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Assessment of the Effect of Urban Road Surface Drainage: A Case Study at Ginjo Guduru Kebele of Jimma Town

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Abstract: Drainage is one of the most important factors to be considered in the road design, construction and maintenance projects. It is generally accepted that road structures work well and last longer to give the desired service. When a road fails, whether it is concrete, asphalt or gravel, inadequate drainage is often a major factor to be considered. Researchers have shown that poor drainage is often the main cause of road damages and problems with long term road serviceability. Though provision of proper road surface drainage systems have such a great importance for the urban road to give the intended use and thereby contribute to the overall development of a nation, in particular in road sector, the practice of the construction of proper integrated drainage structures did not get due attention in our country in general and Jimma town in particular for many years. Therefore the problems and achievements on the design, construction and maintenance of surface road drainage systems need to be assessed to provide remedial measures for the better performance of the road infrastructure. The objective of this study was to assess road surface water drainage problems and its net-work integration systems in Ginjo Guduru Kebele of Jimma town. A cross-sectional study was conducted in Ginjo Guduru Kebele of Jimma town from January to August 2014.The data collected was then be analyzed quantitatively and qualitatively, and the result of the study thus presented in tables and in themes. From the study made, generally it was observed that the road surface drainage found to be inadequate due insufficient road profile, insufficient drainage structures provision, improper maintenance and lack of proper interconnections between the road and drainage infrastructures thereby resulting damages to road surface material and flooding in the area.

Keywords: Road Drainage System, Urban Road, Maintenance, Integration

1. Introduction

Though Water is very essential for all life on earth, it can also cause devastation through erosion and flooding. Due to the development of infrastructures as a result of urbanization, the surface runoff water greatly increased in the town damaging the roads. The contributed runoff water thus need to be safely disposed to the rivers/outlet channels so that the functional utility of the road infrastructure maintained and thereby avoid the damages which otherwise occurred to the road and property.

Adequate drainage is very essential in the design of highways since it affects the highway's serviceability and usable life. If ponding on the traveled way occurs, hydroplaning becomes an important safety concern. Drainage design involves providing facilities that collect, transport and remove storm water from the highway.

Inadequate urban storm water drainage problems represent one of the most common sources of compliant from the citizens in many towns of Ethiopia (GTZ-IS,2006), and this problem is getting worse and worse with the ongoing high rate of urbanization in different parts of the country.

The pattern of urbanization and modernization in Ethiopia has meant increase densification along with urban infrastructure development. This has led to deforestation, use of corrugated roofs and paved surfaces. The combined effect of this results in higher rainfall intensity and consequently accelerated and concentrated runoff in the urban areas. Due to inadequate integration between road and urban storm water drainage infrastructure provision, many areas are exposed to flooding problems and road damages in urban roads (Belete, 2011).

There are two major road drainage systems. These are surface drainage and subsurface drainage. This study concerned with the surface drainage since this type of drainage is most advantageous on low permeability soils, the case of the study area soil, restricting the soil layers prevent the ready infiltration of high intensity rainfall. In addition surface drainage is cost effective to implement per unit area on such type of soil and has significant benefit with ease of maintenance. It is essential that adequate drainage systems provisions are made for road surface to ensure that a road pavement performs satisfactorily. Thus a drainage system which includes the pavement and the water handling system must be properly designed, built, and maintained.

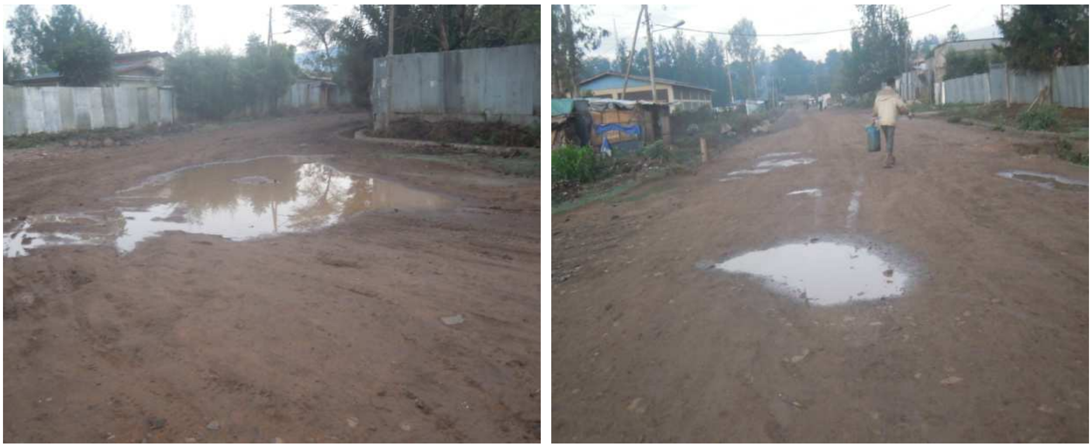

Figure 1. *Ponding of water on gravel road in Ginjo Guduru Kebele in front of Jehovah 's Witness hall.*

