# Gold Coast Rapid Transit

## 19 Hydrology and Hydraulics

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# 1. Introduction

As part of the Concept Design Impact Management Plan (CDIMP) for the Gold Coast Rapid Transit (GCRT), a hydrologic and hydraulic assessment was carried out to predict the impact of a major storm event on the proposed alignment and surrounding properties.

The CDIMP covers the section of the proposed GCRT alignment from University Hospital Station to Broadbeach South station. A number of areas along the alignment are being subject to flood inundation and are therefore sensitive to changes in hydraulic characteristics.

As the proposed alignment is generally at the same grade as the adjacent road network, the impacts of waterways and overland flow along the alignment need to be determined. This is to facilitate a level of flood immunity for the GCRT that is similar to the existing level of flood immunity for surrounding properties. The GCRT also needs to "*minimise impact of any kind to upstream or downstream properties/property*", as required in Gold Coast City Council (GCCC) development guidelines.

Through the completion of the hydrologic and hydraulic assessment, the following objectives were achieved:

- the identification of the locations along the alignment most susceptible to inundation;
- the calculation of estimated peak flood levels at each of these locations;
- the determination of potential impacts of current flood levels on the concept design alignment; and
- the recommendation of mitigation measures to reduce the impacts on the GCRT operation and surrounding properties.

This hydrology and hydraulics chapter documents the methodology of the assessment, outlines any assumptions made, presents the estimated flood levels for the current situation and identifies the potential impacts and mitigation measures.

# 2. Source Data

In conducting the hydrologic and hydraulic assessment, data was obtained from a variety of sources. If a source was considered reliable, the existing data was utilised where possible. Data was sourced as follows:

- Hydrologic data for the Loders Creek catchment was taken from a previous study and utilised in this assessment. The report was entitled *Loders Creek Hydraulic Report*[1] and was produced for GCCC;
- a two dimensional flood model of the Nerang River system, created previously by GCCC, was used to determine the effect that rising water levels within local waterways would have on the GCRT system. The flood model was based on a 72-hour duration and modelled the Q10, Q20, Q50 and Q100 storm event. The flood levels calculated are based on the combined event of storm surge and rainfall;
- hydrologic data was calculated in accordance with GCCC *Land Development Guidelines* (LDG)[2], which refers to *Queensland Urban Drainage Manual* (QUDM)[3] and *Australian Rainfall and Runoff* (AR&R)[4]. Also utilised was the Department of Main Road's *Road Drainage Design Manual*[5] and *Storm Drainage Design in Small Urban Catchments*[6]*;*
- the Geographical Information Systems (GIS) Projections for Urban Planning (PUP) data provided by GCCC was used to identify the layout and pipe diameters of existing stormwater infrastructure. Not all infrastructure data was available from the GIS, but enough was available to make reasonable assumptions on what was missing;
- a long-section showing the current vertical geometry of the GCRT alignment was produced from either a feature survey or aerial laser survey, depending on what was available at various locations. TransLink provided the survey and it was the most accurate survey data available at the time of this assessment; and
- terrain data was sourced from GCCC contours and was utilised in catchment mapping.

[1] *Loders Creek Hydraulic Report*, GCCC, 2004

[2] *GCCC Land Development Guidelines*, 2005

[3] *Queensland Urban Drainage Manual,* Neville Jones & Associates Pty Ltd and Australian Water Engineering, 2005

[4] *Australian Rainfall and Runoff,* Institute of Engineers Australia, 2003

[5] *Road Drainage Design Manual*, Queensland Department of Main Roads, 2003

[6] *Storm Drainage Design in Small Urban Catchments*, John Argue, Australian Road Research Board, 1986

# 3. Methodology

The first step in the hydrology and hydraulics analysis was to identify the areas along the alignment most susceptible to inundation. Low points (troughs) in the GCRT alignment were identified and the corresponding catchments were mapped using a combination of the available contour and survey data.

The next consideration was to determine the driving factor for flood immunity at each inundation location; either the capacity of the existing drainage systems or the flood level of nearby waterways.

At inundation locations where drainage capacity was the driving factor, hydrologic calculations and basic hydraulic modelling was utilised in order to assess the performance of the current drainage system and recommend drainage upgrades that would produce similar flood immunity for that location during a major storm event. The methodology for determining drainage upgrades is contained in Section 3.1 below.

At inundation locations where the driving factor was the flood level of nearby waterways, drainage upgrades could not reduce the inundation; therefore no hydraulic modelling was necessary. Detailed modelling of all the relevant urban catchments was not undertaken as the necessary specific data for individual house levels, all pit and pipe systems and all road and footpath systems is not available. Furthermore, detailed data for previous storm and rainfall information is not available for all the relevant catchments. If the drainage system data was obtained and models were produced, these could not be calibrated until a reasonable amount of actual data was available. Hence the methodology described in this Chapter considered suitable for the purpose of the GCRT system and the Concept Design.

