STATEMENT OF MILES VASS

I, Miles Vass of 295 Ann Street, Brisbane in the State of Queensland, General Manager (Program Delivery and Operations) of the Department of Transport and Main Roads, state as follows:-

Qualifications and experience

1. I am currently employed as the General Manager (Program Delivery and Operations) Division of the Department of Transport and Main Roads (**DTMR**) and I have held this position for approximately 8 months.

2. I report through the Chief Operations Officer to the Director-General of DTMR. Program Delivery and Operations Division (formerly known as Assets and Operations) is responsible for the management of the road and non-rail transport program delivery and operations; the planning, provision, management and operation of the state-controlled road network; and the primary regional representative for roads.

3. Program Delivery and Operations is comprised of 12 regions each led by a Regional Director. The organisational structure for the Division is attached and marked **Attachment A.**

4. I hold the following qualifications: Bachelor of Technology (Civil), Advanced Diploma of Project Management, Company Directors Diploma and an Advanced Diploma in Civil Engineering.

5. I have worked within the transport civil infrastructure industry for over 25 years, with my primary focus being the roads sector of state and local government.

6. Over the past decade I have held several senior roles for the department including Director of Commercial Construction and Maintenance for southern half of Queensland, Regional Director South Coast Region (Gold Coast) and Regional Director, Metropolitan Region (Brisbane). As Regional Director, I was responsible for managing the state government's transport infrastructure including planning and construction, as well as maintenance and operation of the road network and busways in Brisbane and the Gold Coast.

Requirement from the Queensland Floods Commission of Inquiry

7. I have received a letter from the Queensland Floods Commission of Inquiry dated 7 November 2011 and understand that I am required to provide information on the following topics pursuant to the *Commission of Inquiry Act 1950*:

(a) The source or basis of the policy that works on state-controlled roads should not aggravate flood risks in adjacent areas **(Requirement 1)**;

(b) In relation to paragraph 11 (and Attachment C) of my statement dated 8 September 2011, the practical use of the Functional Criteria for PRN Assessment with reference examples **(Requirement 2)**;

.... [redacted]

Miles Vass **Witness**

Document No:

(c) In relation to paragraphs 16 to 19 of my statement dated 8 September 2011, the Queensland Reconstruction Authority's Assessment Criteria including its application to Betterment Proposals **(Requirement 3)**;

(d) In relation to paragraph 20 of my statement dated 8 September 2011, the current status of each of the projects mentioned (in terms of gaining NDRRA betterment funding approval) and a description of any other projects for which NDRRA betterment funding is being, or is to be, sought **(Requirement 4)**;

(e) In relation to paragraphs 16 and 21 of my statement dated 8 September 2011, the funding processes or arrangements supporting these projects **(Requirement 5)**; and

(f) The manner in which Transport and Main Roads manages, maintains and monitors the state, functionality and adequacy of culverts in the state-controlled road network, including details of any locations of concern (in terms of upstream flooding or afflux) or locations identified for future upgrading **(Requirement 6)**.

(g) In addressing these matters, I am asked to:

    (i) provide all information in my possession and identify the source of sources of that information; and

    (ii) make commentary and provide opinions I am qualified to give as to the appropriateness of particular actions or decisions and the basis of that commentary or opinion.

Requirement 1 – State-controlled roads should not aggravate flood risks

8. A relevant extract (sections 1 and 2) of the Transport and Main Roads Road Drainage Manual (**Attachment B**) states that it is mandatory for all projects to consider and address:

    - provision of acceptable level of flood immunity and accessibility;
    - the impact of flooding on private and public property;
    - conveyance of storm water though the road reserve at an development and environmental cost that is acceptable to the community as a whole;
    - protection of the roadway asset; and
    - safety of all road users.

9. That Manual in Chapter 1, sets out the guiding principles for appropriate drainage management.

Requirement 2 – Practical use of the Functional Criteria for PRN Assessment

10. The Priority Road Network (PRN) defines a set of key roads within the state-controlled road network. The PRN is determined by analysing the function of a road and its role within the broader road network. Key evaluation criteria include; regional population growth, socio-economic contribution, traffic volume, community access and network connectivity.

11. The purpose of the PRN Investment Guidelines is to set out a logical framework for road investment decisions in an environment of increasing demand within restricted budgets. The guidelines guide TMR on what, how and when to upgrade the road network by providing indicative visions standards drawn from a range of road planning and design documents. Vision standards are set for all priority routes. The vision standards reflect the need to meet current and future road functional requirements.

12. The PRN provides an initial strategic level prioritisation of the network based on likely future demand pressures. The level of a priority network sets the standard to which the road is developed and how quickly it is achieved. Priority level guides program development. For example, in regard to replacing timber bridges TMR will ensure that replacement occurs on higher priority roads first, that is, TMR will attempt to replace timber bridges priority route 1, before priority 2 and on to priority route 3. Other considerations, may affect a strict application of this rule, but it is applied in general.

Requirement 3 – Queensland Reconstruction Authority's Assessment Criteria including its application to Betterment Proposals

13. The Qld Reconstruction Authority's (QRA) five criteria, each of which needed to be satisfied are:

(a) The essential public asset has been repeatedly damaged in the past and/or is expected to be damaged in the future;

(b) The direct costs of repairing or restoring the asset in the past have been significant (above $5 million);

(c) There is a demonstrable cost to the nation or state when the asset is damaged by natural disasters (for example a major freight route is disrupted) or a significant local benefit will be delivered by the betterment;

(d) For the life of the asset, the potential future costs of (b) and (c) above without betterment are expected to be greater than the cost of betterment plus the potential future costs of (b) and (c) above with betterment; and

(e) Alternative options to mitigate the damage and/or cost to the nation or state have been considered and the betterment proposed is the most cost effective option.

These criteria were used by TMR and the Qld RA to identify potential betterment projects.

Requirement 4 – Current project status (in terms of NDRRA betterment funding)

14. The Qld RA have been informed of the 6 projects (identified in Miles Vass' statement dated 8 September 2011) which TMR wishes to progress for betterment funding under NDRRA. No other projects are proposed to be progressed for betterment funding at this time.

Requirement 5 – Funding processes or arrangements supporting these projects

15. The funding arrangements to support these projects come from the federal government or the state government. Flood immunity works are included as part of the upgrade works for the projects listed below.

16. Federal government funding include:

- Nation Building Program (NBP): provides funding for projects on the National Land Transport Network under Part 3 of the AusLink (National Land Transport Act 2005 (the 'Act'). The NBP also provides funding for projects under Parts 4 and 6 of the 'Act' where the funding is provided directly to Queensland. The NBP agreement - Memorandum of Understanding (MOU) provides a list of projects being funded under this MOU with varying funding conditions.
- Regional Infrastructure Fund – $2b in new funding (separate from NBP) was committed to Queensland during the 2010 federal election over the next 10 years. The Australian Government established the Regional Infrastructure Fund to invest the proceeds of a resurgent resource boom to address urgent infrastructure needs, while supporting the mining industry, boosting export capacity and developing and growing regional economies. (The Budget cash flows provides for $203m to 2013-14 for six Qld projects. Funding for the balance of $231m of the Australian Governments commitments to these projects will be met from revenues arising from the successful passage of the Mineral Resources Rent Tax legislation.)

17. The 2011-12 Federal Budget allocation includes funding commitments under the Nation Building Program and the Regional Infrastructure Fund.

18. Other proposed works that are being planned or are committed for future construction by the department, and for which there will be significant flood immunity outcomes include:

- Yeppen Flood Plain, south of Rockhampton – $5m planning study - federally funded under NBP.
- Mackay Ring Road – $10m project planning - federally funded under the Regional Infrastructure Fund.
- Sandy Corner to Collinsons Lagoon, South of Townsville – $50m federal (NBP) and $12.5m state funds. Joint 80/20 federal and state funding.
- Vantassal to Cluden (Flinders Highway), south of Townsville – $110m federal (NBP) and $27.5m state funds. Joint 80//20 federal and state funding.
- Warrego Highway (Warra to Macalister) – $10m for construction – state funded. Currently under construction.
- Cooroy to Curra Section C – south of Rockhampton – This project is part of the $200m commitment from the federal government towards planning and land acquisition for Sections A, C + D - federally funded under NBP.
- Yellow Gin Creek, north/south of Townsville – $50,000 project planning - state funded.

- Moggill Pocket – access to Colleges Crossing – $200,000 planning study – state funded.
- AJ Wyllie bridge replacement – funded by NDRRA and State. Project is still being scoped and fully costed. State funding will make up the difference between estimated total cost and funding reimbursement under NDRRA arrangements.

Requirement 6 – Management, maintenance and monitoring the state, functionality and adequacy of culverts in the state-controlled road network

Management, maintenance and monitoring of culverts

19. TMR manages more than 34,355 culverts on the state-controlled road network. These are divided into major and minor culverts to allow more intensive management of the structural risk associated with the larger ones.

20. Major culverts are defined as culverts with more than three square meters of waterway area. TMR has 3,990 major culverts. Assessment of their condition is conducted during the scheduled inspections. Major culvert risk scores are calculated from a combination of the condition assessment of all major culvert elements. High risks culverts are managed using individual Structure Maintenance Plans and a prioritised bridge and major culvert rehabilitation funding allocation approach.

21. Minor culverts are subject to inspection and maintenance under the terms of regional Routine Maintenance Performance contracts (RMPC). TMR has more than 30,365 minor culverts on the state-controlled road network. Regions prioritise their maintenance together with RMPC contractor within the available routine maintenance funding.

22. TMR has developed a programmed approach to monitoring and maintaining structures, including bridges and culverts. The approach identifies future activities and seeks to address the need to overcome a backlog of maintenance activities within the funding available.

23. The department aims to achieve an appropriate balance between the capacity of the structure and the type of use. TMR has recently developed, and is currently using, one of the most sophisticated bridge management systems in Australia to highlight priority areas for attention. This system has been adapted to manage major culverts across the state.

24. The safety and condition of the bridge and major culverts on the state-controlled road network is monitored through a three-level hierarchical inspection regime.

25. The frequency of inspections is related to the structure type, age and condition, depending on the assessed risk of deterioration or damage with a maximum inspection interval of four years.

26. Part of TMR's bridge and culverts management program involves inspection of every structure by a qualified inspector. By way of explanation, there are three levels of inspection:

 [redacted]

- Level 1 - routine maintenance inspections are carried out to check general serviceability of the structures for road users
- Level 2 – a bridge condition inspection assesses the bridge or culvert, rating its condition and any damage to its components; and
- Level 3 – a detailed engineering inspection assesses the structural condition, behaviour and capacity of structures and appropriate management options.

27. Level 2 condition inspection assessments are processed through the Whichbridge algorithm with other inventory and data to calculate risk scores. Where an asset is considered by an inspector to be at a sufficiently poor condition (potentially affecting integrity or service life and ultimately user safety), a Level 3 structural engineering inspection will be conducted. The inspection program is managed taking into account risk scores.

28. A Structure Management Plan (SMP) is required for any asset which meets certain criteria (which includes a Whichbridge algorithm risk management score of 1500 or more). A SMP is a detailed assessment of the structure concerned, including specific proposals to replace damaged components, costs for all works, and various options based on resource availability and risk. Where a structure requires attention, a SMP provides appropriate management measures to ensure the safety of road users.

29. Some options that can be recommended in a major culvert SMP include:
    - increasing inspection frequency
    - rehabilitation or replacement of the culvert
    - installing temporary strengthening to support the structure
    - imposing mass, or other access limits on vehicles using the culvert
    - denying access to the culvert for excess-mass vehicles
    - creating a side-track and closing the culvert
    - closing the culvert entirely, if necessary.

30. Load limiting or closure decisions are based on a structural evaluation, including known defects, the relevant standard load and standard factors of safety. Depending on the availability of resources (including both funding and road crews), a decision is made on how best to manage each asset, with a view to maximising road user safety and most efficiently utilising resources.

31. Where safety of road users is potentially compromised, appropriate user restrictions on culverts are imposed. Load limitations and other restrictions will continue to be a necessary option until there is sufficient funding to carry out all upgrade works.

Monitors functionality and adequacy in the SCR (in terms of upstream flooding or afflux)

32. TMR specifically look at issues related to afflux when designing new culverts. The adequacy of existing culverts is considered as part of upgrading works. Afflux issues are considered as part of Development Applications. TMR also investigates afflux issues in response to public concerns.

Details of any locations of concern (in terms of upstream flooding or afflux) or locations identified for future upgrading

33. TMR manages more than 34,000 culverts. Locations of concern are investigated and resolved at a local level. Mitigation measures may include cleaning out as part of routine maintenance, adding additional capacity or replacement as part project works. TMR has a $5 billion (approx) Transport Network Recovery Program which is addressing damage due to the 2010/11 floods. As part of this program damaged culverts have or will be replaced to current design standards. This includes designing to take into consideration known afflux issues.

I make this statement of my own free will believing its contents to be true and correct.

Dated at Brisbane this 14th day of November 2011

[redacted]

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Miles Vass Witness

Attachment A

Organisational structure – Program Delivery and Operations Division

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Miles Vass

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Witness

Document No:

Attachment B

Extract from the TMR Road Drainage Manual

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Miles Vass

. . . .
Witness

Document No:

[redacted]

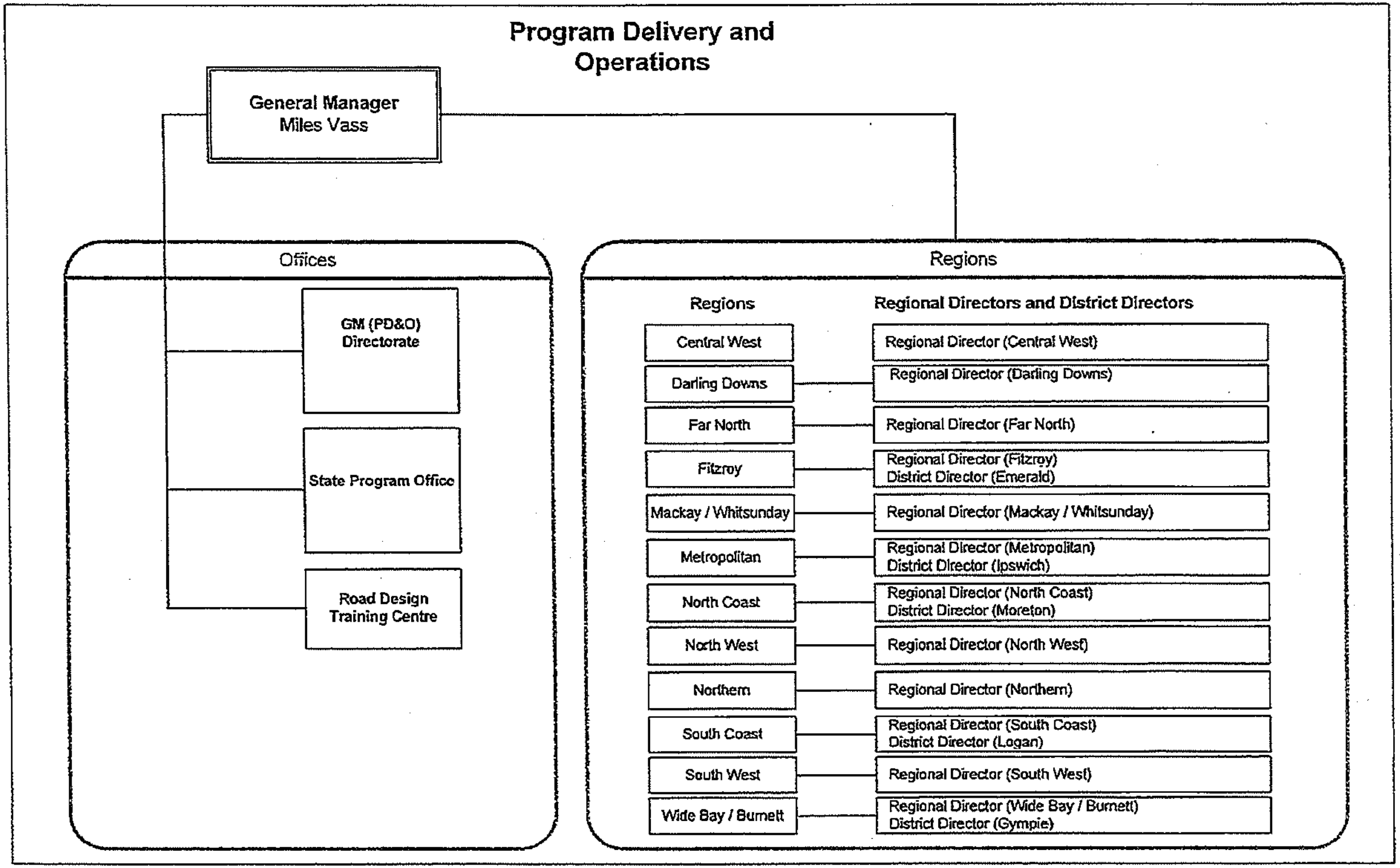
Attachment A

Attachment 1

General Manager (Program Delivery and Operations)