1.1. Problem Statement

Jimma town which is surrounded by steeply or hilly topography is subjected to frequent flooding in rainy season. The occurrence of road over flooding on October 7, 2013 in the town which forced vehicles or automobiles to stop for some hours to give usual service is due to the lack of proper and interconnected drainage systems in the town. The over flooding of road by storm water runoff resulting in the accumulation of silt on the road leading to overturning of cars as happened in the town two times in the year 2013.

The storm water runoff is mainly contributed from the very steep mountain surrounding the town. Ginjo Guduru is one of the 13 Jebeles of Jimma town located at a lower elevation which is directly affected by surface runoff water contributed from Jiren mountain of Guduru sub-catchment water shed area.

1.2. Objectives of the Study

1.2.1. General Objective

To assess road surface water drainage problems and its net-work integration challenges of their provision in Jimma town, in particular in Ginjo Guduru Kebele

1.2.2. Specific Objectives

1. To assess the pavement damage due to improper drainage
2. To identify areas most prone to flooding problems.
3. To assess the existing condition of road and surface drainage infrastructure.
4. To examine the impacts of road surface drainage structures integration on road Performance and related social as well as environment issues
5. To make recommendations on urban road and drainage structures integration, their provision and management.

1.3. Significance of the Research Study

1) To minimize the possible damage of pavement through proper drainage structure provisions.
2) The Jimma town/kebele can use it as reference while they are preparing their annual plans in relation to spatial and financial plans for roads and urban storm water drainage infrastructure.
3) To reduce the environmental and health safety problems.
4) Concerned body and organizations working in the area of roads and urban storm water drainage infrastructures can use it as a reference for proper design, implementation and maintenance of urban road surface drainage.

1.4. Scope of the Study

This research was geographically limited to Guduru sub catchment and the outlet of the Guduru water shed is found in Ginjo Guduru Kebele of Jimma town.

Generally, the study addresses issues related to urban road surface drainage and the integration between drainage and road infrastructures in the Kebele. The specific focus of it includes: existing condition of road and drainage structures, their net-work condition, maintenance of road and drainage infrastructures, impacts of road & drainage infrastructures integration on road performance and associated flood prone areas in the study area.

1.5. Description of the Study Area

The study area is found in Jimma town, which is the largest city in south western part of Ethiopia. It is found in Oromia region at a distance of 335 kilometers from Addis Ababa, capital city of Ethiopia having an average latitude of 7°40’ N and longitude of 36°50’E.The altitude of Jimma town varies from 1718 m to 1842 meters above the mean sea level. The town is surrounded by high steeply mountain in the north and north east. There are three streams; Awetu, Kitto and Guduru which cross the town.

2. Literature Review

Different valuable materials published by various authors have been employed to reinforce this research work. The main valuable materials used were:

1. Road and urban storm drainage network integration in Addis Ababa (Belete D.A ,2011).
2. Roadway and road side drainage (David P.Orr.P.E (2003
3. Highway Drainage and storm water management, road design manual (DelDOT (2008).
4. Local road assessment and improvement drainage manual (Donald Walker (2000).
5. Effects of water on the structural support of the pavement system (AASHTO ,1993).
6. Earth and Gravel roads (Penny state University, 1997).
7. Drainage manual. Addis Ababa, Ethiopia (ERA (2000).
8. Urban storm management planning (Fabian P.Barry JA (2003).
9. Urban drainage design manual (Federal Highway administration, FHWA (1996).
10. Urban storm drainage design manual of Ethiopia (Federal urban coordinating Bureau (2008),.
11. Storm water system design.CE58, University of Colorado (Guo,J.C.Y.(1999).
12. Urban drainage manual series on infrastructure.(GTZ-IS (2006).

3. Research Methodology

3.1. Study Setting/Area

Both descriptive and exploratory types of research methods were employed. The descriptive type was used to describe the existing condition and coverage of roads and urban storm water drainage facilities. Whereas, the exploratory type was particularly used to explore the existing condition by making some required physical measurements, and compare with standards.

The study area is limited to Guduru sub-catchment which encompasses three Kebeles namely Mendera Kochi , Ginjo and Ginjo Guduru. The Guduru sub-catchment watershed comprises an area of about 1102 ha .There are three streams in this watershed namely Samiche, Jiren and Guduru streams.

3.2. Study Design/Data Types

Quantitative as well as qualitative data types were employed. Of the total data about 90% of the research data was collected from primary sources of surveying field measurement. Whereas the rest 10% was collected from secondary data sources in order to reinforce the primary data sources.

