Impact of airport development on Rapid Creek

DEPARTMENT OF LANDS PLANNING AND THE ENVIRONMENT AND
NT AIRPORTS PTY LTD

Assessment of measures to mitigate impacts

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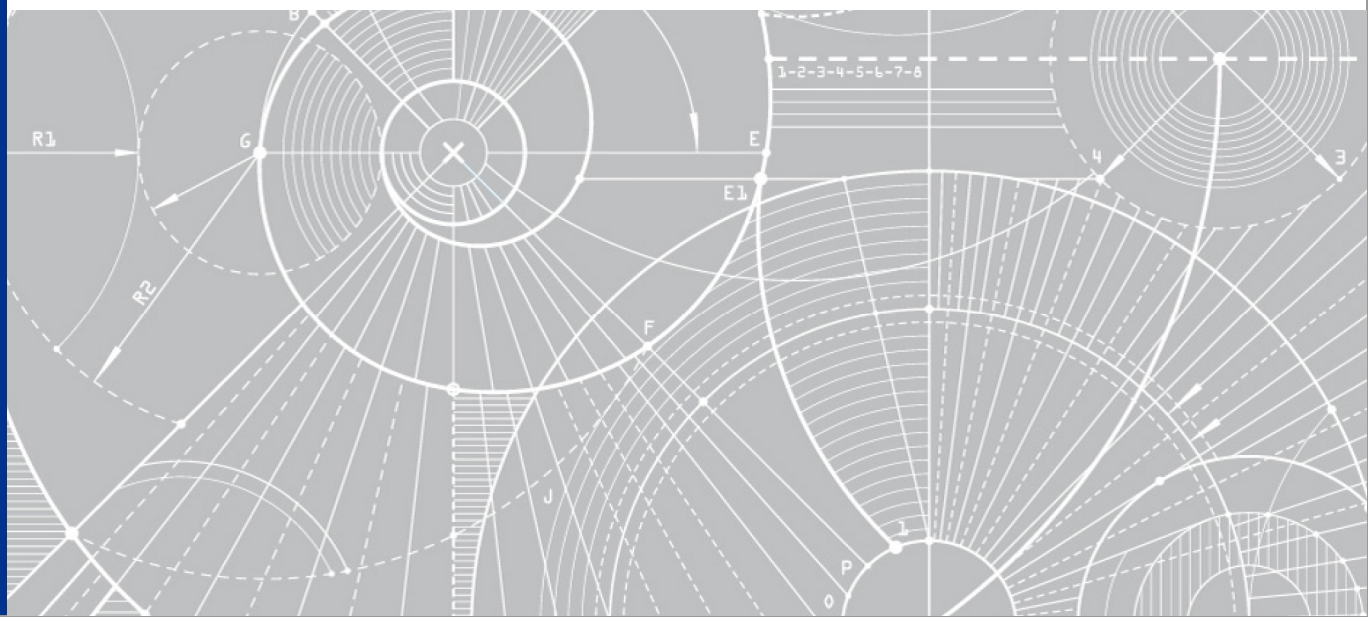
19 February 2016



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Executive Summary

This report examines measures to mitigate flooding in Darwin's Northern Suburbs (particularly the suburb of Millner) from Rapid Creek. It was commissioned jointly by the NT Government Department of Lands, Planning and the Environment and Darwin Airport and follows a report on the impact of airport development and a range of measures that could be carried out within airport land.

This report:

- Examines detention (within the Darwin Airport Lease Area) to the north of the north-south runway, picking up what runoff can be diverted into this area from the main runway and surrounding area
- Examines detention in the triangle of land formed by McMillans Road, Henry Wrigley Drive and Rapid Creek (outside the Darwin Airport Lease Area)
- Quantifies the beneficial impact of diverting the main drain from the area south of Larkin Avenue and east of Sir Norman Brearley Drive to upstream of the flood control weir
- Considers a "channel-pond" in the reserve fronting McMillans Road and quantifies its beneficial impact on flows coming from the developed Axis area and a channel-pond carrying flows from the conservation area across Charles Eaton Drive toward Rapid Creek between Osgood Drive and Murphy Crescent
- Examines additional sites for detention in the McMillans Road area to the east of Rapid Creek including vacant reserve in Section 4522 between the cemetery and McMillans Road and the Mango Orchard covering sections 9763,11085 and 11086
- Compares the effectiveness of the various mitigation measures proposed and makes recommendations as to the best way forward for NT Airports, NT Government and the community.

It is concluded that the best value for money to mitigate flood flows in Rapid Creek at Millner is the construction of a detention basin in the triangle of land formed by McMillans Road, Henry Wrigley Drive and Rapid Creek. This land uniquely combines the following features:

- It is in public ownership (part NT Government and part Darwin City Council)
- It is large enough to construct a detention basin that will mitigate inflows without encroaching on the floodplain of Rapid Creek
- It can capture runoff from a large enough part of the catchment area downstream of the Flood Control Weir to make a difference to flooding at Millner

The calculated peak flow at Millner, with such a detention basin in place, is similar to the calculated flow with no airport development and well below the calculated 1998 level, which was when NT Airports Pty Ltd took over operation of the Airport from the Commonwealth Government's Federal Airports Corporation.

It is recommended that a detention basin be constructed in the triangle of land formed by McMillans Road, Henry Wrigley Drive and Rapid Creek.

It is also recommended that Darwin Airport contribute to flood mitigation with the following measures:

- Develop guidelines for individual new developments or re-developments of existing facilities that aim to limit major storm peak discharges to pre-development levels using on-site detention of runoff.
- Construct a channel-pond in the conservation reserve to the south of the business park "A" areas with a new separate discharge toward Rapid Creek east of Charles Eaton Drive between Murphy Crescent and Osgood Drive to help store and slow runoff.
- Divert the main drain near the intersection of Sir Norman Brearley Drive and Larkin Avenue from downstream of the flood control weir to upstream of the flood control weir. After this diversion, use the remaining deep constructed open drain as detention basin for runoff from the area to the west of Sir Norman Brearley Drive and east of Cecil Cook Avenue.

These measures will result in further reductions in Q100 peak flows in the suburb of Millner than for the Marrara Triangle detention basin alone.

Important note about your report

The sole purpose of this report and the associated services performed by Jacobs is to consider the impact of mitigation measures to offset the impact of development of the Darwin Airport Lease Area on Rapid Creek in accordance with the scope of services set out in the contract between Jacobs and the Client. That scope of services, as described in this report, was developed with the Client.

In preparing this report, Jacobs has relied upon, and presumed accurate, any information (or confirmation of the absence thereof) provided by the Client and/or from other sources. Except as otherwise stated in the report, Jacobs has not attempted to verify the accuracy or completeness of any such information. If the information is subsequently determined to be false, inaccurate or incomplete then it is possible that our observations and conclusions as expressed in this report may change.

Jacobs derived the data in this report from information sourced from the Client (if any) and/or available in the public domain at the time or times outlined in this report. The passage of time, manifestation of latent conditions or impacts of future events may require further examination of the project and subsequent data analysis, and re-evaluation of the data, findings, observations and conclusions expressed in this report. Jacobs has prepared this report in accordance with the usual care and thoroughness of the consulting profession, for the sole purpose described above and by reference to applicable standards, guidelines, procedures and practices at the date of issue of this report. For the reasons outlined above, however, no other warranty or guarantee, whether expressed or implied, is made as to the data, observations and findings expressed in this report, to the extent permitted by law.

This report should be read in full and no excerpts are to be taken as representative of the findings. No responsibility is accepted by Jacobs for use of any part of this report in any other context.

Except where otherwise noted, this report has been prepared as a desk top exercise summarising existing information, including information documented by Jacobs in previous reports, together with computer modelling to calculate the impact of the mitigation measures considered.

This report has been prepared on behalf of, and for the exclusive use of, Jacobs's Client, and is subject to, and issued in accordance with, the provisions of the contract between Jacobs and the Client. Jacobs accepts no liability or responsibility whatsoever for, or in respect of, any use of, or reliance upon, this report by any third party

1. Introduction

Darwin International Airport (DIA) is located in the northern suburbs of Darwin, Northern Territory. It occupies an area approximately 3.1 sq km bounded by Bagot Road to the west, McMillans Road to the north, Amy Johnson Drive to the east and RAAF Base Darwin to the south.