OPERATIONS GROUP

Organisational Structure as at 31 August 2011



[redacted]

Attachment B

Road Drainage Manual

A guide to the Planning, Design, Operation and Maintenance of Road Drainage Infrastructure

Road Drainage Manual

A guide to the Planning, Design, Operation and Maintenance of Road Drainage Infrastructure

Transport and Main Roads

1

Chapter 1
Framework

1

Chapter 1 Amendments – Mar 2010

Revision Register

Issue/ Rev No.	Reference Section	Description of Revision	Authorised by	Date
1	-	Initial Release of 2nd Ed of manual.	Steering Committee	Mar 2010

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Chapter 1 Framework

1

1.1 Introduction

1.1.1 Overview of 2nd Edition of the Road Drainage Manual

In 2002, the Queensland Department of Main Roads released the *Road Drainage Design Manual* (RDDM) that documented a new approach to the planning, design, construction and maintenance of drainage infrastructure that established a multi-disciplinary approach to the provision of drainage infrastructure.

In 2006, a review of the RDDM was initiated to:

- reflect the changes to the planning and design framework introduced in the department's *Preconstruction Processes Manual*;
- provide consistency with the department's *Road Planning and Design Manual*;
- address comments and suggestions for improvements to the existing manual published in 2002;
- better align the department's drainage design practice to accepted industry practice.

This edition has a new title, *Road Drainage Manual - A guide to the Planning, Design, Operation and Maintenance of Road Drainage Infrastructure* (RDM), to better reflect the department's whole-of-life approach to the provision of drainage infrastructure. It is a new manual that replaces the previous edition of the manual and is a guide to those involved in the planning, design, operation and maintenance of road drainage infrastructure for small, simple rural and urban catchments. It does not include the hydrology / hydraulics for major waterways and/or floodplains, complex catchments or significant drainage structures such as bridges.

The principles of a full multi-disciplined approach to the provision of effective road drainage infrastructure that were established in the previous edition have been maintained. The sizing and location of drainage structures are developed by taking into account relevant hydraulic, environmental, safety and maintenance requirements.

Effects of climate change, provided for in the previous edition of this manual, have been reviewed, but no new recommendations or changes have been made. Ongoing review of this issue is required and will continue.

Information on computer aided design of drainage has been included to reflect the department's decision to adopt the software platform, 12d Model™, to embrace an integrated electronic modelling system that provides for seamless interoperability through survey, planning, design, tendering, construction, as-constructed and archiving.

Project electronic modelling and archiving and/or drawing storage provides a common basis for accessing data on a consistent and reliable basis appropriate for use by different personnel over the whole of life of

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the drainage infrastructure. Drawing storage is controlled by Planroom located within the Geospatial Technologies Section, Engineering & Technology Division.

1.1.2 Applicability of this Manual

This manual represents the department's policy with respect to the planning, design, operation and maintenance of road drainage infrastructure and must be applied on all road infrastructure projects for which the department is responsible. As such, the manual applies equally to all personnel, departmental or not, that are involved in the drainage aspects of departmental projects, including:

- Departmental management;
- Departmental and/or consulting project (preconstruction / design / construction / maintenance) managers;
- Planners (strategic / project / town);
- Development control officers;
- Civil designers (engineers / technologists / designers);
- Surveyors;
- Environmental scientists / engineers;
- Geologists / geotechnical engineers; and
- Construction / maintenance personnel.

This manual facilitates the development and implementation of drainage solutions for state controlled roads and roads within Queensland that are part of the National Land Transport Network (Auslink). It operates from Phase 3, Corridor Planning and Stewardship, to Phase 6, Program Finalisation, of the department's *Road System Manager Framework* and therefore provides guidance in relation to the sustainable planning, design, construction, operation and maintenance of most road drainage infrastructure in both urban and rural environments throughout Queensland. Limitations to the application and use of this manual are outlined in Section 1.2 of this chapter.

The manual is to be used by appropriately qualified and experienced personnel or others who have received appropriate training and are supervised by qualified and experienced personnel.

The manual also integrates best practice and environmental management techniques into the provision of road drainage. It includes technical governance requirements for the selection, design and construction of appropriate drainage structures that satisfy hydraulic requirements whilst minimising the potential for environmental and asset harm.

1.1.3 Importance of Road Drainage

It is recognised that a road requires a drainage system to deal with stormwater runoff. Therefore, the drainage system becomes an important and integral consideration in the planning and design of road infrastructure.

In order to provide an appropriate and economic drainage system, all road projects, irrespective of location, size, cost or complexity, must consider and address the following aspects:

- provision of an acceptable level of flood immunity and accessibility;
- impact of flooding of public and private property;

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- conveyance of stormwater through the road reserve at a development and environmental cost that is acceptable to the community as a whole;
- protection of the roadway asset;
- safety of all road users;
- pollutant discharge from the road reserve to receiving waters;
- land degradation caused by erosion and sedimentation during road construction, operation and maintenance;
- any impact on habitats for terrestrial and aquatic flora and fauna;
- any impact on the movement of terrestrial and aquatic fauna.

This requirement particularly applies to projects where it is proposed to keep the existing drainage infrastructure. The original design intent must be reviewed and understood, and then the existing system needs to be assessed against the above aspects for performance, adequacy and continued durability. Design must ensure that the original intent is restored, deficiencies corrected and modifications / changes appropriately considered and detailed.

1.1.4 Reference Documents and Manuals

This manual is underpinned by an integrated, multi-disciplinary approach. That is, the user of this manual must focus at all times on the consideration of hydrologic, hydraulic, environmental, surrounding land use, maintenance and safety factors. Typically, these factors should be considered concurrently.

In using this manual, reference will need to be made to other departmental documents developed to assist in the planning, design, construction and maintenance of drainage infrastructure on state-controlled roads in Queensland.

These reference documents include the:

- *Road Planning and Design Manual - A guide to QLD practice*
- *Preconstruction Processes Manual*
- *Guidelines for Strategic Road Network Planning*
- *Project Cost Estimating Manual*
- *Road Project Environmental Processes Manual*
- *Environmental Legislation Register*
- *Road Landscape Manual*
- *Soils Manual*
- *Roads in the Wet Tropics Manual*
- *Road Traffic Noise Management: Code of Practice.*

It is important to note that the department's *Road Planning & Design Manual - A guide to QLD practice* (RPDM) is its main road design reference, however in the interest of national uniformity, the RPDM primarily references Austroads' *Guide to Road Design* (GRD) series.

Drainage is an integral component of road infrastructure. Drainage design cannot be separated from the overall road planning and design process. Drainage must always be considered in conjunction with the geometric design of a road. Although this manual has been published as a separate document, it has a complementary relationship the RPDM and therefore planners and designers in particular, must

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use this manual in conjunction with the RPDM.

1.1.5 Structure of this Manual

This manual has been designed so that at any stage of drainage infrastructure delivery, users can refer to the chapter or section that is applicable to their needs. However, reference to other chapters will be required. To facilitate this, references have been made to other, relevant sections of the manual, other manuals, guidelines and policies where possible. Additionally, checklists and flow charts are provided throughout the manual to assist the user to proceed from section to section of the manual.

This edition has been structured into parts that reflect the planning and design process. These parts are then further divided into chapters of like purposes. Table 1.1.5 outlines the structure of this manual.

Table 1.1.5 - Structure of Road Drainage Manual

Chapter	Title of Chapter	Purpose of Chapter(s)
1	Framework	Sets the context and limitations of this manual
2	Design Requirements	Defines the general design requirements (including considerations, controls, criteria & standards) for planning and design.
3	Strategic Planning & Development Control	Defines the base drainage requirements for strategic planning (road route strategies & road link plans) and development applications.
4	Data Collection	Defines strategic and project data. Establishes importance of data collection and retrieval. Describes the data collection process and identifies sources of data.
5	Hydrology	Describes the processes for determining and analysing hydrologic data to quantify specific design criteria.
6	Approach to Drainage Design	Describes the design methodology and process to be followed for drainage components.
7	Environmental Consideration and Design	Provides guidance for understanding environmental assessments and the consideration of requirements in design.
8	Open Channel Design	
9	Culvert Design	
10	Floodway Design	
11	Road Surface and Sub-surface Drainage Design	
12	Basins	Provides hydraulic design methods for design of various basins
13	Erosion and Sediment Control	Provides the requirements for drainage in construction.
14	Operation, Maintenance and Remediation	Emphasises the importance of performance monitoring & maintenance of drainage infrastructure.

1.2 Limits of Manual

1.2.1 General

The following sections outline the limitations placed on civil designers in road drainage design and the use of this manual. Furthermore, it should be noted that this manual is not a complete drainage guide covering all aspects of road drainage. It is a guide for small, simple rural and urban catchments only and does not include in detail, the hydrology / hydraulics for major waterways and/or floodplains, complex catchments or significant drainage structures (e.g. bridges).

1.2.2 Hydrology / Hydraulics

This section details the requirements placed on internal and consulting engineering services regarding hydrologic assessment and hydraulic design.

1.2.2.1 Departmental Civil Designers

Departmental civil designers engaging in drainage design must be suitably qualified, have demonstrated capability in drainage design and should also have attended the mandated departmental technical training courses in road drainage.

1.2.2.2 Approved Software for use by Departmental Civil Designers

The following software packages are deemed approved for use on projects by departmental civil designers:

- Hydrology:
  - RAIN (Departmental software)
  - Bureau of Meteorology (BoM) website
- Hydraulic design:
  - Hydraulics package within 12d Model™
  - PC DRAIN™
  - DRAINS™
  - CULVERT (Departmental software) (refer Section 1.2.2.5)
  - CulvertMaster & FlowMaster®
- Multi-purpose:
  - Drainage Design Assistant (DDA) – Basic Tools™

Use of any other software package must be approved in writing by Principal Engineer (Road Design Standards), Road Planning & Design Section, Engineering & Technology Division. Refer also to Sections 1.2.2.5, 1.2.2.6 and 1.2.2.7.

1.2.2.3 Prequalification of Consultant Engineers and Designers

Engineering consultants must be prequalified with the department in the prequalification category of Hydraulic Design (HD) before providing any drainage advice or undertaking any drainage design or review on behalf of the department.

1.2.2.4 Approved Software for use by Prequalified Consultants

The following software packages are approved for use on departmental projects by prequalified consultants:

- Hydrology:
  - RAIN (Departmental software)
  - RORB

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- o RAFTS™
- o URBS™
- o WBNM
- o Bureau of Meteorology (BoM) website
- Hydraulic design:
  - o Hydraulics package within 12d Model™
  - o HEC-RAS
  - o MIKE 11™
  - o PC DRAIN™
  - o DRAINS™
  - o EXTRAN™, SWMM™, UDD™
  - o CULVERT (Departmental software) (refer Section 1.2.2.5)
  - o CulvertMaster & FlowMaster®
- Hydraulic design - 2D Modelling:
  - o SOBEK™, DELFT-FLS™
  - o MIKE FLOOD™, MIKE 21™
  - o TUFLOW™
  - o SMS™
- Multi-purpose:
  - o Drainage Design Assistant (DDA) – Basic Tools ™
- Water quality:
  - o MUSIC™
  - o AQUALM™

The department may allow pre-qualified consultants to use other software packages, but use of any other software package must be approved in writing by Director (Hydraulics), Hydraulics Section, Engineering & Technology Division.

Refer also to Sections 1.2.2.5, 1.2.2.6 and 1.2.2.7.

1.2.2.5 Mandated Software for use by all Civil Designers

The department may require the use of specific software on projects to suit internal processes and systems. This requirement will be specified within this section of this manual, released *Planners and Designers Instructions* and/or relevant project documentation.

All departmental designers and prequalified consultants are required to undertake the 3D modelling and quantity calculation of cross drainage (culvert) infrastructure using the department's CULVERT software. Using this program ensures that departmental processes and practices are followed for:

- drawing drainage cross sections (e.g. location, skew, invert heights, culvert component details, bedding and backfill material quantities, etc.) when used within 12d Model™; and
- producing a culvert electronic model that allows splicing into and storage with the project electronic model, when used within 12d Model™.

The hydraulic design of 'standard' culverts should also use CULVERT, however other approved hydraulic design software can be used. Where other software or manual methods are used, CULVERT should be used as a check.

1.2.2.6 Other Computer Based Tools

Further to Sections 1.2.2.2 and 1.2.2.4, any spreadsheet or computer based tool developed and then used to assist with drainage design must be checked and tested for applicability, accuracy of results and compliance to current standards and methodologies as prescribed in this manual

/ departmental Standard Specifications and Standard Drawings. Certification of design is deemed to cover use of these spreadsheets / tools.

1.2.2.7 Currency of Software

While it is desirable that all software packages used, as listed in Sections 1.2.2.2 and 1.2.2.4, be the latest version, it is not a requirement. However it is a requirement that project workings must clearly state the software package and version being used.

It is also a requirement that users check / test software to be used for compliance to current standards and methodologies as prescribed in this manual / departmental Standard Specifications and Standard Drawings. There is often a time lag between the release of updated manuals / standards / specifications and updates to software packages. Where software is not compliant and difference is minor (major differences would prohibit usage), any output must be adjusted accordingly and adjustments recorded and checked.

Again, certification of design is deemed to cover this requirement.