3.3. Data Collection Methods

Two data collection systems or methods were employed for the study. These are Questionnaire and field measurement of surveying operations. Questionnaire and Interview was employed to collect data related to flooding hazards. The Field survey measurement was done using surveying equipments such as Tape meter, engineering level, total station with their accessories and GPS.

3.4. Data Processing and Analysis

The data collected were checked and analyzed. Software like Auto CAD, Eagle point and EP SWMM5 were used in the analysis of the data besides the common Microsoft office software.

4. Result and Discussion

4.1. Existing Road Types and Drainage Structures

Generally there are four categories of road types observed in the area. These are arterial, sub arterial, collector streets and local road. Based on the surfacing material, four types of road were identified in the study area. These are asphalt (20%), cobble stone (16%), gravel (23%) and earth road (41%). The lengths of these roads are indicated in the table 1.

Table 1. *The distribution of the road pavement for each category of road type.*

Type	Principal arterial(m)	Sub arterial(m)	Collector(m)	Local(m)
Asphalt	3973.120			
Cobble stone			2295.390	719.750
Gravel		2119.920	174.790	2151.390
Earth road				7962.820

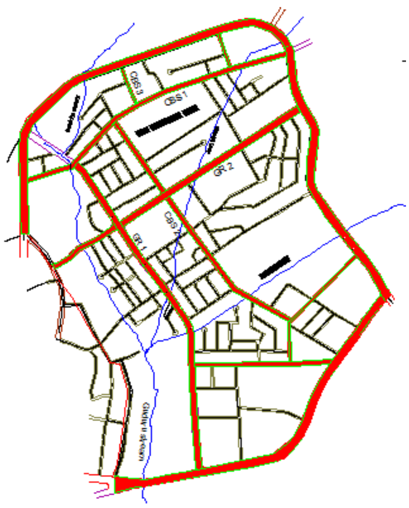

Figure 2. *Road net-work in Ginjo Guduru Kebele of Jimma town.*

4.1.1. Road Profile of CBS 1

The longitudinal profile of cobble stone road (CBS 1) is shown in Figure 3. As per to the master plan of the town, this road is categorized as collector street.

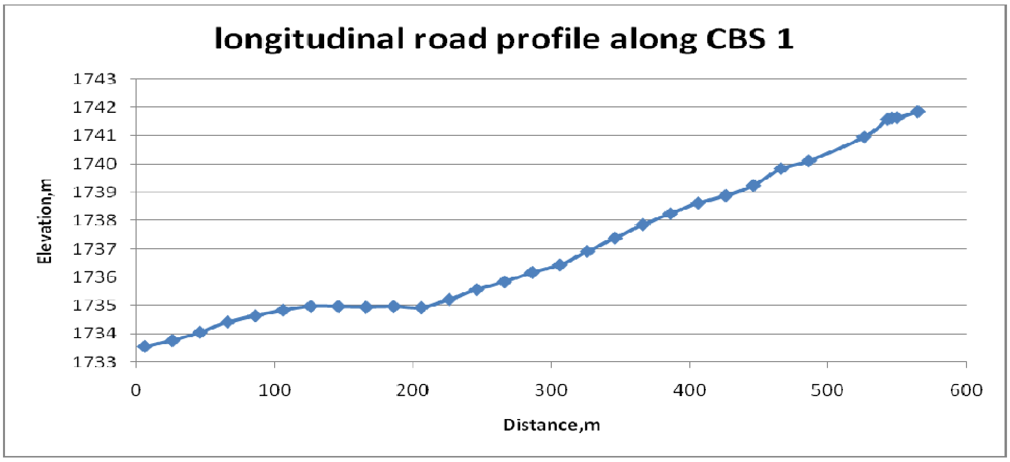

Figure 3. *CBS1 road profile.*

Table 2. *The distribution of longitudinal and cross fall slopes of CBS 1 road.*

Distribution or coverage ,%	Slope in percentage				
	< 0.5	**0.5 - 1.0**	**1.1 - 2.5**	**2.6 -4.0**	**4.1-6.0**
Longitudinal slope	14.80	3.70	62.93	18.50	-
Cross fall	7.41	11.12	44.44	25.93	11.10

As it can be seen from table 2, about 15% of the road length have less than 0.5 percent longitudinal slope and 62.97 % of cross fall slope being less than 2.5 %, which is below the required minimum slope for adequate drainage.

4.1.2. Road Profile of CBS 2

Figure 4 shows the longitudinal and cross sectional profile of cobble stone road (CBS 2), which starts from the junction in front of rural mechanization center towards Aramyik hotel having a length of about 900m.This road also categorized as Collector Street.

