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An Investigation into Drainage Failures: A Case Study of University of Nigeria, Nsukka

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Abstract: This project research is aimed at investigating road drainage failures – taking the University of Nigeria, Nsukka (UNN) as a case study. A statistical approach of sampling was used in conducting/sharing the questionnaires within the scope of study. A physical observation method was used together with photography to gather more data for the study. The target population was the staff and students, together with the engineers of the Physical Planning Unit, of the University of Nigeria, Nsukka. From the results gotten from the questionnaires it was found out that poor maintenance had majorly been the cause of the poor drainage and even failures of some others within the school premises. There is a saying that "pictures do not lie" and it was evident from the field work carried out. Different types of failure mechanisms were identified and all boiled down majorly to the negligence of the authorities concerned. Some recommendations were given out for future purposes.

Key words: Drainage, failure, investigation, photography, observation, sampling questionnaires.

Introduction

As a citadel of learning, University of Nigeria, Nsukka has to have good roads and walk ways linking parts of the institution together and since a good drainage system contributes immensely to the sustainability of the roads, it's worth studying.The government and public should have good value for the money spent in the drainage construction by properly maintaining our drains, which will in turn give us good roads and help to forestall any future possibility of a flood in the institution. According to Zumrawi (2016) "Though water is very essential for all life on earth, it can also cause disasters through erosion and flooding. In fact, the surface runoff water is greatly increased in urban areas as a result of the development of infrastructures". So it is of high importance to really make sure our drains are healthy.

Appropriate drainage is an important feature of good road design. It is often said that 'there are just three factors necessary for getting a good road: *drainage, drainage and more drainage'*. In our world today, the quest for solving everyday problems has become pertinent, and the part which Civil Engineers play cannot be underestimated. One of such issues is the drainage system and the choice of the appropriate sections to use. The choice of the appropriate section for a hydraulic channel is important so as to maximize its usage, safe cost, reduce siltation and scouring to its barest minimum. According to Nyameche (2006), common cross-sectional shapes are rectangular, trape-

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zoidal or circular. Sediment generated from urban and peri-urban catchments often gets deposited in urban drains, and this constitutes a major factor to the poor performance of urban drainage systems. The movement of sediment through a drainage catchment is a complex multi-stage process. The sediment-laden runoff flows first, as overland flow, and eventually into channels. The transport of sediment continues in the channels until at some points along the channels sediment deposition occurs as a result of insufficient kinetic energy of the flowing water to keep some of the sediment particles in suspension.

Roads that are eroded, deformed or unsafe in any way are not only a hazard to the public especially drivers, but also they increase costs for maintaining roadways. By installing proper roadway drainage systems from the beginning you can save a lot of hassles and money. In addition, you can expect your investment in drainage to pay for itself over time. It takes research, careful consideration and engineering to determine the best possible drainage system for a particular roadway.

This is very common in channels constructed in flat terrains. When the sediment deposition continues for a long time without desilting the channels, they get silted and cause flooding of various degrees of magnitude as a result of the reduction of their carrying capacities. A silted channel encourages prolific weed growth in it when soil moisture conditions are favourable. The vegetation increases the roughness factor in the channel, decreases the effective flow area of the channel, hence, reducing the ability of the channel to carry storm water. When the sediment is concentrated at sections (e.g. entrance to culverts), ponding of water often occurs upstream and creates convenient breeding grounds for some disease causing agents. Silted roadside drains produce ponding on roads because of their inability to contain the large quantities of water flowing into them. When this happens vehicular traffic is impeded.

Some localized floods are caused by heavily silted channels whose carrying capacities have been drastically reduced. In the case of buried or completely covered storm channels, the deposited sediment has the ability to act as a pollutant store or generator. These pollutants are only stored temporarily, and are usually released under flood flow conditions, and often cause foul conditions at the outfall points. Biochemical changes in the bed of sediment can result in septic conditions, releasing gases that can be highly corrosive to the channel material sections. Knowing that silting will occur in channels after their construction, it is always recommended by drainage engineers to undertake regular maintenance activities such as desilting, dredging, etc. in the channels. Experience has however shown that this is easier said than done (Nyameche, 2006).

