Assessment of the Hydraulic Performance of the Drainage System in Dire Dawa Town

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Abstract

The constructed drainage structure was expected to carry the design discharge which generated from the catchment area and dispose safely to the outlet points. The study has mainly focused to assessing current status of drainage system and evaluates the hydraulic performance of the drainage system. The rational methods have been used to calculate proposed discharge and HY-8 software used for culvert analysis. The current drainage status of the towns was poor, the road performance was reduced to deliver, the service life of the road reduced, and the cost for maintaining the road increased, the compression between the proposed and existed carrying capacity of drainage structures showed that the exist drainage structures are hydraulically insufficient. HY 8 result shows the existed culvert was hydraulically insufficient and 50-63.5% of the proposed peak discharge overtopped and flows on the road.

Keywords: Poor drainage • Road performance • Hydraulic performance

Introduction

According to Belete DA [1], infrastructure development in Africa is abysmal, lagging behind the rest of the world in terms of quality, quantity, and access. The situation is worse in poor countries like Ethiopia, where a myriad of problems have made the supply of physical infrastructure and services to continually lag behind the urban population growth rate.

Urban storm water drainage facilities are part of the urban infrastructure elements and the design of these facilities requires due attention. In Ethiopia context, where watershed of many urban centers receive a significant amount of annual rainfall and where rainfall intensity is generally high, control of runoff at the source, flood protection, and safe disposal of excess water/runoff through proper drainage facilities becomes essential (AASHTO, 1991).

Due to the development of infrastructures as a result of urbanization, the surface runoff water greatly increased in the town damaging the roads. They contributed runoff water thus needs 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 occurred to the road and property [2].

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 [2].

The pattern of urbanization and modernization in Ethiopia has meant to increase densification along with urban infrastructure development. This has led to deforestation, the 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 the road and urban storm water drainage infrastructure provision, many areas are exposed to flooding problems and road damages in urban roads [1].

Dire Dawa is one of the largest city in Ethiopia and which frequently attacked by flood hazards. Since Dire Dawa lying at the foot of the mountain range, it is subjected to annually flooding by runoff from the mountain during torrential rains and it still occurs when there are heavy rainfalls in the surrounding high land areas of Haramaya, Kersa, Dengego, and Qulubi. So this makes the drainage problems of the town becomes the more serious and main concern [3]. The roads at station S.CM-5, station 1+600.311 has been eroded and formed gullies due to the absence of side ditches the runoff directly flows over the road and distracts the road service to the community and requires high investment cost for maintenances.

The culverts at station S.CM-6, 2+190.36 and at station S.CM-8, 2+060.943 has been filled with sediments and debris from the nearby community, some communities use the culverts as a means of solid waste disposal areas and blocked the culverts working spaces.

The thesis gives high emphasize to assess the hydraulic performance of the drainage system in Dire Dawa town and specifically assess the current conditions of drainage system and evaluate the hydraulic performance of the drainage system.

The research is beneficial to the drainage and roads sectors of different urban areas for future road drainage system construction. This research was also useful for those involved in academicians and researchers who conduct similar researches on the other road drainage system, erosion and scouring prevention mechanisms and degradation of the stream channel [4].

This thesis is limited to the assessment of the hydraulic performance of the drainage system in Dire Dawa Town and recommending some way of reducing or minimizing the problems which are found in this research assessment regarding the drainage system. This research gives high emphasis on water-related problems which lead to poor drainage. The work does not cover the structural analysis rather it simply identifies the shapes, size, and type of drainage required [5].

Materials and Methods

The researcher uses both exploratory and descriptive way of expressions to reach a reasonable conclusion and achieving the research objectives.

Data sources

The researcher uses both primary and secondary data types. Under

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primary data sources the existed cross sectional area, width, elevations, side slope, bed slope, inlet and out let elevations, and roughness coefficient of different types of drainage systems in the town.

Under secondary data sources these researcher collects different data from different organizations. From those Metrological data, drainage master plan of the town, the land use land cover coverage's of the town, and different published and unpublished documents about drainages.

