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EAMAC: Ecole Africaine de Meteorologie et de l'Aviation Civile.
African School of Meteorology and Civil Aviation.
ERNAM: Ecole Regional de Navigation Aerienne et de management.
Regional School of Air Navigation and Management

ERSI: Ecole Regionale de la Securite Incendie Regional School of Fire Safety.

# Flood Abatement on Lagos City Streets: A Survey of Street Planning and Design Parameters for Effective Drainage

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**Abstract**

*As a low-lying city with inadequate provision for runoff, street flooding is an endemic problem in Lagos metropolis with each rainy season. There has been continuing efforts by the state government to combat this flooding as evidenced by the State Drainage Development Plan of 1999 and the recent Flood Abatement Programme of the State Ministry of Environment. These efforts have largely been dwarfed by the enormity of the problem. As part of a comprehensive drainage system for the city, buildings, streets and roads are supposed to feed runoff into tertiary, secondary and primary drainage systems for rapid delivery to collection basins, lagoons and to the sea. But apart from drainage system inadequacy coupled with reckless landuse habits (indiscriminate waste dumping, polythene bags etc) a closer observation of many paved streets and roads reveals non-adherence to some fundamental parameters for effective drainage in their planning, design, construction and maintenance. Cross and longitudinal sections of streets/roads reflect slopes for rapid drainage away from them. Although a rudimentary knowledge to the road engineer, lack of this among some planners/designers, some maintenance crew managers and developers appear to lead to improperly aligned, constructed and maintained streets which contribute to flooding.*
*This paper reviews some salient street planning/design parameters for effective drainage. Then some selected collector and residential streets on the Lagos mainland are surveyed through field observation for their adherence or otherwise to these parameters. Landuse practices which contribute to street flooding are highlighted. Strategies for abatement discussed include education, programmed comprehensive resurfacing, control of indiscriminate development/ proactive comprehensive drainage system and timely evacuation of refuse.*

*Keywords, Environment, drainage, road,, pavement*

## Introduction

Being a low-lying city with inadequate provision for runoff, street flooding is an endemic problem in Lagos metropolis with each rainy season. Whether light or heavy, each rain brings with it traffic gridlock, economic slowdown and unwanted misery on residents and commuters as the streets and roads are severely inundated.

Due to the enormity of the flooding problem, efforts by the State Government to combat it have only yielded mixed results in isolated cases. An example is the Lagos State Ministry of Environment and Physical Planning Drainage Development for Greater Lagos of 1999. In this report, the causes of flooding and problems of storm water drainage in Lagos were identified to include *natural causes (intense rainfall, flat topography, poor infiltration and high tide at outfalls)* and *man-made causes (inadequate design and underdevelopment of systems – drainage facilities lacking or haphazard, improper sizing, encroachment and lack of maintenance* – Lagos State –MEPP, 1999) Recently, this effort is being promoted by the current Lagos State Flood Abatement Programme evidenced by the clearing of some drains by maintenance crews.

Where the city has a comprehensive drainage system as Abuja does, buildings, streets and roads routinely feed runoff into tertiary, secondary and primary drainage systems for rapid discharge to collection basins, lagoons and to the sea. But aside from drainage system inadequacy and reckless landuse habits



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(indiscriminate waste dumping and polythene bags litter etc), a closer observation of many paved streets and roads in the metropolis reveals lack of adherence to some fundamental parameters for effective drainage in their planning/design, construction and maintenance. Planning, design and alignment of roads while aimed appropriately on the provision of safe moving lanes also embody considerations for rapid discharge of incidental runoff from the pavement into collection areas. In this regard, the road cross and longitudinal sections reflect slopes for rapid drainage away for the road centerline, apex and bottom of the vertical curves respectively. These considerations although a rudimentary knowledge to the highway engineer appear to be lacking among some planners and designers, various local managers, some road maintenance crew managers and some private estate developers. In consequence, these appear to contribute to improperly aligned, constructed and maintained streets which readily become involuntary impoundments once it rains.