Rapid Creek is a freshwater creek that arises in the Marrara Swamp in land that is part of the RAAF Base. It flows along the northern boundary of the DIA site. Beyond McMillans Road, Rapid Creek flows through urban areas, discharging to Darwin Harbour between Nightcliff and Casuarina Beach.

Jacobs was commissioned by NT Airports Pty Ltd in September 2014 to prepare a report on the impact of Darwin Airport development on Rapid Creek. That report was completed in March 2015 and recommended several mitigation measures to be adopted within the Darwin Airport Lease Area and also recommended that:

- Further investigation be done to examine opportunities for detention basins within the Darwin Airport lease Area and to quantify the reductions in peak flows resulting from construction of channel ponds in the Axis business park development area,
- The proposed measures to be constructed within the Darwin Airport Lease Area should be compared to measures beyond the Darwin Airport Lease Area to find the most cost-effective way to mitigate flood peaks.

This supplementary report follows up on these two recommendations. In particular it:

- Examines detention (within the Darwin Airport Lease Area) to the north of the north-south runway, picking up what runoff can be diverted into this area from the main runway and surrounding area,
- Examines detention in the triangle of land formed by McMillans Road, Henry Wrigley Drive and Rapid Creek (outside the Darwin Airport Lease Area),
- Quantifies the beneficial impact of diverting the main drain from the area south of Larkin Avenue and east of Sir Norman Brearley Drive to upstream of the flood control weir,
- Considers a “channel pond” in the reserve fronting McMillans Road and quantifies its beneficial impact on flows coming from the developed Axis area and a channel-pond carrying flows from the proposed conservation area toward Rapid Creek,
- Examines additional sites for detention in the McMillans Road area to the east of Rapid Creek including vacant reserve in Section 4522 between the cemetery and McMillans Road and the Mango Orchard covering sections 9763,11085 and 11086,
- Compares the effectiveness of the various mitigation measures proposed and makes recommendations as to the best way forward for NT Airports, NT Government and the community.

The following Section 2 presents a series of figures showing concepts for mitigation measures considered within the Darwin Airport Lease and tables showing the results of hydrologic model runs using these concepts.

Similarly, Section 3 presents concepts and modelling results for measures outside of the Darwin Airport Lease Area.

Section 4 summarises the various mitigation measures examined in this report and Section 5 presents conclusions and recommendations.

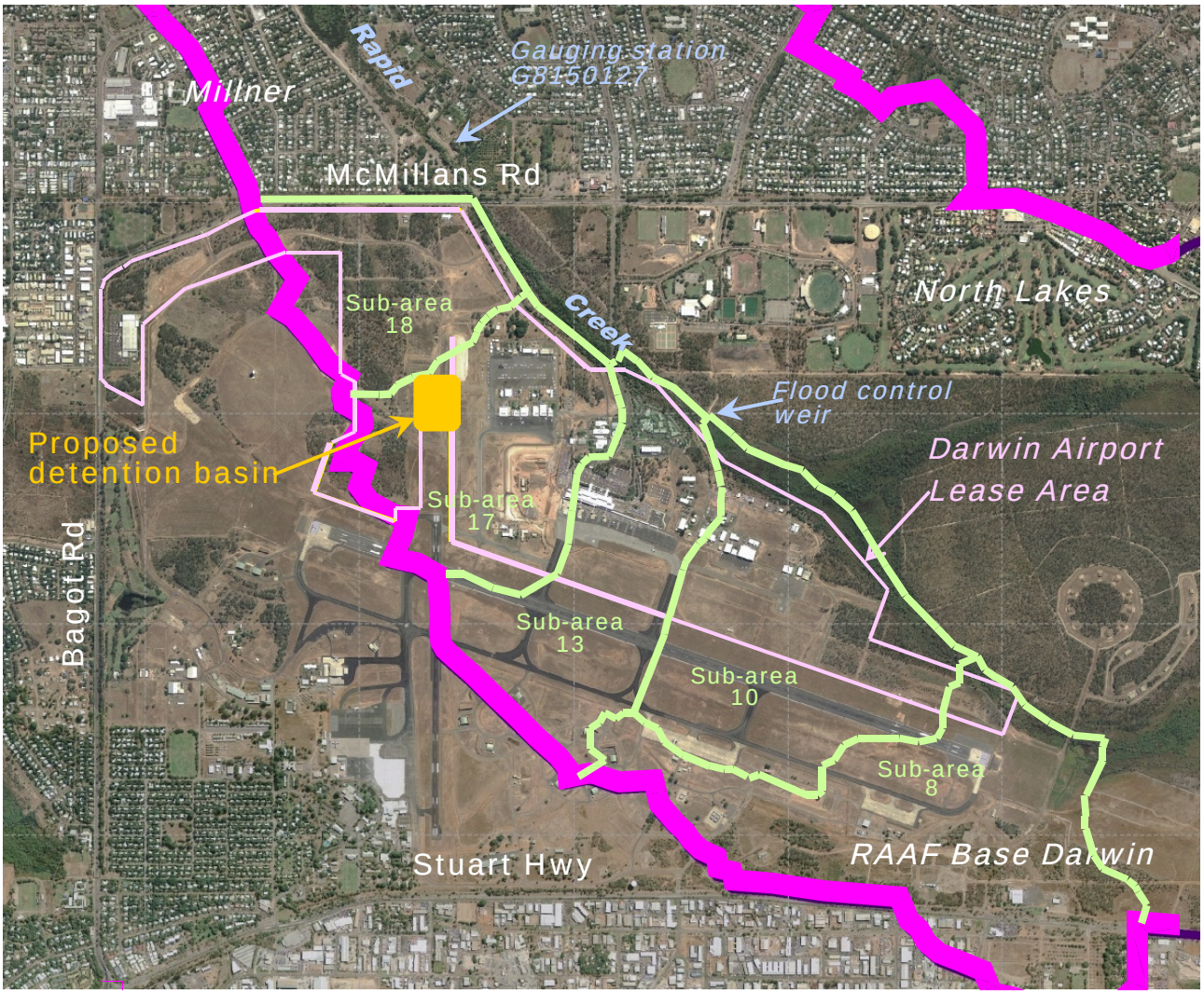
2. Mitigation measures within the Darwin Airport Lease Area

2.1 Detention to the north of the north-south runway

All detention basins considered in this report are for the temporary storage of runoff during flood events and are not intended to hold water permanently.

NT Airports has suggested consideration of detention in the area at the northern end of the cross runway as shown in Figure 1.

Figure 1. Proposed detention basin north of cross runway



Examination of contours for this area suggest a basin of up to 2 m deep and an area of approximately 1.6 ha when full could be constructed at this site. The maximum storage volume would be in the order of 30,000 m^3.

An area of approximately 30 ha could be captured by the basin, which is 28% of sub-area 17 (see Figure 1.)

Results of the calculations are presented in Table 1 and show that in a Q100 flood and ultimate development conditions there is a slight reduction at the gauging station which can be taken as the location where floodwater begins to break out of the channel and cause damaging flooding in Millner.

Table 1. Calculated Q100 peak flows for basin north of cross runway

Location	ULTIMATE DEVELOPMENT		CURRENT CONDITION	
	Q100 Peak flow (m^3/sec)		Q100 Peak flow (m^3/sec)	
	WITH BASIN	WITHOUT BASIN	WITH BASIN	WITHOUT BASIN
Sub-area 17 flow to Rapid Creek	50.1	73.8	39.2	51.2
Gauging station G8150127	169	170	149	152

Table 1 shows that there is a significant reduction in peak discharge from the sub-area: the ultimate development peak flow with the basin reduces to the current conditions peak flow without the basin. However, there are only small reductions to the overall peak discharge in Rapid Creek at Millner. Further, Defence is understood to have identified this land as being required for future runway expansion, negating its utility as a mitigation measure.

2.2 Channel ponds in the proposed business park development area

A channel-pond is a wide and gently sloping unlined channel that is intended to slow runoff as well as providing additional storage. A channel-pond has been proposed to cut off the southern portion of sub-area 18 and discharge to Rapid Creek at a new outlet as shown in Figure 2.

An area of approximately 27 ha could be captured by the basin, which is 35% of sub-area 18 (see Figure 2.)