1.2.2.8 Structural Design of Drainage Elements

This manual does not cover the structural design of drainage elements and structures. While there are standard designs for many drainage elements, non-standard drainage elements and structures must be referred to the department's Bridge Design Section located within the Engineering & Technology Division or suitably prequalified consultants. Where design is conducted by a suitably prequalified consultant, design must be approved by the department's Bridge Design Section.

Examples of these non-standard structural drainage elements include:

- all bridges;
- any proposal to replace an existing bridge with a culvert;
- any culvert installation using non-standard components.

1.2.3 Environmental Design

While this manual promotes environmentally sustainable drainage, it does not give guidance on all relevant environmental design considerations and criteria. Project specific details as defined in environmental approvals, licences and permits will need to be incorporated. Refer also Chapter 2.

1.2.4 Catchment Hydrology in Rural Areas

The Rational Method has been adopted to determine the runoff from small, simple rural catchments up to 25 km^3 in area (refer Chapter 5). The method is not applicable for complex catchments, irrespective of size. Complex catchments include:

- multiple streams;
- branched catchments;
- mixed land use catchments;
- situations where a catchment may be inundated by another catchment;
- situations where the catchment may overflow into an adjacent catchment;

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Table 1.2.4 - Designers for Rural Catchment Hydrology

Catchment Size	Who decides if catchment/design is simple or complex?	Permissible Designer
Over 25 km^2		Hydraulics Section or consultant
10 km^2 to 25 km^2	Hydraulics Section or consultant	Simple – Departmental Region or District
		Complex - Hydraulics Section or consultant
Less than 10 km^2	Departmental Region or District	Simple – Departmental Region or District
		Complex - Hydraulics Section or consultant

Note: The Region/District may elect to refer simple designs to consultants or Hydraulics Section.

- catchments with significant storage capacity (dam, swamp and major retention / detention basin); and
- irrigated land.

Table 1.2.4 details both decision points and permissible designers. In this table, 'Hydraulics Section' refers to the section located within the department's Engineering & Technology Division and 'consultants' refers to suitably prequalified consultants.

1.2.5 Catchment Hydrology in Urban Areas

The Rational Method has been adopted to determine the runoff from simple urban catchments up to 1 km^2 in area and where the flow path is relatively simple (refer Chapter 5). Relatively simple is defined as a channel / flow path with limited floodplain storage or piped drainage systems and/or with no detention / retention basins or similar flood storages (natural or artificial) in the catchment.

Designs and/or reviews of designs involving more complex catchment characteristics are beyond the capability of Rational Method and more detailed computer modelling is generally required. In these cases, project must be referred to the department's Hydraulics Section or suitably prequalified consultants. Complex urban catchments include:

- retention / detention basins or other flood storage areas;
- mainly pipe flow with limited overland flow;
- complex flow path(s) and/or channel system.

1.3 Road Infrastructure Delivery

1.3.1 Introduction

The department's delivery process for road infrastructure is described and detailed in the *Preconstruction Processes Manual*. Delivery is undertaken using the *OnQ* project management methodology.

Drainage requirements are normally established during the identification of the project solution options and selection process.

Actual information and data inputs for drainage projects are usually enhanced as investigations are progressively completed and the solutions developed through an iterative process. This can occur over several years and may involve various studies that are commissioned during the project solution identification process. The outputs from these studies usually identify a range of issues to be addressed by the designer. The issues are included in the *Design Development Report – Small Projects* (Form M4211) or the *Design Development Report – Large Projects* (Form M4212) with the designer including statements on how these issues were considered and incorporated into the design.

All drainage risks are to be recorded in the *Risk Management Record* (Form M4213) with all risks being mitigated or removed as the design evolves. Remaining risks at the end of the design development process are to be costed and the total cost included in the project estimate contingency amount.

1.4 Legislation and Policy

1.4.1 Introduction

The department has obligations under State and Federal legislation.

The department also provides direction through a number of key corporate documents including the department's *Strategic Plan, Road Network Strategy, Roads Implementation Program* and *Environmental Management Policy and Strategy.*

1.4.2 Relevant Legislation and Other Authorities

The following Queensland Legislative Acts are most pertinent to road drainage:

- *Aboriginal Cultural Heritage Act 2003;*
- *Torres Strait Islander Cultural Heritage Act 2003;*
- *Nature Conservation Act 1992;*
- *Land Act 1994;*
- *Coastal Protection and Management Act 1995;*
- *Environmental Protection Act 1994;*
- *Fisheries Act 1994;*
- *Sustainable Planning Act 2009;*
- *Soil Conservation Act 1986;*
- *State Development and Public Works Organisation Act 1971;*
- *Transport Infrastructure Act 1994;*
- *Water Act 2000;*
- *Workplace Health and Safety Act 1995.*

The following Commonwealth Legislative Act also applies to road drainage on Queensland roads:

- *Environment Protection and Biodiversity Conservation Act 1999 (Commonwealth Act).*

The following departments and authorities are considered key stakeholders with respect to road drainage and who also administer some of the above listed Acts;

- Department of Environment and Resource Management (previously Queensland Environmental Protection Agency (EPA) & Queensland Department of Natural Resources and Water (NR&W));
- Department of Employment, Economic Development and Innovation (previously Queensland Department of Primary Industry and Fisheries);

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- Local authorities / Councils

The Queensland Government has also constituted numerous Statutory Authorities across the state to perform specific functions with relation to water resources in local geographic areas.

These include:

- Drainage boards;
- Water boards;
- Water authorities;
- River(s) improvement trusts;
- River(s) commissions;
- Advisory councils;
- Water management authorities;
- Basin commission;
- Referral panels;
- Water supply authorities; and
- Sun Water

The *Workplace Health and Safety Act 1995* and the *Workplace Health and Safety Act Regulation 1997* set out the requirements for safety requirements in workplaces.

Designers of drainage infrastructure need to consider each installation as a workplace during maintenance operations and incorporate provisions that permit maintenance work to be completed in an appropriate way that manages exposure to risk in accordance with amendments to the *Workplace Health and Safety Act* issued in June 2007 (which addresses safety in design and obligations of designers).

It is recommended that project teams include or have access to personal who are current in their knowledge, understanding and application of the above legislation and the functions and responsibilities of local authorities etc.

1.4.3 Key Aspects of Road Drainage Policy

Areas of hydraulic design that may require considerations include:

- changes to afflux from drainage works that cause adverse impacts on neighbouring property;
- diversion of runoff to a different point of discharge than that occurring naturally;
- concentration of runoff into a culvert or open channel which is not a watercourse and where the concentration is not dissipated by the time the downstream flow reaches a property or development boundary;
- changes to stream morphology; and
- outlet works on drainage structures which do not sufficiently dissipate energy, prevent scour or limit siltation.

All of these situations should be avoided. If avoidance is not possible, the relevant stakeholders must be consulted. For a discussion of the wider legal issues relevant to the design of stormwater and drainage, refer to the 2008 edition of the *Queensland Urban Drainage Manual* (QUDM), as published by the Department of Natural Resources and Water (which became Department of Environment and Resource Management in March 2009).

1.4.4 Community Engagement

The department has a strong commitment to engaging all stakeholders, including other levels of government, industry and the public. This is outlined in the department's *Community Engagement Policy, Standards, Principles and Guidelines*.

Community engagement can assist in integrating economic, social, environmental and engineering objectives of road infrastructure delivery. With respect to road drainage, community engagement is both:

- a process to improve departmental understanding of stakeholder expectations; and
- an avenue for stakeholders to be advised of constraints, technical issues and possible options.

Public requests to reduce standards can be considered, but not adopted at the expense of policy, safety and sustainable engineering.

The degree and timing of community engagement regarding drainage will vary between projects. However, the department emphasises the need to commence community engagement as early as possible before decisions are made.

Flooding and drainage issues are important to the community and effort is required to gather and understand these concerns. Members of the public may also provide local data / knowledge for use in the environmental assessment or design of a project.

Flooding and drainage are relevant in several parts of community engagement programmes, with the main aspects as follows:

- Data collection. Information gathered from the community and other stakeholders, particularly those who have long term first hand knowledge of the area, is often very valuable and helps to establish parameters for hydraulic analysis. In the early phases of a project, the consultation programme should gather as much relevant data on flooding as possible. This information can include detailed data such as historical flood levels or more general descriptions of flow patterns or how often a road is closed.
- Assessment of flood criteria. The community and stakeholders may have opinions on the level of service that would be acceptable. While this is only one input to this question, it is valuable and can assist in determining the most appropriate level to be adopted.
- Assessment of impacts. The community who may be affected by a road project (say in areas where afflux occurs) can be consulted to discuss the individual levels of impact.

1.4.5 Impacts on Landowners

Road drainage may have impacts on neighbouring landowners and these landowners may be concerned if there are adverse impacts. There is even the potential for legal action in some situations, so these impacts must be carefully analysed. In some cases, adverse impacts are unavoidable and appropriate mitigation or compensation may be required.

Adverse impacts on landowners include:

(a) Afflux, or changes in flood levels on the property. In particular, roads may increase upstream flood levels.

(b) Changes in distribution of flood flows. The road drainage may divert flow and this could be a problem, if additional flow is diverted on to a property or if

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water is diverted away from a farm dam for example.

(c) Changes in flow velocity. Flow velocity is increased through bridges and culverts and this could cause scour damage.

(d) Concentration of flow. Culverts may concentrate flow that was previously widespread sheet flow and this could cause scour or other problems.

(e) Scour. Concentrated and high velocity flows near culverts / bridges may cause damage to neighbouring properties.

(f) Water quality. Runoff from the road surface and high velocity flows could cause downstream water quality impacts.

(g) Duration of inundation. This can be an issue with agricultural land and some urban areas, if the road increases the time of inundation.

1.5 Guiding Principles

This section introduces guiding principles that should be part of the various consideration processes involved in the planning, designing, constructing and maintaining road drainage infrastructure.

1.5.1 Drainage Infrastructure and Land Use

Changes in land use may create changes to existing drainage patterns with associated environmental, commercial or social consequences. The management of drainage resulting from different land uses or changes to land uses is usually undertaken by a primary authority with responsibility for the catchment which is usually a local authority. Reference to relevant government departments and statutory authorities should be undertaken as applicable.

Roads are a major land use and do influence natural, built, commercial and social environments. These influences result from the design and selection of drainage infrastructure and associated works and designers, constructors and maintenance personnel need to be cognisant of the influence of their designs, construction practices and procedures.

Inappropriate road drainage infrastructure for example, can change the characteristics of a waterway by altering:

- flooding patterns, including flow distribution;
- flood heights;
- peak water levels;
- water velocities, especially through bridges and culverts;
- duration of inundation;
- erosion and sedimentation patterns;
- fauna transfer; and
- terrestrial and aquatic fauna habitats.

These changes may create impacts that lead to in service issues that require additional unplanned investment to address:

- flood mitigation works;
- erosion and sedimentation problems;
- reductions in adjoining land valuations;
- salinity issues; and
- increases in pollutant levels.

1.5.2 Assessment of Future Development

The department needs to plan and design drainage works based on assumptions of future catchment and floodplain conditions. This can be difficult but nonetheless important. Changes in conditions can occur during the life of drainage infrastructure. These changes can affect the runoff to the road or changed floodplain / channel conditions may affect flood levels adjacent to the road.

The department has a responsibility to provide advice on any development applications that affect the department's infrastructure, and can ensure that suitable mitigation measures are applied before approval can be provided. Mitigation measures include detention storages, channel works or other similar measures. As well as being effective initially, some mitigation measures may not be effective in the long term and comments need to be made on these. For example, localised dredging may be filled by later sediment movement or cleared channel vegetation may regrow. As well, cumulative impacts may need to be considered, where individual developments may have minor impacts that are acceptable, but the impact of a number of similar developments may be unacceptable when all have occurred.

It is important that the department maintain close review of any potential impacts on drainage and ensure that these are managed appropriately.

1.5.3 General Hydraulic and Environmental Consideration

This section provides an overview of general hydraulic and environmental considerations relating to drainage infrastructure.

A road embankment may form an obstruction to a natural waterway, bushland corridor or floodplain if there are insufficient or unsuitable bridge and/or culvert openings in the road. Considerations of the following may therefore be required:

- an unacceptably high increase in upstream flood level (afflux) may have adverse impacts on property, infrastructure or the environment;
- an increase in stream velocities through the structures may initiate or cause continuing erosion downstream of the road;
- movement of fish may be affected by higher velocities or changes in the channel invert level and/or extended culvert lengths;
- restricted flow may cause increased time of inundation of the land upstream of the road. In some cases the road may be designed as part of a large retention basin, and in this situation peak discharges in floods are reduced; and
- roads may restrict the movement of fauna from one side of the road to the other. This will be identified in environmental studies and drainage structures may then be designed to allow for this movement (e.g. one culvert cell with a higher invert level).

1.5.4 Economic Considerations

The provision of road drainage infrastructure is typically a consideration of the desired level(s) of flood immunity.

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Solutions to deliver the preferred levels of immunity may be delivered at initial construction, staged construction may be used to achieve higher levels over time, or the lower levels may be acceptable if alternative routes are available.

Where budgets restrict construction of infrastructure that delivers the desired level of flood immunity, a risk analysis that details the costs of providing infrastructure versus those of not providing drainage infrastructure to the nominated standard is necessary.

While budget may affect some aspects of road design, other factors such as safety cannot be compromised.

1.5.5 Maintenance

The provision of any type of road drainage infrastructure should not be undertaken without due consideration of maintenance practices. Key issues include:

- the need to provide adequate access for maintenance purposes. A lack of access will lead to a corresponding lack of maintenance, and hence possible failure of the drainage infrastructure with respect to performance;
- consideration of the cost and frequency of maintenance activities;
- an understanding of what equipment will be needed to undertake the maintenance work;
- assessment of maintenance equipment usage and that it could lead to failures;
- assessment of the maintenance activity and possible special safety considerations.

Specific guidelines relating to the consideration of maintenance issues are provided at several locations within this manual, but in particular, Chapter 14.

1.6 Drainage Issues

This section outlines key drainage issues that planners and designers need to be aware of and incorporate into their thinking during the planning, designing, constructing and maintaining road drainage infrastructure.

1.6.1 Planning the Drainage System

Planning of the drainage system will likely involve input from professionals in many fields, and requires detailed consideration of environmental, recreational, transportation, traffic, social, economic, and infrastructure needs. Because of the high costs associated with drainage works, the drainage aspects of a project should be placed high in the hierarchy of the planning process.

Drainage is a grade related service (i.e. relies on gravity) and therefore can often impose a significant constraint within the planning process.

1.6.2 Urban Drainage

Extracts from QUDM (NR&W 2008) are included in this section to enhance understanding of urban drainage systems, although this is beyond the scope of this manual.

QUDM is not a stand-alone planning and design guideline for stormwater management. It must be used in coordination with other recognised manuals dealing with specialised stormwater topics.