This paper therefore reviews some salient road alignment parameters for effective drainage. Selected collector and residential streets on the Lagos mainland are surveyed for their adherence or lack thereof to these parameters. Landuse practices which mitigate effective drainage in these streets are highlighted. Suggestions toward amelioration briefly discussed include education, programmed comprehensive resurfacing, control of indiscriminate development, proactive comprehensive drainage system and timely evacuation of refuse.

The methodology employed in thi exercise was the review of concepts coupled with field observation on the streets, photography and sketch illustrations. Collector and residential streets selected are in Isolo/Okota/Ejigbo ( Ejigbo Road, Aswani Road, Okota Road and Kogberegbe Street), in Surulere (Ogunlana Drive, Ogunsanya and Bode Thomas Streets), in Ikeja (Awolowo Way) and in Akoka (University Road/Usman Dan Fodio Blvd. and Ransome Kuti Road). Their selection was based on their being representative and symptomatic of the characteristic of streets and roads in their areas. They are generally low speed roads not exceeding the design speed of 50kph. Only paved streets and roads are used in the assessment as they readily provide even surface and slope.

**Road Design Parameters for Drainage:**

The Road Cross section: Universally, the road cross section is characterized by a convex or triangular form [Fig. 1a,b) In a convex section of an undivided 2 or 4 lane street with normal crown, the road centerline is the apex with the pavement sloping uniformly sideways towards the edges or curbs. In an avenue, boulevard or dual carriage street with a median, typical section is triangular with the edge of the median being the apex while the pavement also slopes uniformly sideways to the edges, curbs or shoulders. This cross slope which for asphalt and concrete pavements is a preferred minimum of 2% and 1% (i.e. 6mm/300mm and 3mm/300mm) respectively of the horizontal distance from the apex to the edges or curbs Harris and Dines, 1998; Tables 1&2, Standards for Pavement Cross Slopes). This cross slope ensures the rapid conveyance of incidental runoff from the pavement to the edges from where it is fed into inlets or channels. It is pertinent to add that normal crown is more economically achieved where the horizontal alignment is across the contours. Where however the alignment is along the contours as along the side of a hill, the cross section is usually triangular or 'super elevated' with the higher edge on the up slope and the lower edge down slope.

Table 1. Spatial Standards for Roads: Pavement crown (for Drainage)

| | |
|---|---|
| Natural soil | 15mm: 300mm |
| Gravel, crushed stone | 10-15mm: 30mm |
| Intermediate type bituminous | 5-10mm: 300mm |
| High-Type bituminous | 3-5mm: 300mm |
| Concrete | 2.5-4mm: 300mm |

*Source: Harris and Dines after AASHO*

Table 2. Standards for Pavement Cross Slopes

| Type of Pavement | cross slope (mm/mm) |
|---|---|
| Portland cement concrete | 4.5mm |



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| | |
|---|---|
| Bituminous mix pavements | 4.5mm- 6mm |
| Penetration treated earth or gravel | 7.5mm- 9mm |
| Unsurfaced graded section | 7.5mm- 9mm |

**Source**: *F.M.W Highway Manual*

**Horizontal and Vertical Alignment:**
Placing a street or road on the landscape for safe and efficient vehicular movement normally involves alignment in both horizontal and vertical planes. Horizontal alignment is the direction right, left or straight that a roadway assumes on the landscape. It deals with the road placement planimetrically through the landscape in response to topography and other natural features (Fig 2a). Vertical alignment or profile on the other hand deals with the placement of the road or street over the landscape, that is, over or through the hills and valleys to achieve proper sight distance along with safe, economical vehicular movement (Fig 2b). Both utilizes combinations of curves and tangents to overcome changes or ease transition when there is a change in direction and slope due to topography.
While horizontal alignment ensures spatial connectivity from one place to another, longitudinal slopes associated with vertical alignment help to smoothen the bumps in topography. This slope also facilitates effective drainage from the crest curve downhill along curbs and channels to the sag curve for discharge through interceptor channels or culverts. Generally, vertical curves are required for low speed roads and streets when vertical change in grade exceeds 1% (Strom and Nathan, 1998; Table 5). Although vertical alignment is mainly controlled by topography and in part by horizontal alignment, the Federal Ministry of Works [FMW] clearly stated that "in level terrain" such as in Lagos, "the elevation of the grade line is often controlled by drainage considerations" (F.M.W. 1973 p.1-302.01). Some standards as specified by F.M.W for vertical slopes for drainage are listed as follows: [FMW, p.1-302.01]