Figure 2. Channel-pond from conservation area to new outfall at Rapid Creek

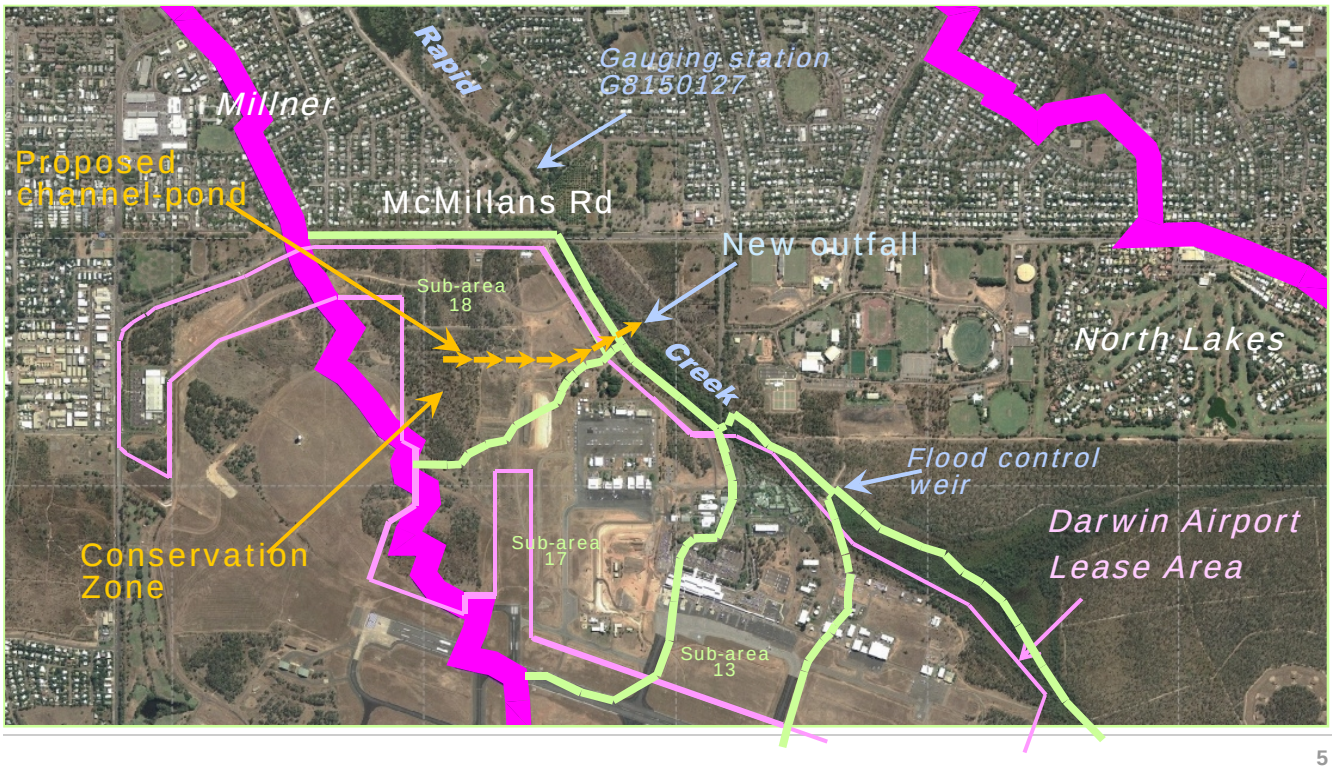


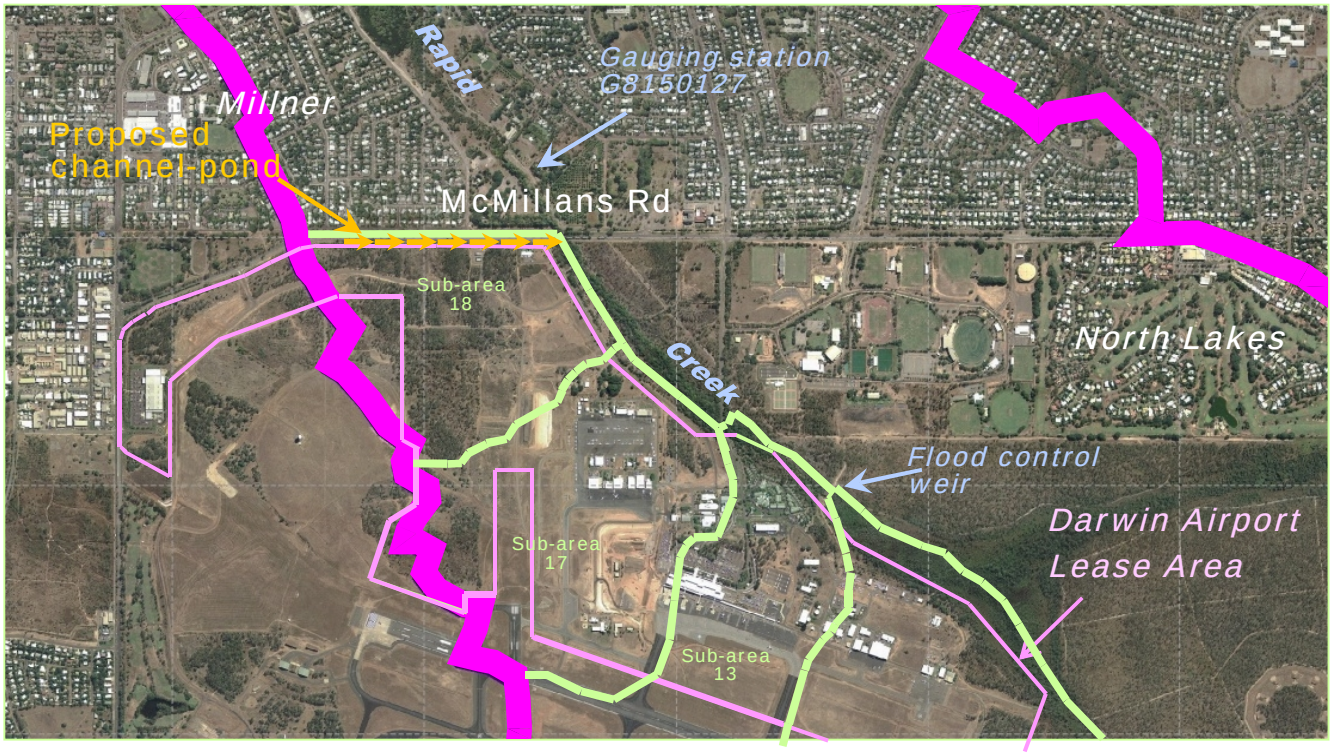
Table 2. Calculated Q100 peak flows for channel-pond taking flow out of the Conservation Area

Location	ULTIMATE DEVELOPMENT		CURRENT CONDITION	
	Q100 Peak flow (m^3/sec)		Q100 Peak flow (m^3/sec)	
	WITH CHANNEL-POND	WITHOUT CHANNEL-POND	WITH CHANNEL-POND	WITHOUT CHANNEL-POND
Sub-area 18 flow to Rapid Creek	34.0	45.9	26.3	30.3
Gauging station G8150127	162	170	140	152

Table 2 shows that there is 8% reduction in Q100 peak discharge at Millner for current conditions. For ultimate development, the model calculates a 5% decrease. Table 2 also shows the reductions in the peak contribution to Rapid Creek from sub-area 18 as a result of constructing the channel-pond.

A channel-pond has also been proposed for the McMillans Road frontage as shown in Figure 3.

Figure 3. Channel pond at McMillans Rd frontage



The area that can contribute directly to this channel-pond is taken to be 50% of sub-area 18.

