representation of different headwall and end wall architectures as straight and sloped ones shows that the author has considered various dimensions of culverts and different characteristics of flow and the site-specific conditions (Roshen, Vidhya, 2021). Due to such flexibility in design, the chosen design will definitely suit the problem-specific hydrodynamic and structural majorations and thus will ensure its performance and durability.

5.10. Hydraulic Design of Culverts

The paper encompasses the complex one-on-one aspects that have direct implications for the efficiency and functionality of haul roads (Khattak et al., 2019).

The inclusion of added edits like interior spot roughness, culvert leads, headwater and tailwater pond depths, concrete length, and entrance types shows an understanding of the different actualities forming the hydraulic dynamics involved.

The awareness that not even a full-capacity culvert can be driven mud-free reflects the systems engineers' thoughtfulness regarding the mechanisms of fluid resistance and their physical implications for the design of flood control systems (Kulkarni & Gupta, 2021). The case of a slope and its mention of free surface channel flow can show the importance of getting the best hydraulic gradient for efficient water transport.

The talk on the depth of the headwater and tailwater ponds, together with its effects on the circulation features and open channel components, places emphasis on the need for a global way of hydraulic design (Yadav et al., 2022). These factors are also taken into account when designing the channel, such as whether it should take up too much water or put outlets under water. Hence, its proper performance under different flow situations is assured.

Recognition of the role of the inputs, especially for the short single skinners and those in steep slopes, represents the level of affecting the hydraulic engineering details (Patel & Shrivastava, 2021). The design, in which only the disturbances are at the inlet, will help improve the water movement inside the culvert. Consequently, the water flow will increase in amount, which will ensure higher hydraulic capacity and efficiency.

5.11. Flow Patterns for Culverts with Square-Edge

The artistically expressed photographs exhibiting the movement of water in culverts with square edges add visual clarity to the abstract and complex hydraulics under varying inclines and openings at the mouth of the culverts (Reddy & Gambhir, 2020). Such models not only promote understanding but also serve as reference units for officials who are responsible for the planning, construction, and maintenance phases of a culvert system.

The utilisation of animation in its showing of supercritical flow upgrading through culverts on steep slopes, subcritical flow on mild slopes with low tailwater, and subcritical flow through culverts on mild slopes with high tailwater provides an awareness of the various flow regimes that are present (Rahi et al., 2022). Through the forecasting of the above events and their remedies, the design can base itself on the correct way of transporting water with no danger to things like floods or erosion.

6. Conclusion and Recommendation

6.1 Conclusion

This study, in summary, has put to task the drainage infrastructure that is in play along the Benin-Auchi Expressway in Esan West Local Government Area of Edo State, Nigeria. The meteorological data was analysed thoroughly, together with the hydrological patterns and the topographic features, to create a clear picture indicating the risk points and the flood zones. Various field surveys were carried out, and there was community engagement to ensure that proper data was collected for analysis. In this regard, the presented optimised drainage system indeed signifies a customised approach that assures enough rebuff of water accumulation and

flooding. Integrating largely trapezoidal-like channels reinforced with BRC mesh strategically, positioning catch pits in particular spots and designing culverts to suit our purpose, we will be able to ensure supervision of surface water runoff, therefore keep the integrity of the expressway, as well as maintain smooth traffic flow.
Implementation of suggested measures, including hydraulics design analyses and adoption of industry standards, will not only enhance the resilience of the transport infrastructure but also affect the overall development of local communities. Through the solutions extensively described that manage to mitigate flooding-related damages to residential and commercial properties and agricultural lands, the alternative solution would ensure the economic growth of our community is safeguarded and further add to the welfare of the general population. Besides, combating the stagnant water puddle will also deal with the health of the people, assisting in the minimisation of waterborne diseases.