Data collection methods

For this study basically the following data collection methods have been employed:

1. Personal observations of the study area to assess the current status of the drainage system of the towns and to show the true state of the drainage system and the roads performance and Field survey of different site and collect the cross section, depths, widths slopes, elevations, etc., to evaluate the hydraulic performance of the drainage system of the towns.

2. Direct interviews with the administrative body of the town sewerage and drainage system to answer the drainage coverage of the tows and to know the root cause for the occurrence of poor drainage in the towns.

Data analysis

The collected data were analyzed by using Microsoft Excel, Global Mapper, ARC-GIS 10.4, and HY-8 culvert analysis software.

The ARC-GIS 10.4 and Global mapper program was used for the preparations of the study areas of sub-catchment areas, location map preparations of the study area, and land use land cover preparations.

HY-8 program was used for the analysis of the existed culvert performance by iterating different discharge and shows how much of the water overtops from the culvert and directly flows on the road.

Microsoft Excel program was used for the computations of proposed maximum discharges from each sub catchment areas by the rational formulae and different interviewed results has been analyzed by the excel sheets by simple mathematics.

Data presentation

Once the data has been analyzed the next step was presenting the data in a clear and concise manner, for that sick of matter the researcher uses figures which have been done by the global mapper and ARC-GIS 10.4 and Microsoft Excel, tables, photographs, and percentages.

Results and Discussion

The current condition of drainage system in the town

The current road coverage of the towns was 14.36% of the total area of the town (124.34 km^2) and most of the roads have been faced problems from the drainage system. Most of the problems which have been directly associated with the poor drainage system of the towns.

From the response of the engineers from drainage and road authority they have been formalized in the following points. The poor drainage affects the road performance every year by overspreading the floods on the road and creates inundation of the road and the nearby houses.

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For each rainy season the administrative body invests much money for maintenance and cleaning of ditches, but still the drainage problem reduced the service life of the road.

The impact of poor drainage condition on road pavement is very adverse.

It causes pavement distresses and deterioration which affect the safety and riding quality on the pavement. The study investigated cases of pavement failures and damages due to poor drainage experienced during the rainy season [6-10].

Generally the effects of poor drainage system on the roads have been listed bellows:

- Reducing the load carrying ability of the subgrade, sub base, asphalts and shoulder of the road.

- Eroding the road side surface by washing away the top surface of the road.

- Runoff the road and block a road by deposited waste material on the road and water leaved debris on the road and thaw weakening and stripping the asphalt in asphalt pavement road.

The results from personal observation of the site have been figure out in pictures which existed in Figures 1- 6 part bellows, and that shows the destruction of traffic flow by flooding the road, side deterioration and formation
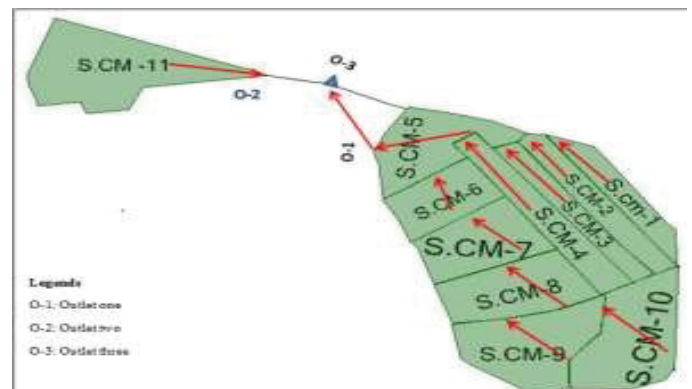

Figure 1. Location map of the study area.

Figure 2. The sub-catchment areas of the study area.

Figure 3. Almost all filled with the sedimentation of side ditches.

Figure 4. Solid waste and dust accumulation in the drainage system and creates water stagnation in the side channel.

Figure 5. Flooding to both the right and left side of the drainage system.

Figure 6. Eroded roads and gully formations due to lack of side ditches.

of gullies on the road sides, culverts has been filled with debris and flood overtopped on the roads etc.