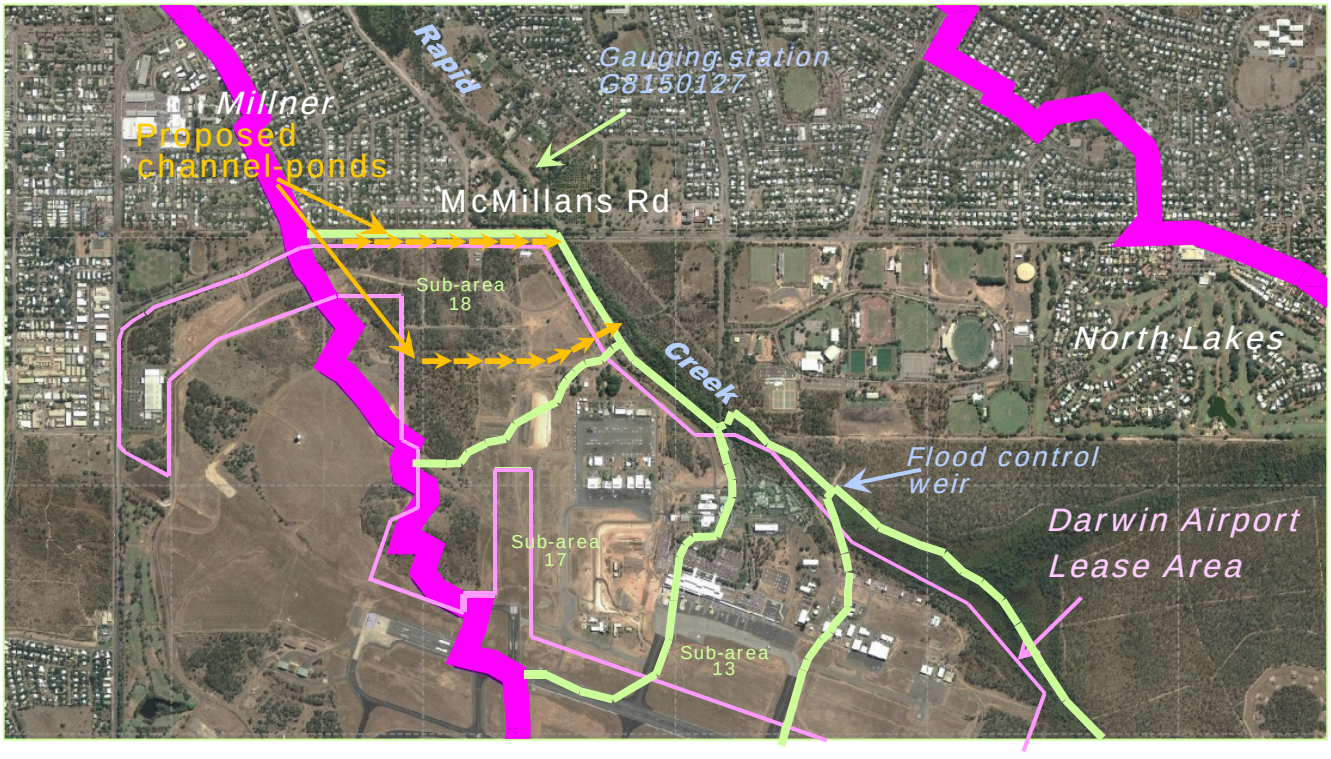
Table 3. Calculated Q100 peak flows for channel-pond at McMillans Rd frontage

Location	ULTIMATE DEVELOPMENT		CURRENT CONDITION	
	Q100 Peak flow (m^3/sec)		Q100 Peak flow (m^3/sec)	
	WITH CHANNEL-POND	WITHOUT CHANNEL-POND	WITH CHANNEL-POND	WITHOUT CHANNEL-POND
McMillans Rd channel-pond	16.5	22.9	12.6	15.1
Sub-area 18 flow to Rapid Creek	34.0	45.9	25.8	30.3
Gauging station G8150127	170	170	151	152

Table 3 shows that there are reductions in flow coming from sub-area 18 and some attenuation at the channel-pond. However, there is little impact on flooding at Millner. A channel-pond alongside McMillans Road would not be recommended

Figure 4 shows channel ponds both at the Conservation Zone and the McMillans Road frontage.

Figure 4. Channel ponds at conservation area and McMillans Rd frontage



The effect of this is shown in Table 4.

Table 4. Calculated Q100 peak flows for channel-ponds at McMillans Rd frontage and coming from Conservation Zone

Location	ULTIMATE DEVELOPMENT		CURRENT CONDITION	
	Q100 Peak flow (m^3/sec)		Q100 Peak flow (m^3/sec)	
	WITH CHANNEL-PONDS	WITHOUT CHANNEL-PONDS	WITH CHANNEL-PONDS	WITHOUT CHANNEL-PONDS
Sub-area 18 flow to Rapid Creek	32.8	45.9	25.2	30.3
Gauging station G8150127	163	170	141	152

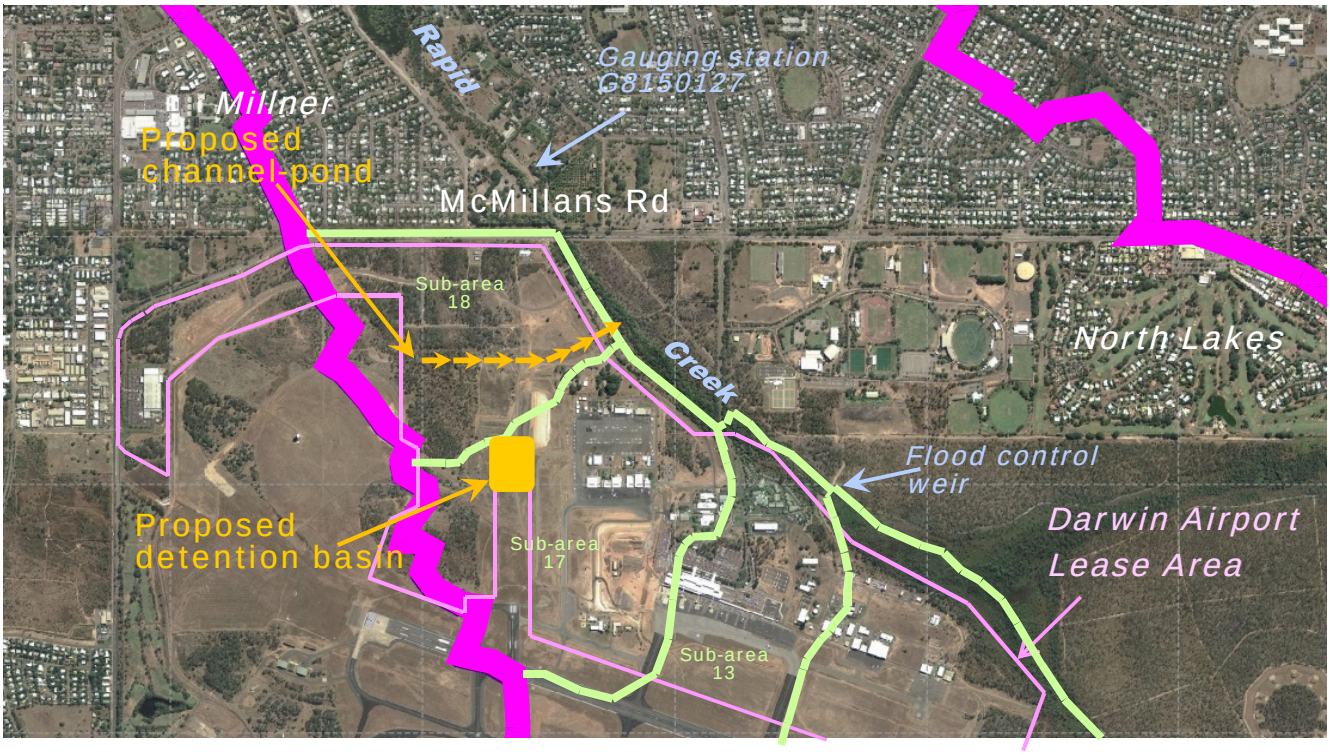
Table 4 shows that for both channel-ponds there is a slight further reduction in the sub-area 18 contribution but this does not translate to a reduction in Q100 peak flow at Millner.

A channel-pond alongside McMillans Road is not recommended.

2.3 Detention to the north of the north-south runway and channel ponds in the business park

Figure 5 shows detention to the north of the north-south runway and a channel pond taking flow out of the Conservation Area.

Figure 5. Detention north of the cross runway and channel ponds in the business park



The effect of this is shown in Table 5.