The drainage problems can directly cause or contribute to crashes. As an example, drainage features that fail to remove runoff water because they are too small or are clogged and pond water on the roadway can cause hydroplaning or force drivers to leave their lane. Additionally, other drainage features which do not have anything to do with causing a crash can significantly contribute to the severity of the crash, such as an errant vehicle striking a culvert headwall (Zumrawi, 2016).

It is important to identify these potentially hazardous situations as soon as possible. Some of these conditions may have been in existence for quite some time, while others may have recently developed as a result of flooding or change in weather conditions. Drainage problem locations can be identified in several ways such as residents' complaints, local police, crash data and field review (Zumrawi, 2016).

Damages to Highways due to Faulty Drainage

Bhatti (2014) in his research itemized the following:

- If the water on the pavement surface is not quickly drained away, it finds its way into the pavement layers through cracks, voids and joints (in concrete pavement). The water entrapped in the structural layer ends up in 'bathtub' condition, which may cause uplift pressures and result in reduced supporting power
- Pumping of fines, usually from a sub-grade into the base of sub-base
- The surface runoff reaches the sub-grade soil, softens it and reduces its supporting power
- In high embankments, the stability of slopes is endangered
- Landslides and subsidences
- Frost action

According to Shailendra et al. (2010), "The entrapment of water within the pavement leads to a "bathtub" condition resulting in premature failures and chronic pavement distresses. This leads to large amount of costly repairs or replacement to the pavements long before they reach their design life". The "bathtub" condition emphasized by Bhatti (2014) and Shailendra et al. (2010) is really a danger to pavements. Veeraragavan et al. (2010) stated, "Adequate and timely maintenance of road drainage system is an important parameter to improve the performance of roads".

In a study, Parkinson (2003) concluded the following, "Quality of drainage is an important parameter that affects the performance of low volume roads. Low-volume roads are a huge network about 60 to 70 percentage of all roads worldwide. Adequate quality of drainage is important to improve the performance of low volume roads. Therefore, there is a need to quantify the impact of quality of drainage on performance of low volume roads in India".

Mwangi (2013) stated further that, in most cases common drainage problems can be avoided if due consideration is given during the design stage of the road. The time and cost spent trying to address problems during the construction stage or later on when the road is finished will normally be less than the costs of mitigating efforts.

Pavements designed without fast internal drainage can stay filled with water during much of the year while they are also subjected to damaging environmental conditions. If pavements are provided with fast internal drainage, water-related damage is almost entirely eliminated which increases pavement life substantially and saves billions of dollars a year in the United States alone (Cedergren, 1988).

Apart from flooding, drainage failures gradually reduce the life span of roads, deface them and make the roads a menace to its users. According to Lines (2002), damage to homes caused by flooding places extra demands on the limited resources of the poor. There are also indirect effects, such as the loss of working days required to repair structural damage, or the increased prevalence of illness, causing families to redirect assets towards treatment. Also, even where filariasis is not a problem, culex mosquitoes cause widespread irritation and the urban poor can spend relatively large portions of their income seeking temporary relief by buying mosquito coils.

In poorly drained areas with inadequate sanitation, urban runoff mixes with excreta – spreading pathogens around communities and increasing risks to health from various waterborne diseases. Infiltration of polluted water into low-pressure water supply systems can contaminate drinking water and is frequently a source of gastrointestinal disorders. Wet soils in poorly drained areas, which become contaminated due to poor sanitation, also provide ideal conditions for the eggs of parasitic worms, such as roundworm and hookworm, which can cause debilitating intestinal infections (Kolsky, 1999).

