Challenges to Management and Treatment of Stormwater Runoff from Newly Constructed Williams Landing Railway Station Car Park

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ABSTRACT

The recently constructed Williams Landing railway station provides a new transport node for the rapidly developing western suburbs of Melbourne. It was designed based on providing state of the art safety and environmental benefits to the community. Management and treatment of stormwater runoff generated from the newly built car park is a major challenge due to the flat nature of the area, additional runoff from an air force base and increased flooding impacts on existing railway tracks, downstream properties and the existing railway culvert crossings. In addition to that, stormwater runoff should be treated to meet the Melbourne Water quality guidelines.

Initially, the Railway asset authority, VicTrack, agreed to provide land along the railway track which can be developed as a detention basin in order to address the stormwater management and flooding issues. The effect of storage on flood management has to be addressed in such a way that the defence facility or other properties should be safe for a 100 year ARI event. Therefore, the design of the detention basin was carried out using EPA-SWMM modelling to optimise the detention basin volume and to achieve the above objectives. Based on MUSIC model results, the detention basin, with a gross pollutant pit on the drainage line from the car park, can treat almost 100% of stormwater runoff from both the car park and the air force base to meet water quality targets.

Keywords

Stormwater, Hydraulic modelling, HEC-RAS, EPA-SWMM, Detention basin, Water quality modelling and MUSIC model

PRESENTER PROFILE

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1 INTRODUCTION

Williams Landing railway station was proposed in 2008 to serve the newly established suburb of Williams Landing under the State Government's Victorian Transport Plan. This station is located on the Werribee railway line in Melbourne, Victoria, Australia, 19 km south west of Melbourne CBD. The construction was commenced in 2011 and was completed in 2013 and was opened to commuters in April 2013.

The station is designed to promote sustainability by providing a 500 space car park, bicycle paths, new bus terminal and a pedestrian bridge across the Princes Freeway. Up to 1000 passengers are expected to board peak-hour trains every morning at the new station, between Hoppers Crossing and Aircraft stations. The $110 million project will give residents in Williams Landing, Point Cook and Truganina access to nearby trains and a new bus network. Figure 1 shows the location of the Williams Landing Station.

The Department of Transport (DoT) appointed Abigroup to design and construct Williams Landing railway station and other appurtenant structures. **pitt&sherry** was engaged by Abigroup for provision of engineering services for the project.

Construction of a commuter car park for the railway station was part of the project. The runoff generated from the car park and surrounding areas, which includes the adjoining Royal Australian Air Force (RAAF) base needs to be managed to prevent future flooding of railway tracks and private properties. In addition the DoT requested that the runoff be treated prior to discharging it to a local creek.