a. Minimum grades:
- Flat or level grades on uncurbed pavements are virtually without objection when the pavement is adequately crowned to drain the surface laterally.
- Where flat or level grades are used, independent profile gradients are required for roadway median and side ditches to insure efficient drainage.
- With curbed pavements (as in Awolowo Way), longitudinal grades should be provided to facilitate drainage. A minimum grade of 0.05% is usual for this case.
- On kerbed sections, attention be given to the design and spacing of storm water inlets to minimize the spread of water on moving lanes.

b. Maximum grades:
- For a design speed of 50kph, maximum grade on a flat topography is 6%; rolling terrain is 7% and mountainous terrain is 9%.
- Maximum grades should be used infrequently.

Table 5. Alignment Standards in Relation to Design speed.

| Design speed km/h | Minimum Radius of Horizontal curve (m) | Maximum % of Grade | Minimum Length of vertical curve for each 1% of algebraic difference (m) |
|---|---|---|---|
| 20 | 25 | 12 | 2.75 |
| 30 | 30 | 12 | 3 |
| 40 | 50 | 11 | 5 |
| 50 | 80 | 10 | 6.5 |

*Source: Strom and Nathan 1998*

**Superelevation or Transverse Slope**

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Superelevation is the tilting of the road surface or cross slope either about its centerline or inside edge. Usually, it is employed to counteract centrifugal force on a horizontal curve in order to maintain the speed of travel. The amount of tilting depends on the design speed and the radius of curve. However, it is recommended that the rate of superelevation should not be less than the rate of crown slope while the maximum value should not exceed 36mm/300mm (FMW.1973 p.1-.301.03). In addition to this main function, superelevation aids rapid drainage of the road cross section from the elevated outside edge to the inside edge of the road curve from where it could be fed into channels (Fig. 3).

### Curbs and Roadside Drainage Channels

In addition to their use to restrain vehicles from leaving the road pavement and protect pedestrians and other street users, curbs are used extensively to control drainage. They prevent water from sheeting or ponding on traffic lanes by directing it through inlets or outfalls to surface and subsurface channels. Used with or without curbs, the main function of street-side or roadside channels where available is to conduct runoff away in order to prevent damage to the pavement and hence impede traffic flow. Often the longitudinal slope associated with vertical alignment facilitates longitudinal transport and discharge of runoff along these channels to the bottom of a sag curve where culverts or interceptor channels conduct into primary channels or natural drainage courses. The standard practice in our urban residential streets is the use of open, surface rectangular channels instead of subsurface system. Where possible, they are on both sides of the street.

### Findings on Streets and Roads Surveyed

### Cross Section and Slope

Except on a segment of University Road, Ransome Kuti Road, Ogunlana Drive and Adeniran Ogunsanya St., all others have triangular cross sections with discernible slopes of the range 2-4%. This is more pronounced on 4 - lane divided roads such as Ejigbo/Egbe Road and Awolowo Way. Here the median is the apex with the pavement sloping uniformly sideways except at superelevated sections. Save for the 4-lane roads, most of others especially Ogunlana Drive and Ogunsanya Street exhibit irregular or uneven cross slope with depressions towards the edges or curbs. In some of these instances, the street edges or curbs are at higher levels than the intervening pavement between them and the apex of the road (Plates 2, 3, 4). Apart from Awolowo Way and University Road, many of the roads/streets exhibiting uneven cross slope have witnessed sporadic maintenance in some sections in recent times. It could not however be determined if the depressions in cross slope are attributable to improper maintenance or differential settlement.

Uneven cross-slope and depressions are evidently some of the prime contributors to ponding on the street pavement. Clearly, it was observed that streets in relatively flat terrain of Surulere and Akoka rèly heavily on cross slope for drainage in comparison with those in undulating terrains of Isolo, Ejigbo and Ikeja.