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The list of broad stormwater objectives of QUDM (NR&W 2008) (as listed in Section 1.03 of that manual) is:

(a) *Protect and/or enhance downstream environments, including recognised social, environmental and economic values, by appropriately managing the quality and quantity of stormwater runoff.*

(b) *Limit flooding of public and private property to acceptable or designated levels.*

(c) *Ensure stormwater and its associated drainage systems are planned, designed and managed with appropriate consideration and protection of community health and safety standards, including potential impacts on pedestrian and vehicular traffic.*

(d) *Adopt and promote "water sensitive" design principles, including appropriately managing stormwater as an integral part of the total water cycle, protecting natural features and ecological processes within urban waterways, and optimising opportunities to use rainwater/stormwater as a resource.*

(e) *Appropriately integrate stormwater systems into the natural and built environments while optimising the potential uses of drainage corridors.*

(f) *Ensure stormwater is managed at a social, environmental and economic cost that is acceptable to the community as a whole and that the levels of service and the contributions to costs are equitable.*

(g) *Enhance community awareness of, and participation in, the appropriate management of stormwater.*

All of the objectives may not be relevant in all circumstances and individual objectives may be expanded to highlight site-specific issues.

1.6.3 Rural Drainage Systems

Many departmental drainage structures in rural areas are located on channels (both natural and artificial) and include farm drains, natural gullies, creeks and rivers.

Most of the guidance in this manual, and many other manuals, is concerned with these watercourses, and appropriate hydraulic design is needed for each. These design considerations include selection of appropriate structures, sizes and locations as well as assessment of afflux, flood immunity and scour. In some cases, future catchment development may need to be considered. This is especially important if urbanisation is possible in the future. However in purely rural catchments, specific consideration may need to be provided for special circumstances, such as soil conservation works, farm dams or laser levelling of farmland.

As well, there are particular drainage problems with extensive flat floodplains where shallow overland flow occurs. There is a risk that this overland flow will be concentrated by drainage structures and sufficient structures must be placed in suitable locations to limit this concentration and to spread the flow. Also in these sheet flow situations, even small structures such as levees can affect flow patterns significantly and these changes in flow

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patterns must be considered to ensure that the structures are located correctly.

In some agricultural areas, the duration of flood inundation is important, therefore the design of roads and road drainage must consider this aspect.

1.7 Climate Change

The department needs to consider the possible impacts of climate change on many aspects during the planning and design process. Part of this consideration is the possible impact on road drainage. This is important because of the value and critical significance of road drainage infrastructure. If a significant change in the risk is identified, the department will update relevant procedures.

With respect to recommended allowances for increases or possible changes to rainfall intensities, the department takes guidance from *Australian Rainfall and Runoff, A Guide to Flood Estimation* (AR&R), published by the Institution of Engineers Australia. AR&R is continually monitored by the department and any changes in procedures that become apparent will be incorporated into this manual.

The previous edition of this manual recommended that designs in coastal regions should make an allowance for an increase in sea level of 300 mm for the effects of climate change. This allowance had considered the consensus of opinion concerning sea level rise and could be regarded as a conservative approach. Many local authorities in coastal regions of Queensland also make a similar allowance. Selection of an approach for design ocean levels allows for a number of conditions such as the tides, storm surge and the risk of coincidental occurrence of floods and high ocean levels. Generally the combination of these conditions in design procedures leads to a conservative ocean level for design. However the adoption of an allowance for sea level rise has been accepted without much debate.

An allowance for a change in rainfall intensity for application in design for bridges and other drainage structures is more difficult. The Queensland Government publication *ClimateSmart Adaptation 2007-12* suggests that bridge design should provide for an increase in rainfall intensity. However, AR&R is the major reference in this field and almost universally accepted for design rainfall estimation throughout Australia. The department therefore adopts the rainfall intensities as recommended by AR&R.

The design rainfall intensities (data and procedures for estimating design rainfall) were prepared by the Bureau of Meteorology and published in the 1987 edition of AR&R.

Any update of rainfall intensities / estimation procedures, will rely on the statistical analysis of recorded rainfall data and historical records. Review of AR&R is currently underway and possible changes in rainfall intensities are being researched / studied.

Because of the potential significance of impacts, the department will continue to monitor relevant literature and recommendations and if changes are appropriate / required, will update this manual to allow for climate change impacts.

This means that there is no recommendation for incorporation of a change in rainfall intensity for road drainage designs included in this edition of the manual.

However because of the uncertainty in estimates of possible changes in rainfall intensity related to climate change, the department requires the assessment of potential impacts using the procedures included in the government's Climate Change Impact Statement (CCIS) procedure. Consideration of rainfall intensity is only one portion of the CCIS, but is the only part mentioned here. This is a risk based procedure essentially involving a sensitivity test, where the impacts of higher rainfall intensities are tested. These implications are then reviewed and appropriate mitigation or management measures are developed. Climate modelling does not give a clear indication of changes in rainfall intensity, so the sensitivity test is the only feasible method of analysis.

While this procedure is adopted, the general drainage analysis does not assume any changes in rainfall intensity.

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Chapter 2 General Design Requirements

Chapter 2 Amendments – Mar 2010

Revision Register

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Issue/ Rev No.	Reference Section	Description of Revision	Authorised by	Date
1	-	Initial Release of 2nd Ed of manual.	Steering Committee	Mar 2010

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Chapter 2
General Design Requirements

2.1 Introduction

The purpose of this chapter is to introduce and discuss a number of general design requirements for road drainage infrastructure. The requirements presented cover a range of topics. More specific design requirements are contained in relevant chapters.

The intention is that this chapter should be referenced first to establish general and some specific drainage requirements for a project. Topic specific chapters, such as Chapters 7, 8, 9 and so on should be then referenced as applicable / required.

2.1.1 Definitions

The term design requirements, encompasses all design:

- considerations;
- controls;
- criteria; and
- standards ... that must be included in or be part of the design process.

Design considerations encompass all aspects, issues, functionality, expectations, demands, constraints, risk and cost, that need to be appropriately addressed, or to be taken into account, in order to satisfy design criteria and determine trade-offs. Refer Section 2.3 for further discussion regarding design considerations.

Design controls are aspects of the road environment or project that cannot be changed, or are extremely difficult to change, and therefore place some restriction or control on the design. Refer Section 2.4 for further discussion regarding design considerations.

Design criteria set the expected level of achievement or conformance for relevant design parameters or design inputs. The design criteria ensure that the end result can be judged and defended. An example of a design criterion with respect to road drainage would be the average recurrence interval for design for a particular project or structure. Section 2.5 presents a number of fundamental design criteria while more specific criteria will be found in relevant, topic specific chapters.

Design standards however, set approved or prescribed values or limits for specific elements of design or set procedures and/or guides that must be followed. A design standard with respect to road drainage would be the use of the Rational Method to determine the runoff from a small rural catchment. Design standards are presented throughout this manual.

Both design criteria and design standards set the mandatory limits designers must work within and/or achieve.

2.1.2 Determining and Understanding Requirements

To assist in determining and understanding the design requirements for a road project, the *Road Planning & Design Manual* (RPDM) describes a 'Hierarchy of Roads', and this provides an overview of the road

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network and defines the roads that the Department of Transport and Main Roads has stewardship for in Queensland. It develops the philosophy that the road hierarchy provides 'a useful planning tool' for many decision making activities concerning the road network. This hierarchy permits the department to set the design requirements for projects on roads according to their function within the network.

The department also sets the 'design criteria' and 'design standards' for road links that will deliver a planned level of service. Therefore, the overall standard of drainage infrastructure for a specific road project needs to reflect and be consistent with the function of that road within the road hierarchy.

In order to satisfy the relevant design criteria for a project and to determine appropriate trade-offs, a number of aspects, issues, functional requirements, expectations, demands, constraints, risk elements and costings need to be appropriately addressed, or taken into account. These 'design considerations', with respect to drainage infrastructure, are progressively identified and developed to address geographic, hydraulic, environmental, cultural, native title and land use issues.

During pre-project planning, target drainage criteria for the road are established and documented in relevant *Road Route Strategies* and *Road Link Plans*. The respective design criteria are then progressively addressed during the Design Development Phase. Excessive cost to provide drainage at the specified Average Recurrence Interval (ARI) may result in a review of the criteria in order to achieve a 'fit for purpose' outcome or may result in the project being delivered in stages over multiple years to achieve the desired outcome.

2.1.3 Immunity Criteria

The immunity criteria discussed within this manual and set in the design brief / contract documentation relates to individual drainage components (such as cross or longitudinal drainage) and not the road project, section or link. Furthermore, by setting the immunity criteria for various drainage components on a project does not imply that the road inherits the same immunity level(s). It is extremely difficult to assess immunity and set criteria for a road.

Refer Chapter 3 (particularly Section 3.2.3.2) for a more detailed discussion regarding this issue.

2.1.4 Design Life / Service Life

It is important to define, in general terms, the difference between design life and service life.

The design life of a component or system of components is the period of time during which the item is expected, by its designers or as required by specification, to work or perform its intended function within specified design parameters / operating conditions. In other words, the design life is the life expectancy of the item under normal / specified operating conditions.

With respect to road drainage, operating conditions can include:

- environmental / atmospheric / geographic conditions;
- foundation, bedding and support / cover conditions; and
- traffic and loading.

For example, the department specifies the design life for a new structural component (such as a culvert) as 100 years. Therefore, it is expected that the culvert will last 100 years before replacement or major repair is expected.

The service life of a component or system of components is the period of time over which the item actually provides adequate or satisfactory performance before repair or replacement is required.

If the operating conditions over the life of the component or system remain within the original design parameters, theoretically, the design life will equal service life. However, if the operating conditions are or move outside of the original design parameters, service life will be less than design life. In some situations, this reduction in time can be considerable, leading to premature failure.

In relation to drainage infrastructure, designers should be mindful of these two terms and ensure, where possible, that the designed drainage components or system are appropriately selected for the anticipated operating conditions. For example, concrete culvert components will have a reduced service life if standard culvert components are used in:

- streams carrying abrasive material (such course gravel or small stones); or
- aggressive environments such as sea water; or
- situations where they are subject to excessive peak loads (generally from overloaded vehicular traffic).

2.2 Road Locality

There are two major environments or zones potentially affected by drainage and are defined as the **road environment** and the **external environment**.

2.2.1.1 Road Environment

The road environment is the zone which the Department of Transport and Main Roads has responsibility for and therefore is under its control. It is defined as the road corridor as defined by property boundaries (also known as road reserve). It is important to note that not all boundaries are clearly defined, particularly within large western properties and reserves. In these situations, the road reserve is usually based about the existing road centreline and planners and designers need to further investigate to establish applicable boundaries.

2.2.1.2 External Environment

The external environment is the zone outside of the road corridor which may include sensitive areas such as wetlands rainforest, sand dunes, waterways or private properties or other infrastructure (e.g. railways). The external environment may extend for some distance from the road environment and is not the responsibility of the department. However the department needs to liaise or work with relevant stakeholders and authorities with respect to any proposed project as drainage work within the road environment may affect the external environment both upstream and downstream of the project.

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2.3 Design Considerations

2.3.1 Identifying Design Considerations

The construction of new or upgraded road drainage infrastructure may lead to changes in the existing road and external environments. Problems associated with erosion and sedimentation, flooding (changes in peak water levels) and water quality are of concern to the department, adjacent land owners, road users and the local community. The occurrence of these problems, particularly after a project is completed, can be costly to remedy and may lead to reduced amenity.

Effective project planning covering both the road and external environments plays a major role in minimising the potential for adverse impacts.

The planning and design of road drainage infrastructure can be quite complicated and involves the consideration of a diverse set of data in order to develop the most appropriate drainage solution for a project.

Collaborative planning by a group of professionals with complementary skills is often a productive way to identify all aspects, issues, functional requirements, expectations, demands, constraints, risks and possible costs to be considered in a project.

The department has identified a generic set of considerations that address drainage issues across Queensland.

In order to develop the most appropriate drainage solution, the project team for each project, must select applicable drainage considerations from the following categories:

(a) Geometric

(b) Geographic

(c) Environmental

(d) Crossing Type

(e) Maintenance

(f) Safety

(g) Staged Construction of Roads

It should be noted that identified design considerations may present several options when being addressed. It is possible that upon further consideration or review, some design considerations may no longer be part of a project while others develop into key design controls.

2.3.2 Geometric Considerations

There are two aspects of geometrics that must be considered in the drainage design for a road project. Some parts or components of these aspects may in turn become design controls. The first aspect deals with the geometry of the stream or creek and the second aspect deals with the geometry of the road-stream crossing.

2.3.2.1 Stream Geometrics

It is important to determine the geometry of the stream or flow path, in particular:

- stream longitudinal alignment;
- stream gradient; and
- channel shape.

Stream alignment refers to the natural meanders of the stream or creek channel. While most streams have only one alignment for all flows, it is possible to have the situation where the alignment for a low flow differs from the alignment for a high flow in the same stream. This situation must be identified and considered when designing the road-stream crossing. It is possible to alter the alignment of existing streams to improve the hydraulic performance of the road-stream crossing, however it is preferable to maintain or preserve the existing stream alignment as changes will affect the existing flow parameters (velocity, depth of flow and energy). Furthermore, it is important to note that licences are required from the Department of Environment and Resource Management to change the alignment of any defined watercourse. Experience has shown that the process of obtaining relevant licence maybe difficult.

Stream gradient refers to the vertical alignment of the stream or creek and changes to gradient will also affect flow parameters. Gradient has a significant influence on flow velocity and velocity in turn has a significant affect on sediment transport and scour potential.

Channel shape needs to be considered as it will tend to dictate the size and configuration of drainage structures. Altering the channel shape to accommodate a drainage structure will affect flow parameters and could increase the risk of erosion. It is preferable to maintain or preserve the existing channel shape as close as possible and culvert structures should be designed to 'fit' the shape of the stream. Some channels may not contain all of the design storm runoff and overtopping of the banks will occur. Multiple culvert installations for the one catchment will be required and in this instance, specialist advice / design will be required.

Lastly, designers must include an understanding of stream morphology when considering stream geometrics. Streams are dynamic and can change over time. This aspect is important.

2.3.2.2 Road Geometrics

As identified in Chapter 1, drainage is an integral component of road infrastructure and therefore drainage design cannot be undertaken in isolation from the geometric design of the road.

In the design of the road-stream crossing, it is important to consider the skew angle between the road alignment and drainage structure. Keeping the skew angle as small as possible (or eliminating it altogether) reduces costs and construction difficulty and is therefore the most desirable option. Given that it is highly recommended to preserve stream alignment, this consideration however does not imply any priority of drainage over road alignment and high skew angles may be unavoidable at times.

The design of the vertical alignment should be undertaken in conjunction with the design of the drainage system. An initial vertical alignment design would be used to undertake the initial drainage design of various structures. It may then be necessary to adjust the vertical alignment in order to achieve the most efficient and effective drainage design (considering allowable headwater levels, afflux and minimum cover requirements for structures). In this instance, the requirements for drainage may become a design control on the vertical alignment. However, the drainage designer needs to be aware that constraints placed on vertical alignment would make it a design control on the drainage system and force the design to change.

Furthermore, vertical alignment together with cross-sectional crossfall of the road also affects longitudinal drainage channels (such as table drains) and therefore must be designed considering minimum grade requirements for flows and minimising

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steeper grades where higher erosive velocities could result.

Another important aspect related to the geometric design of roads is stormwater runoff from the road surface. This aspect is critical as water flow (and depth) on the road surface relates to aquaplaning. Surface flows are as a result of the geometric road design (combination of horizontal, vertical, cross section, crossfall and superelevation elements) and therefore any identified problems should be solved and mitigated through amended geometric road design. A drainage solution to aquaplaning should be only considered as a 'last resort' option. If a drainage solution is required, specialist advice is highly recommended in the development / assessment of design options.