Table 5. Calculated Q100 peak flows for detention north of the cross runway and channel-pond in the business park

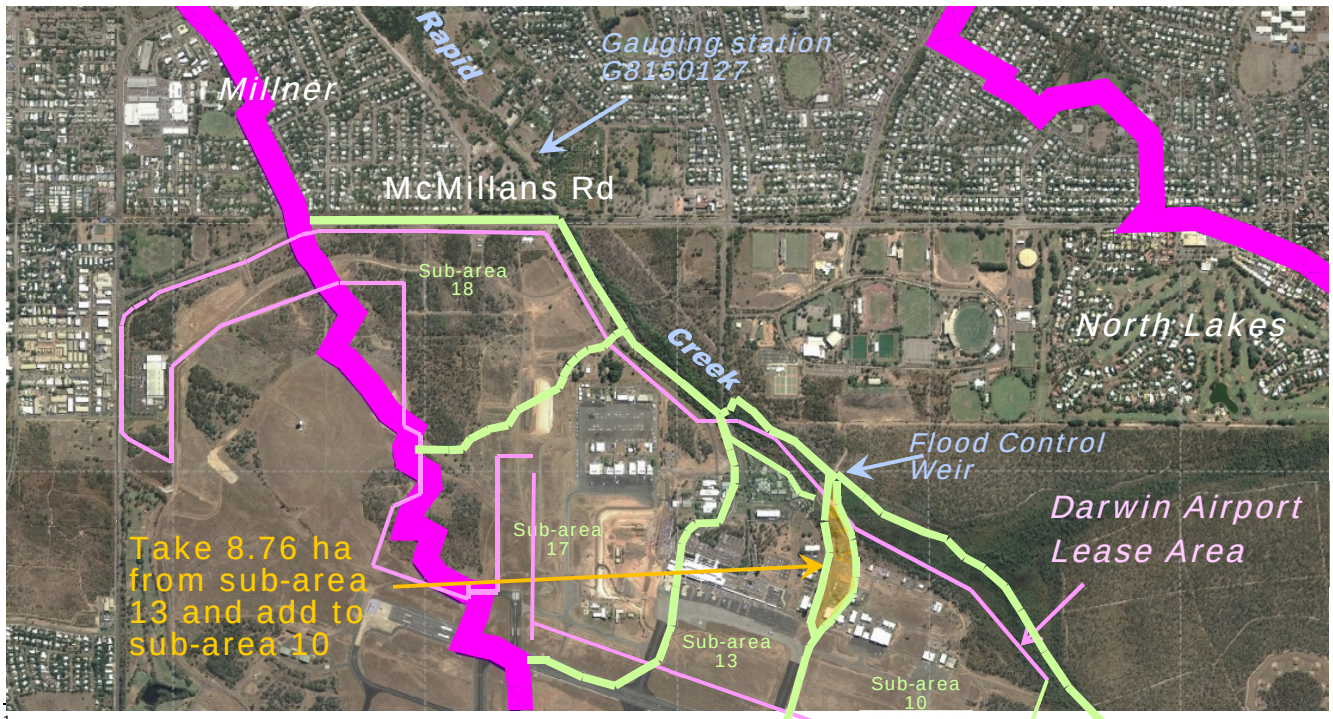
Location	ULTIMATE DEVELOPMENT		CURRENT CONDITION	
	Q100 Peak flow (m^3/sec)		Q100 Peak flow (m^3/sec)	
	WITH BASIN & CHANNEL-POND	WITHOUT BASIN & CHANNEL-POND	WITH BASIN & CHANNEL-POND	WITHOUT BASIN & CHANNEL-POND
Sub-area 17 flow to Rapid Creek	50.1	73.8	39.3	51.2
Sub-area 18 flow to Rapid Creek	34.0	45.9	26.3	30.3
Gauging station G8150127	162	170	139	152

Table 5 shows that for detention together with the channel-ponds there is a slight further reduction in the Q100 peak flow at Millner. However, as discussed in Section 2.1, Defence is understood to have identified the detention pond site as being required for future runway expansion, negating its utility as a mitigation measure.

2.4 Diverting the main drain from the area south of Larkin Avenue and east of Sir Norman Brearley Dr

Figure 6 shows the proposed diversion of 8.76 ha of drainage area from sub-area 13 downstream of the Flood Control Weir to sub-area 10 upstream[1].

Figure 6. Divert outfall drain to upstream of Flood Control Weir



[1] It is also proposed that the deep excavated drain that remains after the diversion is used as detention for the area south and west of Sir Norman Brearley Drive and east of Cecil Cook Avenue. It may be possible to direct the runoff from up to a further 5 ha into this detention. This has not been modelled.

The impact of this diversion is shown in Table 6.

Table 6. Calculated Q100 peak flows for diversion of 8.76 ha from sub-area 13 into sub-area 10

Location	ULTIMATE DEVELOPMENT		CURRENT CONDITION	
	Q100 Peak flow (m^3/sec)		Q100 Peak flow (m^3/sec)	
	WITH DIVERSION	WITHOUT DIVERSION	WITH DIVERSION	WITHOUT DIVERSION
Sub-area 10 flow to Rapid Creek	84.6	79.3	74.9	70.2
Sub-area 13 flow to Rapid Creek	50.0	54.7	42.7	46.8
Gauging station G8150127	168	170	150	152

Table 6 shows that the diversion moves about 9% of the peak flow from sub-area 13 to upstream of the flood control weir and this results in a minor reduction in Q100 peak flows at Millner.

2.5 Channel pond taking flow out of the Conservation Area and diversion of 8.76 ha from sub-area 13

Combining the channel pond and diversion measures proposed within the Darwin Airport Lease Area is shown diagrammatically in Figure 7 and has the results shown in Table 7.

Figure 7. Detention, channel ponds and diversion within the Darwin Airport Lease Area

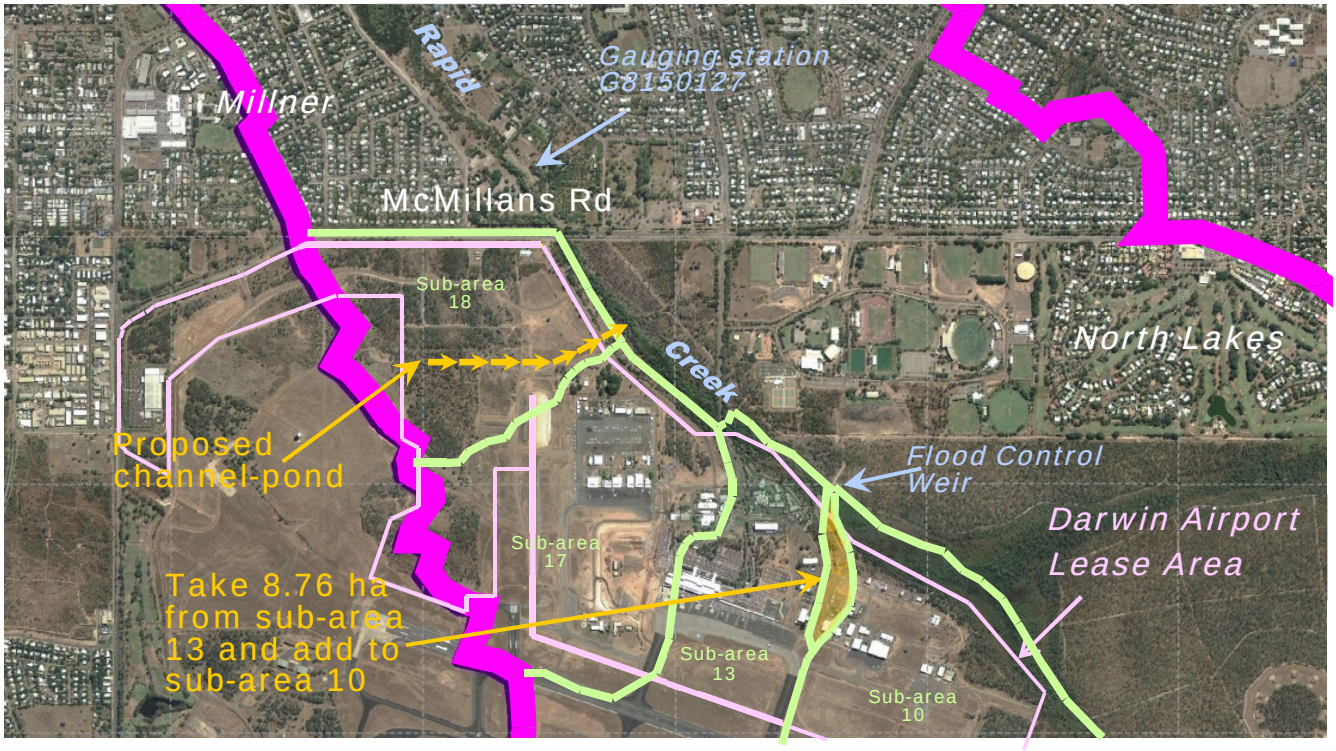


Table 7. Calculated Q100 peak flows for detention, channel ponds and diversion within the Darwin Airport Lease Area

Location	ULTIMATE DEVELOPMENT		CURRENT CONDITION	
	Q100 Peak flow (m^3/sec)		Q100 Peak flow (m^3/sec)	
	WITH DETENTION, CHANNEL-PONDS & DIVERSION	WITHOUT DETENTION, CHANNEL-PONDS & DIVERSION	WITH DETENTION, CHANNEL-PONDS & DIVERSION	WITHOUT DETENTION, CHANNEL-PONDS & DIVERSION
Sub-area 10 flow to Rapid Creek	84.6	79.3	74.9	70.2
Sub-area 13 flow to Rapid Creek	50.0	54.7	42.7	46.8
Sub-area 18 flow to Rapid Creek	34.0	45.9	26.3	30.3
Gauging station G8150127	159	170	137	152

There are decreases in peak flows for the sub-areas where mitigation works are carried out and a further reduction in peak flow at Millner.