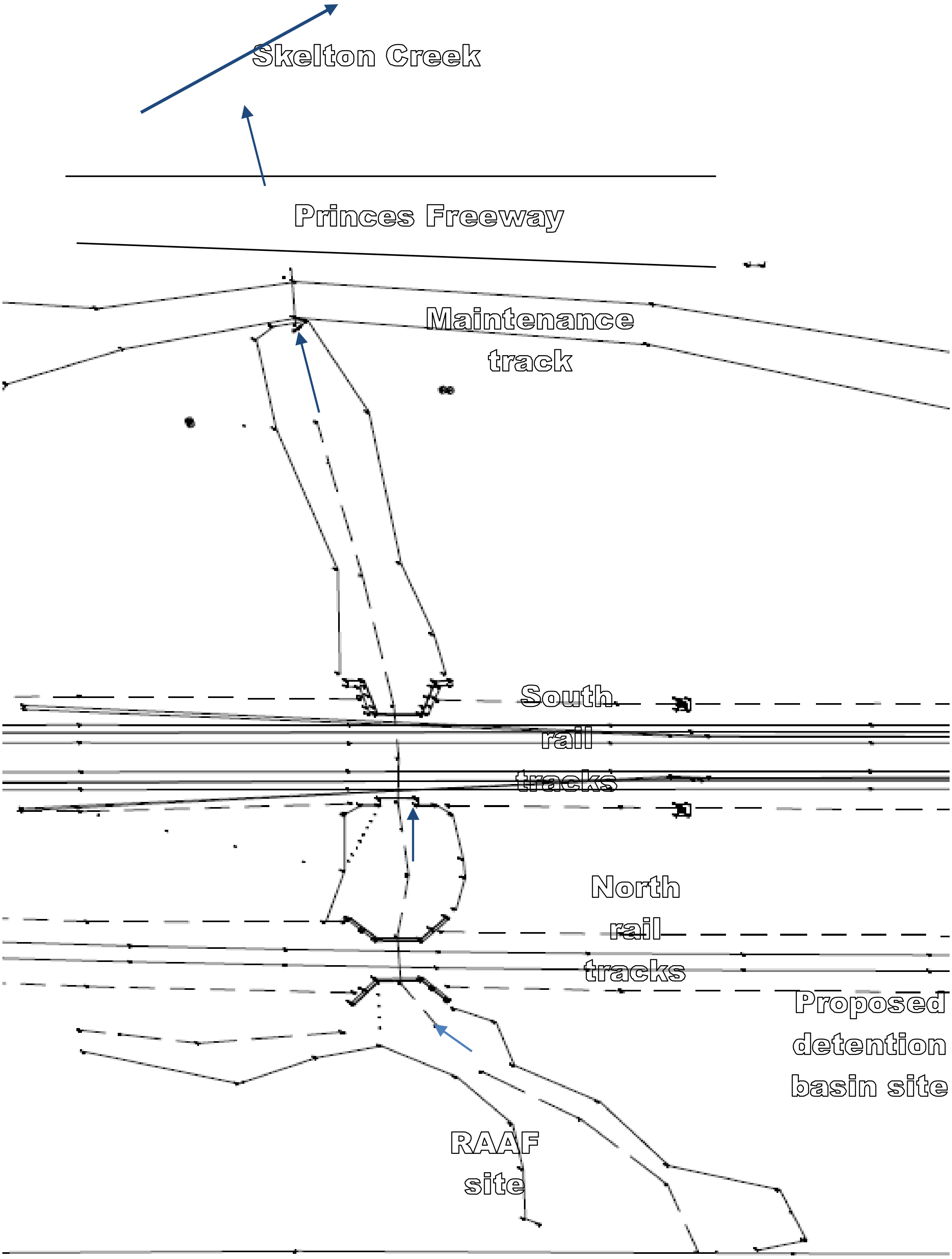
In order to propose a suitable procedure to manage and treat the runoff, a hydrologic and hydraulic investigation was carried out based on available data. Initially, the existing condition was evaluated using the HEC-RAS model which identified flooding impacts on the rail tracks during the 50 year and 100 year storm events. Following this analysis a detention facility was designed to manage and treat runoff using the EPA-SWMM model and MUSIC model.

Figure 1 Location map

2 EXISTING DRAINAGE SYSTEM

The runoff generated from the car park is naturally directed to small creek that runs along the eastern part of the station. This creek runs through several railway and road culvert crossings, prior to discharging to Skelton Creek which is approximately 700 m downstream of Princes Freeway as shown in Figure 2. An aerial view of the project area prior to construction of the car park is shown in Photograph 1.

Figure 2: Existing drainage system



Photograph 1: Aerial view of the project area (Courtesy Google Earth)

The existing drainage system mainly consists of the following components as shown schematically in Figure 2.

1. Drainage flow from proposed car park
2. Drainage from existing RAAF facility
3. Drainage from north and south of rail tracks.

The creek passes through four culverts namely, Southern rail track, Northern rail track, maintenance track and the Princes Freeway. Details of culverts are provided and tabulated in Table 1. All elevations are referenced to the Australian Height Datum (AHD).

Table 1: Culvert data

Name	Location	Type	U/s Invert (m)	D/s Invert (m)	Length (m)
Culvert 1	North rail track	Box (3.5 m x 1.1 m)	10.49	10.48	5
Culvert 2	South rail track	Box (3.5 m x 1.1 m)	10.37	10.36	8
Culvert 3	Maintenance track	Pipe (0.9m diameter)	10.35	10.37	5
Culvert 4	Princes Freeway	Pipe (1.05 m diameter)	9.62	7.36	80

It is noted that Culvert 3 underneath the maintenance track is at an adverse slope and is a comparatively lower opening than upstream culverts. This creates a bottle neck within the drainage system, and flooding between Culvert 3 and Culvert 4. The main reason for this culvert configuration is an underground oil pipe line which does not permit lowering of Culvert 3. In addition to that, runoff from a swale between those culverts would increase the flooding risk further. This was confirmed by frequent flooding complaints from a private property owner whose property is located between Culvert 3 and 4.