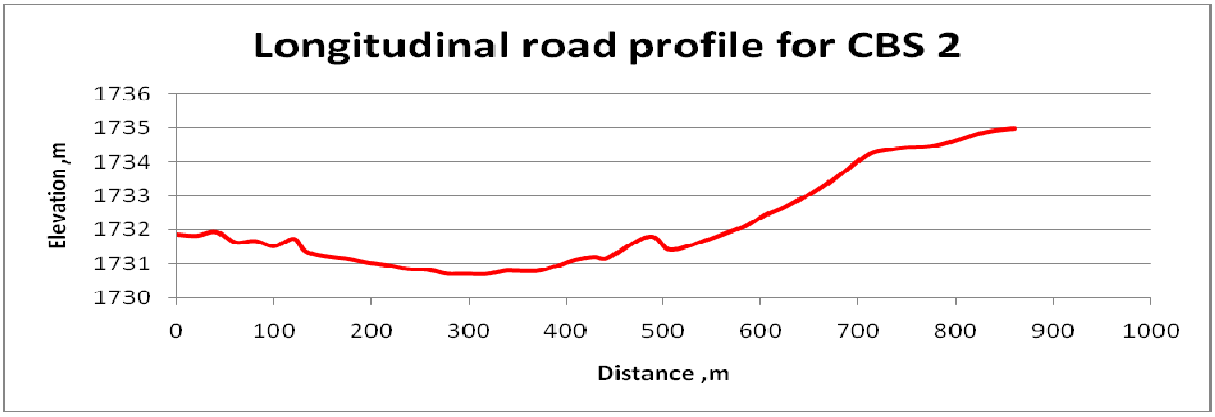

Figure 4. *Profile of CBS2 road.*

Table 3. *The distribution of longitudinal and cross fall slopes of CBS 2 road.*

Distribution or coverage ,%	Slope in percentage				
	< 0.5	**0.5 - 1.0**	**1.1 - 2.5**	**2.6 -4.0**	**4.1-6.0**
Longitudinal slope	48.93	31.92	17.02	2.13	-
Cross fall	10.64	2.13	38.30	31.91	17.02

In this part of road segment of 0.9 km, about 48.93 % of the road likely to have less than 0.5 percent longitudinal slope and 51.07 % of the road have less than 2.5 % cross slope. The distribution of the longitudinal as well as cross fall slope between stations of the road is also not uniform and this retards the safely disposal of water from the road.

4.1.3. Road Profile of CBS 3

Table 4. *The distribution of longitudinal and cross fall slopes of CBS 3 road.*

Distribution or coverage ,%	Slope in percentage				
	< 0.5	**0.5 - 1.0**	**1.1 - 2.0**	**2.0-4.0**	**4.1-6.0**
Longitudinal slope	14.29	28.57	57.14	-	-
Cross fall	74	26	-	-	-

In this cobble stone road, the cross fall is totally less than 1.0 percent and there is no uniform longitudinal slope as it can be seen from the table which gives favorable condition for accumulation of water on the road.

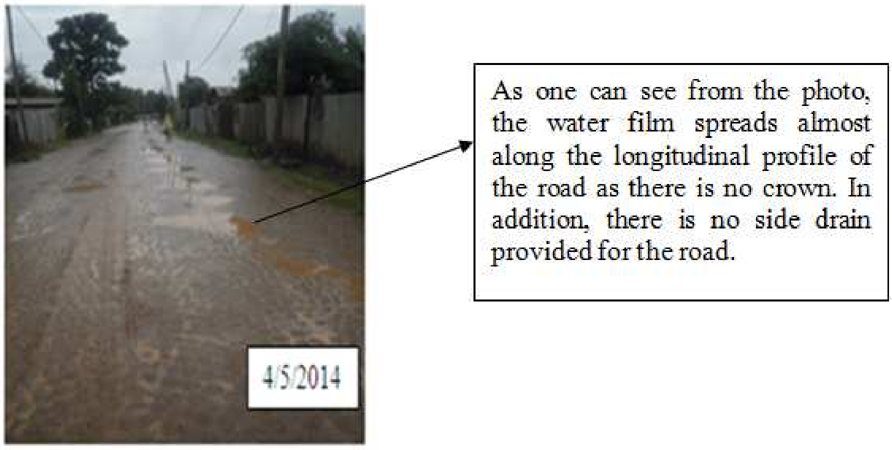

Figure 5. *Photo of CBS 3 road.*

4.1.4. Profile of Asphalt Road

The profile of Asphalt road segment from Dipo to Kidene Mihert church junction was also determined from the surveying field measurement of the study. This road categorized as Arterial Street on the Jimma town master plan with relatively high traffic volume.