3. Mitigation measures beyond the Darwin Airport lease Area

3.1 Detention basin for Marrara, Anula and Moil flows

A potential site for a detention basin exists in the triangular shaped area of land bounded by McMillans Road, Henry Wrigley Drive and Rapid Creek. Any detention basin constructed here would need to temporarily store water above Q100 flood level and be located so as not to encroach on existing flood storage that is engaged in low-lying land on the right bank of the Creek during major floods. This limits the basin area to approximately 6 ha out of the 9.5 ha of Section 4294.

The storage volume would be approximately 80,000 m^3. The catchment area that can be diverted into such a basin is 167 ha, comprising modelled sub-areas 15 and 16 as shown in Figure 8.

Figure 8. Marrara-Anula-Moil detention basin

The calculated flows for a basin in this location are shown in Table 8.

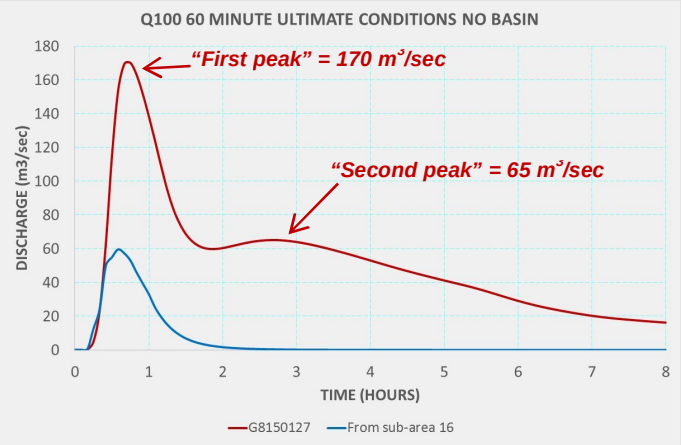
Table 8. Calculated Q100 peak flows for Marrara-Anula-Moil detention basin

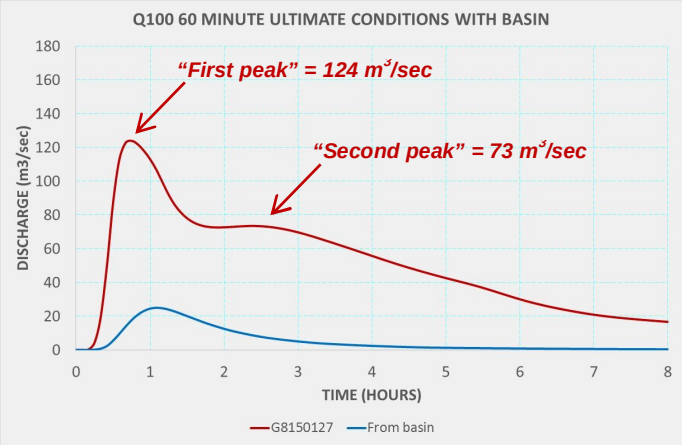
Location	ULTIMATE DEVELOPMENT		CURRENT CONDITION	
	Q100 Peak flow (m^3/sec)		Q100 Peak flow (m^3/sec)	
	WITH BASIN	WITHOUT BASIN	WITH BASIN	WITHOUT BASIN
Sub-area 16 flow to Rapid Creek	25.5	59.6	25.5	59.6
Gauging station G8150127	124	170	111	152

There is a substantial reduction in Q100 peak flow. In fact, the basin takes the Q100 peak flow for ultimate conditions to well below the calculated Q100 for 1998 conditions – effectively winding back the impact of development at Darwin Airport.

The reason for this substantial reduction is shown in Figure 9.

Figure 9. Comparison of ultimate development flows with and without the Marrara-Anula-Moil basin





It can be seen that the proposed detention basin reduces and delays the peak of inflows form the Marrara-Anula-Moil area by about half an hour. The delayed sub-area inflow peak contributes to the flow coming from the Flood Control Weir, such that the 'second peak' at Millner increases from 65 to 73 m^3/sec.

3.2 Detention basin for Jingili flows

Also considered is a detention basin to the north of McMillans Rd to catch flows from the Jingili area. As Figure 10 shows[2], land between Rapid Creek and Freshwater Road is in private (freehold) ownership except for:

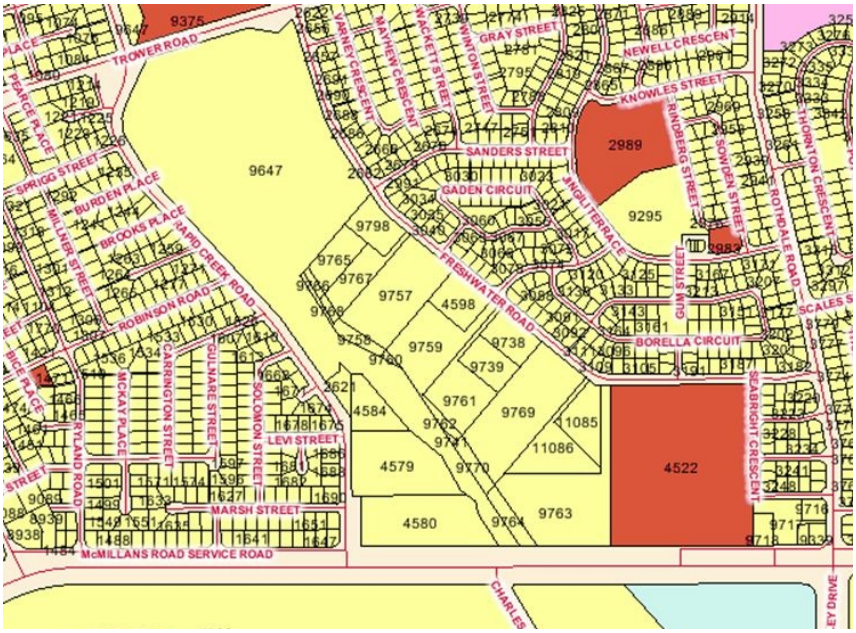
- Section 4522 – the Jingili Cemetery
- Section 9647 – a narrow corridor containing the creek plus the Freshwater Gardens in the care of Darwin City Council

It is unlikely that a detention basin would be constructed in the Freshwater Gardens, which is a well-patronised iconic parkland serving the Northern Suburbs

It is also unlikely that the cemetery could be disturbed for construction of a basin.

It may be possible to construct a basin in vacant land at the McMillans road frontage of the cemetery and in Section 9763, 11085 and 11086, which are currently covered in mango orchards.

Figure 10. Land tenure around Rapid Ck between McMillans Rd and Trower Rd



[2] Source of Figure 10 is http://www.ntlis.nt.gov.au/imfPublic/imf.jsp?site=nt_atlas

It is estimated that a detention basin with a volume in the order of 40,000 cubic metres can be constructed in this area. However, examination of drainage system plans shows that the catchment area that can be diverted from Jingili into it is limited to around 6 ha and as a result the reductions in peak flow at Millner are small (compared to the proposed Marrara Triangle Basin) as shown in Table 9.

Figure 11. Jingili detention basin.

Table 9. Calculated Q100 peak flows for front of cemetery-mango orchard basin

Location	ULTIMATE DEVELOPMENT		CURRENT CONDITION	
	Q100 Peak flow (m^3/sec)		Q100 Peak flow (m^3/sec)	
	WITH BASIN	WITHOUT BASIN	WITH BASIN	WITHOUT BASIN
Sub-area 19 flow to Rapid Creek	5.6	17.6	5.6	17.6
Gauging station G8150127	167	170	150	152

This scenario is also unlikely to be feasible, given the number of private land holders. Modelling was done because the private land is relatively undeveloped but a basin would require the acquisition of three separate private land parcels. The outcome of modelling has also determined that there are also limited flows that can be directed here, therefore the mango orchards basin is not recommended.