### Horizontal, Vertical Curves and Longitudinal Slope

Except for very short curves on the Oke-Afa segment of Ejigbo Road and on the canal end of Kogberegbe Street, Isolo, the horizontal alignment of most other streets are within tolerable limits and standards. Also except for above locations, requisite horizontal sight distances of a minimum of 80meters on the design speeds of urban roads (30mph or 50kph) appear achieved especially on the minimal crest and sag curves present on a few of them which include Okota, Ejigbo, Aswani Roads. and Awolowo Way.

Major elements of the vertical or longitudinal slope observed are the following:

a. In areas of sloping topography as in Isolo, Ejigbo and Ikeja, the streets and roads surveyed have perceivable longitudinal slope of range 3-5% which aids rapid drainage along the edges and into the channels (Plate 5).

b. In relatively flat areas as in Surulere, Akoka, longitudinal slopes of the streets are hardly perceivable at a range of 1-2% as observed on University Road at Atan Cemetery and Adeniran Ogunsanya Street.

c. Also streets in areas of flat terrain rely more on cross slope for drainage than longitudinal slopes.

d. In flatter areas, ponding or flooding occurs more on the road pavement between the crown and the edges either



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due to depressions or higher elevations of adjoining curbs and gutter as evident on parts of Ogunlana Drive and Ogunsanya Street.

e. Inconsistent profile or roller-coaster longitudinal slope between the crest and sag curves occur on a number of these streets with the exception of Awolowo Way. This is most pronounced on Aswani Road and Kogberegbe Street, Isolo. This situation aids ponding on many segments of the road pavement [Plates 2, 3].

**Curbs and Gutters**

Only Awolowo Way, University Road/Usman Dan Fodio Bvld have curbs on both sides and median for most of their entire length. Ejigbo / Egbe Road has curbs entirely on its median and outbound lane up to Oke-Afa bridge. Others like Ogunlana Drive and Adeniran Ogunsanya Street. have kerbs only at some points on their entire length. On channels, only Awolowo Way has subsurface drainage with curb inlets connected to them. Those in Isolo and Ejigbo have clearly recognizable rectangular channels aligned with longitudinal slopes on both sides with the sloping terrain aiding their effectiveness. The streets in Surulere and Akoka generally have shallow swales or channels either on one side or part of their entire length. Also in these areas, inappropriate or questionable inverts characterize these channels where they exist as evidenced by stagnant effluent in them. Of the sag curves found on some of the streets namely Awolowo Way, Okota Road and Ejigbo Road, Oke-Afa, only the interceptor channel or culvert on Awolowo Way by Oregun Road junction is effective as minimal ponding occurs there. Severe flooding occurs on similar curve on Okota Road (near Gideon School) even with the lightest rain. The general problems identified with channels where they exist can be summed up as questionable or haphazard inverts and inappropriate sizing of channels and culverts.

**Land Use and Maintenance Factors Influencing Street Flooding**

Landuse and maintenance factors identified include:-

a. Curb-cuts and ramps for access
b. Siltation on pavement edges and curbs
c. Non-evacuation of silt and refuse cleared from channels
d. 'Patchwork' maintenance and resurfacing
e. Speed bumps on streets
f. Reactive instead of proactive street development.

***Curb-Cuts and Ramps for Access***

*On streets with curbs and those without, curb cuts and concrete ramps for individual access projecting on to the street pavement are found to have significantly altered street geometry and drainage directions near their locations. These produce a damming effect by blocking the drainage path particularly on low lying streets with little longitudinal slope to propel drainage towards lower levels. This is evidently so for cuts and ramps executed after street construction, e.g. Ogunlana Drive, Ogunsanya Street.*

***Siltation on Pavement Edges***

*Sand drifting on the street is found deposited on pavement edges or curbs and near medians. Even on streets with side channels, this siltation as it piles higher over time appears to affect the street cross section by preventing run-off from emptying freely into the channels. This is noticeable on almost all streets except Awolowo Way. This is one of the sore evidence of our lack of street maintenance through street sweeping [Plates 5, 6, 7].*

**Non-Evacuation of Silt and Refuse**

Too often, silt and refuse cleared from channels either from drainage clearance or environmental sanitation are left uncleared for long periods. These may become small dams or subsequent rains either return them to the same channel or disperse them on the road sometimes resulting in unintended floods and traffic jams.