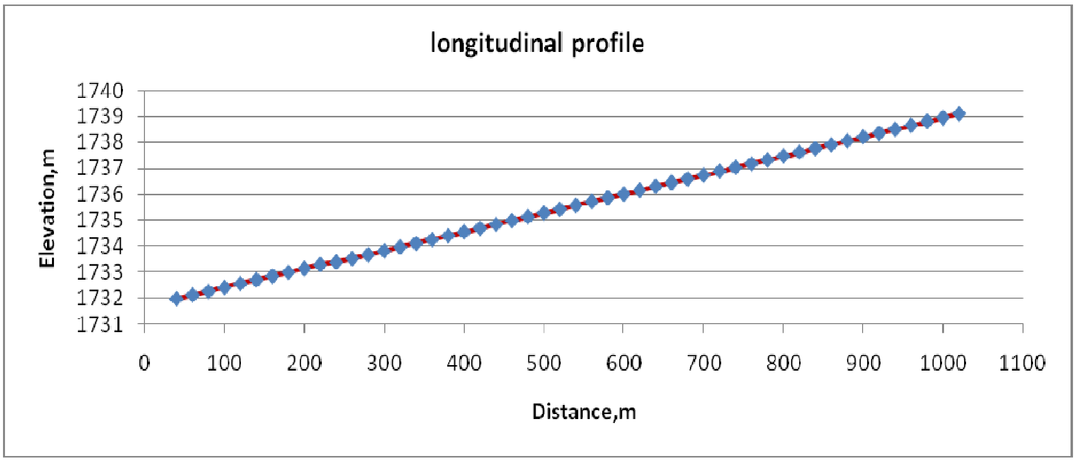

Figure 6. *Longitudinal Profile of Asphalt road.*

The profile of the asphalt road shown in Figure 6 indicates a uniform longitudinal slope of about 0.86 percent and a cross fall of 3.98 % respectively, which provides rapid removal of storm water from the carriage way of the road to the side drain ditch. The width of shoulder provided for this road ranges from 1.8 m to 2.4 m but the shoulder material is not sealed and subjected to erosion. The erosion of this shoulder is one of the main sources of material that fills the side ditch and results clogging. No manhole provided for the drain ditch of the road to regulate the flow of runoff water.

4.1.5. Road Surface Drainage Structures

As it was observed, there are nine small bridges and twenty two culverts for road crossing drainage structure in the Kebele .There are also eight drainage manholes for the surface drainage system along the newly constructed sub arterial gravel road (GR 2) built in this year and these manholes provide proper connection at the junctions of drainage ditches for regulating the water flow in the drainage structure

Table 5. *Road side ditch drainage structure distribution.*

Type of road	Side ditch (one side),m
Principal arterial	2741.570
Sub arterial	1124.290
Collector street	1403.680
Local road	1514.060
Total	6783.600

As it can be seen from table 5, about 6783.600 meters of side drain ditch were constructed on each side of the roads. From this, one can infer that only about 35 % of the road provided with defined side drain drainage structure. Masonry trapezoidal and rectangular types of side drain ditch were provided along the roads. From the constructed side ditches, only about 37 % provided with reinforced concrete cover to protect the ditches from any intrusions or garbage.

4.1.6. Road Surface Damage

Different types of damages to the roads in the Kebele were observed during the study. These are potholes, washing and deformations of the road pavements. About 5 cm to 30 cm deformation were observed on cobble stone and gravel road respectively while washing of asphalt road shoulder in the order 5 to 7 cm also observed due to improper slope. Figure 7 shows different damages occurred to roads in the study area as it was observed in the field investigation.

Figure 7. *Photo showing Road damages of the study area.*

4.2. Runoff Water and Hydraulic Capacity

In this study, the runoff water generated from the drainage basin was determined based on urban storm water drainage design manual of our country prepared by ministry of works and urban development in 2008. The hydraulic capacities of the open channels in the study area were determined using the Manning's equation. Accordingly, the peak rate of runoff and hydraulic capacities of the channel constructed were computed by the formulae stated and the obtained result presented in table 6.

Table 6. *Peak runoff rate and hydraulic capacity of channels in the study area.*

Sub-catchment	Area (ha)	Peak runoff rate (m^3/s)	Hydraulic capacity, (m^3/s)
1	2.598	0.347	0.748
2	5.306	0.708	0.814
3	3.719	0.496	1.024
4	5.524	0.737	1.783
5	15.353	2.049	3.587
6	5.254	0.701	1.024
7	7.298	0.974	0.706
8	19.902	2.324	2.381

As it can be seen from table 6, all the channels except that of sub catchment 7, are sufficient to carry the runoff water contributed to them with regard to their hydraulic property.