Lastly, where the possibility of stormwater crossing over the road exists (whether intentional or unintentional), adequate stopping sight distance must be provided and this factor could affect the vertical alignment design (refer *Road Planning & Design Manual*).

2.3.3 Geographic Considerations

Geographic conditions play a significant role in the determination of what type of drainage structure and/or controls may be adopted at a given location. Structures and controls that are appropriate in one part of the state may not be suitable in other areas. This is also true for the prevention of erosion.

This section discusses some key issues for different situations and regions across the state.

Most of the department's roads are located in rural regions, so standard practices for the planning and design of road drainage should address most of the issues that will arise in these areas. However, it is important to note that these issues can also apply also in urban regions. The design of drainage systems in all regions should ensure that the road level and associated drainage infrastructure is adequate to provide the specified level of flood immunity. Furthermore, the drainage structures should be sized to ensure that the flow velocities and afflux are acceptable. Specific issues to be addressed include:

- awareness of local drainage and management plans;
- ensuring property and crops will not be affected by an increase in water levels or duration of inundation;
- concentration of flow on floodplains should be minimised because of the risk of scour;
- maintaining free drainage, and not to create ponding of low flows;
- changes to flow patterns; and
- consideration of seasonal variations in hydraulic roughness linked to changes in vegetation cover.

Urban regions have similar issues to rural areas, but may also present other constraints. Constraints may be present in the form of adjacent infrastructure (including businesses and housing) or a limit in available space. Because of the more intense level of development, afflux is usually of more concern in urban areas than in most rural locations. In addition, local authorities may have prepared catchment or stormwater management plans, which will affect the future management of stormwater and watercourses in the area. The drainage

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design should be compatible with these plans wherever they exist.

Considerations in urban regions include:

- provision for higher peak flows arising from uncontrolled upstream development (many local authorities now require flow increases to be mitigated);
- assessment of the requirements of any catchment management plan or stormwater management plan prepared for the watercourse;
- need for pollution control measures;
- interaction of road drainage provisions with existing services;
- minimisation of ground disturbance during construction as urban environments often have limited space for large control measures such as sediment basins; and
- consideration and control of afflux effects. There is often a requirement that negligible afflux increases be generated upstream / downstream of the proposed drainage structure. With respect to possible changed water levels, it is important that each case is assessed fully in keeping with a risk management approach.

Coastal regions provide unique conditions and hence may other require special considerations. Conditions include regular tidal inundation, a corrosive environment and sandy soils (i.e. soils with little cohesion). Coastal environments are also often highly sensitive to pollution.

Considerations in coastal regions include ensuring that:

- legal requirements with respect to the protection of marine environments (e.g. protection of fish habitats and marine plants) are met;
- natural flow systems (e.g. tidal exchange) are properly assessed and will therefore not be compromised;
- corrosion resistant materials are used;
- potential Acid Sulphate Soils (typically below 5 metres AHD) are identified and managed appropriately;
- storm tide influence upon peak water levels and greenhouse related sea level rise is considered;
- designs allow for the presence of highly erodible or mobile materials such as sand;
- consideration is given to directing drainage to natural channels or swales rather than to hard structures; and
- bi-directional flows (due to tidal effects) are identified and appropriately considered.

Design of road drainage in flat terrain is often difficult for several reasons, including:

(a) Flow velocities in flat areas are usually low so larger structures are needed to convey the flow.

(b) Flow may be widespread and/or shallow so minor obstructions to the flow may divert flow significantly. These minor obstructions include levees and other floodplain works. Even the road itself may cause major diversions.

(c) It is often difficult to determine the catchment areas accurately because of minimal relief in terrain and the

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presence of minor obstructions as discussed in (b) above.

(d) Poorly defined flow paths also mean that it is sometimes difficult to place culverts in the most suitable locations.

(e) In flat terrain, the impacts of the road on flood levels may extend for significant distances upstream of the road. Where afflux is a concern, this impact may often be critical.

(f) There is usually an increased risk of erosion at culvert outlets because flow will be concentrated by drainage structures, particularly where there are poorly defined flow paths and/or most flow occurs across the floodplain.

In mountainous or steep terrain, the most common factor influencing design is the gradient of the natural ground. Issues for consideration where topography is steep include:

- control of velocities in roadside drains and culvert outlets;
- collection and discharge of water from the upslope side of the road to the downslope side;
- prevention of erosion at outlets onto steep areas; and
- need for small scale drop structures, weirs or drop manholes.

Locations subject to inundation by water, such as floodplains or coastal areas, either by tidal flow or backwater, require careful consideration of how drainage infrastructure will operate under a range of water levels. The presence of high and low water levels requires significantly different approaches:

- when downstream water levels are high, the hydraulic capacity of a structure may be limited; and
- when downstream water levels are low, high velocities can result, thereby maximising the potential for erosion to occur.

It is therefore very important that both cases are considered during the design of drainage infrastructure.

Regular inundation (i.e. changing water levels) can also accelerate the erosion process, through the saturation of banks, which may then fail as water levels reduce.

In coastal regions, the effects of tidal influence and climate change allowance (refer Chapter 1) on areas of inundation will need to be assessed.

2.3.4 Environmental Considerations

Drainage has the potential of causing environmental harm. Therefore it is important that environmental impacts are assessed and mitigated (as appropriate) as part of the development and operation of a road drainage system.

The risk of scour / erosion and sediment movement caused by the concentration of flows that typically occurs with drainage structures is of particular concern. Causal factors, including changes in flood flow patterns and changes in peak water levels should also be checked. In some instances, a new road embankment could lead to long term ponding of water which in turn could have adverse environmental impacts.

Environmental considerations will vary significantly from project to project, and hence it is not practical to list all potential issues in this section. However, there are two types of environmental consideration for which details have been provided. These are; the provision for fauna passage and the maintenance of water quality. In many projects, it will be important to ensure that the design of drainage infrastructure adequately caters for the existence of fauna, and also for the maintenance (or improvement) of the quality of stormwater runoff.

Chapter 4 describes the role of the environmental assessment (process and documentation) in obtaining and analysing data for the purposes of identifying potential environmental considerations for a project's drainage design.

Careful review of any relevant environmental assessment documentation, including any recommended management strategies, needs to be undertaken, as some of these strategies may become design requirements or criteria. The recommended management strategies are generally based on the requirements of relevant legislation, policy, codes, guidelines and current best practice within the industry.

Streams are usually riparian corridors. Therefore, they can provide a corridor for fauna movement as well as providing a habitat for terrestrial and aquatic fauna. All drainage works on the road should minimise any adverse impact on these important corridors.

Further to the above discussion, there are two important documents that should also be referenced when considering environmental issues. The first is *Australian Runoff Quality – A guide to Water Sensitive Urban Design* (2006), published by Engineers Australia and the second is *Water Sensitive Urban Design – Technical Design Guidelines for South East Queensland* (2006), published by Moreton Bay Waterways and Catchments Partnership.

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2.3.5 Selection of Drainage Infrastructure

Determining the type of structure for any crossing is an important consideration and there are a number of factors that need to be addressed in this process. It may be necessary to assess several options of different crossing type and size, in order to appropriately meet the design requirements and objectives. There are three main types of cross drainage structures used on roads and each has particular advantages and disadvantages. The three types are bridges, culverts and floodways as shown in Figure 2.3.5.

2.3.5.1 Relevant Factors

The relevant factors that need to be considered in selecting infrastructure are grouped into hydraulic and other factors.

The hydraulic factors include:

- *Flood discharge.* Defined waterways with a large discharge are more suited to a bridge because of the larger waterway area. The large discharge will also generally occur in rivers or large creeks, where a bridge is more appropriate and cost effective. Depending on location and importance of road, in flat terrain where the waterways are less defined and road embankment is typically low, a floodway may be the better option.

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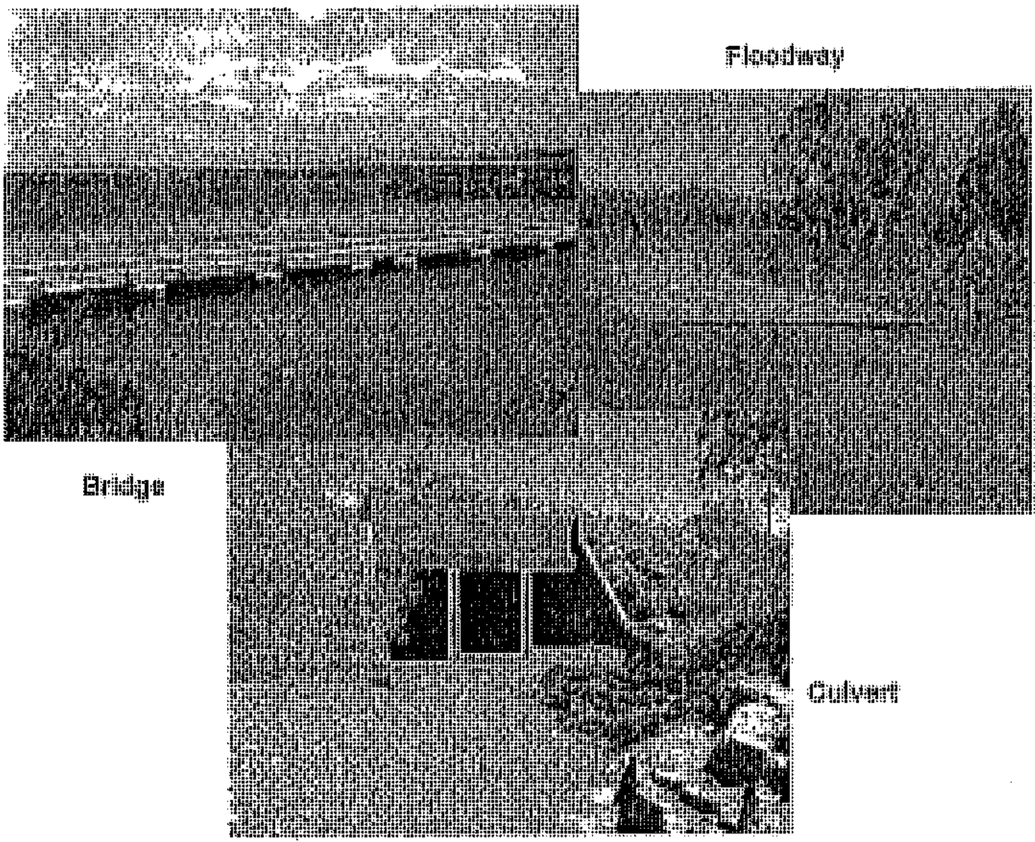

Figure 2.3.5 - Primary Drainage Infrastructure Types

- *Stream channel conditions and topography.* Similarly with the consideration of discharge, the shape and size of the channel and the catchment will also indicate a bridge, culvert or floodway. Large and well defined channels will be better suited to a bridge, while less well defined, smaller channels will be more suited to a culvert, especially where multiple openings are required (such as on floodplains). Floodways again could be considered, particularly in flat terrain / low embankment situations.
- *Afflux constraints.* The most suitable structure may be indicated by the amount of flow that can pass through / over the structure with acceptable afflux. The location and extent of afflux needs to be considered in detail and the alternatives assessed to minimise afflux.
- *Debris properties.* Culverts will normally have a smaller waterway area and present a greater obstruction to the flow. They are more prone to collection of debris. If there is a large amount of debris conveyed by a stream, a bridge or larger culvert may be more suitable.
- *Scour risk.* Scour can be affected by the size and type of waterway

structure. If a structure concentrates flow significantly, risk of scour may be increased, so structures that spread the flow may be favoured in these locations. This is especially important for drainage in floodplains where the flow paths may not be well defined.

Other relevant factors that need to be considered include:

- *Road alignment.* Sometimes, the alignment of the road is well defined and this may not be the best arrangement for drainage. This may sometimes occur where land tenure needs to be considered and the alignment follows streams rather than crossing at a zero skew. In these cases, the sizing and locating of drainage structures must be carefully considered.
- *Level of serviceability.* This includes the required flood immunity or trafficability and the type of structure that will be best for meeting this requirement.
- *Navigation.* Structures crossing rivers where boat traffic needs to be considered must allow for specified clearances for this traffic.
- *Soil conditions.* Particular soil conditions, such as marine mud or acid sulphate soils for example may be a problem and this can affect the selection of drainage structures.
- *Fauna and fish movement.* This is an important consideration in many locations.

2.3.5.2 Bridge, Culvert or Floodway

There are a number of factors and issues that need to be considered in the selection of the most suitable / appropriate structure for a particular crossing. These are listed in Table 2.3.5.2.

2.3.5.3 Culvert Types

Selection of the culvert type is important in some applications. The choice is between the following predominate types:

- pipes (any material type);
- box culverts including slab link culverts;
- slab deck culverts (cast in-situ); and
- multi-plate arches.

Arches and 'cast in-situ' culverts are not common and if being considered, specialist advice must be obtained including from the department's Bridge Design Section located within the Engineering & Technology Division.

There are two issues of particular concern for selecting the type of culvert. The first is related to the waterway area at low flow depths and secondly, the extent to which the culvert spreads the flow.

Box culverts and slab deck culverts provide for a greater waterway area at shallow depths, while pipes need to flow at a greater depth before the maximum flow capacity is reached. The use of pipes however does tend to spread the flow to a greater extent, which is often desirable for consideration of concentration of flow and risk of scour.

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Table 2.3.5.2 - General Selection Factors

Structure	Advantages	Disadvantages
Bridges	• Waterway area generally increases with increased deck height • Provides greatest flood immunity • Large flow capacity • Fewer problems with debris • Deck widening does not affect capacity • Less disturbance to riparian environment about waterway • Less impact on fauna / fish passage	• Higher design, construction and maintenance costs • More structural maintenance required • Spill slopes can be affected by erosion (potential for costly batter protection requirements particularly for higher / exposed approach embankments) • Pier and abutment can be affected by scour • Increased buoyancy, drag and impact risks • Susceptible to stream / channel migration
Culverts	• Simplest structure to design / construct • Generally most cost effective option • Can accommodate future changes to road geometry • Less structural maintenance • Can spread flows	• Generally require higher levels of maintenance • Most susceptible to failure • Higher siltation / debris risk (blockage) • Increased environmental impacts (fauna / fish passage) • Potential for scour at outlet • Subject to abrasion • Future extension may reduce capacity • Potential for separation at joints • Potential for failure by piping (leading to failure of embankment)
Floodways	• Generally, simple to design • May offer environmental advantages over culverts and bridges, since they will tend to spread flows more widely • Typically have low embankments • Risk of scour to waterway and surrounding land is reduced	• Allow water flow over road – immunity and safety issues • Increased disruption to traffic due to overtopping • Can have higher construction costs than culverts • Batter slopes can be affected by erosion / scour (particularly for higher embankments) • Generally have costly batter protection requirements • Susceptible to stream / channel migration • Can have environmental impacts (fauna / fish passage) • Potential for failure of embankment (depending on provided protection)

A further consideration for pipe culverts is material type. There are several different material types available:

- reinforced concrete;
- corrugated steel (plate or rolled);
- polyethylene and polypropylene; and
- fibre reinforced.