Furthermore, Francis (2000) explained that, "The problems of poor drainage and flooding of domestic properties tend to have a disproportionate effect upon women. Women have to deal not only with the economic devastation and disruption of livelihood systems but also are often left to cope with the social and emotional upheaval that comes from dealing with the death, disease and food shortages that invariably occur in the aftermath of floods. In addition to this, cultural practices in some countries require women always to be escorted in public by male relatives, which can increase women's vulnerability during flood events and may even result in women drowning if they are unable to leave their homes without being accompanied".

Successful drainage and maintenance depends on early detection of problems before conditions require major action. Signs of drainage problems requiring attention include: puddles on the surface area, poor surface flow, slope erosion, clogged ditches, pavement edge raveling, preliminary cracking, pavement pumping, and surface settlement (Charlotte, 2013).

There are a number of possible causes of drainage problems ranging from human errors to natural causes. Most drainage problems result from improper grading. Grading is the slope of the yard. In general terms, a properly graded yard should slope gently downward from the house and toward the street and alley, in the case of residential buildings (Causes of Drainage Problems, 2017).

Poor and inadequate drainage system blocks normal water flow and creates water logging and flash-floods during heavy rainfall and natural calamities. Therefore, appropriate drainage system is very important for safe and sustainable urban environment (Kirby and Laurson, 1932).

Drainage problems are also exacerbated by the high clay content in metroplex soil. The clay content causes the soil to resist absorbing moisture, and low areas hold standing water more readily (Causes of Drainage Problems, 2017).

There's no one-size-fits-all solution for roadway drainage systems. Instead, there are many factors that influence the best way to go about creating an efficient drainage system. For one thing, a good estimation of runoff must be calculated. Runoff has to do with location of the road, intensity and duration of rainfall in the area as well as just upstream from the area. It's also important to consider how frequently rainfall is expected to exceed averages (Kleenco Construction, 2016).

In summary the following can be considered:

Three important considerations when building efficient roadway drainage systems:

1. Total size of drainage area needs to fall in line with the amount of runoff an area is prone to. A solid basin area estimate will help you when using runoff formulas and charts.

2. *The topography of the land* is important in regards to the average slope and elevation of the basin.

3. Soil type and characteristics will determine permeability and infiltration capacity. The amount of water a certain soil type is able to absorb will influence runoff rate. Certain characteristics may negatively impact soil absorption, leading to hydrophobicity, frozen earth and compaction (Kleenco Construction, 2016).

To determine whether a drainage system is adequate or not, Gurjal et al. (2013) presented a table of AASHTO classification of drainage system as shown in Table 1.

Table 1: AASHTO classification of drainage system

S/N	*Drainage quality (DQ)*	*Water removed from layer within*
1	Excellent	2 hours
2	Good	1 day
3	Fair	7 days
4	Poor	1 month
5	Very poor	Water will not drain

According to Rokade et al. (2012), Pavement service life can be increased by 50% if infiltrated water can be drained without delay.

Hence the main aim of this project is to investigate road drainage failures in UNN. The objectives are to: evaluate the existing condition of roads and drainage structures, examine the problems experienced concerning drainage system of UNN roads, explore the impacts of poor drainage on road performance and life time, identify the reasons behind drainage problem in roads focusing on current situation of UNN roads, and suggest technical improvements for the existing drainage facilities.

Research Methodology

The University of Nigeria, Nsukka Campus which is located at Lat. 651′24″°N and Long. 723′45″°E and has a land area of 2150 acres (8,700,740.4 sq m), encompasses our scope of study. The climate of Nigeria is tropical; there are wide climatic variations in different regions of the country. Near the coast temperatures rarely exceed 32 degrees Celsius (90 degrees Fahrenheit), but humidity is very high and nights are very hot. Inland there are two different seasons. A wet season from April to October is experienced, then a lower monthly temperatures and wettest month being June. Also a dry season is experienced from November to March with midday temperatures that rise above 38°C (100°F) but relatively cool nights.