4.3. Road and Drainage Network Integration

As it was observed during the field investigation of the study, proper connections were made along the newly constructed gravel road (GR2) in which the curbstone properly constructed and inlet spacing was provided every 2m to 3 m interval. In addition drainage manholes were constructed at required locations along this road. However on the rest of the roads proper connections were not provided. In CBS1 road, non-uniform curbstone was provided with no inlet or opening to dispose water from road to the side ditch.

In the junction of CBS1 to CBS3, improper (under- sized) pipe culvert was provided and this create an obstruction to convey the water along the ditch and thus over flooding of water occurs at road crossing junction after every rainfall event. Figure 8 shows flooding due to improper connections or integrations at this location.

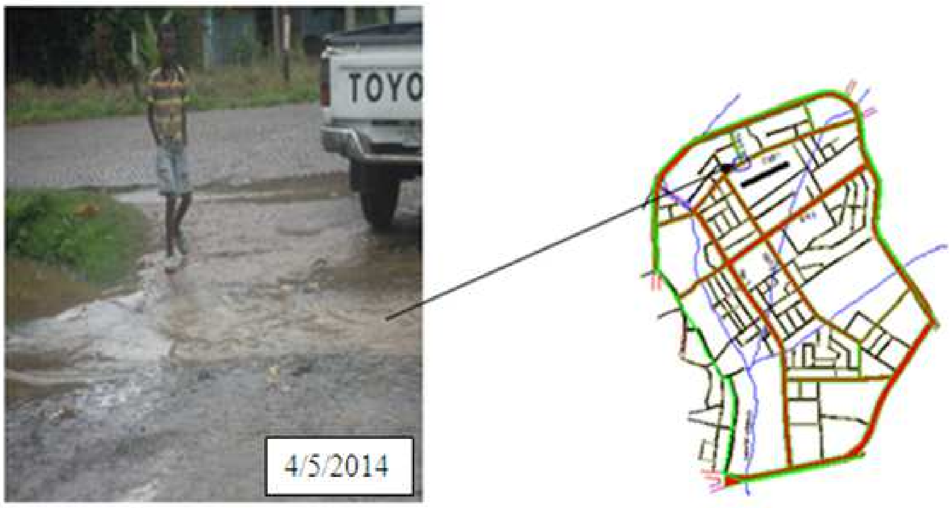

Figure 8. *Over flooding of water from side drain ditch at road crossing.*

According to field observation made, some of the side drain ditches were constructed for nothing as there is no inlet or opening to collect storm water from the adjacent surrounding area or road. In some cases, the inverted levels of the ditches are above the elevation of the adjacent surrounding area and thus water cannot enter to the ditch. The drain ditch along road besides Jimma Town Water Supply office compound can be cited as the case and no water flow in this channel. Rather, runoff water accumulated on the road damaging the pavement.

4.4. Maintenance of Road Surface and Drainage Structures

There is no regular maintenance of road and drainage structures as it was investigated during the study. Most of the side drain ditch is full of garbage and sediment at many places which obstruct the normal flow of water in the channel. Some drain ditches are also covered totally with grasses and shrubs and thus not giving the desired function for which it was constructed.