Evaluating hydraulic performance of the drainage system

Comparison of proposed peak design discharge and existed drainage structure capacity: From the Table 1 which show that the proposed maximum discharge computations which indicated that column number 1 shows the sub-catchment name in the study area, the column number 2 shows that the area coverage of each sub-catchments measured by hectares, the column number 3 shows the weighted runoff coefficients of each sub-catchments, the column number 4 indicates that time of concentration from each sub-catchments, the column number 5 indicates that for each sub-catchments the intensity from ERA IDF curve measured by mm/hr for different return periods, and column number 6 indicates the computed proposed maximum discharge by rational methods (Q=0.00278CIA).

From Table 2 which show the existed working spaces of different types of drainage structures in different sub-catchments of the study area measured using tap meters and also observing the roughness coefficients, and side and bed sloped of each drainage structures. Finally the computations of the carrying capacity of the drainage structures have been shown by manning formulae.

From the computed proposed peak discharge which stated in Table 1 and the existed carrying capacity of drainage structures show in the Table 2, the existed drainage structures are fully hydraulically insufficient and most of the drainage structures need rehabilitations and additional drainage structures installations.

From Table 3 which has shown below puts clearly the comparison between the existed drainage structures and the proposed maximum design discharge on each sub-catchment. From the Table 3 column 1 indicates that the sub-catchments name in the study area, the column number 2 indicates that the total discharge in each sub-catchment measured by m³/s, column number 3 indicates that existed drainage structures and their carrying capacity measured by m³/s, column number 4 indicates that the propped maximum design discharge for both the design and check periods measured by m³/s and finally column number 5 indicates the amount of flood which overtops from the existed drainage structures(col(4) for both design and check – col(3)) measured by m³/s.

Based on the comparisons of the existed and proposed peak discharges at Table 4 the difference at sub-catchment one (S.CM-1), 69.67% for design and 75.46% for check, sub- catchment four (S.CM-4), 12.07% for design

Table 1. Proposed maximum discharge computation by the rational formulae for the study area.

Col (1)	Col (2)	Col (3)	Col (4)	Col (5)			Col (6)		
				Intensity (mm/hr) for Different Return Period			Proposed Discharge (Q=0.00278CLA)		
Catch ID	Area (Ha)	C	Total (min)	5 YR	10 YR	25 YR	Q5	Q10	Q25
S. CM 1	5.75	0.57469	12	97	107	120	0.865	0.982	1.21369
S. CM 2	6.42	052974	21	79	90	100	0.745	0.847	1.01218
S. CM3	5.45	0.5898	19	12	93	104	0.679	0.773	0.9513
S. CM4	975	055	16	18	98	110	1.312	1.461	1.80384
S. CM5	419	0.51885	26	67	77	86	0.405	0.465	0.57173
S. CM6	1319	0.44121	12	94	107	120	1.538	1.745	2.15803
S. CM7	1149	0.48333	12	95	107	121	1.841	2.089	2.58351
S. CM8	2353	0.475	10	99	112	126	3.063	3.473	4.2996
S. CM9	1459	0.485	10	91	111	125	1.92	2.177	2.69477
S. CM10	1638	056145	13	92	105	119	2.352	2.684	3.34662
S. CM11	20.04	0.49568	19	82	93	104	2.254	2.562	3.15508

Table 2. Existed drainage channels and their hydraulic carrying capacity.

Catchments Name	S.C.M 1	S.C.M 5	S. CM 4	S. CM 11
Drainage type by shape	Rectangular	Curricular Pipe	Rectangular	Rectangular
Cross section data (W,Y)	W=45 cm, Y=30 cm	90 cm	W=45 cm, Y=25 cm	W=45 cm, Y=45 cm
Area (m²)	0.135	0.63585	0.1125	0.2025
Perimeter (m)	1.05	2.826	0.95	1.35
Hydraulic Radius R (m)	0.128571428	0.225	0.118421053	0.15
Slope	0.03	0.026	0.03201331	0.012658
Roughness coefficient	0.02	0.014	0.02	0.013
Side slope	1 V:1h	-	1v:1h	1v:1h
Calculated discharge m³/s	0.2978247	2.709162108	0.242929561	0.49475749

and 28.66% for check, sub-catchment five (S.CM-5), 47.76% for design and 57.51% for check, and finally at sub-catchment elven (S.CM-11), 80.69% for design and 84.32% for checks has been overtopped directly on the surface of the roads. The over topped discharge directly affects the roads performance and creates an environmental problem.