"Patchwork" Maintenance and resurfacing: The periodic efforts of Lagos State Government through its Ministry of Works and Infrastructure to selectively repair and re-surface failed sections of streets and roads are quite commendable. Without these along with other actions, street flooding, potholes and their attendant traffic grid-lock would have reached crisis proportions. Nevertheless, the stop-scratch or 'patch work' re-surfacing as noted in some instances result in bumpy or uneven cross and longitudinal slopes due to poor workmanship. The surface level of repaired sections in some of



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these instances is higher than the unaffected sections thereby influencing the overall geometry and drainage patterns. This may be due to the practice of filling over damaged sections and asphalting rather than excavating these sections and making up levels appropriately. It may also be due to the asphalting technique which is usually cold-*laid manually.*

**Speed Bumps**

These devices for the control of vehicular speed which are not part of the original street design tend to affect street geometry. Where they are directly connected to the kerbs (if any) without leaving a small drainage gap, this effects free flow of runoff alongside kerbs thereby creating unintended impoundment. It is not surprising therefore that with this ponding and vehicular vibrations, pavement failure and potholes almost always develop on the toe of these bumps. Examples are the bumps located on Ransome Kuti Road in front of Unilag Consult Building and in front of Unilag Sports Center.

Reactive instead of Proactive Street Development. Site and services scheme enables orderly urban development wherein access roads and streets with appropriate geometry for drainage and other requirements are built before wholesale development commences. This also allows appropriate drainage channels with requisite inverts, outfalls, tie-ins and linkages to be emplaced prior to development. However the current practice of mostly reactive street development in which other developments far outpaces proper street and drainage construction will only lead to less than satisfactory street geometry for drainage especially in low lying areas. Approving new building plans and layouts with no field confirmation that street geometry, necessary inverts and interconnections are adhered to, leads to the current situation where street runoff has few places to go.

**Strategies for Abatement.**

Possible strategies geared towards correcting some of the identified deficiencies include education, programmed comprehensive resurfacing, control of indiscriminate development and comprehensive drainage system coupled with timely evacuation of silt and refuse.

**Education**

Education of the state's road maintenance crew on wise practices is crucial especially the field supervisors. They should be trained on road geometry especially as pertains to drainage and the need for constant maintenance. The field crew should be headed by appropriate road engineer. Education of the public is equally desirable especially regarding proper curb-cuts and ramping for access so as not to disrupt surface drainage. This can easily be delegated to the local councils through the local planning and engineering departments. Awareness creation, environmental education and behaviour modification of the public as rightly recommended and implemented in Folorunsho and Awosika (2001) are equally applicable.

**Programmed Comprehensive Resurfacing**: Apart from the piecemeal resurfacing, a batch of selected streets drawn from some local government areas can be comprehensively (i.e. in their entirety) resurfaced or rebuilt (as Itire Road.) to their original standards or better every 5-8 years in rotation. By rotation, several streets in many areas will be covered over a period of time. Alternatively, instead of the patchwork approach hitherto used, striping down the failed sections and building back to original levels with undamaged sections can be adopted. This approach has frequently been employed in the repair of Sagamu-Benin Expressway satisfactorily.

**Control of Indiscriminate Development and Comprehensive Drainage System**: Site and services along with comprehensive drainage system remains good tools to check indiscriminate development. Alternatively, primary, secondary and tertiary control inverts marked with beacons for both existing and newly developing areas can be established and enforced either through the state's Surveyor General's office or engineering departments of local councils. This way these inverts become bench marks for individuals and streets to tie into in constructing their drainage channels.

**Timely Evacuation of Silt and Refuse from Channels**: The removal of refuse from channels has already been suggested in Folorunsho and Awosika (2001). Timely evacuation of silt and refuse so removed however cannot be over emphasized. No benefit is served by removing refuse from the channels to let them sit on the



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streets. The inauguration of the Environmental Flood Abatement Gang (EFAG) by the Lagos State Government in June 2005 and the operation of the teams in local government areas has

brought an improvement in clearance and evacuation.