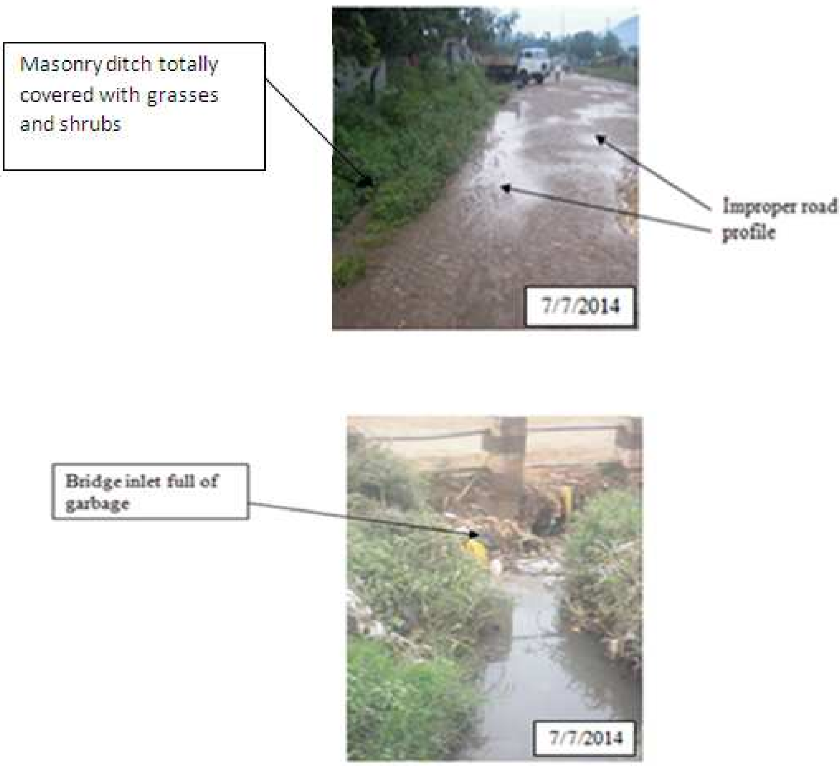

Figure 9. *Poor maintenance of drainage ditch, bridge and road surface.*

4.5. Rating and Evaluation of Road Drainage Condition

Table 7. *Rating and evaluating roadway drainage.*

Type of road	Side ditch (one side), m	Drainage condition
Principal arterial	2741.570	Good
Sub arterial	1124.290	Fair
Collector street	1403.680	Fair
Local road	1514.060	Poor
Total	6783.600	

From the investigations made concerning the road and drainage structure infrastructures in the study area as presented in the previous sections of this document, the surface drainage condition of the road was analyzed by adopting drainage evaluation system of *Wisconsin–Madison transportation center* as our country drainage manual does not have such rating. Accordingly about 59 % of the constructed drainage structures likely to have fair to poor drainage condition as per to the required standards and thus needs major improvement.

4.6. Flooding Problems

The result of the study shows that though the drainage problem is common in the area, the hazard of the flooding problem is dominant for about 38.6 % of the area and this flooded prone area is located at downstream reach of the Guduru sub-catchment along the streams. Two small bridges over flooded with runoff water in July 2013 due to blockage by debris and the flooding extended to the surrounding residential buildings causing damages or loss to their property. In 2014 rainy season, over flooding of runoff water also occurred to the bridge three times in a season.

Figure 10. *Over flooding of road due to bridge and pipe culvert blockage by debris.*

Generally, separate type of storm water drainage ditch constructed in the study area. But it was observed that liquid wastes released to the storm water drainage ditch & streams from some residential buildings and JU compound which affected the proper functioning of the drainage structures and creating environmental pollution.

As per to the interview made with key personnel, before 18 years the depth of Jiren and Guduru streams were about 0.7 m and 0.8 m below natural ground level respectively, which currently increased to 1.68 m and 1.84 m at the cross section stated. This shows that there is erosion of the stream bed every year in the order of 5.44 cm and 5.78 cm per year on the average respectively.

The sides of the embankment also eroded at different section along the streams by the high driving force of the surface runoff water contributed from the surrounding upstream reach of steeply area.

4.7. Storm Water Management

The study area was divided in 14 sub-catchment areas for modeling with EPA SWMM 5.0 version. The required parameters determined for each sub catchment to input for running the simulation and the obtained results are indicated in figures 11 and 12.