Existed culverts analysis using HY 8 Software: From the Tables 5-9 the result shows that there is flooding or overtopping from the culverts at each

maximum floods which have a magnitude of greater than 8.41 m³/s for the culverts one at station sub-catchment six (S.CM-6) and7.21 m³/s for the culvert two at station sub-catchment eight (S.CM- 8).

Depending on the observed difference between the proposed design discharge and the existed carrying capacity of the culverts the structure is hydraulically insufficient both for the design and check of proposed discharges. For culvert one the from the proposed design discharge, 35.8% for the 25

Table 3. Comparison of proposed peak design discharge and existed drainage structure capacity.

Col (1)	Col (2)	Col (3)	Col (4)		Co l (5)	
Catchment Identification	Total Discharge (Q,m³/s)	Existed structure (Q,m³/s)	Proposed design discharge (Q,m³/s)		Difference discharge (Q,m³/s)	
			Q.Design (10 yr)	Q.Check (25 yr)	Q.Design (10 yr)	Q.check (25yr)
S.CM 1	Q1	0.2978247	0.932	1.21369	0.68418	0.91587
S. CM 4	Q2+Q3+Q1	2.709162108	3.081	3.79732	0.37184	1.08816
S. CM 5	Q1+Q5	0.242929561	0.465	0.57173	0.22207	0.3288
S. C31 11	Q11	0.494756749	2.562	3.15508	2.06724	2.66032

Table 4. Percentage of the flood which overtopped and flows on the road.

Catchment ID	% of Flood Overtopped from Existed Drainage	
	Q (m³/s) Design	Q (m³is) Check
S.CM 1	69.6716%	75.4612%
S.CM 4	12.0687%	28.6559%
S.CM 5	47.7571%	57.5097%
S.CM 11	80.6887%	84.3187%

Table 5. Summary of flows at the crossing - Culvert one for a 25 year return period, 13.1 m³/s.

Col (1)	Col (2)	Col (3)	Col (4)	Col (5)
Headwater Discharge (m)	Total Discharge (m³/s)	Culvert Discharge (m³/s)	Roadway Discharge (m³/ s)	Interations
1202.1	10	9.66	0.34	6
1292.13	10.5	10	0.19	4
1202.15	11	10.34	0.66	3
1202.18	11.5	10.66	0.83	3
120121	12	10.98	1.01	3
1202.23	12.5	11.29	12	3
120215	13	11.6	1.4	3
1202.26	13.1	11.66	1.44	3
1202.3	14	12.19	1.81	3
1202.33	14.5	12.48	2.02	3
1202.35	15	12.76	2.24	3
1202	8.41	8.41	0	Overtopping

Table 6. Summary of flows at the crossing Culvert one for a 50 year returns periods, 18.1 m³/s.

Col (1)	Col (2)	Col (3)	Col ((4)	Col (5)
Headwater Discharge (m)	Total Discharge (m³/s)	Culvert Discharge (m³/s)	Roadway Discharge (m³/ s)	Interations
1202.1	10	9.66	0.34	6
1292.13	10.5	10	0.19	4
1202.15	11	10.34	0.66	3
1202.18	11.5	10.66	0.83	3
120121	12	10.98	1.01	3
1202.23	12.5	11.29	12	3
120215	13	11.6	1.4	3
1202.26	13.1	11.66	1.44	3
1202.3	14	12.19	1.81	3
1202.33	14.5	12.48	2.02	3
1202.35	15	12.76	2.24	3
1202	8.41	8.41	0	Overtopping

Table 7. Flow summery at the crossing - Culvert two for a 25 year returns periods, 13.00 m³/s.