Research survey was employed in order to obtain information that would describe the current state of drainage infrastructure in the University of Nigeria, Nsukka and how poor drainage system has affected road users during the rainy seasons and the residents living in the surrounding. The survey involved staff, students and engineers at the Physical Planning Unitand residents living in the affected areas of University of Nigeria, Nsukka road. For the purposes of achieving the objectives of the study therefore, a case study design was adopted where survey research was used.

Apart from the research survey (in this case, questionnaires), other means of data collection like photographs, observation among others were employed in this work in a view to obtaining the necessary information required to meet the layed out objectives *ab initio.*

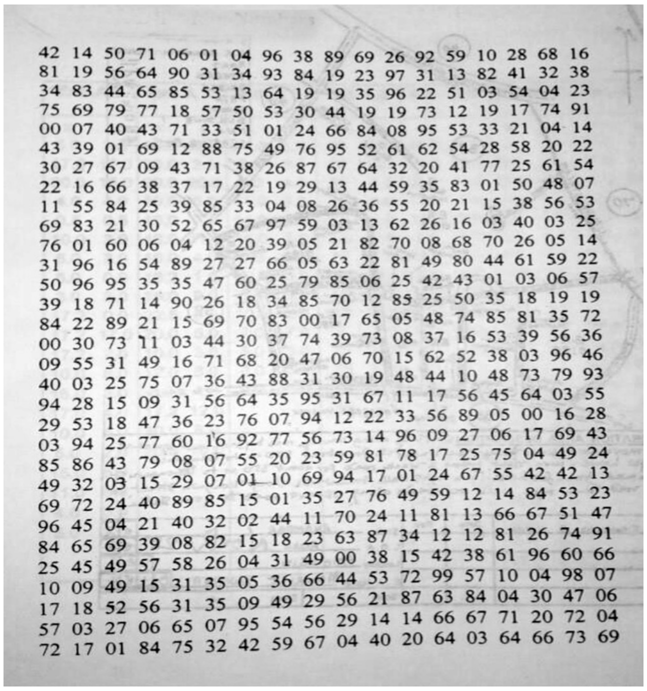
Also, a unique methodology was developed for this research – while physically observing the state of the road drainages in the university, data was carefully recorded on the state of drainage within at least a 5-metre interval, so that in a particular stretch of road of about 100 m long (the typical length of a road/street in UNN is about 100 m), at least five points would have been analyzed. The observation method was extensively done – covering more than 70% of the major roads and linkages in the school. Figure 1 shows the aerial view of the major roads in the campus.

The random table numbers was used in the distribution of questionnaires to various faculties (made up of students and staff), while a particular number was randomly given to the engineers at the Physical Planning Unit.

The following faculties were assigned a particular number, then using a random number table (and with the intention of choosing only seven out of the 10 faculties), some faculties were chosen.

- Faculty of Agriculture 1
- Faculty of Arts 2
- Faculty of Biological Sciences 3
- Faculty of Education 4
- Faculty of Engineering 5
- Faculty of Pharmacy 6
- Faculty of Physical Sciences 7
- Faculty of Social Sciences 8
- Faculty of Veterinary Medicine 9
- Faculty of Vocational Training Education 10

Figure 1: Aerial view of the major roads in UNN.