3.3 Detention basin for Marrara, Anula and Moil flows and channel-pond and diversion works in airport

Figure 12 shows the combination of the works within Darwin Airport as described in Section 2.5 and the recommended Marrara Triangle detention basin.

Figure 12. Marrara-Anula-Moil detention basin and recommended airport works as in Section 2.5

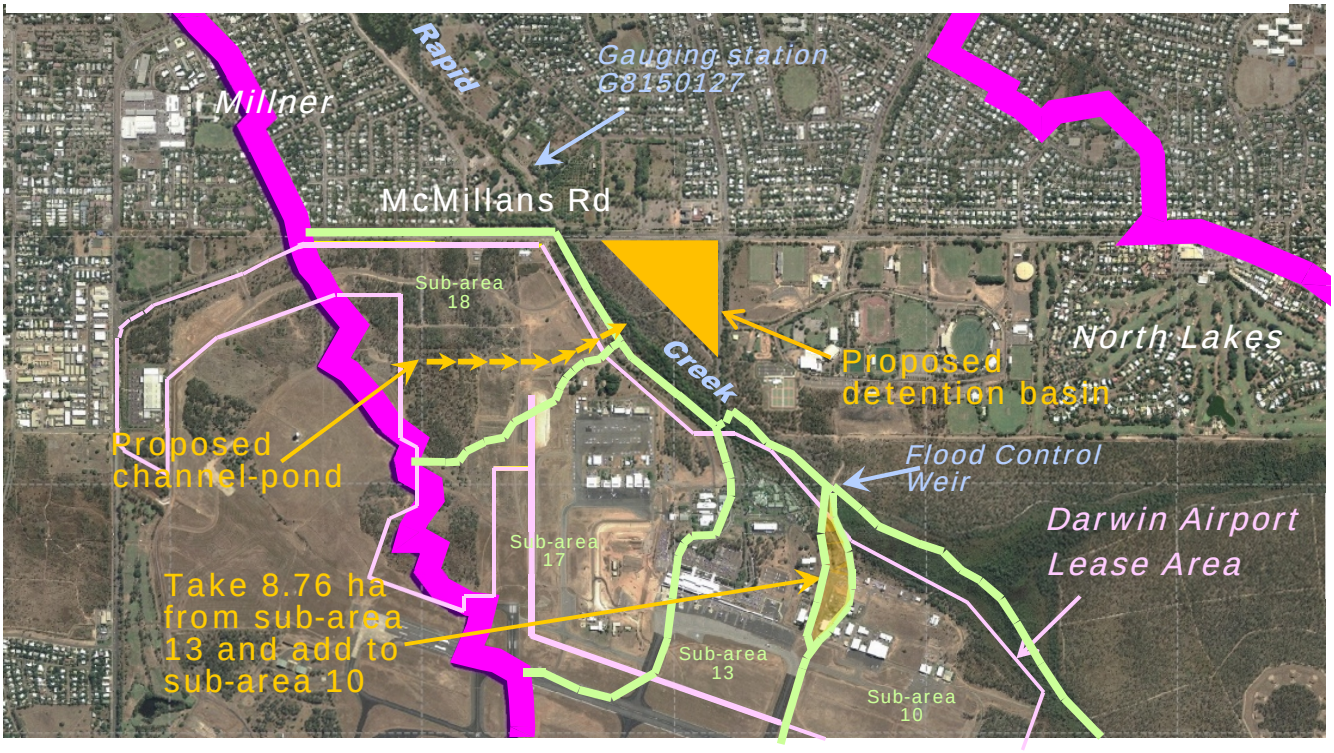


Table 10. Calculated Q100 peak flows for Marrara-Anula-Moil detention basin

Location	ULTIMATE DEVELOPMENT		CURRENT CONDITION	
	Q100 Peak flow (m^3/sec)		Q100 Peak flow (m^3/sec)	
	WITH BASIN	WITHOUT BASIN	WITH BASIN	WITHOUT BASIN
Gauging station G8150127	117	170	110	152

Table 10 shows there is a further reduction in the Q100 flows if the recommended works within the airport lease are carried out together with the Marrara Triangle Detention Basin works.

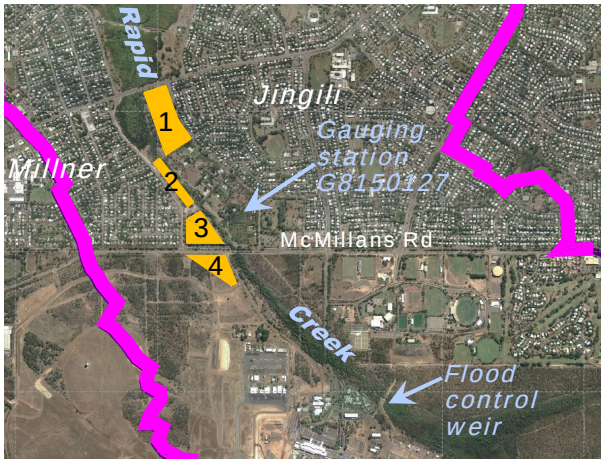
3.4 Other detention basin locations

Other locations could be considered for detention and are shown in Figure 13. There are constraints that would limit the effectiveness of detention basins at each of these locations and these are summarised in Table 11. Because of these constraints, these basins were not modelled for the present study.

Table 11. Constraints associated with other basins considered

No.	Location	Constraints
1	Jingili - Freshwater Gardens	Too far downstream Affects amenity of iconic well-patronised park Encroaches on flood plain of Rapid Creek[3]
2	Millner - between Rapid Creek Road and Creek	Limited space to install basin Encroaches on flood plain of Rapid Creek
3	Millner - Stables between Rapid Creek Road and Creek	In private ownership Limited size of basin east of rapid Creek Road without encroaching on existing flood plain of Rapid Creek. Limited catchment area from Millner could be diverted into it
4	Darwin Airport – McMillans Road-Charles Eaton Drive corner	There is existing development including a child care centre on this site and it is unlikely that this will be relocated to address stormwater issues. Further development in this area will be subject to DIA development guidelines that aim to restrict increases in post-development peak flows

Figure 13. Other detention basin locations considered



[3] If the construction of a basin takes up flood storage that would otherwise be engaged by Rapid Creek during a major flood, then this may offset the benefit of the basin

4. Summary of mitigation measures considered

The various measures considered above are summarised in Table 12.

Table 12. Summary of mitigation measures

Mitigation measure		Figure number in this report	Table number in this report	Peak flow at Millner for ultimate development (m^3/sec)			Comment
No.	Description			Without mitigation measure	With mitigation measure	% reduction by mitigation measure	
1	Detention basin north of cross runway	Figure 1	Table 1	170	169	0.5%	Not feasible. Site has been identified by defence for extension of the runway
2	Channel-pond from conservation park to new outfall	Figure 2	Table 2	170	162	5%	Feasible. DIA should further explore this option[4]
3	Channel-pond McMillans Rd frontage	Figure 3	Table 3	170	170	No impact	Not recommended Existing drain is in road reserve not DIA land and in coffee rock. Also, makes no impact on flooding downstream
4	Channel-pond from conservation area to new outfall + McMillans Rd frontage	Figure 4	Table 4	170	163	4%	Not recommended as above
5	Detention basin to the north of the cross runway + channel-pond from conservation area	Figure 5	Table 5	170	162	5%	Not feasible as the detention basin site has been identified by defence for extension of the runway
6	Diversion of 8.76 ha from downstream to upstream of the flood control weir	Figure 6	Table 6	170	168	1%	Feasible. Further reduction possible if drain that remains after the diversion is used as detention for an additional 5ha.

[4] DIA should further explore this option. It is a scheme to which we understand DIA is amenable and is consistent with proposed future developments. Although not modelled, further reductions in peak flows from the sub-area may be able to be achieved by limiting flows under Charles Eaton Drive from this source and further spreading/slowing the flow between Charles Eaton Drive and Rapid Creek

Mitigation measure		Figure number in this report	Table number in this report	Peak flow at Millner for ultimate development (m^3/sec)			Comment
No.	Description			Without mitigation measure	With mitigation measure	% reduction by mitigation measure	
7	Channel-pond from conservation area + diversion	Figure 7	Table 7	170	159	7%	Feasible. Greater reduction than either measure alone.
8	Detention basin catching Marrara-Anula-Moil runoff	Figure 8	Table 8	170	124	27%	Feasible. Largest reduction by a single measure because it commands a large enough catchment area to make a difference
9	Detention basin catching Jingili runoff	Figure 11	Table 9	170	167	2%	Not feasible. Basin site largely in privately-owned land.
10	Detention basin catching Marrara-Anula-Moil runoff + channel-pond from conservation area + diversion	Figure 12	Table 10	170	117	31%[5]	Feasible and recommended
11	DIA development guidelines	N/A	N/A	Firm estimate of peak flows not possible			Feasible and recommended. Further peak flow reductions possible. Expected to result in reduced peak flows between the calculated ultimate development flows and current condition flows.