The GCRT system would be closed in the inundated section until the floodwater receded to an acceptable depth. The methodology for determining the period of closure is contained in Section 3.2 below and was dependant on the availability of sufficient data to accurately model flood hydrographs.

In accordance with Table 3-5B the LDG, a storm with an average recurrence interval (ARI) of 100 years was used as the major storm event. It was assumed that for the minor storm event, as defined in the LDG, the existing pit and pipe systems would have adequate capacity. Therefore all evaluations, assumptions, calculations and conclusions are based on the major storm event. A reduction in the ARI of a major storm event was not considered possible given the heavily developed nature of the GCRT corridor and surrounding catchments and the ramifications for the road authority of having a reduced level of flood immunity for one specific piece of infrastructure within a shared road reserve. The LDG also states in Table 3-5B that all upstream properties shall be immune from the 100 year ARI backwater.

On this basis, whether or not the GCRT infrastructure could or could not need immunity for the 100 year ARI event, the approach for the GCRT must accommodate the potential flood impact of the project on properties upstream of it.

## 3.1 Drainage Upgrades

At inundation locations where the cause was determined to be the limited capacity of the drainage system, a hydrologic and hydraulic assessment was completed in order to determine upgrades to the existing drainage infrastructure. The locations where this assessment was required are contained within Section 2 of the proposed GCRT alignment.

### 3.1.1 Hydrology

The purpose of the hydrologic assessment was to estimate the peak flow that would cross the GCRT alignment during a major storm event. If no previous hydrologic data was available for the catchment, then flow data was calculated. The peak flow rate was calculated at the point in the catchment where the overland flow path crosses the GCRT alignment. The method employed to calculate this peak discharge was the rational method as outlined in section 5.02 of QUDM. Insufficient data was available to construct and calibrate more detailed hydrologic models for each catchment.

The use of the rational method required the determination of three catchment characteristics. These were the rainfall intensity, catchment area and the coefficient of runoff. The corresponding values were calculated in accordance with QUDM and the LDG.

#### Rainfall Intensity

In order to calculate the rainfall intensity for a catchment, a number of design rainfall values were taken from design rainfall isopleths specific to the Gold Coast, as given in the LDG. All other rainfall intensities were calculated in accordance with AR&R and presented in the form of an Intensity-Frequency-Duration (IFD) graph (Figure 19-1). Relevant rainfall intensities were obtained from this graph by utilising the rainfall duration and average recurrence interval. In accordance with AR&R, the rainfall duration was taken as equal to the time of concentration ($t_c$), hence a $t_c$ value was calculated for each catchment.

The time of concentration is defined as the maximum time taken by water to travel from within the catchment boundary to the catchment outlet. For areas of undeveloped urban catchment, the $t_c$ was taken as the addition of the sheet flow time and the overland channel flow time, determined using Figures 3.3 and 3.4 of the *Road Drainage Design Manual*. In areas of developed urban catchment, the $t_c$ was taken as the addition of the roof-to-gutter flow time, given in *Storm Drainage Design*, and the overland channel flow time, determined using Figure 3.4 of the *Road Drainage Design Manual*.