Reinforced concrete pipes are the most common type used by the department. This is primarily due to the product's availability, strength, serviceability, durability and overall cost (design, construction and operation).

The selection of steel rather than concrete for the culvert material can be suitable as these culverts are generally quicker and easier to construct as well as easy (and potentially cheaper) to handle and transport. Designers should note that traditional steel culverts are no longer used by the department as they do not meet the required 100 years design life. To achieve this requirement, steel culvert must have added protective coatings (refer Section 9.2.6.8). Steel culverts with protective coatings need to be product approved by the department's Bridge Design Section.

Polyethylene and polypropylene pipes are limited to smaller diameter sizes, but can provide an acceptable alternative in some circumstances. These pipes however cannot be used in locations subject to traffic loads unless they meet the requirements within MRTS29 (TMR 2010c) and are product approved by the department's Bridge Design Section.

Fibre reinforced pipes are also limited to smaller diameter sizes. These pipes have some flexibility within the walls of the culvert and tolerate construction loads and low cover installations better than reinforced concrete pipes. Fibre reinforced pipes must meet the requirements within MRTS26 (TMR 2010c) and be product approved by the department's Bridge Design Section.

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Considerations in selecting culvert type and material type are product and installation costs, availability (including transport of product to site), constructability, site conditions, environmental requirements, product longevity and serviceability and will also influence the decision as to which structure type and material type is most appropriate for a given site.

Many of these aspects and issues will be discussed and/or addressed throughout the remaining chapters of this manual.

2.3.6 Maintenance Considerations

The provision for maintenance is an integral component of the planning and design phases of road drainage. Adequate maintenance is necessary for the proper operation of the drainage system. The lack of maintenance is one of the most common causes of failure of drainage systems (and erosion and sediment controls). This may be attributed to reasons such as a significant reduction in hydraulic or storage capacity (e.g. blockage by debris or sediment).

Specific details on maintenance procedures and requirements for road drainage systems are provided in Chapter 14 of this manual.

To enable maintenance to be properly and safely undertaken during road construction and operation, consideration must be given at the design stage to the requirement of the *Workplace Health and Safety Act 1995* to make a safe maintenance workplace.

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2.3.7 Safety Considerations

An integral aspect of the detailed design of all road drainage systems is the underlying consideration of safety.

Some of the safety issues that require consideration as part of the road drainage design process, excluding workplace health and safety issues, are described below. Reference should also be made to Chapter 12 of *Queensland Urban Drainage Manual* (QUDM) (NR&W 2008).

- *Maintenance Access* - Safe access needs to be provided to all drainage structures that require either ongoing (i.e. mowing of drains) or occasional (i.e. removal of debris) maintenance. This access is required for vehicles and maintenance crews depending on the type of maintenance that will be undertaken. Safe access to erosion and sediment control devices during the construction phase should also be allowed.
- *Human Safety* - Where long culverts potentially provide a hazard (particularly in urban areas) to human safety, preventative measures should be considered. Safety measures include fencing, swing gates and grates at culvert inlets. Any safety device needs to ensure that it prevents both access to the culvert and trapping of a human against the grate. The effect of any proposed human safety measure on culvert capacity and efficiency needs to be checked.
- *Traffic Safety* - Projecting culvert ends have the potential to act as obstructions to 'out of control' vehicles. Where there are no safety barriers; culvert ends should be designed to not present an obstruction. If obstructions from projecting culverts or head walls are unavoidable then safety barriers should be considered.
- *Floodway Safety* - The main issue associated with safety at floodways is adequate sight distance for drivers to ensure vehicles can stop before entering the floodwaters. Preferably, the floodway longitudinal profile should be horizontal so that the same depth of water exists over the entire floodway length. The floodway length should be limited and on a straight stretch of road where possible. Adequate permanent and temporary signing must be erected. As flood water recedes, silt and debris can be left on the road surface of a floodway and this can be a hazard to road users. The department should inspect each affected floodway as soon as possible after a flood event and clear the surface if required.
- *Energy Dissipators* - Energy dissipation is necessary due to high flow velocities. Dissipation devices usually consist of large obstructions to the flow and result in a high degree of turbulence. For these reasons, energy dissipation structures should be avoided in urban areas where possible. Otherwise access should be limited by appropriate fencing. Reference should also be made to Chapter 12 of QUDM (NR&W 2008).

Energy dissipators are also very costly to build and maintain and changes to the design, such as flattening of channel gradient to reduce high velocities, is preferred.

2.3.8 Staged Construction of Roads

Whole of life considerations dictate that the design of a road takes proper account of both expected and potential changes that will or may occur as traffic grows and the surrounding land use develops or changes. This aspect is most important for projects that are planned to be built in stages over a period of time. Making allowance in current designs for these changes ensures that future enhancements can be accommodated in a cost effective, efficient and safe manner.

Other future benefits include:

- reduced disruption to road users and adjacent property owners;
- early / coincident resumption of properties; and
- reduced environmental impacts.

If designs ignore the requirements for future upgrading, future projects will be more difficult and very much more expensive to implement than they would have been if appropriate provisions were included in the original design.

The fundamental elements to be addressed in designs to allow for future upgrades include:

- carriageway or formation widening (e.g. for an additional through, auxiliary and/or overtaking lane, for a noise barrier, for a safety barrier);
- duplication of carriageways; and
- intersection and interchange changes or upgrades.

Providing for the future cross-section and ultimate road configuration when designing drainage systems requires careful consideration of the various components of the drainage system.

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2.3.8.1 Cross Drainage

Aspects of cross drainage that require special consideration for staged construction include:

- hydraulic efficiency and capacity of the culvert in its initial (short) and ultimate (long / extended) forms;
- possible change in culvert operation (inlet control / outlet control) and subsequent outlet velocity changes;
- potential variation in afflux and/or allowable headwater changes;
- positioning of culvert inlets and outlets (within the stream);
- changes to the inlet / outlet of adjacent culverts (in the same stream) where these are located within the median of a dual carriageway and where future widening will be within the median (e.g. culverts may become connected);
- environmental considerations (e.g. scour prevention measures, fish or animal passage);
- resumptions (e.g. land required to accommodate future culvert inlets and outlets, allowance for maintenance access); and
- cover over future culvert extensions due to carriageway widening (on the outside of the formation and/or in the median).

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2.3.8.2 Longitudinal Drainage

Aspects of longitudinal drainage that require special consideration for staged construction include:

- drainage of the ultimate median which must be provided for with:
- height of pipes and inlets designed to fit the initial and ultimate shapes of the median and carriageway;
- designed capacity and hydraulic operation suitable for the initial and ultimate configurations;
- conversion of an open channel within the median to an underground piped system and the requirements for outlets;
- road safety impacts with drainage inlets structures within the median.
- drainage connections to bridges (including any pollutant control devices) may need to be designed for the ultimate configuration (e.g. need to cope with additional surface runoff from a widened structure);
- resumptions (e.g. land required to accommodate catch drains, diversion drains or channels, maintenance access, sedimentation basins);
- environmental considerations (e.g. size and location of sedimentation basins).

2.3.8.3 Surface Drainage

Aspects of surface drainage that require special consideration for staged construction include:

- aquaplaning (e.g. pavement widening may create a problem where before there was none, the application of superelevation in the initial stage may need to suit the ultimate stage);
- use of crowned multi-lane one-way carriageways to reduce aquaplaning will impact on drainage design (e.g. a third lane added to the median inside of a two-lane carriageway may be crowned and so drain towards the median); and
- addition of kerbing / kerb and channelling in the future (e.g. channelisation of an unchannelised intersection, when widening a two-lane carriageway to three lanes).

2.3.8.4 Sub-surface Drainage

Aspects of sub-surface drainage that require special consideration for staged construction include:

- location and capacity of sub-soil drains;
- location of outlets and cleanout points to allow for ultimate shape; and
- changes to the water table and groundwater flows.

2.3.8.5 Medians and Obstructions

In divided roads where the ultimate median has a concrete safety barrier and the median width is at or near the absolute minimum, the ultimate median drainage system will require the use of drop inlets to an underground drainage which can be located beneath the barrier itself.

The location of obstructions or immovable features such as bridge piers and abutments must be carefully considered to enable the future stage development of the cross section of the road to be implemented without major change to these features.

Preserving the required above ground horizontal and vertical clearances to these features is essential in this process as well as providing underground clearances from footings or abutments to the underground stormwater drainage system.

2.4 Design Controls

Design controls are aspects of the road environment or elements of the project that cannot be changed, or are extremely difficult or costly to change. These aspects and elements therefore place restrictions and controls on the design. Design controls can either place a direct restriction on a project or at least influence the development of design options, becoming design considerations.

One example of a design control with respect to drainage may be the width of the road reserve. Where resumptions are undesirable, the existing right-of-way could limit the available space for drainage infrastructure and therefore control what can be done.

Another example may be the location of the horizontal alignment / centreline. While the design of the horizontal alignment should consider drainage elements, there are many reasons why the location of the horizontal alignment may be fixed. This could then directly restrict or influence the drainage design. While it is possible, vertical alignment should rarely be a design control over drainage design as the both elements need to be developed holistically in order to achieve an appropriate design solution.

2.5 Design Criteria

2.5.1 Introduction

Drainage infrastructure for a road project is planned and designed to provide a standard or level of drainage immunity that conforms to good engineering practice and that also meets government and community expectations. It is conventionally specified based on an Average Recurrence Interval (ARI). This is defined as the average interval in years between exceedances of a specified event (i.e. rainfall or discharge) and is written as 'ARI x years'. The ARI is really a probability rather than an actual period between occurrences.

Within a project, the design criteria will vary in accordance with road type and whether the design relates to cross drainage, surface drainage, urban drainage, or construction phase drainage, including erosion and sediment control. Guidance as to suitable ARIs for each of these situations is provided in the following sections.

Further to the use of ARI, the Annual Exceedance Probability (AEP) is also used in relation to flood flows. The AEP is the probability of exceedance of a given discharge within a period of one year. It can be considered as the reciprocal of the average recurrence interval in years expressed as a percentage, for example, 50 years ARI is equivalent to 2% AEP or 1:50 AEP.

For further discussion on ARI and AEP, reference should be made to Book 1, Section 1.3 of *Australian Rainfall and Runoff, A Guide to Flood Estimation, Vol 1* (AR&R) (IEAust 2001).

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2.5.2 General Hydraulic Criteria

Hydraulic criteria include the following:

(a) Design discharge

(b) Flow velocities

(c) Permissible velocities

(d) Flood and stream gradient

(e) Fauna passage requirements

(f) Fish passage requirements

(g) Erosion and sediment control

(h) Permissible afflux

(i) Tailwater levels and Backwater potential

(j) Pollution control

(k) Road closure periods / AATOS/AATOC

(l) Inundation of adjacent land

(m) Maintenance of flow patterns

Establishing the hydraulic criteria requires an understanding of the hydrologic and hydraulic conditions of the site or project.

2.5.2.1 Design Discharge

The design discharge is the flow rate of the defined probability (or Average Recurrence Interval) for the required drainage works. Usually the design discharge is used to provide the size of the drainage structure and the level of the road. The design discharge is expressed as a flow rate, usually as cubic metres per second (m^3/s).

Usually the discharge is calculated directly by a hydrology procedure, such as the Rational Method for the drainage structure and this discharge is used directly.

In more complex situations, the design discharge is calculated while accounting for attenuation or diversions.

2.5.2.2 Flow Velocities

The flow velocity is a critical parameter used in design of drainage structures. It is the velocity of the flow of the water in the flow path. The flow velocity can be calculated for a particular location in a stream cross section or it can be an average over a portion or the whole of the cross section.

Flow velocity can be calculated using Manning's Equation, by a hydraulic model or it can be measured during an actual flood event.

Flow velocities are usually calculated initially for the natural channel, without any drainage works. This velocity indicates the natural conditions which can be used as a basis for the consideration of the drainage works. Flow velocities can then be calculated for the conditions with the addition of the proposed infrastructure.

Flow velocity in a flow path depends on the slope and geometry of the flow path as well as the channel roughness and the amount of flow. It is often very variable across a cross section and along a reach of a stream.

2.5.2.3 Permissible Velocities

When designing a drainage structure or channel, the flow velocity is an important input to the design process. This is because excessive flow velocities will cause scour.

The risk of scour depends on the gradient (slope) and geometry of the channel, the soil conditions and the vegetation cover. When the velocity of the flow increases beyond a limit, the risk of scour will increase. In the design, the permissible flow velocities need to be defined to help in the design process.

The process used is as follows:

- The drainage structure (culvert, bridge, floodway or channel) is designed, based on the best available information.
- The design flow velocity for the preliminary design is calculated.
- The maximum permissible flow velocity is compared to the calculated design velocity.
- The design may be modified to meet this limit, by increasing the waterway area or reducing the slope for example.
- If this is impossible because of constraints, appropriate mitigation measures will be needed.

The permissible velocities depend on the material of the channel bed as well as the type of soil, channel gradient and shape as well as vegetation cover. Permissible flow velocities are listed in tables that can be found in Chapter 8.

While the permissible flow velocities are set mainly to counter the risk of scour, the permissible flow velocity may also depend on other environmental factors, such as the allowance for fish passage.

2.5.2.4 Flood and Stream Gradient

Flood and stream gradients are considerations in drainage designs, since these affect stream discharges (hydrology) and flow velocities and flood levels (hydraulics).

As discussed in Chapter 8, there are three different gradients or slopes that are relevant in road drainage design:

- Energy gradient; the profile of the energy line in a flood. While this slope is not easily measured, it is the gradient used in the hydraulic calculations. It is usually estimated for use in calculations.
- Water surface slope; the profile of the surface of the water. This is the slope measured by observing a series of flood levels along the waterway. In open channels, the water surface slope is also the Hydraulic Grade Line (HGL).
- Bed slope; the profile or slope of the bed of the channel. This slope can be measured from survey data or topographic maps. While not directly used in the hydraulic analysis, for reasonably uniform channels, the bed slope can be used to approximate the water surface slope / energy gradient.

Another term used is ground or catchment slope and the value is used in some hydrology procedures. The value is a representative slope for the whole catchment.

Higher gradients lead to greater flow velocities, which result in lower flood levels, but increased risk of scour.

2.5.2.5 Fauna Passage Requirements

When a road is built it tends to fragment habitat and lead to greater risk to fauna that cross the road. Since the drainage structures cross under the road, these can potentially be used to provide a safe means for fauna to cross between habitats. To provide this, the drainage structures may need to be modified to make this passage easier. Both terrestrial and aquatic fauna (especially fish) need to be considered.

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Fish passage is an especially important case and this is described in Section 2.5.2.6.

When considering the requirements for fauna transfer, several issues must be considered as follows:

- Consult with environmental experts to confirm that the best information possible is being incorporated.
- Identify the relevant environmental issues.
- Identify fauna types that may use the transfer.
- Determine the appropriate requirements.

Usually the culvert can operate effectively as a drainage structure while also providing a means for fauna to cross the road.