It is clear that construction of a detention basin at the triangular-shaped area bounded by McMillans Road, Charles Eaton Drive and Rapid Creek offers the best contribution towards mitigation of flooding at Millner out of all the options considered.

The investigations suggest that in order to be effective, a detention basin or channel pond needs to be:

- Of sufficient size to delay and reduce the peak discharge to Rapid Creek from the sub-area in which the basin is located,
- Commanding sufficient sub-catchment area,

[5] The combined mitigating effect is less than the sum of individual reductions. It is believed that this is because, as the peak discharge from more and more areas is delayed, the peaks from these areas start to line up at a later time and reinforce each other. Although there is still attenuation because the flood waves from these areas engage more temporary storage, the effect is diminished.

- Located downstream of the flood control weir and upstream of Millner.

It is also clear that a single basin meeting these criteria is more effective than combining several basins that have a small impact.

However, there is benefit in constructing both the Marrara Triangle Basin and the recommended works within the Darwin Airport Lease (channel pond and diversion works). This produces a larger mitigating effect than the Marrara Triangle basin alone.

For the Q100 design flood, the DIA channel-pond and diversion together reduce the peak discharge at the gauging station by an estimated 7% (Row 7 of Table 12). The Q100 design flood, the Marrara Triangle Detention Basin is estimated to reduce the peak discharge at the Gauging Station by 27% (Row 8 of Table 12).

Combined the reduction is estimated to be 31%. Whilst this is less than the sum of the individual reductions[6] it is worth pursuing and these combined works form part of the recommended scheme in the following Section 5.

[6] Refer to Footnote 5.

5. Conclusions and recommendations

Of all the options considered, the detention basin in the land bounded by McMillans Road, Henry Wrigley Drive and Rapid Creek (the Marrara Triangle) produces the most significant reduction in peak flows at Millner.

It is recommended that

- A detention basin is constructed in the land bounded by McMillans Road, Henry Wrigley Drive and Rapid Creek (see Figure 8). As much catchment area as possible should be diverted into this basin. The main open drains that carry flows to Rapid Creek from parts of Marrara, Anula and Moil cross the basin site. It may also be possible to divert flows from the McMillans Road corridor to the west of its intersection with Rothdale Road and Henry Wrigley Drive into the basin.

- The 8.8 ha catchment draining to the intersection of Sir Norman Brearley Drive and Cecil Cooke Avenue and Larkin Avenue be diverted so as to enter Rapid Creek upstream of the flood control weir.

- The deep excavated open channel that remains just downstream of the flood control weir after diversion of that drain is converted into a detention basin for runoff generated in the area to the west of Sir Norman Brearley Drive and East of Cecil Cook Avenue.

- A channel-pond is constructed to intercept and slow/store flows from the conservation area and north-south runway area and divert them to flow toward Rapid Creek via a new flow path beyond Charles Eaton Drive located between Osgood Drive and Murphy Crescent.

- Darwin International Airport prepares and implements guidelines that aim to restrict major storm peak flows from developed allotments to pre-development levels.

Figure 14 shows the areas mitigated and not mitigated after the recommended flood mitigation measures are implemented in the Rapid Creek catchment. After mitigation works are completed, the majority of the catchment area above Trower Road will be subject to some form of control on runoff generation.

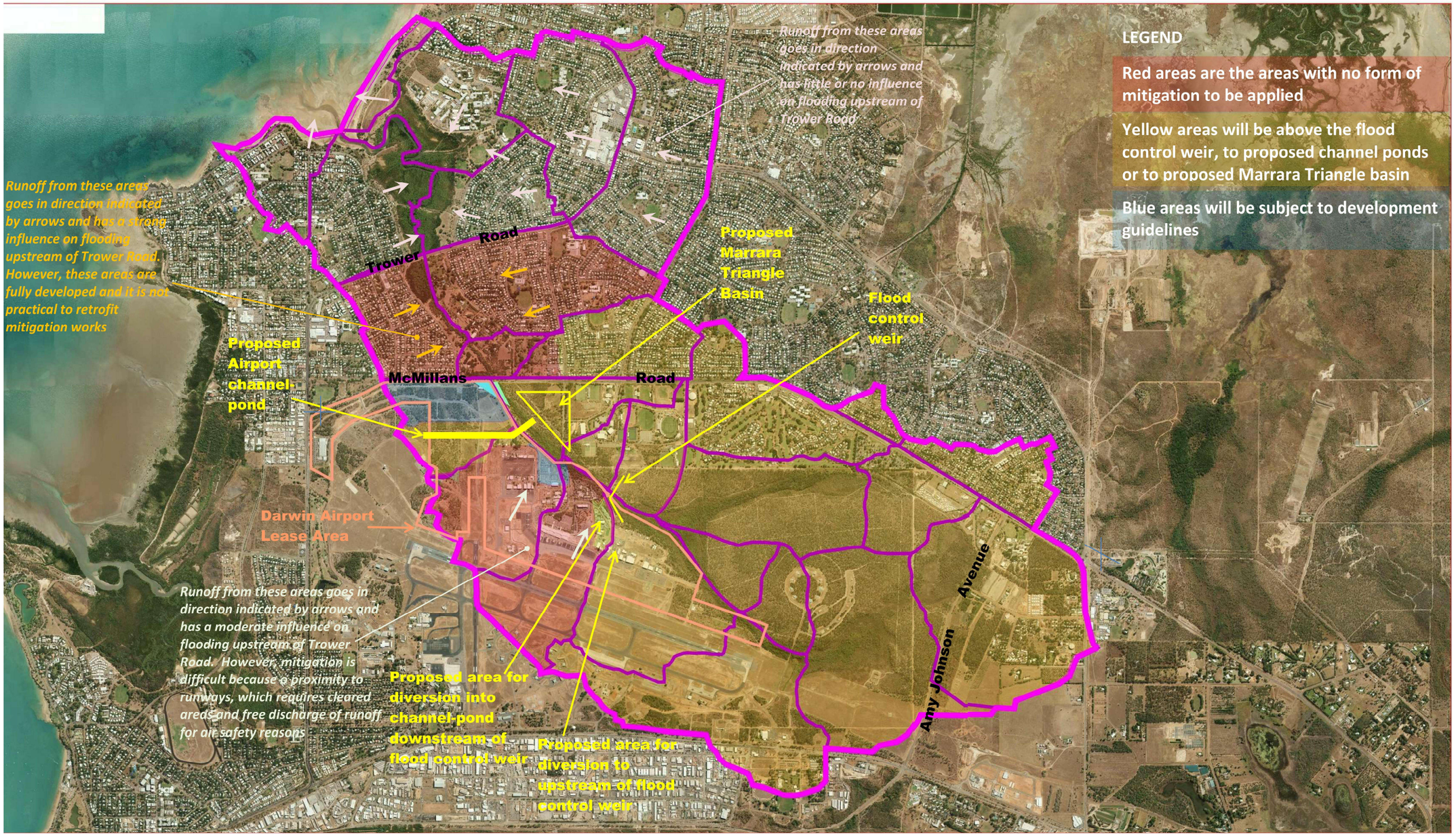
The only areas from which flood flows are not mitigated will then be:

- The suburbs of Jingili and Millner, which are already fully developed and sites cannot be practically found for retro-fitting cost-effective mitigation works.

- Some parts of the airport where aviation safety requires cleared areas and free discharge of runoff.

- Some older parts of the airport such as the terminal area which are also fully developed.

Figure 14. Areas mitigated and not mitigated after recommended mitigation works



Almost all of the damaging flooding occurs in the suburb of Millner between McMillans Road and Trower Road.

For the catchment area to Trower Road:

- Runoff from 75% of the area will be mitigated by the existing Flood Control Weir or Channel-Pond immediately downstream of it, the proposed Marrara Triangle Basin or (subject to further investigation) the proposed Airport Channel-Pond
- Runoff from a further 2% of the area will be mitigated in accordance with the Airport Development Guidelines