42	14	50	71	06	01	04	96	38	89	69	26	92	59	10	28	68	16
81	19	56	64	90	31	34	93	84	19	23	97	31	13	82	41	32	38
34	83	44	65	85	53	13	64	19	19	35	96	22	51	03	54	04	23
75	69	79	77	18	57	50	53	30	44	19	19	73	12	19	17	74	91
00	07	40	43	71	33	51	01	24	66	84	08	95	53	33	21	04	14
43	39	01	69	12	88	75	49	76	95	52	61	62	54	28	58	20	22
30	27	67	09	43	71	38	26	87	67	64	32	20	41	77	25	61	54
22	16	66	38	37	17	22	19	29	13	44	59	35	83	01	50	48	07
11	55	84	25	39	85	33	04	08	26	36	55	20	21	15	38	56	53
69	83	21	30	52	65	67	97	59	03	13	62	26	16	03	40	03	25
76	01	60	06	04	12	20	39	05	21	82	70	08	68	70	26	05	14
31	96	16	54	89	27	27	66	05	63	22	81	49	80	44	61	59	22
50	96	95	35	35	47	60	25	79	85	06	25	42	43	01	03	06	57
39	18	71	14	90	26	18	34	85	70	12	85	25	50	35	18	19	19
84	22	89	21	15	69	70	83	00	17	65	05	48	74	85	81	35	72
00	30	73	11	03	44	30	37	74	39	73	08	37	16	53	39	56	36
09	55	31	49	16	71	68	20	47	06	70	15	62	52	38	03	96	46
40	03	25	75	07	36	43	88	31	30	19	48	44	10	48	73	79	93
94	28	15	09	31	56	64	35	95	31	67	11	17	56	45	64	03	55
29	53	18	47	36	23	76	07	94	12	22	33	56	89	05	00	16	28
03	94	25	77	60	16	92	77	56	73	14	96	09	27	06	17	69	43
85	86	43	79	08	07	55	20	23	59	81	78	17	25	75	04	49	24
49	32	03	15	29	07	01	10	69	94	17	01	24	67	55	42	42	13
69	72	24	40	89	85	15	01	35	27	76	49	59	12	14	84	53	23
96	45	04	21	40	32	02	44	11	70	24	11	81	13	66	67	51	47
84	65	69	39	08	82	15	18	23	63	87	34	12	12	81	26	74	91
25	45	49	57	58	26	04	31	49	00	38	15	42	38	61	96	60	66
10	09	49	15	31	35	05	36	66	44	53	72	99	57	10	04	98	07
17	18	52	56	31	35	09	49	29	56	21	87	63	84	04	30	47	06
57	03	27	06	65	07	95	54	56	29	14	14	66	67	71	20	72	04
72	17	01	84	75	32	42	59	67	04	40	20	64	03	64	66	73	69

Figure 2: Random number table. (*Source:* Okafor, 2002)

Selected Faculties

- Faculty of Veterinary Medicine 9
- Faculty of Biological Sciences 3
- Faculty of Vocational Training Education 10
- Faculty of Physical Sciences 7
- Faculty of Agriculture 1
- Faculty of Education 4
- Faculty of Pharmacy 6

One hundred copies of the questionnaires for staff/students were printed, while 10 were given to the engineers at the Physical Planning Unit.

Data Analysis and Presentation Techniques

Data analysis is for the purpose of obtaining usable and useful information irrespective of whether the data is qualitative or quantitative. The research employed various statistical tools for analyzing of the data collected from the field.

Results and Analysis

Results from Questionnaires

Questionnaires were administered to the engineers from the Physical Planning Unit of the University. Another questionnaire was given to the staff and students of the University, herein referred to as road users. The questionnaire comprised of open ended and structured questions on issues that are related to the study.

Table 2: Results from questionnaires

Respondents	*No. of planned questionnaires*	*The response*	*The response rate*
Engineers	10	7	70%
Staff and students	100	91	91%
Total	110	98	80.5%

A response rate of 50% is adequate for data analysis and reporting, 60% is good and above 70% is very good (Mugenda and Mugenda, 1999). From Table 2, there was an average response rate of 80.5% for this study and therefore good enough for the analysis of the data.

Results from Questionnaire Type One: Response from the Engineers

Appropriateness of the Drainage System

From Figure 3, it was important to know the critical factors considered when designing a road drainage system. This is because they helped to understand the reasons behind the design of every road in the University. The engineers indicated that the drainage system provided for most of the University roads were inadequate and therefore inappropriate. The magnitudes of the water from the hills around some of the areas in which some of the roads are situated over the years have outweighed the design. They also indicated that studies that were carried out before designing the road were not sufficient to satisfactorily ascertain the amount of water that would cross the road at a particular point in time. Therefore the design lacked capacity to adequately drain the runoffs during the rains. However, poor workmanship (seen through poorly worked stone pitching and gabions) by the contractor during construction and poor maintenance also contributed to the drainage problems As part of understanding the background of the poor drainage system provided in the University, this study sought to find out from the engineers the percentage of roads that lacked adequate drainage.