Col (1)	Col (2)	Col (3)	Col (4)	Col (5)
Headwater Elevation (m)	Total Discharge (m³/s)	Culvert Discharge (m³/s)	Roadway Discharge (m³/ s)	Interations
1207.27	0	0	0	1
1207.68	1.5	1.5	0	1
1207.91	3	3	0	1
1208.11	4.5	4.5	0	1
1208.29	6	6	0	1
1208.45	7.5	7.5	0	1
1208.61	9	9	0	1
1202.75	10.5	10.5	0	1
1208.89	12	12	0	1
1208.98	13	13	0	1
1209.15	15	15	0	1
1209.27	16.34	16.34	0	Overtopping

Table 8. Flows summary at the crossing - Culvert two for a 50 year returns periods, 19.60 m³/s.

Col (1)	Col (2)	Col (3)	Col ((4)	Col (5)
Headwater Elevation (m)	Total Discharge (m³/s)	Culvert Discharge (m³/s)	Roadway Discharge (m³/ s)	Interations
1207.5	10	9.45	0.55	5
1208.57	11	10.17	0.83	3
1207.64	12	10.89	1.11	4
1208.71	13	11.65	1.35	5
1208.79	14	12.47	1.54	9
1208.87	15	13.3	1.72	7
1208.96	16	14.14	1.88	11
1202.04	17	14.79	2.23	9
1208.13	18	15.52	2.5	9
1208.13	18.1	15.58	2.52	4
1209.29	20	16.93	3.07	5
1209.27	7.21	7.21	0	Overtopping

Table 9. Comparison of proposed design discharge and existed culverts capacity.

Culverts ID	Proposed design Discharge (m³/s)		Existed culverts Carrying Capacity		Difference between Proposed and Existed Design Discharge	
	25 yr Design	50 yr Design	25 yr Design	50 yr Design	25 yr Design	50 yr Design
Culvert one @S.CM-6	13.1	19.63	8.41	8.41	4.69	11.22
Culvert two @S.cm-8	10.5	18.1	4.32	4.32	3.29	13.78

year return period and 57.1% for the 50 years check the flood flows out of the culvert and directly flows on the road and sometimes causes flooding the nearby community houses. For culvert two depending on the proposed design discharge, 31.1% for the 25 year return period and 76.13% for the 50 year return period for check this much flood flows out of the culverts.

Conclusion

After careful assessments of the effects of the poor drainage system on the road performance, the following main results had observed and described as below.

From the road and drainage authorities interview they have still used the ERA IDF curve, from the compression made in this thesis between own prepared IDF curve to the town and ERA IDF curve for the tows, the intensity from ERA IDF curve was less than that of own IDF curve for the town this leads to the underestimation of the design discharge.

From personal observation of the site the drainage system of the town was highly used the rectangular open channel without covering the top part of the channels this leads the channel to filled with wastes, commercial residues,

and the community itself use the channel as a means of the trade area. Those activate create reducing the size of the drainage structure and immediately it creates an overtopping of channels and flow on the roads also some portion of the drainage blocked with waste crates water stagnation for long period of times.

From hydraulic performance assessment of the existed drainage structures almost all the drainage systems design is hydraulically insufficient means that the proposed design discharge for both the design and check is much greater than the existed drainages structure working space (hydraulic capacity), this happens due to less involvement of professionals (hydraulic engineer, hydrologist), future projection of the design structures was not considered the land use land cover change highly affects the peak discharge but not highly considered in the design stage, the communities awareness about the drainage structures was not good they did not consider the drainage system as a means of disposing storm water rather they think of that as solid waste material disposal means.

Still, areas without drainage channels construction exist and the flow from those places create an overflow on the road and deteriorates the side of the roads highly this happens due to poor drainage alignment system with the roads.

From HY 8 culvert analysis the existed culverts have encountered an overtopping problem and the active working space of the culvert was insufficient to carry and bypass the coming proposed peak discharges.

Acknowledgment

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