In order to study the behavior of the drainage system, hydrologic and hydraulic modelling of the system was carried out.

2.1 HYDROLOGIC ANALYSIS OF EXISTING DRAINAGE SYSTEM

Peak runoff for each subcatchment was estimated using the rational formula except for the car park. A detailed hydrologic study for the car park was carried out using the DRAINS model. Estimated drainage flows under different return periods from each subcatchment are shown in Table 2.

Table 2: Estimated drainage flows

Location	Catchment Area (ha)	100 year ARI flow (m^3/s)	50 year ARI flow (m^3/s)	20 year ARI flow (m^3/s)	10 year ARI flow (m^3/s)
RAAF	5.53	1.27	1.09	0.87	0.62
Car park	1.52	0.42	0.40	0.32	0.17
North rail track	0.21	0.02	0.01	0.01	0.01
South rail track	3.19	0.41	0.35	0.28	0.20
Total	10.45	2.12	1.85	1.48	1.00

2.2 HYDRAULIC ANALYSIS OF EXISTING DRAINAGE SYSTEM

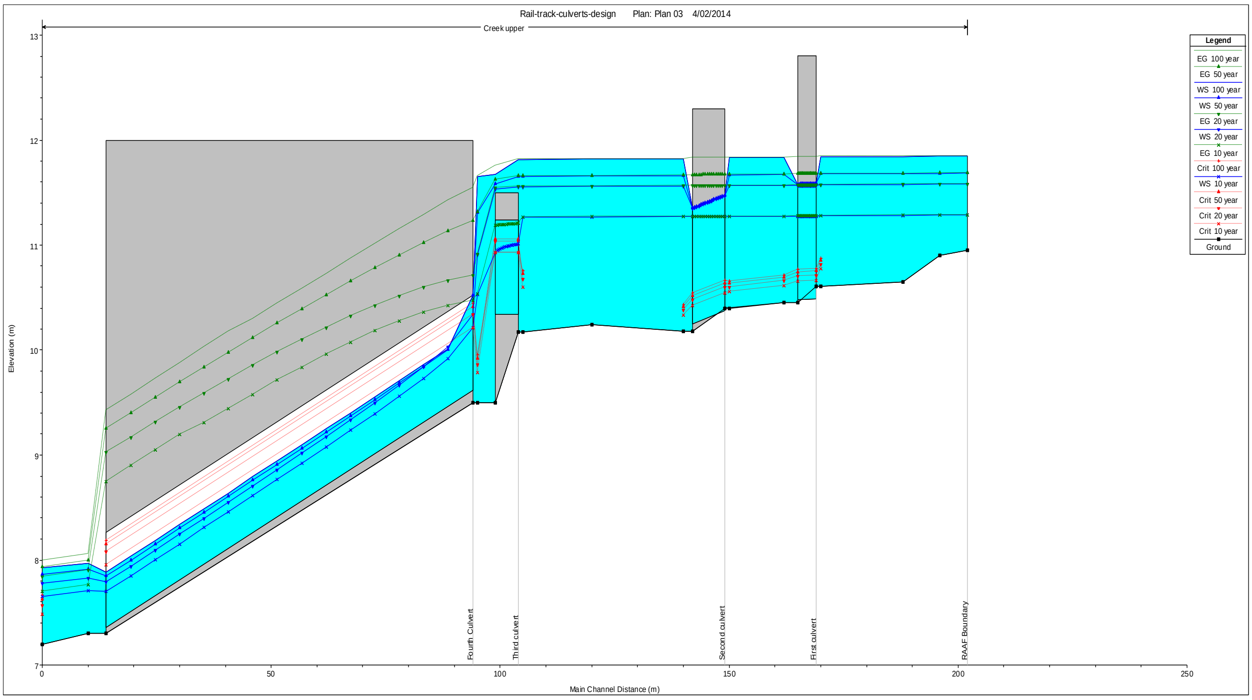
Hydraulic analysis was carried out using the HEC-RAS model, which adopted hydrologic and available geometric data of the drainage system. Due to a lack of information, drainage cross sections were estimated from spot level data, and reasonable assumptions based on existing information. The main intention of this study was to check the effect of the 100 year return period flood levels on railway lines, freeway and RAAF site.