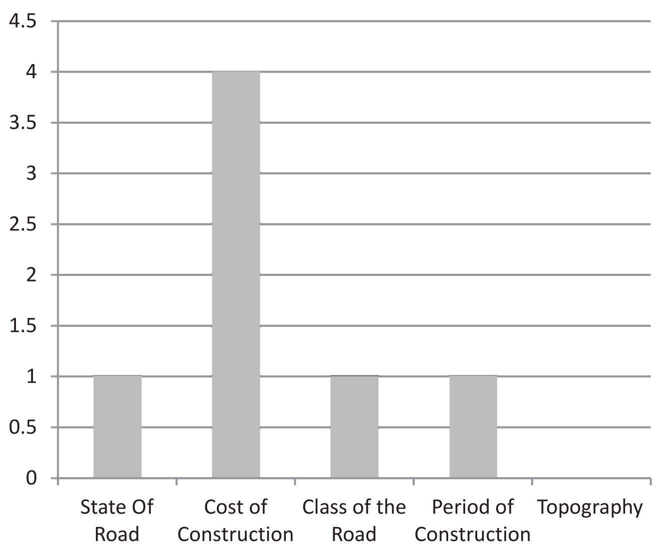


Figure 3: Considerations in drainage design.

Percentages of Roads with Inadequate Drainage System

From Figure 4, it can be observed from the engineers' perception, that most of the roads in the University lack adequate drainage system. Some of the reasons cited were inadequate designs, lack of enough studies to establish the drainage requirements of the road and poor workmanship as a result of corruption.

State of the Drainage Facilities

The engineers were of the consensus that the drainage facilities were in a poor state and therefore needed action with immediate effect. The engineers at the Physical Planning Unit agreed that inspection isn't carried out regularly to ascertain the state of the drainage system on campus, and it is not surprising that the results we are getting are failing or failed drainages. They both agreed that there was need for redesigning and reconstruction of the drainage system. There was also need to carry out maintenance on the existing drainage facilities to increase their efficiency and effectiveness. They reported that lack of commitment by the University administration has led to the situation being aggravated. Combined system was specifically cited as the appropriate drainage system; however; separate system, open channel system and subsurface drainage system were also recommended by the engineers for the different parts of the road.

Results from Questionnaire Type Two: Response from Road Users on the State of the Drainage System in the University

This research sought to find out how poor drainage affected both the road users and the residents through the questionnaire. From Figure 5, greater percentage of the road users are extremely dissatisfied.

Effects of Poor Drainage on the Road Users

From Figure 6, it can be seen that water leaving debris on the road had the greatest negative effect on the road users.

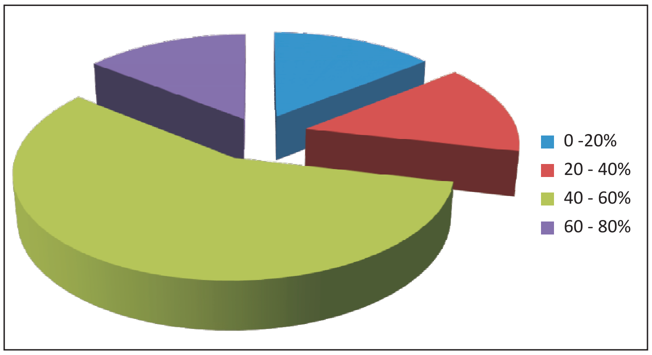


Figure 4: Inadequate drainage.