Particular considerations for the fauna transfer are as follows:

- Normally it is important to supply a dry passageway so that the fauna can move through the culvert without getting wet.
- This can be provided by dividing the culvert into wet and dry cells, with the inverts of some cells kept higher than others. When larger floods occur, the whole culvert set will operate.
- A low flow channel can provide the same benefit.
- Fencing may be needed to direct the fauna towards the culvert, but hydraulic issues should be considered.
- The culvert should not provide habitat for the fauna, since this habitat will be removed when a flood occurs.
- Lighting may be needed in long culverts so that fauna can enter the culvert is not discouraged by the dark.
- Vegetation is required at the entrance and exit of the culvert to provide cover in otherwise exposed areas.

2.5.2.6 Fish Passage Requirements

A waterway barrier is any structure that limits fish movement along the waterway. Examples of waterway barriers include:

- dams;
- weirs;
- bridges;
- culverts;
- tidal barriers;
- fords;
- causeways / floodways;
- silt curtains; and
- any other barriers that restrict fish movement.

Constructing or reconstructing (or significantly repairing) any waterway barrier across a (freshwater or tidal) waterway requires a development approval under the *Integrated Planning Act* 1997 and the *Fisheries Act* 1994. Under this legislation the application will be refused unless movement of fish across the waterway barrier is adequately provided. An exemption can be given if no fish or habitat exists above the barrier.

The definition of a waterway under the *Fisheries Act 1994* includes a river, creek, stream, watercourse or inlet of the sea. This definition does not distinguish between freshwater and tidal waters and incorporates both permanent and ephemeral flowing waterways.

The definition includes:

- any artificially modified or improved waterway; and
- channels that connect water bodies to waterways during times of flow, along which fish would be expected to move.

It does not include isolated water bodies such as lakes or some wetlands (e.g. spring-fed wetlands).

There is no indication in the legislation that there should be an upstream limit to the application of 'waterway' and hence the requirement for a development approval for waterway barrier works. However, an upstream limit is relevant, as there is usually little to be gained in terms of fish movement from consideration of waterway barrier works on natural drains and gullies. To determine whether a site is above or below the upstream limit, the following guidelines are provided:

1. Defined bed and banks
   - The bed and banks of the waterway need to be continuous rather than isolated and broken sections of a depression.
2. An extended, if non-permanent, period of flow
   - Flow must continue for a reasonable period after rain ceases and have some reliability commensurate with rainfall.
3. Flow adequacy
   - The flow needs to be sufficient to sustain basic ecological processes and to maintain biodiversity within the feature.

If the crossing being assessed is determined to be above the upstream limit, design can progress normally, however, if a crossing is below the upstream limit (that is, all 3 conditions met), a structure catering for fish passage has to be designed and approved as part of the development approval process.

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Further guidance and information can be obtained from the *Fish Habitat Management Operational Policy (FHMOP 008) – Waterway barrier works development approvals* (2009) issued by Queensland Fisheries (part of Department of Employment, Economic Development and Innovation). Document is available < http://www.dpi.qld.gov.au/documents/Fisheries_Habitats/FHMOP008-Fish-Hab-Manage.pdf>, correct as of January 2010.

Development applications, as required under the Act, must be submitted to Queensland Fisheries for approval.

The department is currently working with Queensland Fisheries to develop requirements and self-assessable codes for the design, construction and operation of drainage structures. Updates regarding requirements will be issued either as a *Planners and Designers Instruction* or directly as an update to this manual.

2.5.2.7 Erosion and Sediment Control

One of the most important environmental concerns for road drainage is erosion and sediment control. This should be considered in all situations, and appropriate assessment and mitigation measures must be supplied. Scour at drainage structures can be a serious environmental problem as well as providing a risk of structure failure and possible road embankment failure.

Control of scour at culverts and channels needs to consider the permissible flow velocities noted in Section 2.5.2.3 and Chapter 8, which indicates the velocity limits where scour begins to become a problem. While these are good guidelines, each individual situation needs to be considered on its own merits, since there may be a large variation for different situations.

Where necessary, erosion control measures will be needed and these are described in later sections of this manual.

2.5.2.8 Permissible Afflux

Afflux is the increase in peak water levels produced by the introduction of a culvert or bridge and is the comparison between the water levels for the existing conditions and the proposed conditions once the road has been built. Afflux is defined for a particular location and will vary across the floodplain or along the length of a channel.

The allowable afflux is often a controlling factor in design of drainage structures and can be a serious community concern. While the department must assess the afflux expected during the planning and design process, local authorities will often specify the requirements that they expect in a region.

Afflux is usually caused by a constriction in a flow path, from the construction of a culvert, bridge or floodway. However in some cases, especially in flat terrain and where flow may be diverted from one catchment to another, it could be caused by a redistribution of flow. Afflux can also be negative, that is a reduction in flood level, downstream of a constriction or where flow is diverted away from a stream or creek.

The point of maximum afflux occurs immediately upstream of the road and then dissipates while moving further upstream. There is a point where the afflux drops to zero and the influence of the bridge on flood levels disappears. In flat terrain, this point may be a considerable distance upstream, but in steep country with high flow velocities, the afflux may extend only a very short distance.

The afflux also reaches a maximum at the point of overtopping of the road. Smaller floods will be conveyed easily through the structure, while larger floods may eventually drown out the structure. For very large floods, there may be no impact on flood levels, where the structure is submerged to a significant depth.

Afflux needs to be considered in all drainage designs. During the planning phase, any properties, infrastructure or other feature upstream of the crossing must be reviewed. These structures then need to be considered in the design and the impact on flood levels at each of these must be included in the design process. If there is nothing that could be adversely impacted by an increase in flood levels, afflux does not necessarily form a part of the design. In this case, the maximum permissible flow velocity through the structure is the critical factor.

The allowable afflux will vary for individual locations. In some particularly sensitive areas, no afflux may be the appropriate limit. This would be in areas where there are already flood prone properties and even a small increase in level could cause a significant increase in damage. In some locations, a small amount of afflux may be acceptable. In regions where upstream development does not provide a control, the flow velocity and/or allowable headwater requirement generally set the limit. In this instance, the afflux is often of the order of 250 mm, though higher afflux may be possible in some situations.

Afflux is reduced usually by increasing the waterway area of the drainage structure, but it can also be reduced by channel works or other mitigation measures.

Reducing the afflux may lead to higher costs for drainage infrastructure and it may be impossible to reduce the afflux at some sensitive locations, even with extensive mitigation measures. In these cases, careful assessment of the hydraulics and potential damage is needed and this should be followed by consultation with affected property owners to develop an acceptable result.

2.5.2.9 Tailwater Levels and Backwater Potential

Tailwater is important for drainage design, as it sets the water level at the outlet of a drainage structure. It therefore can control the hydraulic performance of the structure.

Tailwater levels must be calculated as part of the hydraulic design for all drainage structures. There are a number of situations required for the calculation of tailwater, as follows:

- Normal stream depth. In this case the tailwater level is defined by the normal water level in the downstream channel, and this depends on the conditions of the stream or creek. These conditions are the slope, channel geometry and stream roughness. The tailwater level is calculated using Manning's Equation, backwater analysis or a stream rating curve.
- If there is a downstream confluence (junction) with another stream, the tailwater level may be held at a higher level than would naturally be the case. In this case, the flow is at a lower velocity and the water levels are higher, which means that the culvert will not operate as efficiently as it would if the downstream water level was lower. This is especially the situation if the road crosses a tributary just before this tributary joins a major stream. Two cases need to be analysed. Firstly, assuming a major flood in the downstream catchment of the major stream. This may result in a higher flood level in the tributary, which may be critical for the design. Secondly, assuming normal to low flows in major stream, a local catchment flood in tributary may result in lower flood levels but a critical case for the consideration of velocities through the structure.
- Similarly to the tributary situation, a downstream lake or dam can affect the tailwater level. In this case, the stream flows into a lake, natural or artificial, and this body of water holds up the flood levels and thereby increases the tailwater level. This increase can occur over time, giving a dynamic tailwater.
- Also, another infrastructure crossing or artificial constriction downstream of proposed crossing can affect tailwater levels.
- If the road crossing is close to the ocean or an estuary, the tailwater level may be controlled by the level of the ocean. In this case, the water level will depend on tidal levels as

well as possible effects from storm tides or waves. The assessment of an appropriate tidal tailwater level for design of drainage structures is a difficult problem. A major issue is the risk of occurrence of a particular tide at the same time as a major flood. Analysis of a range of tidal levels may be of value as for the consideration of a downstream tributary. If a high tide is analysed, this may give the critical event for flood levels on the road, but the flow velocities will be low. On the other hand, analysis of a lower tide will give lower flood levels, but the flow velocities may be critical for the design.

2.5.2.10 Pollution Control

While roads may make up a relatively small proportion of the catchment area, they can contribute a relatively high proportion of contaminants which are washed into streams, creeks and other receiving waters. The contaminants include a range of materials, especially sediment, metals, oils and greases, rubber and gross pollutants. The export of these contaminants may need to be mitigated by measures provided as part of the drainage system for the roads.

The *Environmental Protection Act 1994* identifies the objective to protect Queensland's waters while allowing for development that is ecologically sustainable. This purpose is achieved within a framework that includes:

- identifying environmental values for Queensland waters (aquatic ecosystems, water for drinking, water supply, water for agriculture, industry and recreational use);
- deciding and stating water quality guidelines and water quality objectives to enhance or protect the environmental values.

The Department of Environment and Resource Management, formerly Queensland Environmental Protection Agency (EPA), published the *Queensland Water Quality Guidelines 2006* (QWQG), based on the *Australian Water Quality Guidelines for Freshwater and Marine Waters 2000* developed and published by the Australian and New Zealand Environment and Conservation Council (ANZECC). The QWQG provides technical guidelines for the protection of aquatic ecosystems. These guidelines initially focus on the protection of aquatic ecosystems across three geographic regions for which regional data is available;

- South-east;
- Central; and
- Wet tropics.

For other regions of Queensland, the national guidelines are adopted until local guidelines are developed.

Most environmental protection agencies tend to rely on the ANZECC guidelines. These guidelines generally are used as the default framework for setting water policy objectives for managing water resources on a sustainable basis.

The QWQG identifies three levels of ecosystem condition for which different levels of protection can be applied:

- Level 1 - high conservation / ecological value systems;
- Level 2 - slightly to moderately disturbed systems; and
- Level 3 - highly disturbed systems.

Both the ANZECC guidelines and QWQG are primarily focussed upon deriving guideline values for Level 2 aquatic ecosystems, as these represent a significant proportion of Australian waters.

The sensitivity of the receiving aquatic ecosystems and the potential impact of the road corridor, both in construction and operation, should have been identified in the project's environmental assessment documentation and/or *Environmental Impact Statement* (EIS). Traffic volumes and heavy vehicle content will be documented in the planning report.

This information, in conjunction with the water quality requirements noted within the environmental assessment documentation and/or EIS, will assist in identifying and selecting appropriate key water quality objectives which may include:

- capture of pollutants upstream of a sensitive water body; and
- discharges from sediment basin to achieve water quality levels (ANZECC guidelines) owing to the sensitivity of downstream aquatic ecology.

In 2008, the EPA (now the Department of Environment and Resource Management) released the *EPA Best Practice Urban Stormwater Management - Erosion and Sediment Control Guideline* in support of the *State Coastal Management Plan* (2002) for planning schemes and development assessment.

Although this guideline has been specifically prepared for urban land development within the coastal zone, it has relevance to this manual for the construction and operation of drainage infrastructure located in this zone. Best practice environmental management of an activity is defined in the guideline as:

"...the management of the activity to achieve an ongoing minimisation of the activity's environmental harm through cost-effective measures assessed against the measures currently used nationally and internationally for the activity".

In urban catchments, reference should also be made to *Australian Runoff Quality – A Guide to Water Sensitive Urban Design* (EA 2006) and to QUDM (NR&W 2008). These reference documents together with *EPA Best Practice Urban Stormwater Management* guidelines provide the standards for erosion and sediment control.

Pollution control guidelines for a particular drainage infrastructure project are specific to that project and are detailed in the environmental assessment documentation and/or EIS for that project. No specific guidance is therefore provided in this manual.

Guidelines for the selection of specific pollution control options for a project are set out in Chapter 7.

Erosion and sediment control guidelines for a particular drainage infrastructure project are specific to that project may be detailed in the environmental assessment documentation or EIS for that project. Guidelines for the selection of design standard (average recurrence intervals) for erosion and sediment controls are contained within Chapters 7 and 13.

2.5.2.11 Road Closure Periods / AATOS/AATOC

Consideration of times of closure is important in some situations to supplement the flood immunity assessments. The time of closure is a measure of the disruption to

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traffic and in some ways is a better measure of the performance of the road. This measure can be expressed at either the average annual time of submergence or closure, the average time each year when the road is affected or as the duration of submergence or closure.

More details on this topic are provided in Chapter 10 where the methods of calculation are included.

2.5.2.12 Inundation of Adjacent Land

Roads can provide a restriction to flow across a flow path or floodplain and can cause ponding upstream. This inundation must be considered carefully (extent and duration of) in the planning and design of the road and any adverse impacts identified and mitigated. These impacts are important in urban areas, where there may be development or infrastructure that may be affected. However there may also be concerns in rural areas, where there may be impacts on agricultural land.

Generally the drainage systems for roads are sufficiently large enough that the duration of ponding is not increased greatly, but this may be possible in some situations. These cases need particular attention.

2.5.2.13 Maintenance of Flow Patterns

The road is a linear structure across the floodplain and therefore may divert flow across the floodplain, especially in flat areas. This diversion may have impacts on both economic and environmental factors. Any diversions should be identified and generally there should be minimised to maintain the existing flow patterns as well as possible.

In some situations diversions may be worth considering especially where there are benefits to the cost and complexity of the drainage system, but the potential impacts must be carefully assessed to determine if they are acceptable.

2.5.3 Cross Drainage Criteria

The design criteria for cross drainage for a particular project may be set either by the client or by departmental strategies and may be based on any of the following conditions:

- *Flood Immunity* - This is defined as the average recurrence interval (ARI) of a flood that just reaches the height of the upstream shoulder. In other words, the road surface remains 'dry' / is immune to flood of set ARI. Furthermore, freeboard may be required to 'lower' the water level further to keep the pavement dry and/or provide a buffer in case of error in calculation.

  Another definition used is the (ARI) of a flood that just reaches the point of overtopping the highest point of the road. This definition is used to calculate the flood immunities in the Bridge Information System (BIS).

- *Trafficability* - In some instances, it is desirable to allow traffic to continue to use the road while floodwater crosses the road surface. The design criteria therefore may be specified in terms of the ARI of the flood at the limit of trafficability. This limit is based on a combination of depth and velocity of flow over the road or floodway and is defined as occurring when the total head (static plus velocity) at any point across the carriageway is equal to 300 mm. The road is defined as closed if the flow is greater than this limit, as used below. This standard is in line with recommendations made by Austroads.

- *Time of Submergence (TOS)* - This is a measure of the expected time that the road is submerged in any flood but especially in a major flood such as the ARI 50 year event. Submergence is defined as the point where the road is just overtopped, even by very shallow water.
- *Average Annual Time of Submergence (AATOS)* - This is a measure of the expected average time per year of submergence of the road caused by flooding. It is expressed as time per year.
- *Time of Closure (TOC)* - This is a measure of the expected time of closure of a road (road not trafficable) in any flood but especially a major flood such as a ARI 50 year event.
- *Average Annual Time of Closure (AATOC)* This is a measure of the expected time of closure of the road due to flooding, expressed as time per year.