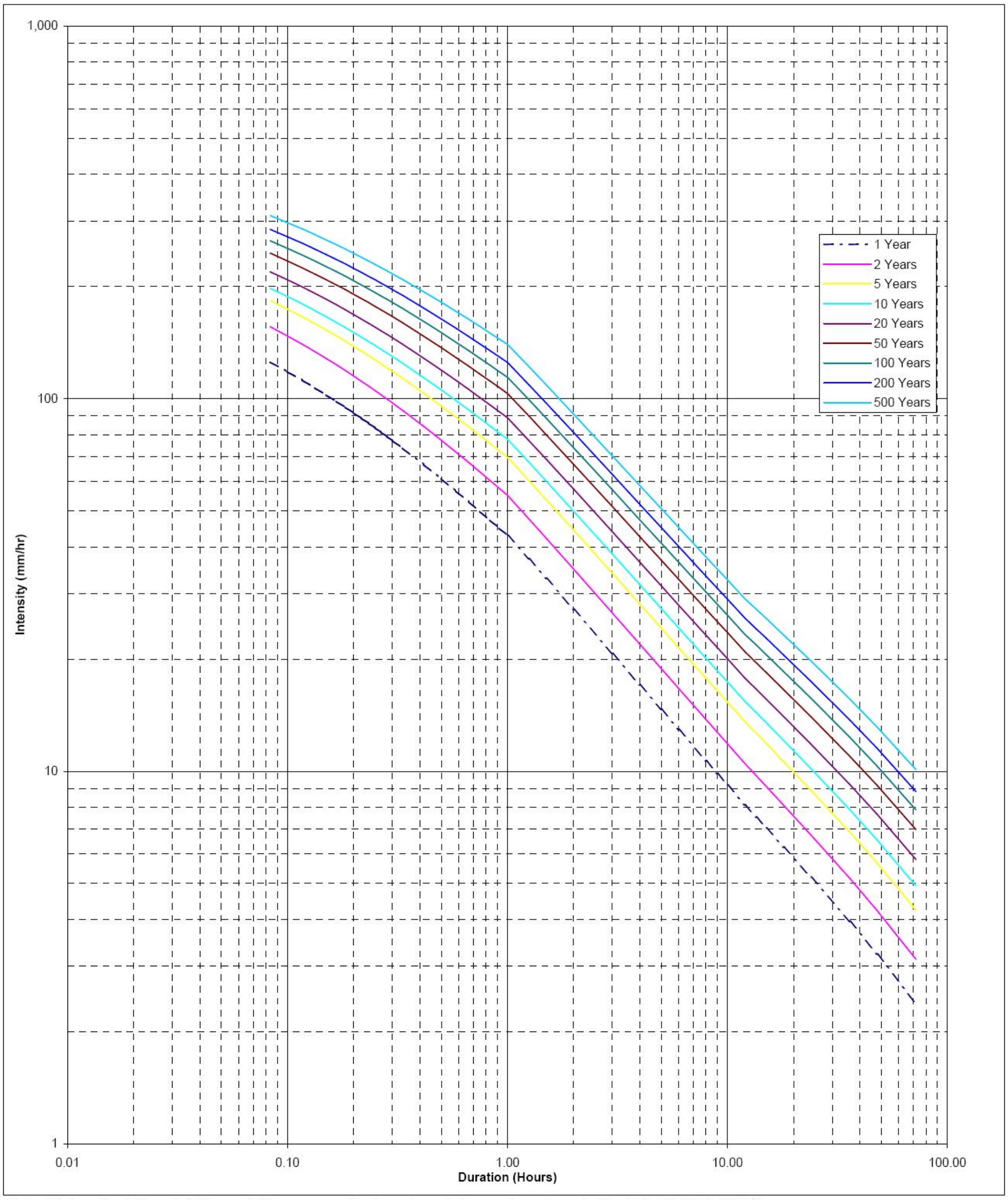
#### Catchment Area

Catchment boundaries were determined using a combination of contour maps and survey. For the purposes of this assessment, the Catchment Area A, was considered to be the area of the catchment existing upstream of the alignment.

#### Coefficient of Runoff

The coefficient of runoff (C), for each catchment, was determined by relating the land use and the average slope of the catchment. The $C_{10}$ was obtained from Table 3.5A of the LDG and this was utilised to calculate the C values for the major storm event in accordance with Table 5.04.3 from QUDM.

For each catchment, the catchment area was calculated and the coefficient of runoff was determined. These values, along with the values taken from the rainfall IFD graph (Figure 19-1), were utilised in the rational method to estimate the peak discharge within each catchment that crossed the GCRT alignment. The next step was to model the hydraulic response to this peak discharge.




Note: Values for 200 and 500 yearARI are approximate only and does not conform to Book 6 of AR&R (1999)

**Figure 19-1 Intensity-Frequency-Duration (IFD) Graph for Southport**

*Source: Australian Rainfall and Runoff, 2005*

### 3.1.2 Hydraulics

The hydraulic assessment was undertaken in order to determine how the flow resulting from a major storm event would affect the GCRT alignment and the surrounding properties.

Within the urban catchments surrounding the alignment, it was found that the underground stormwater network generally followed the overland flow paths. Hence at each location where a catchment's flow path crossed the alignment, an underground crossing also occurred. Crossings were either in the form of culverts or a pit and pipe network. Basic hydraulic modelling of the pipe flow and weir flow was performed using software CulvertW.

CulvertW calculates the flow conditions within a culvert based on Hydraulic Charts for the Selection of Highway Culverts[7]. This software provided a fast yet relatively accurate approach to modelling culverts and pipe crossings.

#### Pipe Crossing Data

In order to use CulvertW to model pipe flow under a road, certain details of a pipe crossing were required. Where the details were not available, conservative values were assumed. As CulvertW cannot model multiple pipe sizes, wherever a variety of pipe diameters occurred at a single crossing location, an equivalent pipe area was taken and a representative pipe configuration was modelled.

Feature survey provided invert levels and pipe grades of some of the pipe crossings. Where accurate survey data was not available, inlet invert was calculated assuming 150 millimetres cover between obvert and road surface. The grade of the pipe was assumed to be the minimum, as specified by Table 5.17.1 from QUDM, and the outlet invert was then calculated.