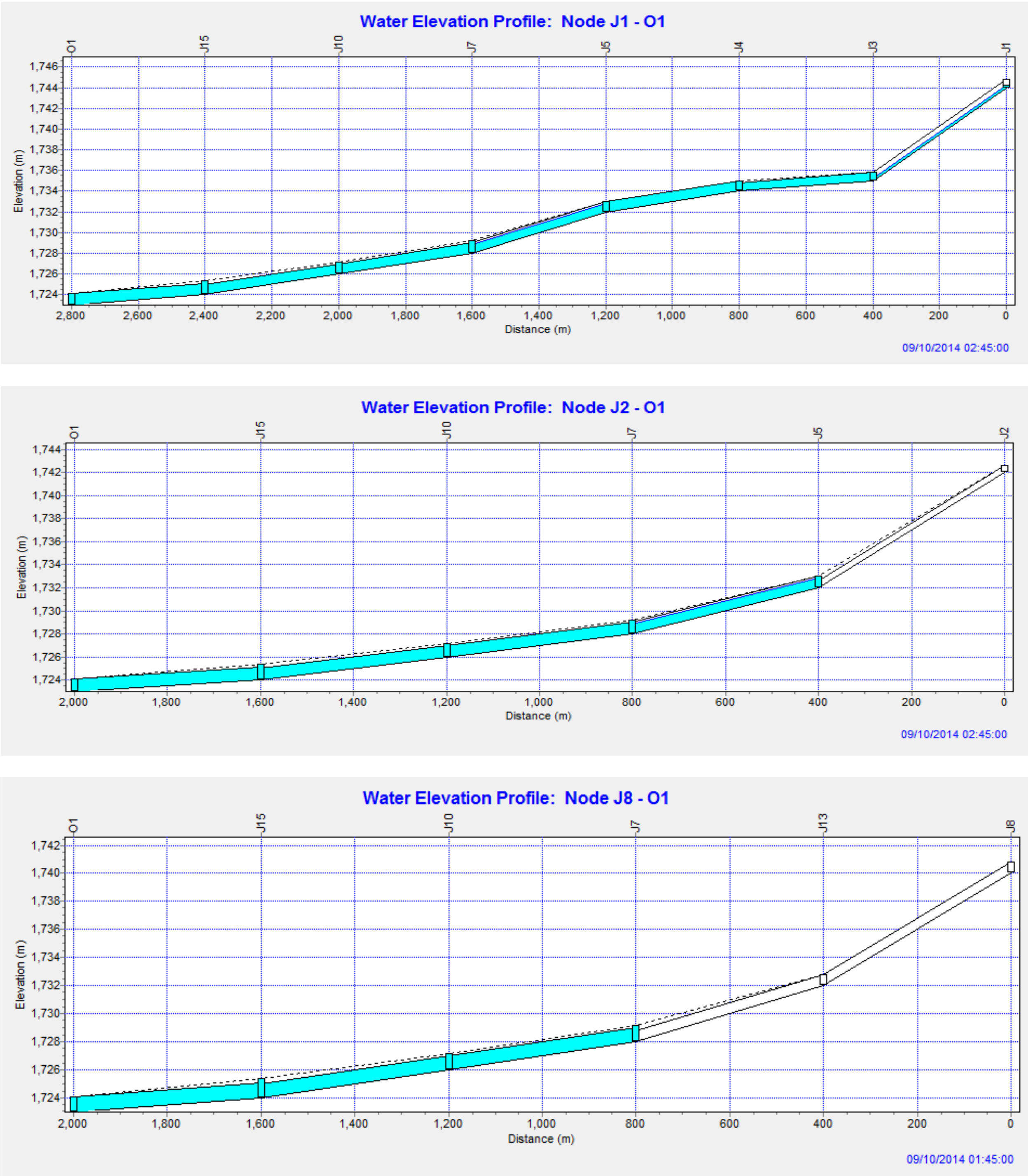

Figure 11. *Water elevation profile for three different paths of the modeling.*

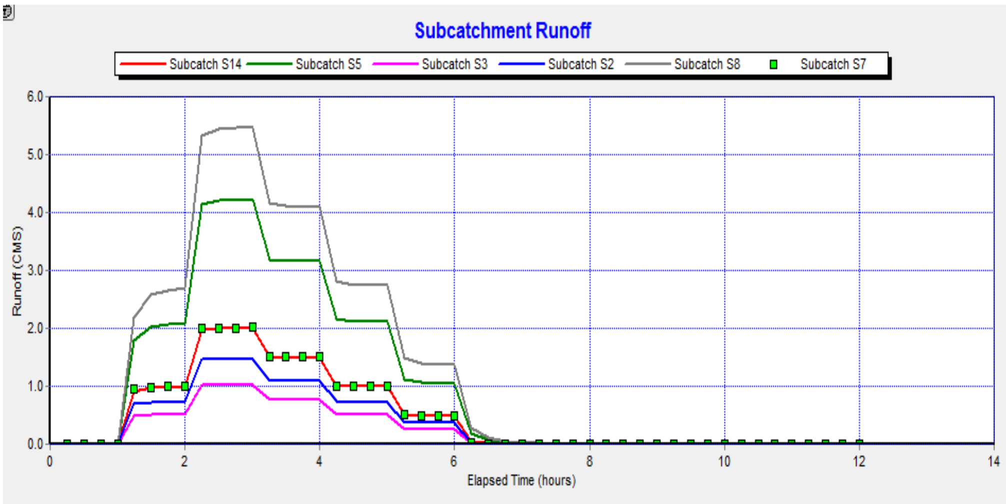

Figure 12. *Runoff water for different sub-catchment for the given rainfall event.*

5. Conclusion and Recommendation

5.1. Conclusion

Generally it can be concluded that road surface drainage of the study area found to be inadequate due insufficient road profile, insufficient drainage structures provision, improper maintenance and lack of proper interconnection between the road and drainage infrastructures thereby resulting damages to road surfacing material and flooding problems in the area.

5.2. Recommendations

- Proper road geometry need to be maintained to provide required crown and proper side drain drainage structures need to be provided for roads without drainage structures.
- Provision of proper connections or integrations between the road network and drainage network systems is required with regular maintenance.
- Improvement of surface drainage system layout as per to the master plan of the town and implementing the urban storm water drainage design manual of the country to improve storm drainage systems of the area.
- Developing the skill of SWMM soft ware for planning, analysis and design of storm water runoff and drainage systems in urban areas and monitoring the infrastructures.
- Use of the research study results for further study of other sub catchment of the Jimma town in order to have a standardized and harmonized urban drainage systems.

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