Results of the hydraulic analysis on the existing system are shown in Table 3. It shows the water surface profile for each return period with formation and finished levels of the crossings. Formation levels of rail tracks/freeway were not provided, therefore, they were estimated by deducting 700 mm from the respective rail/finished level. However, maintenance track is not sealed therefore, no difference between formation and finished level. Figure 3 shows water level elevations at each culvert crossing compared with rail levels or finished level of freeway. The grey shapes indicate culvert crossings and blue colour indicates water profiles.

Table 3: Results of hydraulic analysis

Culvert location	100 year ARI flood level (m)	50 year ARI flood level (m)	20 year ARI flood level (m)	10 year ARI flood level (m)	Formation level (m)	Rail or finished level (m)
North track	11.84	11.68	11.57	11.28	12.10	12.80
South track	11.83	11.67	11.57	11.27	11.70	12.40
Maintenance track	11.81	11.65	11.56	11.27	11.50	11.50
Freeway	11.66	11.31	10.91	10.53	11.30	12.00

Figure 3: Water surface profile under existing conditions



2.3 DISCUSSION ON HYDRAULIC BEHAVIOUR OF DRAINAGE EXISTING SYSTEM

As shown in Table 3, all water surface profiles are below formation level of the Northern rail track; however, the formation of the Southern rail track would be under water during a 100 year ARI event. The maintenance track (Culvert No 3), would be under water for an event just greater than a 10 year ARI event.

The main reason for this is due to insufficient capacity of the culvert underneath the maintenance track and it's adverse slope. The waterway opening of this pipe culvert is less than one sixth of the upstream box culverts, and it cannot be lowered due to the presence of an underground oil pipe. Therefore this pipe culvert acts as a constriction to the whole system, thus affecting the two upstream culverts.

In addition, the outfall of the culvert underneath the maintenance track (Culvert 3) has been connected to the existing culvert underneath the Princes Freeway (Culvert 4) via an open gap. This discontinuity of pipe caused overland flows to flood the adjacent private property. This can be avoided by connecting both culvert pipes via a grated pit.

In order to eliminate this problem, retention of flood water between the RAAF facility and the Northern rail track was investigated. The following section describes the proposed detention system and its effect on the drainage system.

3 PROPOSED DETENTION SYSTEM

Previously, a separate pipeline of about 100 m long was proposed to discharge runoff generated from the car park, to the drainage line across the railway lines. However, by constructing a detention system cum swale the runoff from the car park can be treated prior to discharging it to the drainage line. This proposal not only eliminates the pipeline but also provides environmental benefits.