#### Weir Data

CulvertW was used to model the flow across the alignment at sags in the road. When calculating weir flow, CulvertW assumes a weir of rectangular cross-section. It was therefore necessary to identify a rectangular cross section that best represented the actual weir characteristics. The actual shape of the weir was provided by survey along the alignment from which a long section was produced. The representative weir was modelled to produce the same flow width, flow area and headwater level as the actual weir. In this way, each crossing was modelled, with headwater and maximum flow depths over the road being recorded.

## 3.2 Period of Closure

At inundation locations where the cause was determined to be the flooding of local waterways, the GCRT system would be required to cease operation in the inundated section. Where sufficient data was available to accurately model flood events, hydrographs were produced to determine the period of closure at each location.

A total of 20 points from the GCCC Nerang River flood model were interrogated and flood data extracted. The location of the points is shown in Figure 19-2 and Figure 19-3 and they are generally contained

[7] *Hydraulic Charts for the Selection of Highway Culverts*, Hydraulic Engineering Circulars No's. 5 & 10, Bureau of Public Roads, Washington, USA 1965

within Section 3 of the proposed GCRT alignment as the drainage infrastructure for major storm events is dominated by the flood characteristics of the Nerang River catchment. The points chosen were within the waterways but as near as possible to the GCRT alignment so as to be representative of the flood levels along the alignment. From the flood data, a hydrograph was produced for each point, showing the changing flood level over time.


**Figure 19-2 Flood Model Points 1-13** (Gold Coast City Council)


**Figure 19-3 Flood Model Points 14-20** (Gold Coast City Council)

# 4. Description of the Existing Environment

## 4.1 Section 2

Section 2 of the GCRT alignment begins at the proposed University Hospital[8] station at the corner of Olsen Avenue and Parklands Drive and ends on the southern side of Sundale Bridge. The major waterways crossed by this section of the alignment include Loders Creek and the Nerang River.

Areas along the Section 2 alignment were identified where the current level of the roadway is below the peak flood level, hence making the GCRT and surrounding properties susceptible to inundation during a major storm event. For the purpose of this assessment, these areas were identified as shown in Table 19-1 below.

**Table 19-1 Section 2 Catchments**

| Catchment ID | Inundation Location | Existing RCP Crossing |
|---|---|---|
| Parklands 1 | Parklands Drive, west of roundabout at Alumni Place | 3x1050 |
| Loders Creek | Queen Street, west of Bambarra Street intersection | 7x1650 |
| Queen 1 | Queen Street, between Wardoo Street and Salmon Street | 3x1350 |
| Queen 2 | Queen Street, opposite Southport Primary School entrance | 2x1200 |
| Queen 3 | Queen Street, west of Mal Burke Street intersection | 1x600 |
| Queen 4 | Queen Street, western arm of the Nerang Street intersection | 1x300 & 1x375 |
| Nerang 1 | Nerang Street, at the intersection of Cougal Street | 1x300 & 1x375 |
| Nerang 2 | Nerang Street, at the intersection of High Street | 1x600 |
| Scarborough 1 | Scarborough Street, at the intersection of Young Street | 2x1200 & 1x1350 |
| Scarborough 2 | Scarborough Street, at the intersection of Short Street | 1x525 & 1x900 |
| Broadwater | Queen Street, between Ada Bell Way and Marine Parade | N/A |

### 4.1.1 Brief description of Section 2 Catchments

**Parklands 1**

With a catchment area of approximately 17 hectares, Parklands 1 is located on the southern side of Parklands Drive, between University Drive and Engineering Drive. The University grounds take up the

[8] Further to work undertaken in preparing this CDIMP, there has been significant additional activity to finalise the concept design for the rapid transit alignment along the Parklands Knowledge Precinct and a rapid transit station to serve the main entrance of the new Gold Coast University Hospital. Reference should be made to the *Parklands Knowledge Precinct Report* that supplements the CDIMP and provides updated information on the proposed concept design and assessment of impacts.

majority of the urban catchment, including multistorey buildings and connecting roads. Overland flow converges on Alumni Place, then before reaching Parklands Drive, the overland flow path merges into a channel just east of Alumni Place roundabout. Beneath Parklands Drive are three 1050 millimetres Reinforced Concrete Pipes (RCPs) that flow from south to north.

**Loders Creek**

As part of the Broadwater Catchment, Loders Creek originates in the foothills of Ashmore and Southport and then winds through Southport. The watercourse intersects the GCRT alignment at Queen Street, just west of Bambarra Street. Seven 1650 millimetres RCPs, approximately 24 metres long, flow from south to north beneath the road.

**Queen 1**

Catchment Queen 1 is located toward the western end of Section 2 with an area of approximately 36.4 hectares. The majority of the catchment is currently undeveloped land, however, there is a roadway that runs down the centre of the catchment that conducts overland flow. The overland flow path exits the road reserve as it nears Queen Street and crosses the GCRT alignment on Queen Street between the Wardoo Street and Salmon Street intersections. At the point where the overland flow path reaches Queen Street, the pit and pipe system consists of three 1350 millimetres RCPs beneath the road. During a storm event, water flows from a pit on the southern side of the road, through the pipes, and outlets on the northern side of the road into an open channel, which contributes to Loders Creek.