**Conclusion**

With each rainy season and the attendant perennial floods, the tendency is to focus on obvious causes of blocked drains and canals for blame. But through the issues enunciated here, we need to be reminded that small ponds on the street pavements which result from uneven surface, with consistent vehicular vibrations help to weaken these pavements. This systematically develops into cracks, potholes, craters and ultimately lagoons or wading pools on streets with consequent traffic snarls. It is essential to recognize and begin to correct these small imperfections on the streets which along with obvious causes contribute to the larger flooding in the metropolis.


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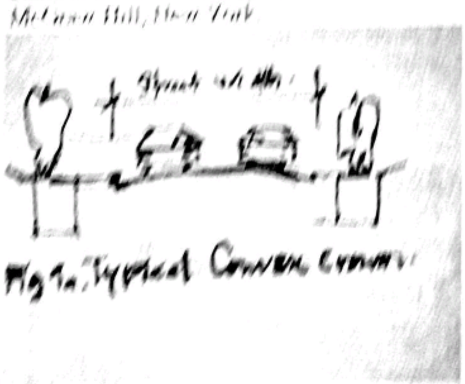


Fig. 1a: Typical Convex Crown

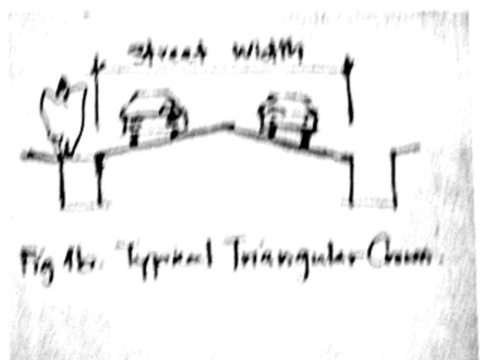


Fig. 1b: Typical Triangular Crown

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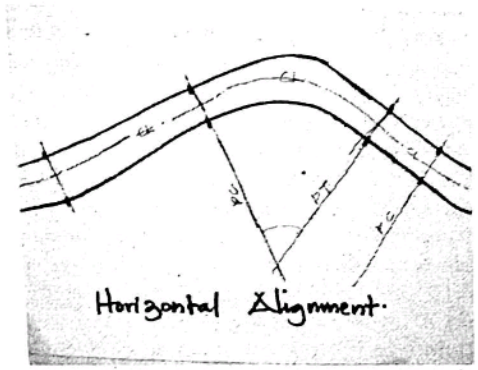


Fig. 2a Horizontal Alignment.

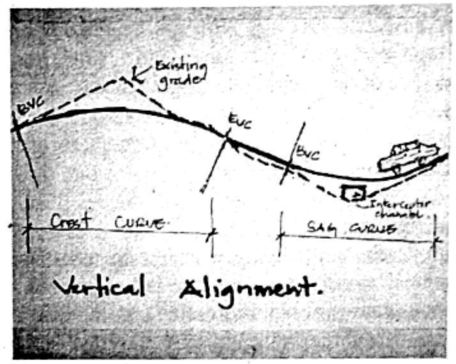


Fig 2b. Vertical Alignment.

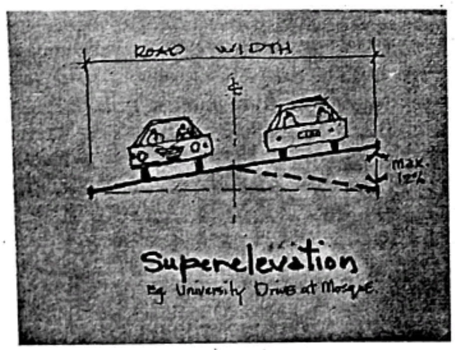


Fig. 3. Superelevation.

Plate1. Street with convex crown and slope.

Plate 2. Irregular Cross and longitudinal slopes resulting in ponding.

Plate 3. Ponding resulting from roller-coaster slopes.



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Plate 4. Street edges at higher levels than the center of street.

Plate 5. Aswani Road exhibiting fair longitudinal slope with siltation along the edges.

Plate 6. University Road – siltation and non-evacuation of silt from edges.

Plate 7. Bode Thomas St. – siltation on pavement edges.



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