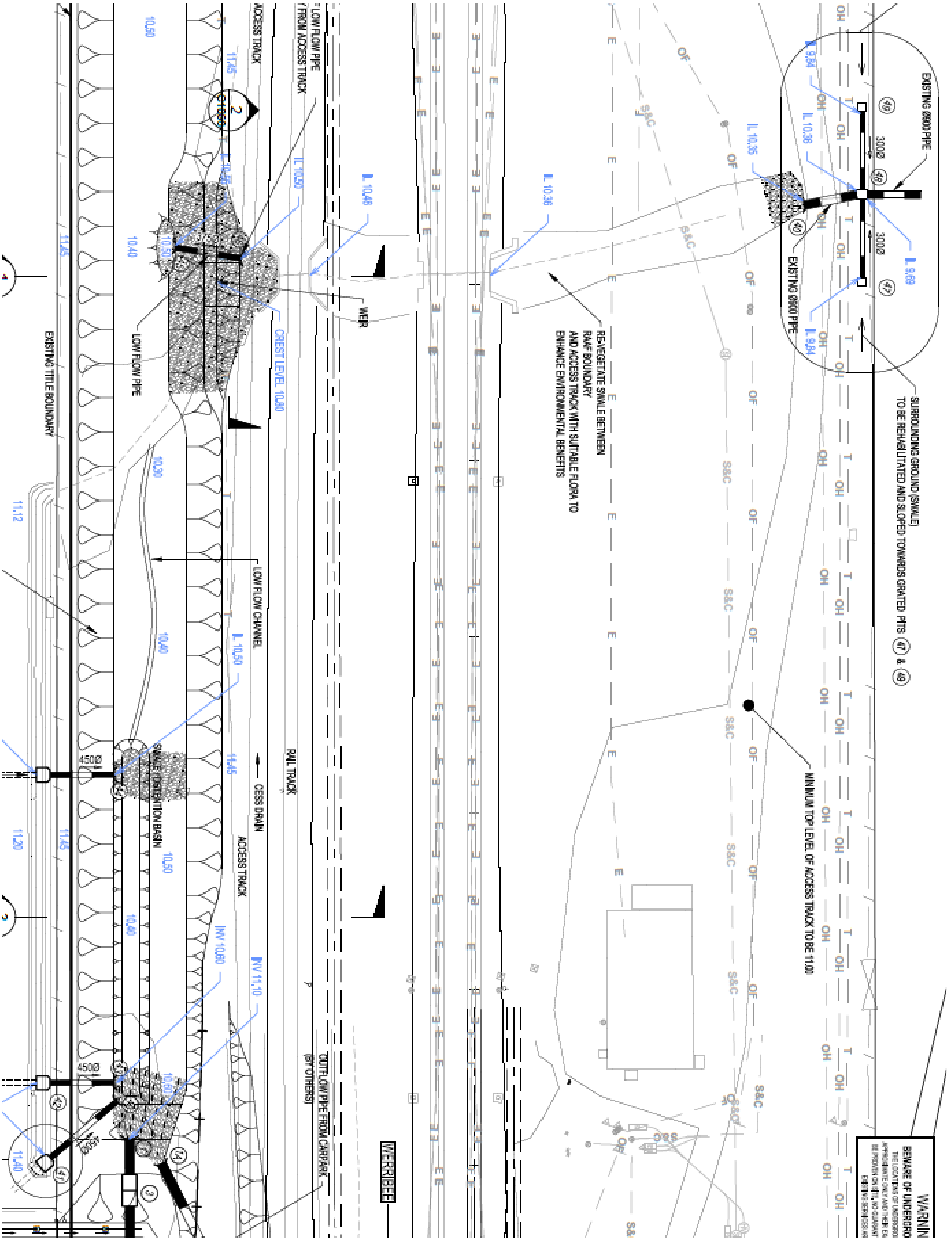
A detention system can be constructed between the Northern rail track and the RAAF facility. The available gross area is about 2,250 m^2. However, allowing for batters and buffer zones, the effective area for the detention would be about 2,000 m^2. Having a maximum effective depth of about 0.92m, the detention basin can hold nearly 950 m^3. The proposed maximum depth would be around 1.0m and based on geotechnical information, this depth can be excavated without any problem.

The detention system receives runoff from the car park from a pit equipped with gross pollutant trap, and also receives flows from the RAAF facility via three pipes. The detention system is equipped with a pipe to drain flood water gradually, and dead storage to accumulate sediments and a weir to pass excess water during floods. There is a small lower basin/swale between the maintenance track and the outfall of this detention basin. Water accumulated within the lower basin would then flow into a new pit which connects culverts No 3 and No 4 under the Princes Freeway.

Two grated pits would be constructed on the eastern and western sides of the new pit, to collect stormwater from the small swale between the maintenance track and the private property. This arrangement would permanently address the flooding issue of the private property up to a 100 year ARI event.

The plan view of the detention system including other components is shown in Figure 4.

Figure 4: Proposed detention system



3.1 HYDRAULIC ANALYSIS OF PROPOSED DRAINAGE SYSTEM

Hydraulic analysis of the detention system was carried out using EPA-SWMM developed by US EPA. This model simulates unsteady hydraulic behaviour based on hydrologic and other parameters. EPA-SWMM was run for the 100 year ARI event using hydrographs from the car park, RAAF facility and lower basin. A 100 year ARI hydrograph for the car park was developed by pitt&sherry based on the DRAINS model. As only the peak flow value of the 100 year event of the RAAF facility was provided, the hydrographs of pipe outlets from the RAAF facility are assumed to be of similar pattern to the car park hydrograph. The runoff from the lower basin was also assumed to have a similar pattern of hydrograph to the car park. Hydrographs for the 10 year, 50 year and 100 year ARI event are shown in Table 4.