**Queen 2**

Queen 2 has a catchment area of approximately 22.4 hectares. The urban catchment is made up of residential housing with the overland flow path following both road reserve and grassed channels between houses. The overland flow path crosses the alignment at Queen Street, opposite the entrance to Southport Primary School. Beneath Queen St are two 1200 millimetres RCPs that flow from south to north. The flow then continues through the pit and pipe system to Loders Creek, located to the north of the school.

**Queen 3**

Queen 3 is an urban residential catchment with an approximate area of 3.7 hectares. The overland flow within the catchment is limited to road reserve. The overland flow path crosses the GCRT alignment on Queen Street, west of the Mal Burke Street intersection. At this crossing, a 600 millimetres RCP flows under Queen St, continues under Owen Park and outlets into Loders Creek.

**Queen 4**

Queen 4 is an urban residential catchment surrounding the intersection of Queen Street and Nerang Street. The four arms of the intersection constitute the overland flow path for the catchment, with each arm draining into the intersection. Gully inlets positioned along the kerbs collect the flow. One 300 millimetres RCP and one 375 millimetres RCP cross beneath the western arm of the intersection. These two pipes converge on the northern side of the road and flow north in a single 450 millimetres RCP that is part of a larger pipe network which outlets into the Broadwater. Flow that exceeds the capacity of the pipe network travels over the road and down an easement to the north of the western arm.

### Nerang 1

Nerang 1 is a small urban industrial catchment of approximately 1.3 hectares. During a rainfall event, water flows from rooftops to the kerb of Nerang Street. The overland flow path follows the road reserve until reaching the sag at the intersection of Cougal Street and Nerang Street. At this location the gully inlets convey the flow to an underground pipe crossing. The crossing includes two RCPs, one 300 millimetres and the other 350 millimetres in diameter. In a major storm event, when the capacity of the underground pipe crossing is exceeded, excess flow will travel over the overland down Cougal Street.

### Nerang 2

Nerang 2 is an urban industrial catchment with an area of approximately 1.7 hectares. The road reserve provides the overland flow path, directing the water toward the centre of the High Street intersection. The overland flow path of the catchment crosses the GCRT alignment at this intersection and continues down High Street to the north. Beneath the road, a single 600 millimetres RCP flows from south to north across Nerang Street.

### Scarborough 1

Scarborough 1 is an urban catchment made up of approximately 19.7 hectares of industrial and commercial development. The overland flow path follows a number of roads toward Young Street then continues down Young Street and across the GCRT alignment at a sag in Scarborough Street. At the lowest part, the sag contains a relatively flat stretch of road. Beneath this flat section, two pipe crossings occur approximately 50 metres apart. The most northern crossing consists of two 1200 millimetres RCPs while the southern crossing is a single 1350 millimetres RCP.

### Scarborough 2

Scarborough 2 is an urban and commercial catchment with an area of approximately 5.6 hectares of residential housing. The overland flow is contained within the road reserves. The overland flow path crosses Scarborough Street at the Short Street intersection, continuing down Short Street. Crossing beneath this intersection are two RCPs, one 525 millimetres and the other 900 millimetres in diameter.

### Broadwater

The Nerang River starts in the Lamington plateau on the NSW border and heads north, then east where it flows into the Broadwater at Southport. The GCRT alignment crosses the Nerang River at Sundale Bridge, which is located at the southern end of Section 2. During a major storm event, the water level within the Nerang River and the Broadwater rises due to a combination of storm surge and rainfall. This causes inundation of nearby segments of the GCRT alignment.

## 4.2 Section 3

For the majority of Section 3, the GCRT alignment follows, very closely, the existing Gold Coast Highway. This entire stretch never deviates greatly from local waterways, with the northern part of Section 3 travelling adjacent to the Nerang River and the southern part adjacent to Little Tallebudgera Creek, a significant tributary of the Nerang River.

Areas along the Section 3 alignment were identified where the current level of the roadway is below the peak flood level, hence making it susceptible to inundation during a major storm event. For the purpose of this assessment, these areas were identified as shown in Table 19-2 below.

**Table 19-2 Section 3 Catchment Areas**

| Catchment ID | Inundation Location |
|---|---|
| Ferny Avenue | Ferny Avenue, from Surfers Paradise Boulevard intersection to Staghorn Avenue |
| Cascade Gardens | Gold Coast Highway, from Cascade Gardens to Convention Centre |
| Hooker Boulevard | Gold Coast Highway, from Jupiters Casino to Pacific Fair Drive |

Within Section 3, existing pit and pipe systems outlet into the nearby waterways. These are generally designed to convey runoff from a minor storm event; however during a major storm event, flooding within this section is due to backflow from adjacent waterways, not direct rainfall. Therefore the pit and pipe system was not considered further within the Section 3 assessment.