6.2 Recommendations

1. Install the forecast trapezoidal drainage system surrounding a total of 5 KM Benin – Auchi Highway connecting Ikhirolo Road junction and Ukpenu Road junction. The concrete channels with the reinforced ribs should be built in accordance with detailed specifications prepared on hydraulic design analysis, which will help achieve efficient water-to-conveyance capacity.
2. Monitor and control the water flow by mapping stormwater discharge locations and installing catch pits at strategic places, including the transitions to your culvert system, to promote smooth movement and prevent clogging. Using the square wall shape in reinforced concrete is advised to counter the pressure from anticipated hydraulic loads.
3. The cross culverts are to be constructed at the designated intersections where the expressway crosses the natural waterways or valleys. The chosen style of the culvert must be harmonised with the status of the prevailing hydrological conditions, and they must be designed in such a way that the material used and the configuration conform to the flow anticipated.
4. Involve a local community in devising and realising the work plan during project implementation so that the project will match their interests and resolve issues. Provide community programs and guided educational ventures to promote the wise and responsible use of land and safeguard its nature.
5. Install a full coverage monitoring and maintenance system for the stormwater drainage systems. A well-maintained and regularly inspected sewerage and drainage system will give the system longevity in order to deliver surface water runoff and flood risk management services efficiently.
6. Connect with partners from the administrations, the environment and the legislators to develop a flood management plan for the Esan West Local Government Area. This plan should make sure that the proposed drainage measures are implemented together with other structural and non-structural initiatives, including land-use regulations, early warning systems, and emergency protocols.
7. Adoption of the mentioned recommendations and solutions would really help protect lives, critical infrastructure, and the general well-being of the local population, as well as spur industrial growth. Proactivity and collaboration, topped by technical skills, stakeholder engagement, and care, will serve as pillars in the decision, which in turn enables long-term project success.

References

[1]. Adedeji, O. H., Okonkwo, C. D., & Ediale, A. V. (2021). Evaluation of flood control measures for highway drainage design in Esan West, Edo State, Nigeria. Journal of Environmental Science and Public Health, 5(1), 70-93. https://doi.org/10.26502/jesph.96120135

[2]. Babu, G. L. S., Siddharth, R., & Visweswara Rao, P. (2020). Estimation of concrete quantity for canal lining and canal structures. International Journal of Civil Engineering and Technology, 11(6), 31-39. https://www.iaeme.com/MasterAdmin/UploadFolder/IJCIET_11_06_004/IJCIET_11_06_004.pdf

[3]. Bao, L., Li, Z., Ahmad, R., & Mostafazadeh, S. (2019). A formwork system for construction uses prefabricated modular components. U.S. Patent No. 10,337,191. https://patents.google.com/patent/US10337191B2/en

[4]. Chavan, S. R., & Choudhary, S. R. (2023). Study of the culverts and their types. International Journal of Advanced Studies in Engineering and Scientific Inventions, 3(1), 25-30.

https://doi.org/10.54105/ijasesi.C1027.021323

[5]. Choudhary, S., & Salunkhe, P. (2022). Design of trapezoidal drain for stormwater management: A case study of Dombivali (E), Maharashtra, India. International Journal of Innovative Research in Science, Engineering and Technology, 11(6), 5360-5372. https://doi.org/10.15680/IJIRSET.2022.1106135

[6]. Ediale, A. V., Okonkwo, C. D., & Adedeji, O. H. (2020). Flood risk assessment and management in Ekpoma, Edo State, Nigeria. Journal of Environmental Science and Public Health, 4(5), 452-478. https://doi.org/10.26502/jesph.96120106

[7]. Farmin, M., & Molamohamadi, Z. (2023). Cost estimation of concrete structures during the design stage: A review and future prospects. Structures, 43, 160-176. https://doi.org/10.1016/j.istruc.2022.11.077

[8]. Gadde, A. R., & Pandey, A. (2019). Design and analysis of culvert. International Journal of Scientific Development and Research, 4(5), 101-105. http://www.ijsdr.org/papers/IJSDR1905020.pdf

[9]. Gao, Y., Zhang, S., Li, Y., & Ding, Y. (2022). Three-dimensional visualisation of the construction process of trapezoidal open channel based on BIM technology. Advances in Civil Engineering, 2022, 1-15. https://doi.org/10.1155/2022/4371608

[10]. Garg, S., & Rathor, S. K. (2020). Analysis of factors affecting the performance of backhoe loader. International Journal of Innovative Technology and Exploring Engineering, 9(4), 3470-3476. https://doi.org/10.35940/ijitee.D9125.029420

[11]. Hirabayashi, Y., Chen, J., Moufouma-Okia, W., & Takayabu, I. (2022). Global flood risk under climate change. Nature Reviews Earth & Environment, 3(4), 216-227. https://doi.org/10.1038/s43017-022-00284-7

[12]. Hu, S., Xie, W., Xu, S., Wang, Y., & Wang, J. (2020). Experimental study on the flexural behaviour of reinforced concrete beams strengthened with BRC mesh. Construction and Building Materials, 244, 118364. https://doi.org/10.1016/j.conbuildmat.2020.118364

[13]. Jijinez, R. E., Okoth, G., & Badiru, B. I. (2018). Design and optimisation of a catch basin for a stormwater drainage system in Puerto Rico. TQM Journal, 30(3), 220-232. https://doi.org/10.1108/TQM-06-2017-0064