Table 4: Inflow hydrographs

Time (min)	100 year ARI		50 year ARI		10 year ARI	
	car park (m^3/s)	RAAF (m^3/s)	car park (m^3/s)	RAAF (m^3/s)	car park (m^3/s)	RAAF (m^3/s)
0	0.00	0.00	0.00	0.00	0.00	0.00
10	0. 3	0.90	0. 25	0.75	0. 14	0.42
20	0.42	1.26	0.37	1.11	0.20	0.60
30	0. 2	0.60	0. 16	0.48	0. 09	0.27
40	0.03	0.09	0.02	0.06	0.01	0.03
50	0.00	0.00	0.00	0.00	0.00	0.00

The design of the detention basin was optimised to protect downstream areas, upstream areas and the detention basin itself by varying the design parameters of the system. The optimised design parameters of the detention system are shown in Table 5.

The EPA- SWMM model was run for three different return periods, 100 year ARI, 50 year ARI and 10 year ARI. The accuracy of the model runs were up to 99.95%, and thus acceptable. Peak flow rates and water levels based on the modelling results are shown in Table 6.

Table 5: Design parameters of the detention system

Parameter	Value
Size of RAAF pipes (mm)	450
Invert of RAAF pipes (m)	10.7 to 10.6
High flood level at RAAF (m)	11.16
Detention basin upstream level (m)	10.60
Detention basin downstream level (m)	10.30
Bund top level (m)	11.45
High flood level (m)	11.07
Live storage (m^3)	1000
Dead storage (m^3)	200
Main weir crest level (m)	10.8
Main weir length (m)	5
Size of outflow pipe from storage (mm)	375
Invert of outflow pipe (m)	10.55

Table 6: Model results

Model result	**100 year ARI**	**50 year ARI**	**10 year ARI**
WSE at RAAF pits (m)	11.16	11.09	10.94
WSE at detention basin near RAAF pits (m)	11.07	11.02	10.91
WSE at lower storage across railway (m)	10.99	10.92	10.66
WSE at new pit (m)	9.98	9.95	9.8
Weir flow at detention near RAAF (m^3/s)	1.07	0.85	0.32
Low flow pipe at detention near RAAF (m^3/s)	0.24	0.27	0.12
Flow through new pit (m^3/s)	1.22	1.01	0.32

3.2 DISCUSSION ON HYDRAULIC BEHAVIOUR OF PROPOSED DRAINAGE SYSTEM

Designing a detention basin across the existing drain just south of the RAAF facility is intended to prevent flooding of the RAAF site, rail tracks and private property located at the southern end of the rail track. By constructing this detention basin the combined peak flows from both the car park and the RAAF facility are reduced at the downstream end from 2.12 m^3/s to 1.22 m^3/s. This is slightly more than the existing (without the detention basin) 10 year ARI flow of 1.00 m^3/s.

The predicted maximum water level at the RAAF facility during the 100 year ARI event is 11.16 m which is slightly (4 cm) above the minimum ground level of the RAAF basin. It can be expected that about 20 m^3 would be spilled into the RAAF facility during the extreme event. There is no impact on the RAAF facility during the 50 year event.

The private property is mainly affected by flooding due to no connection between the culverts across the maintenance track and the Princes Freeway. As a result of the construction of the proposed new pit to connect both culverts this flooding would reduce for all events up to the 100 year event. The predicted flood level upstream of the maintenance track is 11.00 m during the 100 year event. However, the existing minimum level of the maintenance track is about 10.93 m. In order to prevent stormwater overflow the minimum level of the track needs to be raised to 11.20 m.

The predicted maximum water level within the proposed new pit is about 10.5 m which is nearly 0.4 m below the lowest ground level of the property, thus flooding is avoided. Two grated pits would be constructed on the eastern and western sides of the new pit to collect stormwater from the small swale between the maintenance track and the private property. The top level of these grated pits would be at 10.8 m to collect storm runoff from the swales, and to prevent over spills from the new pit.