# 5. Potential Benefits, Impacts and Mitigation Measures

The following section contains details of any potential impacts arising from the occurrence of a major storm event, as well as possible mitigation measures.

## 5.1 Section 2

### 5.1.1 Impacts

Peak flood levels were determined for each of the identified catchment crossings along the GCRT Section 2 alignment. It was found that in the event of a major storm, each crossing would be inundated. Table 19-3 presents the calculated flood levels and inundation depths.

**Table 19-3 Section 2 100 year Average Recurrent Interval (ARI) Flood Levels**

| Catchment ID | Road Level (m AHD) | Flood Level (m AHD) | Inundation Depth (m) |
|---|---|---|---|
| Parklands 1 | 12.30 | 12.44 | 0.14 |
| Loders Creek | 4.34 | 4.50 | 0.16 |
| Queen 1 | 4.43 | 4.59 | 0.16 |
| Queen 2 | 4.75 | 5.02 | 0.27 |
| Queen 3 | 9.49 | 9.66 | 0.17 |
| Queen 4 | 13.50 | 13.66 | 0.16 |
| Nerang 1 | 15.33 | 15.42 | 0.09 |
| Nerang 2 | 12.46 | 12.61 | 0.15 |
| Scarborough 1 | 6.25 | 6.48 | 0.23 |
| Scarborough 2 | 6.57 | 6.78 | 0.21 |
| Broadwater | 1.36 | 2.17 | 0.81 |

* AHD refers to Australian Height Datum. This is the standard elevation reference for mapping purposes adopted by the National Mapping Council of Australia. As a general guide, 0.0m AHD is approximately equal to mean sea level. (Gold Coast City Council Website.)

The maximum inundation depth through which the GCRT vehicle is generally able to operate is 50 millimetres. When the inundation depth becomes more than 50 millimetres, drivers will have difficulty seeing the surface of the RT corridor.

With current road levels and the current pit and pipe systems, the occurrence of a major storm event would cause inundation of the Section 2 alignment to a level that would impede operation of the GCRT vehicle at each identified catchment crossing. While a hydrograph was not calculated for each of the scenarios mentioned in Table 19-3 above, the modelling suggests that the time of inundation at most locations would be less than two hours.

### 5.1.2 Mitigation

In this section, mitigation measures are suggested in an attempt to minimise the impacts that a major storm event would have on Section 2 of the GCRT alignment.

#### Parklands 1

The proposed GCRT alignment is on a structure above this overland flow path, so the GCRT will not have any impact on the outlet of this catchment.

#### Loders Creek

During a major storm event, it was estimated that the flow within Loders Creek would cause inundation of the GCRT alignment to a level that would impede operation of the GCRT vehicle. The peak flow from the major storm event would also cause an increase in the headwater afflux passing through the existing culvert due to the widening of the road and the corresponding lengthening of the culvert. This headwater increase would cause an unacceptable impact to surrounding upstream properties.

To mitigate these impacts, it is recommended that the existing culverts be replaced with a row of nine 1800 millimetres by 1800 millimetres Reinforced Concrete Box Culverts (RCBCs).

By implementing these mitigation measures, it was calculated that the peak flood level would be reduced to approximately 3.85 metres AHD, eliminating road inundation and adverse upstream impacts. This will allow the GCRT vehicles to operate in this area during a major storm event.

#### Queen 1

In the occurrence of a major storm event, it was calculated that the overland flow of catchment Queen 1 would cause inundation of the GCRT alignment to a level that would impede operation of the GCRT vehicle.

To mitigate these impacts, it is recommended that one 900 millimetres RCP be added to the existing pipe crossing beneath Queen Street. The additional pipe would extend from the pit on the southern side of the street and outlet into the open channel on the northern side.

By implementing these mitigation measures, it was calculated that the peak flood level would be reduced to approximately 4.35 metres AHD, eliminating road inundation and allowing the GCRT vehicle to operate in this area.

#### Queen 2

In the occurrence of a major storm event, it was calculated that the overland flow of catchment Queen 2 would cause inundation of the GCRT alignment to a level that would impede operation of the GCRT vehicle. The peak flow from the major storm event would also cause an increase in the headwater afflux passing through the existing culvert due to the widening of the road and the corresponding lengthening of the culvert. This headwater increase would cause an unacceptable impact to surrounding upstream properties.

To mitigate these impacts, it is recommended that two 1800 millimetres RCPs be added to the existing pipe crossing beneath Queen Street. The additional pipes would extend from the pit on the southern side of the street and follow the existing pipes under the road, across the southwest corner of the school and down Beale Street. A bubble-up pit would be constructed opposite the northeast corner of the cemetery and the additional pipes would end in the bubble-up pit. Existing pits may need to be lowered in order to accommodate the larger pipe diameter.