The times of submergence and closure provide useful data to supplement the flood immunity results. They give an indication of the extent of disruption to transport that may result from flooding on the road. In some cases, low flood immunity may be acceptable if the times of closure are low and the expected disruption is relatively minor.

The average annual times of submergence and closure depend on the frequency of submergence / closure as well as the duration of each occurrence. For example, two streams may have a similar average annual time of submergence, but a quite different flood immunity, if one is closed frequently for short durations, while the other is closed more rarely for longer times. The impacts of these different patterns can be analysed to determine the most appropriate design for each particular crossing.

The time of submergence / closure is related to catchment area and response times as well as the flood immunity. These times are calculated either from design flood events or from stream flow data, as described later in this manual.

Refer Sections 2.5.6, 2.5.7 and 2.5.8 for specific detail regarding flood immunity criteria for cross drainage for various road types.

2.5.4 Longitudinal Drainage Criteria

The requirements for longitudinal drainage will vary from project to project. The design considerations for the site will dictate the choice between alternative longitudinal drainage options such as kerb and channel, grassed swales, and lined or unlined table drains. It is also important that the longitudinal drainage (drain type and capacity) of the adjoining projects be considered when determining the criteria for the site being planned or designed to ensure consistency of drainage capability and to mitigate potential system failure.

In urban environments, kerb and channel has historically been favoured for most roads, though grassed channels and swales are also common on divided roads.

Reference should be made the *Road Planning & Design Manual* to determine the cross sectional components of table

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drains and other drains associated with the formation / carriageway.

The following criteria are to be considered in determining the standard for longitudinal drainage. It is important to note that the standard for longitudinal drainage should be compatible with the standard adopted for cross drainage as these two components of the drainage system typically work in combination.

Refer Sections 2.5.7 and 2.5.8 for specific detail regarding flood immunity criteria for longitudinal drainage for various road types.

2.5.4.1 Shape of Table Drains

Flat-bottomed drains are the preferred type or shape. Parabolic can also be used although these are difficult to construct / maintain. The use of 'V' drains is to be limited / confined to constrained sections where cross sectional width is critical. The flat-bottom of the drain is to be sloped away from the carriageway and be wide enough to allow access for maintenance machinery.

2.5.4.2 Minimum Grades

The minimum grade for unlined drains, including table drains, is 0.5% and 0.2% for lined drains however 0.3% may be regarded as the minimum practical slope for construction (allowing for construction tolerances). This is to ensure that the drain will flow and, if applicable, minimise ponding against formations and pavements. This criterion also applies to both crest and sag vertical curves where grades fall below 0.5%. Generally, to achieve the required minimum grades, widening of the table drains is needed over the critical length (length where grade is less than that required). Widening of the table drain means that when travelling away from the vertical curve apex, the table drain invert is gradually shifted away from and then back closer to the shoulder edge, in order to deepen the drain and effect sufficient grade. However, this solution may not always work, therefore modification / adjustment of the road geometry may need to be made.

2.5.4.3 Flow Velocities

Flow velocities in longitudinal drainage should be limited to prevent erosion. Limiting flow velocities is preferred over maintaining high flow velocities and providing armouring. Acceptable velocities should be based on the soil conditions and characteristics of the site.

2.5.4.4 Flow Depths

Flow depths should be limited to prevent erosion and inundation of the pavement. An increase in the number of outflow points (e.g. turnouts or level spreaders) from the longitudinal drainage should be considered to assist in managing depth of flow.

2.5.4.5 Median Drainage

Median longitudinal drainage will usually have a concrete lined invert to assist maintenance and reduce the risk of errant vehicles rolling after hitting ruts caused by tractor mowing.

2.5.4.6 Bridge Runoff

Road runoff from bridge scuppers should be discharged into a sediment basin, gross pollutant trap or other relevant first flush containment removal device. This is particularly important where the scupper would direct bridge run-off into a base flow channel or upstream of a sensitive environment (e.g. wetland, fish habitat reserve).

Reference should also be made to Standard Drawing No: 1178 (DMR 2009b).

2.5.5 Road Surface Drainage Criteria

The requirements for surface drainage primarily relate to safety (e.g. aquaplaning and ponding) and are dealt with in Chapter 11.

For surface drainage, the main criterion is the allowable flow width on the road. However flow velocity also needs to be addressed particularly when pedestrian movement is adjacent to or crosses the flow.

Refer Sections 2.5.7 and 2.5.8 for specific detail regarding flood immunity criteria for road surface drainage for various road types.

2.5.6 Immunity Criteria for the National Land Transport Network

Generally, the adopted flood immunity criteria for cross drainage on the National Land Transport Network (Auslink) is ARI 100 years and for other drainage components, refer Tables 2.5.7 and 2.5.8 as applicable.

For major projects on the Auslink network, the Australian Government's Department of Infrastructure, Transport, Regional Development and Local Government will set project specific drainage design criteria which may differ from the ARI values specified in this manual in and may also include time of closure requirements. The criteria will be agreed to and set in relevant project documentation and approvals.

2.5.7 Immunity Criteria for State Controlled Roads - Rural Catchments

For rural catchments, the generally accepted design criteria for various drainage components are specified in Table 2.5.7.

In some situations, it might not be possible to design for this level of flood immunity without causing intolerable impacts on existing development or because of extensive flooding that could not be managed without unacceptable cost. In such situations the ARI may be relaxed to a lower level. In this instance, assessment and use of time of closure / submergence (TOC/TOS) for design criteria may be more appropriate. Refer discussion in Chapter 1 regarding road infrastructure delivery.

This criterion also applies to rehabilitation and reconstruction projects where existing structures are assessed as hydraulically or structurally deficient and need to be completely replaced.

Designers should check departmental strategies for flood immunity or trafficability requirements for specific routes and individual projects (refer Chapter 3).

2.5.8 Immunity Criteria for State Controlled Roads - Urban Catchments

The design ARI for a project in urban areas will often be influenced by the capacity or capability of the existing drainage system or network that the new work needs to connect into.

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Table 2.5.7 – Design ARI for State Controlled Rural Roads

Location	ARI
Cross drainage – excl. floodways	50 years
Diversion channels	50 years
Road surface drainage[A]	10 years
Bridge deck drainage	10 years
Road surface drainage of pavements	1 year
Water quality treatment devices	1 year
[A]. Road surface drainage includes kerb and channel, table drains, diversion drains, batter drains and catch drains.	

For urban catchments, the generally accepted design criteria for various drainage components are specified in Table 2.5.8. The Department of Transport and Main Roads has also adopted the ARI criteria as described in Table 7.02.1 of *Queensland Urban Drainage Manual* (QUDM) (NR&W 2008). Key values are included in Table 2.5.8. Designers should confirm the requirements of any existing / connecting systems with the relevant authority.

Urban drainage systems are generally based on the major / minor drainage system or dual drainage system. This type of system or drainage concept has two distinct components:

- **The minor drainage system** is designed to fully contain and convey a design minor stormwater flow of specified ARI with road flow limited in accordance with the requirements set out in Chapter 11 on this manual. Refer to the glossary for full definition.
- **The major drainage system** conveys the floodwater beyond the capacity of the minor drainage system and up to a specified ARI. Refer to the glossary for full definition.

The minor and major design storms correspond to the rainfall events for the ARI chosen for the design of the minor and major systems respectively.

Designers should note that the design discharge for the major system ARI may require that the capacity of the gully inlets and underground pipes be increased beyond that required by the design discharge for the minor system ARI, in order to meet the major system design criteria.

Another important design consideration is that with any proposed drainage system adjacent to sensitive areas where flood inundation will not be tolerated, the design of the major drainage system should also consider the flow conveyed in the underground minor drainage system should this system fail due to malfunction or blockage.

2.5.9 Environmental Criteria

The environmental considerations and strategies for managing aspects of a project (refer in Section 2.3.4) that are predicted to cause environmental harm will most likely become environmental criteria for the project.

Chapter 7 deals further with the development of environmental criteria.

Table 2.5.8 – Design ARI for State Controlled Urban Roads

Location	ARI
Major System – includes all above and below ground components	50 or 100 years[A]
Minor System Components	
Cross drainage – excl. floodways	50 years
Diversion channels	50 years
Road surface drainage including intersections[B]	10 years
Bridge deck drainage	10 years
Sediment basins	2 years
Road surface drainage of pavements	1 year
Water quality treatment devices	1 year
[A]. Refer to relevant local authority for confirmation of required Design Storm ARI particularly where connecting / discharging to an existing system under their control. [B]. Road surface drainage includes kerb and channel, underground pits and pipe networks, table drains, diversion drains, batter drains and catch drains.	
ARI for design of retention and detention basins is project specific and must be specified in design brief.	

2.6 Water Sensitive Urban Design

Water Sensitive Urban Design (WSUD) is a particular issue for urban planning and design, but the key principles of WSUD are also applicable to road infrastructure in the rural environment. These principles are:

(a) Protect existing natural features and ecological processes.

(b) Maintain the natural hydrologic behaviour of catchments.

(c) Protect water quality of surface and ground waters.

(d) Integrate water into the landscape to enhance visual, social, cultural and ecological values.

Conventional water management has been compartmentalised with water supply, wastewater and stormwater traditionally treated as separate entities. However integrated water management needs to consider the total water cycle and this concept is increasingly being accepted and/or adopted.

While the principal concern for the department is related to stormwater drainage, the department also has an interest in a range of other issues such as the use of water for construction and water quality controls.

Roads may represent a relatively small proportion of the total catchment, but they sometimes contribute significantly to water quality concerns. This is especially the case on roads with high traffic volumes, where a number of different contaminants may be produced. Between rainfall events, contaminates can build up and then runoff at a greater rate than normal into receiving waters.

The principles that the department need to consider include:

(a) Consider all parts of the water cycle, natural and constructed, surface and subsurface, recognising them as an integrated system.

(b) Consider all requirements for water, both anthropogenic (human activity) and ecological.

(c) Consider the local context, accounting for environmental, social, cultural and economic perspectives.

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(d) Include all stakeholders in the process.

(e) Strive for sustainability, balancing environmental, social and economic needs in the short, medium and long term.

The department also needs to be aware of all water related issues, not only in the road reserve, but also both upstream and downstream.

2.7 Extreme Rainfall Events

While the planning and design of road drainage systems is based on a determined average recurrence interval or set of average recurrence intervals, it is also a requirement to review designs for possible adverse outcomes that may occur during an extreme rainfall event.

To illustrate this, most roads are designed to an ARI 50 year standard. However should an ARI 100 year event or larger occur, culvert velocities may become unacceptably high causing significant environmental harm, afflux may increase above the acceptable ARI 50 year limit causing excessive flooding, the road may overtop threatening the integrity of the road embankment, safety of road users, and so on.

The extent of the extreme events to be analysed depends on particular circumstances, so the requirements cannot be defined exactly. Furthermore, while the risk of occurrence of these extreme events is low, the impacts of an extreme event must be assessed.

In the case of the likelihood of the event occurring and the adverse outcomes / risks being unacceptable, the design criteria may need to be altered and the design recalculated or appropriate mitigating measures developed and included into the project.

It is important to note that any outcomes (adverse or otherwise) resulting from an extreme rainfall event could occur within both the **road and external environments** (refer Section 2.2) therefore identification of possible outcomes should not be limited to the road reserve and/or chainage limits of the project.

The following sections outline some situations where the design of a project should be assessed for adverse outcomes and risks that may occur during an extreme rainfall event. However, other situations may also exist where assessment should be undertaken, therefore careful engineering consideration and judgement should be exercised. Assistance in identifying or confirming situations requiring assessment and at what level (ARI) assessment should be undertaken at can be provided by Director (Hydraulics), Hydraulics Section, Engineering & Technology Division.

2.7.1 Erodible Soil Environments

Part of the road drainage design process is the determination of acceptable or maximum allowable velocities for stormwater flows. It should be noted that these velocities are largely based on research that identified the velocity when erosion / scour started to occur in different soil / stream types. The maximum allowable velocities for a project are then used in the design of various drainage structures / devices (for example, culverts and channels) to ensure design discharge through those devices is below the set maximum allowable velocity for that location. Some design solutions that may be adopted, equal or are just below the set maximum allowable velocity. In an extreme rainfall event occurs, the maximum allowable velocity for a given structure / device will most likely be exceeded which in turn could result in excessive scour, erosion or environmental harm. It is therefore important that these situations are identified and assessed.

If this situation is considered applicable on a project, specialist advice needs to be sought from the department's Hydraulics Section or suitably prequalified consultant as analysis methods are beyond the scope of this manual.

2.7.2 Excessive Flooding

Larger floods may need to be considered in locations where the impacts of the road on flood levels (based on a normal design ARI) are / will be significant / very severe. These impacts will most likely be worse in a large flood / extreme rainfall event. This issue is particularly important where the road embankment is relatively high and the flood immunity provided by the high embankment is much greater than the usually adopted standard of ARI 50 years. In this case, while larger floods may not overtop the road, a higher peak water level will build up on the upstream side of the road causing excessive flooding and in some cases may cause the overtopping of the catchment boundary, directing or diverting flow to an area not able to handle the increased flow. Furthermore, the higher peak water level may produce larger flow velocities through the drainage structure, which has been designed for a smaller ARI. The higher velocity may cause scour problems or could cause the catastrophic failure of the structure itself.

The above issues may be further aggravated by blockage of the drainage structure(s) (by silt and/or debris) which may lead to a greater risk to the drainage infrastructure and surrounding area, if the flow cannot overtop the road.

Therefore, where flood impacts would be significant / very severe, it is necessary (and can be specified in design / contract documentation) to consider floods up to the Probable Maximum Flood (PMF). The PMF is defined as the largest flood event that can reasonably be expected. In some situations, extreme events, though smaller than the PMF, may be more appropriate.

If the situation of excessive flooding is considered applicable on a project, specialist advice needs to be sought from the department's Hydraulics Section or suitably prequalified consultant.

2.8 'Self Cleaning' Sections

'Self cleaning' sections, for example, culverts and channels, require a reasonably regular flow of a specific velocity / energy, that will pickup and transport any silt or debris within the section to a specific location beyond the section.

The required minimum velocity / energy for a 'self cleaning' flow through the section must be determined based on the anticipated sediment and/or debris (type / size / weight) that may accumulate in the section. This flow must be generated by a design storm with a suitable Average Recurrence Interval (ARI) such as ARI 1, 2 or 5 years depending on how often the channel should be 'cleaned'. Intervals of 1 or 2 years are preferred while intervals greater than 5 years are not recommended.

The requirement for 'self cleaning' sections and the selected design interval (ARI) must be specified in the design brief / contract documents.

The location that any silt or debris can be transported to (and deposited) must also be considered as it must:

- be accessible to allow maintenance / clean out;
- must not cause any adverse effects to the environment (for example, water quality and fish passage); and
- must not adversely affect any future flows (for example, cause ponding / increase tailwater levels).

The inclusion / presence of a 'self cleaning' section does not remove or lessen the requirement for regular / routine maintenance inspections. 'Self cleaning' sections may reduce the requirement for maintenance (cleaning) of the section.