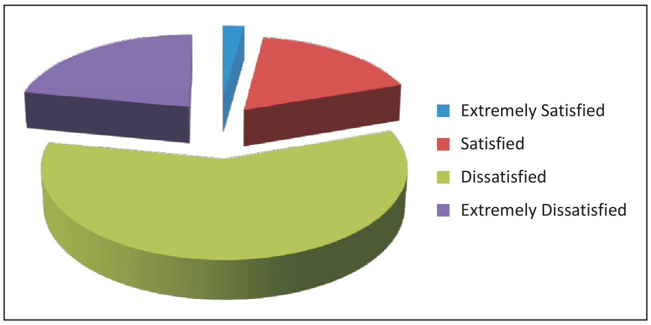


Figure 5: Drainage satisfactory level.

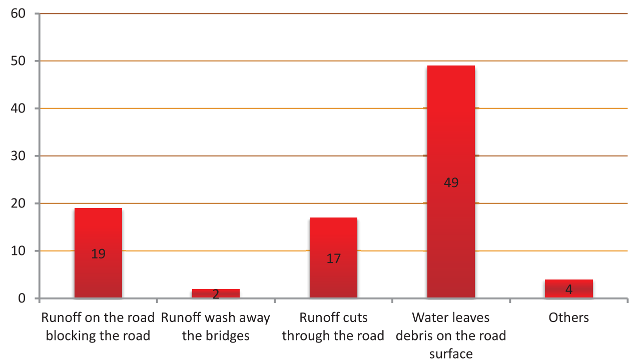


Figure 6: Poor drainage-road user relationship.

Results from Observation and Photography

As mentioned earlier, this research work used both observation and photography as tools from which data were collected. This comprised observation and taking of photographs to show the current state of the drainage system in University of Nigeria Nsukka. From observation, brief description of what was observed in the field work was given with the aid of photographs (Figures 7-10). From observation, the state of the drainage system in University of Nigeria Nsukka roads is impoverished. However, some parts of the road have no problem with drainage. From Nnamdi Azikiwe Drive to the place where the road intersects Fulton Avenue the drainage system is fairly good although the system is poorly maintained.

Figure 7: Silted-up culvert.

Figure 8: A culvert blocked with debris.

Conclusion and Recommendations

This study was majorly concerned with the state of the road drainage facilities in University, and whether the existing drainage system was adequate. It is general knowledge that good drainage is fundamental in the provision of a good road network system. The greatest concern that prompted this study was the manner in which water disrupted traffic and further washed away parts of the roads in the University e.g Fulton Avenue, Obuka Road, Kwame Nkrumah etc. during a heavy downpour. The problem as was established through this

Figure 9: Ditches blocked by soil and grass verge.

Figure 10: Channel runoff blocked by pedestrian lane.

study is the drainage system that is not adequate. Going by the responses from both the engineers, road users and residents, the problem lies in the drainage system. There was a general feeling that the type of drainage system used is not adequate. There is therefore need for immediate remedies in order to achieve a good drainage system. Maintenance of the existing drainage facilities was also found to be poor. There is therefore need to maintain the existing drainage facilities in order to mitigate to some extent the harmful effects of flood water especially during the rains.

Recommendations

The recommendations are given for both short-term and long-term bases:

Short-term Measures

The following are the recommendations in the short-term period:

- Improvement of drainage facilities through maintenance
- Public awareness campaign. This should be carried out so that people can be aware of the impacts of the rains
- Carry out frequent inspections to check faults that may occur
- Building of gabions/healing of gullies using gabions
- Constructing soil and water conservation structures including water pans
- Continuous monitoring of rainfall in the area

through establishment of rainfall observation stations
- Improve the drainage systems along the highways

Long-term Measures
These include:

- Increase tree cover in areas especially the neighbouring hills, with appropriate tree species including planting of agro-forestry tree species to avoid erosion
- Re-seeding of denuded land with grass cover
- Redesign the drainage system
- Complete overhaul and reconstruction of the whole system
- Proper and frequent maintenance of the drainage facilities

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