4 WATER QUALITY MODELLING

Hydraulic modelling quantified the flooding aspects of the proposed car park development and suitable mitigatory measures. In addition to flood risk assessment, an estimation of the water quality benefits is essential prior to getting approval from the Melbourne Water Authority.

4.1 MODELLING APPROACH

The water quality modelling software package MUSIC (Version 5.1, Build 16) has been used to model the proposed detention basin and swales under the two different scenarios.

Melbourne Water's 'MUSIC Guidelines – recommended input parameters and modelling approaches for MUSIC users' (Melbourne Water, 2010), has been used to inform model development where applicable.

These guidelines include recommended rainfall templates for a number of sites across the Melbourne Metropolitan area. It is stated that the MUSIC models created after January 2011 should use the templates included in these guidelines, and the use of local data is permitted only if it can be proven to be of high quality. The assessment of the quality of local data is outside the scope of this investigation, thus the Melbourne Water templates have been adopted.

Assessment of the regional map included in the Melbourne Water MUSIC guidelines suggests the Williams Landing site is contained in the region of rainfall similar to the Melbourne Airport weather station (mean annual rainfall of 500 – 650 mm, with a reference year of 1996). This rainfall template has therefore been used in the modelling of each of the scenarios.

In addition to this, the following pervious area properties have been adopted from the Melbourne Water guidelines:

- Soil store capacity – 30 mm

- Field capacity – 20 mm
- Exfiltration rate – 0 mm/hr.

All other non project specific values have been left as the Music model defaults. As there is no local flow data for this catchment, calibration of the model has not been possible.

4.2 WATER QUALTY GUIDELINES

Water Sensitive Urban Design (WSUD) principles are used to reduce the increase in mean annual pollutant loads due to developments. Generally, Melbourne Water requires treatment of stormwater so that annual pollutant loads achieve targets set out in the Best Practice Environmental Management Guidelines as follows:

- 45% reduction in Total Nitrogen from typical urban loads
- 45% reduction in Total Phosphorus from typical urban loads
- 80% reduction in Total Suspended Solids from typical urban loads
- 70% reduction in litter from typical urban loads
- Maintain discharges for the 1.5 year ARI event at pre-development levels.

The performance of the proposed WSUD components will be assessed against these targets.

4.3 CATCHMENT DESCRIPTION FOR WATER QUALITY MODELLING

The pollution generation subcatchment area for the proposed detention basin is mostly car park, road reserves and the existing RAAF site. Table 7 lumps the pollution generation subcatchment areas draining to the WSUD treatment train, along with the estimated flow rates under various ARI events.

Table 7: Estimated catchment areas, percentage impervious and drainage flows for each subcatchment

Location	Catchment Area (ha)	Estimated Percentage Impervious	100 year ARI flow (m^3/s)	50 year ARI flow (m^3/s)	20 year ARI flow (m^3/s)	10 year ARI flow (m^3/s)
RAAF	5.53	95%	1.27	1.09	0.87	0.62
Car park	1.52	95%	0.42	0.40	0.32	0.17

The proposed configuration of the swales and detention basin showing inflows from the car park and RAAF site is shown in Figure 4.
The RAAF site is currently fully developed and drains through an existing concrete channel to the outlet. As part of the development, land use of the proposed car park area will be changed from grass to fully developed condition and both sites will have additional treatment in the vegetated detention basin.

Initially, treatment of the runoff from the proposed car park is the focus of this investigation as it is a pre requisite for the development. However, the performance of the treatment train including flows from the RAAF site will also be investigated.

In addition to this, runoff from the rail tracks will drain through the existing swale system south of the detention basin. This has been excluded from this investigation; however it should be noted that the swales and detention basin will treat a greater quantity of water than just that from the proposed car park.

A site survey has been used to estimate the cross sections of the swales connecting the detention basin and the system outlet. It has been assumed that the swales under this development would be approximately equal to those already in place.

Swales have been assumed to have mowed vegetation, with an approximate height of 0.10 m in accordance with the Melbourne Water modelling guidelines. The detention basin is assumed to be vegetated.