By implementing these mitigation measures, it was calculated that the peak flood level would be reduced to approximately 4.77 metres AHD and the road inundation would be reduced to approximately 20 millimetres, allowing the GCRT vehicle to operate in this area.

**Queen 3**

In the occurrence of a major storm event, it was calculated that the overland flow of catchment Queen 3 would cause inundation of the GCRT alignment to a level that would impede operation of the GCRT vehicle. The peak flow from the major storm event would also cause an increase in the headwater afflux passing through the existing culvert due to the widening of the road and the corresponding lengthening of the culvert. This headwater increase would cause an unacceptable impact to surrounding upstream properties.

To mitigate these impacts, it is recommended that one 1200 millimetres RCP be added to the existing pipe crossing beneath Queen Street. The additional pipe would extend from the pit on the southern side of the street and follow the existing pipe under the road, down the embankment and under the Owen Park car park. A bubble-up pit would be constructed at the northern edge of the car park and the additional pipe would end in the bubble-up pit. Existing pits may need to be lowered in order to accommodate the larger pipe diameter.

By implementing these mitigation measures, it was calculated that the peak flood level would be reduced to approximately 9.44 metres AHD, eliminating road inundation and adverse upstream impacts. This will allow the GCRT vehicle to operate in this area.

**Queen 4**

In the occurrence of a major storm event, it was calculated that the overland flow of catchment Queen 4 would cause inundation of the GCRT alignment to a level that would impede operation of the GCRT vehicle. The peak flow from the major storm event would also cause an increase in the headwater afflux passing through the existing culvert due to the widening of the road and the corresponding lengthening of the culvert. This headwater increase would cause an unacceptable impact to surrounding properties.

To mitigate these impacts, it is recommended that two 1050 millimetres RCPs be added to the existing pipe crossing beneath the intersection of Queen Street and Nerang Street. The additional pipes would extend from the pipe junction beneath the road and follow the existing pipes to the north. A bubble-up pit would be constructed at the eastern end of Carey Lane and the additional pipes would end in the bubble-up pit. Existing pits may need to be lowered in order to accommodate the larger pipe diameter.

By implementing these mitigation measures, it was calculated that the peak flood level would be reduced to approximately 13.42 metres AHD, eliminating road inundation and adverse upstream impacts. This will allow the GCRT vehicle to operate in this area.

**Nerang 1**

In the occurrence of a major storm event, it was calculated that the overland flow of catchment Nerang 1 would cause inundation of the GCRT alignment to a level that would impede operation of the GCRT vehicle.

To mitigate these impacts, it is recommended that one 450 millimetres RCP be added to the existing pipe crossing beneath Nerang Street. The additional pipe would extend from the pit on the southern side of Nerang Street and follow the existing pipes to the pit on the northern side of the street. Existing pits may need to be lowered in order to accommodate the larger pipe diameter.

By implementing these mitigation measures, it was calculated that the peak flood level would be reduced to approximately 15.36 metres AHD and the road inundation would be reduced to approximately 30 millimetres, allowing the GCRT vehicle to operate in this area.

**Nerang 2**

In the occurrence of a major storm event, it was calculated that the overland flow of catchment Nerang 2 would cause inundation of the GCRT alignment to a level that would impede operation of the GCRT vehicle.

To mitigate these impacts, it is recommended that one 600 millimetres RCP be added to the existing pipe crossing beneath the intersection of Nerang Street and High Street. The additional pipe would extend from the pipe junction beneath the road and follow the existing pipe down High Street. The additional pipe would end at the next pipe junction, which is approximately 170 metres from the intersection.

By implementing these mitigation measures, it was calculated that the peak flood level would be reduced to approximately 12.47 metres AHD and the road inundation would be reduced to approximately 15 millimetres, allowing the GCRT vehicle to operate in this area.

**Scarborough 1**

In the occurrence of a major storm event, it was calculated that the overland flow of catchment Scarborough 1 would cause inundation of the GCRT alignment to a level that would impede operation of the GCRT vehicle.

To mitigate these impacts, it is recommended that two 1350 millimetres RCPs be added to the existing pipe crossing beneath the intersection of Scarborough Street and Young Street. The additional pipes would extend from the pipe junction beneath the road and follow the existing pipes down to Marine Parade, approximately 250 metres.

By implementing these mitigation measures, it was calculated that the peak flood level would be reduced to approximately 6.12 metres AHD, eliminating road inundation and allowing the GCRT vehicle to operate in this area.

**Scarborough 2**

In the occurrence of a major storm event, it was calculated that the overland flow of catchment Scarborough 2 would cause inundation of the GCRT alignment to a level that would impede operation of the GCRT vehicle.