5 MODELLING RESULTS

Water quality modeling study has been carried out in two phases. The first phase would consider pollution generation from the proposed car par area and the second phase would consist of both car park and RAAF site.

5.1 DISCHARGE FROM CAR PARK

The car park is the only new development within the treatment train catchment, therefore to determine the treatment effectiveness in dealing with increased pollutant loads as a result of this development; the model has been initially run with only the car park area as the catchment input. The results of this assessment can be seen in Table 8.

Table 8: Summary of the reduction in pollutant loads of the car park run off

Pollutant parameter	Source load (kg/yr)	Reduction in pollutant load due to treatment (kg/yr)	Reduction in pollutant load due to treatment (%)	Target pollutant reduction (%)
Total Suspended Solids	1,230	1,165	94.7	80
Total Phosphorus	2.6	2.1	79.3	45
Total Nitrogen	17.8	11.3	63.4	45
Gross Pollutants	251	251	100	70

As can be seen, this treatment option is expected to meet each of the Melbourne Water's treatment requirements for total phosphorus, total nitrogen, total suspended solids and gross pollutants.

5.2 DISCHARGE FROM CAR PARK AND RAAF SITE

As the stormwater runoff from the pre-existing RAAF site is to also enter the treatment train, this has been included in this scenario. Table 9 shows the predicted treatment characteristics of this scenario:

Table 9: Summary of the reduction in pollutant loads of the car park and RAAF site run off

Pollutant parameter	Source load (kg/yr)	Reduction in pollutant load due to treatment (kg/yr)	Reduction in pollutant load due to treatment (%)	Target pollutant reduction (%)
Total Suspended Solids	5,820	5,300	91.1	80
Total Phosphorus	11.7	8.2	69.8	45
Total Nitrogen	82.8	31.8	38.4	45
Gross Pollutants	1,160	1,160	100	70

As can be seen, this treatment train option exceeds Melbourne Water's treatment targets for total suspended solids, total phosphorus and gross pollutants. The target for removal of total nitrogen is approximately 85% achieved.

The treatment train is removing significantly more than the target values when considering only the pollutants generated from the car park.

5.3 DISCUSSION ON WATER QUALITY MODELLING

The proposed detention basin across the existing drain just south of the RAAF facility is intended to prevent flooding of the RAAF site, rail tracks and private property located at the southern end of the rail track. This system has the added benefit of treatment for the water passing through the network.

MUSIC modelling of the region suggests that the treatment benefits of the detention basin and swales exceed the Melbourne Water guidelines when the pollutant loading from the car park only are considered.

With the additional flows from the pre-existing RAAF site, the Melbourne Water targets for phosphorous, total suspended solids and gross pollutants are met, however totals nitrogen removal is expected to be less than the target of 45% removal.

Although the treatment of the total catchment is not expected to meet all water quality targets set by Melbourne Water, the proposed system is adequate to treat the runoff from the proposed car park. The benefits of the system including flood mitigation and water quality improvements are significant given the site constraints including existing culverts and limited space available for use.

Gross pollutant traps in the car park or RAAF site have not been included in the MUSIC model, however they will improve performance and aesthetics of the detention basin and swales.

6 CONCLUSIONS

The existing drainage system with inflows from both the RAAF facility and the car park provides protection to all rail/road tracks up to a 10 year ARI event. Providing a detention basin between the RAAF facility and the northern rail track would provide protection to the RAAF facility, rail/road tracks and the private property at the southern end almost up to the 100 year ARI event.

MUSIC modelling of the region suggests that the treatment benefits of the detention basin and swales exceed the Melbourne Water guidelines when the pollutant loading from the car park only are considered.

With the additional flows from the pre-existing RAAF site, the Melbourne Water targets for phosphorous, total suspended solids and gross pollutants are met, however total nitrogen removal is expected to be less than the target of 45% removal.

Although the treatment of the total catchment is not expected to meet all water quality targets set by Melbourne Water, the proposed system is adequate to treat the runoff from the proposed car park. The benefits of the system including flood mitigation and water quality improvements are significant given the site constraints including existing culverts and limited space available for use.

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REFERENCES

Melbourne Water (2010) *MUSIC Guidelines – recommended input parameters and modelling approaches for MUSIC users*.