To mitigate these impacts, it is recommended that one 1350 millimetres RCP be added to the existing pipe crossing beneath Scarborough Street. The additional pipe would extend from the pit on the southern side of the street and follow the existing pipes down Short Street. The additional pipe would end at the next pipe junction along Short Street, approximately 70 metres from the intersection. Existing pits may need to be lowered in order to accommodate the larger pipe diameter.

By implementing these mitigation measures, it was calculated that the peak flood level would be reduced to approximately 6.55 metres AHD, eliminating road inundation and allowing the GCRT vehicle to operate in this area.

**Broadwater**

In the occurrence of a major storm event, it was calculated that the rising water level of the Broadwater would cause inundation of the GCRT alignment to a level that would impede operation of the GCRT vehicle. To mitigate this problem, the GCRT vehicles would not be allowed to operate within the inundated area until the water level has receded to approximately 1.41 metres AHD, 50 millimetres above the road level. The period of closure was estimated at approximately 44 hours.

## 5.2 Section 3

### 5.2.1 Impacts

The data from the Nerang River flood model indicated that a storm with a 10-year return period would not cause local waterways to rise enough to flood any part of the Section 3 alignment. A storm with a 20-year return period would only inundate the identified catchment areas for a short time, if at all. In the event of a 50-year or 100-year storm, local waterways would rise and cause inundation of the GCRT alignment for a significant period of time.

Peak flood levels were determined for each of the identified catchment areas along Section 3 of the GCRT alignment. Table 19-4 presents the calculated flood levels and inundation depths due to a major storm event.

**Table 19-4 Section 3 100 year Average Recurrent Interval (ARI) Flood Levels**

| Catchment ID | Road Level (metre AHD) | Flood Level (metre AHD) | Inundation Depth (metre) |
|---|---|---|---|
| Ferny Ave | 1.65 | 2.44 | 0.79 |
| Cascade Gardens | 2.65 | 3.63 | 0.98 |
| Hooker Blvd | 2.95 | 3.81 | 0.86 |

The maximum inundation depth through which the GCRT vehicle is generally able to operate is 50 millimetres. When the inundation depth becomes more than 50 millimetres, drivers will have difficulty seeing the surface of the RT corridor. With current road levels and the current pit and pipe systems, the occurrence of a major storm event would cause inundation of the Section 3 alignment to a level that would impede operation of the RT vehicle at each identified catchment area.

While the table above relates to the 100-year ARI storm event, as mentioned above, the Nerang River flood model was interrogated for other storm events. Ferny Avenue and Hooker Boulevard will not be inundated during a 20-year ARI storm event; however this storm event will flood the Cascade Gardens area for approximately four hours to a level that impedes the operation of the GCRT system.

### 5.2.2 Mitigation

In this section, mitigation measures are suggested in an attempt to manage and lessen the impacts that a major storm event would have on Section 3 of the GCRT alignment.

#### Ferny Avenue

In the occurrence of a major storm event, the GCRT vehicles would not be able to operate within the inundated area until the water level has receded to approximately 1.70 metres AHD, 50 millimetres above the road level. The period of closure was estimated at approximately 38 hours.

#### Cascade Gardens

In the occurrence of a major storm event, the GCRT vehicles would not be able to operate within the inundated area until the water level has receded to approximately 2.70 metres AHD, 50 millimetres above the road level. The time of closure was estimated at approximately 35 hours.

#### Hooker Boulevard

In the occurrence of a major storm event, the GCRT vehicles would not be able to operate within the inundated area until the water level has receded to approximately 3.00 metres AHD, 50 millimetres above the road level. The period of closure was estimated at approximately 34 hours.

# 6. Conclusion

### Modelling

The hydrology and hydraulics of the catchment areas surrounding the GCRT alignment were assessed. Some of the modelling techniques utilised in this assessment are relatively basic, as a more detailed modelling procedure was not considered beneficial given the amount of flood data available in some areas. Certain catchments have a reasonable level of information available, while in others the information is limited. Undertaking detailed modelling under these circumstances would become unreliable without consistent and detailed data available. Similarly, where data has not been available, any modelling undertaken would require time to calibrate the model with actual data.

### Flooding

It was calculated that in the occurrence of a major storm event, the GCRT alignment would become inundated at a number of locations. Mitigation measures are suggested to reduce the flood level and inundation depth over the roadway and also the upstream afflux. For example, the flood mitigation works identified for the Loders Creek area and the western end of Queen Street are required on the basis that the GCRT could affect upstream properties. These properties require a level of flood immunity no matter what acceptable level of flooding for the GCRT is determined. As such the works are aimed at mitigating upstream flood impact rather than providing flood immunity for the GCRT.

When this mitigation of flooding is not considered feasible, because the GCRT is not causing the impact, an estimated period of closure is provided during which GCRT vehicles would be prevented from operating in the inundated areas.